NOTE: This paper is under update, correction and revision - expected to be available Fall 2017

Energy and Renewable Energy in Arizona
League of Women Voters of Greater Tucson
December 2016

This paper introduces the consumer to energy use and electrical power generation in Arizona, with special emphasis on the use and generation of renewable energy. The paper presents facts that may be of interest to the consumer and the voter in evaluating energy-related issues, candidate positions and ballot measures in state and local elections. Topics covered include

- *Total Energy Consumption in Arizona*
- *Household Energy Consumption in Arizona*
- *Electric Power Generation and Delivery in Arizona*
- *Renewable Energy Programs in Arizona*
- *Issues for Renewable Energy Electric Rates*

The League of Women Voters of Greater Tucson commissioned this paper to "address problems with large scale renewable energy and the inadequacy of the grid system to accommodate energy from solar, wind and thermal sources." While researching the alternative energy material, the authors determined that a survey of energy in Arizona was needed to provide context for the problems associated with the large-scale use of renewable energy in Arizona.

Supplemental information is presented in appendices, including discussions of energy form transformation, fuel economic viability, solar power generation pilot projects and electric utility consumer charges.

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1. Introduction

Consumers in Arizona use energy for heat, light, communications, mechanical work, transportation and refrigeration. They buy the energy in the forms of fuel and electric power.

Fuels are primarily used for heat, heat-originated power generation and transportation. Virtually all transportation fuels are “mined”, that is, extracted from sources that are not replenished within a human lifetime. Fuels are burned and release carbon dioxide and other greenhouse gases and pollutants into the atmosphere. The greenhouse gases are part of the ashes associated with fuel consumption.

“Renewable energy” is extracted from sources that can be replenished within a human lifetime. Renewable energy sources (excluding biomass sources) are used almost exclusively to generate electrical power, which may be used for any purpose. Renewable energy is also often called “clean” energy, in that it does not increase the concentration of greenhouse gases or particulates in the atmosphere.

A note on units: *In this paper, all data not stated as a percentage of a total amount is stated in units of kilowatt-hours or multiples of kilowatt-hours. Kilowatt-hours based units are used in order to state energy in the same units as appear on Arizona consumers’ power bills. The kilowatt-hours based units are related as follows.*

1 Megawatt-hour (MWh) = 1,000 kilowatt-hours (kWh)
1 Gigawatt-hour (GWh) = 1,000 MWh = 1,000,000 kWh
1 Terawatt-hour (TWh) = 1,000 GWh = 1,000,000 MwH = 1,000,000,000 kWh

2. Total Energy Consumption in Arizona

The United States Energy Information Association (EIA) provides summaries and data for energy sources and consumptions for each state and the United States as a whole. Summaries of information from the EIA website are included below, with sources.

Total energy consumption by source for Arizona is summarized in Table 2.1 below. The information is tabulated and converted to Terawatt-hours (TWh) as stated in the note on units. Currently, fossil fuels account for 74% of energy consumption statewide, nuclear power accounts for 19% and renewable energy sources account for 7% of total energy consumption.

Table 2.1 Total Energy Consumption in Arizona by Source

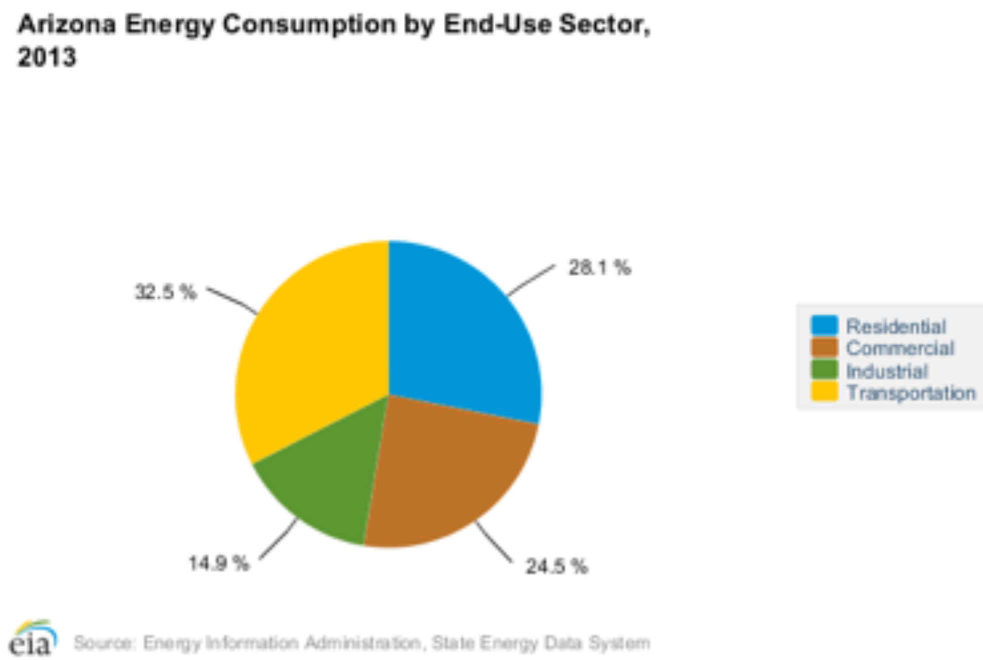
Source	Consumption (TWh)	Percentage of total
Fossil Fuels		
Coal	131	26%
Natural Gas	97	19%
Gasoline (no ethanol)	88	17%
Distillate Fuel (furnace oil)	41	8%
Jet fuel and other petroleum	9	2%
Clean Fuels		
Nuclear	95	19%
Renewable Sources		
Hydroelectric Power	18	4%
Biomass	6	1%
Other renewables	10	2%

