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Can a Smarter Grid Slow Down Climate Change While Accelerating Energy Independence?

Symposium ID 4120, Organized by Dr. Hassan Farhangi, PI NSMG-Net

American Association for the Advancement of Science
Vancouver, BC, Canada, February 2012

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Agenda

Speaker #1:	Dr. John Macdonald – Day4 Energy (Founder and Chairman)
Title:	Future of energy systems and unsustainability of status quo
Speaker # 2:	Mr. Kip Morison – BC Hydro (Chief Technical Officer)
Title:	Utility perspectives on issues confronting the energy industry
Speaker # 3:	Dr. Hassan Farhangi – BC Institute of Technology (Director)
Title:	Smart Grid and its role in achieving energy independence
Speaker # 4:	Dr. Reza Iravani – University of Toronto (Professor)
Title:	Managing demand through a smarter distribution system
Speaker # 5:	Dr. Geza Joos – McGill University (Professor)
Title:	Expanding production capacity thru renewable sources of energy
Speaker # 6:	Dr. David G Michelson – University of British Columbia (Professor)
Title:	Role of ICT in transforming the existing grid into smart grid
Discussant:	Dr. Chris Marnay - Lawrence Berkley National Lab (Staff Scientist)

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Can a Smarter Grid Slow Down Climate Change While Accelerating Energy Independence?

Expanding production capacity through renewable sources of energy

G. Joos

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Outline

- In the form of an introduction
  - Opportunities in alternative energy – recent announcements
  - Fossil fuel impact – a need for alternative energy sources
  - Wind energy – its tremendous growth and challenges
- The electric power grid – a need for renewal
  - Present and proposed grid configurations
  - Challenges and opportunities
- Renewable energy – types and issues
  - Types and required interface technologies
  - Political and regulatory framework
  - Integration requirements and technologies
  - Balancing and storage
  - Creating a new market and new opportunities
- Final thoughts

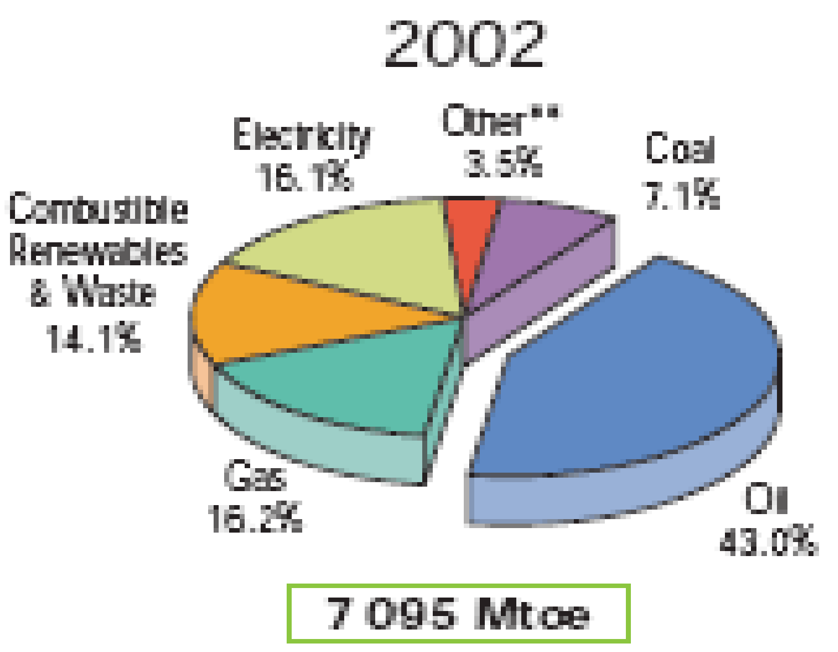
Typical recent announcements – news clips

