Course Outline

What we will cover...

- About the DOE Office of Indian Energy Education Initiative
- Course Introduction
- Resource Map & Project Scales
- Technology Overview(s):
  - Siting
  - Costs
- Successful Project Example(s)
- Policies Relevant to Project Development
- Additional Information & Resources
Introduction

The U.S. Department of Energy (DOE) Office of Indian Energy Policy & Programs is responsible for assisting Tribes with energy planning and development, infrastructure, energy costs, and electrification of Indian lands and homes.

As part of this commitment and on behalf of DOE, the Office of Indian Energy is leading education and capacity building efforts in Indian Country.
Training Program Objective & Approach

Foundational courses were created to give tribal leaders and professionals background information in renewable energy development that:

- Present foundational information on strategic energy planning, grid basics, and renewable energy technologies;
- Break down the components of the project development process on the commercial and community scale;
- Explain how the various financing structures can be practical for projects on tribal lands.
NREL’s Presenter on Solar is

Otto Van Geet

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Course Introduction

- **Course Purpose** – define different solar technology, applications, cost, and performance

- **Key Takeaways** – solar technologies work in all parts of the United States, economics of solar are dependent on first cost (including incentives), solar resource, and cost of energy being displaced
Maps of Resources

• [http://www.nrel.gov/gis/maps.html](http://www.nrel.gov/gis/maps.html)
  – Biomass
  – Geothermal
  – Hydrogen
  – Solar
    • Photovoltaic (PV)
    • Concentrating Solar Power (CSP)
  – Wind
• State and national level maps
PV Solar Resource

Photovoltaic Solar Resource of the United States

Annual average solar resource data are shown for a tilt-latitude collector. The data for Hawaii and the 48 contiguous states are a 10km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2003. The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).

This map was produced by the National Renewable Energy Laboratory for the US Department of Energy. October 13, 2009 Author: Billy J. Roberts.
Photovoltaic Solar Resource and Transmission Lines on Tribal Lands of the United States

Annual average solar resource data are shown for a tilt-latitude collector. The data are a 10km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005. Resource has been filtered to exclude slopes greater than three percent and major water bodies.

PV Resource kWh/m2/day
- 4.66 - 5.25
- 5.26 - 5.50
- 5.51 - 5.75
- 5.76 - 6.00
- 6.01 - 6.25
- 6.26 - 6.51

Tribal Land
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Simple Direct Drive PV System

Illustration by Jim Leyshon, NREL
PV Technology

- Direct conversion of sunlight into direct current (DC) electricity
- DC converted to alternating current (AC) by inverter
- Solid-state electronics, no-moving parts

- High reliability, warranties of 20 years or more
- PV modules are wired in series and parallel to meet voltage and current requirements

Illustration by Jim Leyshon, NREL
Photovoltaic Cell Structure

- Cover (e.g., glass)
- Transparent adhesive
- Antireflection coating
- n-type semiconductor
- p-type semiconductor
- Back contact and cover
- Front contact
- Current

Solar cell efficiency (%) = \[
\frac{\text{Power out (W) \times 100}}{\text{Area (m}^2\) \times 1000 \text{ W/m}^2}
\]

10% efficiency = 100 W/m^2 or 10 W/ft^2

Illustration by Jim Leyshon, NREL
PV is Modular

Cells are assembled into **modules**... and modules into arrays.
Flat Plate PV Systems

Dangling Rope Marina, Glen Canyon National Recreation Area, Utah
Photo by Warren Gretz, NREL

Arizona Public Service, Prescott, Arizona
Photo from Arizona Public Service

Alamosa PV System, Alamosa, Colorado
Photo by Tom Stoffel, NREL

5–10 acres per megawatt (MW) for PV systems. Land can be left as is or graded
Single Axis Tracking PV

• Increase energy production by 20%
• Large ground mount only
• V is Modular

Photo by Warren Gretz, NREL
Total Area Required for PV

- Varies by technology, tilt, and location
- Roof mount - sloped roof, flush-mounted power densities of 11 DC-watt (W)/square foot (ft²) crystalline
- Flat roof, slope panel = 8 DC-W/ft²
- Ground mount:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Fixed Tilt Energy Density (DC-W/ft²)</th>
<th>Single Axis Tracking Energy Density (DC-W/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystalline Silicon</td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>Thin Film</td>
<td>3.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Hybrid High Efficiency</td>
<td>4.8</td>
<td>3.9</td>
</tr>
</tbody>
</table>
In My Backyard and PVWatts

Benefits of using In My Back Yard (IMBY) and PVWatts:
- Easy to use
- Very quick
- Useful for users of all technical levels
- Widely accepted tool

Link to IMBY: http://mercator.nrel.gov/imby/
Link to PVWatts: http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/
Link to PVWatts Map serve: http://mapserve3.nrel.gov/PVWatts_Viewer/index.html
Priorities: Where to Install Solar

