

# The Enphase Bidirectional EV Charger

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**Mohammad Alkuran, Ph.D.** – Sr. Director of Systems Engineering

**Martin Degener** – Principal Systems Engineer

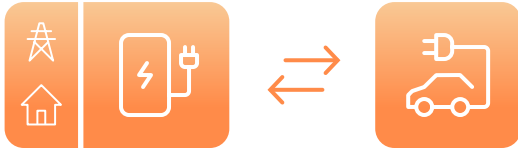
**Shatruddha Kushwaha** – Sr. Staff Systems Engineer

# Introduction

The Enphase Bidirectional EV Charger enables vehicle-to-home (V2H) and vehicle-to-grid (V2G) functionality. This product will leverage the power of grid-forming IQ8™ Microinverters and Ensemble™ energy management technology to seamlessly integrate into Enphase® home energy systems, and will enable homeowners to manage their solar, battery storage, and EV (electric vehicle) charging all from a single app. In addition, Enphase's Bidirectional EV Charger will be simple to install and will work with most EVs that support bidirectional charging.

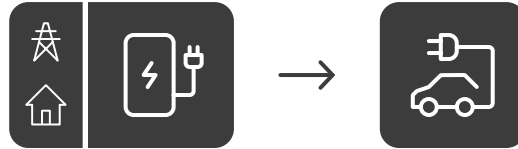
# What is a Bidirectional EV Charger?

## Bidirectional EV charger



Can take energy from the grid / home and charge the car battery, or take energy from the car battery and feed it back to the grid / home

## Unidirectional EV charger



Only takes energy from the grid / home and charges the car battery

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## Features of the Enphase Bidirectional EV Charger

- Vehicle-to-home charging (V2H)
- Vehicle-to-grid charging (V2G)
- Green charging
- Savings mode
- Self-Consumption

