



Vehicle - Grid Integration Initiative

April 12, 2019



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GRIDWORKS

Thank you to our hosts!



ENERGY FOUNDATION

Agenda

10:00 - 10:20 - Introduction

10:20 - 11:00 - VGI Definition Exercise

11:00- 12:00 - VGI Market Potential (Eric Cutter, E3)

12:00 - 12:30 - Lunch

Lunch provided by Gridworks

12:30 - 1:15 - VGI Use-Case Valuation (Karim Farhat, PG&E)

1:15 - 1:30 - Use-Case Evaluation Examples (Adam Langton, BMW)

1:30- 1:45 - Break

1:45 - 2:45 - Methodology Discussion

Capture feedback on PG&E's use-case evaluation method

Identify the group's principles/priorities for use-case evaluation methods

2:45 - 3:00 Wrap Up and Next Steps

Next meeting date/time

Action items

3:00 – 5:00 – Networking and Community Building

Location: Bar 333 (333 Battery Street, next door to workshop location)

Recap March VGI Meeting

What we did:

- *Got acquainted*
- *Discussed scope and schedule*
- *Reviewed interview and literature review results*
- *Strategized next steps*

What we agreed to:

- *We will work together*
- *Pursue a method for use case evaluation*
- *Meet again April 12 and beyond to address CPUC questions*

Initiative Scope:

Initiative Objectives:

- 1. Identify and assess opportunities in which VGI can create value from multiple market participants' perspectives*
- 2. Identify regulatory, labor, or industry market barriers to realizing VGI value creation, and*
- 3. Provide recommendations on the market or policy actions needed.*

Initiative Scope:

Address the CPUC's Questions:

- *What VGI use cases can provide value now, and how can that value be captured*
- *What policies need to be changed or adopted to allow additional use cases to be deployed in the future?*
- *How does the value of VGI use cases compare to other storage or DER?*

Initiative Scope:

Out of Scope

- *Communication standards and protocols*
- *Recommendations on transportation electrification beyond VGI (e.g., new infrastructure investment proposals)*
- *Other?*

Initiative Scope:

Timeline:

- *March - June: Preparing for the CPUC's Working Group*
 - *Scope the work needed to answer the PUC's questions*
 - *Develop an approach to completing that work*
 - *Identifying what further information we need and start gathering*
 - *Finalize Framing Document*
 - *Build community*
- *July - ?:*
 - *Execute steps needed to answer PUC's questions*

Beyond VGI

- *Rule 21 Working Group Update*
- *CEC DER Research Roadmap Update*
- *Others?*

VGI Definition Exercise

“the many ways in which a vehicle can provide benefits or services to the grid, to society, the EV driver, or parking lot site host by optimizing plug-in electric vehicle (PEV) interaction with the electrical grid.”[1]

[1] “VGI Glossary of Terms” California Public Utilities Commission. <http://www.cpuc.ca.gov/vgi/>

VGI Definition Exercise

VGI includes:

- *active management of electricity (e.g., bi-directional management, such as vehicle-to-grid power flow [also known as V2G]);*
- *unidirectional management such as managed charging [also known as V1G]) and/or active management of charging levels by ramping up or down charging; and*
- *passive solutions such as customer response to existing rates, design of improved utility rates (e.g. time-of-use (TOU) charges, demand charges and customer fees), design of the grid to accommodate EVs while reducing grid impacts to the degree possible, and education or incentives to encourage charging technology or charging level (e.g. rebates for lower level charging, modifying current allowance policy).*



VGI Market Potential (Eric Cutter, E3)



Energy+Environmental Economics

California Framework for Grid Value of Vehicle Grid Integration (VGI)

Presentation to VGI Working Group

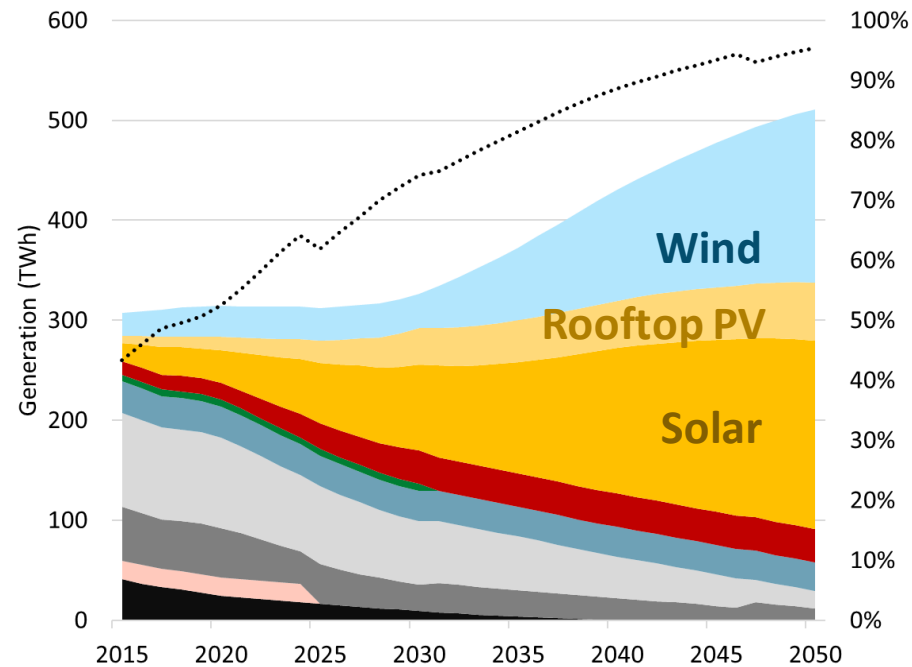
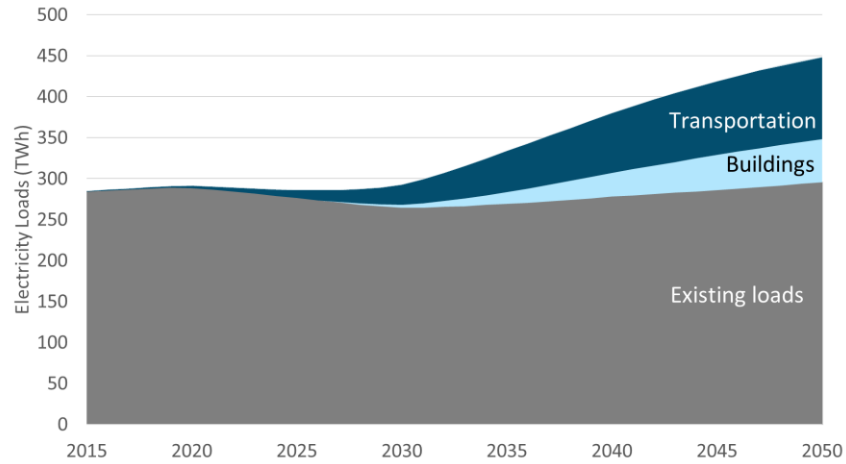
April 12, 2019

Eric Cutter
Brian Conlon
Oliver Garnett
Jun Zhang
Nancy Ryan



VGI is crucial for low carbon pathways

California PATHWAYS
High Electrification with No Hydrogen Scenario



Transportation is first, new flexible load in pathways portfolio...



