THERMOCHEMICAL STORAGE BREAKOUT

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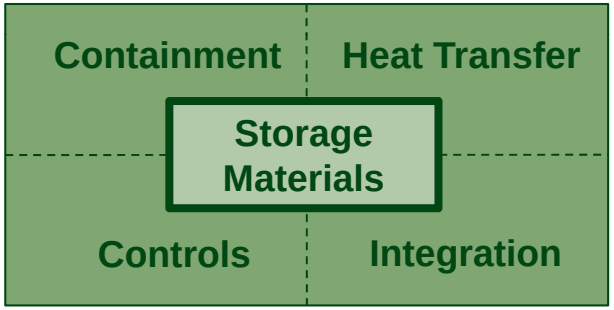
BASIC THERMAL STORAGE CONSIDERATIONS

Key Metrics of Performance	Example Units	Material Property	System Property
Storage Energy Density	MJ /kg, MJ /L	✔	✔
Transfer Power Density	MJ /kg•hr, MJ /L•hr	✔	✔
Operating Temperature	ºC	✔	✔
Cycle Life	# Cycles	✔	✔
Self-Discharge Rate	% /hour		✔
Roundtrip Efficiency	%		✔
Cost	$/MJ	✔	✔

Thermal Storage System



- Several important metrics to consider
- Both materials and system level considerations are important
- Properties may be complex or coupled, for instance:
  - e.g. power capability may change as heat is extracted and reactions proceed
  - e.g. power capability may degrade after several cycles

PRIMARY APPLICATIONS OVERVIEW

Buildings

Impact Objective: Dramatically reduce building energy consumption by storing and redeploying heat or cold to match building loads or optimize time of electricity use

Solar Thermal Power Generation

Impact Objective: Enable widespread deployment of solar thermal power by firming and extending the time window of output power generation

Industrial waste heat capture and storage

Impact Objective: Dramatically reduce industrial energy consumption by storing and redeploying waste heat for processing and manufacturing

Operational Mode(s)	Current Solution(s)	R&D Needs
Buildings: diurnal load shifting	water tanks, ice, embedded building materials, etc.	• Energy density • Power density • Longer storage time and less loss • Thermal cycling stress • Reaction reversibility • Cost
Buildings: seasonal load shifting	soil, sand, water, concrete, etc.	
Buildings: thermal storage coupled to CHP	water, oil, organic phase change materials, etc.	
Solar thermal storage	molten salts, organic phase chance materials	
Industrial waste heat capture and storage	non-water Rankine cycles, thermoelectric materials etc.	