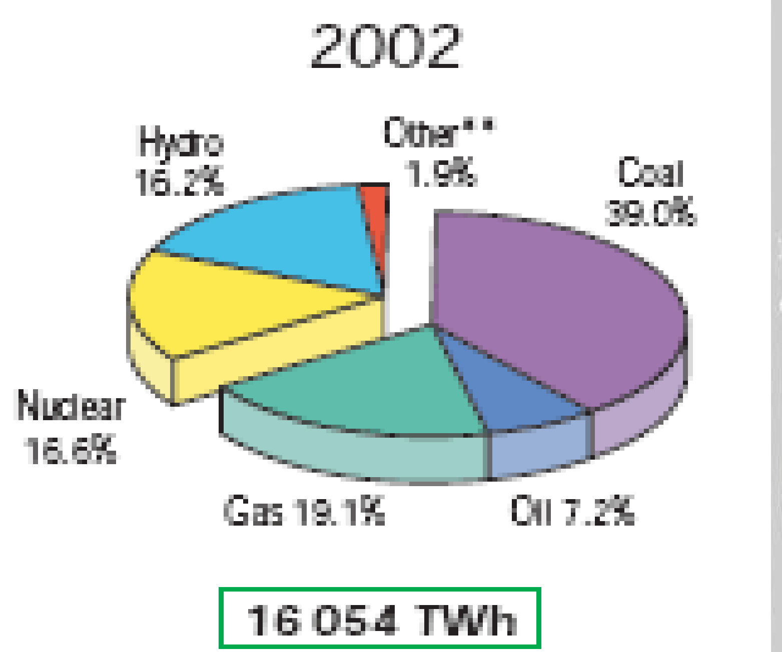
- India seeks $4 billion for alternative energy
- Wave, tidal energy draws renewed interest
- California solar thermal company raises $60.6 million
- Philippine government saves billions by utilizing geothermal power
- First U.K. home warmed up with hydrogen energy
- Italian wind farm company plans to erect solar panels alongside WT
- Clean technology faces investors' reluctance
- Studies explore wind power potential of Great Lakes
- New Jersey aims to triple wind power use by 2020 - New Jersey to announce winning bid for offshore wind farms

RE: ASEE News Clips

World energy consumption – the numbers

Total world energy and electricity production/consumption: is this situation sustainable?





Energy: fossil fuels = 66 %

Electricity: fossil fuels = 66 %

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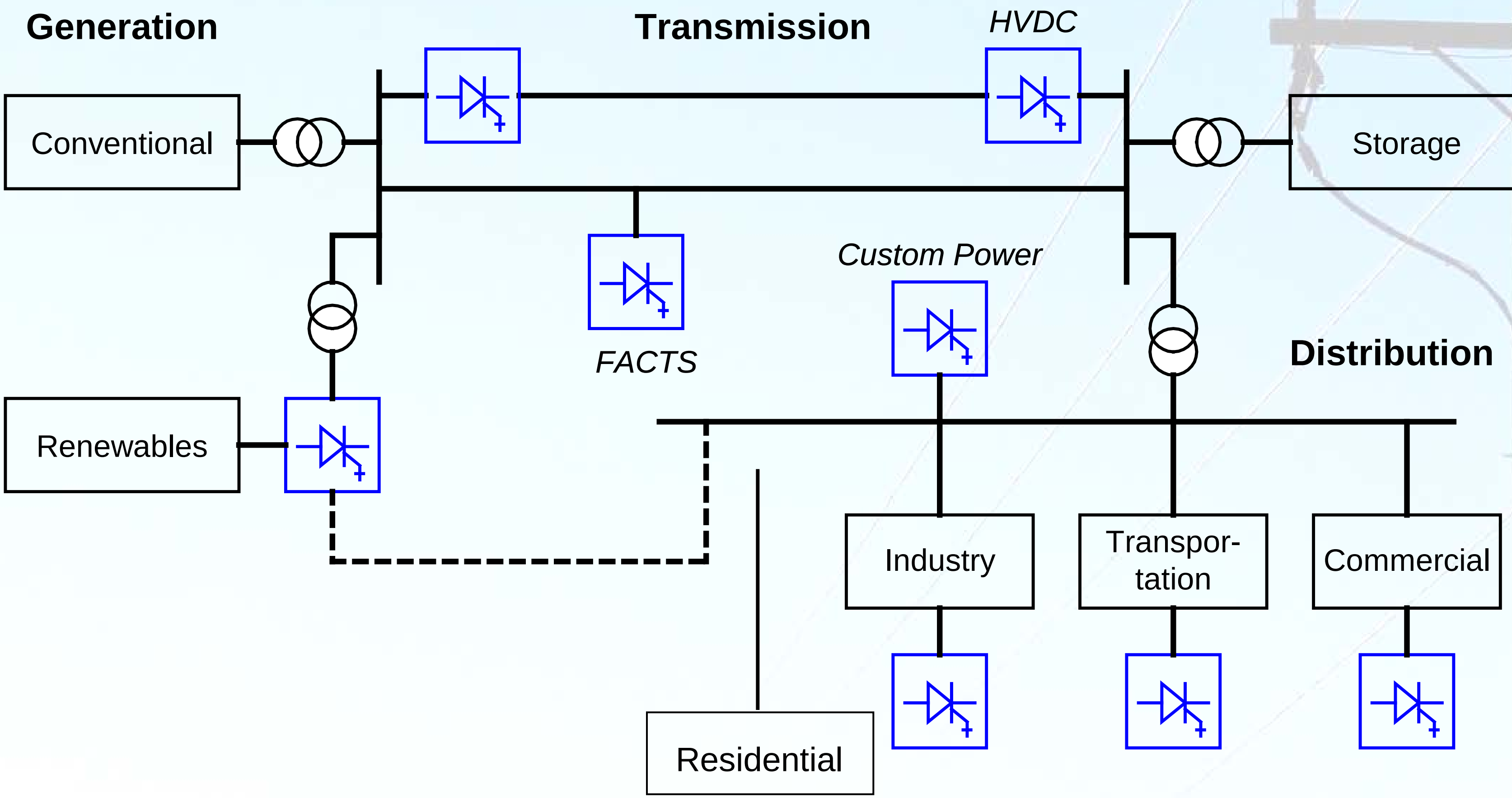
Fossil fuels – why break the dependence?

