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Solar Energy Technologies and the Utilization on Native American Tribal Lands

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Abstract

As an undergraduate researcher, I worked on a new technology called nanofluid-based direct absorption solar collectors (DASC) which is a type of solar water heater that has the potential to be more efficient than traditional solar water heaters. Because of my experience with this type of technology, I decided to look into other types of solar energy technologies which could be used on Native American tribal lands. Some types of solar energy technologies that I wanted to focus on are photovoltaic solar energy systems, passive solar design, and solar water heaters.

It is my opinion that tribes in all types of climates should consider using solar energy technologies as alternatives to traditional heating, cooling, electrical energy, and water heating methods because the technologies are mature, several tribes have some experience with them, and they are cost effective. Over the course of my internship, I had the opportunity to see all of these types of solar technologies in action on various tribal lands. These observations further validated my opinion that all tribes have the potential to install these types of technology to help themselves become less energy dependent and help to reduce their impact on the environment.

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Introduction

There are several types of technologies that can be implemented to utilize the energy that can be harvested from the sun. The technologies that will be discussed are photovoltaic solar energy systems, passive solar design, and solar water heaters. Figure 1 below shows the generation potential on Native American Tribal lands in the continental United States. It shows that several tribes have great potential for PV electric energy generation and several others have a decent potential for PV generation. This potential for solar generation is why tribes should be looking into solar energy technologies.

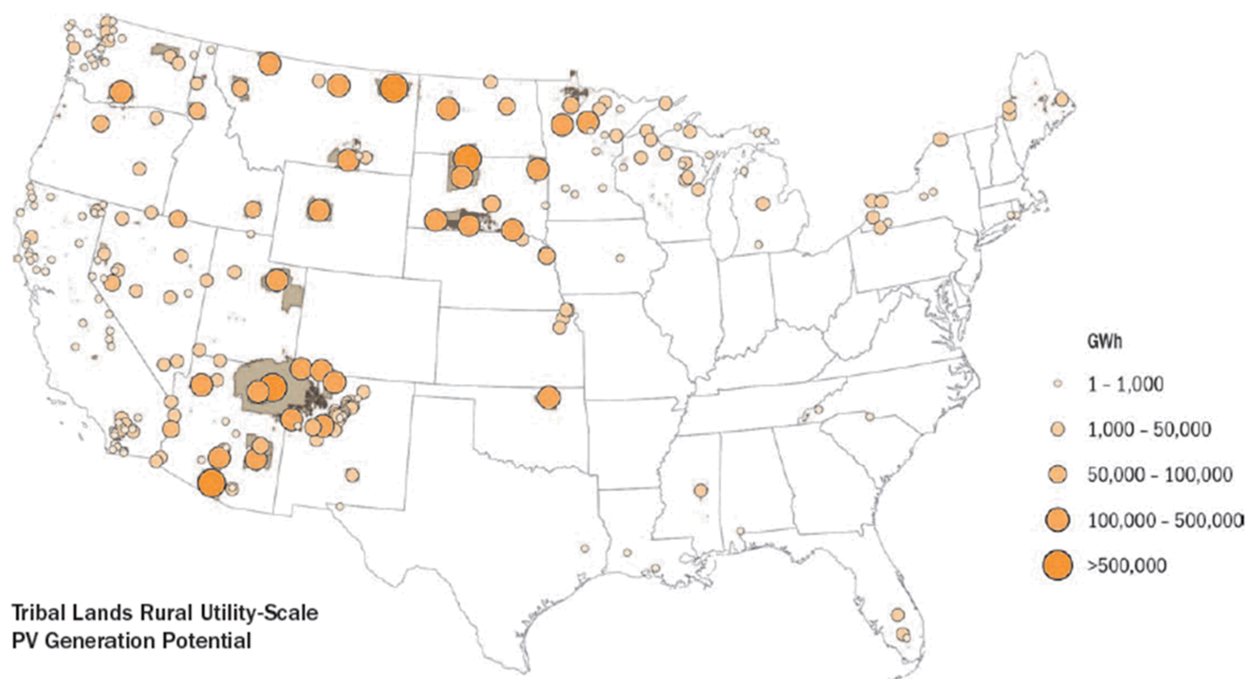

Figure 1 Tribal Lands Rural Utility-Scale PV Generation Potential [1]

Photovoltaic Solar Energy Systems

Photovoltaic (PV) solar energy systems absorb energy given off from solar rays and turn this energy into useable electric energy. PV systems consist of PV panels, an inverter to convert the direct current (DC) generated in the PV cells into alternating current(AC), energy storage, mounting structures for these panels and any accessory parts that the system at hand may require. If the system is going to be off the electrical grid, energy can be stored in the form of batteries will be required so that the system can operate during cloudy days or at night-time. If the system is going to be tied to an electrical grid, then a meter will be required. Battery storage could be added if the building requires power at all times, especially in the event of an emergency such as a natural disaster. Pictured below in Figures 2 and 3 are off- and on-grid AC solar systems.

