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Oil-Independent Life Style: Solar Oasis

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Abstract: The objective of this study is to introduce solar energy as an electric and water source to distant communities in desert areas. Fossil fuel dominates world as the major source of energy that can be easily transformed into electricity and used for water reclamation in many societies. However, ambiguities and questions for supplying necessary fuels, such as fossil fuels, leads to more reliable energy sources. The sun is the major source of an alternative energy source and water, and establishing of solar energy dependent community will be explained in the paper, solar oasis. CSP, solar energy generation systems and their comparisons are introduced.

Keywords: CSP, Tower Systems, Parabolic Trough Systems, Solar Desalination, Heliostat

1. Introduction

With continuously rising energy costs, the solar power has become an increasingly attractive option for electricity production and water distillation. Solar power has the direct ability to drastically lower energy and operating costs. The significant amount of solar energy is available in many regions of the world, see Figure 1. Solar energy generation systems can be classified into two categories: thermal (Concentrated Solar Power) and electric (photovoltaic) systems see Table 1.

Recent advances in solar technology in power systems and water distillation need to be utilized to offset the continuously increasing electricity and water demand in Saudi Arabia. These technologies can be applied to save conventional energy consumed by inhabitants as well as energy used for water distillation. This will assist in satisfying the consumption demands of electricity in Saudi Arabia. Present energy sources are based on oils, which leads in overpopulated cities to pollution that is emissions of greenhouse gases, economy and depletion of resources of fossil fuels can be considered as a problems; and also all other difficulties of urban life.

In the present study, an appropriate Concentrated Solar Power (CSP) Steam/Electricity Generation Systems for production electricity and water by using solar energy are considered [1]. The proposed research will design solar power plant and water distillation system; establish appropriate principles and improvement of design concept of solar power plants. It should be noted that areas of at least 2000 kWh/m²/y are usable for CSP plants due to profitability of investments [2]. This solar system can be established in any area with low quality of water resources. In many desert areas, the brackish water exists as groundwater which could be used after desalination, which can be performed as a solar desalination process; see, Figures 2, 3 and 4.

Table 1. *Comparison of solar energy systems.*

	Solar Tower	Parabolic Trough	PV
Cost of Electricity Production	Optical heat transfer, high operating temperatures, better steam quality	Oil-based heat transfer medium, restricted operating temperatures	Comparable
Operating and Maintenance Costs	Commercial components and no heat transfer fluid circulation in the solar held	Specialized components and circulation of oil-based heat transfer fluid throughout the solar field	Comparable
Efficiency	Direct steam generation (DSG) with high temperature and high pressure steam	Steam production through heat exchanger	Lower
Thermal Storage	Heat tracing is as long as the tower height, therefore very efficient and simple design	Heat tracing is extremely longer and expensive with many complicated pumps,	Non-existent

	Solar Tower	Parabolic Trough	PV
		extra energy demand to keep the system running	
Capital Cost	Commercialized components, simpler and widespread supply chain	Specialized components complex and limited supply chain	Higher
Water Consumption	More efficient thermodynamic cycle with reduced water requirements for cooling per electricity produced, closed loop water circulation	Less efficient thermodynamic cycle with more waste heat produced generated per electricity produced	Not relevant
Terrain Requirements	More flexible in terrain requirements as each heliostat is independent from one another	More stringent terrain requirements as placement of troughs poses many challenges on uneven surfaces	More land required

