Outline

• RE Policy
  o Laws
  o Executive Orders

• RE Technologies
  o Operating Principle
  o Cost and Performance
  o Incentives
  o Case Studies
  o Helpful Resources

• Integration Issues
  o Net Zero and Beyond
  o RE Project Planning
What is the Federal Definition of Renewable Energy?

Electric energy generated from:

- Solar
- Wind
- Biomass
- Landfill gas
- Ocean (including tidal, wave, current, and thermal)
- Geothermal
- Municipal solid waste
- New hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project
  - EPAAct 2005
Renewable Energy Technologies

**Photovoltaics**
- Photo from City of San Jose, NREL/PIX 19487

**Solar Vent Air Preheat**
- Photo by Warren Gretz, NREL/PIX 00595

**Daylighting**
- Photo by Joe Ryan, NREL/PIX 19424

**Wind Power**
- Photo by David Hicks, NREL/PIX 18455

**Concentrating Solar Heat/Power**
- Photo by Geri Kodey, NREL/PIX 14380

**Ground Source Heat Pump**
- Photo by Devin Egan, NREL/PIX 17440

**Solar Water Heating**
- Photo by Joe Ryan, NREL/PIX 19691

**Biomass Heat/Power**
- Photo by Kim Yost, NREL/PIX 11915

**Landfill Gas**
- Photo by Warren Gretz, NREL/PIX 03793
EPAct 2005

- Not less than 5% of electricity consumed by the Federal government must come from renewable energy in fiscal years 2010-2012
- Not less than 7.5% in fiscal year 2013 and thereafter
- Renewable energy projects provide bonuses if energy is:
  - produced on Federal lands and used at a Federal facility; or
  - produced on Native American land and used at a Federal facility.
Legislation

EISA 2007

• 30% solar hot water in new buildings
• 0% fossil fuels by 2030 in new buildings
• 40 year analysis period for RE
• Facilitates ESPC for RE
Executive Orders

• Executive Order.  
  13423
    o ½ of RE goal must be “new”
    o Thermal counts in ½ new requirement

• Executive Order 13514

• GHG accounting and sustainability plans
Guidance Available from FEMP

- For on-site projects, agency must retain or replace RECs to show use
- Simply hosting a renewable project without RECs does not help meet Federal goals
- Excludes system mix energy and energy used to meet state RPS requirements
- Rules are stricter for GHG accounting than for EPACT 05 accounting

www1.eere.energy.gov/femp/pdfs/epact05_fedrenewenergyguid.pdf
Energy Efficiency  Renewable Energy

Any questions?
EE + RE = 0

Strive for 40-70% energy reduction

$1 spent on EE lighting = $6 of PV (an NPS project)
$1 spent on EE refrigeration = $2 of PV (an NPS project)
$1 spent on EE = $2 spent on RE (EIA Press Release Aug 2011)
ARRA/FEMP Assessment
PNNL evaluated EE measures
NREL evaluated RE measures

EE+RE Example: Camp Smith, HI
Photovoltaics (PV)

- Photovoltaic cells directly transform solar energy to an electrical energy
- DC converted to AC by inverter
- Solid-state electronics, no-moving parts

Photo from MREA, NREL/PIX 18707
Grid Connect PV System

PV Modules

Combiner Box

AC Disconnect

DC Disconnect

Electrical Panel (150 - 225 Amp)

Inverter (500V DC & 240V AC)

Transformer

Image by Al Hicks, NREL
Flat Plate PV Systems

Dangling Rope Marina, Glen Canyon
National Recreation Area, UT

Arizona Public Service, Prescott, AZ

Alamosa PV System, Alamosa, CO

• 5 – 10 acres per MW for PV systems
• Land can be left as is or graded
Concentrating PV Systems

Reflective

Photo from David Parsons, NREL/PIX 06639
Concentrating Solar Resource: Direct Normal