Arizona energy consumption is divided by end-use sector as shown in Figure 2.1 below. Agricultural energy use is included in the industrial sector. The largest single end-use sector is transportation at 32%, as Arizona has widely scattered population centers, and housing and workplaces are often widely separated with limited access to public transportation. For comparison, United States energy consumption divided by end-use sector is summarized in Appendix C.

Arizona energy profile information sources:
http://www.eia.gov/state/?sid=AZ#tabs-2
http://www.eia.gov/state/print.cfm?sid=AZ

QUICK FACT:
Although fifteenth in population, Arizona (population 6.73 million) is ranked 44th in the nation in per capita total energy consumption. Arizona's relatively low per capita energy consumption is partly due to the state's small industrial sector.

Figure 2.1 Arizona Energy Consumption by End-use Sector



3. Household Energy Consumption in Arizona

Household energy consumption in Arizona is analyzed in Table 3.1. Also in the table is a comparison with household energy use in the United States overall and the Mountain State area (Arizona, Nevada and New Mexico). This energy consumption data includes heating fuel and electrical energy and excludes transportation.

Household energy consumption source http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/AZ.pdf

Table 3.1 Household Energy Consumption Comparison

Use	Arizona	Mountain State	US overall
Air conditioning	25%	17%	6%
Space heating	15%	25%	41%
Appliances, electronics, lighting	43%	40%	35%
Water heating	17%	18%	18%

Conclusion: Technical advances leading to cheap, clean, plentiful power for use in refrigeration (air conditioning!) are highly desirable, especially for Arizona!

> **QUICK FACT**
> As shown in Table 3.1, 25% of all of the household energy not used for transportation that is consumed in Arizona homes is used for air conditioning. This is more than four times the national average of 6%, according to EIA's Residential Energy Consumption Survey. Only Florida exceeds Arizona's percentage of consumption for air conditioning, at 27%.

4. Electric Power Generation and Delivery in Arizona

All discussions of power generation and delivery are based on the answers to three basic questions as illustrated in Figure 4.1.

Figure 4.1 Major Drivers for Power Generation and Delivery

Availability overall:	Can I even get power?
Cost:	Can I afford it, if I can get it?
Time dependent issues:	Can I get power when I want it?

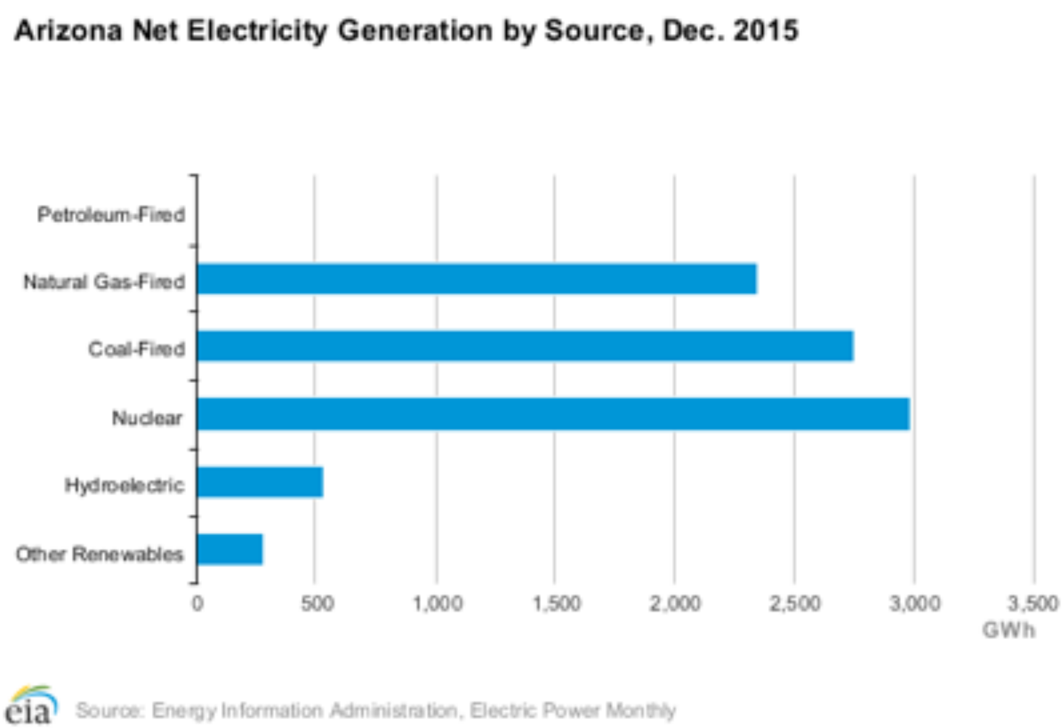
These questions are answered for each specific set of conditions found. For example, solar power in the Arctic in winter is not available. Power from ethanol (basically whiskey) is possible, but not economically viable once the cost of growing the corn, transportation to the distillery and distillation is included. If a large amount of power is needed urgently at 3AM, it must be generated on site or delivered by the grid, as large-scale storage of power is not currently technically feasible.

