# The Feasibility of the Molten Salt Storage Technology

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**Abstract.** Nowadays, the situation of the energy consumption is quite serious for many reasons. One of the significant contributors is the utilization of some traditional energy generating and storing systems, making the advancement of the technologies fairly important for human. Consequently, this paper focuses on a green energy storage system called molten salt storage system for sustainability development of humans. This paper mainly discusses the current situation of energy consumption. A collaborate illustration of molten salt storage in the industry is show, and a concentrated solar power station which uses molten salt storage in US is displayed. Advantages are explained in three aspects including chemistry aspect, economic aspect, and environment aspect. The paper uses the comparison of some properties of different compounds to highlight the advantages of molten salts. Furthermore, the paper uses some methodologies like Leveled Cost of Energy, and Life Cycle Assessment of different stages of the molten salt storage system to show its influence to the environment. Last but not least, the disadvantages and its further improvement is illustrated. After analyzing the both sides of this technology and the possible future improvement, the conclusion comes out that it is still feasible to use the molten salt storage system despite of some flaws required to be improved.

**Keywords:** energy, molten salt technology, concentrated solar power.

## 1. Introduction

Energy markets started to tighten in 2021 as a result of a number of causes, including the incredibly quick recovery of the economy after the epidemic. The situation became a full-fledged global energy crisis in February 2022. In multiple markets, the increase in natural gas prices had an effect on electricity prices. The price of oil has reached its highest point since 2008 [1]. What's more, the rapid consumption of energy has made the adequate energy supply a problem. Also, the traditional energy supply causes a variety of environmental problems. In fig.1, the current situation of energy consumption can be analyzed. To be more precise, traditional energy use accounts for a significant portion of the overall increase in energy demand. Although new technologies are emerging, they still only play a modest role and require additional development. What should humans do is to find a new technology to substitute the tradition one and make progress on the current green technology. The new technology should be featured with clean, stable, and efficient. Thus, this paper will illustrate the feasibility of the molten salt storage in concentrated solar power stations in terms of its advantages and disadvantages, and then propose a future improvement people should make. Different aspects of this technology are being explored by numerous studies. The topic of discussion pertains to the future of molten chloride salt for CSP. [2]. The cost of the whole system was analyzed using System Advisor Mode (SAM) [3]. Now, this paper will analyze the feasibility of the whole molten salt system in CSP and show some further perspective.

