Smart Garage Charrette Pre-Read *v2.0 (Oct 6)*

Updates: Typos fixed, visual clarity improved

To get updates of this document, please visit move.rmi.org/smartgarage

Rocky Mountain Institute

Smart Garage Project Manager:
Laura Schewel, MOVE lschewel@rmi.org
Practice Leader:
Michael Brylawski, MOVE VP, mbrylawski@rmi.org
Smart Garage Team:
Kitty Wang, ERT Principal
Mike Simpson, MOVE
Mark Gately, MOVE
Schuyler Senft-Grupp, MOVE
Bryan Palmintier, ERT
Stephanie Johns, MOVE
Luisa Lombera, ERT
Kristine Chan-Lizardo, MOVE
Natalie Mims, ERT
Derek Supple, ERT
Prateek Chourdia, MOVE

Who is Putting on This Event?

Rocky Mountain Institute (RMI) is an independent, entrepreneurial, nonprofit organization that fosters the efficient and restorative use of resources to make the world secure, just, prosperous, and life-sustaining. For 25 years RMI has been crafting profitable resource and energy efficiency solutions. Our research and consulting teams focus on the three core sectors for Smart Garage: transportation, built environment and energy.

Rocky Mountain Institute

The Smart Garage Charrette and research is sponsored by the Lemelson Foundation and Google.org. The Lemelson Foundation, founded by inventor Jerome Lemelson, "celebrates and supports inventors and entrepreneurs in order to strengthen social and economic life." Google.org, the philanthropic arm of Google, "aspires to use the power of information and technology to address the global challenges of our age: climate change, poverty and emerging diseases."

Many of our participants also contributed to Charrette expenses.

Google

THE LEMELSON FOUNDATION

RMI's Role at the Charrette

RMI has successfully conducted numerous charrettes and innovation workshops for a variety of industries, from transportation to cellulosic ethanol to green buildings. These workshops are dynamic events where different stakeholders are brought together to collaborate and develop solutions around a central topic.

At the Charrette itself, the RMI team will lead small, structured breakout groups that focus on specific sub-topics or challenges for the broader project. Throughout the three days of the Smart Garage Charrette, we will guide the participants through processes of brainstorming and converging on ideas to understand the biggest barriers to the evolution of Smart Garage and develop action plans to implement solutions addressing those barriers. Our role is that of a helping facilitator that provides structured process to encourage the collaboration and creativity of the group while capturing the outcomes.

Source: www.lemelson.org and www.google.org

Executive Summary: Charrette Designed to Accelerate the Build Out of Smart Garage

Introduction: What is this Document?

Smart Garage brings transport, the electricity grid, and the built environment together via the enabling technology of electrified vehicles (including electrified vehicle hybrids, extended-range EVs, and electric vehicles) and their smart integration with the grid.

Historically, our transport and electricity infrastructures have operated independently. With the rapid commercialization of a new generation of electrified vehicles—that will not just plug into the grid but communicate with it, help firm and regulate its operation, and possibly act as a storage resource—our major energy infrastructures are about to conjoin.

If implemented with foresight and care, the Smart Garage will integrate building, vehicle, and grid energy systems to improve the efficiency of all, and increase transparency for the consumer, leading to a complete shift in the way consumers use and make decisions about energy.

Economically, Smart Garage can reduce operating costs for vehicles, avoid large investment costs for utilities, and open up new business opportunities in fields such as software to manage communication between vehicles and the grid.

Importantly, Smart Garage is much broader than bidirectional charging (commonly known as "vehicle to grid" or V2G) as vehicles and the grid can integrate in many different ways (such as Smart Charging or V2B) that can provide economic and environmental benefits.

Smart Garage requires collaboration between many players, from utilities and OEMs to battery makers, grid service providers, entrepreneurs and start-ups, retailers, car share companies, and more.

What is Smart Garage?

The goal of this pre-read is to prepare Charrette participants for the unusual and exciting three-day event with information on what we'll be doing, and background on the topic at hand: the Smart Garage.

Smart Garage—the convergence of electrified vehicles, the smart and clean electricity grid, and advanced building energy systems—has the potential to significantly improve the efficiency of the transportation and electricity sectors and help make renewable energy available via the grid. Implemented carefully, it may also be highly profitable to key stakeholders like utilities.

However, many implementation challenges still exist, and critical questions remain: *e.g.*, How do you facilitate integration among industries that to date have largely operated independently? How do you bring together the multiple "visions" of vehicle and grid interaction into a cohesive technology roadmap? How do you align incentives between stakeholders to facilitate the financing and scaling of infrastructure and electrified vehicles? How do you bring together large, established players with smaller, entrepreneurial firms and non-traditional sectors to accelerate development?

This document contains an overview of these and other critical questions, while providing background on relevant technologies and developments in the market; findings from RMI's financial analysis on Smart Garage scenarios; and an environmental benefits discussion.

Document updates and in-depth appendices are available at *move.rmi.org/smartgarage.* If you have comments or additions to the documents, please add them at *smartgarage.rmi.org/tiki-forums*

What is a Charrette?

Our goal is to accelerate the build-out of Smart Garage, focusing on the U.S., in the most environmentally and economically beneficial way by aligning the vision of critical and diverse stakeholders and designing collaborative next steps.

Employed for centuries in the architecture field, today a *charrette* is a structured process in which a critical number (80 in our case) of experts from diverse backgrounds and industries come together for an an immersive and interactive problem-solving session. During a charrette, participants alternate between breakout sessions focused on a solving a clearly defined challenge and plenary sessions where they share output from their breakout groups and get feedback and input from the other groups.

The breakout sessions and plenaries in our Charrette will build upon each other and lead participants to the final goal: identifying 3–5 specific and collaborative projects that can be started immediately and that are a meaningful first step to realizing the Smart Garage vision, as defined by the participants earlier.

Day One will Ground participants in consumer experience, expose differences in participants' near-term visions, begin to rectify differences, and flesh out a value chain for the longer-term Smart Garage roadmap.

Day Two will test the value chain's robustness in extreme scenarios, use lessons from this exercise to select the top ~10 barriers, and identify solutions.

On Day Three we will create 3–5 concrete project plans that tackle the top barriers, reinforce commitments and alignment among participants, and kick off the new projects.

Executive Summary (cont'd): Research and Financial Modeling Highlight the Need for Integration

Technology

Most of the major requisite technologies for Smart Garage are "ready for prime time," with the possible caveat of advanced batteries. Batteries have made steady improvements in the past two decades, enabling a recent surge of interest in electrified vehicles, but they have a bit farther to go to reach the price/performance point required to fully realize the benefits of Smart Garage.

Even though most of the key technologies (for communications, IT, conversion, etc.) are available, installing them in an integrated infrastructure will be expensive and will require the commitment from many stakeholders, including the government.

Economics: What is the Value of Smart Garage?

RMI estimates the net present value (NPV) of vehicle and grid integration would be from -$63B to +$34B under our current set of assumptions. The first major driver of value is how vehicles connect to the grid:

- *V0G* (-$63B), *i.e.*, doing nothing, maximizes risk to the grid and would be the most costly scenario,
- *Timed Charge* (-$32B), would be roughly half the cost of convenience charging, avoiding many of V0G's pitfalls;
- *V1G* (-$11B) would even be less costly, enabling communications in real-time with utility, allowing utility benefits with unidirectional charging;
- *V2B* ($34B) would actually be profitable, confining bidirectional integration to buildings systems, maximizing benefits while minimizing cost and difficulty, and
- *V2G* ($15B) would also be profitable, utilizing vehicles' capacity to act as grid storage, but this regime could require significant investments in infrastructure and advances in battery chemistries.