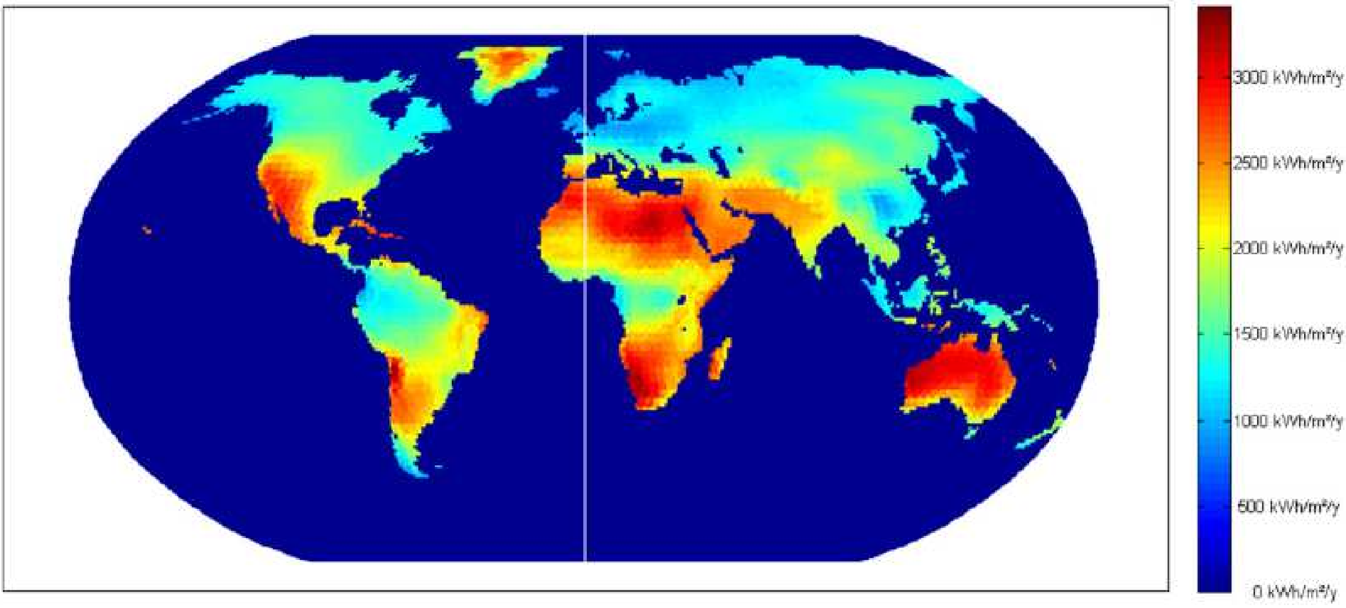

Figure 1. *Direct normal irradiance in the world, [2] and [3].*

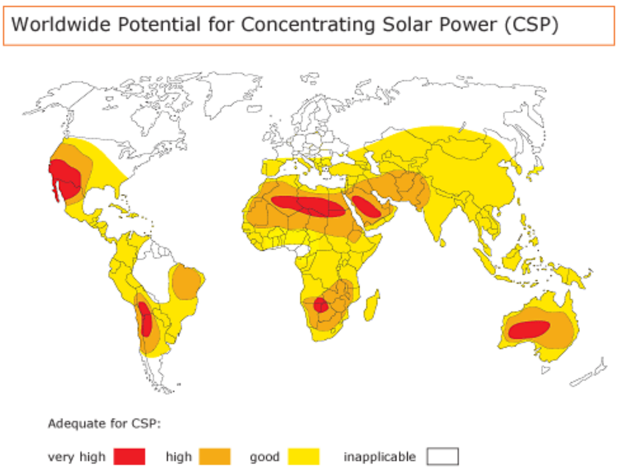

Figure 2. *Worldwide Potential for Solar Power, CSP, [5].*

Renewable energy such as solar thermal, particularly CSP Tower, can be used in remote area, due to

- Increasing overall energy efficiency;
- Utilizing an abundant renewable source of energy such as sun.

Figure 3. *CSP Tower plant, [5].*

Large cities and energy intensive life style, restricted agricultural production and increasing pollution, the existing successful CSP plants in world are considered as quite encouraging due to the fact that they use the solar energy [4, 5], see Figure 5.

