CLEAN SCALABLE ENERGY STORAGE™

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MAJOR REVIEW RESULTS

TESS Technology Description

The TESS design has key sub-systems servicing a renewable power plant as illustrated in Figure 1. Other variations of the technology are the TESS-IND and GAS-TESS. The technical status and performance of each sub-system defines the overall TESS technology status and helps prioritise areas for further development.

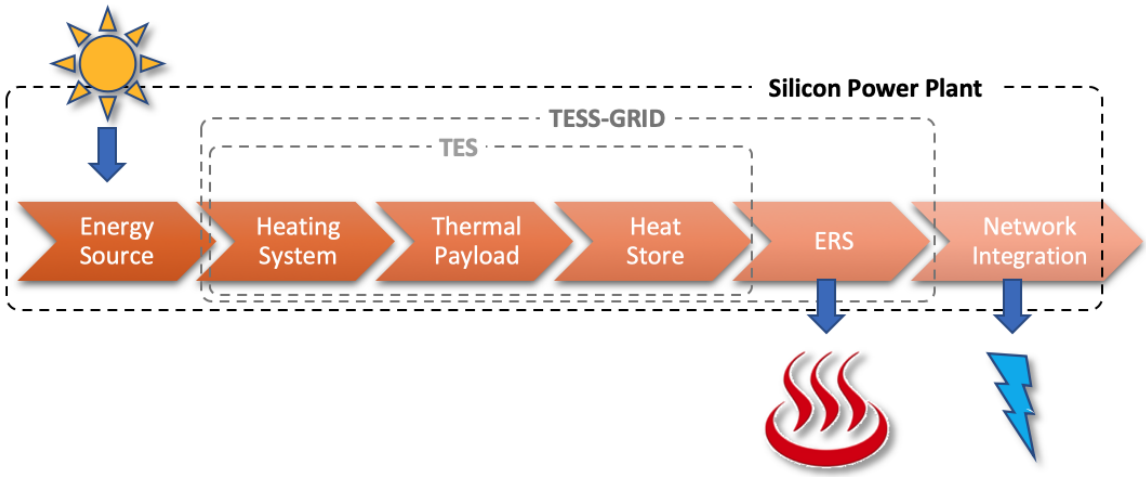

Figure 1: Energy flow via sub-systems for a complete Silicon (TESS-GRID) Power Plant

Key findings of the TESS Technology review are:

- **Technology Readiness:** The TESS requires further development work before it is commercially robust. That is, it should generally be considered at a Technology Readiness Level (TRL)* of 4-5 (Technology Development) with sub systems and a commercial readiness level (CRI) * of 1 -2:
    - Heating systems: TRL of 8 and highly efficient. The GAS-TESS burners delivered 83% efficiency compared to predicted 75%. Electrical TESS use nominally 100% efficient commercial elements.
    - Thermal payload: TRL 4. The prototype storage solution provided excellent heat transfer in the TESS-IND tests but was not robust nor scalable. A new 1414 Degrees silicon phase change storage technology that can operate in air with combustion products is producing very good test results and continues to demonstrate robustness.

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- Energy Recovery System: TRL 5 because a high efficiency, turbine-based system is required for the TESS-IND and GAS-TESS. Note that the larger TESS-GRID device potentially has a higher TRL because commercial steam turbine based ERS systems are efficient at larger scale.
- The overall TRL is consistent with other electrically heated high temperature thermal energy storage technologies currently being commercialised around the world.

