Report on Business Case in Hawai‘i for Storage Options

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Subtask 11.2 Deliverable 3
Report on Energy Storage Systems

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Task 11.2 Energy Storage Systems: Business Case in Hawai‘i

Because Hawai‘i does not have an established market for the sale and purchase of generation and ancillary services, it is difficult to determine the value of storage systems. Determining the possible suite of technologies and services that can support the integration of a high percentage of intermittent renewable energy into the system is necessary. We must understand the value of energy storage and its relationship to other ancillary services that together will address the specific needs of the Hawai‘i grids.

HNEI, in cooperation with the Hawai‘i Reliability Standards Working Group, has contracted with GE to conduct an Ancillary Services Definitions and Capability Study whose objective is to define and quantify the ancillary services necessary to integrate new renewable resources. The specific tasks of the study are:

Task 1 - Identify and define the ancillary services needed for integration of new generation resources, including various renewable generation technologies;

Task 2 - Identify which technologies can provide each ancillary service;

Task 3 - Identify the physical requirements of ancillary services needed for each Hawaiian Island; and

Task 4 - Outline considerations for specifying and acquiring ancillary services for Hawai‘i grids to ensure that the Hawai‘i utilities can acquire a least-cost portfolio of resources that can supply ancillary services that protect reliability, maximize renewable output, and minimize energy costs.

This study will help determine where energy storage technologies can best fit in and compliment the suite of ancillary services that will be essential to the integration of renewable resources into Hawai‘i’s grids.

Attached in the pages following this text are slides from GE describing the study parameters and some of the preliminary analyses:

Slide No.	Description
1-2	Study Overview and Introduction
3	Task 1 Objectives
4	Inter-Related Responses for System Reliability
5	Functions of Ancillary Services

Ancillary Services Def. & Cap. Study

Overview of Study

Purpose:

Study sponsored by HNEI with support and guidance from Hawaii RSWG to identify, define, and quantify ancillary services required to support new generation (including renewable generation) on the Hawaiian islands.

Objectives:

- Task 1: Provide a standardized set of ancillary services along with their associated definitions (in functional terms) which reflect the operational needs of the Hawaii system.
- Task 2: Technologies (generation, transmission, storage, and demand response (DR)) will be assessed for their ability to support the respective ancillary services
- Task 3: Identify the physical requirements of the ancillary services needed for each Hawaiian island (Oahu, Maui, Big Island)
- Task 4: Outline considerations for specifying / acquiring ancillary services for the Hawaii grids that protect reliability, incent renewable generation, and minimize production costs.

Introduction

Ancillary services & additional functions required for power system operation

- **Ancillary services*** are those functions performed by the equipment and people that generate, control, transmit, and distribute electricity to support the basic services of generating capacity, energy supply, and power delivery. They are required to maintain reliable operations of the electric power system.

- In addition to ancillary services, other **interconnection requirements** are placed on resources to ensure reliable operation of the grid

- These ancillary services and interconnection requirements enable the system operator to meet the required operations **reliability standards** set by NERC.

- The ancillary services, interconnection requirements, and reliability standards are dependent on the characteristics of a power system.

** FERC defined ancillary services as those "necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system."*

Task 1: Scope & Deliverables

Identification & definition of ancillary services

<u>Objectives</u>:

- Provide a standardized set of ancillary services along with their associated definitions (in functional terms).
  - Highlight emerging ancillary services and the entities pursuing them
  - Scope added by GE: Discussion on interconnection requirements due to inter-relationship w/ ancillary services
- Explain how each ancillary service is used for grid operation
  - Incorporate perspective during normal and contingency conditions
- Identify "Hawaii-specific" differences relative to the standardized definitions
  - Consider how ancillary functionality is currently provided
  - Adjust standardized definitions for Hawaii (finalize during Tasks 3 & 4)

