Thermochemical Seasonal Energy Storage

A breakthrough technology to displace fossil fuel consumption

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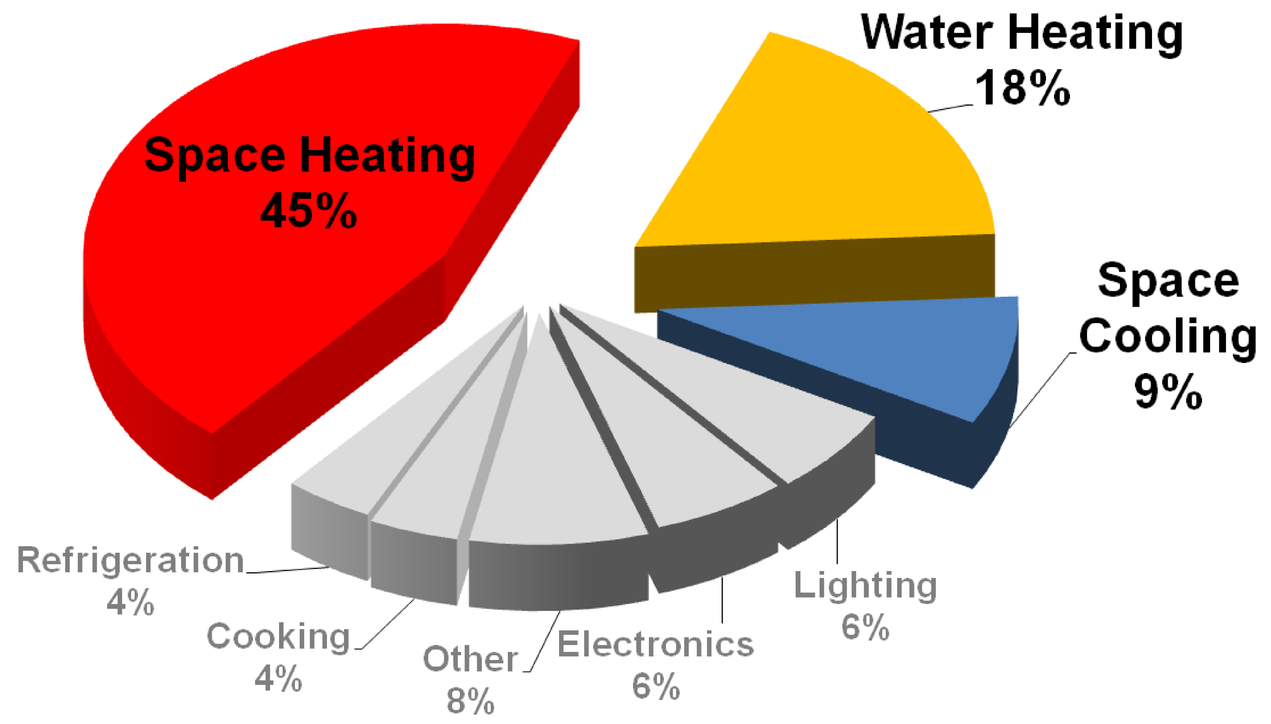
Motivation

