DOE OFFICE OF INDIAN ENERGY

Foundational Courses

Renewable Energy Technologies

DIRECT USE FOR BUILDING HEAT & HOT WATER

Presented by the National Renewable Energy Laboratory

U.S. DEPARTMENT OF ENERGY | Office of Indian Energy

Course Outline

What we will cover…

- About the DOE Office of Indian Energy Education Initiative
- Course Introduction
- Solar Thermal and Solar Ventilation Air Pre-Heat
  - Resources, Technology, Examples & Cost, and References
- Biomass Heat
  - Resources, Technology, Examples & Cost, and References
- Geothermal Building Heat
  - Resources, Technology, Examples & Cost, and References
- Additional Information & Resources

Introduction

The U.S. Department of Energy (DOE) Office of Indian Energy Policy and 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:

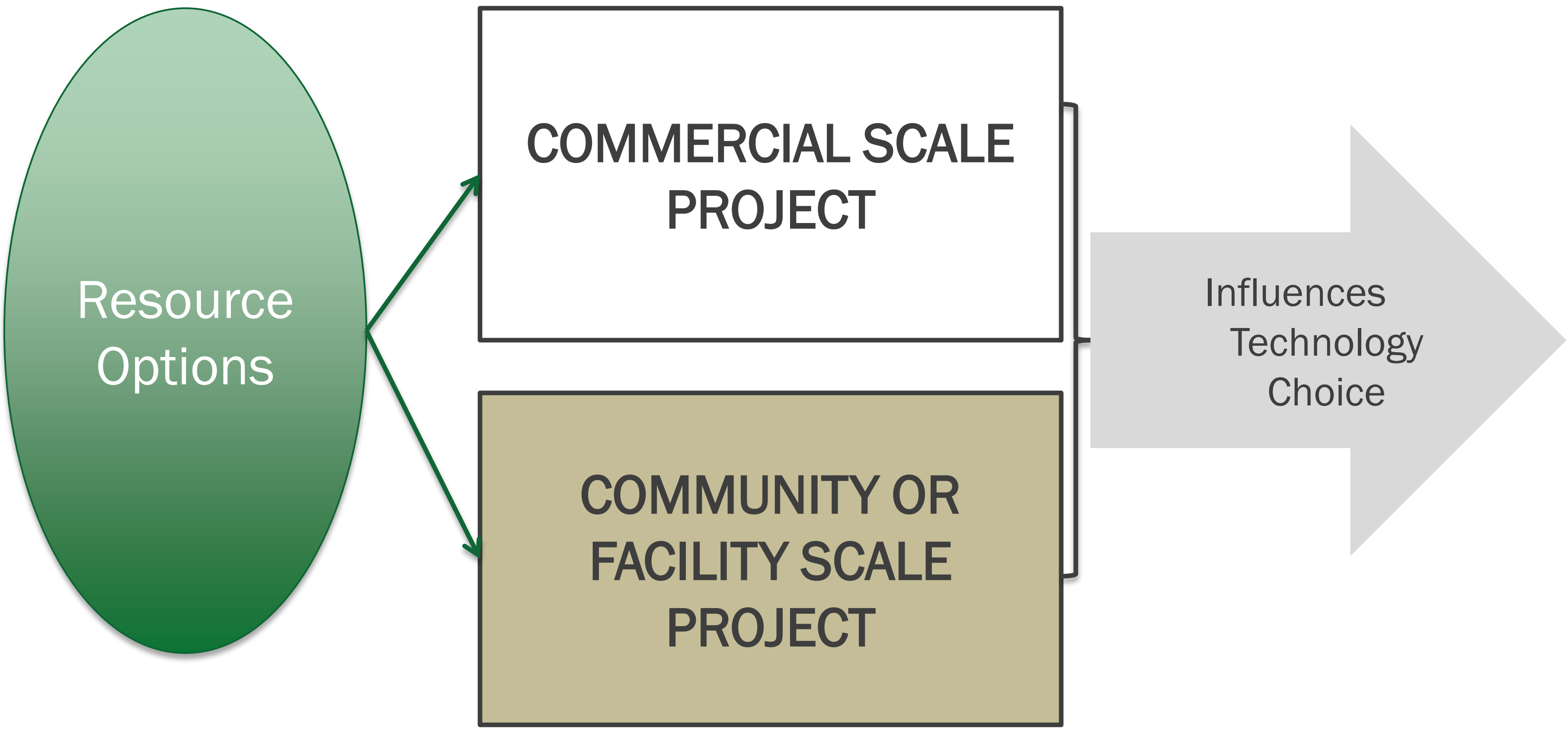
- *Present foundational information on strategic energy planning, grid basics, and renewable energy technologies;*
- *Break down the components of the project development process on the commercial and community scale; and*
- *Explain how the various financing structures can be practical for projects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

NREL's Presenter on Direct Use for Building Heat and Hot Water

Amy Hollander

Amy.Hollander@nrel.gov

Community or Facility Scale?



Why Renewable Energy for Building Heat and Hot Water?

Advantages of Direct Use (Heating & Hot Water) Renewables

- Energy cost savings ($/year)
- Avoid cost of infrastructure (power line extension, upgrade)
- Reduce environmental emissions (tons of CO_2 per year)
- Reduce energy cost volatility (fuel adjustment charges)
- Hedge against rate increases (%/year)
- Fuel supply shortage/interruption
- Redundant and/or backup energy supplies
- Employ local trades for install and operations and maintenance (O&M)

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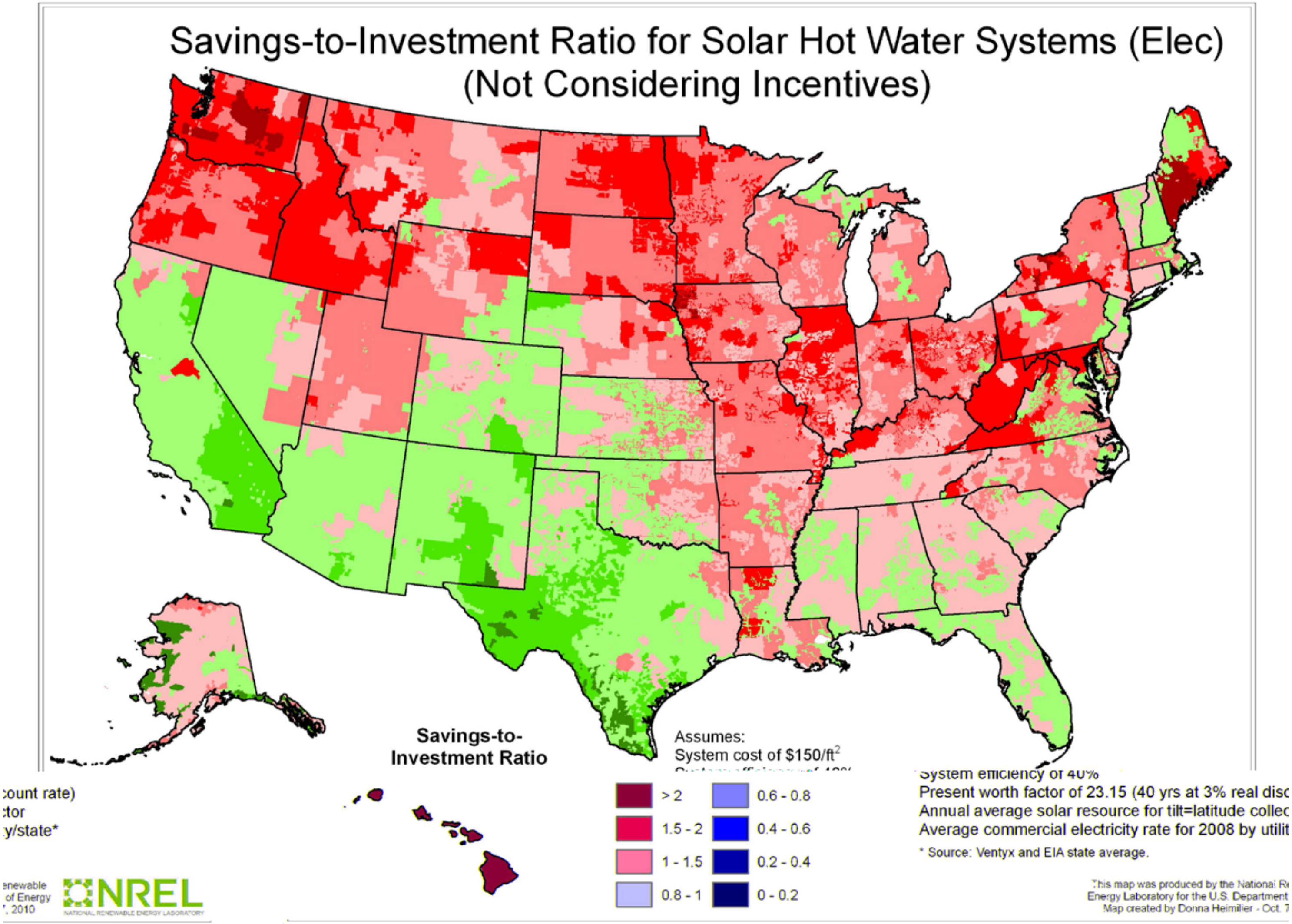
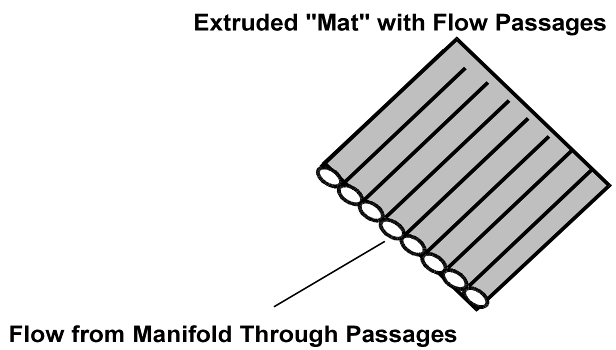
Solar Hot Water Resource and Economics

