The Economics of Clean Energy Development in Humboldt County:
Preliminary Results from a Renewable Energy Secure Communities (RESCO) Study

Dr. Steven Hackett and Luke Scheidler
Schatz Energy Research Center
February 24, 2011
Sustainable Futures Speaker Series
Copyright © Schatz Energy Research Center 2011
RESCO Participants and Sponsors

- Redwood Coast Energy Authority - Lead Agency
- Schatz Energy Research Center - Primary Research Team
- Pacific Gas and Electric Company - Integration Issues
- Local Stakeholders - Input on Strategic Plan
RESCO Project Goals

- Create strategic plan to develop local renewable energy resources to meet 75%-100% of local electric demand and a significant fraction of heating and transportation energy needs
- Identify integrated mix of renewables that can be coupled with demand management and grid-integration technologies to best capture environmental, economic, and social benefits for Humboldt County
- Develop a long-term development strategy and identify near-term next steps
- Build local support for the RESCO vision
Fall Presentation Recap

- The basis for clean energy development in Humboldt County
- SERC optimization model preliminary results
Humboldt is Unique

Energy transmission constrained

Geographically isolated
Humboldt’s Energy Resources

Conventional Energy

- **Natural Gas:** pipeline connection with limited production in Eel River Valley; used for electricity, heating, and process needs

- **Conventional Electricity:** Local natural gas powered generation and imported from western US grid via interconnection lines

- **Transportation Fuels:** Gasoline and diesel barged into the county
Humboldt’s Energy Resources
Biomass as a key resource today and in the future
Humboldt’s Energy Resources

Emerging resources: Wind, wave, solar, and hydro
Humboldt’s Energy Sector
State, national, and global political context

California policy:
- AB 32 upheld in recent election – Greenhouse gas (GHG) reduction goal of “1990 levels by 2020”
- Reach 20% of 1990 levels by 2050 (S-3-05)
- Held up in court?

National action fragmented and/or stalled:
- Legislative action to address GHG pollution stalled
- Action is fragmented and regional at best

International trends:
- EU as policy leader
- China as RE equipment manufacturing leader
Climate Change Imperative

Potential 100-yr temperature rise in California

Mean July temperatures

Source: Dan Cayan et al. 2009.
Climate Change Imperative
Coastal communities at risk

Lost property estimates after 100-year flood with 1.4 meter sea level rise.

Heberger et al. (2009) CEC 500-2009-024-F

Del Norte $0.35 billion
Humboldt $1.4 billion
Mendocino $0.15 billion

Replacement value of buildings and contents (billions of dollars*)
- 0.1
- 1
- 10

* Values are in year 2008 dollars
Data sources: USGS/Scipps Institution of Oceanography, FEMA HAZUS model, CalSIS, EDRH.
http://www.pacifici.org/reports/sea_level_rise
San Francisco International Airport
One Meter Sea Level Rise

Flight delays, anyone?

Oakland International Airport
One Meter Sea Level Rise
Optimization Model Framework

Key Inputs: Demand levels, installed capacities

Demand Modules
- Electricity
- Heat
- Transportation
- Efficiency

Supply Modules
- Natural Gas
- Photovoltaic
- Wind
- Wave
- Hydroelectricity
- Biomass

Balance Support Modules
- Import / Export
- Elec. Storage
- Elec. Load Shift

Energy Balance Algorithm
- Supply Dispatch
- Grid Stability
- Power Reliability

Post Processing
- Economics:
  - Cost of Energy
  - Job Creation
  - Local Economy
- RESCO Goals:
  - GHG Emissions
  - Fraction Renewables

Key Outputs: Cost of Energy, GHG Emissions, Service Quality
"Unconstrained" by cost. Other constraints on transportation and heating fuel utilization prevent greater carbon emissions reductions in the model.
Preliminary Results

Achieves ~80% RE, and is made up primarily of wind, biomass, and small hydro. This scenario also features an approximate load reduction of 5% through increased energy efficiency programs and load building through a 30% penetration of heat pumps and a 38% penetration of electric vehicles.
Preliminary Results

Much of the 5% increase in cost is due to investment in electrified vehicles and alternative heating strategies like heat pumps.
Today’s Talk

- Deriving the costs of:
  - renewable energy
  - reducing petroleum use in transportation
  - energy efficiency
- Economic value of avoided emissions
- Economic impact analysis modeling concept and purpose
- Economic impacts of renewable energy and energy efficiency
- Summary of benefits
Cost Terms

Three main indicators of cost:
- Instant capital cost
- Marginal cost of supply
- Levelized cost of energy (LCOE)

