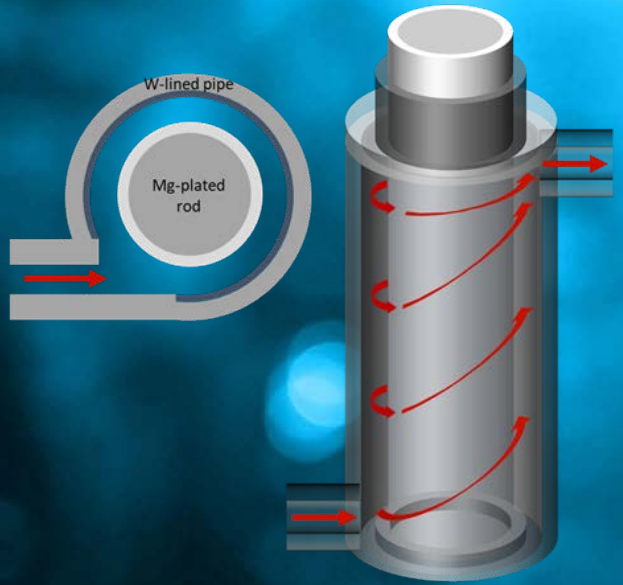
NREL
Transforming ENERGY



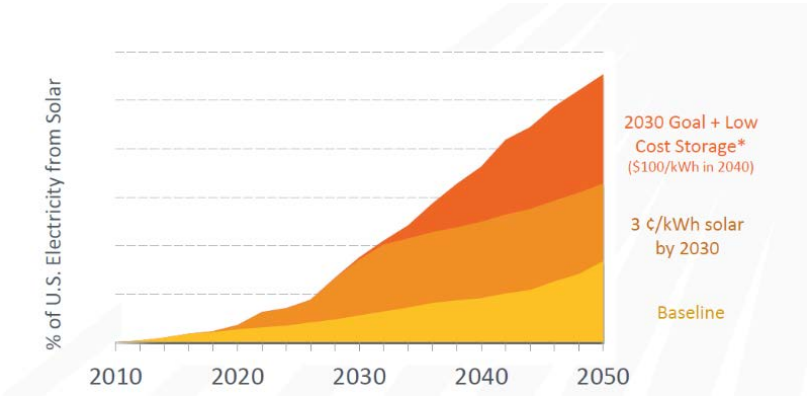
Electrochemical mitigation of corrosion in concentrated solar power systems

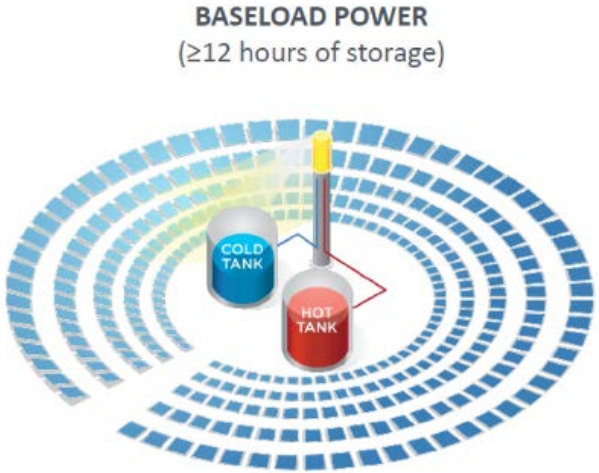
Kerry Rippy

ASES2021 · Boulder, Colorado

August 4, 2021

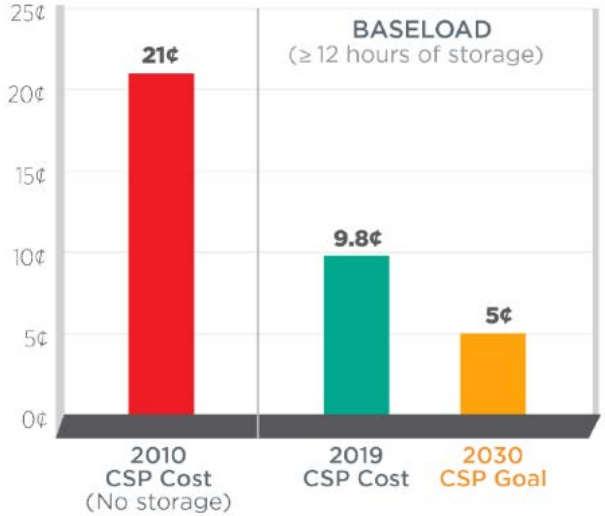
Low Cost Solar ***and Storage*** will Drive Deployment