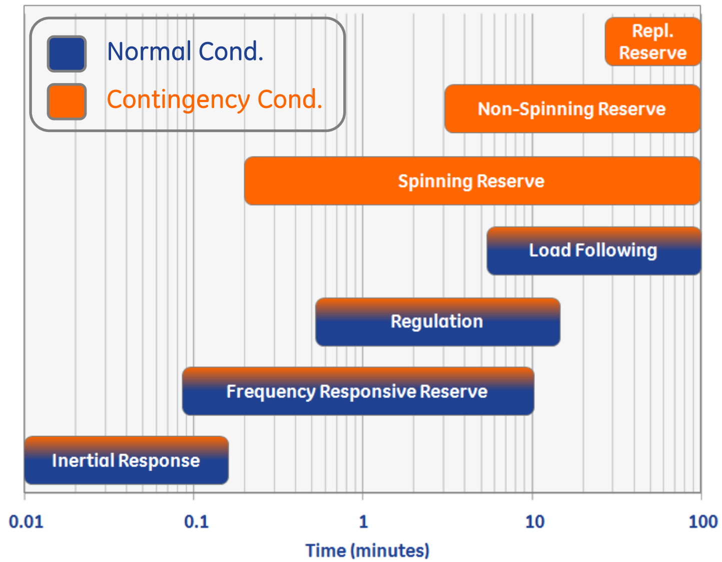
Continuous Spectrum of Protection

Progressive series of inter-related responses to ensure system reliability

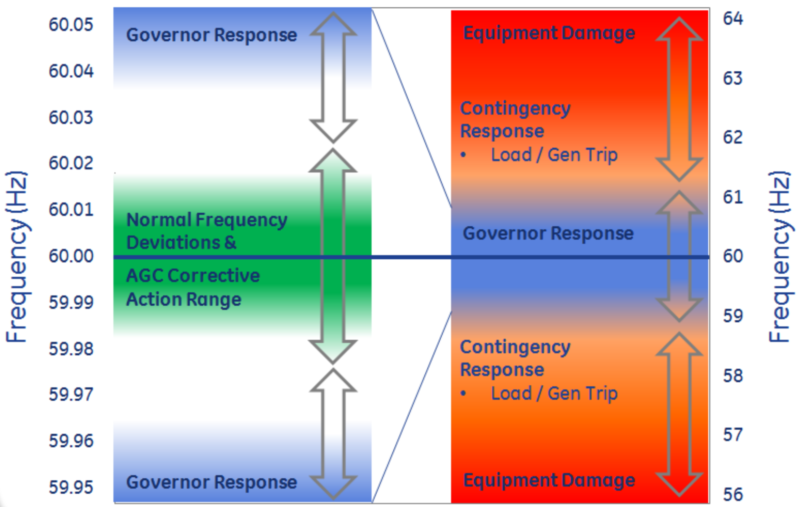
Combination of automated and manual actions link Normal and Contingency Conditions

- Inertial Response provided autonomously from synchronized generation (or synthesized via power electronics)
- Frequency Responsive Reserve automatically driven by frequency deviations (droop governor response, etc.)
- Regulation drives automatic output adjustments thru Automatic Generation Control (AGC), precipitated by changes in Area Control Error (ACE)
- Automatic and Manually deployed reserves (Spinning / Non-Spinning / Replacement)

Response Times and Durations[5]



Progression from Normal to Contingency Conditions[5]



imagination at work

Ancillary Services

Functions Required to Maintain System Flexibility & Reliability

- Normal Cond.
- Contingency Cond.
- Additional Services

Inertial Response	Provides system stability during normal conditions. Slows the frequency fall-off during contingency events. Provided by synchronized resources (also via power electronics).
Frequency Responsive Reserve	Automatic response triggered by frequency swings. Typically deployed during contingency events. Arrests and helps to recover the frequency fall-off.
Regulation	Used continuously during normal operations to correct short-term imbalances between supply and demand. Deployed via AGC signals.
Load Following	Slower than "Regulation" and used primarily during normal operations. Typically deployed via economic dispatch to correct an imbalance that will occur in the future.
Spinning Reserve	Type of contingency reserve that consists of resources which are connected to the power system and poised, ready to respond immediately.
Non-Spinning Reserve	Type of contingency reserve that consists of resources which are capable of providing full response within a specified time; however, the response does not need be immediate.
Replacement Reserve	Deployed following a contingency event. Intended to replenish contingency reserves; response does not need to begin immediately.
Black Start	Provided by resources capable of starting themselves quickly without support of an external electricity source. Used to restore a power system following a major blackout.
Voltage Support	Provided by resources capable of injecting/consuming reactive power which is required to maintain voltages within acceptable limits throughout the power system.

