System-of-Systems Approach to Integrated Future Electricity Grids

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We are shaping the future | ALSTOM

“How Many Things are Judged Impossible Before They Actually Happen”

***Pliny the Elder*, Naturalis Historia, VII**

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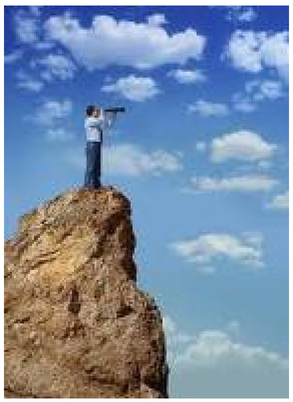
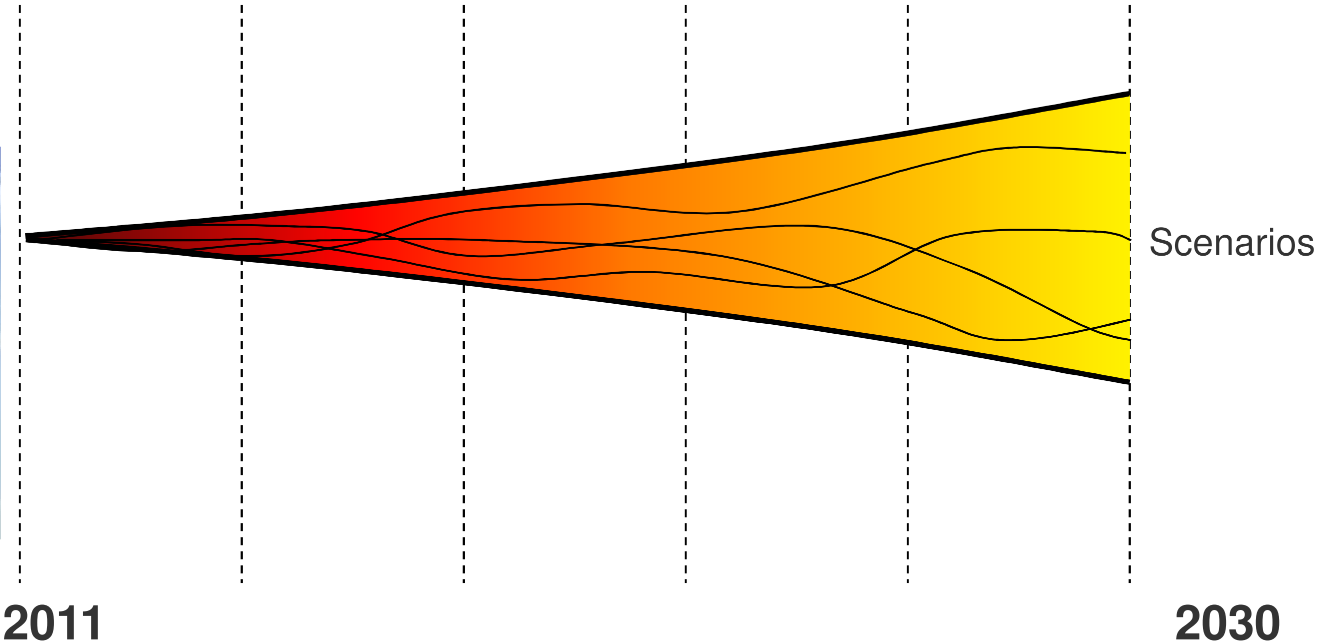
Modernizing the Grid & Cone of Uncertainty - Today and towards 2030





Key Factors

- Energy policy (not long term)
- Economic policies
- Stakeholders' diverse set of objectives
- Customer behavior
- Regulatory (siting, permiting, etc)
- Technology adoption

Key Factors

- Population demographics(aging workforce, insufficient qualified worforce)
- Resource constraints (energy, water, food, raw materials)
- Energy security & independence
- Globalization – trade agreements

The "Smart & Optimal" Challenge for Integrated Systems

How to integrate the basic abilities of *awareness* and *reaction* into a device, system or system-of-systems with minimum cost and complexity, in order to achieve predefined *functionality* and *performance goals*?