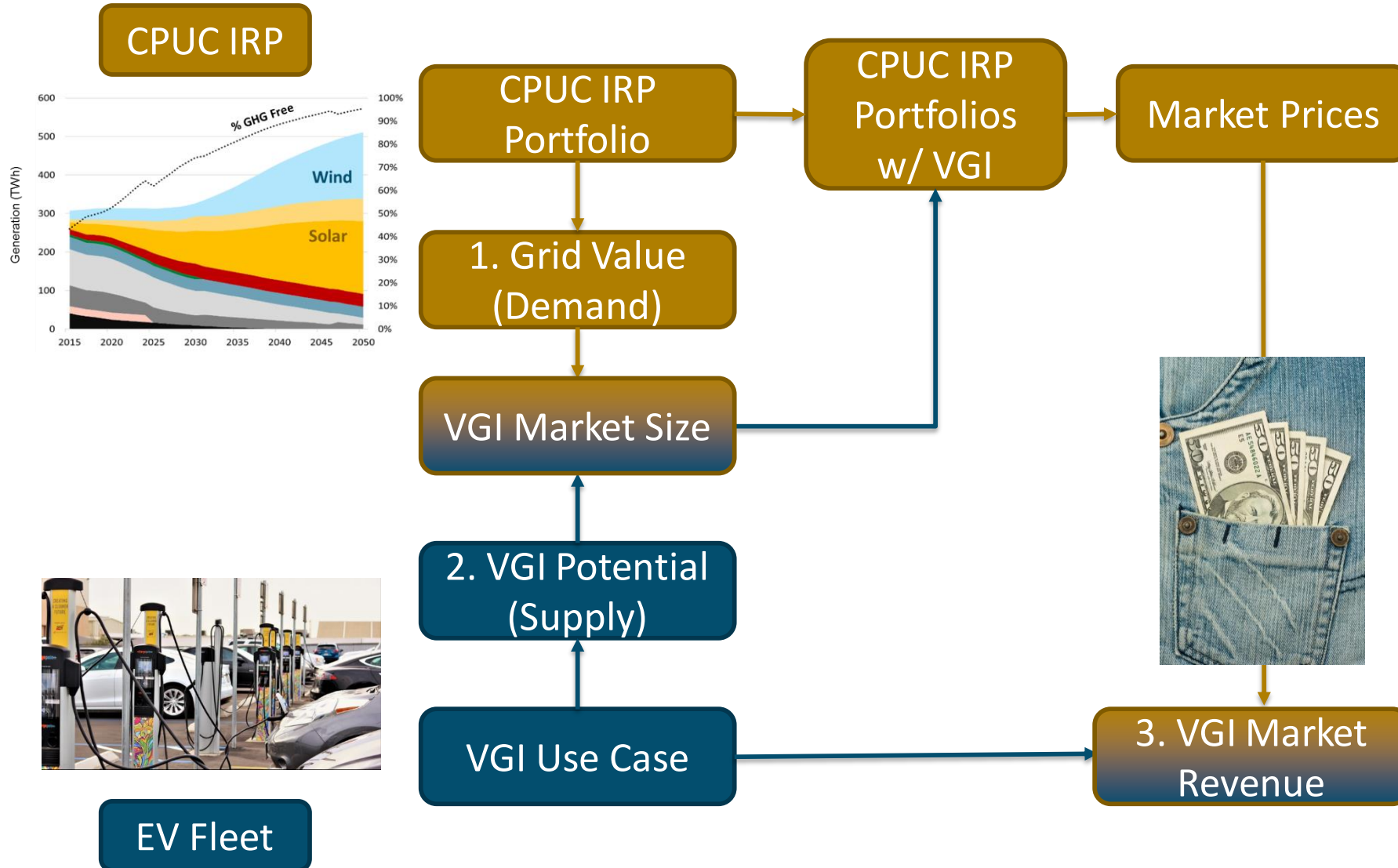
...establishing business models for flexible building loads to follow...



...enabling increase in low carbon electricity



California VGI Grid Value Framework





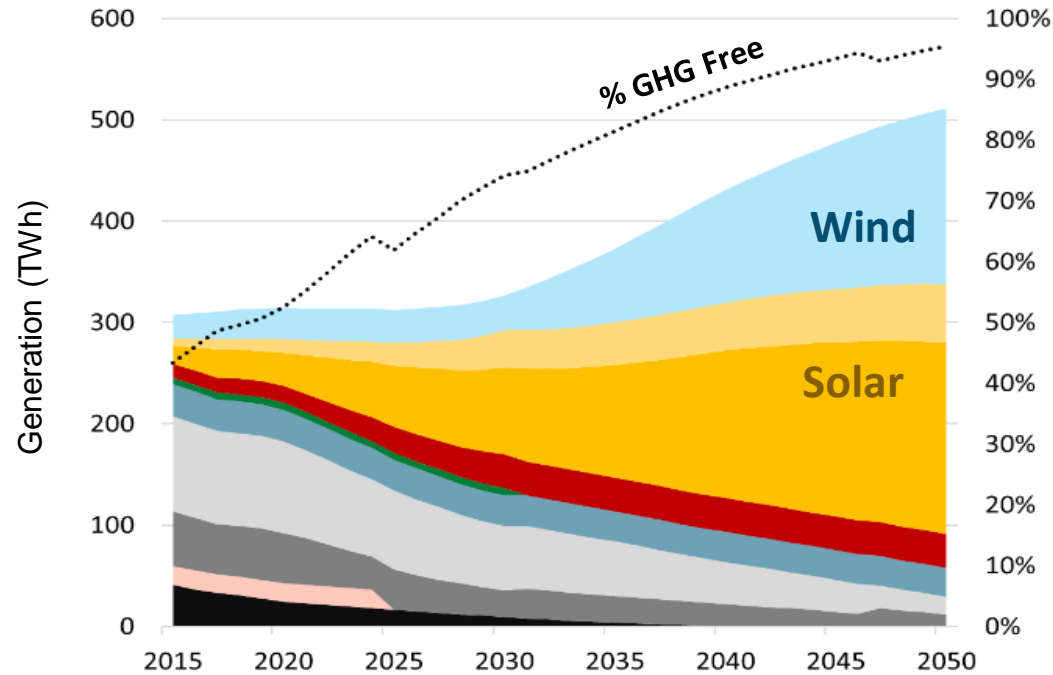
1. Grid Value (Demand)



