“Roadmapping the California Smart Grid through Risk Retirement”

(Technology manufacturer and vendor perspective)

Agreement # 500-09-021 between NASA/JPL
and the California Energy Commission
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December 17, 2010

Committee Workshop on Smart Grid Research Road Mapping Projects
California Energy Commission
Sacramento, CA

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And the 214 members of ACORE and NEMA who responded to the study's Smart Grid Key Attributes Survey

The Smart Grid is the seamless integration of an electric grid, a communications network, and the necessary software and hardware to monitor, control and manage the generation, transmission, distribution, storage and consumption of energy by any customer type.

Austin Energy

Moreover, the smart grid encompasses the integration of renewable energy and electric vehicles, and reflects the importance of appropriate policy, regulations and standards.

Landscape

- Major changes are needed in the electric (and natural gas) infrastructure to meet anticipated energy needs and to address climate issues in the next decade and beyond.
- The concept of a smart grid is driving development of advanced energy conversion, storage and reliable power delivery technologies, the integration of renewable resources and more efficient grid operations.
- Clean transportation and GHG emissions from electricity production create the need to examine efficiency and energy consumption differently than has been done in past operations.

2020 Vision

Reduction in energy consumption and GHG emissions from electricity production and clean transportation are inextricably linked.

To provide electricity producers, distributors and consumers with options for their preferred business models and operation choices means that sustainable, cost-effective, secure and reliable solutions must be developed, demonstrated and implemented.

A new paradigm is evolving where electricity generation, storage and control are more distributed, along with an attendant modification to grid interconnections.

Microgrids are at the heart of this new paradigm – providing cogeneration options with the integration of renewables, including rooftop PV systems and CHP, while enabling options for reducing consumption through demand aggregation, distributed storage, electric vehicle accommodation and net zero buildings.

This will lead to a smart grid that provides ratepayers with a greater voice in energy flexibility, efficient operations and cost structures.

2010 CA Smart Grid Baseline

- **Solar and wind integration**
  - California Solar Initiative (CSI): As of September 2, 2010, 22% (385 MW) of the target 1750 MW goal has been installed, 25% (435 MW) is in the application process, and 53% (931 MW) is remaining
  - In addition to the largely consumer or commercial customer-owned PV systems installed under the CSI program, the PV industry is seeing solid evidence of “utility owned and operated” collections of distributed PV systems

- **Demand aggregation**
  - Net-zero buildings in commercial space: 31 Tannery Road project in Branchburg, NJ, as an example
  - Difficult to determine the extent to which any Demand Management Zone is deployed because of little media exposure

- **Distribution Automation**
  - Proprietary products developed by small number of Original Equipment Manufacturers (OEM)s
  - Research needed to determine if AMI communications networks are suitable for distribution automation applications
  - Government is leading the concurrent development of standards
  - Control & protection products and deployment lags transmission communication systems and AMI

- **EV Accommodation**
  - Technology factors and load impacts need to evolve
  - Advancements in batteries being made, but more needed
  - Charging infrastructure requires much more support
  - Communication technology & systems are currently inadequate

2010 CA Smart Grid Baseline

- **Net Zero Construction**
  - *Distributed Generation* (Solar PV, Wind, CHP): Financing and incentives available; single transaction
  - *Energy Efficiency*:
    - Prescriptive solutions (CFLs, refrigeration rebates, weatherization);
    - Multiple transactions, financing not readily available , e.g. reduced availability and increased uncertainty regarding PACE funding. Federal Investment Tax Credit (ITC) and IOU rebates available, applied /funded by measure, not whole house
  - *Distributed Generation* (Solar PV): $7-8 installed Watt (before incentives) < 10 kW systems
  - *Energy Efficiency*: $1.50 - $2.50 installed Watt, depending on Energy Conservation Measure (ECM)
- **AMI and Control & Communications**
  - Proprietary products developed by a small number of OEM meter vendors, with some sourced proprietary technology by relatively smaller companies
  - Largely 915 MHz unlicensed band, short-range mesh network architecture on the utility-to-consumer part of link
  - Large and small software vendors provide the utility with the back-end meter data management and network monitoring products and technologies
  - Government is leading the concurrent development of standards
  - Customer benefits not clear
- **Microgrids**
  - *Substation (20+ MW)*: Maui Smart Grid – Wind integration DSM, energy storage, peak reduction
  - *Feeder (5-20 MW)*: DOD 29 Palms, CA – Renewable integration, island/on the grid, DSM/DER optimization
  - *Multi-facility (2-5 MW)*: Maritime DLC – Direct load control in commercial buildings, wind firming
  - *Single-facility (<2 MW) / off-the-grid system*: Bella Coola, BC Canada – Off-the-grid project, optimization of diesel, hydro, hydrogen storage

2010 CA Smart Grid Baseline

- **Storage**
  - Present-day operations depend primarily on the real-time balance of supply and demand
  - Meeting daily electrical demands is accommodated through a limited range of options
    - Spinning reserves for increased output
    - Increase output from intermediate load suppliers
    - Load shedding and shifting
    - Thermal storage
  - Electrical energy storage is commonly derived from the shifting of energy production during low demand periods
    - Pumped hydro (where applicable, mostly at capacity in CA)
    - Compressed air energy storage (CAES) for economical gas turbine operations
    - Steam generator/storage systems
  - Some alternatives are in limited use
    - Thermal units which generate ice during off-peak time for day-time air conditioning operation
    - NaS batteries for electrical energy supply during peak demand
  - Most newer options are being investigated to a greater extent as part of the recent Smart Grid initiatives
    - Li-ion batteries
    - Ultracapacitors
    - Flow batteries
    - Flywheels

Microgrids

- **From DOE-CEC Microgrid Workshop / Navigant Consulting:**
  - A microgrid is an integrated power delivery system consisting of interconnected loads and distributed energy resources (DER) which as an integrated system can operate in parallel with the grid or in an intentional island mode.
  - Integrated DER are capable of providing sufficient and continuous energy to a significant portion of the internal load demand even in island mode.
  - The microgrid possesses independent controls and can island with minimal service disruption.

- **From DOE-CEC Microgrid Workshop / Navigant Consulting: "What unique value(s) does a microgrid provide beyond distributed generation alone, and who would pay for it?"**
  - <u>Allows operation with a larger power system; this provides two key capabilities</u>:
    - Flexibility in how the power delivery system is configured and operated
    - Optimization of a large network of load, local DER and the broader power system
  - <u>These two capabilities can deliver three important value propositions</u>:
    1. *Custom Energy Solutions*: Provide customized power to individual customers/tenants or groups of customers/tenants
    2. *Independence/Security*: Support enhanced energy and infrastructure availability and security
    3. *Reduced energy cost*: Provide end users with less expensive energy over current rates.

How Do We Get to the CA Smart Grid 2020?

- **The smart grid is an engineering system whose complexities span technological, operational, policy, regulatory, market and social factors.**
  - Planning for its design, development, deployment and sustainability must be driven by objective, top-down systems analyses
  - Advanced energy conversion, storage and reliable delivery technologies, renewable resources and clean transportation are integral to its system architecture,
  - Customer (ratepayer) expectations and benefits must be met
- **System-level risk retirement is needed through an integrated series of key demonstration projects**
  - Identify, prioritize, mitigate and *systematically* "buy down" risks
  - For validation and verification (V&V) of *integrated systems*
    - Technical performance and cost
    - Controls and interfaces, interoperability
    - Scale-up, safety, reliability and security
    - Codes and standards
    - Business model feasibility
    - Market transformation needs
    - Leveraging between applications
    - Lessons learned (utilities, developers, customers/public), benchmarks, best practices

Some Results from the ACORE Membership Survey

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Q2: What is the greatest barrier to the establishment of a smart grid?

- **Lack of consumer knowledge/education**
  - Consumers not understanding the benefit of establishing the smart grid. A sentiment that consumers were only aware of the initial cost increase associated with upgrading to smart grid technology. The present costs were more important than the future benefits, because people were too worried about their rates going up.
- **Loss of consumer autonomy/control**
  - Concern that the rigidity of the consumer would prevent them from being comfortable with smart grid telling them when to do things. Also a concern for privacy and the intrusion of smart grid.
- **Not enough financial incentives**
  - Due to the regulatory inertia associated with energy there are not enough government subsidies and incentives to encourage smart grid conversion. Lack of market mechanisms to encourage smart grid and therefore the government is needed to step in and create a market through legislation.
- **No regulatory integration**
  - There is neither uniformity nor consistency with the federal, state, and local regulations. There is insufficient communication between public and private sector leadership working to create unified regulations, and people are unwilling to make the jump in the uncertainty created by the fractured policies.

Some Results from the ACORE Membership Survey

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Q6: What are the three most important technologies for smart grid implementation and why?