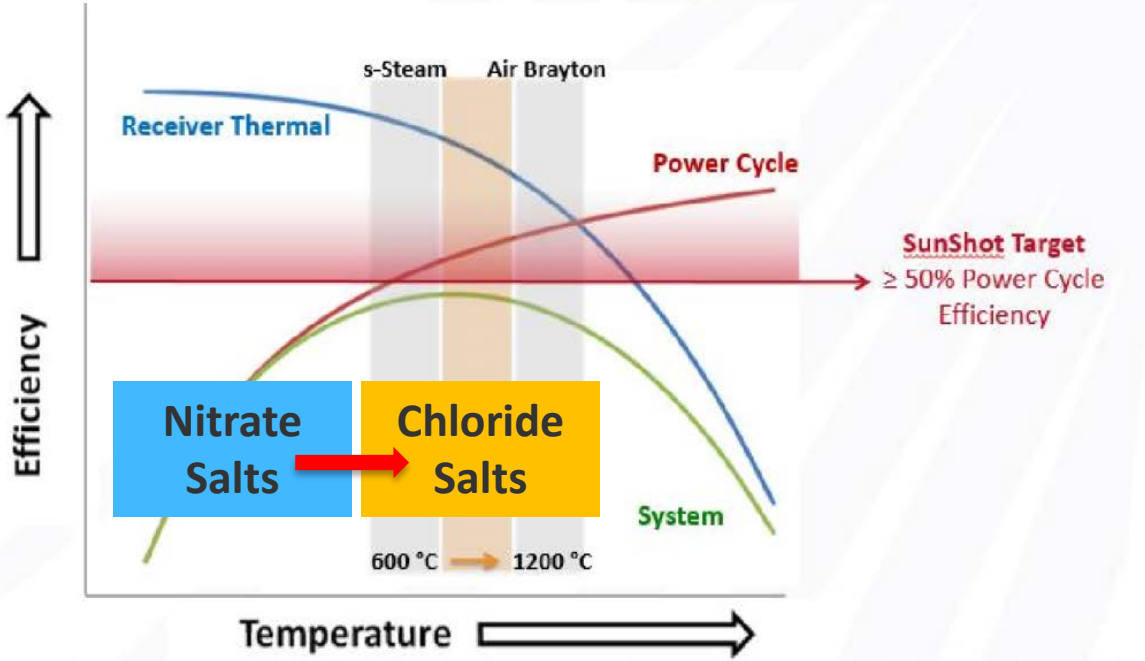




Mehos, Turchi et al. Concentrating Solar Power Gen3 Demonstration Roadmap, 2017

Decreasing the cost of CSP

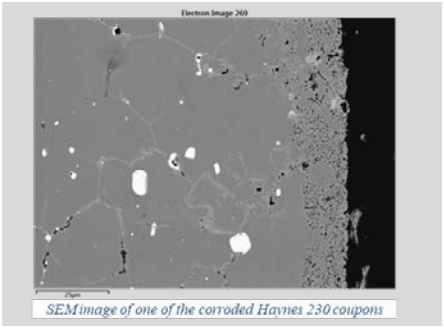




Mehos, Turchi et al. Concentrating Solar Power Gen3 Demonstration Roadmap, 2017

Molten Chloride Salt Candidates

Salt	Notable Advantages	Notable Disadvantages
Zn-based chloride	• Lowest melting point • Corrosion mitigation via control of melt redox potential (oxygen and water exclusion) in inert atmospheres	• Measureable vapor pressure disperses $ZnCl_2$ in headspace • Very corrosive in liquid and vapor phases if oxygen or water exist. Intergranular corrosion can occur. • Lowest heat capacity • Requires controlled purification and pre-melting procedures under vacuum
Mg-based chloride	• Lowest cost per kg • Corrosion mitigation via control of melt redox potential using active-metals such as Mg in inert atmospheres with oxygen/water exclusion	• Highest melting point • Very corrosive in liquid and vapor phases if oxygen or water exist. Intergranular corrosion can occur. • Intergranular corrosion if Mg concentration decreases below required value • Requires controlled purification and pre-melting procedures under inert atmospheres

