Low Temperature Solid Oxide Fuel Cells for micro-CHP Applications (256694)

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HyGear Fuel Cell Systems

http://www.fch-ju.eu/
The LOTUS consortium

**LOTUS** is:

the development, construction and testing of a μCHP system based on low temperature SOFC stack technology

Duration: 3 years (1 January 2011 - 31 December 2013) + extension of 6 months (30-6-2014)
Budget: € 2,955 → FCH- Contribution: € 1,632

<table>
<thead>
<tr>
<th>Partner</th>
<th>Main task in Project</th>
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</thead>
<tbody>
<tr>
<td>HyGear Fuel Cell systems (NL)</td>
<td>Coordinator, system design and construction</td>
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<tr>
<td>SOFCPower (I)</td>
<td>SOFC stack development</td>
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<td>Fraunhofer IKTS (D)</td>
<td>System modeling</td>
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<td>Domel (Slo)</td>
<td>Gas- Air system development</td>
</tr>
<tr>
<td>University of Perugia (I)</td>
<td>User profile input, SOFC single cell testing</td>
</tr>
<tr>
<td>European Commission/ JRC (B)</td>
<td>SOFC stack testing, test harmonization</td>
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<tr>
<td>Associated partner: Vaillant (D)</td>
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</tbody>
</table>
• 6 month delay due to stack production delay (origin by causes outside project)
WP2: Cell improvements

- New material, high performances at low temperature
  - Improvement mainly cathode and barrier layer
- Performance improvements of approx. 75%
  - VI and durability tests performed
- Round robin test between SOFCpower and FClab facilities was carried out
  - Good reproducibility (<10% difference, due to temperature differences)
WP2: Short Stack improvements

Test conditions:

\[ T_{\text{air out}} = 600 - 750 \, ^\circ C \]

Fuel: \( \text{H}_2/\text{N}_2 \) 60/40 (\( \text{H}_2 = 1.44 \text{ NL/min} \))

Air: \( \lambda = 3 \)

Comparison between SoA (red marks) and improved (blue one) cells
• **WP3: System Design & Modeling**
  – System Requirements Document (SRD) was compiled at joint workshop
    – *Based on Customer demands*
    – *Basis for system design and process layout*
  – 0-D SOFC stack model was parameterized using ASC measurement data
    → *Basis for system performance estimation*
  – System design and preliminary process layout calculation was
    → *Basis for component design and system engineering*
  – Dynamic process modeling ready
    → *Next step validation of the model using system data*
• Double staged impeller blower by Domel developed
  – Improved lifetime
  – Built and tested at Domel, prototype is delivered

• Single blower strategy → lower number of components to improve reliability and cost
• **Simplification of hardware**
  – Single blower
  – Single burner
  – Certification ready design

• **Modules built, tested and improved**
  – E.g. second iteration on evaporator
    • First design was tested
      – providing data for modeling and testing principles.
    • 2nd generation less bulky
    • Easier to insulate
    • Low cost design
    • Same functionality: flue gas cooling, steam generation, gas mixing
• System built together with dummy stack to develop controls without stack damage

• LOTUS module testing

• The LOTUS system
The LOTUS project is delayed:

- Further stack improvements on sealing need pilot production equipment – supplier of stack conditioning equipment in delay
- Shipment damage of dummy-stack
• **Main events to come:**
  – System testing (w/o stack) on-going
  – Stack delivery to HFCS dec 2013 (M 36)
  – Working prototype Jan 2014 (M 37)
  – System testing and model validation Jan – Jun 2014
• LOTUS is part of Application area AA3: micro-CHP residential, natural gas based
  – Electrical efficiency > 45%
    • LOTUS Modeling data: ±43%. Measurement data available 2014.
  – CHP efficiency > 80%
    • LOTUS Modeling data: ±80% : design for very low heat loss
  – System cost: €5000 / 1kWe in 2020
2. Alignment to MAIP/AIP

- LOTUS cost prediction: meeting the MAIP

<table>
<thead>
<tr>
<th>Module/component</th>
<th>Cost estimate (&gt;10,000 pcs)</th>
<th>Source</th>
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</thead>
<tbody>
<tr>
<td>Stack</td>
<td>€ 520</td>
<td>Supplier info</td>
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<tr>
<td>Air Preheater</td>
<td>€ 650</td>
<td>Supplier info</td>
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<tr>
<td>Burner/Reformer assy</td>
<td>€ 910</td>
<td>Engineering calc.</td>
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<tr>
<td>Blower</td>
<td>€ 130</td>
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<tr>
<td>Controls</td>
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<td>Engineering calc.</td>
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<td>CHP Hex</td>
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<td>Steam generator</td>
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<tr>
<td>Inverter</td>
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<td>PV info</td>
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<tr>
<td>BoP</td>
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<td>Engineering calc.</td>
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<tr>
<td>Enclosure</td>
<td>€ 325</td>
<td>Engineering calc.</td>
</tr>
<tr>
<td>Total</td>
<td>€ 4,745</td>
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</table>
2. Alignment to MAIP/AIP

- **Cost of € 5,000/kW**
  - **Reduction of SOFC temperature to 650°C**
    - Rational: Use of less expensive materials; Longer life-time
    - Status: single cell and short stack tests are ongoing with good results so far
  - **Simplify system design**
    - Rational: Less components lowers costs and increases reliability; Combining functions within same hardware
    - Status: New system design model made combining functions: e.g. 1 blower, 1 burner for start-up and peak burning, combine steam generator with gas mixing
  - **Use commercial available components**
    - Rational: Use of less expensive materials: proven reliability and long life-time
    - Status: several components sourced and in house
2. Alignment to MAIP/AIP

- Develop system for real market conditions
  - LOTUS will deliver a prototype unit
  - BUT, is based on Voice-of-customer demands and requirements
    - System Requirement Document finished

- Input from Vaillant GmbH
- Input from market analysis HyGear, SOFCPower
- Using user profiles North and South Europe
  - Vaillant GmbH
  - University of Perugia
• Training and Education within LOTUS
  ➢ University of Perugia makes students familiar with fuel cells and their applications

• Safety, Regulations, Codes and Standards
  ➢ System will be designed to meet CE criteria, which includes creation of a HAZOP document and a FMEA
  ➢ Harmonization of testplans for single cells, stacks and systems

• Dissemination and public awareness
  ➢ LOTUS website
  ➢ Partners are taking part in many other international projects
  ➢ Partners are members of many (inter)national organizations (IPHE, IEA HIA, EHA, etc)
4. Enhancing cooperation and future perspectives

- Technology transfer/collaborations
  - Vaillant GmbH. as associated partner provides input on the customer specifications
  - National collaborations in all partner countries on Fuel Cell Technology
  - Specific national collaboration on SOFC CHP:
    - Italy: Efeso
  - Interactions with other EU SOFC projects: (ADEL), DESIGN...
  - Technology improvement in HyGear, DOMEL, SOFCpower products
  - Component reliability improvements
4. Enhancing cooperation and future perspectives

• Collaboration with other European funded SOFC projects: ADEL, SUAV, Design
• Partner discussions on further collaboration on-going
  – Market approach plan
  – Size range
  – Market uptake
  – JDA