ICT as Enabler of Smart Infrastructures

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What is PISA?

- *Pervasive Infrastructure Services and Applications*
- A proposed Canada Network of Centres of Excellence

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Agenda

- → ICT Trends and Connected Environments
- Why Smart Infrastructures Now?
- Smart Infrastructure Opportunities and Research Challenges
- Conclusions

Information and Communications Technology Drives Major Socio-Economic Change

Multi-decade digital transition to Intelligent Network
1980 $300/line

Signaling Network: Enhanced Services
E2E Digital:
DSL & SONET;

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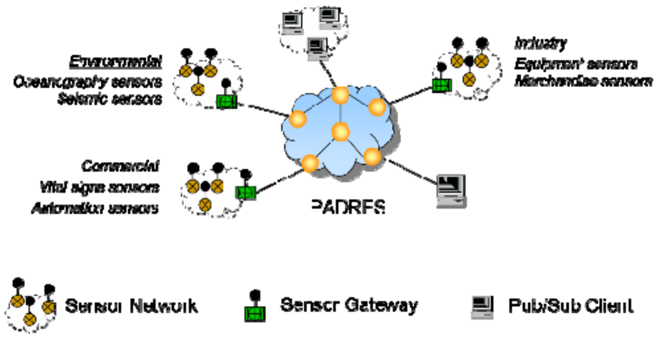
Moore's Law and Economies of Scale Drive Technology Commoditization

- Commoditization of PCs
- Commoditization of Software
  - Standards-based web browsers
  - Open source Linux (Apache server)
- Commoditization of Bandwidth
  - Broadband Access from Telcos & Cablecos
  - Ethernet in datacentres
- *New Computing Models*
  - *Google, Amazon*
  - *Virtualization and X-as-a-Service*
  - *Skype, BitTorrent*

More Change on the Way: Connected Environments



Pervasive ICTs poised to fill new environments

Cloud Computing Benefits & Challenges

- Pay-as-you-go utility computing
- No upfront cost, granular billing
- Resource management offloaded to provider

- Large-scale statistical multiplexing of computing demand
- Dynamic movement of virtual machines
- 5-7x reduction in cost

- Availability, performance, bandwidth bottlenecks, security
- Scalability, energy proportionality
- Fast growth in volume of carbon emissions

Smart Infrastructures

- Pervasive infrastructure & cloud computing provide the monitoring and control that enable smart infrastructures
  - Smart Power Grids
  - Green Computing
  - Networked Vehicles
  - Communications and Collaboration

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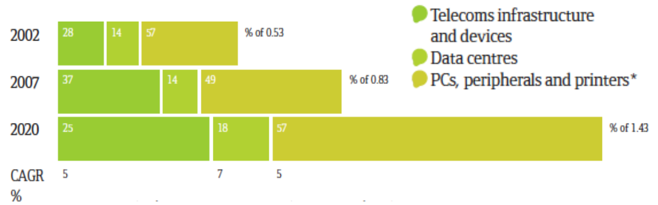
Why Smart Infrastructures Now? ICT Global Footprint



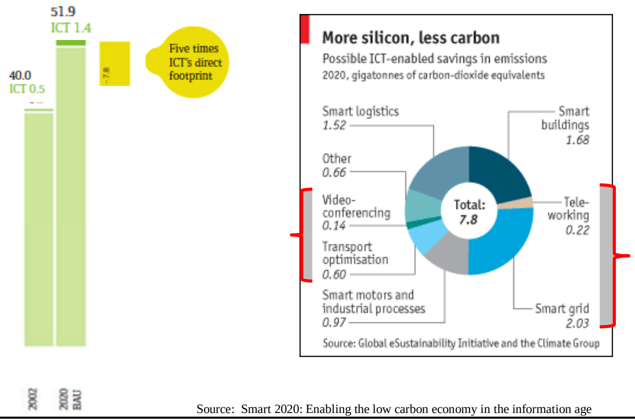
- Green cloud computing
- Green microgrid computing
- Green networking

Source: Smart 2020: Enabling the low carbon economy in the information age

Why Smart Infrastructures Now?

