Outline

1. About IT Power Group
2. Australia’s exports in a low carbon world
3. Concentrating solar for ammonia production
4. Conclusion
Established in the UK in 1981

Key country offices

- UK
- India
- Australia
- China

Specialist sustainable energy engineering consulting

- renewable energy and efficiency consulting
- climate change policies and carbon trading market analysis
- business consulting and due diligence

Solar Thermal across group lead by Keith Lovegrove (MD ITP Thermal Pty Ltd)

More than 1,500 sustainable energy projects in 150 countries.
2 - Australia needs innovative new exports in a low carbon world.
‘Energy’ doesn’t just mean Electricity

Meeting COP21 climate goals implies decarbonising all energy by 2050

Australian Energy End Use 2013-14

- Electricity 20%
- Liquid fuels for engines and transport 47%
- Chemical feedstocks 4%
- Heat 29%

Derived from Australian Energy Statistics 2015
‘Energy’ doesn’t just mean Electricity

Meeting COP21 climate goals implies decarbonising all energy by 2050


Derived from Australian Energy Statistics 2015

(All) Australian Energy Use 2013-14

- Energy for export income ($40b/yr) 79%
- Electricity 4%
- Heat 6%
- Chemical feedstocks 1%
- Liquid fuels for engines and transport 10%
- ?
Australia and Japan (Asia) have a large energy trade.

Australia 2012-13 coal exports:
- To Japan: 43%
- China: 21%
- Korea: 18%
- Taiwan: 10%
- Other Asia: 6%
- Europe: 2%

118 million tonnes = 3304 PJ
AUD 15.4 billion = $4.7/GJ

Japan's 2012 coal imports:
- Indonesia: 18%
- Russia: 18%
- Other: 1%
- Canada: 2%
- China: 3%
- Russian Federation: 9%

From Australia: 67%

Australia 2012-13 LNG exports:
- To Japan: 72%
- Others?: 14%
- China?: 14%

15.7 million tonnes = 857 PJ
AUD 10.3 billion = $12/GJ?
# Japan and Australia compared

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>128 million</td>
<td>22 million</td>
</tr>
<tr>
<td>Electricity Installed cap.</td>
<td>285GW</td>
<td>49GW</td>
</tr>
<tr>
<td>Land area</td>
<td>0.38 million sq km</td>
<td>7.7 million sq km</td>
</tr>
<tr>
<td>Primary energy</td>
<td>22,000 PJ/a</td>
<td>5,800 PJ/a</td>
</tr>
<tr>
<td>Direct Normal Irradiation</td>
<td>Around 1100kWh/m²/year (10.5MJ/m²/day)</td>
<td>Around 2300kWh/m²/year (22.7MJ/m²/day)</td>
</tr>
<tr>
<td>Net energy flow</td>
<td>importer</td>
<td>exporter</td>
</tr>
</tbody>
</table>
Primary energy sources in Japan

- 22,000PJ/a
- Virtually all energy is imported:
  - World’s largest LNG importer,
  - second largest coal importer, and
  - third largest net oil importer.
- Post Fukushima, nuclear dropped to zero by 2013, will it grow again?
- A very large dependence on oil from middle East
- Strong concerns about energy security
- Push for PV, but a long time to any real contribution
- A continuing commitment to reducing GHG emissions
Japanese policy initiatives towards hydrogen

- In FY 2012, invested approximately $240 million in fuel cell and hydrogen energy programs.
- Plan to sell two million fuel cell electric vehicles by 2025, and install 1,000 hydrogen fueling stations.
- Goal of fuel cells powering 2 million homes by 2020.
- Major hydrogen imports expected around 2030.

**USD 20m “New Energy (Hydrogen) Carrier Project” started April 2013**

- Kawasaki Heavy Industries favour liquid $H_2$ – but electricity requirements $>>$ LNG
- Chiyoda corp. working on reversible hydrogenation of Toluene – but small payload in tankers
- Ammonia is already manufactured and traded on a global scale – gaining increasing attention
Progressing plans for Latrobe valley coal gasification + CCS for hydrogen production in Australia

Kawasaki Heavy Industries
Australian connection

Hydrogen Production
Capacity: 770 t/day

Oxygen blown gasification & gas purification plant in Latrobe Valley

Loading & Export Base at a port in Gippsland

Hydrogen gas pipeline

CarbonNet project (CCS hub project) promoted by Australian governments

Source: Victorian State Government
Europe’s Desertec (electric) vision for the future?

- HVDC links across Mediterranean are a few 100kms, readily achievable
- Who would connect Australia 6000km to Japan ?????
Ammonia is already traded globally.
Australia’s ‘Desertec’ – solar ammonia to Japan, Korea and others

- Australia has >100% more solar intensity and available land
- Energy cost of tanker transport < 5% of ammonia payload
## Build on a history of Japanese investment in Australian Oil and gas projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Japanese equity</th>
</tr>
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<tbody>
<tr>
<td>Ichthys LNG Project, Browse Basin, Western Australia</td>
<td>Inpex, 66% Japanese electric utilities: 2.74%.</td>
</tr>
<tr>
<td>Pluto LNG Project</td>
<td>Tokyo Gas 5% and Kansai Electric 5%</td>
</tr>
<tr>
<td>Timor Sea Joint Petroleum Development Area</td>
<td>Inpex, Tokyo Gas, and TEPCO, combined 20%</td>
</tr>
<tr>
<td>Prelude LNG</td>
<td>Inpex 17.5% acquired from Shell in 2012.</td>
</tr>
<tr>
<td>Darwin LNG</td>
<td>Inpex 11.3%, TEPCO 6%, and Tokyo Gas 3%</td>
</tr>
<tr>
<td>Wheatstone LNG</td>
<td>Japanese electric &amp; gas utilities: 9.5%</td>
</tr>
<tr>
<td>Browse LNG</td>
<td>Mitsubishi and Mitsui 14.7% in LNG terminal. 16% in East Browse and 8% in West Browse.</td>
</tr>
<tr>
<td>Van Gogh and Ravensworth oil fields</td>
<td>Inpex: 47.5% of Van Gogh, 28.5% of Ravensworth</td>
</tr>
<tr>
<td>Timor Sea Joint Development Area</td>
<td>Inpex: 35% of Kitan oil field</td>
</tr>
<tr>
<td>NW Shelf Mutineer and Exeter fields</td>
<td>JX Nippon: 25%</td>
</tr>
</tbody>
</table>
3 - Concentrating Solar for ammonia production
Abengoa’s Solana system started operation October 2013.

