Effect of plant location on the annual performance of a hydrogen production plant based on CeO$_2$ thermochemical cycle

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Introduction

Thermochemical cycles

H₂ production is an attractive way to store solar energy
APSRC 2017: “Dynamic Modelling of a Continuous Hydrogen Production Plant Based on CeO$_2$ Thermochemical Cycle”
Simulations

- 10 locations across Australia
  - Wide range of latitudes
  - Wide range of climates

- Solar field at design: 1 MW$_{th}$ (SolarPILOT™)

- Annual simulations (Dymola 2018)
Results
Optical Efficiency Analysis

Summer solstice
Results

Effect of plant location

From land to receiver (ideal)

\[ \eta_{op} = \int \eta_{op}(t) dt \]
Results

Effect of plant location

From land to receiver (real)

Variation due to plant operation

\[ \eta_{\text{re}} = \frac{Q_{\text{re}}}{Q_{\text{sol}}} \]

-2.7%

-9.74%
Results

Effect of plant location

From receiver to fuel

Variation due to plant operation

Max = 28.5% (\(\eta_{th,\text{design}}\))

Low variation with location

\[\eta_{th} = \frac{m_{H_2} \cdot HHV_{H_2}}{Q_r}\]
Results

Effect of plant location  

From land to fuel

\[ \eta_{\text{fuel}} = \eta_{\text{op}} \eta_{\text{re}} \eta_{\text{th}} \]

<table>
<thead>
<tr>
<th>Location</th>
<th>( \eta_{\text{fuel}} ) (%)</th>
<th>( m \text{ H}_2 ) (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darwin</td>
<td>8.4</td>
<td>8.12</td>
</tr>
<tr>
<td>Learmonth</td>
<td>10.1</td>
<td>17.46</td>
</tr>
<tr>
<td>Alice Springs</td>
<td>10.2</td>
<td>18.53</td>
</tr>
<tr>
<td>Chinchilla</td>
<td>9.0</td>
<td>11.99</td>
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<tr>
<td>Geraldton</td>
<td>9.6</td>
<td>15.85</td>
</tr>
<tr>
<td>Perth</td>
<td>8.5</td>
<td>11.97</td>
</tr>
<tr>
<td>Port Augusta</td>
<td>8.6</td>
<td>13.35</td>
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<tr>
<td>Sydney</td>
<td>8.1</td>
<td>8.79</td>
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<tr>
<td>Canberra</td>
<td>8.2</td>
<td>11.16</td>
</tr>
<tr>
<td>Melbourne</td>
<td>6.4</td>
<td>6.03</td>
</tr>
</tbody>
</table>

Variation due to plant operation

Max = \( \eta_{\text{op}} \eta_{\text{th,design}} \)
Conclusions

10 locations across Australia has been tested covering a wide range of latitudes and climates.

Location → $\eta_{\text{solar-to-fuel}}$ in 3.8% & $m_{\text{H}_2}$ in 67%

Latitude + Annual DNI → Large variation

Low variation → $\eta_{\text{re}}$ → $\eta_{\text{solar-to-fuel}}$

Plant operation → $\eta_{\text{solar-to-fuel}}$ → Off design performance

Thank you

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