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The Bright Future of Concentrated Solar Power

The human race is currently in dire need of a new primary source of energy production, and preferably one which is highly sustainable or at least will not run out quickly. We are going through the current available resources at an alarming rate that is far from sustainable. The high rate of consumption also attributes to the issue of global climate change due to the increased amount of carbon emissions which are currently being emitted. It is for this reason that scientists have turned towards the long lasting intensity of the sun as a potential supply of power. Each hour of everyday the sun generates enough energy to power 2880 trillion light bulbs. This is an astronomical figure. Of all the energy output that the sun has, only one tenth of it is utilized worldwide for electrical purposes.[1] The tricky part, which scientists are currently trying to figure out, is how to harness this energy in the most efficient way possible. It is nearly impossible to be one hundred percent efficient with any one source of power. Currently the primary source of fuel and energy for the global community as a whole is fossil fuels, accounting for over 80% or production.[2] In order to tap into all the potential energy the sun emits, something would have to be created that could convert the light, the heat, the UV rays,

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[1] Llorens, Dave. "How Much Energy Does the Sun Produce? (and Other Fun Facts)." *Solar Power Rocks*. 12 Oct. 2009. Web. 4 May 2015. <http://www.solarpowerrocks.com/solar-basics/3-reasons-the-sun/>.
[2] "Energy Smart." *Greenhouse.gov.au*. Web. 4 May 2015. <http://www.whitehorse.vic.gov.au/IgnitionSuite/uploads/docs/Sustainable Living Guide Energy.pdf>.

and other components into pure power. The contraption would also ideally have to have zero or at least very minimal emissions in order to help combat the rising issue with CO2 pollution. The current most capable system for capturing the suns energy is the SunCatcher solar thermal system has an efficiency of 31.25 percent conversion from heat energy to raw electricity.[3] This is over double the efficiency of roughly eighty years ago when these technologies were being developed for commercial use. In 1936 secretary of the Smithsonian Institution Dr. Abbot created a sun powered machine that had an efficiency of fifteen percent.[4] Technology will continue to improve and so will the effectiveness.

The concept of global warming is no new proposal to anyone. People have been well aware of the influence which humans have on the earth's atmosphere, ecosystems, and delicate chemical balance. There are many opponents to global warming who claim that it is a myth and that the earth is simply going through the same cycle that it has gone through during its 4.5 billion years in existence. While parts of this may be true, human influence has exponentially sped up this process at a dangerous rate. This could have dire consequences, particularly for coastal communities throughout the world due to the melting ice caps which cause sea levels to rise and flood areas. Scientists are developing ways in which to combat this rapid influx of carbon emissions, which are also attributing to the greenhouse effect. It is this battle against carbon emissions which has sparked a renewed interest in further developing

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[3] Moulton, Cyrus. "Introducing the Most Efficient Solar Power in the World." *Discover Magazine*. 8 Oct. 2009. Web. 4 May 2015. <http://discovermagazine.com/2009/oct/08-introducing-most-efficient-solar-power-in-world>.

[4] Abbot, C. G. "Solar Energy Now Caught with 15 per Cent. Efficiency." *The Science News-Letter* 29.770 (1936): 23. *JSTOR*. Web. 4 May 2015. <http://www.jstor.org/stable/3913033>.

solar power. There are two main ways of harnessing the suns energy. One way is the commonly thought of photovoltaic panels. This converts direct light into energy. Another potential source that is currently being put to the test on a large scale is the use of concentrated solar power or CSP for short. CSP systems make use of the sun's heat in order to generate energy. There are four main types of concentrated solar power techniques which are prominently used today: parabolic troughs, power towers, compact linear Fresnel reflectors, and dish engines.

Varieties of Concentrated Solar Power

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[5] *Parabolic Trough Solar Collectors*. Digital image. *The Green Technology Blog*. 1 Jan. 2009. Web.

Parabolic troughs have large, curved mirrors which are used to direct the sun's light energy at the receiver tube in the middle of the trough. The mirrors are positioned north to south and are able to pivot on a central axis which allows them to follow the sun as it moves across the sky. The receiver tube is full of some sort of fluid (synthetic oil is commonly used) which absorbs the suns heat energy. This causes the fluids temperature to rise to over 400 degrees Celsius, upon which the fluid then travels through a heat exchanger which utilizes the heat to convert water into steam that is used to power a turbine which produces energy. [6]


[7]

Power towers utilize a similar system, but instead of the light being reflected at a tube, the energy is directed at a focal point on the top of the tower. It does this through the application of hundreds or even thousands of acres of large flat mirrors that are angled to face at a particular point on a tower. Each mirror, known formally as a heliostat, is roughly the same

[6] "Concentrating Solar Power." *SEIA*. Web. 4 May 2015. <http://www.seia.org/policy/solar-technology/concentrating-solar-power>.
[7] *Khi Solar One*. Digital image. *ESI-Africa.com*. 17 Mar. 2015. Web.

size as a garage bay door. The focal point on the tower is filled with a salt substance that is super heated by the reflected light in order to generate steam to power the turbine that generates energy for use. The mirrors must produce enough heat by reflecting the sun to keep the salt in the focal point at a molten state; this is roughly 290 degrees Celsius. The salt solidifies at about 220 degrees Celsius, but if kept in specialized storage units can maintain its heat for up to six hours which enables it to keep producing energy after the sun has dropped below the horizon.[8] A single 100 megawatt power tower with only twelve hours of storage is capable of producing enough electricity to power 50,000 homes. A unit such as this only requires roughly 1000 acres of otherwise unusable arid land. [9] The newly constructed Ivanpah plant in the Mojave is currently the largest power tower facility in the world.

