
IDEA2021
Powering the Future: District Energy/CHP/Microgrids
Sept. 27-29 | Austin Convention Center | Austin, Texas

Multi-Source Heat Pumps for Large Scale Applications

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Seasonal Storage Technologies

NDSU NORTH DAKOTA STATE UNIVERSITY

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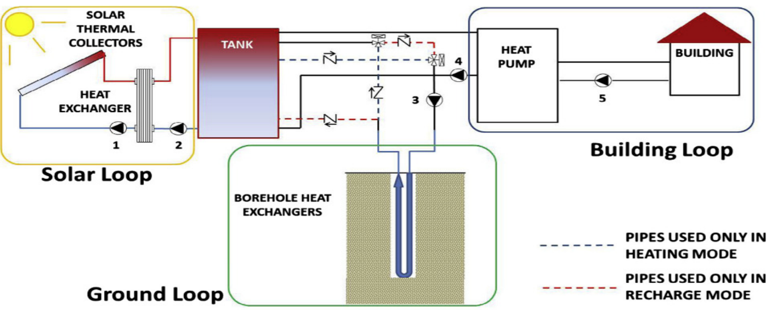
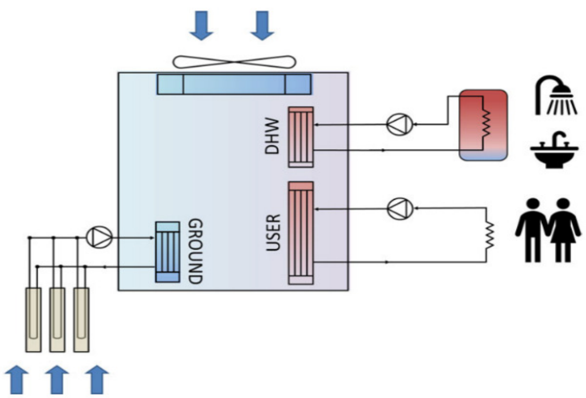
Introduction

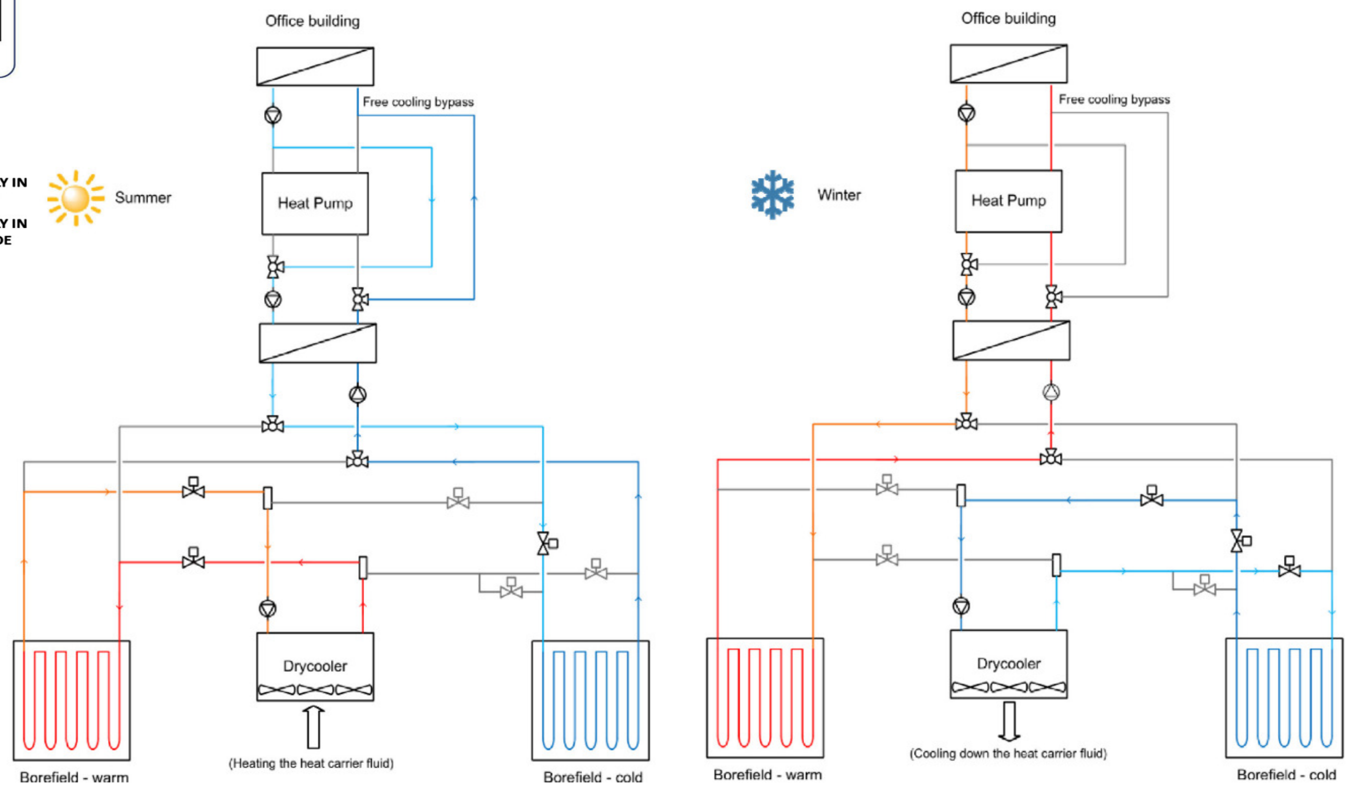
- Although a Ground Source Heat Pump (GSHP) system has the potential for achieving a high system efficiency, the high initial cost is a major barrier for the broad application of GSHP systems in the market.
- Additional source(s) can be used within a heat pump system along with the ground, such as solar thermal, ambient air, water (lake, river, etc.). A heat pump system with more than one source is known as a multi-source heat pump system.
- Recent studies [1][2][3] indicate that the size of the underground loop of a conventional GSHP system can be reduced by about half without a reduction of system efficiency if an additional source is used along with the ground, such as a solar thermal collector or an air-to-liquid heat exchanger.



SAGSHP system design [3]



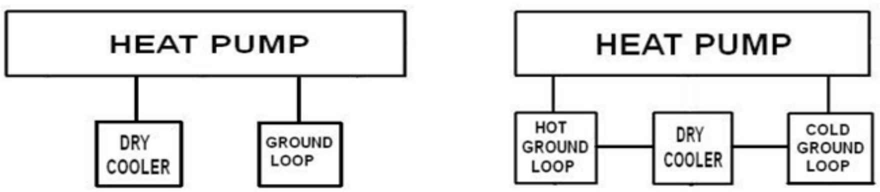
Dual source heat pump system design [2]



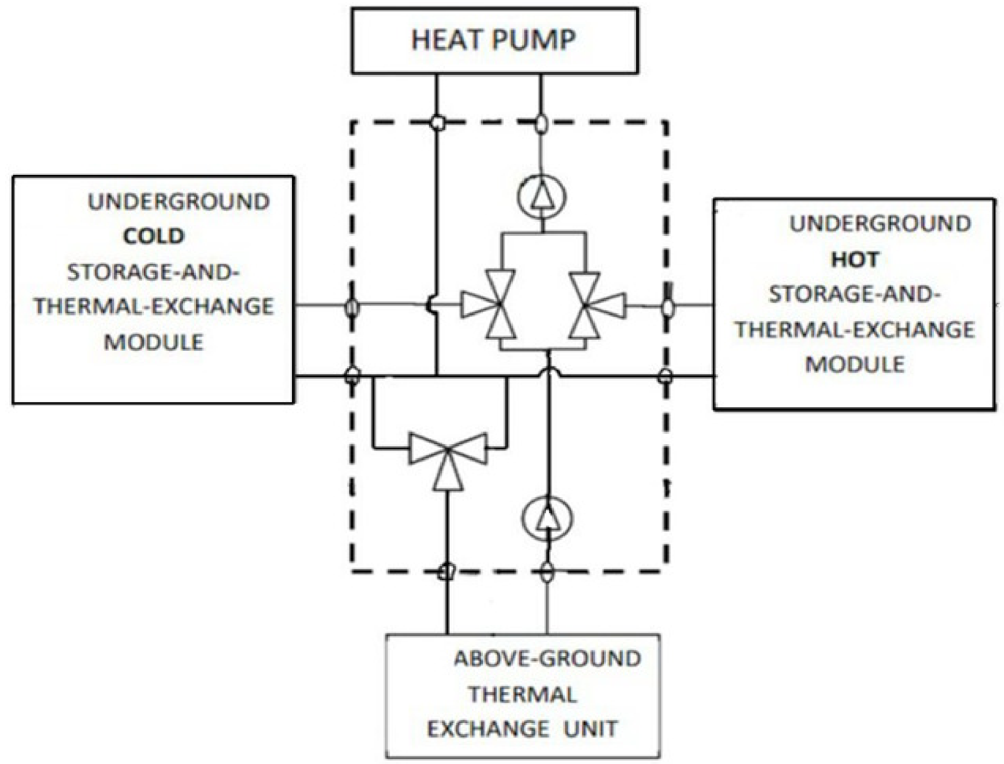
Multi-source system design: (a) cooling mode (b) heating mode [1]

- The use of inexpensive solar thermal collectors or dry fluid coolers instead of more expensive ground loops contributes to the reduction of the overall system cost, thus providing a cost-effective way to overcome this barrier of GSHP systems.
- This presentation introduces an innovative multi-source heat pump system design for large scale applications, which is lower cost to build (much smaller ground loop) and use (higher average annual efficiency) compared to standard, conventional GSHP systems.