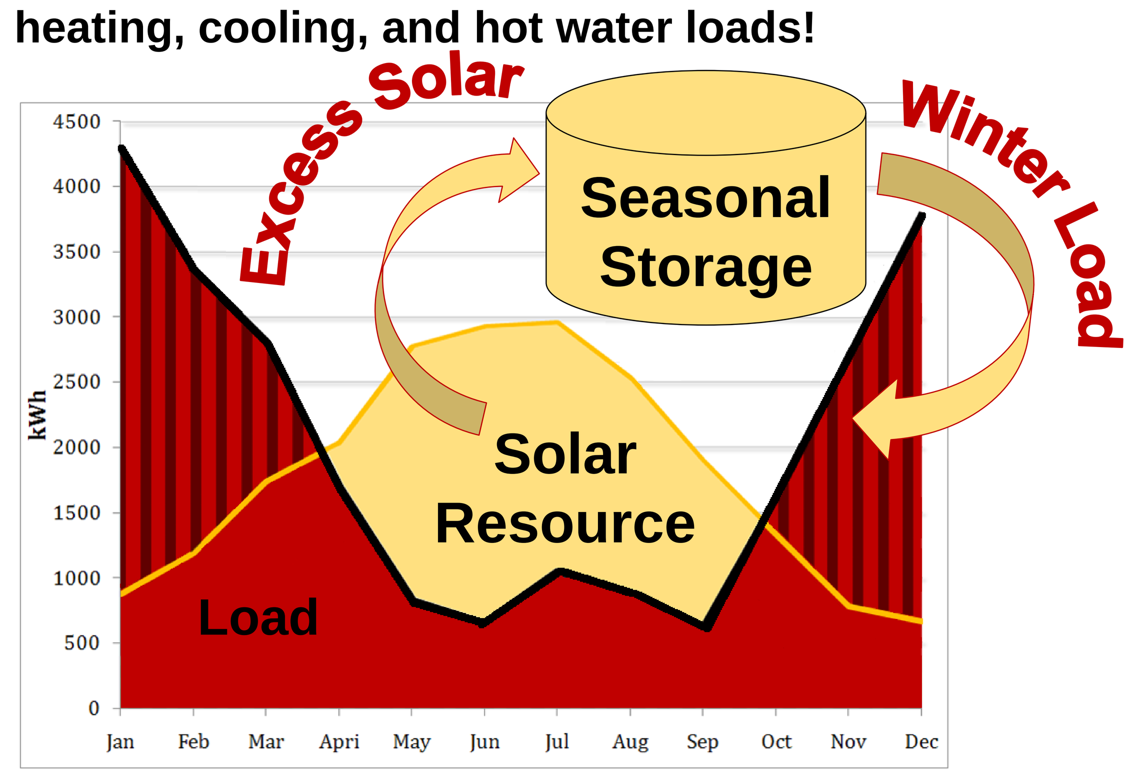
2010 U.S. Residential Energy Use[1]



•A staggering ***72%*** of residential energy (***16% of all U.S. energy***) is for residential heating, cooling, and hot water (4.55 × 10^{12} kWh/yr).

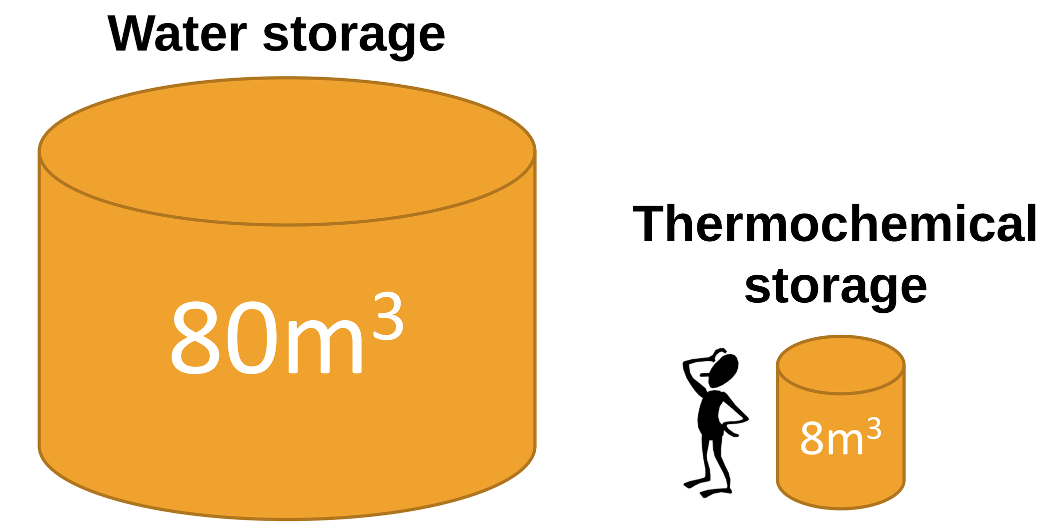
•These energy loads are predominately met by burning fossil-fuels.

