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Smart Grids and Distributed Renewable Energy Generation: Innovation for sustainability

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Electricity Generation Using Renewable Energy

S&T Collaboration between Govt of India and Canada through ISTP (Canada) and GITA /CII (India)

At IIT Delhi

October 9-10, 2009

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SUSTAINABLE ENERGY:
Policies, Programs, Directions

- Social marketing
- Sustainable building
- Demand management
- Conservation behaviour

- Hydrogen production
- Fuel cells (solid oxide and PEM)
- Thermoelectric materials and devices
- Lithium ion batteries

- Centre for Advanced Photovoltaics Systems & Devices (**CAPDS**)
- Solar thermal applications
- Wind turbine design and performance
- Bioenergy
- Distributed generation

- CO2 capture, storage & mitigation
- Clean diesel engines
- Clean coal technology
- Nuclear power plant reliability

- Sustainable energy policy and planning
- Sustainable urban design
- Emissions reduction
- Green batteries
- Green auto power train

- Power quality
- Energy systems reliability
- Large scale optimization
- Energy forecasting
- Electricity markets

Preserve & Create Energy Options
Multi-Disciplinary Research Teams
Economic Growth & Environmental Performance
Business, Government, Industry , Civil Society Engagement

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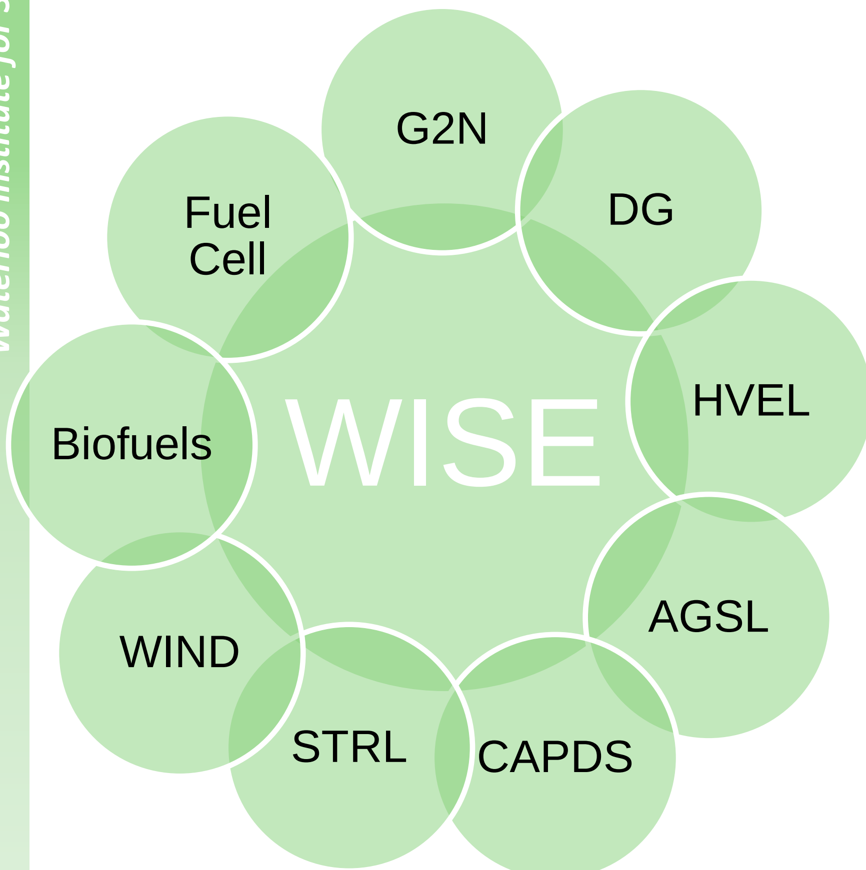
The Waterloo Institute for Sustainable Energy (WISE)



G2N Giga-to-Nano Lab

- Andrei Sazonov, Electrical & Computer Engineering

DG Distribution Generation Lab

- Ehab El-Sadaany, Electrical & Computer Engineering

HVEL High Voltage Engineering Lab

- Shesha Jayaram, Electrical & Computer Engineering

AGSL Advanced Glazing System Lab

- John Wright, Mechanical & Mechatronics

CAPDS Centre for Advanced Photovoltaic Devices and Systems

- Siva Sivoththaman, Electrical & Computer Engineering

STRL Solar Thermal Research Lab

- Michael Collins, Mechanical & Mechatronics

WIND Lab

- David Johnson, Mechanical & Mechatronics

Biofuel/Biomass Lab

- Ray Legge, Biometric Engineering & Environmental Engineering

Fuel Cell Lab

- Michael Fowler, Chemical Engineering

Select Highlights

3 Signature Projects

Decreasing Diesel Dependency in Remote Northern Communities

- Off-grid hybrid power system provides a lower-cost, environmentally friendly solution for remote communities.