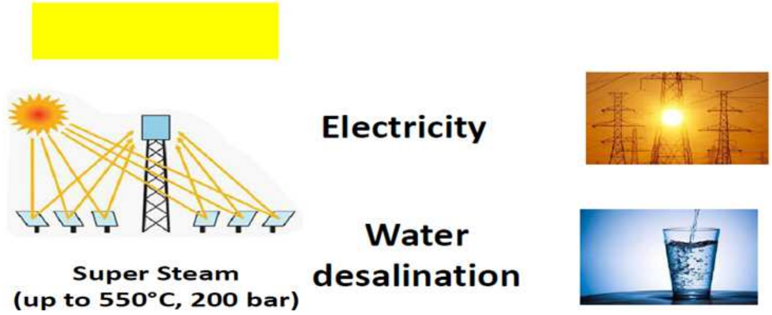

Figure 4. *Schematic CSP Tower plant and products, [5].*

Figure 5. *The existing CSP plants in world, [4, 5].*

Figure 6. *A sample solar oasis, [5].*

Small CSP plants 5-20 MW is quite appropriate in remote areas of Saudi Arabia, the brackish water is quite abundant in desert environment. Electricity and water brings life to the location. The agricultural and live stocks can be grown easily; and a sample solar oasis is presented in Figure 6. Concentrated Solar Power (CSP) Tower System efficiently generates energy with zero pollution or zero emission, and 100% clean energy in a wide variety of markets and applications world-wide. The application of small power plants will lead small energy loses in the system, which leads to more efficient energy uses for consumption instead of large plants.

The information presented is for clear and concise explanations of basic concepts, associated with Concentrated Solar Power (CSP) Tower System which enables the people to use inexpensive and hundred percent clean energy world-wide.

