HARNESSING CHEAP SOLAR ENERGY THROUGH THE USE OF CONCENTRATED SOLAR POWER

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Abstract. *Energy is a very important component for our country's economy. If we manage to produce energy at an economically advantageous price, moreover, in a renewable and ecological way, we will be able to extensively develop the country's economy and become important players in world markets. Thus, a technology that shows promise in completing this role is Concentrated Solar Power. This differs from the classic solar energy collection technology in that it collects thermal energy. That allows us to directly supply consumers with this type of energy, which substitutes burning fuel, but also offers different storage possibilities, which are cheaper to build compared to electricity storage. This article explores current technologies and how they can be applied in the context of Rep. Moldova to fulfill the proposed goal: the production of cheap, green and renewable energy.*

Keywords: *heat energy storage, heat transfer liquid, line-focusing systems, sensible heat*

Introduction

Energy is an essential part of current civilization. Modern life would not be possible without the power plants that now bring light into our homes. But now is the time to find alternative solutions to the ways used in the past. More than that, the Republic of Moldova needs a new energy sector that can support a future growing industry. Thus, Concentrated Solar Power (CSP) is proposed to be a way to build and balance a renewable energy industry, having the ability to effectively replace industrial processes that still need combustion to generate heat, by compensating this source with thermal energy from the sun but also offers an efficient energy storage solution for long-term or short-term keeping, solving one of the biggest problems of solar panels and wind farms, namely the production of energy only in certain parts of the day. A typical system would follow the scheme in Fig. 1, and each compartment will be discussed individually in the current paper.

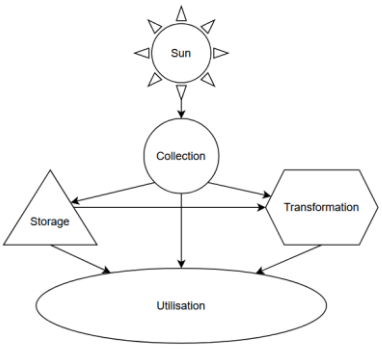

Figure 1. A typical CSP system

Energy collection

Thermal energy harvesting technologies are diverse and quite developed. To begin with, the most common solar energy collection systems are water-based collectors. They are mainly used for domestic water or home heating. Due to the fact that they use water as a transport liquid, the maximum temperatures reached can only be 100 °C. Instead, Concentrated Solar Power (CSP) provides higher working temperatures, up to 600 °C and more advantages than the previous technology. This consists in focusing the solar energy either in a line, or in a point, for the production of energy.

Line focusing systems, such as linear Fresnel reflector systems, use long, laterally positioned mirrors to focus solar radiation into a tube-shaped receiver positioned along the focusing line. This tube contains a liquid with the help of which the collected energy will be transported to the consumer or will be used to produce steam that will drive a turbine. Systems with parabolic mirrors work in a similar way, with the help of a curved mirror, the light is reflected on a receiver that is on the focusing line of the curved mirror [1,2].

Table 1

Key Takeaways of Concentrated Solar Power Technologies[1]

Technology	Linear Parabolic Systems	Linear Fresnel Reflectors	Dish-Stirling Systems	Solar Tower Systems
Capacity range [MW]	10–250	5–250	0.01–1	10–100
Capacity installed [MW]	4800 (1200 under construction)	20 (10 under construction)	Several prototypes	1200 (300 under construction and 1300 under development)
Annual solar to electric efficiency (%)	14–16	8–10	16–29	20–35
Concentration ratio	70–90	35–170	<3000	200–1000
Land use factor (%)	25–40	60–80	20–25	20–25
Development status	Commercially proven	Recently commercial	Prototype tests	Semi-commercial
Benefits	Proven reliability and durability. Simple design of optical systems that also guarantee acceptable concentration ratios. Possibility of assimilating commercial CSP systems to parabolic collectors that use oil as the HTF to other types of industrial plants, thus taking advantage of existing industrial supply chains	High concentration ratio. Simple structure. Direct steam generation proven	Highest concentration ratio. High modularity and high efficiency of the power cycle. Low level of land occupation. Wide range of applications.	Very high concentration ratio. High efficiency of power cycle and potential options for powering gas turbines and combined cycles
Drawbacks	Limited HTF temperature.	Lower optical efficiency as compared to other CSP technologies. Storage for direct steam generation is still in the R&D stage	Not commercially proven. High cost related to the complex design and components. Difficulty of integration with TES	High installation and maintenance costs

