Harnessing the Power of Electric Vehicles

July 24, 2025

Vehicle-grid integration (VGI) is the practice of intentionally integrating EVs with the electric grid to maximize the use of renewable energy resources, increase efficient use of grid infrastructure, and avoid otherwise necessary grid upgrades—and to benefit the driver participant.

VGI takes two primary forms

- (unidirectional) managed charging (V1G)
- bidirectional managed charging (V2G)

VGI Terms Definitions

VGI Terms	Details
Managed charging	The management of when, how, or where EVs are charged
Grid-parallel, exporting bidirectional charging	The management of when, how, or where EVs are charged and discharged back to the grid
Grid-parallel, nonexporting bidirectional charging	Powering a home or business with an EV battery while connected to the grid
Islanded bidirectional charging	Powering a home or business with only an EV battery while disconnected from the grid
Vehicle-to-load	Powering a device with an EV battery via an outlet in an EV or a connector at the charging port

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We set out to answer three key research questions:

1. To what extent do varying levels and types of VGI reduce the need for additional grid infrastructure and its associated costs?

2. What incremental system benefits does electricity discharge from EVs provide over managed charging alone?

3. How much must vehicle batteries be used to provide the benefits of battery discharge to the grid?

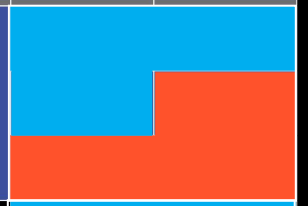
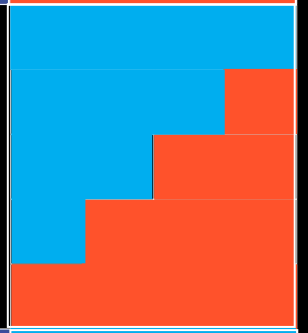
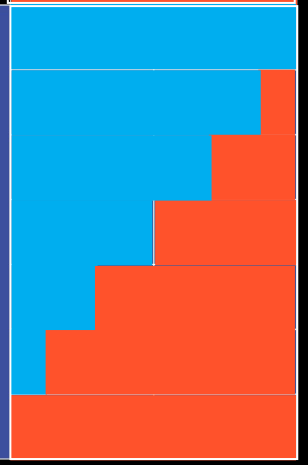
VGI Enrollment Scenarios (Level 2 Charging)

Scenario	Scenario Group
1	Low Enrollment
2	
3	
4	Medium Enrollment
5	
6	
7	
8	
9	High Enrollment
10	
11	
12	
13	
14	
15	

VGI Enrollment Scenarios (Level 2 Charging)

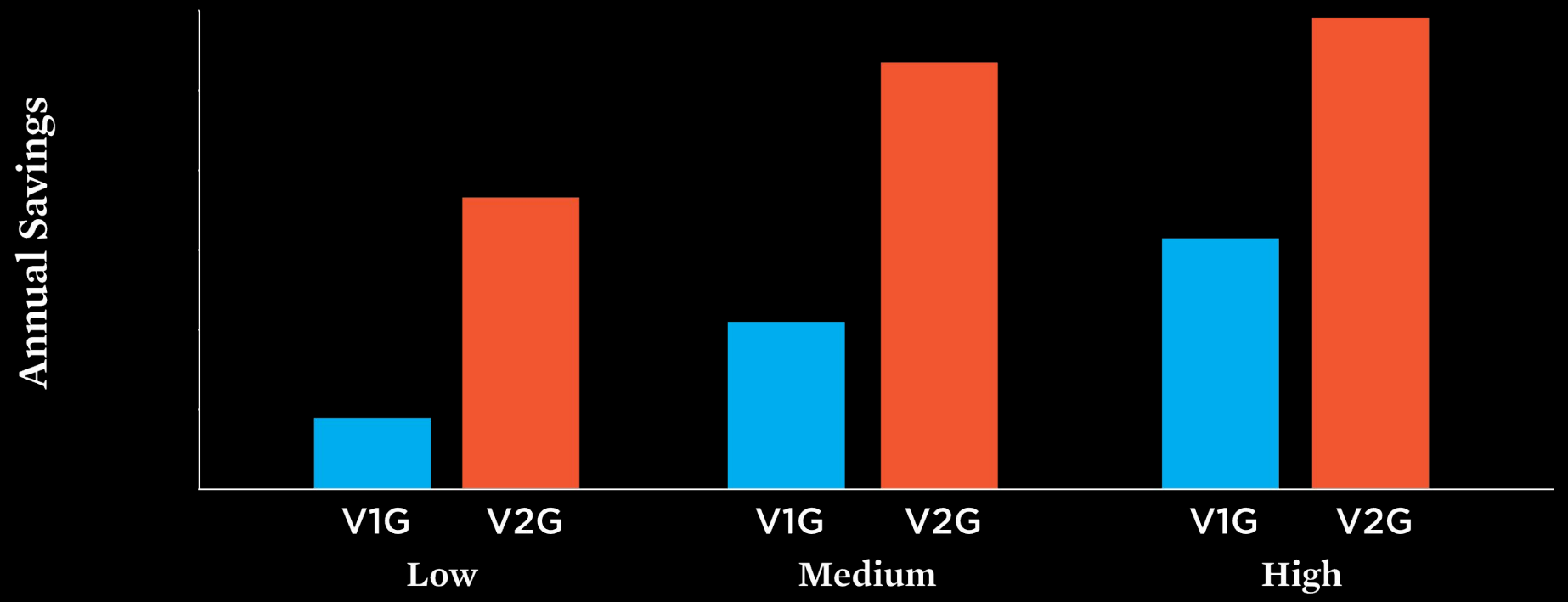
Scenario	Scenario Group	V1G	V2G
1	Low Enrollment	20.0%	0.0%
2		10.0%	10.0%
3		0.0%	20.0%
4	Medium Enrollment	50.0%	0.0%
5		37.5%	12.5%
6		25.0%	25.0%
7		12.5%	37.5%
8		0.0%	50.0%
9	High Enrollment	80.0%	0.0%
10		66.7%	13.3%
11		53.3%	26.7%
12		40.0%	40.0%
13		26.7%	53.3%
14		13.3%	66.7%
15		0.0%	80.0%

