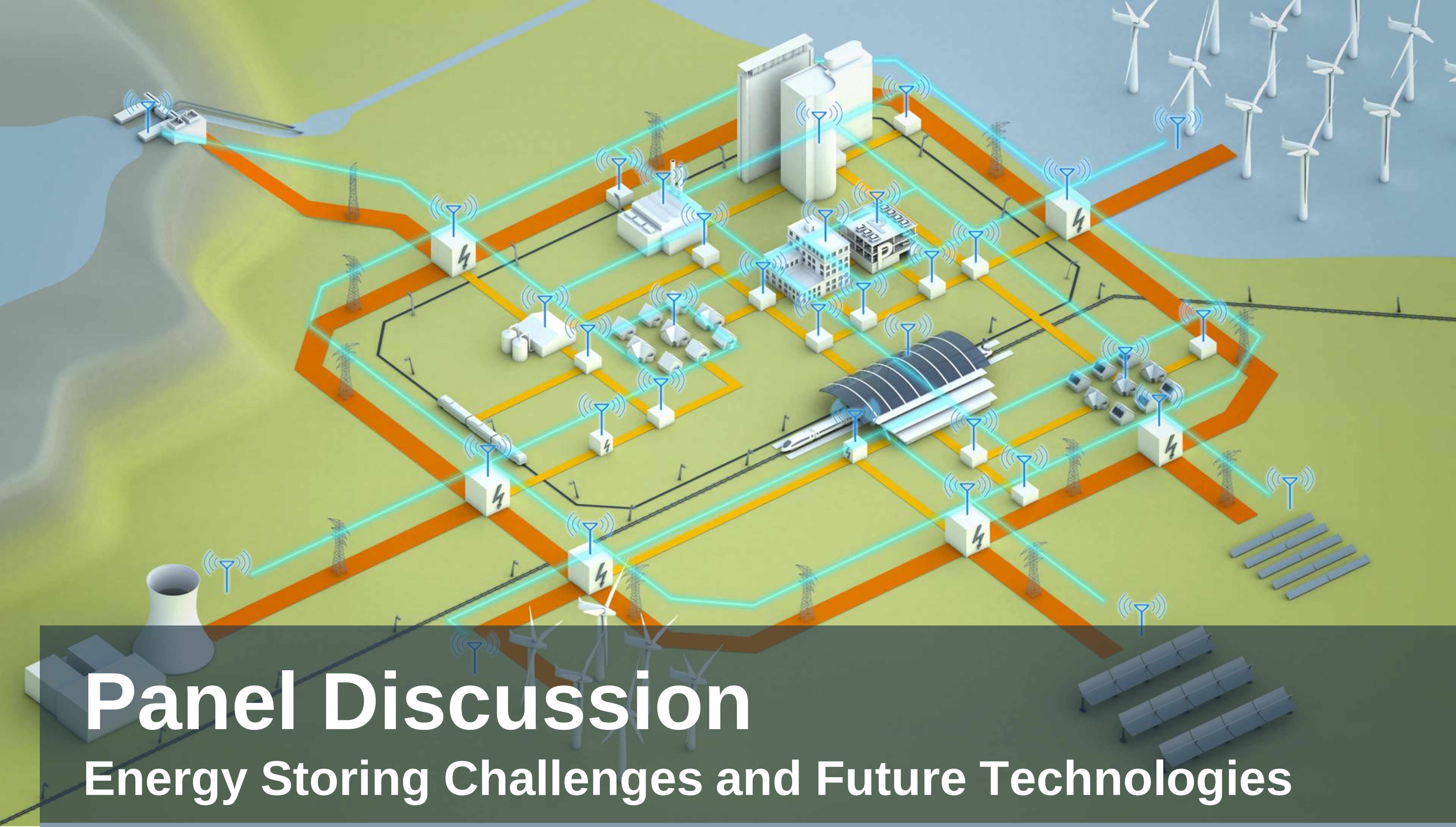

Panel Discussion

Energy Storing Challenges and Future Technologies

March 26th, 2013

Energy 2013, Lisbon, Portugal

Participants

- Moderator
  - Steffen Fries, Siemens AG
- Panelists
  - Petre Dini, Concordia University , Montreal, Canada
  - Mark Apperley, University of Waikato, New Zealand
  - Steffen Fries, Siemens AG, Munich, Germany

Energy Storage is connected with different Challenges How do we address them?