280 MW trough plant with six hours of thermal storage. 70 miles southwest of Phoenix, Arizona. Construction began at the end of 2010. Largest CSP plant with storage so far.

Solar Reserve’s Crescent Dunes project

- Nevada, north of Las Vegas
- 110MW$_{e}$ with 10 hours molten salt energy storage
- Biggest ever tower system
- Final commissioning 2015
Leveraging the technology of solar concentrators for:

\[ \text{H}_2\text{O/CO}_2\text{-splitting} \]

\[ \text{Solar High-T Electrolysis} \]
\[ \text{Solar Thermochemical Cycle} \]

\[ \text{Concentrated Solar Energy} \]
\[ \text{Solar Electricity + Electrolysis} \]
\[ \text{Solar Reforming} \]
\[ \text{Solar Cracking} \]
\[ \text{Solar Gasification} \]

\[ \text{Long-term goal} \]

\[ \text{Short/mid-term transition} \]

\[ \text{Solar Fuels (H}_2\text{, syngas, liquid fuels)} \]

\[ \text{Optional CO}_2/C Sequestration \]

Fossil Fuels (NG, oil, coal)
Near-Term Solar Production of $H_2$ and Syngas

Solar pilot plants demonstrated in the power range of 200-500 kW$_{th}$

- Solar steam reforming of natural gas / methane
  - SOLGAS (200 kW$_{th}$)
  - SOLREF (400 kW$_{th}$)

- Solar steam gasification of carbonaceous feedstock
  - SYNPET (500 kW$_{th}$)
  - SOLSYN (200 kW$_{th}$)
Long-term: Solar Production of H₂, Syngas, and Liquid Fuels

Metal oxide based thermo-chemical processes for H₂ and syngas production demonstrated at the 100 kW\textsubscript{th} power level

Non-volatile metal oxides

- H₂ production using Ferrite H₂O-splitting cycle

Volatile metal oxides

- H₂/CO (syngas) production using Zn/ZnO H₂O/CO\textsubscript{2}-splitting cycle

\textbf{HYDROSOL (100 kW\textsubscript{th}) at PSA, Spain}

\textbf{Solar2Zinc (100 kW\textsubscript{th}) at Odeillo, France}
CSIRO lead Concentrating Solar Fuels Road Map for Australia

- 3 year project to develop a credible, industry validated road map
- Identifies key issues and what a staged development looks like
- Current status, potential and challenges/barriers
- Examines markets and product opportunities
- Maps out research, development and demonstration priorities to move technologies towards commercialisation
- Includes PV / Electrolysis assessment as reference case
- Completed end 2015,
# Results from Levelised Cost of Fuel calculations (2020 AUD)

<table>
<thead>
<tr>
<th>Process</th>
<th>Input fuel cost</th>
<th>Solar product gas LCOF</th>
<th>Final fuel (eg NH3) LCOF</th>
<th>Technol. readiness</th>
<th>GHG intens.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference: crude oil at $100/bbl</td>
<td>$16/GJ</td>
<td>$8/GJ</td>
<td>$15/GJ</td>
<td>$0.42/L</td>
<td>High</td>
</tr>
<tr>
<td>Solar gasification of brown coal</td>
<td>$1/GJ</td>
<td>$8/GJ</td>
<td>$15/GJ</td>
<td>$0.42/L</td>
<td>Medium</td>
</tr>
<tr>
<td>Solar reforming of natural gas</td>
<td>$8.4/GJ</td>
<td>$10/GJ</td>
<td>$17/GJ</td>
<td>0.48/L</td>
<td>High</td>
</tr>
<tr>
<td>Solar gasification of biomass</td>
<td>$8/GJ</td>
<td>$9.8/GJ</td>
<td>$17/GJ</td>
<td>$0.48/L</td>
<td>Medium</td>
</tr>
<tr>
<td>Solar water splitting</td>
<td>Zero</td>
<td>$29-35/GJ</td>
<td>$58/GJ</td>
<td>$7/kg H₂</td>
<td>Low</td>
</tr>
<tr>
<td>PV Electrolysis</td>
<td>Zero</td>
<td>$94/GJ</td>
<td>$11/kg</td>
<td>High</td>
<td>Zero</td>
</tr>
</tbody>
</table>

2020 solar field costs estimated at $173/m² for heliostats. 6.4% discount rate, 30 year amortisation.
Conclusions

- Australia’s export income is very dependent on coal and LNG in a carbon constrained world.
- Japan is Australia’s number one customer for energy exports.
- Japan has major initiatives on sustainable hydrogen as a fuel.
- Japan’s manufacturing base and history of investment in Australia combined with superior Australian solar resources is a good combination.
- The cost of transporting energy dense ammonia fuel is easily justified by the extra level of solar resource in Australia.
- Concentrating solar is a promising approach for producing hydrogen feedstock.
- **Government to government negotiations are needed to establish the framework for international renewable fuels trade.**