Integrating Humboldt County Energy Systems

Maximizing Local Renewable Energy
Michael Winkler – Schatz Energy Research Center
Structure of Humboldt County Energy, 2007

- Three Separate Systems
  - Electricity
  - Transportation
  - Heating
Humboldt County Energy (2007)

- Running primarily on fossil fuels
- One-way flow of energy from sources to users
- Generators use fuels
- Grid operator controls output of generators to meet independent time-varying demands
Energy Systems Analysis Model (Humboldt 2007)

Grid Operator Controls Fuel/Storage Based Generators to Meet Time-Varying Demand

Problems with Existing Energy Sources

- Imported from outside the County and outside the U.S.
- Fossil Fuels
- \( \text{CO}_2 \)/Global Climate Change
- Major financial drain on citizens and community
Humboldt County Renewable Energy Opportunities

- Major renewable energy potential in County
- Much greater than total current County consumption (electricity, transportation, heating)
Barriers to Increasing Renewables

- Demand mostly for fuels, Supply mostly electricity
- Most renewables are intermittent; Supply/Demand time mismatch
- Transmission line capacity limits exports and imports
- Cost
Solution – Create Single Integrated Energy System

1. 100% renewable, eliminate fossil fuels
2. Heating – switch to electric heating (heat pumps)
3. Transportation – switch to Plug-In Hybrids and H$_2$ (ICE’s & fuel cells)
4. Energy Storage – vehicle batteries, H$_2$
5. Flexible Demand
6. Smart Grid – control demand, storage and biomass generators
7. Energy Efficiency – reduce demand
8. Financing - Revenue bonds through JPA/CCA
Grid Operator uses Demand Control and Storage to Match Time-Varying Demand with Time-Varying Supply

- Firm Power: Electricity Import/Export
- Source: Sunlight, Wind, Waves, Trees, River Water
- Fuels/Storage: Wood Waste, WW Plant, Dam, Hydro Plant
- Converters: Motor Vehicles, Wave Generators, Batteries, Hydrogen, Fuel Cell PP, Electrolyzer
- Demand: Transportation Demand, Energy Demand
- Grid Control: Demand Control, Conservation/Efficiency, Generator Control

Energy Flows:
- Renewables: Electricity, Heat/Cold, Hydrogen, Transportation Energy Control

Symbols:
- Renewable Energy Source
- Energy Storage
- Energy Converter
- Energy Control
- Energy Demand

<table>
<thead>
<tr>
<th></th>
<th>Current System</th>
<th>100% Renewable System</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Renewable</td>
<td>11%</td>
<td>100%</td>
</tr>
<tr>
<td>% Imported</td>
<td>89%</td>
<td>0%</td>
</tr>
<tr>
<td>Electricity Sources</td>
<td>Mostly fossil fuels</td>
<td>100% Renewable</td>
</tr>
<tr>
<td>Vehicle Fuels</td>
<td>Gasoline and Diesel</td>
<td>Electricity and H₂</td>
</tr>
<tr>
<td>Heating Fuels</td>
<td>NG, Wood &amp; Propane</td>
<td>Electricity &amp; Wood</td>
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<tr>
<td>Generation Sources</td>
<td>Available on demand</td>
<td>Random output</td>
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<tr>
<td>Loads</td>
<td>Random &amp; Independent</td>
<td>Demand-Responsive</td>
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<tr>
<td>Demand</td>
<td>Immediate</td>
<td>Flexible</td>
</tr>
<tr>
<td>Use of transmission lines</td>
<td>Import only</td>
<td>Bi-directional</td>
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<tr>
<td>Energy Storage</td>
<td>Mostly fossil fuels</td>
<td>Vehicle batteries, H₂ &amp; Biomass</td>
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<tr>
<td>Rates (commercial &amp; industrial)</td>
<td>Time of use</td>
<td>Real time, Flexible Demand</td>
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<tr>
<td>Rates (residential)</td>
<td>Flat</td>
<td>Real time, Flexible Demand</td>
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<tr>
<td>Meter Reading</td>
<td>In person</td>
<td>Remote</td>
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<tr>
<td>Grid Back-up</td>
<td>None</td>
<td>Vehicles</td>
</tr>
<tr>
<td>Net CO₂ Emissions</td>
<td>High</td>
<td>None</td>
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<tr>
<td>Energy Costs</td>
<td>Mostly fuel costs</td>
<td>Equipment and Labor</td>
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<tr>
<td>Energy Prices</td>
<td>Volatile</td>
<td>Stable</td>
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<tr>
<td>Home refueling</td>
<td>No</td>
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</table>
EnergyPlan Model

- Energy Analysis Software
- Designed to do Energy Scenarios for Single Countries
- Developed by Henrik Lund, University of Aalborg, Denmark
- Free to download and use
Simulations of Humboldt County Energy Use

- Simulations performed using data from: “HUMBOLDT COUNTY GENERAL PLAN 2025 ENERGY ELEMENT BACKGROUND TECHNICAL REPORT”
Energy Units of Measurement

- **Power - Rate of Energy Flow**
  - W – Watt, unit of electric power
  - KW – Kilowatt, 1000 Watts
  - MW – Megawatt, 1 Million Watts

- A toaster uses about 1 KW
- PG&E power plant is 137 MW peak

- **Energy Quantity**
  - Wh - Watt-hour, One Watt of power for one hour
  - kWh – kilowatt-hour, 1000 Wh, Units on your electric bill
  - MWh – Megawatt-hour, 1000 kWh
  - GWh – Gigawatt-hour, 1 Million kWh
  - TWh – Terawatt-hour, 1 Billion kWh

