CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Concentrating Solar Power

—Transcript of a webinar offered by the Clean Energy Solutions Center on 1 May 2019—
For more information, see the clean energy policy trainings offered by the Solutions Center.

Webinar Presenter

Hugo Lucas Porta International Renewable Energy Agency (IRENA)

This Transcript Because this transcript was created using transcription software, the content it contains might not precisely represent the audio content of the webinar. If you have questions about the content of the transcript, please contact us or refer to the actual webinar recording.

Speaker

Hugo Lucas Porta: Hello, ladies and gentlemen. I'm very happy to welcome you to today's session on Concentrated Solar Power. We would like to thank the International Solar Alliance and the Clean Energy Solutions Center who facilitated this webinar series. The background for me, when I joined the Factor in 2010, and I've been Director for Policies and Finance of International Renewable Energy Agency (IRENA). Previously, as a Spanish civil servant, I have been involved in many national and European regulations for the promotion of renewable energy and energy efficiency.

This lecture on Concentrated Solar Power is part of Module 2 on policies. In this lecture, we will, as always, start with a brief description, a definition of what Concentrated Solar Power is, and afterwards, jump into the main body of the presentation. Don't forget that at the end of the presentation, you will be given the chance to test your knowledge with a little quiz. The learning objective, which this module on Concentrated Solar Power or solar thermal power aims to provide, can be divided into four parts.

First off, we will learn about the technical aspect of Concentrated Solar Power followed by an update on trends of CSP markets over the world. We will continue with our discussion on the costs of CSP, finalized with the struggles of the main research and development programs for CSP. Concentrated Solar Power, also called Solar Thermal Power Generation, plants produce electric power by using mirror to concentrate a large area of sunlight onto a small area, the boiler.

Electricity is generated when the concentrated light is converted to heat, which drives a heat engine, usually a steam turbine, connected to an electrical power generator. Concentrated Solar Power, or CSP, plants can integrate thermal energy storage system to generate electricity during cloudy periods or even several hours after the sunset. CSP system can be also combined with combined cycle power plants resulting in hybrid power plants to provide high-value dispatchable power. Concentrated Solar Power system can be sized for village power, 10 kilowatts, or grid-connected application, more than 100 megawatts.

Worldwide, historical evolution. At the beginning of the ‘70s, with the rapid increase in oil prices, is when the great impulse to solar concentration technologies take place. High intensity of research activity in Solar Concentration Systems was developed between the mid ’70s and the end of the ‘80s. During the 1980s and the 1990s, the first commercial initiatives were built in the USA, which were the SEGS plant in the Mojave Desert of California. The thermoelectric solar sector is currently in the commercial takeoff phase throughout the world, and especially in United States and Spain.

The research and development centers. The solar, the main ones in the world, are the Solar Platform of Almeria, Spain belongs to the Center for Energy, Environmental and Technological Research, the CIEMAT. It is the largest public research and testing center dedicated to solar concentration technologies. The Solar Platform Sanlucar la Mayor, SOLUCAR, belongs to the Abengoa group, and it is the largest private centre of solar energy, with technologies of all the solar areas, mainly thermoelectric. Sandia National Laboratory in the United States carried out the National Solar Thermal Test Facility in Albuquerque, New Mexico, with a tower plant of five megawatts per component tests. Other centers with tower plants such as Weizmann Institute in Israel and Rehovot, Colonia in Germany, and soon in the French Pyrenees, former THEMIS plant.

There are four types of commercial CSP systems: tower, parabolic through, dish, and Fresnel. Parabolic through and linear Fresnel are [inaudible] capable of concentrating the sun’s energy to produce temperatures of 400 Celsius degrees, while power towers and [inaudible] system that can produce temperatures of 800 Celsius or higher. Parabolic dish is the only known commercial technology. It is assigned for small-size generation [inaudible] size. On the other hand, it needs complex operation and maintenance. With more than [inaudible] technology as parabolic through.

