NREL
NATIONAL RENEWABLE ENERGY LABORATORY

PEV Integration with Renewables

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Overview

Timeline

- **Project Start Date: 10/1/2012**
- **Project End Date: 9/30/2014**
- **Percent Complete: 75%**

Budget

- **Total Project Funding: 470K**
  - DOE Share: $400K
  - Contractor Share: $70K (including in-kind)
- **Funding Received in FY13: $100K**
- **Funding for FY14: $300K**

Barriers

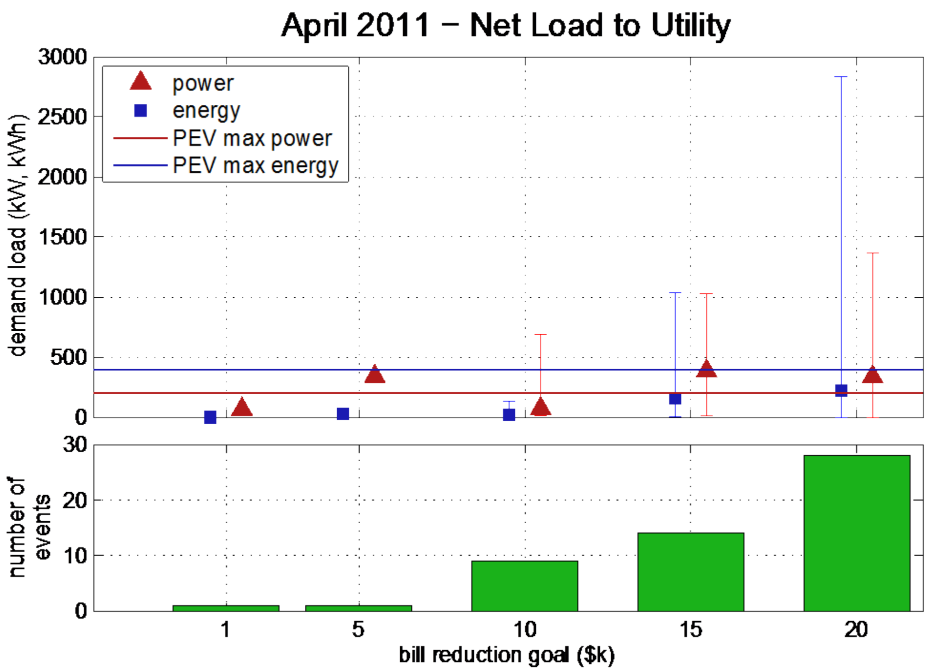
- **Barriers addressed**
  - Grid impacts of PEV adoption
  - Value opportunity for PEV grid integration
  - Interaction with Renewables

Partners

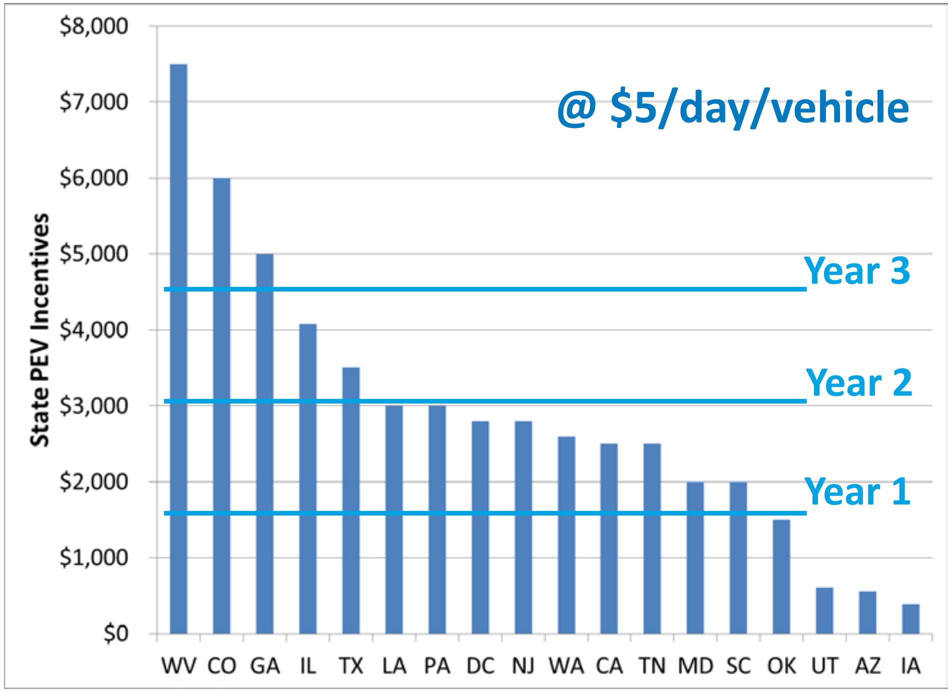
- GE Global Research
- Ideal Power Converters
- Project Lead: National Renewable Energy Laboratory (NREL)

Relevance – Additional Value to Enhance Marketability

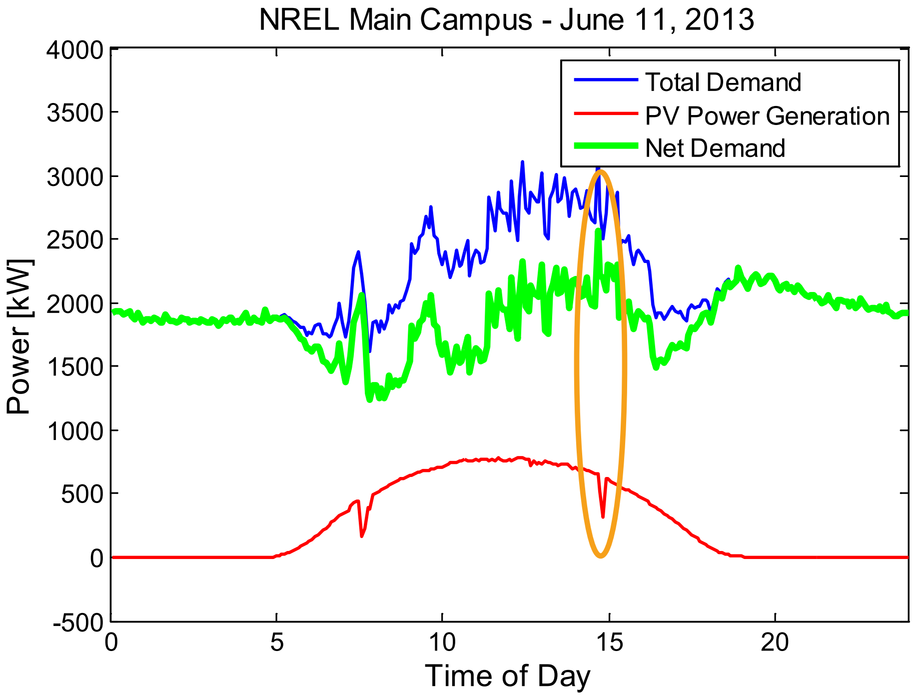
Specific Building Load Profile Analysis Gives Storage Attribute Requirements



