100-Gigawatt-Hour Crushed-Rock Heat Storage for CSP and Nuclear

Can We Achieve Capital Costs of $2-4/KWh?

Charles Forsberg and Ali S. Aljefri

Massachusetts Institute of Technology
Cambridge, MA 02139, Email: cforsber@mit.edu

SolarPaces2020; Albuquerque, New Mexico (Now Webinar)
September 29-October 2, 2020

Low-Carbon Systems Require Massive Storage

- **The U.S. energy system has 45 to 90 days of storage** (fossil fuels, hydro, nuclear) to deliver energy when needed
- Most of that storage is in the form of fossil fuels that will not be available in a low-carbon world
- U.S. annual energy consumption: 25,155 TWh; one month storage is 2,000,000 GWh
- **Require storage strategies at the million GWh scale**

We are Examining 100-GWh Scale Heat Storage

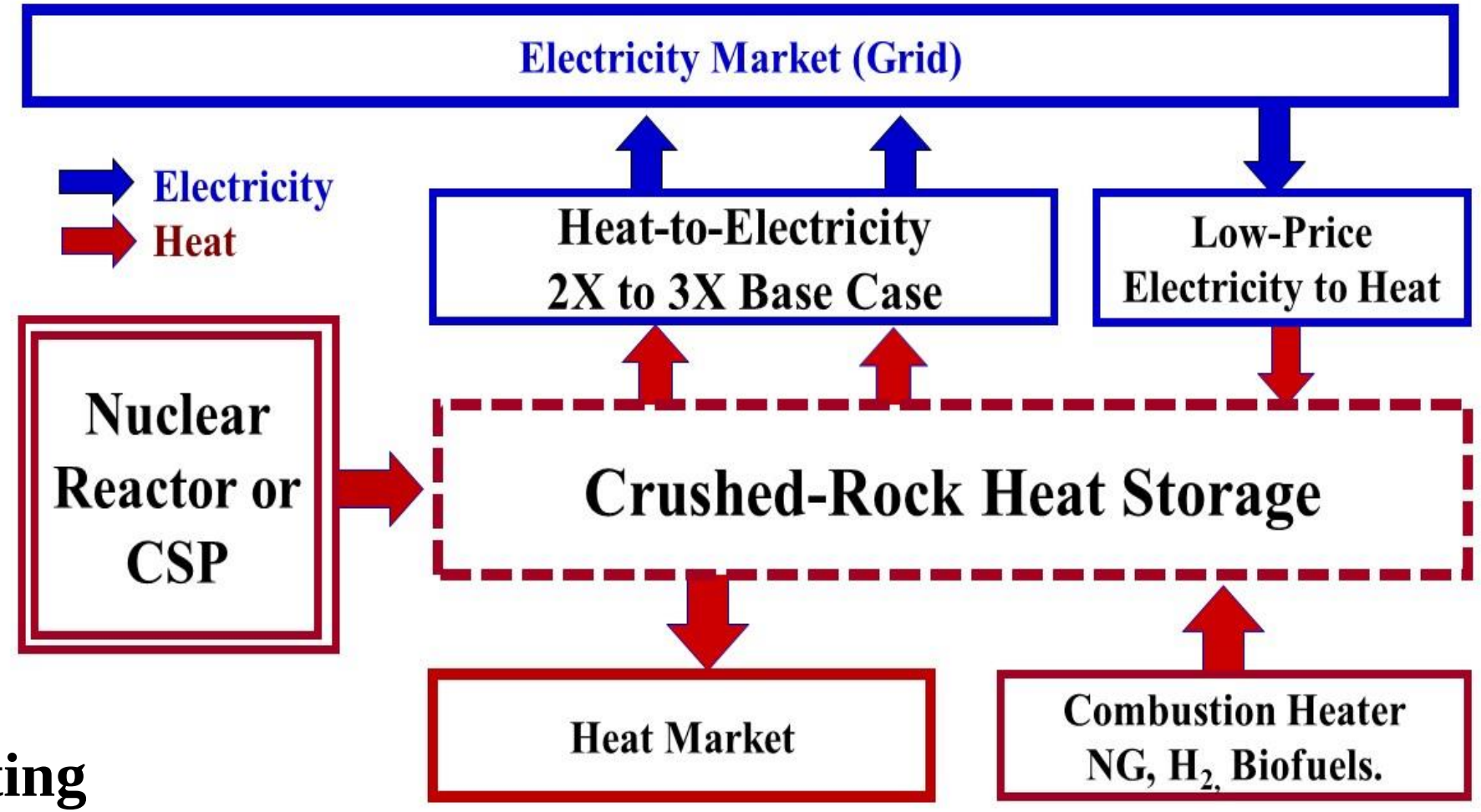
10,000 Units Equal one Million GWh

100-GWh Heat Storage System Capabilities Similar to a Large Hydro Pumped Storage Facility

TVA Raccoon Mountain Pumped-Storage Plant:
1,652 MW maximum output for 22 hours

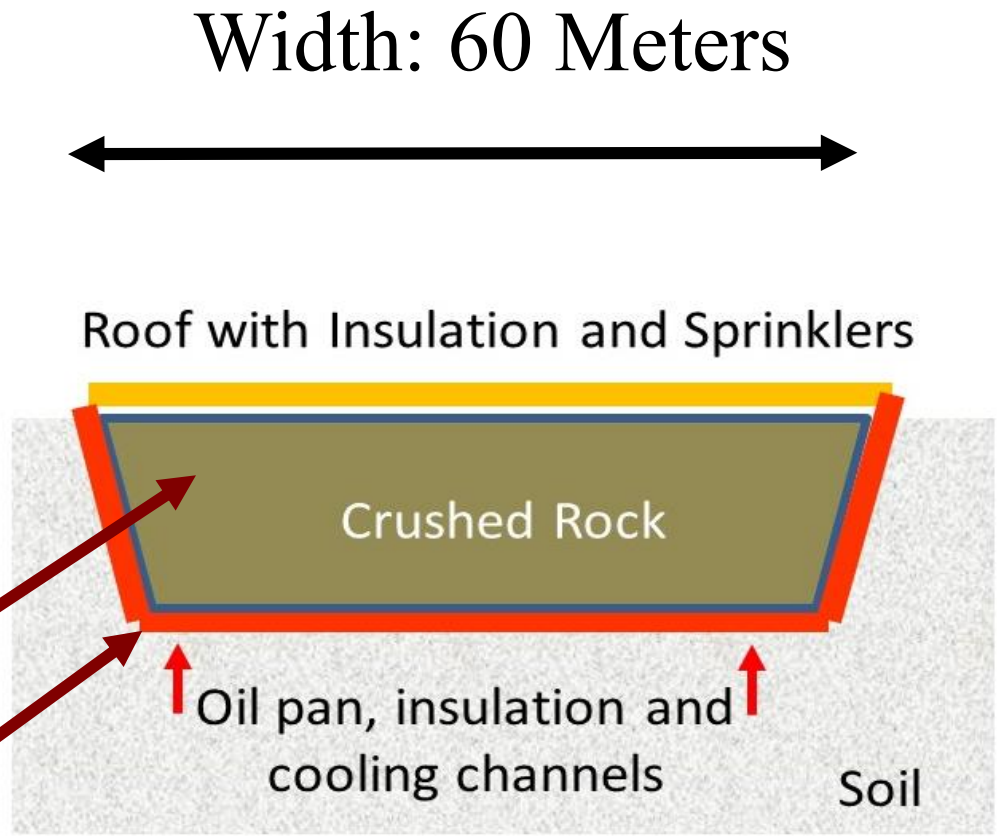
System Design with Heat Storage

- Electricity
- Electricity Conversions
- Heat Storage & Generation
- Heat Markets, Assured Generating Capacity



100-GWh Crushed-Rock Trench Heat Storage

- Single trench storage container
  - 60 m wide
  - 20+ meter high
  - Up to 1000 meters long
- A gigawatt-hour of heat storage or more per 10 meters of trench length
- **Crushed rock: lowest-cost heat storage**
- **Minimize surface (steel and insulation) to volume ratio to minimize costs**

