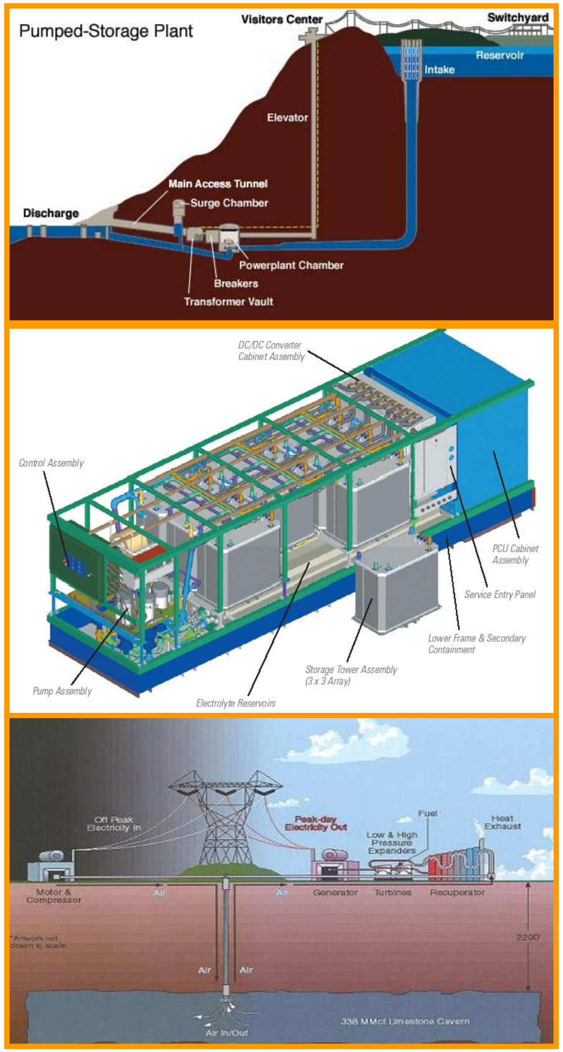
Balancing Grids with Electrical Storage

IEA Committee on Energy Research and Technology
STRATEGIC AND CROSS-CUTTING WORKSHOP
International Low-Carbon Energy Technology Platform
15 February 2011

Ir. Dr. John W M Cheng

Overview:

- Drivers to make the grid “smarter”
- In a smart grid, we have…
- Potential roles of storage devices
- Development stage of different types of storage
- Some experiences on the newer technologies such as …
- Challenges & needs
- Outlook



Drivers to make the grid "smarter"…

Social norm shifts: Environmental consciousness, increasing renewables contents, electrification of transportation, customers demand more transparency and higher expectation on services

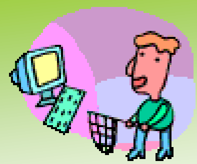
Government's drives: Climate change policy, end-use efficiency, energy independence, economic stimulus, global competitiveness…

Technology pushes: Information age, telecom network expansion, advanced sensors, power electronics accessibility

Utilities' own needs: Integratio… and controllable demands, reliability, safety… asset management, competitive pressure…

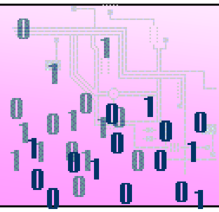
Disasters:
September 11, 2001 - NY;
August 14, 2003 - NA;
Jan-Feb 2008 - China
Next one ???

What is a Smart Grid ?