Dual Source System Design Options



Dual source system design options: (a) Spanish/German system approach (b) Belgian approach [4]



Revised multi-source system design [4]

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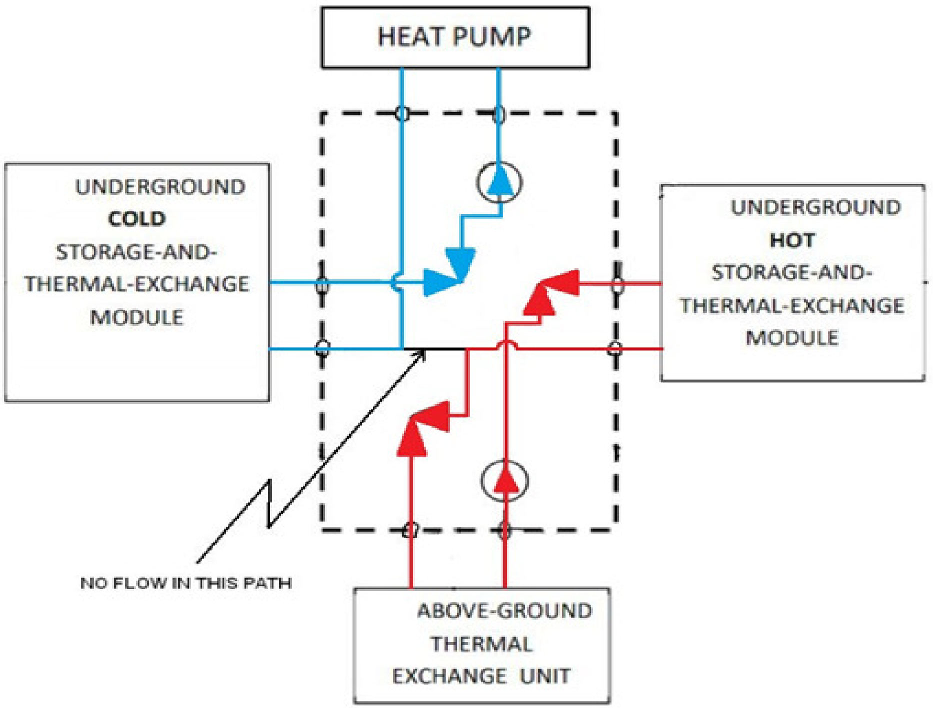
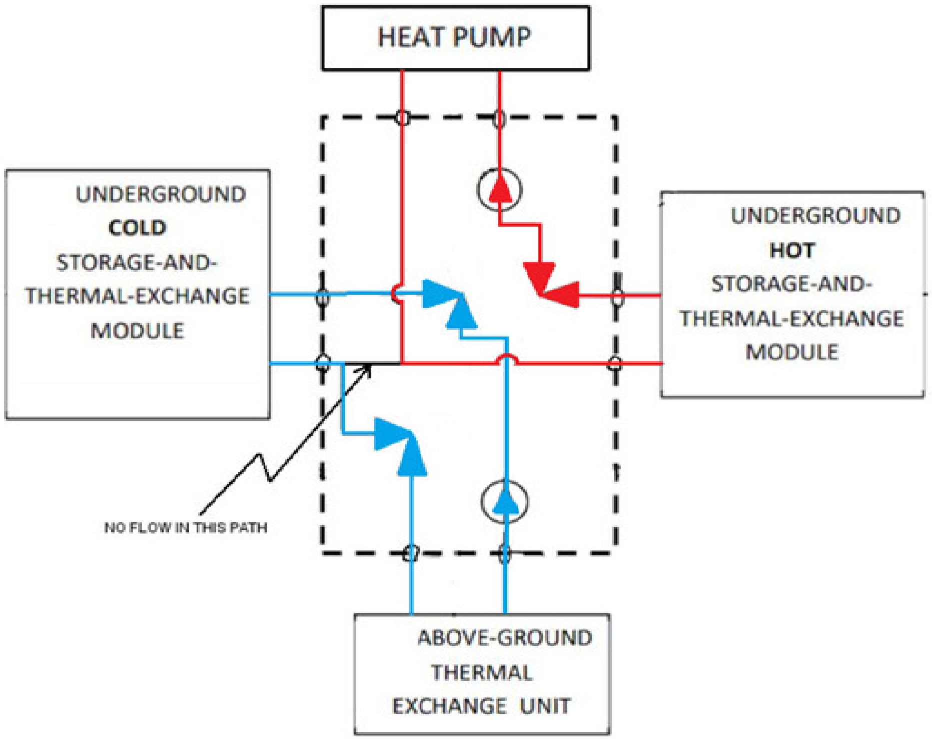
System Design



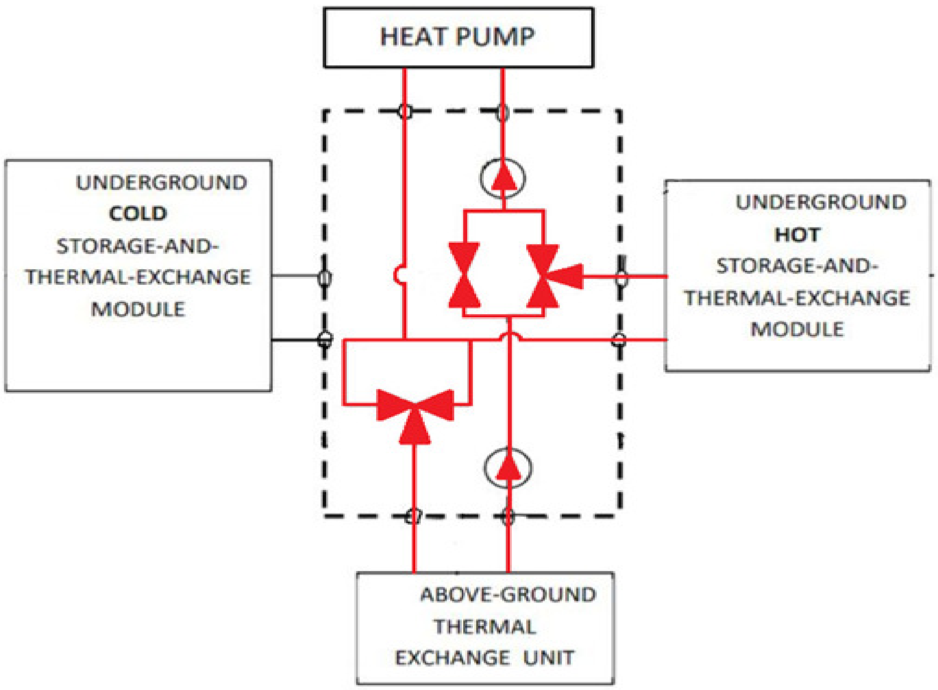
(a)



