EXECUTIVE SUMMARY

This report summarizes activities of the Advisory Council during October 2014, consolidating a presentation received, and subsequent discussion and consideration by Council members.

The following presentation was made at the October 8, 2014 Advisory Council meeting:

The Integrated Grid: Energy Storage and Smart Grid Technologies and their Relationship to 2050 GHG Goals

Haresh Kamath
Program Manager
EPRI, Electric Power Research Institute, Palo Alto, CA

A video recording of this presentation and the Council's discussion is available at: http://baaqmd.granicus.com/MediaPlayer.php?publish_id=ee8a8cdd-4f30-11e4-bf9a-00219b9a9d7d

EPRI states that its mission is to conduct research, development, and demonstration on key issues facing the electricity sector on behalf of their funding members, energy stakeholders, and society. EPRI also states that it does not advocate any particular position, but provides information about the effects of policy decision systems as they relate to the electric utility industry. EPRI receives funding from electric utilities, as well as from other sources.

Building on other presentations to the Council in 2014 that focused on energy conservation and renewable sources of energy, the October meeting focused on energy storage and integrated electric transmission systems, aka smart electric grids.

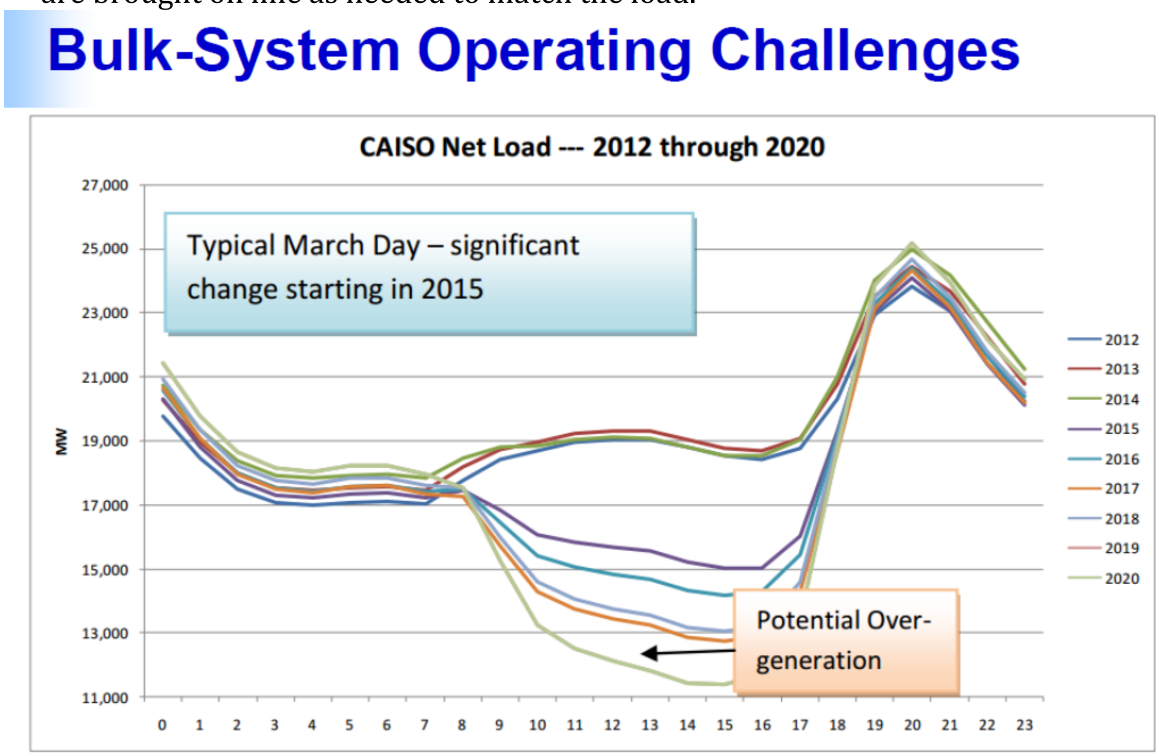
The value of this report is to provide clarity and the context of the prior speakers. This context will be reflected in a refinement of our synthesized recommendations.

BACKGROUND FROM SPEAKER

Managing the Electric Energy Flow in CA

1. Energy storage is key, as we develop an electric system increasingly powered by renewable sources. Solar and wind power are unable to provide consistent levels of power, due to their inherent dependence on variable solar and wind patterns over hourly, daily, or monthly periods. Hydro power is also variable, depending on season and previous winter precipitation. Energy storage technologies, however, can help make these electricity forms available when power is needed.