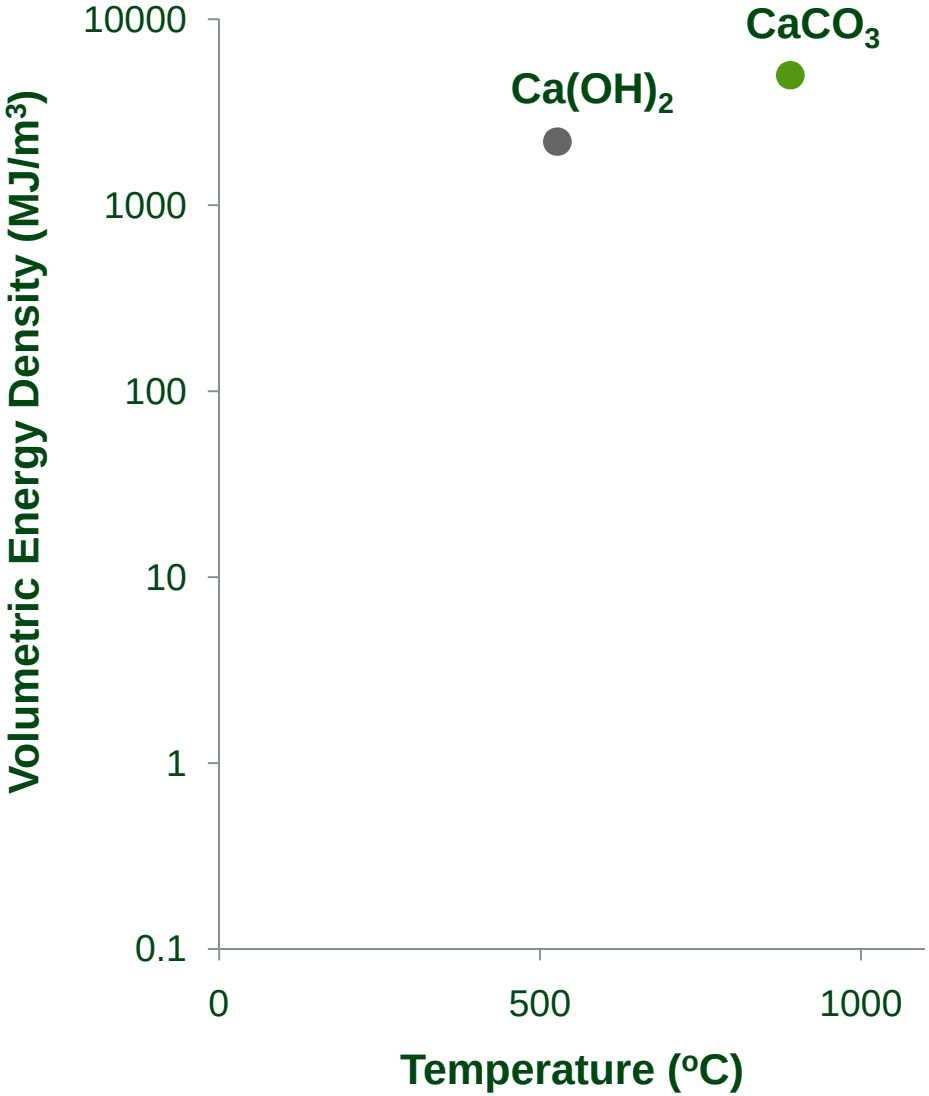
SCALE

Each furnace used to turn scrap metal into steel could be used to recycle about 15 megawatts of electricity.

THERMOCHEMICAL STORAGE REACTIONS

$Ca(OH)_2 \rightarrow CaO + H_2O$ $\Delta H = 73.92$ kJ/mol		
$Ca(OH)_2$	0.99 MJ/kg	2197 MJ/m^3
CaO	1.32 MJ/kg	4422 MJ/m^3
H_2O (g)	4.1 MJ/kg	1.13 MJ/m^3

$CaCO_3 \rightarrow CaO + CO_2$ $\Delta H = 178.5$ kJ/mol		
$CaCO_3$	1.96 MJ/kg	4998 MJ/m^3
CaO	3.19 MJ/kg	10678 MJ/m^3
CO_2 (g)	4.06 MJ/kg	8.02 MJ/m^3