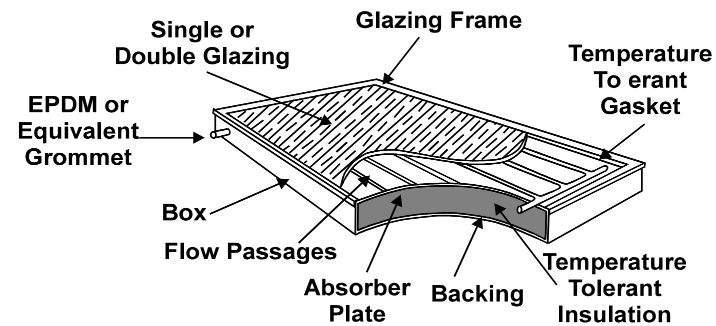


Solar Thermal Collector Types

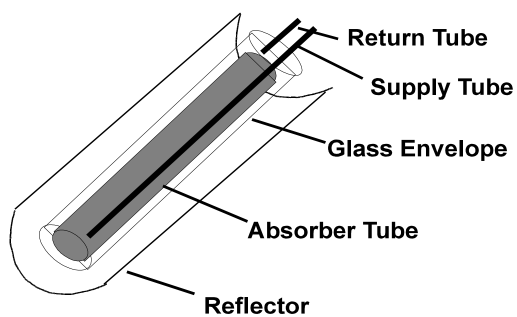
Unglazed EPDM Collector



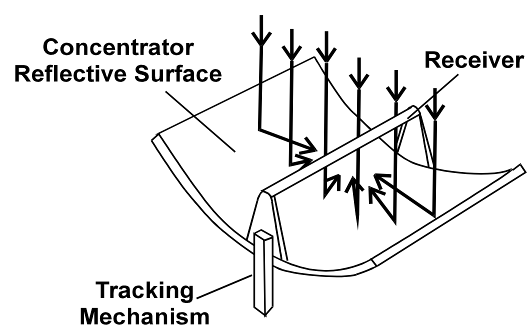
Flat Plate



Evacuated Tubes



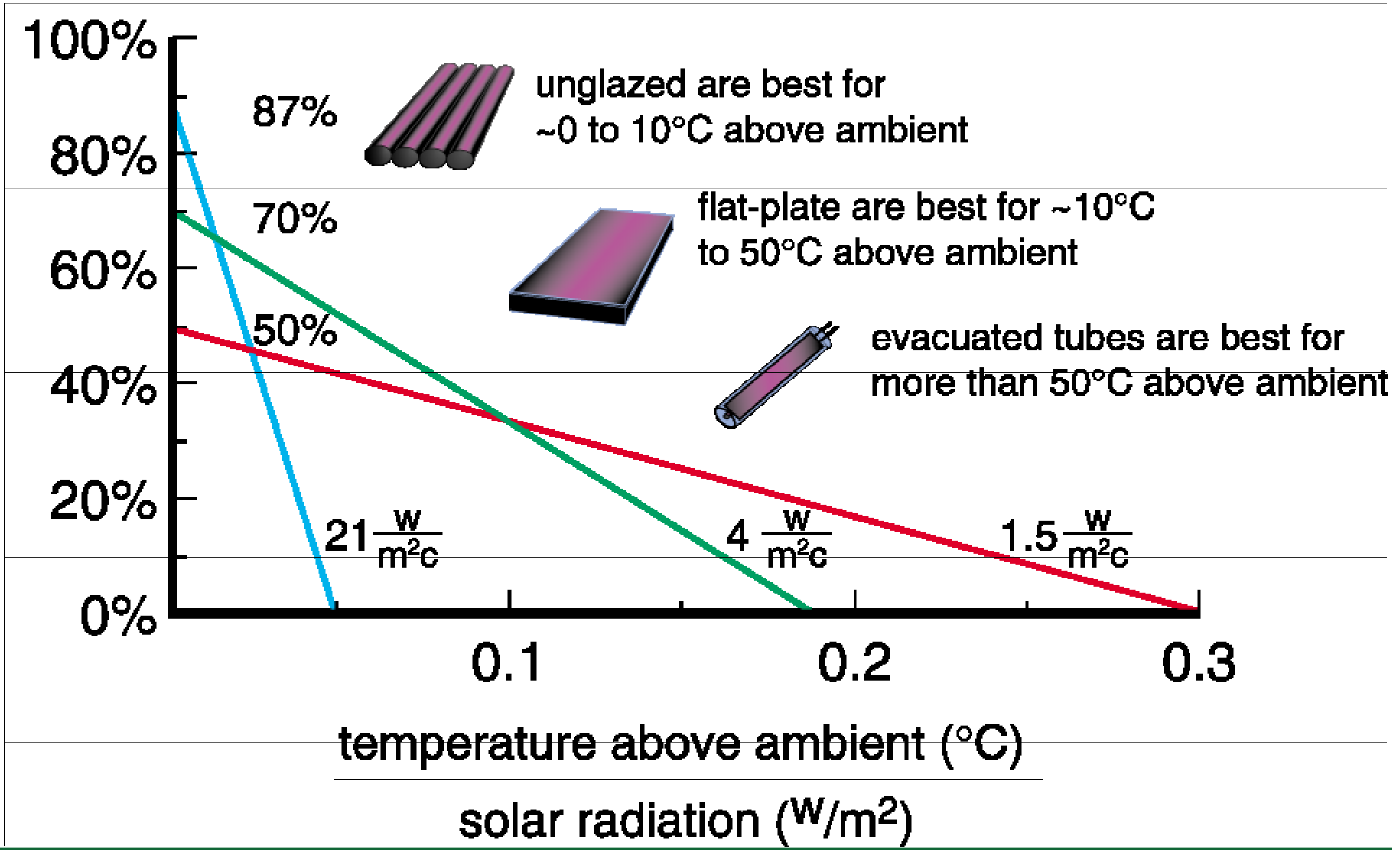
Parabolic Trough



Which Collector is Best?