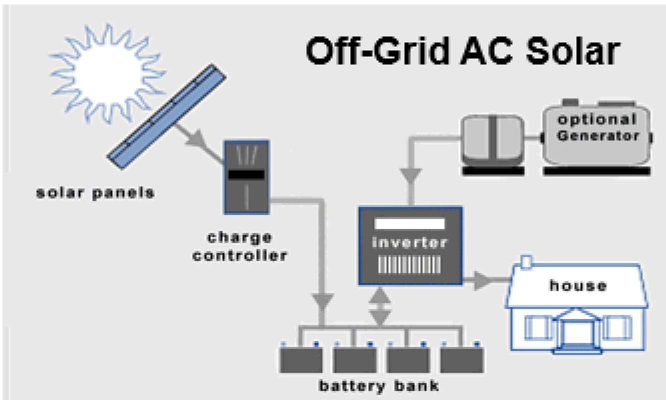

Figure 2 An off-grid AC solar system. [2]

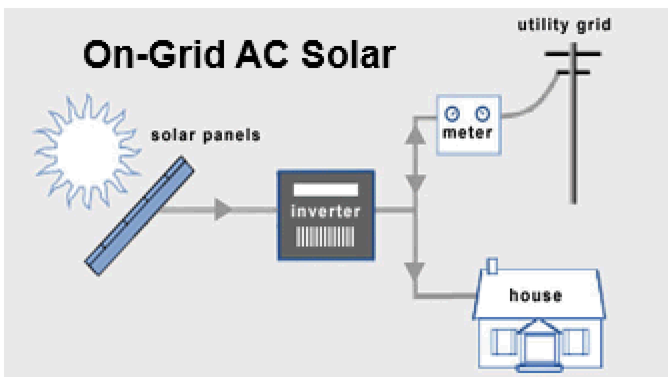

Figure 3 An on-grid AC solar system. [2]

PV Cells

The photovoltaic (PV) effect is the process of converting light (photons) into electricity (voltage). French physicist, Edmund Becquerel, first discovered the PV effect in 1839 using copper oxide in an electrolyte. Radiation from the sun (sunlight) hits a PV cell to create the PV effect. PV cells are made up of two layers of semiconducting material, usually silicon, that have been chemically treated. These layers are typically referred to as P and N. Figure 4 below depicts a schematic of a PV cell. The boundary between P and N acts as a diode allowing electrons to move from N to P, but not P to N. When photons with sufficient energy hit the cell, they cause electrons to move (from N to P only) causing excess electrons in the N-layer and a shortage in the P-layer. This voltage difference is typically in the range of 0.5V for as long as the cell is in sunlight. If shading, such as cloud cover should occur, the performances is significantly affected. The voltage pushes the flow of electrons or 'DC current' to contacts at the front and back of the cell where it is conducted away along the wiring and circuitry that connects the cells together. When the cells are arranged in series, it is called a PV panel. These panels can be used individually or connected to form arrays. [3]

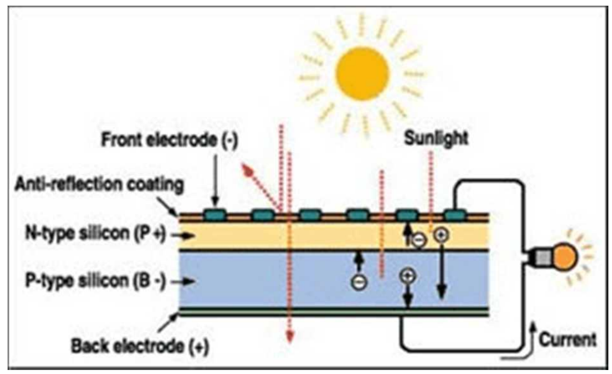

Figure 4 Schematic of a PV cell [3]

There are a wide variety of PV cell types which can range in size from smaller than a postage stamp to several inches across. The cells are typically less than the thickness of four human hairs. PV cells are composed of semiconductor material, meaning this material combines some properties of metals and some of insulators. The following types of photovoltaics will be discussed: silicon, thin-film, organic, and concentration. [4][5]

Silicon PV Cells

Silicon is the most common material used in solar cells. It is also the second most abundant material on Earth which makes it a very affordable material to use. Along with being affordable, silicon has a high efficiency and long lifetime. Modules made with silicon have an expected lifetime of 25 years or more while still producing 80% of their original power at the end of their lifetime. [6]

Thin-film PV Cells

Thin-film solar cells are made by depositing one or more thin layers of PV material on a supporting material such as glass, plastic, or metal. The two main types of thin-film PV used today are cadmium telluride (CdTe) and copper indium gallium diselenide (CIGS). These materials can be deposited on either side of the supporting material. CdTe is the second most common PV material used. It is low cost but the efficiencies are not as high. CIGS cells have favorable electronic and optical properties but is more challenging to manufacture because of the complexity involved in combining four elements. Both CdTe and CIGS require more protection than silicon to allow for long-lasting outdoor operation. [6]

Organic PV Cells

Organic PV (OPV) cells are made of carbon-rich polymers which can be tailored to enhance a specific function of the cell, such as sensitivity to a certain type of light. OPV cells are only about half as efficient as crystalline silicon and have shorter operating lifetimes, but could be less expensive to manufacture in high volumes. [6]

Concentration PV Cells

Concentration PV (CPV) focuses sunlight onto a solar cell by using mirrors or lenses. Since the sunlight is focused onto a smaller area, less PV material is required. The PV material is more efficient at energy conversion when the sunlight is more concentrated. This means that the highest overall efficiencies can be obtained with CPV cells and modules. However, the materials and manufacturing techniques used in this set up are more expensive. Tracking systems are also required, which adds more cost to this type of PV cell. [6] This technology is only used for utility scale applications.