Start with CPUC Integrated Resource Plan

California PATHWAYS
High Electrification with No Hydrogen Scenario

Least-Cost Planning Scenarios to meet GHG target



Utility Scale Solar



Energy Storage

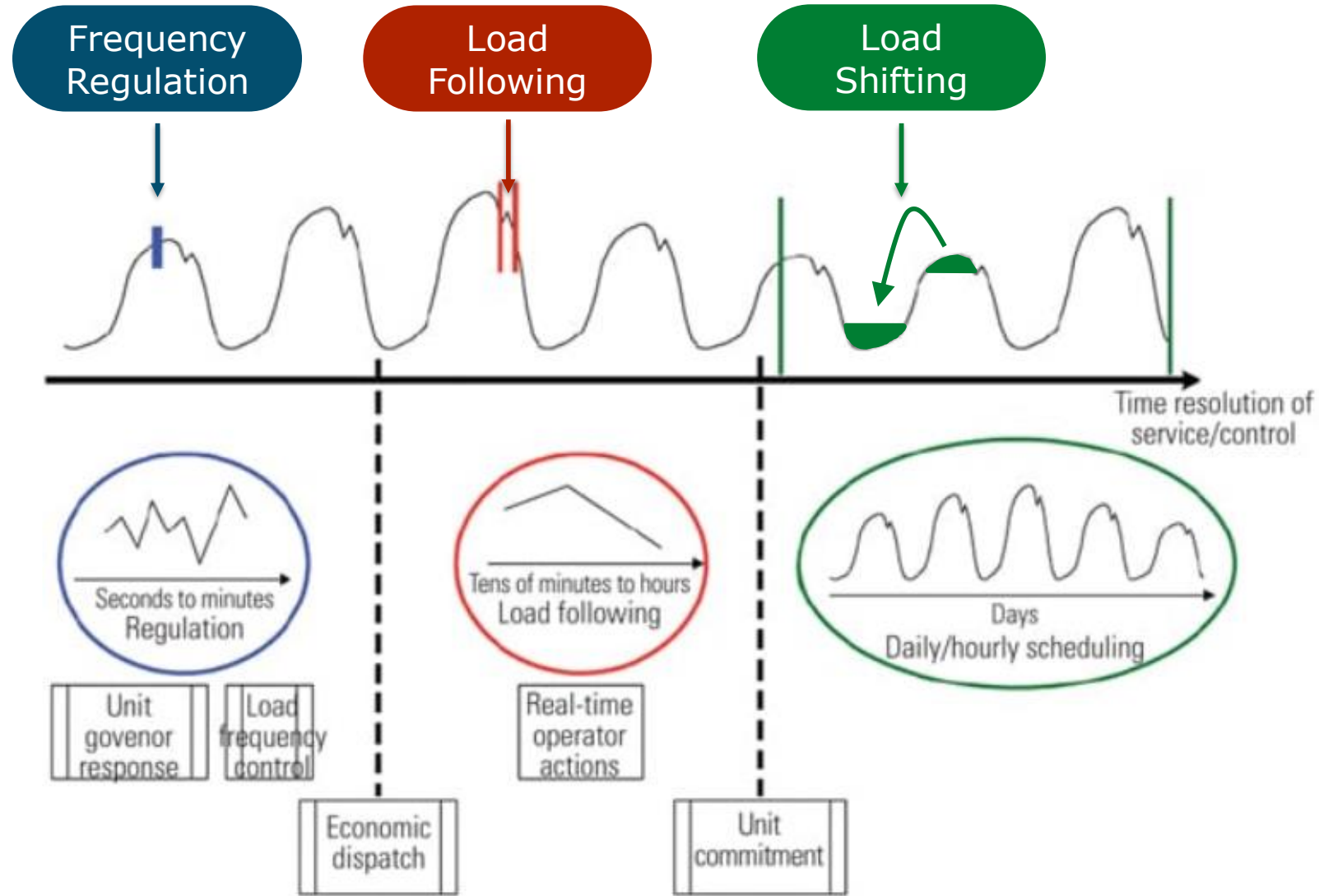


Regionalization and EIM

Baseline System Cost (2016 \$M)	Baseline Storage Build (MW)	Baseline Curtailment (%)
\$5,332	2,679	5.4%