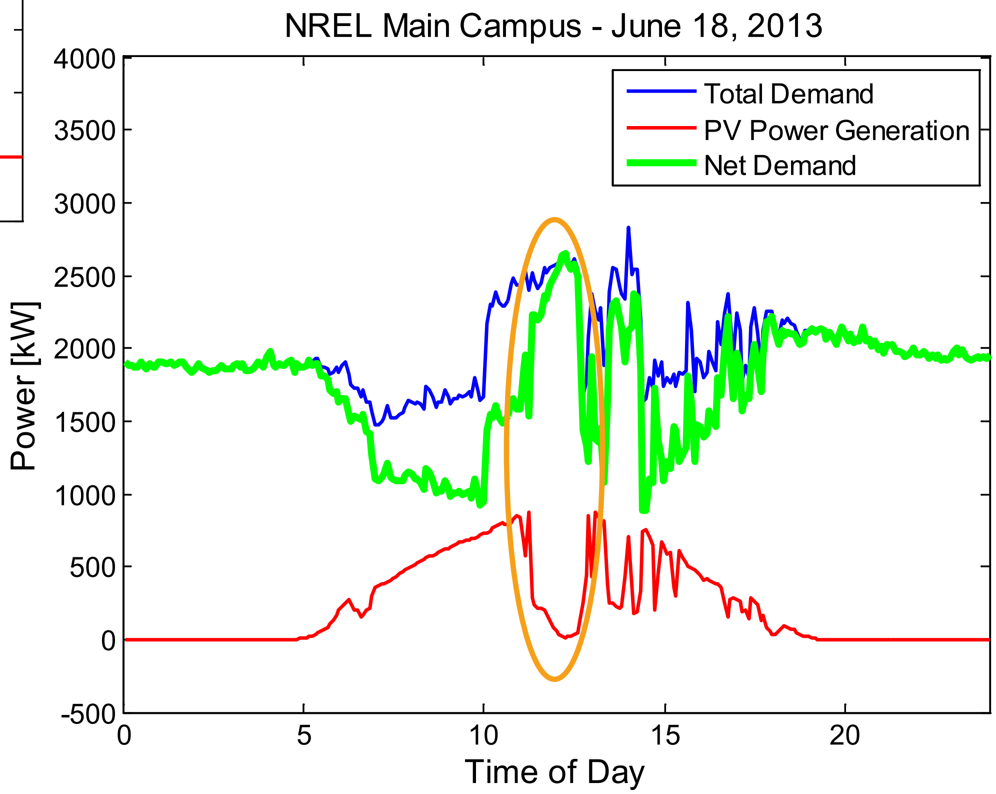
PEV Grid Services Provide Similar Value to Purchase Incentives



Relevance – Renewable Integration Impacts



- **In both cases net demand peaks during a solar dynamic event**

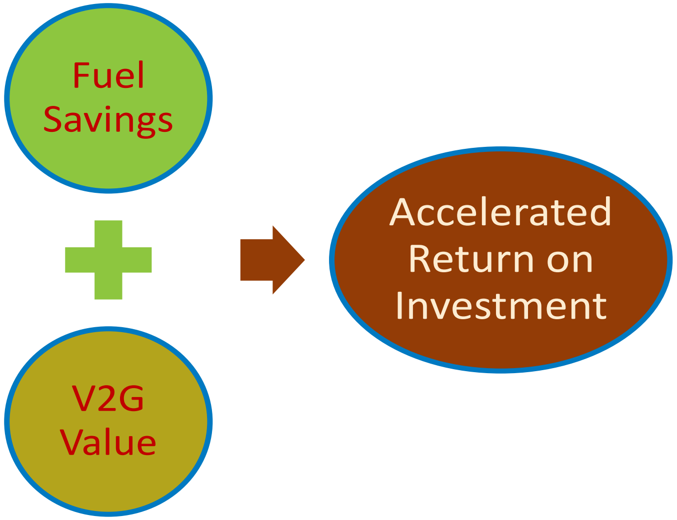


Milestones

Month / Year	Milestone or Go/No-Go Decision	Description	Status
9/2013	Report: "Communications and Integration of Fast Charging with Renewables Report Developed Offering Technology and Strategy Guidance"	• Highlighted the growing fast charge systems market in Japan • Showed the impact of solar system orientation on fast charge system costs • Tested a fast charge + storage integration scenario	100%
9/2014	Project reports covering value creation from vehicle integration with renewables	• Focus on how photovoltaics (PV) influences demand charges and how vehicles can contribute • Leverage solar inverter technology for vehicle export power integration	60%

Approach – Electric Vehicle Grid Integration Strategy

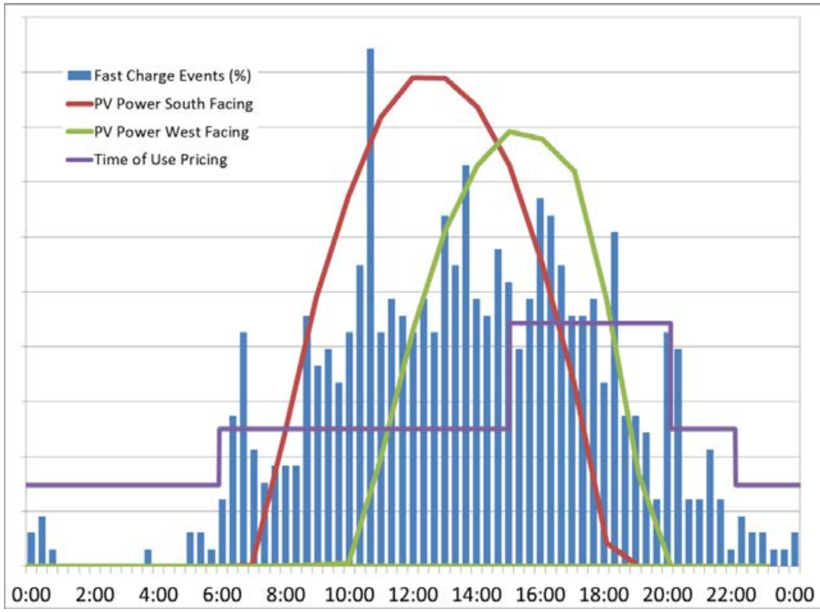
- **Objectives:**
  - Infrastructure planning supporting vehicle adoption
  - Operational benefit identification with V2x communications and powerflow
- **Integration Strategies**
  - Renewables and the Grid
    - Charging and discharging in sync with RE generation or grid ancillary services
  - Integration with Buildings and Campuses
    - Maximize use of local renewable generation
    - Minimize peak demand with charge management and export power functions
- **Why?**
  - Savings and revenue generation to complement fuel savings value
- **Challenges and Research**
  - Advancing communication between vehicles and load management tools
  - Understanding alignment of grid and building loads with vehicle utilization
  - Development of low-cost infrastructure options enabling V2G functions