Depends on Temperature!

Efficiency = % of solar energy captured by collector



Solar Water Heating Technology Applications

Water Temperature Above Average Ambient Air Temperature	System Applications	Collector Technology
Low 0 to 10°C 0 to 18°F	Swimming pool heating	Unglazed mats
Medium 10 to 50°C 18 to 90°F	• Domestic water and space heating • Facility cafeterias, laundries, hotels	Glazed and insulated collectors
High > 50°C > 90°F	• Industrial process heating • Electricity generation	• Evacuated tubes • Focusing collectors or parabolic troughs

Solar Thermal Market Sector Applications

- Residential Facility
  - Domestic hot water
  - Space heating and cooling
  - Swimming pool heating
- Facility or Community
  - Service hot water for hotels, motels, multifamily buildings, hospitals, recreation centers, swimming pools, and casinos.
- Industrial
  - Food or chemical processing
- Water Purification
  - Desalination
  - Pasteurization

Photos top to bottom: NREL/PIX 03971; Andy Walker, NREL; NREL/PIX 08295

Solar Water Heating System Types

Passive Systems	Active Systems
Integral Collector Storage (ICS) • Minimal freeze protection • Minimal hard water tolerance • Lower maintenance	**Open Loop, Pumped Direct** • No freeze protection • Minimal hard water tolerance • High maintenance
Thermosyphon • No or minimal freeze protection • Minimal hard water tolerance • Lower maintenance	**Open Loop, Direct with Drain Down** • Freeze protection • Minimal hard water tolerance • High maintenance
	Closed Loop, Antifreeze, Indirect • Excellent freeze protection • Good hard water tolerance • High maintenance
	Closed Loop, Drain Back, Indirect • Excellent freeze and overheat protection • Good hard water tolerance • High maintenance
	Recirculation Loop (for larger facilities) Requires well-insulated collector (evacuated tube)

Solar Water Heating: Simple Evaluation Procedure

- Estimate daily water heating load
- Determine solar resource
- Calculate solar system size
  - Meet load on sunniest day
  - Undersize rather than oversize
- Calculate annual energy savings
- Calculate annual cost savings
- Estimate system cost
- Calculate savings-to-investment ratio as well as simple payback period
- Analyze in RETScreen www.retscreen.net
- Levelized cost of energy (LCOE): 1 kilowatt-hour (kWh) is $.12 to $.20 (Source: SunShot 2012)

Case Study: Arizona Recreation Center

Financing (2010)

$192,000	Total System Cost (includes full service, parts, delivery, installation, warranty)
(75,000)	*Utility rebate*
$117,000	**System Price Post Rebate**
(57,600)	*DOE Grant*
(19,200)	*State tax credit*
$ 22,800	**Net Cost w/ Tax Benefits**
$ 151,800	*Total rebates/grants*

- Solar company owned system for 1 year
- System then sold to the city for the discounted price of $22,800
- The solar installation company collected the rebates and incentives.

The Solar Thermal System

- The solar panels heat water for the swimming pool, spa, domestic water supply, and building space heat
- The recreation center solar thermal heats water for the pool and hot tub.

NREL/PIX 05183

Example: Solar Thermal with PV and Efficiency

Statistics over 30 Days

Energy Used:
40.4 megawatt-hours (MWh) ($5,246 used)

Energy Generated:
8.94 MWh ($1,163 saved)

Net Utility Energy Bought:
31.4 MWh ($4,083.33 spent)

Other Efficiency Measures Taken:

- Installed variable frequency drives that will adjust circulation automatically to meet needs versus running 24 hours a day for items like pool pumps and heating, ventilating, and air conditioning (HVAC) fan motors
- Replaced chillers and boilers and added controls that address building comfort levels
- Weatherized building with insulation and air sealing
- Replaced existing water fixtures with low-flow devices

Photo from Glen Magee

Example: Colorado Recreation Center

Solar Thermal System

- Rated output: 7,400 therms
- Number of panels: 144 (ground-mounted)
- Annual energy savings: 9,360 therms
- System cost: $360,000
- Installed Oct. 2011
- Building energy load offset: 23%
- Carbon reduced: 109,587 lbs
- Annual cost savings: $8,854

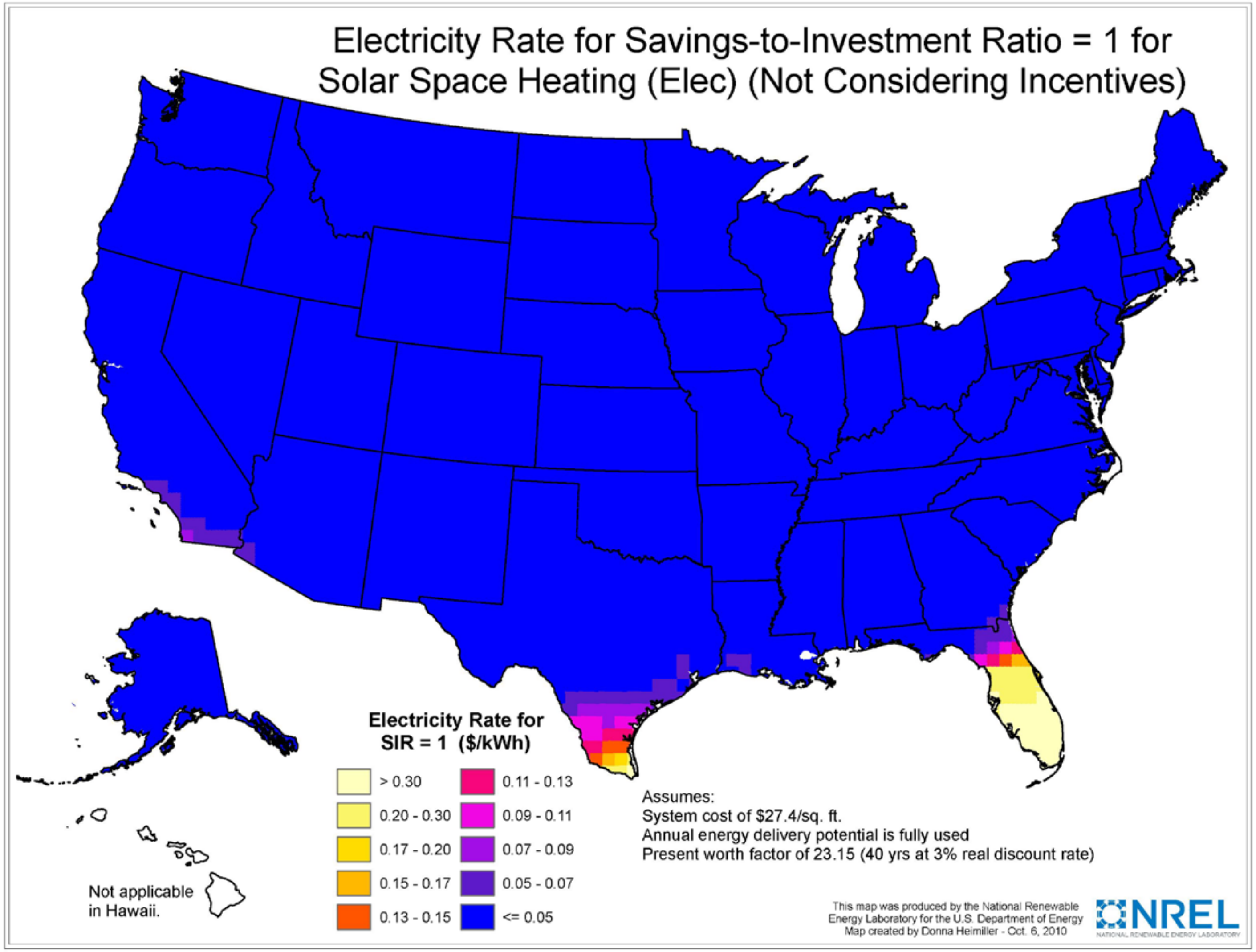
Solar PV System

- Rated output: 72 kilowatts (kW)
- Number of panels: 319 (roof-mounted)
- Annual energy savings: 86,537 kWH
- System net cost: $209,935
- Installed Feb. 2011
- Building energy load offset: 16%
- Carbon reduced: 147,199 lbs
- Annual electric cost savings and renewable energy credits: $10,591

