Monitoring Progress Towards a Clean Energy Economy

Energy Storage as a Tool to Address GHG Emissions

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A123 Systems

A123 Systems

Manufacturer of Advanced Energy Storage

- #1 lithium ion battery manufacturer in U.S.
- #1 supplier globally of lithium ion systems for grid applications

Transportation

Passenger Hybrids, PHEVs and EVs

Commercial Hybrids, PHEVs and EVs

Electric Grid

Regulation, Grid Reliability

Renewable Integration, Congestion Relief

Commercial

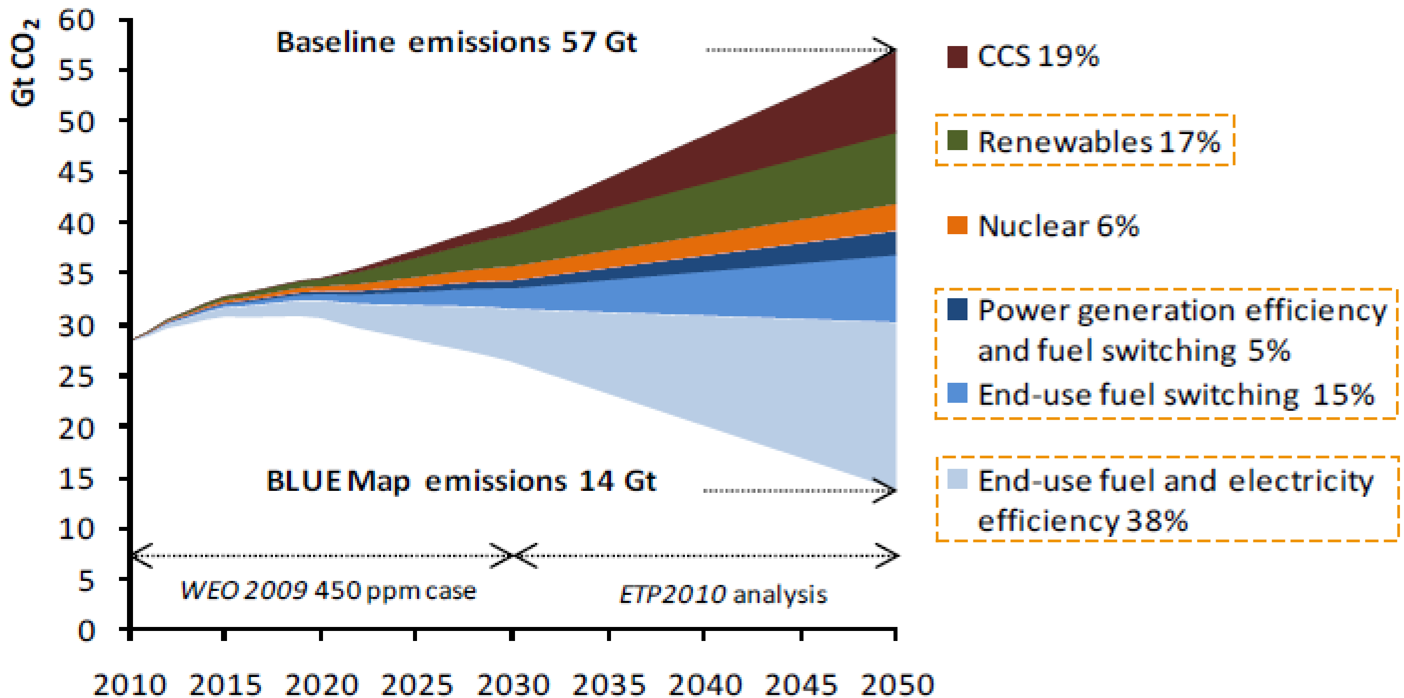
IT & Telecomm

Medical Systems

Material Handling

Industrial Controls

Energy storage can impact several key technologies for reducing global GHG



Energy storage is transforming how energy is generated and used in transportation and grid sectors

Key Questions

- *Compared to ETP Blue Map scenarios from present day to 2050, which technologies appear to be making progress as expected, and which are not?*
- *What are the major barriers to inhibiting greater development and deployment? Can these be characterized by categories, such as: (a) policy; (b) socio-economic; and (c) technical and/or cost?*
- *What would be the most important messages for the audience (IEA, CEM Ministers, etc.)?*
- *What are the most important actions that IEA member countries might take to address barriers?*
- *For technical and cost-reduction barriers, what are the most fruitful areas or opportunities for enhanced R&D cooperation to address technologies that are not progressing as expected?*

Are EV-PHEVs making progress as expected?

- Initial sales have been slower than hoped in the U.S.
  - Nissan Leaf sales: ~8000 as of October 2011
  - Chevy Volt sales: ~4000 as of October 2011
  - Still higher than first year sales of Toyota Prius (~3000)
- Development activity has been strong
- Growing interest in commercial vehicles and start-stop/micro hybrids

http://www.rolandberger.com/media/press/releases/Study_on_development_of_automotive_Li_Ion_battery.html

Global Vehicle LiB Market Study

Global Study

Detroit/Munich, August 2011

Roland Berger
Strategy Consultants

Management summary

> The **global automotive Li-Ion battery market** is forecast to grow from **USD 1.5 bn** to **USD 8.9 bn** by 2015

> Further growth to **USD 53 bn** forecast in the **2020 high scenario**

> **Light vehicles** will **dominate** the market development – over **80%** of total value in 2015

> **Truck** market will be driven by electrification of **class 3** and **class 4** pickup and delivery trucks

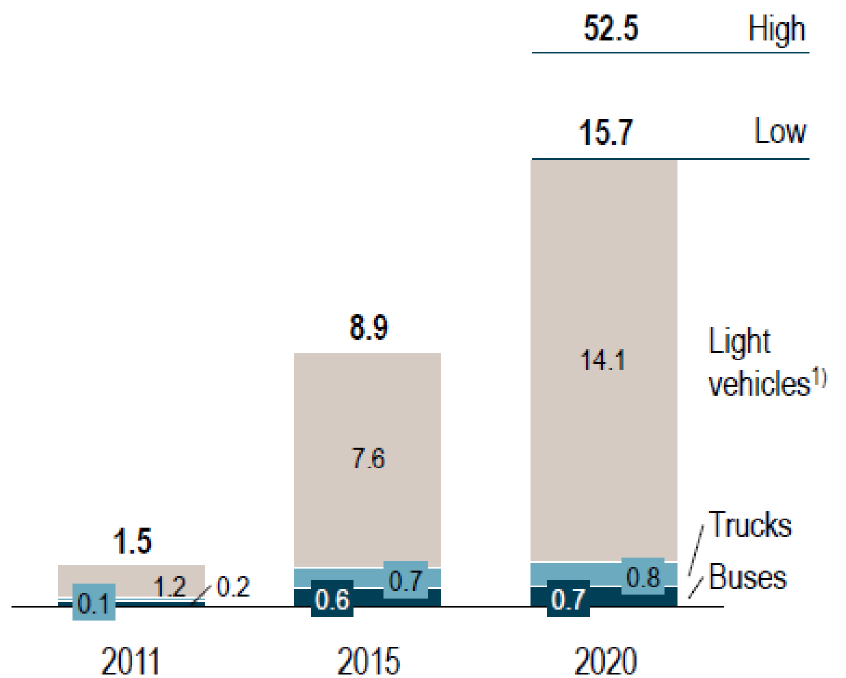
> **China** will account for over **80%** of the **bus** market value