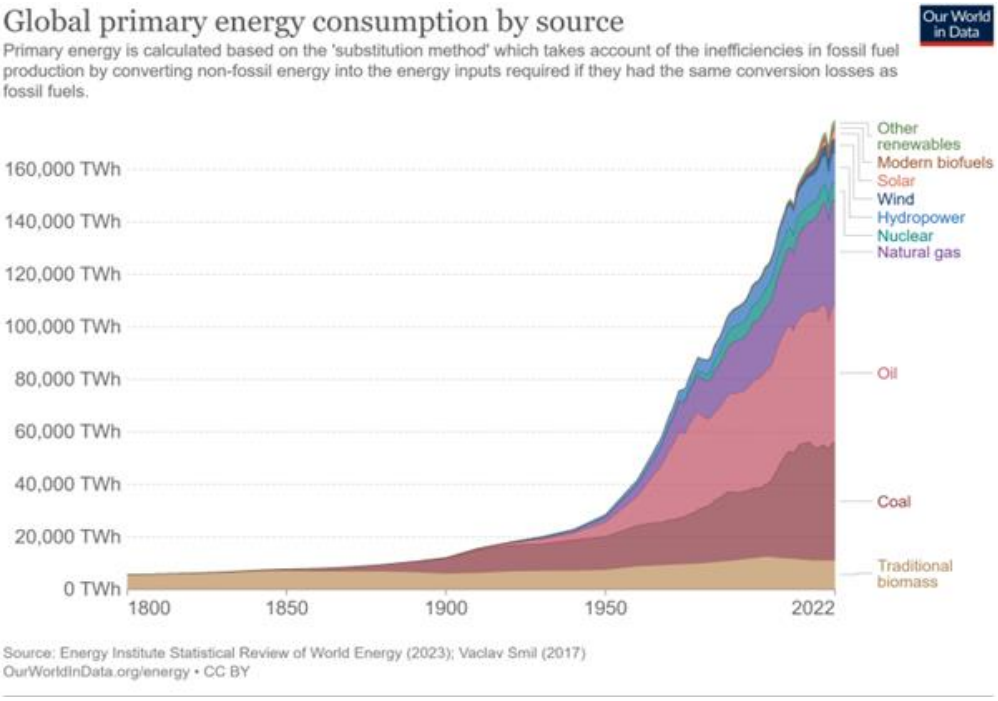



**Figure 1.** The current situation of energy consumption [4]

## 2. Principle of Molten Salt Storage

Molten salt storage (MSS) is a system which can be utilized in a concentrated solar power (CSP). The material of molten salts is typically made up of 3/5 of sodium nitrate and 2/5 of potassium nitrate [5]. The conversion of thermal energy to electricity is the major method used by MSS. Salts are stored in an insulated container and heated during off-peak hours. Salt is added to a steam generator to generate energy, which boils water, turns a turbine, and generates electricity [6]. MSS has the potential to be utilized in peak shaving.

MMS is frequently employed in the CSP. The principle of power station is shown in fig. 2. The solar receiver is used to reflect sunlight and contains preheated liquid salt from a cold storage tank. The liquid salt is heated up to about 600℃. When electricity is required, heated steam can be generated to energize the turbine and create electricity [6].

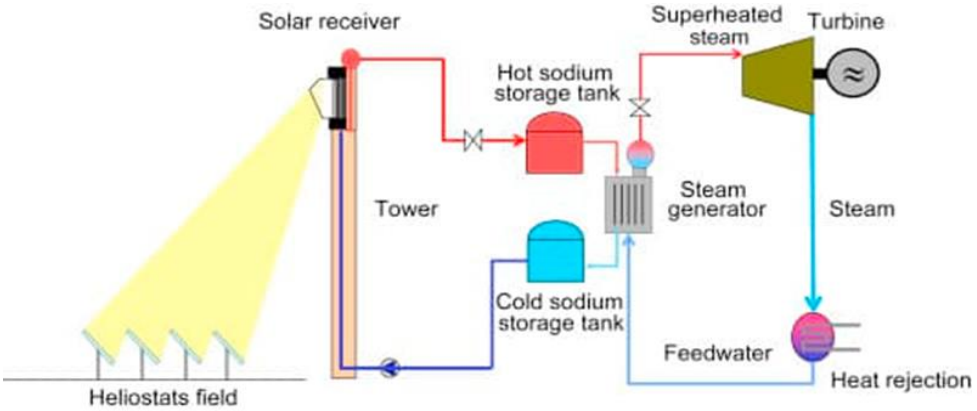



**Figure 2.** The flow chart for the CSP [7]

## 3. Real Life Application

Near Tonopah, about 310 km northwest of Las Vegas, is the Crescent Dunes Solar Energy Project, a CSP example. It is a first-of-its-kind commercial CSP. That solar power is very advanced since it has sophisticated MSS technology at full scale (110 MW). The performance of that project can be

shown in fig. 3 [8]. The production is fairly a large amount, but there are some serious problems with that. The thermal energy storage tank for molten salt produced a leak. The developer of Crescent Dunes, Solar Reserve, has been unable to land any of the authorized projects in its global pipeline since the tank spill almost ten years ago [9]. This problem will be discussed later in the Disadvantage and Further Improvement.