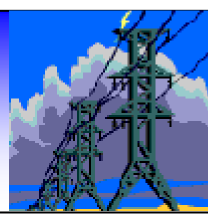
Intelligent Applications

+



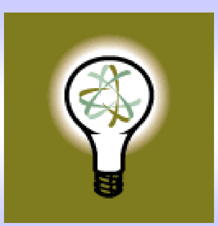
IT Networks & Sensors

+



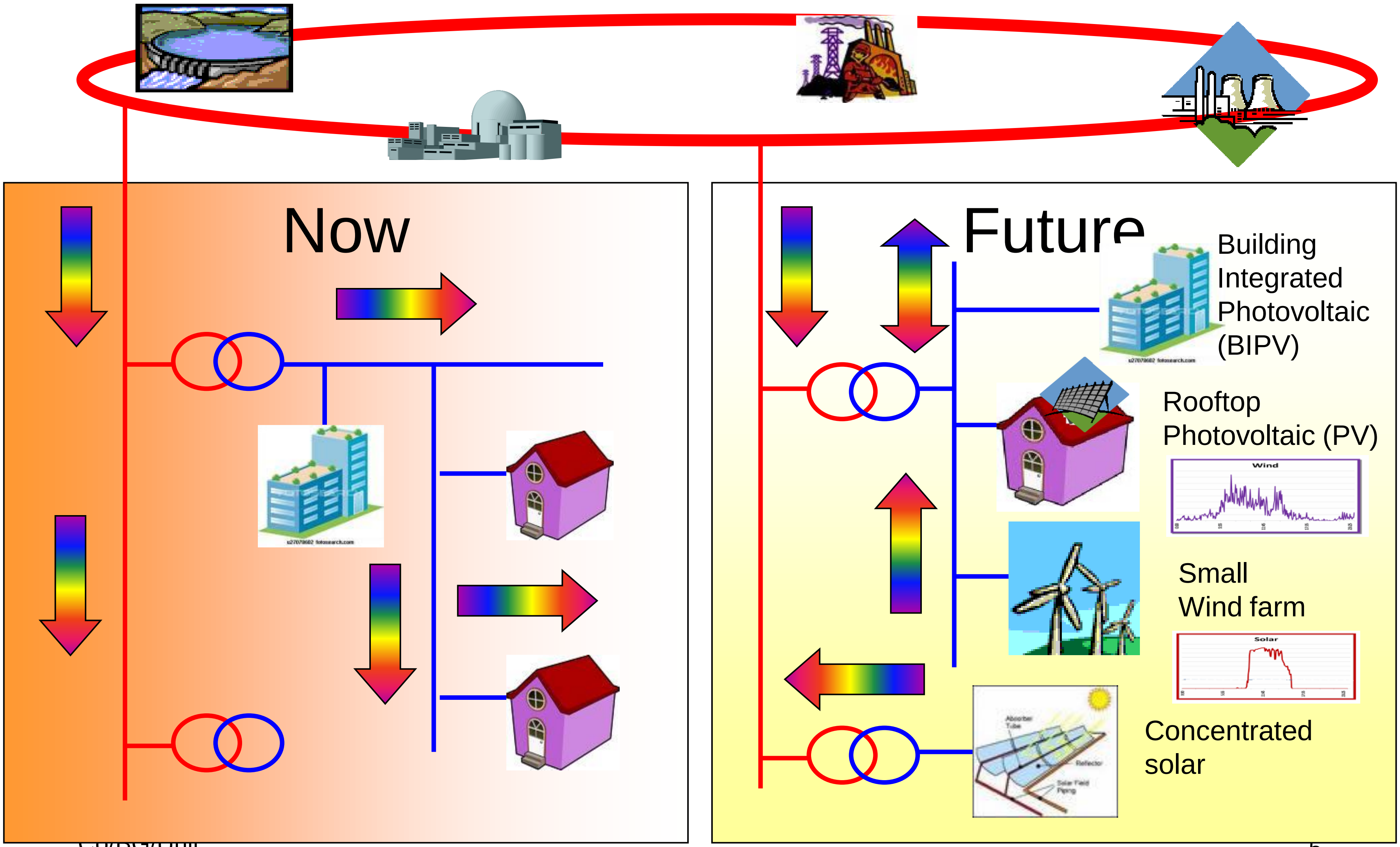
Power Systems

=

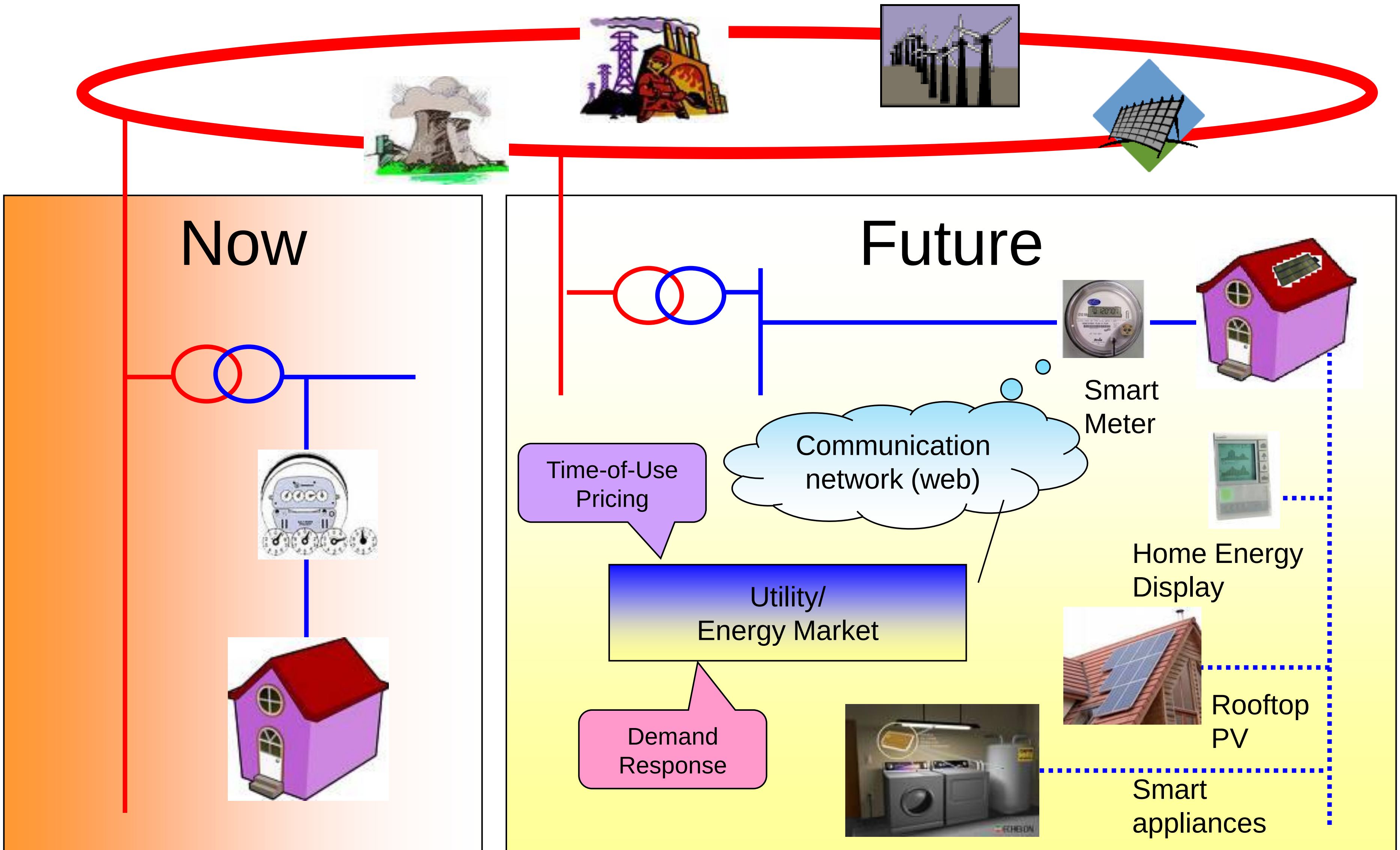


Smart Grid

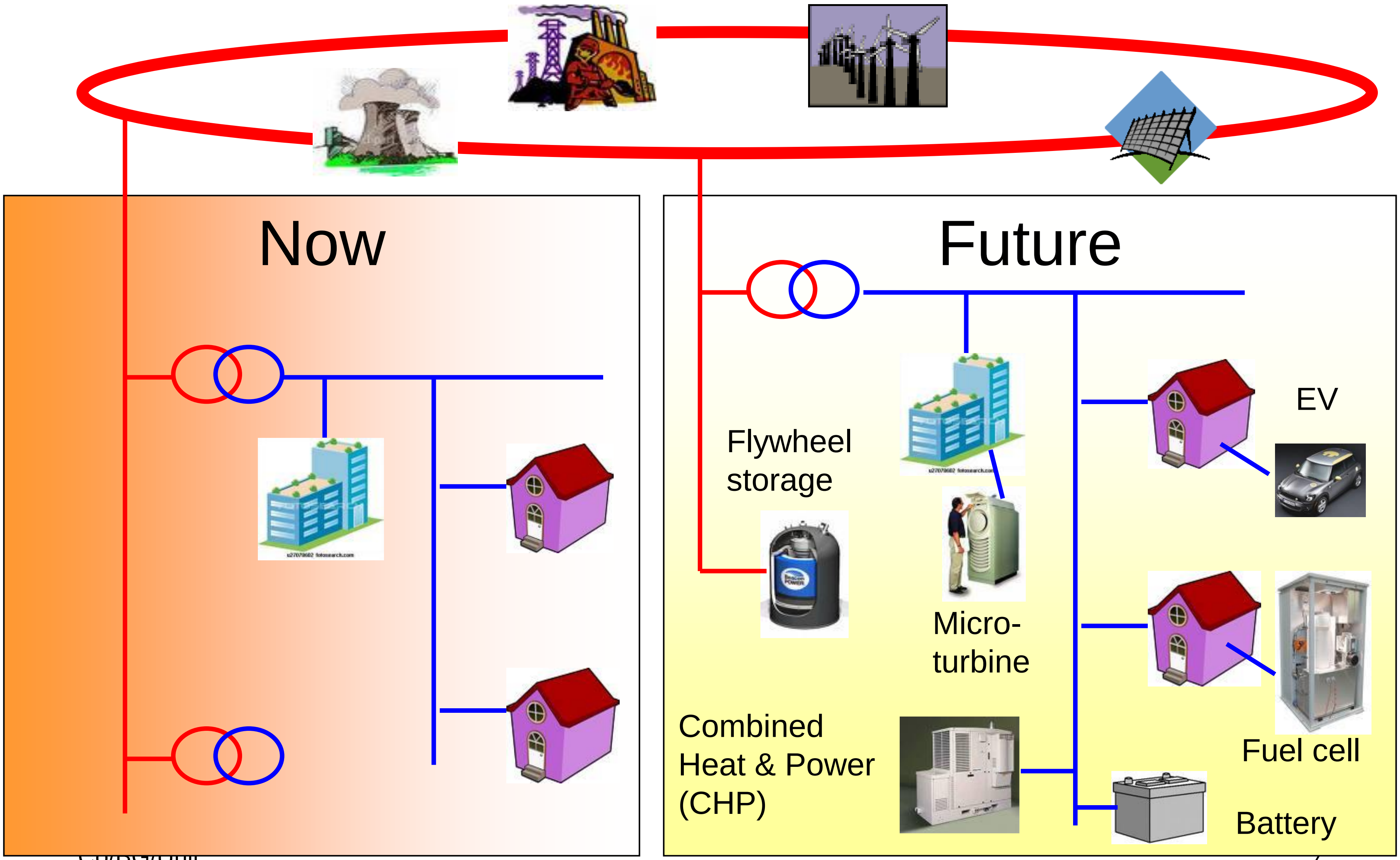
Smart Grid: to integrate Renewables



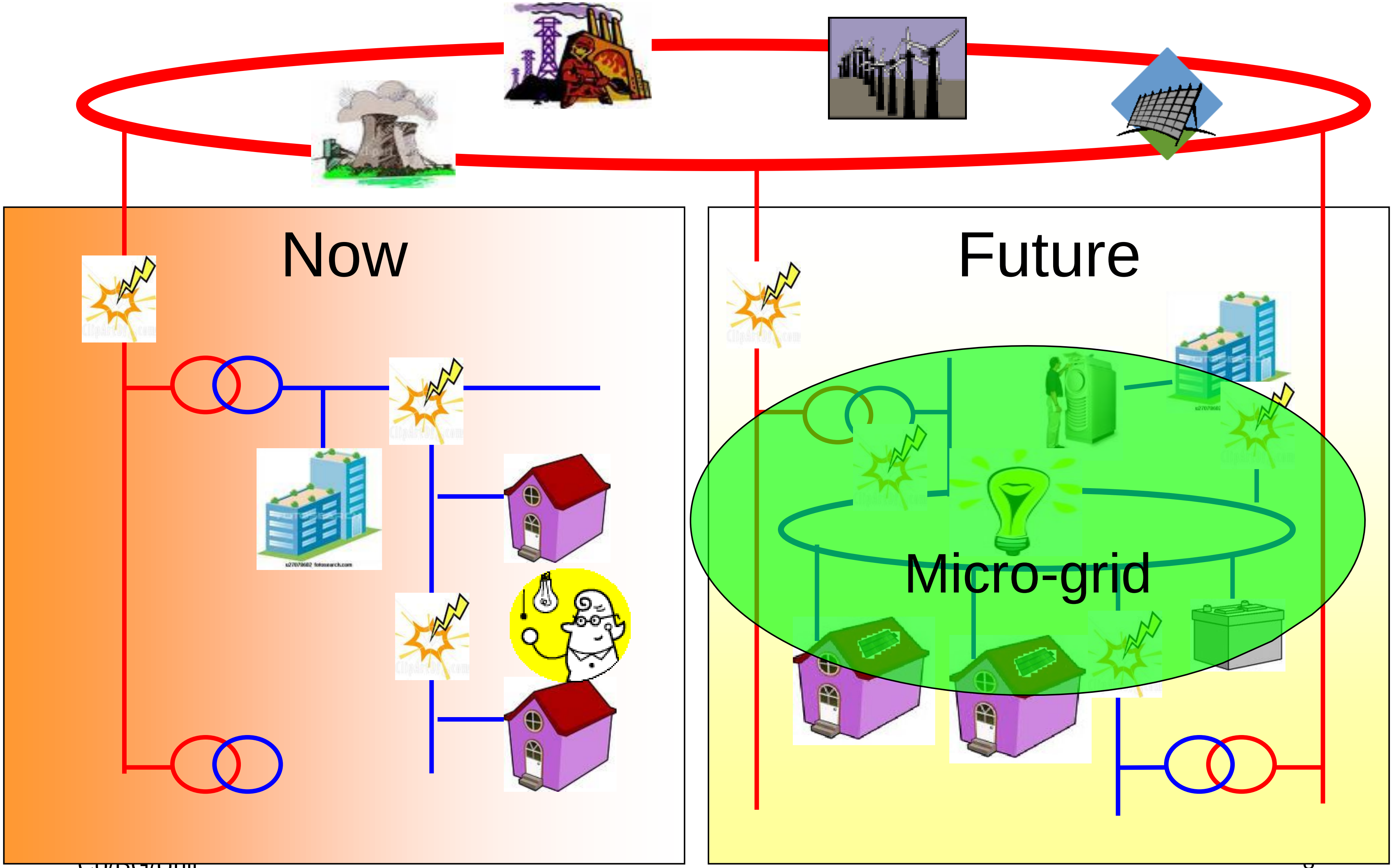
Smart Grid: to engage customers



Smart Grid: to accommodate DER



Smart Grid: to self-heal and resist attack



Potential roles of storage devices

Governor Response: generator autonomous dynamic response to frequency

Power Requirement: 1 – 5% of associated generation
Duration Requirements: seconds to a few minutes
Response time: mil-second response

Regulation: Sec by sec adjustment of power production to match load

Power Requirement: 1 -2 % of system peak overall
Duration Requirements: 15- 30 minutes
Response time: <10 sec response

Spinning Reserve: energy back-up against failure of resources

