Commercially Sustainable CSP
Scalable, High Efficiency, Low Cost

ASTRI Symposium
11 February 2015
Commercial in Confidence
Collaboration - strategic partners
Over 5 years, Vast Solar has developed key partnerships to support innovation & commercialisation

**ARENA**
Australian Renewable Energy Agency

**ŠKODA**
ŠKODA POWER
Steam turbines & steam cycle design

**WorleyParsons**
resources & energy
Project design

**CLEAN ENERGY FINANCE CORPORATION**
Australian Government Green Bank

**Creative Engineers**
Sodium engineering, process design

**TWYNAM**
Investor

**Evans & Peck**
Project Governance

**essential energy**
Grid integration

**METAUX SPÉCIAUX**
Sodium supply

**Australian National University**

**Micro turbines**
Air cooled condensers

**YOKOGAWA**
Control System & Instrumentation

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Commercial in Confidence
Low-cost, small module design
Competitive advantages in solar array and heat transfer systems, biodiversity and amenity

Key Differentiators
1. Low cost heliostats = low cost solar energy: Reduces cost of the largest capital component of the CSP plant
2. Small modular solar array – high efficiency: Modules 100x120m, 27m tower, ~300kWe
   No need for large EPC contractors, competitive subcontracting using local/regional contractors & trades
3. High efficiency thermal energy transfer & storage: High flux heat transfer medium = higher efficiency
   Small receiver reduces thermal shock issues and significantly reduces overall system costs
Research, Development & Demonstration Facility, Phase 1
200 heliostats, ; 300kW\textsubscript{th}, HTF cycle - completed December 2011 (Forbes, NSW)

- 200 heliostats
- Thermal performance independently verified
- Mirror manufacture processed developed
- Control and communications systems
Research, Development & Demonstration plant: Phase 2
‘1U’ Module – 1.2MWth system (2012-2014)

- 700 heliostats manufactured onsite - ‘factory in the field’ manufacturing system
- Solar array control, self-calibration and communications systems tested and refined
- Validation of performance projections
- Extensive third party technical due diligence

Jemalong 1U – February 2013

Partners: ARENA TWINAM ŠKODA ŠKODA POWER VastSolar
Jemalong Solar Station Pilot Project
Forbes, NSW, Australia

6MWth (1.1MWe) grid connected power generation CSP pilot plant

- 5 Vast Solar modules ~3,500 heliostats; 3 hours’ thermal energy storage
- Construction completion Q2 2015, commissioning mid 2015
Commercialisation Program
Phased approach has progressively reduced risk and opened market opportunities

1U RD&D
- 1 module
- Full heat transfer loop
Status: Completed

6MW_{th} Pilot
- 5 modules
- Sun-to-storage-to-grid
Status: Nearing completion, pre-commissioning

30MW Commercial Proof
- 90 modules
- Salt storage integration
- Commercial plant proof-point
Status: In development

250MW+ Annual volume
- Equivalent of 800 modules
- Sustainable scale
- Optimal volume/cost

Utility scale

Commercial scale distributed power

Barrier Removal
Risk Reduction
Scale Up
Vast Solar plant design
Focus on cost reduction in solar array and heat transfer systems

1. Solar Array
   - 700 heliostat module
   - <130m focal distance
   - Low cost (<$100/m²) 3.6m² heliostats
   - 30m towers
   - 2.25m² high flux receivers

2. Sodium HTF
   - High thermal conductivity
   - Wide operating range (low melt point)

3. Molten Salt Storage
   - High heat capacity
   - Proven technology
   - Multiple providers
   - Room for significant cost innovation

4. Conventional Steam Cycle
   - Proven technology
   - Multiple suppliers, emerging low-cost providers
   - Innovations in deployment, packaging reducing cost
   - Oversupply as new coal build wanes
   - Wet or dry cooling

Receiver Tower
HTF 570°C
Receiver
Module
Turbine
Generator
To Transmission Grid
Steam
538°C/150 bar
Feed water
Modular Air Cooled Condenser

Commercial in Confidence
Objective: Deliver cost-effective dispatchable, large-scale solar power

**Steam Turbine**
- Proven technology
- Many suppliers
- Plant efficiency/capital cost ~538°C for 40-43% performance

**Molten Salt**
- Proven technology
- High heat capacity
- Can deliver steam at 538°C
- Low cost

**Sodium HTF**
- High thermal conductivity
- Low freezing point (98°C)
- Enables distributed arrays
- Reactive with water

**Modular Arrays**
- Smaller components reduce materials cost
- Economies of scale through replication
- High array efficiency
- Simplified deployment/construction systems
Design Hits Receiver Efficiency Sweet-Spot

Modular array design and high thermal conductivity of heat transfer media deliver high receiver efficiencies.

Receiver efficiency increases with concentration factor$^1$

Vast Solar Design Point

High Concentration at Moderate Temp = High efficiency

Note: 1 Efficiency of the solar receiver versus $T_{\text{abs}}$ and versus solar concentration ratio, assuming $T_{\text{amb}} = 20^\circ\text{C}$, $\varphi=770\,\text{W/m}^2$ and $\alpha=\varepsilon=0.95$. Handbook of Energy Efficiency and Renewable Energy
Vast Solar - cost reduction innovations

‘Root and branch’ reappraisal of how CSP systems are delivered

• 30 year utility grade components
• Modular systems to provide redundancy, replicability (volume)
• Commonly available materials and components
• Simple manufacturing, enabling high levels of automation at low tooling cost
• Simplicity and ease of deployment
• Automated O&M
• Collaboration with like-minded OEMs to drive out integration costs
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