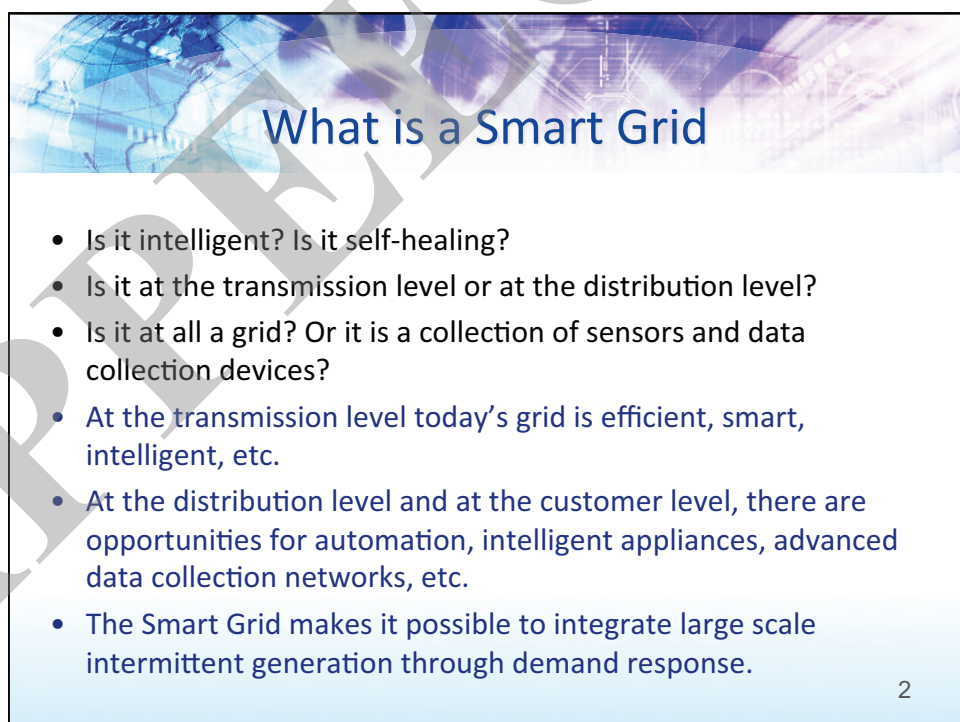


*An Introduction to Intelligent Grids for Distributed Generation and Demand Management*

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## What is a Smart Grid

- Is it intelligent? Is it self-healing?
- Is it at the transmission level or at the distribution level?
- Is it at all a grid? Or it is a collection of sensors and data collection devices?
- At the transmission level today's grid is efficient, smart, intelligent, etc.
- At the distribution level and at the customer level, there are opportunities for automation, intelligent appliances, advanced data collection networks, etc.
- The Smart Grid makes it possible to integrate large scale intermittent generation through demand response.

2

## Smart Grid Definition

- According to United States DOE's modern grid initiative, an intelligent or a smart grid integrates advanced sensing technologies, control methods and integrated communications into the current electricity grid.