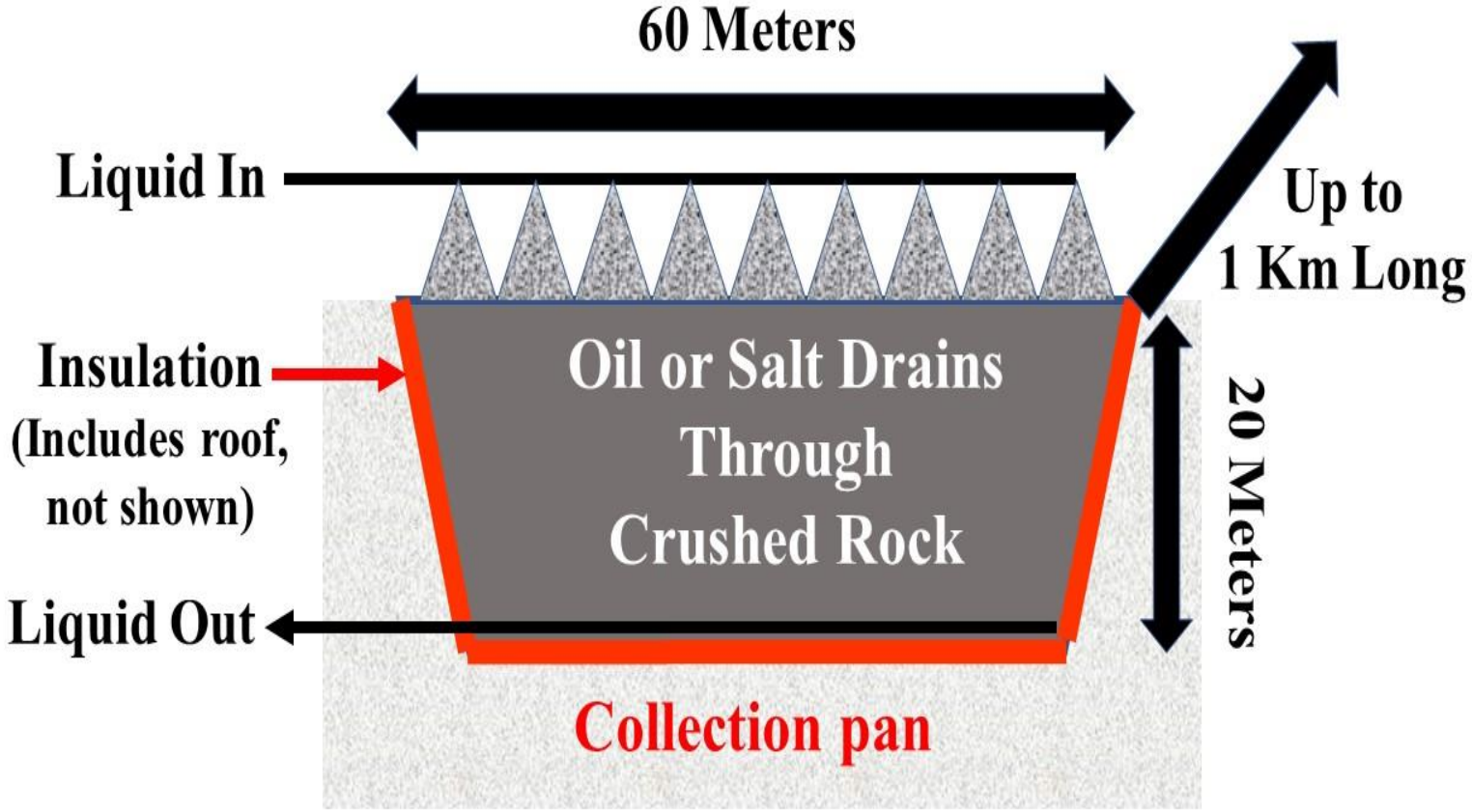


Neyland Stadium (U. of Tenn.) Vs Hot Rock Storage

- American Football Field
  - 44.8 m Wide
  - 91.44 m Long
- Kilometer long heat storage