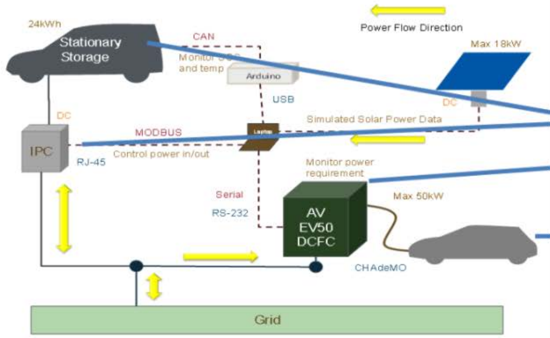


RE = renewable energy
V2G = vehicle to grid

FY13 Milestone Report Highlights

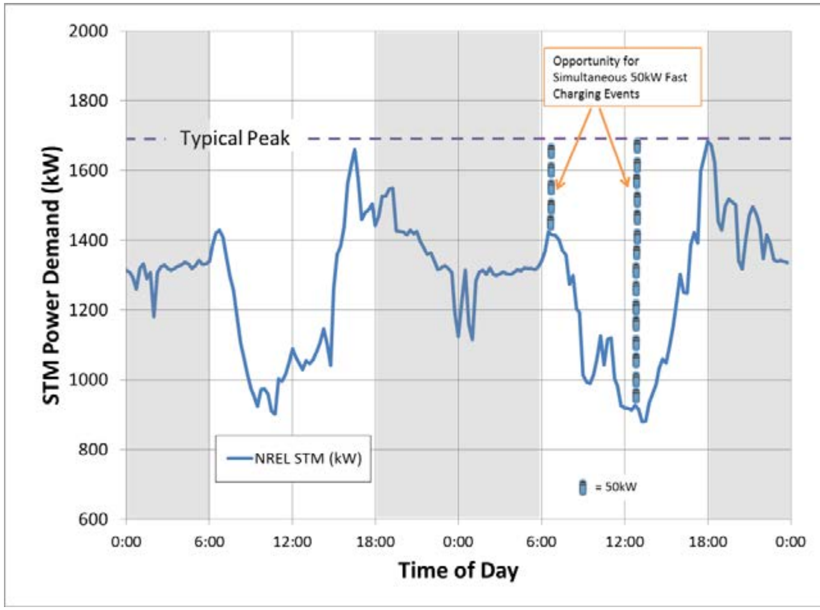
- Solar orientation should be considered with respect to fast charge usage and rate schedule
- Load reduction from solar offers opportunities for fast charge without demand charge
- Storage system control with respect to fast charge and renewables was tested in Vehicle Testing and Integration Facility (VTIF) lab





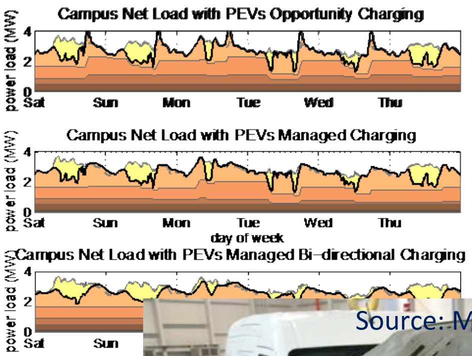
RIPD System Architecture

Testing System in VTIF



RIPD = Renewables Integration Platform Development

Laboratory Resources Applied to Tech Introduction



Scenario Simulation

Tech Development

System Confirmation

5x 60-kW Bi-directional Stations Integrated with Microgrid Operations

System expected to provide:

- ~2K–3K/mo of electricity cost reduction
- Improved RE microgrid integration

** Office of Electricity Funded over 3 yrs

Leveraging Solar Inverter for V2G

IPC 3-Port Inverter

Ford TCE Battery Interface

SCADA-controlled AC and DC Electrical Bus

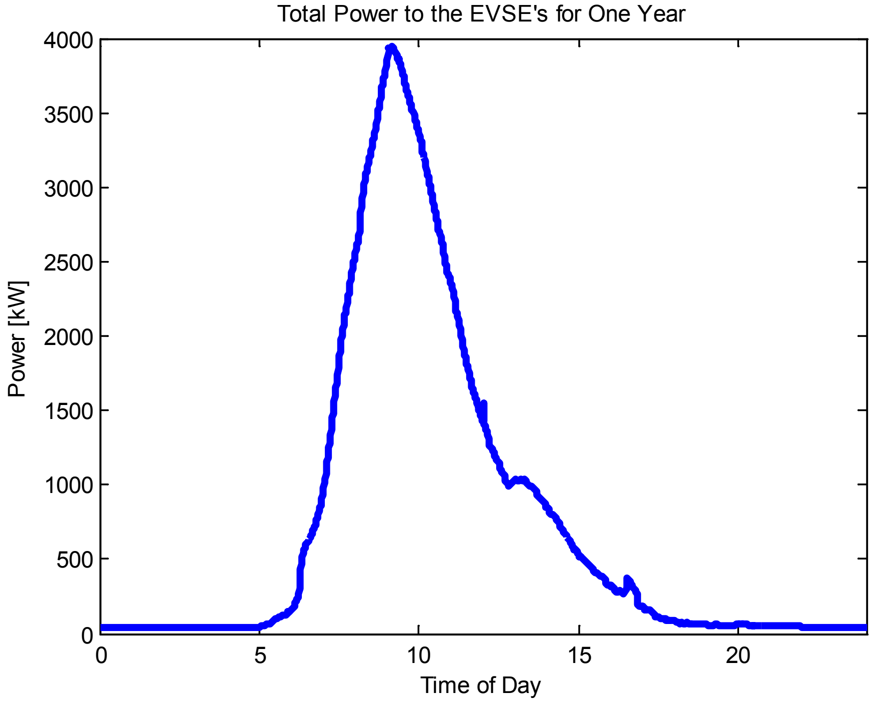
IPC Unit provides 2 DC ports, 1 AC port, 60 A, 0–500 Vdc