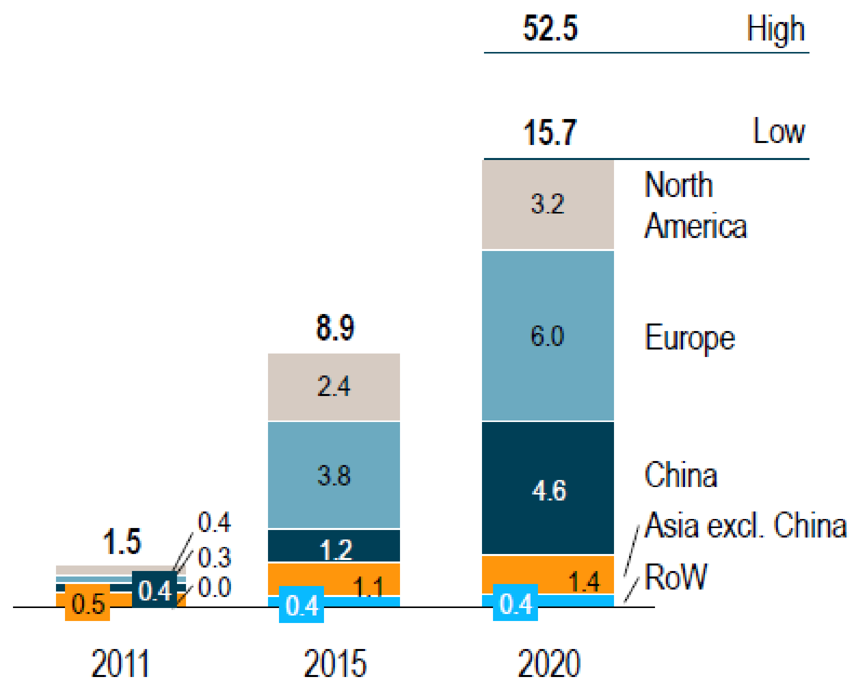
> As the market takes off, **five frontrunners** will dominate and the industry will consolidate

> **Consolidation** was already forecasted in a 2010 Roland Berger report which concluded that **industry overcapacity** will exist in **2015**

Source: Roland Berger

The global LiB market is expected to be USD 9 bn in 2015 – Light Vehicles dominate and high growth in China occurs after 2015



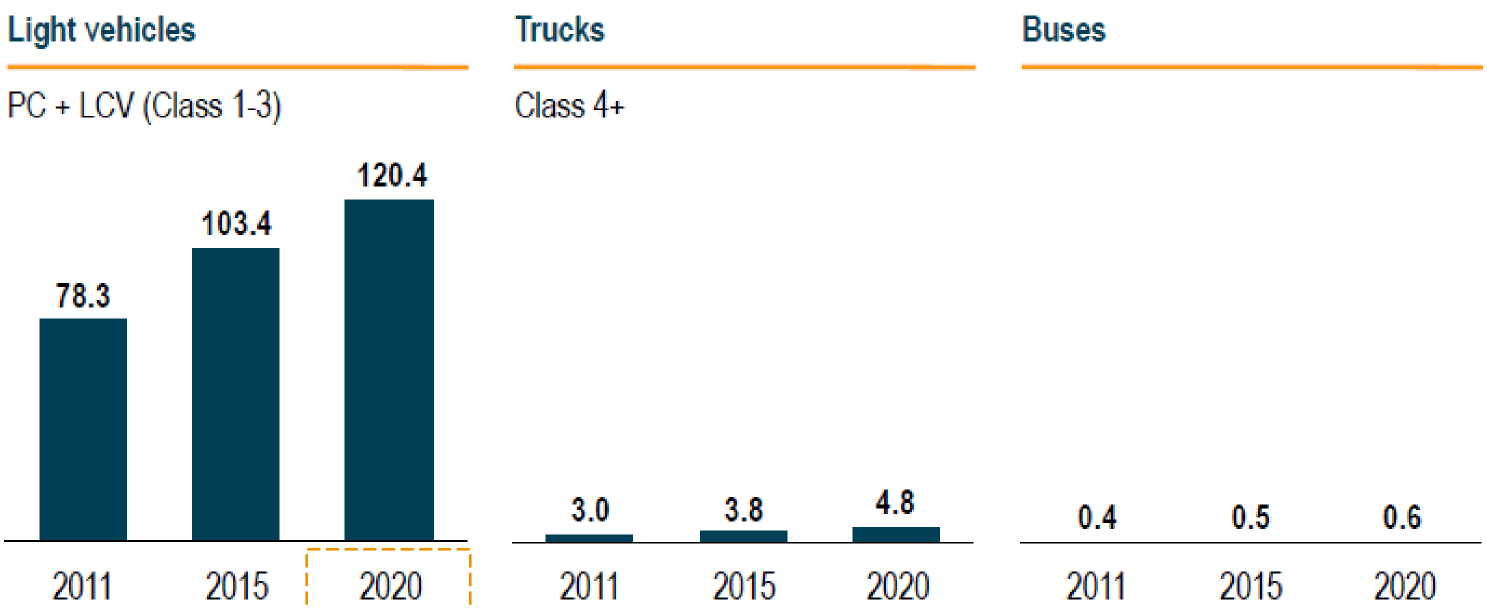


1) Light vehicles = passenger cars + light commercial vehicles (class 1-3)

Source: Roland Berger LiB market model

Light vehicles dominate the xEV market because of the large volume base and relatively high penetration rates

Total vehicle build and penetration rate assumptions by vehicle class [m units]



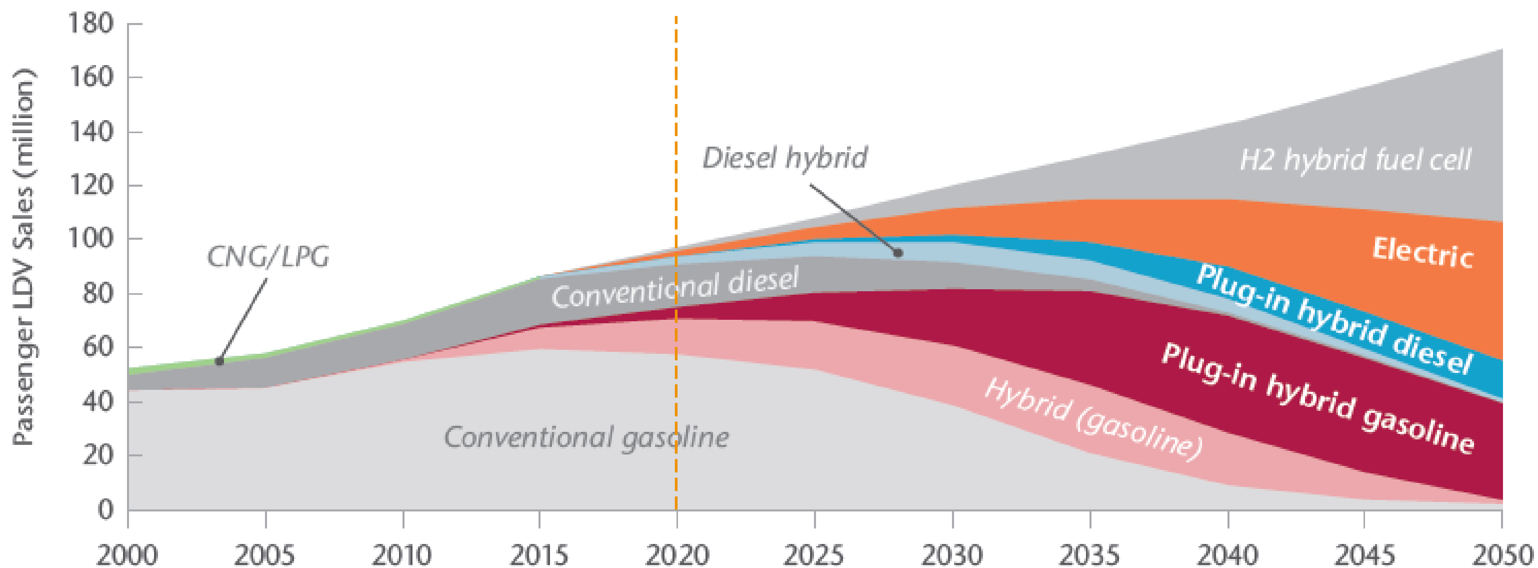
PENETRATION

	Light vehicles 2011	Light vehicles 2015	Light vehicles 2020 Low	Light vehicles 2020 High	Trucks 2011	Trucks 2015	Trucks 2020 Low	Trucks 2020 High	Buses 2011	Buses 2015	Buses 2020 Low	Buses 2020 High
EV/PHEV [%]	0.1%	0.8%	2.2%	8.2%	0.1%	0.5%	0.7%	1.3%	0.4%	1.4%	2.3%	3.0%
HEV [%]	1.7%	2.6%	6.5%	9.4%	0.1%	2.3%	1.2%	4.1%	1.9%	6.2%	9.5%	14.0%