•Annually the solar energy that strikes the roof of the average residential home ***greatly exceeds*** these heating, cooling, and hot water loads!



•Seasonal energy storage ***enables*** solar thermal space heating by overcoming the limitation of an inadequate winter solar resource.

•Conventional water storage is impractical for seasonal storage due to low energy density and thermal losses.

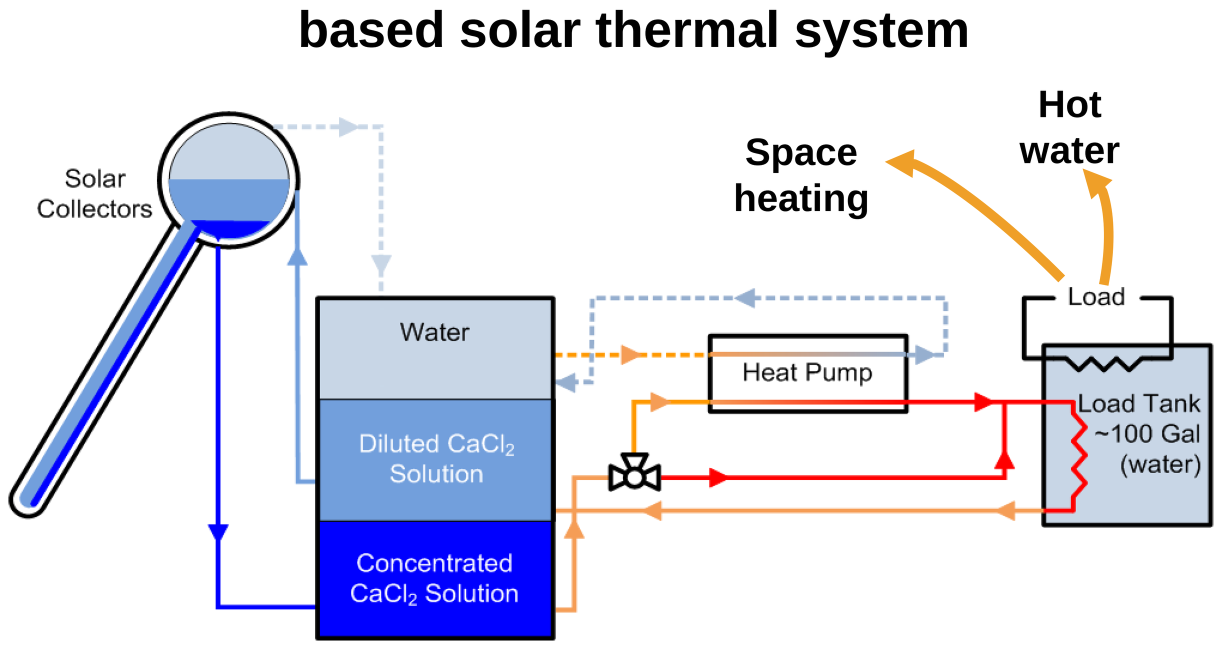


•A typical Minneapolis home would require ~80 m^3 of water storage!

•In contrast, thermochemical storage has the potential to store ***10x more energy in the same volume!***

Objective: Develop a compact seasonal thermochemical storage to enable year-round solar thermal space heating

