CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF ELECTRICAL ENGINEERING

Distribution System with Renewable Energy Sources

Bachelor's Thesis

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Czech Technical University in Prague
Faculty of Electrical Engineering

Department of Electrical Power Engineering

BACHELOR PROJECT ASSIGNMENT

Student: **Ahmad Alshammari**

Study programme: Electrical Engineering, Power Engineering and Management
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Title of Bachelor Project: **Distribution System with Renewable Energy Sources**

Guidelines:

1. General information on renewable energy sources, types of power plants utilizing renewable energy sources, specifically photovoltaic power plants.
2. Describe the rules for connecting dispersed energy sources to the distribution system.
3. A case study for the selected part of the distribution system MV in Central Bohemia

Bibliography/Sources:

[1] Distribution network codes
[2] eVIivy application manual
[3] SCHLABBACH, J, D BLUME a T STEPHANBLOME. Voltage quality in electrical power systems. London: Institution of Electrical Engineers, c2001, x, 241 p. IEE power and energy series, 36. ISBN 978-085-2969-755.

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Dean

Prague, April 18, 2016

Abstract

This bachelor thesis focuses on this bachelor thesis focuses on

1) Wind energy
2) Hydro
3) Geothermal
4) Photovoltaic
5) Solar thermal electric conversion
6) Biomass energy
7) Case study of the distribution network with PVPP

Key words

Renewable energy sources, distribution network, reverse impacts, voltage profile

Abstrakt

Bakalářská práce je zaměřena na oblasti

1) Větrná energie
2) Vodní energie
3) Geotermální energie
4) Fotovoltaika
5) Solární termální konferze
6) Energie biomasy
7) Studie připojení fotovoltaické elektrárny k distribuční síti

Klíčová slova

Obnovitelné zdroje energie, distribuční síť, zpětné vlivy, profil napětí

Declaration

I hereby declare that this thesis is the result of my own work and all the sources I used are in the list of reference, in accordance with the Methodological Instructions on Ethical Principles in the Preparation of University Theses.

Ahmad Alshammari

In Prague, 26. 5. 2016

Acknowledgments

I would like to express my sincere gratitude to my supervisor and teacher Ing. Frantisek Vybiralik, CSc. for continually advising and helping me to complete my bachelor thesis. Without his supervising it could never be done as it is today. I would like also to thank my family and friends for their support during the whole semester.

Contents

Renewable energy sources

1. Wind energy

Wind Energy and Wind Power

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity.

How Wind Power Is Generated

The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like.

Wind Turbines

Wind turbines, like aircraft propeller blades, turn in the moving air and power an electric generator that supplies an electric current. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.

Wind Turbine Types

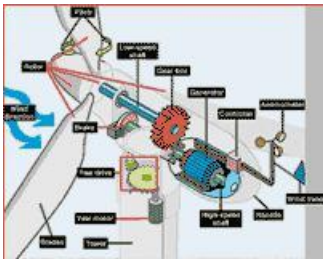
Modern wind turbines fall into two basic groups; the horizontal-axis variety, like the traditional farm windmills used for pumping water, and the vertical-axis design, like the eggbeater-style Darrius model, named after its French inventor. Most large modern wind turbines are horizontal-axis turbines.

Turbine Components

Horizontal turbine components include:

- blade or rotor, which converts the energy in the wind to rotational shaft energy;
- a drive train, usually including a gearbox and a generator;
- a tower that supports the rotor and drive train; and
- other equipment, including controls, electrical cables, ground support equipment, and interconnection equipment.

Wind turbine diagram - click for enlarged image.



Turbine Configurations

Wind turbines are often grouped together into a single wind power plant, also known as a wind farm, and generate bulk electrical power. Electricity from these turbines is fed into a utility grid and distributed to customers, just as with conventional power plants.

Wind Turbine Size and Power Ratings

Wind turbines are available in a variety of sizes, and therefore power ratings. The largest machine has blades that span more than the length of a football field, stands 20 building stories high, and produces enough electricity to power 1,400 homes. A small home-sized wind machine has rotors between 8 and 25 feet in diameter and stands upwards of 30 feet and can supply the power needs of an all-electric home or small business. Utility-scale turbines range in size from 50 to 750 kilowatts. Single small turbines, below 50 kilowatts, are used for homes, telecommunications dishes, or water pumping.

Wind Energy Resources in the United States

Wind energy is very abundant in many parts of the United States. Wind resources are characterized by wind-power density classes, ranging from class 1 (the lowest) to class 7 (the Highest). Good wind resources (e.g., class 3 and above, which have an average annual wind speed of at least 13 miles per hour) are found in many
. Wind speed is a critical feature of wind resources, because the energy in wind is proportional to the cube of the wind speed. In other words, a stronger wind means a lot more power.

A Renewable Non-Polluting Resource

Wind energy is a free, renewable resource, so no matter how much is used today, there will still be the same supply in the future. Wind energy is also a source ofclean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases. According to the U.S. Department of Energy, in 1990, California's wind power plants offset the emission of more than 2.5 billion pounds of carbon dioxide, and 15 million pounds of other pollutants that would have otherwise been produced. It would take a forest of 90 million to 175 million trees to provide the same air quality.

Cost Issues

Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment than fossil-fueled generators. Roughly 80% of the cost is the machinery, with the balance being site preparation and installation. If wind generating systems are compared with fossil-fueled systems on a "life-cycle" cost basis (counting fuel and operating expenses for the life of the generator), however, wind costs are much more competitive with other generating technologies because there is no fuel to purchase and minimal operating expenses.

Environmental Concerns

Although wind power plants have relatively little impact on the environment compared to fossil fuel power plants, there is some concern over the noise produced by the rotor Blades, aesthetic (visual) impacts, and birds and bats having been killed (avian/bat mortality) by flying into the rotors. Most of these problems have been resolved or greatly reduced through technological development or by properly siting wind plants.

Supply and Transport Issues

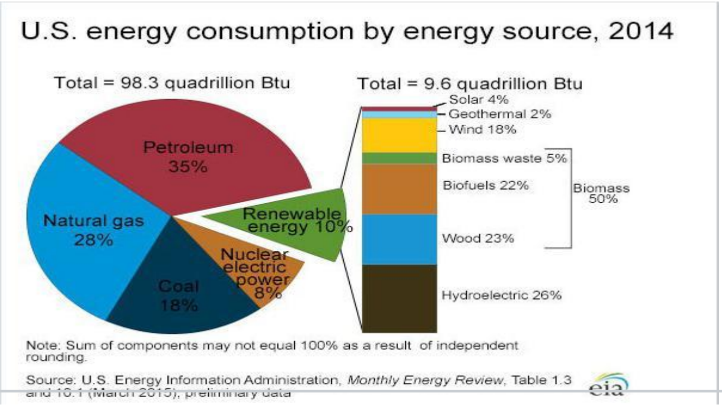
The major challenge to using wind as a source of power is that it is intermittent and does not always blow when electricity is needed. Wind cannot be stored (although wind-generated electricity can be stored, if batteries are used), and not all winds can be harnessed to meet the timing of electricity demands. Further, good wind sites are often located in remote locations far from areas of electric power demand (such as cities). Finally, wind resource development may compete with other uses for the land, and those alternative uses may be more highly valued Than electricity generation. However, wind turbines can be located on land that is also used for grazing or even farming.

2. Hydro energy

Hydroelectric power must be one of the oldest methods of producing power. No doubt, Jack the Caveman stuck some sturdy leaves on a pole and put it in a moving stream. The water would spin the pole that crushed grain to make their delicious, low-fat prehistoric bran muffins. People have used moving water to help them in their work throughout history, and modern people make great use of moving water to produce electricity.

Hydroelectric power for the Nation

Although most energy in the United States is produced by fossil-fuel and nuclear power plants, hydroelectricity is still important to the Nation, accounting for about 7% of total energy production. Nowadays, huge power generators are placed inside dams. Water flowing through the dams spin turbine blades (made out of metal instead of leaves) which are connected to generators. Power is produced and is sent to homes and businesses.