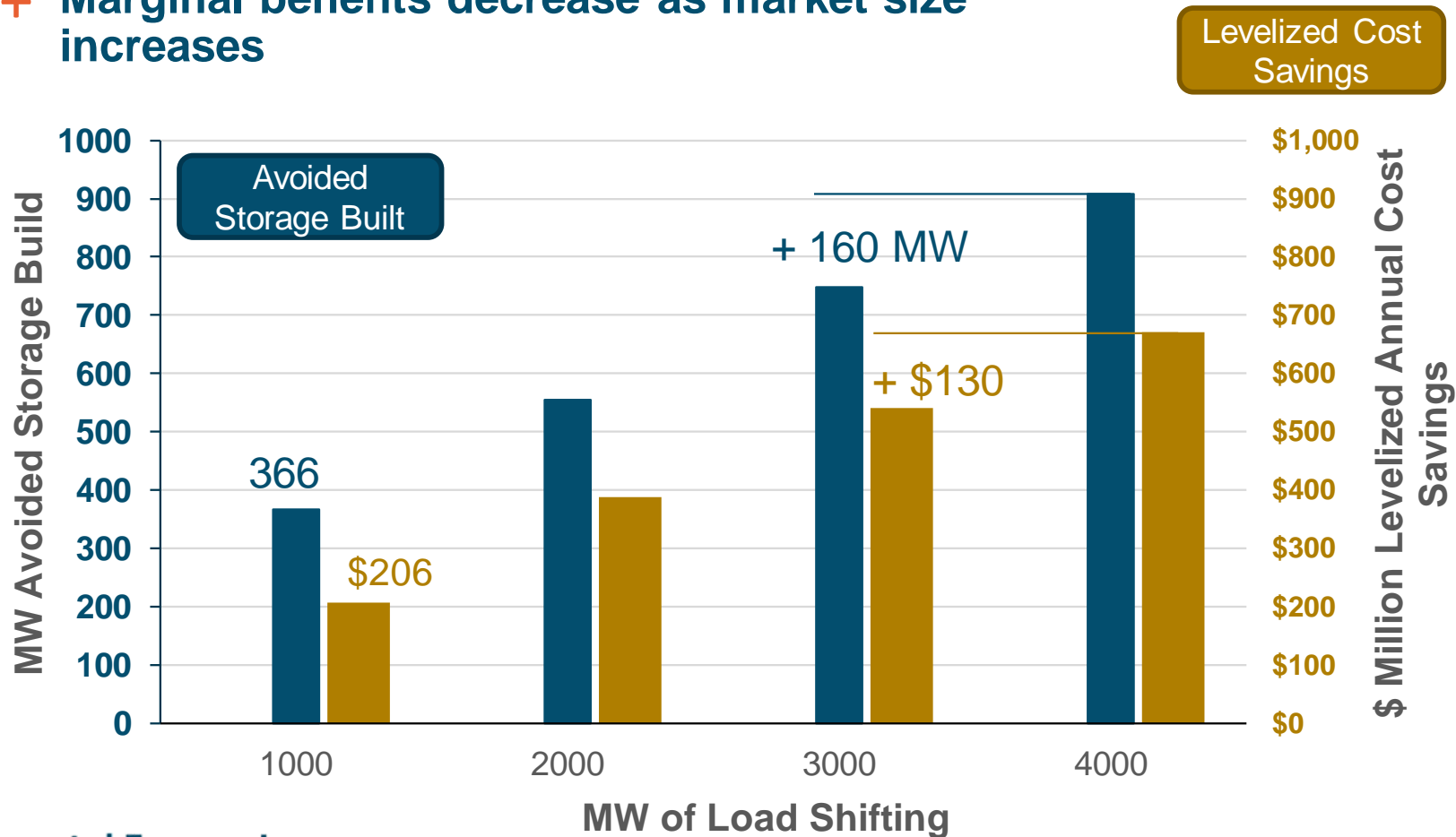
Three Illustrative VGI Grid Services





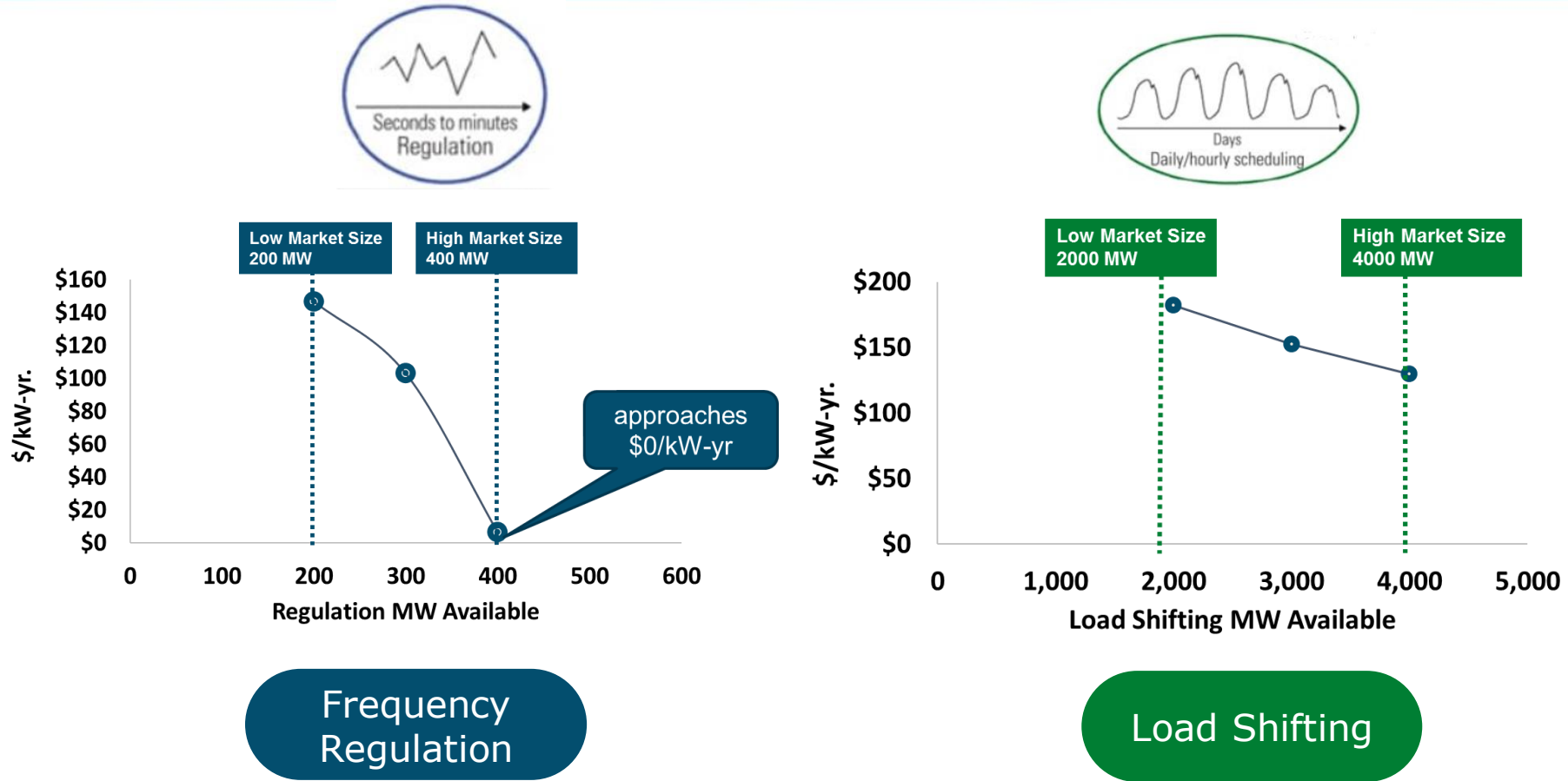
Grid Benefits (Load Shifting)