An inexpensive calcium chloride (road salt) based solar thermal system

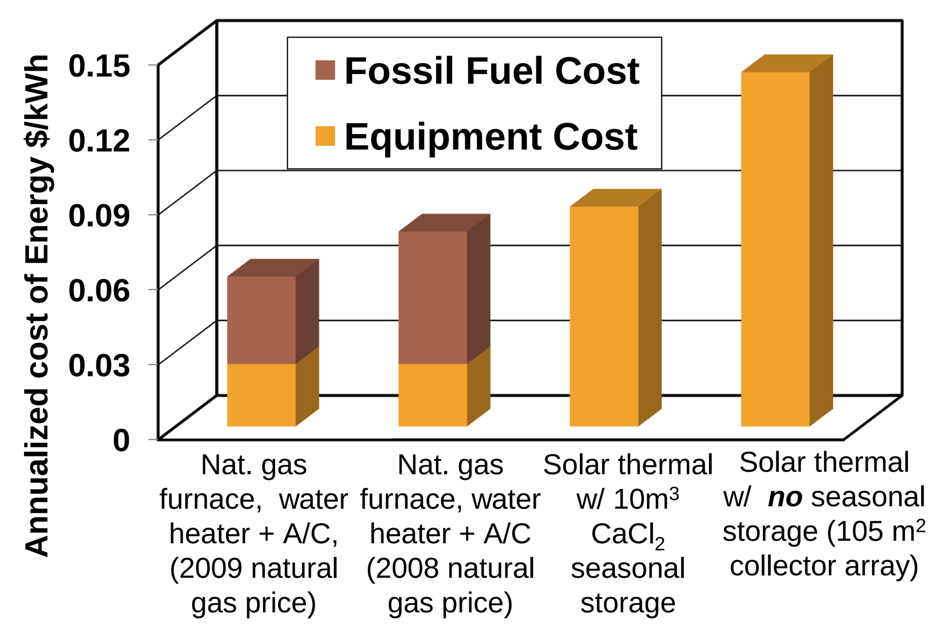


•Solar collectors store energy in the summer by boiling water from diluted calcium chloride, $CaCl_2$(aq)[2].

•Water and concentrated $CaCl_2$(aq) are stored separately until the winter.

•Energy is released in the winter by absorbing the water back into the concentrated $CaCl_2$(aq) using a heat pump.

•Seasonal storage drastically reduces the cost of solar thermal systems for heating, cooling, and hot water!

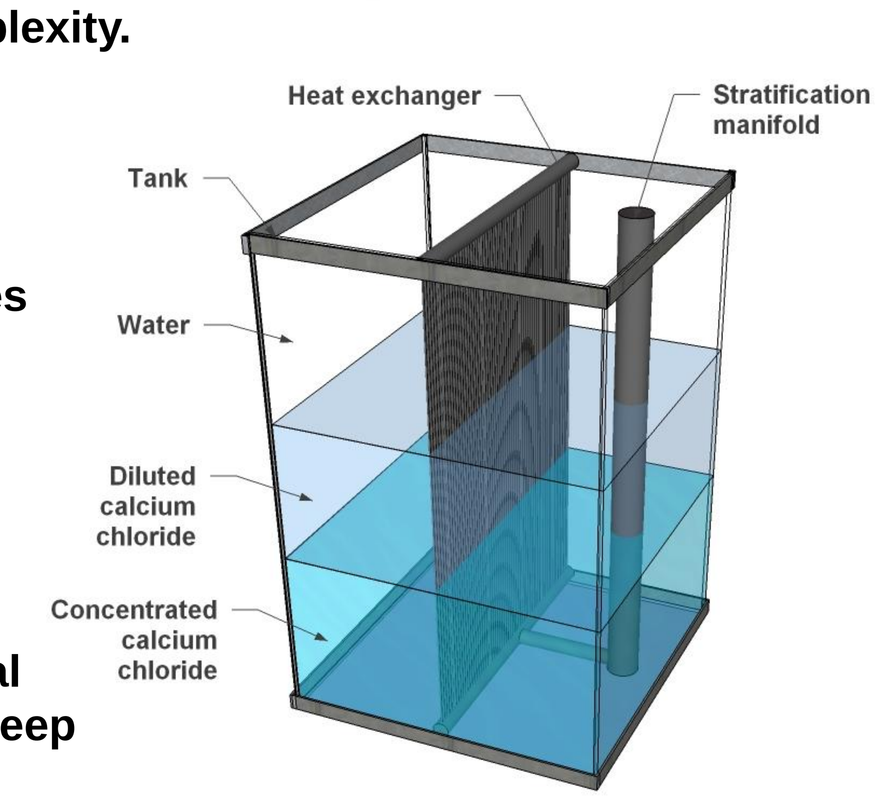


•A solar thermal system with calcium chloride storage is ***cost-competitive*** with conventional fossil-fuel equipment over system life![3]

•We propose a single vessel thermochemical $CaCl_2$ storage design to minimize volume, cost, and complexity.