• On the “built environment” where unshaded
  – On existing building roofs that have an expected life of at least 15 more years and can accept added load - typically 2-4 pounds (lbs)/ft². Reduces solar load on building
  – On ALL new buildings – all new buildings should be “solar ready”
    • See http://www.nrel.gov/docs/fy10osti/46078.pdf
  – Over parking areas, pedestrian paths, etc. – energy generation and nice amenity

• On compromised lands such as landfills and brown fields
  – Saves green fields for nature
  – If installed on green fields, minimize site disturbance; plant native low height vegetation as needed
Veterans Administration
Jerry L. Pettis Memorial Medical Center
Loma Linda, California

Project Specifications:

• 309 kilowatt (kW) DC
• 1,584 Sanyo 195-watt PV modules
• SunLink (ballasted) racks minimum roof penetration
• Advanced Energy Solaron 333 kW inverter
• Feasibility study by the National Renewable Energy Laboratory (NREL) estimates: 475 megawatt-hours (MWh)/year delivery

Photo by Warren Gretz, NREL
Solar Assessment – PV is VERY Shade Sensitive

Once preliminary site assessment has been completed, you want to know:

• Estimated system size
• Estimated production (kilowatt-hour [kWh]/yr)
• Estimated cost
• Some economic analysis

Photos top to bottom: NREL/PIX 10314 and 17509
Photovoltaics System
(Grid Connected)
Utility Interconnection - Where to land the power?

• Backfeed breaker in building panel (sum of main breaker and PV breaker not to exceed 120% of panel rating for commercial building, 100% for residential)

• Too big?
  – Survey loads and reduce main breaker rating
  – Upgrade panel (few hundred dollars for home)
  – Line-side-tap
  – Upgrade electrical service
Price of PV Modules

Soft Balance of System (BOS) Cost Analysis
National Renewable Energy Laboratory

RESIDENTIAL SCALE PV

- ~72% reduction in soft BOS costs is needed between 2012 and 2020 to reach SunShot cost targets

Inverter
BOS Hardware
BOS Non-Hardware
Module

SunShot Goal

Office of Indian Energy
PV Installed Costs

- $5/W in 2012 before financial incentives and tax credits
- Utility scale (1 MW+) $3.5/W

Photo by Dennis Schroeder, NREL
Project Specifications:

- 720 kW (1,200 MWh) single-axis tracking, ~ 5 acres
- 20-year power purchase agreement (PPA) contract (utilizing Western Area Power Administration)
- 20-year easement
- Renewable energy credits (RECs) sold to Xcel Energy for renewables portfolio standard (RPS) solar set-aside (20-year contract)
- PPA price equal to or less than utility electricity prices (based on Energy Information Administration projections)
- Operational December 2008
Solar Concentrating Technologies

Parabolic Trough
- Absorber Tube
- Curved mirror
- Pipe with thermal fluid

Linear Fresnel
- Absorber tube and reconcentrator
- Curved mirror

Dish/Engine
- Receiver / Engine
- Reflector

Central Receiver
- Solar Receiver
- Heliostats
Solar Concentrating Technologies

Photos by (clockwise): Warren Gretz, NREL; AREVA Solar, David Hicks, NREL; Solar One
Thermal storage:
- Provides **higher value** as the produced power can adapt to the demand and be dispatched at the request of power grid operators.
- Provides **lower cost** as thermal storage introduction into CSP power plants is cheaper than turbine capacity increase.
- Is based on the use of **high heat capacity fluids** as heat transfer storage mediums.
Additional Advantages of CSP

• Can be easily integrated into conventional thermal power plants, just connecting the “solar boiler” either in series or in parallel with the “fossil boiler”

• Not affected by abrupt changes into the output power (very common in PV plants)

• Disadvantages:
  – Viable only for large (50 MW+) plants
  – Only works in the desert Southwest that receives high “direct beam” solar
  – Normally requires water for cooling towers

Photos from Solar One and ACCIONA
Thermal Storage System

Thermal storage system based on one tank

Solar Field → Thermal Storage → Boiler → Industrial Process

Thermal storage system is needed to provide stability and guarantee the output power, independently of meteorological changes.