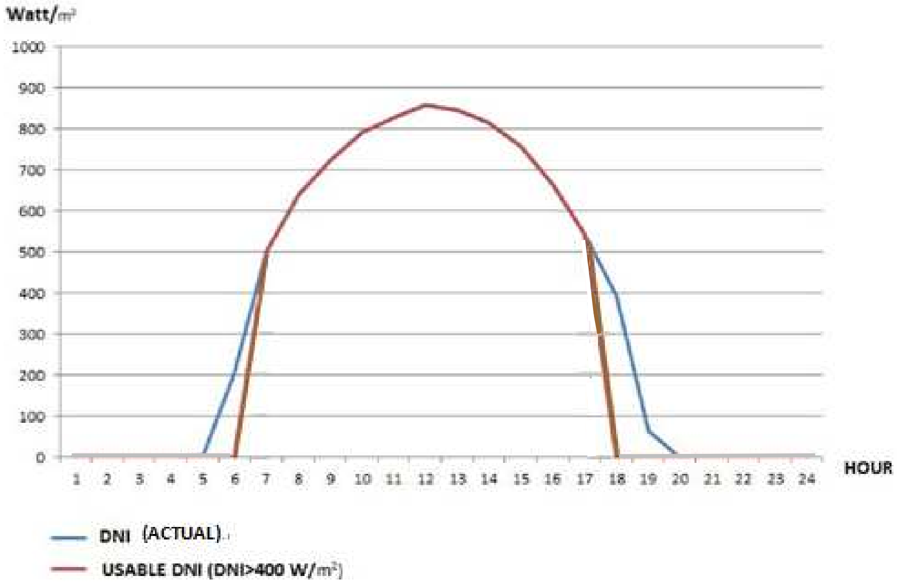

Figure 7. *Direct Normal Irradiation per hour, {5}.*

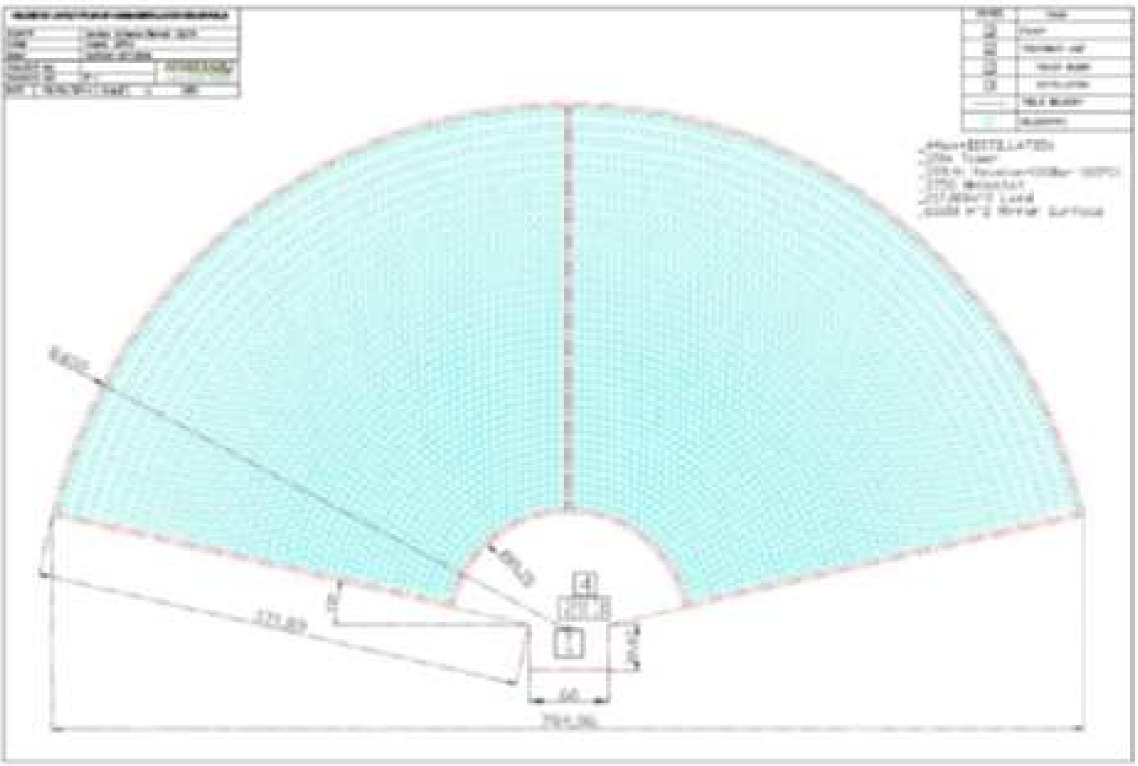

Figure 8. *Heliostat field layout, [5].*

2. Design Features

In CSP projects, solar beam is concentrated on the thermal receiver surface by reflective mirrors, called heliostats. Mirrors can only focus the solar beams which come perpendicular to the mirror's surface; therefore Direct Normal Irradiance (DNI) values are used for output calculations in CSP systems, see Figure 7.

The CSP Tower systems generate high volume and high quality steam that is ready to use in steam turbines for various industrial applications, including drinking water production. CSP tower's operational internal electric consumption is significantly less to compare to parabola troughs. The system is highly efficient flexible, reliable, consistent, and customer oriented. The environmental problems are minimal and can be solved within its company limits and simplistic. The technology is reputable and has several research and supply chain partners. The system is self sustaining, low cost, light weight, and high efficient, it offers heliostats which are easy to install and maintain. Heliostat field and control system have an efficient communication which reduces field erection cost and complexity as well as maintenance costs. The other important features are the modular design and infrastructure (both software and hardware) for quick customer support and feature modifications. The plan footprint is relatively small due to a compact design.

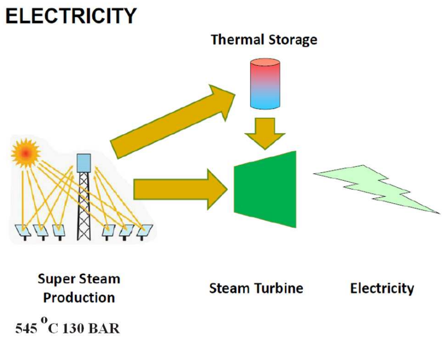

Figure 9. *The CSP solar power plant, [5].*

The heliostats are computer controlled for reflector positioning and wireless system for maximum optical efficiency. The heliostats and the CSP plant are presented by Figures 8 and 9, respectively.

Available solar energy is calculated as follows:

Available Solar Energy = Number of Heliostats × Surface Area (per Heliostat) × DNI

Tower is made as strong and durable construction, and the receiver is a heat recovery boiler which proven design of 150 year old and 50 years life time. Tower system consumes less area respect to other CSP systems of the same energy output. The Tower system has very short piping; there is very small probability for pipeline failures, which is a common problem in parabolic troughs. As a result of thermal stresses on pipes. There is no toxic thermo fluids in Tower systems as in parabolic troughs and these fluids are quite expensive fluids and increase production cost of electricity and water and they must be replaced every two years. Tower systems are designed for these high thermal stresses. It is much easy and less costly cleaning of mirrors since heliostats are flat. The heliostats are self tracking and self calibrating for collecting solar energy at maximum level. Even more, initial installation of Tower system is extremely simple with respect to other systems and the lifetime operation is straightforward, see the comparison in Table 2, [6, 7].