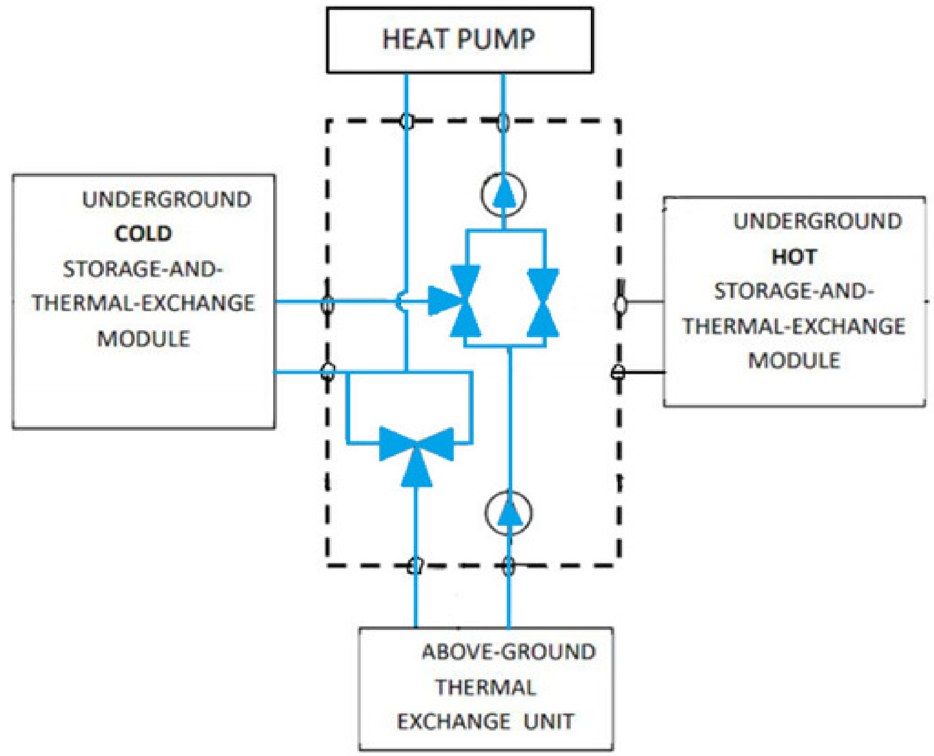
(b)

Flow paths during (a) the coldest winter night and (b) the hottest summer day [4]

System Design



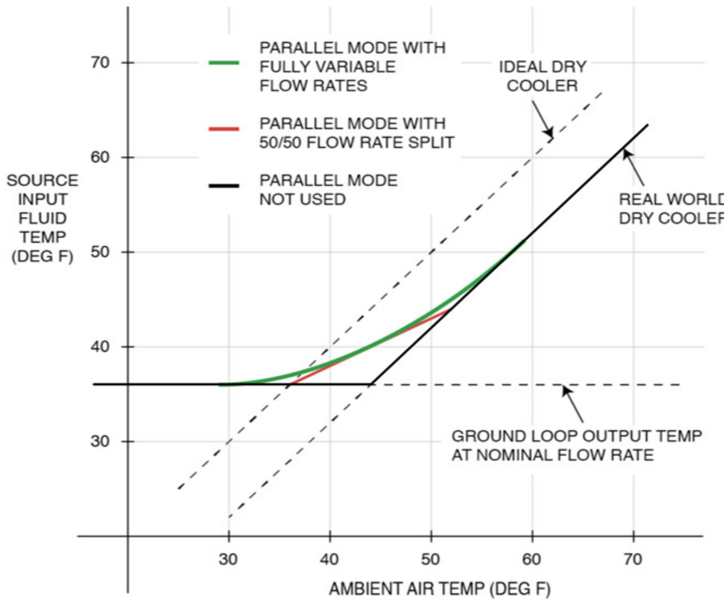
(a)



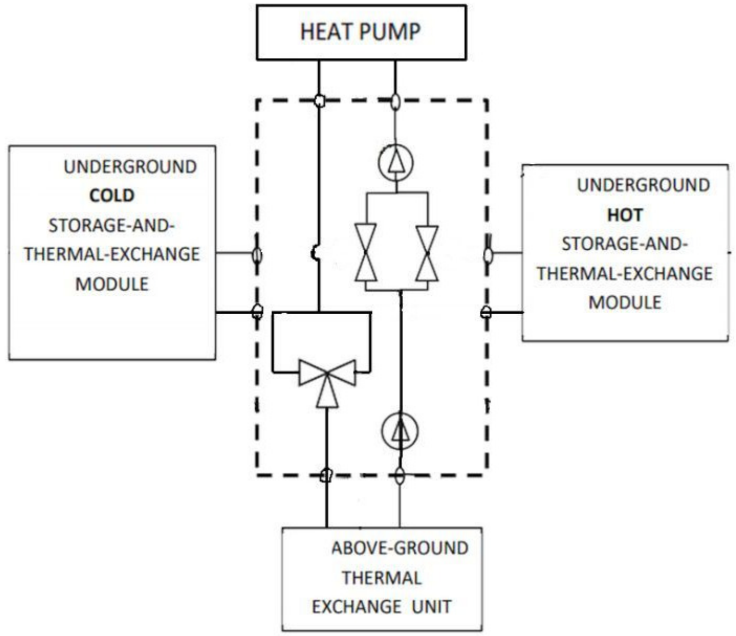
(b)

Parallel modes using (a) hot module and (b) cold module [4]

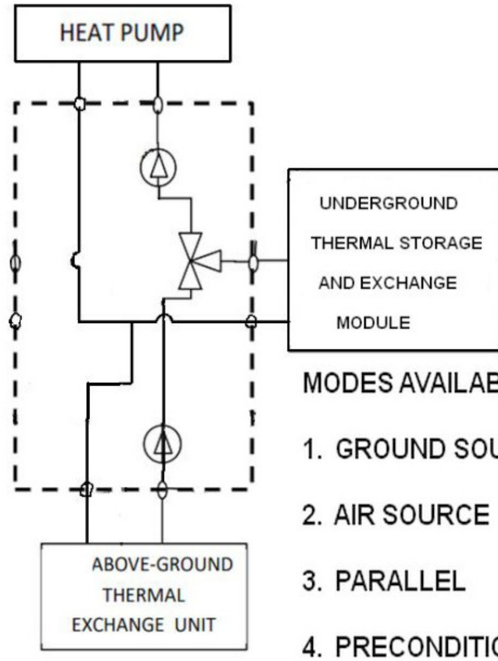
System Design



Temperature curve [4]



Air source mode flow paths [4]

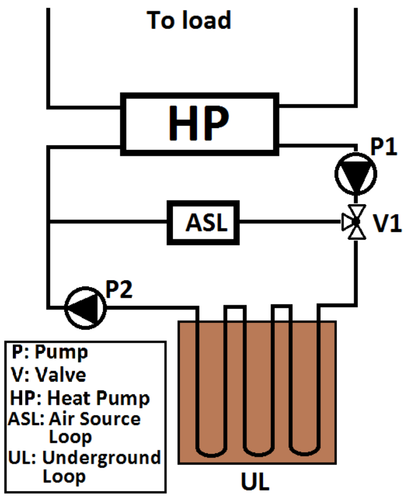


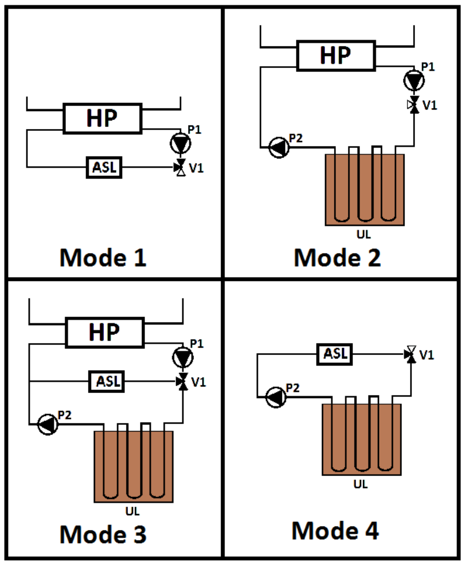
MODES AVAILABLE:

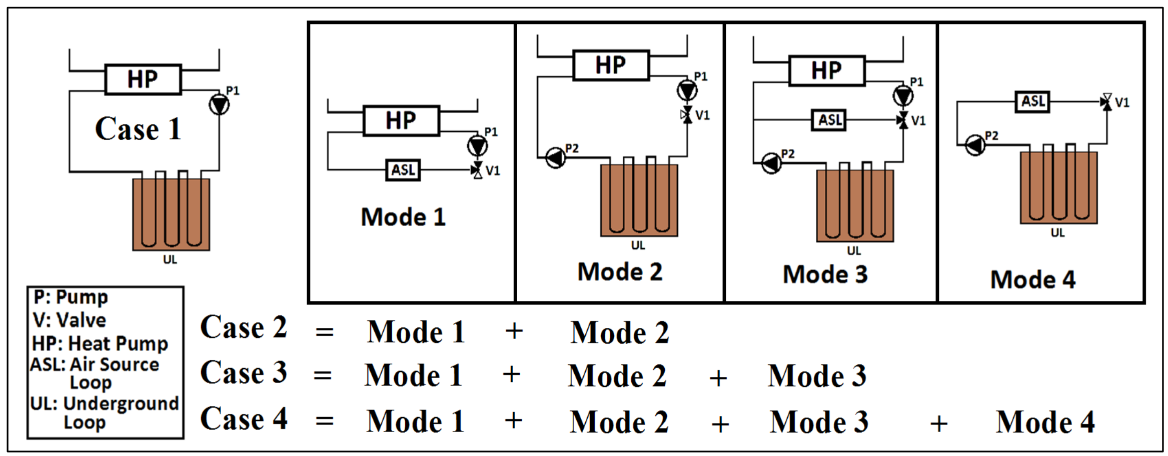
1. GROUND SOURCE
2. AIR SOURCE
3. PARALLEL
4. PRECONDITIONING

Modification for a single ground loop [4]

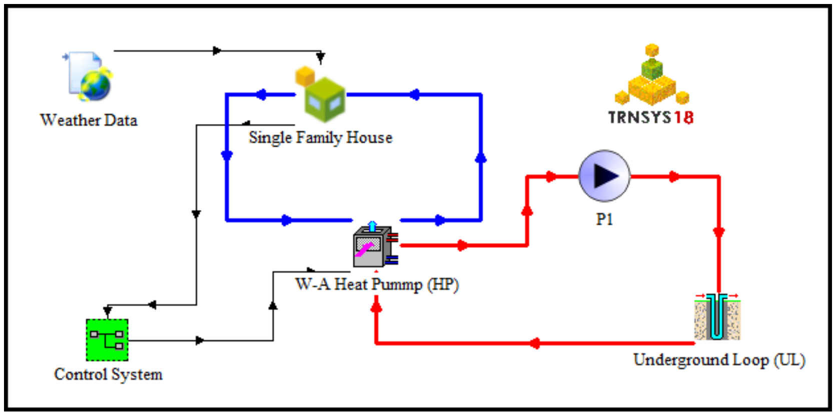
Case Study – Single Family House



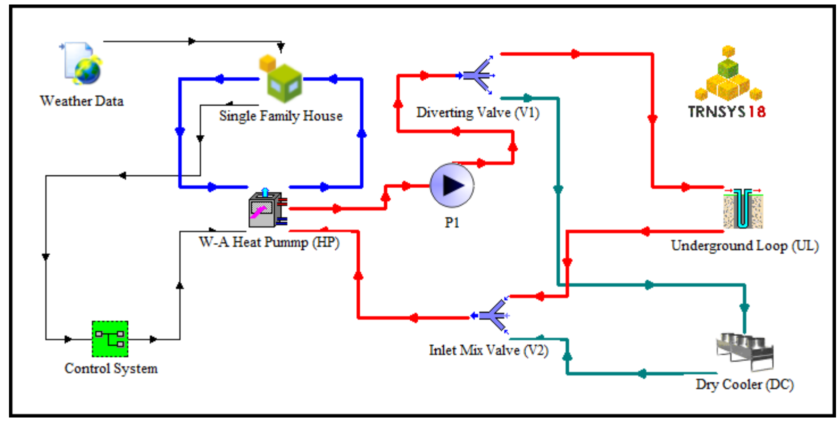




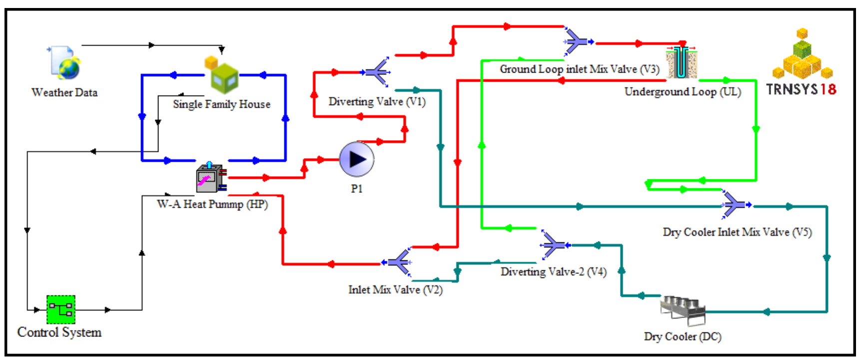
TRNSYS Simulation Models



Case 1 Model



Case 2 & 3 Model



Case 4 Model

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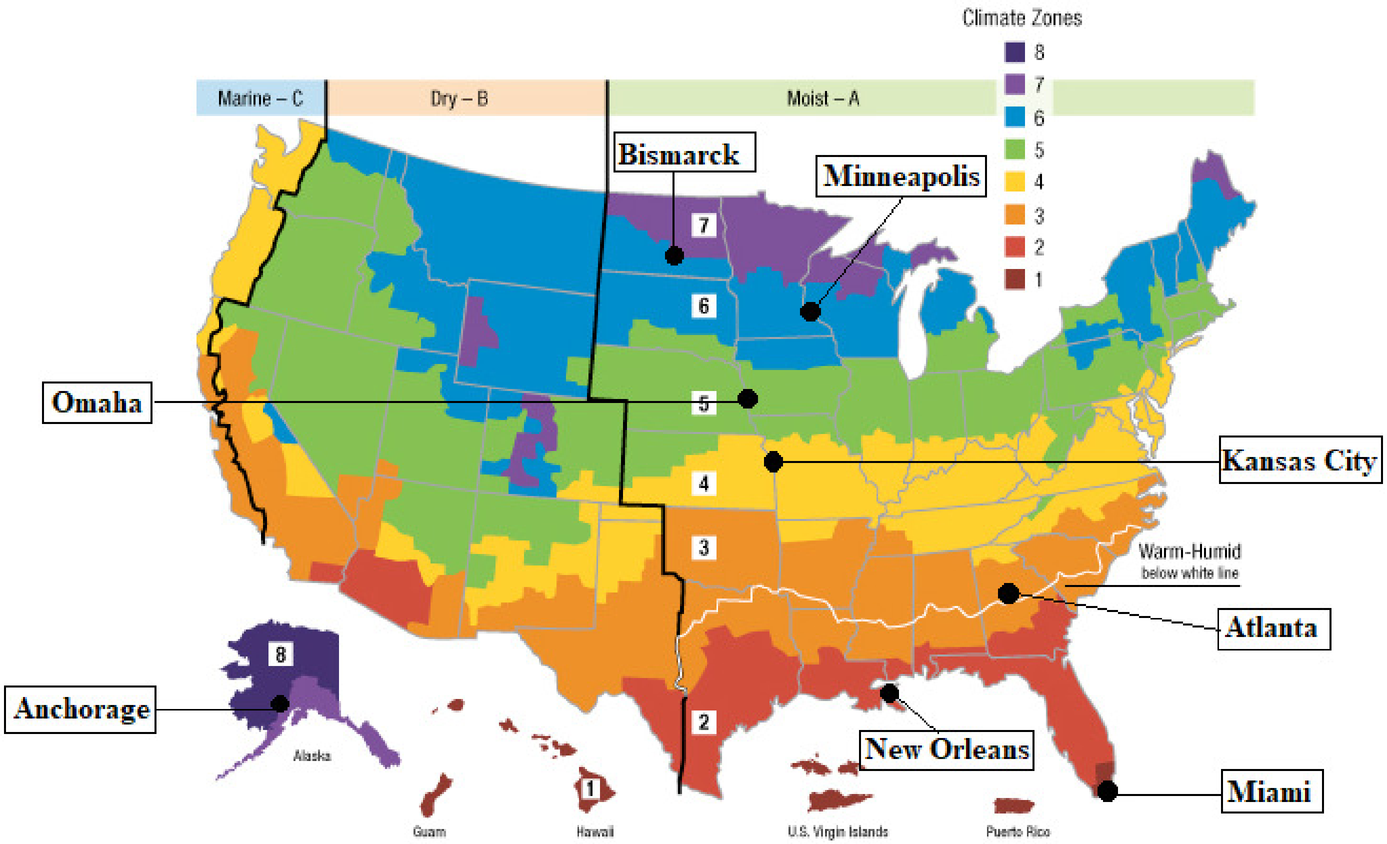
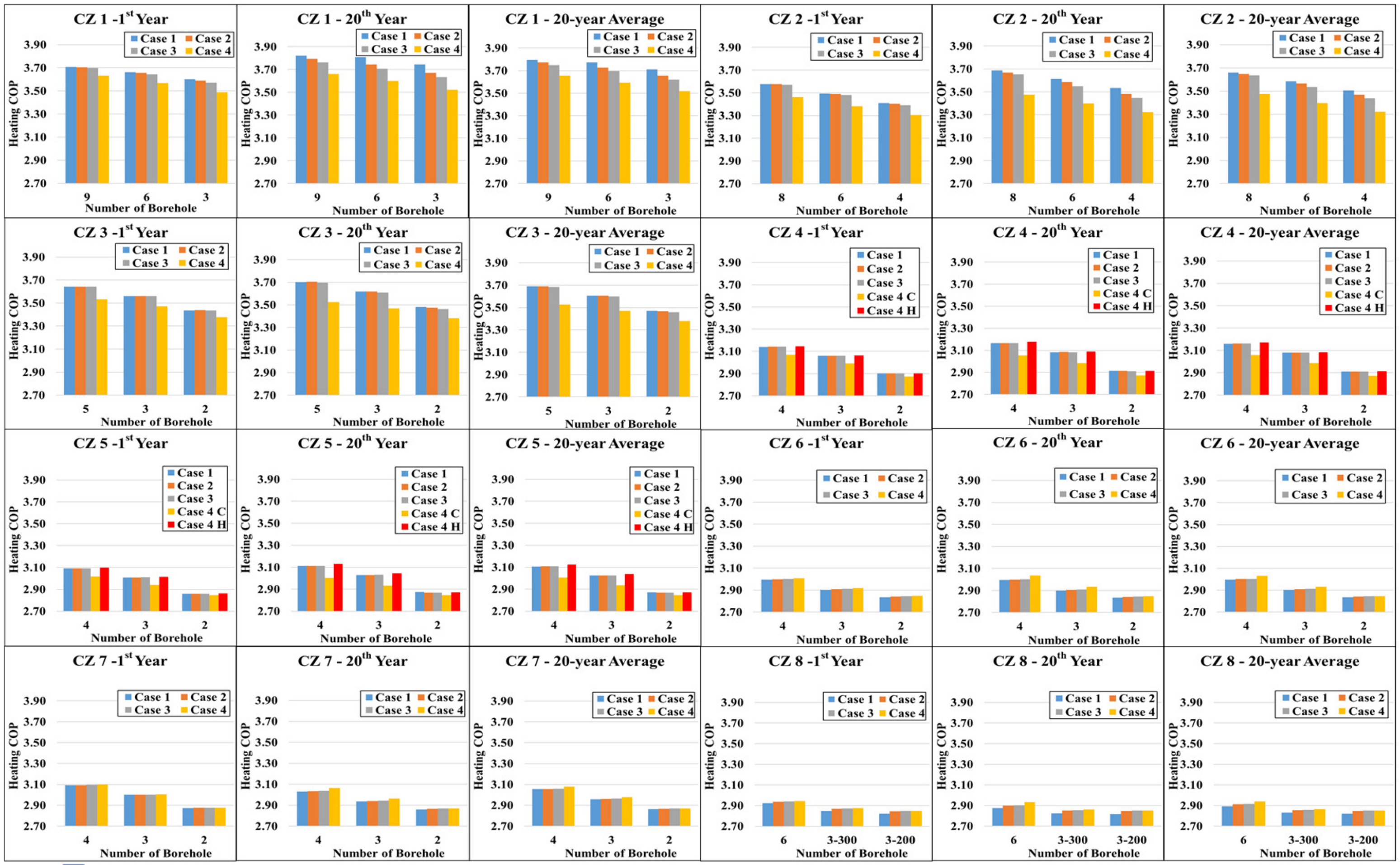
Simulations in Eight Climate Zones