- Impact of fossil fuels – carbon dioxide emissions
  - Greenhouse gas production – responsible for climate change
  - Intergovernmental Panel on Climate Change (IPCC) – a reality
  - Stabilization/reduction – defining maximum absorbable emissions
- Fossil fuel reserves
  - Coal – long term (250 years)
  - Oil – medium term (20-50 years)
  - Gas – short term (20 years)
- Approaches to stabilization/reduction – expensive and experimental
  - Carbon sequestration
  - Gasification of coal
- Substitute energy sources – alternative and renewable

Alternative energy – a partial solution

- Adding alternative energy to the energy portfolio
  - Wind energy – large (wind farms), small (distributed generation)
  - Solar energy – residential, commercial, utility
  - Other – biomass, biofuels, landfill gases, geothermal
  - Hydrogen – fuel cells – hydrogen economy (2030?)
- Advantages
  - Clean and free fuel – or cleaner and cheaper
  - Potential reduction in cost of electricity generation – feasible
- Challenges – integrating renewable and alternative energy sources
  - Integrating new resources into the conventional electric grid
  - Developing a smart power delivery system
  - Maintaining SQRT – Security, Quality, Reliability, Availability

Electric power grids – from generation to load



Wind energy – issues and challenges

- Free energy source
- Capacity factors (installed/average): variable, land (30-35 % at best), offshore (40-45 % expected)
- Intermittency, variability, and operation under high wind conditions: need to provide power balancing
- Balancing options: coordination with other generation (hydro), storage (batteries), or demand management
- Life expectancy: not yet defined – 15-20 years
- Decommissioning: cost and disposal
- Environmental: local visual impact, noise, danger for birds, interferences
- Cost of electricity – economies of scale (to 5 MW/unit)

RE: Pembina Institute (adapted)

Integrating renewable energy sources

- Bulk transmission level (100 MW or more)
  - Mostly wind farms, some solar farms
  - Need to behave ideally as conventional power plant (hydroelectric, thermal, nuclear)
  - Energy management - balancing and forecasting needed
- Distribution level (5 kW to 10 MW, typically)
  - Wind turbines and photovoltaic systems – individual or aggregated (small farms)
  - Requires an adaptation of conventional passive (radial) distribution systems – smart grids
- Customer on site generation (possible replacement for diesel emergency generators)
  - Distribution system level technologies
  - Allows operation of the site as an autonomous grid (microgrid)

Distributed generation – drivers in Canada

- Promoting the use of local energy sources, an economic empowerment and a job creation opportunity – energy sources: wind, solar, hydro, others
- Distribution system expansion deferral and the resulting lower visual impact of distribution lines
- Lower grid integration costs – local generation reduces the size of the connection to the grid
- Reduced energy transit losses on the transmission grid –load fed from local distributed generation

Ref: Presentation by Hydro-Quebec Distribution, 2011

Distributed generation – typical installations

- Connected to the MV grid
- Typical power plant types/sizes
  - Hydraulic 243 MW
  - Biomass 31 MW
  - Biogas 40.5 MW
  - Wind 2.25 MW
- Total installed power (2011): 61 plants, 350 MW
- Approved plants (2011-2015)
  - Biomass, 4 plants, 24.6 MW
  - Small Hydro, 8 plants, 53.6 MW
  - Wind farms, 5 plants, 125 MW

