Thermochemical Energy Storage with Ammonia

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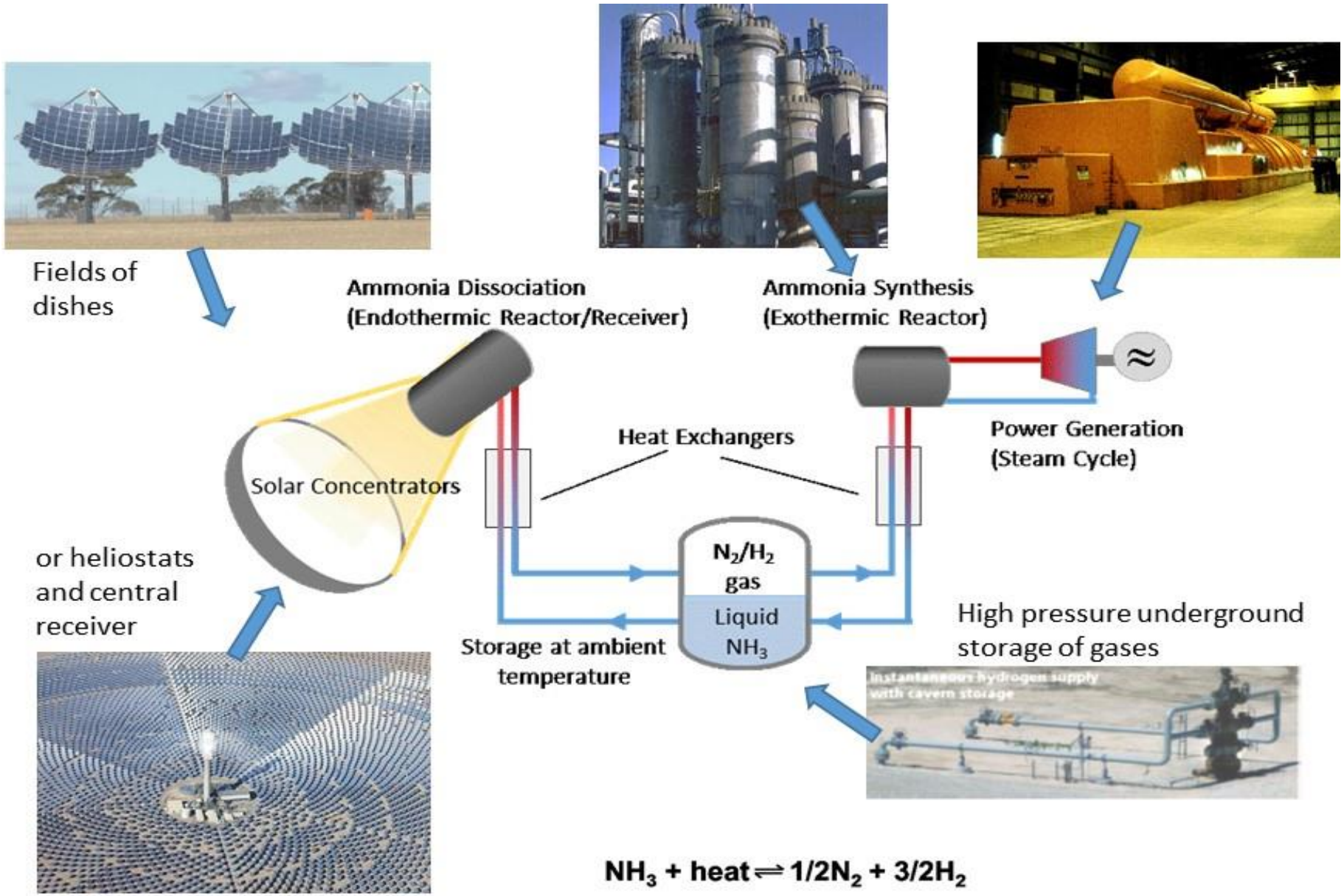
Ammonia for H2 @ scale