Average Heating COPs



- Higher COPs are achieved in hot/warm climates.
- Heating COPs decrease as the borehole size is reduced.
- Lower COPs for Case 4 when collecting cold, and higher COPs for heat collection.

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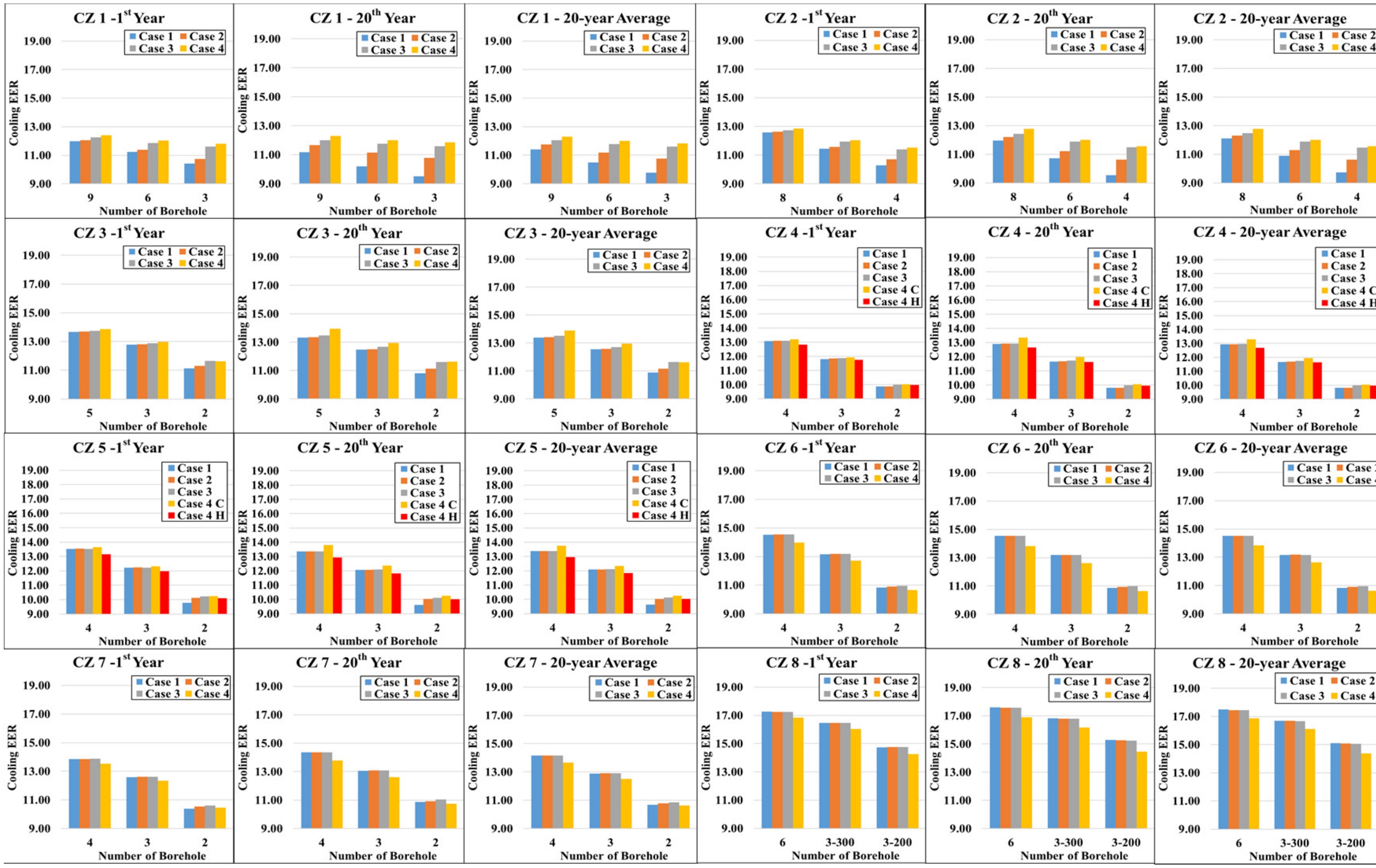
Average Cooling EERs

- Higher EERs are achieved in cold climates, and cooling EERs decrease as the borehole size is reduced.
- Higher EERs in Cases 2, 3, and 4 in hot/warm climates, especially when shorter borehole lengths are used.
- The charging mode (Mode 4 in Case 4) contributes to the balance of the ground temperature between heating and cooling, especially in extreme hot/cold climates, and thus the changes in cooling EERs over 20 years for this case are not significant.