Power Requirement: matched to largest unit in control area
Duration Requirements: 15-30 minutes
Response time: less than 10 minutes

Renewable Levelising: storing renewable energy for use at peak load

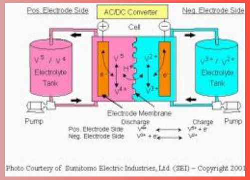
Power Requirement: as much as 50% of renewable resource production
Duration Requirements: 6 – 12 hours
Response time: sub-second response

Developmental stage of different types

R&D

Zinc bromine Flow battery

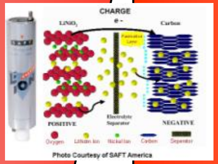
Vanadium redox flow battery



Ultra-capacitor

Metal air battery

Lithium ion battery

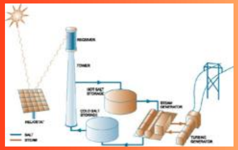


Superconductor Magnetic Energy Storage (SMES)

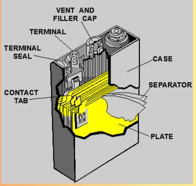
Demonstration

Flywheel

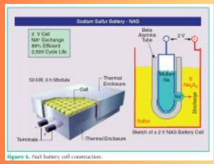
Molten Salt



NiCd battery

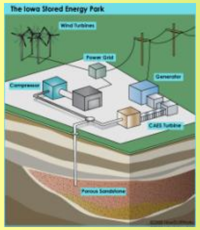


NaS battery

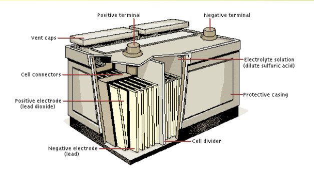


Commercial

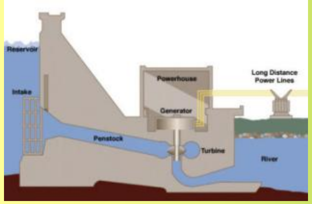
Compressed air (CAES)