- **Energy Efficiency:**
  - The Thermal Energy Store (TES) efficiency is high with a theoretical upper limit of 98% for the thermal payload. The overall TES target is 95% efficiency but operationally will depend on run mode: continuous, short or long cycling
  - Combined Heat & Power (CHP) efficiency is variable depending on the heat offtake to the client process – a heat only supply could be 70% efficient. Heat with electricity efficiency depends on the ERS exhaust temperatures - some examples based on current TESS technology are:
    - Oil heat transfer fluid 325°C, 55% CHP
    - Saturated steam 180°C, 60% CHP
    - Hot water 80°C, 70% CHP
  - Net round-trip electrical efficiencies as demonstrated to date are low: prototype (2-3%), TESS-IND (6.8-16.8%) and GAS-TESS (0.1-3.0%)
  - The electrical efficiency of an electric charged TESS (TESS-GRID) is estimated to have an upper limit of 42%, with 35% practically achievable with available technologies
  - The upper limit of the GAS-TESS electrical efficiency is estimated to be 24%, for CHP of 65%.
- **Build cost:** currently, cost estimates are high for the heat store, thermal payload and ERS sub-systems, but will reduce with technical improvements and volume production.
- **Temperature advantage:** The higher temperature of the TESS provides advantages over molten salt thermal energy storage. In particular the operation of molten salt systems at temperatures below 600°C limits the ERS solutions that can be coupled with them. 1414 Degrees' TESS technology provides the flexibility to use next generation supercritical-CO2 turbines or ultra-supercritical steam turbines in future and at the same time supply high temperature heat (>800°C) for industrial use. A future TESS could be developed to provide ≥ 1000°C heat to drive thermochemical hydrogen production.
- **Development Pathways:** R&D priorities have been identified and robust R&D project plans prepared that will increase efficiency and decrease costs.

Key findings of the Commercial Review

- When fully developed the GAS-TESS will provide an integrated competitive solution for utilities seeking efficient biogas disposal and time shifting of energy value.
- The electrical charged TESS is most efficient when storing electricity and supplying heat only, but this is not competitive with fossil fuel heating in most customer sites without a significant emissions cost to defray the higher input cost of electricity.
- The economics of CHP supply to customers and the grid will improve with further reduction in TESS build costs and increasing payments for system strength services. The Aurora Project is well located to supply local customers and the NEM with power and services.
- There is a huge future market for energy storage - BloombergNEF estimate that the market for stationary energy storage will see a 122-fold increase by 2040. There are many solutions under development for long duration energy storage because it is a market for which batteries are not suitable. 1414 Degrees goal should be to have a commercially competitive storage solution able to compete in this market supplying power and high temperature heat.

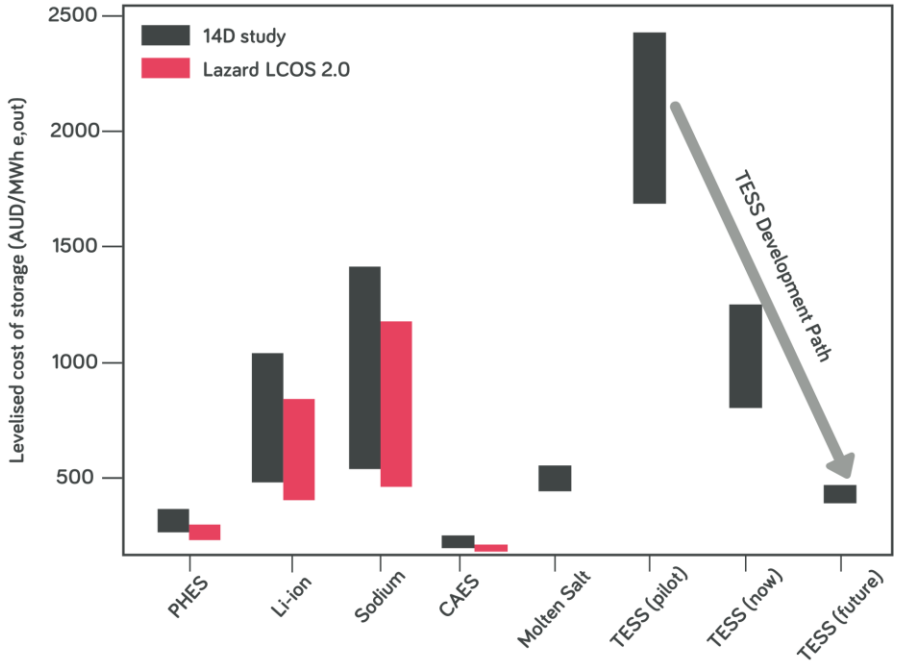
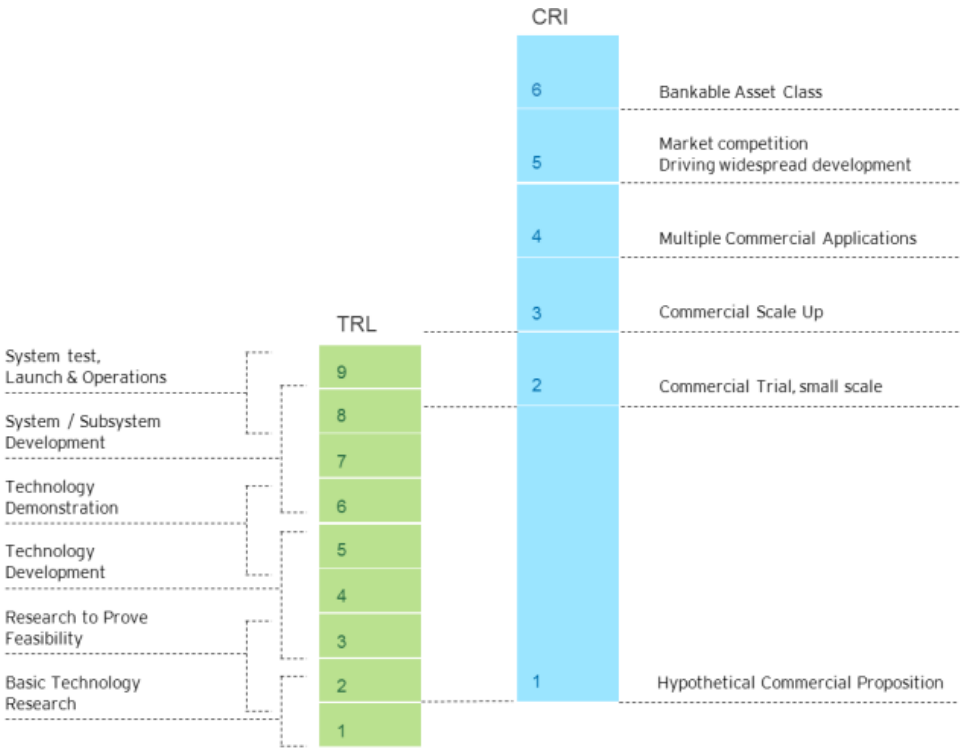