Point focusing systems, including those using Stirling engines and tower systems, concentrate solar energy into a single point or small area. Stirling engine systems use a parabolic mirror to focus all the solar radiation on the engine's hot chamber and a cooling system to dissipate the heat from the cold chamber. Thus, thanks to the laws of thermodynamic processes, a higher efficiency is obtained. Then this rotational energy is converted into electrical energy by methods already known for a long time. Solar tower systems are made up of several reflectors that direct solar radiation to a receiver positioned in the middle above a tower. It absorbs the energy, transmits it to the transport liquid, which in turn will generate steam that will turn a turbine [1,2]. A recent study [3], analyzed the performance and costs of a solar tower based on a supercritical carbon dioxide Brayton cycle. They found a thermal efficiency of 46.66%, much higher than traditional steam-based operating methods and a cost of approximately $0.1046 per kilowatt-hour (kWh). The discoveries made are promising and prove that Concentrated Solar Power can be a cheaper source of energy than the photovoltaic panels used today.

In the context of Rep. Moldova, according to the data observed in the Tab. 1, it may be advised to use the technology of focusing in line, either with the help of Fresnel Reflectors or Parabolic Mirrors, because of their greater potential due to their commercially proven status. Moreover, their modular nature contribute to the possibility of building a small, experimental installation, which can be extended in the future in a fully-fledged plant, capable of producing hundreds of MW of thermal energy. Another key point is the land needed for this technology to be effective. The line focusing technology holds an advantage here too, because it is not needed for all of the mirrors to be adjacent to one another, thus giving us the option of avoiding unavailable land. This is also one of the cheapest options to implement and in the future it is advisable to explore ways in which the price of this technology can be reduced further, either by increasing efficiency or using low cost materials.

Energy Storage

To make this technology cost-effective, an inexpensive method of storing this energy overnight, or even for 2-3 cloudy days, is needed to ensure continuous energy supply to consumers. As the most common sense solution to this problem is the storage of energy also in thermal form without its transition into electrical or mechanical energy, since the conversion between one type and another takes place with energy losses and also, the methods of storing those energies are not at the necessary level of development to justify further research towards such a solution. It follows, therefore, that we should focus on thermal energy storage technologies, where we can distinguish several options, which are divided into 3 large categories, sensible heat, latent heat and thermochemical Fig. 2 [4].

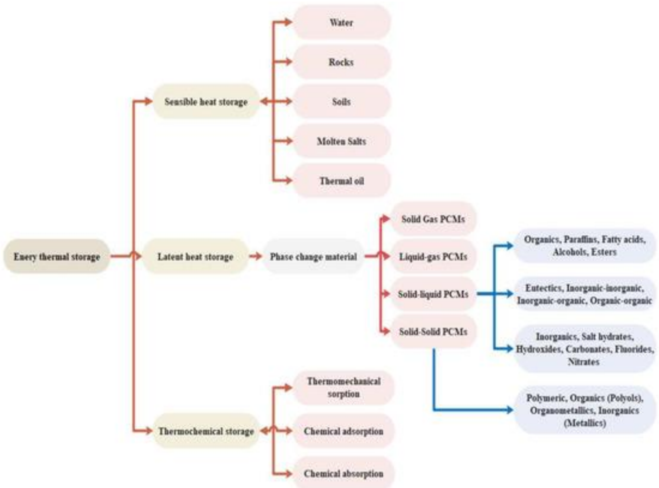

Figure 2. Thermal storage methods and materials that are commonly used

All three offer promising perspectives, but following the principles of cost and accessibility, it is advisable to use and investigate sensible heat technology, as it gives us the opportunity to use cheap materials that are found in considerable quantities, such as cement, sand, gravel, etc., we find a lower technological complexity of implementation compared to other choices and the stored energy is easier to access and use compared to latent heat and thermochemical, as it doesn't imply any process. Moreover, studies in these directions are very optimistic, such as a recent study, published in *Engineering proceedings* where slag and concrete were compared for thermal energy storage for medium or high temperature applications. Below Tab. 2, which shows the thermal properties of these materials [5].