Annual average direct normal solar resource. The data for Hawaii and the 48 contiguous states is a 10 km, satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005. The data for Alaska is a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).
PV Cost, O&M, and Efficiency

### PV System Type

<table>
<thead>
<tr>
<th>PV System Type</th>
<th>Annual O&amp;M Cost as a Percentage of Installed Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Mounted - Fixed</td>
<td>0.17%</td>
</tr>
<tr>
<td>Ground Mounted - Tracking</td>
<td>0.35%</td>
</tr>
</tbody>
</table>

### Efficiency vs. Size

- 1 kW of 15% eff. crystalline 71ft²
- 1 kW of 9.5% eff. amorphous 99ft²
- 1 kW of 19.3% eff. hybrid 55ft²

### Efficiency = Power Out/Power In

<table>
<thead>
<tr>
<th>Module Efficiencies</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Crystal</td>
<td>14-19%</td>
</tr>
<tr>
<td>Multi Crystal</td>
<td>13-17%</td>
</tr>
<tr>
<td>Thin Film</td>
<td>6-11%</td>
</tr>
</tbody>
</table>

### Balance of System Efficiency

77%
Table II. Maintenance cost as a percentage of capital investment

<table>
<thead>
<tr>
<th>Year</th>
<th>Scheduled (%)</th>
<th>Unscheduled (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>0.08</td>
<td>0.01</td>
<td>0.09</td>
</tr>
<tr>
<td>2003</td>
<td>0.07</td>
<td>0.22</td>
<td>0.29</td>
</tr>
<tr>
<td>2004</td>
<td>0.06</td>
<td>0.04</td>
<td>0.10</td>
</tr>
<tr>
<td>2005</td>
<td>0.06</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>2006</td>
<td>0.04</td>
<td>0.03</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Figure 7. Unscheduled maintenance events by component

Figure 8. Unscheduled maintenance costs by category
Veterans Administration Jerry L. Pettis Memorial Medical Center in Loma Linda, CA

- 309 kWdc
- 1,584 PV modules
- SunLink racks minimum roof penetration
- Advanced Energy Solaron 333kW inverter
- Feasibility Study by NREL estimates: 475 MWh/year delivery; $60k/year savings; $2.9million cost without any incentives
- Procured off GSA Schedule for complete PV systems
Results

• Veterans Administration Loma Linda, CA
Electricity Rate for Savings-to-Investment Ratio = 1 for Photovoltaic Systems (Not Considering Incentives)

Assumes:
- System cost of $7/Watt
- Present worth factor of 23.15 (40 yrs at 3% real discount rate)
- Annual average solar resource from tilt=latitude collector

Electricity Rate for SIR = 1 ($/kWh)

- > 0.30: 0.11 - 0.13
- 0.20 - 0.30: 0.09 - 0.11
- 0.17 - 0.20: 0.07 - 0.09
- 0.15 - 0.17: 0.05 - 0.07
- 0.13 - 0.15: <= 0.05

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Map created by Donna Heimiller - Oct. 4, 2010

NATIONAL RENEWABLE ENERGY LABORATORY
Electricity Rate for Savings-to-Investment Ratio = 1 for Photovoltaic Systems (With Incentives)

Assumes:
System cost of $7/Watt
Present worth factor of 23.15 (40 yrs at 3% real discount rate)
Annual average solar resource from tilt=latitude collector

Incentives from DSIRE March 2010 release, representing incentives available to non-profit/government entities for a 100 kW system.

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Map created by Donna Heimiller - Oct. 4, 2010

NATIONAL RENEWABLE ENERGY LABORATORY
Where to Install Solar

• On the “Built Environment” where unshaded
  o On existing building roofs that have an expected life of at least 15 more years and can accept added load. Reduces solar load on building. NEPA categorical exclusion.
  o On ALL new buildings – all new building should be “solar ready”
    − See http://www.nrel.gov/docs/fy10osti/46078.pdf
  o Over parking areas, pedestrian paths, etc. – energy generation and nice amenity.

