Project Notes:

Project Title: **Advancing Thermoelectric Battery Technology for Sustainable Energy Storage**
Name: **Maya Sushkin**

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Contents:

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
Different types of thermal energy systems	Article #7	In project notes	9/11/23
PCM to use in battery	Article #17	In project notes	11/26/23

Literature Search Parameters:

These searches were performed between (Start Date of reading) and XX/XX/2019.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Google	Thermal Energy storage, Phase change materials	

Tags:

Tag Name	

Article #1 Notes: Title

Article notes should be on separate sheets

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Source Title	
Source citation (APA Format)	
Original URL	
Source type	
Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/ Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	

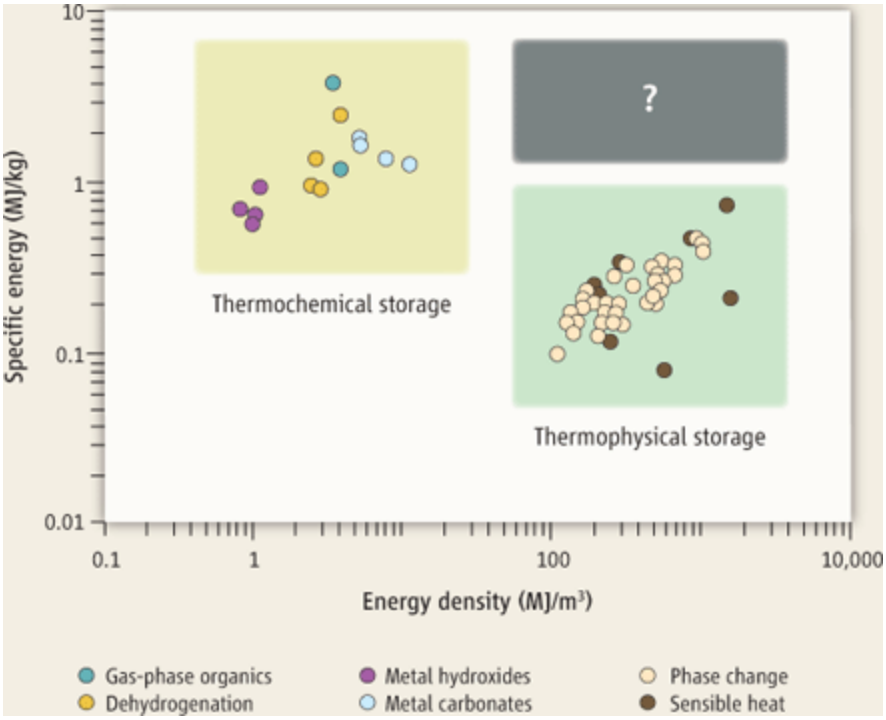
Article #1 Notes: Thermal Energy Storage is No Longer Just Hot Air

Source Title	Thermal Energy Storage is no longer just hot air
Source citation (APA Format)	Xu, T. (2023, June 23). *Thermal energy storage is no longer just hot air*. IEEE Spectrum. https://spectrum.ieee.org/thermal-energy
Original URL	https://spectrum.ieee.org/thermal-energy
Source type	Article
Keywords	Ieee, thermal energy
#Tags	
Summary of key points + notes (include methodology)	Mini Summary: A company called Cheesecake Energy is studying techniques for alternative forms of energy storage. The process goes as such; excess solar electricity is used to power a motor, which drives a piston to compress air, remove the heat generated, and store it in silos of sand. The output heat is suitable for many different uses, such as the food industry.
Research Question/Problem/ Need	Can we use thermal storage as a battery for energy storage where generation exceeds demand?
Important Figures	N/A
VOCAB: (w/definition)	Decarbonization - The process of reducing or completely eliminating carbon emissions
Cited references to follow up on	https://cheesecakeenergy.com/ https://spectrum.ieee.org/compressed-air-energy-storage-makes-a-comeback https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/
Follow up Questions	1. How does the method of using compressed air to generate heat and to extract heat into electricity work? 2. How much sand would you need to make an effective battery for a house?

	3. How does this compare to other battery systems?

Article #2 Notes: Searching For a Better Thermal Battery

Source Title	Searching For a Better Thermal Battery
Source citation (APA Format)	Gur, I., Sawyer, K., & Prasher, R. (2012). Searching for a Better Thermal Battery. *Science*, *335*(6075), 1454–1455. https://doi.org/10.1126/science.1218761
Original URL	https://www.science.org/doi/10.1126/science.1218761
Source type	Article
Keywords	Thermal energy storage
#Tags	
Summary of key points + notes (include methodology)	Mini Summary: Thermal energy storage materials can be grouped into two classes, thermophysical and thermochemical. Although thermochemical technologies have many advantages, they are not widely used. There are many different approaches currently being studied.
Research Question/Problem/ Need	What materials can be used for the most efficient thermal storage?

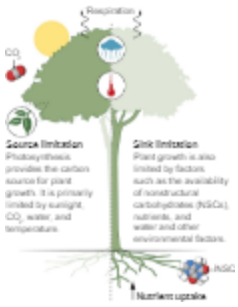
Important Figures	
VOCAB: (w/definition)	Thermochemical - relating to or involving chemical reactions during which quantities of heat are evolved or absorbed
Cited references to follow up on	http://arpa-e.energy.gov/ProgramsProjects/HEATS.aspx Farrington R., Rugh J., *Impact of Vehicle Air-Conditioning on Fuel Economy, Tailpipe Emissions, and Electric Vehicle Range* (NREL/CP-540-28960, 2000; www.nrel.gov/docs/fy00osti/28960.pdf). Kunze K., Wolff S., Lade I., Tonhauser J., *A Systematic Analysis of CO_2-Reduction by an Optimized Heat Supply During Vehicle Warm-Up* (SAE paper 2006-01-1450, 2006; http://papers.sae.org/2006-01-1450).
Follow up Questions	1. What material is the best material for thermal storage? 2. The article mentions it would be good to have a thermal battery in electric vehicles for heating and cooling. Is this a good idea? Is it practical? 3. What are some examples of thermochemical storage?

Article #3 Notes: MIT engineers create an energy-storing supercapacitor from ancient materials

Source Title	MIT Engineers Create an Energy-Storing Supercapacitor From Ancient Materials
Source citation (APA Format)	David L. Chandler | MIT News. (n.d.). *MIT engineers create an energy-storing supercapacitor from ancient materials*. MIT News | Massachusetts Institute of Technology. https://news.mit.edu/2023/mit-engineers-create-supercapacitor-ancient-materials-0731
Original URL	https://news.mit.edu/2023/mit-engineers-create-supercapacitor-ancient-materials-0731
Source type	Journal Article
Keywords	Supercapacitor, carbon black, energy storage
#Tags	
Summary of key points + notes (include methodology)	MIT engineers created a supercapacitor from entirely sustainable materials. They used three materials, cement, carbon black, and a standard electrolyte material such as potassium chloride. A cement and conductive carbon black mixture is made while the water in the cement creates natural openings throughout the mixture, allowing the carbon black to make a network. This design has an extremely large surface area for conductivity. The hardened structure is then drenched in the electrolyte material to equip the carbon with charged particles. The team was only able to successfully light up a 3-volt LED using three small supercapacitors, but they calculated that a cube of “nanocarbon-black-doped concrete” about 3.5 meters across could store 10 kwh of energy.
Research Question/Problem/ Need	While the world steers away from carbon-based energy sources, there needs to be a reliable way to store the renewable energy that is becoming more popular.
Important Figures	N/A

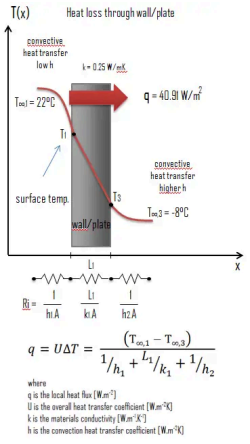
VOCAB: (w/definition)	Supercapacitor - alternative to batteries, delivers energy quicker Electrolyte - liquid/gel that contains ions Hydrophobic - water repelling
Cited references to follow up on	Related: https://cshub.mit.edu/
Follow up Questions	Can a specific combination of cement, carbon black, and water store more or less energy?

