Thermochemical Seasonal Energy Storage using Calcium Chloride

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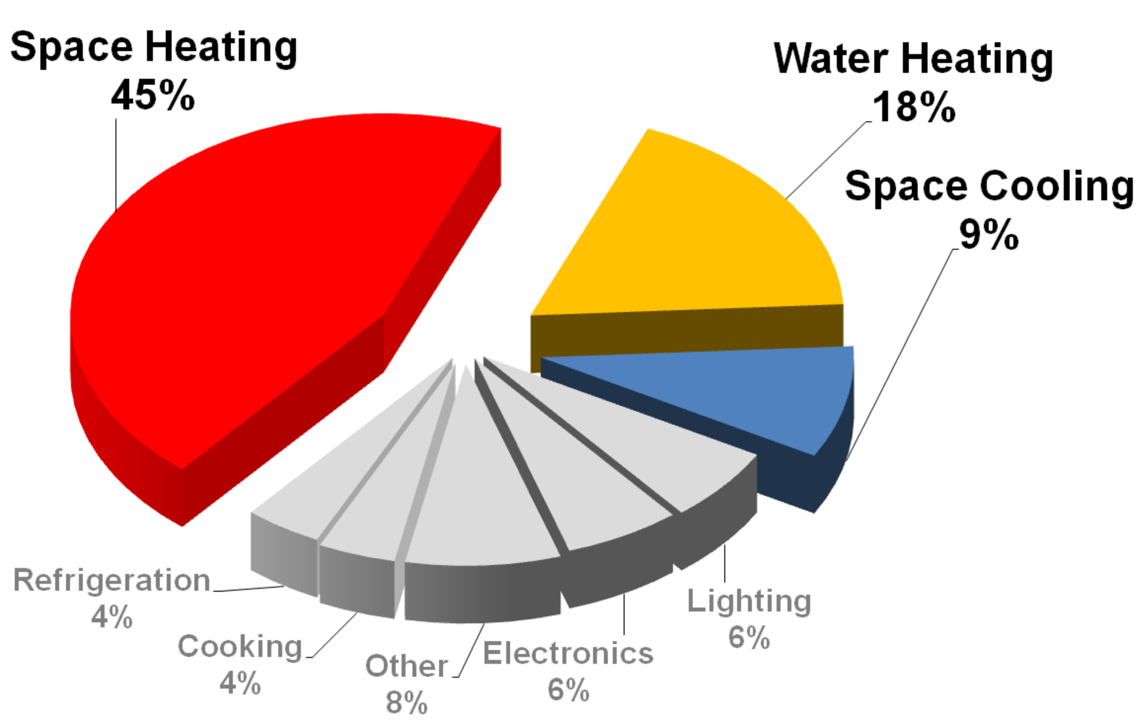
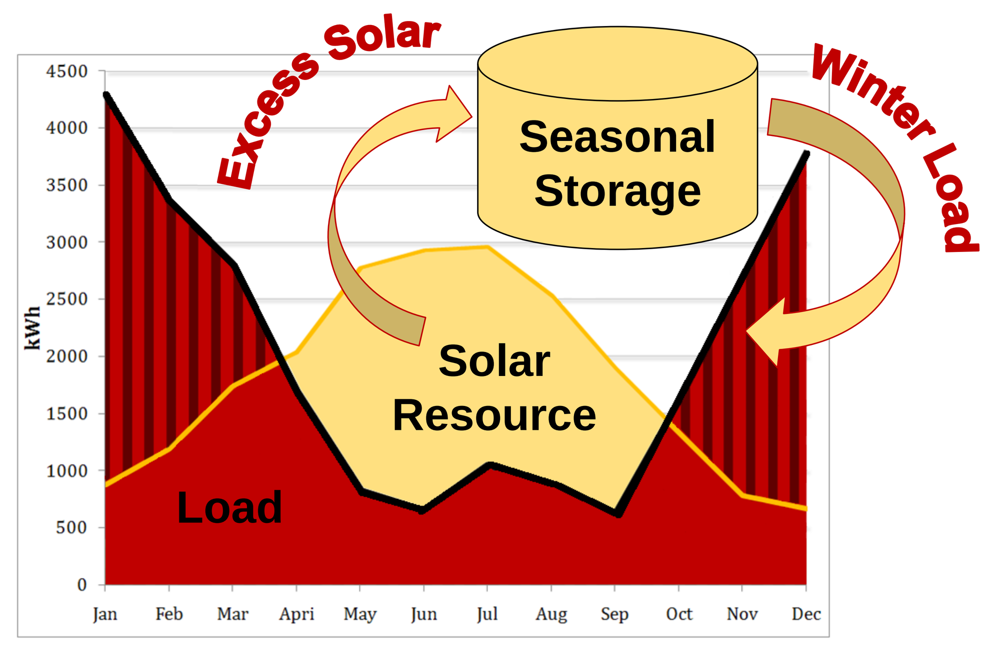
Motivation