There are 700 megawatts of [inaudible] CSP [inaudible] Fresnel. Parabolic disc is the leader. Capacity factor for parabolic through and [inaudible] tower are from 20 to 30 solar storage, and from 50 to 70 percent with storage. [inaudible] thermal energy storage [inaudible]. Parabolic through [inaudible] tower [inaudible] can be hybridized. This common de-hybridization with natural gas [inaudible]. Parabolic through, CSP system, the sun’s energy is converted by parabolic [inaudible] curve through [inaudible] reflectors onto our receiver pipe running along about a meter above the [inaudible] face of the mirrors. The temperature of the heat transfer fluid flowing through the pipe [inaudible] thermal oil is increased from 293 Celsius to 393 Celsius, and the heat energy is then used to generate electricity in a conversion steam generator.

A collector field compresses multiple parabolic through [inaudible] mirrors in parallel rows lined to enable single access through same mirrors to track the sun from east to west during the day to ensure that the sun is continually focused on the receiver pipes. As of 2018, 80 percent of the CSP commercial operation is parabolic through. At the [inaudible] solar collector field contains hundreds of parabolic roads of through connected as series of loops which are placed on a north-south axis, so the [inaudible] can track the sun from east to west.

Similar to the [inaudible] of parabolic through to CSP system are Fresnel concentrated collector field consist of a large number of collector in parallel rows. These are typically aligned in a north-south orientation to maximize [inaudible] of solar energy collection. The mirrors are laid flat on the ground and reflect the sunlight to the pipe above. Fresnel can incorporate the storage in a power block or generate the steam for [inaudible] use. Tower, or centralized system utilize sun-tracking mirrors called a heliostat to focus sunlight onto our receiver at the top of the tower.

A heat transfer fluid, usually [inaudible] or water heated the receiver used to generate the steam, which is used in a conventional turbine generator to produce electricity. This engine, a parabolic dish engine consists of a concentrate turning the fan of this. That reflects solar radiation onto our receiver mounted at the focal point. These concentrators are mounted on a structure with a two axis tracking system to follow the sun. The collected heat is typically utilized [inaudible] by a heat engine mounted on the receiver moving with the [inaudible] structure to follow the sun [inaudible] use for proper convection.

A CSP plant can be hybridized with other renewable energy technologies following two approaches. Electric hybridization. Generation is producing parallel while other renewable energy technologies are ongoing, keeping the same [inaudible] infrastructure. On the other hand, CSP can be used to pre-heat the steam that will go to a biomass boiler or to the steam turbine. Most commonly, CSP is hybridized with fossil fuels. Higher shares of renewable generation are achieved when the CSP is generated in parallel with a natural gas turbine, [inaudible] to full evaporation. CSP represent lower shares when it is used to pre-heat the steam previous to the fossil fuel boiler or filling heater with [inaudible] steam generator.

On production cost alone, PV is, today, significantly cheaper than CSP. It is also more modular and easier to design, construct, maintain, and operate. When dispatchability is required, CSP together with thermal energy storage is cheaper to install and to run than [inaudible] with batteries, which gives CSP a competitive advantage. Nevertheless, this is changing fast. Hybridizing CSP with fuels can ease the path, reducing emissions while providing track record to CSP, and time to amortize plants in operation.

Regarding the status and trends of CSP markets, 100 megawatt of capacity came online in 2017, bringing lower capacity around 4.9 gigawatts. Several projects were due to enter operation during the year [inaudible] 2018 or later. Although lower capacity increased by just over two percent, the CSP industry was active. By [inaudible] of about two gigawatts of projects [inaudible] around the world, particularly in China, in the Middle East, and also north Africa [inaudible] were later on, in 2018, commissioned. The only country commissioned in a CSP planning in 2017 was South Africa. They would include [inaudible] CSP capacity at the end of 2017. [inaudible] facilities, and a facility with capacity of five megawatts or less are excluded from this table.

These are the countries that had a small, five megawatts or less, power or [inaudible] plants in operation by years, and include Australia, Canada, France, Germany, Italy, Oman, Thailand, and Tokyo. An estimated 13 gigawatt hour of thermal energy storage based almost entirely on model [inaudible] in conjunction with CSP plants across five continents by the end of 2017. The vast majority of CSP plants that's still under construction will incorporate some form of thermal energy storage, which continues to be viewed with [inaudible] to the competitive business of concentrated solar power.

Although South Africa was the only market [inaudible] capacity [inaudible] 2017, several [inaudible] were approaching [inaudible] operation [inaudible] with high [inaudible] solar radiation. In 2018, it is estimated that 1.3 gigawatts of new CSP capacity entered into operation. Apart from operating in France, the rest of the capacity is in developing countries. Morocco was the main market, followed by China and Israel. Other countries commissioning CSP plants were South Africa, India, Kuwait, and South Africa. Total installed capacity in 2018 reached six gigawatts worldwide.

Parabolic through have dominated the concentrated solar power industry for the last two decades, winning the confidence of utilities and infrastructure. Technology landscape may be about to change. With solar power tower technology from [inaudible] unique advantage. Central receiver system are considered to have a large potential for midterm cost reduction of electricity compared to parabolic through technology, because they can achieve higher temperatures, resulting in more efficient steam cycles, or ultimately, higher SEG cycles using gas turbine at temperatures above [inaudible] Celsius. To further increase efficiency, the latest driver of cost reduction is by encasing a plant sufficiency. A slight increase in efficiency can lead to significant cost decrease.

The storage is another key advantage of the tower model. Ability to generate higher [inaudible] improves efficiency of the storage system. A further advantage of stored technology is its feasibility when it comes to [inaudible] whereas even or level [inaudible] area is needed for parabolic through. Heliostat does not need to be seated on even surface. Tower technology can even be applied in a moderate [inaudible]. On the other hand, a key advantage of parabolic through is that it's [inaudible]. Yes, by having more loops in parallel, the capacity of the plant can be expanded. It is clear that the two technologies will co-exist in the near future.

We mentioned global concentrated thermal power capacity reached 4.9 gigawatts in 2017, and six gigawatts in 2018. In 2017, South Africa was the only country that commissioned a new CPS plant of 100 megahertz.

However, an estimated 13 gigawatts [inaudible] of thermal energy storage was operational, and most new plants [inaudible] thermal energy storage. Spain remained in 2017 the global leader in assisted CSP capacity followed by the United States, with Spanish CSP plants achieving record electricity generation in 2017. That year also saw record low CSP [inaudible] being built [inaudible] in competitive [inaudible] in Australia, Chile, and United Arab Emeritus, where a 700 megawatt CSP [inaudible] was awarded.

CSP with thermal energy storage emerged as a viable competitor to fossil fuel power plants. Price reduction was driven by competition, as well as by technology cost reduction aided by ongoing research and development activity in the sector. CSP is expected to grow 87 percent, 4.3 gigawatts over the forecast period of 2019 and 2020, 32 percent more than in 2012 to 2017 period. [inaudible] at 1.9 gigawatts, followed by [inaudible] economic development-backed support in Morocco and South Africa.

One gigawatt in the Middle East and 300 megawatt each in Australia and Chile. Since Spain and the United States, the two countries with the most installed capacity are not expected to commission plants over the forecast period, China is expected to overtake United States and have the second largest CSP installed base by 2020. Recent action results indicate significant cost reduction potential but technology [inaudible] access to financing, long project lead times, and market designs that do not value storage continue to challenge CSP [inaudible]. In an accelerated case, CSP growth could be 60 percent higher, 2.6 gigawatts, [inaudible] faster progress [inaudible] in China, South Africa, Morocco, and United Arab Emirates.

If we continue with the forecast [inaudible] for CSP markets, we can see how half of the [inaudible] expectation for CSP deployment were much higher than the current situation. Most long-term forecasts and country plans have not been fulfilled. [inaudible] cost prediction. The scenarios from the international [inaudible] agency, [inaudible], found 40 gigawatts installed capacity by 2030 optimistic scenario to nine gigawatts [inaudible]. With a business as usual scenario predicting 26 gigawatts [inaudible]. Finally, when it comes to a scenario, International Renewable Energy Agency, IRENA, has modeled the needed scenario to reach the UN goal of doubling renewable energy by 2030. If we want to reach the UN goal, IRENA estimate that 400 gigawatt of CSP will be needed to be deployed by then.

Total installed costs for CSP plants that includes thermal energy storage tend to be higher than those without. But the storage also allows for higher capacity factor. For example, for parabolic through system, the total installed plant cost can range between $255 US and $1,265 US per kilowatt for system with no storage. If we add to the system four to eight hours of storage, however, we can see that this range increase to between $6,000 and $1,300 kilowatt, US dollar per kilowatt for project, for which cost data is available in the International Renewable Energy Agency, IRENA, renewable cost database.

Capacity factors have increased over time as a shift towards new technologies with larger thermal storage capacity has coincident with a trend towards the growth of markets in higher irradiation locations. The dominance of the Spanish CSP projects, often with no storage capacity, has given way to projects with significant levels of storage, often in location with higher radiation than in Spain. Notably as projects in Morocco, Chile, South Africa, and United Arab Emirates have come online. [inaudible] in the use of thermal storage or not, capacity factor of assisting plants varied from 20 percent to more than 60 percent.

The NCOE of CSP plants stayed relatively stable between 2009 and 2012. A downward trend in NCOE started in 2012. Indeed, during 2013 and 2014, the NCOE estimates were, on average, about one-fifth lower than those of the 2009/2012 [inaudible]. This decreased coincides with geographic shifts away from Spain to newer markets with higher solar resources, and sometimes lower installed costs. Higher level of [inaudible] irradiance were, however, likely the main factor behind lower realized costs during that period. [inaudible] effects on technology improvements have not yet, therefore, been the main driver of cost reduction, leaving significant cost reduction potentials to be unlocked as already highlighted.

During 2016, the capacity [inaudible] NCOE of CSP plant was estimated to be 0.27 USD per kilowatt hour, a fifth lower than in 2009. Although IRENA data suggests that NCOE was 80 – has an 80 percent reduction in 2017 down to $0.22 of solar per kilowatt hour. Recent announcement of analysis of plant project since the [inaudible] are clear downward trend that was mentioned was started already in 2017. Indeed, recently, very low beats for CSP project has been around. Examples include the 0.073 USD per kilowatt [inaudible] beat announced by the Dubai Electricity and Water Authority, DEWA, for a 700 megawatt plant, [inaudible] received [inaudible] solar [inaudible]. And therefore, [inaudible] CSP project in Australia worth $0.06 of USD per kilowatt hour.

These results should be treated with caution, as [inaudible] with [inaudible] NCOE is complicated, given [inaudible] NCOE often do not represent lag for like corporations due to the auction prices being dependent on a set of obligation and terms in the contract that can be very market and project specific. The [inaudible] important point to take into consideration is that these prices applied to project that will be commissioned in the period 2020 to 2022 and beyond. However, this announce will point towards the increased competitiveness of renewable energy projects compared to fossil fuel [inaudible].

Parabolic through with 7.5 hours of storage could see the total installed cost fall from $5,550 USD per kilowatt today to $3,700 USD per kilowatt in 2025. The total installed cost of solar powered technology with nine hours of storage could decline from around $1,700 USD per kilowatt today to $3,600 by 2025. Most of this installed cost reduction will be driven by technological improvements in the solar field elements by leveling effects from larger deployment volumes along with industry experience. This factors are expected to reduce the indirect EPC and owners' costs of [inaudible].

Significant and direct EPC cost declines are expected for both technologies, although these cost components for solar [inaudible] are at $12,700 USD per kilowatt, around 20 percent higher in 2015 than for parabolic through plants. Indirect EPC and owner cost together are expected to decrease by about 16 percent for parabolic through system, and by about 68 percent for solar power. The expenditure for the solar field component of CSP plant has the potential to decrease by 23 percent and by 28 percent for parabolic through on solar tower technology respectively.

By 2025, the per kilowatt hour of thermal energy installed cost for the storage system of CSP plants could decrease by about 38 percent for parabolic through, and by about 17 percent for solar polar plants. For parabolic through, the mile drivers are an increase in the temperature level enabled by the switch over to [inaudible] as the heat fluid transfer, which accounts for about 13 percent of the total NCOE reduction. The second important cost driver is the reduction of solar field cost. For solar tower, the largest single driver for NCOE reduction is related to gains in the [inaudible]. [inaudible] EPC costs alone is expected to contribute about one-fifth of the overall NCOE reduction [inaudible].

Last but not least, CSP is still very sensitive to the cost of finance. In 2025, the NCOE of parabolic through can increase from $.09 to $.13 USD per kilowatt hour depending on how in a capital cost of five percent or 10 percent. Similarly, for solar tower, NCOE can increase from $.07 to $.11 of USD per kilowatt hour depending on the cost of finance, with the capital cost five percent or 10 percent. Regarding research and development programs for CSP. The main objective of research and development on CSP is to reduce the NCOE. This can be achieved by improvement in the components of the CSP plant, or in the system.

Research today focuses on finding new heat transfer fluids, such as [inaudible] or suspension of articles, adding [inaudible] to the structure, adding nano [inaudible] into the reflector for less intensive maintenance in terms of [inaudible] and watt. Another innovation [inaudible] working at higher temperature, allowing for new cycles. Regarding thermal energy storage, there are recent research and development activities that are ongoing in order to achieve the [inaudible] of [inaudible] such as low facility temperature and other high maximal operational temperatures. High heat capacity – thermal [inaudible], low thermal instability, low corrosion to the containment material, low cost.

Finally, research is also going on new [inaudible] for thermal energy storage innovation. There is an increasing discussion about the cost and the value of electricity. Electricity has to be not only cheap but also available when needed. CSP plants are researching a lot on improving their dispatchability. CSP is very intensive in the use of land. The scale of [inaudible] is limited by the distance of the reflector to the tower. Research [inaudible] of the plant, and omitted factor in the operating and maintenance of the plant is the need of water, usually in very arid environments, to clean the reflectors. New equipment and approaches are being developed to reduce the use of water.

Last but not least, once again, to increase dispatchability, there is increasing research on optimization of CSP with thermal storage or other generation [inaudible]. Unfortunately, other aspects affecting the NCOE of the CSP lacks attention in the research and development activity. Some key aspect are not included in typical research and development activities, such as [inaudible] in development in EPC, risk reduction of [inaudible] costs in new business models. Investment in research and development activities for CSP has considerably increased in the last decade. In the last year, investment has been around $250 million USD [inaudible]. Historically, the origin of these funds are coming equally from private and public sources. Main region investing public funds in research and development for CSP are the European Union and the United States of America.

As concluding remarks, half a decade ago, expectations for CSP deployment were higher than the current situation: most long-term forecast and country plans have not been fulfilled. There is not only one reason for this. The quick cost reduction of PV made it a more attractive alternative, so some efforts were moved from CSP to PV. Several other initiatives were halted, hoping that a PV-like cost reduction would bring CSP's LCOE closer to grid parity. When the cost reduction was not as quick as expected, the sector risked entering a vicious circle as a slower deployment further slowed cost reduction.

The future development of CSP is linked to its ability to provide value to the electric system in comparison with other alternatives. CSP's strengths, beyond possible cost breakthrough, are cheap storage, demand management capabilities, ancillary services. There is potential for cost reduction in both hard and soft costs, but some chapters, civil works, power block, EPC costs, and owners' costs, have barely improvement despite its significant impact. Soft costs are not a typical target in research and development programs.

Hybridization can be a key to the future of CSP. Hybridizing CSP with fuels can ease the path, reducing emissions while providing track record to CSP, and tie to amortize plants in operation. CSP integration costs are as low as conventional, especially if hybridized. Risk is concentrated on investment in CSP, and on operation in conventional. Hybrids can have a balance between both, diluting them. And with this, we conclude the lecture for an overview of concentrated solar power. And now you will have an opportunity to test your knowledge with a small quiz. Thank you very much.