# Principles of operation

## Enphase IQ Microinverters enable full Ensemble OS stack

- Tertiary control
- Secondary control
- Primary control
- Hardware

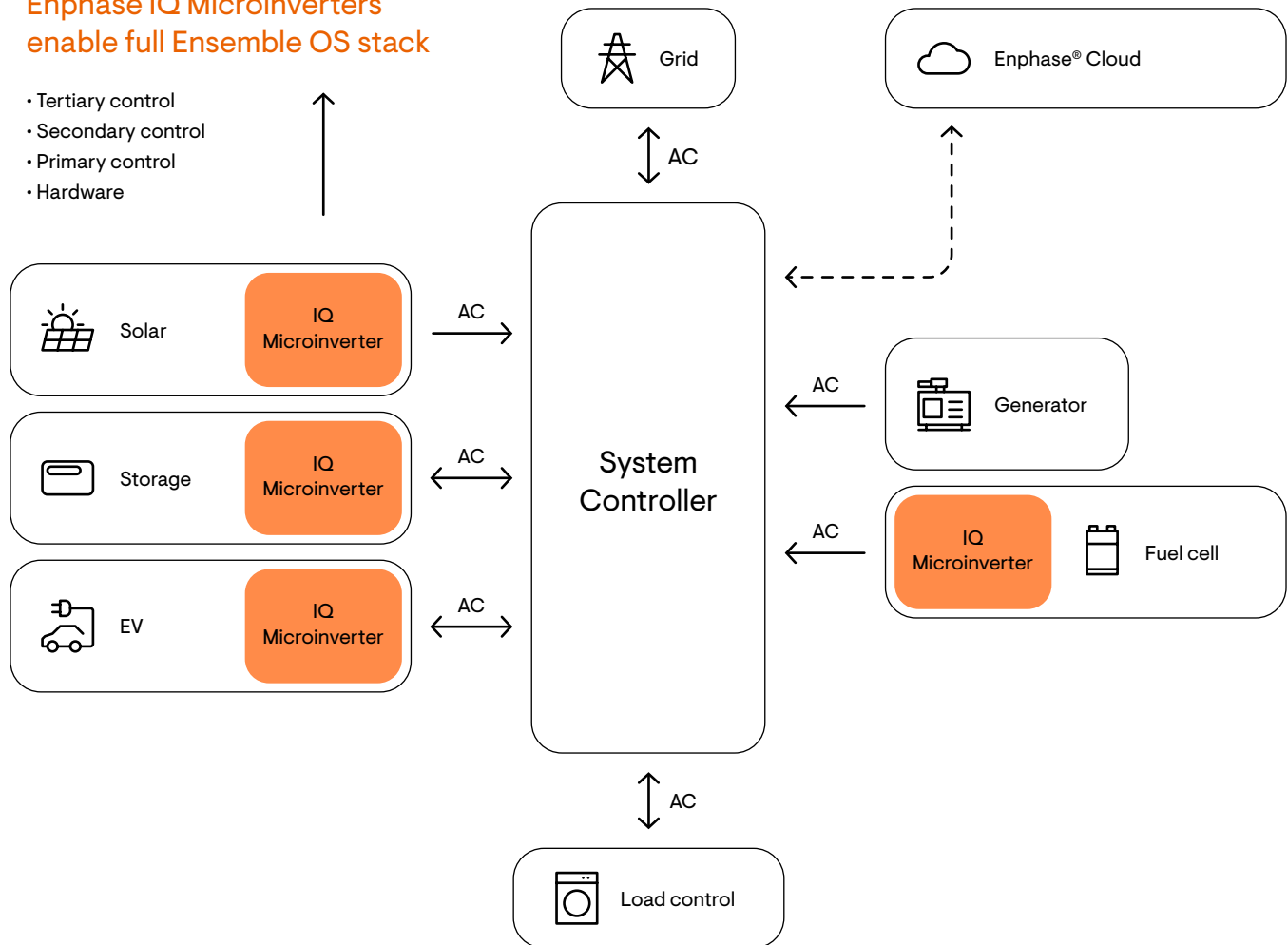


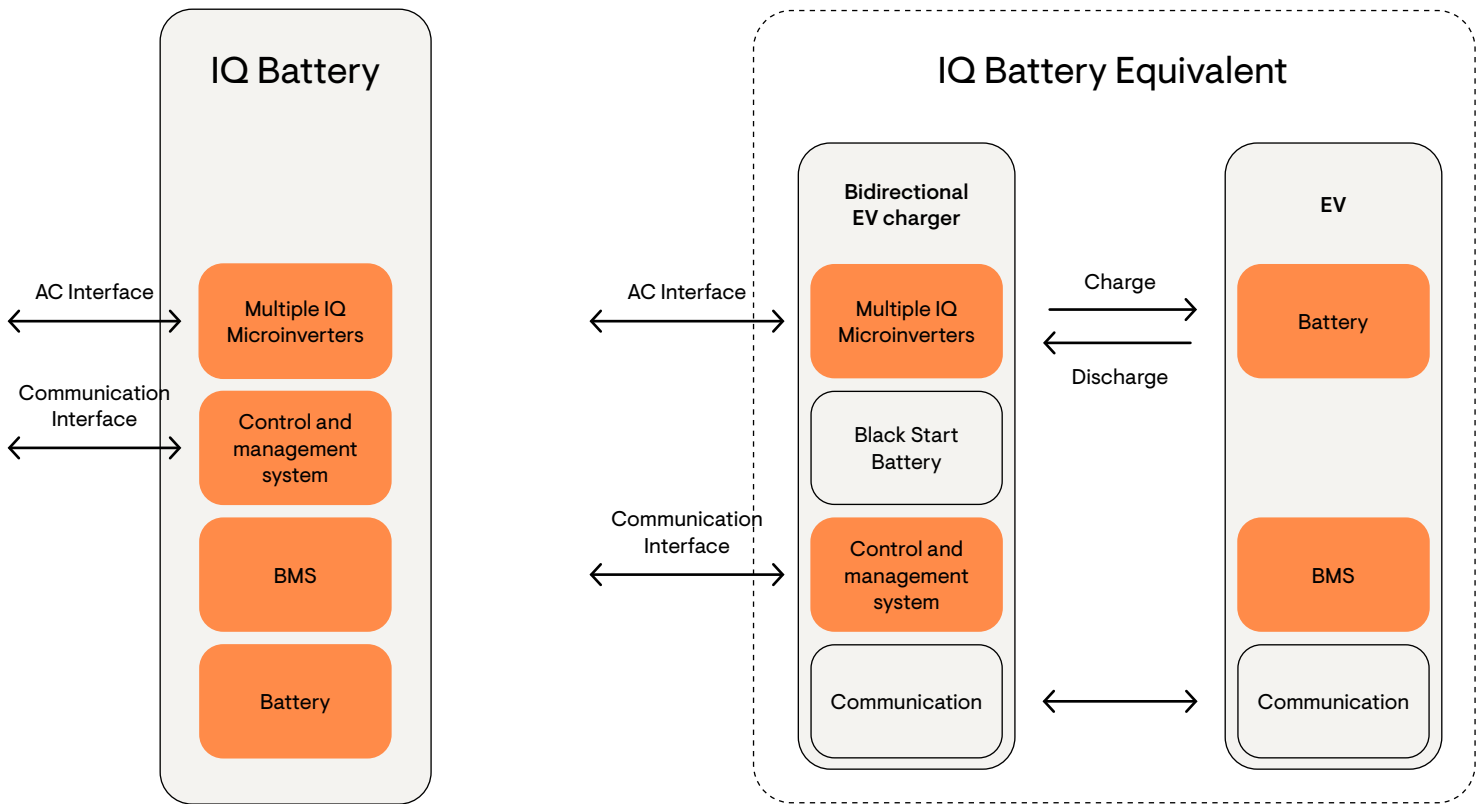
Figure 1: IQ8 Microinverters at the forefront of Grid Interface

The Enphase Bidirectional EV Charger is part of the Ensemble energy management technology, which is the heart of the Enphase® Energy System™. The Enphase Energy System is a complete solution that produces, stores, monitors, exports, controls, and analyzes the energy in your home.

To achieve this, Enphase Energy System brings solar, batteries, other energy resources like generators, fuel cells, connected appliances and software together in one complete package so that a homeowner can make, use, save, and sell their own power—all through the Enphase mobile app.

Enphase has pioneered power conversion devices called IQ8™ Microinverters. These microinverters are best-in-class power electronics components that convert power and comply with standards like UL1741 for grid reliability functions and IEEE1547 for interconnection of distributed energy resources (DER). These microinverters can create their own grid, also known as microgrid. They can operate in on-grid mode (as grid-tied) and off-grid mode (creating a microgrid). Enphase microinverter technology is at the forefront of the grid interface for our solar microinverters, storage batteries, and EV chargers.

The Enphase Bidirectional EV Charger leverages Enphase’s IQ Microinverter technology and IQ™ Battery architecture. When the charger is used with a vehicle that supports bidirectional charging, it enables the transfer of power and communication between the Enphase Energy System and the EV. The combination of the EV and the bidirectional charger is similar to an Enphase IQ Battery and can be controlled in an equivalent fashion.