Selection of fuel and/or energy sources, methods of electrical power generation and electrical power delivery within a particular region are entirely driven by the conditions within the region consuming the power or its very close neighbors. Therefore, fuel sources, power generation methods and delivery technologies (grid structure) vary from location to location.

Large-scale electrical power storage at low cost is not technically feasible at the present time, and very long-range power transmission is not within the capability of the current power transmission grid. The storage and transmission constraints have major impact on the fuel sources chosen. For renewable energy sources especially, the lack of large-scale electrical power storage capabilities is a major issue.

In Arizona, power is generated from fossil fuel and renewable sources. Arizona electricity generation by source is presented in Table 4.1 and Figure 4.2. Note that nuclear, coal and natural gas are the major fuels used for electrical power generation. The choice of fuel used for electric power generation depends upon availability and base and peak load capacities needed.

Figure 4.2



Some fuels are more economically viable than others and some energy uses generate less waste heat (unusable energy). Appendix A summarizes various physical principles governing the efficiency of transforming energy from various sources (fuels, sunlight, falling water, etc.) from one form of energy into another (sunlight to power, power to heat, etc.). Appendix B discusses the economic viability of fuels and energy sources by comparing how much energy must be expended in order to extract energy for the desired use.

Table 4.1 Total Electric Power Production by Fuel Source in Arizona

Source	**Generation (TWh)**	**Percentage of total**
Nuclear	3000	34%
Coal	2700	31%
Natural Gas	2300	26%
Hydroelectric	500	6%
Other renewables	250	3%

Nearly all of the "other renewables" in Arizona come from solar power. Using currently available technology, renewable energy has the fewest possible applications for transportation and the most possible applications for generating electrical power.

General Source for Arizona Energy Information
http://arizonaexperience.org/innovate/powering=Arizona
Other Sources
http://www.eia.gov/todayinenergy/detail.cfm?id=23972
https://en.wikipedia.org/wiki/Solar_power_in_Arizona

The electrical power delivery transmission infrastructure, the "power grid", connects consumers to power generators and connects power generators with other power generators. Funds to build and maintain the grid are collected from the consumers through electric power bills. The basic infrastructure and technology of power lines, transformers and other equipment is adequate in general. The grid control systems would benefit from investment in modernization, that is, smart grid technology.

Source:
http://www.epri.com/Our-Work/Pages/Grid-Modernization.aspx

The power grid's challenges are almost entirely dependent on the fact that electricity cannot be stored in utility scale amounts. Some shifts in demand can be managed by exchanging power with other utilities over the grid, as peak loads shift with time in coordination with the hour of the day. For example, power can be transmitted within a region over the grid (for example, Tucson to Los Angeles) but not from coast to coast.

One of the greatest challenges for an electrical power provider is meeting peak demands. Nuclear and coal fired plants work most efficiently for base loads, that is, the amount of power that is needed at all hours of the day and night. Excess power from nuclear and coal-fired plants may be sent over the grid at moderate distances to meet increased demand in other parts of the region. For acute, short-term local electric power needs, gas-fired Brayton cycle generators (basically jet engines) are brought on line as needed for peak loads. Natural gas-fired combined cycle electric generators are used by Tucson Electric Power and are very efficient electric power producers.

The base load, that is, the power that is needed at all times, can be a challenging issue. If solar power is to be used, it must be stored to be available during the night. For a large nuclear or coal-fired power plant to be used most efficiently, it must be in operation constantly, night and day. If the plant is shut down and cools off, it takes many hours to restore the plant to peak generating capacity.

Arizona has three major electricity providers. All of the electric utilities use natural gas fired generators for peak load situations and exchange electric power over the grid. The major providers are listed below.