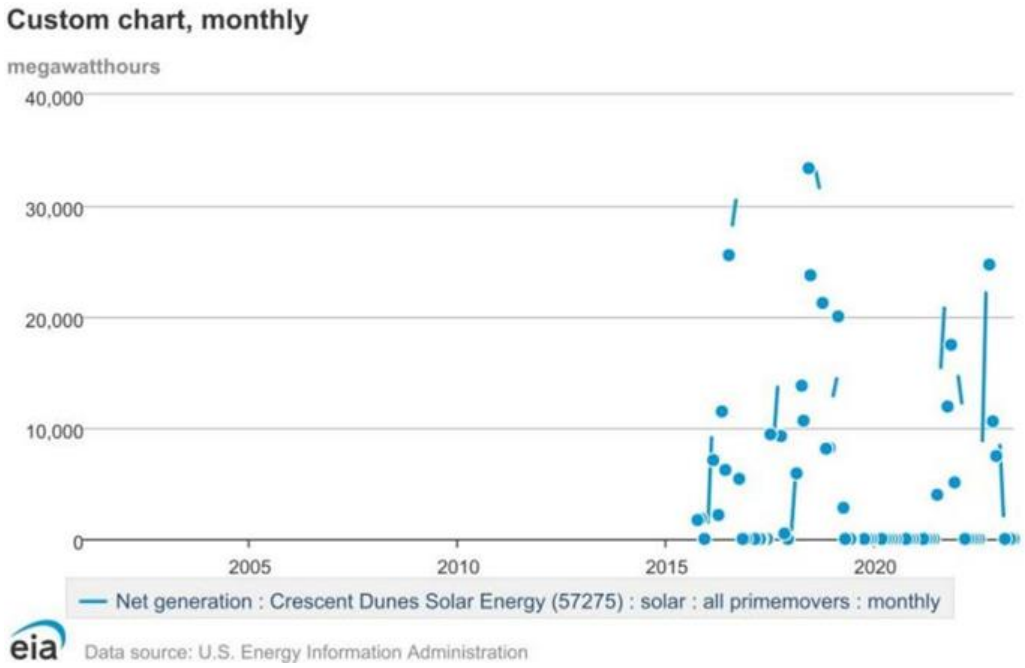



**Figure 3.** The production of electricity from Crescent Dunes Solar Energy Project [8]

## 4. Advantages

From the Chemistry aspect, MSS is an accepted ionic liquid like in fig. 4 with a strong polarizing force, a relatively higher melting and boiling point illustrated in fig. 5, making it difficult to volatilize, and low vapor pressure, in contrast to the prior high-temperature heat conductive medium. As a result, salt won't lose its effectiveness quickly, minimizing waste, cost hikes, and environmental harm. However, if the molten salt evaporates fast, less energy will be generated, rendering the procedure ineffective [10].