Both Combo and CHAdeMO standard inputs to vehicle

SCADA = System Control and Data Acquisition
TCE = Transit Connect Electric

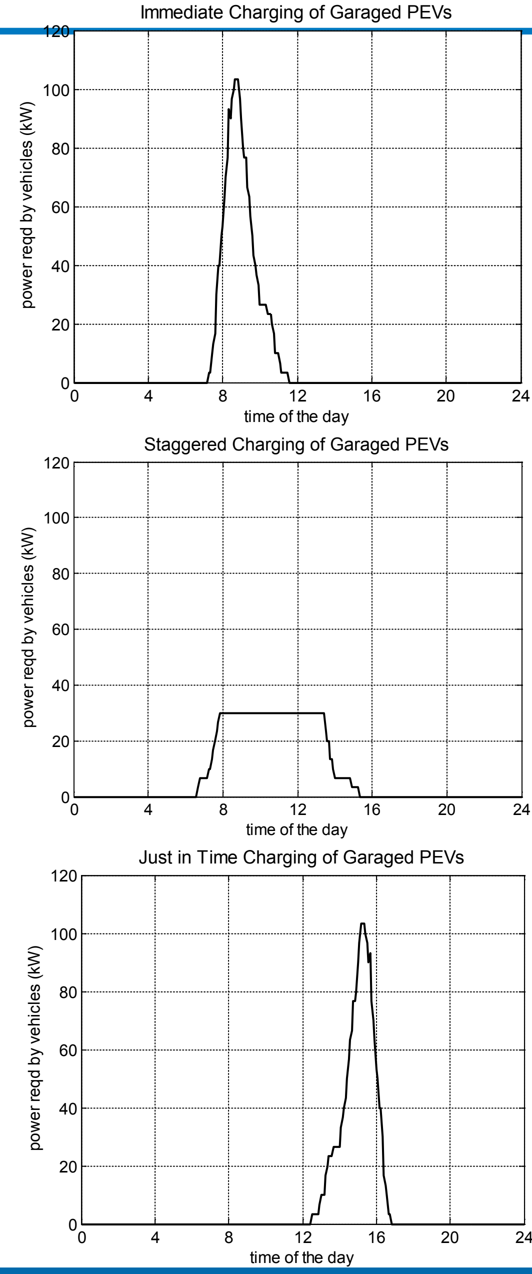
NREL Parking Garage EV Load Profile Comparisons

- **Peak timing was predicted well**
- **Tail longer than modeling prediction**
  - Most vehicles using 3-kW charge rates
  - User-selected delayed charging through car
  - Multiple charges per day



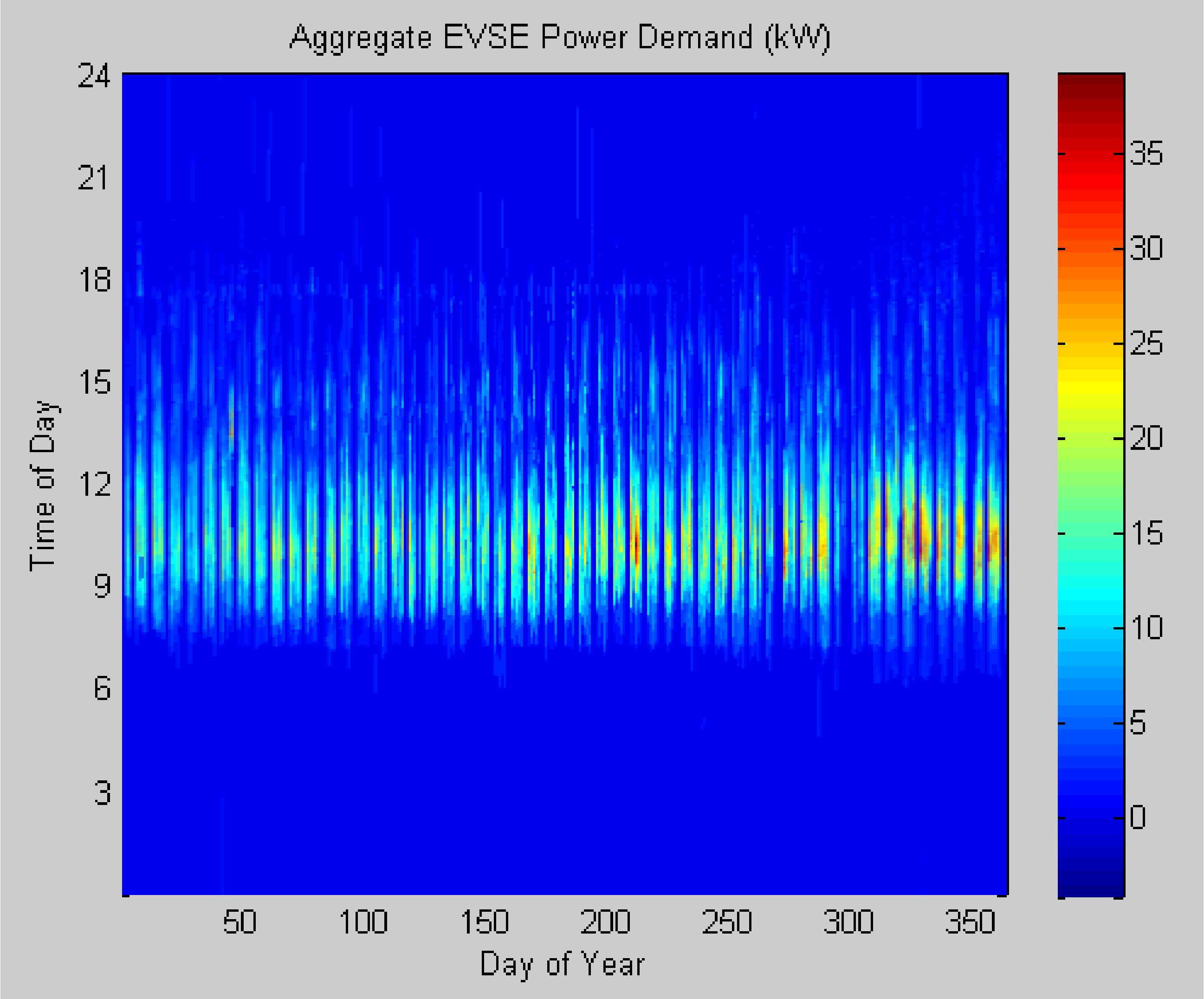
EVSE = electric vehicle supply equipment

Model Predictions



EVSE Power Usage Analysis by Time of Day

- Average power demand is about 10 kW
- Maximum peak is about 40 kW
- Daily peak typical around 10 a.m.
- Slight demand increase after lunch break