Source: Roland Berger LiB market model

International Energy Agency

Annual light-duty vehicle sales, BLUE Map scenario, 2000-2050



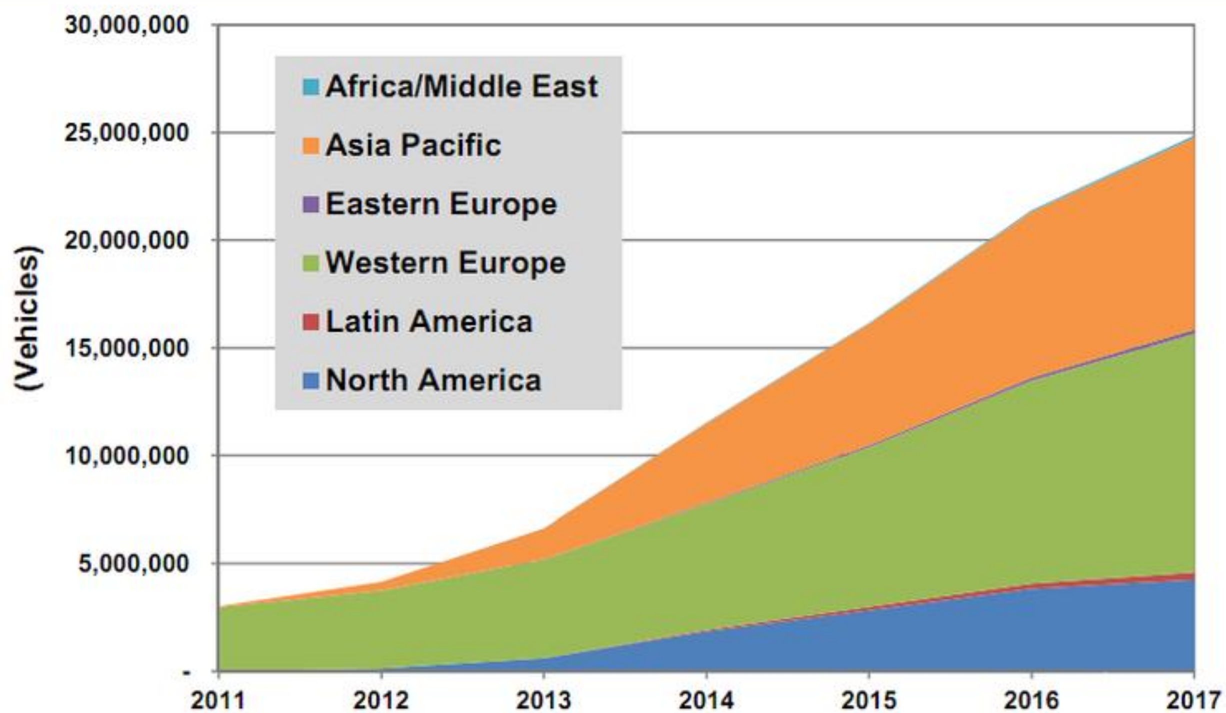
PENETRATION	2011	2015	2020 Low	2020 High	RB 2020
EV/PHEV [%]	0.1%	0.8%	2.2%	8.2%	**5%**
HEV [%]	1.7%	2.6%	6.5%	9.4%	**8%**

Source: Roland Berger LiB market model

Micro-Hybrid Applications
Fuel economy gains for limited incremental cost

Upgrading a conventional vehicle's battery, starter & alternator enables significant fuel savings for limited cost & development effort

Annual Micro-Hybrid Sales by Region



(Source: Pike Research)

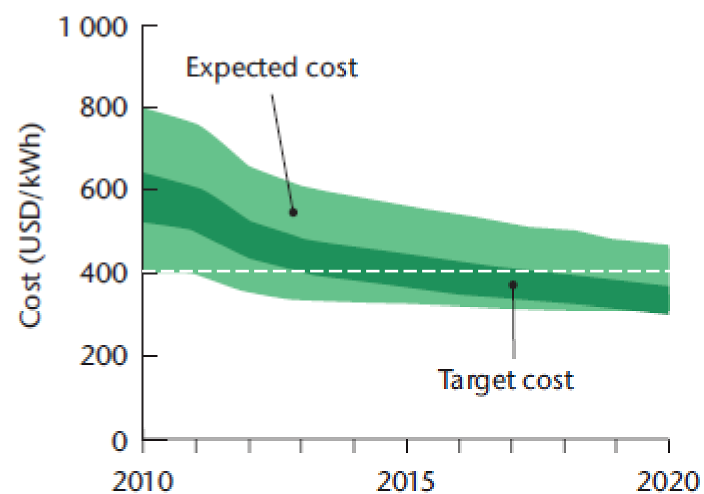
What are the major barriers to EV-PHEV deployment?

- Consumers:
  - Initial cost
  - Range anxiety
  - Awareness, lack of authoritative information
  - Lack of customer choice
  - Charging infrastructure
- Automakers
  - Cost
  - Technology integration, manufacturing
  - Regulatory certainty

Battery costs *are* dropping rapidly

- Battery manufacturers are bidding programs with prices close to the target range
  - Current costs are $500-700/kWh, with prices dropping to $400-500/kWh in the next few years
  - Industry analysts expect battery pricing to drop to <$400/kWh within five years
- Suggested metrics
  - Usable energy, not total energy
  - Total cost of ownership, not initial cost