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- Thermal: Power to Heat
- Electrochemical: Battery
- Chemical: Power to Gas
- Mechanical: Hydroelectric
- Electrical: Super capacitor
- …

- Local Control
- Remote Administration
- Authorization
- …

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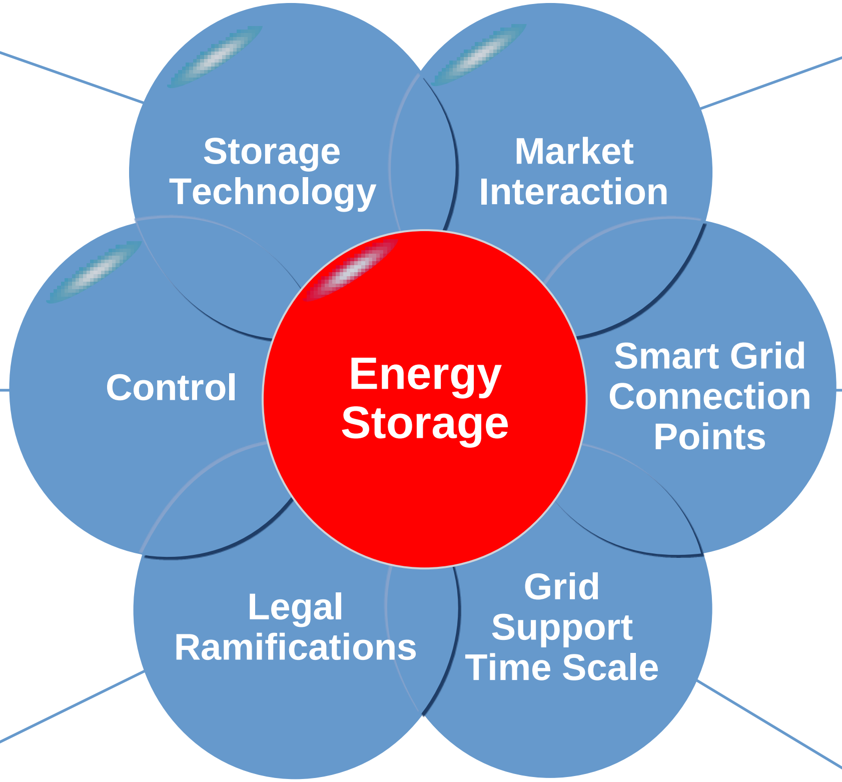
- Country specific laws
- Privacy regulations and appreciation
- …



- Tariff Options
- Contract Handling
- Clearing (Energy, Money)
- Peer authentication
- …

- Low / Medium Voltage
- Communication and its protection
- Source integrity
- …

- Short: Power Quality
- Mid: Operating Reserve
- Mid: Time Shift
- Long: Energy Reserves
- …

Communication Support:
Core Communication Standards for Smart Grids
IEC TC57 Reference Architecture