Figure 2: Levelised Cost of Storage prediction for TESS compared to other energy storage technologies.

- A fully developed, large scale TESS will have significant competitive advantage. Excluding heat value, our levelised cost of storage (LCOS) analysis (Figure 2) has shown that, on the basis of a standardised 100 MW-e output with 8 hours of storage and one cycle in a day, the successful delivery of proposed TESS R&D projects will deliver a TESS-GRID system with an LCOS of $433-551/MWhe, which is lower than molten salts and competitive with large-scale pumped hydro.
- Grid scale energy storage is attracting substantial financial backing and since heat is currently relatively low value, 1414 Degrees should focus on bringing the technology to market readiness for:
  - Network utilities to use TESS storage for daily time-shifting of energy, with system strength and inertia
  - Power Stations & Utilities seeking to replace fossil fuels with thermal energy supplied from TESS storage to drive existing or new generation turbines
  - Larger off grid sites such as mines or countries with unreliable grids

  Since TESS technology is forecast to be competitive with pumped hydro and substantially cheaper than lithium-ion for long duration energy storage over the next decade, and noting that the lead time for projects like Aurora is aligned with the TESS development schedule, the Commercial Review recommended that 1414 Degrees focus on:
  - commercialisation for the larger scale or high temperature thermal energy markets and,
  - seek further joint ventures with substantial partners and utilities who have an appetite for innovation, following the SA Water model.

*** Technology and Commercial Readiness Levels (TRL and CRI)**



Source: https://arena.gov.au/assets/2014/02/Technology-Readiness-Levels.pdf

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ABOUT 1414 DEGREES LIMITED
1414 Degrees believes in a sustainable energy future, where energy is available to all, at all times. Its clean energy storage is set to reduce energy costs by increasing the efficiency of renewable generation and stabilising grid supply. The 1414 Degrees thermal energy storage system (TESS) is unlike any other energy storage system in the world.

1414 Degrees' technology stores energy generated from electricity or gas and supplies both heat and electricity in the proportions required by consumers. It is unique in its combination of low cost, flexibility of location, scalability, and sustainability. Following the successful development of its electrically charged TESS demonstrator, and commissioning of its pilot GAS-TESS at SA Water's Wastewater Treatment Plant, the Company is now in an early stage of product development and commercialisation.

For more information please visit www.1414degrees.com.au