2010 U.S. Residential Energy Use



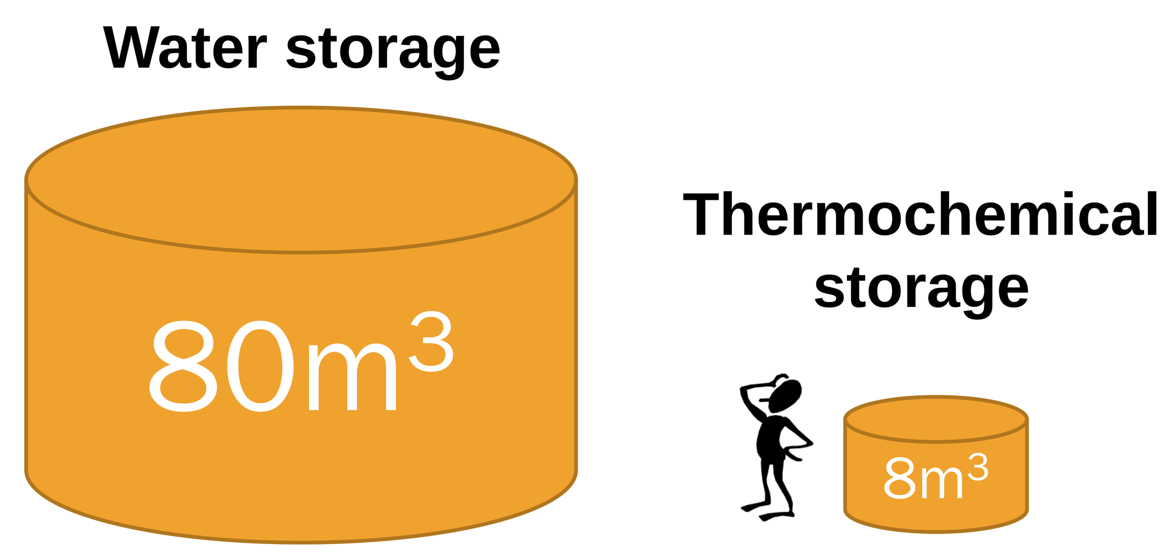
•A staggering *72%* of residential energy (*16% of all U.S. energy*) is for residential heating, cooling, and hot water (4.55 × 10^{12} kWh/yr).

•In Minneapolis, the annual the solar resource ***greatly exceeds*** heating, cooling, and hot water loads!



•Seasonal 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.