Article #4 Notes: The Limits of Forest Carbon Sequestration

Source Title	The Limits of Forest Carbon Sequestration
Source citation (APA Format)	Green, J. K., & Keenan, T. F. (2022). The limits of forest carbon sequestration. *Science*, *376*(6594), 692–693. https://doi.org/10.1126/science.abo6547
Original URL	https://www.science.org/doi/10.1126/science.abo6547
Source type	Journal Article
Keywords	Carbon sequestration, forest
#Tags	
Summary of key points + notes (include methodology)	Due to climate change, there is an interest in planting more trees to remove CO2 from the atmosphere. It was assumed that more CO2 would lead to more plant growth, but this was not the case. The use of GPP enables the study to find out the limitations of tree growth.
Research Question/Problem/ Need	How can we find a way to reduce carbon dioxide in the atmosphere naturally, but not overwhelmingly so that it reduces its effects? What are the limitations on tree growth to absorb carbon dioxide?
Important Figures	
VOCAB: (w/definition)	GPP - gross primary production
Cited references to follow up on	Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2022: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the IPCC* (Cambridge Univ. Press, 2022). P. H. S. Brancalion, K. D. Holl, *J. Appl. Ecol.* **57**, 2349 (2020). G. M. Domke, S. N. Oswalt, B. F. Walters, R. S. Morin, *Proc. Natl. Acad. Sci. U.S.A.* **117**, 24649 (2020).

Follow up Questions	Can planting trees still be a viable solution for carbon removal from the atmosphere?

Article #5 Notes: Sand - Density - Heat Capacity - Thermal Conductivity

Source Title	Sand - Density - Heat Capacity - Thermal Conductivity
Source citation (APA Format)	*Sand | Density, Heat Capacity, Thermal Conductivity*. (2021, May 27). Material Properties. https://material-properties.org/sand-density-heat-capacity-thermal-conductivity/
Original URL	https://material-properties.org/sand-density-heat-capacity-thermal-conductivity/
Source type	Web Page
Keywords	Sand, properties
#Tags	
Summary of key points + notes (include methodology)	Sand is a material composed of rock and mineral particles. There are many different properties of sand, such as density, thermal conductivity, specific heat capacity, etc.
Research Question/Problem/ Need	N/A
Important Figures	
VOCAB: (w/definition)	Heat flux - heat loss

	Tensile - relating to tension - ex. Tensile strength
Cited references to follow up on	https://material-properties.org/what-is-density-physics-definition/ https://www.thermal-engineering.org/what-is-thermal-conductivity-definition/ https://www.nuclear-power.com/nuclear-engineering/heat-transfer/convection-convective-heat-transfer/newtons-law-of-cooling/
Follow up Questions	For the specific purpose of heat storage, is less or more thermal conductivity optimal?

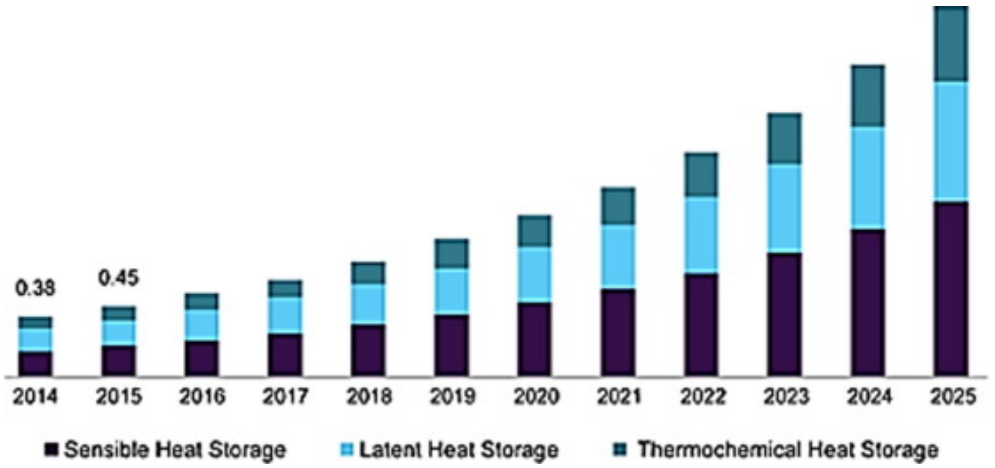
Article #6 Notes: 1752 A DIY Sand Battery - The Theory, Practice and Use

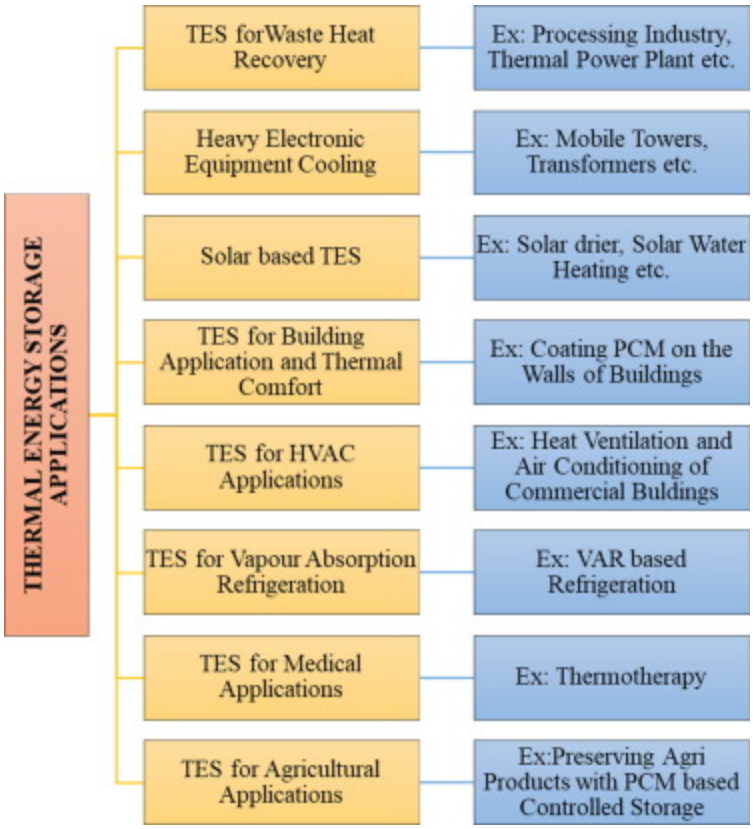
Source Title	1752 A DIY Sand Battery - The Theory, Practice and Use
Source citation (APA Format)	*1752 A DIY Sand Battery - The Theory, Practice And Use*. (n.d.). Retrieved September 4, 2023, from https://www.youtube.com/watch?v=Icai6OOIh2M
Original URL	https://www.youtube.com/watch?v=Icai6OOIh2M
Source type	Video
Keywords	Sand battery, DIY
#Tags	
Summary of key points + notes (include methodology)	Building and testing a basic sand battery to show methodology and functionality.
Research Question/Problem/ Need	Can we make a sustainable, low cost sand battery that is viable to use?
Important Figures	N/A
VOCAB: (w/definition)	Ambient heat - the thermal condition of the surrounding environment Althernate current - a type of electrical current, in which the direction of the flow of electrons switches back and forth at regular intervals or cycles.
Cited references to follow up on	N/A
Follow up Questions	How could the sand battery be made to be more efficient? Could this design be more secure to possibly use it not as just a demonstration/proof-of-concept, but as an actual battery?