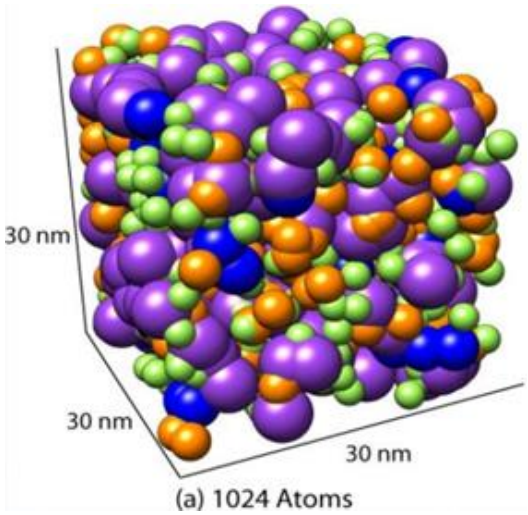



**Figure 4.** Simulation ionic structure of a type of salt [11]

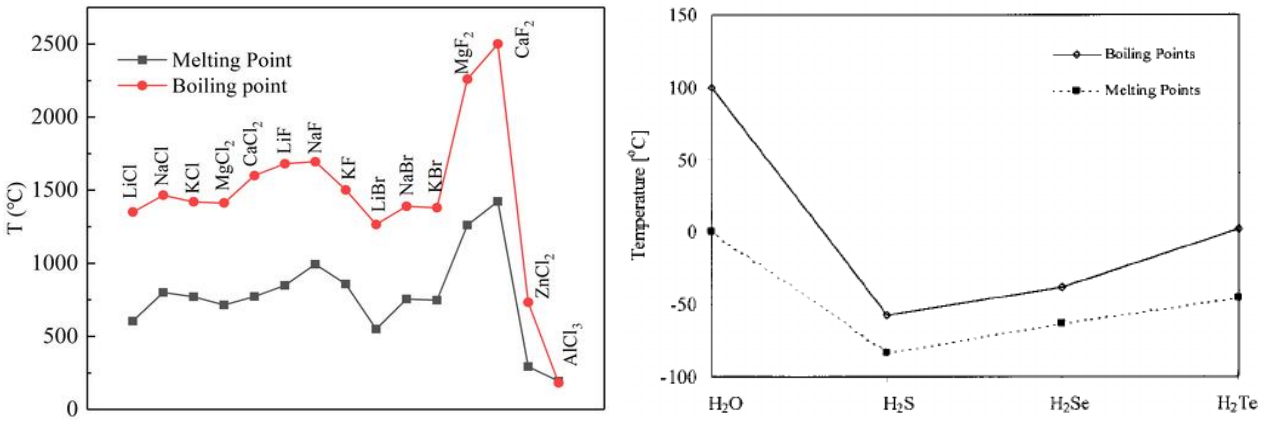
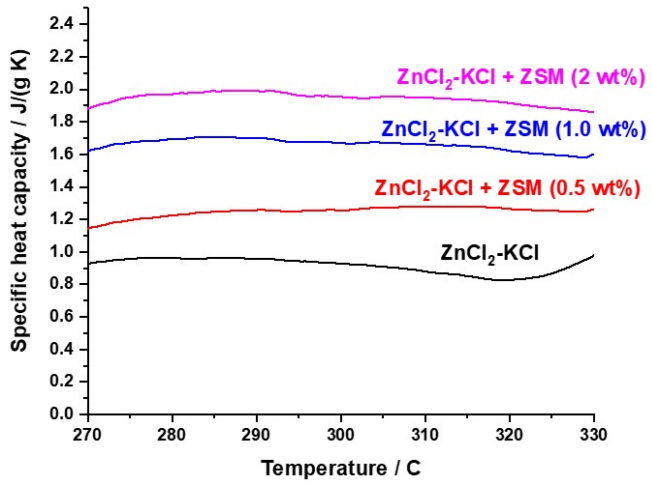



**Figure 5.** Comparison of the melting and boiling points between molten salts and other compounds [12]

High heat capacity is another attribute. Having a large heat capacity, molten salt is a fluid that transfers heat. The fluid's ability to retain heat without altering its temperature is indicated by its heat capacity. It also shows how much heat salt can tolerate before boiling and ultimately vaporizing. Sodium nitrate and potassium nitrate is included in a conventional alt, which between 260 and 550°C is a liquid. 1.53 J/ (g K) of heat capacity and 161 J/g of fusion heat are its respective heats of operation. Salts with 116°C melting temperatures and heat capacities of 1.54 J/ (g K) may be produced experimentally using lithium. When we compare the two graphs in fig. 6, some forms of molten salt have specific heat capacities that are comparatively larger than those of other chemical compounds, which implies that the molten salt is an effective heat transfer fluid [13].




| Substance | Phase | Specific heat -cp- J/gK |
|---|---|---|
| Air | gas | 1.0035 |
| Aluminium | solid | 0.897 |
| Beryllium | solid | 1.82 |
| Cadmium | solid | 0.231 |
| Carbon Dioxide | gas | 0.839 |
| Helium | gas | 5.1932 |
| Hydrogen | gas | 14.3 |
| Iron | solid | 0.412 |
| Lead | solid | 0.129 |
| Nitrogen | gas | 1.04 |
| Oxygen | gas | 0.918 |
| Polyethylen | solid | 2.3027 |
| Sodium | solid | 1.23 |
| Steel | solid | 0.466 |
| Uranium | solid | 0.116 |

**Figure 6.** Comparison of the specific heat capacity between molten salts and other compounds [12]

From the Economy aspect, an economic model known as Leveled Cost of Energy (LCOE) analyzes the lifetime costs of producing energy across various production types. The tendency of LCOE of CSP is decreasing, and, more importantly, the blue part which is the cost of the material for molten salts is decreasing shown in fig. 7. The weighted average LCOE for CSP saw a 70% decrease from 2010 to 2011, reaching USD 0.107/kWh. The primary variables were lower total installation costs (64%), lower total operating and maintenance expenses (10%), greater capacity factors (17%), lower weighted average cost of capital (9%), and cheaper total installation costs (64%) [14].