Arizona Public Service (APS)
Service area is downtown and north Phoenix and northern Arizona.
Fuels used:
Coal: owns part of the coal-fired Four Corners and Navajo Generating Stations
Nuclear: owns part of the Palo Verde Nuclear Generating Station.
Solar: buys all the output of the Solana solar concentrator plant at Gila Bend.
Other Renewables: interactive map at
https://www.aps.com/en/ourcompany/aboutus/renewableportfoliomap/Pages/home.aspx#

Salt River Project (SRP)
Service area is Phoenix and the area south of Phoenix.
Fuels used:
Hydroelectric: power generation from stations along the Salt River basin
Coal: owns part of the coal-fired Four Corners and Navajo Generating Stations
Nuclear: owns part of the Palo Verde Nuclear Generating Station.
Other Renewables: complete listing at
http://www.srpnet.com/environment/renewable.aspx

Tucson Electric Power (TEP)
Service area is Tucson and southern Arizona.
Fuels used:
Natural gas: Combined cycle generators
Solar: Distributed solar program, utility solar (Bright Solar program)
(Coal: TEP stopped burning coal in 2015.)

Renewable energy comes from sources that are replenished within a human lifetime. This includes wind, sunlight, hydroelectric power, some biological products and geothermal energy.

Clean energy does not release greenhouse gasses in the atmosphere. Clean energy includes solar, wind, hydroelectric, geothermal and nuclear energy.

A comment on biomass energy: Biomass energy is renewable energy, but since burning forest waste, land-fill methane and other biomass fuels releases greenhouse gasses into the atmosphere, biomass energy is not clean energy.

A comment on nuclear energy: Although nuclear energy is clean energy, since it does not release greenhouse gases, most currently used nuclear fuel is not regenerated within a human lifetime. Thus, nuclear energy is not considered renewable energy.

QUICK FACTS:
Arizona's Palo Verde Nuclear Generating Station, rated at 3.937 net Gigawatts, (GW), is the largest power plant by net generation in the United States. It provides electric power for an estimated population of 4 million.

Arizona's only operating coal mine, Kayenta, on the Navajo and Hopi reservations, supplies the 7-to-8 million short tons burned annually by the Navajo Generating Station's three 750-megawatt units.

In all, Arizona now produces more total and electrical energy than it consumes (for 2009, 111.9 vs. 73 thousand GWh). The excess is sold to nearby states.

CO_2 emissions from burning natural gas are half the CO_2 emissions from burning coal. Arizona's greenhouse emission per capita is 2/3 the U.S. average, that is, 14 vs. 22 CO_2-equivalent tons per capita per year).

Source, year 2000:
https://www3.epa.gov/region9/climatechange/ariz.html

5. Renewable Energy Programs in Arizona

In 2010 the United States Environmental Protection Agency (EPA) announced its "Renewable Energy Tax Incentive”. This incentive encourages investment in renewable energy sources for both commercial and residential uses. Arizona's Renewable Environmental Standard, announced in 2006, requires 15% of the state’s electricity consumed in 2025 to come from renewable energy resources.

Source:
https://www.epa.gov/cleanpowerplan/clean-power-plan-community-page

Arizona's major public utilities, especially APS and SRP based in Phoenix, have active renewable energy programs, with hydroelectric power, wind and utility scale solar power production, as listed in the fuel source discussions of Section 4.

Arizona has a very active solar energy program. Currently 19 projects for large-scale photovoltaic installations on federal lands have been presented to the U.S. Bureau of Land Management totaling 13 Gigawatt-hours power production. Just one, the Sonoran Project (300 MW), has been approved to date.

Source:
http://www.blm.gov/az/st/en/info/nepa/environmental_library/eis/feis.html

Large project information:
https://en.wikipedia.org/wiki/Solar_power_in_Arizona and
https://en.wikipedia.org/wiki/List_of_photovoltaic_power_stations ,

Sunlight's extreme abundance in Arizona and lack of any fuel cost makes solar power an incredible bargain, even though the efficiency of energy transformation from sunlight to electric power is comparatively low. Solar energy is also renewable and relatively clean.

Solar power is especially good for peak load air conditioning type demands during the day, but is far more problematic at night. The ability to store heat to be used for generating electrical power is a major research effort, and vital for the expanded use of renewable energy, especially solar power.

Sources:
http://www.npr.org/sections/alltechconsidered/2016/04/05/470810118/solar-and-wind-energy-may-be-nice-but-how-can-we-store-it
http://www.popularmechanics.com/science/energy/a9961/3-clever-new-ways-to-store-solar-energy-16407404/

In addition to current utility company solar projects, innovative applications of existing photovoltaic technology are being developed. One application calls for placing photovoltaic cells on "waste land" from mine tailings. The pilot program now being realized is described in Appendix D.

Residents interested in installing solar units on their home may contact the Arizona Solar Watchdog Program. The state program provides consumers with information and guidelines for evaluating a solar installation contractor's license and work history. For commercial installations the Arizona Solar Business Directory contains a list of about 100 solar installation companies.

Source:
(http://www.gosolarinarizona.com/solar/arizona-solar-watchdog-program.asp)

For those consumers who wish to buy solar power but can't install their own rooftop solar panels, Tucson Electric Power customers has made a program available to its customers to buy shares in TEP's industrial scale solar panel farms. The Bright Tucson Community Solar Program provides power from solar panels in 150 kWh blocks for an additional $3.00 monthly surcharge per block.