Energy Consumption Management System Gives Consumers Control

- A smart web-based tool gives consumers control to change the way they use energy, and move to on-site alternatives like solar and wind energy.

Connecting Solar Farms to the Grid

- UW and U Western are developing comprehensive solutions to help grid operators incorporate large-scale solar farms to their networks.

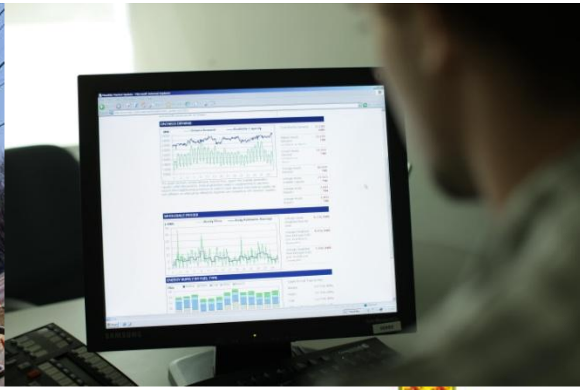
- Smart Grid Forum
- Plug-In Hybrid Electric Vehicles Ontario Action Plan
- "Affordable solar for the masses"- A major international initiative
- Integration of Distributed Generation into system
- Advanced batteries and storage technologies

Enabling Tomorrow's Electricity System

Report of the Ontario Smart Grid Forum

Ontario Smart Grid Forum

- Industry leaders brought together to develop a smart grid vision for the province
- Vision designed to guide:
  - a co-ordinated approach across the sector
  - the mitigation of technology risks
  - the development of capital investment plans
  - a supportive regulatory framework



Forum Members

- Paul Murphy, IESO President and CEO
- Michael Angemeer, President and CEO, Veridian Corporation
- David Collie, President and CEO, Burlington Hydro
- Norm Fraser, COO, Hydro Ottawa
- Anthony Haines, President, Toronto Hydro Electric System
- David McFadden, Chair, Ontario Centres of Excellence
- Keith Major, SVP - Property Management, Bentall LP
- Jatin Nathwani, Professor/Executive Director, Waterloo Institute of Sustainable Energy, University of Waterloo
- Paul Shervill, VP – Conservation and Sector Development, OPA
- Wayne Smith, VP – Grid Operations, HydroOne

Why Smart Grids?

What is a Smart Grid?

- Smart grids comprise sensors, monitors and information technology – bringing together all elements of the electricity system
- They include distributed generation, accommodate electric vehicles and provide greater consumer choice

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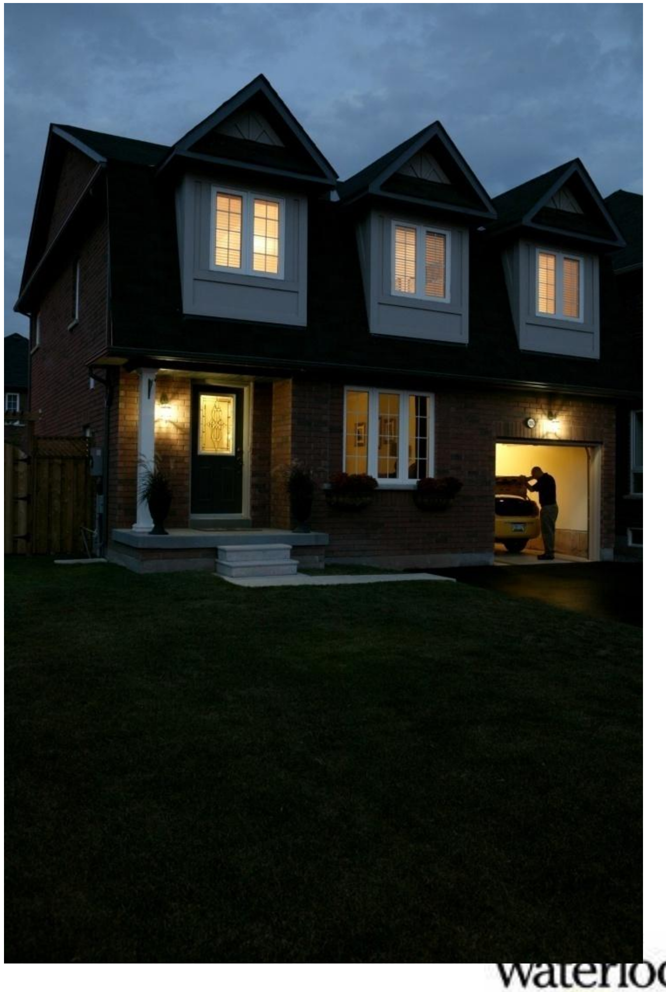
Smart Grid Benefits