Transfer Heat to and from Heat Storage with Heat Transfer Oil or Liquid Nitrate Salt

- Spray hot or cold fluid over rock with gravity flow to salt or oil pan at bottom
- **Minimize heat transfer fluid inventory and cost, fluid moves heat, not heat storage**



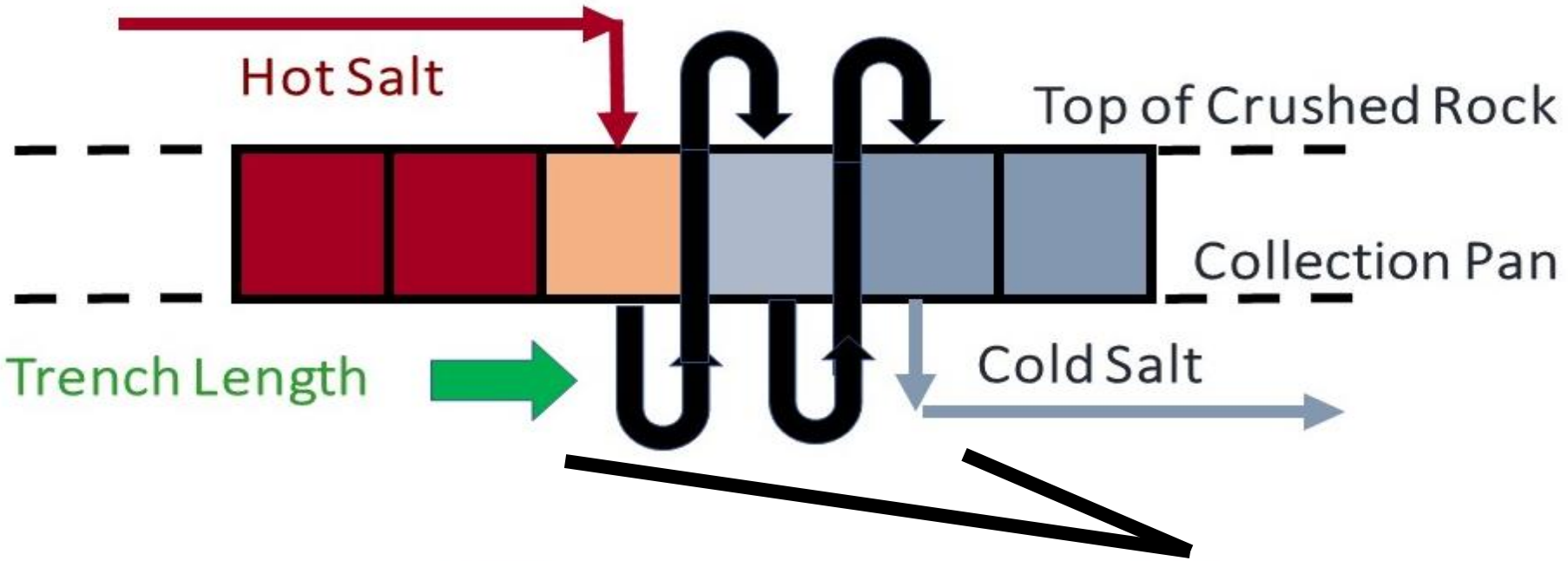
Chose Heat-Transfer Oil or Nitrate Salt Depending Upon Reactor or CSP Peak Coolant Temperatures