Article #7 Notes: A comprehensive review on current advances of thermal energy storage and its application

Source Title	A comprehensive review on current advances of thermal energy storage and its applications
Source citation (APA Format)	Chavan, S., Rudrapati, R., & Manickam, S. (2022). A comprehensive review on current advances of thermal energy storage and its applications. *Alexandria Engineering Journal*, *61*(7), 5455–5463. https://doi.org/10.1016/j.aej.2021.11.003
Original URL	https://www.sciencedirect.com/science/article/pii/S1110016821007328
Source type	Journal Article
Keywords	HVAC, Phase change materials, Thermal energy storage, Thermal storage materials, Waste heat recovery
#Tags	
Summary of key points + notes (include methodology)	Current common energy production that use fossil fuels release a lot of waste thermal energy which can be recovered and stored with different techniques, such as latent heat storage and sensible heat storage. There have been many studies as to how thermal energy can be stored and used. One system described used solar energy to heat water for homes with energy storage in a thermal energy storage system. Applications discussed include waste heat recovery, electronic equipment, solar thermal energy storage, thermal comfort in buildings, HVAC (Heating Ventilation and Air Conditioning), refrigeration, and medical applications. These systems are expected to grow in the future as a response to increase efficiency of energy systems and the growth of renewable energy requiring energy storage capacity. ● Three types of heat storage - latent, sensible, and thermochemical ● Most of the energy (66%) we produce today is wasted through heat
Research Question/Problem/ Need	How can we best optimize the production of thermal energy and what are its applications?

Important Figures





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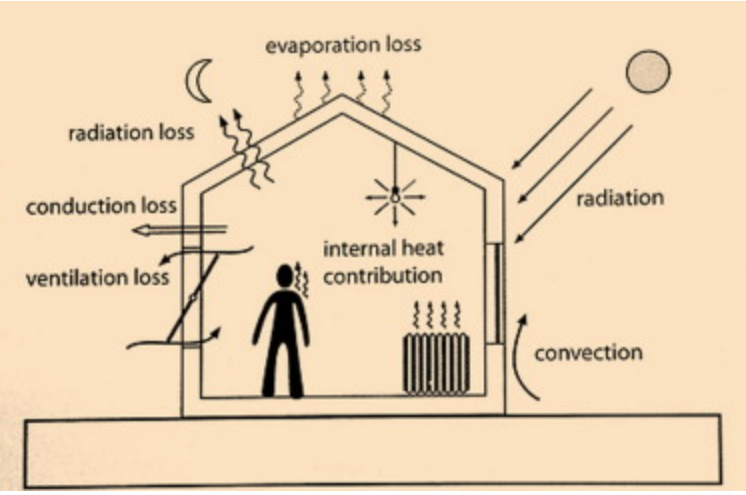
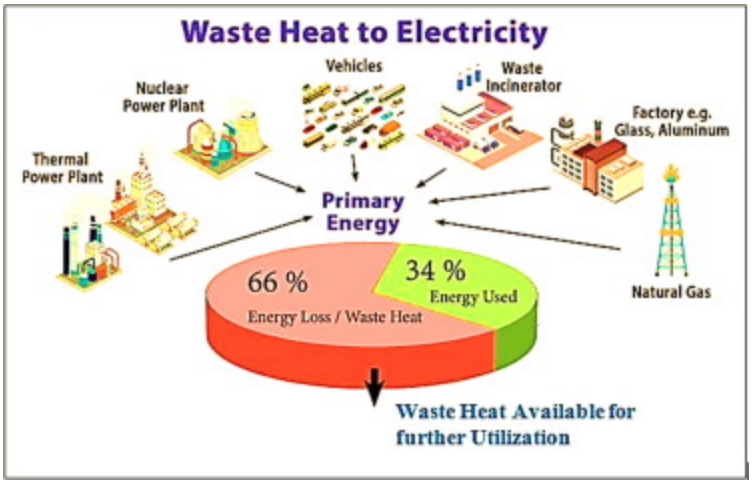
<tr><td></td><td> 


</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>Latent heat form- usage of phase-change materials to store heat
Sensible heat form - usage of solid-state materials to store heat
Thermochemical storage - stores heat in chemical reaction
Cogeneration - the simultaneous or sequential production of mechanical energy and thermal energy.</td></tr>
<tr><td>Cited references to follow up on</td><td>F. Agyenim, N. Hewitt, P. Eames, M. Smyth
A review of materials, heat transfer and phase change problem formulation for latent heat thermal energy storage systems (LHTESS)
Renew. Sustain. Energy Rev., 14 (2) (2010), pp. 615-628,
10.1016/j.rser.2009.10.015

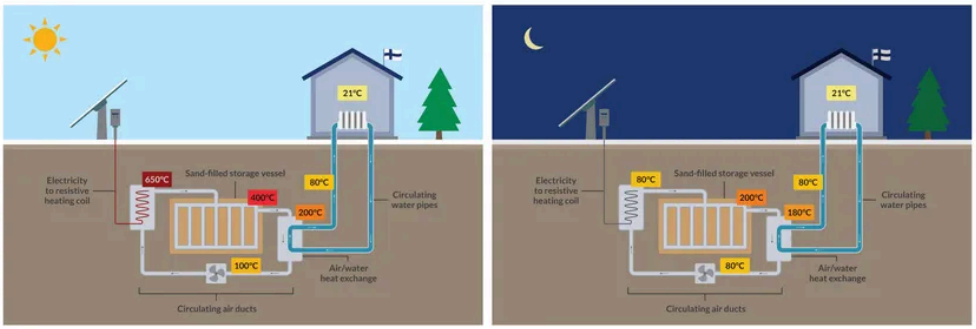
Y. Jiang, M. Liu, Y. Sun
Review on the development of high temperature phase change material composites for solar thermal energy storage
Sol. Energy Mater. Sol. Cells., 203 (2019), p. 110164,
10.1016/j.solmat.2019.110164

Y. Lin, Y. Jia, G. Alva, G. Fang
Review on thermal conductivity enhancement, thermal properties and</td></tr>
</table>

	applications of phase change materials in thermal energy storage Renew. Sustain. Energy Rev., 82 (2018), pp. 2730-2742, 10.1016/j.rser.2017.10.002
Follow up Questions	Could TES be used for electrical production to the home rather than simply supplying hot water? Could TES be viable at a home level using a common cost-effective storage medium such as sand? If phase-change material is to be used, what would be the best material? Is it better to store heat from solar using heated water from the sun, or to convert to electricity and use electrical heaters?

Article #8 Notes: Heating buildings with solar energy stored in sand

Source Title	Heating buildings with solar energy stored in sand
Source citation (APA Format)	Petrillo, A. (2023, January 18). *Polar Night Energy Designs a Sand-Based Heat Storage System - IEEE Spectrum*. https://spectrum.ieee.org/polar-night-energy-sand-battery
Original URL	https://spectrum.ieee.org/polar-night-energy-sand-battery
Source type	Article
Keywords	Thermal energy storage, sand battery, Finland
#Tags	
Summary of key points + notes (include methodology)	The process takes place in Finland where there is a great need for heating. The project, “think globally, act locally” was started by two university students in an attempt to “build an energy-self-sufficient and cost-effective hippie commune for engineers using only solar power” The project grew into a pilot plant that uses sustainable energy to heat air and water and circulate it through the homes of Finland. Engineers studied ways to develop sustainable batteries. There were no cost-effective ways to store electricity, so they decided to make a battery that stores heat. By using the sun as well as heating ducts, they were able to create a “hot core” out of sand that could gain heat during the day, and slowly release it at night.
Research Question/Problem/ Need	How can we create heat on a large scale while not increasing our fossil fuel consumption?