[8] "Concentrated Solar Power." *Solar Cell Central*. Web. 4 May 2015. <http://solarcellcentral.com/csp_page.html>.

[9] "Solar Power Towers Deliver Energy Solutions." *Solar Power Towers*. Waste Isolation Pilot Plant. Web. 4 May 2015. <http://www.wipp.energy.gov/science/energy/powertower.htm>.

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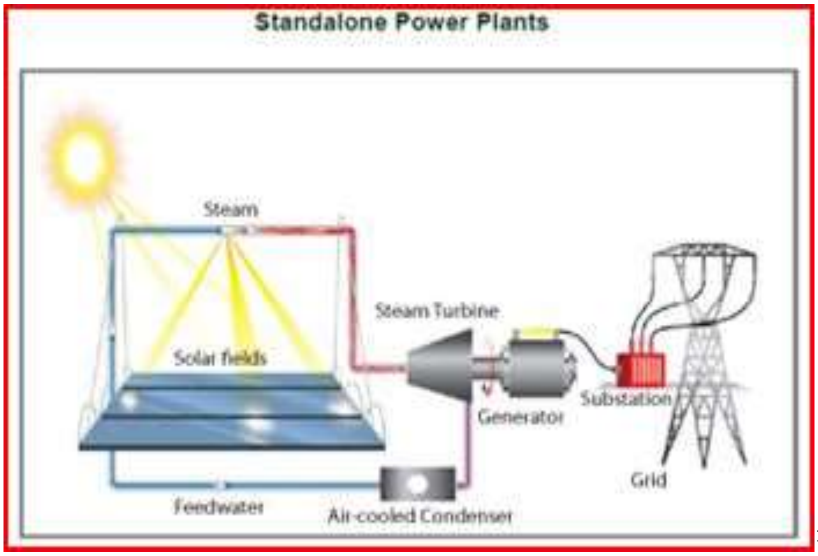
The next type of concentrated solar power unit is called a compact linear Fresnel reflector, CLFR for short. In 1961 Giovanni Francia, a professor at the University of Genoa in Italy, developed the first Fresnel reflector.[11] Over time the technology has improved and now this system consists of a series of modular flat mirrors that can be arranged in a trough like fashion to focus the suns heat onto the elevated receivers which are comprised of a series of boiler tubes that have water flowing through them. The light heats the water to its boiling point of 100 degrees Celsius in order to generate steam for facilitating the generators. This technology is able to be scaled to adapt to the energy demands and can be applied in three different ways:

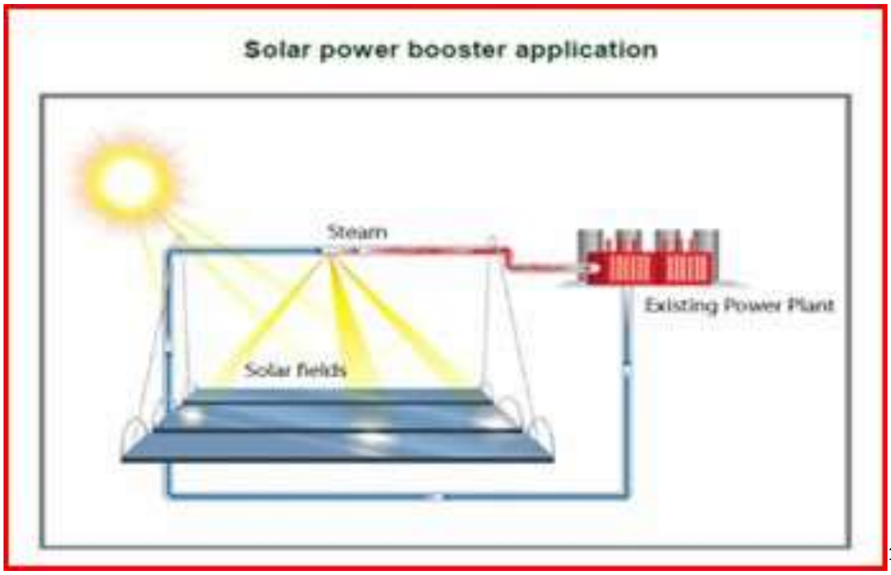
[10] *Compact Linear Fresnel Reflector*. Digital image. *SEIA*. Web.
[11] Mills, D.R. (2004). "Advances in solar thermal electricity technology". *Solar Energy*. 76 (2004): 19–31.



[12]

The first way is the standalone system. This uses the produced steam to power a generator which makes energy that is then fed directly into the power grid, and immediately distributed.

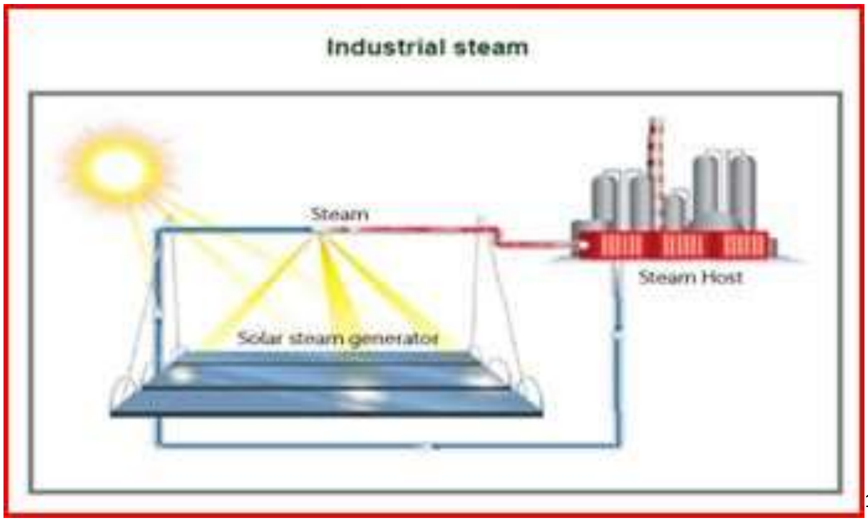
[12] *SCALABLE AND ADAPTABLE TECHNOLOGY*. Digital image. *AREVA*. 1 Jan. 2013. Web.