- **Control and Communications**
  - A theme throughout the survey was a need for education, and specifically about the way smart grid technology would control energy use behaviors. One reason is the need for the smart grid to react to changes in voltage used, as well as consumer inputs into the system. Additionally a need for real-time data was cited as an important aspect of system functionality.
- **Advanced Metering Infrastructure**
  - Cited as the backbone to creating a successful smart grid. The general feeling was that education was important for the ratepayer to understand how they and their smart grid technologies would interact with the delivering utility. For AMI to work it would need to be accommodating to any and all technologies.
- **Photovoltaic and Wind/Integration and Storage**
  - Picked as the technologies with the greatest potential because they have been proven and are economically viable. It was stated that "for a substantial percentage of renewables to behave like base load there needs to be widespread access to distributed storage…" Storage of intermittent resources was a common concern for the widespread integration of these technologies.

Study Approach

- *<u>Overall Philosophy</u>: Rely on input from a wide range of smart grid technology manufacturer/vendor stakeholders through workshops and surveys, and take a top down system engineering approach to roadmapping the key actions needed.*
- Key Technologies / Use Cases
- TIMA Campaign Phase Workshops
- The **Technology Infusion and Maturation Assessment (TIMA**) process and attendant software developed by the NASA Jet Propulsion Laboratory is used to explore architectural options for the smart grid and to define an RD&D roadmap
  - Capture and analyze expert viewpoints, including top-level IEPR goals, with physical, functional and business objectives obtained from key technology use cases
  - Prescribe optimal risk retirement pathways from a 2010 baseline to 2020 that mitigate the elicited barriers to attaining this set of goals and objectives

Key Technologies Identified Through Series of Three Study Workshops
(Pasadena, Sacramento and Washington DC)

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- Storage
- Rooftop Photovoltaics
- Demand Aggregation
- Biomass, Biogas and Fuel Cells
- Combined Heat and Power (CHP)
- Microgrid Development & Accommodation
- Command, Control & Communications
- Distribution Automation
- Advanced Metering Infrastructure (AMI)
- PHEV/PEV Accommodation
- Solar & Wind Integration (for RPS)

Smart Grid Technology Roadmap Use Cases

1) **Evaluation of the potential impact of GHG reduction goals, as defined in Assembly Bill 32 (Nunez, Chapter 488, Statutes of 2006), on meeting the energy growth needs of California through new and innovative smart grid technologies**

    Objective: Reduce GHG emissions to 1990 levels across all sources in 2020

2) **Natural gas impacts and benefits of the smart grid, including consideration of CHP**

    Objective: Additional 5,400MW of combined heat and power in 2020

3) **Command and control technologies (C^2), Distribution Automation, including consideration of AMI**

    Objectives: Electricity peak demand reduction goal of 4,885MW in 2013; DR: Demand response that reduces TBD % of peak demand in 2020

4) **C^2 and PHEVs/PEVs**

    Objective: Accommodation of electric vehicles into smart grid

5) **Bio-sources and Fuel Cell energy storage**

    Objective: 20% of renewable power supplied by biopower sources in 2020 (~20,000 GWh/year)

6) **Large scale storage, integration of solar and wind, intermittency.**

    Objective: 33% of generation by renewables (~104,000 GWh/yr) in 2020

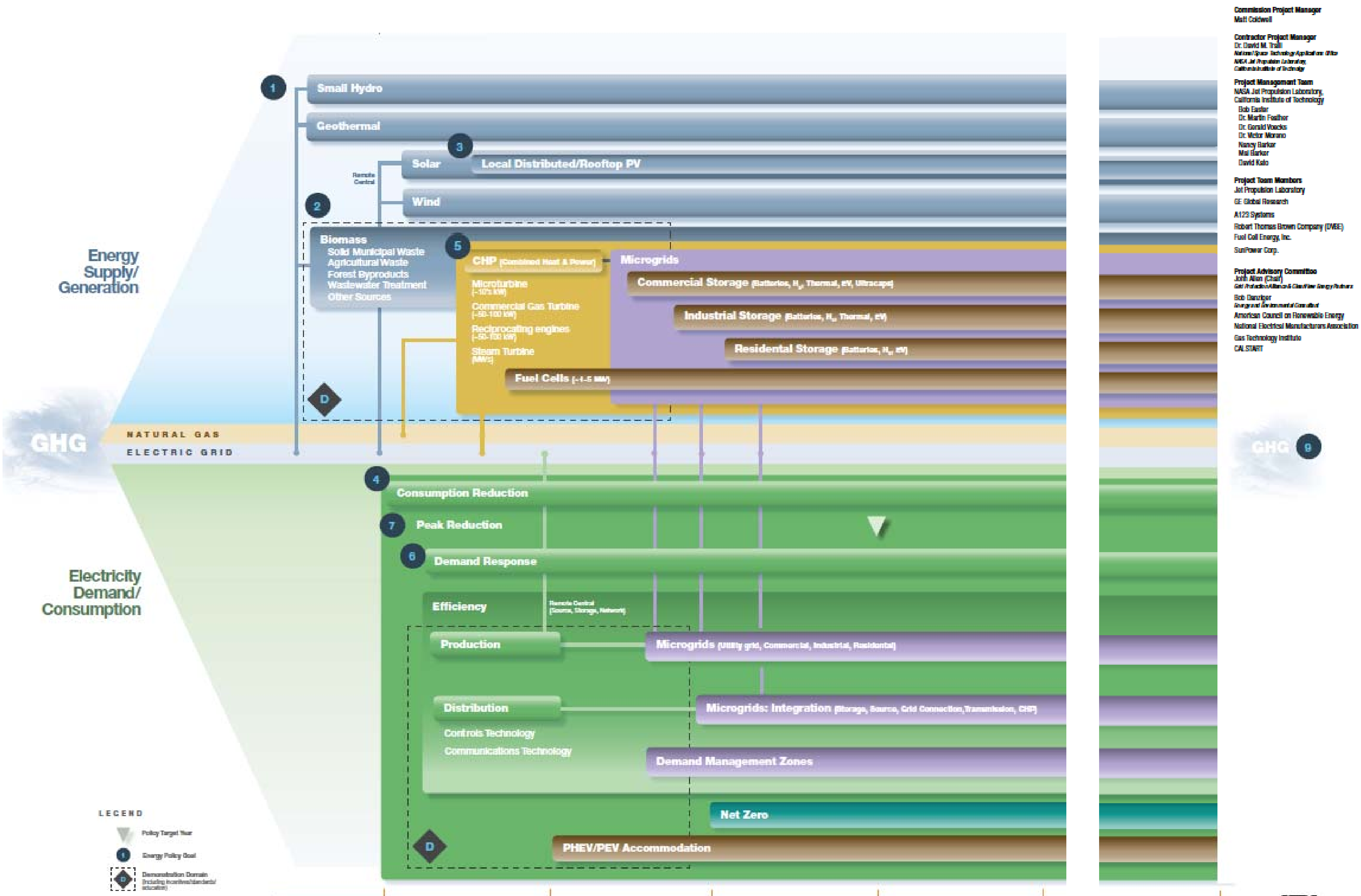
Key California Energy Policy Goals

① 33% of generation by renewables (~104,000 GWh/yr) in 2020
② 20 % of renewable power supplied by biopower sources in 2020 (~20 GWh/year)
③ 3,000 MW of new rooftop solar PV by 2016 (~5000 GWh/yr)
④ 10% reduction in total forecasted electrical energy consumption in 2016
⑤ 5,400MW of combined heat and power in 2020
⑥ Demand response that reduces TBD % of peak demand in 2020
⑦ Electricity peak demand reduction goal of 4,885MW in 2013
⑧ All new residential construction is net zero energy in 2020
⑨ Reduce GHG emissions to 1990 levels across all sources in 2020

Note: The CEC /JPL Smart Grid 2020 Study also carries as secondary objectives the following Smart Grid Attributes from the 2009 DOE Smart Grid System Report

A. Enables Informed Participation by Customers
B. Accommodates All Generation and Storage Options
C. Enables New Products, Services, and Markets
D. Provides Power Quality for the Range of Needs
E. Optimizes Asset Utilization and Operating Efficiency
F. Operates Resiliently to Disturbances, Attacks, and Natural Disasters

Smart Grid Roadmap Development Framework (Draft)



Preliminary Findings

- Barriers cited by industry are not exclusively technical — economic, financial, regulatory and social barriers are at least equally important
- Stimulus funding is good, but not enough to overcome lack of capital needed for large-scale deployments
- Distribution grids are not set up to evolve into grids of microgrids
- [There will be] Increased opportunities for physical attacks
- Time of use retail pricing changes the interface between retail and wholesale market system
- Smart grid system models for use of all stakeholders are badly needed to help allay uncertainties, although some support service suppliers are beginning to address portions of this need
- [Much more] Development needed for storage

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Preliminary Findings

- Energy storage is needed for a variety of smart grid applications—such as peak shaving, VAR support, renewable energy integration, PEVs, frequency regulation and islanding.

- Distributed generation, in combination with distributed storage, offers many opportunities to achieve the greatest efficiency and operational benefits.

- Biomass offers significant potential for reducing GHG emissions and adding to distributed generation.