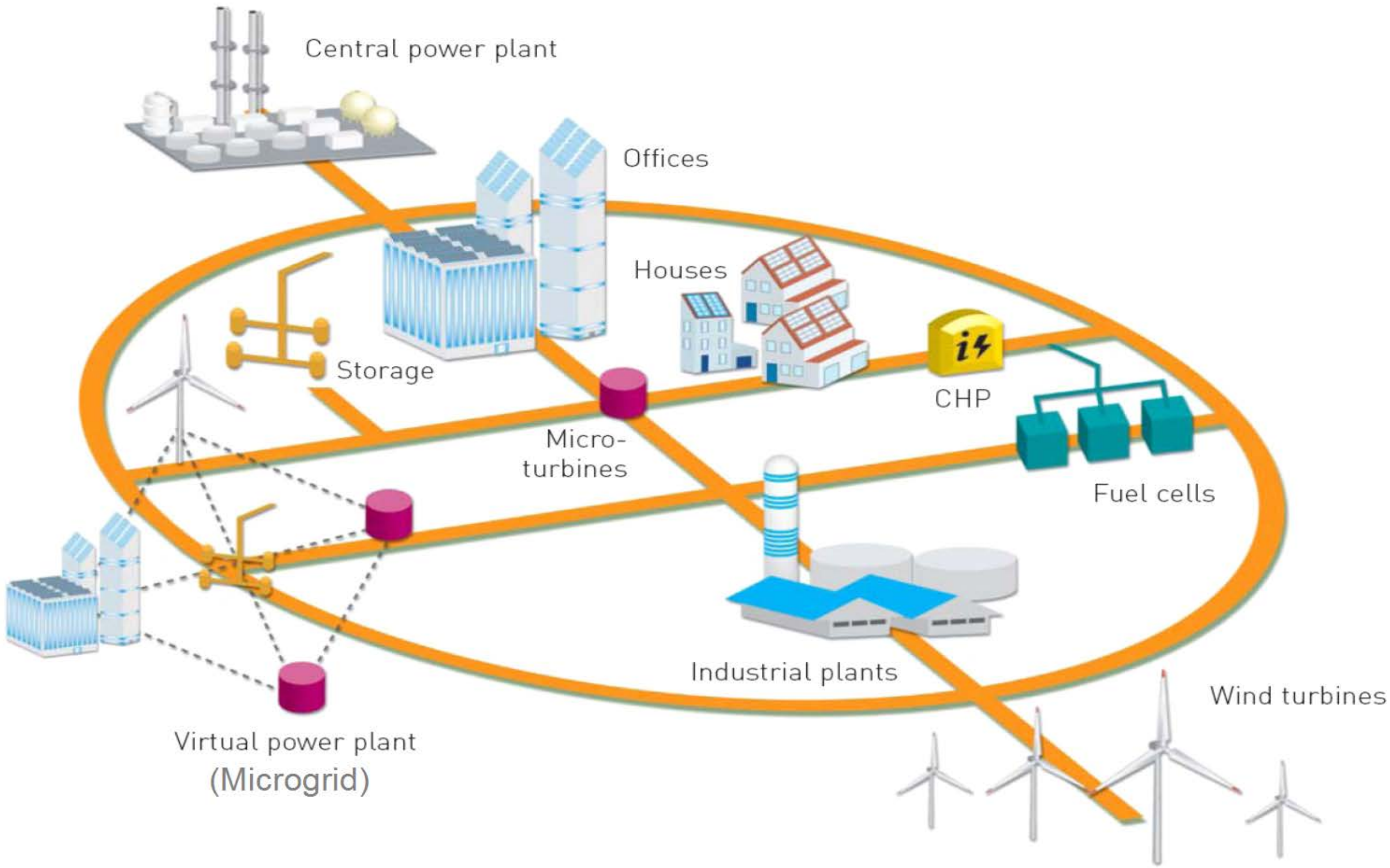
Ref: Presentation by Hydro-Quebec Distribution, 2011

DG interconnection new issues/constraints

- Increased monitoring – real-time data acquisition
- Protection and anti-islanding functions
- Integrating DG production forecasting – energy dispatch/balancing
- Participation in ancillary services – reactive power, voltage support
- Managing a large penetration of distributed generation – need for smart grid related controls and tools
- Future of DG deployment depends on:
  - The cost of power produced, impact of feed in tariffs
  - Cost of integration, including control and protection