Our "default" assumptions are based on RMI research and interviews with participants.

However, by changing certain key assumptions, the system can become much more profitable. For example, even costly scenarios could get to a $10B positive NPV, if:

- Give V0G a $6700/vehicle gov't subsidy
- Give Timed Charge $6/gallon gas, or
- Give V1G $325/kwh batteries.

V2G NGU, because it relies on a future, renewables-heavy generation scenario, is the most sensitive to assumptions. However, it does show the potential synergies from Smart Garage when the utilities move towards wind and solar.

While we find that Smart Garage can be profitable in the long run, there will be winners and losers. The utility and battery makers appear to be clear winners in all scenarios, as is any third party who can capitalize on the enormous amount of money and information that will be changing hands.

The high capital costs on the vehicle side indicate that either the OEM or the consumer (or both) will lose money. The consumer may put value on the lifetime fuel savings at purchase and/or the differentiated benefits of electric drive, but it is highly unlikely that the OEMs will be able to capture the fuel savings for themselves. This indicates the value of exploring novel vehicle ownership/sales models. Current subsidies being explored in congress could alleviate this problem, as could sharing profits from other sectors.

Industry

Almost every major automaker has announced some form of electrified vehicle during the past year, led by GM, Toyota, and Nissan-Renault. Electrified vehicles are also the source of a flowering of start-up OEMs. Implementation of the Smart Grid finally appears to be a reality, and several cities have set up pilot projects.

Internationally, Israel, Denmark, and Japan are leading in electrified vehicle pilots and grid integration.

Environment

The scope of potential climate benefits of Smart Garage significantly exceeds the scope of financial benefits. Smart Garage represents a shift in the transportation energy use paradigm to greater efficiency while enabling deep penetration of renewables onto the electric grid. In other words, the Smart Garage is a single system that can significantly reduce the GHG emissions from multiple sectors simultaneously.

Highest loss — Convenience charging, no subsidies, $750/kwh batteries, $1.50/gal gasoline, slow penetration of electrified vehicles, replacing vehicles that drive fewer miles/year, mpg of ICE fleet meets (or fails to meet) CAFE

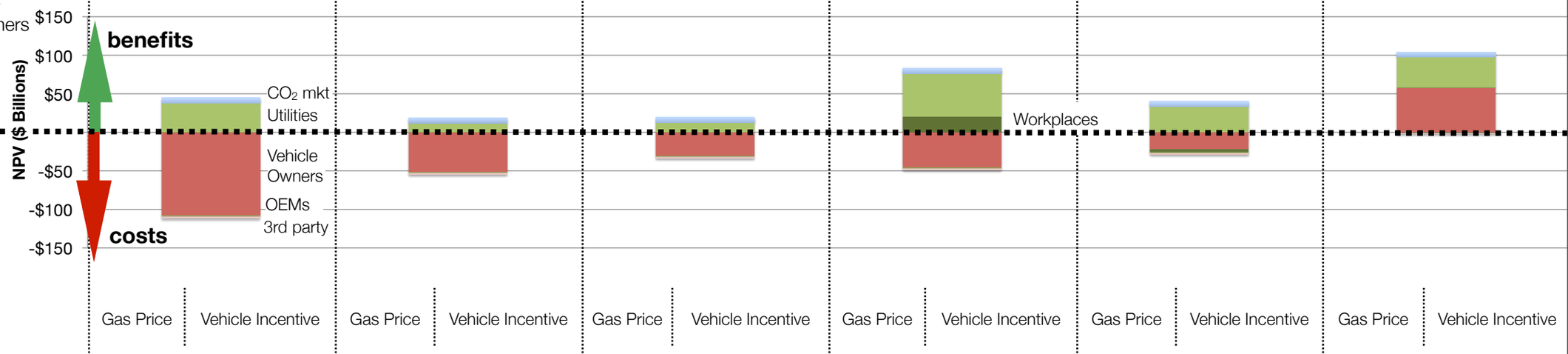
V2B and V2G, $4.50/gallon gasoline, $500/kwh batteries, vehicle purchase or production subsidy faster penetration, replacing vehicles that drive more miles/year, baseline ICE (or HEV) fleet gets to over 50mpg. — **Highest profit**

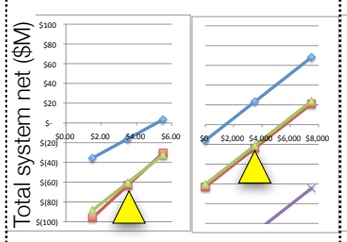
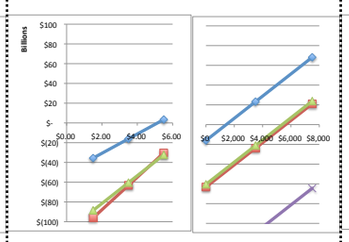
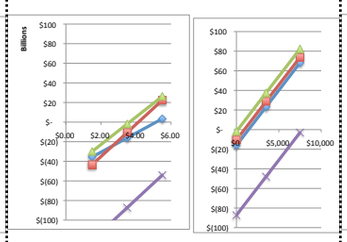
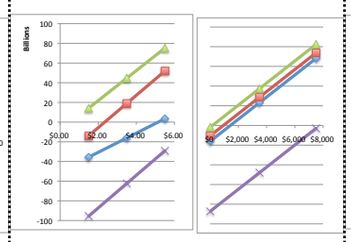
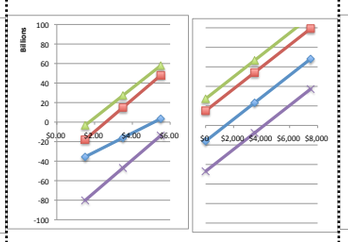
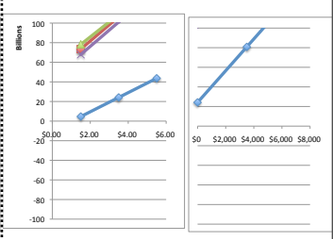
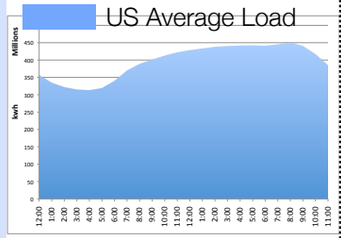
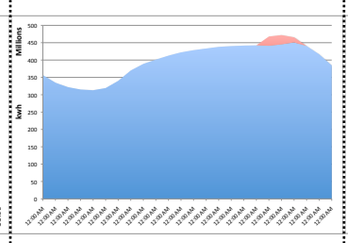
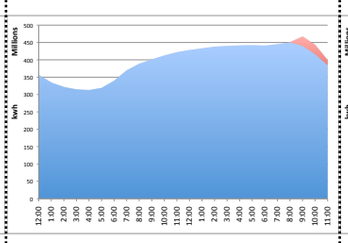
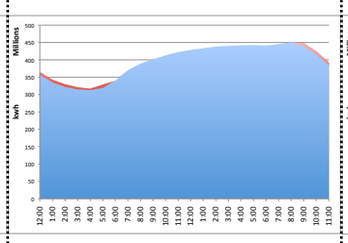
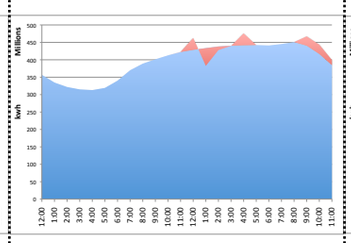
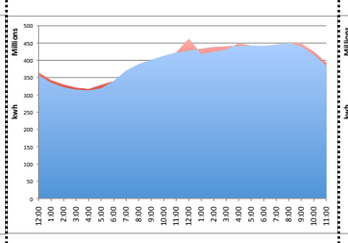
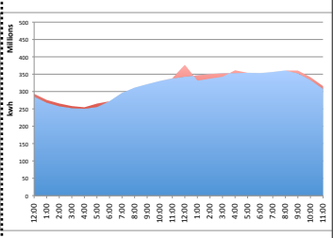
The most important variables in the Smart Garage Financial system are: level of Smart Grid penetration, cost of battery, government incentives, price of gasoline, cost of hybrid drive train, electrified vehicle penetration, ancillary service benefits, penetration of fast charge station, and whether or not the vehicles can charge at