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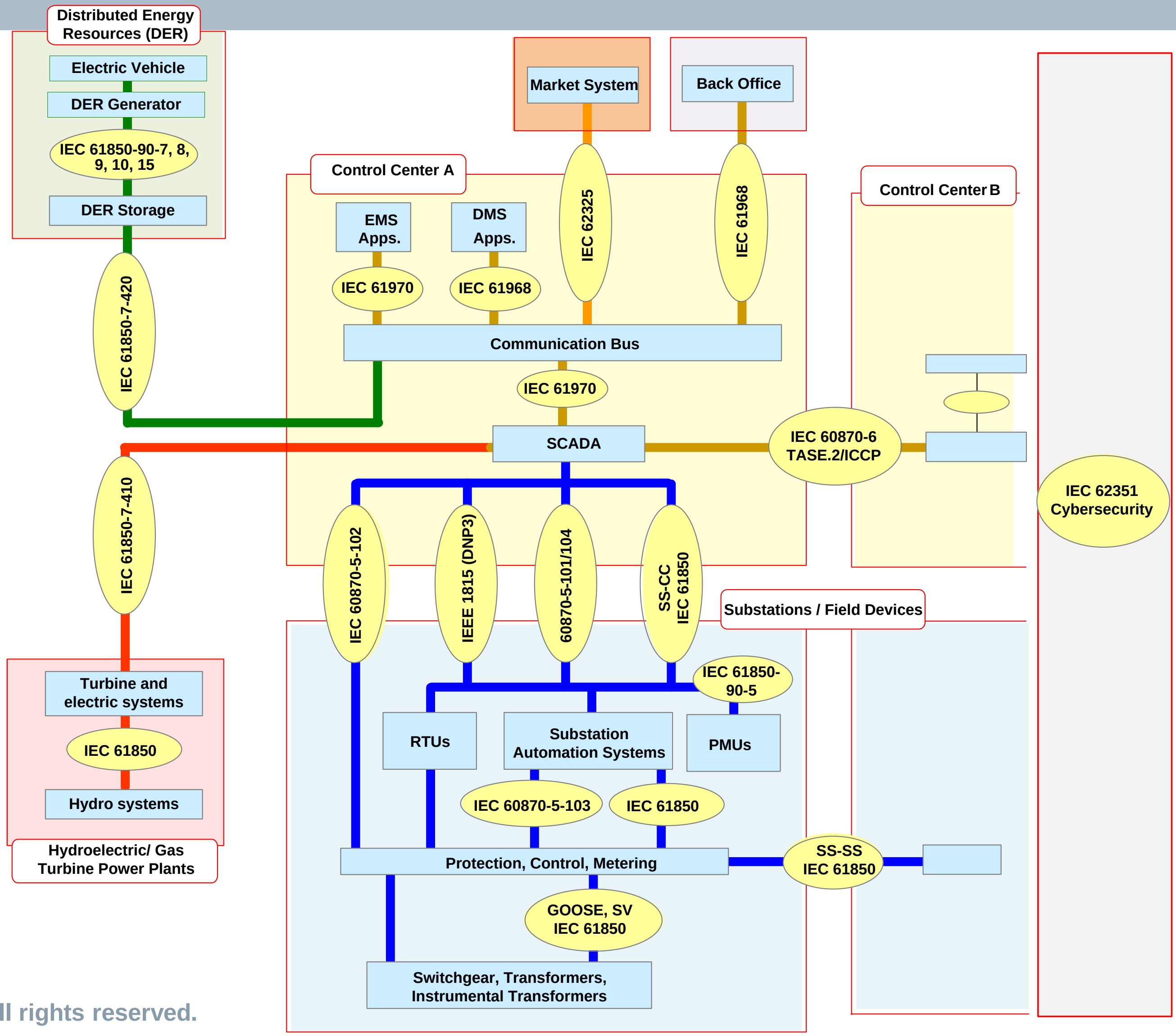
- **IEC 61970 / 61968**
  Common Information Model (CIM)
- **IEC 62325**
  Market Communication using CIM
- **IEC 61850**
  Substation, Distribution, DER Automation
- **IEC 60870**
  Telecontrol Protocols
- **IEC 62351**
  Security for Smart Grid