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Optimization with *Evergreen* Solutions

"

Evergreen" is a business, technology and service concept aimed at retaining and extending the value of a legacy investment through migration to new technology platforms.

- Existing grid assets must be enhanced to harness ICT and perform more efficiently, meeting new and emerging requirements and standards.
- Evolutionary process bridging the gap from now into the future means we will have a grid in a hybrid state of old and new assets.
- Must have view of total system to make optimized decisions.

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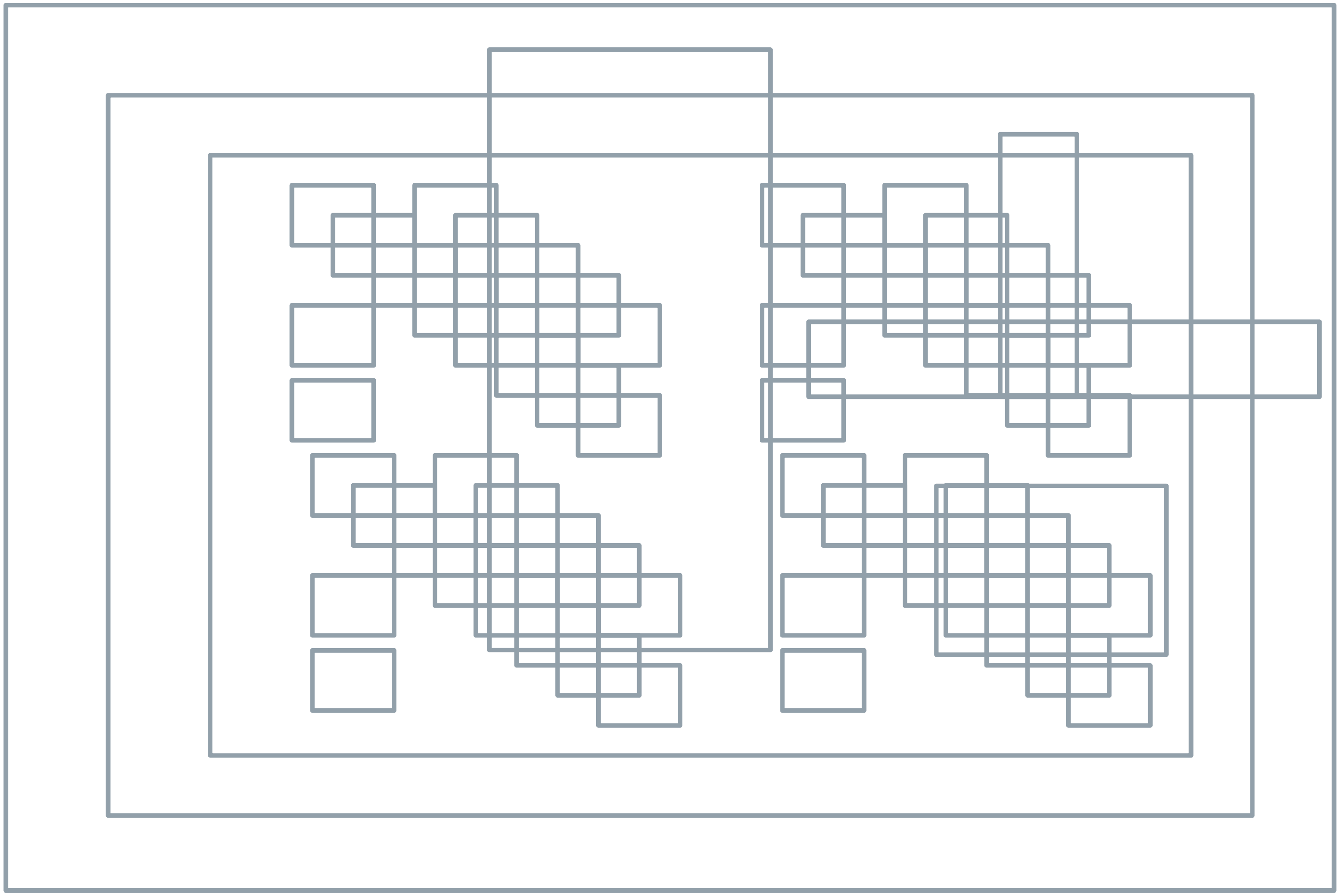
Electricity System : A System-of-Systems (SoS)