- Smart infrastructures need to be deployed sooner to deal with climate change
- From 2002 to 2020, ICT carbon emissions will nearly triple
- Application of ICT in other sectors can lead to 15% reduction in global emissions in 2020

Why Smart Infrastructures Now? Application of ICT



Source: Smart 2020: Enabling the low carbon economy in the information age

What is the Opportunity for Communications?

- Vodaphone and Accenture detailed follow up study to Smart 2020 report
- Focus on 13 opportunities for wireless communications
  - Dematerialization
  - Smart Grid
  - Smart Logistics
  - Smart Cities
  - Smart Manufacturing
- Can save 2.4% of (20%) expected reduction in EU emissions
- €43 billion in energy cost reductions
- 1 billion mobile connections required
- 87% machine-to-machine connections

Research Challenges

1. How to enable trustworthy applications in connected environments building on innovations in sensor and wireless networks, and service-oriented applications design;
2. How to develop large-scale management systems that enable smart infrastructure;
3. How to apply the findings in connected environments and smart infrastructures to provide socioeconomic solutions in:
   a. Cloud computing and datacentres
   b. Smart power grids
   c. Intelligent transportation and networked vehicles.
   d. Next-generation human communications and collaboration.

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Research Challenges in Smart Infrastructures

Smart Infrastructure Challenge

- Mediating supply and demand of critical resources
- Estimate supply/demand from a network of sensors
- Demand driven by aggregate behaviour of community of users
- Performance and reliability requirements and impacts
- Environmental impacts, especially carbon emissions

Research Challenge

- Wireless sensor networks in new environments
- Data gathering/filtering/mining, event handling
- Social incentives and pricing strategies to influence consumption behaviour
- SLA and policy-driven scalable control and management systems
- Security and reliability

PISA approach exploits synergies across application areas, common ICT standards and methodologies, facilitating interoperability and promoting economies of scale.

Multidisciplinary & Multisector Teams

		Areas of Socio-Economic Impact			
		Cloud Computing & Datacenters	Smart Power Grids	Intelligent Transportation & Networked Vehicles	Next-Gen Communications & Collaboration
Areas of Research Challenges	Application Themes		✔	✔	
	Next Generation Wireless Systems & Devices				
	Wireless Heterogeneous Sensor Networks				
	Data Management,Event Handling, Threat Mgmt.				
	Social & Economic Issues	✔	✔	✔	✔
	Large-Scale Management Systems				
	PISA Design Lab				

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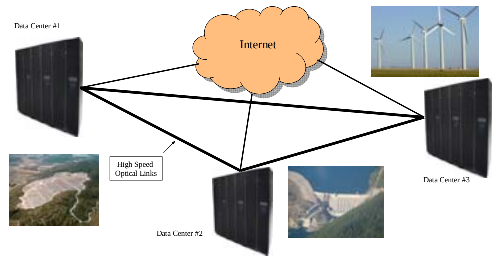
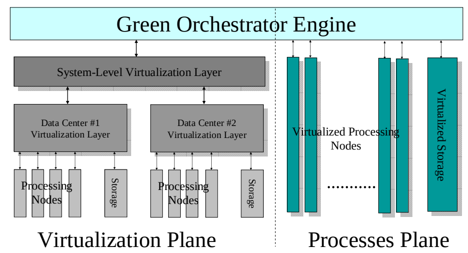
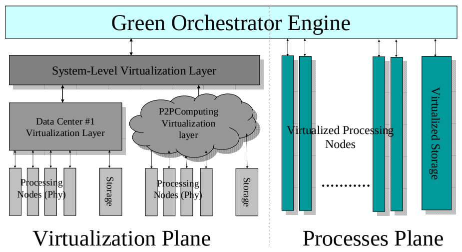
Green Data Centers



GCC Management System



Hybrid GCC and P2P Management System



- Complements Green P2P micro grid initiatives

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Definition of Smart Grid

- Smart Grid integrates conventional and leading-edge:
  - power system apparatus,
  - power electronic switches and converters,
  - sensing and monitoring technologies,
  - information technologies and communications,
- through the leading-edge control and protection strategies to:
  - improve power grid performance,
  - minimize environmental adverse effects,
  - enable (real-time) interactions among customers, operators, power producers, service providers and market.