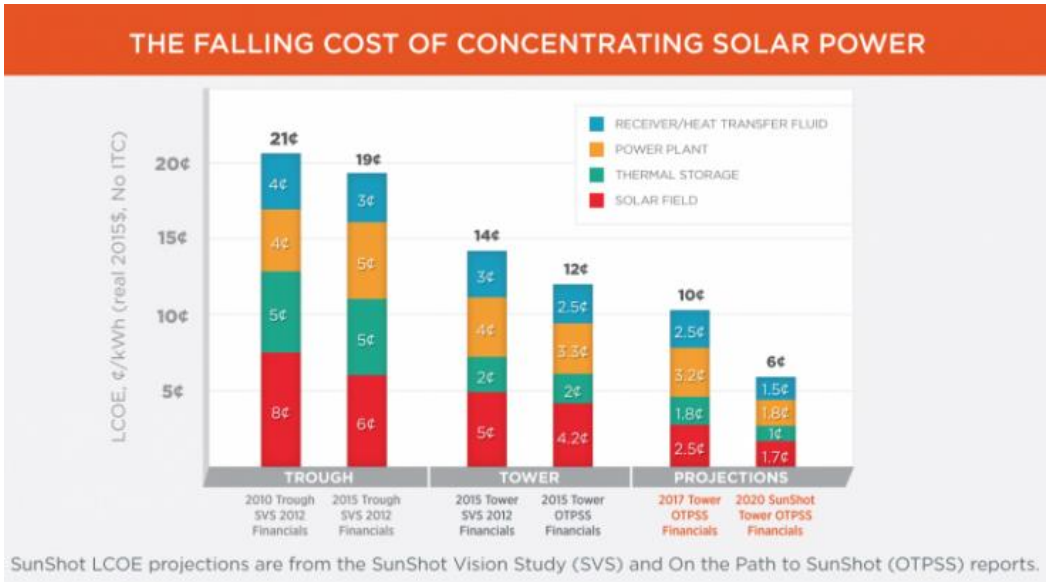



**Figure 7.** The LCOE of CSP using MSS [15]

In terms of primary energy demand, fig. 8 is the result of comparing the Cumulative Energy Demand, which means the sum of all energy inputs required to create a product. Compared to other plants, the CSP needs manufacturing its raw material from most of green energy, resulting in a huge advantage in the energy demand to the environment.

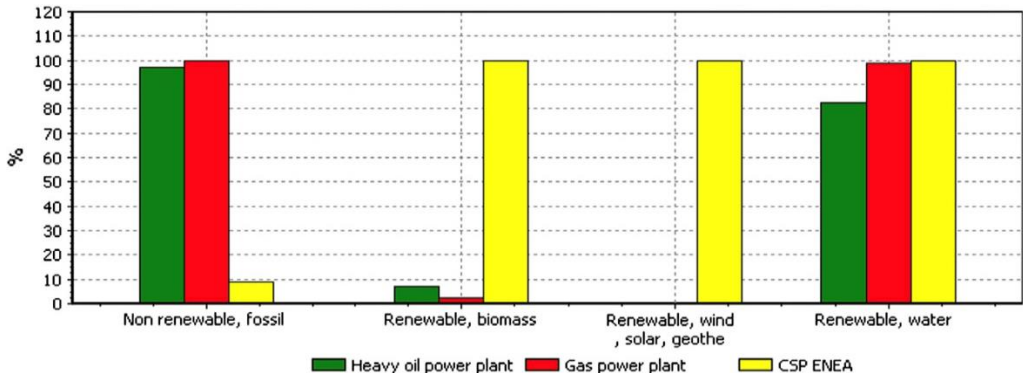



**Figure 8.** Comparing LCAs according to CED (Cumulative Energy Demand) [16]

In terms of the emissions contributing to damage of the environment, fig. 9 compares the IPCC GWP 100a of different power plants. In essence, GWP assesses a gas's ability to influence global warming. GWP100 is the unit of measurement that is most frequently used to calculate greenhouse gas emissions [17].