Capacity Support: Incorporation of Electric Vehicles as dynamic Storage

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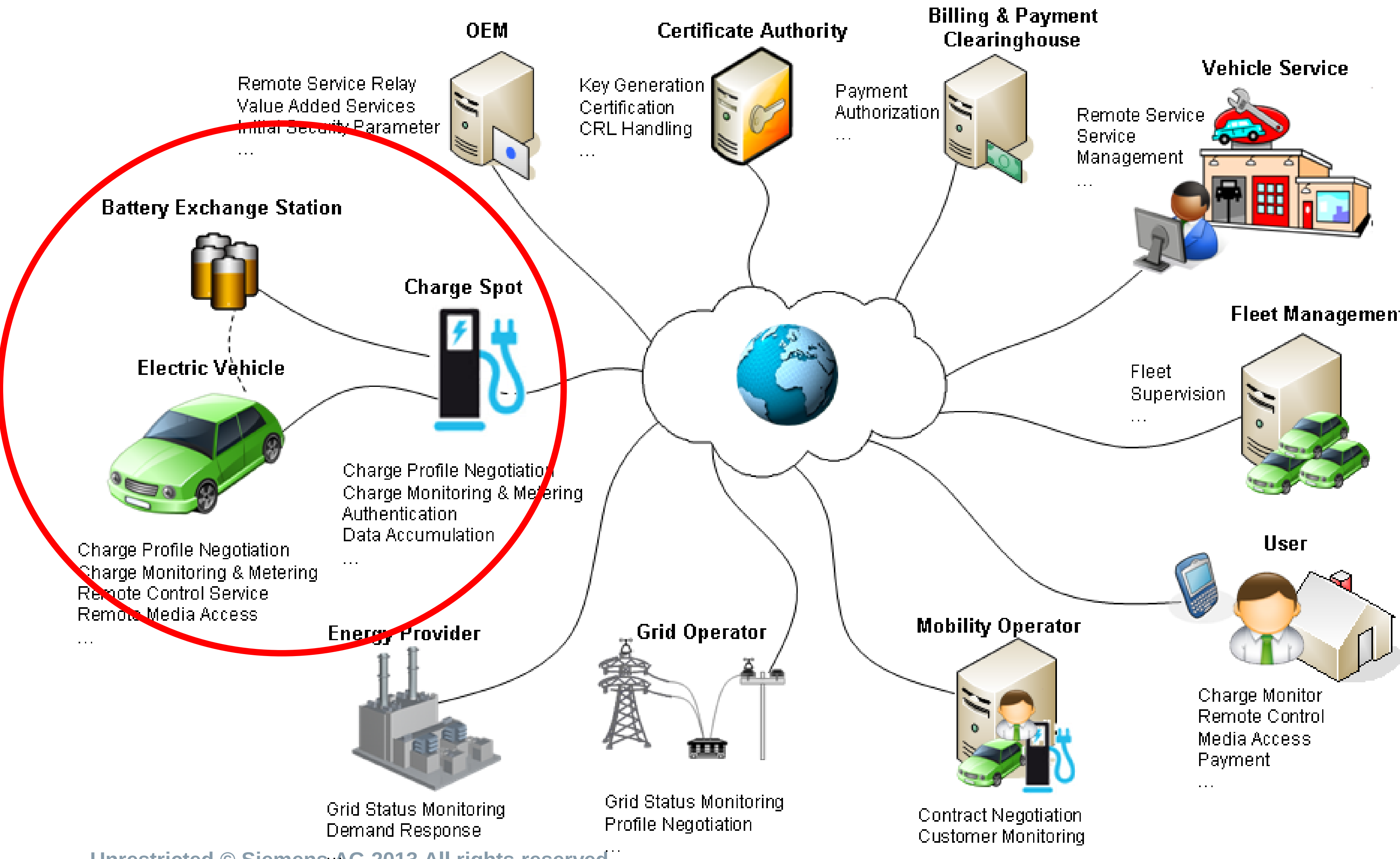

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PANEL ENERGY
Energy Storing Challenges and Future Technologies

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Basic inquiries

- Time
- Location

- Supply vs. demand
- Production vs. consumption
- Production costs vs. storage costs
- Availability vs. access
- Production vs. transport
- Storage maintenance

Evolution i

- An early solution to the problem of storing energy for electrical purposes was the development of the battery

- In the 1980s, a number of manufacturers carefully researched thermal energy storage (TES) to meet the growing demand for air conditioning during peak hours. Today, several companies manufacture TES systems.
- The most popular form of thermal energy storage for cooling is ice storage since it can store more energy in less space than water storage and it is also less costly than energy recovered via fuel cells.
- Thermal storage has cost-effectively shifted gigawatts of power away from daytime peak usage periods, and in 2009 was used in over 3,300 buildings in over 35 countries. It works by creating ice at night when electricity is usually less costly, and then using the ice to cool the air in buildings during the hotter daytime periods.

Evolution ii

- Chemical fuels have become the dominant form of energy storage, both in electrical generation and energy transportation. Chemical fuels in common use are processed coal, gasoline, …biodiesel
- All of these materials are readily converted to mechanical energy and then to electrical energy using heat engines (via turbines, for example
- Heat-engine-powered generators are nearly universal, ranging from small engines producing only a few kilowatts to utility-scale generators with ratings up to 800 megawatts. A key disadvantage to hydrocarbon fuels are their significant emissions of greenhouses gases that contribute to global warming, as well as other significant pollutants emitted by the dirtier fuel sources such as coal and gasoline.

Evolution iii

- **Electrochemical devices called fuel cells**

Fuel cell development has increased in recent years due to an attempt to increase conversion efficiency of chemical energy stored in hydrocarbon or hydrogen fuels into electricity.