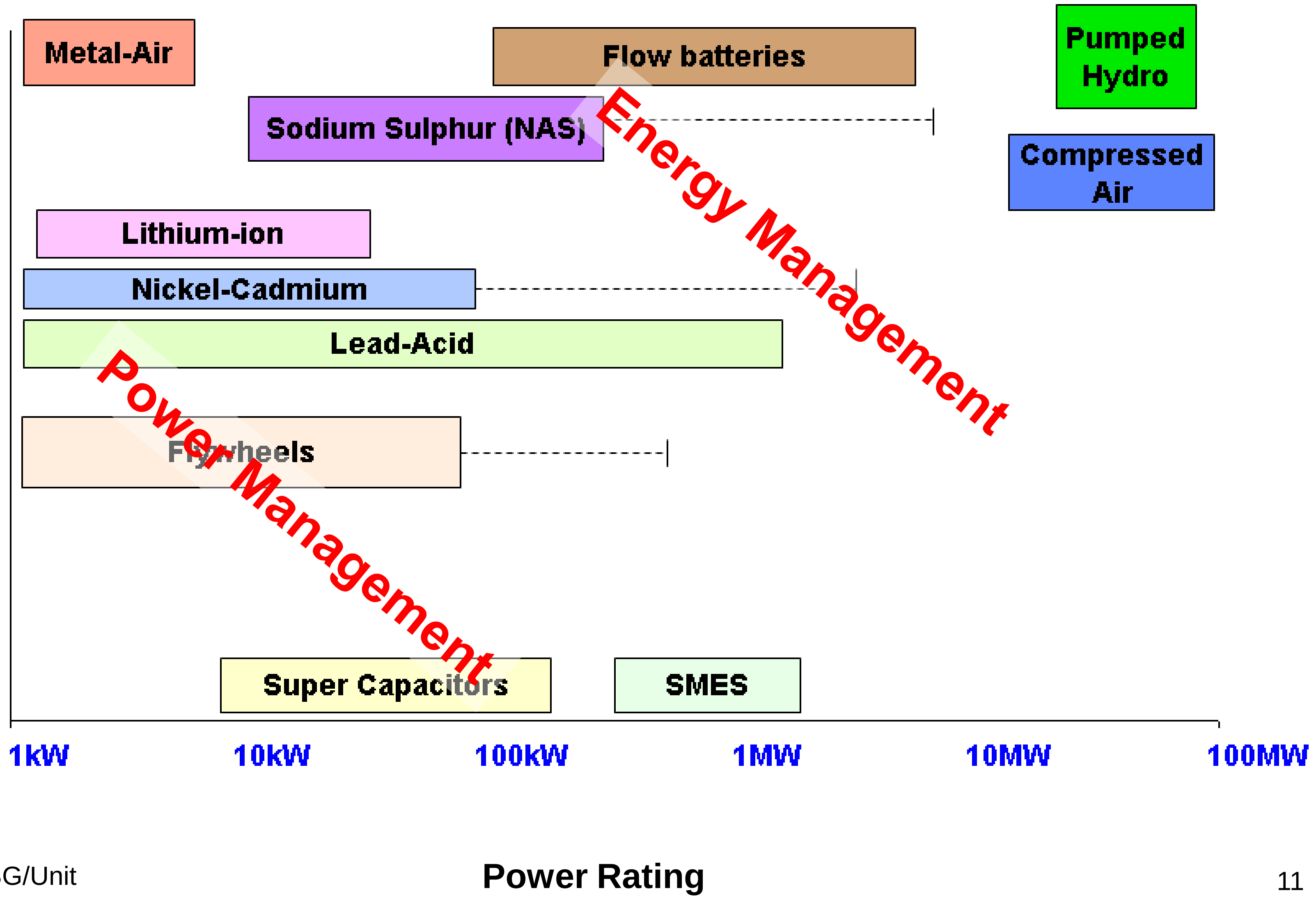
Lead acid battery



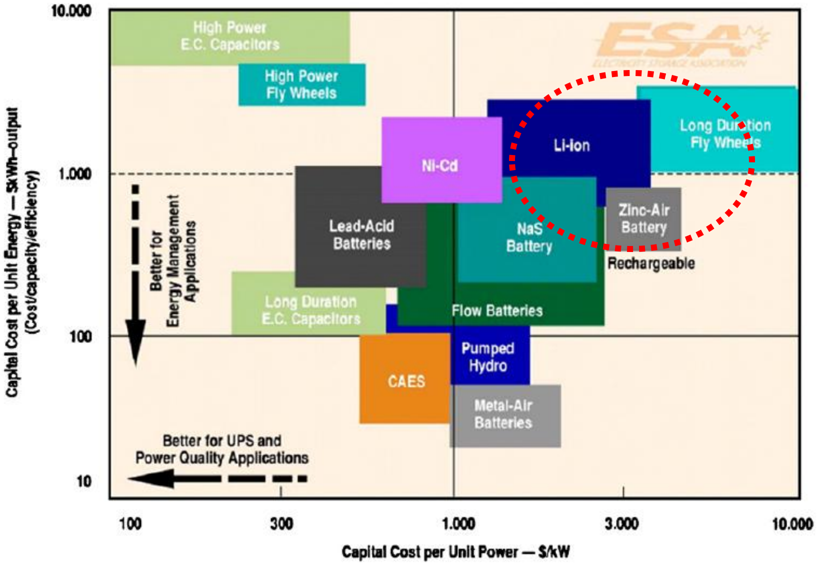
Pumped hydro

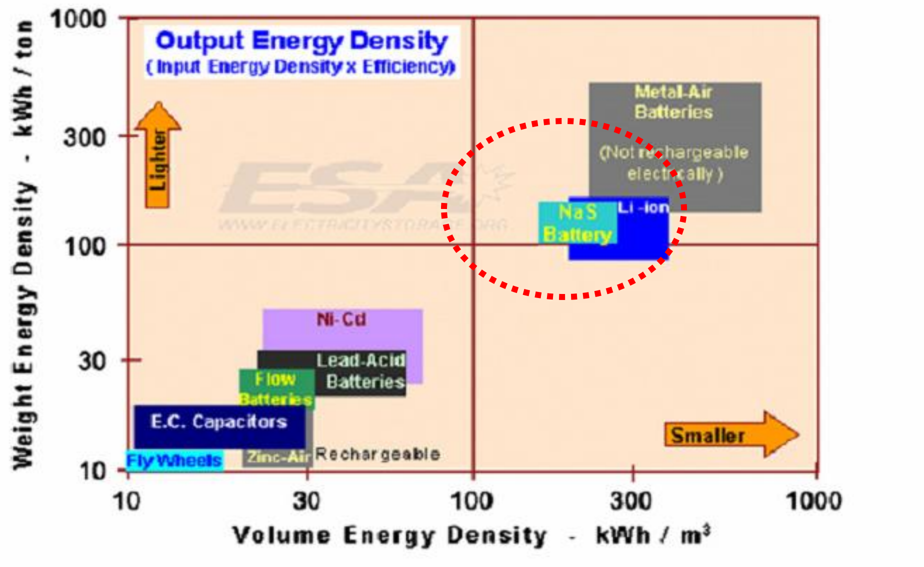


Technology Comparison



Different costs and features

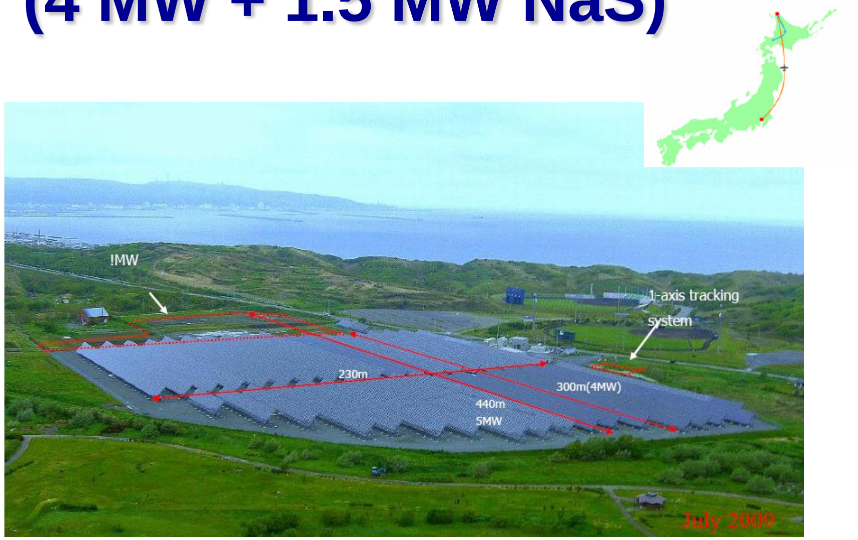


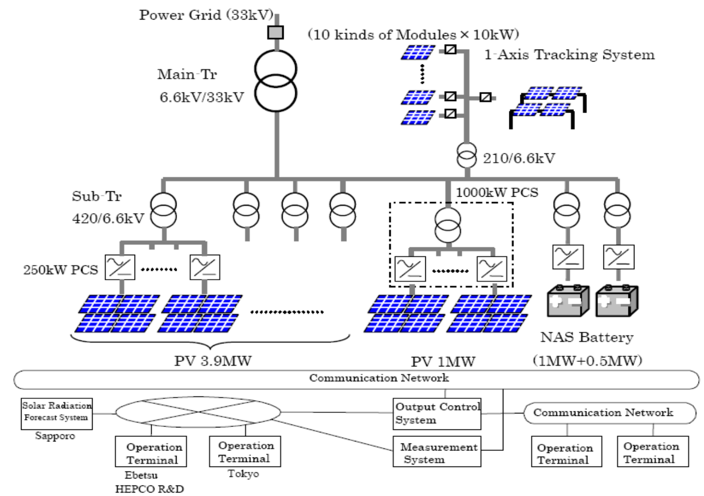


	Operational temp (ºC)	Lifetime (years)	Energy density (Wh/kg)	Cycle Life (DOD 80%)	Energy Efficiency