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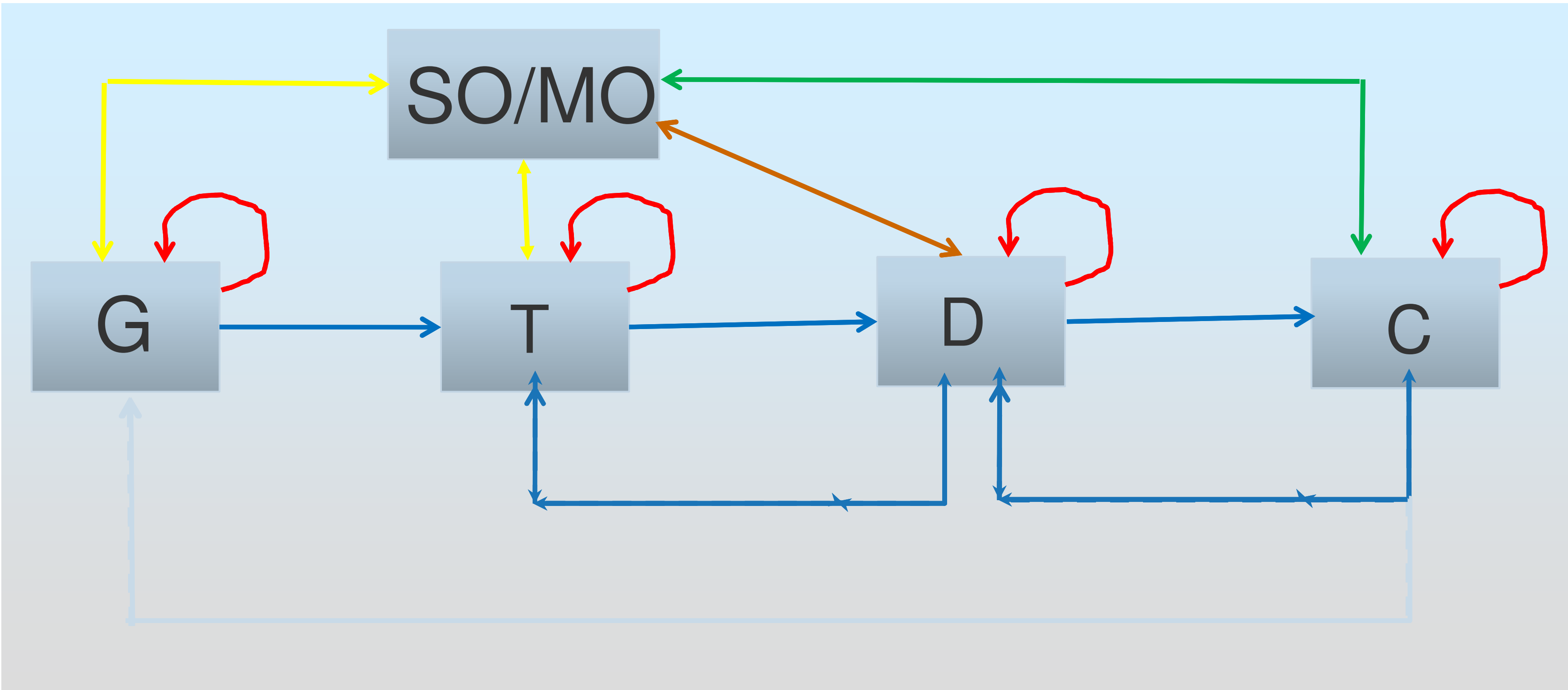
Smarter Grids1.0, 2.0, 3.0 . . . X.0