- Modernizing the electricity system to serve the digital age:
  - Better integration of renewables and distribution generation
  - More efficient use of energy infrastructure and reduced energy losses
  - Empowered consumers with increased participation in conservation and demand response
  - More reliable distribution service with reduced outages and quicker response times



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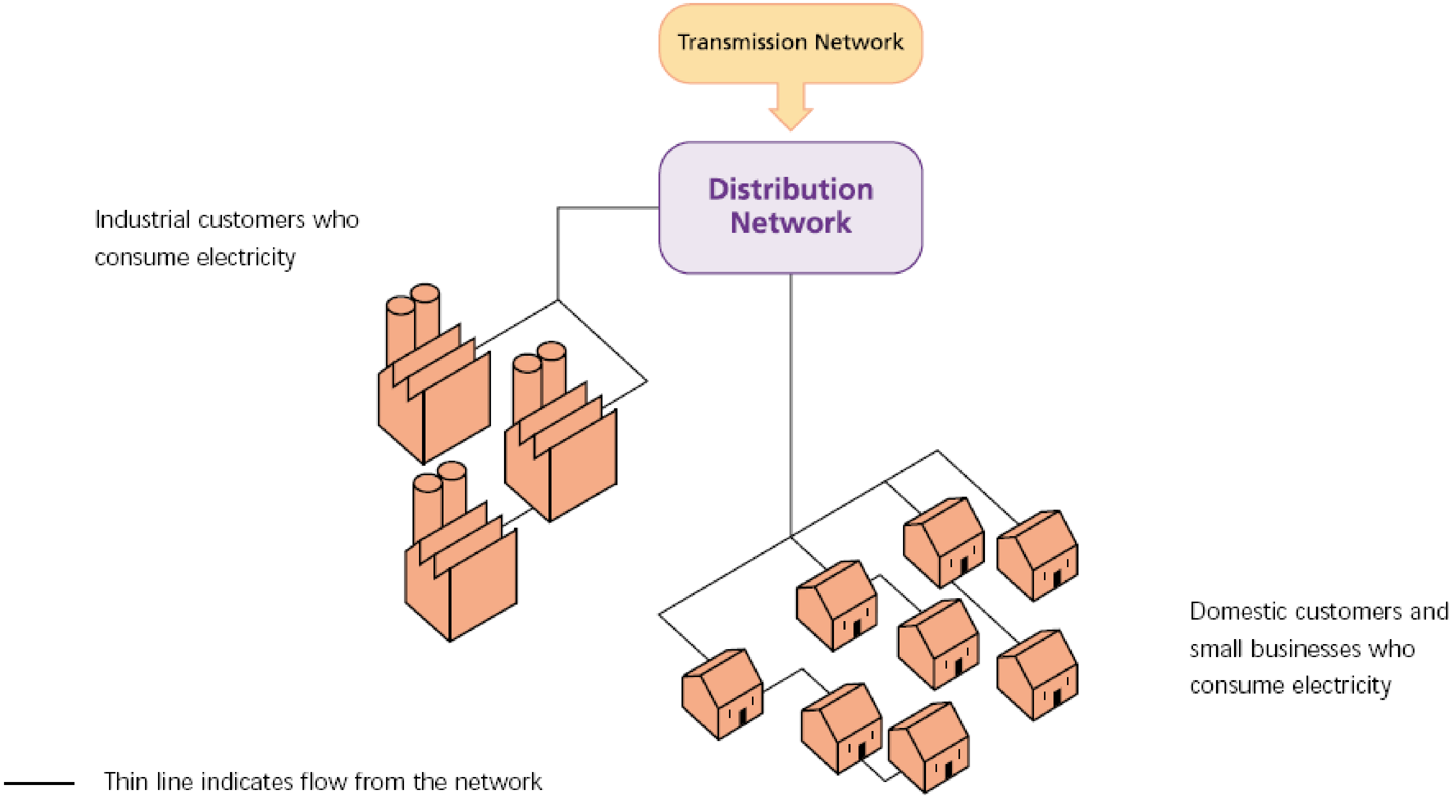
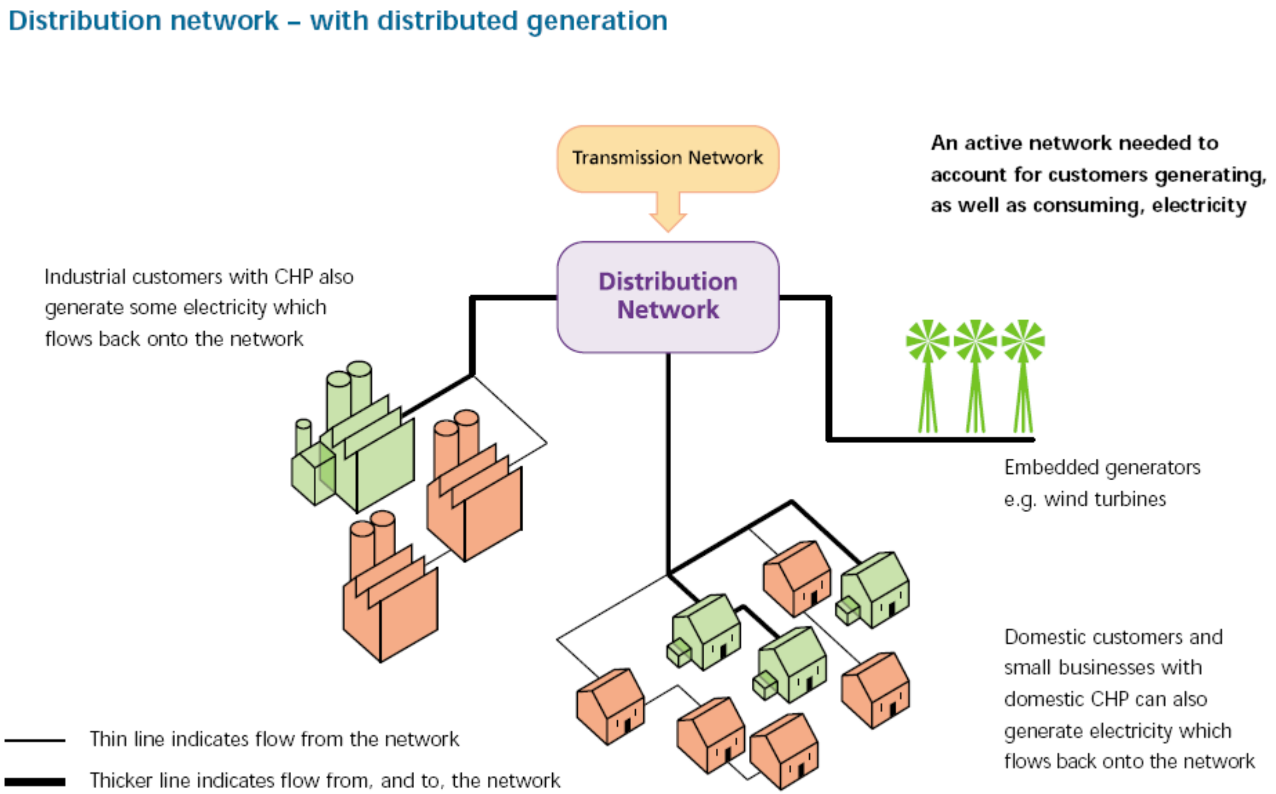
Power flows one way: network to the customer