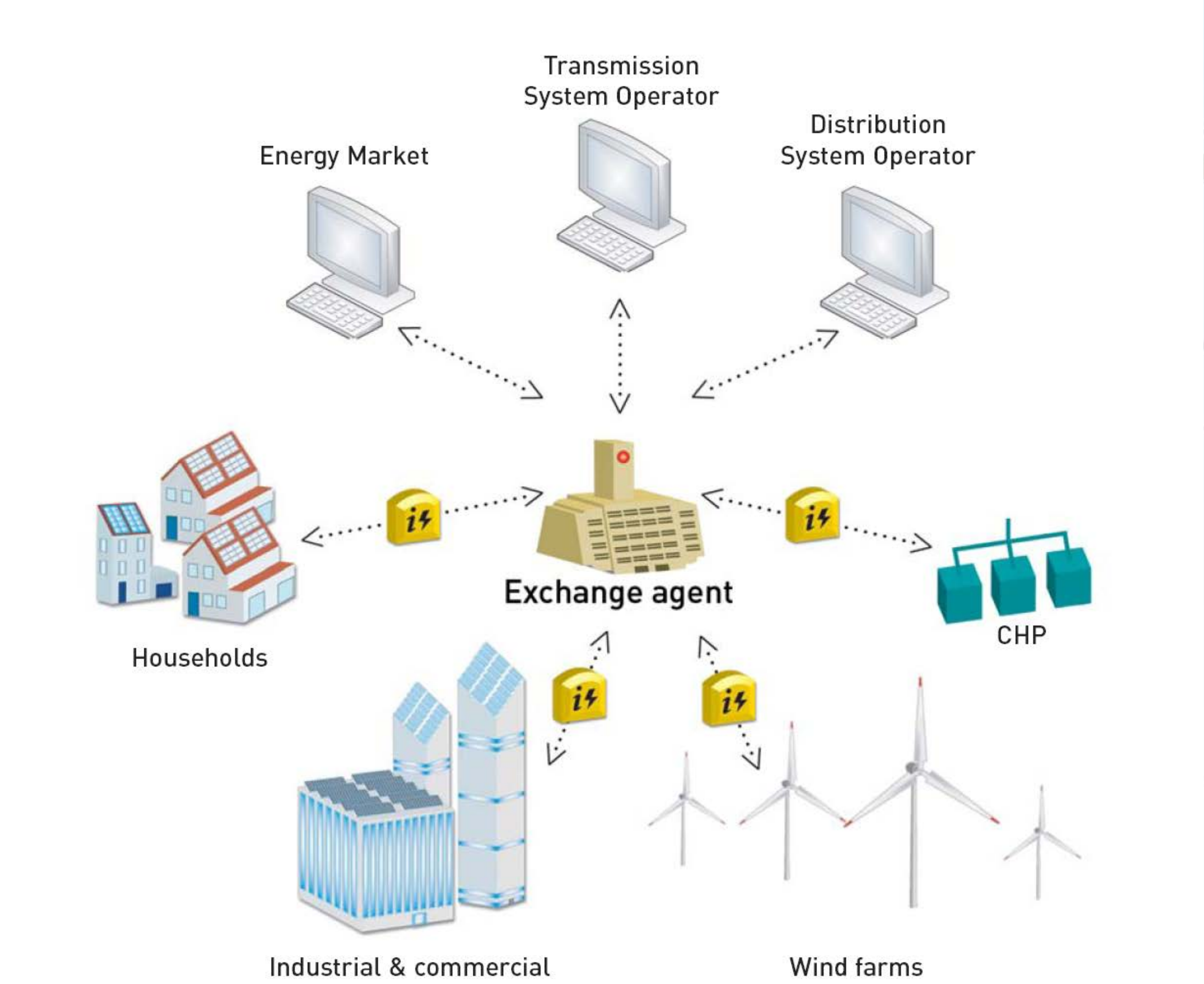
Ref: Presentation by Hydro-Quebec Distribution, 2011