VGI Enrollment Scenarios (Level 2 Charging)

Scenario	Scenario Group	V1G	V2G
1	Low Enrollment		
2			
3			
4	Medium Enrollment		
5			
6			
7			
8			
9	High Enrollment		
10			
11			
12			
13			
14			
15			

V2G can produce 2-4 times the savings of V1G alone.

California Electricity System Savings from V1G vs. V2G for Each Scenario Group in 2045



VGI Enrollment Scenarios (Level 2 Charging)

Scenario	Scenario Group	V1G	V2G
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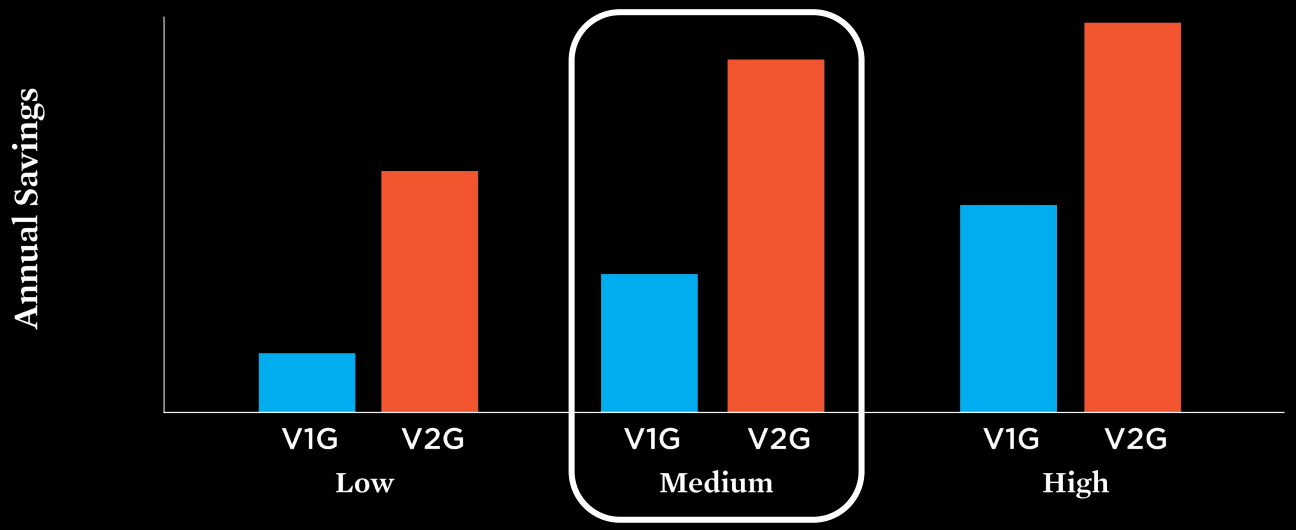
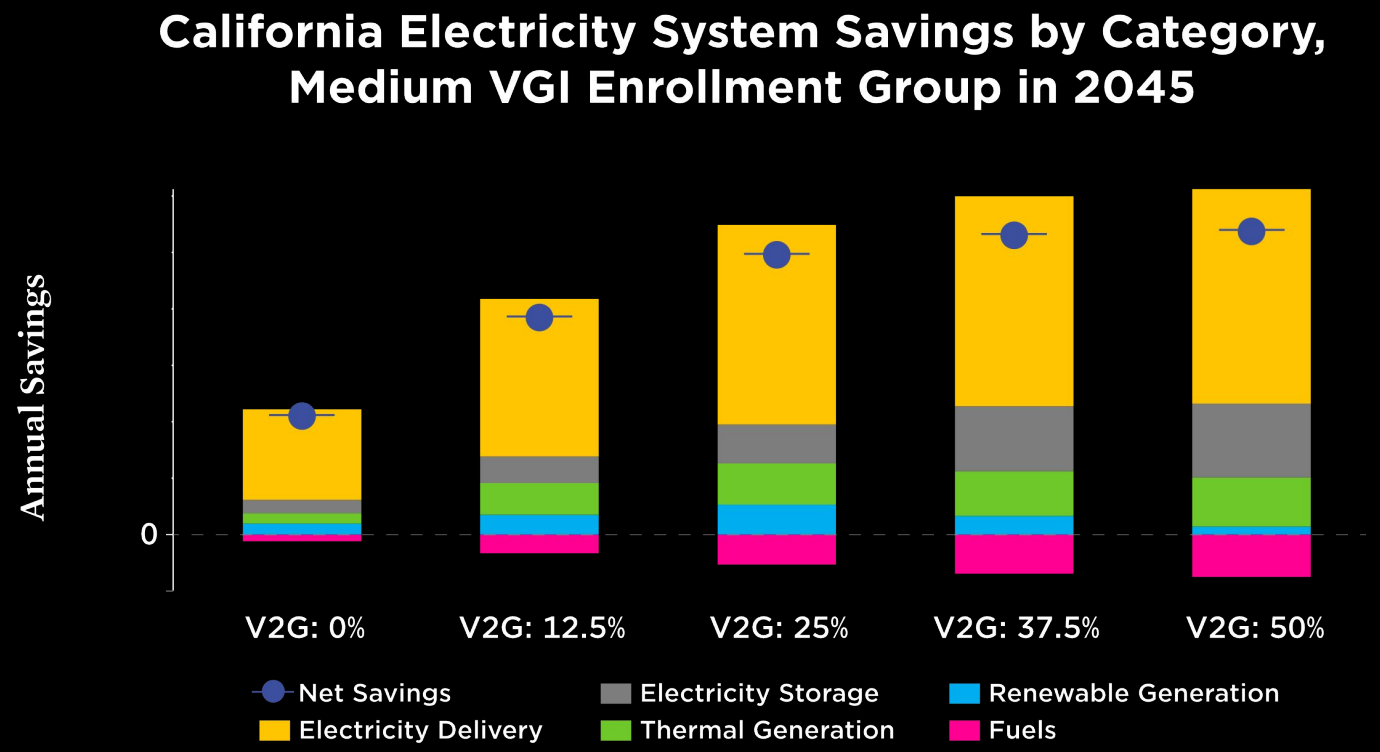


VGI can promote long-term grid cost containment

- VGI reduces peak demand to reduce the cost of delivering electricity (yellow bars), with most delivery savings coming from the distribution system.
- VGI matches charging demand to variable renewable energy generation, reducing the build-out of thermal generation (green bars) and storage (gray bars).



Recommendations

- **Prepare the electricity system and plan on VGI:** communication protocols, tech for visibility into grid conditions, EVs as distributed resources in planning
- **Establish systems for efficient interconnection:** increase the efficiency and throughput of the interconnection queue
- **Support and incentivize drivers:** support for upfront cost of VGI equipment, increase number and variety of V1G and V2G programs
- **Require bidirectional charging capability in vehicles**
- **Update battery warranty protections to cover discharging**

{ Thank You

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https://www.ucs.org/resources/harnessing-power-electric-vehicles

Union of Concerned Scientists

Additional Slides

Vehicle-Grid Integration Arrangements

Feature	V1G	V2G
Charge an EV on the grid	✓	✓
Discharge an EV to the grid		✓
Discharge an EV to a home while grid-connected		✓
Set a schedule and other charging preferences	✓	✓
Set preferences and constraints for discharging		✓
Support efficient grid operation	✓	✓
Support the grid during extreme events	✓	✓
Reduce grid upgrade costs	✓	✓
Reduce participant's electricity bill	✓	✓
Key benefits	Adjust charging to increase grid efficiency and save money	Use an EV as a grid-connected battery and save money