Evolution of Data and Information Flows in Electricity Networks
- The Great Convergence of ET and IT -

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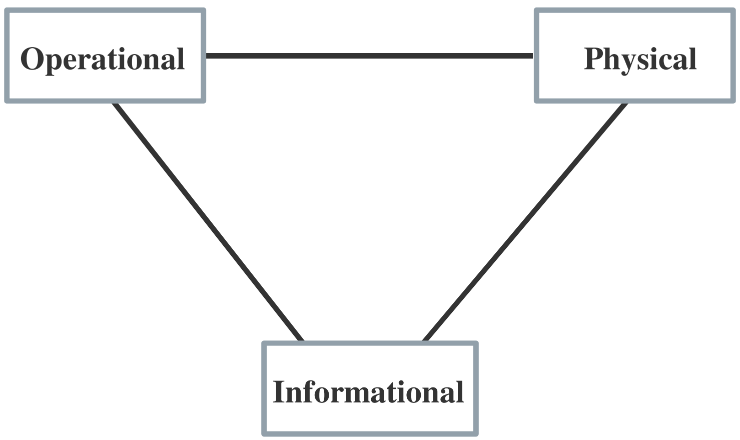
How to Analyze the “Abilities” of Integrated Systems

- Availability
- Configurability
- Controllability
- Dispatchability
- Flexibility
- Interoperability
- Maintainability
- Predictability
- Probability
- Reliability
- Securability
- Stability
- Sustainability
- Variability
- Vulnerability
- Reachabilty

Optimizing these “abilities” leads to more efficient electricity systems

Integrating System-of-Systems

Three Dimensions of Integration



- Physical
  - How transmission, and distribution components, equipment, devices, controls, sensors etc are operated
  - How wind plants are connected to the grid
- Operational
  - Considers the system conditions and performance goals
  - Also includes operational requirements and guidelines
- Informational
  - How information is managed and used by assets
  - How wind forecast in integrated in control room

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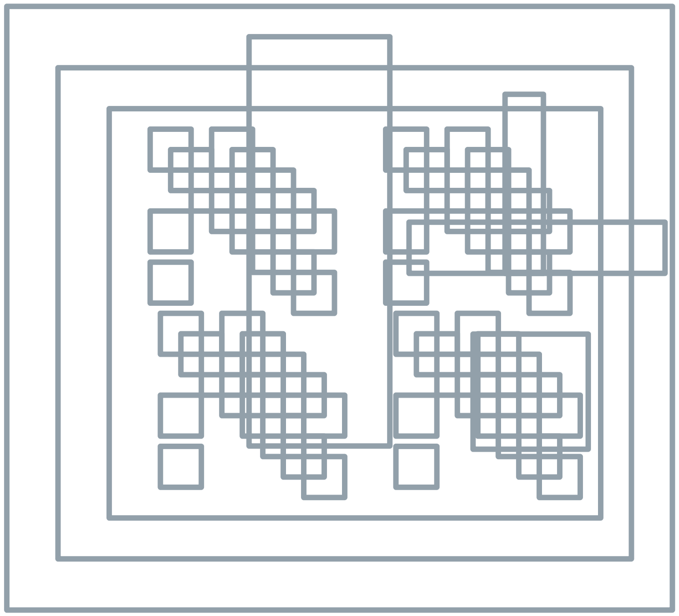
Optimizing "Abilities" of Energy Systems

- Optimization at various levels
  - System
  - Sub-systems
  - Devices

- Multi-objective functions and constraints
  - Policy
  - Reliability
  - Economics
  - Environment
  - …