- + Load shifting reduces both grid capital investment and operating costs by reducing the amount of storage built, and PV curtailment
- + Marginal benefits decrease as market size increases





Declining Marginal Value with Increasing Supply



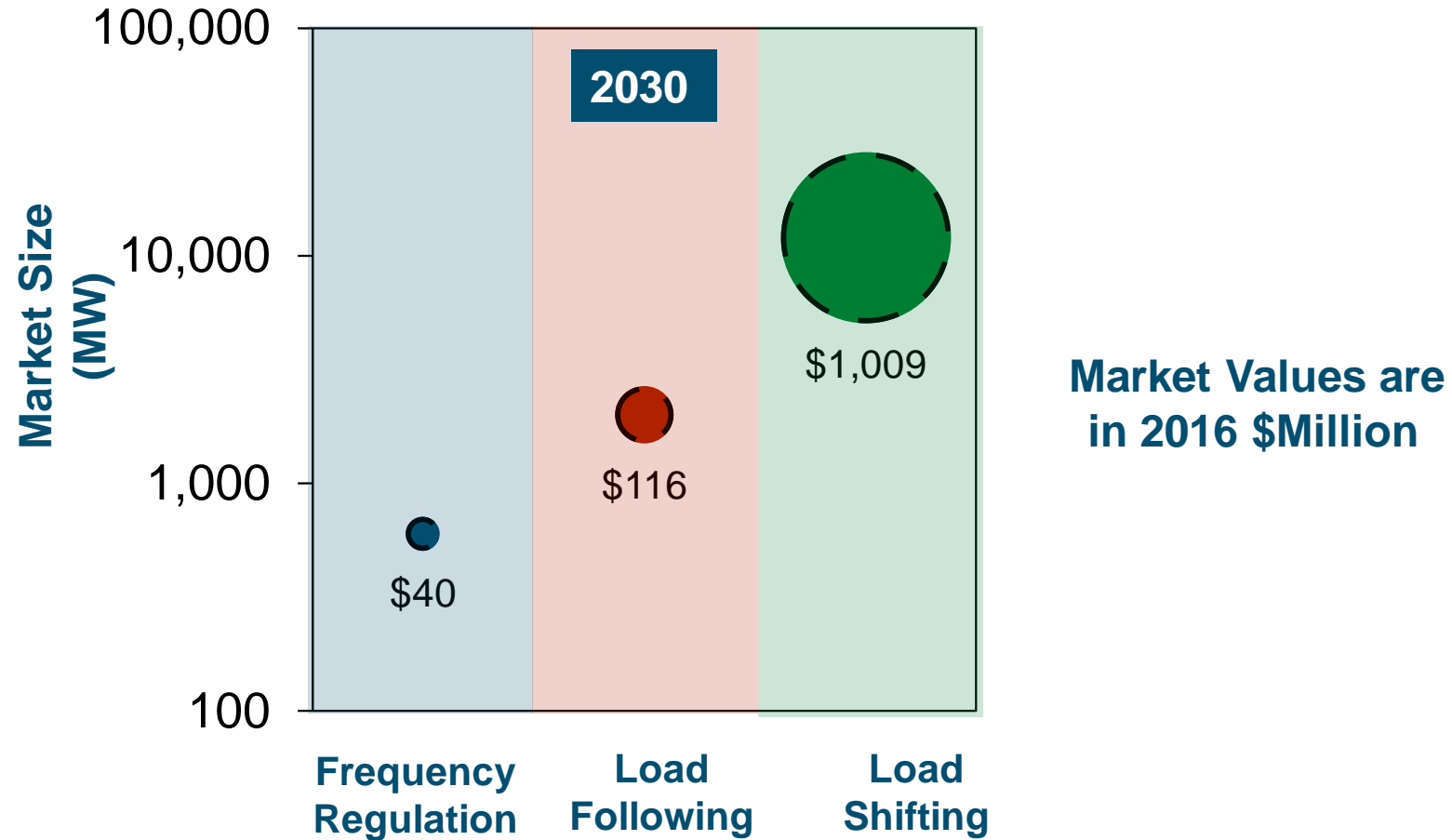
- + Small market for Frequency Regulation is easily saturated
- + Larger market for Load Shifting

2018 42MMT Case in 2016 \$/kW-yr. (CA 2018-2030 levelized value)



CA VGI Market Estimation Results

+ Load shifting has highest market size and value potential



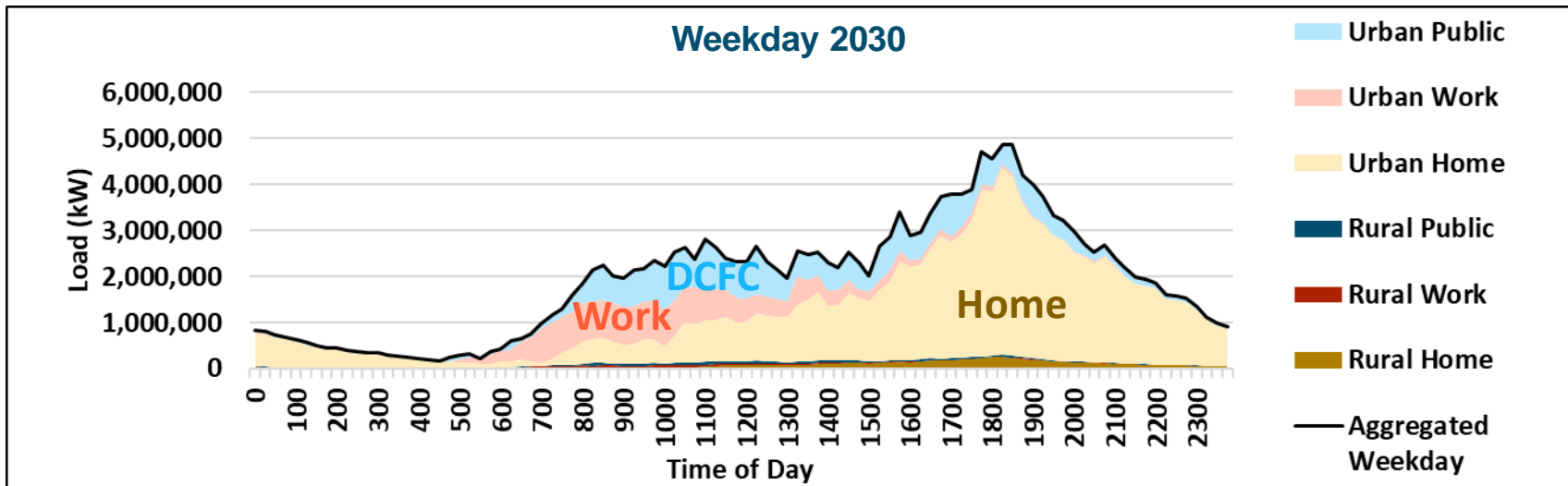
2018 42MMT Case in 2016 \$/kW-yr. (CA 2018-2030 levelized value)



