ELECTRIC
UTILITY OF
THE FUTURE

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Everything is Energy

Our energy system is the intentional conversion of certain forms of energy to perform work.
Energy Conversion Megatrends

What (Fuels)

When (Time)

How (Technology)

Why (Workloads)

Where (Location)

Who (Decision-makers)
Net Generation by Energy Source, 2009

- Coal: 45%
- Natural Gas: 23%
- Nuclear: 20%
- Other Gases: 0%
- Hydroelectric Conventional: 7%
- Hydroelectric Pumped Storage: 0%
- Petroleum Liquids: 1%
- Petroleum Coke: 0%
- Other Renewables: 4%
- Other: 0%

Source: Energy Information Administration, Department of Energy
What (Fuels)

Decarbonization

Fossil Fuels

Renewable Energy
### 2030 Projected Resource Mix

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<th>EPA</th>
<th>Google</th>
<th>NREL</th>
<th>UCS</th>
<th>CRA</th>
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<td>Other Renew</td>
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<td>Total Renew</td>
<td>16</td>
<td>67</td>
<td>30</td>
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<td>16</td>
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Source: Peter Fox-Penner, *Smart power, Climate Change, the Smart Grid, and the Future of Electric Utilities*
What (Fuels)

From Few To Many

- Oil
- Nuclear
- Solar
- Geothermal
- Gas
- Hydro
- Wind
- Ocean
- Biofuel
- Synthetic Liquid
- Coal
What [Fuels]
The Transition Will Be Slow
Energy Transition History

- Wood
- Wood to Coal
  - Industrial Revolution
- Transition to Oil
  - Vehicles
- Driven by Technological Development
  - But slow until breaking point is reached

Graph showing the transition from Wood to Coal to Oil to Natural Gas and Petroleum, with a peak around 1950.
Energy transitions take decades, if not centuries

Large sunk investments in current system

Extensive and expensive new infrastructure requirements

Persistence and adaptability of established prime movers

Skilled labor requirements
How (Technology)

- Electricity
- Planes
- Cars & Trucks
- Shipping
More productivity from less material

"Accelerating Ephemeralization" – Fuller

"Law of Accelerating Returns" – Kurzweil

"Moore’s Law" – Moore
More productivity from less motion – Principle of Least Action

Pierre-Louis Moreau de Maupertuis
Leonhard Euler
Gottfried Wilhelm Leibniz
Technology Megatrend
Embedded Intelligence

Sensors and Actuators

Engineering Specifications
Technology Megatrend

Engineering Specifications

Water Wheel

Turbine
Where (Location)

Decentralization

Increase space used
Area to Power 100% of U.S. Onroad Vehicles
Shifting the time of both energy conversion and consumption is a game changer for utilities, transportation and buildings.

Ordinary materials may become storage capacity.
**Why (Workloads)**

- Electrification of transportation system
- Computer loads
- Electrification of industrial processes
- Robotics
Sam Insull
Centralized Power Plants
Transmission and Distribution System
Volume
Regulated Monopoly
Future Business Models

- Services vs. Commodity
- Broker of distributed power
- Smaller, discrete companies
- Energy storage and ancillary service companies
- Centralized power for industry
Future Utility Business Models

Energy Service Utility

Smart Integrator
Future Role of Grid

- Coordination and Integration among multiple suppliers and distributed generation
- Broker of energy sales
- Moving energy among storage and demand
- Power Quality protection
The New Prosumer

- We produce more of what we consume
- Building owners will be both buyers and sellers of electricity
- Dynamic pricing will be key
- Computer interface will develop as “decision maker”
Future Fuels

Solar
Regional Renewables
Synthetic Liquid Fuels

Nuclear
Hydrogen Economy
Niche Fossil Fuels
Nanotechnology and Energy

- Low cost solar cells
- Hydrogen production from water
- Catalysts for clean manufacturing
- Solid state lighting
- Super strong lightweight materials
- Transmission lines
- Energy Storage
Future Technology

- Nanotechnology
- Biotechnology
- Superconductors
- Nuclear Fusion
- Carbon Capture and Sequestration
- Ubiquitous Sensing
- Ubiquitous Computing
- Robotics/Al
Robotics and Energy

- Manufacturing
- Service Robots
- Domestic Robots
- Building construction
- New energy loads
- Ubiquitous sensing, computing, automation
“Is a Thermostat Conscious?”
- David Chalmers
Sentient Appearing Machines (SAM)

Optimization

Delegation of Decision Making
Energy Systems of the Far Future

- Multiple Energy Sources
- Highly Integrated between buildings, transportation and generation sources
- Complex Prosumer relationships
- Ubiquitous Sensing and Computing
- Zero Carbon
- Sentient Appearing buildings and machines
Utility of the Future

PHEV/BEV

Distributed Utility

Fossil Fuels

Nuclear

Solar

Wind

Zero Energy Home
Megatrend’s Summary

Decarbonization  Conversion Efficiency  Prosumerism