Pumped Hydro	ambient	40 - 60	Low	10,000+	70-85%
Li-ion	-20 to 45	5–10	75 to 200	5,000-8000	90-97%
NaS	300 to 350	10-15	150 to 240	2500-4500	89%
VRB	5 to 45	5-10	10 to 30	12,000+	85%

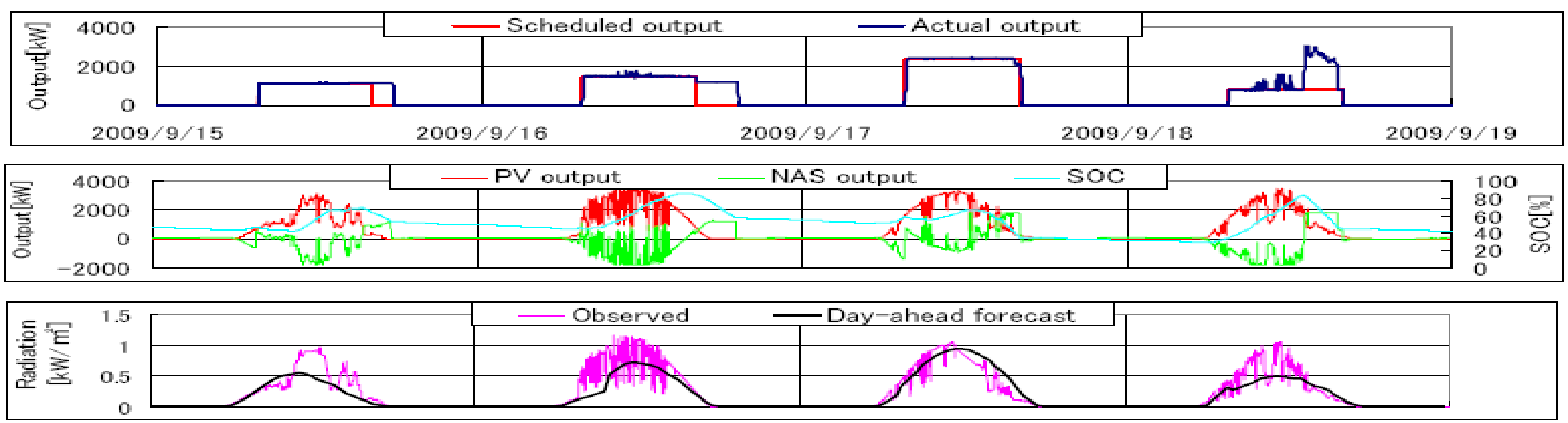
Case 1: Wakkanai PV farm & NaS system

(4 MW + 1.5 MW NaS)



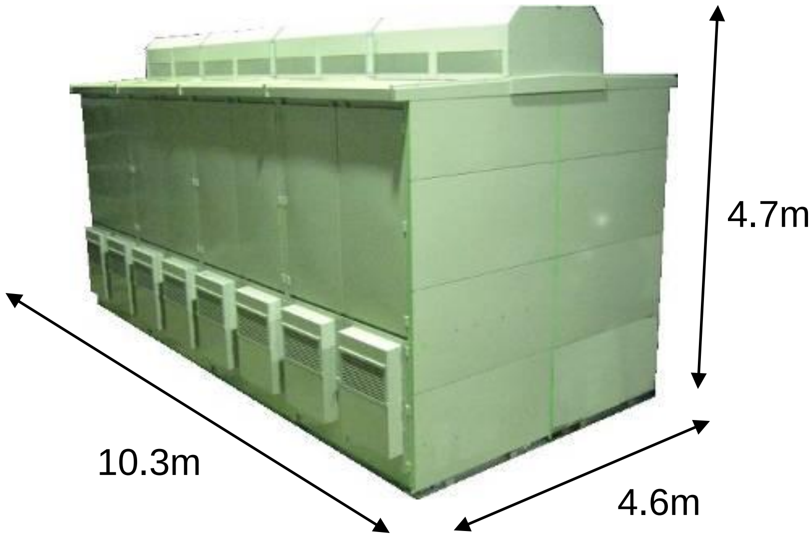


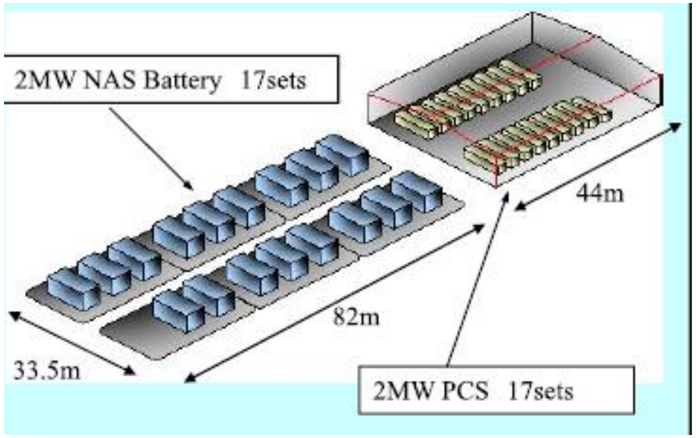
- Field test results of 4-day Scheduled operation (PV:4MW,NAS1.5:MW)



