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SolarReserve's Crescent Dunes CSP Project, near Tonopah, Nevada, has an electricity generating capacity of 110 megawatts.
(credit: SolarReserve)

# Harnessing the Potential of Metal Hydrides for Concentrated Solar Applications

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# Concentrated Solar Power – Thermal Energy Storage (CSP-TES)

| Material | Energy Storage Density (kJ/kg) |
|---|---|
| Molten salt | 153 |
| PCM ($NaNO_3$) | 282 |

| Hydrides | |
|---|---|
| $CaH_2$ | 4934 |
| LiH | 8397 |
| $TiH_2$ | 1900-2842 |
| $NaMgH_3$ | 1721-2881 |
| $Mg_2FeH_6$ | 2090 |
| $MgH_2$ | 2814 |

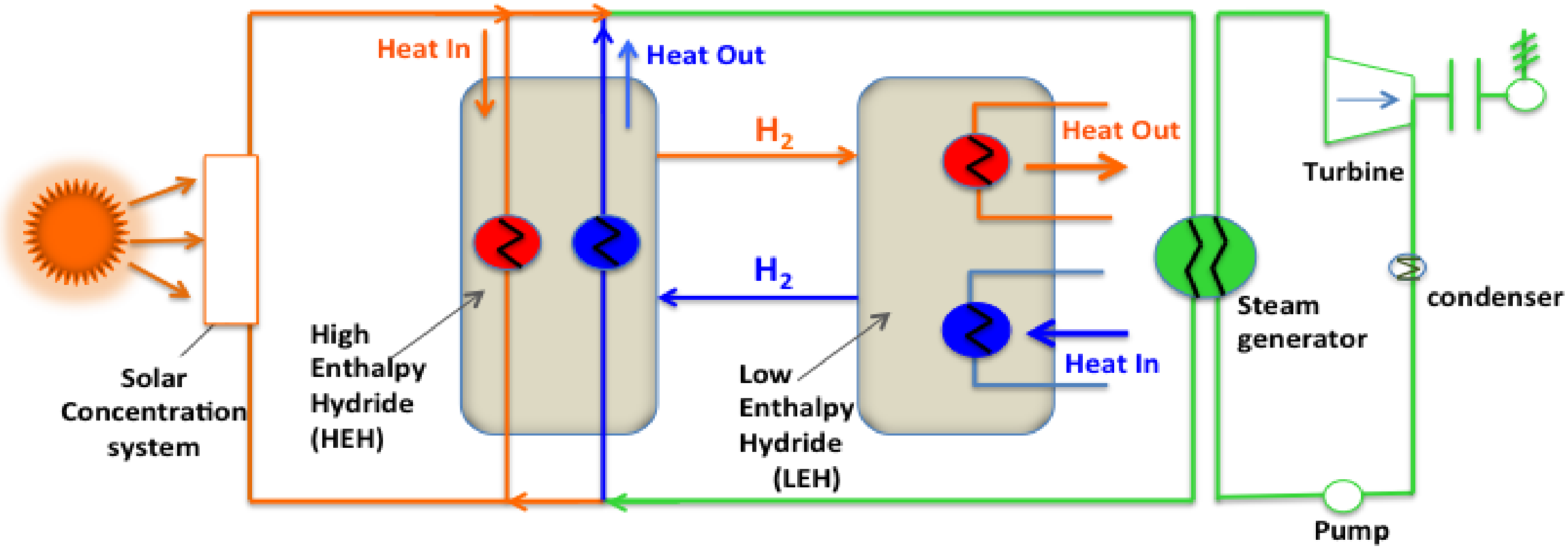
Thermal Energy Storage is Based on Reversible Chemical Reactions

**Chemical reactions are attractive ..why metal hydrides?**

*Metal hydrides have exceptional energy storage density which can minimize the cost and footprint of the TES system for CSP*

**Stirling Engine Energy Systems (SES)** at UNLV.

# Schematic of Heat Storage System



# SRNL Approach

**SRNL's unique approach, based on the integration of modeling and hydride material development, is being applied to help solve this tremendous challenge**

- **Modeling, system optimization and techno economics**
- **Material development, tuning and modification**

**Modeling guides material modification and material properties direct system design**

**Project resulted in developing new materials**
**Cost analysis**
**Engineering Modeling**

# DOE goals and a New Higher Temperature System

Different approach

In order to meet the DOE goals the HTMH needs to operate at > 650 C, pairs with LTMH and the over all system must be inexpensive to reach 15c KW/h. The ultimate goal is 3c

Options $Mg_2FeH_6$, TiH , LiH, $CaH_2$

None of the above materials are suitable to meet the targets

Different approach is needed:

$$XMH_z + yA \rightleftharpoons M_xA_y + \frac{xz}{2} H_2 \uparrow\downarrow$$

The above equation describes a composite consisting of a hydride $MH_z$ and a metal $A$ when heated an alloy $M_xA_y$ is formed releasing hydrogen and the processes is reversible