- **Solar**
- **Research is being conducted on harnessing the quantum effects of nanoscale capacitors to create digital quantum batteries.**
- **Although this technology is still in the experimental stage, it theoretically has the potential to provide dramatic increases in energy storage capacity**
- **Grid energy storage**
- **A proposed variant of grid energy storage is called vehicle-to-grid**

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Panel: Energy Storing Challenges and Future Technologies

Mark Apperley

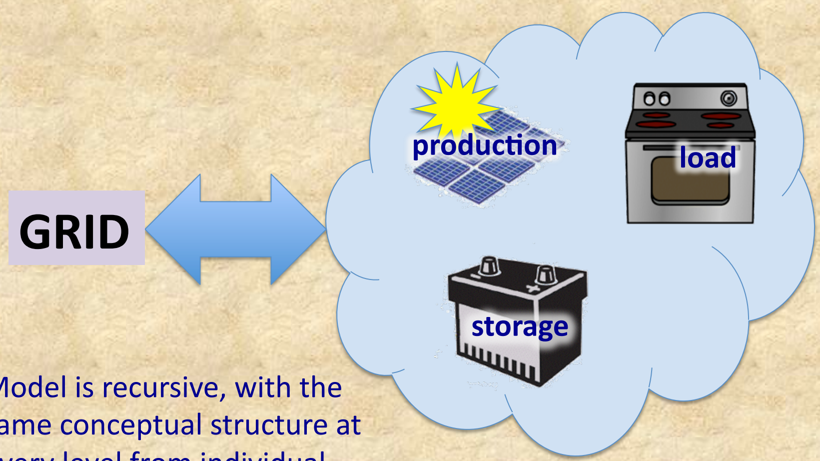
Energy storage issues

- **Capacity:** high/central, low/distributed
- **Role:** load smoothing, supply smoothing, quality maintenance, infrastructure enhancement, renewable integration, …
- **Storage time scale:** minutes, hours, days, weeks, seasons, years…
- **Technology:** battery/chemical, gas, mechanical, gravitational…
- **Domain:** national, regional, local, consumer…
- **Business model:** Grid resource or generator?

Load smoothing:

Water storage:
Charge: 30 litres/min
Discharge: 140 litres/min

Re-thinking: the smart grid node



Model is recursive, with the same conceptual structure at every level from individual consumer to entire grid.

Additional Viewpoints from Active Attendees

Robert S. Brewer, University of Hawai`i at Mānoa, USA
Chris Yakymyshyn, FieldMetrics, Inc., USA
Kore Sileshi, Addis Ababa University, Ethiopia

Robert S. Brewer

http://excitedcuriosity.wordpress.com/2013/04/08/thoughts-on-energy-2013-conference/

Extracted from that, here are three points from the panel discussion I wrote up:

Mark pointed out that we all have a storage system in our homes for a different resource: toilets. Toilets store water, dispensing it at 140 l/m, but refill at 30 l/m. The water storage provides two benefits to water-providing utility: it smooths out the load generated when people flush, and it also provides an "infrastructure improvement" since the water pipe coming to homes is not sized to provide water at the rate needed to flush. Electricity storage would also provide these same two qualities. For example, as electric vehicles become more widely used, the distribution lines to neighborhoods may become overburdened as adding an electric vehicle roughly doubles the electricity use of a home. In a neighborhood with many EVs, some vehicles may discharge to provide their neighbors with power which the utility is not able to provide with the existing distribution lines.

In talking about the growth of renewable energy, Chris Yakymyshyn pointed out that fossil fuel power plants need to run a certain percentage of the time in order to make a profit. If they are only being used a small percentage of the time to support intermittent renewable energy sources, they will shut down and go bankrupt.

I shared point made by Mark Duda, a founder of residential-solar installing company RevoluSun in Hawaii. He pointed out that since electricity prices are very high in Hawaii, PV is quite cost-effective for many homeowners, some of whom also install a battery storage ystem so they can go completely off the grid. Hawaiian Electric (like all utilities) has large fixed costs (power plants are expensive!) that it has to pay regardless of how much electricity they actually generate. Thus as more people are able to switch to solar, Hawaiian Electric will have to spread the fixed costs over fewer customers, leading to higher rates. This makes solar cost effective for even more homeowners, who then disconnect from the grid, which could lead to a spiral when the utility can no longer afford to pay its fixed costs.

Chris Yakymyshyn

Massive, centralized pumped hydro energy storage is feasible in some countries with sufficient altitude differentials (for example, the Great Lakes on the U.S./Canada border is being proposed), but it faces almost insurmountable regulatory and public acceptance hurdles. It is currently the least expensive form of electricity storage.

Large, centralized solar or wind energy farms are feasible in some countries, but they face environmental and public acceptance hurdles.

Interconnecting large centralized energy sources and/or large centralized energy storage with load centers will require tremendous amounts of new transmission capacity. For example, in the U.S., connecting solar farms in Arizona and/or wind farms in West Texas with load centers along the East coast would require more than 1000 new high voltage (500kV) DC transmission lines.