Advanced electricity grids – local generation

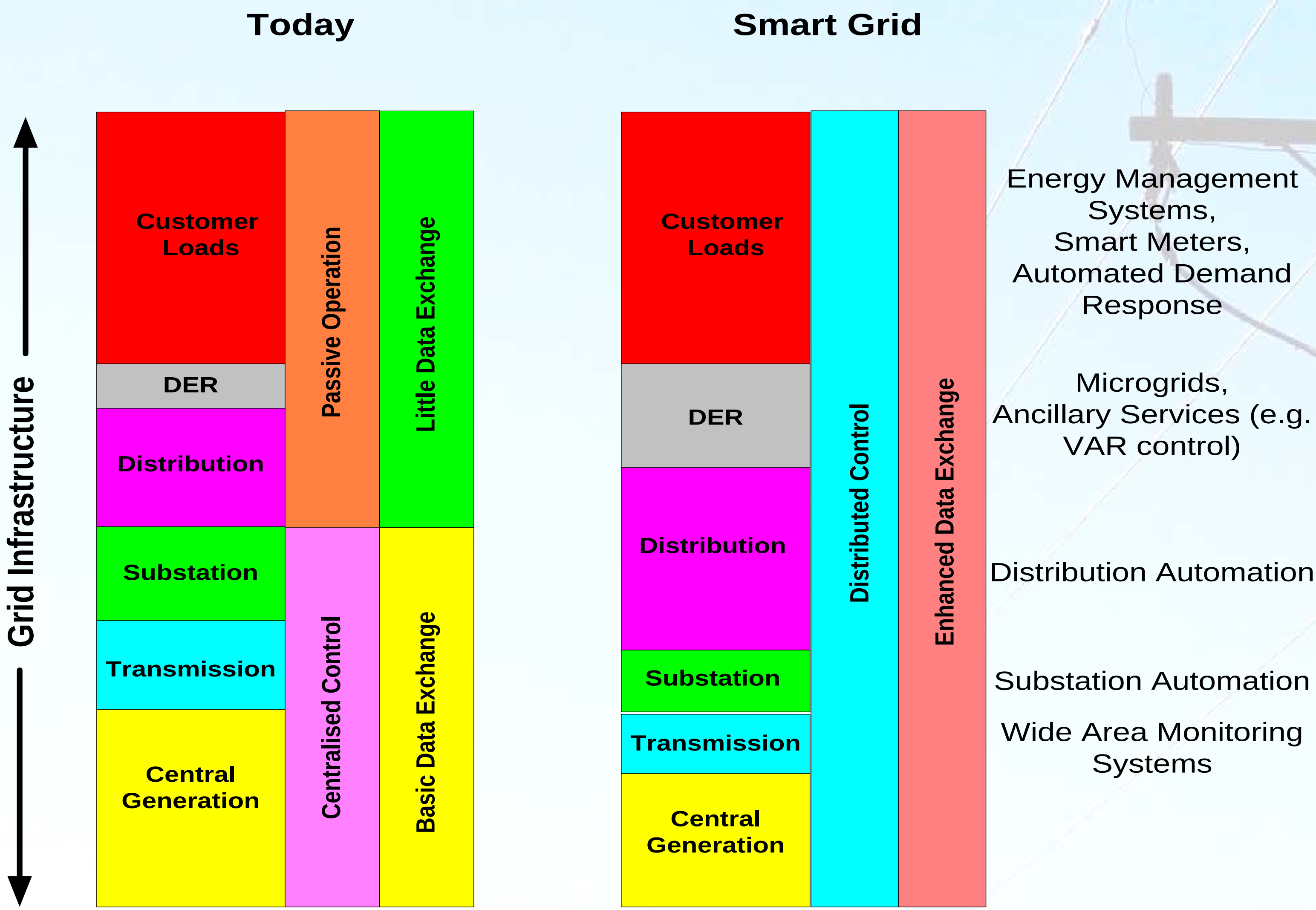


Future: *Operation of system will be shared between* ***central and distributed generators****. Control of distributed generators could be aggregated to form microgrids or 'virtual' power plants to facilitate their integration both in the physical system and in the market.*

Advanced electricity grids – enabling markets



Electricity distribution – evolution



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Enabling technologies for smart grids

- Power electronic switching converters
  - Required for renewable energy sources – wind, solar, other
  - Modifies the operation of conventional power grids
- Digital control
  - Computer based
  - Integrated control, protection and monitoring functions
- Information technologies
  - Management of large data bases
  - Information visualization – system awareness
  - Use of real time information for real time control
- Communication technologies
  - Fiber optics and wireless communications
  - Integration of communication and information technologies

Control possibilities for smart electric grids

- Integrating distributed generation and storage
  - Control of distributed generation
  - Plug-in hybrid electric vehicles
- Integrating electrical and communications systems
  - Enabling demand side management and demand response
  - Intelligent metering
  - Intelligent electrical devices
- Intelligent digital control of the power system
  - Distribution automation
  - Enabling a self healing power delivery system
- Implementing a deregulated electricity market
  - Enabling consumer decision making