• On compromised lands such as landfills & brownfields.
  o Saves green fields for nature.
  o IF installed on green fields minimize site disturbance, plant native low height vegetation as needed.
Customs and Border Protection

- **Solar-Powered SBInet Towers**
  Secure the U.S. Southwest Border
  - Solar panels
  - Battery system
  - Propane-fueled backup generator

- **Federal funding and appropriations** covered the installation costs and continues to cover testing and maintenance costs.
Photovoltaics Resources

- **Solar Energy Resources**
  - NREL
  - Firstlook
    - [http://firstlook.3tiergroup.com/](http://firstlook.3tiergroup.com/)
  - TMY or Weather Data

- **State and Utility Incentives and Utility Policies**
  - [http://www.dsireusa.org](http://www.dsireusa.org)

- **Solar PV Analytical Tools**
  - Solar Advisor Model (SAM)
    - [https://www.nrel.gov/analysis/sam/](https://www.nrel.gov/analysis/sam/)
  - HOMER
    - [https://analysis.nrel.gov/homer/](https://analysis.nrel.gov/homer/)
  - PVWatts
  - RETScreen
    - [http://www.retscreen.net/](http://www.retscreen.net/)
  - IMBY
Solar Water Heating
Solar Water Heating Applications

• **Low Temperature**
  - Swimming pool heating

• **Medium Temperature**
  - Domestic water and space heating
  - Commercial cafeterias, laundries, hotels
  - Industrial process heating

• **High Temperature**
  - Industrial process heating
  - Electricity generation

Photo from Gen-Con, Inc., NREL/PIX 09320
Photo by Amy Glickson, NREL/PIX 14167
Photo from Alan Ford, NREL/PIX 09501
Solar Thermal Collector Types

1. Unglazed
2. Low-Cost Plastic Flat Plate
3. Glazed, Insulated Flat Plate
4. Integral Collector Storage (ICS)
5. Evacuated Tube
6. Parabolic Trough
Solar Water Heating System
Solar Water Heating System Cost

Unglazed Flat Plate: Cost vs Size

Glazed Flat Plate: Cost vs Size

Parabolic Trough

Evacuated Tubes: Cost vs Size

ICS Batch: Cost vs Size

Thermosiphon: Cost vs Size

Large Flat Plate Collectors

Average: Around $150/sf
USCG Housing, Honolulu HI

- 62 units installed 1998
- Savings of 9,700 kWh/yr and $822/yr per system
- $4000/system cost
- Simple payback of 4 years (with rebate)
Electricity Rate for Savings-to-Investment Ratio = 1 for Solar Hot Water Systems (Elec) (With Incentives)

Incentives from DSIRE March 2010 release, representing incentives available to non-profit/government entities for a 1000 sq. ft. system.

Assumes:
- System cost of $150/ft²
- System efficiency of 40%
- Annual average solar resource for tilt=latitude collector

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy. Map created by Donna Heimiller - Oct. 7, 2010.
Solar Water Heating Resources

• **Design Tools**
  - RETScreen - Solar Hot Water
    - [http://www.retscreen.net/ang/g_solarw.php](http://www.retscreen.net/ang/g_solarw.php)

• **Fchart – Active and Passive Systems Analysis**

• **Resources**
  - DOE Energy Efficiency and Renewable Energy Solar Energy Technologies Program
    - [http://www1.eere.energy.gov/solar/solar_heating.html](http://www1.eere.energy.gov/solar/solar_heating.html)
  - FEMP Federal Technology Alerts
    - [www.eere.energy.gov/femp/pdfs/FTA_para_trough.pdf](http://www.eere.energy.gov/femp/pdfs/FTA_para_trough.pdf)
  - FEMP Case Studies
    - [www.eere.energy.gov/femp/technologies/renewable_casestudies.html](http://www.eere.energy.gov/femp/technologies/renewable_casestudies.html)
  - Resource maps
  - Solar Radiation Data Manual
Concentrating Solar Power
Concentrating Solar Power Technology