[13]

The second system is known as the booster application. This method ties directly into a pre-existing natural gas-fired or coal-fired power plant in order boost production. The steam created by the CLFR is used to provide a boost in productivity during peak hours when the demand is high. At the same time the set up is also reducing the emissions that are expelled by the plant. This solar technology can also increase the projected lifetime of the plant.

[13] *SCALABLE AND ADAPTABLE TECHNOLOGY*. Digital image. *AREVA*. 1 Jan. 2013. Web.



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The third way in which compact linear Fresnel reflectors are implemented is the industrial steam set up. This utilizes the steam driven generator to directly supply power to a factory or other industrial facility. In doing so it limits the emissions and cuts back on expenses by not purchasing power from external sources.[15]


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[14] *SCALABLE AND ADAPTABLE TECHNOLOGY*. Digital image. *AREVA*. 1 Jan. 2013. Web.
[15] "CLFR: How It Works." *Compact Linear Fresnel Reflector Technology*. 1 Jan. 2013. Web. 4 May 2015. <http://www.areva.com/EN/operations-3422/concentrated-solar-power-technology.html>.
[16] *The Imperial Valley Solar Project and Calico Solar Project Will Use Stirling Engine Technology*. Digital image. *SolarServer*. Web.

The final commonly used system of concentrated solar power is known as Dish-Engines. These produce relatively low amounts of energy compared to the other forms of concentrated solar power. Energy production is typically in the range of three to twenty five kilowatts. The structure is comprised of a dish, known also as a concentrator, which gathers the sunlight and directs it to a power conversion unit. The concentrator dishes are facilitated onto a fulcrum which is designed to pivot throughout the day in order to follow the sun as it travels across the sky. This ability to maneuver into the most optimal positions relative to the sun, enables the unit to maximize productivity and efficiency by reflecting the highest percentage of the sun's rays onto the thermal receiver of the power conversion unit. This element is comprised of a thermal receiver and the engine or generator. The receiver absorbs the reflected light energy and converts it to heat energy. This energy is then used to heat the cooling fluid, which is generally hydrogen or helium, which is in a tube bank. After the cooling fluid is heated inside the tubes, it is then sent to power the engine or generator that produces the desired energy. Stirling engines are the standard energy generating units that dish-engine systems are fitted with. These motors use the pressure from the super heated liquid to drive the pistons which manufacture mechanical power that is utilized in the production electricity.[17]

The History of the Development of Concentrated Solar Power

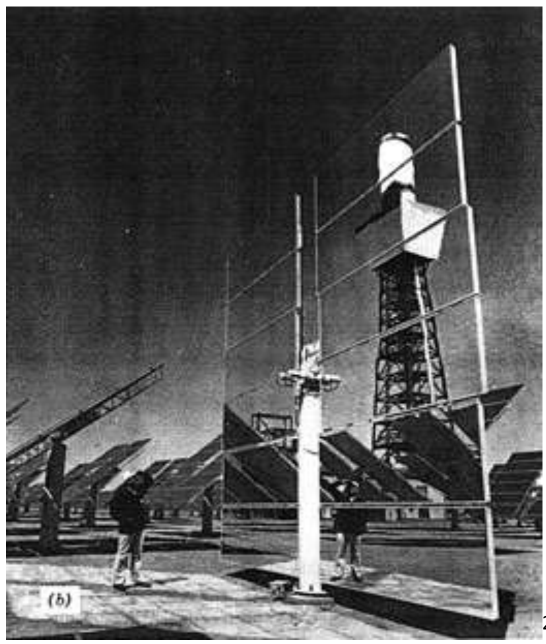
[17] "Concentrating Solar Power Dish/Engine System Basics." *Energy.gov*. Office of Energy Efficiency & Renewable Energy, 20 Aug. 2013. Web. 4 May 2015. <http://energy.gov/eere/energybasics/articles/concentrating-solar-power-dishengine-system-basics>.

Concentrated solar power may be innovative in the realm of renewable and sustainable energy, but the concept of using the suns thermal heat via CSP has been around for centuries and is by no means a new theory; it is merely being refined for more practical purposes and is another step in the direction of an energy self-sufficient America. The use of concentrated solar power can be traced back to the second century BC when the Greek engineer Archimedes developed a contraption to be used as a weapon and defense tactic. He positioned a large parabolic mirror on a cliff by the ocean and used it to aim the light energy of the sun into a powerful beam of heat, of which the focal point was trained on the incoming fleets of ships. Allegedly this beam of light produced enough heat energy to cause the vessels to catch fire and he was credited with successfully fending off the assault. His invention became known as a death ray.[18] Now whether or not Archimedes's invention actually worked and was able to burn ships is left to interpretation, but the concept that he came up with is essentially the same basis as in the CSP towers. Archimedes was far ahead of his time with his ability to harness the suns energy. It wasn't until over two thousand years later, in the nineteenth century that people began using super concentrated sunlight as a tool.