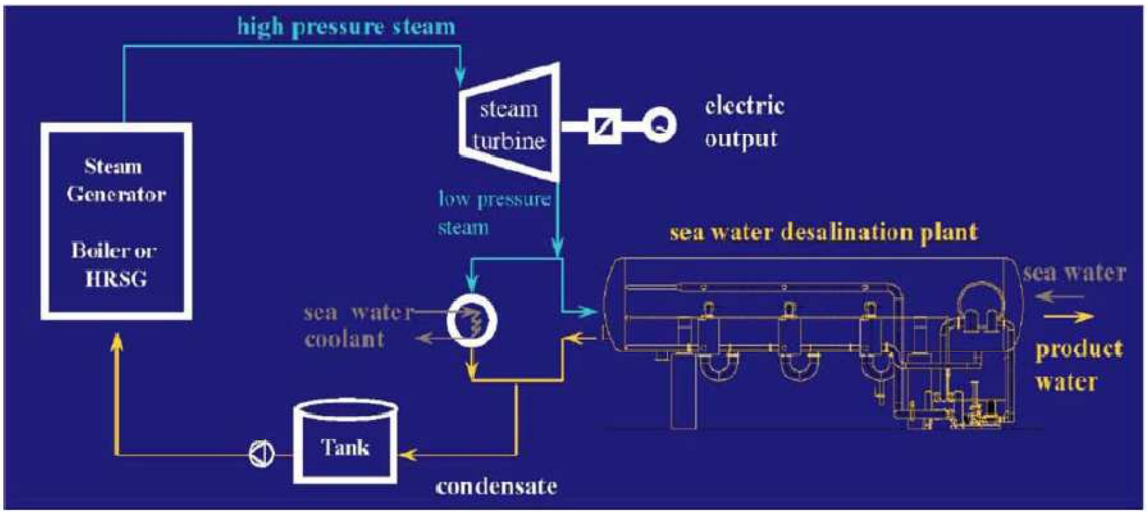

Figure 10. *Water Desalination System, [5].*

Table 2. *Comparison of CSP Tower and CSP Parabola Trough systems.*

	CSP TOWER SYSTEM	CSP PARABOLA TROUGH SYSTEM
Cost (Capital)	Lower	Higher
Cost (Operational)	Lower	Higher
Efficiency	Higher	Lower
Molten Salt Storage	Easy and low cost	Very complex and expensive
Maintenance	Easy and low cost	Complex and expensive
Cleaning	Easy	Complex
Land Requirement	Less	More
Operational Robustness	Strong	Fragile