DOE workshop 7 May 2021

ITP Thermal Pty Ltd www.itpthermal.com

Ardent Underground Pty Ltd www.ardentunderground.com

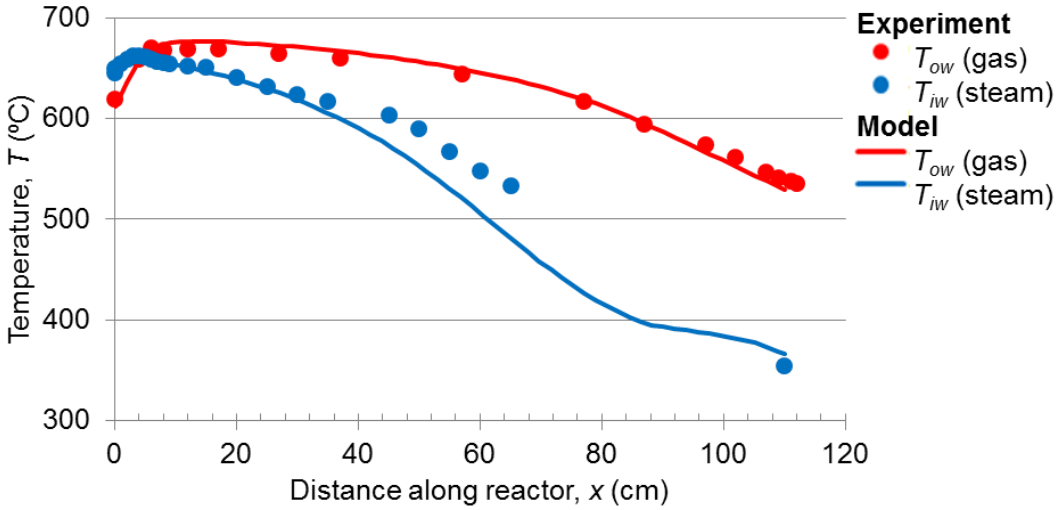
How it Works

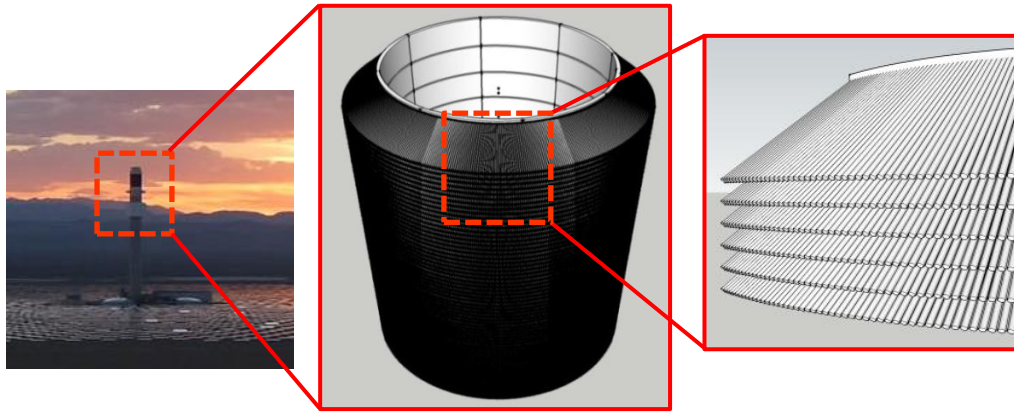


- Extensive industrial experience
- Low cost medium
- Ambient temperature storage
- Automatic phase separation between products/reactants
- **Synergy with net green ammonia production**

Three challenges successfully addressed in UCLA Sunshot project

- Project built on previous solar driven closed loop at ANU
- **Challenge 1:** Carrying out ammonia synthesis reaction at temperatures consistent with modern power blocks (i.e., ~650°C).
- **Challenge 2:** Storing required volume of reactants cost effectively.
- **Challenge 3:** Showing feasibility of integrating endothermic reactors within a tower receiver.