3

## Intelligent Power Delivery Systems

**SMART GRID**  
A vision for the future — a network of integrated microgrids that can monitor and heal itself.

**Smart appliances**  
Can shut off in response to frequency fluctuations.

**Demand management**  
Use can be shifted to off-peak times to save money.

**Processors**  
Execute special protection schemes in microseconds.

**Sensors**  
Detect fluctuations and disturbances, and can signal for areas to be isolated.

**Storage**  
Energy generated at off-peak times could be stored in batteries for later use.

**Generators**  
Energy from small generators and solar panels can reduce overall demand on the grid.

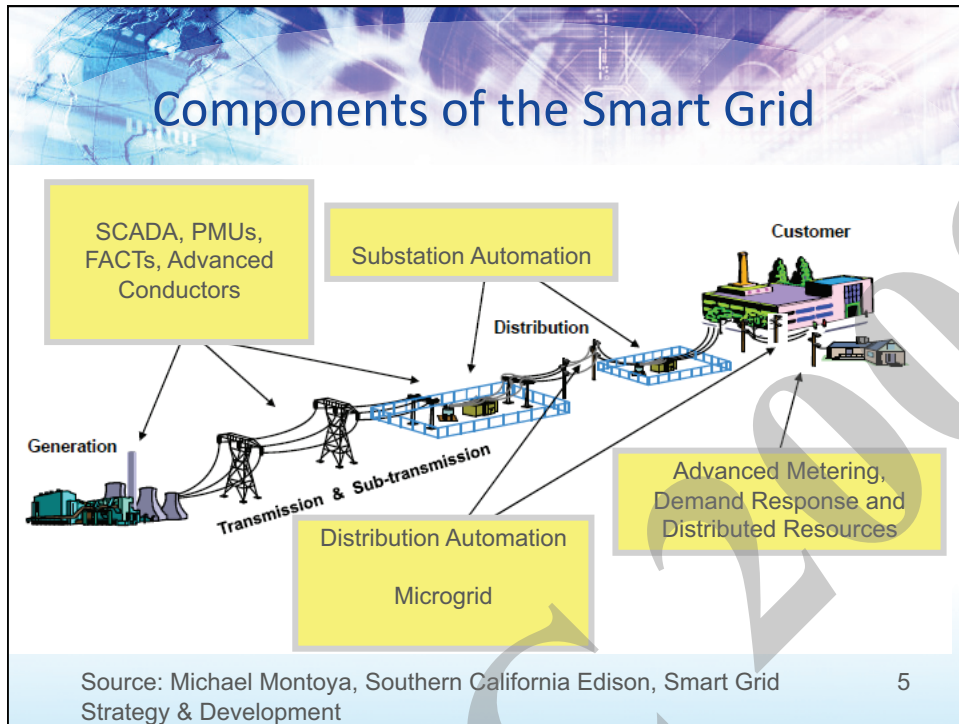
**Disturbance in the grid**  
Isolated microgrid