Table 2

Thermal properties of heat storage materials as a function of temperature [5]

Temperature (K)	Density (kg/cm^3)	Specific Heat Capacity ($J \cdot g^{-1} \cdot K^{-1}$)	Thermal Conductivity (w/m K)
		Concrete	
673	2750	0.916	5.00
		Slag	
295	3610	0.717	1.84
373	3610	0.717	1.84
573	3610	0.911	1.80
773	3610	0.975	1.78

From this it can be seen that concrete is an excellent material for such application. Given the relatively low cost, it is one of the most brilliant methods discovered so far. Another fact that confirms the viability of this method of storage is the fact that MIT engineers are exploring the possibility of building a storage system of up to 100 GWh, which uses gravel as a thermal energy storage medium [6]. Such a system would be able, fully loaded, to provide all of Moldova with energy for days. As can be seen, the problem of thermal energy storage can be solved with a low cost and in an economically profitable manner. Moreover, thanks to the advantages offered by massive systems, where the surface-to-volume ratio is small, the prospect of batteries that will be able to store the energy collected in summer until winter is realistic. All these data do nothing but contribute to the statement that sensible heat is the way forward for a balanced and long term thermal energy production and storage system.

Heat Transfer Liquid

To transport energy for storage or use, it is necessary to find the best liquid to fulfill this function. Currently, the 2 technologies competing for this title are thermal oils and molten salts. In the aforementioned article [6] a comparison is made between these 2 methods, one of the most important conclusions being the fact that oils are preferable when we have systems with a temperature up to 400 °C and salts are better for systems up to 600 °C. In the context of Republic of Moldova it may be more optimal to choose thermal oils as an energy transfer liquid, because the climate we are in doesn't have a huge solar potential, such as the Mediterranean region or Australia, but also because the use of thermal oil gives us the opportunity to exploit the thermal energy of low temperatures, in opposition with molten salts, which become solid at lower temperatures, perfect for the applications that will be mentioned in the next section.

Methods of using the energy generated

After establishing the ways of collecting, storing and transporting this type of energy, it is also necessary to highlight the ways through which this energy can be used to the maximum. Thus, we can draw attention to the use of thermal energy in a steam turbine to generate electricity during times when other renewable energy sources are not producing anything. It can also be used in industry (desalination, deshidratation, cooking, chemical processing), which consumes up to 35% of the world's energy production, of which, on average, 30% of the thermal energy consumed is up to 150 °C, 22% between 150 °C and up to 400 °C and the remaining 48% is above 400 °C [7]. This evidence shows a preference for thermal oil at the disadvantage of molten salt, since in this way we can also ensure the low temperature thermal needs of the industry. More than that, it is expected that the concrete data on the consumption of thermal energy in the Republic of Moldova will further favor the lower temperatures, since high temperatures can be found more often in the heavy, metallurgical industry, which does not occupy a significant part of the local economy. On the other hand, for electrical energy generation high temperatures are needed for high efficiency. A special synergy can be achieved by combining a turbine, which uses the thermal energy of high temperatures, so that the remaining energy can then be used to heat a nearby greenhouse. This type of technology is now used in Sundrop CSP, Australia, and other CSP facilities can be found all over the globe, some of them are shown in Tab. 3.

Table 3

Concentrated Solar Power Facilities Around the World [8]

Name	Location	Technology	Nominal Capacity
City of Medicine Hat ISCC Project	Medicine Hat, Canada	ISCC, Trough	1.1 MW
Atacama I / Cerro Dominador 110MW CSP + 100MW PV	Calama Antofagasta, Chile	Power Tower	110 MW
Aalborg CSP-Brønderslev CSP with ORC project	Brønderslev North Jutland, Denmark	Biomass-Hybrid, Trough	5.5 MW
Sundrop CSP Project	Port Augusta South Australia, Australia	Power Tower	1.5 MW
Liddell Power Station	Liddell New South Wales, Australia	Linear Fresnel	3 MW
Shams 1	Madinat Zayed Abu Dhabi, United Arab Emirates	Parabolic Trough	100 MW
Noor Energy 1 / DEWA IV - 100MW tower segment	Dubai Dubai, United Arab Emirates	Power Tower	100 MW
Noor Energy 1 / DEWA IV 3x 200MW trough segment	Dubai Dubai, United Arab Emirates	Parabolic Trough	600 MW
ISCC Kuraymat	Kuraymat, Egypt	ISCC, Trough	20 MW
Ilanga I	UpingtonbZF Mgcawu District Municipality Northern Cape, South Africa	Parabolic Trough	100 MW

Conclusions

Following this analysis, of the perspectives of solar thermal power plants in Moldova, we can see that it represents a cost-effective alternative, compared to other solar technologies, which comes to balance energy production throughout the year and day, having a wide application in the entire industrial field. A renewable energy generation system that will include this technology will be more stable in the face of weather changes, but also more independent from non-renewable energy resources, currently needed for the operation of industry and electricity production. Moreover, the economic profitability will ensure the benefit of the initial investments for the development of this new branch of the energy industry of the Republic of Moldova.

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