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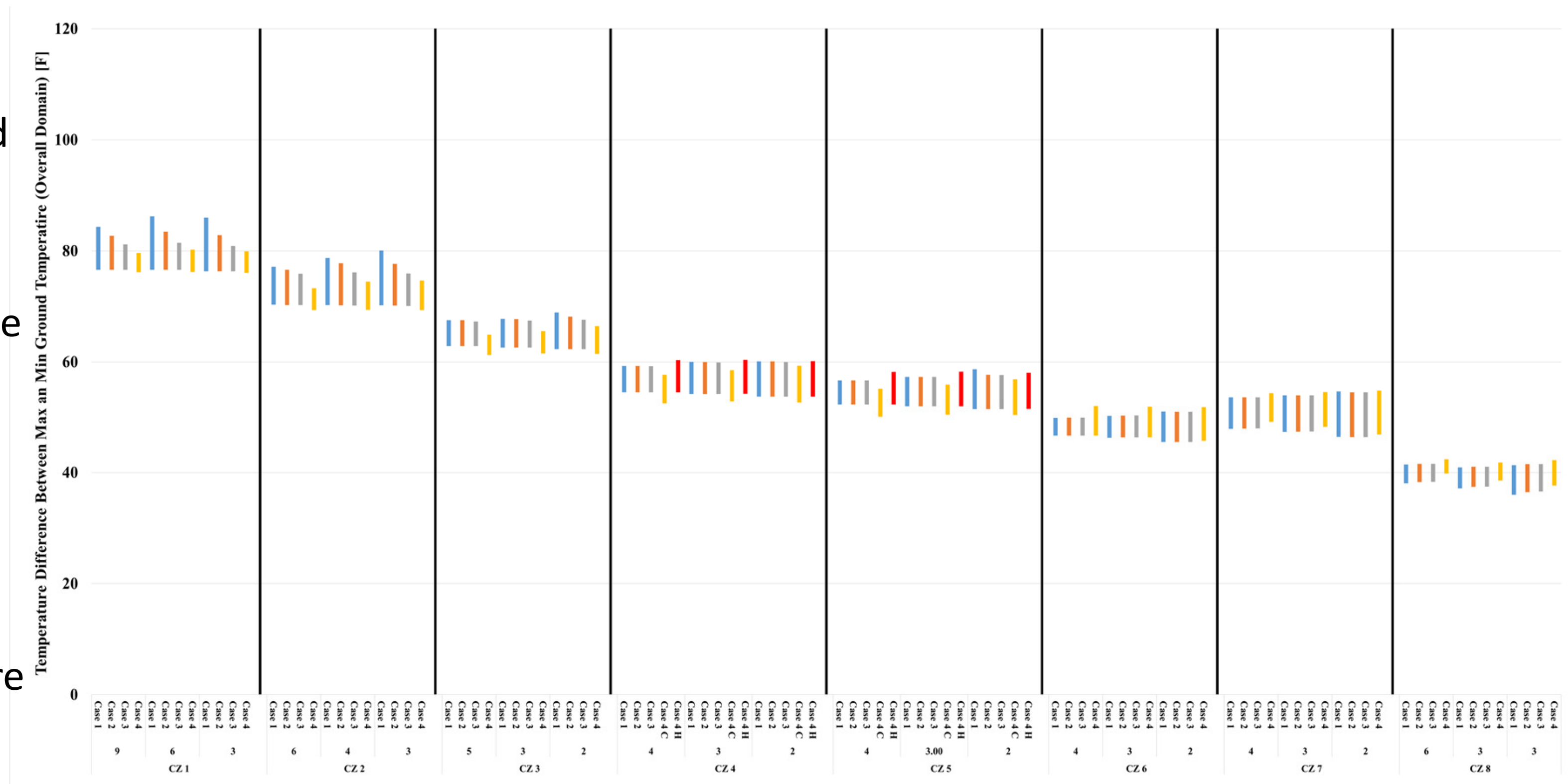
Max. and Min. Ground Temperatures Over 20 Years

- In hot climates, the max. ground temperatures decrease as the advanced control strategies are used in Cases 2, 3, and 4, and lower min. ground temperatures were observed for Case 4, where cold is collected by using the dry fluid cooler and then transferred to the underground region.
- For Mode 4 in Case 4, the effectiveness of charging cold in hot climates is more significant than that of charging heat in cold climates.



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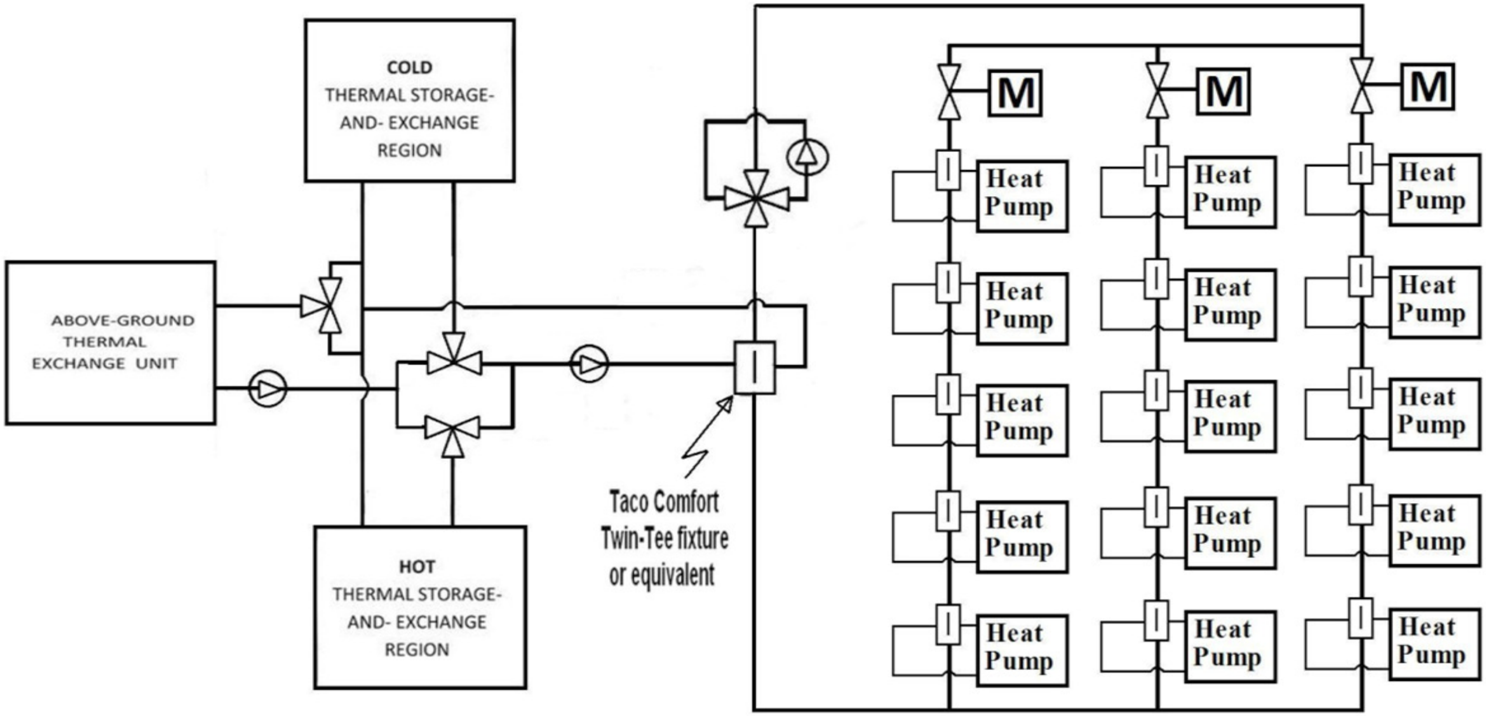
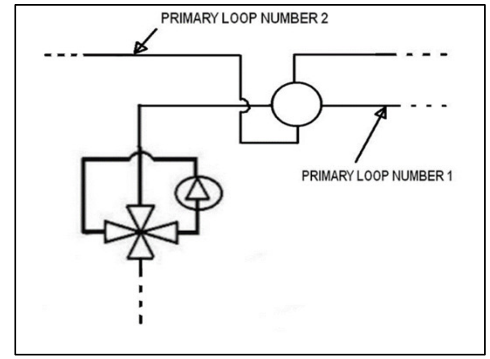
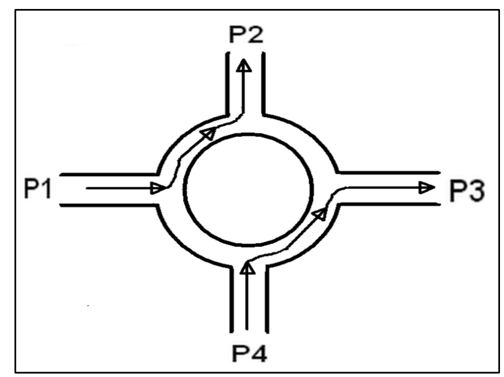
Larger Scale System Design