Distribution network – conventional



Paradigm shift: Power flows both ways



Getting There: Innovation

- **New technologies need to be invented and brought to market**
  - opportunity to create green jobs
- **Sustained and significant investments are required**
  - All utilities required to develop Smart Grid plans for regulatory approval
  - Provincial government commitment to support R&D efforts
  - OEB proactive in facilitating these initiatives

Getting There: Discipline

- **Develop Standards and Standardized Approaches**
  - Significant work is already being done
  - Industry needs to develop standards so that technology developers can work together
  - Need a North American approach to standards
- **Ensure Fiscal Responsibility**
  - Need to ensure investments are prudent

Getting There: The Customer

- **Achieving the benefits of smart grid requires social change**
- **Provide consumers with tools so they can become more active energy users**
  - Offer access to timely consumption information
  - Promote energy management devices, services and systems
  - Raise smart meter standards
  - Support “energy literacy” through education
  - Offer dynamic price signals
  - Create PHEV Plan

The Future

2011

- Smart meters and time of use rates
- More in-home displays and LDC smart technologies
- Preparing the grid for plug-in electric vehicles

2015

- Substantial increase in smart appliances
- Renewables, demand response, storage projects and LDC automation technologies are widespread
- Electric car infrastructure in place

2020

- Coordination across the sector complete
- Smart appliances standard
- Micro-grids begin to emerge

Microgrids for rural and remote needs

Vision: an integrated model of electrification to meet basic human needs at 1000kWh/person