Solar Performance and Efficiency

The conversion efficiency of a PV cell is the percentage of solar energy shining on a PV device that is converted into usable electricity. There are several factors that affect conversion efficiency which include: wavelength of sunlight, recombination (direct and indirect), temperature, and reflection. Improving conversion efficiency is key goal of current PV research as higher conversion efficiencies will make PV more cost-competitive with conventional sources of energy. Currently, most commercial grade solar cell efficiencies are in the range of 14-19%, so there is much room for improvement. [6]

Mounting Structures

PV arrays must be mounted on stable and durable structure that can support the weight of the array and withstand corrosion, hail, rain and wind over its multiple decade lifetime. The mounting structures tilt the array at a fixed angle determined by the local latitude, orientation of the structure, and electrical load requirements. In the northern hemisphere, modules are pointed due south and inclined at an angle equal to the local latitude to achieve the highest annual energy output. The most common type of mounting is rack mounting because it is robust, versatile, and easy to construct and install.

PV arrays can also be mounted on the ground and include a tracking system. The tracking mechanism can automatically move the panel to follow the sun across the sky. This tracking capability allows for more energy to be produced and in turn a higher return on investment. One-axis trackers are usually designed to track the sun from east to west. Two-axis trackers allow for modules to remain pointed directly at the sun throughout the day. There are moving parts in tracking systems, which generally tend to have higher up-front costs as well as more expensive maintenance costs than stationary structures. [5]

Inverters

Inverters are used to convert the direct current (DC) electricity that is generated by the PV cells into alternating current (AC) electricity, which is used for local transmission of electricity. PV systems either have one inverter that converts the electricity generated by all of the modules, or micro-inverters that are attached to each individual module. A single inverter is typically less expensive and easier to cool and service. Micro-inverters are useful if some modules might be shaded. Inverters will need to be replaced at least once in the 25-year lifetime of a PV array. Advanced inverters, or "smart inverters," allow for two-way communication between the inverter installation and the electrical utility user/monitor. This capability allows utility operators or users to reduce costs, ensure grid stability, and reduce the likelihood of power outages. [5]

Energy Storage

Since solar panels only generate electricity during sunny daytime hours, it is necessary to store the excess energy that is not used. Batteries allow for the storage of the energy generated by the PV cells so that it can be used to power homes at night or when weather elements keep sunlight from reaching PV panels. [5]

Economics and Environmental Impact

The levelized cost of electricity (LCOE) for solar PV ranges from $.04 to $.22/kWh. When compared to coal and coal gasification produced electricity the LCOE for coal is $0.06-$0.14/kWh and the LCOE for IGCC is $0.09-$0.21/kWh. [8] In the past five years the cost of solar has basically cut in half. In December 2012, it was reported that the LCOE for solar PV ranged from $0.14 to $0.54. The price of PV technologies is dropping due to scale of deployment and technological advances, especially by the countries of Germany and Japan. Projected costs for PV in 2020 are $1.50/watt (W) for residential and $1.25/W for commercial (these are installed cost). [1]

It is known that the manufacturing of solar panels does produce some CO2 emissions but the amount of CO2 that a solar panel displaces over its lifetime far outweighs the amount that is produced during its creation. About 960 lbs. of CO2 are produced from the making of a 100-watt solar panel CO2, but over its 30-year lifespan, it will produce enough electricity to offset 8,400 pounds of CO2 from a coal-burning power plant. [9]

Tribal Examples

Several tribes have had experience with PV solar systems. The PV systems used by tribes range from individual hybrid systems to community scale micro grids all the way up to utility scale facilities. An individual hybrid solar system includes using a solar panel and a small wind turbine that supply electricity to a home and extra energy that is not used is stored in batteries. A community scale micro grid is a cluster of panels that are used to power a few homes or a small to medium sized business. Utility scale facilities are the large clusters of panels, sometimes acres of panels, that are positioned in an large open area and are tied to the electric grid.

An example of several individual hybrid systems can be found on Navajo Nation through its tribally owned entity, Navajo Tribal Utility Authority (NTUA). NTUA rents out solar units to customers who live off-grid. These individual systems range from 880 kW to 1800kW with price ranges from $75-$110/month. [10]

A few examples of tribal community scale micro grids: the Hualapai tribe who have a micro-grid that powers the water pumps that pump water to their facilities at Grand Canyon West, as well as supplying electricity to some of those same facilities; the Blue Lake Rancheria who built a community scale micro grid that includes a 500 KW solar array which began construction in May 2016 [11]; and the Forest County Potawatomi who installed 15 panels on 15 buildings on their reservation which produce a combined 1 MW of power that was completed in 2015. [12]

A few tribal examples of utility scale solar facilities: the Navajo Solar Facility in Kayenta, AZ which is a 27.3 MW facility that was commissioned in June 2017 [13]; the Fort Mohave Solar Project on Fort Mohave Indian Reservation in AZ and CA who have plans for 310 MW facility in the works and a 13.8 MW and 5 MW system have already been commissioned [14] [15]; and the Moapa Solar Facility in Moapa, NV which is a 353 MW facility that was commissioned in August 2016. [16]

Passive Solar Design

Passive solar design is a design strategy that is used to heat and/or cool and to daylight buildings. The goal of this design strategy is to reduce or eliminate the use of heating or cooling accessories such as heaters or air conditioners. This type of design strategy is very climate dependent. In warmer climates internal-load passive solar design is recommended and in temperate or cold climates skin-load passive solar design is recommended. Figure 5 shows the five elements of passive solar design. Figure 6 is a building that has passive solar design concepts, such as a clerestory and a Trombe wall. [17]

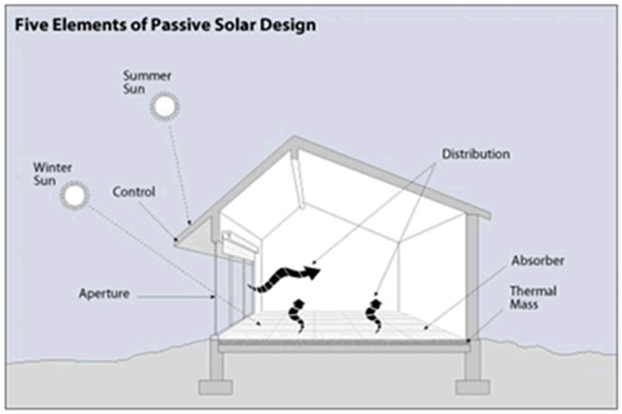

Figure 5 Five Elements of Passive Solar Design[17]