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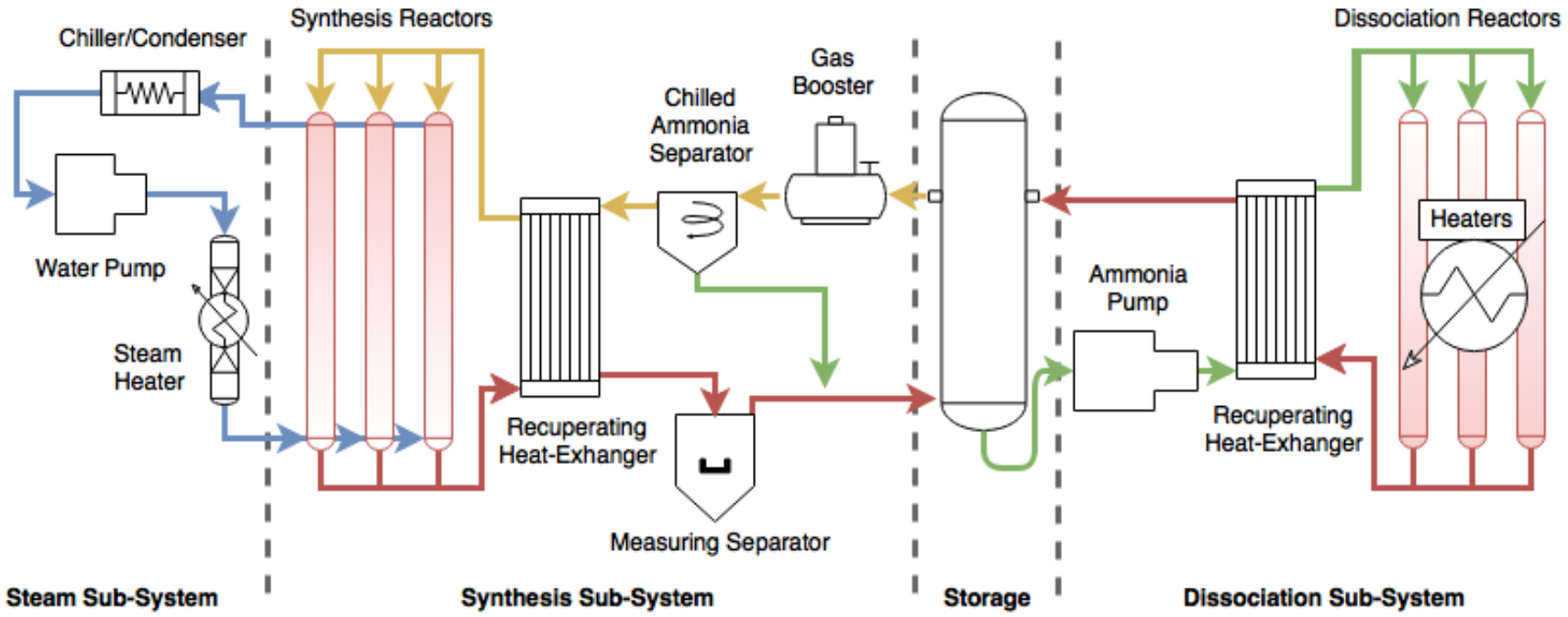
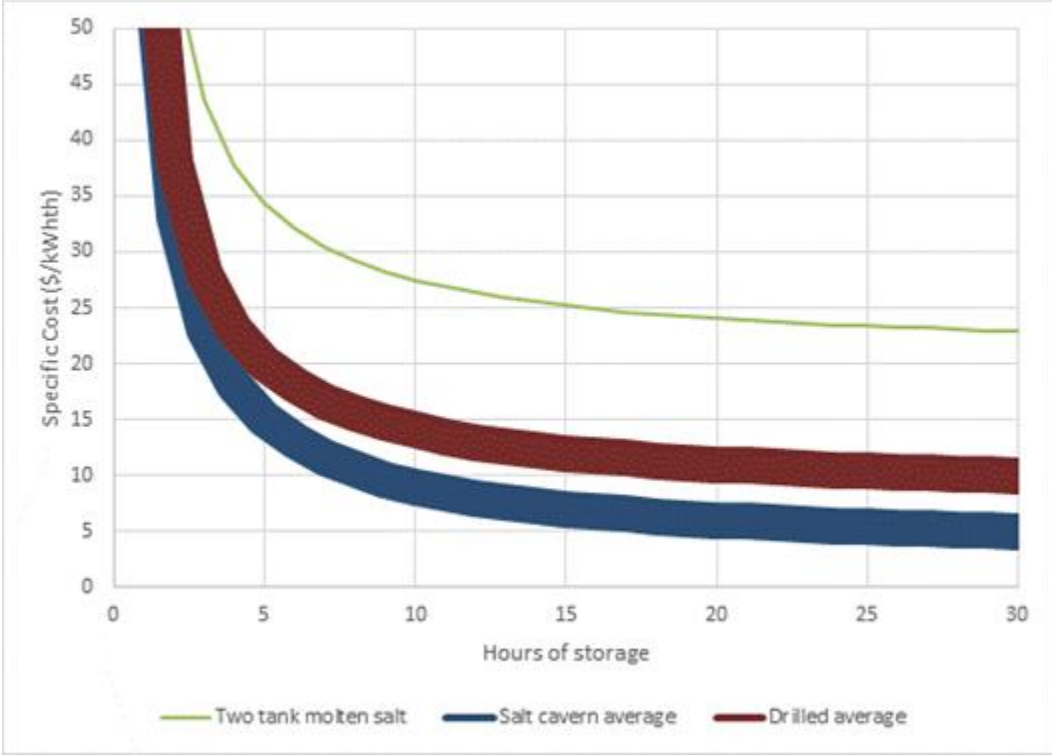
UCLA Experimental system evolved to closed loop configuration

- Three dissociation and three synthesis reactors for 5 kWt operation.