- Abundant, clean, secure, reliable and a flexible energy source.
- Resource endowment, knowledge, economic base varies with each community
- Focus on renewable resources (solar, wind, water, bio)
- Community size can vary from 500- 50,000
- Modular system design from 500kW- 10MW
- Rapid installation; tailored to community needs
- Social & economic development capacity build-up to own, operate, maintain infrastructure

Microgrid Benefits

Choice: Extend Dx and Tx infrastructure (at a high cost) or provide local service through a microgrid

- **Reduced cost**—reducing the cost of energy service for affordability
- **Reliability**— attain level of reliability comparable to grid system
- **Green power**—manage the variable nature of renewables and promote deployment and integration of energy-efficient and environmentally friendly technologies
- **Service differentiation**—tailor to specific needs of a wide range of communities; provide levels and quality of service at different price points

When operating in grid parallel mode :

- **Power system**—assisting in optimizing the power delivery system, including the provision of Services
- **Security**—increasing the power delivery system's resiliency and security by promoting the dispersal of power resources

Microgrid: what is it?

- An aggregate of small loads and distributed generation resources
- Operates as a single system that provides both power and heat..
- An integrated system that must be able to provide sufficient and continuous energy to a significant portion of the demand internal to the microgird
- A microgrid's distributed energy resources can include
  - High-frequency AC (microturbines)
  - DC systems (e.g., solar, fuel cells)

Microgrids - technical and functional requirements

- 3 levels of control
  - Internal
  - External
  - Individual asset
- Greatest challenges are associated with protection, monitoring and control

Micro Grids: if and when operated in "grid-parallel" mode

- Distributed energy resources must operate as a single aggregated system
  - Present itself to the bulk power system as one "control area" that meets the local needs for reliability and security.
- Must possess independent controls that can island and reconnect with the electric power grid with minimal service disruption.
- Grid parallel mode provides flexibility in configuring and operating the power delivery system and the ability to optimize a large network of loads, distributed energy resources and the power system.

DG Technologies and Characteristics

- Wind power (small projects with outputs from 50kW to 10MW)
- Biogas and biomass (landfill sites, agricultural and livestock operations, wood forest residues, wastewater treatment facilities:1-10MW)
- Combined Heat and Power (CHP) schemes including micro-CHP (residential 1kW-25 kW) and Stirling engines (1kW to 55kW)
- Solar photo-voltaic (PV) cells (50kW- 1MW)
- Fuel cells (1kW to 1MW)
- Microturbines (20-100kW)
- Natural Gas reciprocating engines (30kW- 3MW) and dual fuel reciprocating engines (90kW- 2MW)
- Gas and diesel fired combustion turbines (>1MW)
- Large DG applications & mobile systems for standby generation
  - (0.5 to 2MW),
  - peaking (1-5MW)
  - T&D support (0.5-10MW modules) and crisis operations

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Distributed Generation Resources: Reality Confronts Vision

- Performance has not equaled promise
- Fuel cells, microturbines, photovoltaics - still too expensive
- Fundamental business case?
  - Availability of “cheap” fossil based energy?
- Transmission and Distribution
  - Capital deferral, utilization, congestion….