Smart Garage Scenarios: Under a Reasonable Set of Assumptions, System Can Be Profitable over 15 Years

For background and instructions on how to read this graphic, please see slide 47

	ICE	V0G	Timed Charge	V1G	V2B	V2G	V2G NGU
Vehicle Operating Benefit (regardless of other stakeholder losses)		$	$	$	$	$$	$$$
Of note	-	Vehicle owner cost could be born by OEM or gov't.	Smart Charging mitigates much of losses from V0G	Communications equipment needed for V1G tempers profits	V2B can lead to massive utility savings if widely deployed	Extra costs of e- in V2G are compensated by utility gains	V2G in the future exceeds other options in profits because X
Description (see appendix A for more)	Fleet continues to be ICE vehicles. Average US MPG increases to meet CAFE standard of 35mpg. Each car drives 32 mi/day. Gas at $3.50/gal. (This ICE "basecase" car and assumptions hold for all scenarios to create delta costs and benefits).	PHEV-40s reach 30% of new car sales by 2025. Electricity rates are TOU. No government incentives. The cost of batteries starts at $750/kwh, and goes down 6.5% per year. Drivetrain costs also decrease at 7%/yr.	Same as V0G scenario, except electrified vehicles all have additional "smart charge" capability based on simple timer at the plug site, and only charge between 9pm and 6am.	Same as Timed Charge scenario, but vehicles have sophisticated on-board communication devices that react to market/utility signals that allow them to play in ancillary service markets with uni-directional charging. Only 4% of total US vehicle can play in this market. Vehicles can also charge at work.	Vehicles do not play in the ancillary service market. Instead, they charge extra during AM off-peak, and discharge into their workplaces grids during peak hours, offsetting peak (benefit to utilities) and decreasing workplace energy bill. No communication with the grid.	Similar to V1G, but vehicles play in the ancillary services, wind firming, and load shifting markets by both charging and discharging their batteries in reaction to utility/market signals.	V2G but starts in 2025, and influenced by a 50% penetration of renewables, distributed generation, and widespread deployment of the smart grid. The need for ancillary services double, and the cost of batteries and drivetrains has gone down. Base case vehicle efficiency fixed at 35 mpg.
Net system costs and benefits	CO_2 Market, Utilities, Workplaces, Vehicle Owners, OEMs, 3rd Party	Net: $-63B	$-32B	$-11B	$34B	$15B	$100B



	ICE	V0G	Timed Charge	V1G	V2B	V2G	V2G NGU
Sensitivity Analyses	option shown above; Conversion; PHEV 40; BEV 200; Hypercar PHEV; Electric Vehicles; US Average Load						
Average Day US Load Profile + fleet in year 15 12% Fleet Adoption							
Name	ICE	V0G	Timed Charge	V1G	V2B	V2G	V2G NGU
Diagram and Hardware	[additional cost per vehicle]	+$6-10,000; battery & hybrid architecture	$15-50; timer	$200-$10,000; communication and charge stations	$200?; Building EMS plus on-board comp.	$400-?; Real time utility two-way comms.	$-400-8,000; Smart Grid already installed (no comms), cheaper batteries
Overview	electrified vehicle starts charging as soon as you plug it in	electrified vehicle starts charging as soon as you plug it in	electrified vehicle only charges b/t certain hours	electrified vehicle only charges b/t certain hours, and can play into real-time responsive markets, such as demand response and ancillary services	The electrified vehicle provides back-up power to the building, and can store cheap power to use later during expensive hours.	Like V1G, but the electrified vehicle can both charge and discharge in response to signals.	Like V2G, but occurring in a grid that has over 50% renewable penetration, DG, and Smart Grid.

Guide to the Graphic on the Previous Page

Each column represents an analysis of each scenario (V0G, V1G, etc) under a set of given assumptions

This row explains the major assumptions for each scenario.

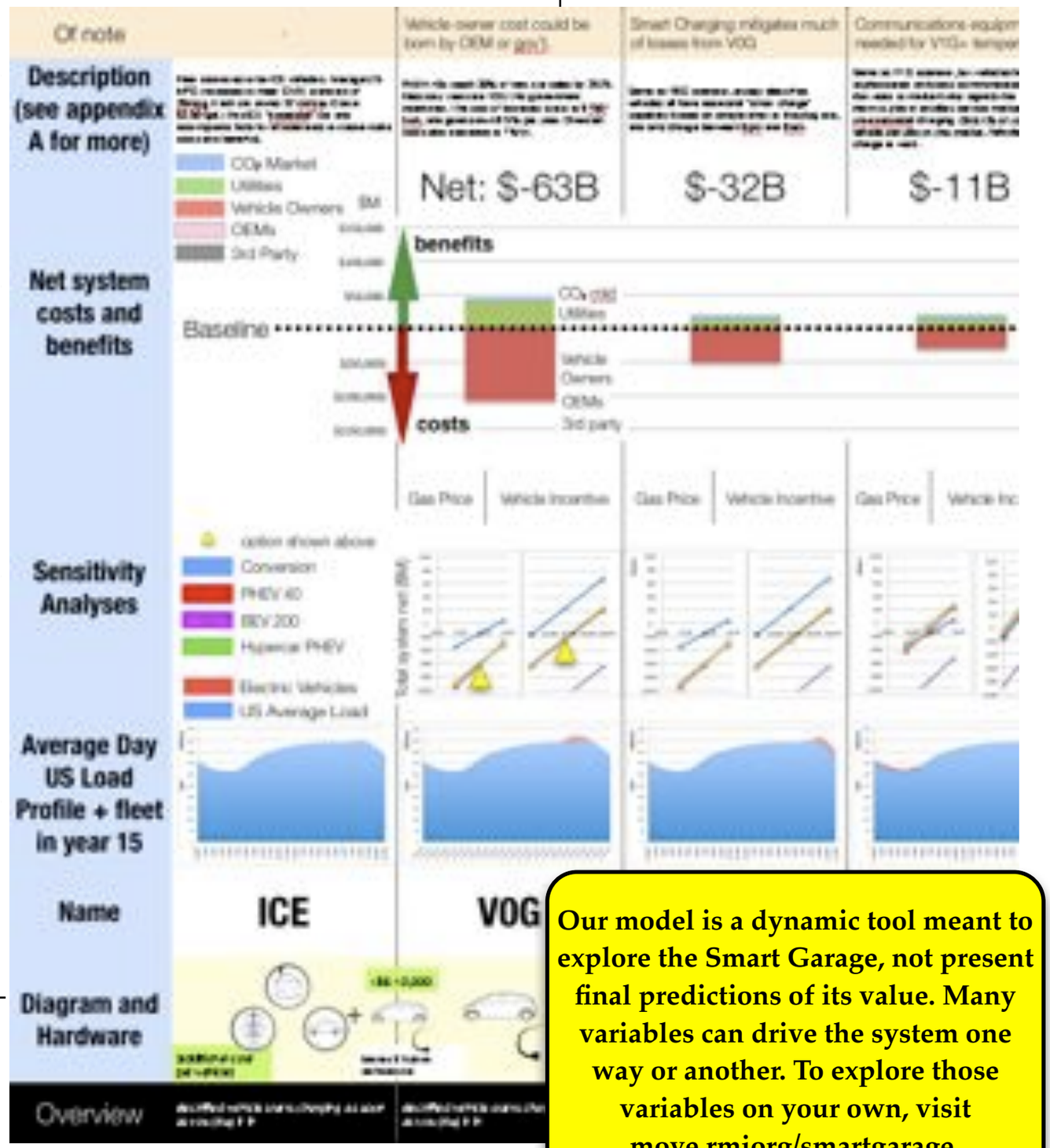
This row shows the benefits and costs of each scenario (broken down by stakeholder), all in present value. It is for the "default" analysis, a PHEV40 at $3.50/gallon gas, no subsidy. This is the configuration that is used for the dominant graphs on all succeeding pages.