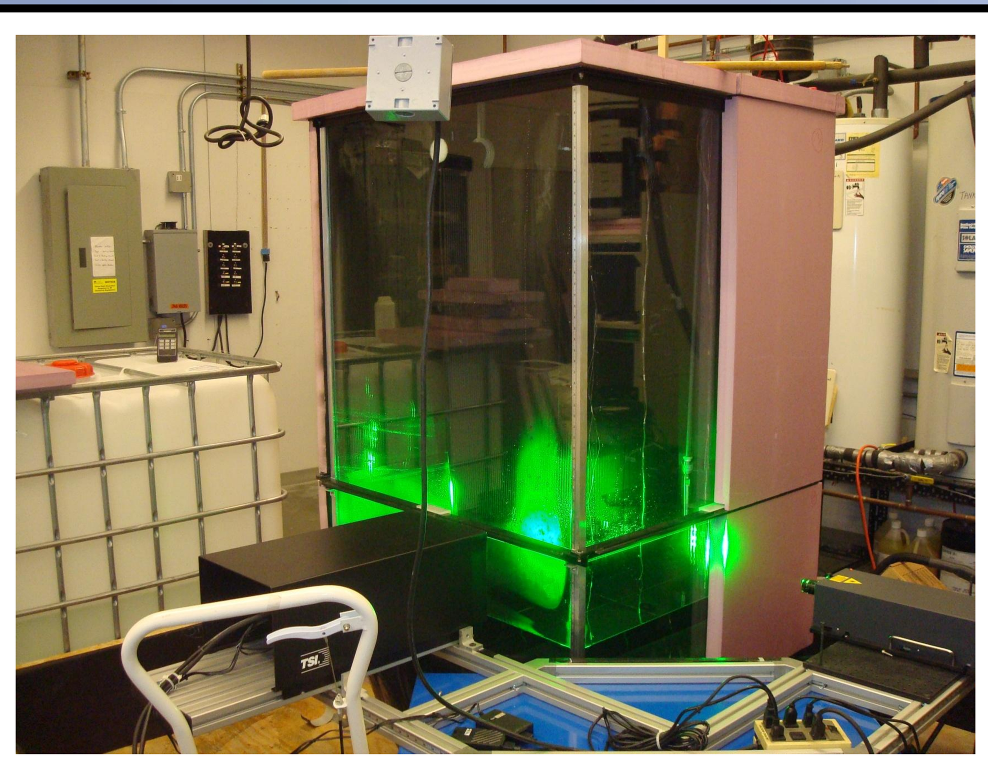
•The engineering ***challenge*** is to prevent the different liquids from mixing because mixing introduces energy losses, which deplete the storage.

•Our ***solution*** stores water and aqueous calcium chloride in a single vessel and uses the natural density difference (interface) to keep the liquids from mixing.



•Two internal devices separate heating the tank from returning fluid to the tank reduce to mass transfer (mixing) and control the energy distribution.