Thus, IPCC GWP 100a is known as GWP100 criteria in Intergovernmental Panel for the Climate Change (IPCC). It is evident that CSP has a smaller number of GWP than other two, which shows a less impact to the environment.

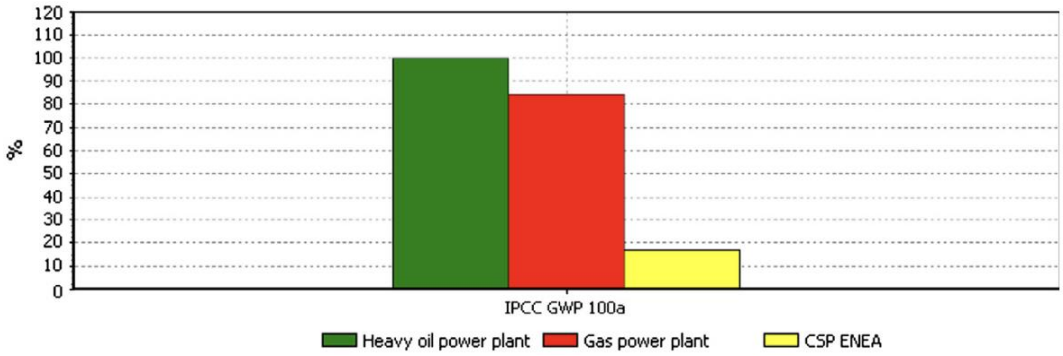



**Figure 9.** Evaluation of LCAs with respect to global warming 100a (IPCC) [16]

In terms of the impact on the whole society, the damage-oriented Eco-indicator 99 Methodology is used. Each environmental theme's impact on human, ecosystem, or resource damage is determined during the modeling process [18]. It is clear that there is lower impact on the different types of damage, as shown in fig.10.

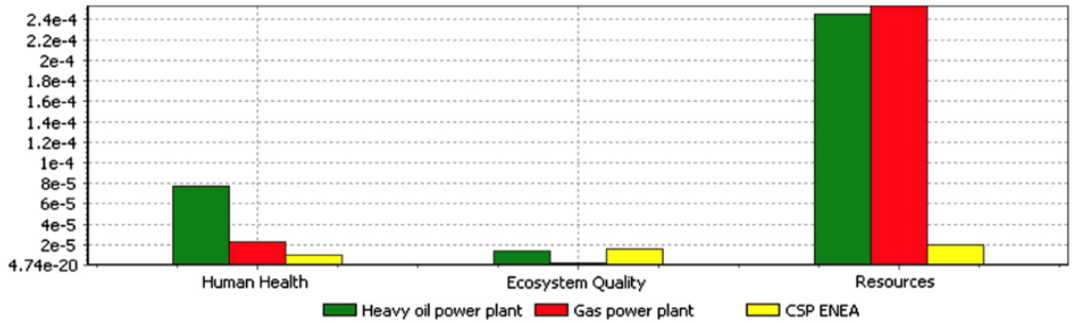



**Figure 10.** Comparison of LCAs using the damage-oriented Eco-indicator99 Methodology [16]

## 5. Flaw

In section 3, the problem of the molten salt system in CSP, a leakage in molten salt storage tank, is pointed out. The cause of that significant shortage is the huge temperature difference and friction inside the hot tank. These constructions are prone to buckling because the circular membrane is compressed, contributing to a leakage shown in fig. 11 [9].