2. What is often termed the “duck curve” (below), is a graph of net electric load (forecasted load after variable generation is accounted for) that shows the lack of alignment (as the difference) during a 10 year period between renewable energy supply and peak energy demand. Peak renewable generation occurs mid-afternoon, but net load ramps up in the late afternoon and evening. Additional energy resources (typically fossil fuel generators) are brought on line as needed to match the load.



Source: CAISO

3. After a certain point, adding more renewables to the generation mix no longer reduces GHG emissions, unless demand can be shifted to daylight hours or if renewable energy can be stored for night-time hours.
4. The California Public Utilities Commission (CPUC) has set a statewide goal of adding storage capacity equivalent to 2% (1325 MW) of grid capacity by 2020; California already has 1.5% storage, Europe 5%, and Japan 10-15%.
5. More advanced solutions to bulk energy storage are projected to be two decades away. While research into advanced storage continues, storage implementation is likely to be dominated by present-day technologies at least for the next 10 years and is likely to be most effective at smaller scales.
6. Energy storage technologies:
    a. Energy storage with advancements in lithium ion battery technology is being applied to the grid, but it is early in its development. Batteries, however, are likely to continue to be expensive, inefficient, and relatively short-lived.
    b. Within the last four years, new electric vehicles (EVs) added to the US fleet represent 5 GWh of storage capacity. It is unknown what kind of system storage benefit these batteries could offer if they were

properly networked together. Such an approach is theoretically possible, but would face significant technical, economic, and regulatory hurdles.

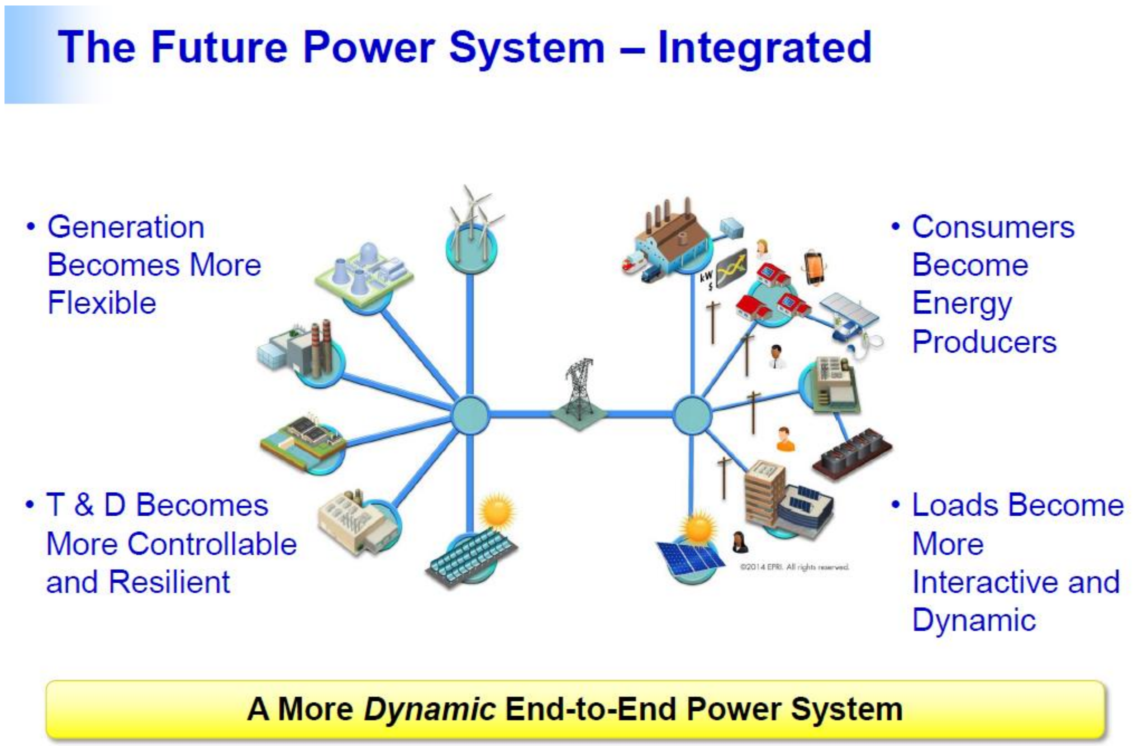
c. Pumped storage is relatively efficient and can scale to increase capacity. Pumped storage is a system of two reservoirs connected by a penstock and an electric generator. Water flows downhill through the generator during electrical demand. When excess electricity is available from renewable or nuclear power plants, water is pumped back up the mountain to be used later as needed. The addition of new pumped storage capacity has environmental issues related to the construction of new, or modification of existing, hydro electric facilities and potential alteration of river flow. However, as the value of storage increases, developers may consider new sites previously considered economically unfeasible. PG&E has a large pumped storage, 1,200 megawatts, power plant (Helms Power Plant) east of Fresno. Pumped storage is the single largest storage technology currently in use by a wide margin.
d. Compressed air has been explored as an energy storage mechanism, but has not been fully developed. Underground caverns in California, from depleted natural gas fields, are being considered as possible storage locations. Germany and Alabama each have 400 MW demonstrated energy storage from compressed air.
e. Energy can be stored by making hydrogen from excess renewable electricity, however, significant challenges exist (conversion efficiency of only 25%). Hydrogen is a huge opportunity for use for storage, but the technology is not ready now for commercial application.
f. Thermal (high heat) storage, combined with concentrated solar thermal generation and the use of flywheels, are other energy storage concepts that may emerge as viable.