World distribution of hydropower

- Hydropower is the most important and widely-used renewable source of energy.
- Hydropower represents about 16% of total electricity production.
- China is the largest producer of hydroelectricity, followed by Canada, Brazil, and the United States
- Approximately two-thirds of the economically feasible potential remains to be developed. Untapped hydro resources are still abundant in Latin America, Central Africa, India and China.

Producing electricity using hydroelectric power has some advantages over other.

Advantages to hydroelectric power:

- Fuel is not burned so there is minimal pollution
- Water to run the power plant is provided free by nature
- Hydropower plays a major role in reducing greenhouse gas emissions
- Relatively low operations and maintenance costs
- The technology is reliable and proven over time
- It's renewable - rainfall renews the water in the reservoir, so the fuel is almost always there

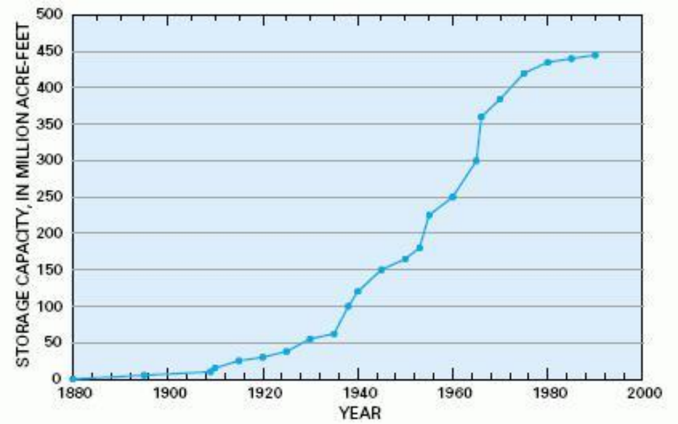
Hydroelectric power is not perfect, though, and does have some disadvantages:

•High investment costs
•Hydrology dependent (precipitation)
•In some cases, inundation of land and wildlife habitat
•In some cases, loss or modification of fish habitat
•Fish entrainment or passage restriction
•In some cases, changes in reservoir and stream water quality
•In some cases, displacement of local populations

Hydropower and the Environment
Hydropower is nonpolluting, but does have environmental impacts
Hydropower does not pollute the water or the air. However, hydropower facilities can have large environmental impacts by changing the environment and affecting land use, homes, and natural habitats in the dam area.

Most hydroelectric power plants have a dam and a reservoir. These structures may obstruct fish migration and affect their populations. Operating a hydroelectric power plant may also change the water temperature and the river's flow. These changes may harm native plants and animals in the river and on land. Reservoirs may cover people's homes, important natural areas, agricultural land, and archaeological sites. So building dams can require relocating people. Methane, a strong greenhouse gas, may also form in some reservoirs and be emitted to the atmosphere. (EPA Energy Kids)

Reservoir construction is "drying up" in the United States

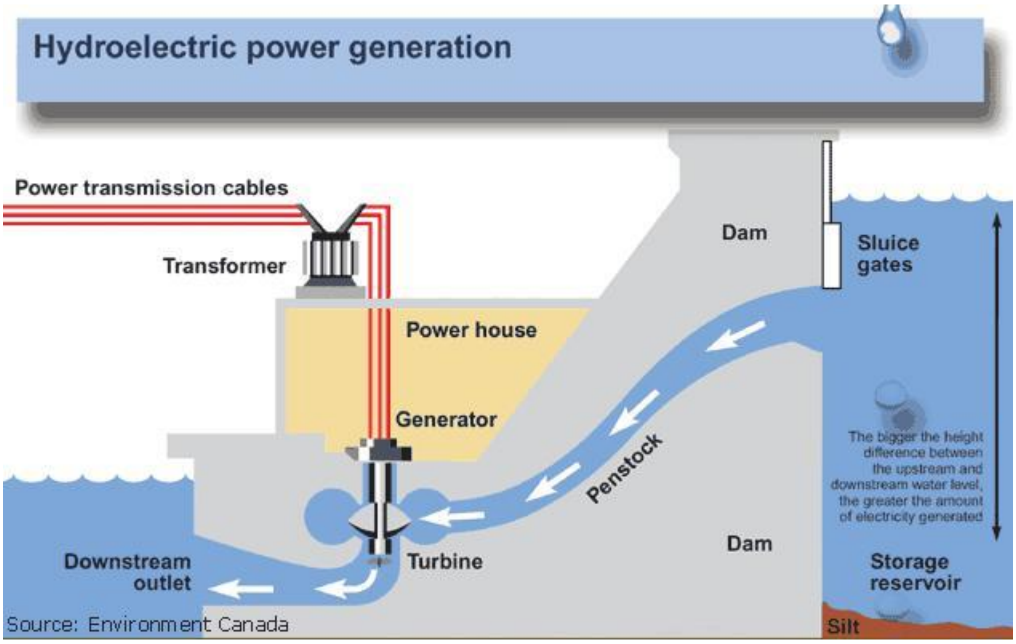


Gosh, hydroelectric power sounds great -- so why don't we use it to produce all of our power? Mainly because you need lots of water and a lot of land where you can build a dam and reservoir, which all takes a LOT of money, time, and construction. In fact, most of the good spots to locate hydro plants have already been taken. In the early part of the century hydroelectric plants supplied a bit less than one-half of the nation's power, but the number is down to about 10 percent today. The trend for the future will probably be to build small-scale hydro plants that can generate electricity for a single community.

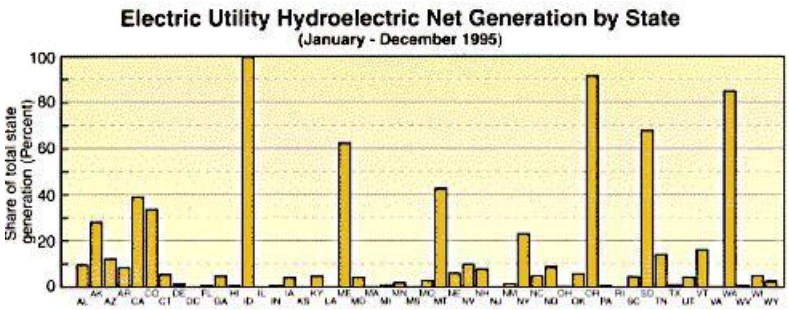
As this chart shows, the construction of surface reservoirs has slowed considerably in recent years. In the middle of the 20th Century, when urbanization was occurring at a rapid rate, many reservoirs were constructed to serve peoples' rising demand for water and power. Since about 1980, the rate of reservoir construction has slowed considerably.

Typical hydroelectric power plant

Hydroelectric energy is produced by the force of falling water. The capacity to produce this energy is dependent on both the available flow and the height from which it falls. Building up behind a high dam, water accumulates potential energy. This is transformed into mechanical energy when the water rushes down the sluice and strikes the rotary blades of turbine. The turbine's rotation spins electromagnets which generate current in stationary coils of wire. Finally, the current is put through a transformer where the voltage is increased for long distance transmission over power lines. (Source: Environment Canada)

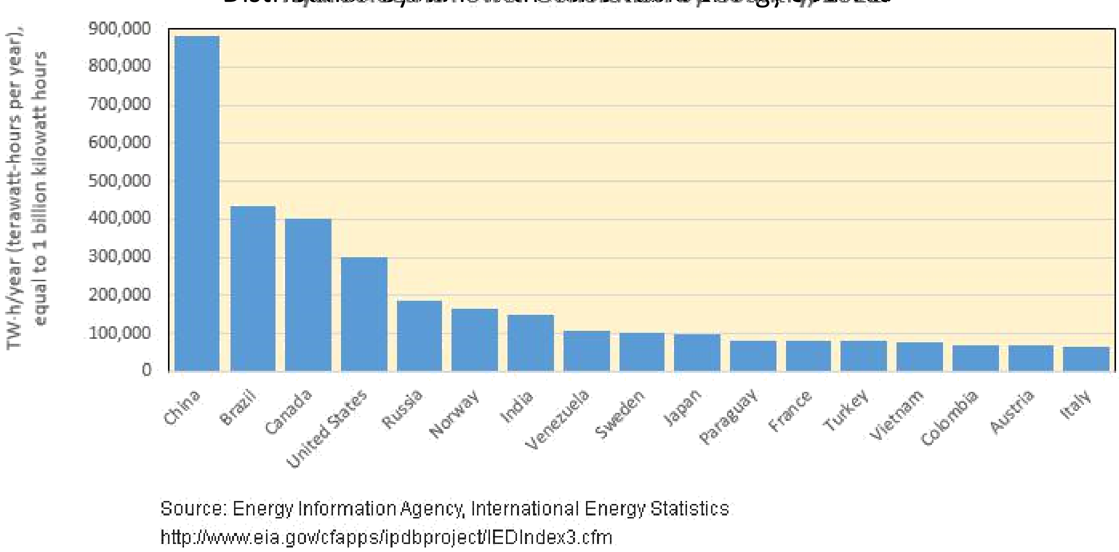


Hydroelectric-power production in the United States and the world



As this chart shows, in the United States, most states make some use of hydroelectric power, although, as you can expect, states with low topographical relief, such as Florida and Kansas, produce very little hydroelectric power. But some states, such as Idaho, Washington, and Oregon use hydroelectricity as their main power source. in 1995, all of Idaho's power came from hydroelectric plants.