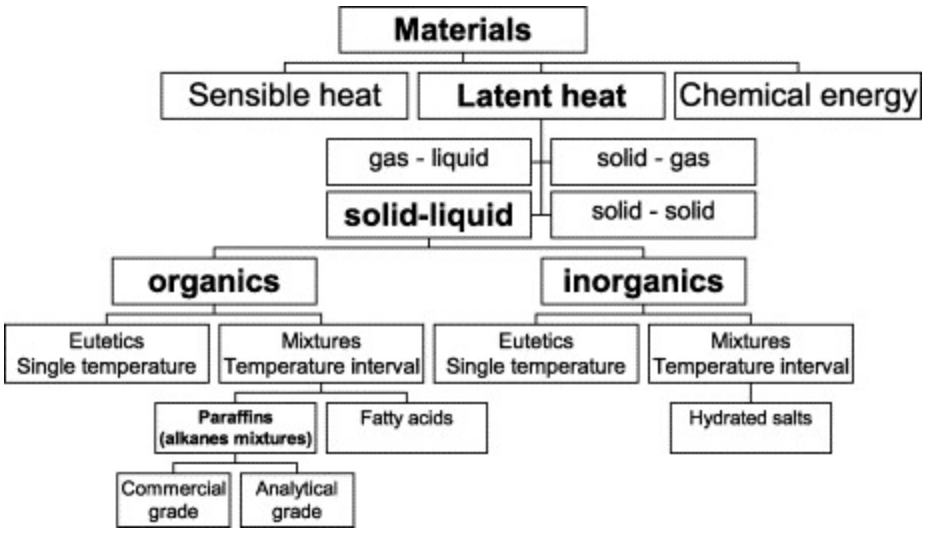
Important Figures	
VOCAB: (w/definition)	Heat exchanger - a device for transferring heat from one medium to another Combustion-based - requires the use of burning fossil fuels for energy
Cited references to follow up on	*Statistics Finland*, "Over one-half of Finland's electricity was produced with renewable energy sources in 2020", November 2021.
Follow up Questions	In combating climate change, how does Polar Night Energy's system contribute to reducing emissions, and how does it help in the global effort to meet climate goals?

Article #9 Notes: Review on thermal energy storage with phase change: materials, heat transfer analysis and applications

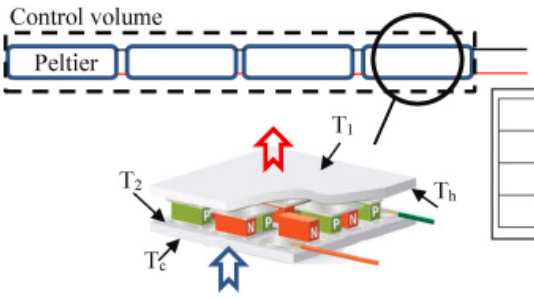
Source Title	Review on thermal energy storage with phase change: materials, heat transfer analysis and applications
Source citation (APA Format)	Zalba, B., Marín, J. M., Cabeza, L. F., & Mehling, H. (2003). Review on thermal energy storage with phase change: materials, heat transfer analysis and applications. *Applied Thermal Engineering*, *23*(3), 251–283. https://doi.org/10.1016/S1359-4311(02)00192-8
Original URL	https://www.sciencedirect.com/science/article/pii/S1359431102001928?via=ihub
Source type	Journal Article
Keywords	PCM, phase change materials, latent thermal energy storage, Heat transfer
#Tags	

Summary of key points + notes (include methodology)	- Reviews over 150 commonly used PCMs.
	- Consolidates over 230 references
	- 45 commercially available PCMs
	- Can be used to lower the costs of a heat pump through a link between PEM-TES and heat pump/heat distribution system
	- Properties:
	  - Melting temp
	  - Heat of fusion
	  - Thermal conductivity
	  - Density
	Mini-Summary:
	The paper, “Review on thermal energy storage with phase change: materials, heat transfer analysis and applications” by Belén Zalba lists over 150 materials that are used in research as PCMs, including 45 commercially available PCMs. The article consolidates over 230 references and is a good paper to reference for PCM materials, heat transfer characteristics, and applications.

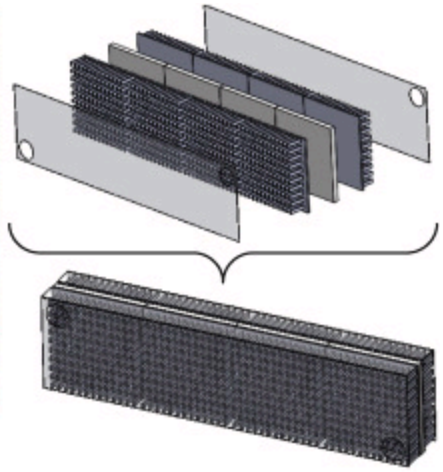
Research Question/Problem/ Need	What are the different properties of phase-change materials?

Important Figures	 Classification
VOCAB: (w/definition)	Heat transfer - The movement of heat across the border of the system due to a difference in temperature between the system and its surroundings. PCM - phase change material Heat of fusion - heat required to melt a solid
Cited references to follow up on	A. Abhat Low temperature latent heat thermal energy storage: heat storage materials G.A. Lane Solar Heat Storage: Latent Heat Material, vol. I, Background and Scientific Principles
Follow up Questions	With paraffin wax having a melting temperature of 64 degrees C, is it be ideal for my use? What is the best material for the cold and hot sinks for my battery? What is the best heat transfer device into hot and cold sinks?

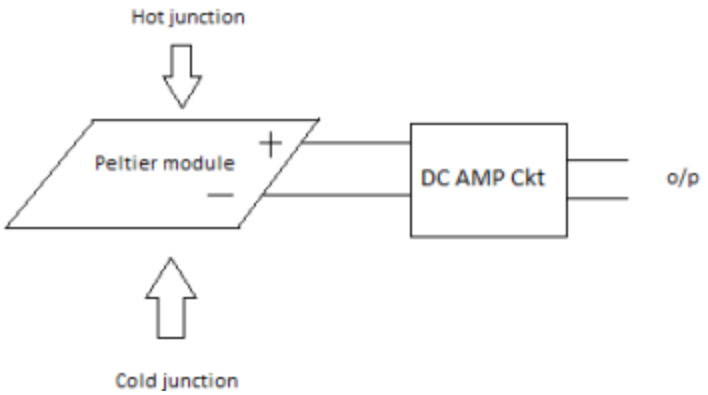
Article #10 Notes: Economic-effectiveness experimental case study for instant cooling of drinking-water using Peltier module

Source Title	Economic-effectiveness experimental case study for instant cooling of drinking-water using Peltier module
Source citation (APA Format)	Shi, L., M Eldin, S., Abdulghani, Z. R., Ali, E., Guo, W., Anqi, A. E., & Alkhamis, N. (2023). Economic-effectiveness experimental case study for instant cooling of drinking-water using Peltier module. *Case Studies in Thermal Engineering*, *42*, 102710. https://doi.org/10.1016/j.csite.2023.102710
Original URL	https://www.sciencedirect.com/science/article/pii/S2214157X23000163
Source type	Journal Article
Keywords	Cost economic, SPECO, Thermoelectric, Peltier, Cooler, Water cooler, Experimental
#Tags	
Summary of key points + notes (include methodology)	Peltier devices are commonly used for cooling applications. In this article, "Economic-effectiveness experimental case study for instant cooling of drinking-water using Peltier module" (Shi et al., 2023), a study was conducted to build an instant water-cooler with peltier devices. They found that in order to maximize cooling effects, they needed to find a way to cool down the hot side of the device.
Research Question/Problem/ Need	How can the efficiency of Peltier devices be maximized to create an instant water cooler?
Important Figures	 Diagram of peltier device

Element	Fuel	Product
Hot side ceramic	E_{QH}	E_1
Cold side ceramic	E_2	E_{QC}
Thermocouples	E_1+E_p	E_2

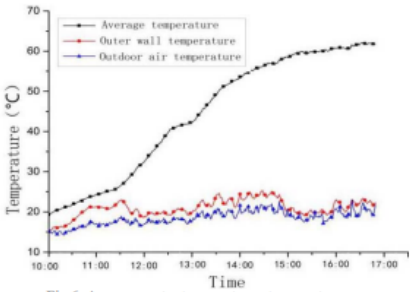
	 Cooling design
VOCAB: (w/definition)	SPECO - Specific Energy Costing
Cited references to follow up on	H.S. Dizaji, S. Pourhedayat, F. Aldawi, H. Moria, A.E. Anqi, F. Jarad Proposing an innovative and explicit economic criterion for all passive heat transfer enhancement techniques of heat exchangers H.S. 2, S. Jafarmadar, S. Khalilarya, A. Moosavi An exhaustive experimental study of a novel air-water based thermoelectric cooling unit
Follow up Questions	What is the best voltage for creating a greater heat differential between the hot and cold side of the peltir devices? What is the best fan speed for cooling? Can I calculate the efficiency using a computer program like SolidWorks?