Figure 6 Example of a passive solar design with clerestory and a Trombe wall.[17]

Internal-Load Building Design

Buildings in warmer climates that may require year round cooling should be designed using an internal-load building design. Examples of buildings that would be appropriate for this type of design are educational facilities, offices, or large retail complexes. The design for this type of building emphasizes cooling avoidance by using shading, high performance glazing and daylighting. Internal-load building designs should include: daylighting workspaces with properly oriented and controlled windows to reduce the need for using lights, specifying high-performance glazing for the windows which will reduce heat gain while admitting visible light, high efficiency heating ventilation and cooling (HVAC) systems, and incorporating appropriate shading devices. [17]

Skin-Load Building Design

Buildings in temperate and cold climates that need heating for the majority of the year should be designed using a skin-load building design. This type of design would be appropriate for a variety of building types which include: barracks, low-rise housing, small warehouses, and small retail facilities. Skin-load building design involves using solar energy to provide space heating. Buildings with this design should include: south facing windows to allow for maximum sunlight penetration, shade to avoid summer sun, providing properly sized and installed insulation, downsizing HVAC equipment, and incorporating thermally massive construction materials (thermally massive materials refers to building materials with high heat capacity such as concrete slabs, brick walls, or tile floors). Figure 7 shows some general design strategies for skin-load type passive solar design. [17]

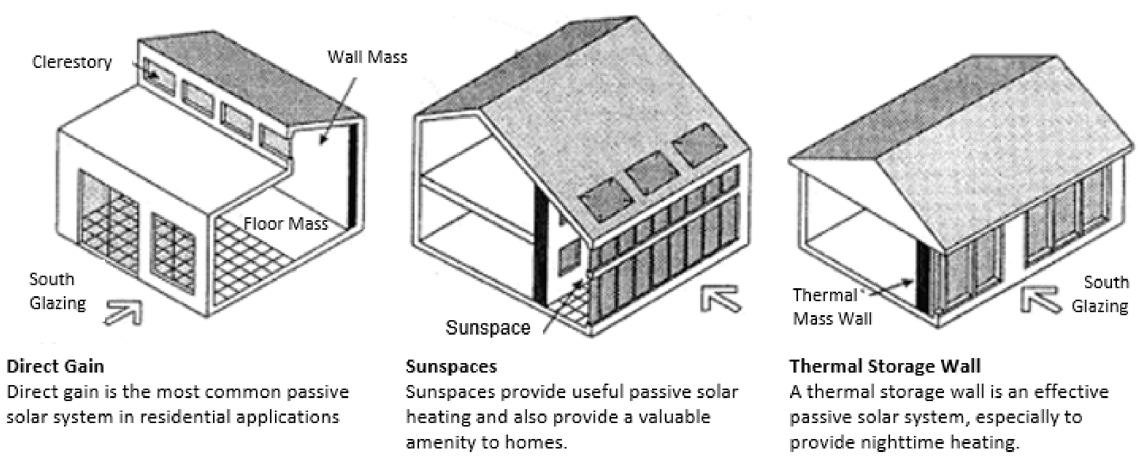

Figure 7 General types of skin-load passive solar design[17]

Economics

It is best to incorporate passive solar design during the initial design phase of a new building. Incorporating the design early on will allow for costs to remain low or equivalent to what the building would cost with traditional building design methods. If a modest level of passive solar design is used, it can reduce heating requirements from 5% to 25% at little or no incremental initial cost. This level of design should be implemented on all small buildings in temperate to cold climates. If a more aggressive passive solar design is utilized, it could reduce heating requirements from 25% to 75% compared to a traditional structure while being cost effect on a life-cycle basis. This type of design should be considered for many small buildings in cold and temperate climates. [17]

Tribal Examples

There are several tribal examples of passive solar design. In some of the cases it is called green building design.

- The NTUA headquarters in Chinle, AZ is LEED Gold Certified which means that the building is highly energy efficient and aims toward maximizes the usage of its renewable resources such as water and sunlight. The building includes water saver technology and is designed to maximize daylighting and shading from summer sun.
- The Hualapai Tribe had a Clinic/Community Center in Peach Springs which has a green build design that is aimed toward summer cooling through the use of shading and large windows for winter heating.
- The Akwesasne Housing Authority has Sunrise Acres housing project which is a senior living community that is in the construction stages. The apartments are aimed toward

passive solar heating with energy efficient heating ventilation and cooling (HVAC) systems. [18]

- Osage Nation in Oklahoma has the Osage Nation Campus Master Plan which is a building plan that utilizes passive solar design techniques. [19]
- Lakota Solar Enterprises is a native owned company that makes a product called a solar furnace which produces hot air to help heat homes in the colder months. [20]

Solar Water Heaters

There are a wide variety of designs for solar water heaters. Each system consists of a collector and storage tank and use the sun's thermal energy to heat water. Three types of collectors include: batch collectors (also called Integrated Collector-Storage (ICS) systems), flat-plate collectors, and evacuated tube collectors. There are also several types of circulation systems which include: direct, closed-loop (indirect), active (forced-circulation), and passive. Figure 8 shows a basic schematic of a solar hot water system which is located on the roof of a home. The system depicted is an evacuated tube collector with an active flow circulation and directly uses the work fluid which would be the water. [21]

