Solar Thermal Electricity

Highlights & Trends from SolarPaces2014

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agenda

• Main CSP technologies

• Technological road map & trends
  • Installed capacities
  • Projections
  • Dispatchability

• Highlights from SolarPaces
  • Main technological paths
  • Continuous improvements
  • Direct particle cycle
Main CSP technologies

- Conventional power cycles: Rankine, Brayton...
  - Fuel replaced via sun light (concentrated solar irradiation)
Status Quo

- Disruptive success of PV?
PV versus STE

CSP Investment cost projections in the hi-Ren Scenario

Projections of LCOE for new-built CSP plants with storage in the hi-Ren Scenario

<table>
<thead>
<tr>
<th>USD/MWh</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2045</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>146</td>
<td>116</td>
<td>96</td>
<td>86</td>
<td>72</td>
<td>69</td>
<td>66</td>
<td>64</td>
</tr>
<tr>
<td>Average</td>
<td>168</td>
<td>130</td>
<td>109</td>
<td>98</td>
<td>80</td>
<td>77</td>
<td>72</td>
<td>71</td>
</tr>
<tr>
<td>Maximum</td>
<td>213</td>
<td>169</td>
<td>124</td>
<td>112</td>
<td>105</td>
<td>101</td>
<td>96</td>
<td>94</td>
</tr>
</tbody>
</table>

Technology Roadmap
Solar Thermal Electricity

PV investments cost projections in the hi-Ren Scenario

Technology Roadmap
Solar Photovoltaic Energy

Projections for LCOE for new-built utility-scale PV plants to 2050 (USD/MWh) in the hi-Ren Scenario

<table>
<thead>
<tr>
<th>USD/MWh</th>
<th>2013</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2045</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>119</td>
<td>96</td>
<td>71</td>
<td>56</td>
<td>48</td>
<td>45</td>
<td>42</td>
<td>40</td>
</tr>
<tr>
<td>Average</td>
<td>177</td>
<td>133</td>
<td>96</td>
<td>81</td>
<td>72</td>
<td>68</td>
<td>59</td>
<td>56</td>
</tr>
<tr>
<td>Maximum</td>
<td>318</td>
<td>250</td>
<td>180</td>
<td>139</td>
<td>119</td>
<td>109</td>
<td>104</td>
<td>97</td>
</tr>
</tbody>
</table>
Dispatchability

- **Thermal energy storage**
  - thermo oil
  - molten salt
  - particles
  - phase change materials

- **Grid needs flexibility – dispatchability creates value!**
STE Roadmap until 2050

- **Policy**
  - Difficult financing due to delayed market growth
  - Incentives have to be created
  - South Africa: pays 2.7 times the spot price at peak times
The Road to SunShot

- Higher performance
- Higher Temperatures
  - Materials
  - Compatibility
- Reduce losses
  - Smaller size
  - Higher flux
  - Modified surfaces
- Alternate working fluids
  - Solids
  - PCM’s
  - HTF’s
  - SCO₂
  - Air

Let’s talk about some more specific conference topics...

- Heat transfer fluid exit temperature from the receiver > 650°C
- Thermal efficiency > 90%
- Lifetime > 10,000 cycles
- Cost < $150/kWₘ
Continuous Improvements

- **Solar Collectors and receivers**
  - Increase aperture area and handle wind loads
  - Non imaging concentration
  - Improve coatings and insulations
  - Optimization of heliostat field design and tracking system
  - Investigation on durability and maintenance
Continuous Improvements

- **Thermal energy storages**
  - Salts at higher temperatures
  - PCMs at higher temperatures with large heat of fusion
    - Metallic eutectics
    - Heat pipes
  - Using solid filler materials as storage media
    - Bulks/stacks
Direct Particle Cycle

- **State of the art**
  - Direct storage cycle applying molten salt
- **Replace salt with particles**
  - Higher temperatures and cheaper materials
Direct particle cycle
Thank you for your kind attention!