- The impact and benefits of PHEVs/PEVs on the smart grid architecture and GHG will require a significant degree of customer/utilities joint learning.

PHEV/PEV Impact on Smart Grid*

- **Primary Goals of Original Equipment Manufacturers (OEMs)**
  - Determine how to meet customers' needs/expectations to generate a viable, saleable product
    - Dependable, safe, cost-effective and appealing to the masses
  - Help reduce (a) dependency on oil and (b) GHG emissions
  - Coordinate charging procedures with SAE standards
- **Impact on Smart Grid**
  - Integrate into Smart Grid infrastructure with minimal effort and expense
    - Efficient vehicle operation and convenient recharging equipment/procedure
    - Evaluate additional benefits that may be derived from grid-connection
    - Load profiles and distribution throughout grid compatible with incremental increase in PHEV/PEV purchases[†]
  - Incorporate PHEV/PEV operations into Smart Grid as the grid evolves over the next decade
  - Role of utilities and third parties needs only to be unified through required standards
- **Options for Enhancing Overall PHEV/PEV Benefits**
  - Although several suggestions have been postulated regarding potential alternative roles that PHEV/PEVs may serve in Smart Grid infrastructure operation, no specific direction has been identified
    - Automotive operation and customer satisfaction is paramount at this time
    - Expect to gain better understanding about technology improvements (batteries, vehicle operations, etc.), infrastructure compatibility (charging equipment and availability) and customer needs over the first 5 years of marketing PHEV/PEV vehicles

**Based on discussion with GM.*

[[†]Also recognize potential impact of additional loads]

Summary – Preliminary Recommendations

- Incentivize residential, commercial and industrial energy consumers to engage in smart grid-related activities
  - Create opportunities for utilities to engage customers in joint learning projects
- Conduct studies, analyses and tests to elucidate smart grid architectures
  - Novel integration of communities/businesses/industries in grid architecture options
- Conduct education campaigns to engage all stakeholders, including the customer
- Conduct additional demonstrations of smart grid functions and smart grid elements
- Expand microgrid demonstration projects
  - Various venues to ascertain technology integration benefits
  - Determine controls, communications and security issues
- Develop improved energy storage technologies and functioning within grid operations
  - Investigate shared costs/operations with industry/utility operations
- Community education campaigns are needed, (e.g. Green Street Scene campaign in Fresno, but much broader)
- Ensure that regulations, taxes, etc. do not unbalance the value propositions between transmission buildup and distributed generation
- Energy Efficiency Resource Standard (EERS)
- Develop testing and certification safety standards for equipment and interconnections
- Charge power marketers for power reliability consequences

Preliminary Findings and Recommendations

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✓ **Energy Storage**

- Finding: Lack of appropriate energy storage is the most frequently mentioned technological barrier to meeting California's smart grid related goals, by supplier representatives at first workshop
  - Storage is needed for a variety of smart grid applications—such as peak shaving, islanding, VAR support, renewable energy integration, PEVs, frequency regulation (Ref: A123 Storage roadmap material)
- **Recommendation**: California should undertake a carefully planned campaign to address the need for language updates in tariffs and standards to ensure proper valuation of storage in a range of smart grid applications.
  - Trade-offs between the cost-effectiveness of modifying existing infrastructure and aged equipment vs. changes that will provide longer-term advances that include new technology with flexibility/modularity for continual improvements (i.e. Smart Grid evolution)
  - Once proper valuation of storage is established, the State should consider augmenting the subsequent increase in private investment in technology development in key barrier areas

Energy Storage

- **Incorporation of energy storage in microgrid operations offers several opportunities for efficiency savings, power management and peak demand reduction**
  - Use of flow batteries and Li-ion batteries offers rapid response to assist in power management and voltage control at customer location
  - Batteries can be modularized to accommodate growth of microgrid demand
  - Ice production/storage from thermal energy operation reduces electrical demand for air conditioning
  - Various methods of energy storage can be used in CHP operations
- **Energy storage coupled with microgrid operations allows for islanding during emergencies**
  - Allows continued uninterruptible operations
  - Takes load from grid operations during high demand or emergency operations
- **Customer use can be tailored with minimal grid impact**
  - Local generation coupled with storage
    - Rooftop PV coupled with battery storage
    - CHP couples electric grid with natural gas and thermal storage
    - EV impact in future uses unclear at this time
  - Modular installations
    - Both generation and storage can be altered to meet changes
    - Grid integration can be customized to meet changing customers/demands
  - Grid can benefit from distributed storage
    - Flexibility in storage location (i.e. at load or at generation)

Preliminary Findings and Recommendations

✓ **Microgrids (1 of 2)**

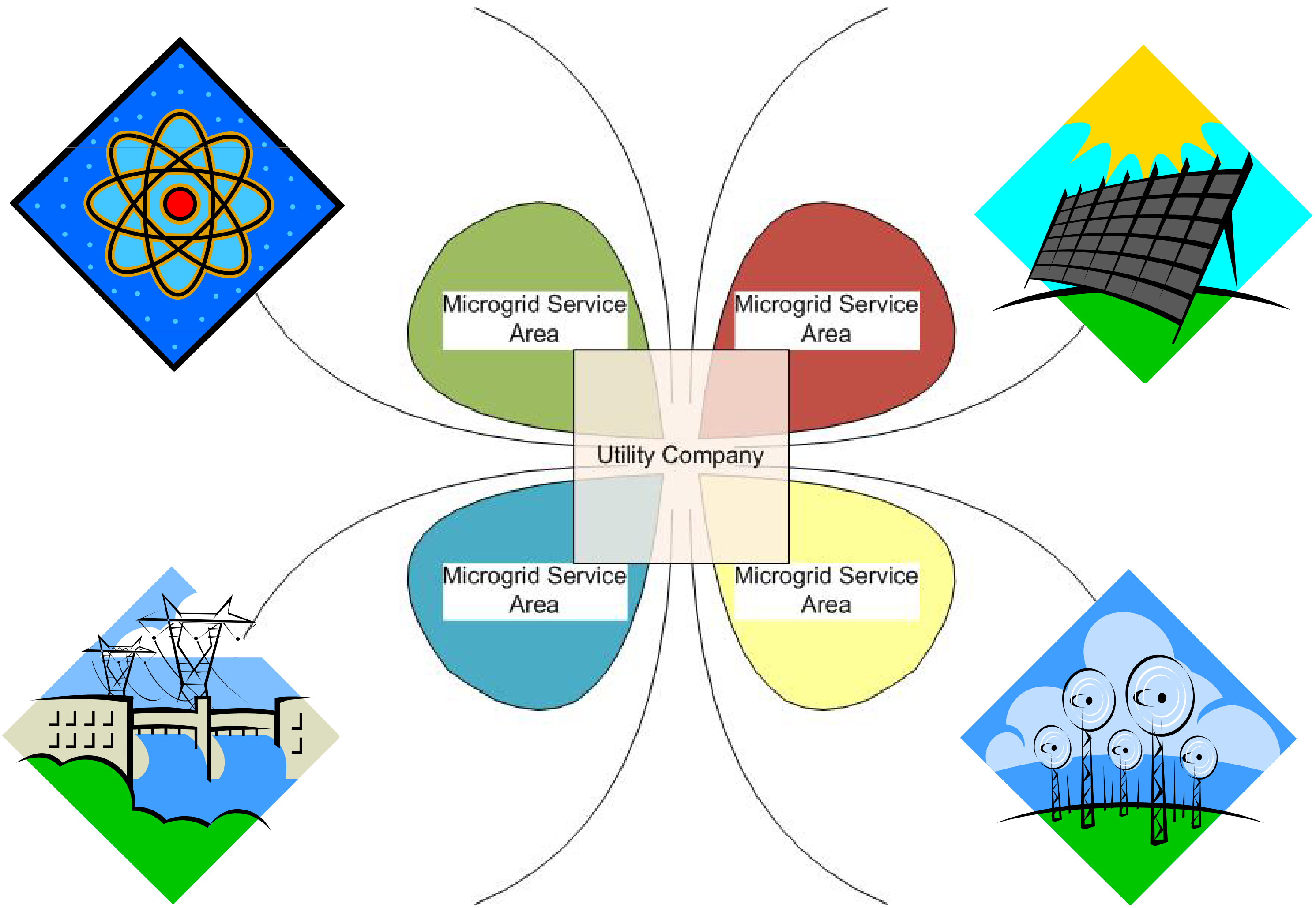
- Finding: Industry study participants are most interested in microgrid approaches to the California Smart Grid goals, presumably because of the versatility of operation and potentially huge new market—i.e., every energy user in California (Ref: First workshop)
- Finding: Microgrid growth is inhibited by a variety of factors (Ref: First workshop) including the status of:
  - Readiness of residential, commercial and industrial energy consumers
  - Distributed generation and microgrid system architecture knowledge
  - Energy storage (the most frequently mentioned technology-related barrier, as cited earlier)
  - Regulations and standards for communications and interoperability, and
  - Availability of suitable financing arrangements for potential stakeholders
  - Need to understand the trade-offs in value/service/cost and technology advancement against future requirements (i.e. the Smart Grid is evolving, not static)

Preliminary Findings and Recommendations

✓ **Microgrids (2 of 2)**

- Recommendation: Microgrid implementation must be incorporated into the current grid for optimal efficiency and customer satisfaction
  - Microgrids can be assembled in many different architectures and adapted to accommodate various electrical and thermal requirements, all resulting in significant energy and GHG savings
  - Microgrids and distributed generation/storage systems can take advantage of the natural gas distribution system, as well as renewable energy generation, to achieve greater savings through hybridization of operations
  - Demonstrations of microgrids and distributed generation/storage need to be pursued in different settings to understand and illustrate the value to utilities and customers
  - Possibilities of co-ownership and maintenance should be explored
  - Limits on size of operations and grid integration need to be examined
  - Strategic value of development needs to be evaluated for longer-term benefits associated with the use of advanced technology

Interconnected Microgrids



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Preliminary Findings and Recommendations

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✓ **Demand Response**

- Finding: No clear-cut ownership preference (utility or customer or 3rd party demand aggregator) emerges from discussion of demand response management issues with suppliers
  - While suppliers are very interested in the markets associated with demand response management, there is no consensus as to the "best" approach.