Battery costs through 2020

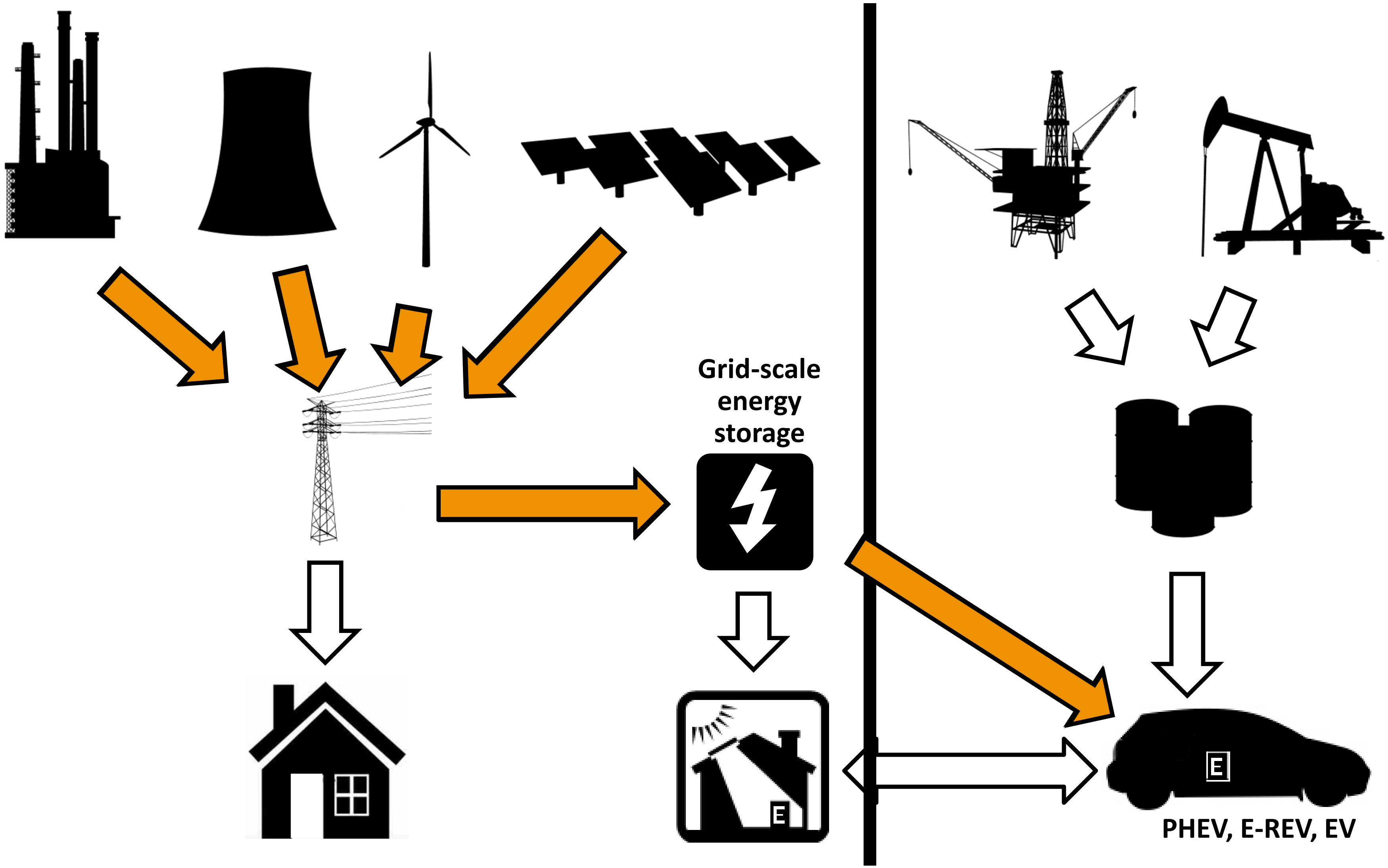


Battery costs for PHEVs and EVs must drop rapidly toward USD 300/kWh in order to bring vehicle costs to competitive levels.

What are the most important messages?

- Regulations drive action in industry
- Policy support must be consistent and sustained
- Stop thinking about vehicles as transportation devices and start thinking of them as mobile energy storage resources
  - EVs and PHEVs work synergistically with other technologies
  - EVs and PHEVs are the only vehicles that get cleaner the longer they're on the road (because the grid gets cleaner)
  - EVs and PHEVs are an opportunity to "future-proof" the transportation sector
  - PHEVs are neutral regarding liquid fuel use: can be gasoline, diesel, biofuels
  - The future generation mix is TBD, but if we start deploying EVs and PHEVs *now*, we will magnify the benefit of a cleaner, *future* grid

The paradigm shift in energy usage

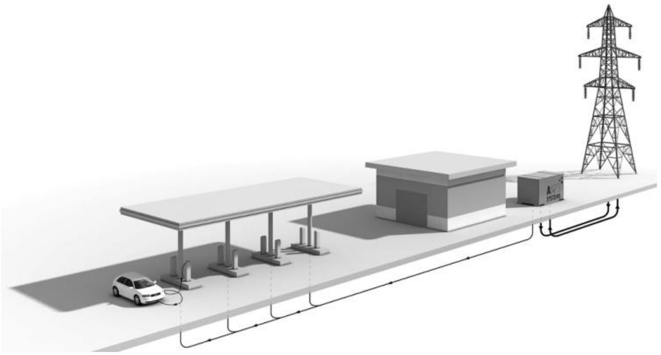


What are the most important actions to address barriers?

- Progressive fleet fuel economy or emissions rules which favor EV-PHEV adoption
- Financial incentives for EV-PHEV owners
  - Higher petroleum-based fuel costs relative to electricity, rebates at point-of-sale, tax credits, reduced registration fees, reduced electricity prices for off-peak charging, revenue from grid services, etc.
- Non-financial incentives for EV-PHEV owners
  - HOV lane use, parking, access to city center, etc.

What are the opportunities for enhanced R&D cooperation?

- Opportunity exists at government-level that are much more difficult for private industry to undertake
  - Systems-level approach: create the ecosystem
  - Infrastructure, standards, protocols
- Fast charge system development
  - Batteries, charging infrastructure



- Alternative vehicle architectures, business models
  - Vehicles are vastly underutilized resource (2 out of 24 hours)
  - If a vehicle battery could offer some other service while plugged in, it would improve the economics and accelerate adoption

What is grid energy storage?

Chemical Storage

Battery

Electrical energy is stored for later use in chemical form.
Example technologies include: lithium ion, sodium sulfur, and lead acid batteries.

Thermal Storage

Ice Storage

Air conditioners create ice at night, when power rates are low. This stored ice then runs a cooling system during the afternoon, when power costs are highest and the power grid is most stressed.

Mechanical Storage

High Speed Flywheel

Flywheels convert electrical energy to kinetic energy, then back again very rapidly.
Flywheels are best suited for power conditioning and short-term storage.

Bulk Mechanical Storage

Compressed Air Energy Storage (CAES)

Electricity is used to compress air into small or large modular storage tanks or a large underground cavern. The compressed air is used to spin turbines when electricity is needed.

Bulk Gravitational Storage

Pumped Hydro

Excess electricity is used to pump water uphill into a reservoir. When power is needed, the water can run down through turbines, much like a traditional hydroelectric dam.

Slide adapted from Janice Lin, California Energy Storage Alliance (CESA)

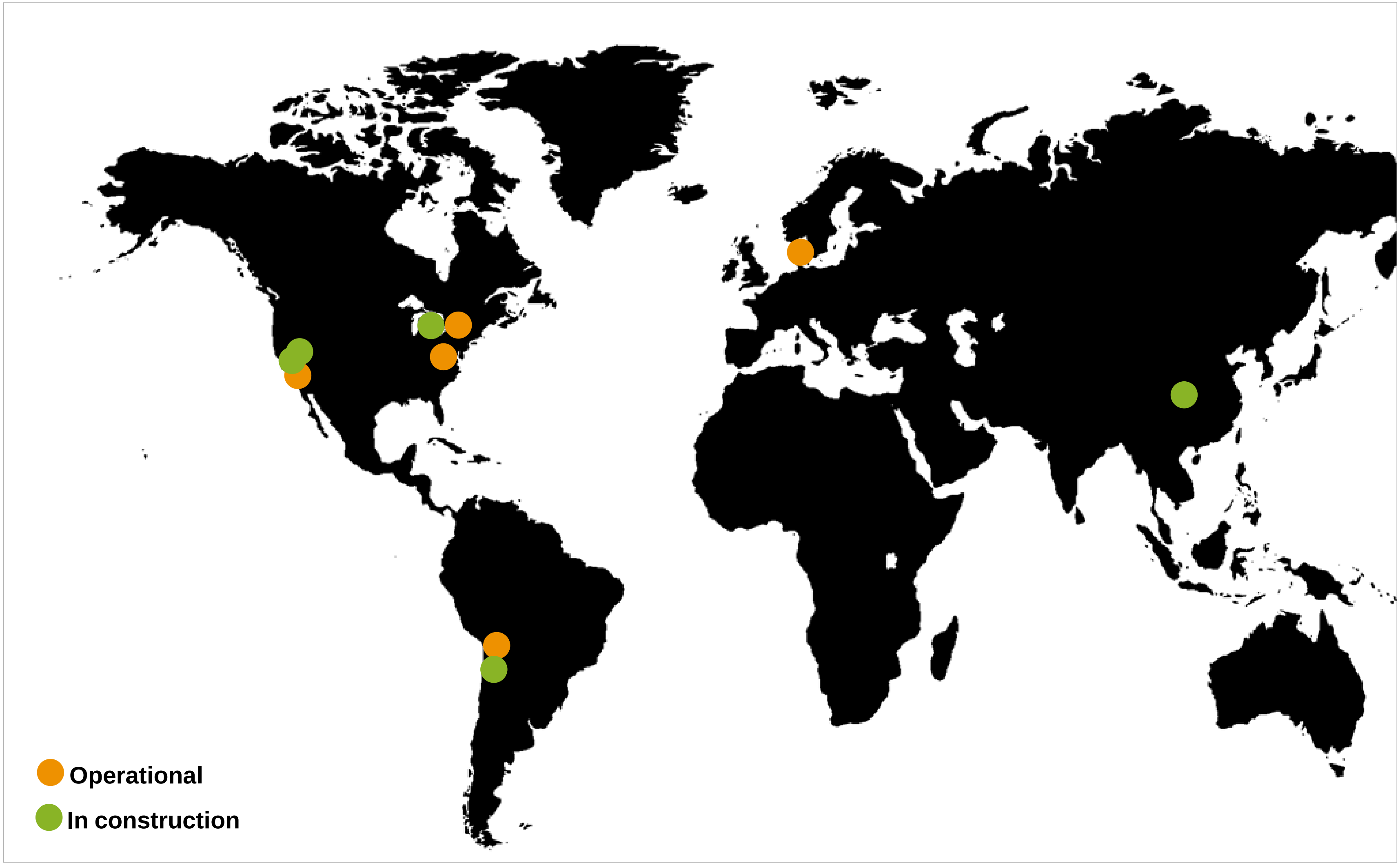
Grid energy storage allows energy to produced when it is most efficient to do so

- Problem: energy is needed but can not always be generated by the most efficient (least CO_2 intensive) means
  - Due to lack of availability of the generation resource or the inability of the grid to use the generation for load when/where it is needed
  - Result: wasted energy, greater emissions
- Grid energy storage:
  - Allows greater use of renewables
  - Increases efficiency of fuel-burning plants, thus reducing emissions
  - Increases reliability and reduces need for backup generation
  - Facilitates micro-generation
  - Maximizes utilization other technologies and grid assets (synergistic)

Is grid energy storage making progress as expected? Yes!

A123 SYSTEMS

A123 will have deployed 90MW of grid energy storage by end of 2011



Coming in 2012: Tehachapi Storage Project

- Customer: Southern California Edison
- Location: Tehachapi Windfarm
  + California's largest wind resource
  + Wind development potential driving grid infrastructure upgrades and expansion
  + 2nd largest wind park in the world
    – 660MW installed / ~5,000 turbines
- System
  + 8MW – 4 hour (32MW-hour) GBS system
    – World's largest Li-ion battery system when complete
  + Dynamic 4-Quadrant PCS/Grid Interface
  + A123 Prismatic Cells
  + Installation / Operation 2012
  + 13 Targeted Operational Uses – Individually and Stacked

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13 Operational Uses and Investment Recovery

Use	Market	T Rate Base	D Rate Base
1. Voltage support/grid stabilization	★	★	★
2. Decreased transmission losses		★	★
3. Diminished congestion	★	★	★
4. Incr. reliability by load shed deferral		★	★
5. Deferred transmission investment		★	★
6. Optimize renewable-related transmission		★	★
7. Provide system capacity	★		
8. Renewable integration (smoothing)	★	★	
9. Renewable output shifting	★		
10. Frequency regulation	★		
11. Spin/non-spin replacement reserves	★		
12. Deliver ramp rate	★		
13. Energy price arbitrage	★		

What are the major barriers to grid energy storage deployment?

- Cost
- Market design, regulatory barriers
- Insufficient data, conservatism in utility customers

Cost is the primary challenge

- Beyond bulk mechanical storage (hydro, CAES), batteries are the main focus of effort
  - Lithium ion
  - Sodium sulfur
  - Lead acid
- Most batteries technologies are $300-1000/kWh, but need to be below $200/kWh with 10+ year life
- Lithium ion-based grid energy storage is benefitting from lithium ion usage in consumer electronics and transportation
- Some usages are economically attractive today and many more will become attractive as battery prices drop

What are the most important messages?

- Grid energy storage can do more than just store energy at night for discharge during peak day hours
  - In fact, the most valuable applications occur over much shorter time scales (seconds and minutes, not hours)
- Lack of clarity in how energy storage services will be compensated has slowed deployment by utilities
  - Facilitating the deployment in today's applications will accelerate the use of storage in future applications
  - Grid energy storage is being deployed commercially today, without government subsidies or support, for ancillary services
- To achieve high levels of PV and wind penetration, some form of energy storage is required

Ancillary services

Ancillary services provide the resources the system operator requires to reliably maintain the instantaneous and continuous balance between generation and load.

Table 1. Definitions of key ancillary services

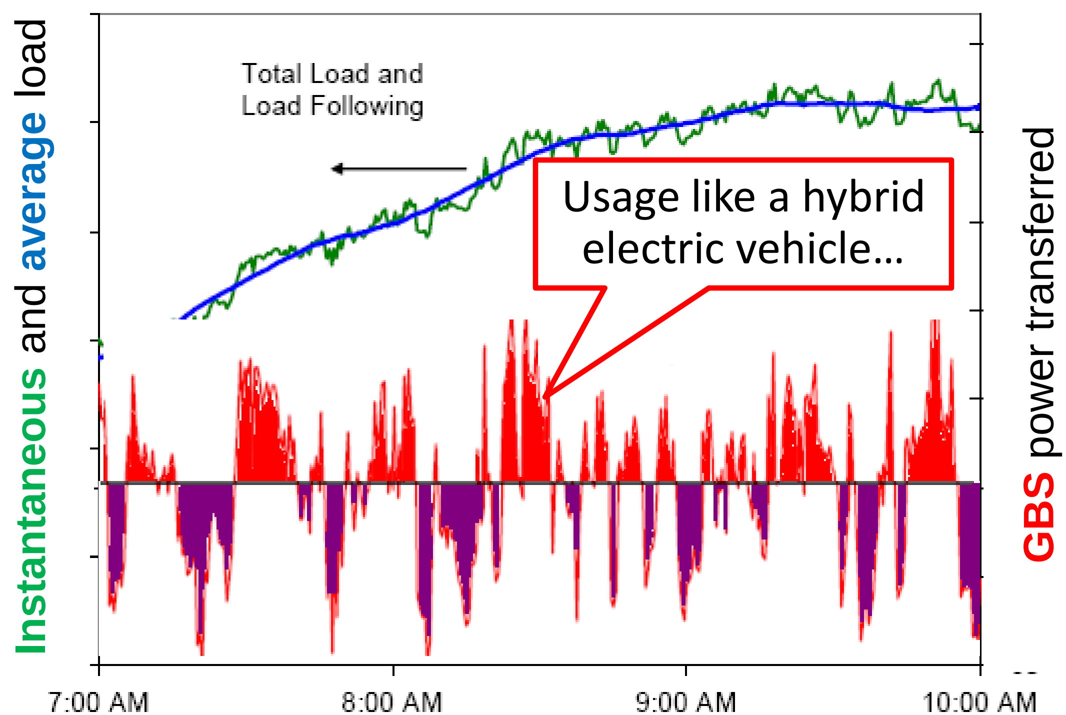
Service	**Service Description**		
	Response Speed	*Duration*	*Cycle Time*
Regulation	Power sources online, on automatic generation control, that can respond rapidly to system-operator requests for up and down movements; used to track the minute-to-minute fluctuations in system load and to correct for unintended fluctuations in generator output to comply with Control Performance Standards (CPSs) 1 and 2 of the North American Reliability Council (NERC 2002)		
	~1 min	*Minutes*	*Minutes*
Spinning reserve	Power sources online, synchronized to the grid, that can increase output immediately in response to a major generator or transmission outage and can reach full output within 10 min to comply with NERC's Disturbance Control Standard (DCS)		
	Seconds to <10 min	*10 to 120 min*	*Days*
Supplemental reserve	Same as spinning reserve, but need not respond immediately; units can be offline but still must be capable of reaching full output within the required 10 min		
	<10 min	*10 to 120 min*	*Days*
Replacement reserve	Same as supplemental reserve, but with a 30-min response time; used to restore spinning and supplemental reserves to their pre-contingency status		
	<30 min	*2 hours*	*Days*
Voltage control	The injection or absorption of reactive power to maintain transmission-system voltages within required ranges		
	Seconds	*Seconds*	*Continuous*

Frequency Regulation
Grid Battery System (GBS) hybridizes a power plant

Standard power plant

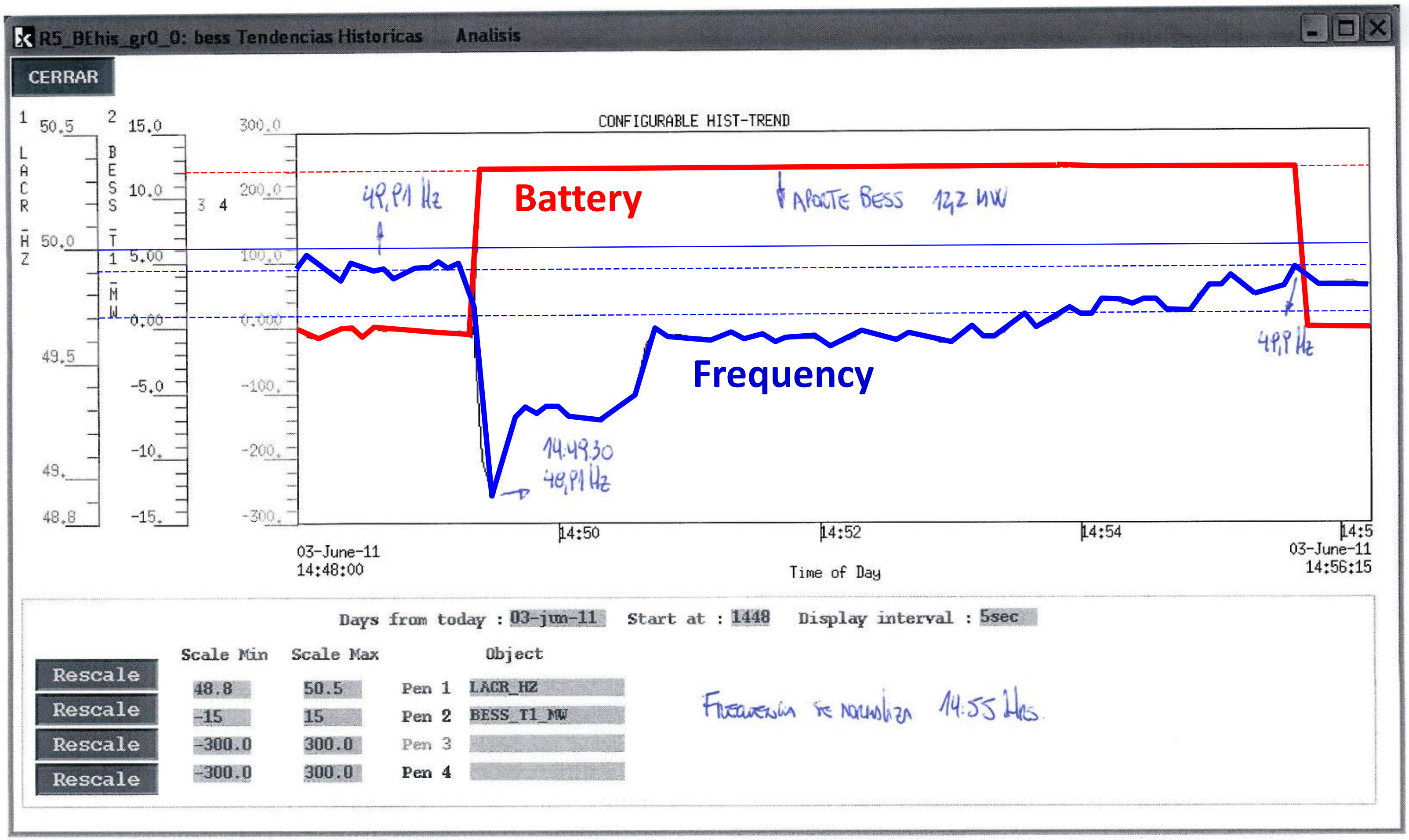
96 to 100 MW output

GBS provides power (discharges)
Average output of power plant
GBS is charged by power plant



Spinning Reserve

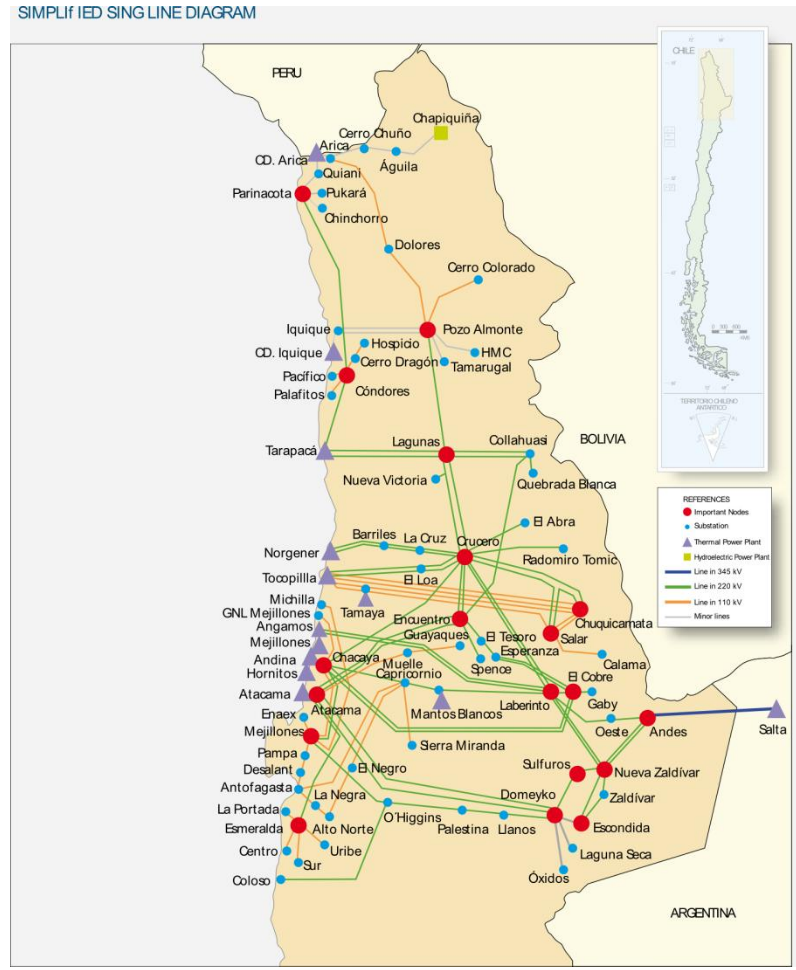
Autonomous Response to Loss of Generation



CDEC-SING Fault Report No. 2777, June 3, 2011

Spinning Reserve: Chile Case Study

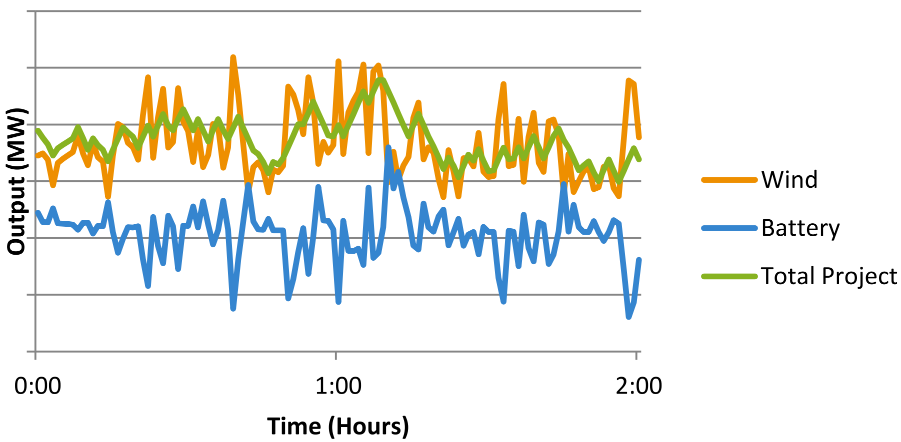
- Challenge: Fragile power system drives high generation reserve requirement
- Solution: 12 MW/4MWh in 8 Packaged systems
- Result: replaced unpaid generator reserve
  - Frees up generating capacity for paid energy service
  - In commercial service since 2009 with <3 year payback
  - Superior fault response performance



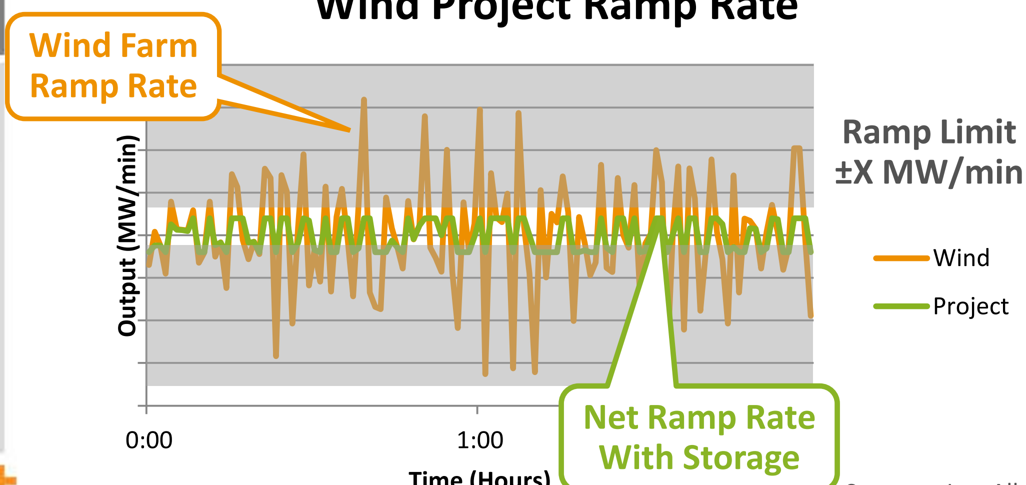
Renewable Ramp Management

Absorb sudden changes in wind farm output

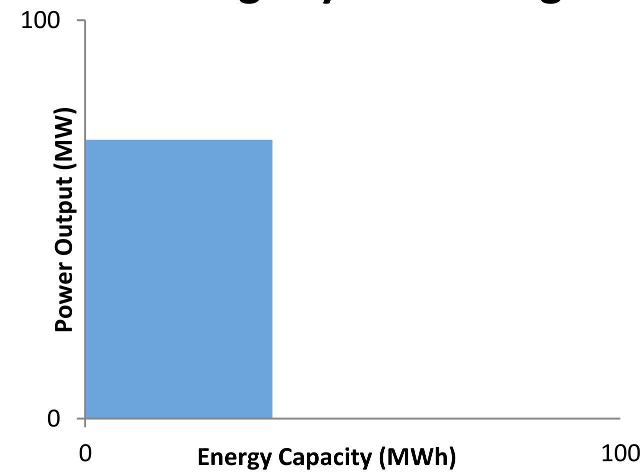
Wind Project Output



Wind Project Ramp Rate



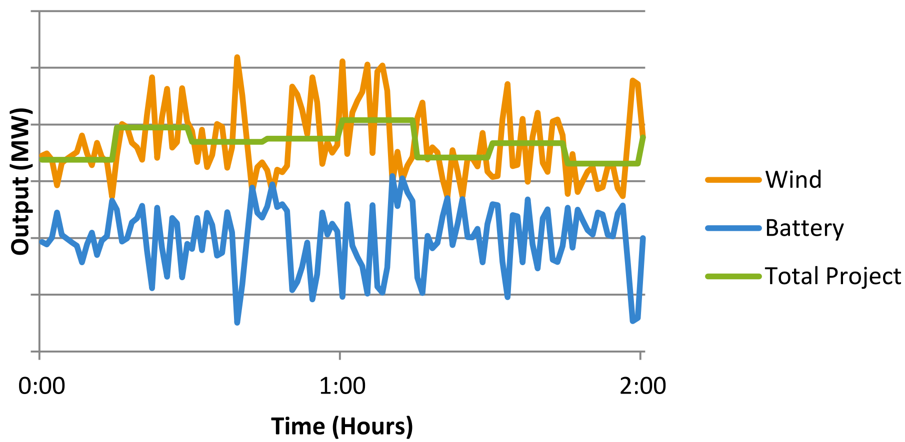
Storage System Sizing



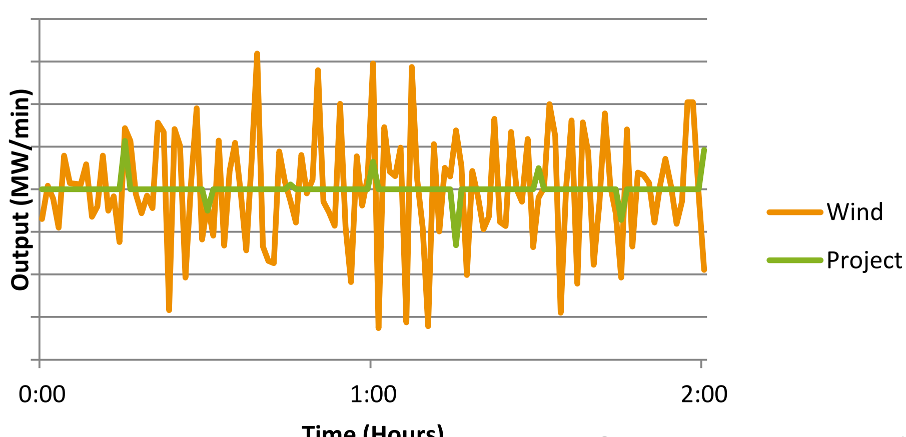
Renewable Firming

Improve forecast accuracy through output buffering

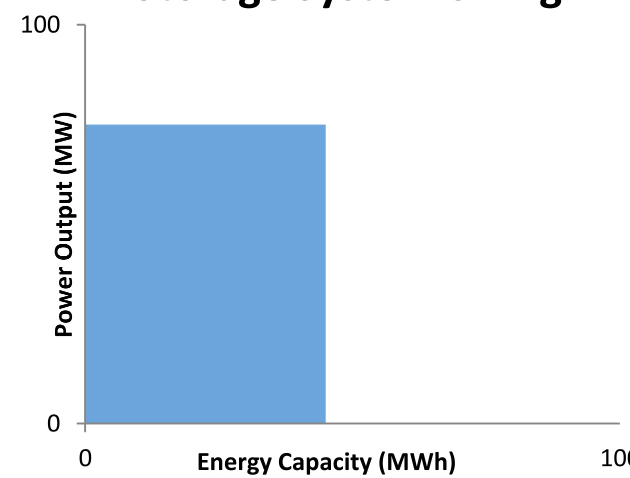
Wind Project Output



Wind Project Ramp Rate



Storage System Sizing



What are the most important actions to address barriers?

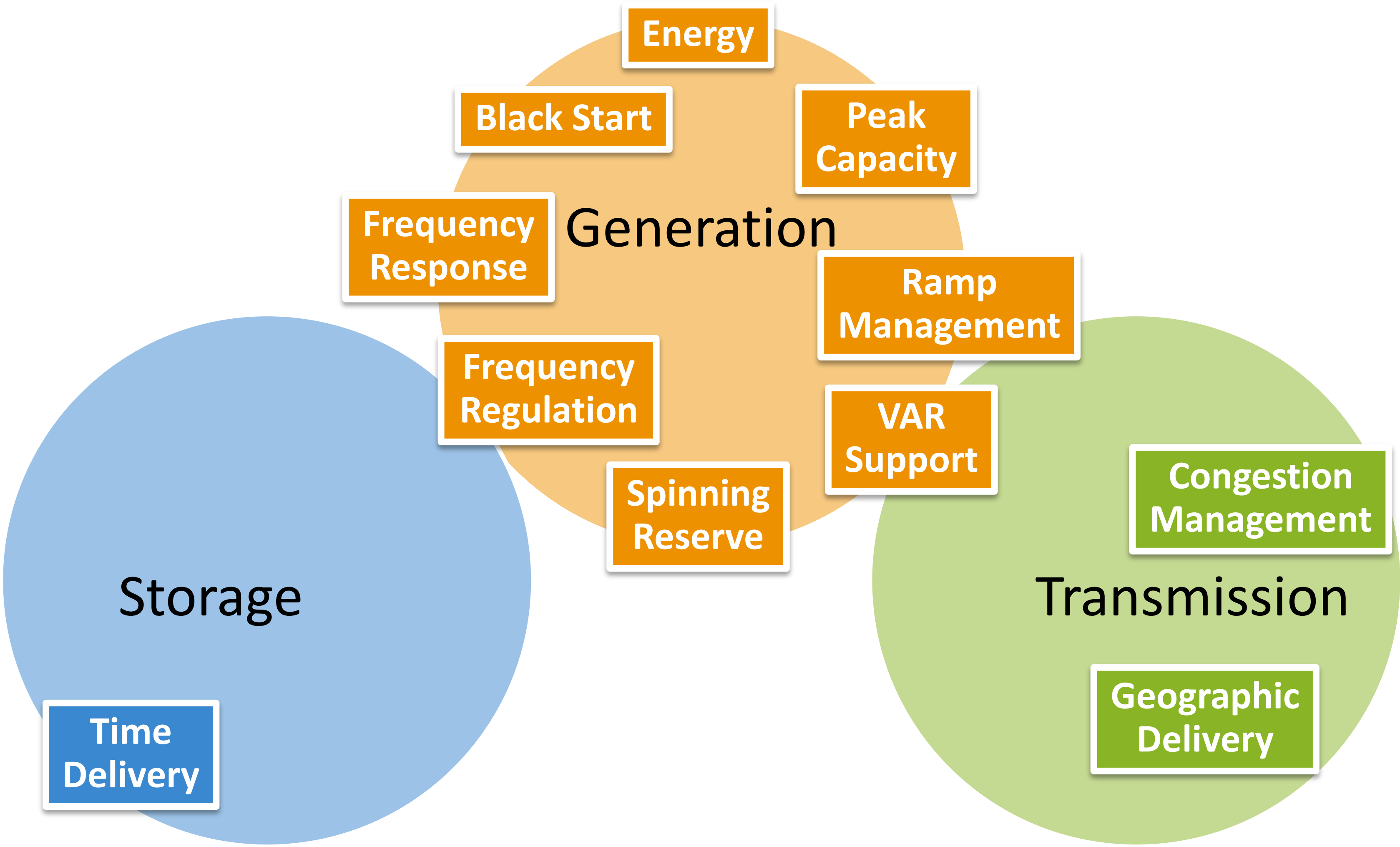
- Design energy markets to compensate energy storage for the value it provides to the grid
  - Remove uncertainty about asset recovery
- Regulatory structure
- Funding for more large-scale deployments
  - Data from government-funded projects should be openly shared

Example of harnessing the free market: FERC Pay-for-Performance Rule

- Pay-for-Performance Rule: fast-responding assets should receive higher payment.
- Implementation starts in 2012
- This rule should reduce the amount of frequency regulation that is procured, thus lowering emissions
- Market design and regulatory framework are key to accelerating use of new technologies

Policy Recommendation: Simultaneous Markets

Storage rearranges traditional functional separations



Policy Recommendation: Simultaneous Markets

Allow an asset to participate in all relevant markets

- Barrier: legal restrictions impede full storage asset utilization
  - Restrictions in place to protect against cross-subsidization
  - State/Federal: an asset is usually categorized as either distribution or transmission
  - Generation/Transmission: a transmission asset cannot participate in energy and ancillary service markets
- Solution: remove restrictions or create mechanisms to facilitate modular ownership and full utilization
  - Option: Contractual, competitive solicitations for grid functions
  - Option: Transparent accounting of new storage assets

What are the opportunities for enhanced R&D cooperation?

- Demonstration projects employing grid energy storage to solve specific local challenges (e.g. wind integration)
- Studies to quantify and demonstrate the benefits of grid energy storage, with the goal of establishing structures for assets to be compensated for their value
  - State-owned grid operators that self-provide have unique opportunity to deploy energy storage for multiple services
- R&D into new materials and energy storage architectures that reduce cost while improving reliability and life
- Studies to demonstrate the ability of plug-in electric vehicles to offer grid services, such as frequency regulation, renewable integration, and spinning reserve

Business Case Comparison

Minimal incremental benefit from bi-directional flows

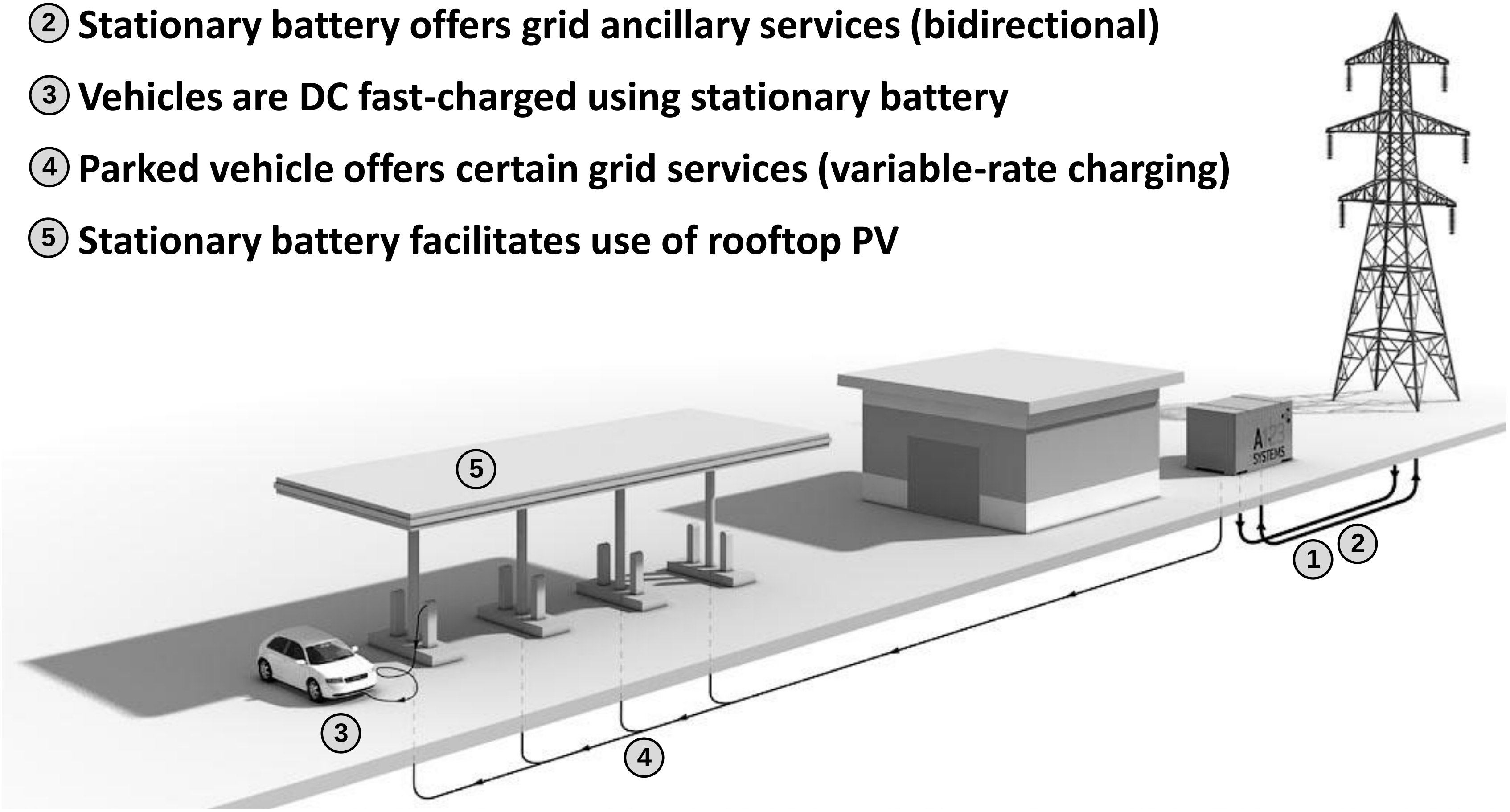
Highest-valued applications for today's standalone energy storage projects

	Frequency Regulation	Renewables Ramp Management	Spinning Reserve	Energy/Peak Shaving	Capacity
Steady State Charging	**No**	**No**	**No**	**Partial (with dynami pricing)**	[illegible]
Variable Rate Charging	**Yes**	**Yes**	**Yes**	**Partial (no arbitrage)**	**Partial**
Bidirectional Flows (V2G)	**Yes**	**Yes**	**Yes**	**Yes (but reduces battery life)**	**Yes (but reduces battery life)**

Likely sweet spot for near-term electric vehicles

Fast charge system using stationary batteries

1. Stationary battery gradually charged, minimizing negative impact to grid
2. Stationary battery offers grid ancillary services (bidirectional)
3. Vehicles are DC fast-charged using stationary battery
4. Parked vehicle offers certain grid services (variable-rate charging)
5. Stationary battery facilitates use of rooftop PV



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