Both Coolants Used in CSP Heat Storage Tanks

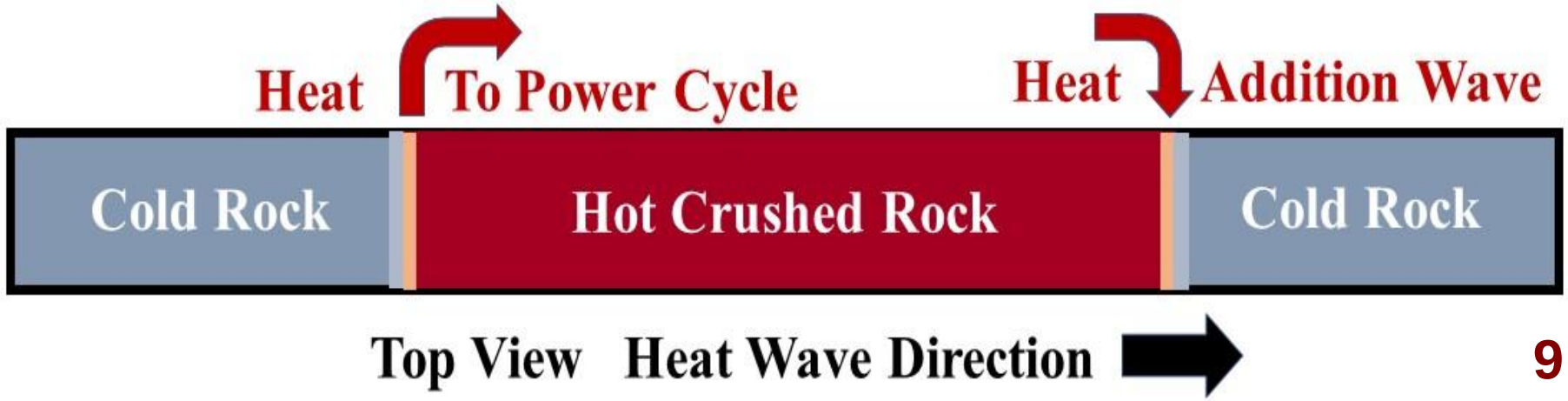
- **Heat transfer oils for less than 400°C**
  - Inert relative to most types of rock
- **Nitrate salts for less than 600°C**
  - Must carefully chose compatible rock types

Sequential Heating or Cooling of Crushed Rock Section by Section with Hot Fluid Flowing By Gravity