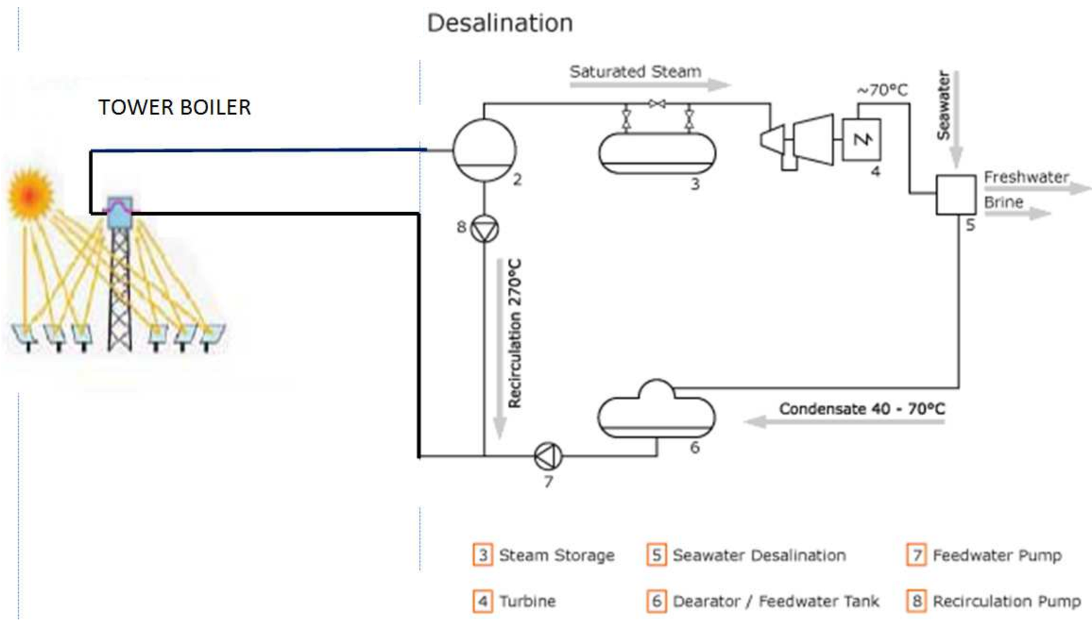

Figure 11. *Schematic Water Desalination System, [5]*

CSP Parabola Trough system is considered proven technology; however it has no further improvement left to move forward. This system's molten salt operation is very risky and expensive, and heat tracing is expensive and energy consuming. This system is very difficult to erect and line up for the first time; and needs expensive calibrations.

CSP Tower system is a new and highly efficient method; and plenty room to excel its capacity and decreasing in cost. Piping and heat tracing requirements are very short; only between tower and storage. Molten salt moves only within tower height with a very low operational cost. Erections of independent heliostats are easy; less costly; and calibrated automatically and require minimal maintenance.

It becomes clear that seawater desalination has already been understood as potential source to resolve the fresh water problems in numerous countries. However, it should be noted that in spite of the good reliability and favorable economic aspects of desalination processes, the problem of high energy consumption needs to be resolved. The solar Tower energy system can be considered as an answer to this problem. A most efficient steam turbine (back pressure turbine) must be used for maximum efficiency. A "large amount compact water distillation system" can be adapted back to power block, back pressure turbine. This unique technology enables fresh water distillation available while electricity production continues, see Figure 10 and 11. The Tower system needs small area and standalone configuration, and the capacity can be increased at reasonable small cost and leads to lower energy cost.

During day-time, necessary heat for the boiler to generate steam is provided by focusing solar energy onto the receiver using solar concentrating mirrors (heliostats). CSP's innovative technology must include an optimization algorithm to most efficiently track the sun throughout the day for maximum energy output.

Molten salt is selected in solar power tower systems for heat or energy storage, since it is liquid at atmospheric pressure at high temperatures; it provides an efficient, less expensive medium in which to store sun's thermal energy, its operating temperatures are compatible with high-pressure and high-temperature steam turbines, and it is non-flammable and nontoxic, [8]. The molten salt is a mixture of 60 percent sodium nitrate and 40 percent potassium nitrate, and calcium nitrate in some cases, [9], [10] and [11]. Electricity can be generated in periods of less solar radiation days and at night using the stored thermal energy in the hot salt tank. Normally tanks are well insulated and can efficiently store energy for up to seven days, see Figures 12 and 13.