The second chart shows hydroelectric power generation in 2012 for the leading hydroelectric-generating countries in the world. China has developed large hydroelectric facilities in the last decade and now lead the world in hydroelectricity usage. But, from north to south and from east to west, countries all over the world make use of hydroelectricity—the main ingredients are a large river and a drop in elevation (along with money, of course).



Source: Energy Information Administration (EIA): http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

3. Geothermal energy

Heat from the earth can be used as an energy source in many ways, from large and complex power stations to small and relatively simple pumping systems. This heat energy, known as geothermal energy, can be found almost anywhere—as far away as remote deep wells in Indonesia and as close as the dirt in our backyards.

Many regions of the world are already tapping geothermal energy as an affordable and sustainable solution to reducing dependence on fossil fuels, and the global warming and public health risks that result from their use. For example, as of 2013 more than 11,700 MW of large, utility-scale geothermal capacity was in operation globally, with another 11,700 MW in planned capacity additions on the way [1]. These geothermal facilities produced approximately 68 billion kilowatt-hours of electricity, enough to meet the annual needs of more than 6 million typical U.S. households. Geothermal plants account for more than 25 percent of the electricity produced in both Iceland and El Salvador [2].
With more than 3,300 MW in eight states, the United States is a global leader in installed geothermal capacity. Eighty percent of this capacity is located in California, where more than 40 geothermal plants provide nearly 7 percent of the state's electricity [3]. In thousands of homes and buildings across the United States, geothermal heat pumps also use the steady temperatures just underground to heat and cool buildings, cleanly and inexpensively.

The geothermal resource

Below Earth's crust, there is a layer of hot and molten rock, called magma. Heat is continually produced in this layer, mostly from the decay of naturally radioactive materials such as uranium and potassium. The amount of heat within 10,000 meters (about 33,000 feet) of Earth's surface contains 50,000 times more energy than all the oil and natural gas resources in the world.

Iceland's Nesjavellir geothermal power station. Geothermal plants account for more than

The areas with the highest Underground temperatures are in regions with active or geologically young volcanoes. These "hot spots" occur at tectonic plate boundaries or at places where the crust is thin enough to let the heat through. The Pacific Rim, often called the Ring of Fire for its many volcanoes, has many hot spots, including some in Alaska, California, and Oregon. Nevada has hundreds of hot spots, covering much of the northern part of the state.

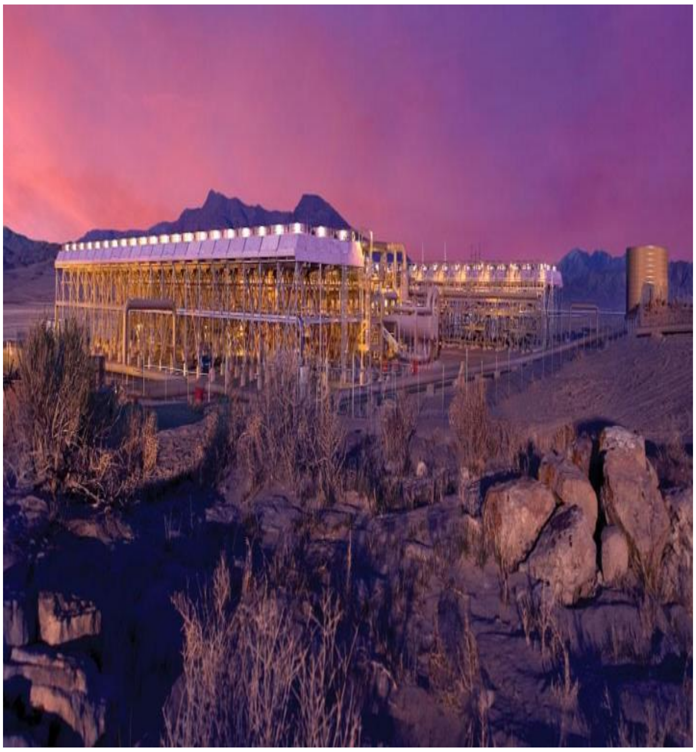
These regions are also seismically active. Earthquakes and magma movement break up the rock covering, allowing water to circulate. As the water rises to the surface, natural hot springs and geysers occur, such as Old Faithful at Yellowstone National Park. The water in these systems can be more than 200°C (430°F).

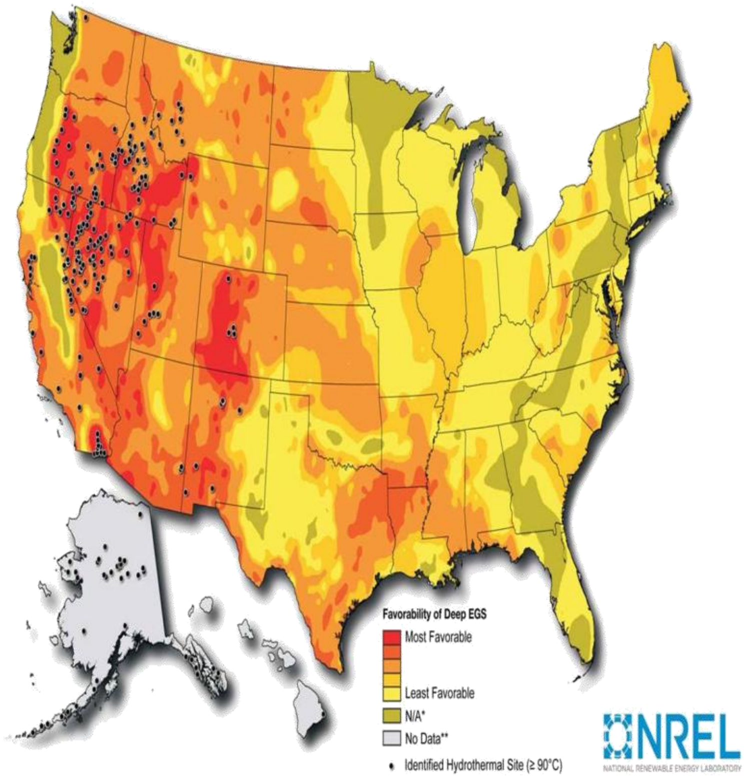
Seismically active hotspots are not the only places where geothermal energy can be found. There is a steady supply of milder heat—useful for direct heating purposes—at depths of anywhere from 10 to a few hundred feet below the surface virtually in any location on Earth. Even the ground below your own backyard or local school has enough heat to control the climate in your home or other buildings in the community. In addition, there is a vast amount of heat energy available from dry rock formations very deep below the surface (4–1 km). Using the emerging technology known as Enhanced Geothermal Systems (EGS), we may be able to capture this heat for electricity production on a much larger scale than conventional technologies currently allow. While still primarily in the development phase, the first demonstration EGS projects provided electricity to grids in the United States and Australia in 2013.

If the full economic potential of geothermal resources can be realized, they would represent an enormous source of electricity production capacity. In 2012, the U.S. National Renewable Energy Laboratory (NREL) found that conventional geothermal sources (hydrothermal) in 13 states have a potential capacity of 38,000 MW, which could produce 308 million MWh of electricity annually [4].