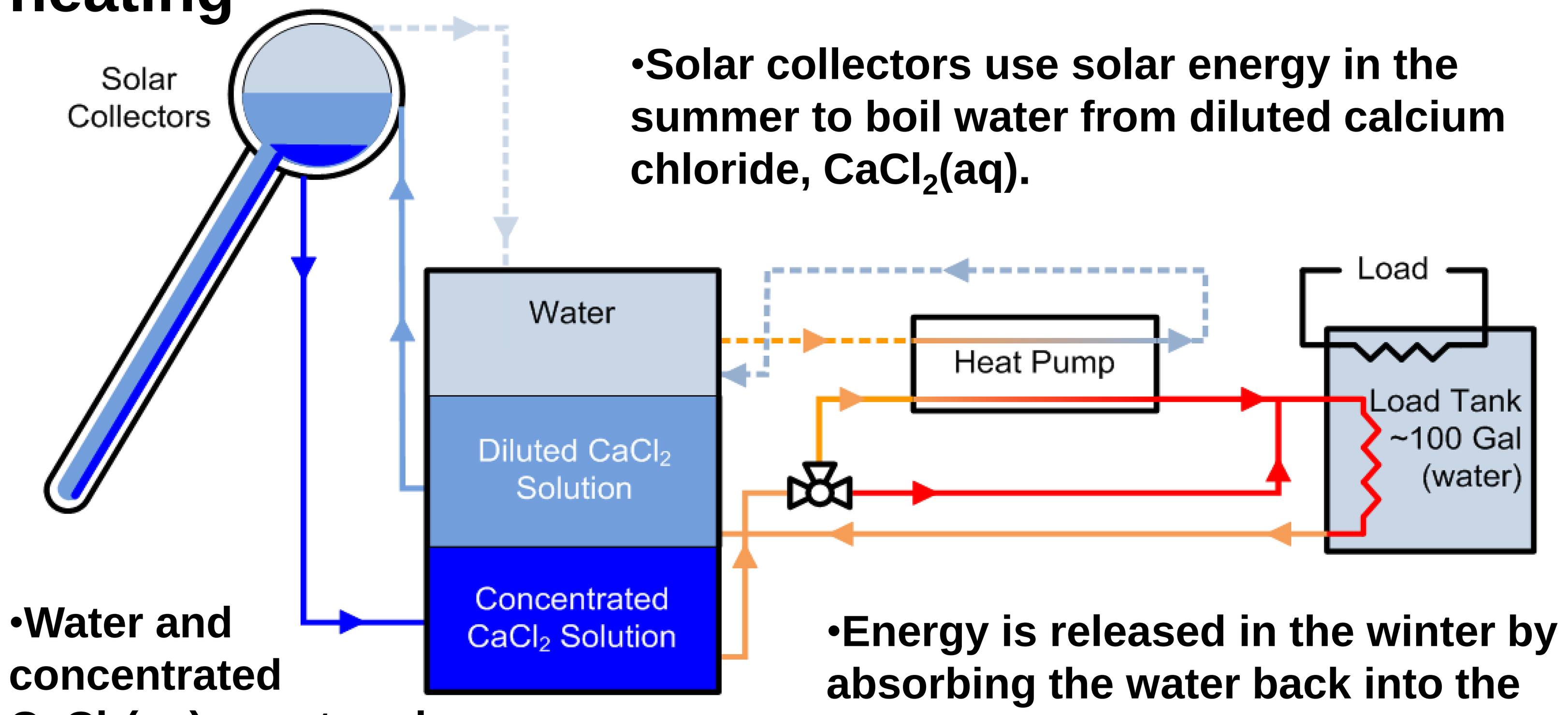
•A typical Minneapolis home would require ~80 m^3 of conventional water storage!

•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

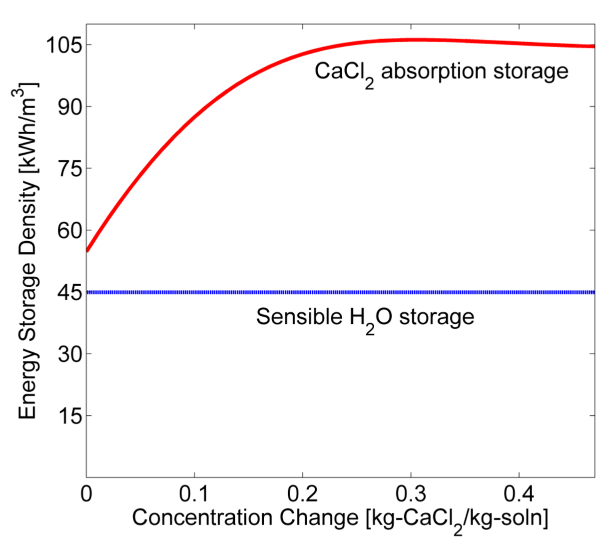
•Solar collectors use solar energy in the summer to boil water from diluted calcium chloride, $CaCl_2$(aq).