7. Electricity demand response management and energy conservation may offset some electric storage capacity needs.

Integrated Transmission Systems/Smart Grids

1. High reliability, stable voltage, stable frequency (60 cycles), affordable, and safe access to electricity is critical today in our ever increasing digital world. Electric transmission and distribution systems play a critical role in the management of these attributes and are essential in connecting sources of electricity to end users. Historically, a small number of large remote power plants provided electricity to users throughout the state. With a move towards the production of electricity at many small sources (distributed generation), often operating intermittently when the sun shines or the wind blows, new challenges emerge that change how the grid operates (figure below).

2. Transmission and distribution grids are not currently designed to facilitate large "backward" electricity flows as will exist with future increased amounts of renewable sources of electricity.
3. The grid provides a number of essential services to all consumers (even those with their own distributed generation sources), including power reliability, start up power, voltage quality, and energy trading and transactions. An integrated grid would allow distributed generation to enhance grid operation for everyone by providing the additional services of resiliency, voltage support, emissions reductions, loss reduction, demand response, and distribution optimization.
4. Grid operators must balance the variability of renewable energy sources. For example, Germany’s 2013 hourly solar and wind generation fluctuated from zero to 36 GW of electric capacity, and older, central generation plants (primarily coal) are being used to fill the voids. It is presently unknown precisely how variable is California’s renewable energy portfolio. Natural gas power plants are currently the most common source of electricity to smooth out its renewable generation in California.
5. Demand response allows utilities to meet peak electrical demand by influencing or managing customer demand. For example, some customers willingly curtail electric usage (e.g., cut off air conditioners) during times of high demand. Perhaps charging of electrical vehicles will be controlled to occur after evening peak loads or during the day (through workplace charging), if solar power is abundant enough to allow low-cost charging approaches.
6. Zero net energy homes, while producing at least as much energy as they consume on an annual basis, must still be connected to the grid to receive electricity when electric demand exceeds the home’s ability to provide power (when the sun isn't shining). The grid must be designed to still handle peak power demands, even if less and less electricity comes from central generation on an annual basis as California moves closer to achievement of its zero net energy home-building goals.



Renewable Power and Distributed Power

1. Distributed generation refers to generation of electricity at localized sites. Distributed Energy Resources (DER) includes such things as home and business owned solar panels, fuel cells, back-up generators, storage facilities. Combined heat and power (CHP) allocates waste heat from distributed generation plants to space heating, water heating, and industrial processes requiring heat, thereby improving overall energy efficiency to 80-90%.
2. Solar photovoltaic (PV) costs have dropped dramatically to where they are cheaper than installation of conventional large fossil fueled power plants when normalized on a $/kW of unit production capacity. This metric is a little deceptive, in that a fossil power plant can produce power 8760 hours each year, while solar and wind have more limited hours of operation. However, the energy for solar and wind power plants is free, while the energy for fossil fuel is costly and escalating with inflation. Operations and maintenance costs are associated with all power plants.
3. Utility scale solar power plants produce more power than the aggregate sum of all domestic solar panels.
4. A renaissance of natural gas usage, with its low cost, is occurring with its abundance of supply. New combined cycle power plants are at least 50% efficient, compared to older conventional power plants with efficiencies of 30-40%, less transmission line loss.
5. For now, natural gas is the fuel of choice for power plants in California, and these plants fill the void when renewable power is not available.