State and federal policies are likely to spur developers to tap some of this potential in the next few years. The Geothermal Energy Association estimates that 125 projects now under development around the country could provide up to 2,500 megawatts of new capacity [3]. As EGS technologies improve and become competitive, even more of the largely untapped geothermal resource could be developed. The NREL study found that hot dry rock resources could provide another 4 million MW of capacity, which is equivalent to more than all of today's U.S. electricity needs [4].

Not only do geothermal resources in the United States offer great potential, they can also provide continuous baseload electricity. According to NREL, the capacity factors of geothermal plants—a measure of the ratio of the actual electricity generated over time compared to what would be produced if the plant was running nonstop for that period—are comparable with those of coal and nuclear power [5]. With the combination of both the size of the resource base and its consistency, geothermal can play an indispensable role in a cleaner, more sustainable power system.




Favorability of Deep EGS
Most Favorable
Least Favorable
N/A*
No Data**
Identified Hydrothermal Site (≥ 90°C)
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Geothermal sources is to tap into naturally occurring "hydrothermal convection" systems, where cooler water seeps into Earth's crust, is heated up, and then rises to the surface. Once this heated water is forced to the surface, it is a relatively simple matter to capture that steam and use it to drive electric generators. Geothermal power plants drill their own holes into the rock to more effectively capture the steam.

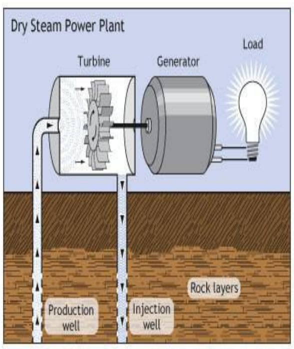
There are three basic designs for geothermal power plants, all of which pull hot water and steam from the ground, use it, and then return it as warm water to prolong the life of the heat source. In the simplest design, known as dry steam, the steam goes directly through the turbine, then into a condenser where the steam is condensed into water. In a second approach, very hot water is depressurized or "flashed" into steam which can then be used to drive the turbine.

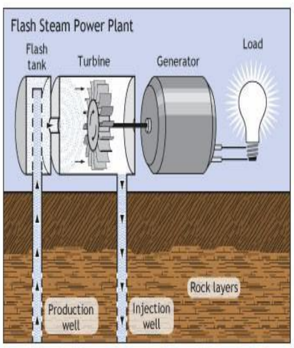
In the third approach, called a binary cycle system, the hot water is passed through a heat exchanger, where it heats a second liquid—such as isobutene—in a closed loop. Isobutene boils at a lower temperature than water, so it is more easily converted into steam to run the turbine. These three systems are shown in the diagrams below.

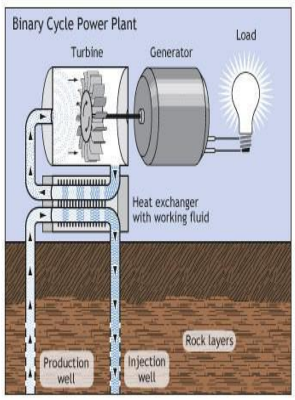
The choice of which Design to use is determined by the resource. If the water comes out of the well as steam, it can be used directly, as in the first design. If it is hot water of a high enough temperature, a flash system can be used; otherwise it must go through a heat exchanger. Since there are more hot water resources than pure steam or high-temperature water sources, there is more growth potential in the binary cycle, heat exchanger design.

The largest geothermal system now in operation is a steam-driven plant in an area called the Geysers, north of San Francisco, California. Despite the name, there are actually no geysers there, and the heat that is used for energy is all steam, not hot water. Although the area was known for its hot springs as far back as the mid-1800s, the first well for power production was not drilled until 1924. Deeper wells were drilled in the 1950s, but real development didn't occur until the 1970s and 1980s. By 1990, 26 power plants had been built, for a capacity of more than 2,000 MW.

Because of the rapid development of the area in the 1980s, and the technology used, the steam resource has been declining since 1988. Today, owned primarily by the California utility Calpine and with a net operating capacity of 725 MW, the Geysers facilities still meets nearly 60 percent of the average electrical demand for California's North Coast region (from the Golden Gate Bridge north to the Oregon border) [6]. The plants at the Geysers use an evaporative water-cooling process to create a vacuum that pulls the steam through three basic designs for geothermal power plants: dry steam, flash steam, and binary







Turbine, producing power more efficiently. But this process loses 60 to 80 percent of the steam to the air, without re-injecting it underground. While the steam pressure may be declining, the rocks underground are still hot. To remedy the situation, various stakeholders partnered to create the Santa Rosa Geysers Recharge Project, which involves transporting 11 million gallons per day of treated wastewater from neighboring communities through a 40-mile pipeline and injecting it into the ground to provide more steam. The project came online in 2003, and in 2008 provided enough additional electricity for approximately 100,000 homes [7].

One concern with open systems like the Geysers is that they emit some air pollutants. Hydrogen sulfide—a toxic gas with a highly recognizable "rotten egg" odor—along with trace amounts of arsenic and minerals, is released in the steam. Salt can also pose an environmental problem. At a power plant located at the Salton Sea reservoir in Southern California, a significant amount of salt builds up in the pipes and must be removed. While the plant initially put the salts into a landfill, they now re-inject the salt back into a different well. With closed-loop systems, such as the binary cycle system, there are no emissions and everything brought to the surface is returned underground.

Direct use of geothermal heat. Geothermal springs can also be used directly for heating purposes. Geothermal hot water is used to heat buildings, raise plants in greenhouses, dry out fish and crops, de-ice roads, and improve oil recovery, aid in industrial processes like pasteurizing milk, and heat spas and water at fish farms. In Klamath Falls, Oregon, and Boise, Idaho, geothermal water has been used to heat homes and buildings for more than a century. On the east coast, the town of Warm Springs, Virginia obtains heat directly from spring water as well, using springs to heat one of the local resorts [8].

In Iceland, virtually every building in the country is heated with hot spring water. In fact, Iceland gets more than 50 percent of its primary energy from geothermal sources [9]. In Reykjavik, for example (population 118,000), hot water is piped in from 25 kilometers away, and residents use it for heating and for hot tap water.

Ground source heat pumps

A much more conventional way to tap geothermal energy is by using geothermal heat Pumps to provide heat and cooling to buildings. Also called ground-source heat pumps, they take advantage of the constant year-round temperature of about 50°F that is just a few feet below the ground's surface. Either air or antifreeze liquid is pumped through pipes that are buried underground, and re-circulated into the building. In the summer, the liquid moves heat from the building into the ground. In the winter, it does the opposite, providing pre-warmed air and water to the heating system of the building.

In the simplest use of ground-source heating and cooling, a tube runs from the outside air, under the ground, and into a building's ventilation system. More complicated, but more effective, systems use compressors and pumps—as in electric air conditioning systems—to maximize the heat transfer.

In regions with temperature extremes, such as the northern United States in the winter and the southern United States in the summer, ground-source heat pumps are the most energy-efficient and environmentally clean heating and cooling systems available. Far more efficient than electric heating and cooling, these systems can circulate as much as 3 to 5 times the energy they use in the process. The U.S. Department of Energy found that heat pumps can save a typical home hundreds of dollars in energy costs each year, with the system typically paying for itself in 8 to 12 years. Tax credits and other incentives can reduce the payback period to 5 years or less [10].

More than 600,000 ground-source heat pumps supply climate control in U.S. homes and other buildings, with new installations occurring at a rate of about 60,000 per year [12]. While this is significant, it is still only a small fraction of the U.S. heating and cooling market, and several barriers to greater penetration into the market remain. For example, despite their long-term savings, geothermal heat pumps have higher up-front costs. In addition, installing them in existing homes and businesses can be difficult, since it involves digging up areas around a building's structure. Finally, many heating and cooling installers are simply not Familiar with the technology.

However, ground-source heat pumps are catching on in some areas. In rural areas without access to natural gas pipelines, homes must use propane or electricity for heating and cooling. Heat pumps are much less expensive to operate than these conventional systems, and since buildings are generally widely spread out, installing underground loops is often not an issue. Underground loops can be easily installed during construction of new buildings as well, resulting in savings for the life of the building. Furthermore, recent policy developments are offering strong incentives for homeowners to install these systems. The 2008 economic stimulus bill, Emergency Economic Stabilization Act of 2008, included an eight-year extension (through 2016) of the 30 percent investment tax credit, with no upper limit, to all home installations of EnergyStar certified geothermal heat pumps [11].