•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.

Energy Density



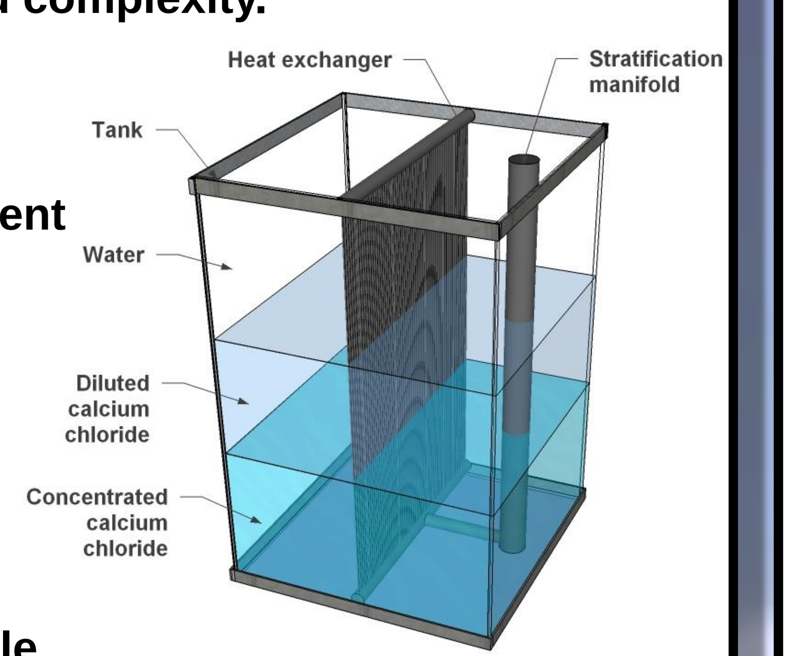
•Energy density is the stored energy per unit volume.

•A $CaCl_2$ absorption storage has up to *2.4x the energy density* of conventional water storage.

Design

•We propose a single vessel a to minimize volume, cost, and complexity.

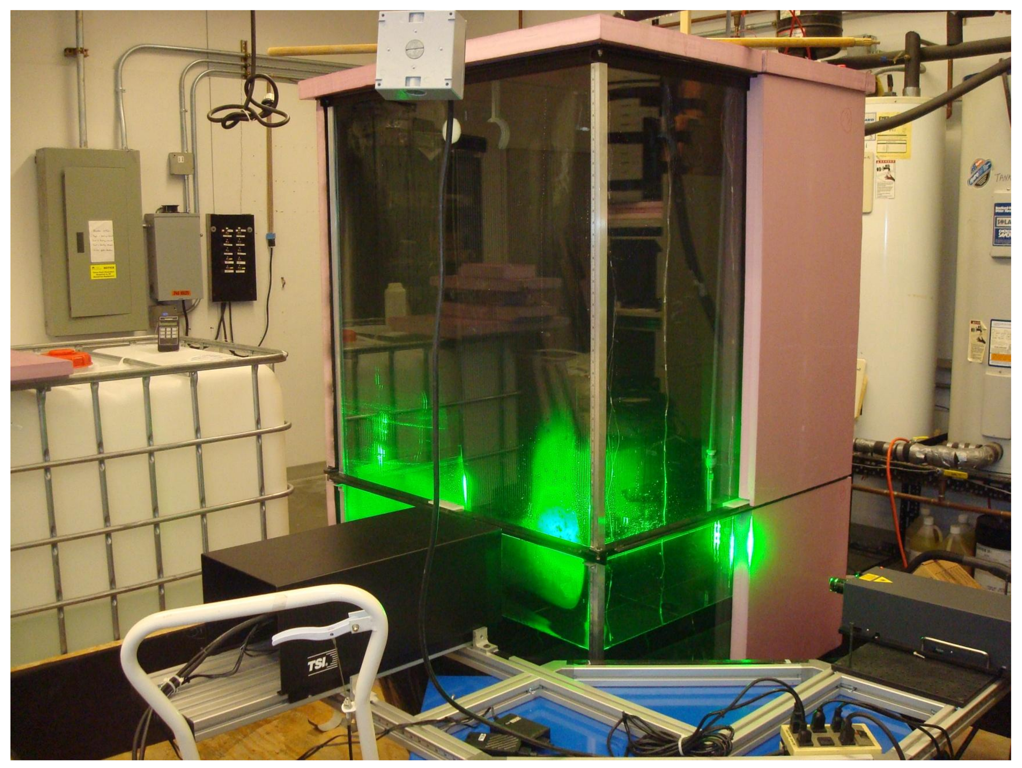
•The engineering *challenge* is to prevent the different liquids from mixing. Mixing causes losses.