Mirrors are used to reflect and concentrate sunlight onto receivers that collect this solar energy and convert it to heat.
CSP Applications

- Typically utility-scale applications
- Heat from CSP
  - Generate hot water or steam
- Steam
  - Generate electricity

Photo by Geri Kodey, NREL/PIX 14383
Concentrating Solar Thermal (Industrial Process Heat)
Federal Correctional Institution - Phoenix, AZ

- 17,040 square feet of parabolic trough collectors
- 23,000 gallon storage tank
- Installed cost of $650,000
- Delivered 1,161,803 kWh in 1999 (87.1% of the water heating load).
- Saved $77,805 in 1999 Utility Costs
Solar Ventilation Air Pre-heat
Project Considerations

- Panels are aluminum or steel
- Roll-punch slots with three porosity options
- Corrugated to increase structural rigidity

- High outdoor air ventilation requirement in heating dominated climate
- South-facing wall surface is best
  - $45^\circ$ of south gives 80%
- Unshaded surface
  - Especially during low winter sun angles
- Dark collector color
  - Black is best, other colors have efficiency loss up to 10%

Photo by Warren Gretz, NREL/PIX 14383
Solar Vent Preheat Principle

- Sun warms the collector surface
- Heat conducts from collector surface to thermal boundary layer of air (1 mm thick)
- Boundary layer is drawn into perforation by fan pressure before heat can escape by convection
System Components

- Transpired solar collector
  - Perforated sheet of corrugated metal
- Air distribution
  - Ductwork, fan and bypass damper
- Controls
  - Temperature and timeclock, or EMCS
Solar Vent Preheat Resource

Energy Savings Utilizing Solar Vent Preheating Technology

Energy Savings (kWh/m²/year):
- 800 - 1000
- 600 - 800
- 400 - 600
- 200 - 400
- 0 - 200
- No Data

Not Applicable

U.S. Department of Energy
National Renewable Energy Laboratory

DM Heimiller 09-MAY-2001 1.3.8
Electricity Rate for Savings-to-Investment Ratio = 1 for Solar Space Heating (Gas) (With Incentives)

Incentives from DSIRE March 2010 release, representing incentives available to non-profit/government entities for a 100 kW system.

Assumes:
System cost of $27.4/sq. ft.
Annual energy delivery potential is fully used
Present worth factor of 23.15 (40 yrs at 3% real discount rate)

Not applicable in Hawaii.
Solar Ventilation Air Preheating: EPA Lab (Golden, CO)

• Hazardous material storage building
• Installed in 2001
• 296 sf, 2000 cfm
• 58% measured efficiency
• Saves 60 Mil Btu/yr and $450/yr of natural gas
• Payback = 13 years
Advantages

• Relatively low cost for on-site renewable energy utilization
• Reliability of equipment and system
  – Only moving part is the fan
  – Operates at ambient temperature
• Very low maintenance
• High efficiency
• No storage
Solar Vent Preheat Resources

• **FEMP Federal Technology Alert**
  - Solar Ventilation Preheating Resources and Technologies

• **NREL**
  - Solar Process Heat
  - Solar Space Heating Maps
    - http://www.nrel.gov/gis/femp.html#space

• **Conserval Systems, Inc.: SOLARWALL®**
  - www.solarwall.com/sw/solarwall.html

• **ATAS International, Inc.: InSpire™**
  - www.atas.com

• **American Solar Inc.: Solar Thermal Tile System**
  - www.americansolar.com

• **RETSscreen® International Clean Energy Project Analysis Software**
  - www.retscreen.net
Passive Solar in New Construction
Passive Solar

- **Types:**
  - Direct Gain
  - Sunspace
  - Thermal Storage Wall (Trombe Wall)

- For new construction, in areas with low internal heat gain
- South-facing Solar Apertures
- Added thermal mass to absorb heat and release at night
- Controls such as operable shades and windows