This row shows the results of a sensitivity analysis run on the graph above (system NPV). Each scenario is run for a range of vehicle types, gas prices, and capital cost reductions (via subsidy or technology cost reduction). Each point on the graph represents the system NPV in one combination of gas/capital reduction and vehicle type. The point with the yellow triangle shows where the default analysis (PHEV40 at $3.50/gallon, $0 capital reduction) falls in respect to the other options.

This row shows the load of our default PHEV fleet (12% US fleet) in year 15 laid on top of an average day's load for the U.S.

This row shows how the vehicle, grid, and buildings interact. The "additions" between each column show the type and approximate cost of whatever technology is necessary to move between the scenarios represented in adjacent columns.

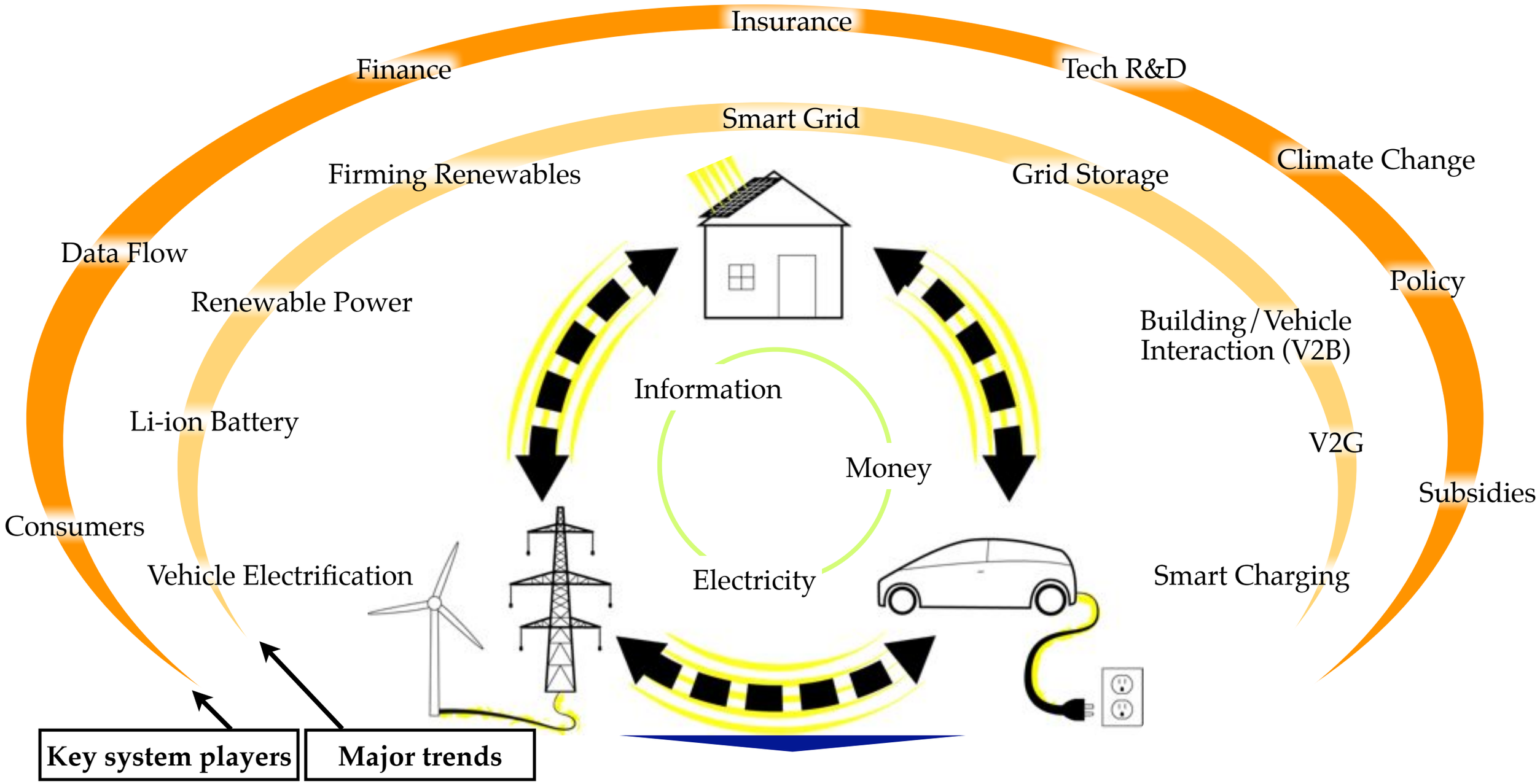
This row gives a brief explanation of the scenario being analyzed in each column.



Our model is a dynamic tool meant to explore the Smart Garage, not present final predictions of its value. Many variables can drive the system one way or another. To explore those variables on your own, visit move.rmiorg/smartgarage.

Source: Tufte 2006

Smart Garage: A New Energy Paradigm Driven by Multiple Industry Trends



The Smart Garage: Incorporates industry trends in building, vehicle, and grid energy systems to improve the efficiency of all, and increase transparency for the consumer