2. VGI Potential (Supply)



Unmanaged EV Charging Load Shape Results – CA 2030



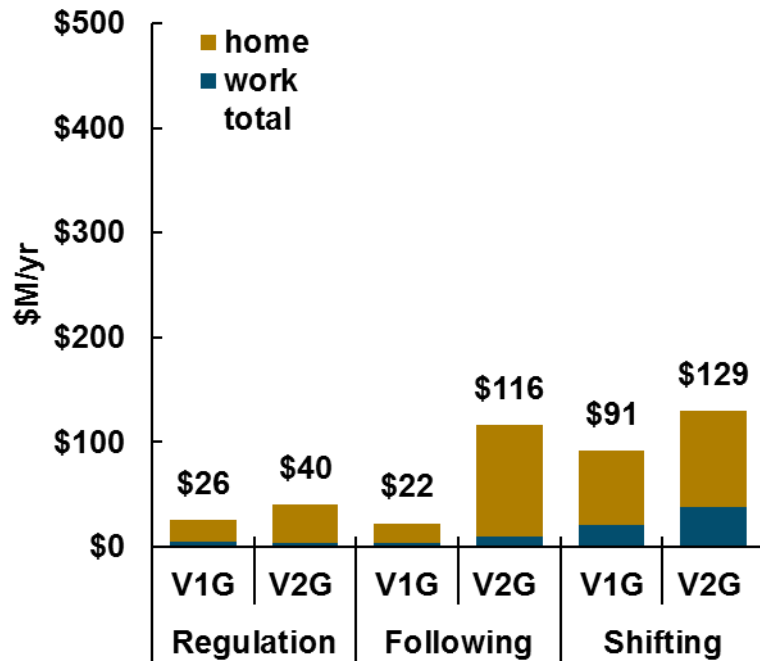
	Average hourly load (GW)	Peak load (GW)	Total Energy (GWh)
Home	1.3	4.3	30.2
Work	0.3	0.9	6.5
Public	0.4	1.0	9.8
Combined	1.9	4.9	46.5

- + VGI potential from EV fleet
- + Based on vehicle types, charging level and location and driving patterns



VGI Market Results Summary (2030)

$$\text{Market Value (\$M)} = \text{Total Market Value (\$M)} \times \frac{\text{VGI Supply for EV (MW)}}{\text{Grid Demand for VGI (MW)}}$$



25% EV Participation

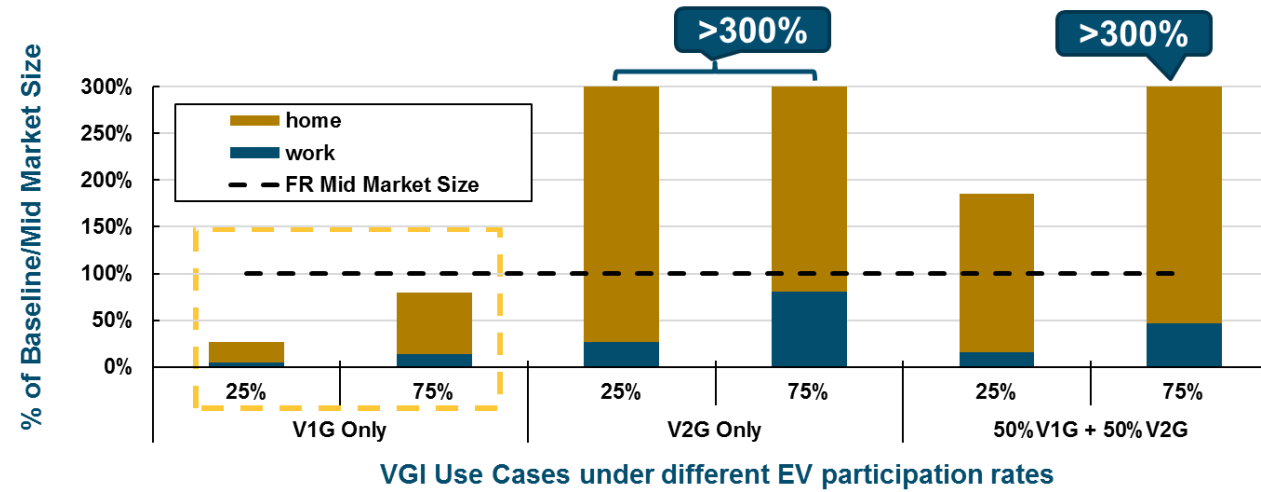
% Market Size	V1G	V2G
Regulation	64%	100%
Following	19%	100%
Shifting	9%	13%

+ With 25% EV participation and V2G capability Frequency Regulation and Load Following market is fully saturated by EVs alone