Cost per kWh_t decreases with longer storage duration

- Marginal cost to add more hours of storage:
  - Just cost of underground gas storage
  - Low relative to fixed costs (unlike molten salt)
- Longer storage duration will be favored over time as PV erodes value of energy during sun hours.



Cost of ammonia-based TCES system vs. storage hours

- At 10 to 15 hours of storage, cost drops well below Sunshot target in both cases.

NEW APPROACH TO HYDROGEN STORAGE COMMERCIALISED

ARDENT UNDERGROUND
HYDROGEN STORAGE

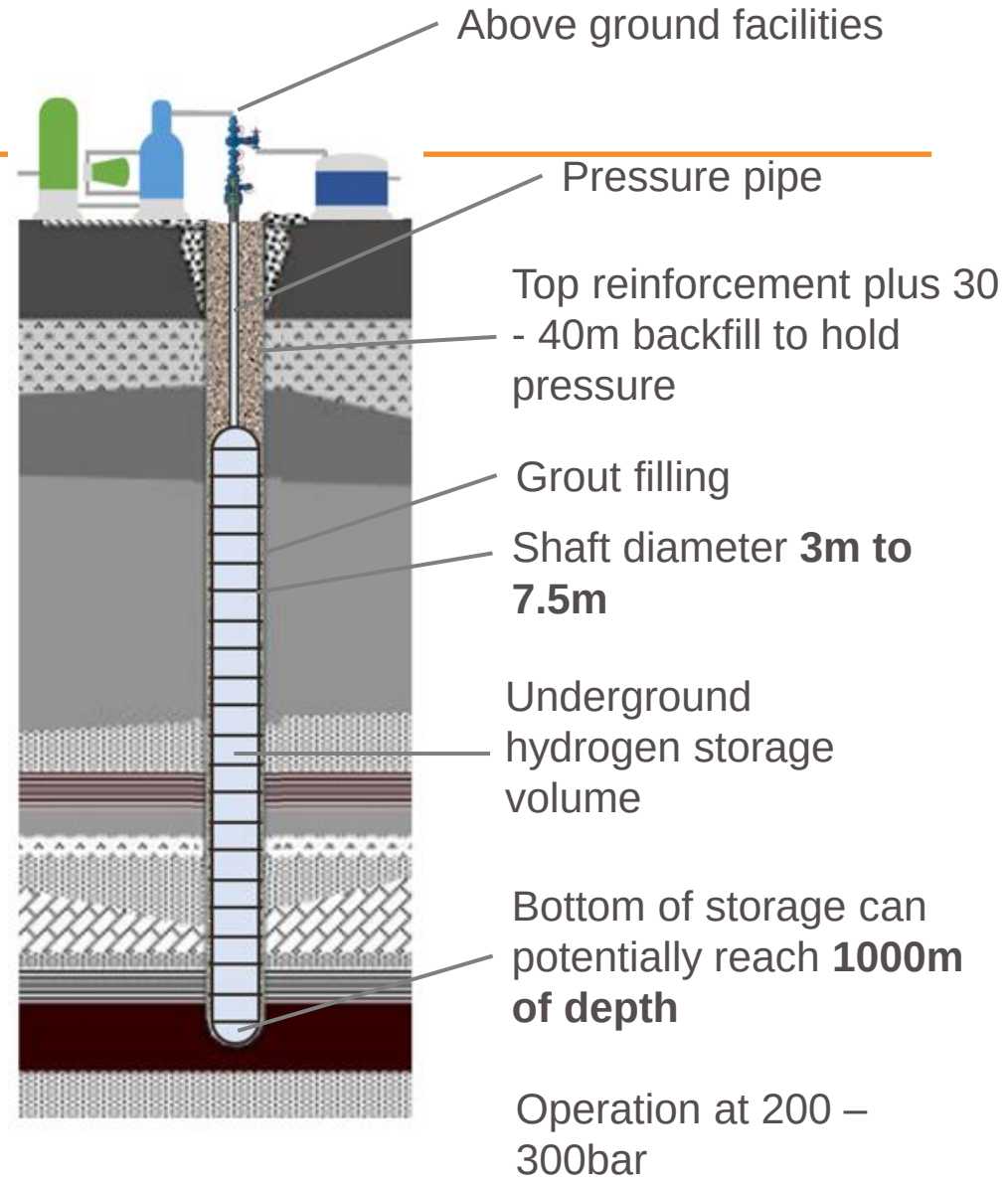
Adapting proven shaft drilling techniques from the mining industry to storing hydrogen in a purposely built underground cavity.