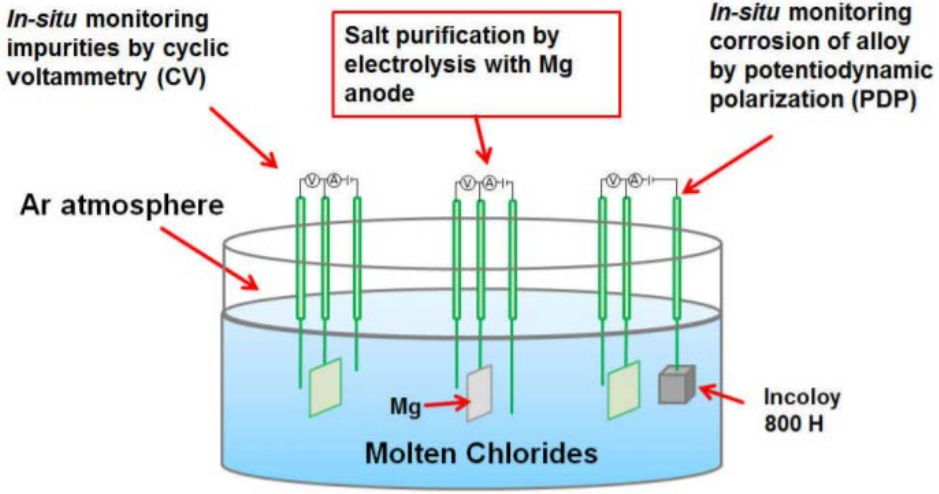


SEM image of one of the corroded Haynes 230 coupons

Alloy	OCP vs. pseudo-RE [mV]	E_{corr} vs. pseudo-RE [mV]	j_{corr} [μA/cm^2]	CR [mm/year]
650 °C				
SS347	−784±113	−847±91	713.00±30.74	7.49±0.32
SS310	−888±170	−938±218	626.16±38.72	6.42±0.40
In800H	−876±32	−910±22	573.79±34.19	5.94±0.33
IN625	−849±73	−856±57	233.00±94.68	2.80±0.38
700 °C				
SS310	−506±70	−571±75	1213.61±148.10	12.45±1.52
In800H	−453±5	−474±3	1387.79±131.96	14.31±1.36

Corrosion rates mm to cm per year

Gomez-Vidal, J. C.; Tirawat, R., Solar Energy Materials and Solar Cells. **2016**
Mehos, Turchi et al. Concentrating Solar Power Gen3 Demonstration Roadmap, 2017



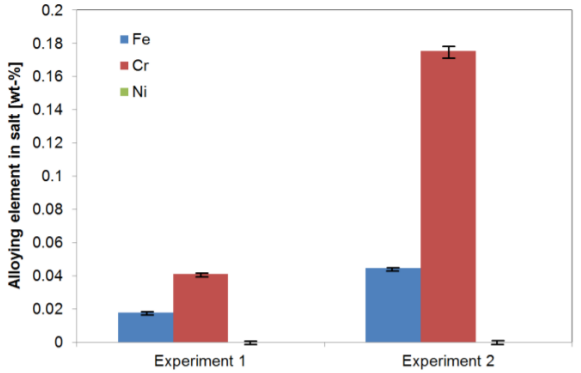


Figure 13: Alloying elements Cr, Fe and Ni dissolved in the chloride salts after 450 h (Experiment 1, purified salt) and 340 h (Experiment 2, unpurified salt) exposure, measured with AAS. Ni Content is below the detection limit of AAS (10 ppm in weight). The error bar represents the standard deviation of three measurements.

Ding, W.; et. Al. *Solar Energy Materials and Solar Cells* **2019**.