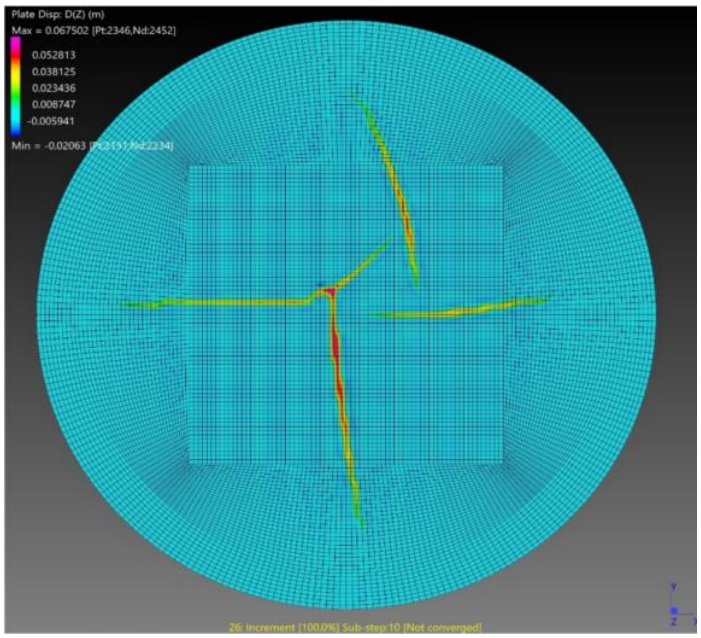



**Figure 11.** FEA results on the molten salt storage tank [9]

Several solutions are proposed to solve the problems. Change in mechanical design can be employed. Multiple layers of the protections can be used. To be more specific, putting each layer one below one can stop the leakage efficiently. Even if one layer is penetrated, the layer after it can stop the damage.

## 6. Future improvement

As far as I am concerned, the above solution cannot be effective, since all the layers can be passed through eventually, which means it does not work out the flaw fundamentally. New materials should be employed in the tank design. Nowadays, the stainless steel is typically used in the tank design [19]. Nevertheless, new materials are supposed to be featured with high intensity and high temperature

resistance. Carbon steel can be utilized to improve tank design. Iron and carbon are the same fundamental components of both carbon steel and stainless steel, but different alloying elements are added. Carbon steel is stronger and more durable than stainless steel [20]. However, the carbon steel is easy to be oxidized when exposed to moisture. Thus, a coating can be put on surface. When siloxane-bonds are cured, they create a cross-linked structure that is typically highly robust, chemically resistant, heat resistant, and light-degradation resistant, resulting in an appropriate choice [21].

In short, proper material should be developed to improve the tank design. Many materials have not been discovered by humans, which means more efforts should be devoted into that. Since the energy loss of the solar panel is up to 25-30 percent [22]. The loss of energy is in forms of heat, so we can utilize it. In the protocol of the solar panel, it uses the hydrogel to absorb the energy and produce the liquid water. Thus, we substitute the hydrogel by the molten salt to store the energy wasted, which can save the energy wasted and store it for peak shaving.

## 7. Conclusion

To put it in a nutshell, the paper mainly discusses the feasibility of the molten salts in terms of both advantages in different aspects and flaws, and then point out some possible solution to them. Some further applications are also mentioned. According to above discussion, the molten slats storage system is a promising, since it has the advantages in chemistry, economy and environment aspects. It is still feasible, even though it has some flaws needed to be solved. This is also why there are already several concentrated solar powers using the molten slat technology. This paper concludes those results and provide my own thoughts. Those analyzes can be used to evaluate whether this technology can be utilized more in the current energy storage system, and some flaws that humans need to deal with. In the future, more effort should be put into studying the stronger material in the tank design in order to prevent the tank leakage.

## References

[1] IEA. Global Energy Crisis. Retrieved on September 9, 2023. Retrieved from: https: //www.iea.org/topics/global-energy-crisis.

[2] Gage, S. H., Kesseli, D., Dupree, J., et al. Technical and economic feasibility of molten chloride salt thermal energy storage systems. Solar Energy Materials and Solar Cells, 2021, 226, 111099.

[3] U.S. Energy Department. Molten Salt Power Tower cost model for the System Advisor Model (SAM). February, 2013, Retrieved on September 9, 2023. Retrieved from: https://doi.org/10.2172/1067902.

[4] Our World in Data. Energy Production and Consumption. Retrieved on September 9, 2023. Retrieved from: https://ourworldindata.org/energy-production-consumption.

[5] Johnson, S. C., Davidson, F. T., Rhodes, J. D., et al. Selecting favorable energy storage technologies for nuclear power. Storage and Hybridization of Nuclear Energy, 2019, 119 - 175.