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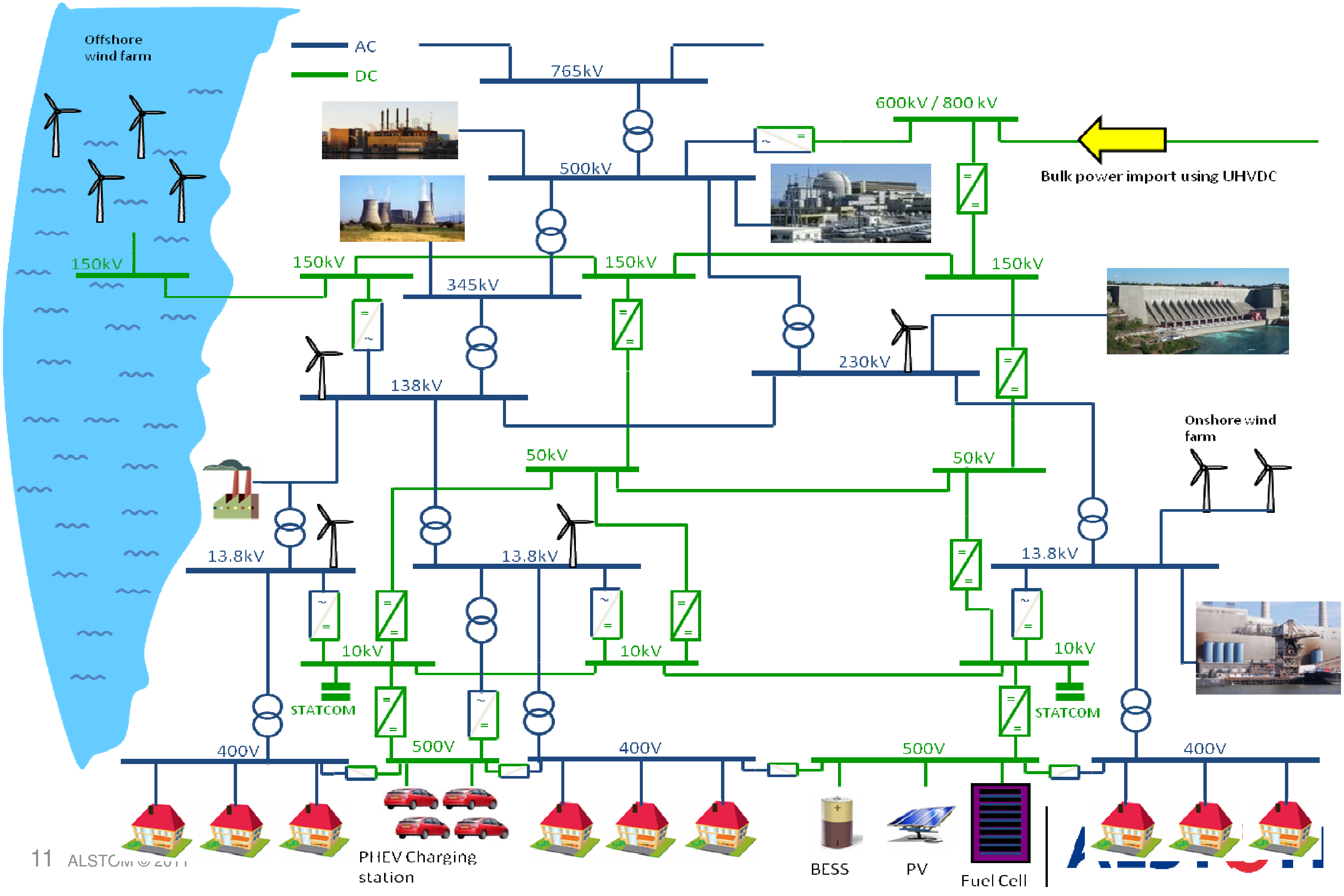