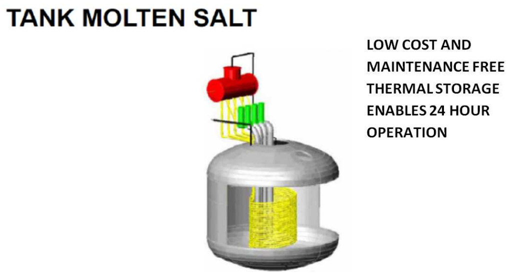

Figure 12. *Molten salt tank, [5].*

3. Investments

Production of electricity, drinking and agricultural water from brackish water are final product of the investment. This water can be used also for animals. The investment cost of tower systems is thirty or thirthtfive percent lower CSP parabolic trough systems [12, 13 and 14]. These plants are free of large energy losses, and the feasibility studies are extremely encouraging. CSP tower plants of 10-40 MW systems are excellent power and water source for desert dwellings. The CSP tower systems are not fragile and their maintenance is not costly and efficient respect [1, 4 and 5], see Figures 14 and 15. It should be mentioned that construction of linear Fresnel systems were stopped due various technical and economical reasons, [1]. Due to long piping arrangements with thermal shocks and thermal insulations, CSP parabolic trough systems are not suitable for the moving tracking systems. Moreover, construction and operating expenses of these systems are incomparable to CSP tower systems. These plants are free of large energy losses, and the feasibility studies are extremely encouraging. CSP tower plants of 10-40 MW are excellent power and water source for desert dwellings. These systems are not fragile. Their maintenance is very minimal and efficient respect CSP parabolic trough systems, [1], see Figures 14 and 15; [1], [4] and [5].

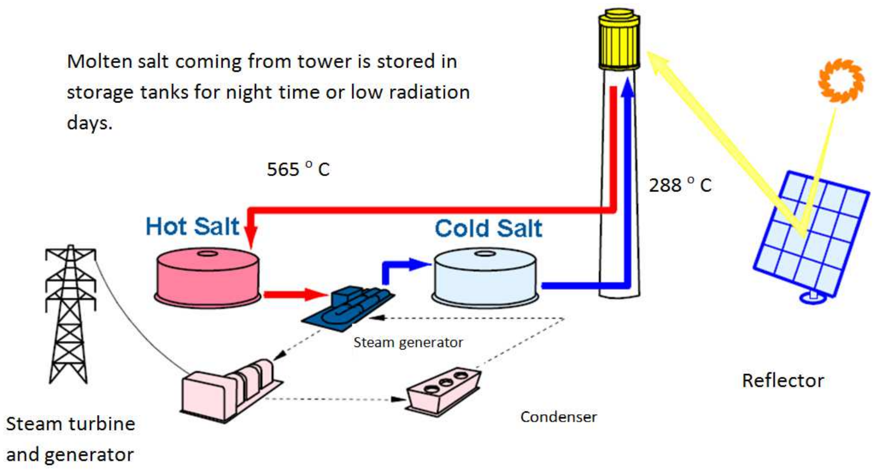

Figure 13. *Separate molten salt tower. [5].*

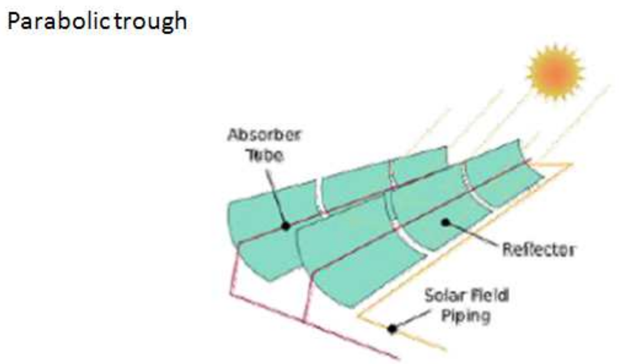

Figure 14. *Parabolic troughs, [5].*

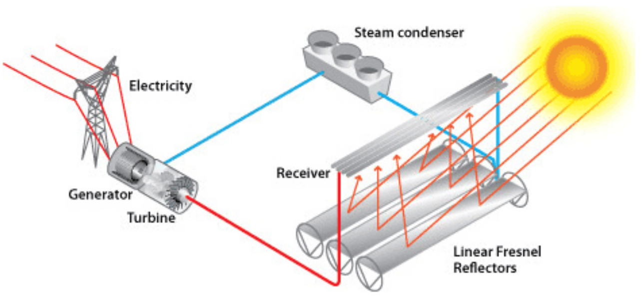

Figure 15. *Linear Fresnel System, [5].*

4. Conclusion

It is obvious that the CSP tower power plans are pollution free and excludes problems due to thermal fluids as in CSP parabolic tough systems. The produced water can be used for agriculture and possible industrial activities. The initial investment is very reasonable and risk free. The end product of CSP tower systems is non-oil dependent continuous energy and water from sun. The system can be used in remote areas and islands. These areas will gain economical value which does not have potable water and energy sources in place. It is known that these ideas may be known, however the paper is putting out the oil free society is a survival many areas without energy and water.

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