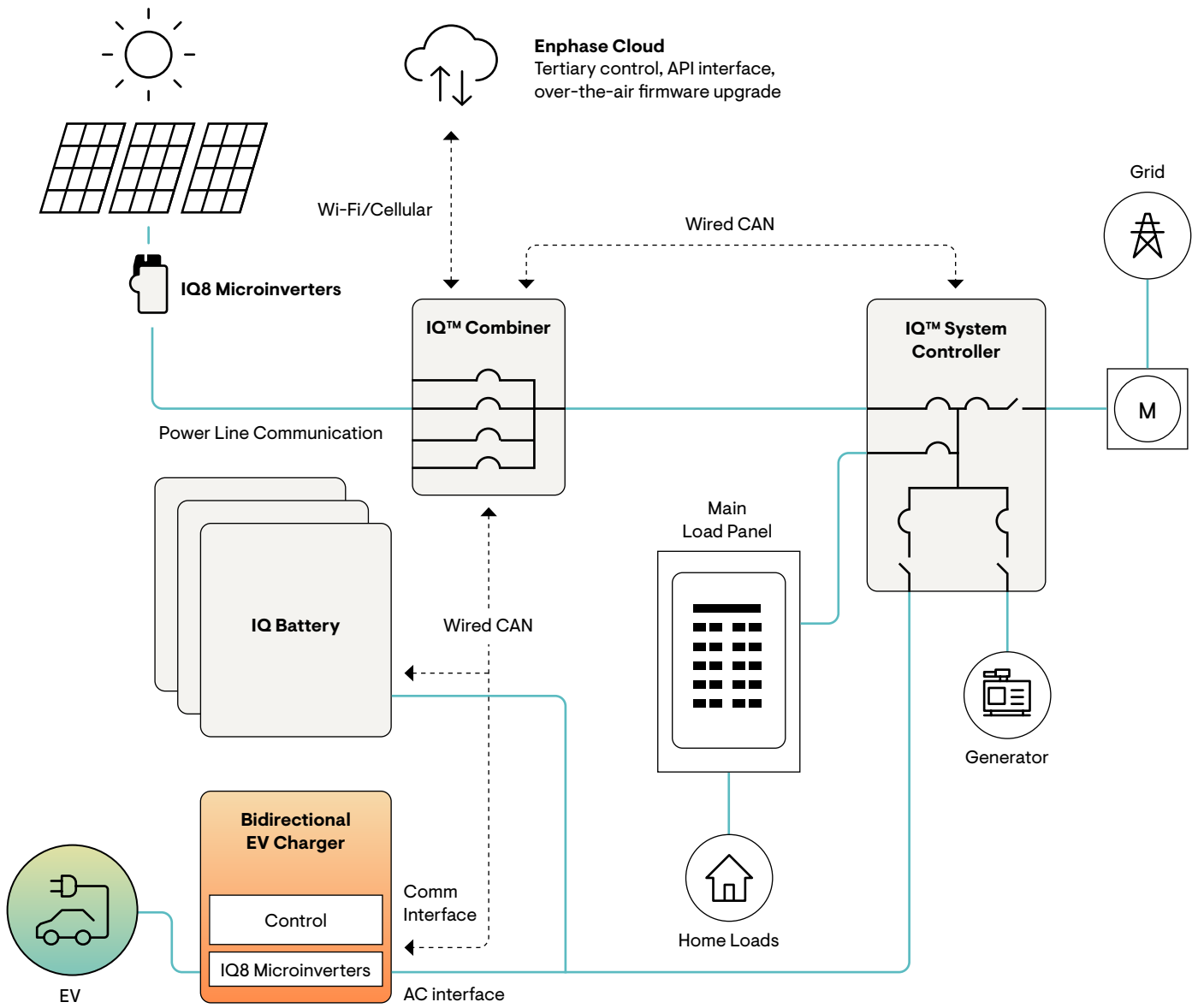
**Figure 2: The combination of the Enphase Bidirectional EV Charger and the EV can be controlled by the Enphase Energy System like an IQ Battery**

The table below elaborates on the functionality of each component.