Corrosive Species in Chloride Salts can be removed by electrolysis!

$2MgOHCl \rightarrow 2MgOH^+ + 2Cl^-$ [*molten salt*]

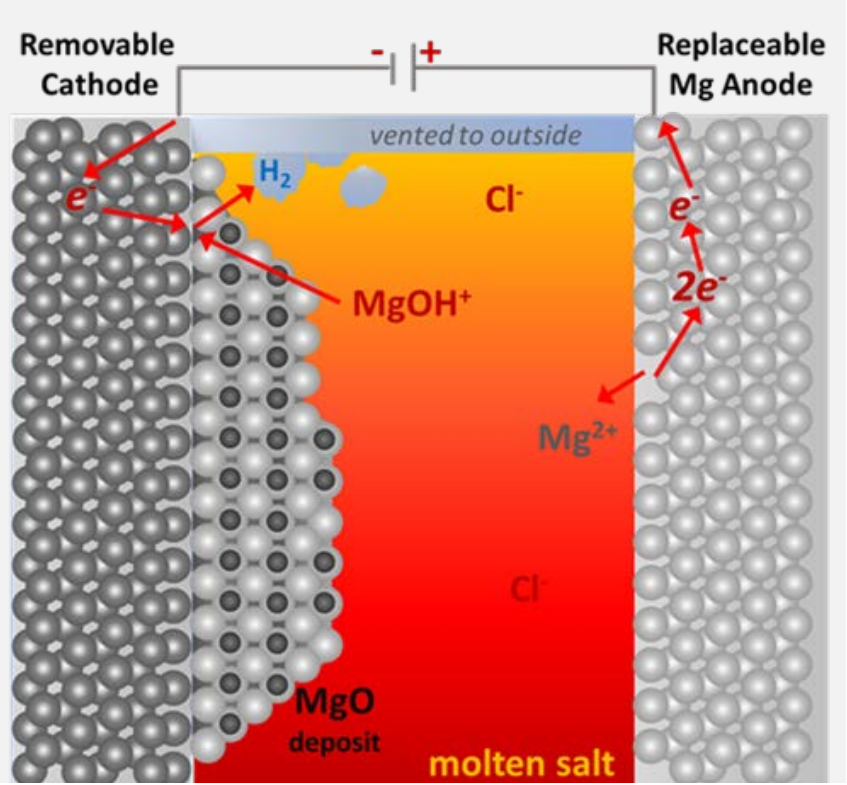
$Mg^{2+} + 2Cl^- \rightarrow MgCl_2$ [*molten salt*]

$2MgOH^+ + 2e^- \rightarrow 2MgO + H_2(g)$ [*cathode*]

$Mg(s) \rightarrow Mg^{2+} + 2e^-$ [*anode*]

$2MgOHCl + Mg(s) \rightarrow MgCl_2 + 2MgO + H_2(g)$ [*overall reaction*]

Electrochemical Purification



$2MgOHCl \rightarrow 2MgOH^+ + 2Cl^-$ [*molten salt*]

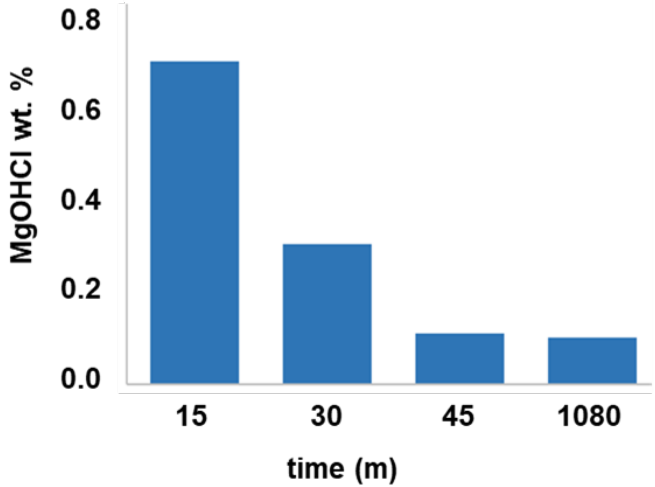
$Mg^{2+} + 2Cl^- \rightarrow MgCl_2$ [*molten salt*]