CHEAP
The surrounding rock takes on the duty of containing the hydrogen pressure – **no need for costly pressure containment materials.**

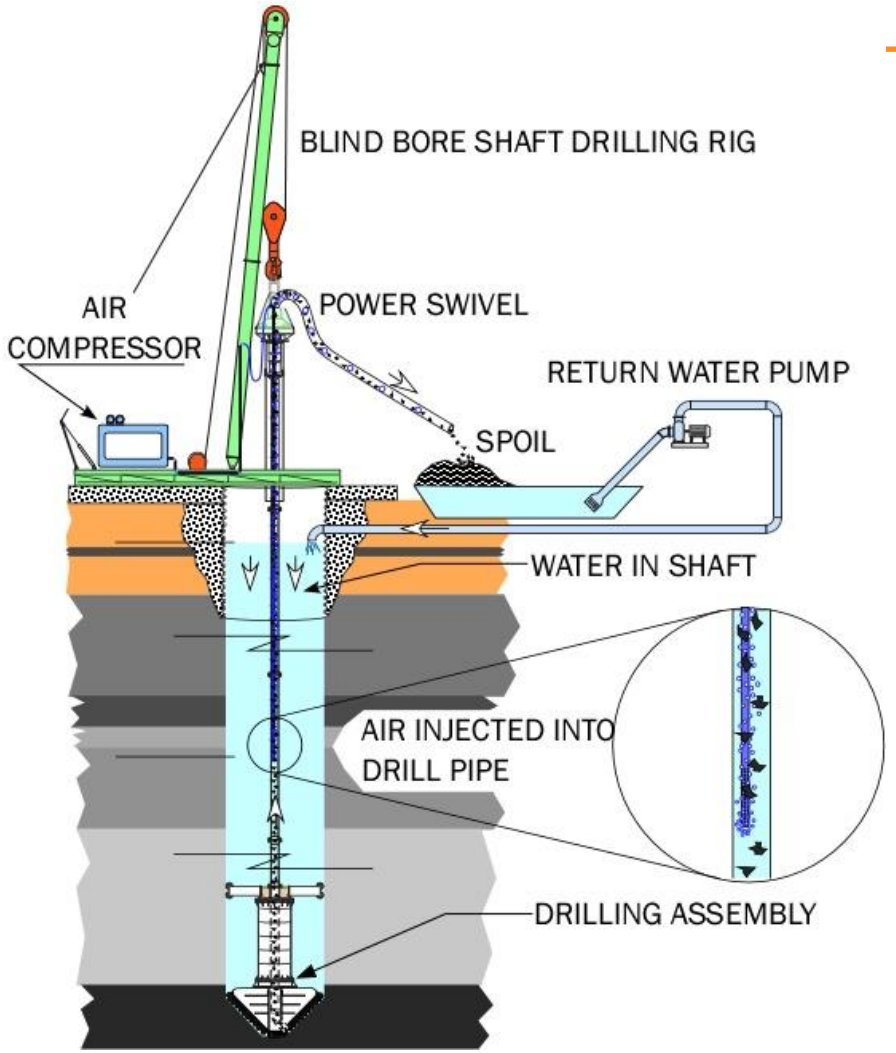
REPLICABLE
The shaft storage construction process can be reproduced in different locations with minimal design adjustment.

LARGE SCALE
Hydrogen storage sizes of **50 to 500 tonnes per shaft.** For larger storage, multiple shafts can be built in the same location.