- Recommendation: The state needs to carry out further studies to determine whether action needs to be taken to focus investment and development efforts on a specific form of demand response management or whether it should be left to market forces
  - The value of modularization and modernization as the Smart Grid evolves should be incorporated to prevent myopic changes that do not take advantage of lessons from changes globally
  - Smart grid changes should not be California-centric in order to allow for learning that will translate into advantages in a national (and global) market

Preliminary Findings and Recommendations

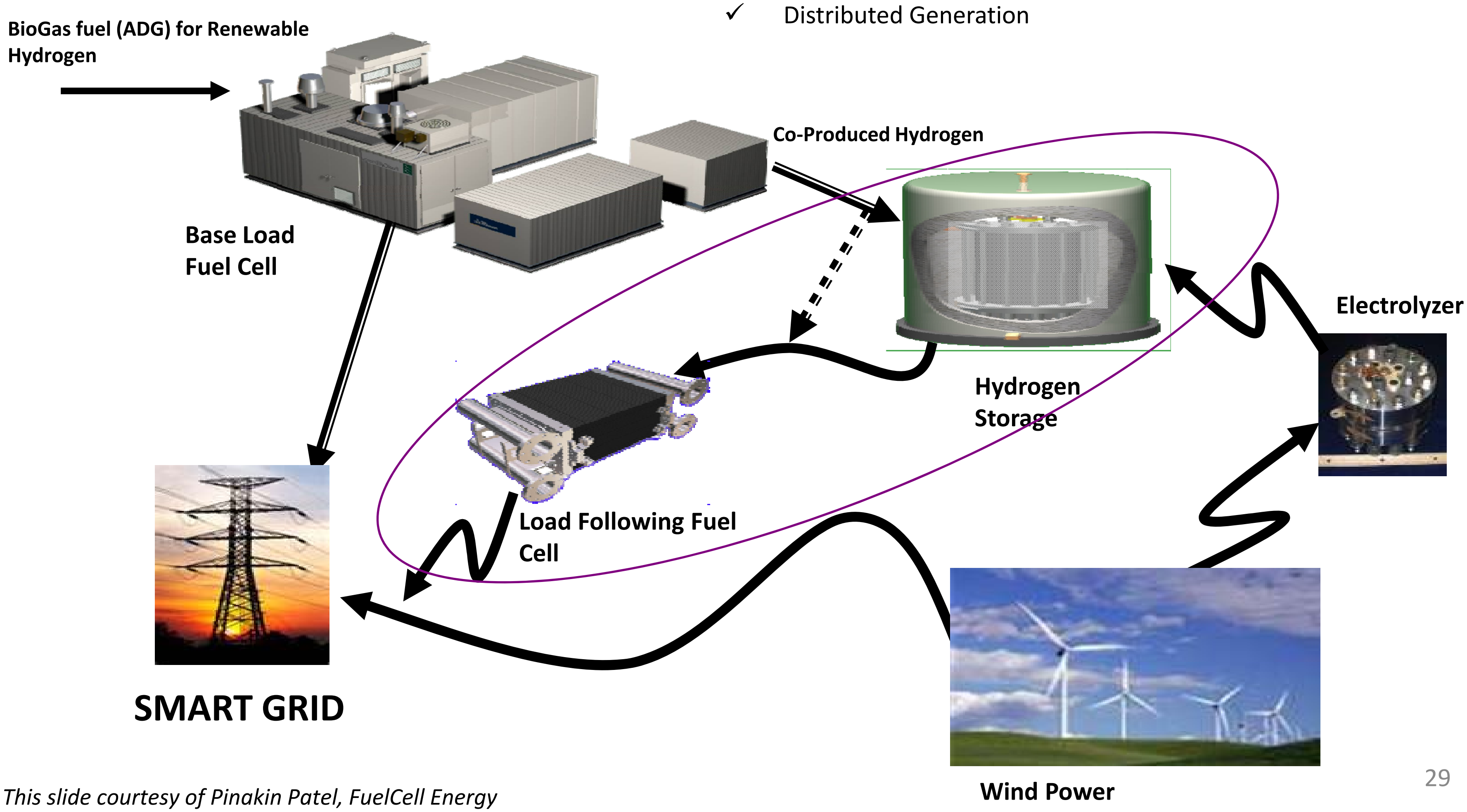
✓ **Biomass Hydrogen for Energy Storage**

- Finding: Co-production of renewable hydrogen and electricity using high-temperature fuel cells offers an attractive option for addressing multiple IEPR goals through distributed generation, peak reduction, supporting the integration of solar and wind energy resources, and providing a hydrogen option for clean transportation.

- Recommendation: Demonstration of CHP peaker technology at utility scale (1-10 MW)
  - Demonstration of fuel flexibility
  - Integration with biorefinery (waste biomass gasification demonstration)
  - Technologies to increase use of waste biomass
    - Gasifier scale-up and reliable operation
    - Gas clean-up system for multiple biogas sources
  - Expansion of biomass conversion for use in advanced transportation such as hydrogen for vehicular and industrial operations

Advantages of Biomass Hydrogen for Energy Storage

- ✓ Maximizes value of solar & wind (paradigm shift for round trip efficiency)
- ✓ Fuel Flexible (Renewable and Natural Gas)
- ✓ No fuel consumption in spinning reserve state
- ✓ High 50%+ efficiency regardless of output level
- ✓ Zero emissions
- ✓ Rapid load following capability
- ✓ Super-peaking capability
- ✓ Distributed Generation



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Next Steps

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- Analysis and evaluation of 2 or 3 smart grid architecture options that point to key tradeoff space domains, such as:
  - Biomass, CHP, industrial-scale microgrids, hydrogen, storage
  - Demand Aggregation, Demand Management Zones, commercial/residential microgrids, net zero buildings
  - PHEV/PEV accommodation, command and control structures, AMI, security
- Implementation of energy balance formalism (in progress) for quantification of IEPR goals attainment through the TIMA process/tool
- Recommendation of risk retirement demonstrations for integration of key technologies addressing multiple IEPR goals
- Final Report and roadmap, including recommendations for RD&D and for integration of all 3 study perspectives (IOU, MOU, technology manufacturer/vendor)
  - Study Completion Date: March 1, 2011

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Backup

How Should Key Technologies be Integrated into the California Smart Grid 2020?

- ***The Smart Grid System Tradeoff Space*** spans RD&D, investment needs and functionality parameters captured in legislation (i.e. CA IEPRs, Energy Policy Act of 2005, EISA 2007) and addresses:
  - Energy consumption, measurement and efficiency
  - Energy supply, including distributed energy resources
  - Energy storage for transportation and stationary sectors
  - Component and systems technologies, including C^3
  - Infrastructure (monitoring, storage, transmission, distribution, security)
  - Environmental impact
  - Economic and regulatory considerations

In other words, what system architectures are best for the set of California goals and key technologies?

Total Electricity System Power in California

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2008 Total System Power in Gigawatt Hours					
Fuel Type	In-State Generation [1]	North west Imports[2]	South west Imports[2]	Total System Power	Percent of Total System Power
Coal*	3,977	8,581	43,271	55,829	18.21%
Large Hydro	21,040	9,334	3,359	33,733	11.00%
Natural Gas	122,216	2,939	15,060	140,215	45.74%
Nuclear	32,482	747	11,039	44,268	14.44%
Renew-ables	28,804	2,344	1,384	32,532	10.61%
Biomass	5,720	654	3	6,377	*2.08%*
Geo thermal	12,907	0	755	13,662	*4.46%*
Small Hydro	3,729	674	13	4,416	*1.44%*
Solar	724	0	22	746	*0.24%*
Wind	5,724	1,016	591	7,331	*2.39%*
Total	**208,519**	**23,945**	**74,113**	**306,577**	**100.0%**

Source: 2008 Net System Power Report - Staff Report,
Publication number CEC-200-2009-010, to be considered for adoption
July 15, 2009. (PDF file, 26 pages, 650 kb)
EIA, QFER, and SB 105 Reporting Requirements
*Note: In earlier years the in-state coal number included coal-fired power plants owned by California utilities located out-of-state.
1.In-state generation: Reported generation from units 1 MW and larger.
2.Net electricity imports are based on metered power flows between California
3.and out-of-state balancing authorities.
The resource mix is based on utility power source disclosure claims, contract information, and calculated estimates on the remaining balance of net imports.