> **QUICK FACT**
> 8.9% of Arizona's net electricity generation comes from renewable resources, primarily from the Glen Canyon and Hoover Dams.
>
> Arizona ranked third in the nation in utility-scale electricity generation from solar energy in 2014. Considerably more solar energy production per capita is possible.

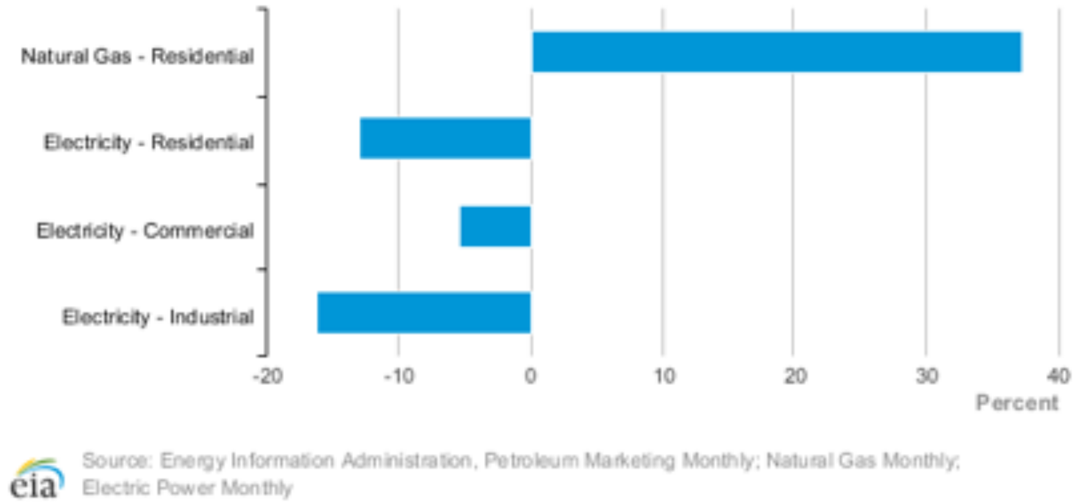
6. Arizona Electric Rates

Although natural gas imported from other states is about 37% more expensive in Arizona than the national average price, electricity costs are lower in Arizona than the nation as a whole. In Figure 6.1, note that although natural gas costs are high (blue bar to the right of zero, above the national average natural gas price), all of the costs of electricity are below the national average (blue bars to the left of zero, below the national average electric power price).

Figure 6.1 Arizona Electricity Price Compared to the US National Average

Price is less expensive <<<<< 0 >>>>>>> more expensive

↓



Electric rates include charges for fuel, maintenance and construction of the grid, operation and maintenance of generating equipment, state and local taxes and company profits. As an example of charges on residential electric bills, Appendix E presents a breakdown of charges for a residential TEP customer. Green energy fees and charges are included as separate items on all bills.

All of the electric utility companies are subject to Arizona Corporation Commission (AZCC) oversight and regulation when setting electric rates. The AZCC's five board members are elected at large statewide (not by district or county), to four year staggered terms. Rates are proposed by the utility companies, subject to rate hearings open to the public and adjudicated by the Corporation Commission, assisted by the Commission's supporting technical and legal staff.

The most contentious topic at Arizona Corporation Commission current rate hearings is the increased imposition of demand charges on residential consumers. Demand charges are used to recover costs for increased grid and generation capacity that is needed to meet peak loads.

Demand charges have been imposed on commercial electric power customers for many years, but demand charges for residential consumers are new in Arizona. Demand charges are a rate that is dependent on the customer's maximum power demand over a short time. They are levied in addition to fuel charges and access charges.

Sources for demand charge discussions: https://www9.nationalgridus.com/niagaramohawk/non_html/eff_elec-demand.pdf
https://www.aps.com/en/residential/accountservices/serviceplans/Pages/demand-rates.aspx

Maintenance and construction of the electric grid is of special interest to all power users, even those with access to private energy generation. The grid provides power when private sources are not available. In the case of rooftop solar panels, power is drawn from the grid when the sun is not up. Most consumers with rooftop solar can't afford and don't have the space for the battery storage that would allow them to disconnect their houses from the electrical grid.

Rate hearings held by the Arizona Corporation Commission in 2015 and 2016 for all three major electric providers include proposed increases to base charges for customers, crediting household rooftop solar panel owners with much less than the retail price on all power put onto the grid and decreasing support for rooftop solar power.

The Arizona legislature, the utility companies and the rooftop solar installers have taken adversarial positions at the latest rate hearings for each of the public utilities. The utility companies and the rooftop solar installers have competing economic interests and have both been active interveners (legally taking part) in the rate hearings.

Several propositions were developed for the November 2016 election concerning increased base charges, imposition of demand charges and lowering the reimbursement rate given to rooftop solar power owners for excess power sent by homeowners to the grid at large. In particular, one proposition was developed by the legislature to limit reimbursement to homeowners for surplus electricity generated on their property. Another proposition was developed by rooftop solar installers and leasers, particularly Solar City, to maintain the status quo rates of retail reimbursement to the consumer for surplus power.