Other important considerations:
- Environmental impacts
- Financing and ownership structures (not today)
- Political environment (not today)
Cost of Development

Cost of Energy

Humboldt County Marginal Cost of Supply

- Solar PV
- Wind
- Wave
- Biomass
- PG&E IC Engines - Natural Gas

Generating Capacity (MW)
Marginal Cost of Supply ($/MWh)
Cost of Energy

Levelized Cost of Energy Estimates

<table>
<thead>
<tr>
<th>Technology Type</th>
<th>Literature Average</th>
<th>Humboldt County Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>$50</td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$90</td>
<td>$134</td>
</tr>
<tr>
<td>Wave</td>
<td>$90</td>
<td></td>
</tr>
<tr>
<td>Hydro</td>
<td>$82</td>
<td>$116</td>
</tr>
<tr>
<td>Solar PV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Range of LCOE Estimates w/ Humboldt County Estimates Displayed (2010$/MWh)

Transportation Fuels

Humboldt County End Use Energy Consumption, 2003
(17.38 trillion BTUs)

- Natural gas: 28%
- Gasoline/diesel: 49%
- Electricity: 18%
- Wood: 3%
- Propane: 2%

Humboldt County End Use Energy Expenditures, 2003
($319.4 million)

- Natural gas: 11%
- Gasoline/diesel: 43%
- Electricity: 42%
- Propane: 3%
- Wood: 1%

Source: Zoellick et al., 2005
Transportation Strategy

- There are many ways to reduce petroleum use in transportation
  - Fuel switching
  - Carpooling
  - Public transit
  - Bicycles
- Today we will focus our discussion on the costs associated with fuel switching
Transport Economy

### mi/$ (in charge depleting mode)

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>PHEV 10 (Prius)</th>
<th>PHEV 40 (Volt)</th>
<th>EREV 30</th>
<th>EREV 40 (Volt)</th>
<th>BEV 100 (Leaf)</th>
<th>Average EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>mi/$</td>
<td>8.2</td>
<td>28.0</td>
<td>28.2</td>
<td>29.7</td>
<td>29.4</td>
<td>31.8</td>
<td>29.4</td>
</tr>
</tbody>
</table>

Based on Santini et al. (2010) study on vehicle performance and cost, $4/gal gas., $0.12/kWh
Electric Vehicle Cost

Estimated PV Total Cost of Ownership (2010)

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>PHEV 10 (Prius)</th>
<th>PHEV 40 (Volt)</th>
<th>EREV 30</th>
<th>EREV 40 (Volt)</th>
<th>BEV 100 (Leaf)</th>
<th>Average EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>$19,715</td>
<td>$31,636</td>
<td>$37,782</td>
<td>$38,510</td>
<td>$40,280</td>
<td>$45,000</td>
<td>$38,765</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>$13,208</td>
<td>$7,699</td>
<td>$6,350</td>
<td>$6,514</td>
<td>$6,173</td>
<td>$3,328</td>
<td>$5,908</td>
</tr>
</tbody>
</table>

Based on Santini et al. (2010) study on vehicle performance and cost, EPRI utility factors, 11 yr lifecycle of 11,000 mi traveled/yr, $4/gal gas., $0.12/kWh, and a 6.4% discount rate.
Electric Vehicle Cost

Based on Santini et al. (2010) study on vehicle performance and cost, EPRI utility factors, 11 yr lifecycle of 11,000 mi traveled/yr, $4/gal gas., $0.12/kWh, 6.4% discount rate, and static fuel economy,
Energy Efficiency
Residential Energy Efficiency

Residential Energy Efficiency Potential and Costs
Electricity: 2007-2026

Levelized Cost of Energy

- **$0.027/kWh**: 286 GWh
- **$0.032/kWh**: 213 GWh
- **$0.040/kWh**: 149 GWh

SCHATZ ENERGY RESEARCH CENTER

Humboldt County Renewable Energy Secure Community
Residential Energy Efficiency

Residential Electrical Market Potential Supply Curve, 2007-2026

Cumulative GWh Market Savings Potential, 2007-2026

LCOE ($/kWh)

0

$0.00

$0.05

$0.10

$0.15

$0.20

$0.25

0

100

200

300

400

500

600

700

Cumulative GWh Market Savings Potential, 2007-2026

Water Heating

Misc.