Experimental Prototype

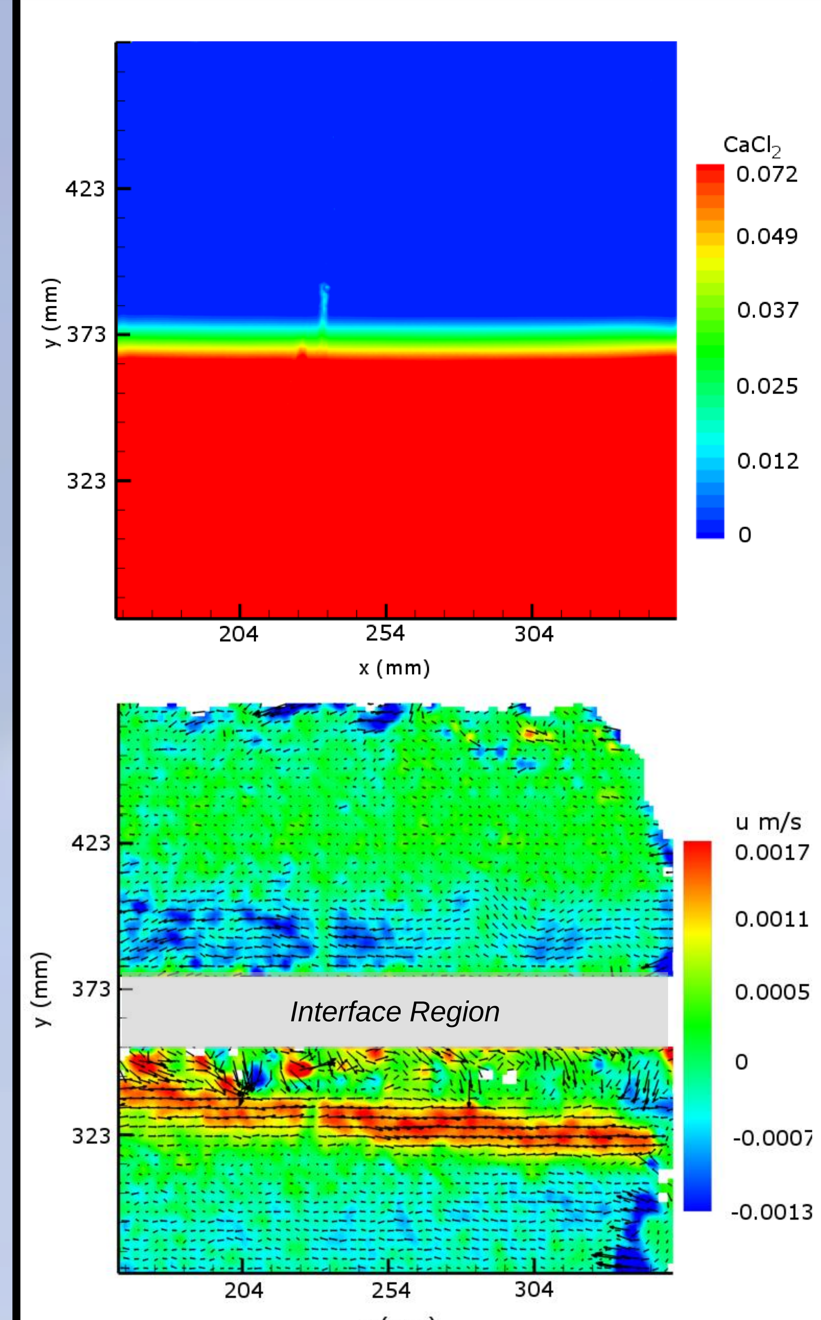


•Experiments are conducted in a 400 gallon tank to characterize the performance for seasonal modeling and engineering design.

•A laser illuminates particles and a fluorescing dye suspended in the fluid to measure the fluid velocity and calcium chloride concentration during heating.

•These measurements are used to determine the rate of mass transfer (mixing) between the different liquids in the storage.