The future of geothermal energy

Geothermal energy has the potential to play a significant role in moving the United States (and other regions of the world) toward a cleaner, more sustainable energy system. It is one of the few renewable energy technologies that can supply continuous, baseload power. Additionally,

unlike coal and nuclear plants, binary geothermal plants can be used a flexible source of energy to balance the variable supply of renewable resources such as wind and solar. Binary plants have the capability to ramp production up and down multiple times each day, from 100 percent of nominal power down to a minimum of 10 percent [1].
The costs for electricity from geothermal facilities are also becoming increasingly competitive. The U.S. Energy Information Administration (EIA) projected that the levelized cost of energy (LCOE) for new geothermal plants (coming online in 2019) will be less than 5 cents per kilowatt hour (kWh), as opposed to more than 6 cents for new natural gas plants and more than 9 cents for new conventional coal [12]. There is also a bright future for the direct use of geothermal resources as a heating source for homes and businesses in any location.
However, in order to tap into the full potential of geothermal energy, two emerging technologies require further development: Enhanced Geothermal Systems (EGS) and co-production of geothermal electricity in oil and gas wells.
Enhanced geothermal systems. Geothermal heat occurs everywhere under the surface of the earth, but the conditions that make water circulate to the surface are found in less than 10 percent of Earth's land area. An approach to capturing the heat in dry areas is known as enhanced geothermal systems (EGS) or "hot dry rock". The hot rock reservoirs, typically at greater depths below the surface than conventional sources, are first broken up by pumping high-pressure water through them. The plants then pump more water through the broken hot rocks, where it heats up, returns to the surface as steam, and powers turbines to generate electricity. The water is then returned to the reservoir through injection wells to complete the circulation loop. Plants that use a closed-loop binary cycle release no fluids or heat-trapping emissions other than water vapor, which may be used for cooling [13].
A 2006 study by MIT found that EGS technology could provide 100 gigawatts of electricity by 2050 [14]. The Department of Energy, several universities, the geothermal industry, and venture capital firms (including Google) are collaborating on research and demonstration projects to harness the potential of EGS. The Newberry Geothermal Project in Bend, Oregon has recently made significant progress in reducing EGS project costs and eliminating risks to future development [15]. The DOE hopes to have EGS ready for commercial development by 2015. Australia, France, Germany, and Japan also have R&D programs to make EGS commercially viable.
One cause for careful consideration with EGS is the possibility of induced seismic activity that might occur

From hot dry rock drilling and development. This risk is similar to that associated with hydraulic fracturing, an increasingly used method of oil and gas drilling, and with carbon dioxide capture and storage in deep saline aquifers. Though a potentially serious concern, the risk of an induced EGS-related seismic event that can be felt by the surrounding population or that might cause significant damage currently appears very low when projects are located an appropriate distance away from major fault lines and properly monitored. Appropriate site selection, assessment and monitoring of rock fracturing and seismic activity during and after construction, and open, transparent communication with local communities are also critical.

Low-temperature and co-production of geothermal electricity in oil and gas wells. Low-temperature geothermal energy is derived from geothermal fluid found in the ground at temperatures of 150ºC (300ºF) or less. These resources are typically utilized in direct-use applications, such as heating buildings, but can also be used to produce electricity through binary cycle geothermal processes. Oil and gas fields already under production represent a large potential source of this type of geothermal energy. In many existing oil and gas reservoirs, a significant amount of high-temperature water or suitable high-pressure conditions are present, which could allow for the co-production of geothermal electricity along with the extraction of oil and gas resources. In some cases, exploiting these geothermal resources could even enhance the extraction of the oil and gas.

An MIT study estimated that the United States has the potential to develop 44,000 MWs of geothermal capacity by 2050 by coproducing geothermal electricity at oil and gas fields—primarily in the Southeast and southern Plains states. The study projected that such advanced geothermal systems could supply 10 percent of U.S. baseload electricity by 2050, given R&D and deployment over the next 10 years [17].

According to DOE, an average of 25 billion barrels of hot water is produced in United States oil and gas wells each year. This water, which has historically been viewed as an inconvenience to well operators, could be harnessed to produce up to 3 gigawatts of clean, reliable baseload energy [16]. This energy could not only reduce greenhouse gas emissions, it could also increase profitability and extend the economic life of existing oil and gas field infrastructure. The DOE's Geothermal Technologies Office is working toward a goal of achieving widespread production of low-temperature geothermal power by 2020.

These exciting new developments in geothermal will be supported by unprecedented levels of federal R&D funding. Under, the American Recovery and Reinvestment Act of 2009, $400 million of new funding was allocated to the DOE's Geothermal Technologies Program. Of this $90 million went to fund seven demonstration projects to prove the feasibility of EGS technology. Another $50 million funded 17 demonstration projects for other new technologies, including co-production with oil and gas and low temperature geothermal. The remaining funds went towards exploration technologies, expanding the deployment of geothermal heat pumps, and other uses. These investments are already beginning to expand the horizons of geothermal energy production and will likely continue to produce significant net benefits in the future [17].

4. Photovoltaic

Photovoltaic (Solar Electric)

Photovoltaic (PV) devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain types of material, called semiconductors. Electrons in these materials are freed by solar energy and can be induced to travel through an electrical circuit, powering electrical devices or sending electricity to the grid.

PV devices can be used to power anything from small electronics such as calculators and road signs up to homes and large commercial businesses.

Residential Photovoltaic Installations Increase Home Value in California

Photons strike and ionize semiconductor material on the solar panel, causing outer electrons to break free of their atomic bonds. Due to the semiconductor structure, the electrons are forced in one direction creating a flow of electrical current. •Solar cells are not 100% efficient in Diagram of a typical crystalline silicon solar cell. Solar cells are not 100% efficient in part because some of the light spectrum is reflected, some is too weak to create electricity (infrared) and some (ultraviolet) creates heat energy instead of electricity.

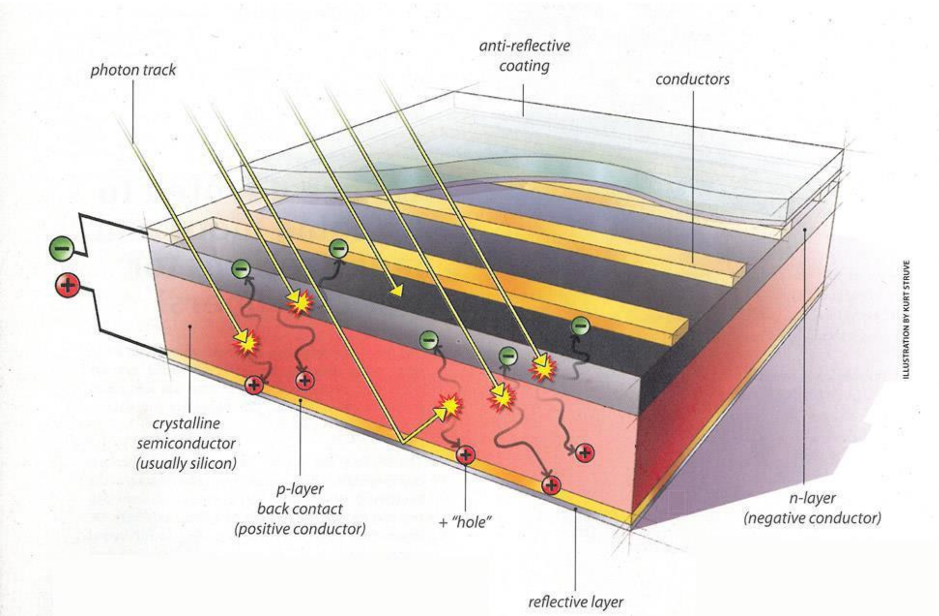


Diagram of a typical crystalline silicon solar cell. To make this type of cell, wafers of high-purity silicon are "doped" with various impurities and fused together. The resulting structure creates a pathway for electrical current within and between the solar cells.