Interconnection Requirements

Interconnection Standards* (Grid Codes)

- *Power Factor and Voltage Control*
- *Voltage and Frequency Ride Through*
- *Ramp Rate Limits and Control*
- *Over and Under Frequency controls*
- *Inertia*

*Related to the control requirements for generators

Reliability Standards

- *BAL- Resource and Demand Balancing*
- *FAC- Facilities Design, Connection & Maintenance*
- *TPL - Transmission Planning*
- *VAR – Voltage and Reactive*

Ancillary Services

- *Voltage regulation*
- *Regulation*
- *Reserves*
- *Black Start*

Interconnection Standards enables the system to meet its reliability standards by requiring generators:

- To have certain capabilities that directly helps with the system reliability
- To have certain capabilities that enables it to provide ancillary services that are required for system reliability

Task 2: Scope & Deliverables

Identification of technologies capable of providing each ancillary service

<u>Objectives</u>:

- Develop a summary table which identifies which technologies can supply each ancillary service. Consider:
  - Generation (including both conventional and variable renewable), storage, demand-response, and transmission technologies
  - Identify the approximate resource sizes
  - Include perspective on product attributes which can be used to assess ancillary compatibility

- Adhere to the following constraints:
  - Limit discussion to technologies in commercial or pilot applications today
  - Focus on current deployment costs – do not speculate about future costs
  - Avoid screening technologies based on cost-effectiveness

- Provide reference citations (as available) for each technology / ancillary match-up

Technology Capability Table

Screening Resources for their Ancillary Compatibility

Technologies	Ancillary Services Compatibility								
	Inertial Response	Frequency Responsive Reserve	Regulation	Load Following	Spinning Reserve	Non-Spinning Reserve	Replacement Reserve	Voltage Support	Black Start
Generation									
Solar Thermal	A	T	T	T	T	---	---	T	T
Solar Photovoltaic (Transmission Connected)	T	T	T	T	T	T	T	T	---
Wind (non-synchronized / power conversion)	A	A	E	A	T	T	T	A	---
Wind (synchronized)	A	A	E	A	T	T	T	A	T
Hydropower	A	A	A	A	A	A	A	A	A
Geothermal	A	A	A	A	A	---	---	A	T
Biomass	A	A	A	A	A	---	---	A	---
Coal	A	A	A	A	A	---	---	A	---
Combined Cycle (Gas/Oil: Sm. HD/Aero) (1x1)	A	A	A	A	A	A	A	A	A
Combined Cycle (Gas/Oil: Heavy-duty) (1x1)	A	A	A	A	A	A	A	A	A
Simple Cycle (Gas/Oil: Small HD/Aero)	A	A	A	A	A	A	A	A	A
Simple Cycle (Gas/Oil: Heavy-duty)	A	A	A	A	A	A	A	A	A
Reciprocating Engines (Gas/Diesel/Bio)	A	A	A	A	A	A	A	A	A
Energy Storage									
Pumped Hydropower	A	A	A	A	A	A	A	A	A
CAES - Comp. Air Energy Storage	E	E	E	E	E	E	E	E	T
Solid Batteries	E	E	A	E	A	E	E	E	E
Flow Batteries (Redox)	T	T	T	T	T	T	T	T	T
Flywheels	E	E	A	---	---	---	---	T	---
PEV	T	T	E	T	T	T	T	T	T
Fuel Cells (PEM)	T	T	T	T	T	T	T	T	T
Demand Response									
Fast Auto DR	T	A	A	T	A	A	A	---	---
Direct Load Control	T	A	E	T	A	A	A	---	---
Interruptible Load	T	A	T	T	A	A	A	---	---
Price Responsive Demand	T	T	T	T	A	A	A	---	---
Transmission									
Synch. Cond.: Large motor frame	A	---	---	---	---	---	---	A	---
Synch. Cond.: Air-cooled generator frame	A	---	---	---	---	---	---	A	---
Synch. Cond.: H2-cooled generator frame	A	---	---	---	---	---	---	A	---
Desirable Attributes / Retrofit Options									
Improved Turndown (MinGen) Capability	✔	✔	✔	✔	✔			✔	
Elevated Ramp-rate Capability		✔	✔	✔	✔	✔	✔		✔
Faster Startup Capability						✔	✔		