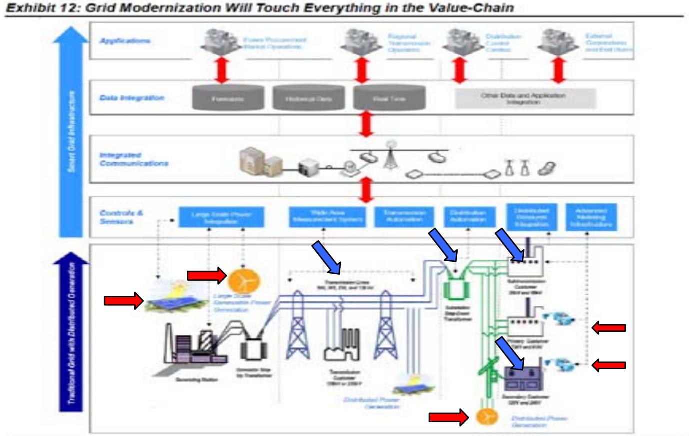
Comparison of Telecom & Power Grid

Communications	None or one-way, not real-time	Two-way, real-time
Customer Interaction	Limited	Interactive
Metering	Electromechanical	Electronic, interactive
Operations & Maintenance	Manual equipment check, time-based maintenance	Automated, real-time
Generation	Centralized	Distributed
Power Flow Control	Limited	Dynamic, real-time
Reliability	Reactive; Prone to failures & cascading outages	Proactive; Resilient architecture
Restoration following Disturbance	Manual	Automated
System Topology	Radial, one-way	Mesh, two-way

Source: ABB White Paper & Dundee Securities Report

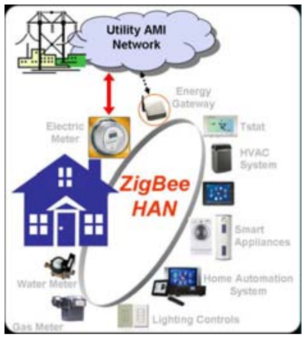
Grid Modernization

Exhibit 12: Grid Modernization Will Touch Everything in the Value-Chain



Source: EPRI – Smart Grid Study, Electricity Advisory Committee – Smart Grid Enabler of the New Energy Economy, Areva Energy, Booz & Co. – Commercializing the Smart Grid, Dundee Securities Corp.

Smart Meters and Home Area Networks



- Enable users to adapt consumption to time-of-use pricing
- Reduces peak usage periods
- Could interact with smart appliances
- What degree of control can be given to utility?
- What social/pricing incentives are effective?
- What is impact of plugin hybrid electric vehicles?
- What role do PHEV's play in future infrastructure?

Source: Ashton, Smart Energy Networks

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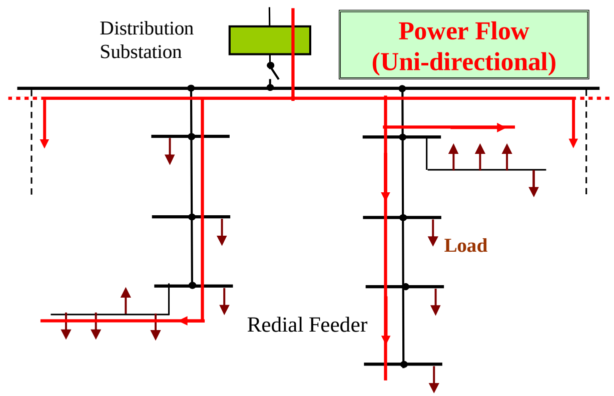
Microgrids (Prof. Reza Iravani)