$2MgOH^+ + 2e^- \rightarrow 2MgO + H_2(g)$ [*cathode*]

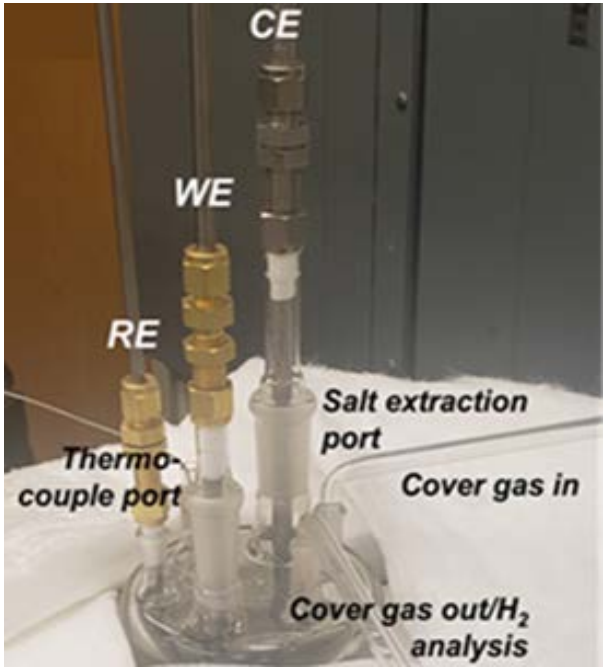
$Mg(s) \rightarrow Mg^{2+} + 2e^-$ [*anode*]

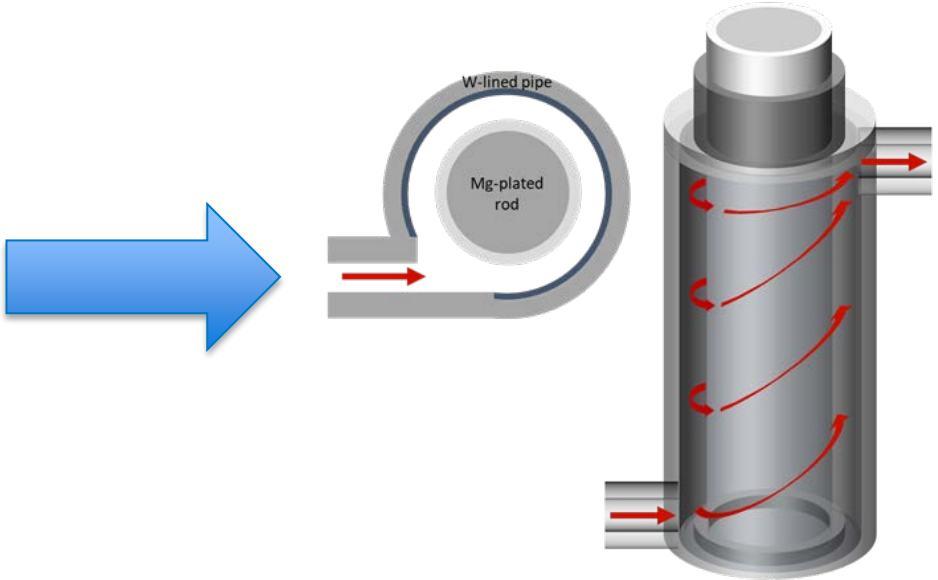
$2MgOHCl + Mg(s) \rightarrow MgCl_2 + 2MgO + H_2(g)$ **[*overall reaction*]**

Results of Purification in Batch Reactor



Lab Scale to Industrial Flow Reactor





Significance & Impact

- Purification cell will ***substantially improve viability*** of molten chloride salt-based systems
  - It will ***decrease LCOE***
  - It will ***decrease maintenance*** costs
  - It will enable ***less expensive containment alloys*** to be used

Thank you for your attention!

Team Members:
Dr. Judith Vidal, NREL
Dr. Patrick Taylor, CSM
Liam Witteman, CSM
Interns: Nick Adams, Elizabeth Howard, Abigail Monasterial

NREL/PR-5500-81439