Solar Water Heating References

- American Society of Heating, Air Conditioning and Refrigeration Engineers (ASHRAE)
  - ASHRAE 90003 -- Active Solar Heating Design Manual
  - ASHRAE 90336 -- Guidance for Preparing Active Solar Heating Systems Operation and Maintenance Manuals
  - ASHRAE 90346 -- Active Solar Heating Systems Installation Manual
- Solar Rating and Certification Corporation (SRCC)
  - SRCC-OG-300-91 -- Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems
- National Renewable Energy Laboratory (NREL)
  - Resource Maps: http://www.nrel.gov/gis/maps.html

Solar Vent Preheat Resource and Economics



Solar Vent Preheat

- A preheating air system
- Sunlight strikes south facing vertical box wall.

- South-facing wall surface is best
  - 45° of south gives 80%

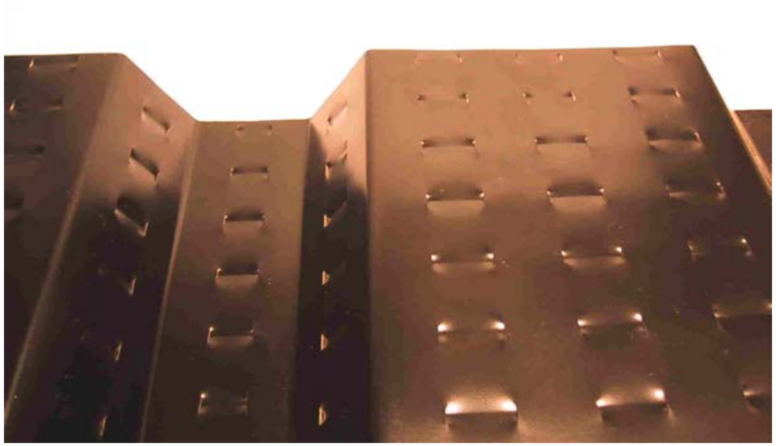
NREL/PIX 09173

NREL/PIX 09355

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

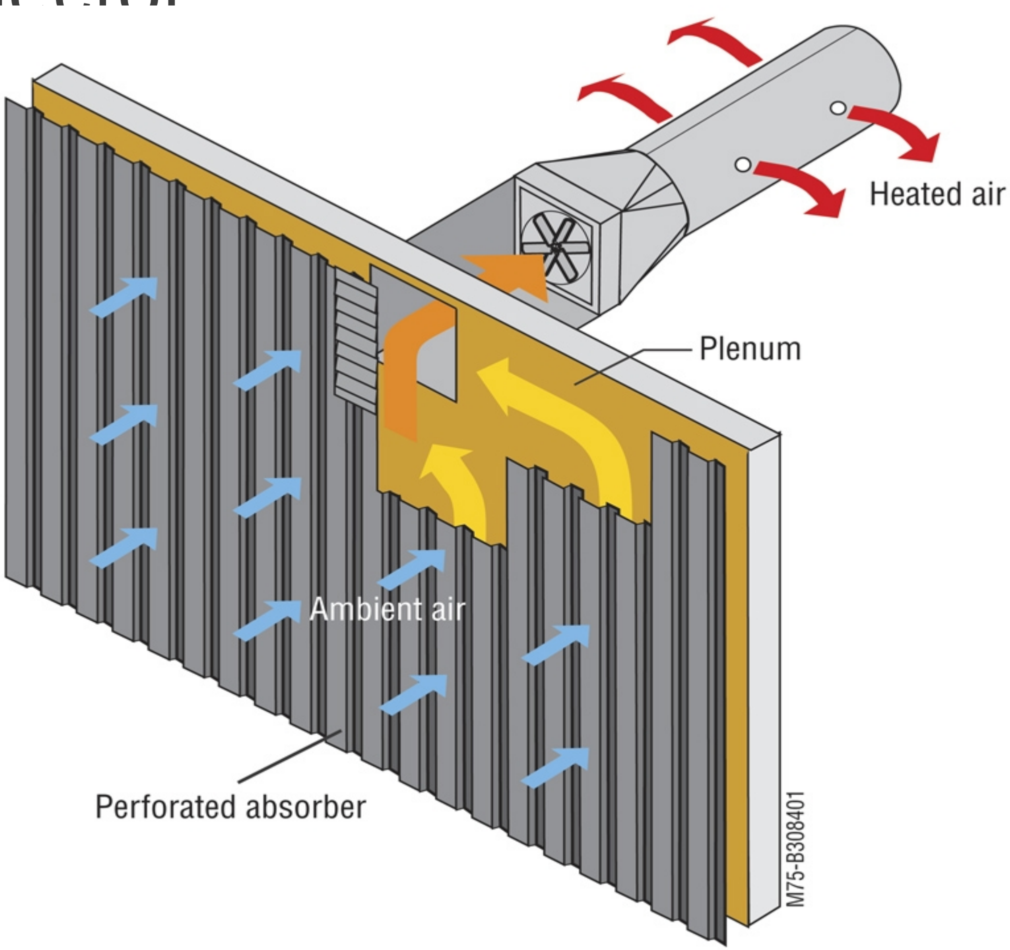
Solar air collector material. NREL/PIX 09212