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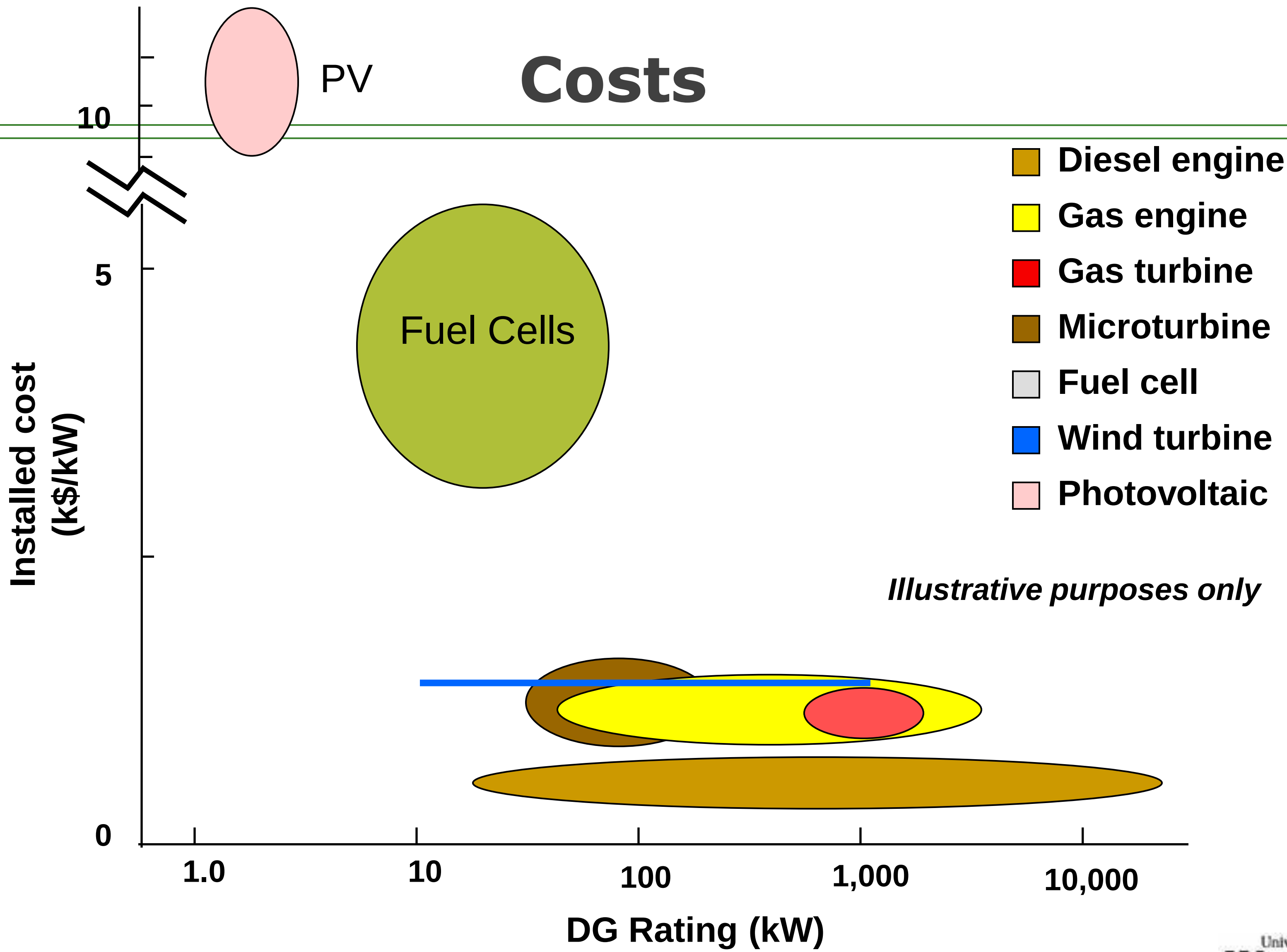
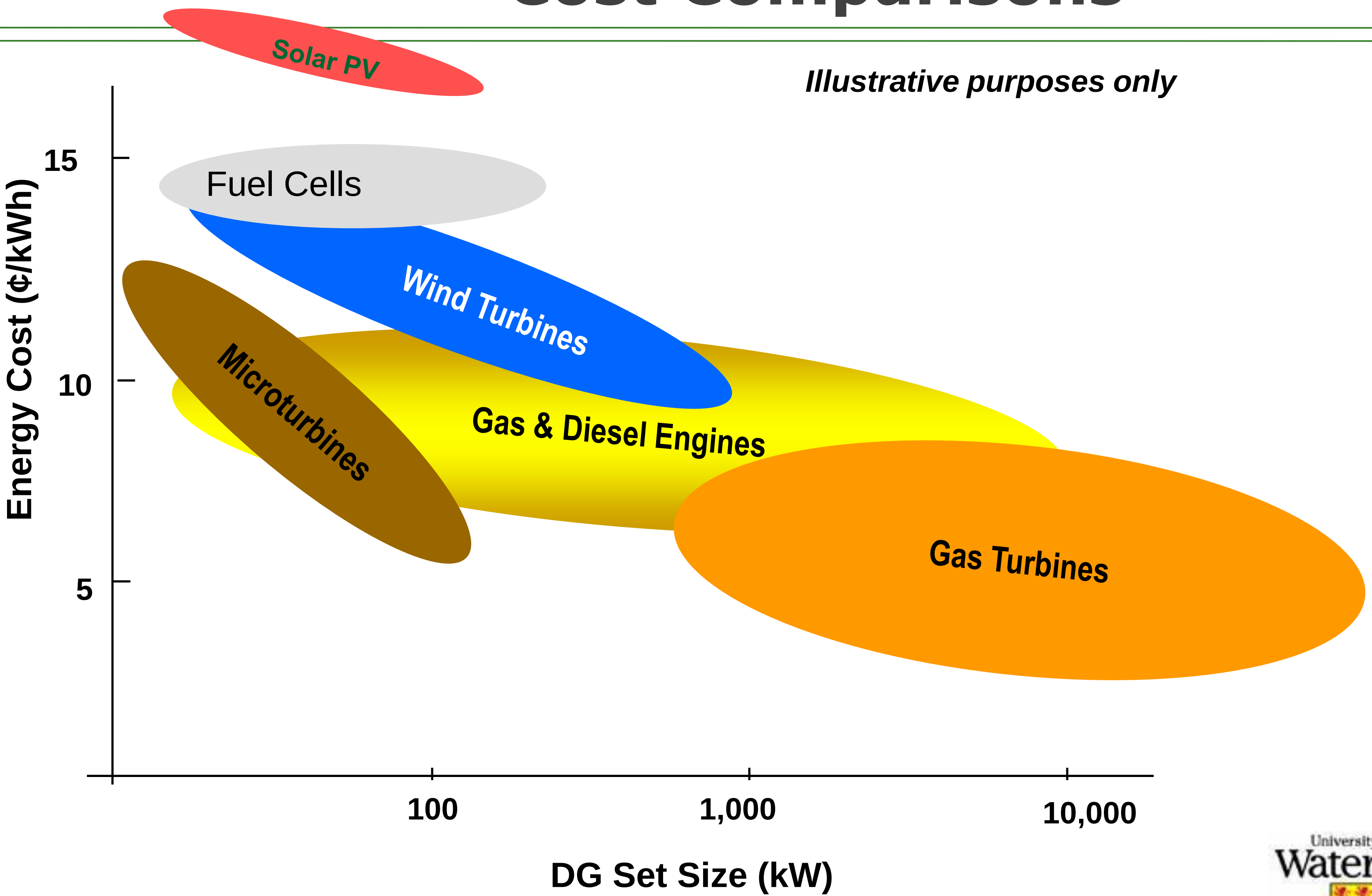
Costs