Trombe Wall, NREL. Photo by Warren Gretz, NREL/PIX 01693,
Daylighting

- Lighting accounts for 25% of total electricity used in Federal sector
- Daylighting uses windows & skylights in conjunction with automatic light controls to minimize the need for electric lighting during daylight hours
- Daylighting combined with lighting controls can reduce lighting energy consumption by 40 -60%
Wind
Wind Sizes and Applications

Small ($\leq 10 \text{ kW}$)
- Homes
- Farms
- Remote Applications
  (e.g. water pumping, telecom sites, icemaking)

Intermediate (10-250 kW)
- Village Power
- Schools, businesses
- Hybrid Systems
- Distributed Power

Large (660 kW - 2+MW)
- Central Station Wind Farms
- Distributed Power
- Community Wind
Wind Generation in the U.S.

Source: U.S. Energy Information Administration.
Warren Air Force Base, Cheyenne

- 600 kW wind turbines
- $2.5 million installed
- Generates energy to power 522 households on base
- Avoids 5,000 tons/year in GHG emissions
- Saves $3 million in energy costs over 20 years
- Additional capacity planned
• Awarded 09/03
• Initial capital investment $5.4M, 19 year term with NORESCO
• Scope includes HVAC controls upgrade, 750 kW wind turbine, and 74.5KW PV Carport
• First ESPC financed wind turbine
• SCE provided RE generation financial incentive $4/W
• Escrow account for wind turbine maintenance
The annual wind resource data shown are a composite of available high resolution wind power resource produced by NREL, AWS TrueWind Solutions, states, and other organizations. For states that did not have high resolution data available, low resolution wind power resource data produced by the 1987 "Wind Energy Atlas of the United States" is shown. For more info, visit Wind Powering America:
http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_map.aspx

Wind Power Classification

<table>
<thead>
<tr>
<th>Wind Power Class</th>
<th>Resource Potential</th>
<th>Wind Power Density at 50 m Wind at 50 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>0-200</td>
<td>0.0-5.6 m/s 0.0-12.5 mph</td>
</tr>
<tr>
<td>Marginal</td>
<td>200-300</td>
<td>5.6-6.4 m/s 12.5-16.3 mph</td>
</tr>
<tr>
<td>Fair</td>
<td>300-400</td>
<td>6.4-7.9 m/s 16.3-19.9 mph</td>
</tr>
<tr>
<td>Good</td>
<td>400-500</td>
<td>7.0-7.5 m/s 19.9-23.5 mph</td>
</tr>
<tr>
<td>Excellent</td>
<td>500-600</td>
<td>7.5-8.0 m/s 23.5-27.9 mph</td>
</tr>
<tr>
<td>Outstanding</td>
<td>600-800</td>
<td>8.0-8.8 m/s 27.9-31.7 mph</td>
</tr>
<tr>
<td>Superb</td>
<td>&gt;800</td>
<td>&gt;8.8 m/s &gt;31.7 mph</td>
</tr>
</tbody>
</table>

* Wind speeds are based on a Weibull k value of 2.0
## Installed Costs and O&M Costs

<table>
<thead>
<tr>
<th>Installed Costs</th>
<th>Operation and Maintenance Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt; 500kW $2500 to $3500/kW</td>
<td>$&lt; 500kW $0.035/kWh</td>
</tr>
<tr>
<td>$&gt;500kW $2000/kW</td>
<td>$&gt;500kW $0.025/kWh</td>
</tr>
</tbody>
</table>

These numbers can be used for feasibility calculations. There is huge variability depending on the current market and the site selected.
Wind for the Coast Guard

- Generate 2.4 kW at 24 mph wind
- 1 kW for augmenting power at telecom sites
Wind Resources