[6] John Dodaro. Molten salt storage. December 15, 2015. Retrieved on September 9, 2023. Retrieved from: http://large.stanford.edu/courses/2015/ph240/dodaro2/.

[7] Solar thermal energy news. Concentrated Solar Power Tower: Use molten salt as an energy storage system. Retrieved on September 9, 2023. Retrieved from: https://helioscsp.com/concentrated-solar-power-tower-use-molten-salt-as-an-energy-storage-system.

[8] EIA. Electricity data browser. Retrieved on September 9, 2023. Retrieved from: https://www.eia.gov/electricity/data/browser/#/plant/57275/?pin=ELEC.PLANT.GEN.57275-SUN-ALL.M&linechart=ELEC.PLANT.GEN.57275-SUN-ALL.M

[9] Solarpaces. Vast Solar's fix for tank leaks that stymied the first Tower CSP. Retrieved on September 9, 2023. Retrieved from: https://www.solarpaces.org/vast-solar-has-a-fix-for-crescent-dunes-thermal-storage-tank-leak.

[10] Li, S., Song, J., Che, Y., et al. Advances in molten salt synthesis of non-oxide materials. Energy & Environmental Materials, 2021, 6 (2).

[11] Porter, T., Vaka, M. M., Steenblik, P., et al. Computational methods to simulate molten salt thermophysical properties. Communications Chemistry, 2022, 5 (1).

[12] Li, S., Song, J., Che, Y., et al. Advances in molten salt synthesis of non-oxide materials. Energy & Environmental Materials, 2022, 6 (2).

[13] Wikipedia contributors. Molten salt. Retrieved on September 9, 2023. Retrieved from: Wikipedia. https://en.wikipedia.org/wiki/Molten_salt.

[14] Solar thermal energy news. Between 2010 and 2021, the cost of electricity of concentrated solar power (CSP) plants fell by 68%. Retrieved on September 9, 2023. Retrieved from: https://helioscsp.com/between-2010-and-2021-the-cost-of-electricity-of-concentrated-solar-power-csp-plants-fell-by-68/.

[15] U.S. Energy Department. On the Path to SunShot. Advancing Concentrating Solar Power Technology, Performance, and Dispatchability. 2016, Retrieved on September 9, 2023. Retrieved from: https://doi.org/10.2172/1256863.

[16] Piemonte, V., De Falco, M., Tarquini, P., & Giaconia, A. Life Cycle Assessment of a high temperature molten salt concentrated solar power plant. Solar Energy, 2011, 85 (5), 1101 – 1108.

[17] CLEAR Center. GWP* — a better way of measuring methane and how it impacts global temperatures. 2023, Retrieved on September 9, 2023. Retrieved from: https://clear.ucdavis.edu/explainers/gwp-star-better-way-measuring-methane-and-how-it-impacts-global-temperatures.

[18] Environmental Justice Organisations, Liabilities and Trade. Life cycle assessment (LCA), life cycle inventory (LCI) and life cycle impact assessment (LCIA). Retrieved on September 9, 2023. Retrieved from: http://www.ejolt.org/2012/12/life-cycle-assessment-lca-life-cycle-inventory-lci-and-life-cycle-impact-assessment-lcia/.

[19] Untrau, A., Sochard, S., Marias, et al. Analysis and future perspectives for the application of Dynamic Real-Time Optimization to solar thermal plants: A review. Solar Energy, 2022, 241, 275 – 291.

[20] Advanced Piping Products. Carbon Steel vs. Stainless Steel: What's the Big Deal? Retrieved on September 9, 2023. Retrieved from: https://www.appmfg.com/blog/stainless-steel-vs-carbon-steel.-whats-the-big-deal.

[21] Forrest. High temperature coatings explained for engineers and manufacturers. Retrieved on September 9, 2023. Retrieved from: https://resources.forrestpaint.com/high-temperature-coatings-explained-for-engineers-and-manufacturers.

[22] Inverse. Solar panels waste a lot of energy. Scientists have a plan to capture it. 2019, Retrieved on September 9, 2023. Retrieved from: https://www.inverse.com/article/60973-hot-electron-harvesting-could-unlock-big-solar-energy-gains.