Lighting

HVAC

Base

Mid

Full

SCHATZ ENERGY RESEARCH CENTER
Commercial Energy Efficiency

Commercial Energy Efficiency Potential and Costs
Electricity: 2007-2026

Levelized Cost of Energy

Electricity Savings (GWh)

- $0.055/kWh: 71 GWh
- $0.061/kWh: 53 GWh
- $0.080/kWh: 58 GWh

SCHATZ ENERGY RESEARCH CENTER
Commercial Energy Efficiency

Commercial Electrical Market Potential Supply Curve, 2007-2026

LCOE ($/kWh)

Cumulative GWh Market Savings Potential, 2007-2026

SCHATZ ENERGY RESEARCH CENTER
Energy Efficiency Costs and Savings

Costs and Savings from Utility Electrical Efficiency Programs
2007-2026

Scenario
- Full
- Mid
- Base

NPV of 20 yr Costs and Savings ($)

- Consumer Savings
- Consumer Cost
## GHG Damage Costs

### Potential Damage Costs at the Humboldt Bay Power Plant

<table>
<thead>
<tr>
<th>Marginal damage cost per ton CO$_2$e</th>
<th>@$30/ton CO$_2$e</th>
<th>@$50/ton CO$_2$e</th>
<th>@$100/ton CO$_2$e</th>
<th>@$120/ton CO$_2$e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal damage cost per MWh</td>
<td>$14</td>
<td>$24</td>
<td>$47</td>
<td>$57</td>
</tr>
</tbody>
</table>

If this were the price on carbon, this would be added to the cost of generation at the natural gas plant.
# Cost of Avoided GHGs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>$51</td>
<td>-$40</td>
<td>-$84</td>
</tr>
<tr>
<td>Wind</td>
<td>$82</td>
<td>-$8</td>
<td>-$17</td>
</tr>
<tr>
<td>Hydro</td>
<td>$90</td>
<td>-$1</td>
<td>-$1</td>
</tr>
<tr>
<td>Biomass</td>
<td>$116</td>
<td>$26</td>
<td>$54</td>
</tr>
<tr>
<td>Wave</td>
<td>$135</td>
<td>$45</td>
<td>$94</td>
</tr>
<tr>
<td>EV</td>
<td></td>
<td>$340 (2010) ➔ $17 (2030)</td>
<td>$1,253</td>
</tr>
<tr>
<td>Solar</td>
<td>$685</td>
<td>$595</td>
<td></td>
</tr>
</tbody>
</table>

Carbon Price $30/ton CO$_2$e
## Criteria Pollutant Damage Costs

### Humboldt County Damage Costs ($/ton)

<table>
<thead>
<tr>
<th>Criteria Pollutant</th>
<th>Ground Level</th>
<th>Low Point Sources</th>
<th>High Point Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (NH₃)</td>
<td>$608</td>
<td>$515</td>
<td>$309</td>
</tr>
<tr>
<td>Particulate Matter (2.5)</td>
<td>$393</td>
<td>$337</td>
<td>$249</td>
</tr>
<tr>
<td>Nitrogen Oxides (NOₓ)</td>
<td>$139</td>
<td>$57</td>
<td>$153</td>
</tr>
<tr>
<td>Sulfur Dioxide (SO₂)</td>
<td>$527</td>
<td>$468</td>
<td>$378</td>
</tr>
<tr>
<td>Volatile Organic Compounds (VOC)</td>
<td>$51</td>
<td>$50</td>
<td>$74</td>
</tr>
<tr>
<td>Particulate Matter (10)</td>
<td>$129</td>
<td>$112</td>
<td>$69</td>
</tr>
</tbody>
</table>

Source: Muller and Mendelsohn (2009)
## Criteria Pollutant Damage Costs

### National Average Damage Costs ($/MWh)

<table>
<thead>
<tr>
<th>Criteria Pollutant</th>
<th>National Average ($/MWh)</th>
<th>Humboldt County ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coal</td>
<td>Natural Gas</td>
</tr>
<tr>
<td>Particulate Matter (2.5)</td>
<td>$3.10</td>
<td>$1.80</td>
</tr>
<tr>
<td>Nitrogen Oxides (NO\textsubscript{x})</td>
<td>$3.60</td>
<td>$2.40</td>
</tr>
<tr>
<td>Sulfur Dioxide (SO\textsubscript{2})</td>
<td>$39.80</td>
<td>$0.20</td>
</tr>
<tr>
<td>Particulate Matter (10)</td>
<td>$0.20</td>
<td>$0.10</td>
</tr>
<tr>
<td>Volatile Organic Compounds (VOC)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Input-Output (I-O) Economics

- Wassily Leontief, credited with development of I-O analysis
- Published *Input-Output Economics* in 1966, won Nobel Prize for Economics in 1973
- The theory is based on the idea that inter-industry interactions can be used to model economic impacts
A Model of the Local Economy

Income Injections: Generated by activities such as the export sale of locally produced goods and services, by taxes or transfers paid to local entities, or by tourist visits to the local area.