Side View



Top View

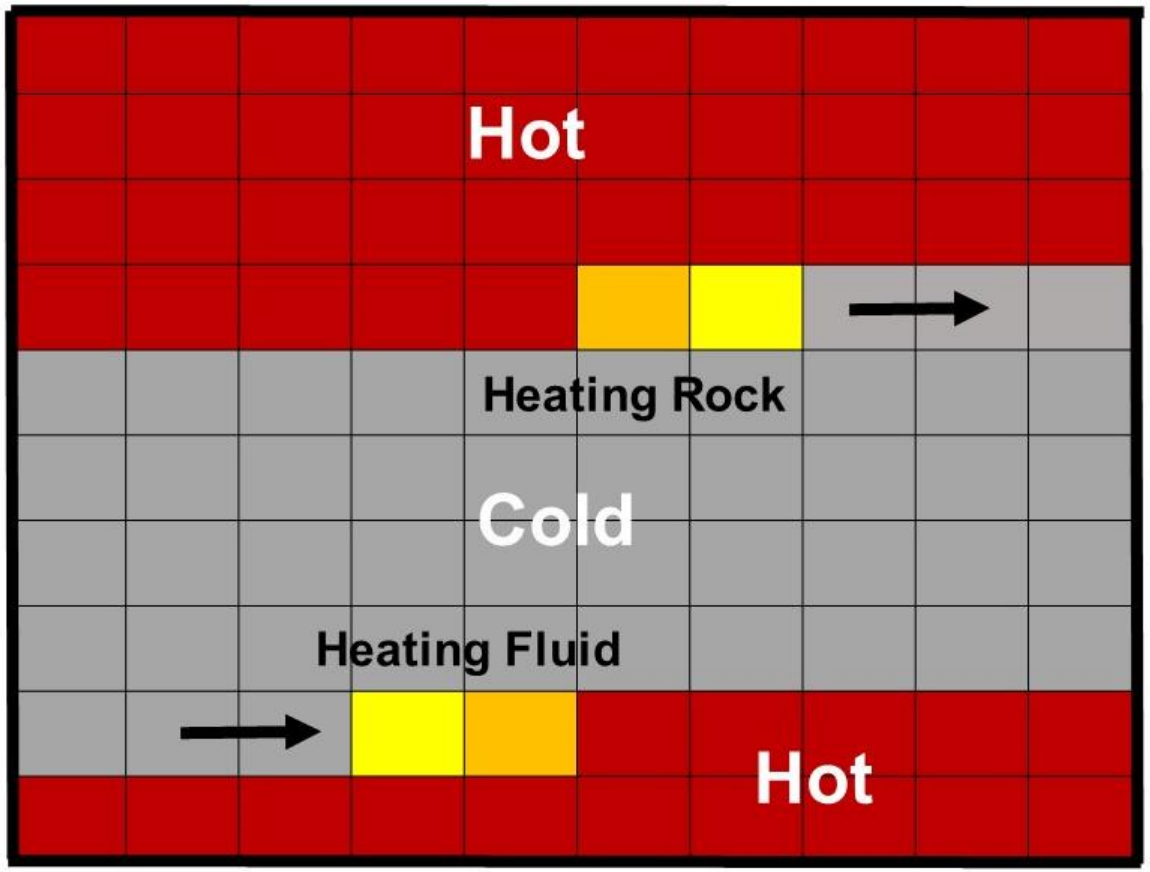


Three Features to Minimize Cost

- Crushed rock heat storage—lowest cost heat storage material
- Minimize salt or oil heat transfer fluid
- Minimize container costs by minimizing surface to volume ratio of storage container
  - Option of 250 m by 250 m by 20 m

Minimizing Container Cost Drives Heat Storage Container Design to Square / Circular Design to Minimize Surface Area

- 250 m by 250 m
- 25 m by 25 m heating and cooling zones
- Crushed rock without flowing fluid acts as an insulator
  - Low-conductivity crushed rock—touch at points
  - Gas acts as insulators



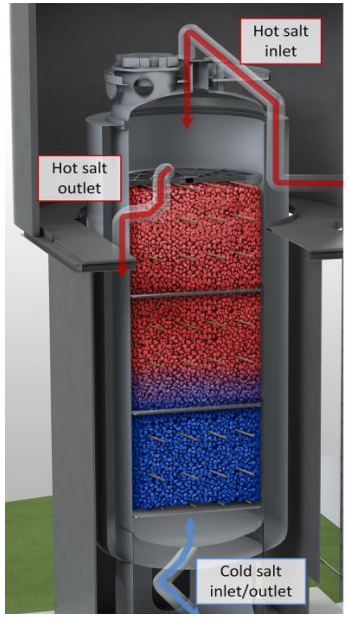
Conclusions: Heat Storage is all about Cost

Progression To Lower-Cost Oil and Salt Systems

Nitrate Salt or Oil (Today)

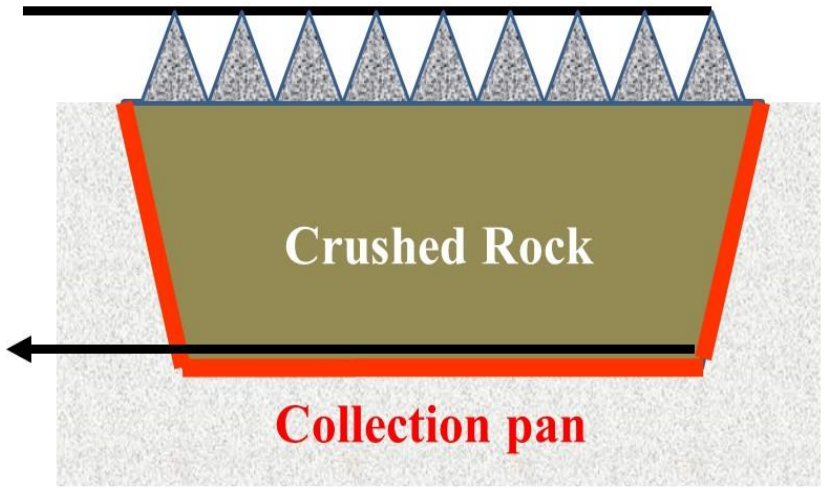
Solana Generating Station
(2013, U.S., ~4200 MWh(t))

Crushed Rock in Oil or Nitrate Salt



DLR: Europe
(Laboratory)

Crushed Rock with Oil / Salt Heat Transfer



MIT
(Early Development)