Source: OPA: IPSP DP#4, 2007

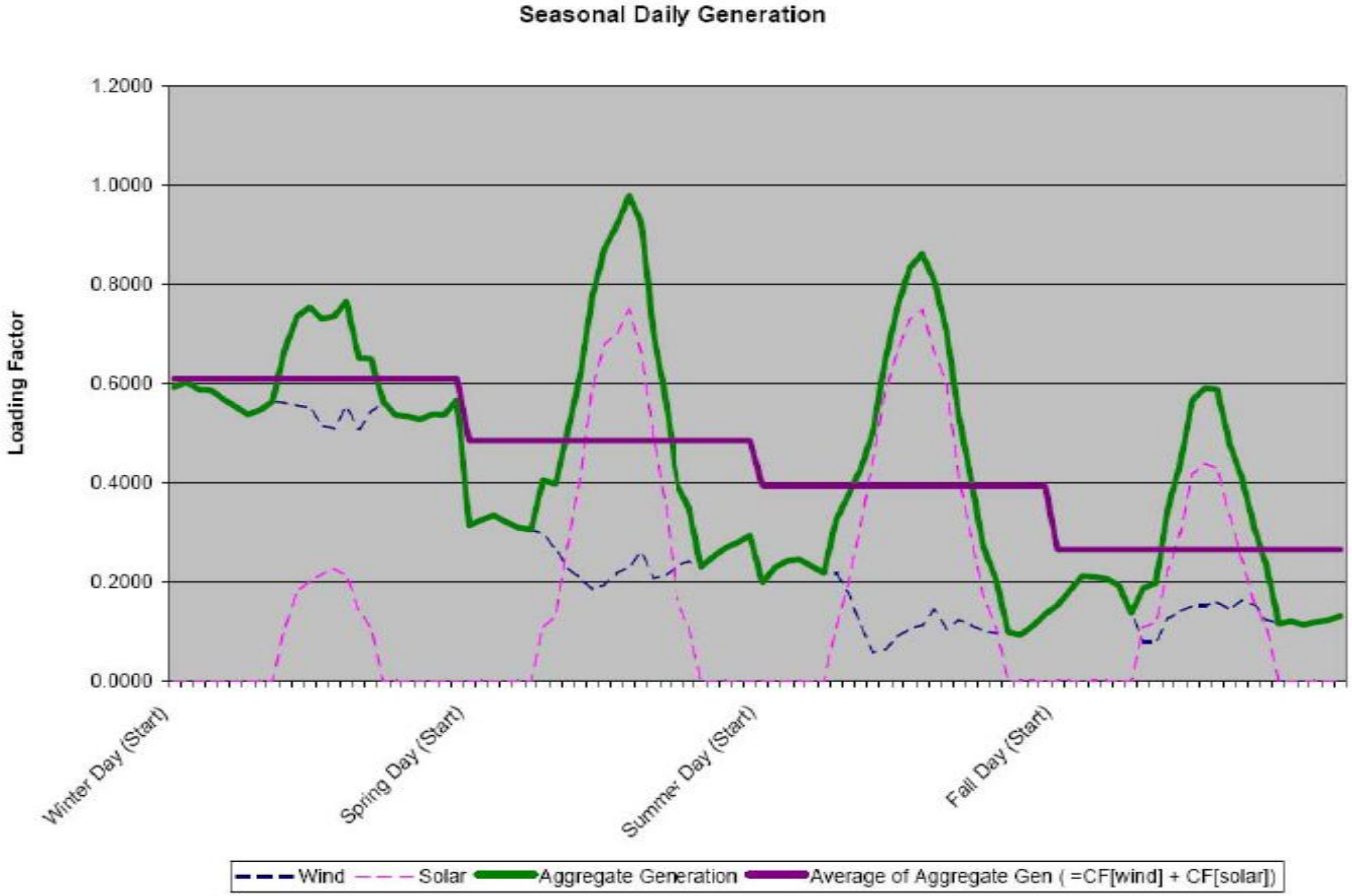
Cost Comparisons

Illustrative purposes only



Source: OPA: IPSP DP#4, 2007

Benefits of Diversity and Distributed Resources

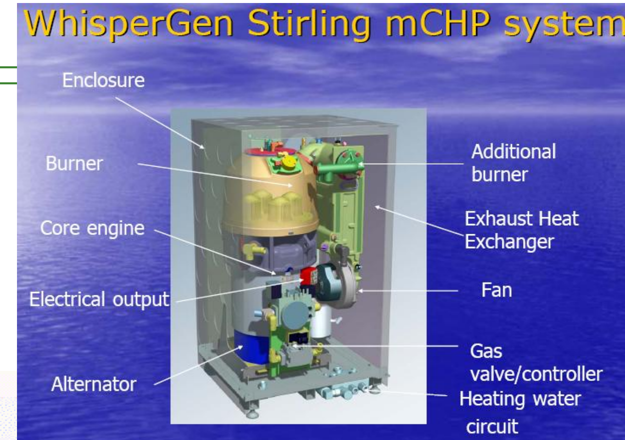


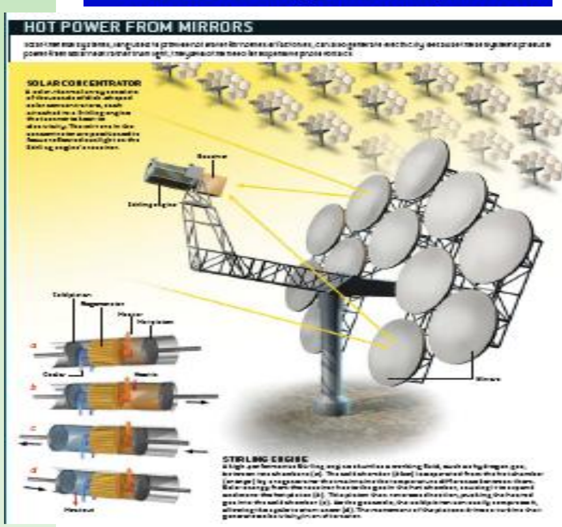
Source: R. Seethapathy, Hydro One Presentation to the Ont Smart Grid Forum

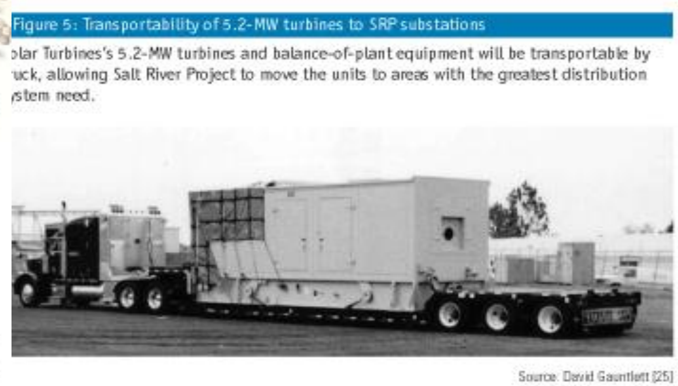
Summary- Vision is an integrated model of electrification to meet basic human needs at 1000kWh/person

- Can we engineer this vision?
- Is a "smart micro-grid" capable of meeting specific needs of rural and remote communities primarily through use of renewable resources?
- Given multiplicity of size, resource endowment and economic capacity, how many projects would be required to establish feasibility of delivering tailored solutions?
- Reducing costs ("technology + transactional") is the key determinant; ease of installation is another.

Technology Innovations







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