Auguste Mouchot, a French inventor, began utilizing the suns power as a means to heat water and produce steam in order to run the world's first solar powered steam engine. Fifty years later, an inventor from Philadelphia by the name of Frank Schuman installed parabolic solar collectors in the small farming town of Meadi Egypt. The troughs produced steam which

[18] "Archimedes Death Ray: Idea Feasibility Testing." *2.009 Product Engineering Processes: Archimedes*. M.I.T, Oct. 2005. Web. 05 May 2015.

was utilized to run massive water pumps that were capable of pumping up to six thousand gallons of water a minute to the dry, arid desert land.[19] In 1968 Italy constructed the very first operational power plant to generate and distribute the power to the public. Built by Professor Giovanna Francia, the plant uses very similar set up as modern plants. It had a central receiver and was surrounded by solar collectors.



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Shortly thereafter, the United States Department of energy began experimenting with CSP as a potential resource. The prototype project was known as Solar One and produced a meager ten megawatts. Within the next four years a solar thermal facility was established in Kramer Junction California that was the largest the world had ever seen. The system used a

[19]"History of Concentrated Solar Power." *Aalborg CSP A/S*. Web. 4 May 2015. <http://www.aalborgcsp.com/what-is-csp/history-of-csp.aspx>.

[20] *The Solar One Plant*. Digital image. *SolarServer*. 1 Jan. 1982. Web.

field of mirrors that were concentrated on a series of pipes which had fluid circulating within them. The fluid was heated and converted to steam which was used to power a turbine that generated electricity. In 1996 the U.S. Department of Energy began operational use of Solar Two, which was an improvement on the Solar One plant fourteen years prior. Solar Two displayed how the suns energy could be harnessed and used to create and store electricity efficiently and economically. This realization sparked the interests of various industrial companies as a means of a potential source of inexpensive power. Currently there are over 35 plants operational worldwide, with many more either under construction or on the drawing boards. [21]

The Ivanpah Power Plant


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[21] "History of Concentrated Solar Power." *Aalborg CSP A/S*. Web. 4 May 2015. <http://www.aalborgcsp.com/what-is-csp/history-of-csp.aspx>.
[22] West, Jim. *Ivanpah Solar Power Plant*. Digital image. *Zuma Press*. 1 Jan. 2013. Web.

December of 2013 marked a milestone in the field of solar energy. The world's largest concentrated solar power plant, the Ivanpah Solar Plant, had finally completed construction in the Mojave Desert in the southwestern corner of the United States. The plant became fully operational two months later, in February of 2014 after six long years of construction. The vast complex covers some 4000 acres of public land, has three 460 feet tall solar power towers along with about 350,000 garage door sized mirrors used to focus the sun's reflected rays on the boilers. BrightSource Energy partnered up with Bechtel Engineering to become the two main developers behind the project. The massive facility was projected to generate 392 megawatts of energy while emitting over 13.5 million tons less CO2 into the atmosphere than the more common fossil fuel plants, throughout the course of its lifetime. Toby Seay, the president of Betchtel's Power Division, commented on the massive compound stating that it is "this generation's legacy, its Hoover Dam, its testament to U.S. ingenuity." The energy produced by the Ivanpah plant was projected to only cost the average homeowner about nine cents on the dollar MW/hr. This was a significant decrease compared to the cost of electricity generated from fossil fuels which can range anywhere from sixty cents on up to over a dollar MW/hr. The 2.2 billion dollar project was funded largely by a 1.6 billion dollar federal loan guarantee from the U.S. Department of Energy, as well as other donors such as the Princeton New Jersey based company NRG Energy, which contributed 300 million dollars, and Google, which invested 168 million dollars.[23] The original blueprints for the vast complex were scaled

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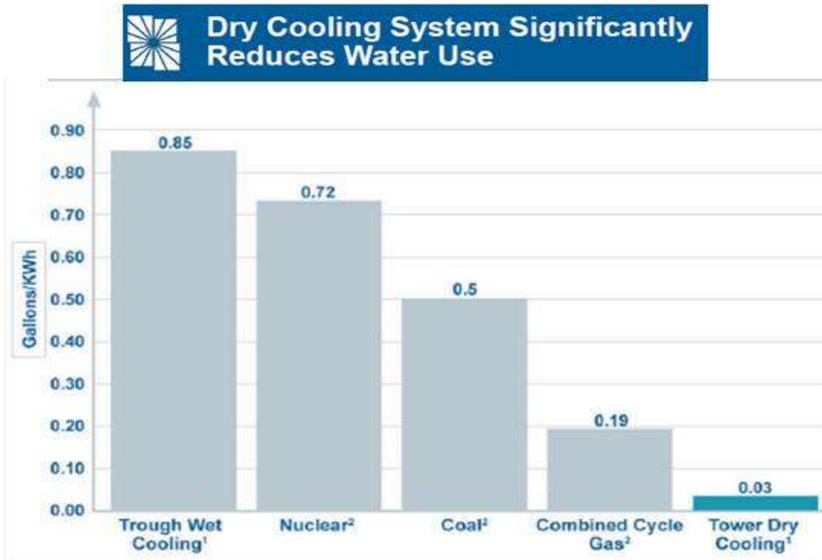
[23] Trabish, Herman. "Ivanpah: World's Biggest Solar Power Tower Project Goes On-Line."*Greentechsolar*. Greentech Media, 13 Feb. 2014. Web. 4 May 2015.

back in 2010 from its initial size of 440 megawatts to 392 megawatts in order to eliminate the issue of intruding on the habitat of the endangered desert tortoise which is native to the Mojave. This was largely a result of local public outcry over the plans invading the already protected public land that is the tortoise's habitat. Local supervising official Brad Mitzelfelt said about the proposed layout "this project is planned on land that the BLM (Bureau of Land Management) along with a local coalition of industry and environmental groups long ago identified as habitat for protected species. This solar project in its current configuration could compromise nearly twenty years of efforts to protect habitat and appropriately grow Desert communities."[24] This resulted in the schematics being altered accordingly. The available land in the Mojave Desert, if utilized, is capable of turning out energy on the same scale that hydro power currently does in the Northwest United States.