**Table 1: Main components of an Enphase Bidirectional EV Charger compared to an Enphase IQ Battery**

	Enphase IQ Battery	Enphase Bidirectional EV Charger
<b>IQ Microinverters</b>	IQ8 Microinverters charge and discharge the IQ Battery cell pack. Microinverters connect to the DC port of the cell pack on one side, and the 240 V AC line on the other side	IQ8 Microinverters charge and discharge the EV's battery. Microinverters connect to the DC port of the EV on one side, and the 240 V AC line on the other side
<b>Battery</b>	IQ Battery contains Lithium-Ion cell pack	EV battery is typically made with Lithium-Ion cells, and is much bigger than an IQ Battery
<b>Battery Management System (BMS)</b>	Within the IQ Battery, the BMS manages the safety of the cell pack in the IQ Battery	Within the EV, the BMS manages the safety of the cells in the EV battery
<b>Control and Management System</b>	Enphase proprietary controller—manages communication with Enphase Energy System and implements different modes of operation	Enphase proprietary controller—manages communication with Enphase Energy System and implements different modes of operation
<b>Communication</b>	Controller communicates to the IQ™ Gateway, the IQ8 Microinverters, and to the internal BMS using proprietary protocol	Controller communicates to the IQ Gateway, the IQ8 Microinverters, and to the EV, using CHAdeMO or CCS
<b>Black start Battery</b>	IQ Battery does not need separate battery for black start, since the cells of the battery are available	Black start is required when an EV arrives at a home that already has a grid outage. Black start battery enables initial communication between EV and charger, until the EV's DC power is available to the charger

In Figure 2, the AC interface connects to the AC lines of the Enphase Energy System, and the communication interface connects to the IQ Gateway. With such a connection, it integrates with the Enphase Energy System and can now be used to charge or discharge the EV.



**Figure 3: An Enphase Bidirectional EV Charger connects to an Enphase Energy System in a similar fashion to an IQ Battery**

# A closer look

Communication is established between the EV and the bidirectional charger the moment the EV is plugged into the charger. The Enphase Bidirectional EV Charger supports CHAdeMO and CCS (ISO 15118-2 for DC

charging; ISO 15118 -20 for DC\_BPT charging) standards. The charger supports the full range of DC voltage in compliance with the standards.