- Conventional distribution feeders
  - radial topology
  - one-way power flow
  - Disconnected & de-energized during faults
- Microgrid is a cluster of distributed generation and distributed storage units
  - serviced by a section of a distribution system and can operate:
  - in the grid-connected mode,
  - in the islanded (autonomous) mode,
  - during transition between the two.
- Intelligent Microgrid also:
  - Incorporates sensing and monitoring technologies and ICT
  - Enables bidirectional power flow with main grid
  - Basis for more resilient decentralized architecture

Conventional (Existing) Distribution Feeders



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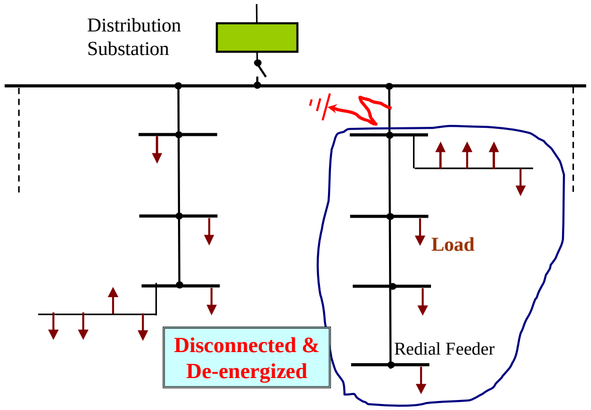
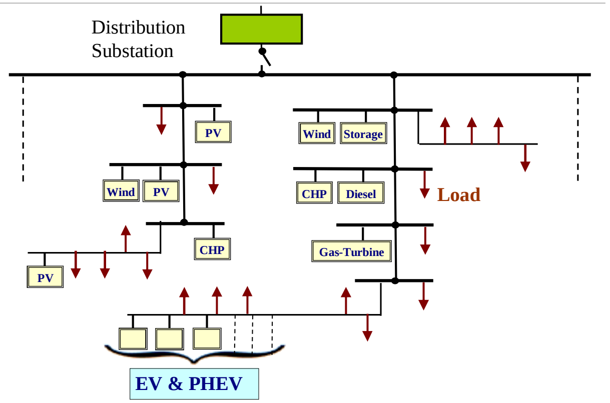


Microgrid



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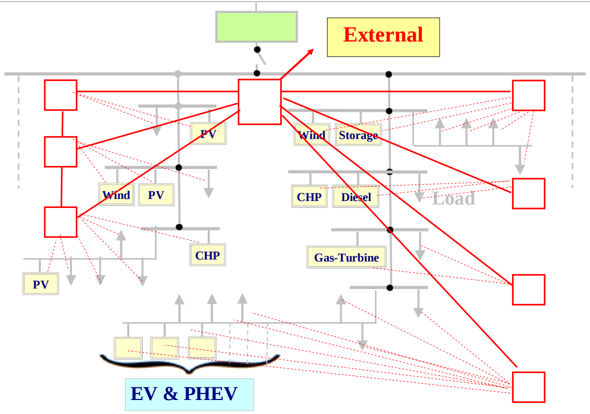
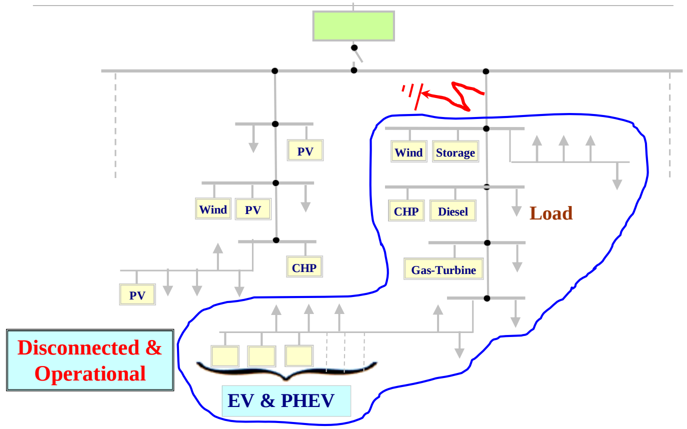
Intelligent Microgrid