2009 Total California In-State Power Generation					
Fuel Type	In-State Generation (GWh)	California In-State Power (%)	North west Imports	South west Imports	Total System Power
Coal	3,735	1.8%	N/A	N/A	N/A
Large Hydro	25,094	12.2%	N/A	N/A	N/A
Natural Gas	116,716	56.7%	N/A	N/A	N/A
Nuclear	31,509	15.3%	N/A	N/A	N/A
Oil	67	0.0%	N/A	N/A	N/A
Other	7	0.0%	N/A	N/A	N/A
Renew-ables	28,567	13.9%	N/A	N/A	N/A
Biomass	5,685	2.8%	N/A	N/A	N/A
Geo thermal	12,907	6.3%	N/A	N/A	N/A
Small Hydro	4,181	2.0%	N/A	N/A	N/A
Solar	846	0.4%	N/A	N/A	N/A
Wind	4,949	2.4%	N/A	N/A	N/A
Total	205,695	100.0%	19,929	71,201	296,827

Source:
EIA, QFER, and SB 105 Reporting Requirements
Note: Due to legislative changes required by Assembly Bill 162 (2009), the California Air Resources Board is currently undertaking the task of identifying the fuel sources associated with all imported power entering into CA
1.In-state generation: Reported generation from units 1 MW and larger.

ROOFTOP PHOTOVOLTAICS (1 of 2)

Current State of Technology	Established in 2007, the **California Solar Initiative** (CSI) allocates $2.167 billion to incentivize 1,750 MW of new solar PV generation capacity between 2007 and 2016, as well as $250 million between 2010 and 2017 to install 200,000 new solar hot water systems. As of September 2, 2010, 22% (385 MW) of the target 1750 MW goal has been installed, 25% (435 MW) is in the application process, and 53% (931 MW) is remaining.
	In addition to the largely consumer or commercial customer-owned PV systems installed under the CSI program, **the PV industry is seeing solid evidence of "Utility owned and operated" collections of distributed PV systems**, as exemplified by Southern California Edison's July 2010 announcement of a 500MW rooftop solar initiative, with at least 250 MW owned and managed by SCE directly. Similarly, PG&E and SDG&E have programs for 500MW and 100MW respectively.
	Growth rates as well as monitoring and control solutions for PV systems in this category seem likely to be more driven by Utility specific needs rather than consumer oriented incentive program needs. This represents some risk that any forecasting, modeling, and monitoring/control solutions that evolve for these systems may be driven down a slightly divergent path from solutions for consumer oriented incentive programs. Ideally solutions for both categories of PV systems can be aligned for operational efficiency and cost effective future integration.
	Note the High Penetration and High Growth-Rate PV of Deployments in Europe
Supporting Needs	***High Penetration PV Grid Integration – Implications and Requirements***: PV system suppliers and utilities are actively discussing the implications of increasing penetrations of variable generators such as PV on distribution circuits.
	At the distribution circuit level, there are concerns that **PV variability could impact local voltage** either by inducing flicker or by excessive cycling of utility equipment such as load tap changers.
	<u>Interconnection Standards</u>: Existing interconnection standards such as IEEE 1547's anti-islanding safety requirement become increasingly at odds with **distribution system stability** as PV penetration increases.
	Forecasting Accuracy: As seen in Spain and Germany, **increasingly accurate wind resource forecasting has had a direct positive impact on spinning reserve costs needed for large scale distributed wind generation**. Work is underway on many fronts to bring solar irradiance forecasting to the accuracy levels that wind forecasting has achieved.

ROOFTOP PHOTOVOLTAICS (2 of 2)

Path from Current State to End State of Technology

Incentive programs such as CSI need to be both extended and modified to accelerate PV system approval and deployment.

Currently, distributed PV interconnections are governed by a series of screens, incorporated into **California's Rule 21**. This allows "fast track" interconnections that do not require an expensive and time consuming study process. Currently, there is a penetration threshold of 15% of a feeder line section, above which an interconnection study is mandated. **Technical justification exists for raising this threshold for PV, which would enable higher local penetration on particular feeders and thereby help to reach the 2016 goal**. (1-2 years)

Standardized models and metrics for modeling the impact of multiple variable, distributed generators within a specific distribution circuit, including an accurate representation of geographical diversity on short time frames. (1-3 years)

Order of events & milestones

- Re-examine CSI program parameters and evaluate feasibility of:
  - Raising program cap to 3,000MW
  - Raising the system size floor for systems that are eligible for EPBB rebates to simplify monitoring and reporting process and requirements.
    - It may make sense to express this threshold as a percentage of distribution feeder capacity and a percentage of other variable generation on the same circuit, so that this size is meaningful from a system operator point of view as well (i.e., make the monitoring requirements for future distribution integration purposes match up with CSI program monitoring requirements, at least at a coarse level).
  - Simplify the reporting and administration requirements for systems that do continue to require PBI based incentives.
  - Increasing the incentive rates or parameters to stimulate faster growth

- Update FERC screens and / or Rule 21 to a higher level of penetration. IREC is currently working on this issue.
- Combined Utility/Industry program to define and develop standardized metrics and models for variable generator fleets that can be used to solidify consensus and unify grid integration requirements state-wide. Will need pilot program to compare real data against modeled data, although pilots are likely feasible using existing high PV penetration circuits.

DEMAND AGGREGATION

Current State of Technology	Difficult to determine extent to which any **demand management zone (DMZ)** is deployed because there is not a lot of press available.	**Net-zero buildings** in commercial space: 31 Tannery Road project in Branchburg, NJ. Other: DMZ proposal submitted to DOE for downtown Chicago (incl. intelligent application of electrical storage) – bulk purchase at night to charge storage assets and provide building cooling to decentralized network of devices.
Supporting Needs	Demand Aggregator: commercial, unregulated entity that builds, owns and operates a **DMZ**. Owns all B2B relationships with the utility power providers and tenants.	***Building Operations Control Center (BOCC)***: Monitoring: supervise network topology, connectivity, loading conditions, including breaker and switch states, and control equipment status. Control: Coordinated by actors in domain (Demand Aggregator, Utility Providers), although may only supervise wide are, substation, local automatic or manual control. Fault management: location, identification, sectioning and service Analysis: Feedback analysis from real-time operation records ***Extension Planning***: Develop long-term plans for power systems reliability, cost, performance and construction ***Meter Reading & Control***: Data collection, disconnect/reconnect, outage management, prepayment POS, power quality/reliability monitoring, MDM & VEE, customer billing, load management incl. load analysis & control, demand response, risk management ***Communications to support operations*** ***Security Management***: security policies, distribution and maintenance of credential,, and centralized authentication and authorization.
End state is a self-sustaining DMZ that takes advantage of maximum own generating capacity, shifting a certain amount of weekday generation requirements to off-peak hours. Couple with collocation of wind and solar resources, addresses multiple IEPR goals.		

Path from Current State to End State of Technology

California energy regulations need to accommodate the Demand Aggregation scenario, allowing the DMZ provider to participate in the bulk power market. At the same time, the regulation needs to support some sort of feed-in for the DMZ to return any excess power (nights/weekends) to the utility grid.

To insure power quality across grid, some regulation to limit the transition behaviors as the DMZ goes from a net provider to a net user of electricity.

Regulations need provisions for BOCC or similar DMZ control facilities to provide valuable management and C2 information (i.e. SCADA or similar) to any adjacent grid operators.

Distributed Generation/Distributed Energy Resources (DG/DER) within the DMZ needs to be tracked in order to establish accountability towards key policy objectives such as rooftop solar and other renewable mandates.

California law should incentivize: a) commercial building operators and DMZ providers to incorporate proven energy efficiency technologies in their operations; b) utilities to create DMZs with third-party providers. (Possibly as a contributor to the overall peak demand reduction.)

California law needs to continue to incentivize the installation of renewable and storage technologies.