- Typical family uses 600 kwh/month
- County electricity consumption was 0.94 TWh (2003)
### Humboldt County Energy Simulations (Sources)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>Heat Pumps, Smart Grid</td>
<td>Plug-in Gasoline Hybrids</td>
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<td>Heat (space, H₂O)</td>
<td>Refrigeration</td>
<td>Water Pumping</td>
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- **Heat-Natural Gas**
- **Transportation-Gasoline/Diesel**
- **Electricity-Natural Gas**
- **Heat-Propane**
- **Electricity-Net Imports**
- **Electricity-Hydro**
- **Electricity-Solar**
- **Heat-Biomass**
- **Electricity-Biomass**
- **Electricity-Wind**
- **Electricity-Waves**

**Scenarios**

- **1:** 2007 Status Quo
- **2:** 100% Local Renewables for Electricity
- **3:** Heat Pumps, Smart Grid
- **4:** Plug-in Gasoline Hybrids
- **5:** Plug-in H₂ ICE Hybrids
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Humboldt County Energy Simulations

Wind + Waves (MW peak)

Scenario #

- New Renewables (wind first)
- New Renewables (waves first)
### Humboldt County Energy Simulations

#### Local Renewables Production vs. CO2 Emissions

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<th>CO2 Emissions (Mt/year)</th>
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<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
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<tr>
<td>3</td>
<td>3</td>
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<tr>
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#### Technologies

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### Humboldt County Energy Simulations

- **Heat (space,H₂O)**
- **Refrigeration**
- **Water Pumping**
- **Flexible Demand**
- **Vehicle Batteries**
- **Plug-in H₂ Fuel Cell Hybrids**
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**Scenarios**

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**Local Renewables Production**

- **CO2 Emissions**
Key Technologies

- Wind Turbines
- Wave Generators
- Smart Grid
- Heat Pumps
- Flexible Demand
- Plug-In Hybrid Electric Vehicles
- Hydrogen
- Fuel Cells
Wind Turbines

- Cost-competitive with coal and natural gas at best sites
- High annual growth rate
- Major electricity source in Denmark and Germany
- Intermittent output perceived as barrier
- Large wind potential in Humboldt County (up to 1 Billion kwh/year)
Wave Generators

- Prototypes exist in Europe
- DG Energy proposing large system (60 MW) for Humboldt County
- PG&E doing multi-year wave energy analysis off our coast
- Resource in Humboldt County up to (5 Billion kwh/year), enough to meet all County energy needs
Electric Grid (Structure)

1. Transmission and distribution lines move electricity from generators to end users
2. Flow of current is two-way (Alternating Current)
3. Flow of energy is one-way (limited exceptions)
4. Grid controlled by Cal ISO (Independent System Operator)
5. No electricity storage; energy used as it is generated
6. No real-time information on individual end-users
Electric Grid (End Users)

- Independent
- Can take any quantity of energy at any time without advance notice
Electric Grid (Cal ISO)

- Controls generator output and energy flow to meet end-user demands
Electric Grid (future smart grid)

- PG&E and other utilities have begun implementing “Advanced Metering Infrastructure (AMI)”
- AMI will allow PG&E to do remote meter reading
- AMI will be two-way and could allow PG&E to monitor and control end-user equipment
- PG&E likely to implement near real-time electric rates (some utilities already have)
Heat Pumps

- Move heat from cold to warm (opposite direction of spontaneous flow)
- Allow replacement of Natural Gas with electricity for heating
- Heat Pumps are the most efficient form of electric heating
- In widespread commercial use
Flexible Demand

- Many end uses need electricity during a period of time; not at a precise time
- Grid operator can send electricity to flexible end uses when supply > demand
- Reduced independent demand improves grid balance
- Allows grid operator to adjust to:
  - changing output from intermittent renewables
  - changing demand from end users
Flexible Demand (examples)

- Space heating and water heating (especially with hot water storage)
- Refrigeration and air conditioning (especially with ice & chilled water storage)
- Water and wastewater pumping (especially with water storage)
- Ventilation (minimum ACH & CO$_2$)
Plug-In Hybrid Electric Vehicles

- Much larger battery packs than existing hybrids
- Could run up to 60 miles on batteries alone
- Batteries mostly recharged by plugging into grid
- Could store excess electricity from intermittent renewables
- Could run on electricity or fuel (gasoline, Diesel, Natural Gas, H₂)
- Prototypes exist; GM promising production in 3 years
Hydrogen

- Could store excess electricity from intermittent renewables
- Could replace gasoline/Diesel in plug-in hybrids
- Better than batteries for large-scale, long-term storage
- Could be used with ICE’s or fuel cells
- Not cost effective until fossil fuels much more expensive
Fuel Cells

- Like a battery with an external fuel supply
- $\text{H}_2$ combined with $\text{O}_2$ from the air to produce electricity
- High efficiency, very low pollution
- Cost & lifetime need to significantly improve
Conclusions:

Benefits of Proposed Systems

1. Allow up to 100% renewables (up to 70% from intermittent sources)
2. Lower overall cost of energy
3. Allow greater use of local energy sources
4. Increase effective capacity of transmission lines
5. Prevent grid overloads and blackouts
6. Provide backup for end users when grid is down
7. Increased information for users
8. Increased energy security
Conclusions

- Humboldt County has renewable resources great enough to meet all our energy needs
- Integrating electricity, heating and transportation into a single energy system would enable us to eliminate fossil fuel use and net electricity imports
- Energy Storage, Flexible Demand and a Smart Grid are needed to operate an integrated system
- An integrated system would have many benefits for our county:
  - Economic
  - Environmental
  - Security