Benefits of storage and demand response

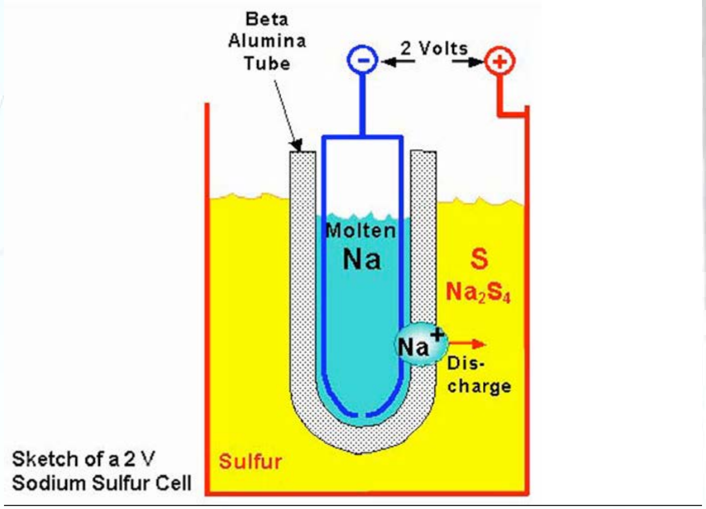
- Accommodating intermittent generation – operation at peak power and efficiency by means of storage
- Ability to dispatch/curtail energy during times of peak demand – peak load management and energy reduction
- Ability to manage peak demand locally and reduce transmission line demand - managing line congestion
- Ability to provide voltage support and voltage regulation (voltage sag compensation, flicker)
- Ability to provide other ancillary services – frequency regulation, black start, reactive power
- Possibility of islanded operation
- Ability to perform arbitrage on electricity prices

Managing variability – use of storage

- The new electricity generation context
  - Increased penetration of renewable energy resources, mainly wind and solar, and biomass
- The issues
  - Managing the intermittency of wind and solar energy, to incorporate them into to the base load generation
  - Managing large load fluctuations – supplying peak consumption
- The solution
  - Storing energy – in the form of electricity or heat
  - Managing consumption – demand response
- The constraints
  - Technologies – equipment availability and life cycle
  - Capital and operating costs (losses, maintenance and others)