572

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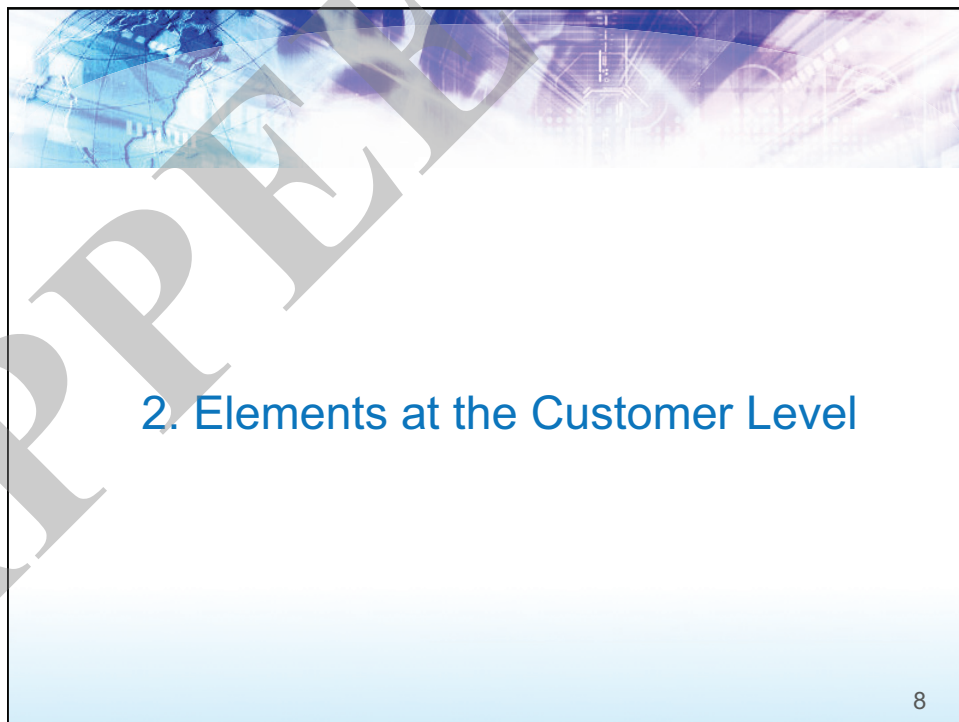
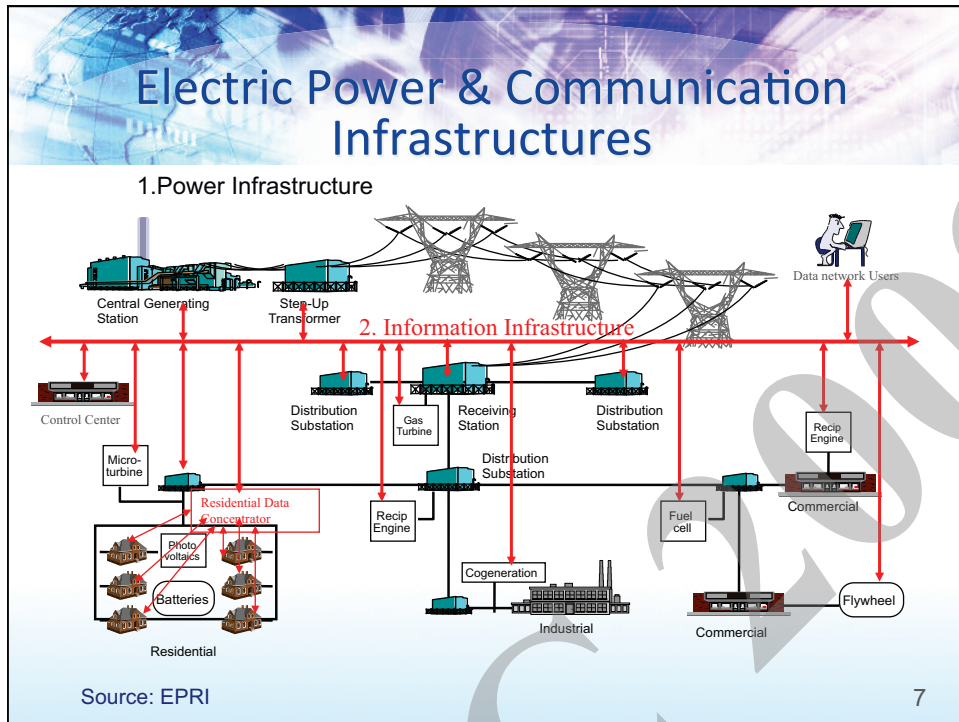
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Source: "Upgrading the Grid", *Nature*, vol 454, pp. 570-573, July 2008



## 1. Integrated Communications

6



## A Conceptual Smart House

**The Smart House**

Xcel Energy's Smart Grid Consortium is imagining a future that would allow you to communicate your energy choices to the power grid and automatically receive electricity based on your personal needs.

**The potential benefits:**

- Lower cost of power
- Cleaner power
- A more efficient and resilient grid
- Improved system reliability
- Increased conservation and energy efficiency

**Plug-in Hybrid Electric Car**

Xcel Energy is studying how plug-in electric vehicles can store energy, act as backup generators for homes and supplement the grid during peak hours.

**Smart Meter**

Real-time pricing signals create increased options for consumers.

**Smart Appliances**

Smart appliances contain on-board intelligence that "talks" to the grid, senses grid conditions and automatically turns devices on and off as needed.

**High-Speed Connections**

Advanced sensors distributed throughout the grid and a high-speed communications network tie the entire system together.

**Customer Choice**

Customers may be offered an opportunity to choose the type and amount of energy they'd like to receive with just the click of a mouse on their computer.

100 percent green power? A mix of sources? The cheapest priced source? In Smart Grid City, it could be up to you.

**Smart Thermostat**

Customers can opt to use a smart thermostat, which can communicate with the grid and adjust device settings to help optimize load management. Other "smart devices" could control your air conditioner or pool pump.

## Customer Gateways


This "energy joule" displays weather forecast, current temperature and current electricity cost.