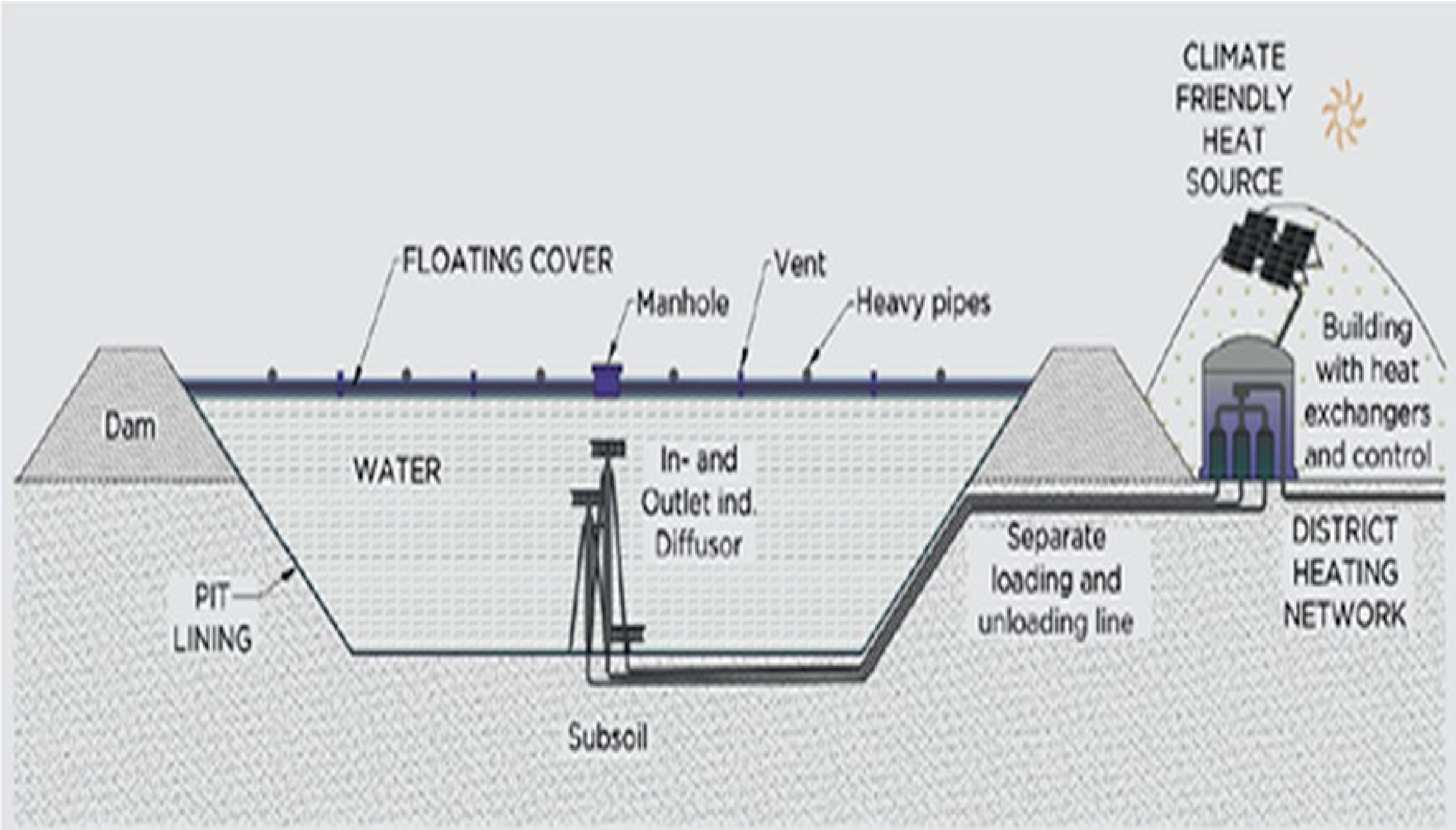


Coupling between two primary loops



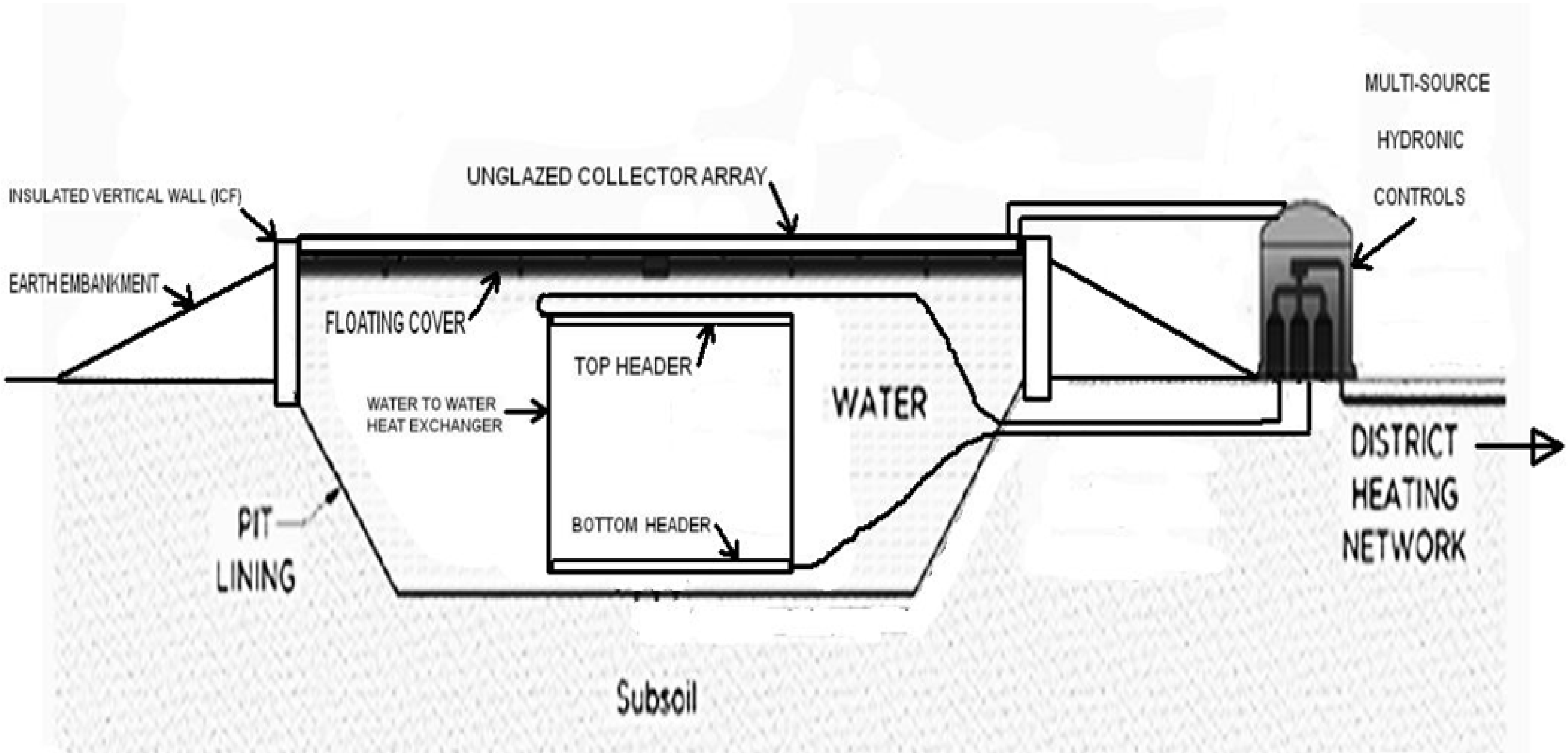
Symmetrical reversible flow fixture

A Typical Pit Thermal Energy Storage (PTES)