Other Types of Photovoltaic Technology

In addition to crystalline silicon (c-Si), there are two other main types of PV technology:

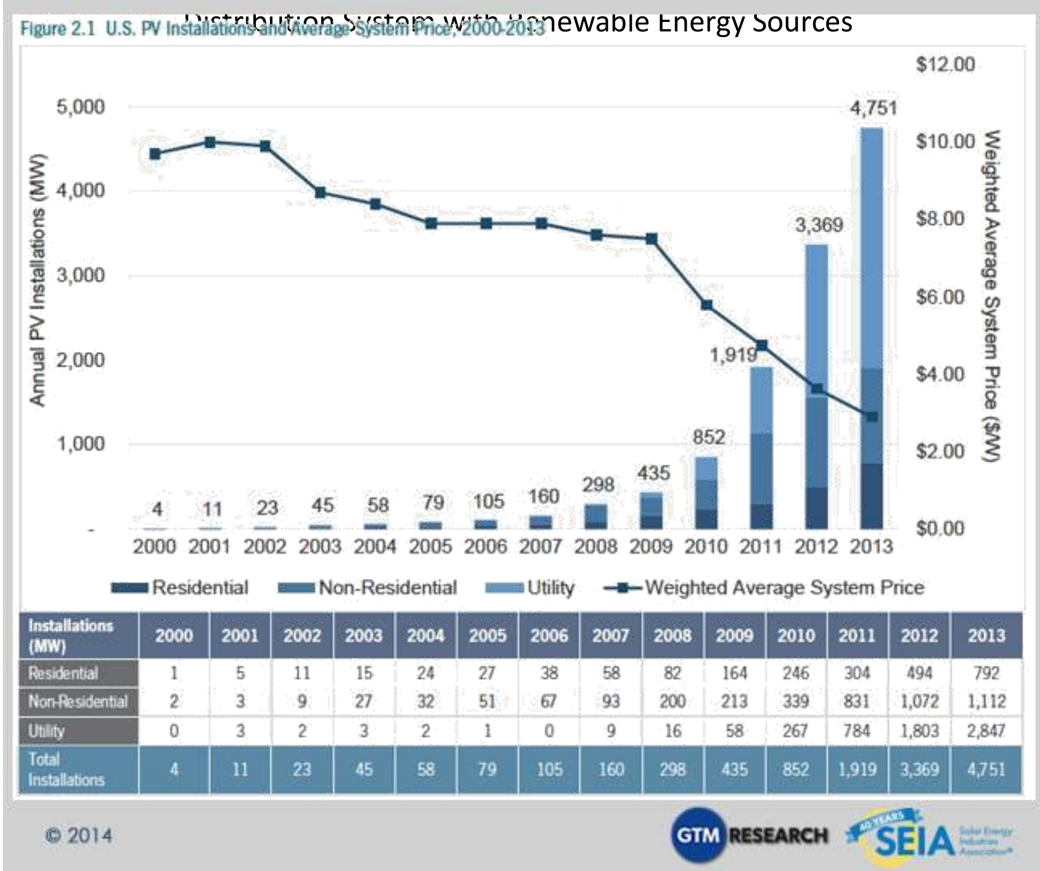
- **Thin-film PV** is a fast-growing but small part of the commercial solar market. Many thin-film firms are start-ups developing experimental technologies. They are generally less efficient – but often cheaper – than c-Si modules.
- In the United States, **concentrating PV** arrays are found primarily in the desert Southwest. They use lenses and mirrors to reflect concentrated solar energy onto high-efficiency cells. They require direct sunlight and tracking systems to be most effective.

History of Photovoltaic Technology

The PV effect was observed as early as 1839 by Alexandre Edmund Becquerel, and was the subject of scientific inquiry through the early twentieth century. In 1954, Bell Labs in the U.S. introduced the first solar PV device that produced a useable amount of electricity, and by 1958, solar cells were being used in a variety of small-scale scientific and commercial applications.

PV panels installed on a private home in Brooklyn Heights, New York (Photo courtesy of Alan Blake) The energy crisis of the 1970s saw the beginning of major interest in using solar cells to produce electricity in homes and businesses, but prohibitive prices (nearly 30 times higher than the current price) made large-scale applications impractical.

Industry developments and research in the following years made PV devices more feasible and a cycle of increasing production and decreasing costs began which continues even today. Costs of Solar Photovoltaics Rapidly falling prices have made solar more affordable than ever. The average price of a completed PV system has dropped by 33 percent since the beginning of 2011.



Installations (MW)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Residential	1	5	11	15	24	27	38	58	82	164	246	304	494	792
Non-Residential	2	3	9	27	32	51	67	93	200	213	339	831	1,072	1,112
Utility	0	3	2	3	2	1	0	9	16	58	267	784	1,803	2,847
Total Installations	4	11	23	45	58	79	105	160	298	435	852	1,919	3,369	4,751

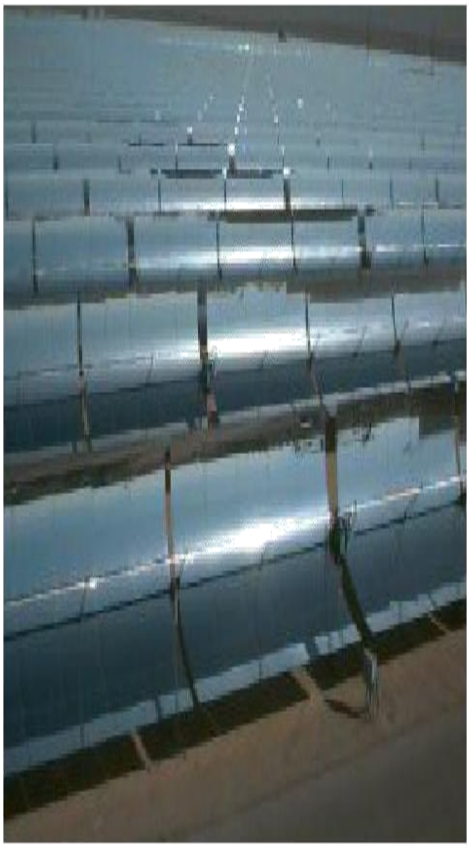
For more information on the state of the solar PV market in the US, visit our solar industry data page. Modern Photovoltaics

The cost of PV has dropped dramatically as the industry has scaled up manufacturing and incrementally improved the technology with new materials. Installation costs have come down too with more expereinced and trained installers. However, the U.S. still remains behind other nations that have stronger national policies to shift energy use from fossil fuels to solar. Globally, the U.S. is the fourth largest market for PV installations behind world leaders Germany, Japan and Spain.
Most modern solar cells are made from either crystalline silicon or thin-film semiconductor material. Silicon cells are more efficient at converting sunlight to electricity, but generally have higher manufacturing costs. Thin-film materials typically have lower efficiencies, but can be simpler and less costly to manufacture. A specialized category of solar cells - called multi-junction or tandem cells - are used in applications requiring very low weight and very high efficiencies, such as satellites and military applications. All types of PV systems are widely used today in a variety of applications.

5. Solar thermal electric conversion

Solar thermal power uses solar energy instead of combustion

Solar thermal power plants use the sun's rays to heat a fluid to high temperatures. The fluid is then circulated through pipes so that it can transfer its heat to water and produce steam. The steam is converted into mechanical energy in a turbine, which powers a generator to produce electricity.



Parabolic trough power plant

Solar thermal power generation works essentially the same as power generation using fossil fuels, but instead of using steam produced from the combustion of fossil fuels, the steam is produced by heat collected from sunlight. Solar thermal technologies use concentrator systems to achieve the high temperatures needed to produce steam.

Types of solar thermal power plants

There are three main types of solar thermal power systems:

- Parabolic trough
- Solar dish
- Solar power tower

Parabolic troughs

Parabolic troughs are used in the longest operating solar thermal power facility in the world, which is located in the Mojave Desert in California. The Solar Energy Generating System (SEGS) has nine separate plants. The first plant, SEGS 1, has operated since 1984, and the last SEGS plant that was built, SEGS IX, began operation in 1990. The SEGS facility is one of the largest solar thermal electric power plants in the world.