Article #11 Notes: Highly efficient electricity generation with Peltier Module

Source Title	Highly efficient electricity generation with Peltier Module
Source citation (APA Format)	Kaphungkui, N., Phukan, A., Sharma, M., Abishaek, G., & Subhani, M. (2016). Highly Efficient Electricity Generation with Peltier Module. *International Journal of Engineering Trends and Technology*, *35*.
Original URL	http://www.ijettjournal.org/2016/volume-35/number-10/IJETT-V35P300.pdf
Source type	Journal Article
Keywords	Peltier Module; Seebeck Effect; Thermocouple
#Tags	
Summary of key points + notes (include methodology)	Because electricity is hard to come by in low-income areas, an experiment was conducted to test the voltage production of Peltier modules. Experiments tested different ways of increasing voltage output, including heating the hot junction of the module with a candle and tin, with a Fresnel lens, and a DC output amplifier circuit. The amplifier could generate an output voltage capable of lighting 6 LEDs and charging a mobile phone.
Research Question/Problem/ Need:	How can we maximize Peltier voltage production?
Important Figures	 Electricity generation with Peltier module

VOCAB: (w/definition)	Fresnel Lens - a flat lens made of a number of concentric rings to reduce spherical aberration
Cited references to follow up on	Tehseen Ilahi, Muhammad Javaid Aslam, Energy Generation Using Reverse Peltier Effect By Fresnel Lens Concentration, Department of Electrical Engineering Sharif College of Engineering and Technology (SCET) affiliated with UET Lahore. Pakistan. Hongnan Fan, Randeep Singh, Aliakbar Akbarzadeh Power Generation from Thermoelectric Cells by Using HighConcentrated Solar Dish, Proceedings of the Solar10, the 48th ANZSES Annual Conference,1 Dec – 3 Dec, 2010,Canberra, ACT, Australia
Follow up Questions	Could this setup be scaled to produce larger amounts of voltage? How long did the cell phone charge for?

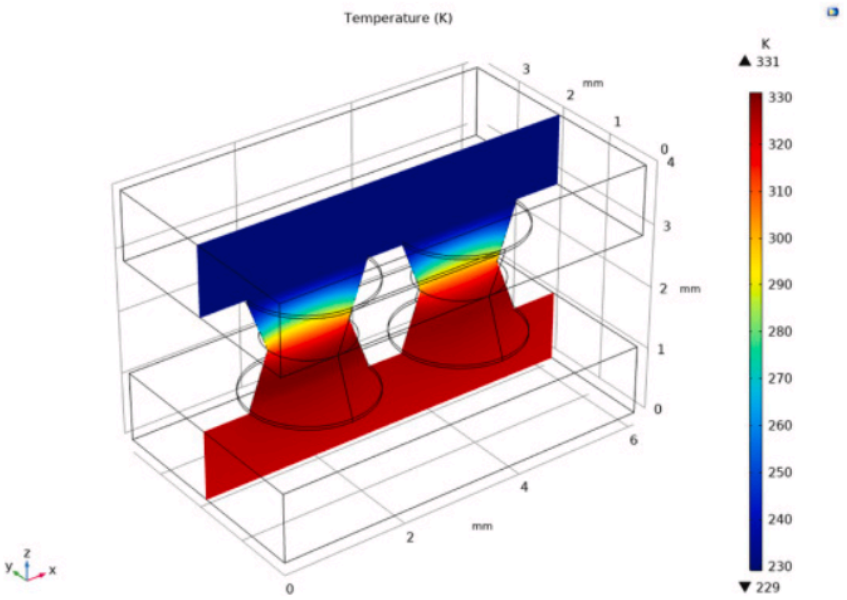
Article #12 Notes: Experimental Study on Thermal Energy Storage Performance of Water Tank with Phase Change Materials in Solar Heating System

Source Title	Experimental Study on Thermal Energy Storage Performance of Water Tank with Phase Change Materials in Solar Heating System
Source citation (APA Format)	Liang, F., Zhang, Y., Liu, Q., Jin, Z., Zhao, X., & Long, E. (2017). Experimental Study on Thermal Energy Storage Performance of Water Tank with Phase Change Materials in Solar Heating System. *Procedia Engineering*, *205*, 3027–3034. https://doi.org/10.1016/j.proeng.2017.10.257
Original URL	https://www.sciencedirect.com/science/article/pii/S1877705817349172
Source type	Journal article
Keywords	Phase change materials; Thermal energy storage system; Temperature change characteristics; Dynamic performance; Experimental test
#Tags	
Summary of key points + notes (include methodology)	With an increasing need for heat, there is also a need for clean and efficient energy. Many experiments were conducted, testing Phase Change Materials, and results showed that the storage tank constructed had a storage capacity of 51222 kJ.
Research Question/Problem/ Need:	How can we use phase change materials to maximize thermal energy storage?
Important Figures	 Fig.6. Average water temperature, temperature of outer wall and outdoor air temperature during the solar thermal storage process

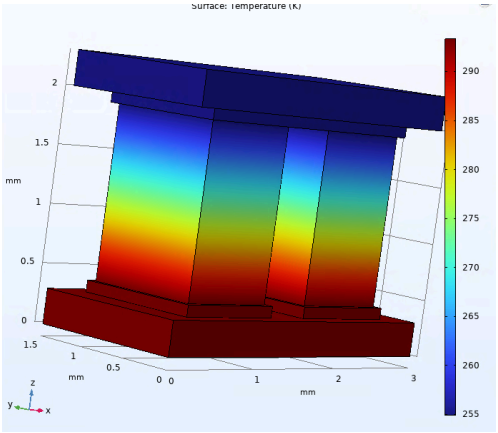
VOCAB: (w/definition)	Endothermic - (of a reaction or process) accompanied by or requiring the absorption of heat
Cited references to follow up on	Elhab BR, Sopian K, Mat S, Lim C, Sulaiman MY, Ruslan MH, 2012. Optimizing tilt angles and orientations of solar panels for Kuala Lumpur, Malaysia. Sci Wei Gaosheng, Xing Lijing, Du Xiaoze, Yang Yongping. Research Status and Selection of Phase Change Thermal Energy Storage Materials for CSP Systems, J. Proceedings of the CSEE.(03) (2014) 325-335.
Follow up Questions:	How can this technology be applied for storing renewable energy?