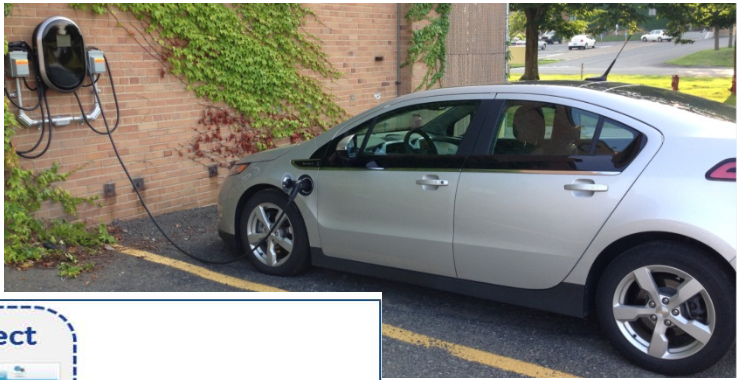


Date range: 03/05/2013 ~ 03/04/2014

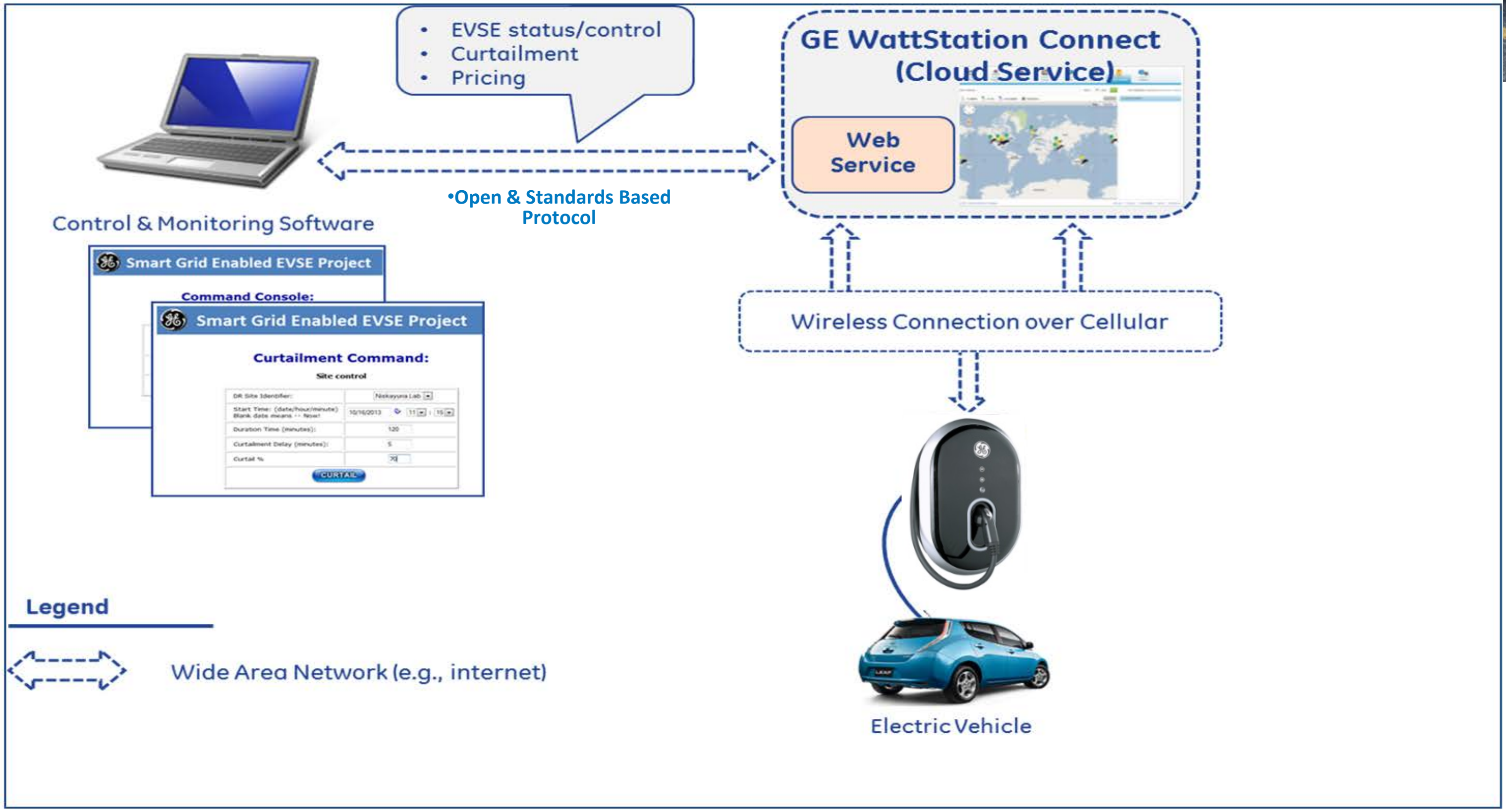
@Day 356, 24 vehicles – 9 Chevy Volts, 12 Nissan LEAFs, 2 Mitsubishi iMievs, 1 Ford C-Max

Leveraging Smart Low-Cost EVSE FOA Development and Integration with NREL Building Energy Management