<http://www.ambientdevices.com/products/energyjoule.html>

**Tendril home display & web access**

<http://www.tendrilinc.com/consumers/products/vantage/>

## Metering Technologies


Traditional Meters	Automatic Meter Reading (AMR)	Advanced Meter Infrastructure (AMI)
		
		
Electromechanical	Hybrid (Electromechanical + Electronic)	Hybrid or Solid State

11

## Customer-Focused Applications for AMI and Customer Gateway


- Pricing:
  - Choices of dynamic pricing, facilitating demand response.
- Outage handling:
  - Automatic response and restoration verification
- Load controls:
  - Customers monitor energy use and determine load control strategies in response to price signals
- Usage information:
  - Real-time meter reading
  - Web data access
  - Hourly, daily or monthly data for customer education

12



3. Renewable Resources as  
Distributed Generation


13



Solar Photovoltaics

14

## Solar Photovoltaics



Roof-mounted Solar panels, Virginia Tech

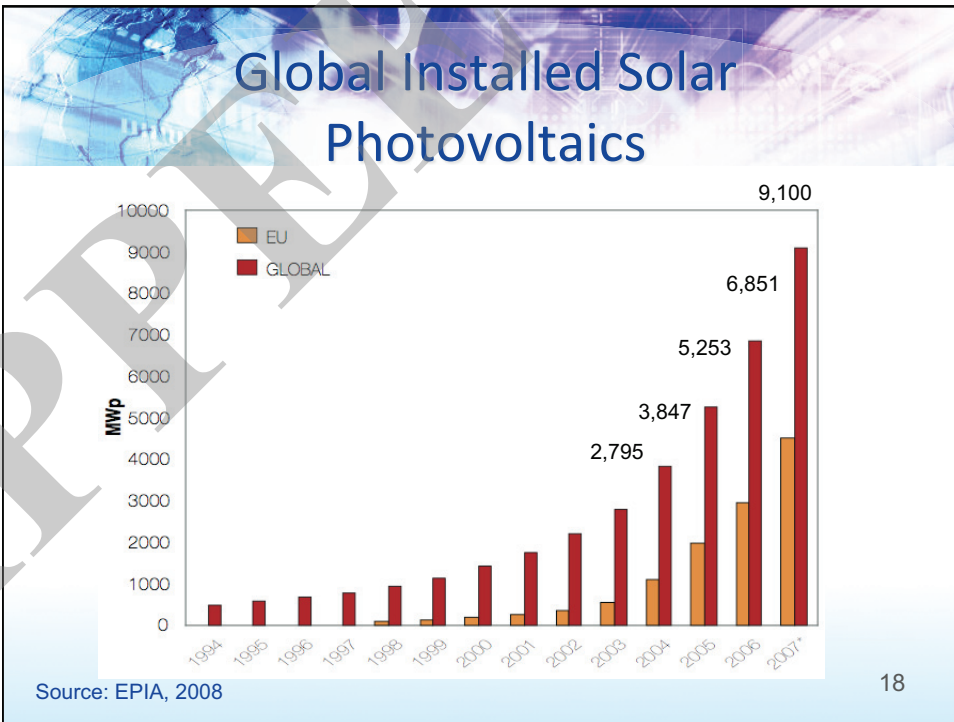
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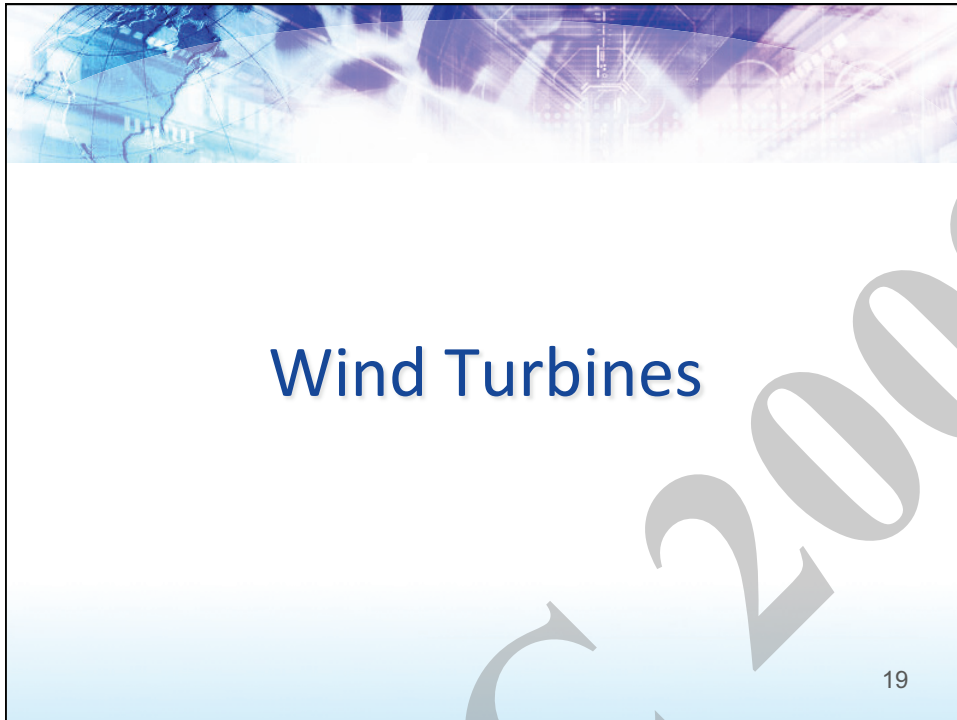
## Grid-connected Photovoltaics, New York City