Level of local income reflects the balance of income injections and income leakages over time.

Income Leakages: Generated by activities such as the import purchase of externally produced goods and services, by taxes or transfers paid to outsiders, or by locals traveling outside the local area.
Impact Model Elements

- Project Cost Breakdown
- % Local Inputs
- BEA Model of Local Economy (538 x 538 Fixed Coefficient Matrices)
I-O Multipliers

![Illustrative Total Inter-industry Requirements Table*](image)

<table>
<thead>
<tr>
<th></th>
<th>Industry A</th>
<th>Industry B</th>
<th>Industry C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry A</td>
<td>1.82</td>
<td>0.73</td>
<td>0.64</td>
</tr>
<tr>
<td>Industry B</td>
<td>0.69</td>
<td>2.03</td>
<td>1.01</td>
</tr>
<tr>
<td>Industry C</td>
<td>0.78</td>
<td>0.69</td>
<td>1.77</td>
</tr>
<tr>
<td>Total</td>
<td>3.29</td>
<td>3.45</td>
<td>3.42</td>
</tr>
</tbody>
</table>

* Total local production required by each producing sector listed in the rows to satisfy each dollar of new demand from each producing sector listed in the columns.

Given the input-output relationships in the illustrative economy, Table 29 shows that each $1 of sales by Sector A, B, and C respectively increases total regional economic production by $3.29, $3.45, and $3.42.
Economic Impact Assessment

Uses local multipliers to predict the economic impact from an exogenous shock to the local economy.

Defining Economic Development Impacts

1. On-site Labor and Professional services
2. Turbine Production and Supply Chain Impacts
3. Induced Impacts (Household purchases due to injection of income)

Source: NREL, 2009
JEDI Models

- Jobs and Economic Development Impacts (JEDI) Model
  - Created by NREL to allow for a simple economic impact assessment based on the amount of RE developed.
  - Builds on IMPLAN – dominant computer modeling software.
- NREL collects renewable energy industry cost data that is essential for I-O analysis. Applicable JEDI Models: Wind, Solar Photovoltaic, Natural Gas (Combined Cycle)
- Upcoming JEDI Models: Hydro (Conventional and Wave/Tidal), Biomass.
JEDI Models

Basic inputs:
- Project location
- Project size (MW)/CF (%)
- Installed project cost ($/kW)
- O&M cost ($/kWh)

Advanced inputs:
- Equipment cost (% local)
- Labor cost (% local)
- Financing and tax parameters
- Many other options

Basic outputs:
- Job creation
- Earnings
- Economic output
SERC Models

- Not all JEDI models available
- Reverse-engineered (and in places improved or fixed) JEDI
- SERC Models
  - Biomass
  - Wave
  - Hydroelectric
  - Energy Efficiency
## Project Descriptive Data

**Project Location:** Humboldt County

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Hourly Wage for Power Plant Workers</td>
<td>$27.85</td>
</tr>
<tr>
<td>Average Hourly Wage for Constr. &amp; Extraction</td>
<td>$19.30</td>
</tr>
<tr>
<td>Total Project Size - Nameplate Capacity (MW)</td>
<td>15</td>
</tr>
<tr>
<td>Estimated Cost ($/kW) of Installed Biopower Plant</td>
<td>$3,447.00</td>
</tr>
<tr>
<td>Project Cost</td>
<td>$51,705,000.00</td>
</tr>
<tr>
<td>Estimated Annual Plant Capacity Factor</td>
<td>85.00%</td>
</tr>
<tr>
<td>Fixed O&amp;M Costs ($/kW)</td>
<td>$160.10</td>
</tr>
<tr>
<td>Variable O&amp;M Costs (not including fuel) ($/MWh)</td>
<td>$6.98</td>
</tr>
</tbody>
</table>

**Fuel Cost Calculations**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass Fuel Cost ($/BDT)</td>
<td>$32</td>
</tr>
<tr>
<td>Typical Biomass Plant Burn Rate (BDT/MWh)</td>
<td>1.1</td>
</tr>
<tr>
<td>Total annual plant production (MWh/yr)</td>
<td>111,690</td>
</tr>
<tr>
<td>Total Annual Fuel Cost ($/yr)</td>
<td>$3,931,488</td>
</tr>
</tbody>
</table>
Job Creation Impacts

Construction Phase Job Creation

- Biomass
- Solar PV
- River Hydro
- Wind
- Wave
- Natural Gas

Jobs/MW(a)

- Jobs/MW
- Jobs/MWa

120

Generation Type
Job Creation Impacts

Operations Phase Job Creation

<table>
<thead>
<tr>
<th>Generation Type</th>
<th>Jobs/MW (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>2.0</td>
</tr>
<tr>
<td>Solar PV</td>
<td>0.5</td>
</tr>
<tr>
<td>River Hydro</td>
<td>1.0</td>
</tr>
<tr>
<td>Wind</td>
<td>0.5</td>
</tr>
<tr>
<td>Wave</td>
<td>0.5</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Legend:
- Jobs/MW (a)
- Jobs/MW

SCHATZ ENERGY RESEARCH CENTER

Humboldt County Renewable Energy Secure Community
Economic Impacts

Economic Impacts from Renewable Energy Development
Construction Phase

- Wind (58 MW)
- Biomass (47 MW)
- Hydro (26 MW)

Jobs (FTE) vs. Millions of Dollars
- Jobs (FTE)
- Earnings (millions of $)
- Output (millions of $)
Economic Impacts from Renewable Energy Development

Operations Phase

- **Wind (58 MW)**
  - Jobs (FTE): 5
  - Earnings (millions of $): 5
  - Output (millions of $): 5

- **Biomass (47 MW)**
  - Jobs (FTE): 40
  - Earnings (millions of $): 10
  - Output (millions of $): 10

- **Hydro (26 MW)**
  - Jobs (FTE): 10
  - Earnings (millions of $): 5
  - Output (millions of $): 5

- **Natural Gas (163 MW)**
  - Jobs (FTE): 10
  - Earnings (millions of $): 5
  - Output (millions of $): 5
Economic Impacts from Energy Efficiency Programs

- **Jobs (FTE)**
- **Earnings** (millions of $)
- **Output** (millions of $)

**Installation Impacts**
- Jobs: 2.0
- Earnings: 1.0
- Output: 0.5

**Energy Bill Savings Impacts**
- Jobs: 6.0
- Earnings: 3.0
- Output: 2.5

**Millions of Dollars/yr**
- 0.00
- 0.50
- 1.00
- 1.50
- 2.00
- 2.50
- 3.00

**Economic Impacts**

- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- 6.0
- 7.0
- 8.0
- 9.0
Recap of Preliminary Results

- One possible development scenario
  - 80% renewable energy → 38% transportation, 30% heating
  - 35% reduction in carbon emissions
  - 5% increase in cost
- The costs will look even better with a price on carbon
- Requires investment in EVs, heat pumps, and energy efficiency
- Substantial net job creation
Economic Development Context: National

- Growing attention focused on job creation in “clean energy” industry sectors/clusters.
Economic Development Context: State

Roland-Horst (2008): CA EE measures have enabled California households to redirect their expenditures toward other goods and services, creating 1.5 million FTE jobs & $45 billion payroll, driven by household energy savings of $56 billion from 1972-2006.
Economic Development Context: Local

- Local initiative: Redwood Coast Green Employer Council is identifying priority areas for “green” industry economic growth.
- Local competitive advantage, agglomeration.
- Strategic Action Plan: Educational/certification programs, work readiness trainings, project development.
- Identify funding sources for implementation of projects that will put trainees to work.
Caveats

- Economic impacts are not the same as economic feasibility. We have shown, however, that many types of EE and some forms of RE are currently cost-effective.

- But ... cost-effectiveness and economic development potential are NOT the only factors influencing the implementation of EE and RE investments.
Beyond the Economics

Other factors influencing development:

- Potential environmental impacts of RE (wind-avians; biomass-deforestation; wave-whale migration....)
- Economic displacement (wave-fishing; competition for biomass....)
- NIMBY (view-shed; noxious facilities & property values....)
- Multiple-jurisdiction, multiple-agency permitting
- Policy stability of incentive programs & investment risk
- Fragile banking system and access to large-$$ financing
- Transmission line infrastructure (who pays & how much; additional siting and permitting)
Strategic Plan:
Some Possible Near-Term Next Steps

- Shell Wind project (50 MW)
- Biomass – fuel reduction efforts, new generation facilities (or repurposing of other mills)
- Small hydro development (permitting challenges)
- Promotion of:
  - Electric vehicles
  - Heat pumps
  - Distributed generation (PV, CHP, landfill gas, food-waste)
- Explore options with PG&E, along with other development, financing, and ownership options.
Thank you!

Questions?
References


References