DISTRIBUTION AUTOMATION

Current State of Technology	DA (control & protection) products and deployment lags transmissions communication systems and AMI	Proprietary products developed by small number of OEMs	Research needed to determine if AMI communications networks are suitable for DA appls.	Government is leading the concurrent development of standards
Supporting Needs	Technology development – standards-based communications and cybersecurity technologies		Studies/analyses/tests: •Communication and system planning tools •Cybersecurity planning and testing •System-level testing for AMI and DA comm systems	

Path from Current State to End State of Technology

- Distributed control algorithms and architectures
- Systems planning tools
- AMI etc. standards
- Cybersecurity standards and tools
- Interoperable software standards
- Future-proof communications solutions
- Communication-enabled Distributed Generation
- Plug-and-play Demand Management devices and systems
- Spectrum for critical control and protection
- Communication capabilities for PHEV systems

Order of events & milestones

- Establishment and retirement of apparent and perceived cybersecurity threats and concerns over privacy
- System design tools
- Open standards-based communications technologies that enable future-proofing of AMI, HAN and DA devices

AMI and CONTROL & COMMUNICATIONS

Current State of Technology	Proprietary products developed by a small number of OEM meter vendors, with some sourced proprietary technology by relatively smaller companies	Largely 915 MHz unlicensed band, short-range mesh network architecture on the utility-to-consumer part of link	Large and small software vendors provide the utility with the back-end meter data management and network monitoring products and technologies	Government is leading the concurrent development of standards

This patchwork of technologies, products and ad hoc approaches is characteristic of the electric utility market evolution over the past decade, demonstrating a lack of standards and national strategy on grid modernization.

Source for below: Cleantech Group Report "2010 U.S. Smart Grid Vendor Ecosystem"

~ 100 Smart Meter projects in progress in the U.S.	Cost breakdown (per customer): •Meter \$60-80 •Communication infrastructure \$30-40 •Meter Data Management (MDM) software \$2-5
ARRA goal of 40 MM Smart Meters by 2015 (~150 MM electric meters total in U.S.)	
>16MM Smart Meters installed through 2010	

Path from Current State to End State of Technology

Important preconditions – supporting technologies

•Systems planning tools	•Future-proof communications solutions
•AMI etc. standards	•Communication-enabled Distributed Generation
•Cybersecurity standards and tools	•Plug-and-play Demand Management devices and systems
•Interoperable software standards	•Spectrum for critical control and protection
•Communication capabilities for PHEV systems	

Supporting regulatory/business assumptions

Regulations that clarify and/or promote:
- •PHEVs/PEVs
- •Appropriate spectrum allocation
- •Performance certification that enables new suppliers from adjacent markets
- •Distributed generation interconnection policy

ELECTRIC VEHICLE ACCOMMODATION (1 of 2)

Current State of Technology	No large-scale consumer deployment of PHEVs/PEVs	Technology factors: •Advancements in batteries •Charging infrastructure •Communication technology & systems	Social factors: •Desire for energy security •GHG emissions from vehicles •Demonstrated use acceptability
Supporting Needs	Technology development – standards-based communications and cybersecurity technologies		Studies/analyses/tests: •Communication and system planning tools •Cybersecurity planning and testing •System-level testing for AMI and distribution automation communications systems

Path from Current State to End State of Technology

Frost & Sullivan: 2020 – for each car sold ~2 EVs sold ["360 Degree Perspective of the Global EV Market – 2010 Edition"]

	Charging Infrastructure	**PHEV/PEV**
Goals	Accelerate technology development for a holistic "systems" approach	Improved battery technology to achieve 30-50% improvement in battery life and range and total reduced support costs of 20% AAGR
	Robust 3rd party retailers and service providers providing charging services	
	Active utility support of PHEV programs and build out of distribution networks to support load growth	Manufacturing capacity growth to meet 2020 projected demand needs
Attributes	Open standards for physical plug connectivity, communications and data exchange	Vehicle cost parity with internal combustion engine (ICE) vehicles so as to support <1 year consumer payback
	Partnership between car manufacturers, charging infrastructure OEMs, and service providers	

ELECTRIC VEHICLE ACCOMMODATION (2 of 2)

Path from Current State to End State of Technology

Supporting Regulatory/Business Assumptions

Utilities supportive of PHEV systems and not thwart for economic gain or to preempt distribution network upgrades

Some level of deregulation of ability for 3rd parties to sell/resell electricity

Regulation/policy needs to be established around "portability" of electricity rates and/or establishment of personal rates that promote and simplify rates for consumers

Supporting Needs

<u>Technology development</u> – need for EVs to have longer range. Battery development & cost out; improve speed of charging without damage to battery life

<u>Studies/analyses/tests</u>:

Impact on weak distribution networks of relatively large penetration of PHEV/PEV deployment

Detailed analysis of real world implementation of PHEVs/PEVs that address all facets: charging time, range, support needs, etc. *from consumers perspective*

Detailed analysis around crashworthiness, post-crash survivability, and pedestrian safety due to inaudible sound from EV engines

Cradle-to-grave studies need to be performed. What to do with batteries at end-of-life when EVs account for a majority of the vehicles on the road? Note: technology improvement will obsolete early-year batteries faster

Lifetime cost of ownership compared to current vehicle choices.

<u>Education campaigns</u> – through demonstrations

<u>Demonstrations</u> – PHEV/PEV communities and use of PHEV/PEV technology with "fleets"

<u>Incentives</u> – For consumers to adopt PHEVs/PEVs so as to offset cost of charging infrastructure; and for utilities from regulators to promote consumer PHEV/PEV usage

NET ZERO CONSTRUCTION (1 of 2)

<table>
<tr>
<td rowspan="3">Current State of Technology</td>
<td>Distributed Generation (Solar PV, Wind, CHP): Financing and incentives available; single transaction
Energy Efficiency:
• Prescriptive solutions (CFLs, refrigeration rebates, weatherization);
• Multiple transactions, financing not readily available with collapse of PACE funding because of Fannie MAE and Freddie MAC. Federal ITC and IOU rebates available, applied /funded by measure, not whole house</td>
<td>Distributed Generation (Solar PV): $7-8 installed Watt (before incentives) < 10 kW systems
Energy Efficiency: $1.50 - $2.50 installed Watt, depending on ECM (Energy Conservation Measure)

(A typical 4kW Solar Home should have about 1.7 calculated kW of EE measures installed.)</td>
</tr>
<tr>
<td colspan="2">1. Distributed Generation – 70-90% of demand
2. Energy Efficiency – 10-30% of Demand
3. Age, climate zone, existing code and construction materials dependent</td>
</tr>
<tr>
<td>Energy Efficiency with no Incentives payback:
1. Payback dependent on avoided cost of energy
2. ECM dependent (2-15 years is typical range)
3. Investment sometimes uses blending ECMs with Solar to reduce overall payback

• The technology is available today . . . but at a price.
• The barrier is NOT technology, it is policy and financing.</td>
<td>HOME AUTOMATION NETWORKS
1. Policy and privacy barriers – not technology
2. ADR pricing signals today can cause a home to shed load!
a. LBNL proof of concept.
b. Commercially available
3. Smart appliances coming
a. Communications standards evolving
b. By 2014-2016 new federal E standards for appliances</td>
</tr>
<tr>
<td rowspan="2">Supporting Needs</td>
<td>Key Energy Efficiency ECMs:
• Weatherization (insulation and windows)
• Power Quality
• Programmable Thermostats
• Energy Efficient Appliances</td>
<td>• HVAC upgrades to SEER 14, 15, 16 (seasonal energy efficiency ratio)
• Duct Sealing
• Lighting / Lighting controls / Daylighting
• Geothermal
• Home Automation Networks</td>
</tr>
<tr>
<td>Building Codes
• Title 24 base case
• Municipal codes exceeding Title 24 (e.g. Chula Vista now mandates 15% above Title 24)
• Expand Energy Star / Benchmarking
• Link to Real Estate transaction-driven Home Energy Rating II (HERS II) and mandate energy efficiency upgrades be made (once fair and equitable finance models are put in place</td>
<td>State-level evaluation on cost-benefit
1. Policy / Rate Tariffs evolution
• Feed-in-tariff
• Renewable Energy Certificates / Carbon Trading
• Cap-and-trade
• TOU-pricing (beyond tiered pricing)
2. Goal – ease the market off of incentives and rebates, nudging toward price-driven cost-benefit decisions
3. Goal – low-income solutions are a necessity</td>
</tr>
</table>

NET ZERO CONSTRUCTION (2 of 2)

Supporting Needs (cont.)

Emerging Technology Investment

a. IOU Emerging Technology R&D
b. PIER-funded R&D
c. Private Sector R&D
d. New Financing models
e. Data / communication standards for HANs (i.e. Zigbee, Bacnet, Modbus, Z-Wave)

Education Campaigns

- Are underway at IOU and State level.
- New CPUC-sponsored Work Force Task Force effort underway to assess and develop training for new Green

Improving Measurement and Verification (M&V)

a. How do we know we are achieving our goals?
   1. A big gap in reporting and results in the 2005-2008 Energy Efficiency Cycle.
   2. IOUs received serious penalty assessments!
b. How can we better measure persistence and investment payback period?

1. Financing

a. Solve the PACE debacle.