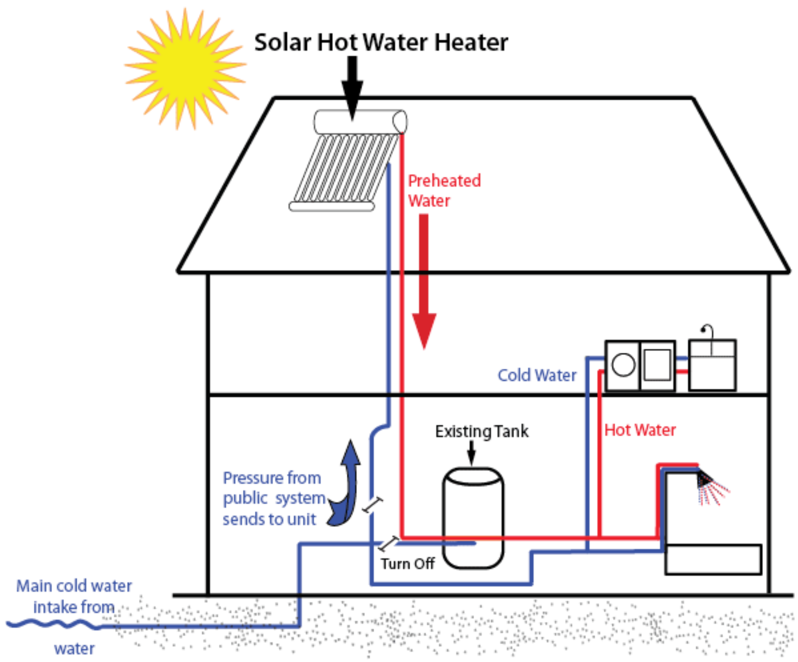

Figure 8 Schematic of a solar water heater installed on the roof of a house.[22]

Integrated Collector-Storage Systems

ICS systems heat water in dark tanks or tubes inside an insulated box, storing water until it is needed. The water in the storage tank can become very hot since it can remain in the collector for long periods of time when demand is low, so a tempering valve should be put in place for safety. Batch collectors are incompatible with closed-loop circulation systems, so they are not recommended for cold climates. Figure 9 shows an integrated collector-storage system. [21]

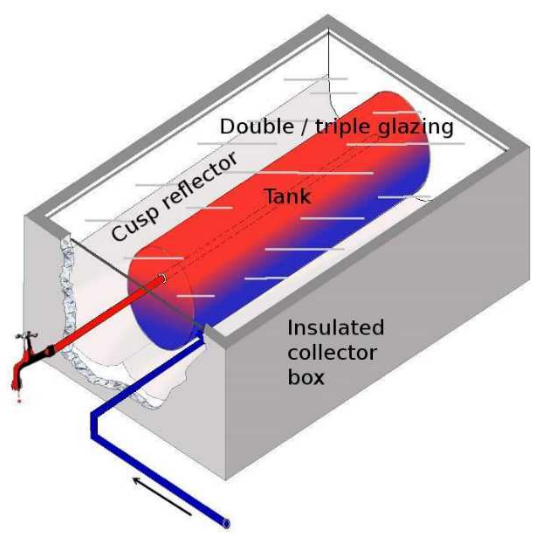

Figure 9 Example of an ICS system.[23]

Flat-Plate Collectors

Flat-plate collectors consist of copper tubes fitted to flat absorber plates. The most common configuration is a series of parallel tubes connected at each end by two pipes, the inlet and outlet manifolds. The flat plate assembly is situated in an insulated box and covered with tempered glass. The typical amount of water contained in this type of collector is 40 gallons. Two collectors can provide about half of the hot water required by a family of four. Figure 10 shows an example of a flat-plate solar collector. [21]

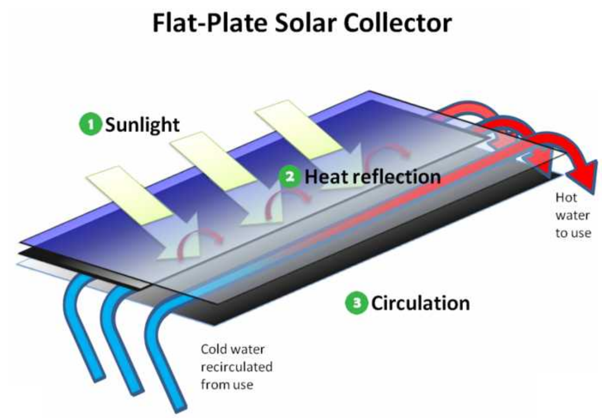

Figure 10 Schematic of a Flat-Plate Solar Collector[24]

Evacuated Tube Collectors

Evacuated tube collectors are the most efficient type of collector currently available. Figure 11 shows a schematic of an evacuate tube solar collector. Each evacuated tube is similar to a thermos. A glass or metal tube containing the working fluid is surrounded by a larger glass tube with the space between the two creating a vacuum. This space allows for very little heat to be lost from the working fluid. This type of collector can work in overcast conditions and operate in temperatures as low as -40F, however they can cost twice as much per square foot as flat plate collectors. [21]

