The Electric Grid

Generation, Transmission and Distribution
The Electric Grid - Overview
Electricity Generation
Electricity Generation

- **Baseload Generation**
  - Coal, Fuel Oil, Natural Gas, Nuclear, and Hydroelectric
  - Approximately 90% Capacity Factor

- **Intermediate Generation**
  - Hydroelectric, Diesel, Natural Gas, Combined Cycle Gas
  - Can be load following power plants

- **Peak Load Generation**
  - Natural Gas or Diesel
  - Dispatchable units based on Peak Demand
Independent System Operators & Regional Transmission Organization

- Integrate new generation sources
- Match power generation to consumer demand
- Manage interstate commerce
Generation Fuel Mix


- **Natural Gas**: 34%
- **Coal**: 30%
- **Nuclear**: 20%
- **Renewables**: 15%
Generation Fuel Mix History

U.S. generation and generation share by energy source, 2011-16

- **Coal**
- **Natural Gas**
- **Nuclear**
- **Non-hydroelectric Renewable**
- **Hydroelectric**

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<tr>
<th>Year</th>
<th>Coal Share (%)</th>
<th>Natural Gas Share (%)</th>
<th>Nuclear Share (%)</th>
<th>Non-hydroelectric Renewable Share (%)</th>
<th>Hydroelectric Share (%)</th>
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<td>2011</td>
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Net generation (GWh):

- 2,000,000
- 1,800,000
- 1,600,000
- 1,400,000
- 1,200,000
- 1,000,000
- 800,000
- 600,000
- 400,000
- 200,000
- 0
Transmission System
Transmission System

United States transmission grid
Source: FEMA
Distribution System
Distribution Transformers

[Diagram showing a transformer and labeled parts: Eyebolt, Bracket, Hot clamp, Lightning arrester, Disconnect switch, Fiberglass with polymer ribs insulator]
Industry Concerns
Fossil Fuel Uncertainty

• Coal Plants expected to retire or undergo conversion to Natural Gas
Incorporating Renewables

California’s Renewables (June 20\textsuperscript{th}, 2016)
Incorporating Renewables

Tipmont’s Community Solar Array

637 kWh  604 kWh  564 kWh  316 kWh  458 kWh  337 kWh  530 kWh

May 23  May 24  May 25  May 26  May 27  May 28  May 29
Hawaii Case Study
Too much of a good thing?
Hawaii Case Study
Too much of a good thing?

• Hawaiian electric grid is self-contained
• Heavy reliance on oil for energy generation
  – High Energy Costs
  – High Volatility to Oil Prices
• Significant wind and solar powering their grid
  – Non-Firm Assets
Hawaii Case Study
Too much of a good thing?

Saturday, February 07, 2015

- Maximum Solar Penetration: 63.9%
- Total Solar Contribution: 20.6%
- Maximum Renewable Penetration: 70.7%
- Total Renewable Contribution: 28.3%
Duck Curve

Net load - March 31

Over generation

Comparison for years 2012 to 2017

Tipmont REMC
Your Touchstone Energy Cooperative

Quack!
Hawaii Case Study
Too much of a good thing?

Renewable Watch - Oahu

January 26, 2015
7:55 PM

Current Renewable Power Production (by regions)
- West Solar MW: 0
- Central Solar MW: 0
- East Solar MW: 0
- South Solar MW: 0
- Wind MW: 20.73

North Solar information to be included at a later time.

Information

Renewable Watch shows at a glance the levels of solar and wind power generated on Oahu and how that energy varies throughout the day.

Below are descriptions of what is currently displayed:

- Net System Load: System Load Served by Hawaiian Electric Company
- Gross System Load: Net System Load + Load Served by Behind the Meter PV
- West Oahu Solar Irradiance: Solar Irradiance [W/m^2] Measured in West Oahu
- South Oahu Solar Irradiance: Solar Irradiance [W/m^2] Measured in South Oahu
- Central Oahu Solar Irradiance: Solar Irradiance [W/m^2] Measured in Central Oahu
- East Oahu Solar Irradiance: Solar Irradiance [W/m^2] Measured in East Oahu
- Oahu Wind Production: Wind Power Production on Oahu

Renewable Watch - Previous Day

http://www.pbs.org/newshour/bb/gridlocked-power-grid-hawaiis-solar-energy-industry-crossroads/
Hawaii Case Study
Too much of a good thing?

Renewable Watch - Oahu

Jun 20, 2016
6:24 PM

Information
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Central Oahu Solar Irradiance: Solar Irradiance [W/m^2] Measured in Central Oahu
East Oahu Solar Irradiance: Solar Irradiance [W/m^2] Measured in East Oahu
Oahu Wind Production: Wind Power Production on Oahu

Current Renewable Power Production (by regions)

- West Solar MW: 0.78
- Central Solar MW: 4.19
- East Solar MW: 2.26
- South Solar MW: 4.51
- Wind MW: 32.68

North Solar Information to be included at a later time.

http://www.pbs.org/newshour/bb/gridlocked-power-grid-hawaiis-solar-energy-industry-crossroads/
What is being done?

- **Battery Technology**
  - Tesla Gigafactory (Nevada)
  - Samsung Gigafactory (Hungary)

- **Inverter Technology**
  - Smart Inverters
  - Advanced islanding techniques
  - Solar forecasting
  - Integrate energy management systems
Grid Modernization

- Advanced Metering Infrastructure (AMI)
- Meter Data Management System (MDMS)
- Supervisory Control And Data Acquisition (SCADA)
- Distribution Intelligence (Feeder Automation)
- Geographic Information System (GIS)
- Outage Management System (OMS)
- Demand Response (DR)
- Fiber Optic Communication Backbone
Grid Modernization

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

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

- **Wind farm**

- **Offices**

- **Houses**

- **Disturbance in the grid**

- **Isolated microgrid**

- **Central power plant**

- **Industrial plant**

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

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

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

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

- **Generator**
  - Energy from small generators and solar panels can reduce overall demands on the grid
Questions?