A parabolic trough collector has a long parabolic-shaped reflector that focuses the sun's rays on a receiver pipe located at the focus of the parabola. The collector tilts with the sun as the sun moves from east to west during the day to ensure that the sun is continuously focused on the receiver.

Because of its parabolic shape, a trough can focus the sun from 30 times to 100 times its normal intensity (concentration ratio) on the receiver pipe located along the focal line of the trough, achieving operating temperatures higher than 750°F.

Solar dish

The solar field has many parallel rows of solar parabolic trough collectors aligned on a north-south horizontal axis. A working (heat transfer) fluid is heated as it circulates through the receiver pipes and returns to a series of heat exchangers at a central location. Here, the fluid circulates through pipes so it can transfer its heat to water to generate high-pressure, superheated steam. The steam is then fed to a conventional steam turbine and generator to produce electricity. When the hot fluid passes through the heat exchangers, it cools down, and is then recirculated through the solar field to heat up again.

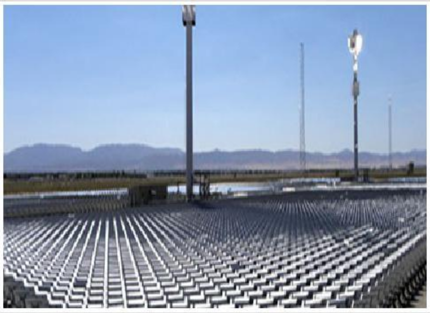
The power plant is usually designed to operate at full power using solar energy alone, given sufficient solar

Energy. However, all parabolic trough power plants can use fossil fuel combustion to supplement the solar output during periods of low solar energy.

Solar dishes

Solar dish/engine systems use concentrating solar collectors that track the sun, so they always point straight at the sun and concentrate the solar energy at the focal point of the dish. A solar dish's concentration ratio is much higher than a solar trough's concentration ratio, and it has a working fluid temperature higher than 1,380°F. The power -generating equipment used with a solar dish can be mounted at the focal point of the dish, making it well suited for remote operations or, as with the solar trough, the energy may be collected from a number of installations and converted into electricity at a central point.

The engine in a solar dish/engine system converts heat to mechanical power by compressing the working fluid when it is cold, heating the compressed working fluid, and then expanding the fluid through a turbine or with a piston to produce work. The engine is coupled to an electric generator to convert the mechanical power to electric power.



Solar power tower
Source: National Renewable Energy Laboratory (NREL)

Solar power tower

A solar power tower, or central receiver, generates electricity from sunlight by focusing concentrated solar energy on a tower-mounted heat exchanger (receiver). This system uses hundreds to thousands of flat, sun-tracking mirrors called heliostats to reflect and concentrate the sun's energy onto a central receiver tower. The energy can be concentrated as much as 1,500 times that of the energy coming in from the sun.

Energy losses from thermal-energy transport are minimized because solar energy is being directly transferred by reflection from the heliostats to a single receiver, rather than being moved through a transfer medium to one central location, as with parabolic troughs.

Power towers must be large to be economical. This is promising technology for large-scale grid -connected power plants. The U.S. Department of Energy, along with a number of electric utilities, built and operated a demonstration solar power tower near Barstow, California, during the 1980s and 1990s.

There are two operating solar power tower projects in the United States:

- A 5-Megawatt, two-tower project, located in the Mojave Desert in southern California
- A 392-Megawatt project located in Ivanpah Dry Lake, California

6. Biomass energy

Biomass is fuel that is developed from organic materials, a renewable and sustainable source of energy used to create electricity or other forms of power.

Some examples of materials that make up biomass fuels are:
•scrap lumber;
•forest debris;
•certain crops;
•manure; and
•some types of waste residues.

With a constant supply of waste – from construction and demolition activities, to wood not used in papermaking, to municipal solid waste – green energy production can continue indefinitely.

Biomass is a renewable source of fuel to produce energy because:
•waste residues will always exist – in terms of scrap wood, mill residuals and forest resources; and
•properly managed forests will always have more trees, and we will always have crops and the residual biological matter from those crops.

Reenergize Holdings is an integrated waste fuel/biomass renewable energy company. Our facilities collect, process and recycle items for use as fuel, as well as green energy facilities that create power from that waste.

Biomass power is carbon neutral electricity generated from renewable organic waste that would otherwise be dumped in landfills, openly burned, or left as fodder for forest fires.

When burned, the energy in biomass is released as heat. If you have a fireplace, you already are participating in the use of biomass as the wood you burn in it is a biomass fuel.

In biomass power plants, wood waste or other waste is burned to produce steam that runs a turbine to make electricity, or that provides heat to industries and homes. Fortunately, new technologies — including pollution controls and combustion engineering — have advanced to the point that any emissions from burning biomass in industrial facilities are generally less than emissions produced when using fossil fuels (coal, natural gas, oil). Reenergize has included these technologies in our facilities.

While the process to create electricity is similar whether using a biomass fuel or a fossil fuel, the equipment needed inside the plant is different. All of Energy's power generation facilities have been outfitted — and new acquisitions are upgraded — to allow for the burning of biomass.

As with any electrical generation process, the facility needs a steady supply of fuel. In all cases, Reenergize has suppliers to deliver a steady stream of biomass, and has engaged other suppliers to ensure the facilities have what they need. In addition, we create fuel for other biomass consumers — as well as other products
— at our recycling facilities.

When anything is burned, it can create emissions and ash. Our facilities have state-of-the-art cleaning processes that keep emissions below state regulatory levels, and we reuse our ash.

Biomass and the US

Biomass fuels provided about 4 percent of the energy used in the United States in 2010. Of this, about 46 percent was from wood and wood-derived biomass, 43 percent was from biofuels (mainly ethanol), and about 11 percent was from municipal waste. Researchers are trying to develop ways to burn more biomass and fewer fossil fuels. Using biomass for energy cuts back on waste and greenhouse gas emissions.

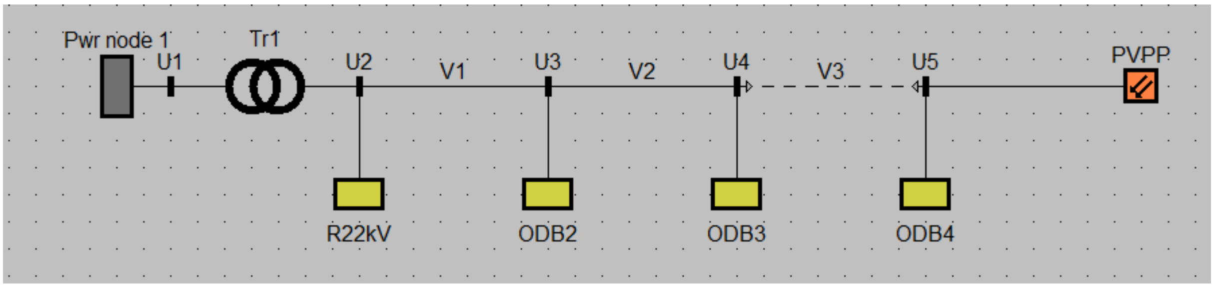
Biomass offers other significant environmental and consumer benefits, including improving forest health, protecting air quality, and offering the most dependable renewable energy source.

7. Case study

Calculation of PVPP impact to distribution network in Central Bohemia region

The PVPP is connected to distribution line 22 kV. The line is feeds from transformer 110/22 kV with capacity 40 MVA. We calculate impact of the new PVPP to voltage profile.