•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.

Experimental Prototype



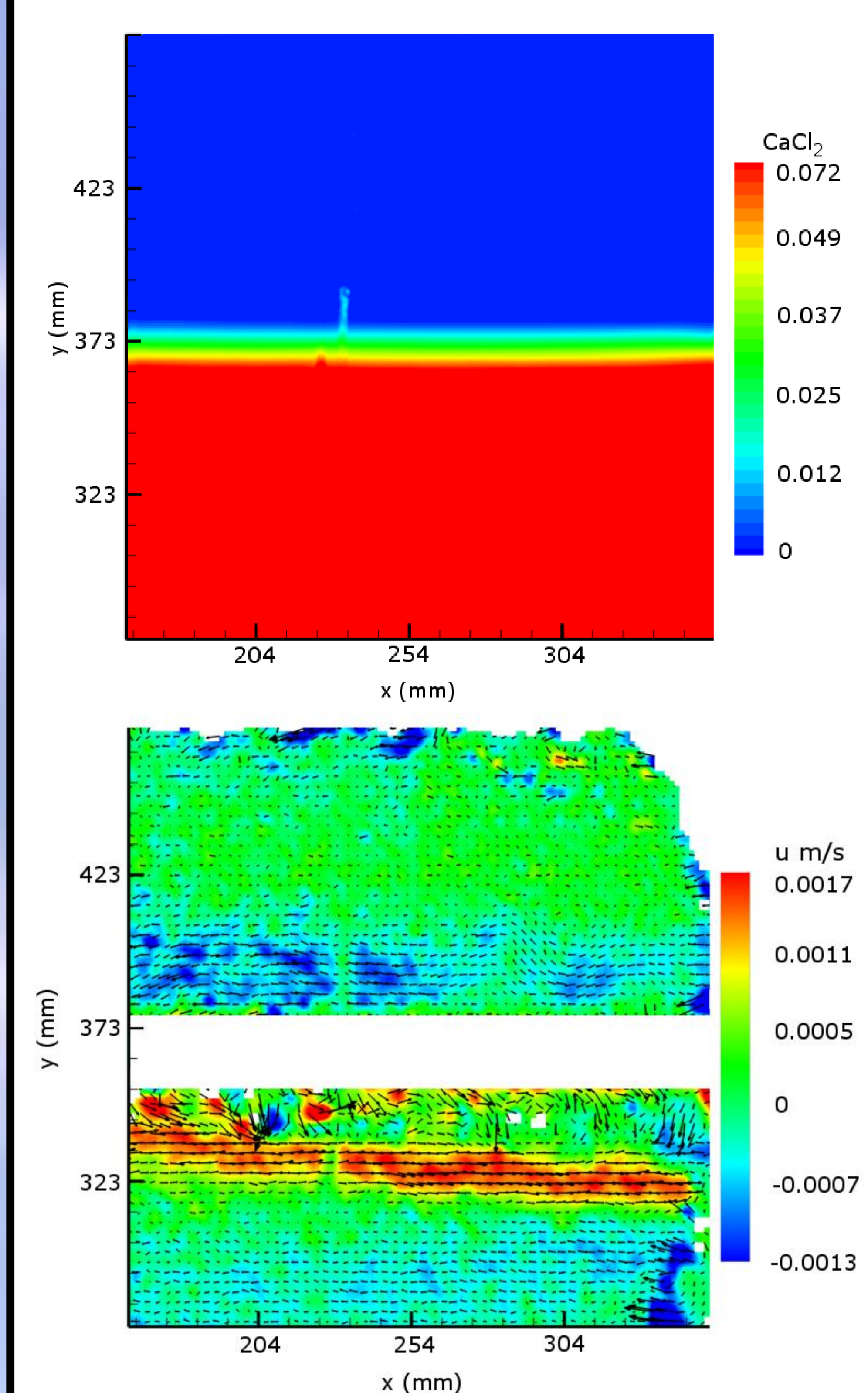
•Experiments are conducted in a 400 gallon tank to characterize the performance for seasonal modeling and engineering design.