- **AWEA Web site**
  - http://www.awea.org

- **NWTC Web site**
  - http://www.nrel.gov/wind

- **National Wind Coordinating Collaborative**
  - http://www.nationalwind.org

- **Utility Wind Interest Group site**
  - http://www.uwig.org

- **WPA Web site**
  - http://www.windpoweringamerica.gov

- **Homepower Web Site**
  - http://www.homepower.com

- **Windustry Project**
  - http://www.windustry.com

- **Best Links**
  - www.fresh-energy.org
Other Wind Resources

- **American Wind Energy Association**
  - AWEA Small Wind Toolbox
    - [www.awea.org/smallwind/](http://www.awea.org/smallwind/)

  - [http://www.nrel.gov/publications](http://www.nrel.gov/publications)


- **Wind Power**; Gipe, Paul; Chelsea Green Publishing, 2004
Biomass
What is Biomass in Terms of Renewable Technologies?

- Wood and wood waste
- Agricultural waste
- Bagasse
- Food processing residues
- Animal wastes
- Municipal solid waste
- Energy crops
- Landfill gas
- Methane from waste and wastewater treatment
Range of Bioenergy

Biomass Feedstock

Conversion Processes

- Combustion
- Gasification
- Pyrolysis
- Co-firing
- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Trans-esterification

Products

Fuels
- Ethanol
- Biodiesel
- “Green” Gasoline & Diesel

Power
- Electricity
- Heat

Chemicals
- Plastics
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty Acids
- Acetic Acid
- Carbon Black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

Food and Feed

- Trees
- Grasses
- Agricultural Crops
- Residues
- Animal Wastes
- Municipal Solid Waste
- Algae
- Food Oils, Waste Oils

Photo by Warren Gretz, NREL/PIX 11597
Biomass Resources of the United States
Total Resources by County

This map was produced by the National Renewable Energy Laboratory for the US Department of Energy.
October 13, 2009 Author: Billy J. Roberts

NATIONAL RENEWABLE ENERGY LABORATORY
Commercial Technologies

• Almost all commercial power systems are combustion/steam turbine
• Efficiencies in 15% – 30% range power only, (60%-70% CHP)
• Stokers and fluidized bed
• 500+ facilities in U.S
• Installed costs $1,700 - $3,500/kW
• Smaller systems (< 5 MW) still have poor economics
• LCOE = $0.06 - $0.20/kWh
NREL Renewable Fuels Heating Plant (Golden, CO)

- $3.3 million cost under an ESPC
- Pine beetle waste wood
- 75% of the 50,000 million Btus to heat campus.
- Cost savings projected $400,000/year
- The wood chips cost $29 per ton or $2.42 per million BTUs
- During cold weather, plant burns a truckload of wood chips per day; produces 600 gallons of hot water per minute
- Stores four days of wood chip fuel
• New 20 MW wood waste cogeneration plant and two biomass heating plants with local fuel source
• 19 year contract
• Includes performance guarantee and O&M
• Annual Savings of $34 M project cost of $183 M
• Task order signed 5/15/09
• Construction completed December 2011
• Important project to meet federal renewable goal/DOE Order 230.2b
• Boiler Conversion to LFG
  o Cogeneration Plant
  o 4 MW Electricity
• 8,000 lb/hr Steam
• 15 year contract length
• Project Investment: $15.0 million
• Annual Savings: $2.5 million
• Offsets 18,000,000 kWh/yr and 71,000 decatherms/yr of Natural Gas
• Operational: April 2009
Biomass in Kodiak, AK

• **Wood pellets in Coast Guard boilers in place of expensive fuel oil**
  o Pellets from wood waste and second-growth trees from local Tongass National Forest

• **Benefits**
  o Save taxpayer dollars
  o Improve operations and resiliency
  o Support energy independence
  o Foster environmental stewardship
Biomass Resources

• DOE Energy Efficiency and Renewable Energy
  - http://www1.eere.energy.gov/biomass/

• NREL
  - http://www.nrel.gov/biomass/
Geothermal
Geothermal Energy Technology Overview

Application opportunities include:

- **Direct Use** - Using hot water from springs or reservoirs near the surface.