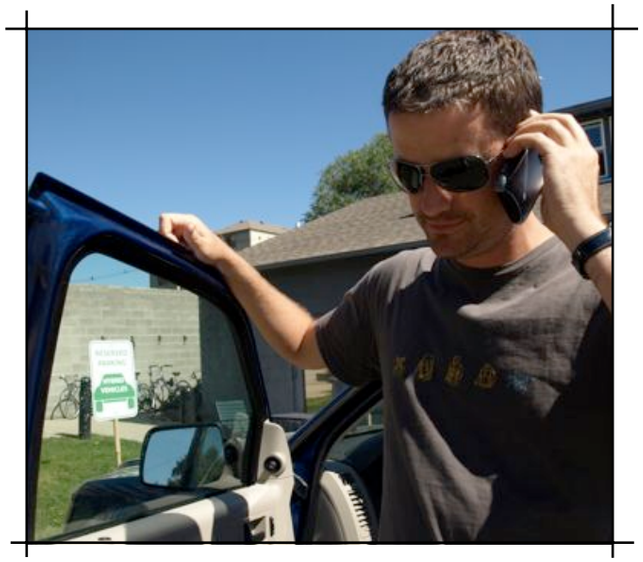
Source: RMI

What is the Smart Garage? A Revolution in the Way Citizens Use Energy

A Day in the Life of Smart Garage: October 8, 2011

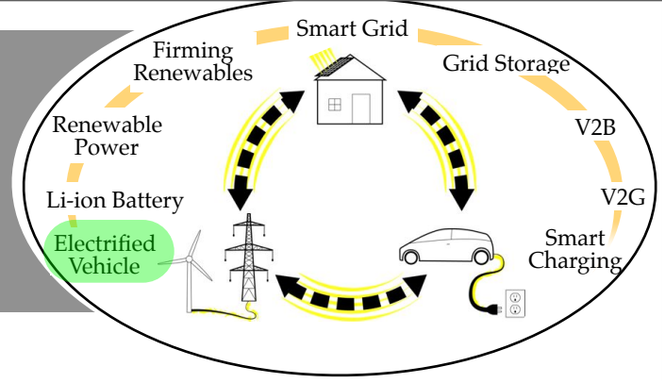
Time	Jason's Activity	3rd Party	Utility
7AM	Jason checks his battery's state of charge on his on-line account at breakfast (it's full, as it is 99% of the mornings) and how much he spent on electricity yesterday ($0.16). Jason sees that the ISO predicts that electricity will be very expensive from 4 to 10 pm due to a repairs at the natural gas plant. He keeps his setting on his default: pay as little as possible for electricity while guaranteeing a 50% charge by 5 pm, and 100% by 7 am		
8AM	Jason drives 15 miles to work. He stays in electric mode the whole way, and is at 60% charge when he arrives. He plugs in at the offices' underground parking garage charge spot (220v).	Notifies utility that Jason has plugged in	
9-10 AM	Jason works. The car charges at a reduced rate for a few minutes, and reaches 70% charge.	Sends bill to Jason's account for energy, pays back the office for energy.	Signals the rate increase at 9.30
12-5 PM	Jason works. The car does not charge because it receives a signal from the utility of the high rates.		Load and rates increase
5PM	Jason drives to the grocery store, the gym, then home for a total of 35 miles. The battery is expended 5 miles away from home and the car starts operating like a typical hybrid, using 1/30th of a gallon of gas for the last 5 miles.		
6-10 PM	The car is in Jason's driveway and plugged into the outlet on the side of Jason's house (standard 110v). It does not charge because of the wireless signal it got from the utility of higher rates.		High demand and low supply mean high rates.
10PM - 6AM	The vehicle receives a signal that rates have dropped and begins to charge, reaching 100% charge around 2 am. The electricity goes onto Jason's normal utility bill, but is noted as "vehicle" on the bill, which he can access online at breakfast the next morning.		Signals lower rates

Source: RMI analysis, consumer profiles



Name: Jason Robertson
Age: 34
Vehicle: Chevy Volt with 40-mile AER
Job: Graphic Designer
Annual Income: $83,000
Location: San Francisco, California
Daily Commute: 15 miles each way
Weekend Activities: Skiing in Tahoe, biking, listening to live music, visiting parents in Marin, farmers markets.
Attitude towards technology: Lives in the Bay Area, addicted to his iPhone, reads his news online, set up his own home network.
Values: Has a fast-paced life. Supports environmental issues and will spend a bit extra in lifestyle changes to do so, but not at the expense of time or convenience.

Smart Garage can Help Electrified Vehicles' Market Adoption



Vehicle electrification has emerged as the dominant new trend in the automotive sector.
There are several types of electrified vehicles:

- Hybrid electric vehicle (**HEV**): has both an internal combustion engine (ICE) and a electric motor for increased mileage but operates exactly like a traditional car (i.e., no plugging in). Example: Toyota Prius.
- Electrified Vehicle hybrid electric (**PHEV**): like an HEV but has a bigger battery and electric motor, and does plug in to the wall to charge up the battery. Most PHEVs have better mileage than a comparable HEV, and potentially an all-electric range (AER). If a PHEV owner does not plug her car in, it can still operate as a normal HEV.
- Extended-range electric vehicle (**EREV**): Term coined by GM to denote a PHEV that has a longer AER.
- Battery electric vehicle (**EV** or **BEV**): a fully electric car that must be plugged in; does not have an ICE or use gasoline.

Companies such as Tesla Motors and Th!nk are already selling electric vehicles, and Toyota and Chevrolet both have committed to a PHEV/EREV available for the U.S. market by 2010. Renault–Nissan just announced the development of a mass-market BEV in conjunction with Project Better Place, a business based around reaping revenues from charging the new vehicles. Almost every other major global OEM has announced a PHEV or BEV in development in the past few months.

Recent Relevant Headlines

The New York Times

Nissan Plans Electric Car in U.S. by '10

By BILL VLASIC
Published: May 13, 2008

THE Atlantic

With the Chevy Volt, General Motors—battered, struggling for profitability, fed up with being eclipsed by Toyota and the Prius—is out to reinvent the automobile, and itself.

BY JONATHAN RAUCH

Electro-Shock Therapy

BusinessWeek

THE ASSOCIATED PRESS September 3, 2008, 4:20PM ET

Chrysler circulating plug-in hybrids to dealers

INTERNATIONAL Herald Tribune

Toyota says it's making progress on plug-in car

The Associated Press — Published: August 14, 2008

THE HUFFINGTON POST

Volkswagen's Plug-In Hybrid Due In 2010, Too

Popular Mechanics

McCain, Obama Promise Plug-in Cars as Detroit Charts a Timetable

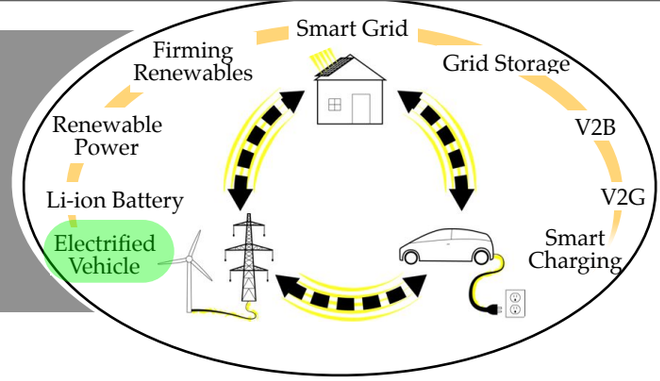
PM's Geek the Vote series takes an in-depth look at the presidential candidates' policies and positions on science and technology. In this installment, car-tech experts evaluate the stances of Senators John McCain and Barack Obama on America's future electric vehicles, including funding for battery research, tax credits and loan guarantees for a struggling American auto industry.

By Chris Ladd

Published on: August 19, 2008

Source: New York Times, Atlantic Monthly, Business Week, International Herald Tribune, Huffington Post, Popular Mechanics, RMI Analysis

Electrified Vehicle Space Getting Crowded with Concepts, But Scale is Critical and Uncertain Issue



Available Now

Planned for Release

Dedicated

Platform

e2 (G.E.M.)

G-Wiz (Reva)

Prius (Toyota)

Chevy Volt (GM)

Karma (Fisker)

Tango T600 (Commuter Cars)

NmG (Meyers Motors)

Civic (Honda)

Jeep Renegade (Chrysler)

Insight (Honda)

VentureOne (Venture Vehicles)

Tesla Roadster (Tesla Motors)

Modified

Hybrid ***Electrification*** ***PHEV*** ***EV***

Edge PHEV (Ford)

Prius PHEV (Toyota)

X-1 (Wrightspeed)

(Electrified Vehicle Conversions)

Plug-In Conversions Corporation

(Hybrid Electric Vehicle Technologies)

hevt™ Hybrid Electric Vehicle Technologies, Inc.