<http://www.greentechmedia.com/articles/read/Ivanpah-Worlds-Biggest-Solar-Power-Tower-Project-Goes-Online>.

[24] Zook, David. "County Supervisor, Concerned by BrightSource Mega Solar Project Impacts, Calls for Full Review." *Best Syndication* 16 Nov. 2009. Web. 4 May 2015. <http://www.bestsyndication.com/?q=20091115_solar_project.htm>.



(from BrightSource Energy) [25]

The Ivanpah Plant utilizes dry cooling technology in order to combat against the heat and drought of the Mojave. This technology employs a closed loop feed-back system which condenses the steam back into water to cool the pipes and keep everything running while also eliminating the need for mass amounts of precious water. Energy Secretary Ernest Moniz was quoted saying "this facility (the Ivanpah Power Plant) will use roughly the same amount of water as two holes at the nearby golf course". In spite of all these projections the plant is not living up to all the hype.[26]

During the first eight months of operation Ivanpah only generated 254,263 megawatt hours of energy which is only about one-quarter of the projected 1 million megawatt hours annually. This puts the plant to be roughly 40% under the projected values. Proponents of

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[25] *Dry Cooling System Significantly Reduces Water Loss*. Digital image. *Greentechsolar*. 24 May 2012. Web.

[26] Phillips, Ari. "World's Largest Solar Thermal Plant Uses As Much Water As Two Holes On Nearby Golf Course." *ThinkProgress RSS*. Center for American Progress Action Fund, 13 Feb. 2014. Web. 4 May 2015. <http://thinkprogress.org/climate/2014/02/13/3289361/worlds-largest-solar-plant/>.

Ivanpah attribute this lack of production to cloudy days early in the year. Another snafu that came up with the project was that the owners of the plant put in a request to use 60% more natural gas auxiliary boilers than previously allowed by the original plan and certification. The initial plan was to run auxiliary power only one hour per day, or as a backup reserve, now the company is requesting permission to use them about four and a half hours per day. This request was eventually approved in August of 2014. [27] Developers are making excuses for the plants low yield by saying that nothing on this scale had ever been developed. Previously the largest power tower in the world was Planta Solar20 in Spain and would generate a mere 20 megawatts annually.[28] Ivanpah is nearly twenty times the size of that plant. Due to its large scale it is not surprising that there are flaws in the system which need to worked out before optimal production can be accomplished.

[27] Danko, Pete. "More Problems for CSP: Ivanpah Solar Plant Falling Short of Expected Electricity Production." *Greentechsolar*. Greentech Media, 30 Oct. 2014. Web. 4 May 2015. <http://www.greentechmedia.com/articles/read/ivanpah-solar-plant-falling-short-of-expected-electricity-production>.

[28] "Concentrated Solar Power." *Solar Cell Central*. Web. 4 May 2015. <http://solarcellcentral.com/csp_page.html>.

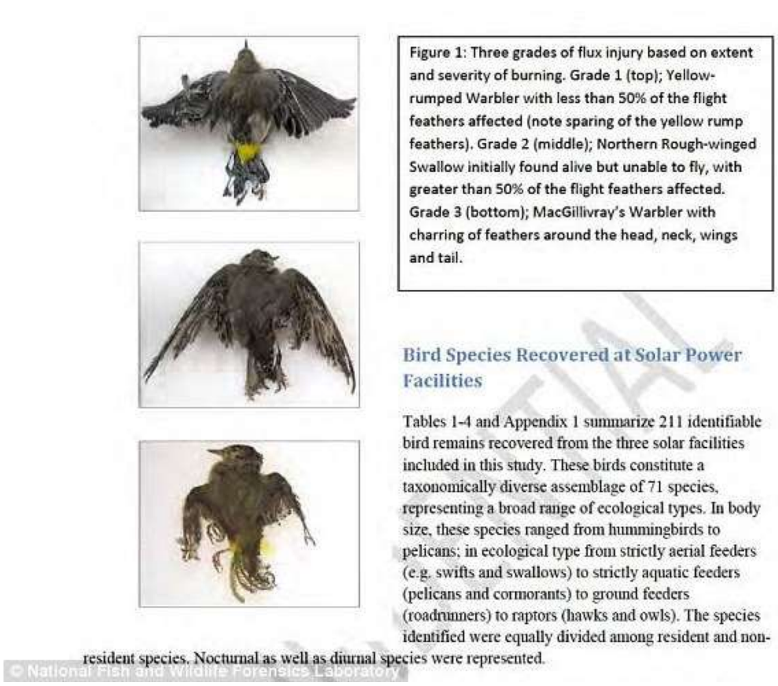
Figure 1: Three grades of flux injury based on extent and severity of burning. Grade 1 (top); Yellow-rumped Warbler with less than 50% of the flight feathers affected (note sparing of the yellow rump feathers). Grade 2 (middle); Northern Rough-winged Swallow initially found alive but unable to fly, with greater than 50% of the flight feathers affected. Grade 3 (bottom); MacGillivray's Warbler with charring of feathers around the head, neck, wings and tail.

Bird Species Recovered at Solar Power Facilities

Tables 1-4 and Appendix 1 summarize 211 identifiable bird remains recovered from the three solar facilities included in this study. These birds constitute a taxonomically diverse assemblage of 71 species, representing a broad range of ecological types. In body size, these species ranged from hummingbirds to pelicans; in ecological type from strictly aerial feeders (e.g. swifts and swallows) to strictly aquatic feeders (pelicans and cormorants) to ground feeders (roadrunners) to raptors (hawks and owls). The species identified were equally divided among resident and non-resident species. Nocturnal as well as diurnal species were represented.

[29]

There is one issue in particular that raises red flags all over the country with people and that is the smoke ribbons that occur within the plant. These smoke ribbons are actually the remnants of birds which were unlucky enough to fly into the plants superheated acres of mirrors. Environmentalists are arguing that Ivanpah could potentially decimate an entire ecosystem in the Mojave. The plant attracts insects which are instantly fried by the intense heat. These insects are the staple food source for many animals which in turn are food sources for apex predators. In the Mojave Desert there are at least six endangered avian species, four mammalian species, two reptilian species, one amphibious species, and two species of insects. A particular concern of people is that among the endangered avian species in the Mojave, one is the Bald eagle, the national bird of the United States.[30] By eliminating even one of these

[29] *Solar Flux Damage*. Digital image. *Daily Mail*. N.p., 15 July 2014. Web.
[30] "Endangered Species." *National Park Service*. Web. 4 May 2015. <http://www.nps.gov/moja/learn/education/classrooms/upload/MDD-Unit-VIII-Endangered-Species.pdf>.

species it could have potential detrimental effects on the ecological community as a whole. The trophic pyramid of energy consumption is a delicate balance of herbivores, omnivores, carnivores, and invertebrates which rely on one another for food. It is a well known fact that the world needs a new renewable source of power, but consumers are less likely to purchase energy from a company which is responsible for the extinction of various species of animals. This could potentially be a huge hit for the plants economic income. As of now the main concern is the birds which are being incinerated due to the sheer heat of the reflections from the mirrors. These birds are literally bursting into flame and being reduced to puffs of smoke, affectionately referred to as “streamers”, instantly. Federal wildlife investigators have determined there to me one streamer roughly every two minutes which amounts to hundreds of thousands of birds each year. Other estimates are more reasonable and estimate that the number of incinerations is more in the neighborhood of 28,000 per year. Still a hefty amount when the chances of one of these “streamers” being an endangered species are one in four thousand six hundred. BrightSource is aware of the situation and has employed its own investigative team to look into it. They gathered their own data and reported that the number of annual deaths is more in the neighborhood of 1000.[31] The Ivanpah officials justified this statistic by comparing it to the hundreds of millions of birds that die annually from flying into

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[31] Anthony, Sebastian. "California’s New Solar Power Plant Is Actually a Death Ray That’s Incinerating Birds Mid-flight." *ExtremeTech*. Ziff Davis, 20 Aug. 2014. Web. 4 May 2015. <http://www.extremetech.com/extreme/188328-californias-new-solar-power-plant-is-actually-a-death-ray-thats-incinerating-birds-mid-flight>.

windows.[32] Still, it is not a shock to anyone that BrightSource's numbers were significantly lower than the others. It is a commonly applied policy in environmental politics for a company to hire people who are in favor of their product to research data on the costs of production. These researchers always find a way to skew the data in favor of the big company so that they don't look so bad on paper regardless of what is actually happening.

There are other ecological implications which include the damaging of habitats due to the sheer size of the plant. The native fauna that was living there has since been forced to relocate. BrightSource and Bechtel did score brownie points from environmentalists by scrapping part of the original plan and downsizing the area in order to accommodate the endangered desert tortoise's habitat. But it still covers some four thousand acres of land which is home to other wildlife. An anthropological concern which was brought to light is that there are many Native American artifacts in the area from multiple tribes including the Pueblo people and the Cahuilla Indians.[33] This history needs to be preserved for generations to come, as well as for the descendants of these indigenous populations. Emerging from a more economic standpoint, the plant currently has no formal storage unit for its power. This reduces both its economic and reliability benefits. Currently the plant is only beneficial during the daylight hours when its towers can produce energy. At night little energy comes from the compound. If

[32] Milius, Susan. "Stop Blaming Cats: As Many as 988 Million Birds Die Annually in Window Collisions." *The Washington Post* 4 Feb. 2014. Web. 5 May 2015. <http://www.highbeam.com/doc/1P2-35659146.html?>.

[33] Feller, Walter. "Native American History in the Mojave Preserve." *Digital Desert*. Web. 4 May 2015. <http://digital-desert.com/mojave-preserve/native-american-history.html>.

Ivanpah can install some sort of storage unit for the energy, it would increase its economic benefit because it would be able to continue to produce usable energy into the night.[34]

Despite all the negative issues that are brought up about the Ivanpah facility, there is some good that has come from it too. Most notably is that the project has provided over seventeen hundred people with jobs to support their families with during the six year construction period. After completing construction, there will be eighty six full-time employees at all times.[35] A large majority of these employees came from parts of California where unemployment has reached levels as high as fifteen percent. Joe Desmond, the Vice President for Government Affairs and Communications at BrightSource, was quoted saying "These are family-wage jobs. They're electricians, pipefitters, welders, heavy equipment operators, engineers and biologists." The company has also instituted a program called helmets-to-hardhats which helps to provide returning veterans with jobs in the construction industry. BrightSource has also focused efforts on decreasing the costs of everything. During the construction process, in an attempt to minimize transport expenses, a heliostat assembly plant was built at the Ivanpah facility. Here a workforce of union members was able to turnout five hundred heliostats a day from flat mirrors.[36] The workers actually managed to make six

[34] Cheyney, Tom. "The Ivanpah Conundrum." *Solar Curator*. 18 Feb. 2014. Web. 5 May 2015. <http://www.solarcurator.com/2014/02/18/ivanpah-conundrum/>.