Intelligent Microgrid



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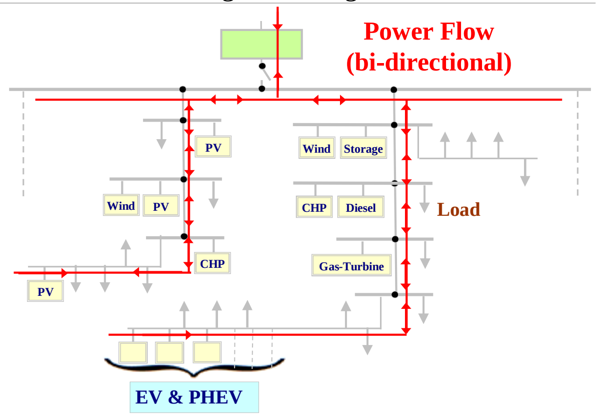
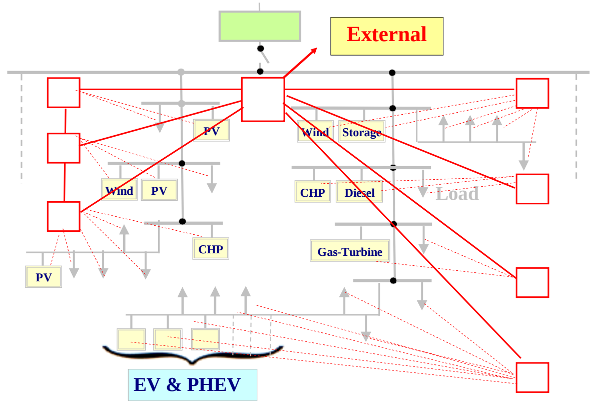


Intelligent Microgrid as a Virtual Power Plant (VPP)



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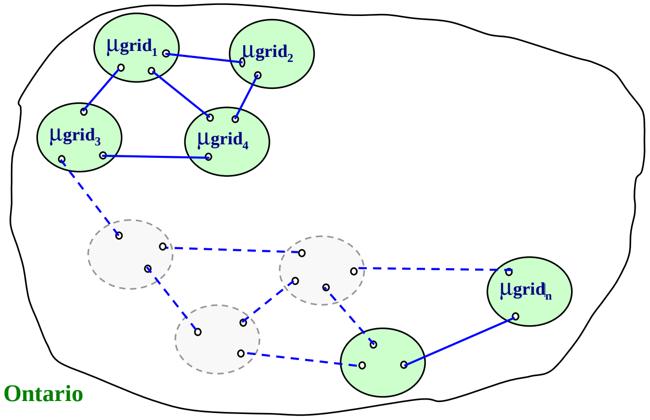
Microgrid as the Building Block of Smart Grid