All of the proposals were removed from consideration for the November 2016 ballot and rate negotiations are continuing.

General List of Sources:

"Powering Arizona":
http:// http://arizonaexperience.org/innovate/powering=Arizona
https://en.wikipedia.org/wiki/Solar_power_in_Arizona

Arizona's realized or potential energy resources:
http://www.nrl.gov/gls/re_potential.html)
http://www.eia.gov/todayinenergy/detail.cfm?id=23972 .]

Arizona Energy Profile Overview:
http://www.eia.gov/state/?sid=AZ

EPA's Renewable Tax Incentive Plan:
https://www.epa.gov/cleanpowerplan/clean-power-plan-community-page
Arizona's Renewable Portfolio

http://www.azsolarcenter.org/economics/incentives/az-renewable-energy-standard.html

For a list of large solar projects, see Wikipedia entries at
https://en.wikipedia.org/wiki/Solar_power_in_Arizona
https://en.wikipedia.org/wiki/List_of_photovoltaic_power_sations ,

http://www3.epa.gov/region9/cleanup-clean-air/pdf/AZ-incentives.pdf

Solar installation:
http://www.gosolarinarizona.com/solar/arizona-solar-watchdog-program.asp

Sonoran Solar Power project announcement:
http://www.blm.gov/az/st/en/info/nepa/environmental_library/eis/feis.html

Distribution of electrical usages and greenhouse gas emissions (2000):
https://www3.epa.gov/region9/climatechange/ariz.html .

Appendix A. Energy Form Transformation

Consumers commonly use energy for:

- Heating
- Lighting & communications
- Electrical power
- Transportation and other mechanical work

Fuel is a form of stored energy used to generate heat, which can be transformed to mechanical energy in transportation engines or electrical power in generators.

Listed below are some generally accepted rules of thumb in estimating the efficiency of transforming one usable form of energy to another. The energy not appearing in the desired form becomes must be dissipated as waste heat.

- Energy in any form transforms to heat with great efficiency, i.e. over 90%.
- Mechanical energy transformation to electrical power (wind and hydroelectric generation) is very efficient, close to 90%.
- Transformation of heat to electric power or mechanical energy (any kind of motion) has a maximum efficiency of about 60%, under ideal circumstances.
- Transformation of energy to and from light (electrical power to light and light to electrical power) ranges from 6% to 40% efficiency, depending on the technology used.
- Refrigeration (moving heat out of a space) is very dependent on temperatures inside and outside the space. Efficiency of electrical power use in refrigeration systems varies from 20% (low end systems) to 50% (high end systems).

Appendix B. Economic Viability and EROEI

One measure of energy cost is that of Energy Returned Output for Energy Input (EROEI). EROEI is a comparison of the amount of energy consumed by a process to generate the amount of energy recovered by the process, that is

$$\textbf{EROEI} = \frac{\textbf{Energy Delivered}}{\textbf{Energy Required to Deliver that Energy}}.$$

- Processes with EROEI **less than 1** result in a net **consumption of energy**.
- Processes with EROEI **greater than 1** result in a net **production of energy**.
- Processes with EROEI **greater than 3** are considered **economically viable**.

ERLOEI is often used as a measure of economic viability. Note that monetary cost has no impact on EROEI. Improvements in the efficiency of extracting the energy delivered for end use DO impact EROEI.

Example: Burning one barrel of oil to extract, process and ship fuel to the consumer yields 6 barrels of oil later used as fuel. Thus, the Energy Returned on Energy Invested (EROEI) for the process is 6.

Naturally occurring oil varies in its EROEI, as different oil sources require more or less energy to extract a barrel of oil. In the United States, EROEI has been falling over the years, as more easily accessed naturally occurring sources of oil become less available.

The following table shows sample EROEI measures for fossil fuels. EROEI estimates are sensitive to how much of the total energy expended for transport, initial well set up and other factors are computed. EROEI estimates for fracking in particular vary greatly. The source of the differences depends on how much of the resource extraction process is included in the EROEI computation and which industry group is doing the computation.

Table B.1 Fossil Fuel EROEI

Fuel source and year	Fossil Fuel EROEI
Oil average: 1990	35
Oil average: 2005	18
Oil average: 2007	12
Shale oil: 2010	5
Tar sands: 2013	2.5-7
Natural gas from fracking	10-100
Coal (US): 2013	45

The increased production of natural gas from fracking has become the primary driver of the current decrease of coal burning for electric power. A recent source on trends in accessing oil and natural gas is the last item on the following list of sources.