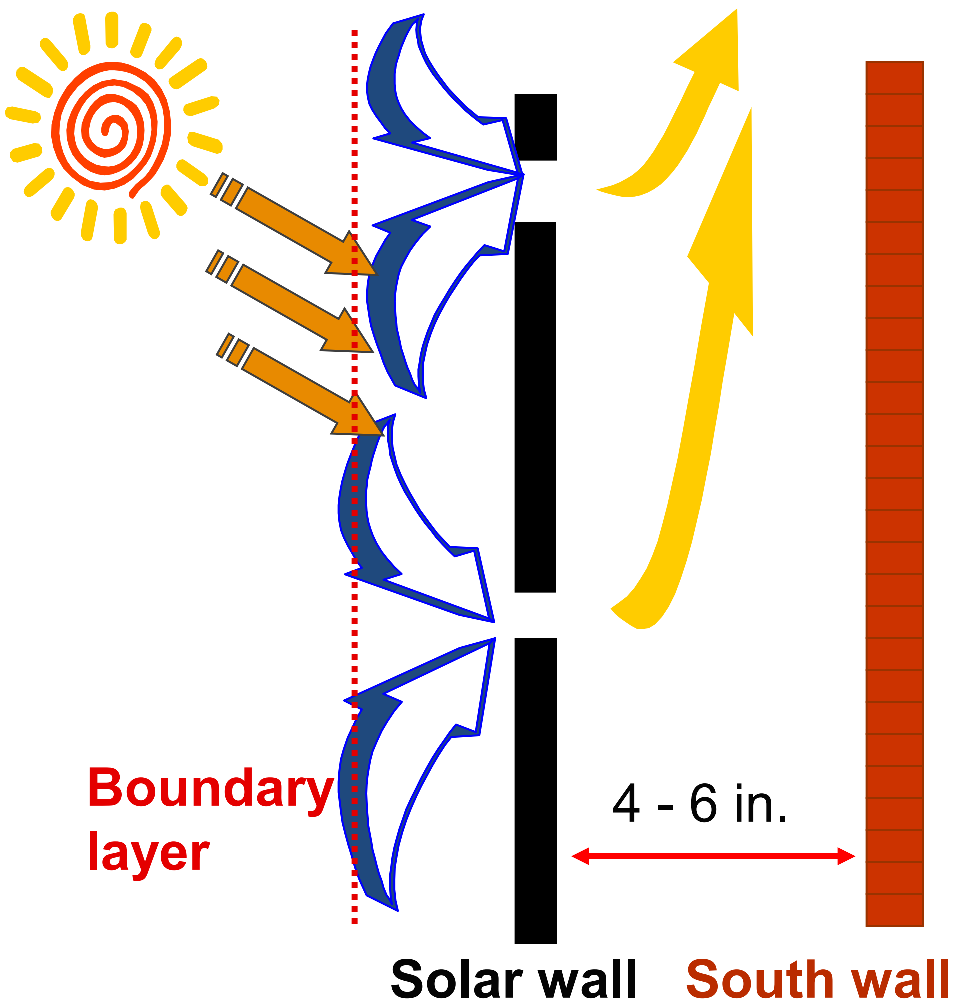
NREL/PIX 00599

System Components

- Transpired solar collector
  - Perforated sheet of
- Air distribution
  - Ductwork, fan, and
- Controls
  - Temperature and ti
    Management Contr



Solar Vent Preheat Principle



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

Advantages of Solar Vent Preheat

- 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

NREL/PIX 17424

NREL/PIX 178254

Generic Cost Example

Building Occupancy	Daytime/7 days/week
Collector Area	30 feet (ft) x 60 ft
Energy Savings	150 kilowatt British thermal unit (kBtu)/square feet (ft_2) x 1800 ft_2 = 270 one million British thermal units (MMBtu)
Collector Cost	$19,800
State Tax Credit	$6,534 (33%)
Federal Tax Credit	10% = $1,980
Accelerated Depreciation	Varies 10% up to $2,000
Net Cost	$10,000
Simple Payback	4 years
Heating Efficiency	70%

NREL/PIX 00957

Solar Vent Preheat

Photo from Rapid City, South Dakota, Recreation Center

Useful Life of Solar Vent Pre-heat is 30 to 40 years. Source: NREL Energy Analysis Website: Distributed Generations of Renewable Energy Estimate of Costs 2012, http://www.nrel.gov/analysis/tech_cost_dg.html

Useful Solar Resources for PV and Vent Preheat

PROJECT DEVELOPMENT & FINANCE "GENERAL"

- For General Project Development & Finance: http://www.nrel.gov/applying_technologies/financing.html
- *Tribal Business Structure Handbook* (Nilles, Kathleen, NAFOA): www.nafoa.org

PROJECT DEVELOPMENT "RESOURCES"

- NREL Learning About Renewables: http://www.nrel.gov/learning/re_photovoltaics.html
- Renewable Energy Atlas: http://maps.nrel.gov/re_atlas
- In My Backyard (IMBY): http://www.nrel.gov/eis/imby/
- PVWatts: http://www.nrel.gov/rredc/pvwatts/

PROJECT DEVELOPMENT "OFF-TAKE"

- Power Purchase Agreement Checklist: http://www.nrel.gov/docs/fy10osti/46668.pdf
- Renewable Portfolio Standards: http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm

Useful Solar Resources for PV and Vent Preheat

PROEJCT DEVELOPMENT "PERMITTNG"

- Federal Energy Management Program Environmental Siting Guide: http://www1.eere.energy.gov/femp/technologies/derchp_envsiting.html
- http://www1.eere.energy.gov/tribalenergy/guide/permitting_licensing.html.
- http://www1.eere.energy.gov/tribalenergy/guide/regulatory_agencies.html.

PROJECT DEVELOPMENT "TECHNOLOGY"

- Tribal Energy and Environmental Information Clearing House: http://teeic.anl.gov/er/index.cfm
- Renewable Energy Resource Assessment: http://www1.eere.energy.gov/tribalenergy/guide/assessing_energy_resources.html.

PROJECT DEVELOPMENT "CAPITAL"

- General Project Development & Finance: http://www.nrel.gov/applying_technologies/financing.html

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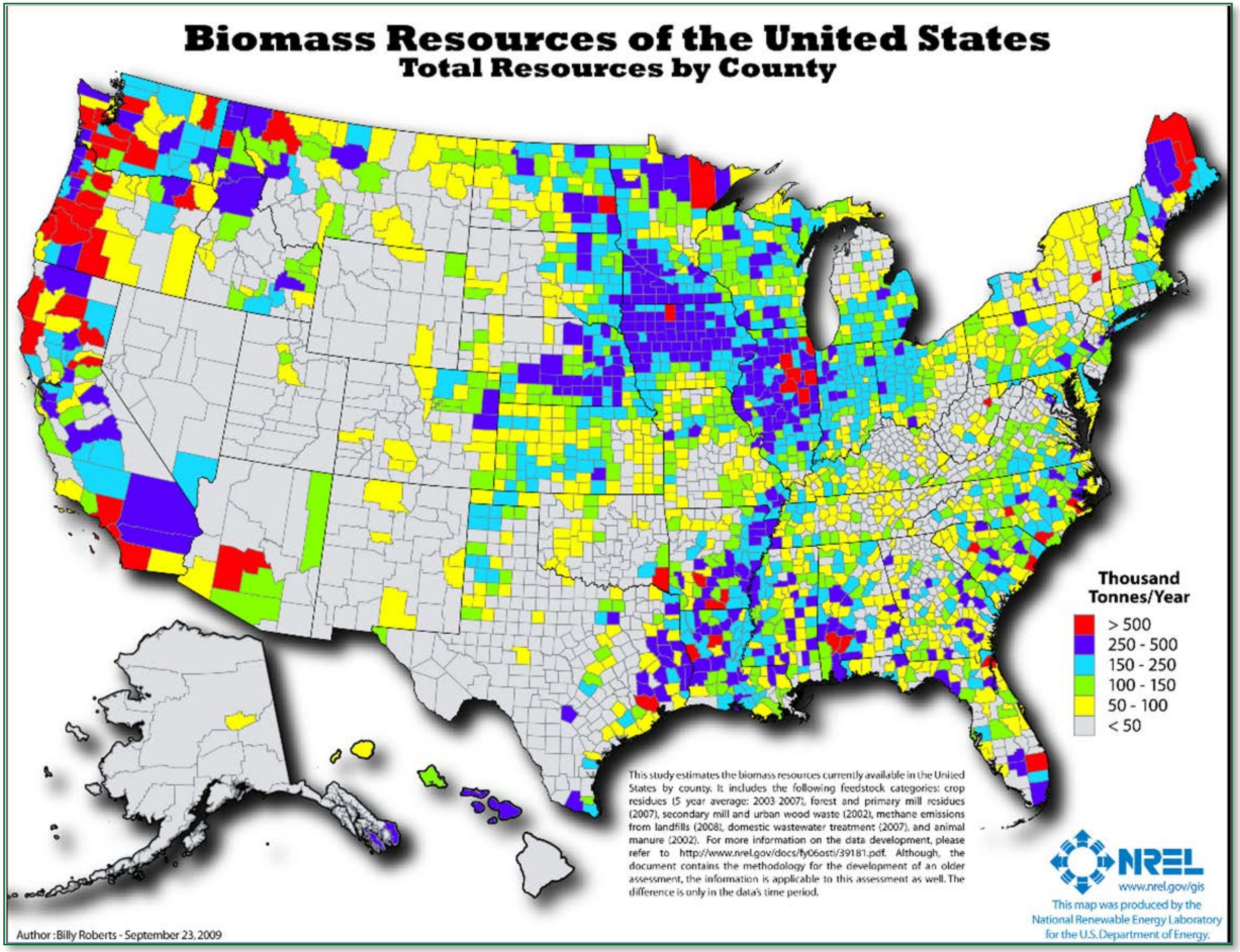
Biomass Resource – GIS Map