Article #13 Notes: Investigation of the impact of the thermoelectric geometry on the cooling performance and thermal—mechanic characteristics in a thermoelectric cooler

Source Title	Investigation of the impact of the thermoelectric geometry on the cooling performance and thermal—mechanic characteristics in a thermoelectric cooler
Source citation (APA Format)	Liu, H., Li, G., Zhao, X., Ma, X., & Shen, C. (2023). Investigation of the impact of the thermoelectric geometry on the cooling performance and thermal—mechanic characteristics in a thermoelectric cooler. *Energy*, *267*, 126471. https://doi.org/10.1016/j.energy.2022.126471
Original URL	https://www.sciencedirect.com/science/article/pii/S0360544222033576
Source type	Journal Article
Keywords	Thermoelectric cooler; GeometryPerformance analysis; Thermal-mechanical analysis; Finite element method; Multiphysics
#Tags	
Summary of key points + notes (include methodology)	Models for TEC legs were constructed and run in a simulation using COMSOL Multiphysics. Results showed an optimal delta T at 50 degrees with the most effective design.
Research Question/Problem/ Need:	What is the most effective TEC design, and under what temperatures does it perform best?

Important Figures	 Example model of TEC leg
VOCAB: (w/definition)	Electrical resistance - a measure of the opposition to current flow in an electrical circuit Coefficient of performance - calculated as the ratio of cooling capacity provided to electrical power consumed
Cited references to follow up on	S. B Riffat, Xiaoli Ma Thermoelectrics: a review of present and potential applications Appl Therm Eng, 23 (Issue 8) (2003), pp. 913-935 Di Liu, Fu-Yun Zhao, Hong-Xing Yang, Guang-Fa Tang Thermoelectric mini cooler coupled with micro thermosiphon for CPU cooling system Energy, 83 (2015), pp. 29-36 ISSN 0360-5442
Follow up Questions	Can these legs be implemented in Peltier Modules for thermoelectric cooling?

Article 14 Notes: COMSOL Multiphysics - Thermoelectric Cooler model

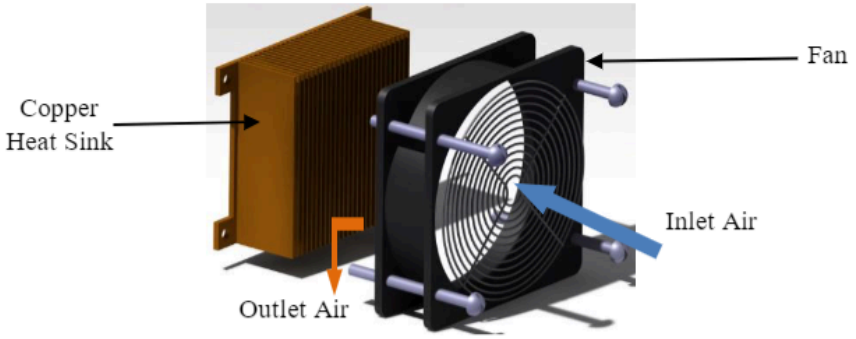
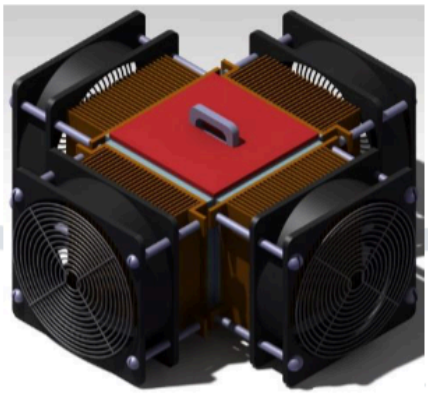
Source Title	COMSOL Multiphysics - Thermoelectric Cooler model
Source citation (APA Format)	*COMSOL Multiphysics - Thermoelectric Cooler model*. (2021). https://www.youtube.com/watch?v=WoQy8i32vbc
Original URL	https://www.youtube.com/watch?v=WoQy8i32vbc
Source type	Video
Keywords	COMSOL, TEC, P-N junction
#Tags	
Summary of key points + notes (include methodology)	Tutorial on how to model a P-N Junction in COMSOL Multiphysics
Research Question/Problem/ Need	How can a P - N junction of a Peltier Module (or Thermoelectric cooler) be modeled?
Important Figures	 Created by Maya Sushkin, Model of P - N junction of Peltier Module (TEC)
VOCAB: (w/definition)	N/A
Cited references to follow up on	N/A
Follow up Questions	How can I model an entire Peltier Module in COMSOL Multiphysics?

Article #15 Notes: How to Simulate Thermoelectric Devices and TECs

Source Title	How to Simulate Thermoelectric Devices and TECs
Source citation (APA Format)	*COMSOL Multiphysics - How to Simulate Thermoelectric Devices and TECs.* (2019). https://www.comsol.com/video/simulate-thermoelectric-devices-tecs
Original URL	https://www.comsol.com/video/simulate-thermoelectric-devices-tecs
Source type	Video
Keywords	COMSOL, Thermoelectric Device, Thermoelectric Cooler
#Tags	
Summary of key points + notes (include methodology)	Tutorial on how to model a TEC in COMSOL Multiphysics
Research Question/Problem/ Need	How can we model Thermoelectric devices in COMSOL MultiPhysics?
Important Figures	N/A
VOCAB: (w/definition)	bismuth telluride - semiconductor use for Thermoelectric cooling
Cited references to follow up on	n/a
Follow up Questions	This tutorial shows how to model a very small TEC, could a TEC1-12706 be modeled?

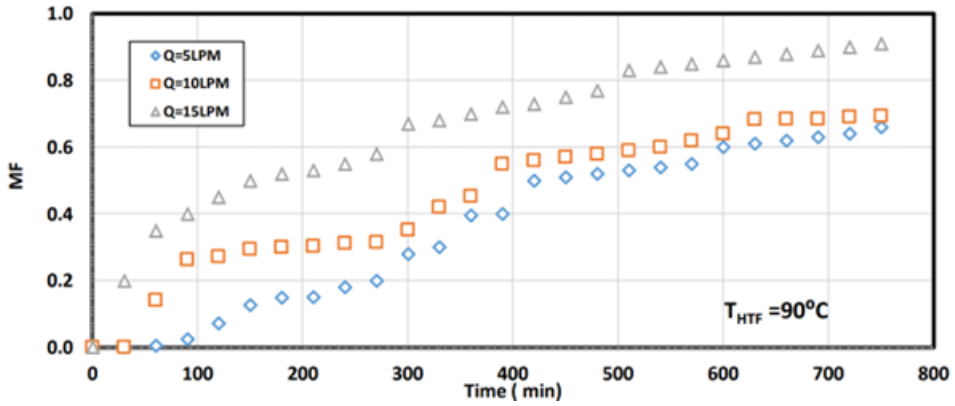
Article #16 Notes: Rapid Water Freezer Using Thermoelectric Module

Source Title	Rapid water freezer using thermoelectric module
Source citation (APA Format)	Patil, S., Khodegaonkar, A. (2019). Rapid water freezing using thermoelectric module. 10.13140/RG.2.2.18694.83520
Original URL	https://www.researchgate.net/publication/333673168_Rapid_Water_Freezer_Using_Thermoelectric_Module
Source type	Journal Article
Keywords	Sub-zero, TEM, Water cooler
#Tags	
Summary of key points + notes (include methodology)	It was attempted to freeze water using TEMs. After designing and testing, a final design to freeze water was constructed using 16 TEMs.
Research Question/Problem/ Need:	How can we freeze water using TEMs?

Important Figures	 Figure 4.3 Air Flow Over Heat Sink  Figure 4.4 Final Thermoelectric Water Freezer Water Freezer design
VOCAB: (w/definition)	Sub-zero - below 0 degrees celsius (of temperature)
Cited references to follow up on	n/a
Follow up Questions	Could I implement this technique in my thermal battery to optimize freezing water to make a phase change?