•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 solutions.

•Mass transfer coefficients over a range of operating parameters characterize the performance.

Experimental Results

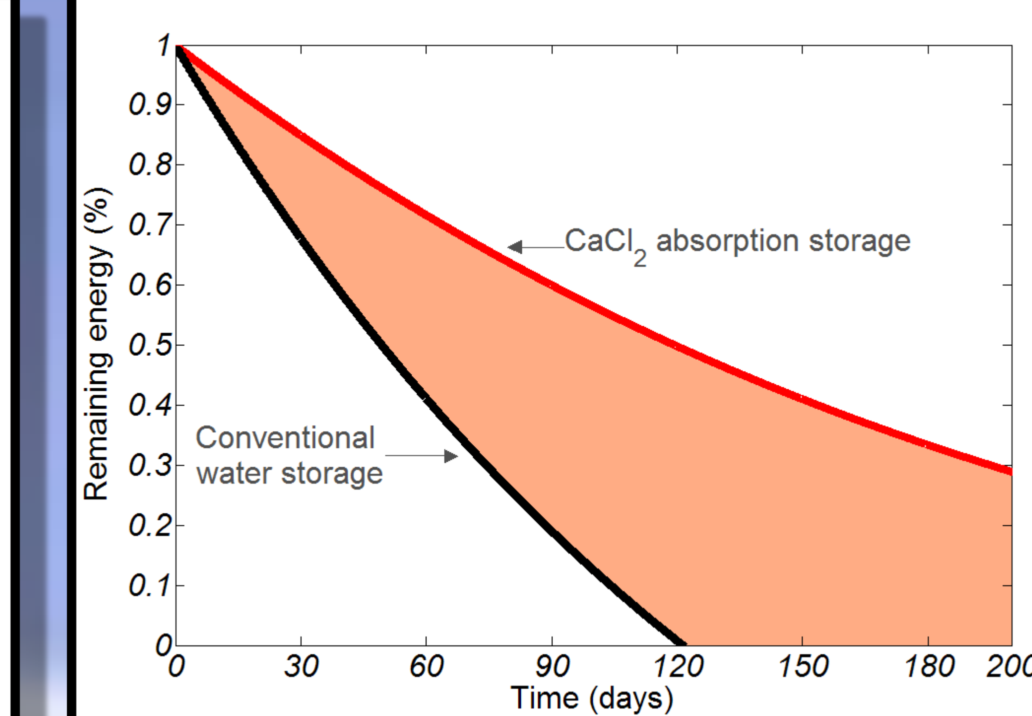


•Each measurement yields $CaCl_2$ concentration and velocity over a 20x20 cm imaging plane.

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

⟵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 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 used for residential heating!

✓ A thermochemical storage using $CaCl_2$(aq) yields a *59% reduction in storage volume* compared to water storage!

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

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