Range of Bio-Energy

Biomass Feedstock

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

Conversion Process

- 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

Photos left to right: NREL/PIX 05086, 12481

Biomass Energy

- Biomass heating is a form of renewable energy generation
- Considered carbon-neutral in the near-term
- It is a base-load (dispatchable) source of power and heat
- Intermediate products include pellets and torrefied biomass
- Industrial boilers can produce 100 to 10,000 boiler horse power (BHP) for:
  - Steam
  - Hot water
  - Thermal oil
  - Hot gas production

NREL/PIX 16161

Types of Biomass

- Residential stoves or boilers use chips, pellets, or logs
- Commercial or institutional heating boilers
- Industrial

NREL/PIX 06656

NREL/PIX 19255

Residential Pellet Fuel Appliances

- Pellet Stoves
  - Have heating capacities that range between 8,000 and 90,000 Btu per hour
  - Suitable for homes as well as apartments or condominiums
- Freestanding stoves or fireplace inserts
- Pellet-fired furnaces and boilers
- Pellet fuel hoppers store the pellets until needed for burning. Most hoppers hold between 35 to 130 pounds (16 and 60 kilograms) of fuel, which will last 15 to 20 hours per day
- For More Information: see the Energy.gov Web page on wood and pellet heating in homes, including system selection, installation, chimney placement and sizing, maintenance, and fuels.

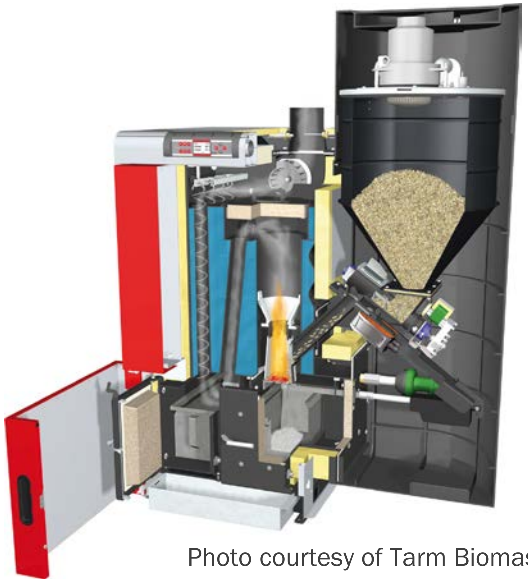


Photo courtesy of Tarm Biomass


NREL/PIX 19254

Biomass Efficiency for Facility

- Typical biomass facility or residential boiler operating on **wood fuel** with a moisture content of 40% has a net efficiency of about 60%-65%
- LCOE can be \$0.05 to \$0.94/kWh. This strongly depends on feedstock cost. A more typical range is \$0.08 to \$0.20/kWh

- A **pellet** stove residential boiler will have higher efficiency because pellets have low moisture and ash content
- Efficiency is influenced by:
  - Moisture content of the biomass
  - Combustion air distribution and amounts (excess air)
  - Operating temperature and pressure
  - Flue gas (exhaust) temperature

Biomass for Community

- Reliability and cost of biomass supply is critical
- Residential and Commercial are proven technologies
- New, highly-efficient technologies making headway in U.S. and around the world

Biomass Heat Exchanger
NREL/PIX 03447

Emissions

- Air emissions from a biomass system depend on:
  - System design
  - Fuel characteristics
  - Operation and maintenance factors
- This table shows typical emissions for a biomass heating system (based on Chiptec gasifier data) operating on 40% moisture content pine (lb/green ton)

Constituent	PM10	NOx	VOC	CO
Typical biomass system emissions [lb/green ton burned]	2.1	2.8	0.6	1.7

Biomass Siting

Depends on:

- Availability and cost of each type of biomass (chips, pellets, or logs)
- Competing fuel cost (e.g. fuel oil, natural gas, etc.)
- Peak and annual thermal load
- Building size and type
- Space availability
- Operation and maintenance staff availability and experience
- Local emissions regulations

Biomass Costs

- Residential
  - Pellet stoves range from $1,750 to $5,000 plus installation
  - Boilers range from $10,000 to $14,000 plus installation (80k to 200k Btu/hour) (some incentives are available)
- Commercial or community operation and maintenance costs include:
  - Fuel
  - Labor (2-5 hours per week, including fuel ordering and a daily walk-through)
  - Repair and replacement of mechanical parts
  - Ash disposal
- Thermal Heating Plants
  - Average $350,000 per MMBtu/hr
  - Smaller plants have higher cost intensity than larger ones

Useful Life of Biomass heat is 20 to 30 years. Source: NREL Energy Analysis Website: Distributed Generations of Renewable Energy Estimate of Costs and Useful Life, June 2012. http://www.nrel.gov/analysis/tech_cost_dg.html

Levelized Cost of Energy for Biomass

- The LCOE of biomass-fired power plants ranges from $0.06 to $0.29/kWh
  - Dependent on capital costs and feedstock costs, where low-cost feed-stocks are available
  - Dependent on capital costs. If modest, biomass can be a very competitive power generation option
  - Depending where low-cost agricultural or forestry residues and wastes are available, biomass can often compete with conventional power sources, even where feed stocks are more expensive
- Even with a large LCOE range, biomass is still more competitive than diesel-fired generation, making biomass an ideal solution for off-grid or mini-grid electricity supply

Source: The International Renewable Energy Agency (IRENA)

Biomass Success in Kodiak, AK

- Wood pellets in Coast Guard boilers are used in place of expensive fuel oil
  - Source of pellets: wood waste and second-growth trees from Tongass National Forest
- Benefits
  - Reduce fuel costs
  - Improve operations and resiliency
  - Support energy independence
  - Foster environmental stewardship

Source: The U.S. Department of Homeland Security

NREL Biomass Heating Plant

- Heats 9 million Btu/hr using pine beetle waste wood
- Tied into an existing hot water distribution system
- Cost was $3.3 million in 2008. Financed by an ESPC (Energy Savings Performance Contract)
- Savings is approximately $400,000 yearly, offering a simple payback of 8.25 years
- During cold weather: 1 truckload of wood chips/day produces 600 gallons of hot water per minute
- Storage capacity: 4 truckloads of wood chip fuel

Heats 725,000 ft_2

NREL/PIX 16579

State Biomass Policy

- Renewable Portfolio Standards:
  - 30 states have enacted a renewable portfolio standard (RPS) within which some kind of biomass is eligible. Mostly electric power, but some states include thermal
- As with biofuels, many biopower incentives have been passed on a state level to encourage biopower production
- For information on your state: http://www.dsireusa.org

Federal Biomass Policy

- Relevant Federal Legislation
  - USDA Farm Bill
  - Healthy Forests Act (HFRA)
  - U.S. Energy Initiative
  - National Energy Policy Act of 2005 http://www1.eere.energy.gov/femp/regulations/epact2005.html

Useful Biomass Resources

RESOURCE

- NREL geographic information system (GIS) maps:
  www.nrel.gov/gis/maps.html
  rpm.nrel.gov/biopower/biopower/launch
  maps.nrel.gov/biomass

TECHNOLOGY

- Woody Biomass Utilization Desk Guide:
  www.forestsandrangelands.gov/Woody_Biomass/documents/biomass_deskguide.pdf

POLICY

- A supply chain analysis framework for assessing state-level forest biomass utilization policies in the United States:
  www.sciencedirect.com/science/article/pii/S0961953410002540