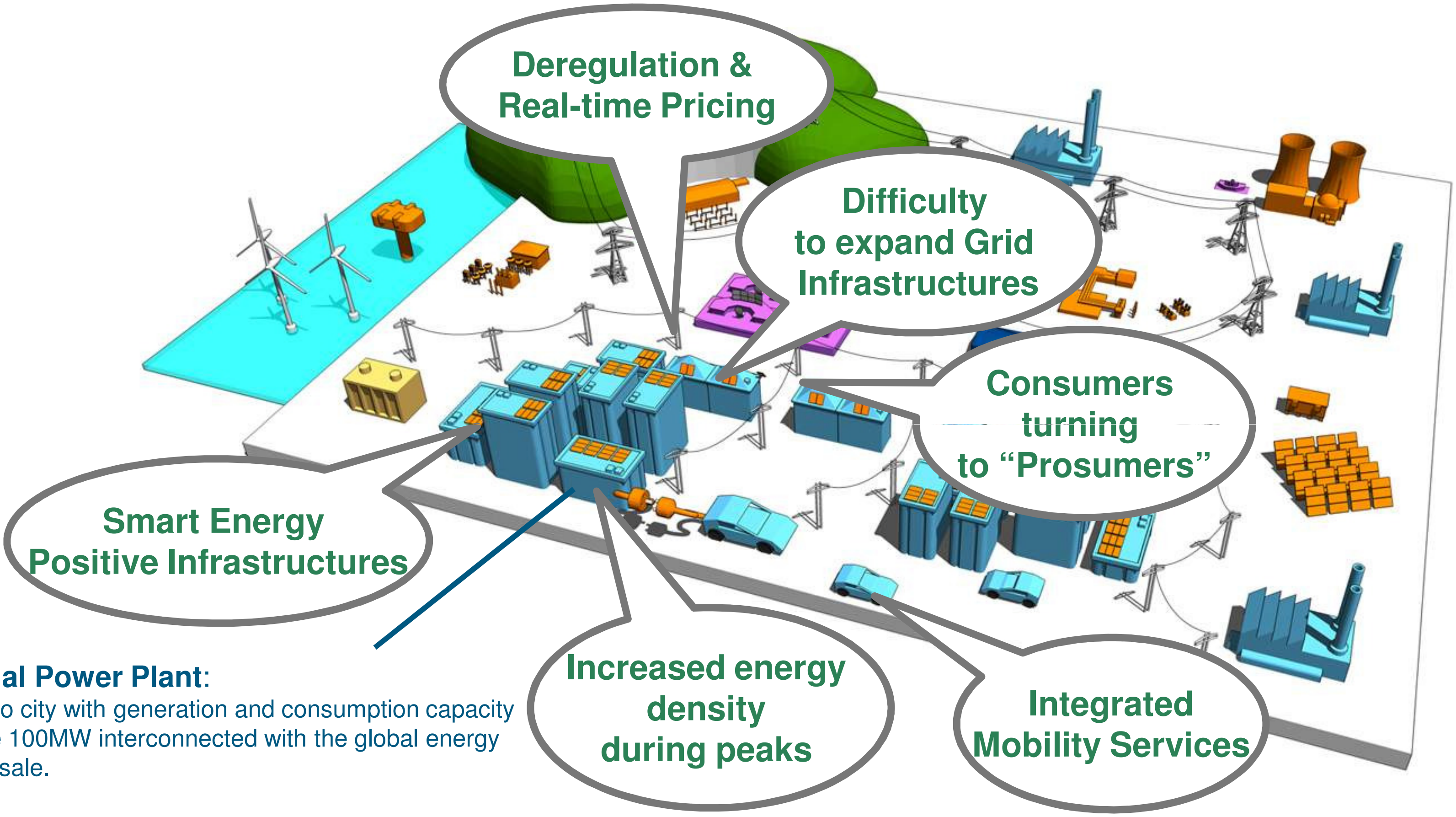
Future Electricity Grids