(Hybrids Plus)

HybridsPlus

EDRIVE™ (E-Drive Systems)

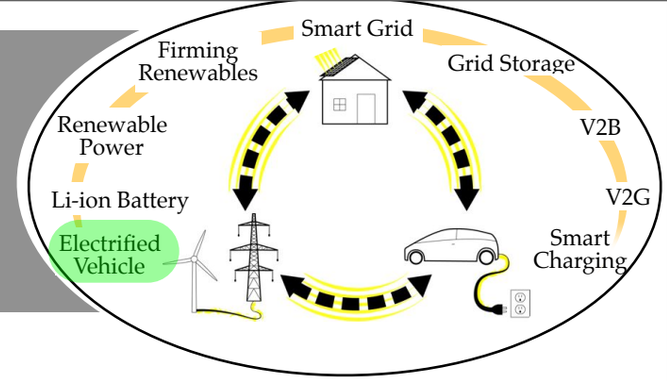
Hymotion (Hymotion)

BG AUTOMOTIVE GROUP Be green. (Be Green Auto Group)

Retrofit

Source: RMI Analysis. Note: this graphic is not exhaustive and new announcements appear almost weekly.

Lithium Ion (Li-Ion) Batteries' Performance and Price Will Drive Market Adoption



The surge of progress in electrified vehicles is closely linked to a technological leap forward in batteries for automotive use, specifically lithium-ion (Li-Ion) batteries. Though other technologies have been proposed for powering electrified vehicles (fuel cells, hydrogen, super capacitors) it appears that Li-Ion will be the dominant vehicle energy storage technology for the near term.

- **Energy:** Specific energy is the energy capacity per mass (Wh/kg). Energy density is the energy capacity per volume (Wh/L).
- **Power:** Specific power is power capacity per mass (W/kg). Power density is the power capacity per volume (W/L).
- **Cost:** In ($/kWh) and ($/kW) terms. The context (cell-level vs. pack-level) should be considered when discussing cost. Current estimates for 2010 production hover around $750/kwh.
- **Lifetime:** Calendar-life and cycle-life is further defined in terms of micro-cycles and full-cycles (full discharge/charge).
- **Safety:** Operating temperature range, heat generation, and response to overcharging, short circuit, mechanical damage, etc.

Lithium-based batteries are ready for early commercialization applications, though no single chemistry has emerged as the leader (and may never, since certain applications favor certain chemistries). However, room for improvement remains, notably in cost and production scalability.

Recent Relevant Headlines

International Herald Tribune — GM unveils Volt on company's 100th anniversary

Popular Mechanics — **Electrified Vehicle Hybrid Electric Cars: How They'll Solve the Fuel Crunch (Popular Mechanics)**

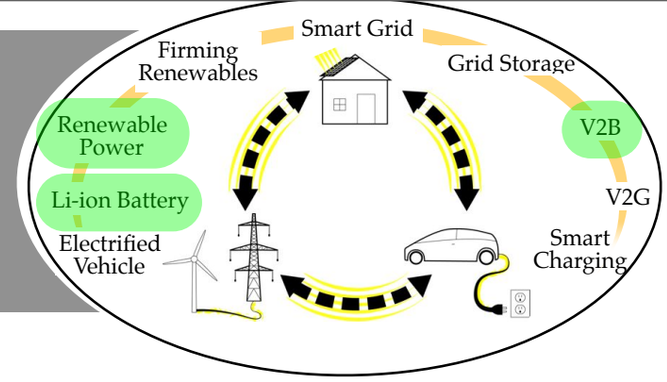
MOTOR TREND — **Lightning GT -- An Electric Ferrari-Killer with Four Motors**

autoblog — WE OBSESSIVELY COVER THE AUTO INDUSTRY — BMW plans 500 Electric MINIs for California

WSJ.com — THE WALL STREET JOURNAL. ONLINE — U.S. Auto Makers Target Battery Gap With Japan

The market for advanced automotive batteries is expected to grow to between $30 billion and $40 billion a year by 2020, compared with today's $900 million market for hybrid batteries, according to Deutsche Bank Securities Inc.

Smart Garage Uses Electrified Vehicles as Grid Storage, Thereby Making it Easier to "Firm" Renewables



Two of the major advances that will improve the efficiency of the electricity grid (renewables and Smart Grid (defined in the next slide)) rely partially on grid storage, which could be provided by electrified vehicles.

Renewable electricity generation technologies—such as wind, solar PV, solar thermal, and wave—are intermittent, which means that grid operators can't know exactly how much power they are going to produce and when they are going to produce it. This causes a few problems which can be alleviated in part with electrified vehicles. First, when a renewable, such as wind, becomes available, there is a period where it "ramps up"—that is, get to a useful level of electricity generation. This ramping-up period must be balanced by another power generation source ramping down, a task which batteries can do relatively inexpensively (if the communications infrastructure is in place between the cars and the operators), thereby reducing the cost of ramping up, which is one of several "integration costs" that are tacked on to volatile renewables.

When renewables reach a large scale, they often face another problem: the times when the renewables are producing power may not be the time when people need the power (like 3 am, when considerable wind energy is available). Electrified vehicles could be programmed to take up renewable energy when it is not needed by other users, making renewable energy markets reliable and allowing renewable power to be stored and deployed at will. Moreover, batteries that have been used to the end of a vehicle's life but still have storage capacity could be redeployed as stationary storage devices.

Recent Relevant Headlines

Technocrat

Lithium Ion Batteries as Peak Demand Grid Storage

One of the leading Lithium ion battery development companies has made an agreement with GE to develop systems that would be used for "grid stabilization", a way to smooth out sudden power demands without having to build and incorporate new power production plants.

Energy Smart

What to do about gas prices?

"Funding of a Smart Grid, with V2G (vehicle to grid) research and development, which will enable this transportation electricity to come from the grid more efficiently and enable greater penetration of renewable power."

The Big Picture on Renewable Energy

Medium-term, we're looking at even more exciting opportunities as the smart grid comes to fruition, along with all its advanced electronics, storage technologies, and vehicle-to-grid possibilities.

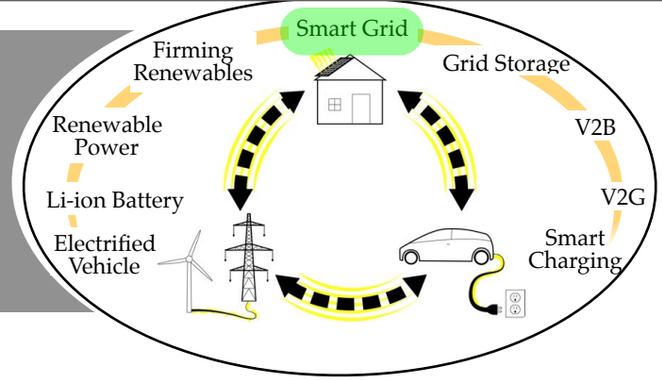
THE WALL STREET JOURNAL.

Sierra Pacific Resources CEO Michael Yackira Addresses Clean Energy Summit

"Whether it's through efficiency, renewables, more stringent building codes or the deployment of electrified vehicle, hybrid-electric vehicles, we are fortunate that in Nevada we have the capability of leading the nation in these important issues."

Source: Technocrat, Energy Smart, blogspot.com, Wall Street Journal

Smart Garage Could be the "Killer App" for the Smart Grid



The Smart Grid is the application of modern technologies to make the electric grid more reliable, more efficient, more resilient, and accommodating new services such as demand response.

The grid industry, relying on infrastructure that is decades old, and has very little information about how energy moves within the system. For example, most utilities have no way to know if a customer's power is on or off, unless the customer calls them. Smart Grid will increase the utility and grid operator's knowledge about their system, enabling many new efficient and cost-effective programs such as demand response, rates that reflect the actual cost of energy at a given moment in the day, and more.

Importantly, Smart Grid is also the key enabler of many perceived future benefits of electrified vehicles, such as time-delayed charging, ancillary services, and load shifting.