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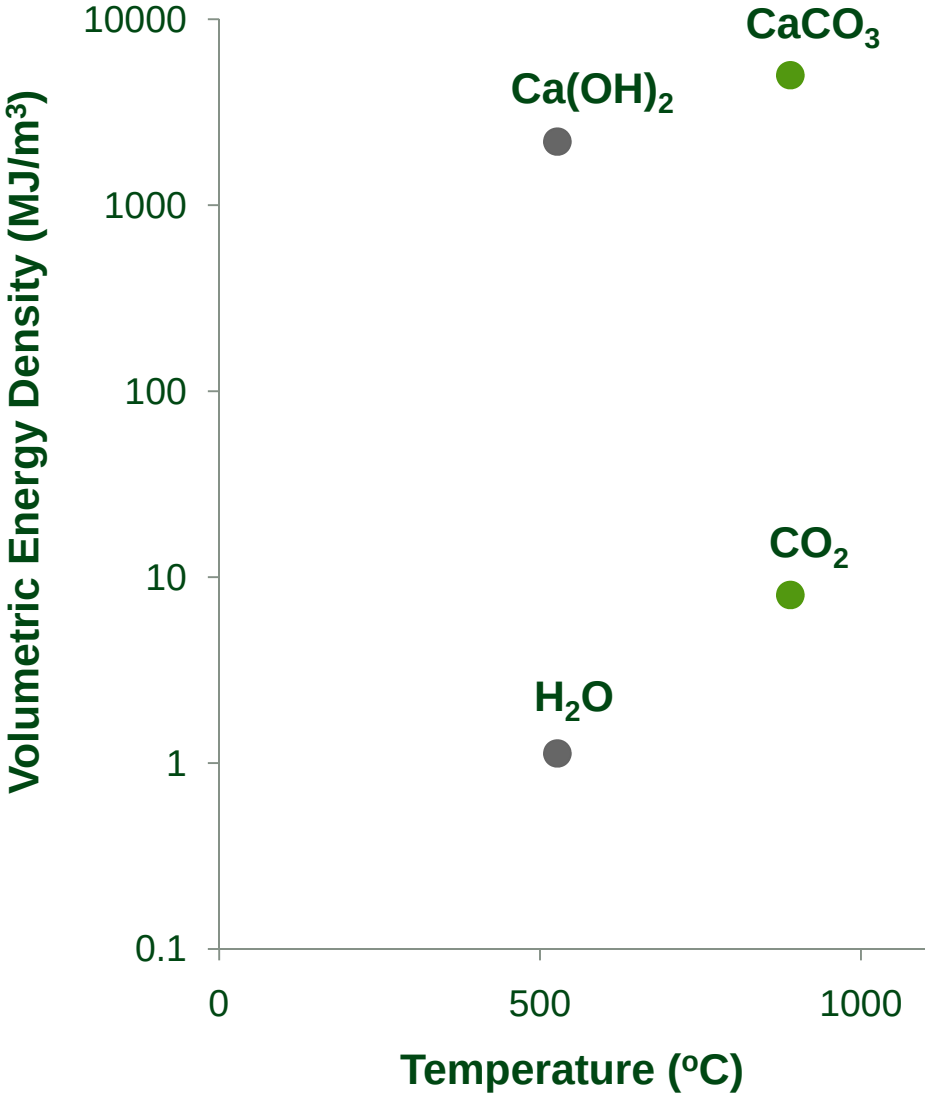


VOLUMETRIC ENERGY DENSITY

CHARGING

1. $Ca(OH)_2 \rightarrow CaO + H_2O(g)$ — *4.1 MJ/kg H_2O*
2. $H_2O(g) \rightarrow H_2O(l)$ — *-2.2 MJ/kg H_2O* → WASTE / USE