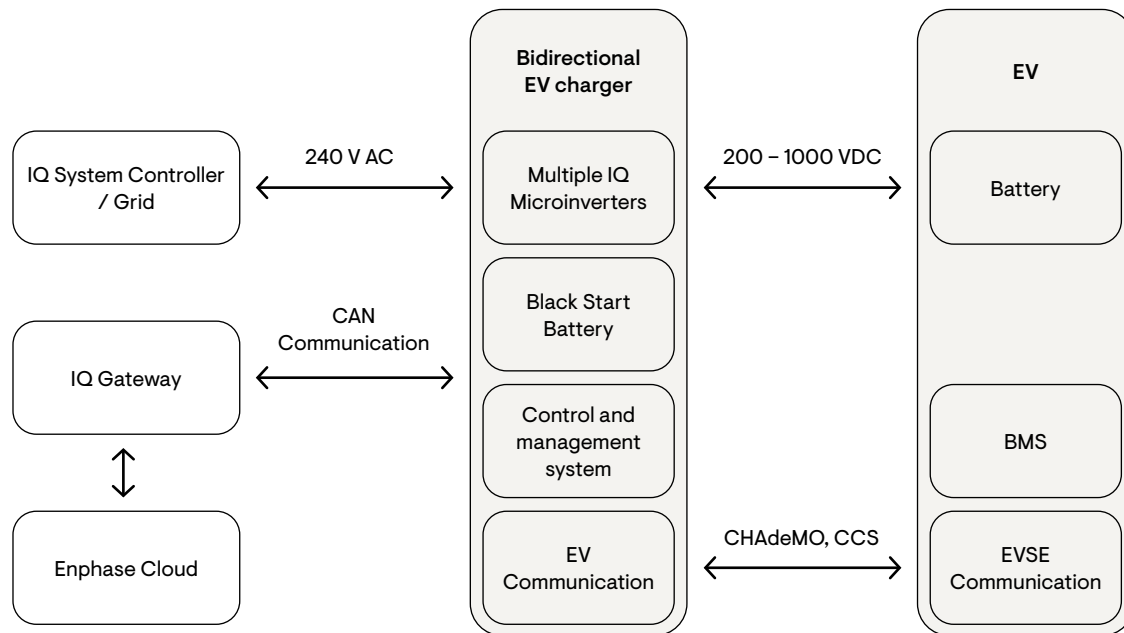


Figure 4: Bidirectional EV Charger interfaces

## Electrical interface

### Grid interface

Connects to 240 V AC. It can connect directly to the grid or through IQ System Controller. When connected directly to the grid, some V2H features are disabled.

### EV interface

Connects to the EV through standard (CCS and CHAdeMO) charging cable. At present, separate demonstration prototypes are made for CCS and CHAdeMO. It supports 200 VDC to 1000 VDC for EV batteries.

## Communication Interfaces

### EV communication

Supports CHAdeMO and CCS (ISO 15118 -2, -20) communication with the EV.

Communicates with Enphase IQ Gateway over CAN to exchange control parameters and manage energy flow.

Communicates with Enphase Cloud to exchange control, schedule and live information.

Homeowners and EV owners will be able to configure their Enphase Energy System and bidirectional charger using the Enphase App. During this process, they are presented with options to configure their grid tariff preferences and time-of-use information. They will set up limits for charging and discharging the EV and configurations for charging from grid, solar, charging schedules, etc.



# Modes of operation

## Vehicle-to-home charging (V2H)

In this mode, the home is provided with uninterrupted power from your EV during a grid outage.

### Case 1:

#### The EV is present and connected during a power outage

In this case, the IQ System Controller detects the grid outage and safely disconnects the home from the grid. The bidirectional EV charger, instantly switches from charging the EV to discharging the EV and begins supporting the home's power needs. The EV battery becomes a source of energy, and IQ Microinverters in the bidirectional EV charger convert this energy into usable power and establish a microgrid.

### Case 2:

#### The EV is not present or connected during a power outage

Due to the absence of a connected power source, the home will lose power. The IQ System Controller still detects the grid outage and safely disconnects the home from the grid. Now, when the EV is connected, the bidirectional EV charger establishes communication with the EV (bidirectional charger has a small black start battery to establish communication) and begins discharging the EV. The EV battery becomes a source of energy, and IQ Microinverters in the bidirectional EV charger convert this energy into usable power and establish a microgrid. This restores power to the home.

When the grid is restored, the IQ System Controller checks for stability of the grid parameters (voltage, frequency, phase) and then instructs the IQ Microinverters to match the parameters of the microgrid to the grid. Once synchronized, the IQ System Controller safely connects the microgrid back to the grid.



Figure 5: On-grid status in Enphase App



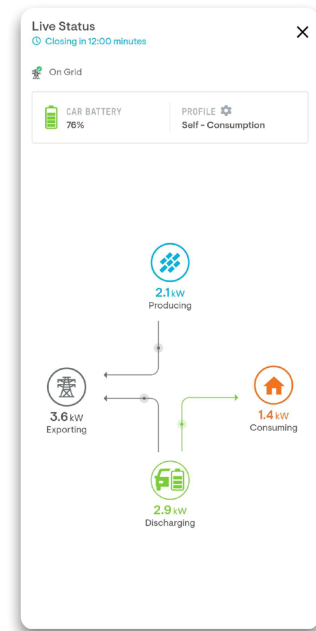
Figure 6: Off-grid status in Enphase App

## Vehicle-to-grid charging (V2G)

In this mode, the Enphase Bidirectional EV Charger enables the EV to participate in grid services programs. This means that when the utility sends a signal to homeowners requesting power, the Enphase Energy System will automatically send energy from the EV battery to the grid.