Sources:
https://en.wikipedia.org/wiki/Oil_shale_economics
http://www.theoildrum.com/node/10011
http://www.resilience.org/stories/2013-01-06/is-fracking-a-happy-solution-to-our-energy-needs
http://www.sciencedirect.com/science/article/pii/S0301421513003856
http://www.resilience.org/stories/2013-01-06/is-fracking-a-happy-solution-to-our-energy-needs
http://onlinelibrary.wiley.com/doi/10.1111/jiec.12040/abstract;jsessionid=7F84CE61C9872C3B98277514CCF19DDE.d03t02
https://www.eia.gov/analysis/studies/drilling/pdf/upstream.pdf

"Clean" energy sources have current EROEI measures as follows. Mechanical renewable energy (wind and hydroelectric power) and solar photovoltaic power are economically viable by EROEI measures. Ethanols and other biofuels are not as economically viable as other clean energy sources by EROEI measures.

Table B.2 Cleaner Fuel EROEIs (Year 2015)

Source	EROEI
Fuel corn ethanol	1.3
Sugar cane ethanol	5
Hydroelectric power	100
Wind power	20-50
Natural gas (2005)	10
Nuclear	50-75
Photovoltaic	8-60

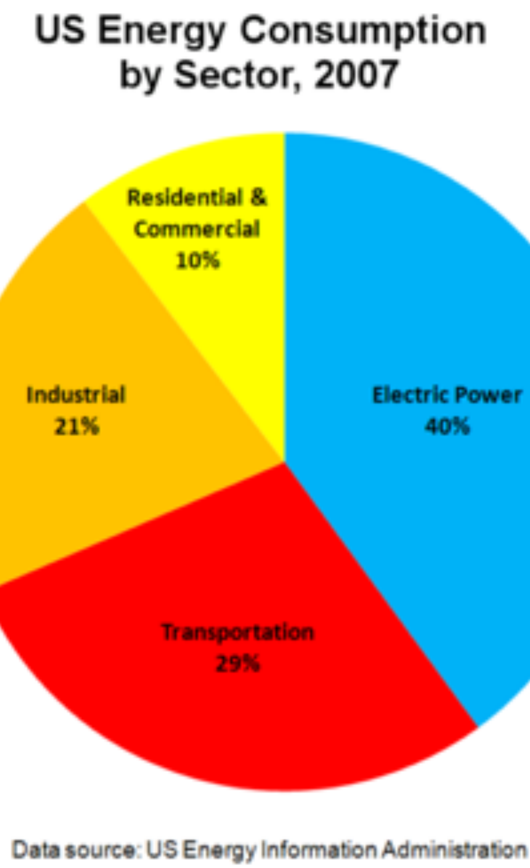
Geothermal	10-30

Source: https://en.wikipedia.org/wiki/Energy_returned_on_energy_invested

Appendix C. Energy Use in the United States

Energy consumed in the United States as a whole is split between economic sectors as follows in Figures C.1.

Figure C.1 US Energy Consumption by Sector



Energy consumption in the United States broken out by supply and demand sector and sources is illustrated in Figure C.2 below. More information may be found in the source summarized in source [20] at the link https://en.wikipedia.org/wiki/Energy_in_the_United_States

Renewable energy generation in the United States comes from sources as shown in Figure C.3 below. Biomass energy often is generated by using waste forest and paper products or other agricultural byproducts as fuel for industrial purposes. 51% of renewable energy use is for electric power generation. The remainder is used for heating of water, space or industrial uses. Renewable energy makes up 10% of the United States' industrial sector energy use and 9% of its electrical power generation.

Figure C.2 Electricity Generation Breakdown by Type for the United States (2014)