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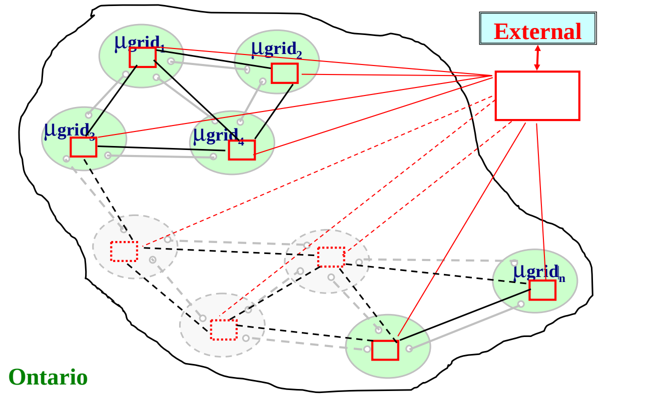
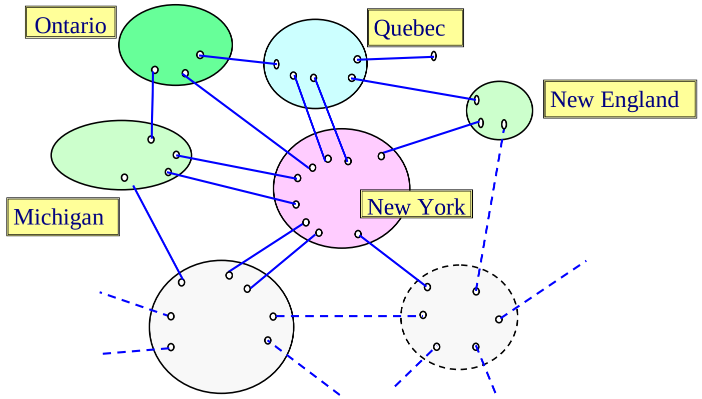
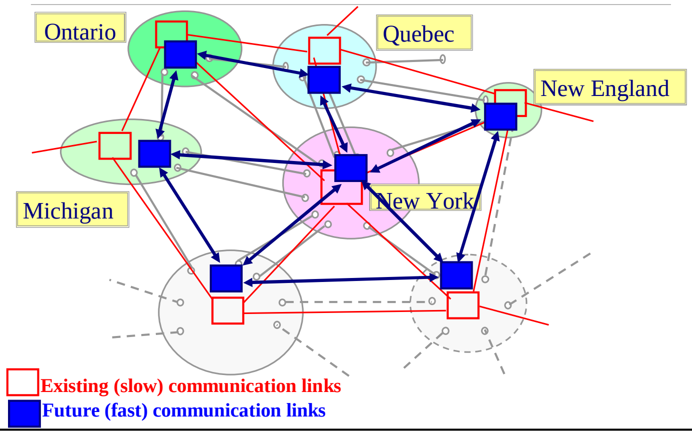


Wide-Area Power System



Wide-Area “Smart Grid”



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More Change on the Way: Intelligent Transportation Systems and Networked Vehicles

Integrated Intelligent Road, Transit, Vehicle System

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Intelligent Transportation Systems

- Manage the flow of people and goods in transportation networks
- Driven by data gathered from sensors and monitors deployed in road system
- Aggregates & displays data in network control centers and exerts controls (e.g. traffic signals) to reduce congestion & improve safety
- Provides access to transportation-related information

Future Intelligent Transportation Systems

- Improved road sensors and monitoring
- Improved communications systems
- Enhanced and intelligent infrastructure
- Networked vehicles
  - On-board processing, sensors, GPS
  - Vehicle-to-device
  - Vehicle-to-infrastructure
  - Vehicle-to-vehicle

- *New and Improved Applications*
  - Safety
  - Energy consumption and carbon emissions
  - Comfort

Future ITS Research Challenges

- *Integrated road and transit systems*
- *Realistic models for traffic, mobility, data usage, system interactions*
- Wireless networking:
  - Refined propagation models: vehicle-to-vehicle?
  - Interworking of heterogeneous wireless systems
- *Right mix of infrastructure & overlay networking*
- Information systems and data processing:
  - Data fusion, filtering; Efficient database design; Data mining
- Fast and flexible creation of new applications and services
- Security, privacy and quality of service issues
- Need of experimental testbeds for real-world evaluations
- *Business models and social and economic incentives*

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Conclusions

- *Smart infrastructures offer a major opportunity to our industry*
- Smart infrastructures are essential to address energy consumption and carbon emission challenges
- Information and ***Communications*** Technologies will play a key role in enabling smart infrastructures
- New interdisciplinary collaborations required to address smart infrastructure research challenges