Smarter Megacities Towards 2050

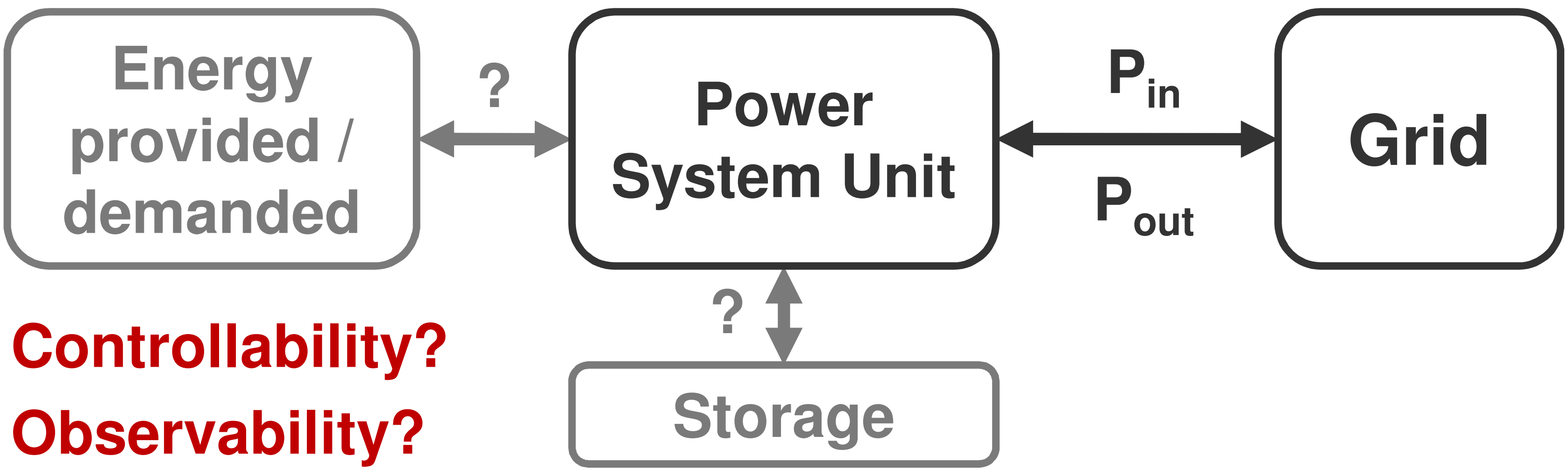


Virtual Power Plant:
An Eco city with generation and consumption capacity above 100MW interconnected with the global energy wholesale.

New urban eco campus are ideal clusters to pilot smart cities

How to model Operational Flexibility in Power Systems?

- Example: Optimal power dispatch simulations do consider units that inject power into the grid or demand power from the grid.
  - Which of these units are storages (and thus energy-constrained)?
  - Which of these units provide fluctuating power in-feed?
  - What controllability and observability (full / partial / none) does the operator have over fluctuating generation and demand processes?



Courtesy of Andreas Ulbig and Prof. Goran Andersson, Swiss Federal Institute of Technology, Zurich

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The Data Avalanche: Challenge vs. Opportunity for Energy System Optimization

- Future Electric Grids will generate a tremendous flow of data.
- This sea of data is a real asset to enable great business opportunities.

- Operating future grids will main right information to the right decision maker.
- Data mining and predictive analytics will be key to support decision making in grid optimizations

Illustration courtesy of Philippe Mack, PEPITe S.A., Belgium

Data Mining Opportunities

- Smart Grids give information at a «DNA» level ... But how to use that information at a decision level ?
- Data mining can help with:
  - better understand phenomena with historical data
  - identify the variabilities that have significant impacts on system performance
  - diagnose root-causes of variability observed in historical data
  - identify the potential actions to reduce the variability
  - forecast the value of key parameters and

Ref: Data mining discussions with Philippe Mack, PEPITe

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