Article #17 Notes: Experimental investigation of melting behavior of PCM by using coil heat source inside cylindrical container

Source Title	Experimental investigation of melting behavior of PCM by using coil heat source inside cylindrical container
Source citation (APA Format)	Tayssir, M., Eldemerdash, S., Sakr, R., El-Shamy, A. R., & Abdellatif, O. E. (2017). Experimental investigation of melting behavior of PCM by using coil heat source inside cylindrical container. Journal of Electrical Systems and Information Technology, 4(1), 18–33. https://doi.org/10.1016/j.jesit.2016.10.008
Original URL	Experimental investigation of melting behavior of PCM by using coil heat source inside cylindrical container - ScienceDirect
Source type	Journal Article
Keywords	PCM, Thermal energy storage, Melting, HTF
#Tags	
Summary of key points + notes (include methodology)	To study the behavior of melting a PCM, a test was conducted in which paraffin wax in a cylindrical container was melted using a 300 mm coil. The results showed that it was most effective in melting paraffin when the inlet temperature of HTF was 90 degrees Celcius.
Research Question/Problem/ Need:	What is the optimal temperature to melt paraffin wax?

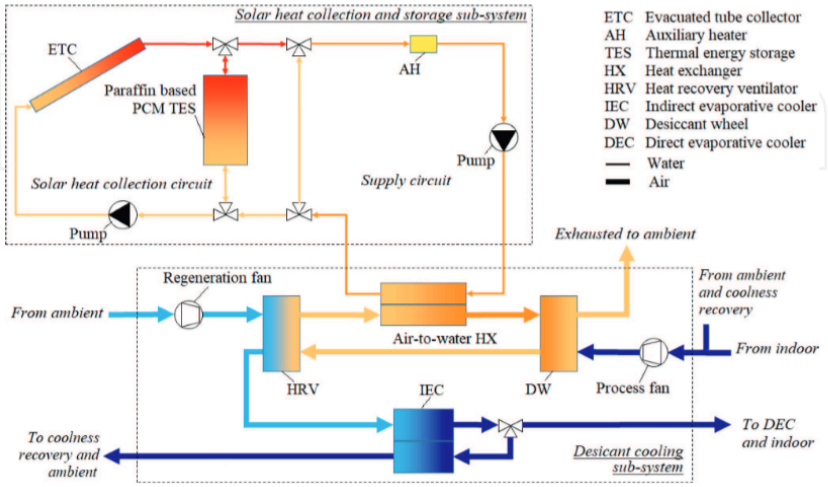
Important Figures	 Different HTF flows with increasing melt factor over a duration of time
VOCAB: (w/definition)	HTF - Heat Transfer fluid
Cited references to follow up on	Thermal Energy Storage-systems and Applications (2nd ed.), John Wiley & Sons Ltd, Chichester, United Kingdom (2011) Assessing long-term performance of centralized thermal energy storage system Appl. Therm. Eng., 62 (2014), pp. 313-321 CFD analysis of melting process in a shell-and-tube latent heat storage for concentrated solar power plants Appl. Energy, 164 (2016), pp. 711-722
Follow up Questions	How can I use this technology to melt Paraffin wax in my thermal battery?

Article #18 Notes: Simulation of temperature distribution in water-cooled induction heating coil - Comsol Multiphysics

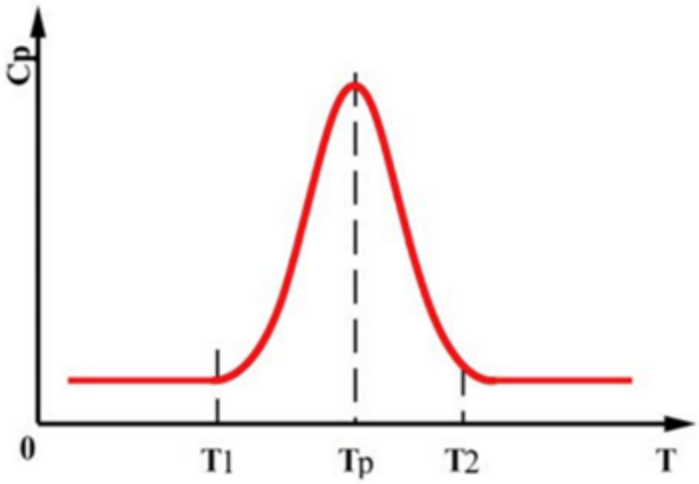
Source Title	Simulation of temperature distribution in water-cooled induction heating coil - Comsol Multiphysics
Source citation (APA Format)	*Simulation of temperature distribution in water-cooled induction heating coil - Comsol Multiphysics*. (2021). https://www.youtube.com/watch?v=AeFbke_y_JE
Original URL	https://www.youtube.com/watch?v=AeFbke_y_JE
Source type	Video
Keywords	Temperature Distribution, Heating Coil, Copper, COMSOL Multiphysics
#Tags	
Summary of key points + notes (include methodology)	Tutorial on how to model temperature distribution within a heating coil.
Research Question/Problem/ Need	How can a heating coil be modeled in COMSOL Multiphysics?
Important Figures	n/a
VOCAB: (w/definition)	Heating Coil - A coil of wire heated by the passage of an electric current and used for producing and maintaining a high temperature in various scientific operations or for industrial purposes.
Cited references to follow up on	n/a
Follow up Questions	Can I use this model to model resistive heating for the paraffin wax in my battery?

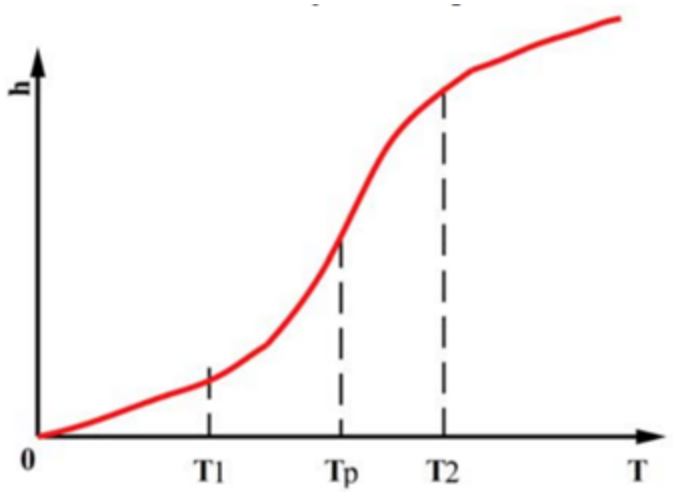
Article #19 Notes: Solar Thermal Energy Storage Using Paraffins as Phase Change Materials for Air Conditioning in the Built Environment

Source Title	Solar Thermal Energy Storage Using Paraffins as Phase Change Materials for Air Conditioning in the Built Environment
Source citation (APA Format)	Lin, W., Ma, Z., Ren, H., Liu, J., Li, K. (2019). Solar Thermal Energy Storage Using Paraffins as Phase Change Materials for Air Conditioning in the Built Environment. Paraffins[] http://dx.doi.org/10.5772/intechopen.86025
Original URL	https://www.researchgate.net/publication/332836254_Solar_Thermal_Energy_Storage_Using_Paraffins_as_Phase_Change_Materials_for_Air_Conditioning_in_the_Built_Environment
Source type	Journal Article
Keywords	Thermal energy storage, phase change materials, HVAC system, solar energy, built environment
#Tags	
Summary of key points + notes (include methodology)	A thermal HVAC system was constructed and tested with the phase change material paraffin wax. Results showed that an HVAC system can be made up to 47% more efficient using paraffin and convective heat fins.
Research Question/Problem/ Need	Energy to demand for HVAC systems are high. Thermal energy is needed as a cost-effective, sustainable solution.