# Higher Temperature Systems

Altering thermodynamics by creating other reactions:

$$RT\ lnf = \sum_i \Delta H_i - T \sum_i \Delta S_i$$

$$RT\ ln\ p = \Sigma_i \Delta\ H_i\ -\ T\ \Sigma_i \Delta\ S_i$$

$$XMH_z + yA \rightleftharpoons M_xA_y + \frac{xz}{2}\ H_2\ \uparrow\downarrow$$

**$LiH + Al \leftrightarrow LiAl + 1/2\ H_2\uparrow$**

**$MgH_2 + Al \leftrightarrow 1/2\ Al_3Mg + 1/2\ Al + H_2\uparrow$**

**$2\ MgH_2 + Si \leftrightarrow Mg_2Si + 2H_2\uparrow$**

**$CaH_2 + 2\ Al \leftrightarrow CaAl_2 + H_2\uparrow$**

**$2\ CaH_2 + Si \leftrightarrow Ca_2Si + H_2\uparrow$**

# Material Development, Characterization and Performance

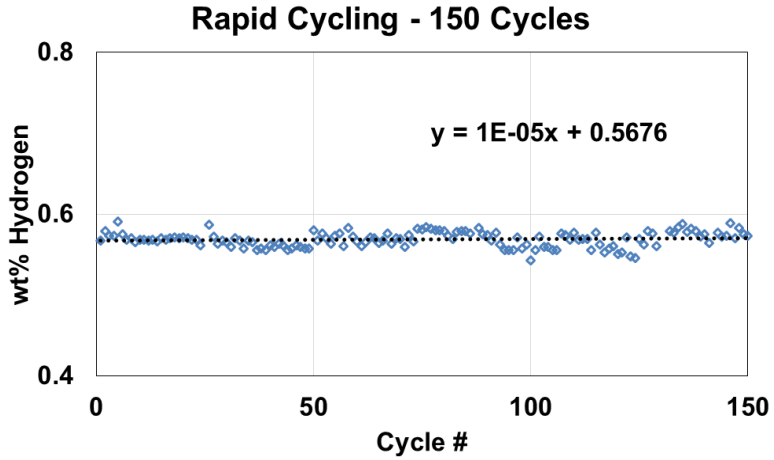
- A variety of HTMH were investigated for TES applications. These include $MgH_2$, $Mg_2FeH_6$, $NaMgH_3$, TiAl, $NaMgH_2F$.
- Thermal and kinetic properties of the above materials were measured including enthalpy, entropy, bulk density, hydrogen capacity, activation energy, thermal conductivity, etc.

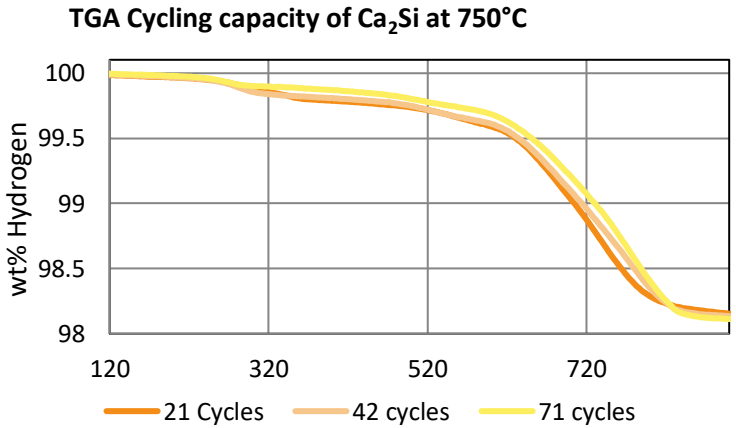
**New approach :** $MH_x/A_y \rightleftarrows M_xA_y + x/2H_2 \uparrow\downarrow$

Example $CaH_2/Si \rightleftarrows Ca_2Si + H_2 \uparrow\downarrow$

A new system inspired by the above two systems (Ca, Si and Al) was developed

- A low-cost metal hydride capable of reversibly storing ~ 2 wt. % hydrogen at 750°C was demonstrated for the first time. *This material is currently the most promising high temperature metal hydride material discovered for TES applications at high temperatures (> 650 °C) which is capable of meeting DOE cost targets*.




**Patents;**

R. Zidan "Storing High Exergetic Thermal Energy Based on Reversible Alloying and High Enthalpy Hydrides", **Patent Granted**

P. Ward and R. Zidan "High Temperature thermochemical energy storage materials" Pending

# Metal Hydride TES Highlights

- The DOE program made SRNL become a world leader in this technology.
- SRNL has been granted and applied for a transformational patents
- 6 peer-reviewed papers published in this area
- With its partners (e.g., Australia and Germany) SRNL initiated an International Energy Agency (IEA) working group for MH TES technology and has facilitated significant international research interest in this area
- SRNL has also received considerable interest from several CSP system design and installation firms, including United Sun Systems, Fluor and Brayton Energy

- SRNL TES technology has been recently licensed by United Solar Systems

# Future Applications of MH TES

- Solar hydrogen production
  - Chemical cycle
  - High Temperature Electrolysis
- Natural gas reforming and conversion to syngas
- Water and waste treatment
- Small Modular dish concentrator systems for home power
- Stirling engines for direct production of electricity

All become cost effective when Thermal Energy Storage is operated at high temperatures