[35] Mufson, Steven. " Solar power project in Mojave Desert gets $1.4 billion boost from stimulus funds." *The Washington Post* 23 Feb. 2010. The Washington Post Company. Web. 4 May 2015. <http://www.highbeam.com/doc/1P2-21308177.html?>.

[36] Trabish, Herman. "BrightSource: The Rumors of Concentrating Solar Power's Demise Are Wrong." *Greentechsolar*. Greentech Media, 24 May 2012. Web. 4 May 2015. <http://www.greentechmedia.com/articles/read/BrightSource-The-Rumors-of-Concentrating-Solar-Powers-Demise-Are-Wrong>.

hundred and fifty panels per day during peak construction. This manufacturing plant can also be used in future projects as well.[37]

Finding a way to store reserve energy for use into the night or during times of inclement weather is a major problem that the developers of the Ivanpah plant and other concentrated solar plants must overcome in order to take this technology to another, more productive and lucrative level. As it stands CSP facilities cannot operate at optimal potential unless it is a sunny day out. Having a backup system to help compensate for this fact would be highly beneficial. Currently there are three different storage systems which are being implemented: the two-tank direct system, the two-tank indirect system, and the single-tank thermocline system.


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The two-tank direct system stores solar thermal energy in the same fluid that is used to collect it. The fluid is retained in two separate tanks at two different temperatures. One tank is

[37] Trabish, Herman. "Ivanpah: World's Biggest Solar Power Tower Project Goes On-Line."*Greentechsolar*. Greentech Media, 13 Feb. 2014. Web. 4 May 2015. <http://www.greentechmedia.com/articles/read/Ivanpah-Worlds-Biggest-Solar-Power-Tower-Project-Goes-Online>.

[38] *TWO-TANK DIRECT SYSTEM*. Digital image. Web.

kept at a high temperature, about 565 degrees Celsius, while the other is kept considerably cooler, more around 290 degrees Celsius. The procedure begins with the fluid in the low temperature tank flowing over to the higher temperature tank. During this process the cold fluid is forced to go through the solar receiver. When this happens, the solar receiver uses the heat energy that it has collected from the sun to warm up the cold fluid before it is deposited in the high temperature tank for storage. Likewise the fluid in the high temperature tank too has to flow out to make room. When this happens the hot fluid goes through the heat exchanger where it generates steam used for driving a turbine for energy production. The fluid then leaves the exchanger much cooler than it was and proceeds into the low temperature tank and the cycle repeats itself. This two-tank direct storage technique was commonly used with parabolic trough plants during the early years of solar power production. Some of these troughs used mineral oil as the fluid, while others used molten salts.[39]

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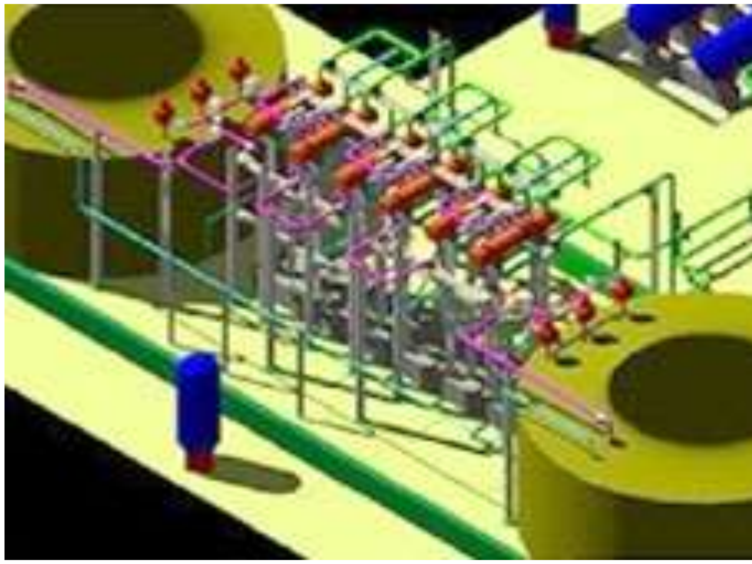
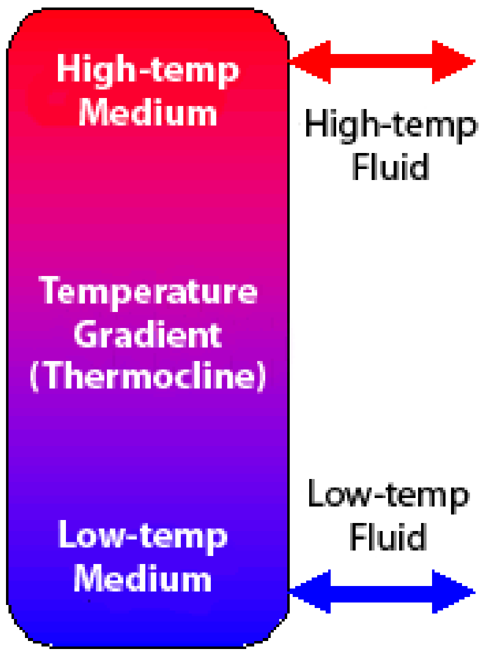
[39] "Concentrating Solar Power Thermal Storage System Basics." *Energy.gov*. Office of Energy Efficiency & Renewable Energy, 21 Aug. 2013. Web. 4 May 2015. <http://energy.gov/eere/energybasics/articles/concentrating-solar-power-thermal-storage-system-basics>.