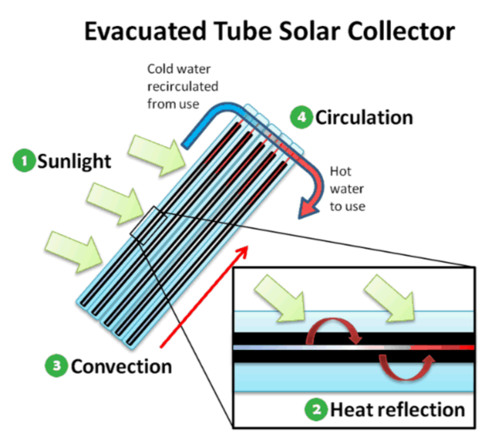

Figure 11 Schematic of an Evacuated Tube Solar Collector[24]

Nanofluid-based Direct Absorption Solar Collectors

The concept of direct absorption solar collector (DASC) was originated in the 1970s as a simplification to solar thermal collector design and as a way to potentially enhance the efficiency by absorbing the energy with the working fluid. DASCs have been proposed for a variety of applications such as water heating. The efficiency of traditional DASCs is limited by the absorption properties of the working fluid. Nanofluid-based DASC has been tested as an alternative to traditional methods. A schematic of proposed nanofluid-based DASC is shown in Figure 12.

Nanofluid DASC utilizes certain nanoparticles (such as graphene) placed inside of a working fluid to absorb solar energy directly within the fluid itself. The highest temperature is in the working fluid and the overall conversion efficiency of energy from solar radiation to thermal form would be improved due to reduced re-radiation heat loss. This is known as the thermal trapping phenomenon. At the nanoscale, the specific surface area is increased and optical properties are more adjustable, which allows for more efficient solar energy utilization. Nanofluids are not transparent to solar radiant energy and absorb and significantly scatter solar irradiance passing through them, which is why they are an excellent option to increase the photothermal conversion efficiency of direct absorption solar collectors. Nanofluid-based DASC has been shown to improve efficiency of DASC with improvements of up to 5% in solar thermal collectors by utilizing nanofluids as the absorption mechanism. [26] [27]

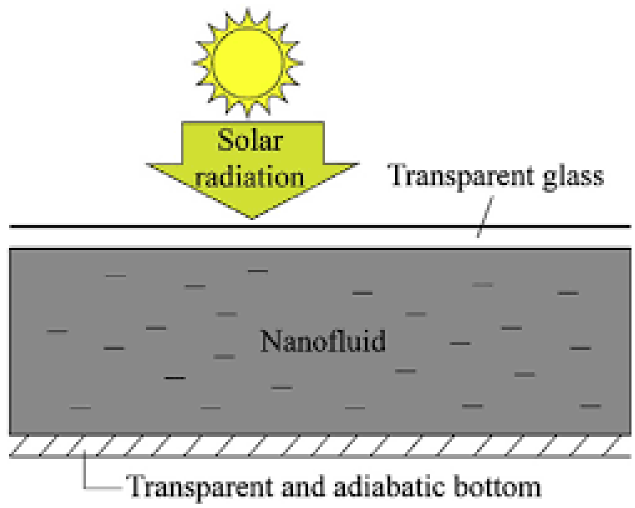

Figure 12 Schematic of proposed nanofluid-based DASC.[25]

Direct Circulation Systems

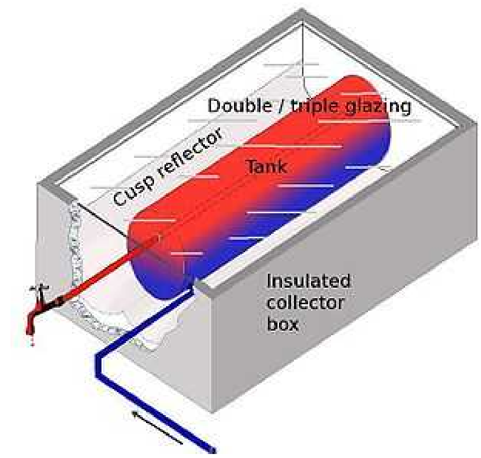

Figure 13 Example of a direct circulation system[23]

Direct systems circulate water through solar collectors where it is heated by the sun. The heated water is then stored in a tank, sent to a tank-less water heater, or used directly. This type of circulation system is preferred in warmer climates where freezing temperatures are unlikely. If used in a cold climate, freeze protection is necessary [21]. Figure 13 shows an example of a direct circulation system.

Closed-loop Circulation Systems

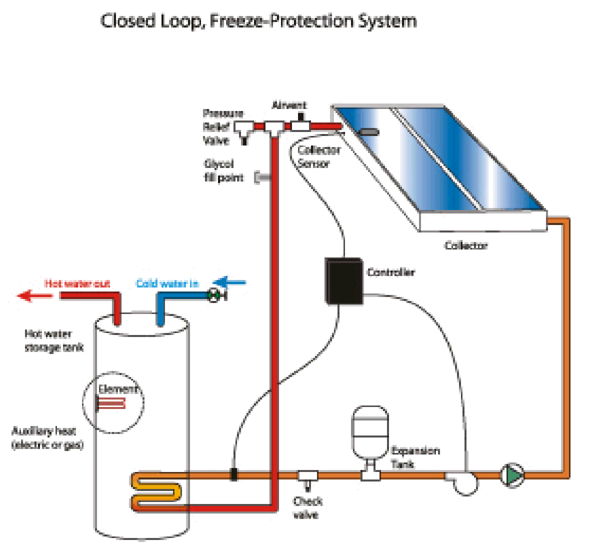

Figure 14 Schematic of a closed-loop circulation system. [28]

Closed-loop, or indirect, systems use a non-freezing liquid to transfer heat from the sun to water in a storage tank. The sun's thermal energy heats the working fluid and this fluid exchanges the heat in a heat exchanger to heat the water. This working fluid is then cycled back to the collectors. This capability makes these type of collectors suitable for colder climates. Figure 14 shows an example of a closed loop circulation system. [21]