Scheme of the distribution line



Distribution network parameters

Transformer station 110/22 kV

Short circuit power 110 kV	2 200 MVA
Transformer 110/22 kV,	40 MVA, typ 5 ER 33 M-O:
Winding losses	219.3 kW
Short circuit voltage	11 %
No load losses	49.3 kW
No load current	0.8 I_n

Overhead/cable line 22 kV

Line section	Wire type	Line length	Resistancer [R/km]	Inductive reactance [X/km]	Nominal current [A]
1	95 AlFe 6	6,5 km	0,301	0,375	290
2	35 AlFe 6	1,4 km	0,775	0,395	150
3	240 AXEKCY	3,1 km	0,125	0,107	410

Consumption on line 22 kV

Odběr	Voltage [kV]	Power factorí [-]	Active power [kW]	Reactive power [kVAr]	Apparent power [kVA]	Current [A]
R22kV	22	0,95	11400	3747	12000	315
ODB2	22	0,95	724	238	762	20
ODB3	22	0,95	362	119	381	10
ODB4	22	0,95	543	178	572	15

Parameters of new PVPP connected to line 22 kV

Name	Voltage [kV]	Power factor [-]	Active power [kW]	Reactive power [kVAr]	Apparent power [kVA]	Current [A]
PVPP	22	1	3 000	0	3 000	79

Calculation results

Condition before PVPP connection

Voltage in network nodes

Node	Name	U [kV]	Voltage difference Un [%]
U1	R110kV	110	0,00
U2	R22kV	23,11	+5,05
U3	U3	22,92	+4,18
U4	U4	22,87	+3,95
U5	U5	22,86	+3,91

Currents and powers in network branches

Větev	Nodes	P [kW]	Q [kVAr]	S [kVA]	I [A]
TRAFO T101	U1	-14391	5060	15255	75
TRAFO T101	U2	14360	4497	15047	376
REGULA_1	U2	-1778	-361	1815	45
REGULA_1	U3	1766	351	1800	45
REGULA_2	U3	-980	-93	984	25
REGULA_2	U4	978	93	982	25
KABEL_1	U4	-587	36	588	16
KABEL_1	U5	587	193	617	16

Currents and powers in network nodes

Uzel sítě	Nodes	P [kW]	Q [kVAr]	S [kVA]	I [A]
R110kV	U1	14391	5060	15255	75
R22kV	U2	12581	4135	13243	331
ODB2	U3	786	253	827	21
ODB3	U4	391	129	412	10
ODB4	U5	586	193	617	16

Condition after connection of the PVPP with capacity 3 000 kW, cos φ = 1

Node	Name	U [kV]	Voltage difference from Un [%]
U1	R110kV	110	0,00
U2	R22kV	23,11	+5,05
U3	U3	23,19	+5,41
U4	U4	23,28	+5,82
U5	U5	23,30	+5,91

Currents and powers in network branches

Větev	Nodes	P [kW]	Q [kVAr]	S [kVA]	I [A]
TRAFO T101	U1	-10063	-4347	10962	54
TRAFO T101	U2	10046	4055	10962	271
REGULA_1	U2	1351	-309	1385	35
REGULA_1	U3	-1358	305	1392	35
REGULA_2	U3	2082	-67	2083	52
REGULA_2	U4	-2090	64	2091	52
KABEL_1	U4	2452	178	2452	61
KABEL_1	U5	-2457	178	2463	61

Current and powers in network nodes

Uzel sítě	Nodes	P [kW]	Q [kVAr]	S [kVA]	I [A]
R110kV	U1	10063	4347	10961	54
R22kV	U2	11397	3746	11997	300
ODB2	U3	724	238	762	19
ODB3	U4	362	119	381	9
ODB4	U5	543	178	571	14
PVPP	U5	3000	0	3000	74

Final evaluation of reverse impacts on distribution network CEZ Distribution at operation PVPP with capacity 3 000 kW

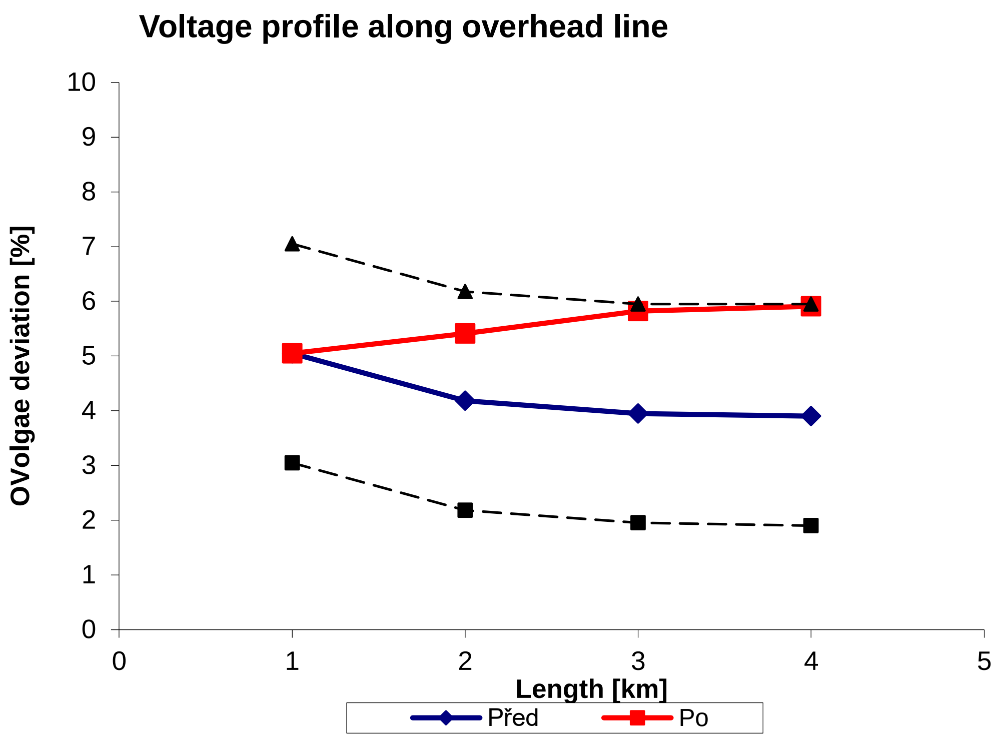
Voltage difference in connection point

Voltage difference in connection point induced with PVPP connection

Node name	Voltage U1 [kV]	Voltage U2 [kV]	Voltage difference [kV]
U2	23,11	23,11	0
U3	22,92	23,19	0,270
U4	22,87	23,28	0,410
U5	22,86	23,30	0,440

In the connection point will be voltage change at PVPP operation 0,44 kV (2 % Un) Voltage change is in limit by Czech standard.

Graph voltage deviation along overhead/cable voltage 22 kV before and after PVPP



Impact on short circuit

At operation of new PVPP will be short circuit power occurred very little. It is supposed that short circuit current of the PVPP will be not more than 1.5 nominal current.

Short circuits power table

Network node	R22kV	R22kV	PVPP	PVPP
	Short circuit power [MVA]	Short circuit current [kA]	Short circuit power [MVA]	Short circuit current [kA]
P = 0 MWp	337	8,85	88	2,31
P = 3,0 MWp	337	8,85	92,1	2,42

Short circuit power will be higher at PVPP operation. Short circuit power will be 92,1 MVA. This value is convenient for distribution network equipment.

Harmonics

Inventors changes DC to AC. This device includes components of power electronics that produce current harmonics. I tis supposed occurrence of 5, 7, 11, 13, 17, 19, 23 and 25th harmonics by type of inventor. The harmonic values not be allowed parameters by the Czech standards. Before come to operation the investor has to insure measuring of the harmonics. The harmonics filtration has to be installed if harmonics values are higher than is permitted in the standards. In the following table are given allowable values of the harmonics.

Number of current harmonics υ	Rated current $i_{vpř}$ [A/MVA] for 22 kV network
5	0,058
7	0,041
11	0,026
13	0,019
17	0,011
19	0,09
23	0,006
25	0,005

Tab : Rated values of the current harmonics in medium voltage system.

Conclusion of the calculation

Connection of new PVPP with capacity 3 000 kV in the given site to the existing distribution network is possible. At operation of the PVPP will not be exceeded the limits for reverse impact to distribution network given Czech standards.

8. General conclusion

The first chapter is devoted to renewable energy sources. All types RES used in the Czech Republic are described. It is photovoltaics, hydro, wind power plants and biogas and biomass station. The description contains expiries from all the world.

Part of the medium voltage distribution network is modelled for connection of photovoltaics power plant to line. All calculation were carry on application eVlivy. Input parameters were gained from the distribution company. Result of calculating were discussed and compared with Czech standards.

9. References

Distribution network code

CSN EN 50 160

eVlivy application manual

Schlabbach, J, D Blume a T Stephanblome: Voltage quality in electrical power systems

Internet: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm