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A Review of Parabolic Dish-Stirling Engine System Based on Concentrating Solar Power

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Abstract

A solar thermal technology which is also known as concentrating solar power (CSP) uses thermal energy from the sun to generate electricity. The electricity generation from solar thermal can be produced with four technologies of concentrating solar systems which are parabolic trough, linear Fresnel reflector, solar tower, and parabolic dish-Stirling engine system. This paper reviews the parabolic dish-stirling based on CSP technology by taking into account the performance, the global performance, site for parabolic dish and levelized cost of energy (LCOE). Generally, the parabolic dish applications have barriers in terms of the technology and the high capital cost compared to the others CSP technologies.

***Keywords**: concentrating solar power (CSP), parabolic dish-stirling system, performance, levelized cost of energy (LCOE)*

1. Introduction

Solar energy can be used with renewable solar technologies to replace conventional energy systems that consume fossil fuels, thus help reduce harmful emissions into the atmosphere and help reduce greenhouse effect and global warming. Concentrating solar power (CSP) uses thermal energy from the sun to generate electricity [1].

Parabolic dish–stirling system is the one of the CSP technology that have been studied and developed for terrestrial applications that allows to reach high temperatures concentrating the radiation in a focus [2]. Parabolic dish–stirling system tracks the sun and focus solar energy into cavity receiver, then the receiver absorbs the energy and transfers it to a heat engine/generator that generates electrical power. The behavior of the thermal machines is based on thermodynamic cycles that take advantages from the cycle maximum temperature achieved by the working fluid (WF) [3].

The Stirling engine consists of a sealed system filled with working gas (typically hydrogen or helium) that is alternatively heated and cooled. It is known as a working gas because it is continually recycled inside the engine and is not consumed. The engine works by compressing the working gas when it is cool, and expanding it when it is hot [4]. More power is produced by expanding the hot gas than is required to compress the cool gas. This action produces a rising and falling pressure on the engine's piston, the motion of which is converted into mechanical power. The direct conversion of solar power into mechanical power reduces both the cost and complexity of the prime mover [5].

In theory, the principal advantages of Stirling engines are their use of an external heat source and their high efficiency. Stirling engine would obtain the economy of scale and could be built as a cheap power source for developing countries. Hence, the Dish/Stirling has been investigated in-depth and achieved good thermodynamic performance in comparison with other CSP Systems [6].

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2. Performance of the Parabolic Dish-Stirling System

1984-1988 Technology

The 1984-1988 technology is represented by the Advanco's Vanguard System and developed by Advanco Corporation. While, 25kW dish/Stirling system is developed by McDonnell Douglas Aerospace Corporation (MDA), 50kW System and 9kW System are developed by Schlaich Bergermann und Partner (SBP). Advanco Corporation developed 25kW Vanguard dish/Stirling system at the Jet Propulsion Laboratory OPL in 1984. The system achieved a reported World's Record net solar to electric conversion efficiency of 29.4% and installed at Rancho Mirage, California [7]. The rated net electrical output of the production system is 25kW. The Vanguard concentrator is approximately 11 meters in diameter and integrating with the United Stirling AB (USAB) Model 4-95 Mark II engine. Engine used in this system is a four-cylinder Stirling engine [8]. The working gas is hydrogen at a maximum mean working pressure of 20 MPa and temperature of 720°C [9].

Schlaich, Bergermann und Partner (SBP) of Stuttgart, developed and constructed three 50kW SBP systems in Germany in 1984. The first system is operated in Europe and the other two systems are located in the Solar Village of the Saudi Arabian National Center for Science and Technology near Riyadh. The rated net electrical output of the production system is 52.5kW [10]. The Schlaich concentrator is a single-facet stretched membrane dish approximately 17 meters in diameter and is integrated with United Stirling 4-275 engines. A four-cylinder, double-acting Stirling engine is used in this system [11]. The working gas is hydrogen at a maximum mean working pressure of 15MPa and 620°C. The Schlaich dish/Stirling receiver is a directly illuminated tube receiver that has many small-diameter heater tubes located in the back of the receiver cavity to absorb the concentrated sunlight. The entire Schlaich-Bergermann und Partner 50kW dish/Stirling system has a maximum net solar to electric efficiency of 23.10% [12].

McDonnell Douglas Corp., Aerospace Division, of Huntington Beach, California (MDAC), developed a 25kW dish/Stirling system in 1984. McDonnell Douglas afterwards sold the manufacturing and marketing rights for the system to Southern California Edison Co. (SCE) of Rosemead, California, in 1986 [13]. Southern California Edison continued to evaluate and improve the dish/ Stirling system at their Solar One facility near Barstow, California, through September 1988. The rated net electrical output of the production system is 25kW [14]. The concentrator is a spherically curved glass mirror facets dish approximately 10.57 meters in diameter and is integrated with United Stirling 4-95 Mark II engine as used in the Vanguard system. The working gas is hydrogen at a maximum mean working pressure of 20MPa and 720°C. The entire McDonnell Douglas dish/Stirling system has a maximum net solar to electric efficiency of 29% to 30% [15].

1991-1998 Technology

Schlaich, Bergermann und Partner (SBP) of Stuttgart developed a 9kW dish/Stirling system in Germany in 1991. Three units are in operation at the Plataforma Solar in Almeria, Spain, aiming to test the system's long-term reliability under everyday operating conditions [17]. Two more units are installed in Stuttgart, Germany: a prototype on the campus of the University of Stuttgart and another unit at the Center for Solar Energy and Hydrogen Research (ZSW) test facility. The rated net electrical output of the production system is 9kW. The concentrator is a single facet stretched membrane dish approximately 7.5 meter in diameter and is integrated with V-160 engine. The working gas is hydrogen at a maximum mean working pressure of 15MPa and 630°C. The engine has an efficiency of 30%. The entire Schlaich-Bergermann und Partner 9kW dish/Stirling system has a maximum net solar to electric efficiency of 23.30% [18].

Cummins Power Generation, Inc. (CPG), of Columbus, Indiana, a subsidiary of Cummins Engine Company, is the first company in the world to put together and operate on-sun a dish/Stirling system that uses a free-piston Stirling engine for solar electric power generation in 1992 [19]. The rated net electrical output of the production system is 7.5kW. The concentrator is a stretched- membrane facets approximately 7.3 meter and integrating with free-piston Stirling engine. The working gas is helium at a maximum mean working pressure of 4MPa and 629°C. This is also the first application of a liquid-metal heat-pipe receiver. The entire Cummins Power Generation dish/Stirling system has a maximum net solar to electric efficiency of 19% [20].

Aisin Seiki Co., Ltd. built the NS30A 30-kW engine under the Japanese government's New Energy and Industrial Development Organization (NEIDO) project at Kariya City, Japan in

1992. The rated net electrical output of the production system will be 8.5kW. The concentrators are Cummins Power Generation CPG-460 stretched membrane dishes and are integrated with Aisin Seiki's NS30A engine. The engine is a four-cylinder fixed swash plate kinematic engine. The working gas is helium at a maximum mean working pressure of 14.5MPa and 683°C. The engine has a directly illuminated tube-type receiver. This is developed by Meidensha Corporation of Japan. The corporation also developed zinc-bromine batteries incorporating two pumped-circulation and tank-storage loops used to incorporate 30kWh electrochemical batteries to each dish, engine, and alternator system. These provide power after sunset and during cloud transients. The entire Aisin Seiki Miyako Island dish/Stirling system has a maximum net solar to electric efficiency of 16% [21].

Stirling Thermal Motors, Inc, and Detroit Diesel Corporation of Detroit designed and tested a solar power conversion system incorporating the STM4-120 Stirling engine in Michigan in 1993. This, prototype package was first sun tested in 1993 which was mounted on Sandia National Laboratories' Test Bed Concentrator [22]. The Stirling Thermal Motors solar power conversion system package includes the STM4-120 engine incorporating variable displacement power control. The power conversion system also includes a directly irradiated tube-bank receiver, an alternator, and the engine cooling system [23]. The working gas is helium at a maximum mean working pressure of 14.5MPa and 683°C. The entire maximum net solar to electric efficiency Science Applications International Corporation 25kW dish/Stirling system has to depend on the concentrator used [24].

SES technology is a dish Stirling unit called SunCatcher. SunCatcher has been constructed by SES in Pheonix, USA together with the sister company, Tessera Solar North America in 1996. The rated net electrical output of the production system is 25kW. The concentrator is an array of curved glass mirror facets approximately 11.28 meter in diameter and is integrated with United Stirling Kinematic engine. Engine used in this system is a double-acting Stirling engine. The working gas is hydrogen or helium at a maximum mean working pressure of 20MPa and 720°C. The entire Stirling Energy Systems (SES) dish/Stirling system has a maximum net solar to electric efficiency of 30% [25].

Schlaich bergermann und partner and European partners developed the EuroDish in 1998. The rated net electrical output of the production system will be 10kW [26]. The concentrator is made up of a sandwich shell from fibre glass reinforced plastic 8.5 meter in diameter and is integrated with a single-acting SOLO Stirling 161. The working gas is helium at a maximum mean working pressure of 20-50bar and 650°C. The entire EuroDish Stirling system has a maximum net solar to electric efficiency of 22-24.5% [27].

2007-2013 Technology

Infinia Corporation is a privately owned technology company that developed free-piston Stirling engines in 1967 at Ogden, Utah, USA. Infinia was designed together with Schlaich Bergermann und Partner in 2006. The rated net electrical output of the production system will be 3.2kW [28]. The PowerDish concentrator is made up of a mirror panel approximately 4.7 meter in diameter and is integrated with a self-developed, low-cost, long-life and maintenance-free 3.2kW free-pistons Stirling engine. The first prototype was erected in 2007. The working gas is helium and the entire PowerDish Stirling system has a maximum net solar to electric efficiency of 24% [29].

The ANU SG4 (Solar Generator 4) was developed and built by ANU in collaboration with Canberra-based Company Wizard Power, and supported by an AusIndustry Renewable Energy Development Initiative (REDI) grant. Construction of the SG4 dish was completed in June 2009. The rated net electrical output of the production system is 50kW. The concentrator is made up of mirror panel approximately 25 meter in diameter and is integrated with a steam engine. The working gas is air at a maximum mean working pressure of 5Mbar and 550°C [30]. Simultaneously, Wizard Power has commenced a construction of a pilot system of 4 such dishes in Whyalla in South Australia. It is expected that upon the completion of this system full commercial power station can be realized in the near future [31].

HelioFocus Ltd of Ness Ziona and Schlaich Bergermann und Partner completed a low cost, large scale dish development in Israel in 2007. The first prototype was erected in mid-2011 as part of a solar boosting experiment with the Israel utility company. The concentrator is a Fresnel arrangement of the mirror facets and is integrated with steam engine. The system was developed under a contract with HelioFocus of Tel Aviv and with 500 m² mirror surface, one of the both largest such concentrators globally. The principle of a Fresnel arrangement of the mirror facets was applied on a solar concentrator of this type for the first time. 219 curved mirrors focus the sunlight, concentrating up to 400kW thermal powers on the receiver. This produces hot air up to 1000 °C to reach high efficiency (up to 24%) and competitive costs [29].

SouthWest Solar Technologies of Phoenix, Arizona, USA, also developed a large dish concentrator and the prototype was commissioned in 2011. The rated net electrical output of the production system will be 5kW. The concentrator is made up of mirror panel in flat metal structure approximately 20 meter in diameter and is integrated with micro turbine from Brayton Energy LLC.

The Australian-based company Solar Systems Pty. Ltd, now owned by Silex Systems Ltd, has been working in CPV with dish concentrators since the late 1990s. Their CS500 dish generates 35kW and is pylon mounted. The rated net electrical output of the production system will be 53kW. Several projects with a total of 40 units have been realized. Today, the system is called 'Dense Array Converter', with a similar dish design measuring 140m^2 and a PV generator with 40% efficiency. According to Silex, a 60 unit/2 MW plant shall be commissioned in early 2013 in Mildura, and another 102 MW (40 kW per dish) will follow [29].

Figure 1 and 2 shows the comparison of the most-developed system efficiency and net electricity produced by different technology of stirling dish system from 1980 to 2013. Besides, the system efficiency in 1984-1988 technology includes three types of system which is developed by Advanco Corporation, McDonnell Douglas Aerospace Corporation (MDA), and Schlaich Bergermann und Partner (SBP). The Advanco's Vanguard System produced the highest percentage of system efficiency compared with McDonnell Douglas and 50kW Schlaich Bergermann und Partner (SBP) which is 29.4% and 25kW net electricity. However, Cummins Power Generation (CPG) produced the highest percentage of system efficiency for 1991-1988 technology with 19% but produced only 7kW which was the lowest net electricity produced when compared with 8.5kW Aisin Seiki system, and 9kW SBP in 1991-1988 technology. Furthermore, as the stirling dish system continue to improve, there are consist of several new system design. CS500 Dense Array produced the highest percentage of system efficiency and was able to produce 35kW net electricity which was the second highest of the net electricity produced when compared with other systems in 2007-2013. Besides, over the last fifteen years, several parabolic dish-stirling systems have been built. However, the reliability of the Dish/Stirling System has to be improved before considering its "real" commercial application. Table 1 show the design and performance specification for different Dish/Stirling Systems.

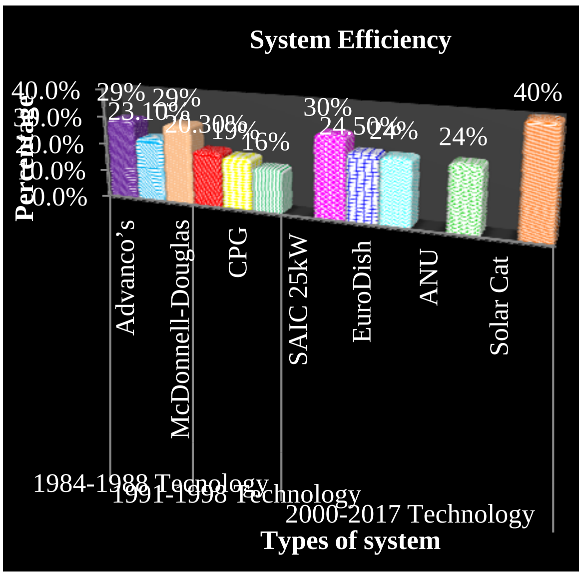

Figure 1. The comparison of system efficiency among different technologies.

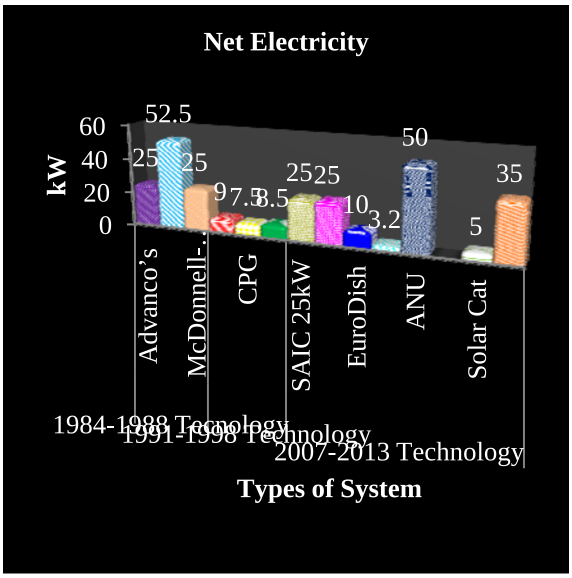

Figure 2. The comparison of net electricity produced by different technologies.

3. Global Parabolic Dish Development

The development of CSP Technologies especially the parabolic dish technology is still at the early stage [32]. At the end of 2010, total worldwide operation of the CSP capacity was amounting about 1,300 megawatts (MW) [33]. Meanwhile, in 2012 the global installed capacity of CSP plants increased to 2 gigawatts (GW). However, by 2015 there is an additional of 12 GW being planned for the installation. However, most of the CSP projects that are undergoing or currently under construction are based on the parabolic trough technology [34] in which, more than 90% are using parabolic trough technology (as Table 2).

Parabolic trough is the dominant and most mature technology in CSP, followed by Power Tower. Meanwhile the other two technologies which are Linear Fresnel and Parabolic dish are still in the early growth of phases. Globally, the installed capacity for solar power tower is 70MW whereas linear Fresnel have a capacity of 31MW in Spain and 4MW in Australia [34]. The electricity generation costs for parabolic dish is quite higher compared to the other CSP technologies such as parabolic trough or tower power plants despite its high efficiencies.

In 2010, the global installed capacity for parabolic dish was 1.5MW and located in Arizona. In 2013, the installed capacity of the Parabolic Dish increased to 3MW with additional plant located in Utah and a few number of prototype dish engine systems are currently operating in Nevada, Arizona, Colorado and Spain.

Table 1. Design and Performance Specification for Dish/Stirling Systems [8][10][12][15][19][21][23][25][27][28]

Name	Year	Net Electricity	System Efficiency	Location	Diameter	Type	Surface	Reflectance	Tracking	Engine Company	Engine Type	Engine(W)	Working Fluid	Pressure	Gas Temp
Advanco's Vanguard System	1984-1988	25kW	29.4% @ 760˚c gas temp.	California	10.57m	Faceted glass mirrors	Glass/Silver	93.50%	Exocentric	USAB	Kinematic		Hydrogen	20MPa	720˚C
Schlaich-Bergermann und Partner(SBP) 50 kW System	1984-1988	52.5kW	23.10%	Riyadh, Saudi Arabia	17m	Stretched membrane	Glass/Silver on Stainless steel	92%	Az-el	USAB	Kinematic		Hydrogen	15MPa	620˚C
McDonnell-Douglas	1984-1988	25kW	29%-30%	California, Georgia, Nevada	10.57m	Faceted glass mirrors	Glass/Silver	91%	Az-el	USAB	Kinematic	25kW	Hydrogen	20MPa	720˚C
Schlaich-Bergermann und Partner(SBP) 9-kW System	1991	9kW	20.30%	3 built in Spain, 2 built in Germany	7.5m	Stretched membrane	Glass/Silver on Stainless steel	94%	Polar	SPS/Solo	free piston	9kW	Helium	15MPa	630˚C
Cummins Power Generation 7.5 kWe Systems	1992	7.5kW	19%	Califonia, Texas, Pennsylvania	7.3m	Stretched membrane	Aluminized plastic film	85%-78%	Polar	Sunpower/ CPG	Kinematic	9kW	Helium	4MPa	629˚C
Aisin Seiki Miyako Island System	1992	8.5kW	16%	Miyako, Japan						Aisin Seiki	Kinematic	30kW	Helium	14.5MPa	683˚C
Science Applications International Corporation	1993	25kW	Depends on concentrator used	Sandia Natioanl Lab's TBC						STM	Kinematic	25kW	Helium	12Mpa	720˚C
Stirling Energy Systems (SES)	1996	25kW	30%	Pheonix, USA	11.28m	Commercial Grade Float	Silvered on Back side	>90%	Az-el	USAB	free piston	27kW	Hydrogen/Helium	20MPa	720˚C
EuroDish	1998	10kW	22-24.5%	Silver coated glass mirror	8.5m	Stretched membrane	Glass fibre resin	94%	Az-el	Solo	single acting	8.4kW	Helium	20-150bar	650˚C
Infinia Corporation	2007	3.2kW	24%	US, Europe, India ,Yuma	4.7m	silver coated glass mirrors	Glass fiber reinforced plastic	86%	Az-el	INFINIA	Free piston	3kW	Helium		
SG4 500-m² Solar Dish(ANU)	2009	50kW		Whyalla in South Australia	25m	Mirror panels	Glass-on-Metal Laminate mirrors	93.50%	Az-el	steam engine			Air	5MPa	550˚C
HelioFocus	2011		24%	Israel		solar mirrors (2 axes)	simple carbon steel	98%	Az-el	steam engine	steam turbines	130kW	Air		1000˚C
Solar Cat/ SouthWest Solar	2011	5kW		Phoenix, Arizona, USA	20m	Mirror panels	Flat metal structure			Micro turbine/ Brayton engine		80kW	oil and liquid free		
Solar Systems CS500 Dense Array CPV dish system	2013	35kW	40%	Mildura	15m	Mirror panels			Az-el						

Table 2. List of Countries with CSP Plant [34]–[36]

Country	Installed Capacity (MW)	Start Year	Technology	DNI value (kWh/m^2/year)
Algeria	25	2011	Parabolic Trough	2,700
Australia	3	2011	Power Tower	2,600
	9	2012	Linear Fresnel	
	44	2013*	Linear Fresnel	
Chile	360	2015*	Parabolic Trough	2,900
China	1.5	2012	Power Tower	2,000 - 2,100
	50	*	Power Tower	
Egypt	20	2011	Parabolic Trough	2,431
France	12	2014*	Linear Fresnel	1,800 - 1,930
	250	2012	Linear Fresnel	
	9	2015*	Linear Fresnel	
Germany	1.5	2008	Power Tower	902
India	50	2013*	Parabolic Trough	2,200
	2.5	2011	Power Tower	
	100	2013*	Linear Fresnel	
	100	2013*	Parabolic Trough	
	50	2013*	Parabolic Trough	
	25	2013*	Parabolic Trough	
	100	2013*	Parabolic Trough	
	50	2013*	Parabolic Trough	
Italy	5	2010	Parabolic Trough	1,936
Mexico	14	2013*	Parabolic Trough	2,050 - 2,30
Morocco	3	2013*	Parabolic Trough	2,400 - 2,600
	1	2014*	Linear Fresnel	
	20	2010	Parabolic Trough	
	160	2015*	Parabolic Trough	
South Africa	50	2015*	Parabolic Trough	2,700
	100	2014*	Parabolic Trough	
	50	2014*	Power Tower	
Spain	50	2008	Parabolic Trough	1,950 - 2,291
	50	2009	Parabolic Trough	
	50	2011	Parabolic Trough	
	49.9	2011	Parabolic Trough	
	50	2013*	Parabolic Trough	
Thailand	5	2012	Parabolic Trough	1,400
United Arab Emirates	100	2013	Parabolic Trough	1,934
United States	1	2010	Parabolic Dish	2,636 - 2,725
	1.16	2006	Parabolic Trough	
	280	2013*	Parabolic Trough	
	600	2016-2017*	Power Tower	
	250	2014*	Parabolic Trough	
	392	2013*	Power Tower	
	5	2008	Linear Fresnel	
	280	2014*	Parabolic Trough	
	250	2014*	Parabolic Trough	
	500	2016*	Power Tower	
	50	2013*	Parabolic Trough	
	150	2016*	Power Tower	
	5	2009	Power Tower	
	13.8	1984	Parabolic Trough	
	30	1985	Parabolic Trough	
	30	1985	Parabolic Trough	
	120	1989	Parabolic Trough	
	89	1989	Parabolic Trough	
	89	1990	Parabolic Trough	
	50	2013*	Parabolic Trough	
	2	2010	Parabolic Trough	
	75	2010	Parabolic Trough	
	2.0	2009	Parabolic Trough	
	200	2014*	Power Tower	
	200	2015*	Power Tower	
	110	2013*	Power Tower	
	75	2007	Parabolic Trough	
	1.5	2013	Parabolic Dish	

*Under development

4. Site selection for the Parabolic Dish technology

Parabolic dish has a few advantages such as it is modular, suitable for small scale plant and most sophisticated for small CSP plant. However, selecting a suitable site is one of the most crucial parts for developing a viable solar CSP plant such as the parabolic dish technology. In selecting a site or the location, the aim is to maximize production and minimize cost. Fundamental to the siting of CSP technologies, the parabolic dish facilities requires abundant direct solar radiation in order to generate electricity as only strong direct solar irradiation can be focused to generate highest temperatures required for electricity generation. Meanwhile, the indirect sunlight cannot be concentrated and locations with considerable cloud cover are unsuitable for parabolic dish plant [37]. The electricity generation of any of the plant is mostly influenced by the solar irradiance. Moreover, more than 5 kWh/m^2/day of Direct Normal Irradiance (DNI) is required in order to function and be economic.

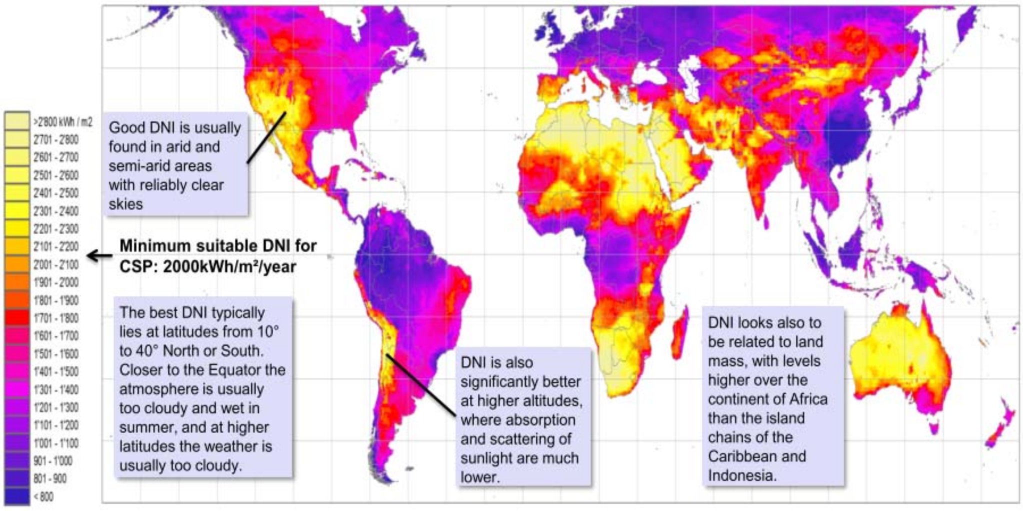

Figure 3. World Direct Normal Irradiance
Source: Meteonorm 7.0 (www.meteonorm.com)

Globally, a few site or locations with an excellent solar resource and most desirable for developing the parabolic dish based CSP plants exist; North Africa, Middle East, Southern Africa, Australia, Western of the United States America and parts of South America. Even so, this apparently depends on average meteorological conditions over a year. Meanwhile, the direct solar irradiance will be influenced by meteorological factors such as the cloud cover, humidity and local environmental factors such as debris and air contamination.

5. Cost and Levelized Cost of Electricity (LCOE)

Generally, good resources for developing CSP plant are widely distributed in several locations. However, the abundance of resources is not an attractive factor to develop CSP, unless the costs start to decline [33]. Nevertheless, since 2006 as a result of declining investment costs and LCOE, as well as new support policies from several countries such as Australia, United States and Spain, a new number of CSP plants have been brought on line [34], [38].

Parabolic dish and linear Fresnel are assumed to have higher risk in both technological and financial. Nevertheless, parabolic trough is the most mature technology; has lowest development risk and has the lower technological risk. This is followed by power tower, in which the technology is closest to the commercial maturity stage. Therefore, the investment, operating and management costs (O&M) for parabolic through and for power tower technologies are known in reducing the financial risks [39]. Furthermore, previous assessments indicate that the LCOE is dominated by the parabolic trough and power tower capital cost [40].

Currently, the levelized cost of electricity (LCOE) for the CSP plants is high. However, LCOE for the CSP technologies usually varies by its technology, country, renewable energy resource, operating costs and the efficiency or performance of the CSP technology [33]. Nowadays, by assuming that the capital cost is 10%, LCOE for parabolic trough plants is in the range USD 0.20 - USD 0.36/kWh and LCOE for solar towers is between USD 0.17- USD 0.29/kWh. Nevertheless, LCOE in areas with excellent solar resources could be as low as USD 0.14 to USD 0.18/kWh. The cost ranges given are inclusive for all of the CSP technologies such as parabolic trough, power tower, linear Fresnel and parabolic dish. The different CSP technologies will show different performance under different DNI level.

Primarily, LCOE depends on the capital costs and solar resource in which, there is a strong relationship among DNI, power output and LCOE [36]. Plants located in high DNI areas will yield more energy, allow greater electricity generation and have lower LCOE compared to the CSP plants that are located in lower DNI areas [34], [36], [41],[42].

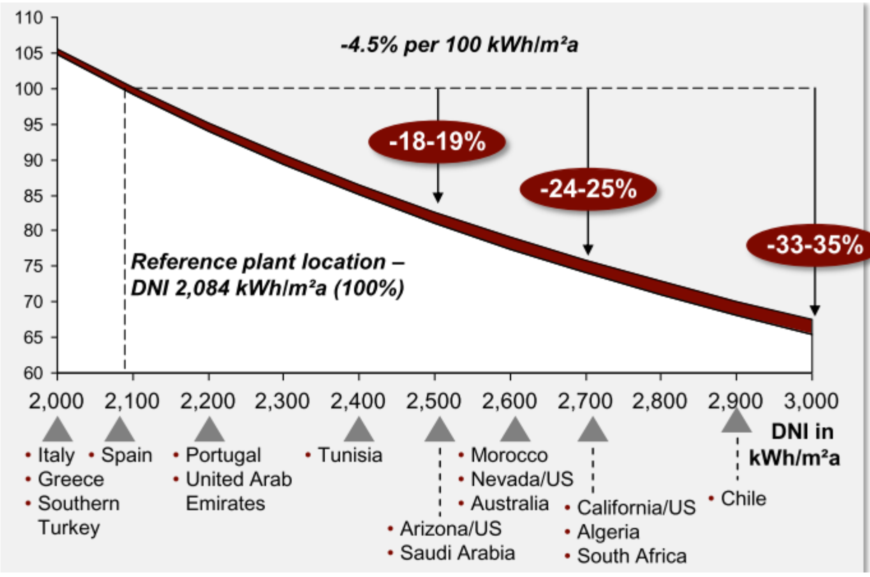

Figure 4. Tariff/LCOE development over DNI level [41]

The LCOE of identical CSP plants will be around one-quarter lower for locations with higher DNI such as United States, Algeria or South Africa with the DNI level of 2700 kWh/m^2/year or 8 kWh/m^2/day compared to the locations such as Spain with DNI level of 2100 kWh/m^2 /year or 5.8 kWh/m^2/day [34]. Nevertheless, the practical impact on the LCOE of a given CSP plant, with individuality design and capital costs, of higher DNI can be substantial [34].

Costs of electricity from CSP plant such as the parabolic dish system are relatively high and currently it is still higher than the conventional fossil fuel technologies. However, cost reduction opportunities will be better if the plant designs are perfect and the CSP plants operate in a larger size of CSP plant [34]. Meanwhile, cost reductions opportunities due to advances in R&D, competitive in supply chain, improvements in the solar field performance, solar-to-electric efficiency as well as the thermal energy storage systems are significant, and the LCOE is expected to reduce [33].

CSP plants which has a thermal energy storage such as parabolic trough, power tower and linear fresnel have similar or lower LCOE than CSP plants without storage such as parabolic dish [34],[40]. The thermal energy storage system in CSP plant help to increase the reliability, capacity factors and the dispatch ability requirements demand [39]. Furthermore, the total installation cost for CSP plants without storage is higher than for PV and it is expected that the costs will fall around 15% by 2015 owing to technology learning, economies of scale, and improvements in manufacturing and performance. Therefore, reducing of the levelized costs of electricity from CSP plants to around USD 0.15-0.24/kWh. By 2020, expectations of the capital cost reductions of 35% - 50% could be achieved and even the higher reductions of 40-55% by 2025 will be possible [34],[33],[43],[44].

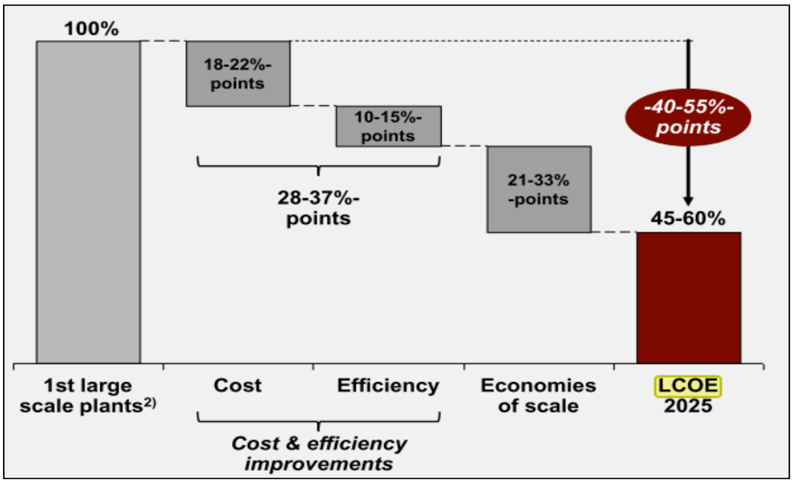

Figure 5. Projected tariff development for CSP Plant by measure or over time [41]

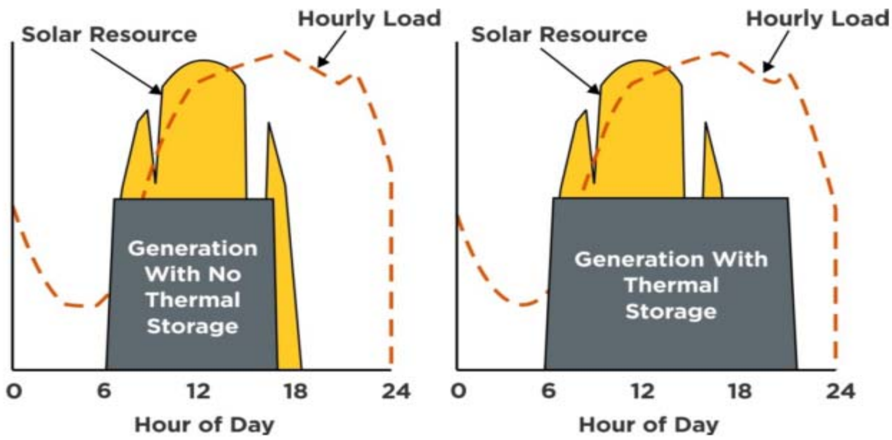

Figure 6. Thermal storage and utility demand [33]

Moreover, the growth of the CSP sector faltered as a result of prices decline for the PV module. This is indirectly driving several high profiles CSP projects convert to PV. Nevertheless, in the long term, the ability of CSPs to combine the energy storage and to supplement conventional power generation offers benefits beyond the kilowatt-hour generated [45].

As the energy storage can become a key for bridging the gap between energy supply and demand across the globe; nevertheless, main obstacle in reaching the "grid parity" exist. Grid parity or the point at which electricity generated from Renewable Energy (RE) sources costs the same as electricity produced by fossil-fuelled power plants. Grid parity occurs when the costs of generating RE is equivalent or lower than the cost of generating electricity from conventional fossil fuels.

Rapid cost reduction for the solar electricity to achieve grid parity is the global objective. However, compared to the CSP systems, the grid parity has been achieved in many places with PV panels. In Malaysia, it is expected that the solar grid parity for the residential consumers will be in year 2026, which is one year earlier than the projected solar grid parity determined by Sustainable Energy Development Authority (SEDA) by using feed-in tariff (FiT) rate [45]. Obviously, the FiT system in Malaysia is designed mainly for achieving the grid parity.

To get a clearer view of where the CSP stands in the race to grid parity, it is necessary to evaluate and compare the cost of both CSP and PV power generation. Several factors should be considered when assessing the cost competitiveness of PV and CSP such as LCOE. After grid parity is reached, the feed-in approval holders will be paid based on the prevailing displaced cost for the remaining effective period of their RE power purchase agreements[44].

6. Conclusion

This paper reviews the parabolic dish-stirling based on CSP technology by taking into account the performance, the global performance, site for parabolic dish and Levelized Cost of Energy (LCOE). Generally, the Parabolic Dish applications have barriers in terms of the technology and the high capital cost compared to the others CSP technologies. Thus, when considering scenarios of the Parabolic Dish technology development and deployment; especially in the context of helping in scaling down the global environment pollution, the initial higher costs should not be counted as barriers to the deployment. The focal point should be on whether learning curves can give assurance that the technology is able to achieve desirable cost reductions within an acceptable timeframe, and how much the pace of deployment is expected to alter the pace of price reduction. Therefore, an innovative development and research of Parabolic Dish CSP should be carried out with detail consideration both on the technical and economic aspects to assure that the Parabolic Dish technology development one day will be matured as the other CSP technologies.

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