Active and Passive Circulation Systems

Active, or forced-circulation, systems use electric pumps, valves, and controllers to move water from the collectors to the storage tank. Passive systems require no pumps; natural convection moves water from the collectors to the storage tank as it heats up. Figures 15 and 16 show schematics of active and passive circulation systems. [21]

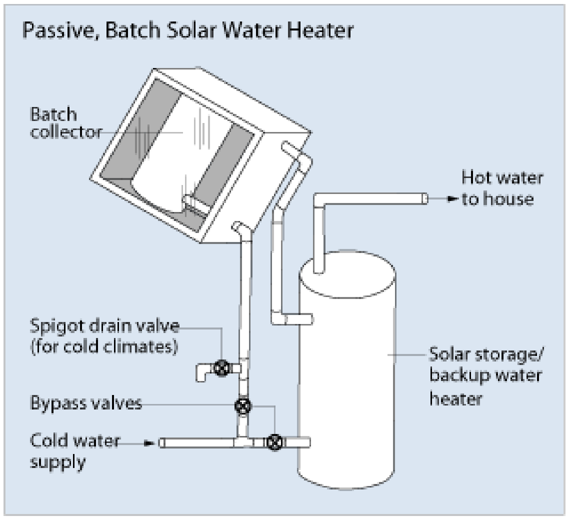

Figure 15 Schematic of a passive circulation system[29]

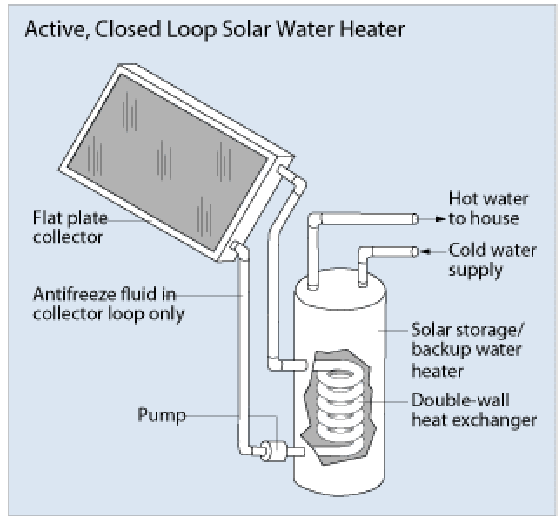

Figure 16 Schematic of an active circulation system[29]

Economics and Environmental Impact

The initial cost of solar water heaters ranges from $2000-$4000 with a 20-year lifespan as compared to standard water heaters which range from $200-$2000 with a useful life of 10-15 years and tank-less water heaters which range from $800-$3000 with a useful life of 20+ years. Solar water heaters are 50% more efficient than gas or electric water heaters but may require back up on cloudy days and peak times. [30] [31]

Since solar water heaters do not require electricity or gas to operate, they have little to no CO2 emissions. Replacing a standard water heater with a solar water heater will “offset the equivalent of 40% to 100% of the carbon dioxide emissions of a modern passenger car” (U.S. DOE). [29]

Tribal Examples

A couple of tribal examples of solar water heater use include NTUA's Chinle AZ office which has solar water heater units on the roof of the building and the Hualapai Tribe in Peach Springs' Community Center/Clinic which also has solar water heaters on the roof of the building.

Combining Technology

All three types of solar energy technologies discussed can be used in combination with each other, or any mixture of the three can be used. A few of the previously mentioned tribal projects fall into this category of combining technology. These projects are: NTUA's Chinle AZ office which is LEED Gold certified, has solar water heater units, and uses two large scale solar arrays to supplement energy to the building; Akwesasne Housing Authority's Sunrise Acres housing project which uses green building concepts along with PV solar power to supplement energy to the housing complex; and the Hualapai Tribe in Peach Springs' Community Center/Clinic which uses individual off-grid solar panels to power their parking lot lights and solar water heaters as well as having a green building design.

Conclusion

Tribes in all types of climates should consider using solar energy technology as an alternative to traditional heating, cooling, electrical energy, and water heating methods because the technologies are mature, many tribes have some experience with these technologies, and the mature technologies are cost effective.

Tribes in cold climates should considered using the passive solar heating design building to heat their homes, as well as cold climate solar water heaters to heat their water. Solar panels in cold climates have a longer payback period but can still pay themselves off within their lifetime.

Tribes in warm climates should consider using passive solar design in a way that will keep their houses shaded during the day from summer sun but can still warm it during winter, as well as using solar water heaters for warm climates. Solar panels in warm climates with plenty of sunny days pay themselves off relatively quickly and will save the tribal users on utility costs and may even make the user money by selling the electricity back to the grid if they choose to tie into the grid.

Sources

[1] *Developing Clean Energy Projects on Tribal Lands*. Department of Energy Office of Indian Energy, Dec. 2012.

[2] "Off-Grid Solar, Wind Power Systems & Off Grid Power System Design." Wholesale Solar Banner, www.wholesalesolar.com/solar-information/off-grid-living.

[3] *ENGINEERING.com | Photovoltaics*, Engineering.com, www.engineering.com/SustainableEngineering/RenewableEnergyEngineering/SolarEnergyEngineering/Photovoltaics/tabid/3890/Default.aspx.

[4] "Solar Photovoltaic Technology Basics." Energy.gov, Office of Energy Efficiency and Renewable Energy, 16 Aug. 2013, energy.gov/eere/energybasics/articles/solar-photovoltaic-technology-basics.