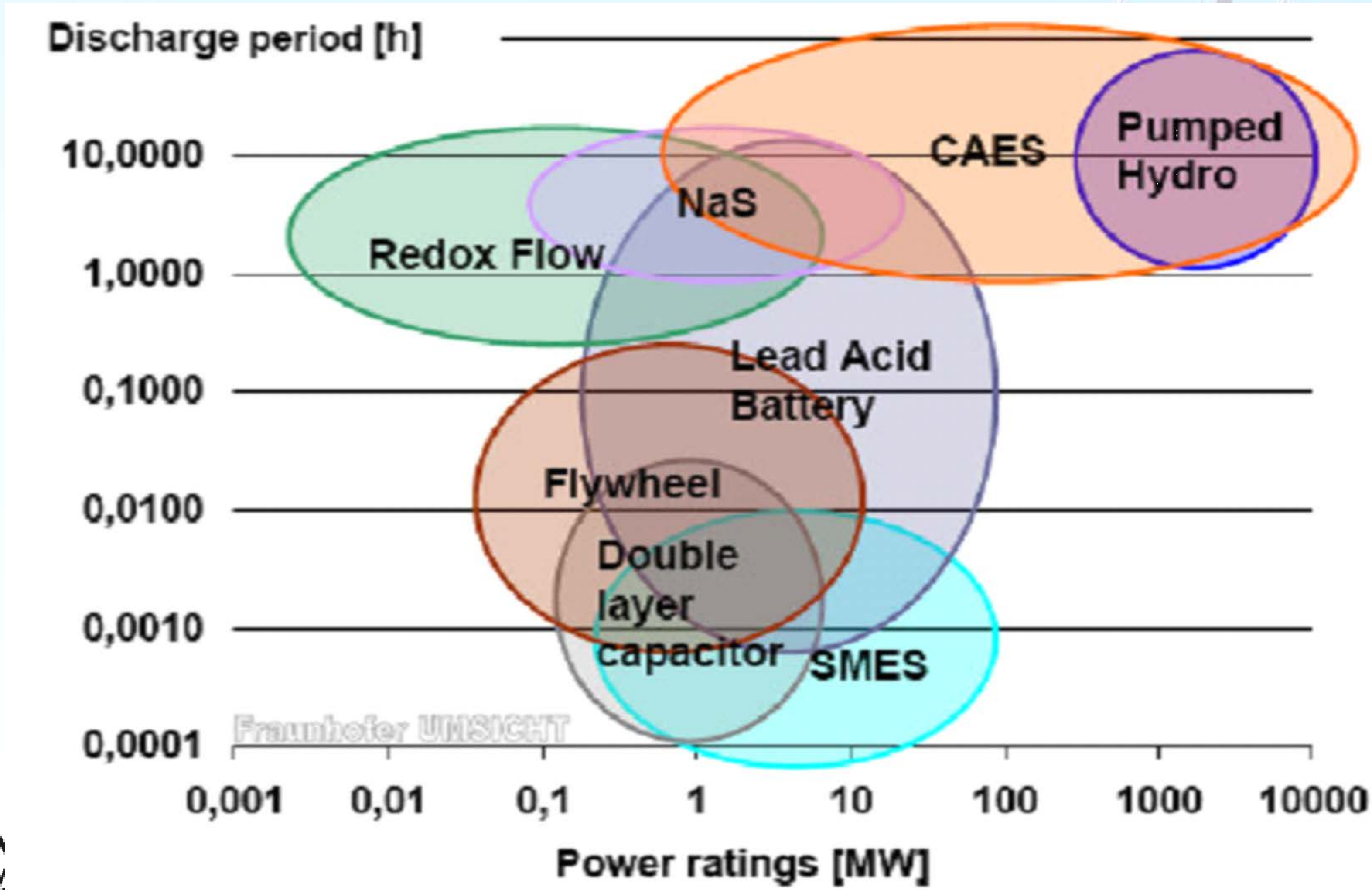
Storage technologies

- Electrical storage
  - Electrochemical batteries – Lead Acid, Lithium Ion, etc
  - Flow batteries – Vanadium Redox, Zinc Bromide, etc
  - Capacitors and supercapacitors
- Magnetic storage
  - Superconducting magnetic energy storage (SMES)
- Mechanical storage
  - Flywheels
  - Compressed air
  - Pumped hydro storage
- Other
  - Plug-in hybrid electric vehicles



Sodium sulfur cell - RE: ESA

Storage technologies – power and energy



Storage – making a good business case

- Deployment limitations – batteries and storage
  - Need to reduce costs – expensive technologies
  - Life cycle and asset management – life cycle costs
  - Life cycle for severe environments – limits to be determined
- Impediments to building a business case
  - Storing vs direct use of electric energy
  - Losses – complete cycle from storage to retrieval
  - Amortizing capital and operating costs – capitalizing losses
  - Current electricity costs – competing with low production costs in large scale generating plants
- Possible business opportunities
  - Remote location and new developments (no electrical infrastructure)
  - New installations requiring high power quality and reliability

Political and regulatory framework

- Renewable energy – impediments to growth
  - Cost of electricity generation – need subsidies (feed-in tariff)
- Renewable energy – new issues
  - Integration – balancing intermittency
  - Interconnection – availability of transmission corridors
- Political framework – renewable energy = clean energy
  - Integrating renewable energy – a political decision
  - Alternative to fossil fuels
- Regulatory framework
  - Utility practices – need to change operating practice
  - Impact on system reliability
  - Impact on the energy supply security

Other opportunities – revenues and jobs

- Renewable energy production – job opportunities
  - Opportunities in manufacturing for local and export marjets
  - Opportunities in construction and operation/maintenance
- Green energy sales – revenue streams
  - Reduction of energy imports in a jurisdiction
  - Opportunities to export and to arbitrage electricity markets

Final thoughts

- Fossil fuels replacement – an opportunity for renewable energy
  - Reduction in greenhouse gases – reduction in rate of change
  - Reduced reliance on fossil fuels (a USA position)
- Renewable technology developments
  - Wind farms – photovoltaic farms
  - Others potential candidates: marine, geothermal, fuel cells (?)
- Drawbacks, impediments and solutions
  - Cost of renewable technologies: need for incentives and subsidies, raising new funds by means of a carbon market or tax
  - Intermittency of renewable energy sources: energy storage
- Economic opportunity – developing new sectors
  - Creating new industries – technology innovations and ICTs
  - Interest investors – new market for renewable energy products