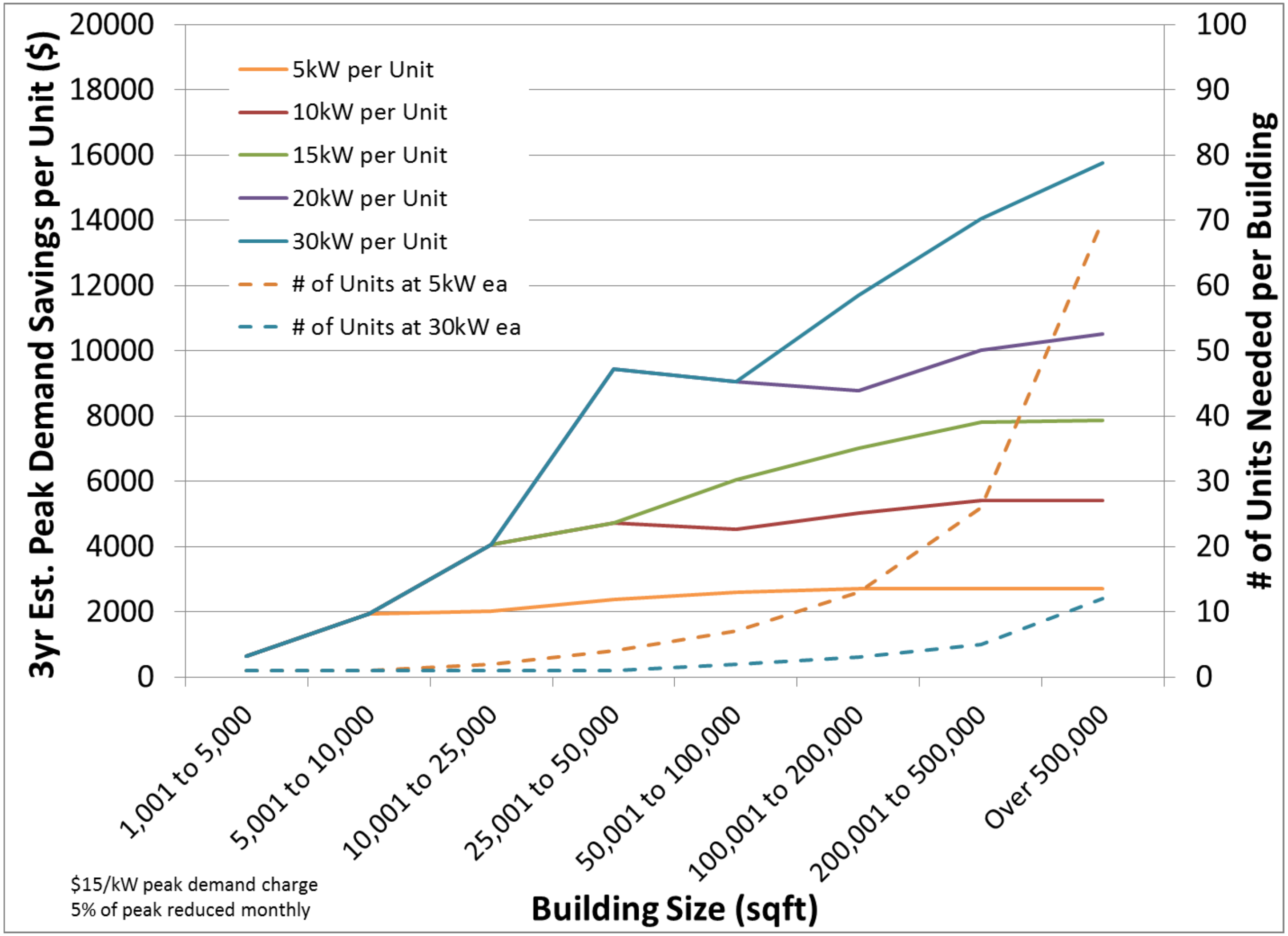
- **GE provided unit**
- **Operational testing expected 1yr starting summer 2014**



Source: GE Global Research



Estimating V2B Value and # of Units by Building Size



- **@6-kW, 1–2.5M units would be needed for 20% of building stock**

V2B = vehicle to building

Responses to Previous Year Reviewers’ Comments

Comment 1: Related to partnerships, How were partners chosen? Should include more Utilities and Fueling Retailers.

The technology and systems application for Vehicle Grid Integration are still at too early a stage to justify utility and fuel retailer partnerships. Results of this work have been presented at EPRI EV Infrastructure Working Council meetings.

Comment 2: Renewables influence is important and should be considered.

More emphasis was placed on understanding and integrating with renewables, including leveraging existing inverter technology for V2G functionality.

Collaboration and Coordination with Other Institutions

- **Existing Collaborations**
  - DOE Office of Electricity – SPIDERS V2G Deployment for Microgrid Integration
  - Ideal Power Converters – Integration of Vehicles, Renewables and Storage
  - GE Global Research – Testing and Demonstration of Low Cost Smart EVSE integration with Building EMS

- **Planned Collaborations**
  - Mitsubishi, Nissan, Via Motors, Chrysler, NRG Energy – V2G Systems Development and Testing
  - INL, ANL, PNL, LBNL, and ORNL on Systems Requirements Development for Smart Grid Vehicle Integration

Remaining Challenges and Barriers

- **Limited understanding of the value stream scope and scale, and system requirements to unlock vehicle grid integration values**
- **Clear details on the risks, costs, and associated benefits**
- **Evolving but still unclear standards for methods of communication and control for vehicle to grid applications**

Future Work Focus for FY14 and FY15

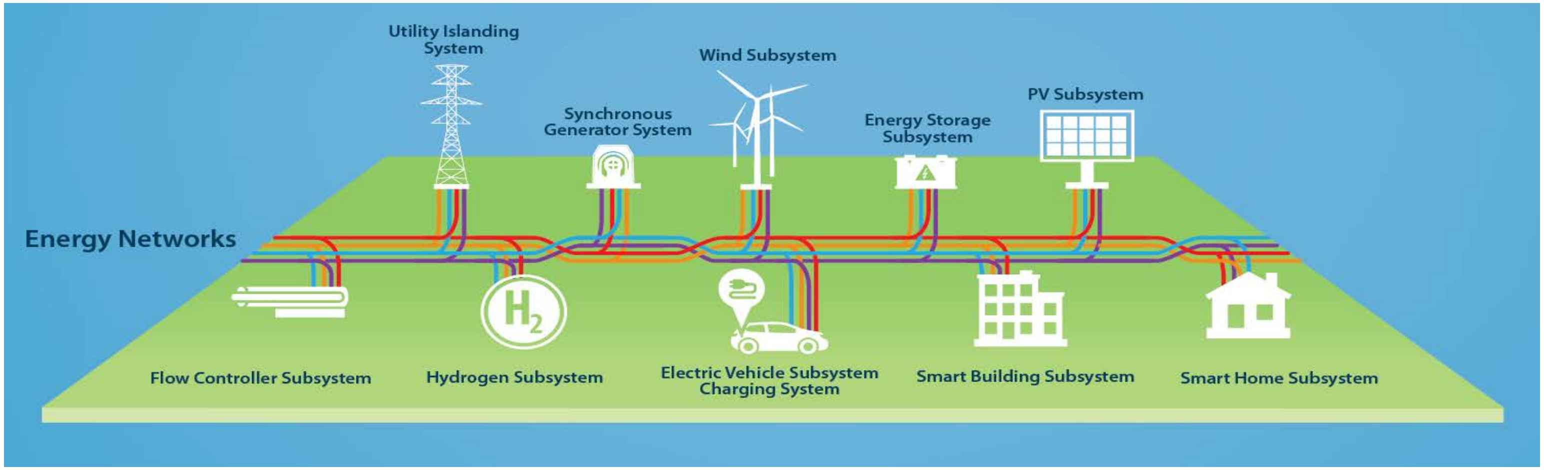
INTEGRATE

Integrated Network Testbed for Energy Grid Research and Technology Experimentation

Enable EERE technologies to increase the hosting capacity of the grid by providing grid services in a holistic manner using an open source, interoperable platform.