Case 2: Rokkasho wind farm & NAS system

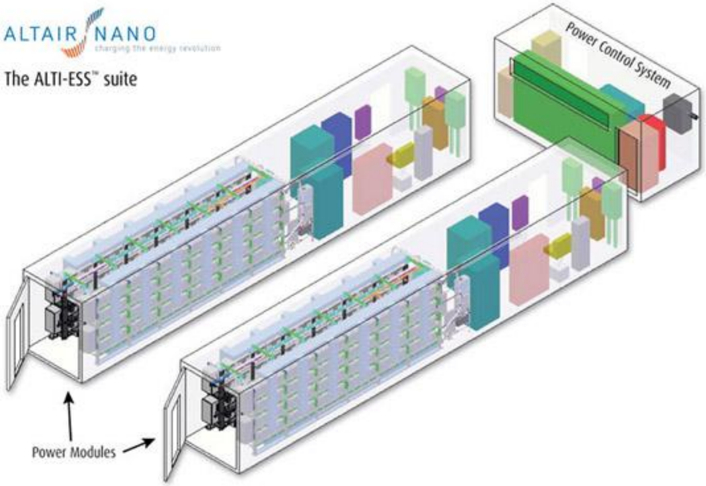
- Wind farm: 51MW
- NaS battery: 34MW, 245 MWh
- Operational April 2008
- Show NAS can provide:
  - Wind firming for weak grids and firm capacity
  - Provide regulation power and spinning reserve
  - Time shift production to meet peak demand





Case 3: AES lithium battery demo

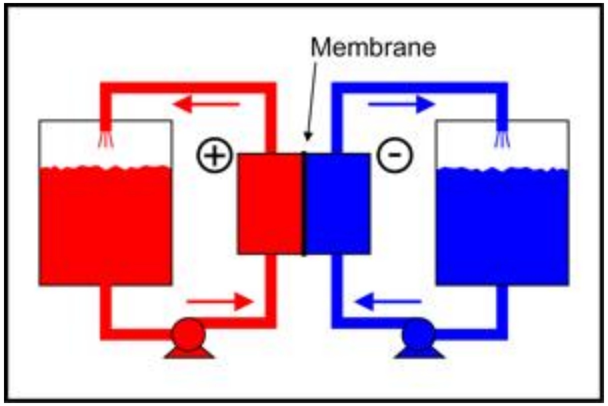
- Initial Validation and testing of two Altairnano 1MW lithium titanate batteries
- 250kWh energy, 15mins of storage
- Regulation response: each unit was able to dispatch between 1MW discharge to 1MW charge within 1 secs
- Regulation cycle effectiveness: no issues under testing conditions of 4sec intervals



Case 4: King Island wind farm & VRB

- **800kWh VRB storage rated at 200kW unit**
- **Provides stabilization and time-shifting services for a 2.5MW wind farm.**
- **Sumitomo VRB device**
- **Technical Challenges**
  - **Maintenance of pumps**
  - **Auxiliary system problematic for battery reliability**

Vanadium Redox Battery System with the tanks containing electrolyte in the foreground and a bank of cell stacks at the far end of the building.

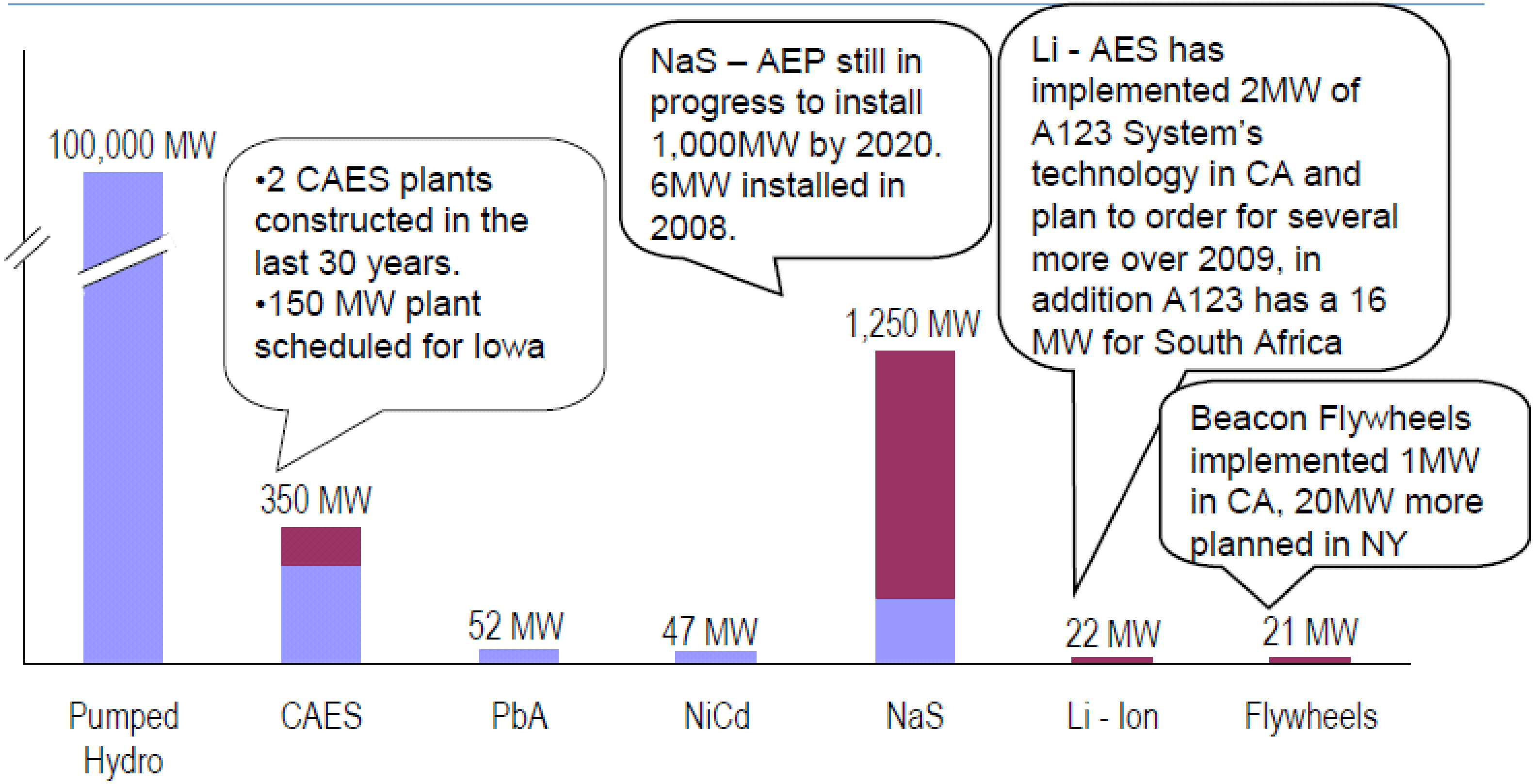


Case 5: New York flywheel regulation plant

- First frequency regulation plant in the world using flywheel
- Beacon Power facility
- 20MW facility with array of 100kW modules
- US$43M DOE loan guarantee
- Supply ~10% New York grid's required frequency regulation
- Expected completion 2010/2011