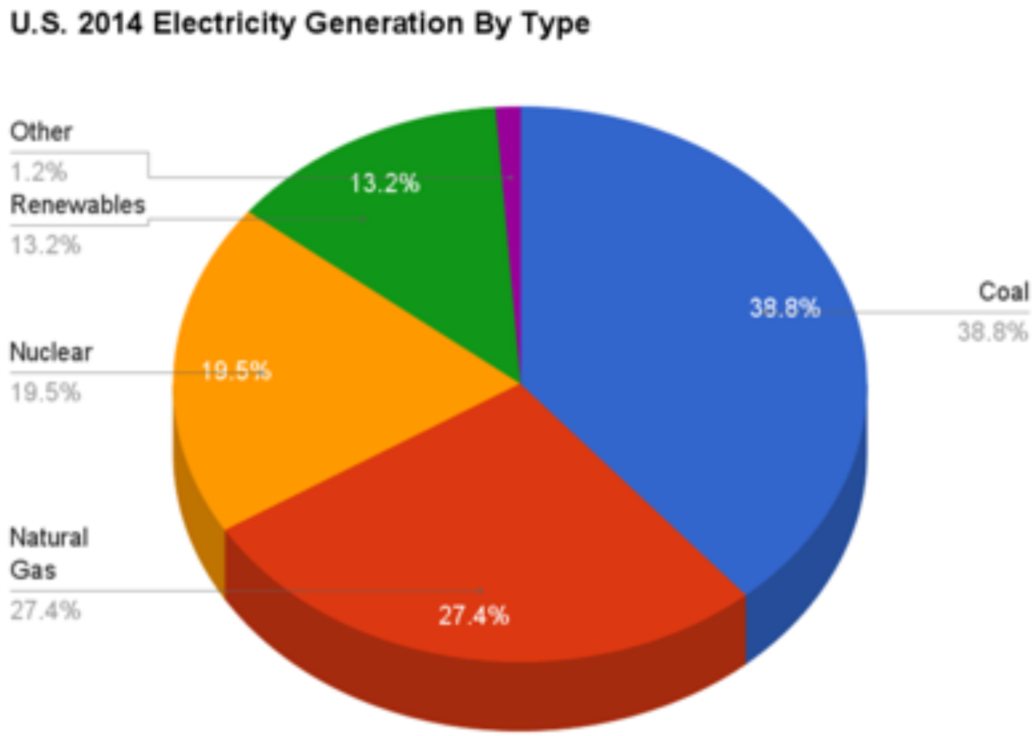
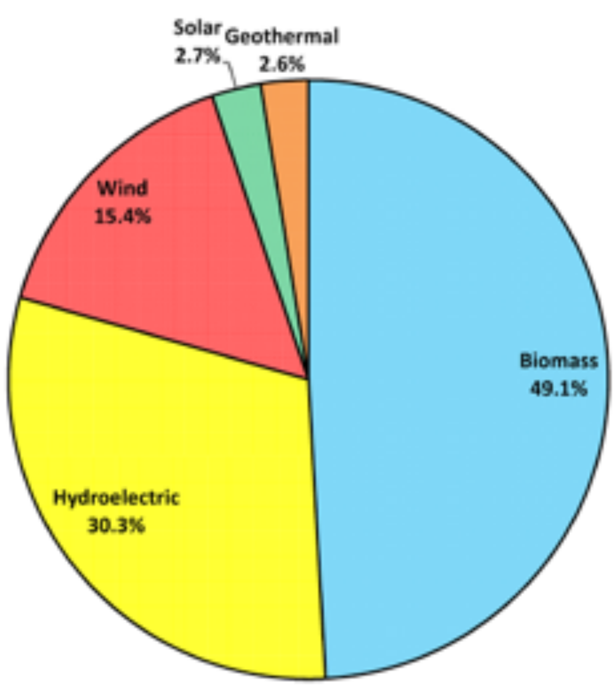


Figure C.3 Energy Generation from Renewable Sources



Appendix D. Solar Power Generation on Mine Tailings

An example of innovative applications of solar power generation is the project undertaken by Dr. Moe Momayez at the University of Arizona. Dr. Momayez is developing the concept of installing solar photovoltaic panels installed on the mining discarded waste acreage ("tailings").

Consider that the total area of US mines is about 9375 square miles.
The energy consumption in the US (2015) was 4087 Billion kWh. Using an estimate of 15.91 W/ft^2 as an industrial standards average for solar panel efficiency, one finds that PV panels covering 50% of this mining area could produce 4160 Billion kWh (assuming, conservatively, an average of only 3.75 hours of “January sunshine” - we arrive at 3.75 hours by assuming that the mines are distributed over the US). If we further assume that the panels will cover half the area of half these mines, they would produce about half the nation’s 2015 electrical energy needs (M. Momayez, private communication). Dr. Momayez assumed the use of Renogy RNG 245-250D solar panels and the web tool at http:://www.enfsolar.com/.

Dr. Momayez has begun a pilot project at Freeport McMoRan's Sierrita mine located 20 miles southwest of Tucson to study the effectiveness of bright soils and water to act as reflectors, and the effect of wind-cooling of installed SV panels, and the management of energy production and delivery of electricity to the local electrical power grid.

The advantages of using mining tailings sites for power generation are that no land need be purchased or expropriated and that much of the necessary power grid connection is already in place at the mines. The mine land application uses “waste” land for an economically valuable product and requires little investment in grid connection infrastructure.

Appendix E. Tucson Electric Power Billing for Green Energy

Included in the charges for power in Tucson are various charges associated with renewable energy. These are itemized on the monthly TEP bill.

Included in Lost Fixed Cost Recovery (LFCR) are charges to recover costs when customers reduce their usage, either through efficiency improvements or use of other power sources (for example, roof-top solar panels).

The “REST,” Renewable Energy Standard Tariff surcharge (maximum charge to bill is $3.75 per month) is a surcharge used to meet current requirements to increase the percentage of total power that TEP generates from renewable energy sources.

The DSM (Demand Side Management) surcharge funds energy efficiency programs to help TEP comply with the Arizona Energy Efficiency Standard adopted in 2010.

Arizona Energy Efficiency Standard:
https://energypolicy.asu.edu/wp-content/uploads/2012/03/Policies-to-Know_Arizona-Energy-Efficiency-Resource-Standards-Brief-Sheet-.doc.pdf

The ECA (Environmental Compliance Adjustor) covers some of the cost of required environmental upgrades at TEP electrical plants. The costs are recovered gradually to reduce future (sudden) rate increases.

Demand charges are imposed on commercial customers with large power demands. Commercial customers are given financial incentives to move heavy electrical use to off-peak periods, lowering peak load requirements.