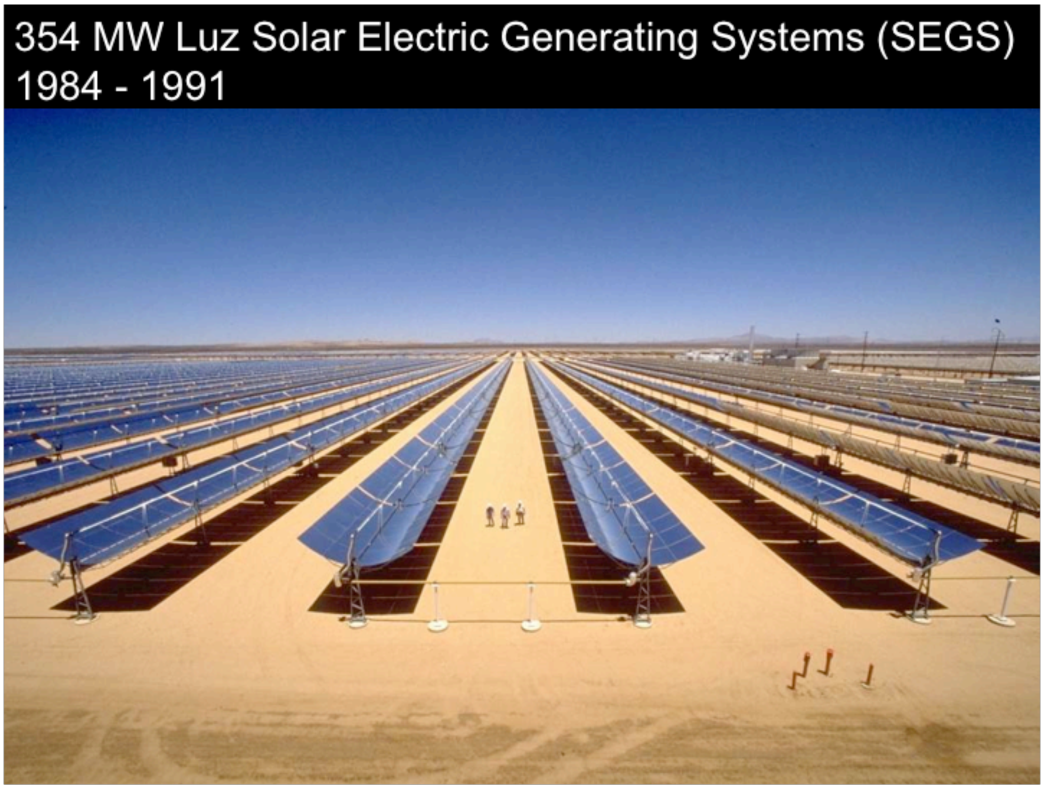
Through a Glass…Brightly?

Summary and Analysis of Chuck Kutscher's Presentation on Concentrated Solar Power to the Santa Fe Institute Global Sustainability Summer School, July 20, 2009.

Figure 1



In the collection of Shinto myths known as the *Kojiki*, there is an intriguing account of a society that, in a period of darkness, disarray, and disorder, ingeniously worked up a conceit using a mirror to restore light, beauty, and culture to the land. What had happened to cast the world in darkness in the first place?

A rather violent domestic dispute between Ama-terasu, the sun-goddess, and her brother, the storm-god Susa-no-wo, resulted in the depressed Ama-terasu's withdrawing into a cave. Of course, she took her illuminating energy with her. She emphatically sealed the entrance of the cave with a boulder to prevent others from pursuing her. Suddenly, robbed of the defined edges that light provides, the world was infused with chaos in the absence of explicit order: "constant night reigned, and the cries of the myriad deities were everywhere abundant, like summer flies; all manner of calamities rose."[1]

So, the minor deities decided to undertake a collaborative effort to lure the sun from her self-imposed seclusion. They commissioned a smith to make a mirror, which they placed opposite the entrance of the goddess's cavernous hiding place. Then they proceeded to have something of a bacchanal, lead by the goddess of sensuality. Intrigued by the celebratory sounds, Ama-terasu peeked out from behind the stone guarding the entrance to her cave. In doing this she caught sight of her reflection, for the first time ever, in the mirror. She was so intrigued by the beauty of her brightly shining face that she emerged from the cave to approach the mirror. Quickly taking advantage of the success of their trickery, the minor deities rolled the stone to seal the cave behind the goddess and prevent her from hiding again. Thus, light, beauty, truth, and order were restored to the land.

Could the curved mirrors of concentrated solar power collectors be the twenty-first century analog to that ancient looking glass that rescued the world from chaos and collapse? Carbon dioxide concentrations in the earth's troposphere are 387 ppm and increasing by 2 ppm per year, an increase of 100 ppm in a century. There is overwhelming consensus in the scientific community that the cause of this increase is anthropogenic. According to Dr. Matthew England, a climate physicist at the Climate Change Research Centre at the University of New South Wales, we are currently tracking

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[1] Donald L. Philippi, trans. *Kojiki* (Tokyo: University of Tokyo Press, 1968), 81.

at the high end of emissions scenarios–even beyond what the IPCC thought possible. If we proceed in business as usual, carbon dioxide concentration will rise even faster and exceed 500 ppm by 2050. If we want to limit global temperature rise to 2˚ C, we need to keep carbon dioxide concentrations peaking at no more than about 450 ppm and then draw down carbon dioxide to keep our ice caps from irreversibly melting in the coming centuries. Reducing dependence on fossil fuels and relying instead on alternative renewable energy sources, such as solar energy, seems to be an obvious step in the direction of a sustainable future. Chuck Kutscher, an engineer with the National Renewable Energy Laboratory, presented a talk on concentrated solar power at the Santa Fe Institute Global Sustainability Summer School on July 20, 2009 that explored that option's viability.

CSP: What it is and how it works

The first thing to note about concentrated solar power (CSP) is that it is not an amplification in degree of photovoltaic (PV) collection, but a completely different kind of machinery. Most people are familiar with the flat PV panels that can be seen on the occasional rooftop or along the highway, powering streetlights and signage. PV panels collect both diffuse and direct radiation, and so can operate under clear and cloudy conditions. CSP, on the other hand, focuses sunlight in order to create the high temperature needed to run a thermodynamic heat engine. Since diffuse light can't be focused (Kutscher uses the example of the childhood entertainment provided by focusing the sun's rays with a magnifying glass; it doesn't work on cloudy days), CSP plants have the most potential to function in areas where most days are bright and clear. In the United States, the deserts of the southwest provide an optimal location.

Of the different kinds of designs of CSP collection plants, the parabolic trough design is the most developed (pictured above, figure 1). Kutscher's talk focused primarily on this type of installation. The troughs are basically parabolic mirrors that focus sunlight and concentrate heat on pipes (with high absorptivity of visible light and low emissivity of thermal radiation) that carry oil, which is then transported to heat water and generate the steam that runs the thermodynamic heat engine. The parabolic troughs are oriented on a north-south axis and track east to west during the day, mimicking the turn of the faces of sunflowers as they follow the sun through the sky.

CSP Installation: What it requires

Due to the nature of their design and how they operate, CSP plants require large, flat installation sites in regions with direct sunlight. This is why desert locations are ideal. The installations need to be large because sunlight, unlike coal or gas, is not a concentrated source that can be mined from a confined point of entry. Basically, because solar radiation is spread out over surface area, you need a large collector-field; intermittent installation negates efficiency. According to Kutscher, the Western Governors' Association commissioned a study (**year?**) that aimed at determining how much land in the southwestern states would be suitable for CSP installation. Excluding land that can't be used (either because it was already being utilized, was environmentally sensitive, non-contiguous, or had a ground slope greater than one-percent), the study found that the desert southwest could provide a substantial amount of land where solar radiation exceeds 6.75 kWh/m2 per day. Enough land, in fact, that if utilized by CSP, could provide six times the current electric capacity.[2]

The Advantage of CSP

This sounds great for daylight hours. But what happens when the sun sets? Can CSP provide the energy required to light the casinos in Vegas or the graveyard shift in the ER? In fact, one major advantage that CSP technology has over PV is the capacity for storage and the ability to continue operations into the night. How does it work? There is enough thermal mass in the hot fluid running through CSP pipes to continue operations for a half an hour during cloud cover. But CSP sites with thermal storage utilize the exchange of molten salt between hot and cold tanks to enable nocturnal generation. Basically, during the day, the molten salt runs from the cold tank to the hot tank, then runs backwards at night, heating the oil that in turn heats the water to generate steam. (See Fig. 2)

[2] Chuck Kutscher, "Talking Climate Change: Concentrating Solar to the Rescue," (*Solar Today*, April 2009), 10.

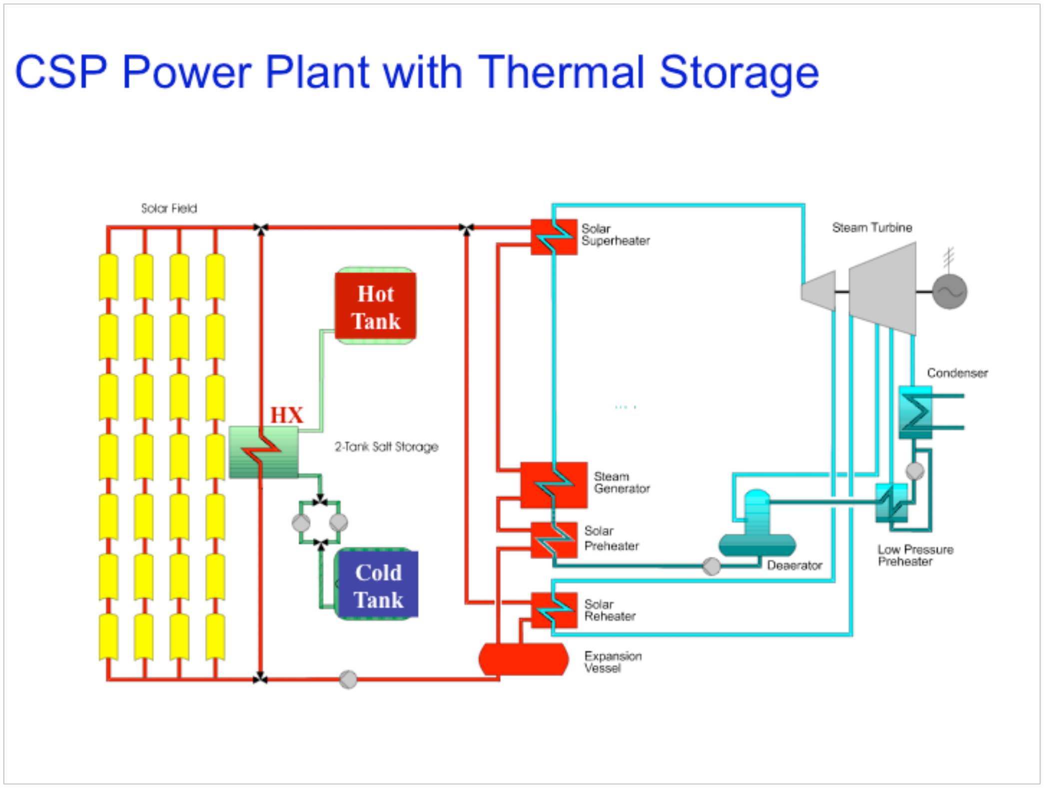

Figure 2

Currently storage capacity is around seven hours, but engineers are working on ways to increase that to twelve. This potential causes current utility companies to hold CSP in high regard as an alternative renewable that can be easily integrated into the existing grid.

Everything Old is New Again

It's been said that there is nothing new under the sun, and in fact, CSP technology is nothing new. An Israeli company, Luz, ran a CSP plant in the Mojave desert from 1984 to 1991. The plant showed the technology to be reliable. The only time during the plant's operation that output was diminished was during the after-effects of the eruption of Mt. Pinatubo, when sulfate particles in the upper atmosphere scattered much incoming sunlight. The company's downfall was not due to inefficiency on the part of CSP, but rather a lethal cocktail consisting of the loss of financial incentives, low natural gas prices, and utility deregulation.[3] But now, with the gap closing between the cost of natural gas and the cost of running a CSP plant, there is a growing resurgence of interest in CSP. In 2006 and 2007, there were two CSP installations in the United States (the first installations in fifteen years). Currently, a 250 MW CSP plant is on order by Arizona Public Service to provide an additional source of power for Phoenix. In Europe, CSP plants have been successfully installed and utilized in Spain and Germany. There is talk of a large-scale installation in the deserts of North Africa that would connect to Europe via high-voltage transmission lines. Similarly, the desert southwest in the United States could provide energy to the east coast, with the added advantage that transmitting solar power from west to east means that it is automatically available during the eastern seaboard's late afternoon, diminishing the need for large storage capacity.

The Dark Side of the Sun

Let's add to the notion that there is nothing new under the sun the old adage that there is, indeed, much evil to be found basking in its rays. Kutscher opened the talk by paraphrasing Mark Twain's comment to the effect that everyone talks about the weather, but no one does anything about it. He then pointed out that we have more control over climate change than we do the weather. Clearly, we have reached the point where urgent action is needed to curb emissions from fossil fuels. But could there be undesirable, even

[3] Kutscher, 10.

dangerous, consequences in relying on large scale CSP to save us from our dependence on fossil fuels? What are the possible drawbacks of CSP?

One possible, and incredibly ironic, scenario, involves the interference with the desert surface's albedo. Dr. Nir Krakauer, Assistant Professor of Civil Engineering at the National Oceanic and Atmospheric Administration Cooperative Remote Sensing Science and Technology Center, The City College of New York, points out that the uninterrupted desert provides a reflective surface for solar radiation, reinforcing subsidence of the overlying air and keeping it dry and cloudless. If enough desert surface area were significantly darkened (CSP installation involves coverage of one third of surface area), creating a dark area of absorption in place of the reflective surface normally present, this could result in convection that draws storm clouds. In effect, if a CSP site were large enough, it has the potential to become a cloud magnet. Since CSP only works with direct sunlight, large-scale installation would turn out to be self-undermining. Kutscher acknowledges that not enough is known about this possible outcome, and more research is needed.

Why not move in the direction of small-scale installation, similar to PV? Not only is such an option cost-prohibitive due to the economy of scale inherent to steam turbines, but the amount of surveillance and level of skill needed to maintain CSP equipment is higher than that of the average home-owner. Once set on the proper access and tracking at the proper angle and speed, the mirrors cannot be disturbed by errant soccer balls or curious pets. Not many folks would be willing to set up molten salt tanks in their front yards for the sake of nocturnal power. And besides, if you happen to live on a lovely tree-lined street, you'd be faced with the wrath of all tree and shade-loving beings–not to mention a self-undermining increase in air-conditioning costs–if you cleared overhanging vegetation for the sake of getting access to direct sunlight for your CSP unit. At this point in time, small-scale residential CSP does not seem to be a viable option.

Returning, then, to large-scale installation problems, we can easily identify a cluster of emergent problems. One would be the high-voltage power lines needed to transmit significant amounts of energy over long distances. In addition to negative aesthetic and health effects in their immediate surroundings, power lines also demand the clearing of land and the creation of a corridor that can upset local ecosystems. The fenced plant installation sites themselves would create an obstruction for wildlife, and often in the preparation for installation, herbicide and sterilizers are applied to the ground beneath the troughs to clear any existing vegetation and prevent any future growth. This makes maintenance and operation of the machinery easier, but is disruptive to sensitive desert ecologies, where life can come in small and camouflaged forms. From cryptogams to tortoises, many beings who make their homes in the desert would find their lives severely interrupted, or ended, as a result of large-scale CSP installation. Kutscher maintains that these are important considerations that should not be easily dismissed.

Kutscher’s talk was given on July 20, 2009, which happened to be the fortieth anniversary of the first lunar landing. Buzz Aldrin, the astronaut famous for the “one small step for man” utterance as he walked on the moon, gave an interview for National Public Radio that aired on the same morning as Kutscher’s talk. Aldrin claimed that the most difficult task was not getting to the moon, but rather returning home to earth. He was referring to his long struggle with addiction in the post-climactic era that followed his retirement as an astronaut. How does one top a trip to the moon? In his autobiography, Aldrin describes the humbling exercise of weaning himself from his addiction to excess. He also describes the virtue and joy of learning to live within limits. Could it be the case that Aldrin's story is all of ours?

As a culture, we in the United States and other developed countries have become addicted to consumption. It makes sense that one of the first things we turn to in the face of catastrophic climate change is technology that has the potential to sustain our current rates of consumption (and possibly deliver more!). No one likes to be cut off, an addict least of all. But even if we persuade the bartender at last call to pour us one final drink, the bar eventually *does* close. We do, eventually, have to return home.

But are we anywhere close to coming to terms with that reality, in terms of how we live our daily lives and concentrate our efforts? As I write, there is talk of growing support for NASA's mission to Mars (Aldrin, in fact, is one of its champions), and China is working on improving its chances of a successful lunar mission in the near future. One of the driving motivations for that hoped-for mission would be to assess the potential for mining titanium and helium-3 on the moon–some estimates indicate that enough helium-3 could be mined to meet the needs of the world's energy demands. Hearing this news conjures up images from the famous early twentieth century film by George Méliès, *Le Voyage dans la Lune*, where a rocket ship splats emphatically into the eye of an indignant moon. Perhaps this imagery heavily anthropomorphizes that austere celestial body, but it also provides a meaningful, emotive sense of caution against hubris and the glib undertaking of high impact actions with unforeseeable, unintended consequences.

Rather than distracting ourselves with obsessive calculations as to how we can mine every last bit of usable resource from the earth and her celestial companions, perhaps we need to turn our gaze back onto ourselves and question what kinds of needs and values we are trying to sustain with our efforts. In many ways, the technological management approach to sustainability, which depends on more and more efficient uses and extractions of energy to supply an ever-increasing demand is more about sustaining technology and the virtual reality that depends on it than sustaining biological life and the humans who dwell in the midst of that community. It is as if we have all become driven by an implicit Platonism that esteems the virtual over the real, causing us to pursue eternally static ideals in the hopes of escaping our finite embodiment. Unfortunately, we do this at our peril, and at the expense of that which is the real ground of our existence: namely, the planet and the complex communities of organisms of which we are a part.

It would be a mistake not to pursue alternative renewable energy sources in the face of the urgency presented by catastrophic, irreversible climate change. We are already so far behind in effectively curbing carbon emissions that it is reasonable to object that we don't have the luxury of time that would allow us to sit around contemplating our navels (philosophers get this objection all the time! we are told that the point is not to talk about the world, but to change it). If we're going to change the world, we need to have a world to change, and alternative renewable resources may buy us a little more time to get our values in order. But concentrating all of our efforts on meeting the increasing demands of an addiction seems to keep us on an unending treadmill: for an addict, there is no such thing as sufficiency. So, in effect, no real change is achieved if we approach sustainability only from a technological management standpoint. I think it's safe to say that in terms of our energy use, as well as in terms of our compulsive consumption, it's time to come clean. The success of pursuing cleaner energy sources and a healthier consumption ethic depends on our willingness to work them in conjunction.