Thermal storage can be integrated either in parallel or in series with the power block.
<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Location</th>
<th>First Year of Operation</th>
<th>Net Output (MW&lt;sub&gt;e&lt;/sub&gt;)</th>
<th>Solar Field Outlet (°C)</th>
<th>Solar Field Area (m&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>Solar Turbine Effic. (%)</th>
<th>Power Cycle</th>
<th>Dispatchability Provided By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nevada Solar One</td>
<td>Boulder City, NV</td>
<td>2007*</td>
<td>64</td>
<td>390</td>
<td>357,200</td>
<td>37.6</td>
<td>100 bar, reheat</td>
<td>None</td>
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<tr>
<td>APS Saguaro</td>
<td>Tucson, AZ</td>
<td>2006</td>
<td>1</td>
<td>300</td>
<td>10,340</td>
<td>20.7</td>
<td>ORC</td>
<td>None</td>
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<tr>
<td>SEGS IX</td>
<td>Harper Lake, CA</td>
<td>1991</td>
<td>80</td>
<td>390</td>
<td>483,960</td>
<td>37.6</td>
<td>100 bar, reheat</td>
<td>HTF heater</td>
</tr>
<tr>
<td>SEGS VIII</td>
<td>Harper Lake, CA</td>
<td>1990</td>
<td>80</td>
<td>390</td>
<td>464,340</td>
<td>37.6</td>
<td>100 bar, reheat</td>
<td>HTF heater</td>
</tr>
<tr>
<td>SEGS VI</td>
<td>Kramer Junction, CA</td>
<td>1989</td>
<td>30</td>
<td>390</td>
<td>188,000</td>
<td>37.5</td>
<td>100 bar, reheat</td>
<td>Gas boiler</td>
</tr>
<tr>
<td>SEGS VII</td>
<td>Kramer Junction, CA</td>
<td>1989</td>
<td>30</td>
<td>390</td>
<td>194,280</td>
<td>37.5</td>
<td>100 bar, reheat</td>
<td>Gas boiler</td>
</tr>
<tr>
<td>SEGS V</td>
<td>Kramer Junction, CA</td>
<td>1988</td>
<td>30</td>
<td>349</td>
<td>250,500</td>
<td>30.6</td>
<td>40 bar, steam</td>
<td>Gas boiler</td>
</tr>
<tr>
<td>SEGS III</td>
<td>Kramer Junction, CA</td>
<td>1987</td>
<td>30</td>
<td>349</td>
<td>230,300</td>
<td>30.6</td>
<td>40 bar, steam</td>
<td>Gas boiler</td>
</tr>
<tr>
<td>SEGS IV</td>
<td>Kramer Junction, CA</td>
<td>1987</td>
<td>30</td>
<td>349</td>
<td>230,300</td>
<td>30.6</td>
<td>40 bar, steam</td>
<td>Gas boiler</td>
</tr>
<tr>
<td>SEGS II</td>
<td>Daggett, CA</td>
<td>1986</td>
<td>30</td>
<td>316</td>
<td>190,338</td>
<td>29.4</td>
<td>40 bar, steam</td>
<td>Gas boiler</td>
</tr>
<tr>
<td>SEGS I</td>
<td>Daggett, CA</td>
<td>1985</td>
<td>13.8</td>
<td>307</td>
<td>82,960</td>
<td>31.5</td>
<td>40 bar, steam</td>
<td>3-hours TES</td>
</tr>
</tbody>
</table>
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Considerations: Financial Incentives

Database of State Incentives for Renewables and Efficiency (DSIRE)

- [www.dsireusa.org](http://www.dsireusa.org)
- Types of incentives: federal, state, local, utility
  - Corporate, personal income, sales, and property tax incentives
  - Grant programs
  - Industry recruitment incentives
  - Leasing/lease purchase programs
  - Loan programs
  - Production incentives
  - Rebate programs
  - RECs sales
State policy applies to certain utility types only (e.g., investor-owned utilities)

Numbers indicate individual system capacity limit in kW. Some limits vary by customer type, technology and/or application. Other limits might also apply.

This map generally does not address statutory changes until administrative rules have been adopted to implement such changes.
<table>
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<td>▪ About the Office of DOE Office of Indian Energy Education Initiative</td>
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<td>▪ Course Introduction (Takeaways)</td>
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<tr>
<td>▪ Policies Relevant to Project Development</td>
</tr>
</tbody>
</table>
| ▪ Additional Information & Resources | }
## Useful Resources

### Solar Energy Resources
- Firstlook: [http://firstlook.3tiergroup.com/](http://firstlook.3tiergroup.com/)

### Solar PV Analytical Tools
- HOMER: [https://analysis.nrel.gov/homer/](https://analysis.nrel.gov/homer/)
- RETScreen: [http://www.retscreen.net/](http://www.retscreen.net/)

### State Utility Policies & Incentives
- DSIRE: [http://www.dsireusa.org](http://www.dsireusa.org)
Thank You & Contact Information

For Technical Assistance:
IndianEnergy@hq.doe.gov.

DOE Office of Indian Energy Website:
www.energy.gov/indianenergy

NREL Technology Websites:
www.nrel.gov/learning/re_basics.html

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Curriculum Structure & Offerings

Foundational Courses
• Overview of foundational information on renewable energy technologies, strategic energy planning, and grid basics

Leadership & Professional Courses
• Covers the components of the project development process and existing project financing structures
Foundational Courses

Energy Basics
- Assessing Energy Needs and Resources
- Electricity Grid Basics
- Strategic Energy Planning

Renewable Energy Technology Options
- Biomass
- Direct Use
- Geothermal
- Hydroelectric
- Solar
- Wind

All courses are presented as 40-minute Webinars online at www.energy.gov/indianenergy