Important Figures	 solar-assisted heating system with PCM of paraffin wax
VOCAB: (w/definition)	CENG - compressed, expanded natural graphite - used in water heater Convection - the movement caused within a fluid by the tendency of hotter and therefore less dense material to rise, and colder, denser material to sink under the influence of gravity, which consequently results in the transfer of heat.
Cited references to follow up on	U.S. Energy Information Administration. Available at http://www.eia.gov/consumption/ (Accessed: 26-01-2019) Perez-Lombard L, Ortiz J, Pout C. A review on buildings energy consumption information. Energy and Buildings. 2008; 40 :394-398
Follow-up Questions	Different paraffin waxes were used in experimentation. Which type with which melting point would be best for my battery?

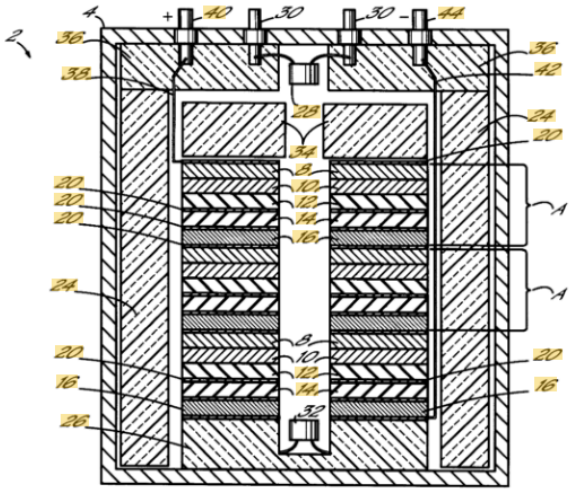
Article #20 Notes: Thermal energy storage: an overview

Source Title	Thermal energy storage: an overview
Source citation (APA Format)	Gabriela, L. (2012). Solar Thermal Energy Storage Using Paraffins as Phase Change Materials for Air Conditioning in the Built Environment. Applied Mathematics and Mechanics https://www.researchgate.net/publication/272179305_Thermal_energy_storage_an_overview
Original URL	https://www.researchgate.net/publication/272179305_Thermal_energy_storage_an_overview
Source type	Journal Article
Keywords	thermal energy storage, heat storage, storage of thermal energy, seasonal heat storage, sensible heat storage, latent heat storage, thermochemical heat storage
#Tags	
Summary of key points + notes (include methodology)	In order to build a heat storage unit, many materials and phase change mediums must be considered, taking into account sensible, chemical, liquid, and separate thermal storage solutions.
Research Question/Problem/ Need	Renewable energy resources vary in availability. A device is needed to store renewable energy in the form of heat during the summer in order to use it during the winter.
Important Figures	 Heat capacity vs PCM temperature

	 Heat input vs. PCM temperature
VOCAB: (w/definition)	Seasonal heat storage - energy is stored for days, weeks, or months to compensate for a periodic variability of the source of heat, such as solar or wind
Cited references to follow up on	incer, I., Evaluation and selection of energy storage systems for solar thermal applications , International Journal of Energy Research, Int. J. Energy Res., 23 1017-1028 (1999) Duffie, J.A., Beckham, W.A., Solar engineering of thermal processes, 3th ed., John Wiley and Sons, 2006
Follow up Questions	Which phase change material can store the most amount of energy and still be within my temperature range?

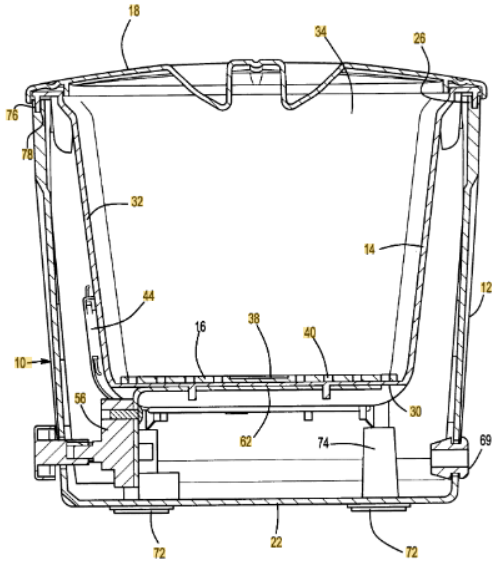
Patents:

Patent #1 Notes: Thermal Battery

Source Title	Thermal Battery
Source citation (APA Format)	Spencer, R. D. (2002). *Thermal battery* (Patent US6475662B1). https://patents.google.com/patent/US6475662B1/en
Original URL	https://patents.google.com/patent/US6475662B1/en
Source type	Patent
Keywords	Thermal Energy, Battery
#Tags	
Summary of key points + notes (include methodology)	A thermal battery that uses a differential temperature using an activatable heat source and an optional non–activated heat source.
Research Question/Problem/ Need	Improve thermal battery efficiency
Important Figures	 Thermal battery diagram
VOCAB: (w/definition)	Pyrotecnic - relating to fireworks
Cited references to follow up on	US3575714A 1953-08-07

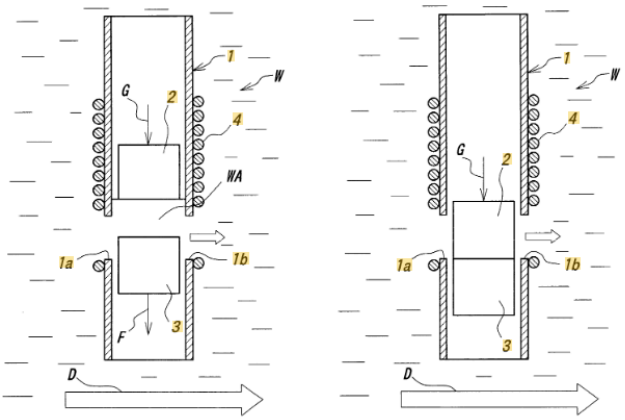
	1971-04-20 Catalyst Research Corp Thermal type primary cell
Follow up Questions	Is this technology applicable to my thermal battery?

Patent #2 Notes: Paraffin Bath

Source Title	Paraffin Bath
Source citation (APA Format)	Glucksman, D. (2003). *Paraffin bath* (Patent US6573481B2). https://patents.google.com/patent/US6573481/en
Original URL	https://patents.google.com/patent/US6573481/en
Source type	Patent
Keywords	Paraffin wax, thermal energy
#Tags	
Summary of key points + notes (include methodology)	A container used for heating and melting paraffin wax. Contains thermostatic sensors to control heating elements. Used for therapeutic and healing purposes.
Research Question/Problem/ Need	Melt paraffin for therapeutic purposes.
Important Figures	 Fig–2 Paraffin bath diagram
VOCAB: (w/definition)	Polypropylene - synthetic resin that is a polymer of propylene, used for molded objects

Cited references to follow up on	US1390719A 1920-01-08 1921-09-13 Lozano Joaquin Grande Thermo-electrical apparatus for boiling and heating purposes
Follow up Questions	Is heating from up underneath the tub necessary for melting most effectively?

Patent #3 Notes: Freezing device for supercooled water

Source Title	Freezing device for supercooled water
Source citation (APA Format)	Hozumi, T., Saito, A., Okawa, S., & Kumano, H. (2002). *Freezing device for supercooled water* (Patent US6354102B1). https://patents.google.com/patent/US6354102B1/en
Original URL	https://patents.google.com/patent/US6354102B1/en
Source type	Patent
Keywords	Supercooled, Freezer, Cylinder, Piston
#Tags	
Summary of key points + notes (include methodology)	A small device capable of freezing water using a piston that expels supercooled water into a cylinder in order to freeze it.
Research Question/Problem/ Need	Freeze water at any desired time.
Important Figures	 Supercooler diagram
VOCAB: (w/definition)	Supercool - to cool a liquid below its freezing point without solidification
Cited references to follow up on	US5533344A * 1995-04-24 1996-07-09 Duh; Shi-Chin Method for rapidly solidifying water in a container

Follow up Questions	Must the water already be supercooled to freeze it? How is the water in the container kept supercooled?