KEY EMERGING ISSUES RELEVANT

1. As increasing amounts of distributed renewable resources come on line in response to statewide energy policies, improvements include:
    - robust integrated transmission systems and
    - expanded energy storage
2. Clean sources of electricity are desirable. However, the grid as a whole requires more supply options than WWS, unless large-scale storage and demand response options are available.
3. Economic and equity challenges exist in the transition to a renewable grid. As the usage of utility-generated electricity drops with the introduction of additional distributed renewable generation, the CPUC and the electric utilities need to modify electric rate structures to recover fixed infrastructure costs (stranded assets) while properly valuing distributed energy resources.
4. The future of the Bay Area's electricity system is integrally connected to the wider grid and to policies and decisions made at the statewide level. Although certain decisions (such as choices of electricity supply) may be more readily made at a local level, other improvements will require statewide coordination.
5. Integrated grids have changed over the last five years, and will experience seminal changes within the next 10 years. A more flexible grid will be needed, including energy storage and other technologies and operational improvements to enhance electric grid reliability and to allow for high levels of renewable energy sources.
6. Energy storage and demand response can work together to reduce the need for fossil fuel generation during periods when renewable power is unavailable. Energy storage may also be able to help provide a dual function in the form of cleaner backup generation in the case of grid outages or other emergencies.
7. Technologies being developed for energy storage can potentially be transferred to back-up generation applications.
8. A tradeoff exists between reliability and cost of electricity.

CONCLUSIONS

The value of this report has been to provide clarity and context of the prior speakers. This context will be reflected in a refinement of our synthesized recommendations.

1. Mr. Kamath's presentation provided important context for understanding and interpreting other energy-related information presented to the Advisory Council in 2014. All five speakers addressing the Advisory Council on the subject of the Bay Area's energy future concurred that a comprehensive energy-related response to the climate change threat necessitates (1) deep energy efficiency, (2) electrification of all possible fossil-fueled end uses, (3)

decarbonization of the electricity supply, and (4) decarbonization of remaining fuel uses.

2. The topic on which the speakers differed was in their estimation of the feasibility of decarbonizing the electricity supply exclusively through Wind, Water (hydropower), and Solar (collectively WWS) or whether an "All of the Above" approach, which includes nuclear, clean coal, and other technologies, would be necessary. Mr. Kamath's presentation echoed the view of Jane Long, which is that the intermittent nature of WWS generation poses significant challenges for balancing generation with load.
3. In particular, Mr. Kamath pointed to the fact that current energy storage technologies are expensive or pose technical challenges deployment at the scale required for grid-scale load balancing. Considerable R&D is underway but cost-competitive, grid-scalable technologies may be a couple decades away. In the short-term, at least, these constraints imply that an "All of the Above" strategy would be the more prudent approach to getting aggressive reductions in our GHG emissions. Over the longer term, however, as more advanced and cost-effective energy storage solutions become available, a more narrowly-focused WWS generation mix may become feasible.
4. The key take away from Mr. Kamath is that significant storage capacity or reserve generation capability (likely to be powered by fossil fuels though it could be nuclear or hydro) would be needed to support an electric grid powered entirely by renewable power (WWS). Load management is another option to help stabilize the grid, though it remains unclear what portion of load balancing could be achieved through load management and what portion requires storage capacity. When over-production from renewable sources occurs, storage capacity is needed for the excess energy. Currently, we have only 1.5% storage capacity with another 2% planned by 2020 in California.

GLOSSARY:

CAISO: California Independent System Operator.

Compressed Air Energy Storage (CAES): Excess power from renewable electricity is used to compress air, which is stored in underground reservoirs (depleted gas field or natural caverns). The compressed air is then withdrawn and used to drive power plant turbines when electricity is in demand.

Combined Cycle Power Plants: A thermodynamic cycle describing the design of a power plant. A combined cycle power plant combines a steam cycle power plant with a gas turbine power plant resulting in greater overall thermodynamic efficiency (waste heat is turned into useful energy (electricity)).

Demand Response: Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.[1]

Duck Curve: A graphic that utility companies use to illustrate concerns about mismatched renewable generation and demand (i.e., lack of availability of solar energy during high use early evening hours).

EPRI: Electric Power Research Institute, based in Palo Alto, CA.

EV: Electric Vehicles.

GWh: Gigawatt-hours, a unit of electricity power.

Integrated Grid and Smart Grid: An electric grid that collates many diverse and perhaps small sources of electricity into a functional grid capable of providing reliable, stable, cost effective, and safe electricity.

Load: The amount of electric power delivered or required over a given period at a constant rate.

Stranded Assets: Being able to capture the cost, through rate making, of power plants and transmission lines when utility power sales are reduced. The current configuration of the electric utility is designed to provide power 24/7, 365 days a year. This allows fixed cost assets to be spread out over the year. With increases in energy conservation and distributed generation, the utility must recover these same fixed costs, either through higher charges per unit of energy sold or through fixed charges that apply to all customers.

WWS: Wind, water, and solar power.

Zero Net Energy Homes: Homes designed to produce enough electricity to meet their annual needs. These homes provide any excess electricity to the grid, while the connection to the grid ensures that electricity is available 24/7.

[1] Federal Energy Regulatory Commission, http://www.ferc.gov/industries/electric/indus-act/demand-response/dr-potential.asp, accessed Oct. 24, 2014.