Enphase has been participating in grid services programs using its IQ Battery. Since the Enphase Bidirectional EV Charger is an extension of the IQ Battery architecture and platform, these capabilities are inherited. The Enphase App lets users configure the power and energy limits that can be exported from the home. Shown below is the sequence of events that occurs when a grid service request arrives from the utility:

1. The Enphase Cloud receives a message from the utility requesting power.
2. The Enphase Cloud checks the participating homes in the requested geolocation.
3. The Enphase Cloud sends a request to the Enphase Energy System and notifies the homeowner.
4. The Enphase Energy System instructs the bidirectional EV charger to produce power to support the grid.



**Figure 7: Exporting energy from EV Battery**

# Other features of the bidirectional EV charger

The Enphase Energy System can be configured to operate in the following modes:

## Green Charging

In this mode, the Enphase Energy System is configured to charge the EV only if there is excess solar power available. Solar power generated by the home is first consumed by the home loads. If power generation is more than the home load, the Enphase Energy System instructs the bidirectional charger to utilize the available extra power to charge the EV.

## Savings Mode

In this mode, the Enphase Energy System is configured with the grid tariff and time-of-use information. The EV is charged from the grid when the tariff is low. When the tariff is high, the EV is discharged to support home's energy needs and reduce import from the grid, thereby minimizing the energy bill.

## Self-Consumption

In this mode, the Enphase Energy System tries to minimize the power import from the grid. When excess solar power is available, it is used to charge the EV. If solar power is less than the home's power requirement, the EV is discharged to make up the deficit. The Enphase Energy System ensures that no energy is exported back to the grid.

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## Standalone Operation

The Enphase Bidirectional EV Charger extracts maximum value and features when integrated with the Enphase Energy System. However, it is also designed to operate independently. When operating standalone, it supports V2G and Savings mode. V2H needs the IQ System Controller. Green charging and self-consumption need solar systems.



Figure 8: EV battery charging only from Solar



Figure 9: Net-zero import from grid. Managing home loads through solar and EV battery

# Challenges and solutions of V2H and V2G charging technology

The Enphase solution to bidirectional charging is unique in that it addresses a broad range of operating modes including V2H, V2G, and green charging.

## EV communication technology

There are multiple charging communication protocols supported by different EVs. The main ones supporting bidirectional charging are CHAdeMO and ISO 15118-20. Test and conformance standards continue to evolve in this new and exciting field.

The Enphase Bidirectional EV Charger will support multiple communication protocols to cover the majority of vehicles that support bidirectional charging.

## Grid interaction for bidirectional energy flow from EV

A bidirectional EV charger needs to regulate the power and electrical parameters when discharging energy back into the grid. Unidirectional charging of EVs is well understood and has established standards. Bidirectional charging on the other hand is nascent and new standards are under development. UL9741 is at a proposed stage, which is trying to unify requirements from UL1741 and IEEE1547 for bidirectional EV chargers.

Enphase has mastered the art of producing power using microinverters in different grids while meeting the relevant grid and safety standards. Enphase is actively involved in developing codes and standards for our industry, allowing us to anticipate changes and design products accordingly.

## Integration with home electrical system

When a bidirectional charger is integrated with a home's electrical system, there is a need for operational safety in different grid conditions (e.g., on-grid and off-grid modes). When supplying energy back to the home (V2H) a bidirectional charger needs to disconnect the home from the grid during a grid outage. It is not enough to just produce power to the home without a full energy management solution.

The Enphase Energy System is a complete solution that manages the safety aspects of how electric power is exchanged over the AC lines for the home, in addition to controlling the energy flow to optimize generation and consumption for the homeowner.

# Summary

The Enphase Bidirectional EV Charger is the next step on our roadmap to building a solar-powered, all-in-one home energy system that further unlocks electrification, stabilizes the grid, increases resilience and savings, and gives control to homeowners. By leveraging our innovative technology platform we have solved the major technical challenges for bidirectional charging. Enphase is working with EV manufacturers to bring this revolutionary technology to market. For more information, please visit the Enphase Bidirectional EV Charger [website](#).