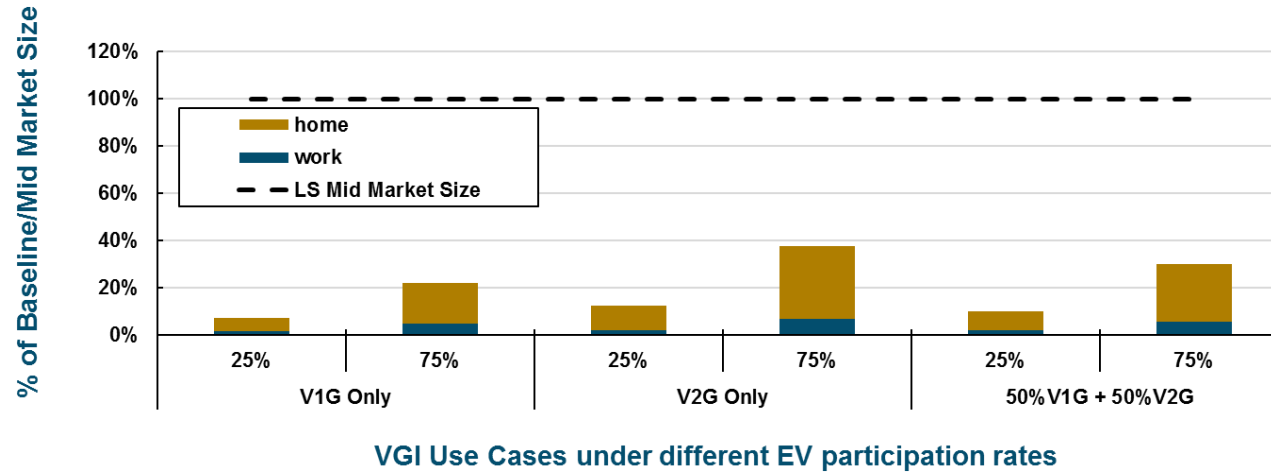


VGI saturates Frequency Regulation but not Load Shifting Market

Frequency Regulation



Load Shifting





3. VGI Market Revenues



Develop Market Prices from CPUC IRP Scenarios



Key Inputs From CPUC IRP Reference Scenarios

- 1 Load Forecast**
(Including Impact of Rooftop Solar, DG Storage, and EV Adoption)
- 2 Resource Buildout**
(To meet policy goals and reliability needs)
- 3 Transmission and Operational Changes**



Hourly Production Simulation and Long-Term Capacity Expansion



Hourly Production Simulation

- Wheeling costs and transactional friction between different zones
- Impacts and pricing from renewable curtailment
- Advanced hydro and storage representation
- Incorporate key energy policies and trends

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Other Major Drivers:

- Gas Prices
- Carbon Prices



Key Model Outputs

Energy Market Price Forecast

- Hourly day-ahead energy market results by scenario and zone



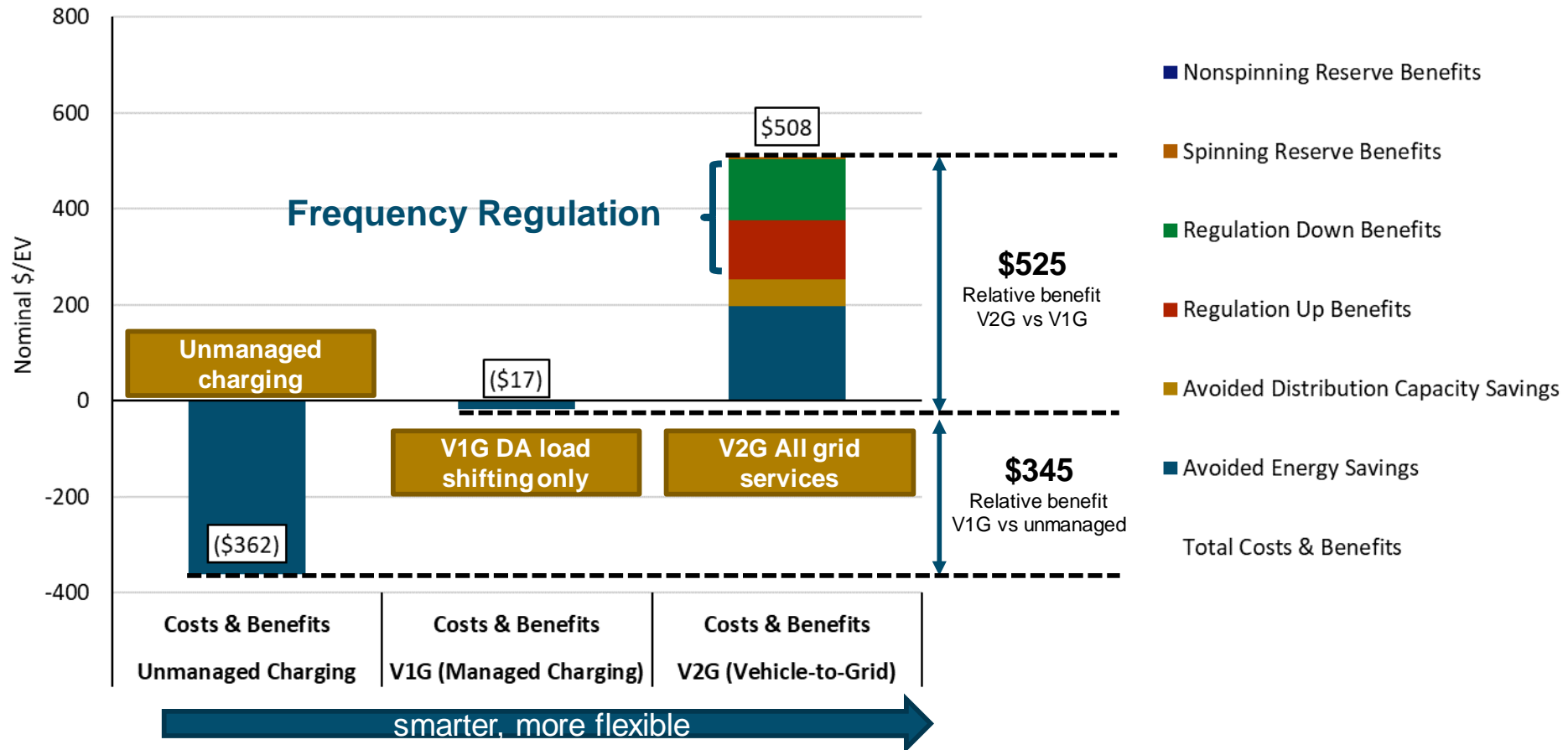
Derivative Outputs

Ancillary Services, Capacity, and Real-Time Energy Forecasts



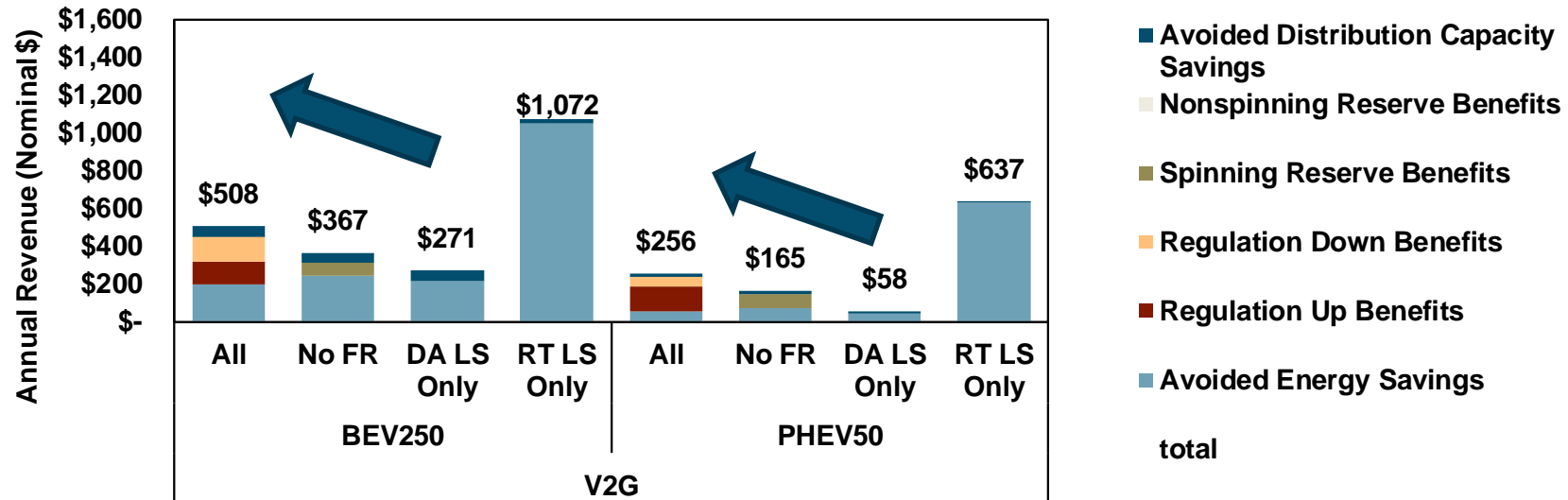
3. VGI Expected Revenue

- + BEV250 in 2025
- + Relative benefit of V2G versus unmanaged charging is \$870/EV-yr. (if Frequency Regulation prices remain high)





V2G Revenue for BEV250 and PHEV50



DA – Day Ahead Energy FR – Frequency Regulation
 RT – Real Time Energy LS – Load Shifting

- + Increasing revenue potential with additional market services
- + Potentially high revenues in real-time energy market, but harder to forecast and capture

Price taker, perfect foresight co-optimized dispatch with market prices derived from 2018 42MMT Case



Key Drivers



Key Drivers and Uncertainties

IRP

EV Fleet

Quantifiable with Scenario Analysis

- + Renewable penetration
- + Cost of PV & storage
- + Regionalization & EIM

- + EV Adoption & BEV ratio
- + Intra- vs. Inter-session VGI
- + Workplace charging

Fillable Knowledge Gaps

- + Distribution costs of high electrification

- + Driver participation and behavior

Known Unknowns

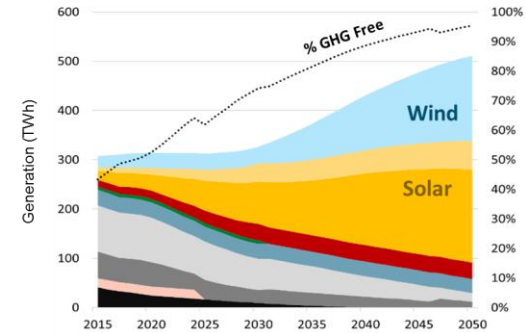
- + Grid Modernization

- + Automated & shared vehicles (3 Revolutions)



In Conclusion

- + Define key drivers that can be quantified with scenario/sensitivity analysis
- + Quantify grid value with CPUC IRP scenarios (Demand)
 - IRP will enhance representation of distributed resources and EVs in next cycle
- + Estimate resource potential from EV's providing VGI services (Supply)
- + Estimate market size for VGI services
- + Develop market price forecasts from CPUC IRP scenarios
- + Estimate revenues from VGI services





Lunch



VGI Use-Case Valuation (Karim Farhat, PG&E)



Use-Case Evaluation Examples (Adam Langton, BMW)

VGI FRAMEWORK

PRINCIPLES FOR APPROACHING IMPLEMENTATION



BMW Mountain View Technology Office April 2019



Focus on Outcomes, not Technologies

- Define the 'what', no dictate the 'how'
- Outcomes are defined as grid services provided (or their value)
- Use the process to foster innovation, not stifle it
- The only technology requirement should be the presence of an Electric Vehicle

Encourage innovation in business models and business relationships between stakeholders

- Create room for stakeholders to collaborate in new ways
- Competition between business models encourages efficiency
- Existing business models provide a good starting point, but should not be used to the exclusion of new approach/strategies

Avoid Assumptions about communication requirements

- Previous process got stuck in 'Standards Miasma'
- Define outcomes and functional requirements such that stakeholders can find the most efficient communication pathway
- Considering how existing communication pathways can enable existing entities to communicate is fine, but it should not exclude new entities and new communication standards from emerging
- Considering how existing stakeholders fit into the value chain is useful, so long as it doesn't restrict future innovation.

PRINCIPLES

Create an inclusive vision of future implementation, then prioritize best opportunities

- What appears valuable/effective today, may not be valuable 5-10 years from now
- Prepare for this by defining universe of use cases
- Non-prioritized activities could be used by CEC as a roadmap for future research

Market players will response when there is a clear path to monetization

- Process should define value for different services
- Process should test out a 'scaled pilot' phase to help learn where value is, in cases where the value isn't transparent.
- Process should lead to programs designed methodically based on proven value, regardless of popular opinion about whether the value is 'high enough or not'

Methodology discussion

- 1. Capture feedback on PG&E's method*
- 2. Identify principles/priorities for use case evaluation methods*



Wrapping Up

Next Steps

- Regroup in June
- Action items
- Other?



Thank you!