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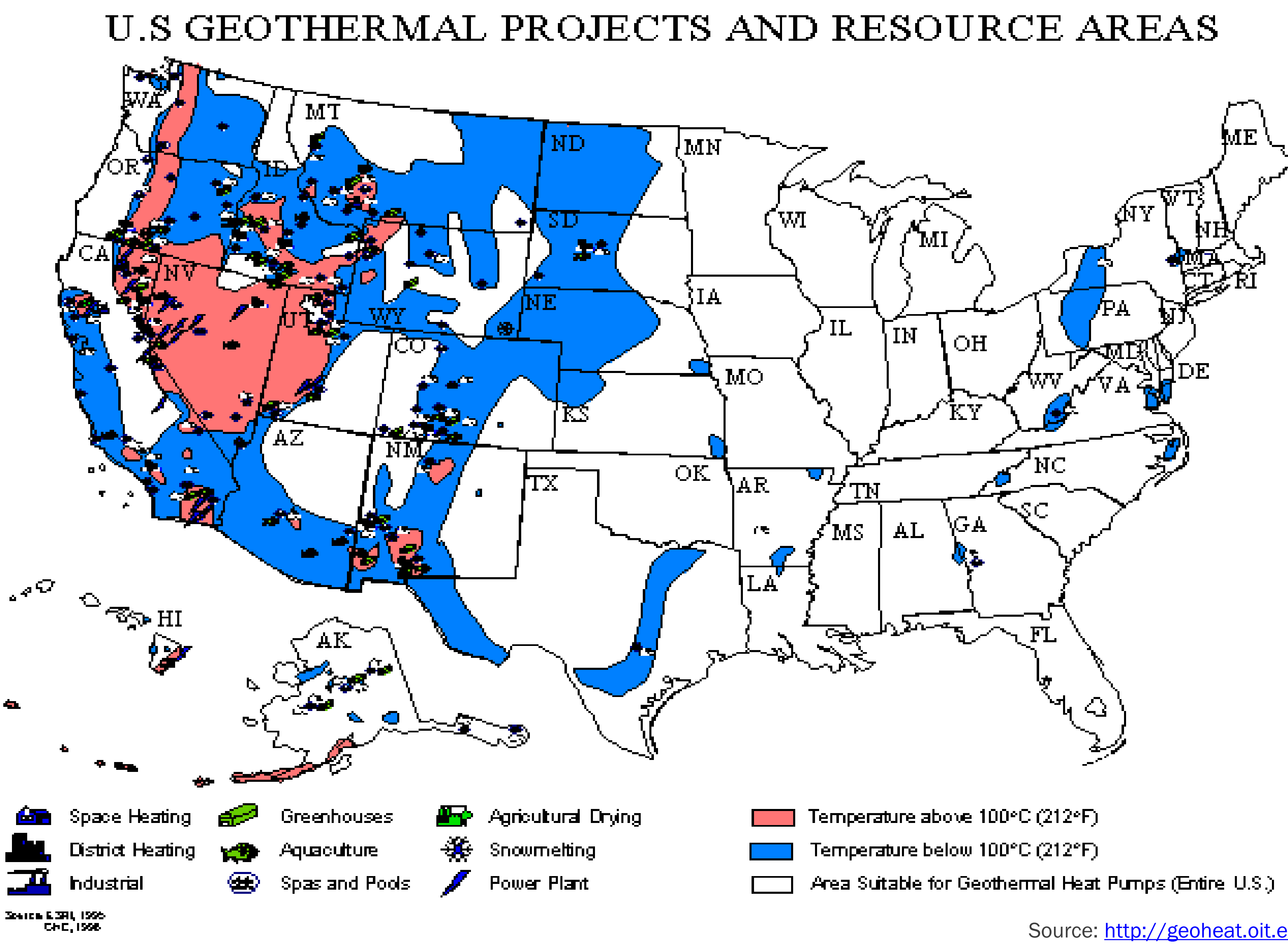
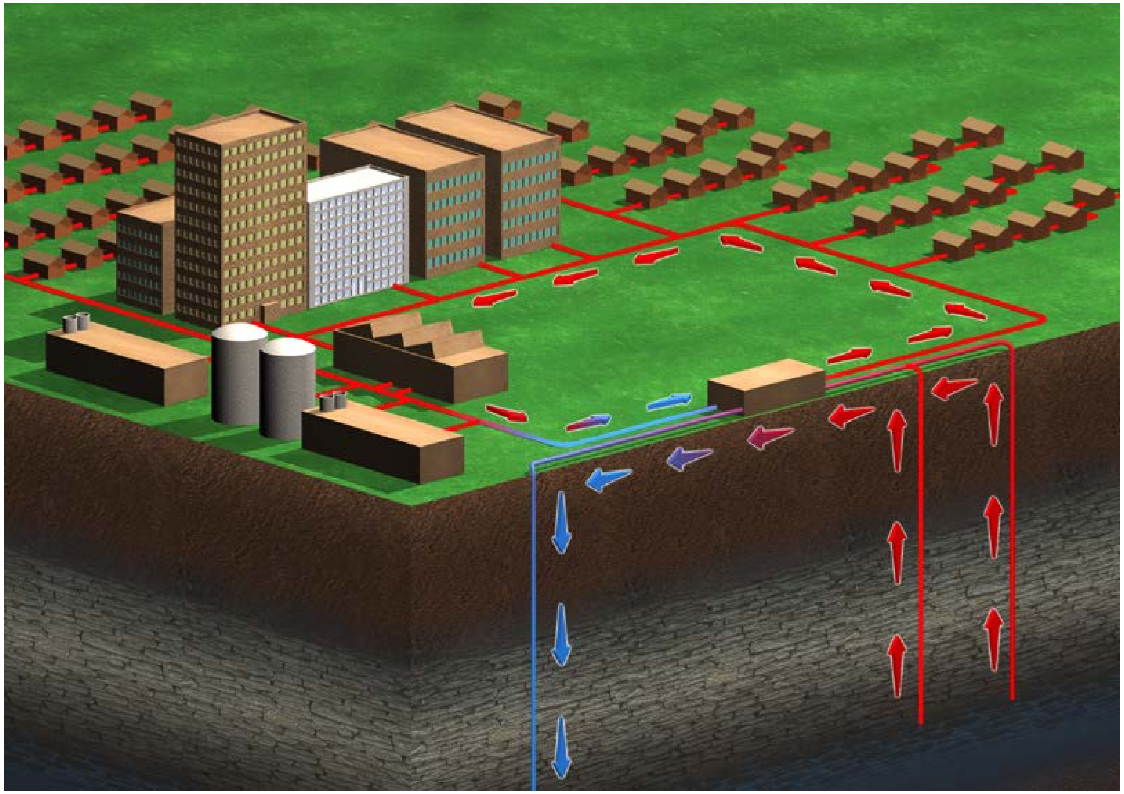
Geothermal Resource



Source: http://geoheat.oit.edu/dusys.htm

Community Scale



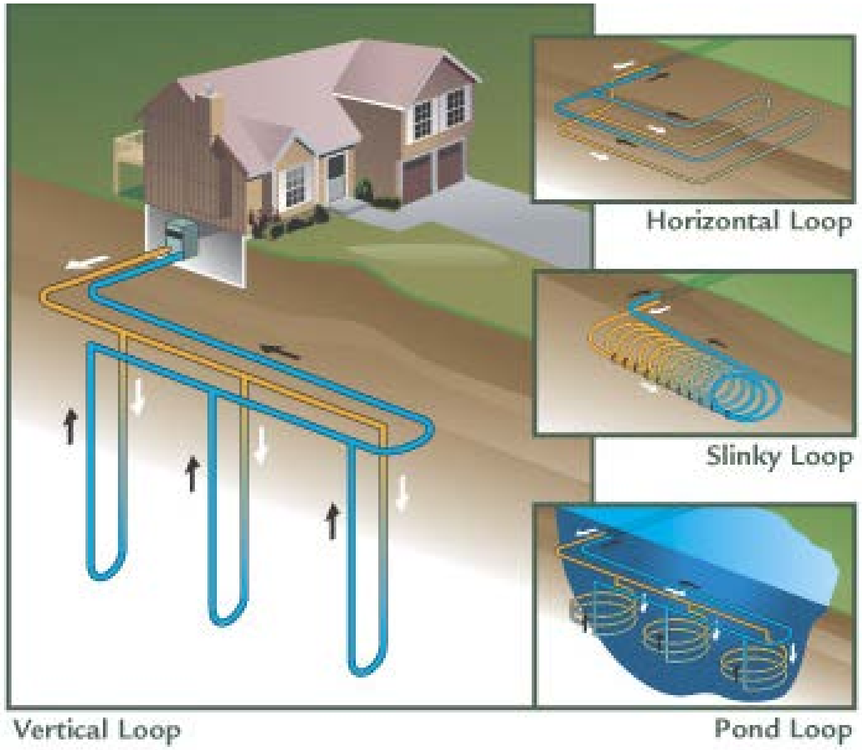
Direct Use

Uses low-temperature resources:

- District Heating
- Process Heat
- Agriculture
- Aquaculture

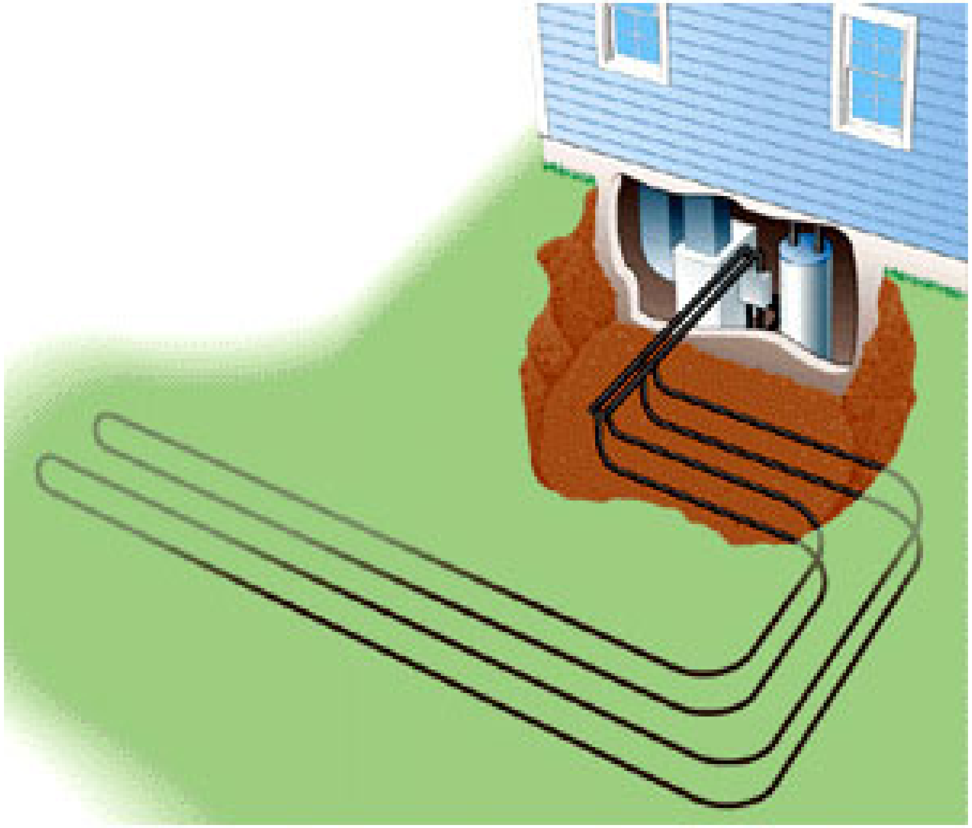
Residential Geothermal Heat Pumps

- Highly efficient method of providing *heating and cooling*
- Work by using ground temperature as a renewable resource for pumping heat in winter and rejecting heat in summer
- Cost effective
- Economic and environmental benefits



Hot Water Facility-Scale Geothermal

- Can provide all or part of a facility's hot water
- An auxiliary heat exchanger uses waste heat from the geothermal compressor (superheated gases) to heat water
- Uses excess heat that would otherwise be expelled to the loop



Low-Temperature Geothermal Example

Chena Hot Springs Resort in Alaska

- Commissioned in 2006
- Off-grid sustainable geothermal power and heat for multiple applications
- Commercial Power Production: Lowest in the world at 165°F

Photos from Chena Hot Spring Resort

Case Study: Citizen Potawatomi Geothermal

Fire Lake Project in Shawnee, Oklahoma: Two Buildings and Greenhouse

Geothermal Pond
Photo from Citizen Potawatomi Nation

- **Commissioned in 2005, completed in 2007**
- Project will offset 50% of HVAC operating costs
- Reduced maintenance costs and recovery of waste heat

Six Part Construction

- ✓ Construction of geothermal pond (a water source heap pump application)
- ✓ Construction of heat exchanger and vault header system
- ✓ Piping network connects pond loops to building
- ✓ Ground source heat pump system for Cultural Heritage Center

Case Study: Citizen Potawatomi Geothermal

Grand Casino completed in August 2007

Photo from Citizen Potawatomi Nation

Sustainable Business Venture:

- Geothermal plant and the Grand Casino provides community jobs
- Project costs were minimal at $476,130
- Project spawned self funded 2011 and 2012 projects:
    - Bowling Center
    - Arena Building
    - Housing Units (70)

Case Study: School

- Facility:
  - 122,989 ft_2 school near Montreal
- System Description:
  - 167 ton multiple-energy (hybrid) horizontal closed loop system
  - System includes a solar wall and natural gas fueled fresh air preheating system
- Installation Costs:
  - Ground source heat pump (GSHP) = $589K
  - Est. conventional system costs = $800K
- Energy Savings:
  - 8% reduction in energy use compared to conventional systems operating at other schools in the area

Source: FEMP Energy Assessment Training

Cost of Geothermal

- Residential (single family)
  - New Construction $15,000 to $20,000 for heating and cooling
  - Remodel $15,000 to $30,000 for heating and cooling
- Community
  - 107,000 ft_2 Middle School (600 students) GSHP built in 2011 $1.3 million
  - Community College: $860,000 GSHP
  - Geothermal Power Plant in Nevada: $4.4 million
- Note that hybrid systems (coupled with a cooling tower or boiler) can make geothermal more cost effective

Geothermal Cost Effective? Yes!

	Electrical Generation	Geo Exchange Systems (Geothermal Heat Pumps)		
LCOE = $42 to $60/MWh		Residential	Commercial	Schools
Cost/Megawatt	$2,000,000 $3,000,000			
Building Size		3,000 ft^2	7,200 ft^2	55,000-112,000 ft^2
Install Cost		$15,000 - $20,000	$408,000	$240,000 - $1,090,000
Annual Savings		$600- $1,500	$ 2,098,000	$20,000- $42,000
Cost/Ton			$1,500	$1,500

Electrical Generation: Glacier Partners, 2009
Geo-Exchange: www.geoexchange.org

Useful Geothermal Resources

RESOURCE	NREL geographic information system (GIS) maps: www.nrel.gov/gis/maps.html
TECHNOLOGY	Geothermal Resources Council
POLICY	A supply chain analysis framework for assessing state-level forest biomass utilization policies in the United States: www.sciencedirect.com/science/article/pii/S0961953410002540

Resources & Maps

- NREL Geothermal:
  http://www.nrel.gov/gis/geothermal.html

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

- Western Area Power Administration:
  http://www.wapa.gov/es/pubs/fctsheet/GHP.pdf

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

Amy Hollander
Amy.hollander@nrel.gov

INFORMATION ON THE CURRICULUM PROGRAM & OFFERINGS

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
- Building Heat & Hot Water
- Geothermal
- Hydroelectric
- Solar
- Wind

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