[5] "Solar Photovoltaic System Design Basics." Energy.gov, Office of Energy Efficiency and Renewable Energy, 20 Aug. 2013, energy.gov/eere/energybasics/articles/solar-photovoltaic-system-design-basics.

[6] "Solar Photovoltaic Cell Basics." Energy.gov, Office of Energy Efficiency and Renewable Energy, 16 Aug. 2013, energy.gov/eere/energybasics/articles/solar-photovoltaic-cell-basics

[7] "Solar Performance and Efficiency." Energy.gov, Office of Energy Efficiency and Renewable Energy, 20 Aug. 2013, energy.gov/eere/energybasics/articles/solar-performance-and-efficiency.

[8] *Lazard's Levelized Cost of Energy Analysis*. version 10.0, Lazard, 2016, pp. 18–20, *Lazard's Levelized Cost of Energy Analysis*.

[9] "Reduce CO2 Emissions with Solar Panels." *SolarChat*, solarchat.org/reduce-co2-emissions-with-solar-panels/.

[10] NTUA Natural Gas Utility Rates, www.ntua.com/utility_rates/pvrates.html

[11] "Blue Lake Rancheria Kicks Off Solar System Construction." *Energy.gov*, 9 May 2016, www.energy.gov/indianenergy/articles/blue-lake-rancheria-kicks-solar-system-construction.

[12] Krall, Ken. "Potawatomi Install 1 Megawatts Of Solar Power." WXPR, Forest County Potawatomi Community, 17 Dec. 2015, wxpr.org/post/potawatomi-install-1-megawatts-solar-power.

[13] Smith, Noel Lyn. "Navajo Tribal Utility Authority Opens First Large-Scale Solar Farm." Farmington Daily Times, Farmington Daily Times, 31 July 2017, www.daily-times.com/story/news/local/four-corners/2017/07/30/navajo-tribal-utility-authority-opens-first-large-scale-solar-farm/493090001/.

[14] YOUNG, NEIL. "Fort Mohave Solar Project Completed." Mohave Daily News, Mohave Daily News, 20 Jan. 2017, www.mohavedailynews.com/news/fort-mohave-solar-project-completed/article_314a4fa8-dede-11e6-8747-534a7c9d0325.html.

[15] FAIRMAN, JULIE. "Solar Plant to Be Built on Reservation Land in California." *Mohave Daily News*, Mohave Daily News, 12 Jan. 2016, www.mohavedailynews.com/news/solar-plant-to-be-built-on-reservation-land-in-california/article_2ef6a16c-b8ff-11e5-9ea0-074c5b206c1f.html.

[16] SB STAFF. "Solar Builder Project of The Year Winner: Moapa Southern Paiute Solar." Solar Builder, Solar Builder, 7 Nov. 2016, solarbuildermag.com/featured/solar-builder-project-year-2016-winner-ground-mount-utility-scale/.

[17] Fosdick, Judy. "Passive Solar Heating." Passive Solar Heating, Whole Building Design Guide, 11 Nov. 2016, www.wbdg.org/resources/passive-solar-heating.

[18] "Sustainable Construction in Indian Country." U.S. Department of Housing and Urban Development, 27 Nov. 2012, www.huduser.gov/portal/SCinIC/stregis_energy_evaluation11_29.pdf.

[19] J-C, Special to the. "Osage Nation Campus Master Plan Phase 1 Construction to Begin Soon." Pawhuska Journal, Pawhuska Journal-Capital, 4 Dec. 2013, www.pawhuskajournalcapital.com/article/20131204/NEWS/312049771.

[20] "Renewable Energy: A New Way to Honor the Old Ways." Lakota Solar Enterprises, Lakota Solar Enterprises, 2016, www.lakotasolarenterprises.com/.

[21] "How It Works - Solar Water Heaters." Products | ENERGY STAR, Energy Star, www.energystar.gov/products/water_heaters/water_heater_solar/how_it_works.

[22] Singh, Nitendra Kumar. "Working Principle of Solar Water Heater." LinkedIn SlideShare, 18 May 2016, www.slideshare.net/nitendrakumarsingh/working-principle-of-solar-water-heater.

[23] "The Full Wiki." Solar Hot Water, The Full Wiki, www.thefullwiki.org/Solar_hot_water.

[24] "Solar Heating and Cooling Technologies." EPA, Environmental Protection Agency, 19 Dec. 2016, www.epa.gov/rhc/solar-heating-and-cooling-technologies.

[25] Muhammad, Mahmud, et al. (2016). The use of nanofluids for enhancing the thermal performance of stationary solar collectors: A review. Renewable and Sustainable Energy Reviews. 63. 226-236. 10.1016/j.rser.2016.05.063.

[26] Hall, Kathryn M. Tailoring Porosity and Nano-Additives of Porous Ceramic Scaffolds for Use in Direct Absorption Solar Collectors. 20 Dec. 2016.

[27] Otanicar, Todd P., et al. "Nanofluid-Based Direct Absorption Solar Collector." Journal of Renewable and Sustainable Energy, vol. 2, no. 3, May 2010, p. 033102., doi:10.1063/1.3429737.

[28] "Solar Thermal Energy." *New Mexico Solar and Wind*, www.newmexicosolarandwind.com/Solar%20Thermal.htm.

[29] "Solar Water Heaters." Department of Energy, energy.gov/energysaver/solar-water-heaters.

[30] "How Much Does Replacing a Water Heater Cost? - CostHelper.com." CostHelper, home.costhelper.com/water-heater.html.

[31] "Traditional v. Solar Water Heaters: A Buyer's Guide." Boulden Brothers, 16 Feb. 2015, bouldenbrothers.com/traditional-v-solar-water-heater-buyers-guide/.