INTEGRATE project will:

a. **Characterize the grid services and grid challenges associated with energy efficiency (EE) and renewable energy (RE) technologies when integrated into the grid at scale**
b. **Utilize an open-sourced, interoperable platform that enables communication and control of EE and RE technologies both individually and holistically**
c. **Develop and demonstrate high-value grid services that EE and RE technologies can provide holistically at a variety of scales**



Summary of EVGI and INTEGRATE Projects

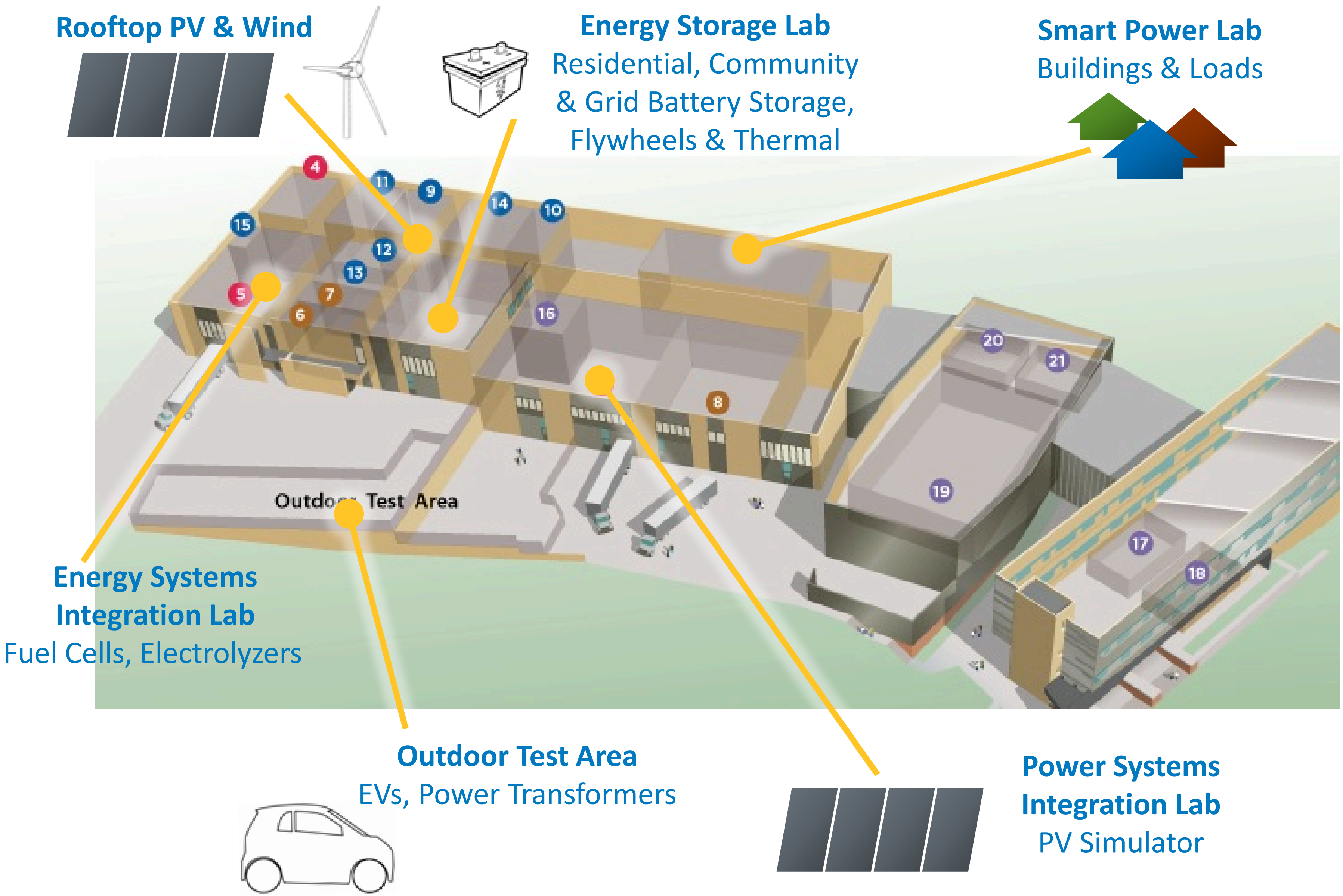
- **Electric Vehicle Grid Integration (EVGI) and INTEGRATE are addressing the opportunities and technical requirements for vehicle grid integration that will increase marketability and lead to greater petroleum reduction**

- **Address Core Questions**
  - Quantify use cases, performance, and life impacts of grid applications
  - Contribute to development of open interface standards
  - Identify and quantify potential grid integration values

- **Opportunities to be Researched**
  - Managed charging systems providing flexibility, demand response capability
  - Bi-directional power to minimize local demand charge and grid frequency control
  - Local power quality monitoring and enhancement value
  - Emergency power system design enabling vehicles to support disaster recovery

Technical Back-Up Slides

NREL Energy Systems Integration Facility



INTEGRATE – Activities Proposed in Task 1 for Lab-Directed Work

1.0 Physical Characterization of EE & RE Technologies → 2.0 Comm., Information, Computation Infrastructure → 3.0 Developing Holistic Grid Services → Increasing & Enhancing the Hosting Capacity

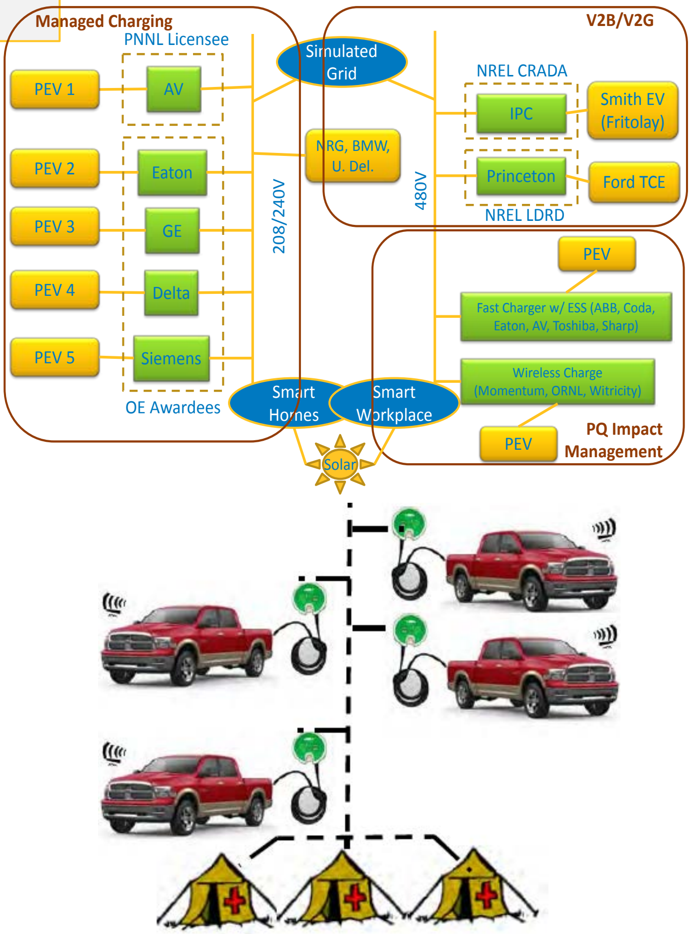
Characterization of Vehicles for Grid Services

DOE ACTIVITIES

- Work with industry to encourage product development
- Help define high priority grid services for characterization

NEW NREL ACTIVITIES

- Characterize the performance of existing devices (EVSEs and vehicles) to provide grid services that include managed charging, bi-directional (V2G/V2B) and other advanced systems (wireless and fast charge).
- Define system interface and component performance requirements needed to support high-value grid services
- Highlight key use cases and answer how grid service applications impact battery life and vehicle performance.