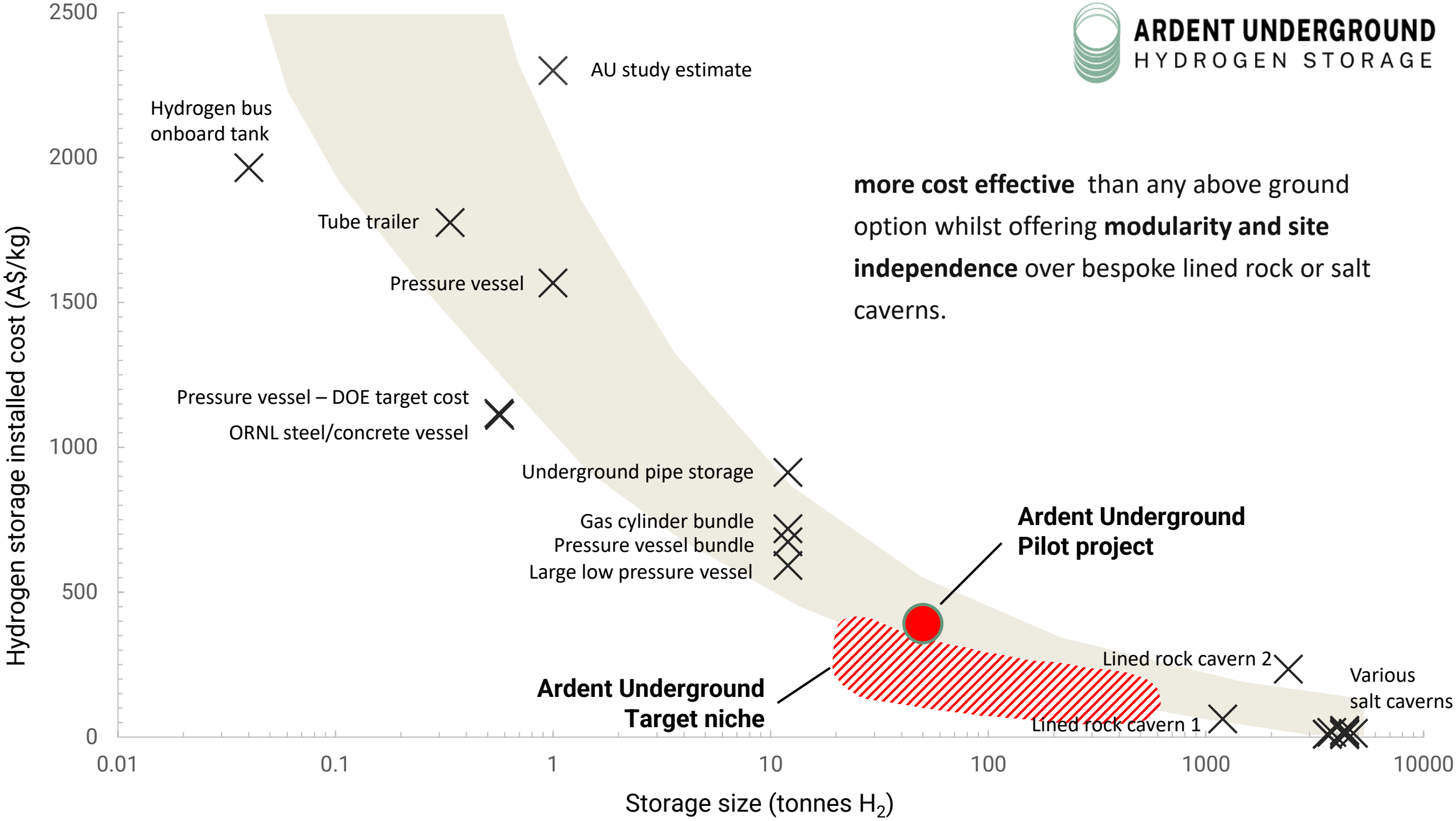
SMALL FOOTPRINT
The above ground footprint is very small compared to equivalent pressure vessel storage.



BLIND BORE SHAFT DRILLING IS A PROVEN TECHNIQUE



ARDENT UNDERGROUND
HYDROGEN STORAGE



more cost effective than any above ground option whilst offering **modularity and site independence** over bespoke lined rock or salt caverns.

Conclusions

- Ammonia TCES potentially competitive with molten salt for storage for power generation
- Established that high temperature heat recovery is possible - could match supercritical CO_2 power cycles
- Patent; High Temperature Synthesis for Power Production and Storage, filed 6/27/2016, PCT/US2016/03964
- Closed loop TCES could be incorporated with green ammonia plants
- Blind bore shaft drilling based gas storage extremely promising
  - General hydrogen storage
  - Supporting green ammonia
  - Enabling TCSE

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