2. Shift emphasis to performance-based incentives

a. New Construction – Accelerate Title 24 upgrades
b. Retrofit – invent new whole home performance incentives with an emphasis on high persistence (M&V based)

Path from Current State to End State of Technology

- Investing in energy efficiency on 130,000 homes in the 2010-2012 funding cycle with ARRA SEP money
- In 2020 will need to build 170,000 homes from scratch
- In the meantime will need to retrofit 12.4 million homes with AMI, ECMs, Solar PV, HANs, et al. That's about 100,000 homes a month, not every three years!
- If spent just $3,000 on energy efficiency only per home, we're still looking at $37 billion over 10 years. That's $3.7 billion per year. That's a $300 million a month industry.

TECHNOLOGY

1. New Homes by 2020 – SMART HOMES are microgrids run by ECMs that talk to AMIs and Smart Appliances, reacting to sensors, price signals and comfort settings to regulate energy
2. Built space by 2020 – ECM retrofits, HERS II transaction standards, incented EE investment upon sale (higher price tag for better HERS II ratings). Solar PV on xx% of built space (thorny issues still ahead on multi-family dwellings for both EE and RE, and older homes with <10 years useful life). AMI everywhere. Smart Appliances. ECM adoption – the home network of the future.

POLICY

1. TOU Pricing that factors the real cost of energy, including carbon, national security, avoided cost and transmission.
2. Let price, not incentives, drive the market!
3. Protect the low income sector.

MICROGRIDS

From DOE-CEC Microgrid Workshop / Navigant Consulting:

- A microgrid is an integrated power delivery system consisting of interconnected loads and distributed energy resources (DER) which as an integrated system can operate in parallel with the grid or in an intentional island mode.
- Integrated DER are capable of providing sufficient and continuous energy to significant portion of internal load demand even in island mode.
- The microgrid possesses independent controls and can island with minimal service disruption.

"What unique value(s) does a microgrid provide beyond DG alone, and who would pay for it?"

Allows operation with a larger power system; this provides two key capabilities:

Flexibility in how the power delivery system is configured and operated
Optimization of a large network of load, local DER and the broader power system
[Modular implementation to meet microgrid/grid needs.]

These two capabilities can deliver three important value propositions:

1.Custom Energy Solutions: Provide customized power to individual customers/tenants or groups of customers/tenants
2.Independence/Security: Support enhanced energy and infrastructure availability and security
3.Reduced energy cost: Provide end users with less expensive energy over current rates.

Current State of Technology (Source: Navigant)	***1. Substation (20+ MW)***	Maui Smart Grid: Wind integration DSM, energy storage, peak reduction
	2. Feeder (5-20 MW)	DOD 29 Palms, CA: Renewable integration, island/on the grid, DSM/DER optimization
	3. Multi-facility (2-5 MW)	Maritime DLC: Direct load control in commercial buildings, wind firming
	4. Single-facility (<2 MW) / off-the-grid system	Bella Coola, BC Canada : Off-the-grid project, optimization of diesel, hydro, hydrogen storage

Supporting Needs	Frequency performance under large generation/load swings
	Mitigation of impact of intermittent renewables on grid stability
	Distribution protection and controls for distributed generation
	Supervisory controls (i.e. system-level energy optimization for electrical and thermal loads)
	Energy storage

Path from Current State to End State of Technology (incomplete) / Order of events & milestones (incomplete)

Operations and maintenance infrastructure required to support a microgrid. This is an essential component that determines safety, reliability and price. More small system (<10 Mw systems) ventures have failed on this point than any other factor.

Residential Microgrid

Electrical Source To Residences
- **Local generation**
- **Baseload supply**

Local Electrical Source
- **Renewables**
- **Natural gas**

Storage [1-5 MW]

Size and type of storage device is a function of several parameters:
- Community needs
- Size of electrical source
- Cost of storage
- Integration with grid
- Controls complexity
- Local electricity source
- Location

Interface between local electrical source and storage/distribution (Batteries, H_2, EV) within a microgrid community

Batteries
- Flow type
- Li ion
- NaS

H_2 production
- Fuel Cell
- Electrolysis

CHP

Interface between grid connect and storage/ Distribution within a microgrid community

Controls

At the local source of electricity interconnect:
- HAN, AMI
- Storage quantity level
- C^2
- MEM
- Microgrid control

At the grid interconnect:
- Storage quantity level
- DA, Microgrid control
- Central Manager

Goal Focus

- Improved Appliances
- Demand Response
- Grid Peak Reduction
- Grid Distribution Loss Reduction
- Generator Efficiency
- Conversion Efficiency
- Fault Isolation
- Safety
- Efficient Use (EV)
- GHG Reduction

Remote Storage
Batteries, Capacitors, Thermal, Flywheels, Ultracapacitors, CAES, Hydro

Peaking supply from local storage

UTILITY GRID

Baseload electricity supply via grid

[Goal – Demand response reduces peak demand]

[Goal - 10% Total Electricity by 2016]

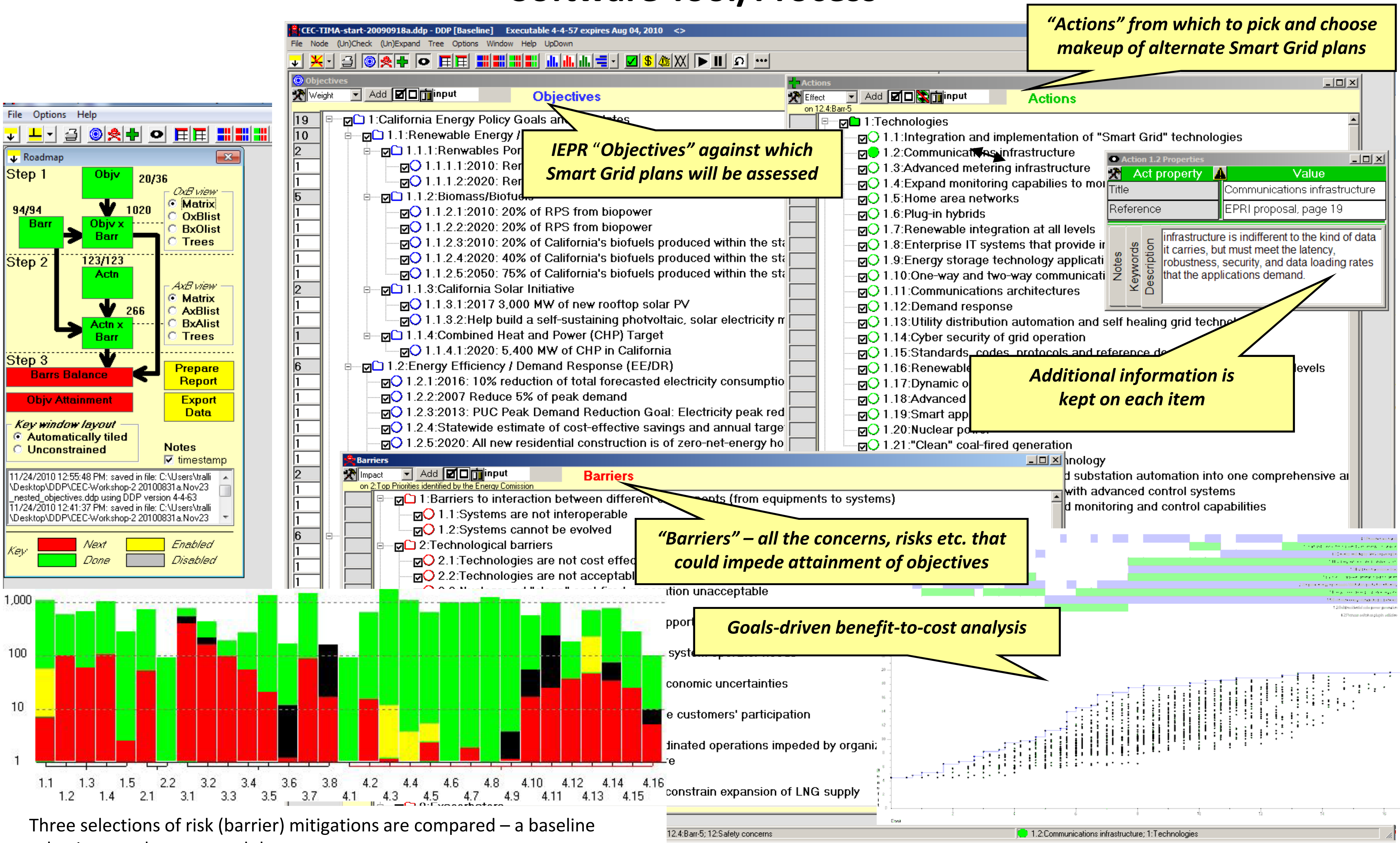
[Goal – Reduce peak demand ~4.9 GW by 2013]

Passive = utility integrated and utility owned, controlled and operated

Active = utility integrated, but consumer &/or third party owned/controlled/operated

Technology Infusion and Maturity Assessment (TIMA) Software Tool/Process

Jet Propulsion Laboratory
California Institute of Technology



Three selections of risk (barrier) mitigations are compared – a baseline selection, an alternate, and the empty set