Electrified vehicles could be the "killer application" for Smart Grid. A coordinated roll-out of electrified vehicles could help push utilities and public utility commissions (PUCs) towards implementing the Smart Grid faster. These vehicles are unique as energy-using "appliances" in the amount of power they draw, their mobility, their ability to discharge and charge, and the fact that they don't need to be charging every moment they're plugged in. Electrified vehicles could also be an important lever in getting consumers to pay more attention to the way their energy use choices affect the grid, an important component of the Smart Grid.

Recent Relevant Headlines

Green Car Congress
Energy, Technologies, Issues and Policies for Sustainable Mobility

eTec and V2Green to Evaluate PHEV Fast-Charging and Smart Grid Interactions; V2Green and Coulomb Also Partner

Eye On Washington Argonne National Laboratory will work with Test Site Sweden to investigate PHEV instrumentation and smart charging systems, and how they interact with the electrical grid; track and evaluate consumer behavior while testing the vehicles in the field; quantify national, utility, and customer benefits; and plan and develop convenient public charging stations.

gas 2.0

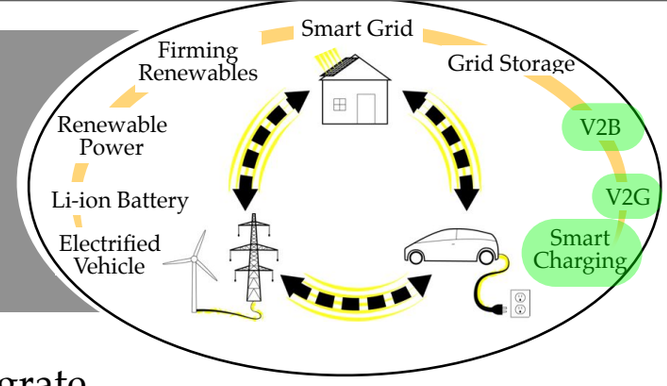
How to Build an Electric Car Charging Infrastructure: Smart Grids, Fast Charging and Universal Access

Coulomb Technologies

Coulomb Technologies Announces New Smart Charging Infrastructure for Electrified Vehicle Vehicles

Source: Green Car Congress, Gas 2.0, blogspot.com, Coulombtechnologies.com

Smart Garage Has Many "Flavors" of Connectivity



In order to collectively discuss the Smart Garage, a common language is necessary. This chart proposes specific terminology for the most important integration scenarios:

Electrified Vehicles can integrate with the grid in several ways. The term "V2G", or bidirectional flow of energy, gets thrown around, but there are many other forms of connectivity that are profitable, and more feasible, for near term solutions.

Benefits → / Other terms	Real Time Comm. with Utility	Cheaper Fuel for Customers	Timed Charging	Back-up Power	Uni-Directional Ancillary Services (A/S)	Bi-Directional A/S	Off-Peak Load	Load Shifting for Wind Firming	
V0G Convenience charging	✗	✓	✗	✗	✗	✗	✓	✗	→ **V0G** (Convenience charging): vehicle starts to charge as soon as it's plugged in, like a typical appliance
Timed Charge TOU charging	✗	✓+	✓	✗	✗	✗	✓	✗	→ **Timed Charge**: vehicle doesn't charge until a given time (from an installed program or a signal from the utility) when rates and grid load are low
V1G Smart charging	✓	✓	✓	✗	✓+	✗	✓	✗	→ **V1G** (Smart Charging): vehicle communicates with the grid in real time, and charges exactly when the grid needs it to. The vehicle also can provide ancillary services for extra revenue
V2B V2Home	✗	✓+	✓	✓	✗	✗	✓	✓	→ **V2B** (Vehicle-to-Building): Like V2G, except the electrified vehicle does NOT communicate with the grid but instead with an individual building's energy management system. No ancillary services.
V2G	✓	✓+	✓	✓	✓	✓	✓	✓	→ **V2G** (Vehicle-to-Grid): Like V1G, except the car can discharge, allowing a wider range of grid services as well as storage and back-up power
V2G NGU	✓	✓+	✓	✓	✓+	✓+	✓	✓	→ **V2G NGU**: V2G but in the future, when the grid has become smarter and more reliant on renewables, efficiency, etc.

Source: RMI Analysis

Smart Garage Implementation Faces Technical, Business, and Collaboration Barriers

The nature of the integrated system demands collaboration to overcome key technical and financial barriers. But the need for collaboration itself triggers its own barriers. The following list highlights the top 10 barriers* that have emerged during the research leading up to this charrette.

...are exacerbated by

Together, these barriers demand the need for cross-industry collaboration which in turn creates....

Technical Barriers

1. It's difficult to manufacture batteries at necessary scale;
2. Bidirectional charging could decrease battery life;
3. Current plug locations are not in places we may want to charge (garages, curb-side);
4. No agreement exists on standards for basic technologies: plug shape, voltage, communication protocol.

Business Barriers

5. Either OEMs or consumers (or both) will lose some money on the first generations of electrified vehicles b/c of high battery and drivetrain costs;
6. Roll-out without timed or smart charging can damage grid, cost money and upgrading the national grid to get "smart" will take time and money;
7. The possibility of a proliferation of unique and proprietary systems exists, and could hinder scaling; and
8. Risk that oil prices collapse or other market factors that could hinder electrified vehicle sales

Institutional Barriers Arising from Collaboration

9. Success requires sharing information and financial exchanges between many businesses who have never previously collaborated, and
10. Disagreement exists about the vision for the future of vehicle and grid integration *(for details, see our "hot topics" section immediately after this one).*

All of the above barriers are surrounded by the need to address potential environmental impacts:

- Managing vehicle usage if electrified vehicles significantly lower cost-per-mile
- Developing a full reuse (e.g., stationary power) and recycling infrastructure for batteries
- Understanding power plant emissions during different charge scenarios, particularly convenience charging in carbon-heavy generation times
- If the non-electrified fleet becomes much more efficient, through platform physics or other means, Smart Garage could become an environmentally unfriendly choice

These barriers are the source of many of the "hot topics" covered in the next section

Disagree? Great! Go to smartgarage.rmi.org/tiki-forums and contribute to the "pre-read forum"

Source: Interviews, RMI Analysis *for more barriers see Appendix E

Hot Topics: Charrette Discussion Will Focus on Questions of Control, Profitability, and Communication

Disagree?
Great! Go to smartgarage.rmi.org/tiki-forums and contribute to the "pre-read forum"

Six months of Smart Garage research (for more details on our sources see Appendix A) combined with our 25 years of experience in advanced energy and transportation, RMI believes these will be the hottest topics of debate at the Charrette:

Issue	One side of the argument...	...opposing side	Why it matters
Who will control the smart charging?	Utilities want control because that will ensure that they have no surprise loads on the grid	Utility control will require expensive infrastructure, and customers may not want to give up control of their charging	Significant investment at stake, and charge control essential to realizing benefits
When will we move to bidirectional charging (if ever)?	The sooner the system goes bidirectional, the sooner we have grid storage and all the benefits that go with it	Bidirectional charging will add stress and expense to the battery; it will require more grid management	V2G offers a wider menu of environmental and economic benefits than V1G (and also more risks, costs)
Where will the intelligence be located: the car or the grid/ building?	On-vehicle intelligence will make it easy to assign costs to the vehicle, higher functionality for the system	Grid- or building-based intelligence may be cheaper because it's stationary, and would probably mean the utility controls smart charging	Related to who controls the charging, could impact infrastructure costs, standards and scale, and ease of product use
What about fast charging (Level 3, i.e., >220V)? Will customers demand it? Will utilities allow it?	Fast charging will make electrified vehicles more attractive, enable more grid services per vehicle, and could speed customer adoption	Fast charging will place extreme strain on residential grids and some batteries, and requires significant infrastructure upgrades	Consumers may demand fast charging, it unlocks some new value opportunities
How much will battery packs cost in in the 2012–15 timeframe?	Still expensive, $650 per kWh and up. Demand is going to shoot up, from cars and stationary storage, scaled production is difficult and won't drive out much cost	$450 or lower. The price of batteries is going to fall fast as economies of scale kick in	The cost of batteries is one of the biggest drivers of system profitability