16





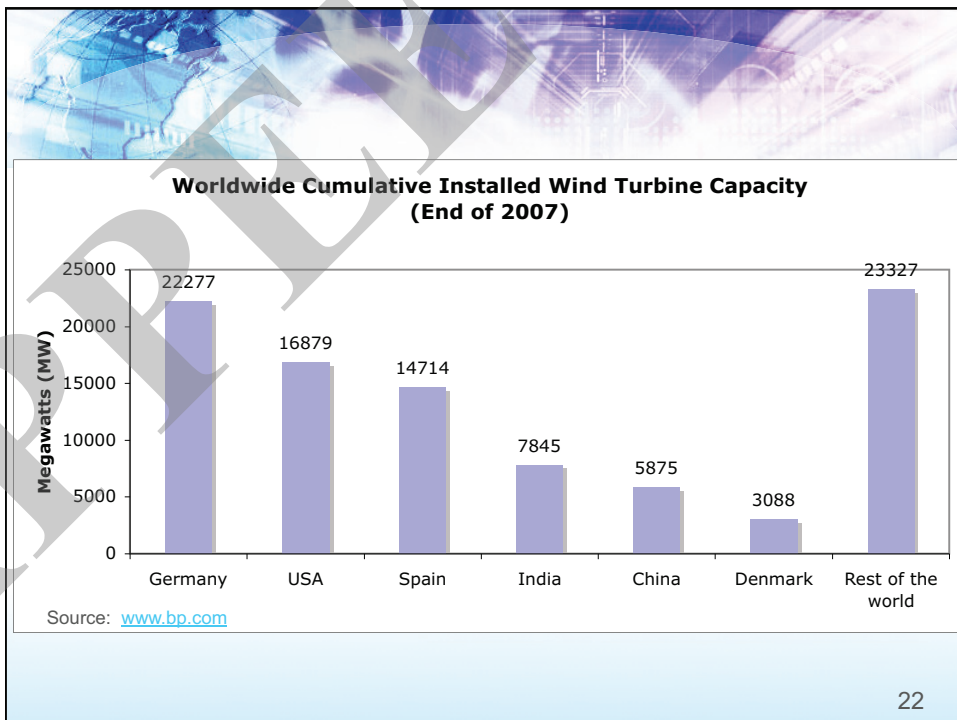


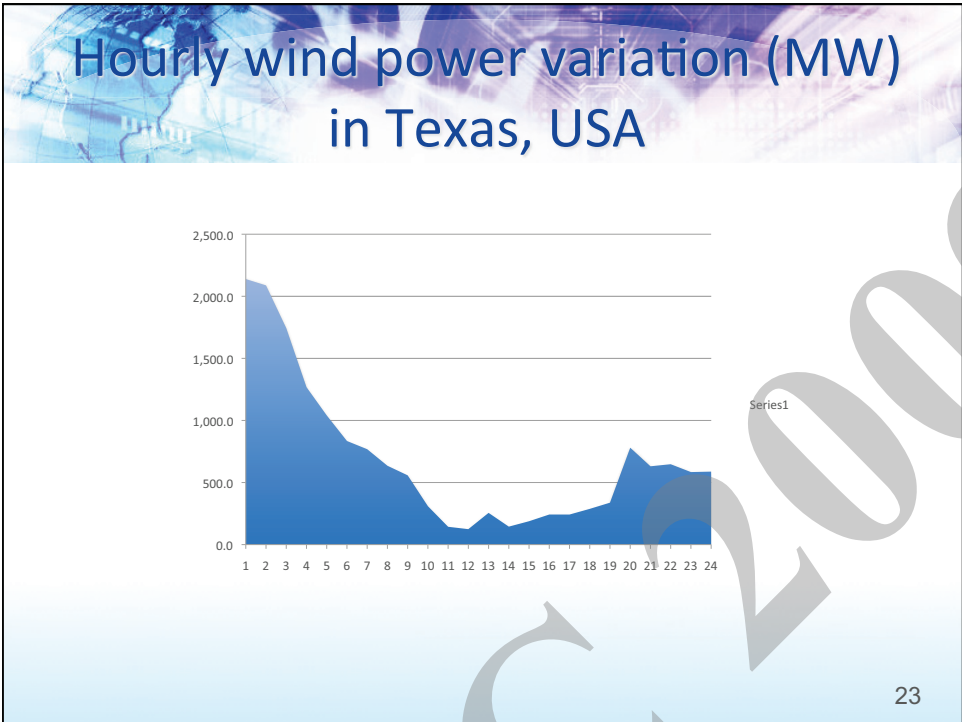
## Wind Farm in Hawaii



Source: NREL

21






### 4. Back-up and Storage Options

1MW Fuel Cell Project  
US Post Office, Anchorage, Alaska

24



## Plug-in Hybrid as a Storage Option

25



### Plug-in Hybrid Electric Vehicle (PHEV)

A plug-in hybrid electric vehicle (PHEV) is a hybrid vehicle with batteries that can be recharged by connecting a plug to an electricity outlet.



**20-40 kWhr of Storage Available**

26

## 4. Cost and Value of Storage Options

Price ranges from  
US \$2,000 to \$4,000 per kilowatt

Return on investment depends  
on life and usage

27

## Impact of Distributed Generation on the Grid

Large Variations in power  
outputs cannot be optimally  
handled by storage and  
back-up generation alone.



Short term load control for a large number of end-  
use devices will make it possible to get quick load  
relief to match fluctuations in generation.

28

## Load Control at Residential Customer Level

Home gateway reads the meter  
Ties to various end-use devices  
Communicates with a service provider

Source: NETL 29

## Demand Response

**Demand response** refers to mechanisms to manage the customer demands in response to supply conditions.

- Shed loads in response to a utility request
- Shed loads in response to market prices
- On-site generation to reduce the demand

**Energy usage monitoring tools:**

<http://www.google.org/powermeter/>

**Kill-a-Watt**  
<http://www.p3international.com/products/special/P4400/P4400-CE.html>

## Grid-Friendly Appliance (GFA) Controller



- GFA is a controller that senses grid conditions by monitoring frequency.
- If a disturbance is detected, the GFA controller will respond by shedding load.
- Example:
  - A GFA-enabled dryer would turn off the heating element but the tumbler would keep turning, resulting in 80-90% load reduction.
  - Appliances are typically turned off for 1-2 minutes

Source: GridWise

31

## Utility's Water Heater Controls



- Water heaters can be controlled in a utility load control strategy.
- Water heaters can be turned off when load peaks.
- Water heaters can be turned off for 30 minutes at a time without customer dissatisfaction.

32



## Summary

- Smart grid makes distributed generation more practical through demand management
- Enabling technologies
  - Integrated communications
  - Sensing and measurement
  - Advanced components
  - Advanced control methods
  - Improved interfaces and decision support
  - Time of Use (ToU) rates

*Thank you for Your Attention*

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