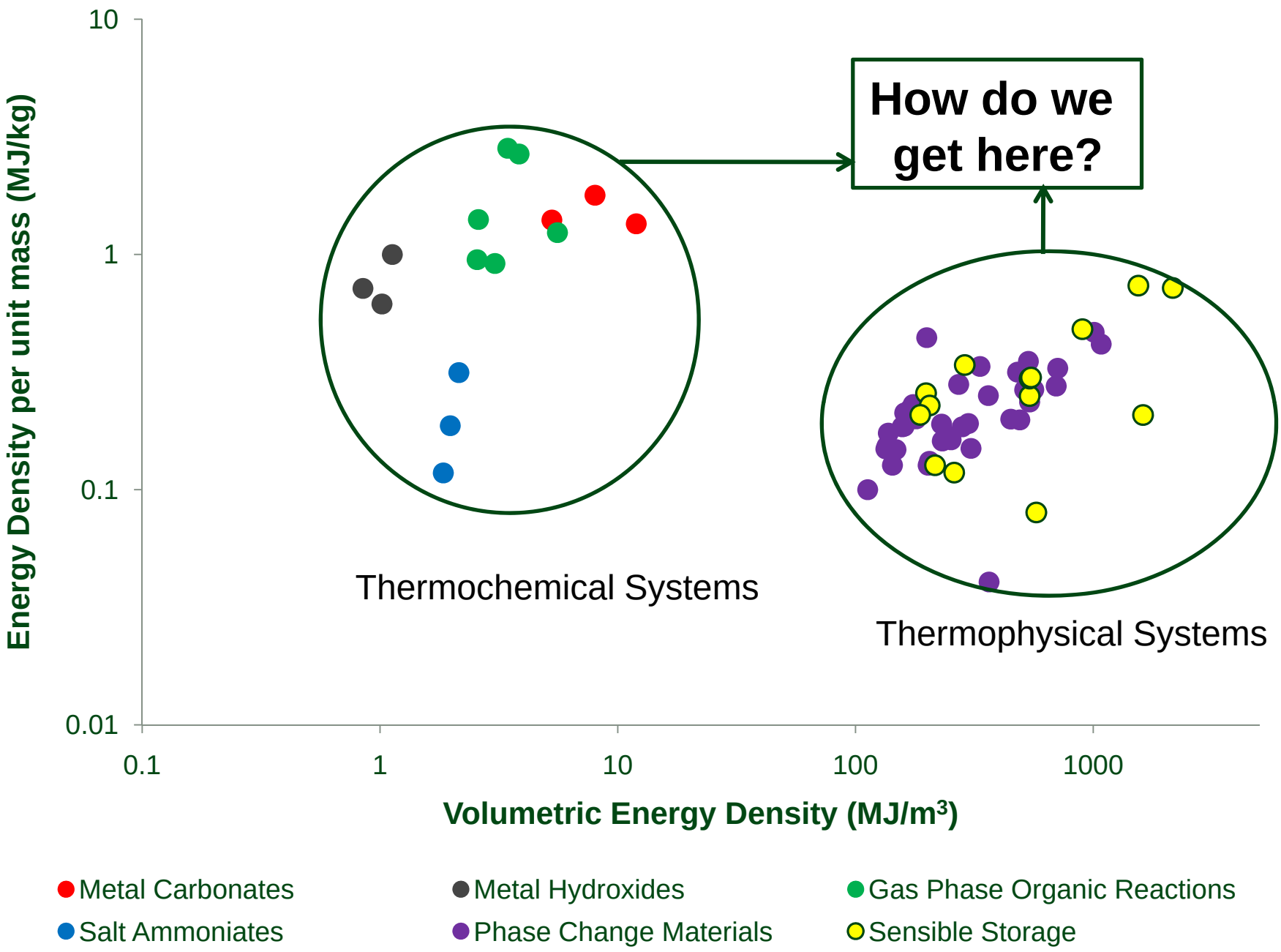
1.9 MJ/kg H_2O stored

DISCHARGING

1. $H_2O(l) \rightarrow H_2O(g)$ — *2.2 MJ/kg H_2O*
2. $CaO + H_2O(g) \rightarrow Ca(OH)_2$ — *-4.1MJ/kg H_2O*

1.9 MJ/kg H_2O released

46% efficient


How do we get here?
Thermochemical Systems
Thermophysical Systems
Energy Density per unit mass (MJ/kg)
10
1
0.1
0.01
0.1
1
10
100
1000
Volumetric Energy Density (MJ/m³)
Metal Carbonates
Metal Hydroxides
Gas Phase Organic Reactions
Salt Ammoniates
Phase Change Materials
Sensible Storage

QUESTIONS

1. What are the 5 most impactful energy applications of thermochemical storage?

What has been the bottleneck in adoption of thermochemical storage?

QUESTIONS

2. How can we increase the volumetric energy density (based on total volume) of chemical storage by two-orders-of-magnitude without compromising on mass energy density and roundtrip efficiency?

QUESTIONS

3. Can non-thermal approaches (pressure-swing, photochemical, electrochemical) be used for discharging?

Is this beneficial?

QUESTIONS

4. How could catalysts (heterogeneous, homogeneous or biomimetic) be used to improve the efficiency of the overall system?

QUESTIONS

5. What will a very high impact research and development program look like for thermochemical storage?

What will be the composition of an ideal research team?

POLL

What are the 5 most impactful energy applications of thermochemical storage?

What has been the bottleneck in adoption of thermochemical storage?