[40]

The second type of storage facility is the two-tank indirect system. This set up embodies the same principles of the fluid exchange as the two-tank direct system, except that there are two separate, different fluids working in this unit. One solution is only used as the transfer substance, and the other is only used for storage. The fluid in the low temperature tank is kept at about 290 degrees Celsius and must flow through an extra heat exchanger so that it can be heated up by the fluid from the high temperature tank which is optimally around 385 degrees Celsius. The high temperature fluid then flows back into its respective tank. The liquid exits the heat exchanger significantly cooler than when it came in, and returns to the solar receiver so it can be heated back up to a high temperature again. The storage fluid in the high temperature tank is utilized to create steam and generate electricity in the same manner as the two-tank direct system by powering a generator of sorts. The main differences are that the indirect system requires the use of an extra heat exchanger and the two substances are housed in

[40] *TWO-TANK INDIRECT SYSTEM*. Digital image. Web.

separate circuits. This of course drives the price of the facility up due to the need to purchase extra equipment. This system is most often used in plants where the heat transfer fluid is either too expensive or is not suited for use as the storage fluid. The United States and Spain have already made plans to utilize this form of storage on multiple parabolic plants in their countries. They have opted to use a heat transfer fluid that is some kind of organic oil, while the storage fluid will be molten salt[41].



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The final energy storage type that is predominantly used is the single-tank thermocline system. This utilizes a solid substance, such as silica sand, to store thermal energy located in a

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[41] "Concentrating Solar Power Thermal Storage System Basics." *Energy.gov*. Office of Energy Efficiency & Renewable Energy, 21 Aug. 2013. Web. 4 May 2015. <http://energy.gov/eere/energybasics/articles/concentrating-solar-power-thermal-storage-system-basics>.

[42] *SINGLE-TANK THERMOCLINE SYSTEM*. Digital image. Web.

single tank. Throughout the entire operation, there is always a portion of the medium which is at a higher temperature of roughly 400 degrees Celsius, and there is also always a portion that is at a low temperature around 290 degrees Celsius. The two temperature ranges are separated by a temperature gradient known as a thermocline. The high heat fluid flows into the top of the thermocline, proceeds through, and then exits the bottom at a much cooler temperature. What is occurring in the tank is that the thermocline is moving downward and adding thermal energy to the system for storage. If the process is reversed, then the thermocline rises up through the tank and the energy is removed from the tank and used to produce steam that then drives a turbine which generates electricity. As a result of the effects of buoyancy, a series of thermal layers are created within the tank which is pivotal for stabilizing and maintaining the thermocline. By using a solid substance for storage, and only requiring one tank for the entire process, the cost of the set up is less than that of a two tank system which, in turn, can make it more attractive for companies to use. The Solar One power tower used a single-tank thermocline system with steam as the heat transfer fluid and mineral oil as the storage fluid.[43]

Concentrated solar power on the scale of Ivanpah is still on the cutting edge of development. It is to be expected that there are some issues with the project as a whole, whether these issues be from an economic production standpoint or from and ecological

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[43] "Concentrating Solar Power Thermal Storage System Basics." *Energy.gov*. Office of Energy Efficiency & Renewable Energy, 21 Aug. 2013. Web. 4 May 2015. <http://energy.gov/eere/energybasics/articles/concentrating-solar-power-thermal-storage-system-basics>.

environmental standpoint. The developers behind Ivanpah are striving to work out the bugs in the system and make the plant live up to its projected potential. As of now it appears that other construction plans for large scale plants similar to Ivanpah are being put on hold until the technology is able to be developed to maximize the profits from both an economic and environmental standpoint. In the meantime researchers are fervently seeking for other new ways of sustainable energy in order to keep the world running as it does. One potential option is a new type of solar tower that is currently under development and could change the whole industry and even the world. SolarReserve is currently working on a compact version of their full size solar power tower. It is known as the "M" class. The unit is going to be able to be disassembled and moved to new locations as needed. The target market with this product is largely mining communities and places that are highly isolated or rural. The "M" class tower has the potential to bring access to electricity to people and places that previous have had zero contact with such technology. It has the abilities to provide constant power 24/7 to locations which are entirely off the grid. The tower is projected to generate between twenty and thirty megawatts of power and will also have storage capabilities, a luxury that some of the most prestigious solar towers in the world do not have. The only issue to date is that it is unclear whether or not the storage facilities are going to be deployed multiple times. The system by which the steam is generated, and the network of pipes for transporting it would have to simplified in order for the idea of portable storage units to be feasible. The heliostats have been design with certain materials that project them to have a lifespan of at least thirty years. The reasoning behind developing such a small tower was to compete with or entirely eliminate and replace the need for diesel generators. [44] A product such as this class “M” tower could play a crucial role is aiding with the global energy crisis. It is not impossible to think that, cost pending, in fifty to one hundred years maybe everyone will have a unit similar to the class “M” at their homes. This could attribute to worrying about fossil fuel shortages and CO2 emissions becoming obsolete. With the rapid exponential increase in population growth something must be done to maintain energy production for fear of the world going into a primal state of being where chaos will ensue and only the super wealthy will be able to afford common luxuries because the cost of the energy will be so high. The demand for energy will never go away, and is ever increasing, therefore there will always be a market and when the solution for the crisis is found the technology will be employed worldwide, in the meantime CSP development may be a quality short term solution for a long term problem.

[44] Cheyney, Tom. "The Ivanpah Conundrum." *Solar Curator*. 18 Feb. 2014. Web. 5 May 2015. <http://www.solarcurator.com/2014/02/18/ivanpah-conundrum/>.

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PLEDGE:

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