A	Available commercially
E	Emerging capability in demonstration phase
T	Technically feasible, but not currently being pursued

** Requires curtailment to provide upward response*

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Technology Capability Table (cont'd)

Screening Resources for their Ancillary Compatibility

Technologies	Plant Size (MW)				Cost Estimates		Flexibility			
	Minimum	Minimum (Typical)	Maximum (Typical)	Maximum	Total Overnight Cost in 2010 (2009 $/kW) for stated size (MW)	Resource Size Assumed in Cost Estimate (MW)	Turndown Load Level	Ramp Rate Capability (thermally stable)	10-Minute Output Available (from offline)	30-Minute Output Available (from offline)
Generation					$/kW	MW	%MW	%MW/min	%MW	%MW
Solar Thermal	0.1	1	100	200	$4600 - 8100	200	12-15%	3-7%*	0%	0%
Solar Photovoltaic (Transmission Connected)	0.001	0.05	5	150	$2100 - 3900	10	---	Rapid*	100%	100%
Wind (non-synchronized / power conversion)	0.001	1	100	450	$1500 - 2500	100	< 10%	Rapid*	100%	100%
Wind (synchronized)	0.001	1	100	450	$1500 - 2500	100	< 10%	Rapid*	100%	100%
Hydropower	0.001	0.5	50	650	$2200 - 4800	500	20-40%	25-100%	100%	100%
Geothermal	0.05	1	30	180	$2500 - 9900	50	12-15%	3-7%	0%	0%
Biomass	0.1	5	50	75	$2900 - 5800	50	35-40%	3-7%	0%	0%
Coal	0.1	10	400	1300	$1900 - 3900	600	35-40%	3-7%	0%	0%
Combined Cycle (Gas/Oil: Sm. HD/Aero) (1x1)	10	25	60	120	$1000 - $1800	55	20-40%	20-40%	0-75%	75-100%
Combined Cycle (Gas/Oil: Heavy-duty) (1x1)	60	120	300	500	$900 - 1500	615	25-70%	3-11%	0-60%	10-100%
Simple Cycle (Gas/Oil: Small HD/Aero)	1	20	40	100	$800 - 1300	45	25-50%	25-50%	0-100%	100%
Simple Cycle (Gas/Oil: Heavy-duty)	40	80	200	330	$500 - 800	211	15-70%	4-16%	0-75%	100%
Reciprocating Engines (Gas/Diesel/Bio)	0.01	1	5	20	$700 - 1300	10	50%	35%	100%	100%
Energy Storage							Resp. Time	%MW/min	%MW	%MW
Pumped Hydropower	---	100	1000	---	$1000 - 3000	500	10s	25-100%	100%	100%
CAES - Comp. Air Energy Storage	---	50	500	---	$600 - 1600	260	1-10min	4%	100%	100%
Solid Batteries	0.1	1	20	50	$1000 - 4000	50	100ms	500%	100%	100%
Flow Batteries (Redox)	---	0.1	20	50	$1700 - 4200	50	100ms	500%	100%	100%
Flywheels	0.1	1	20	40	$900 - 1100	20	1-4s	1500%	---	---
PEV	---	0.02	0.05	---	---	---	100ms	---	---	---
Fuel Cells (PEM)	1E-04	0.001	0.1	10	$3,000	1	10s	500%	100%	100%
Demand Response										
Fast Auto DR	---	---	---	---	---	---	---	---	---	---
Direct Load Control	---	---	---	---	---	---	---	---	---	---
Interruptible Load	---	---	---	---	---	---	---	---	---	---
Price Responsive Demand	---	---	---	---	---	---	---	---	---	---
Transmission										
Synch. Cond.: Large motor frame	---	0	50	---	---	---	---	---	---	---
Synch. Cond.: Air-cooled generator frame	---	38	113	---	---	---	---	---	---	---
Synch. Cond.: H2-cooled generator frame	---	198	478	---	---	---	---	---	---	---
Desirable Attributes / Retrofit Options										
Improved Turndown (MinGen) Capability	---	---	---	---	---	---	---	---	---	---
Elevated Ramp-rate Capability	---	---	---	---	---	---	---	---	---	---
Faster Startup Capability	---	---	---	---	---	---	---	---	---	---

Task 3: Scope & Deliverables

Identify physical requirements of ancillary services

Objectives:

- From recent renewable integration and planning studies, develop two future scenarios
- With HPUC and Hawaiian utilities, specify basic level of required bulk power system reliability for each island (Oahu, Maui, Big Island) [Task 1 and Task 3]
- Propose methodology to estimate required ancillary services and interconnection requirements (under the future scenarios) while taking into account other system considerations
- Suggest a process to determine a set of technologies and associated features

Process to determine technologies
and associated features

Approach:

- Suggest a process to determine a set of resource technologies and associated features that can provide the recommended ancillary services

Observations:

- Many options exist to provide ancillary services including:
    - New generation units
    - Energy storage technologies
    - Demand response programs
    - Transmission technologies
    - Existing generation unit upgrade retrofits and/or modifications

Selecting Resources to Provide A/S

Commentary and some general guidelines

Typically, ancillary service needs are “best-served” by marginal resources. This is driven by the fact that they often have the lowest opportunity cost for providing the service.

- For example, a wind farm typically has a very low variable operating cost. Curtailing the wind for the specific purpose of providing an ancillary service would [typically] result in very high opportunity cost (for both the plant and the power system).
- In most cases, selecting a combustion turbine would likely result in lower opportunity cost and greater system benefit.

During periods where renewables are curtailed (due to must-run resources and/or corresponding over-supply), allocation of ancillary services to the renewables would *potentially* be cost-effective.

Storage devices are unique. Such resources are often “energy-neutral” (i.e. zero net-output on a nominal basis). As a result, storage devices do not have an “opportunity cost” per se. The variable cost to provide ancillary services from a storage device is typically driven by the cost to initiate the devices operation (i.e. startup) and the corresponding variable O&M during operation. The opportunity cost for a storage device is equivalent to its variable operating cost. The hurdle for a storage device is that it’s operational profitability and/or system-level production cost savings must be large enough to offset the initial capital purchase costs for the resource.

Task 4: Scope & Deliverables

Outline considerations for specifying and acquiring ancillary services

Objectives:

- Promote a least-cost portfolio of resources that can supply ancillary services and interconnection requirements that attempt to protect reliability, maximize renewable output and minimize energy costs
- Highlight costs, technology availability, fuel availability or other risks associated with the recommended ancillary services and potential technology mix, with contributions from HPUC and HECO
- Outline factors and provisions to consider for future resources:
    - Type of ancillary services and performance requirements (Task 1)
    - Technology/manufacturer neutral response capabilities for interconnection requirements for new generators (Task 2)
    - Risk, cost and cost-effectiveness methods explored in other power systems
    - Process to compare alternative ancillary service offerings
- Describe any additional study work, including estimated timeline and cost, that may be required to identify the type and amount of ancillary services required

Task 4: Scope & Deliverables

Outline considerations for specifying and acquiring ancillary services

Approach:

- Summarize findings in Tasks 1-3
- Identify potential risks such as Hawaii specific resource costs, technology availability, fuel availability, and other that may impact the ability of the Hawaiian utilities and HPUC to build an effective portfolio of resources to provide ancillary services, fulfill interconnection requirements or address other system considerations

Risk Considerations

Outline considerations for specifying and acquiring ancillary services

- Hawaii specific resource costs
- New/emerging technology availability
- Ability to uprate/upgrade existing resources
- Fuel availability and infrastructure
- Interconnection costs
- Inter-Island transmission connections
- Demand-side participation and programs
- Load shaping programs

- Highlight Risks for each scenario in the next sections

HECO (Oahu)

HSIS Scenario 4A/4B

Potential technology mix

1. Over-frequency/droop response from renewable plants
    - Helps to reduce curtailment
    - Improves the frequency response under loss of load events
    - Reduces the transient burden on thermal unit (valves)
- Risks
    - There should be enough production from renewable plants to be able to respond to such events

2. Synthetic Inertia from Wind Plants
    - Improves the frequency response under loss of generation events
        - Lower frequency nadir
    - Helps to reduce involuntary load shedding on the island
- Risks
    - There should be enough production from renewable plants to be able to respond to such events

HECO (Oahu)

HSIS Scenario 4A/4B

Potential technology mix

3. Lower Turn-down of thermal units
    - Provides more spinning reserves from the same commitment
        - Reduces renewable curtailment
        - Reduces variable cost of operation
- Risks
    - Available down-reserves and stable operating region of thermal units (under loss of load) can become a challenge

4. Quasi Relaxed Must Run Rules
    - Less commitment of baseload units to meet net load + spin
        - Reduces renewable curtailment
- Risks
    - Voltage/Var support may become an issue
    - Inertial response may become an issue
    - Variable cost of operation may or may not decrease
    - Existing contracts may need to be modified to accommodate schedule changes

HECO (Oahu)

HSIS Scenario 4A/4B

Potential technology mix

4. Operating Reserves from BESS/Demand Response
    - Reduces thermal commitment of units
        - Reduces renewable curtailment
        - Reduces variable cost of operation
- Risks
    - Rules and infrastructure should be in place that will guarantee the necessary Demand Response
    - Duty cycle on BESS/DR may make the program cost higher

Storage Technology Risks

- **PHS:**
  - Energy naturally wants to spread out, so compressing water behind a dam creates the risk of an uncontrolled energy release
  - High costs/market liquidity/market price uncertainty (revenues from ancillary services hugely volatile)
  - Arbitrage revenue - after efficiency is taken into account this is not a huge money spinner at some market prices
  - Market risk (i.e. change in ISO rules)
  - Potential negative environmental impact - large installations can disrupt ecosystems/Permitting can be a major issue in Hawaii
  - There is a real option value that may not be captured unless risk is explicitly identified and quantified - plant operations decisions must incorporate these risks
  - A serious disadvantage is dependence on specific geological formations or man-made reservoirs
  - Difficult construction – depends on topography

Storage Technology Risks

- CAES:
  - Energy naturally wants to spread out, so compressing air underground creates the risk of an uncontrolled energy release
  - High costs/market liquidity/market price uncertainty (revenues from ancillary services hugely volatile)
  - Arbitrage revenue - after efficiency is taken into account this is not a huge money spinner at some market prices
  - Market risk (i.e. change in ISO rules)
  - Potential negative environmental impact - large installations can disrupt ecosystems/Permitting can be a major issue in Hawaii
  - There is a real option value that may not be captured unless risk is explicitly identified and quantified - plant operations decisions must incorporate these risks
  - Determining the appropriateness of an underground aquifer geological structure is always challenging - it is difficult to determine, with precision, the exact characteristics of what actually exists underground without core sampling (i.e., test wells)
  - Underground storage requires a special site with the appropriate geological characteristics (normally these are salt caverns but on the mainland depleted natural gas fields, or other types of porous rock formations could be used)
  - Above ground storage requires large pressure vessels or pipelines
  - Need a fuel for the gas turbine - the fuel could be biodiesel, ethanol, or hydrogen (fuel cost impacts exist)

Storage Technology Risks

- **Batteries:**
  - Energy naturally wants to spread out, so packing it into a small space like a battery creates the risk of an uncontrolled energy release like a fire or explosion (lithium-ion batteries, sodium-sulfur batteries) -newer lithium-ion batteries store more electricity than other electrochemical storage systems
  - Cascading failure/thermal runaway happens when a cell fails and releases its energy as heat which can cause adjacent cells to fail and generate heat, as well, leading to melting materials and fires (water can't always be used to extinguish an electrical fire, since water can conduct electricity)
  - Limited lifetime - need to be replaced periodically
  - Maintenance requirements higher than competing technologies
  - Storage capacity is limited – cannot attain same capacity as pumped storage
  - Sensitive to heat: service life can be reduced considerably if operated above rated temperature
  - Battery life depends on cycle-depth
  - Flow batteries complicated compared to standard batteries as they require pipes (susceptible to leakage), valves, pumps, storage tanks sensors, control units, and secondary containment vessels
  - Energy densities in flow batteries are generally lower when compared to portable batteries such as Li-ion

Storage Technology Risks

- **PEVs:**
  - The technology is still in its infancy
  - In a car, a battery is exposed to a wide range of humidities, temperatures and electrical loads, and all of these factors influence the battery's reliability, and if they get too extreme, they can cause a thermal runaway condition
  - Unstable incentive structures (i.e. government tax credits) limits PEV adoption
  - Leverages the existing electrical delivery system but additions to the existing system are necessary:
    - The "smart-grid" infrastructure must be installed to accept PEVs
    - Convenient outlets for households that lack them (e.g. high rise apartments, building without garages etc.) as well as outlets in parking lots and on parking meters
    - Fast chargers that refill a battery in minutes rather than hours (fast chargers can refill batteries in 10-15 minutes) - they require heavier wires than most households have and thus will at least be located at gas stations and other key places
    - Tariffs and monitoring equipment that discourages recharging during peak hours - need large disincentives to discourage filling up during peak hours
  - Uncertain ability of the electrical distribution system to manage bi-directional flow of power (what % of a feeder's load can be back fed through transformers?)
  - New demand may stress low voltage distribution lines
  - Storage degradation (= operating cost) if deep discharge of battery
  - Need to prioritize driving needs

Storage Technology Risks

- **Flywheels:**
  - Energy naturally wants to spread out, so packing it into a small space like a flywheel creates the risk of an uncontrolled energy release like a fire or explosion (i.e. Beacon Power 20 MW flywheel systems in Stephentown, N.Y)
  - Material strength and safety concerns limit energy output
  - While very efficient in short duration response functions, flywheels are not currently designed for providing long-duration energy response
  - Flywheels are not well suited to provide spinning/non-spinning reserve - the limiting factor for flywheels is the duration of the response required

- **Fuel Cells:**
  - The technology is still in its infancy
  - Energy naturally wants to spread out, so packing it into a small space like a fuel cell creates the risk of an uncontrolled energy release like a fire or explosion

Demand Response Program Risks

- **Fast Auto DR:**
  - Regulatory approval (if any)
  - Finding the appropriate DR resource – and sizing/speed for different A/S offerings (frequency control, load following, regulation up/down, spinning and non-spinning reserves)
  - DR resource qualification (meeting the strict requirements)
  - Technical complexity and readiness, system integration, and technical inter-operability
  - Determination of the right level of incentives and pricing scheme

- **Direct Load Control:**
  - Regulatory approval (if any)
  - Finding the right types of resources, resource mix, and resource size
  - Customer selection, agreement, and engagement
  - Determination of the right level of incentives
  - Lack of verification of system breakdowns and customer over-rides in DLC with one-way communication

- **Interruptible Load:**
  - Regulatory approval (if any)
  - Finding the right types of resources, resource mix, and resource size
  - Customer selection, agreement, and engagement
  - Determination of the right level of incentives and rate design
  - Potential for lack of response by customer in the event of instruction by the utility for customer action to interrupt the load

Demand Response Program Risks (Continued)

- **Price Responsive Demand:**
  - Regulatory approval (if any)
  - Finding the right types of resources, resource mix, and resource size
  - Customer selection, agreement, and engagement
  - Technical system design and implementation (AMI, Communications, etc.)
  - Resource aggregation and system integration
  - Appropriate Dynamic Pricing Rate Design and determination of the right level of incentives (different approaches for different dynamic pricing type such as TOU, CPP, CPR/PTR and RTP require)
  - Degree and level customer response (which usually depends on the end-use resource type, impact on comfort and convinience, pricing rates and perceived level of savings, availability of enabling technologies such as in-home-displays, home energy management systems, smart thermostats, smart appliances, or automated, programmable, and communicable response systems, etc.)