Source:acigs.org

Multi-Source Thermal Storage Pond



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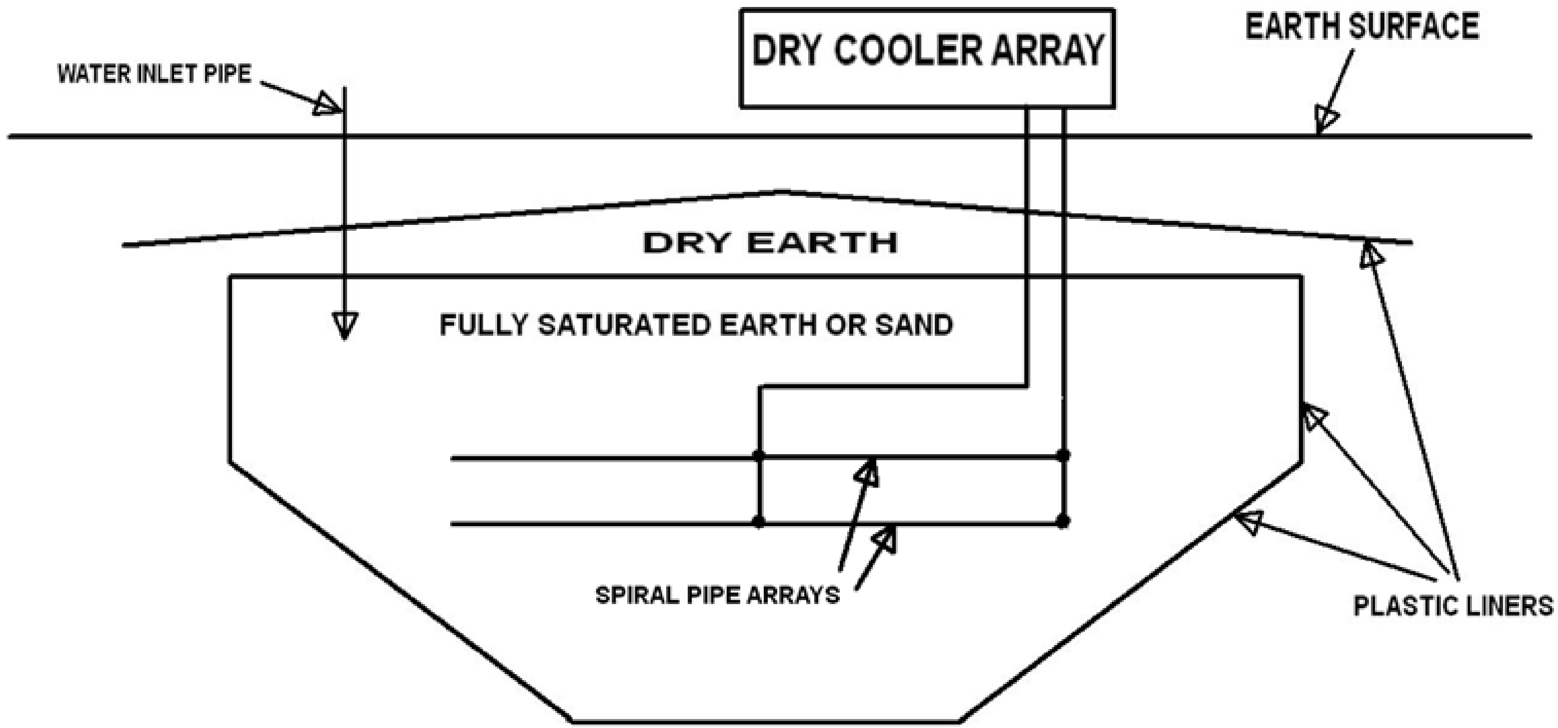
Underground Thermal Storage with Earth and/or Sand



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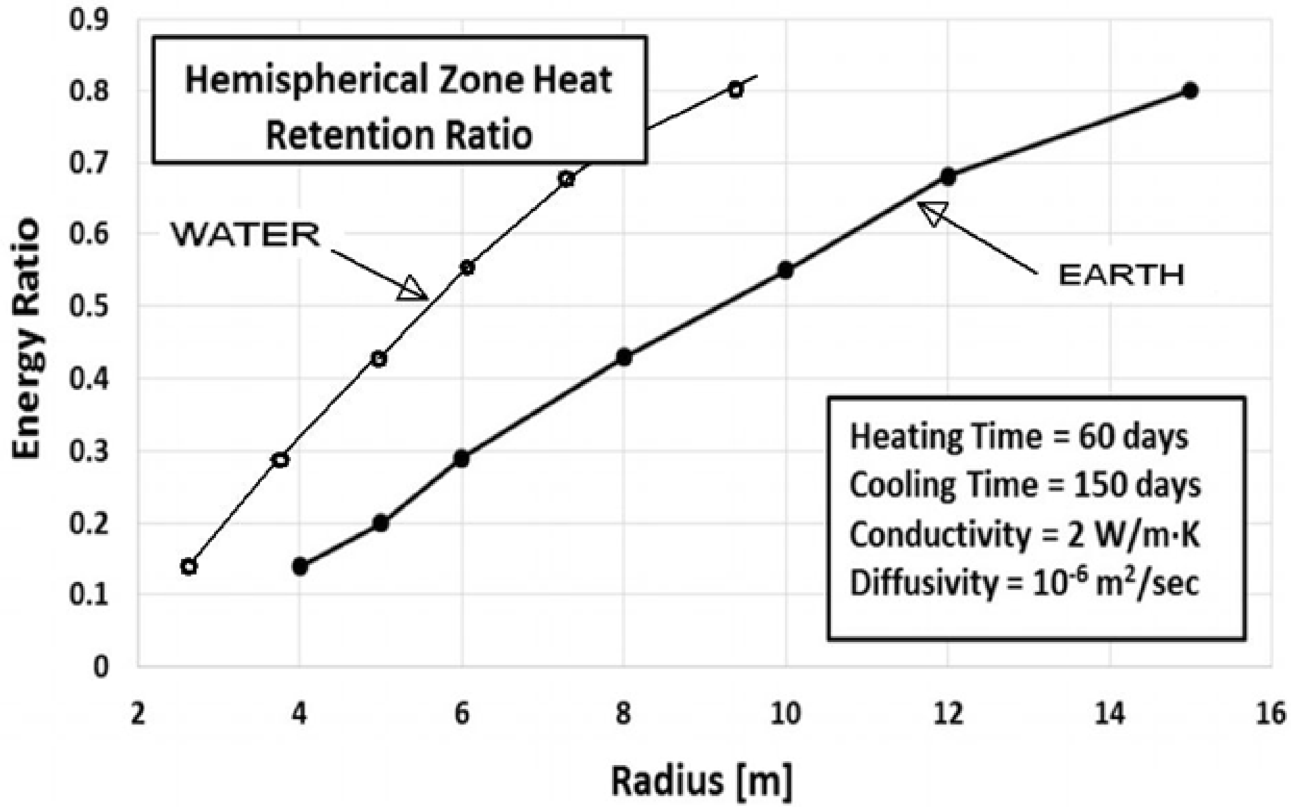
Heat Retention for a Partially Insulated Hemisphere



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Lessons Learned

- The use of a dry fluid cooler with advanced control strategies in a GSHP system contributes to increasing or maintaining the GSHP system's efficiency in the long run by balancing the heating and cooling through charging cold or heat to the ground, respectively.
- Especially, the concept of integrating a dry fluid cooler into a GSHP system with advanced control strategies is proven to be effective for the studied house located in hot climates, such as Miami or New Orleans.
- This presentation provides a cost-effective way to design and use a multi-source heat pump system. It has the potential for a wide and large-scale application when used in dense urban areas due to its requirement of smaller ground loop areas.
- A multi-source system as described here for large scale applications can be lower cost than a conventional ground source system (smaller ground loop) but also provide higher efficiency (lower electricity use).

Bibliography

[1] Allaerts, K., Coomans, M. and Salenbien, R., 2015. Hybrid ground-source heat pump system with active air source regeneration. Energy Conversion and Management, 90, pp.230-237.

[2] Corberán, J.M., Cazorla-Marín, A., Marchante-Avellaneda, J. and Montagud, C., 2018. Dual source heat pump, a high efficiency and cost-effective alternative for heating, cooling and DHW production. International Journal of Low-Carbon Technologies, 13(2), pp.161-176.

[3] Emmi, G., Zarrella, A., De Carli, M. and Galgaro, A., 2015. An analysis of solar assisted ground source heat pumps in cold climates. Energy Conversion and Management, 106, pp.660-675.

[4] Gaylord Olson, Yao Yu, "New Ways to Combine Solar Thermal with Geothermal", American Solar Energy Society (ASES) National Solar Conference 2020. doi:10.18086/solar.2020.01.06

Q&A

Thank You!

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