- **Electricity generation** – Using steam, heat or hot water from deep inside the earth to drive turbines.

- **Geothermal heat pumps** – Using the earth, groundwater, or surface water as a heat source and heat sink.
Geothermal Application

Heat Production
- District Heating
- Process Heat
- Agriculture
- Aquaculture

Electricity Generation
- Distributed Power
- Central Station Power
• Geothermal heat pump technology is the energy-saving centerpiece of this Marine housing facility.

• Energy-efficient geothermal heat pumps replaced 2,500 tons of existing HVAC systems and hot water heaters.

• These heat pumps provide space heating, cooling, and domestic hot water for 1,235 family housing units at the Beaufort Marine Corps installation.

Photo by Belton Tisdale, NREL/PIX 12372
Geothermal Resources

• Western Area Power Administration

• DOE Geothermal Technologies Program
  o http://www1.eere.energy.gov/geothermal/faqs.html

• Resource Maps
  o http://www.nrel.gov/gis/geothermal.html
Hydro and Ocean Energy
What are the Hydropower and Ocean Energy Options?

• Small projects use turbines in place of pressure reducing valves
• Large Hydropower is typically not cost-effective unless the site has access to existing hydroelectric dam
• Hydropower is a common form of Renewable Energy Credits
Ocean Energy

- Wave power
- Marine current power
- Tidal Energy
- Ocean Thermal Energy Conversion
  - Relatively immature
Wave Power for U.S. Coast Guard 1st District Lighthouses
Tidal Energy Resource
Ocean Thermal Technology

OTEC functions best when there is a 36°F (20°C) difference

The OTEC energy resource constitutes an estimated $10^{13}$ W (876,000TWh/yr) for potential base load power generation.
Integration Issues
State policy applies to certain utility types only (e.g., investor-owned utilities)

Note: Numbers indicate individual system capacity limit in kW. Some limits vary by customer type, technology and/or application. Other limits might also apply.
Problems with “Net” Metering

• **Pros:**
  - Incentive for RE
  - Saves Some Fuel (up to a limit)

• **Cons:**
  - Limits to Fuel Savings
  - Doesn’t save any other utility operating costs
  - RE may be curtailed; limits on installations (eg 15% in HI)
  - Socio-economic problem: foists utility costs on those least able to afford it.

• **Utility Cost Recovery**
  - Spinning Reserve
  - Retail/buy-back spread (c/kWh)
  - Stand-by Charges ($/kW/month)
Zero = EE+RE+Microgrid

- **Strategies for “Zero” rather than “Net Zero”**
  - Tracking Solar
  - Solar on different orientations (East-South-West)
  - Spatial Diversity
  - Diversity of RE Measures (Solar, Wind, Etc)
  - Dispatchable RE (biomass, hydro, geothermal, landfill gas)
  - Flexible Grid Layout (circuits) to route power around
  - Isolate Critical Circuits: exercise Demand Control
  - Energy Storage (short and long term, electric and thermal)
  - Micro-grid controls
    - Control requirement: maintain required frequency and voltage levels
    - Grid disconnect and seamless resynchronization
    - Micro-grid start-up (“black start”)
    - Load control (interfaces with SCADA and EMCS)
    - Supply control (optimized operation of DERs)
Tracking the Sun

Single 80 Watt Polycrystalline Output Current
30 April 2008

Amps DC @ 13.2V

Fixed Panel 32°
Harvester DA Panel

Time

Zero = EE+RE+Microgrid
RE Project Planning
Best Mix of Renewable Energy Technologies Depends on:

- **Renewable Energy Resources**
- **Technology Characterization**
  - Cost ($/kW installed, O&M Cost)
  - Performance (efficiency)
- **Economic Parameters**
  - Discount rates
  - Fuel Escalation Rates
- **State, Utility and Federal Incentives**
- **Mandates (Executive Order, Legislation)**
## Summary Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Level of Commercialization</th>
<th>LCOE with tax incentives</th>
<th>Capital Cost ($) 2011</th>
<th>Level of Site Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photovoltaics;</td>
<td>Mature</td>
<td>$0.128/kWh to $0.154/kWh</td>
<td>$6,870/kW</td>
<td>Low, most buildings.</td>
</tr>
<tr>
<td>Solar ventilation air preheating;</td>
<td>Underutilized</td>
<td>$0.064/kWh to $0.154/kWh</td>
<td>$27.40/sf</td>
<td>Medium, limited to low-heat-gain buildings</td>
</tr>
<tr>
<td>Solar water heating;</td>
<td>Mature</td>
<td>$0.08 to $0.20/kWh to $0.154/kWh</td>
<td>$75-225/sf</td>
<td>Medium, hot water loads only.</td>
</tr>
<tr>
<td>Solar thermal and solar thermal electric;</td>
<td>Mature</td>
<td>$0.090 to $0.145/kWh to $0.20/kWh</td>
<td>$5,132/kW</td>
<td>High</td>
</tr>
<tr>
<td>Biomass thermal and electric</td>
<td>Mature</td>
<td>$0.050 to $0.094/kWh to $0.145/kWh</td>
<td>$3,995/kW</td>
<td>High</td>
</tr>
<tr>
<td>Geothermal Power;</td>
<td>Early</td>
<td>$0.042 to $0.069/kWh to $0.145/kWh</td>
<td>$4,000/kW</td>
<td>High</td>
</tr>
<tr>
<td>Ground Source Heat Pump</td>
<td>Mature</td>
<td>$0.027/kWh to $0.069/kWh to $0.145/kWh</td>
<td>$835/ton</td>
<td>Medium</td>
</tr>
<tr>
<td>Landfill gas;</td>
<td>Mature</td>
<td>$0.0493/kWh to $0.145/kWh</td>
<td>$2,100/kW</td>
<td>Medium, virtual power from landfill</td>
</tr>
<tr>
<td>Fuel Cells;</td>
<td>Early</td>
<td>$0.115 to $0.125/kWh to $0.20/kWh</td>
<td>$3,800/kW</td>
<td>Low</td>
</tr>
<tr>
<td>Wind</td>
<td>Mature</td>
<td>$0.044 to $0.091/kWh to $0.145/kWh</td>
<td>$1,966/kW</td>
<td>High</td>
</tr>
</tbody>
</table>
REO: Renewable Energy Optimization

- Optimization
- Life Cycle Cost
- Dispatch Algorithm
- PV
- Wind
- SVP
- SWH
- CSP
- Biomass
- Daylighting

Geographical Information System (GIS) Data
Site Data
Incentive Data from DSIREUSA.ORG
Technology Characteristics.
### REO for Land and Ferry Points of Entry

<table>
<thead>
<tr>
<th></th>
<th>Without Tax Incentives</th>
<th>With Tax Incentives</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV (kW)</td>
<td>0</td>
<td>737</td>
</tr>
<tr>
<td>Wind Energy (kW)</td>
<td>2,491</td>
<td>3,689</td>
</tr>
<tr>
<td>Solar Ventilation Air Preheat (sf)</td>
<td>93,265</td>
<td>119,652</td>
</tr>
<tr>
<td>Solar Water Heating (sf)</td>
<td>28,464</td>
<td>90,703</td>
</tr>
<tr>
<td>Solar Thermal Parabolic Trough (sf)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Solar Thermal Electric (kW)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Biomass Gasification Boiler (MBH)</td>
<td>1.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Biomass Gasification Cogen (kW)</td>
<td>134</td>
<td>193</td>
</tr>
<tr>
<td>Biomass Anaerobic Digester (ft³)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Biomass Anaerobic Digester Cogen (kW)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Skylight Area (sf)</td>
<td>190,951</td>
<td>209,666</td>
</tr>
</tbody>
</table>

![Annual Energy (Mbtu) Graph](image)
Questions?
Thank you!

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Andy.walker@nrel.gov