FUTURE OF DISTRIBUTED POWER GENERATION

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FUEL CELL SYSTEMS
CONVION

- Enables Power generation with SOC technology
- Leading SOFC systems in the 50kW+ power range
- Substantial IPR on SOFC system technologies
- Customer demonstrations ongoing

- History at Wärtsilä: R&D since 2001, Technology demonstration since 2004
- Established in 2012 as an independent company
- Key shareholders: VNT Management (VC), Employees and Wärtsilä Corporation

CORE PRODUCT C60 – MODULAR 60KW POWER UNIT

<table>
<thead>
<tr>
<th>Electric output</th>
<th>60 kW net-AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical efficiency</td>
<td>60+ % (LHV)</td>
</tr>
<tr>
<td>Thermal output</td>
<td>27 kW</td>
</tr>
<tr>
<td>Total efficiency</td>
<td>84 % (LHV)</td>
</tr>
</tbody>
</table>

- Natural gas
- Biogas
- Hydrogen
- Power (Ac or Dc)
- Heat
## The most common fuel cell types, named according to their electrolyte

<table>
<thead>
<tr>
<th>FC Type</th>
<th>Anode Fuel</th>
<th>Cathode oxidant</th>
<th>Operating temp (°C)</th>
<th>Efficiency (LHV)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low temperature</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEM</td>
<td>H₂</td>
<td>Air</td>
<td>60 – 100</td>
<td>30 – 40</td>
<td>Portable Small residential Transportation</td>
</tr>
<tr>
<td>AFC</td>
<td>H₂</td>
<td>O₂</td>
<td>60 – 120</td>
<td>30 – 40</td>
<td>Portable Small residential Transportation</td>
</tr>
<tr>
<td><strong>Intermediate temperature</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>PAFC</td>
<td>H₂</td>
<td>Air</td>
<td>150 – 250</td>
<td>35 – 45 50 – 70 *</td>
<td>Industrial Commercial</td>
</tr>
<tr>
<td><strong>High temperature</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCFC</td>
<td>H₂, CO, NH₃, CH₄</td>
<td>Air+CO₂</td>
<td>550 – 700</td>
<td>45 – 55 80 – 90</td>
<td>Industrial Commercial</td>
</tr>
<tr>
<td>SOFC</td>
<td>H₂, CO, NH₃, CH₄</td>
<td>Air</td>
<td>650 – 850</td>
<td>45 – 65 80 – 90 *</td>
<td>Industrial Commercial</td>
</tr>
</tbody>
</table>

Different technologies are suited for different fuels and application.
Use of gas (LNG, NH3 or H2) as fuel will open marine market for fuel cells

Power generation with Hybrid systems: Main ICE engines + batteries + Fuel cells

Better energy efficiency, flexibility and power security

Lower local emissions: zero NOx, SOx and particulates

Less vibrations

No noise

DRIVERS for change

- IMO: reduction of GHG emissions from ships
  50% reduction by 2050
- IMO: Emission Control Areas or ECAS
  Particularly SOx, NOx and PM
- IMO Energy-efficiency requirements
  30% improvement by 2025
- Customers
Wärtsilä : Methapu  
Wärtsilä Norway :  
ABB : RCCL / Ballard  
Samsung Heavy ind. / Bloom Energy  
ABB, VTT, Syke, Power cell :  
NN  
Etc.

 Basically all main players in Marine industry are involved in fuel cell solutions
- Power density:
  - Both kW/m3 kW/kg ratios are lower than ICE

- Power demand:
  - Propulsion power up to 60,000 kW + hotel load up to 10,000 kW
  - Typical power of fuel cell product is 1 – 400 kW

- Fuel logistics
  - Fuel cells can utilise only clean fuels as gas
  - Fuel storage on board, both space (H2) and safety (NH3).
  - LNG (eNG) currently available also for main propulsion

- Cost and availability of CO2 neutral fuels

- Fuel selection / availability do influence on optimal FC technology
- Hybrid power solutions (engine + storage + fuel cell)
- Energy efficiency is essential. In addition, improved security and flexibility
- Different solution for different application
  - Small vessels, local routes can be electrical with FC power supply as "range extender"
  - Large vessels with long routes have high power demand and fuel storage capacity needs
- Further development of fuel cell technologies and applications in the value chain
  - None of the current FC technologies are ready for commercial deployment for marine applications
- Fuel logistics for safe, affordable, and carbon-free fuels
Finland has unique value chain and opportunity to commercialize highly efficient and clean power solutions for Marine industry.

- RCCL as leader of cruise industry
- Meyer as an innovative ship yard
- Wärtsilä as leading power solutions provider
- Convion as a leading fuel cell system provider
- Elcogen as a leading SOC manufacturer
- VTT as a leading research center in fuel cells
Thank you

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