Black = increase of alternate over baseline

Yellow = decrease of alternate over baseline

Green = unmitigated

TIMA: Objectives-Barriers-Actions

Objective – 3,000MW of rooftop Solar PV by 2016 (~5000 GWh/yr)

✓ ***Barriers***

1.1: Microgrid/DG Architecture
- 1.1.1: One-way flow assumed in many parts of the existing distribution network
- 1.1.2: Current spec for grid-tied DG disallows LVRT
- 1.1.3: Limited DG interconnection process

1.2: Current traditional architecture
- 1.2.1: Need to deal with legacy gear
- 1.2.2: Time of day billing rate for electrical power is not universally available in real time
- 1.2.3: No standard real-time data exchanged at the points where electrical power changes hands

1.3: There is no clear decision on who controls the final DR action: utility or customer

2.1: AMI/AMR
- 2.1.3: "Spectrum" allocations (wireless frequency)
- 2.1.4: No single vendor can offer a solution that covers all terrains, territories and meter reading issues

2.2: Distribution Automation: 2.2.1: Distribution (not substation) SCADA

2.3: General (technology): 2.3.1: Lack of "plug and play" capability so residential customers can easily deploy SG technologies

3.1: Increase of the net metering limits to above 1MW for solar

4.1: Storage
- 4.1.1: Unprecedented scale of use of batteries - collect/recycle/reuse infrastructure at end of life
- 4.1.2: Lack of storage dispatch techniques - grid operators don't have the framework to evaluate how to plan for them
- 4.1.3: Residential/industrial scale storage is unreliable, immature and too costly

5.1: PV
- 5.1.1: Lack of consistent, systematic method of monitoring and controlling PV at all T&D levels, which will be needed to meet state RPS goals
- 5.1.2: Variability forecasting for PV not where it needs to be to enable high penetration of PV (approaching it for wind)
- 5.1.3: Customer value proposition for PV is at odds with system control (who is responsible at other side of meter?)
- 5.1.4: Power quality variation will increase with intermittent power sources

8.1: Equipment mounted on gas distribution systems must be rated intrinsically safe which is an added cost

10.3: Lack of clear market mechanism for ancillary services for PV and DG

TIMA: Objectives-Barriers-Actions

Jet Propulsion Laboratory
California Institute of Technology

Objective – 3,000MW of rooftop Solar PV by 2016 (~5000 GWh/yr)

✓ ***Actions***

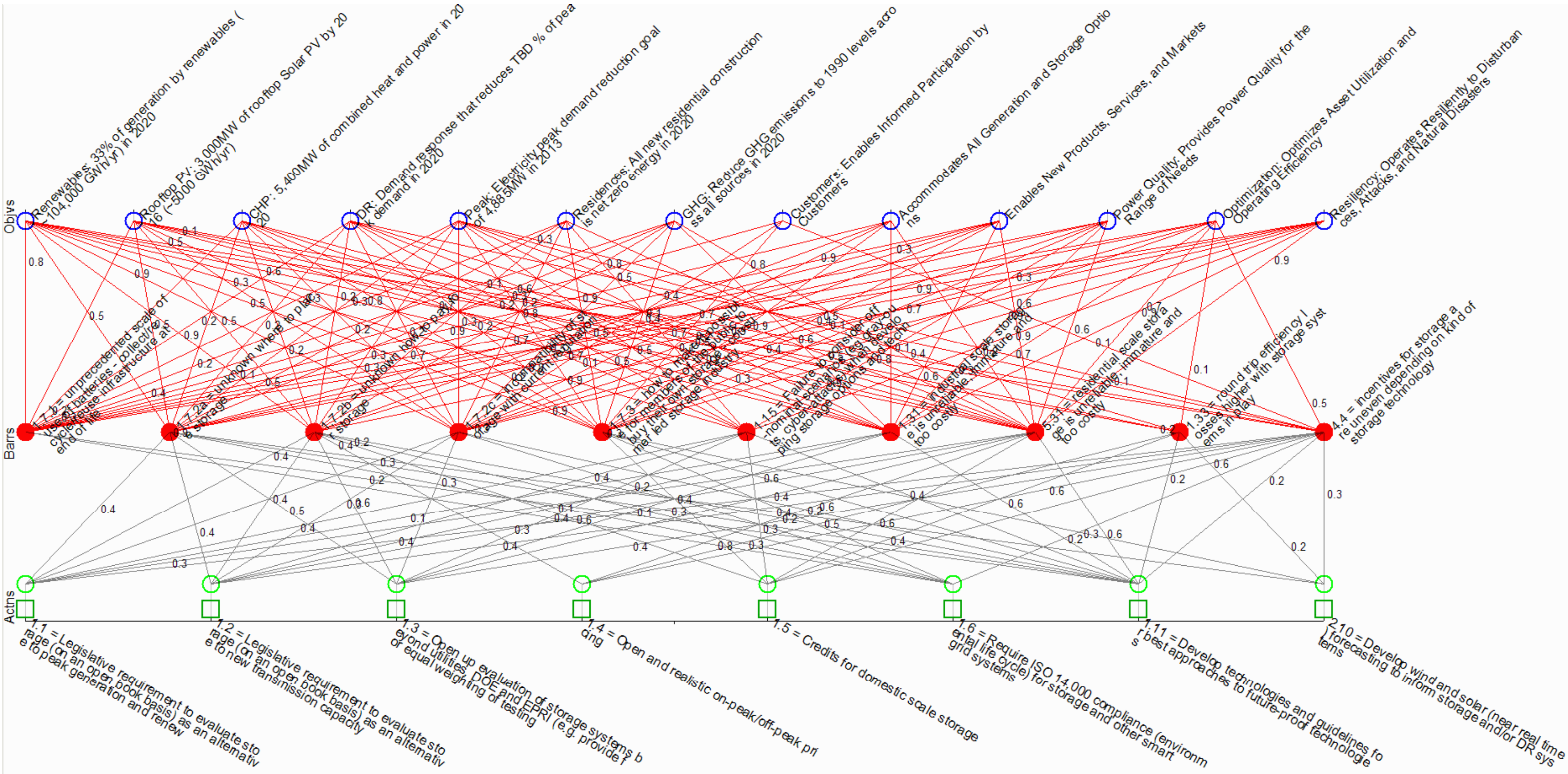
2.1: Evaluate storage (batteries & fuel cells) as an alternative to peak generation
2.2: Evaluate storage (batteries & fuel cells) as an alternative to renewable balancing
2.3: Require ISO 14,000 compliance (environmental life cycle) for storage and other smart grid systems
3.1: Develop wind and solar (near real time) forecasting to inform storage and/or DR systems
3.2: Define a "transaction-based" energy model to promote DER and renewables
3.3: Develop modeling control architecture and control tools for grid integration
4.3: Energy control systems for buildings
4.4: Data communication backbone (eg WAN, LAN, NAN) should have an open architecture if a new software application market is to be created
4.5: Open ADR - flexible architecture for DR control
4.6: Decentralized logic & process control
5.1: Backup NG systems that can be integrated w/ grid
6: PHEV Integration
- 6.1: Time-of-use charging
- 6.2: Smart charging infrastructure
- 6.3: PHEV as storage
- 6.4: Reuse of PHEV batteries

7: Economics/Financing/Incentives
- 7.1: Restructure the utility rate making models to favor smart grid (for off/on peak, backup rates, regional time of day pricing, ...)
- 7.2: Credits for domestic scale storage
- 7.3: Establish economic incentives for DG owners and system operators

8.1: Construct Demonstrations
- 8.1.1: Conduct study to identify the amount of new CHP/DG or backup generation that would penetrate the market if real time pricing were available.
- 8.1.2: Grid
  - 8.1.2.1: Multi-vendor interoperability demo, full network or microgrid; gated community-level demos, including micro-grid/community storage
- 8.1.3: Subgrid
  - 8.1.3.2: ICE boxes energy and PV devices (more generally, PV and storage integration)

8.2: Plan for large employers to be sites for PEV charging, cluster neighborhoods at night - system operator viewpoints important to this
8.3: Develop non-proprietary consistent system analysis models to determine performance requirements for technologies

Model Linkages between Objectives, Barriers and Actions for Storage Only*



The highly cross-coupled nature of this information is the reason why successful technology acquisition is challenging.

*This is a very small fraction of the collected barriers and actions.

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Energy Storage

- **Energy storage plays a strategic role in the Smart Grid**
  - Smoothing/firming the intermittent electrical energy supply from wind and solar renewable sources
  - Accommodating increased needs during peak demand by supplying energy generated during low demand periods
  - Providing a source of electrical energy that will improve electric power quality and maintain uniform power management to customer

- **Several options are available for storing energy to meet ratepayer needs (i.e. at load) or generation needs (i.e. at generation)**
  - Electrical
    - Flow batteries (ZnBr, Vanadium Redox)
    - Static batteries (NaS, Pb acid)
    - Li-ion batteries
    - Capacitors and ultracapacitors
    - Flywheels
  - Thermal
    - Molten salt; solids; ice production
  - Others
    - Hydrogen/fuel cells
    - Natural gas with biogas