Experimental Results

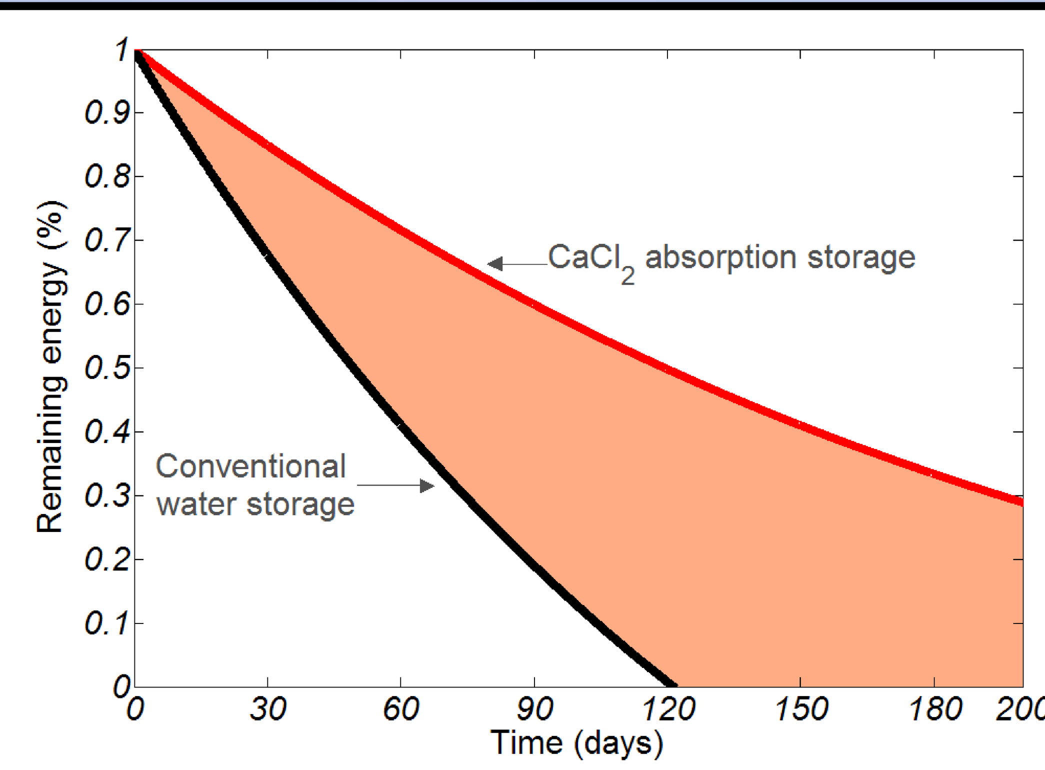


•Each measurement yields $CaCl_2$ concentration and velocity over a 20x20 cm imaging plane.

⟵The water (blue) remains ***completely separated*** from the calcium chloride (red) even after 8 hr of heating[4]!

⟵The low fluid velocity (<2mm/s) near the interface leads to very small rates of mass transfer and ***no large scale mixing!***

Seasonal Storage



•Measurements enable a prediction of energy loss due to mixing on a seasonal time scale.

•The shaded region shows the additional energy available over time in the $CaCl_2$ storage compared to conventional storage.

•The seasonal time scale is critical. ***After 120 d, 50% of the capacity remains in the $CaCl_2$ storage*** and the conventional storage is fully depleted by thermal losses!

Conclusions

✓ Solar thermal systems offer an ***amazing potential*** to displace fossil-fuels and reduce CO_2 emissions in one of the largest energy sectors in the U.S.!

✓ Thermochemical seasonal storage enables ***cost-competitive solar thermal systems*** for residential heating, cooling, and hot water!

✓ Slow mass transfer in our new, inexpensive single-vessel design ***avoids mixing and enables seasonal storage!***

1) Buildings Energy Data Book 2010, Department of Energy, http://buildingsdatabook.eren.doe.gov/, Access October 20, 2011.
2) J.A. Quinnell, J.H. Davidson, and J. Burch, Liquid Calcium Chloride Solar Storage: Concept and Analysis, **J. Sol. Energy Eng.,** Vol. 133(1), 011010, 2011.
3) Adapted from: J. Woods, J. Burch, and E. Kozubal, "High-solar-fraction heating and cooling systems based on liquid desiccants," Proc. Amer. Sol. Eng. Soc., 2011.
4) J.A. Quinnell, and J.H. Davidson, "Experimental study of CaCl2 absorption storage for solar heating," Proc. Amer. Sol. Eng. Soc., 2011.

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