Personal reward is a key element to move distributed storage forward. Distributed electricity storage will quickly grow if financial incentives are structured so that a customer can make money by storing grid energy at low prices (or storing their self-generated solar energy) and selling it back to the grid at peak price times of the day. This is different from a customer just avoiding the use of electricity during peak hours. It requires the ability for the customer to sell to the grid at full real-time prices. It is essentially allowing the general public to participate in the generation market.

If item 4 is put into place, then manufacturers will quickly develop small (<1000 kWhr) energy storage products to meet this market demand. A host of new business models will be created (battery warehouses, virtual energy providers, real-time bidding sites, software tools that optimize a person’s returns, etc).

Converting low cost or intermittent electricity into liquid fuel is an excellent storage technique. It stores energy in a stable, transportable form that has other uses (methanol, for example).

A form of energy storage is achieved by co-locating a concentrating solar thermal array next to a conventional gas fired turbine generation station. The solar thermal energy is used to offset the heat produced by burning natural gas, resulting in reduced natural gas usage. Florida Power and Light spent $400M to build a 75MW demonstration array next to an existing natural gas power plant, saving an estimated $178M in fuel over its 20 year expected life. This calculation was made before natural gas prices collapsed in the U.S. The solar plant cost is still very high.

Geothermal storage of solar thermal energy is being tested in a new small housing development near Calgary, Alberta, Canada. The community of high efficiency homes all feed solar-heated fluid from rooftop collectors into a community underground water tank, to achieve water temperatures of 80-90 Celcius at the end of summer. This may provide enough thermal energy to meet all home heating needs during the cold winter months.

Using all electric vehicles for grid storage has potential, but all-electric vehicles will not be widely accepted by the public until:

The driving range is at least 300 miles in cold weather, with driver comfort comparable to a liquid fuel vehicle (i.e. heat in winter, AC in summer);

The battery does not have a large temperature coefficient;

The unsubsidized cost is similar to a comparable liquid fuel vehicle;

The battery can be 'filled' in a time comparable to a gasoline engine.

A gasoline engine can be filled with 200 miles of range in one minute. Current batteries require 50 times longer to reach 80% of full charge. Battery swapping is the only viable alternative at the present time. A one-minute filling time for a battery would need a multiple MegaWatt cable to transfer the same equivalent energy.

Concentrated Solar Thermal farms have the ability to store several hours of solar energy by heating molten salt in a tank, and using this to power a steam turbine generator in a dispatchable mode. Currently, this technology is much more expensive than solar PV, and several large solar thermal projects have recently either been cancelled or converted to less expensive solar PV. They also require unscattered sunlight (cloudless skies), which limits where they can be deployed.

As renewable energy provides a growing share of total electricity energy, there will come a point when dispatchable fossil fuel plants will not have sufficient energy sales to remain a viable business. In the case of investor owned generation plants, they will go bankrupt. This underscores the need for electricity storage as a backup to intermittent energy sources such as wind and solar.

Kore Sileshi

Energy storage technology can serve at various locations at which electricity is produced, transported, consumed and held in severe (back-up). Depending on the location storage can be large-scale (GW), medium–sized (MW) or micro, local systems (kW). Research and technology development is needed to enable the wider application of many known technologies, and to develop new ones. Some of the key technologies, not all of which are at the stage of commercial applications are:

1. Large bulk energy (GW)
    - Thermal storage, pumped hydro;
    - Compressed Air Energy Storage
    - Chemical storage (e.g Hydrogen energy storage from large scale to smaller ones
2. Grid storage systems (MW) able to provide:

- Power: super-capacitor, Super Conduction Magnetic Storage, flywheels
- Energy: batteries such as lead acid
- Energy and power: lead acid and lithium ion batteries

3. End users storage systems (kW)
    - Power: super capacitors, flywheels
    - Energy: batteries such as lead acid

A varieties of ways to store excess electricity produced by solar and wind power, to be used when the sunshine is not shining and the wind is not blowing, have been and are being developed and tested, and scientists are anxious to find new, better, cheapest ways. Academic departments, businesses, and public energy research laboratories have been bursting with innovations.

Above all, the main challenges for energy storage development are economic. The economic and business case varies from case to case, depending, among other things, on where storage is needed: generation, transmission, and distribution or consumer level. The benefit for uses/operators is also closely linked to the question of storage location.