INTEGRATE – Activities Proposed in Task 2 for Lab-Directed Work

1.0 Physical Characterization of EE & RE Technologies → **2.0** Comm., Information, Computation Infrastructure → **3.0** Developing Holistic Grid Services → **Increasing & Enhancing the Hosting Capacity**

Development of Data, Communication, and IT "standards" to support open integration:

Ft. Carson Deployments

DOE ACTIVITIES

- Support development of common data interoperability/taxonomies

NEW NREL ACTIVITIES

- Contribute to industry standards bodies (UL, SAE, IEC) to implement comm. protocols under development, including SEP2.0, IEC 68150, J2836/2847 specific to vehicles
- Focus on standard, secure, open architectures to encourage industry evolution
- Leverage current small-scale demos at Ft. Carson, LA Air Force Base, and Univ. of Delaware

Univ of Del./PJM Demo

INTEGRATE – Activities Proposed in Task 3 for Lab-Directed Work

1.0 Physical Characterization of EE & RE Technologies → 2.0 Comm., Information, Computation Infrastructure → **3.0 Developing Holistic Grid Services** → Increasing & Enhancing the Hosting Capacity

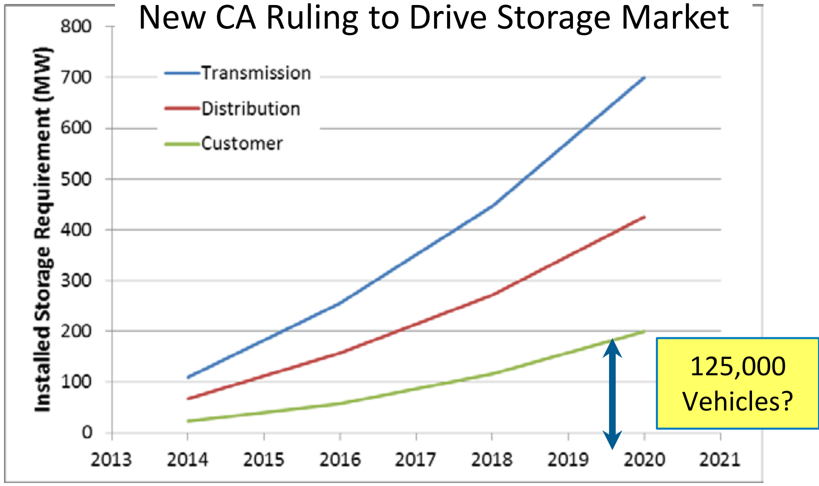
Evaluation of intelligent, integrated system to provide grid services

DOE ACTIVITIES

- Review industry proposed-use cases (e.g., SAE and CAISO)

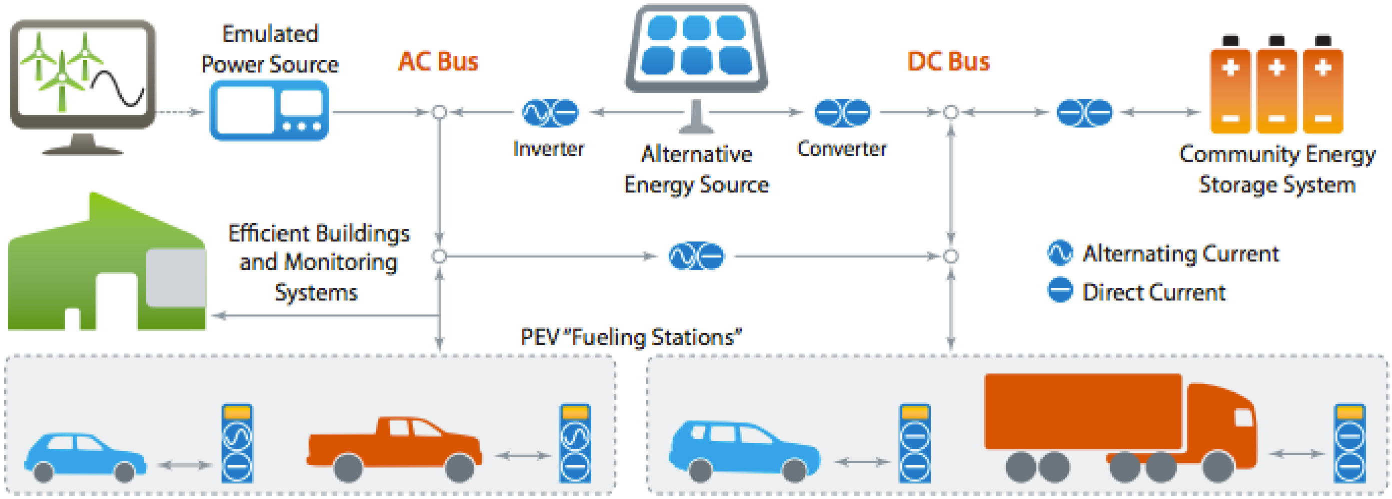
NEW NREL ACTIVITIES

- Review use-case scenarios to highlight monetary and non-monetary flow of value to resource owner
- Analysis and demonstration of value proposition for electric vehicles to provide grid services
- Leverage battery life models to quantify potential impacts of uses cases



Electric Vehicle Grid Integration at NREL

Vehicles, Renewable Energy, and Buildings Working Together



Developing Systems Integrated Applications

Managed Charging

Evaluate functionality and value of load management to reduce charging costs and contribute to standards development

Local Power Quality

Leverage charge system power electronics to monitor and enhance local power quality and grid stability in scenarios with high penetration of renewables

Emergency Backup Power

Explore strategies for enabling the export of vehicle power to assist in grid outages and disaster-recovery efforts

Bi-Directional Power Flow

Develop and evaluate integrated V2G systems, which can reduce local peak-power demands and access grid service value potential

Vehicle-to-Grid Challenges

Life Impacts

Can functionality be added with little or no impact on battery and vehicle performance?

Information Flow and Control

How is information shared and protected within the systems architecture?

Holistic Markets and Opportunities

What role will vehicles play and what value can be created?