Artist rendering of 20 MW Flywheel Energy Storage Plant

Utility-scale energy storage projects



Source: New Energy Finance, May 2009

Challenges & needs

Challenges:

- High cost
- Reliability & Safety
- Performance
- Centralized vs distributed
- System complexity

Needs:

- Government incentives
- R&D on hardware and applications
- Large-scale studies
- Plug & play features
- Reduced costs

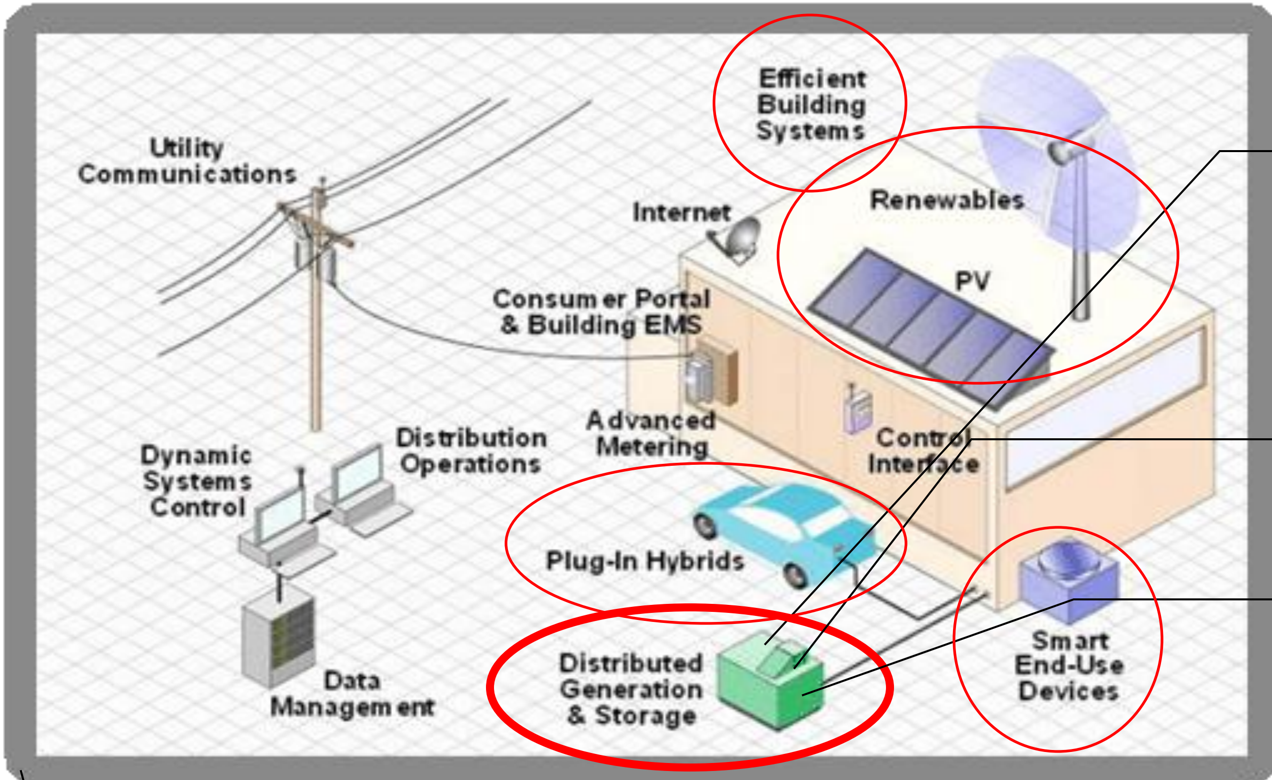
Potential disruptive game-changers:

- Wide spread utilization of Electric Vehicles and/or plug-ins with Vehicle-To-Grid (V2G) capabilities;
- Low cost energy storage medium, e.g. NaS, Li-ion, hydrogen etc.

Electrical Storage Outlook

- **Near-term:**
  - **Utility-scale projects, e.g. at the T&D level, will remain expensive**
  - **Electricity storage will mainly be used for “power” management applications (instead of “energy” except for pumped storage)**
- **Long-term:**
  - **Cost reduction: up to 40% depending on technology (10yrs)**
  - **Growth potential depends on cost reduction and policy**
  - **Lithium-based batteries and NaS greater growth potential**
  - **Storage devices and the aggregated control of these will be a major component of smart grids and decentralization**

Electricity Storage in a Smart Grid



Capturing local renewables …up to 100s of kW range

Charging EV/PHEV

Optimized End-uses in homes and buildings

Potential Impacts:

- Revenue reduction due to more distributed RE integration;
- Reliability issues due to charging, reverse flows and power quality;
- Energy aggregators (Virtual Power Plant or V2G)

Thank you ! Q&A

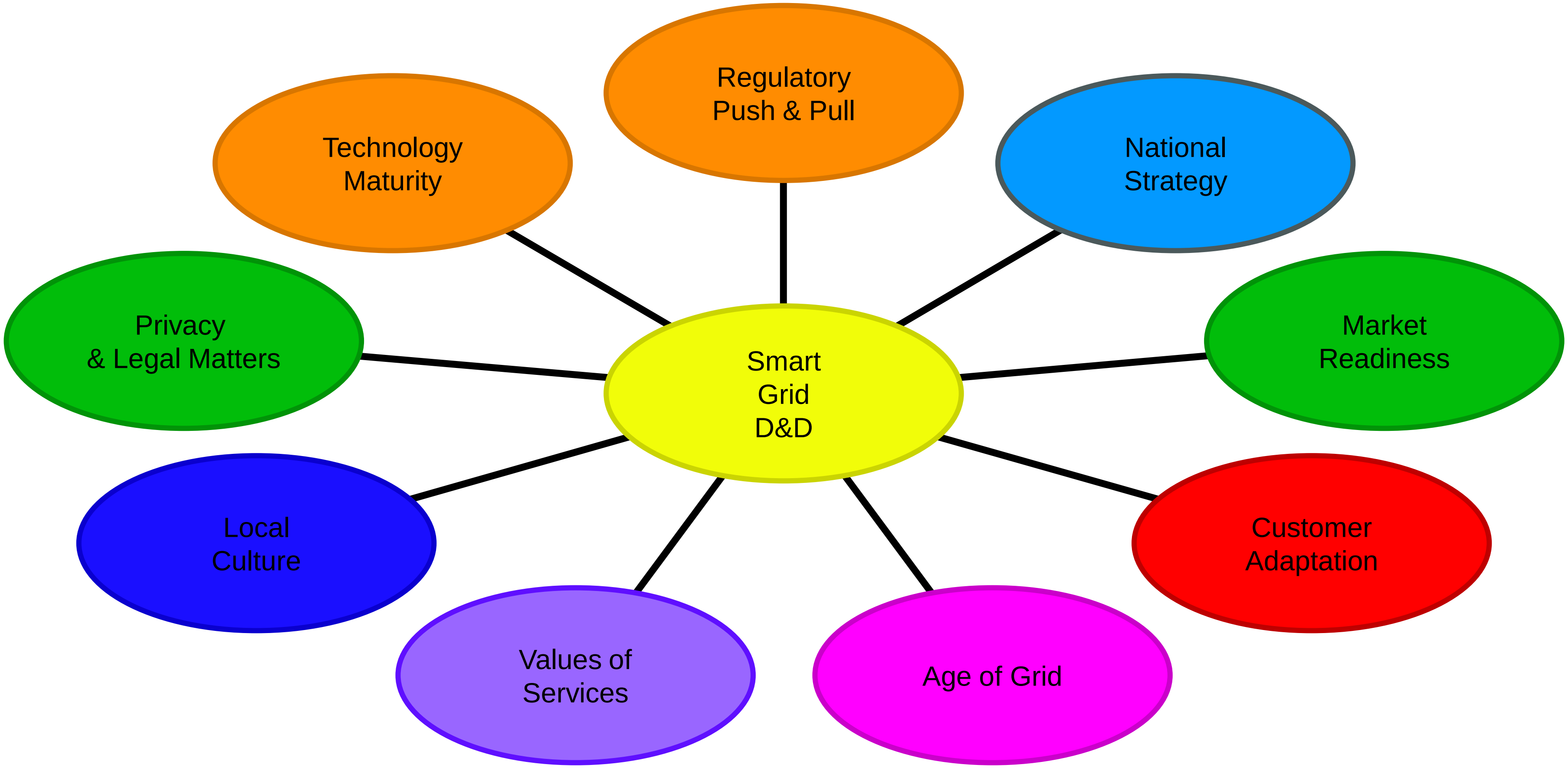
Key Drivers of Energy Storage

- Major funding supports in R&D and deployment trials due to cleantech dev. in US, China and Japan
- Intermittency of renewable resources (distributed and utility-scale)
- Rapid advancements in battery technologies
- Electrical vehicles and plug-in hybrids
- Smart grids
- Broadening scope of applications
- Growing public and political interests

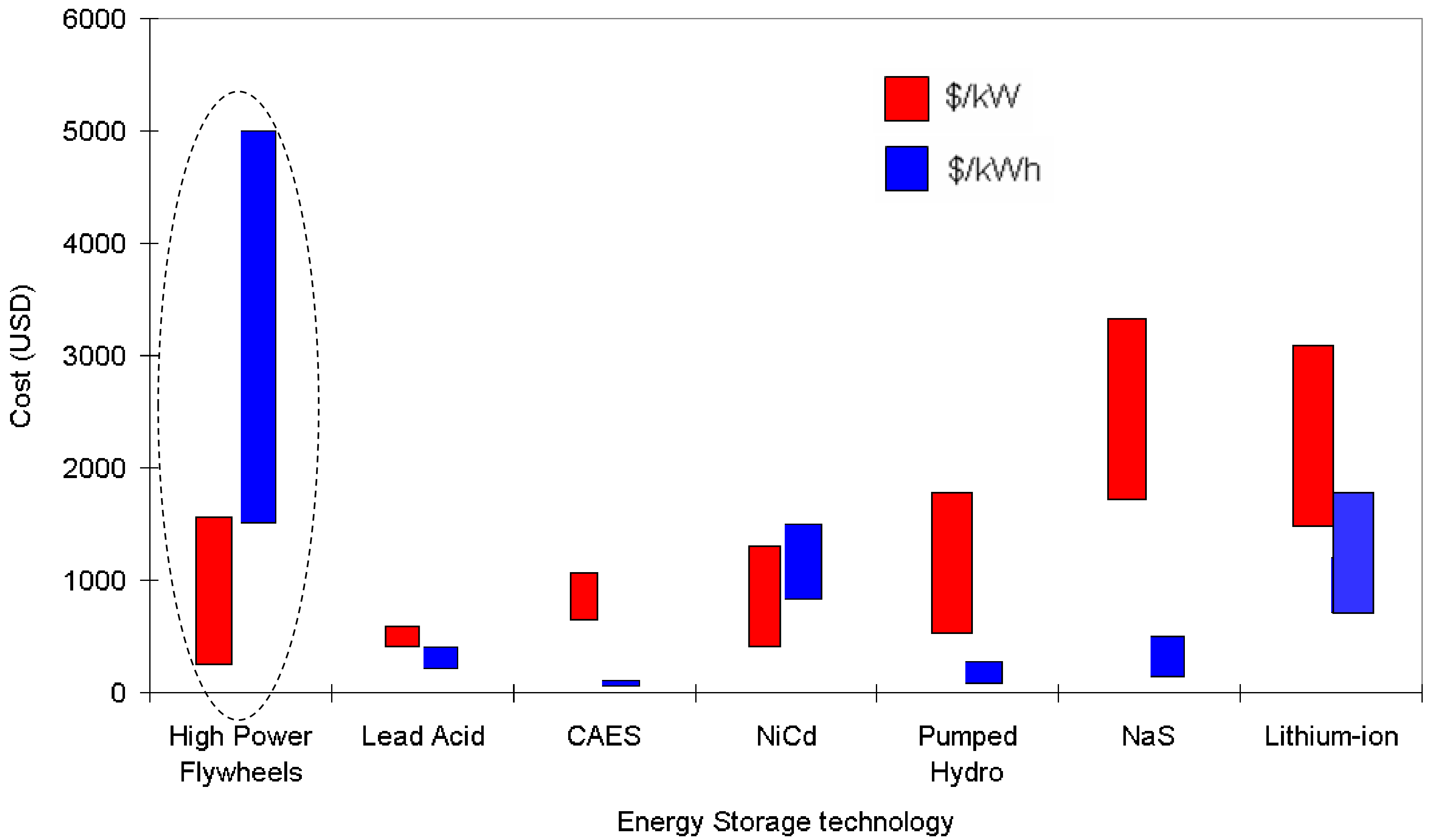
CLP's Experiences

- Large-scale: Pumped hydro station in Guangdong built with the Daya Bay nuclear facilities
- Medium/Small-scale:
  - Data center battery: valve regulated lead acid battery for UPS standby power applications
  - Backup/black start facilities in substations and power stations
  - PSBG has a workshop to test and recondition our battery (mainly NiCd batteries)
  - One and only one flywheel in HK -- SSP power quality centre

Key Issues of Smart Grid Development and Deployment



Cost Comparison



Source: data extrapolated from Electricity Storage Association (ESA)