Source: Interviews, Industry Literature, RMI Analysis

Hot Topics: Charrette Discussion Will Focus on Questions of Control, Profitability, and Communication (cont'd)

Issue	One side of the argument...	...opposing side	Why it matters
Will Li-Ion batteries be ready from a technical perspective?	Batteries have overcome most major hurdles (heat, longevity, safety) and with the amount of investment and gov't support, they should be "ready for prime time"	Batteries are still unproven in volume automotive applications, especially with bidirectional charging	Li-Ion battery cost and performance are critical profitability drivers in Smart Garage
Will there be a government subsidy that we can rely on?	Yes, up to $7,500 a car with recent legislation. Washington will pass, implement, and sustain a tax subsidy	Even if the current subsidy passes it's only for the first 250,000 vehicles per OEM and there's no guarantee it or another subsidy will be sustained	Government subsidies can mitigate high drivetrain costs and lower the payback time per vehicle
Do we need a standardized, national recharging system?	Yes. Consumers need to be able to drive and electrified vehicle anywhere with minimal hassles. OEMs and battery makers need universal platforms to produce at scale	No. Each region will have different electrified vehicle adoption rates, and has a different grid network. Plus, most EVs will be used regionally. A standard system is unrealistic	A universal system might be much harder to implement quickly, but a collage of solutions could hamper long-term, large scale implementation
Who will "pay" for the Smart Grid?	Smart Grids are coming on line anyway, so the Smart Garage shouldn't bear the full cost of smart grid implementation	The inevitable arrival of electrified vehicles will force utilities who weren't planning on Smart Grids to spend millions on them	Assuming the full expense of a smart grid can push the system from a net profit to a net loss
How will the vehicles communicate with the grid?	Wirelessly. Wires are expensive and cumbersome (e.g., signals are destroyed if you go through a transformer)	Wired. We already have a wire system (the grid), and it's more reliable so the smartest thing is to use it	Multiple solutions could lead to unintegrated, incompatible systems, hampering adoption

Source: Interviews, Industry Literature, RMI Analysis

Hot Topics: Charrette Discussion Will Focus on Questions of Control, Profitability, and Communication (cont'd)

Issue	One side of the argument...	...opposing side	Why it matters
Are vehicle conversions/retrofits an important part of the solution?	Yes. We need electrified vehicles fast so we can't afford to wait for new vehicle development, and for the entire fleet to turn over: we should start converting existing HEVs and ICEs en masse to PHEVs	No. Conversions are non-optimal in terms of performance and price. We should focus on make great, dedicated electrified vehicles and finding incentives to speed up fleet turn-over	Scale and speed are critical, but vehicles need to meet performance and cost criteria in order to be sold in meaningful volume
How difficult will it be to have a widespread public charging infrastructure (especially for Level 1 and 2 charging)?	Easy. Many plugs exist, and for new ones it's a simple matter of getting an electrician, the necessary permissions, and setting up a charge station	Difficult. bringing wires to the streets opens an expensive can of worms around regulatory, right-of-way, retrofitting, and billing issues	Lack of public charging infrastructure could make consumers shy away, hampering adoption
How valuable are ancillary services to electrified vehicles?	Very. Ancillary services can significantly reduce payback time for electrified vehicles, perhaps even paying for the car itself.	Overrated. Ancillary services only apply to the first couple percent of electrified vehicles because the market is limited. Plus, setting up the infrastructure to utilize them is costly and difficult	Ancillary services have often been touted as they key to driving early PHEV adoption and could provide a new revenue stream
Should we implement a new communications infrastructure, or leverage existing assets?	New. IT is a fast moving industry, and constraining Smart Garage to fit outdated infrastructure will leave a lot of opportunities on the table.	Leveraging existing assets is worth it in terms of speed of implementation and reduced cost, even if it means a slight sacrifice in performance.	Communications infrastructure is critical in determining the cost and speed of implementation, and the performance of the system.

Got more
hot topics? Tell us about them at
smartgarage.rmi.org/tiki-forums

Source: Interviews, Industry Literature, RMI Analysis

Hot Topics: Charrette Discussion Will Focus on Questions of Control, Profitability, and Communication (cont'd)

Issue	One side of the argument...	...opposing side	Why it matters
Is battery swapping a legitimate solution to providing BEV range in the U.S.?	No. The infrastructure is more expensive than fast chargers, it requires standardized battery packs across dozens of OEMs, and it's expensive to retool vehicles for this functionality	Yes. Battery swapping mitigates that challenges of slow recharge times, the expense of fast chargers, enables more grid-storage applications and facilitates creative and beneficial ownership models for the batteries	Battery swapping, if it spreads, could be a disruptive element in most of the projected visions of electrified vehicles.
Will electrified vehicles penetrate evenly across the nation or appear in clusters?	Evenly. Rising gas prices is showing demand across the U.S. for efficient vehicles.	Clusters. HEVs have been purchased in predictable clusters (like San Francisco and Portland, as well as specific neighborhoods in a given city)	If electrified vehicles emerge in clusters, it will have very different implications for grid T&D as well as public charging infrastructure.
Is there an ideal place or type of customer to start launch a pilot?	Yes. The first region and target customers should be selected to optimized system benefits. Look for early HEV adopters, cities with Smart Grid already going in, etc.	No. If you start with an idealized base and pilot project results will be unrealistic and electrified vehicles will stay a "niche" product. There should be a group of coordinated but diverse pilot projects	One of the key goals of the Charrette is to design strategic first steps, such as pilots.
What should we assume the price of gas should be in our future planning?	$4.00. That's where it is today, and is the expected value of where it it will stay in the future	$1.50. To be robust, we have to design our system to succeed in extreme scenarios	The price of gasoline assumption is a major driver of system profitability. That said, a system that can work at $1.50/gallon would be a incredibly robust.
Is Smart Garage profitable?	Yes, under certain reasonable assumptions it can be highly profitable	No. Batteries are expensive, as is new infrastructure. It's hard to see how this can be profitable	System profitability will bring different players into the mix and alter messaging for policy and consumer audiences.

Source: Interviews, Industry Literature, RMI Analysis

The Goal: Accelerate the Build Out of Smart Garage in the Most Environmentally and Economically Beneficial Way Possible

Day	Outcome
Day 1	Immersion and Vision: Ground participants in consumer experience, work to find common threads in participants' short-to-mid term visions, then use these to clarify stakeholders' roles and needs under different money and resource flows.
Day 2	Identify and Bust Barriers: Test robustness of money flows using couple of extreme scenarios. Use the insights gained to create a list of top barriers for each stakeholder. Brainstorm strategies to mitigate barriers. Brainstorm long-term visions and check that mitigation strategies align with it.
Day 3	Create 3-5 concrete project plans that tackle top barriers, build trust, buy-in among stakeholders, and commitment to kicking off new projects.

Goal

Our goal is to accelerate the build out of Smart Garage in the most environmentally and economically beneficial way possible.

To achieve this goal, the charrette will align the vision of a diverse set of stakeholders far broader than have been previously convened on this topic.

Additionally, the charrette participants will identify 3-5 specific projects that they will start the day after the charrette.

Source: RMI