




# *Solid Oxide Cell and Stack Testing, Safety and Quality Assurance*

Collaborative Project - *FCH JU GRANT AGREEMENT N° 621245*
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***Project Coordinator**: M. Lang – DLR*

# DELIVERABLE REPORT

| *D.2.2 – LIST OF SOC TEST PROCEDURES* | |
|---|---|
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| **PU** | *Public* | *x* |
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| *NATURE OF THE DELIVERABLE* | | |
|---|---|---|
| **R** | *Report* | *x* |
| **P** | *Prototype* | |
| **D** | *Demonstrator* | |
| **O** | *Other* | |

| SUMMARY | |
|---|---|
| **Keywords** | *SOFC, SOEC, terminology, definitions, test module* |
| **Abstract** | The objective of this deliverable is to survey and compile the available procedures for SOFC & SOEC testing and to specify the important terms, definitions and nomenclatures. |

# D.2.2 – LIST OF SOC TEST PROCEDURES

## 1 Introduction

This deliverable surveys and compiles a list of existent SOC test procedures for single cells and stacks especially those from previous projects, e.g. FCTESTNET, FCTESQA, METSOFC, REALSOFC600, and RELHY, and on-going FCH JU projects (ADEL, METSAPP, SCOTAS-SOFC, SOFC-LIFE, STACK-TEST) being public. In addition, the open literature is surveyed whether to include procedures exterior to the mentioned projects while being public. On this basis the important terms, definitions, nomenclatures and abbreviations will be specified. The most relevant test procedures will form the base for the harmonized test modules to be worked out in WP 3.

## 2 Documents used for this survey

The following tables contain the documents that were investigated for SOC terminology and test modules.

### *2.1 Documents containing definitions / terminology*

*Table 1: Documents containing definitions / terminology*

| **Project** | **Document Title** | **Source** | **Publication Date** |
|---|---|---|---|
| FCTES$^{QA}$ | Single Cell Performance and Endurance Test Modules | http://iet.jrc.ec.europa.eu/fuel-cells/sites/fuel-cells/files/files/documents/SOFC_SC_Performance_Endurance.pdf | 2010 |
| FCTESTNET | WP2 Stationary Fuel Cell Systems: Test Programs and Test Modules | Project document (FCTESTNET closed) | June 2006 |
| FCTESTNET | Terminology Document | Project document (FCTESTNET closed) | June 2006 |
| FCTESTNET | Glossary | Edited by Wolfgang Winkler et.al. (VDI/Hamburg University Applied Sciences -WP8) with contributions of the FCTESTNET members | January 2005 |
| International | IEC 62282-7-2: Single | Final version to be published by the | 2010 |

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|---|---|---|---|
| Electro-technical Commission: IEC TC 105 | cell and stack test methods –Single cell and stack performance tests for solid oxide fuel cells (SOFC) | International Electrotechnical Commission (IEC) under http://webstore.iec.ch | |
| IEC TC 105 | IEC 62282-1 TS: Fuel Cell technologies Part 1: Terminology | http://webstore.iec.ch | May 2013 |
| STACKTEST | Master Document | http://stacktest.zsw-bw.de/downloads | 2014 |
| JIS C 8841-1 | Small Solid Oxide Fuel Cell Systems– Part 1: General Rules | Japanese Standards Association Solid Oxide Fuel Cells | March 2011 |
| JIS C 8842 | Single cell and stack performance test methods for solid oxide fuel cells<br>Adopted from IEC 62282-7-2 | Japanese Standards Association Solid Oxide Fuel Cells | December 2013 |
| Plan No. 20132465-T-604 | Single cell/stack performance test methods for solid oxide fuel cells (SOFC). Adaptation from IEC 622282-7-2 | China<br>Fuel Cell Standards | Scheduled for completion by the end of 2015 |

## *2.2 Documents containing test modules*

*Table 2: Documents containing test modules*

| **Project / Institution** | **Document Title** | **Source** | **Publication Date** |
|---|---|---|---|
| FCTES$^{QA}$ | Single Cell Performance and Endurance Test Modules | http://iet.jrc.ec.europa.eu/fuel-cells/sites/fuel-cells/files/files/documents/SOFC_SC_Performance_Endurance.pdf | April 2010 |

| | | | |
|---|---|---|---|
| FCTES$^{QA}$ | SOFC Stack Performance and Endurance Test Modules | http://iet.jrc.ec.europa.eu/fuel-cells/sites/fuel-cells/files/files/documents/SOFC_Stack_Performance_Endurance.pdf | April 2010 |
| FCTES$^{QA}$ | Testing the voltage and power as function of current density (Single Cells) | http://iet.jrc.ec.europa.eu/fuel-cells/sites/fuel-cells/files/files/documents/SOFC_SC_polarisation_curve.pdf | April 2010 |
| FCTES$^{QA}$ | Testing the voltage and power as function of current density (SOFC Stack) | http://iet.jrc.ec.europa.eu/fuel-cells/sites/fuel-cells/files/files/documents/SOFC_Stack_polarisation_curve.pdf | April 2010 |
| FCTESTNET | WP2 Stationary Fuel Cell Systems: Test Programs and Test Modules | Project document (FCTESTNET closed) | June 2006 |
| IEC TC 105 | IEC 62282-7-2: Single cell and stack test methods – Single cell and stack performance tests for solid oxide fuel cells (SOFC) | Final version to be published by the International Electrotechnical Commission (IEC) under http://webstore.iec.ch | 2014 |
| METSOFC | Final Report | http://www.metsofc.eu/Publications/Publications | June 2012 |
| STACKTEST | Test Module Drafts WP2 | http://stacktest.zsw-bw.de/downloads | April 2014 |
| STACKTEST | Test Module Drafts WP3 | http://stacktest.zsw-bw.de/downloads | April 2014 |
| STACKTEST | Test Module Drafts WP4 | http://stacktest.zsw-bw.de/downloads | April 2014 |
| Testcenter for brint og brændselsceller | Delrapport DGC1: Accelerated lifetime testing and standardization of SOFC systems | http://www.dgc.dk/sites/default/files/filer/publikationer/R1212_lifetime_testing_sofc.pdf | July 2012 |
| US Fuel Cell Council's SOFC Focus | Introduction to Solid Oxide Fuel Cell Button Cell Testing | http://www.members.fchea.org/core/import/PDFs/Technical%20Resources/SOFCFG- | July 2007 |

| | | | |
|---|---|---|---|
| Group | | ButtonCellTesting-07-015.pdf | |
| FZ Jülich | Quality Assurance and Solid Oxide Fuel Cell Testing at Forschungszentrum Juelich | Journal of Fuel Cell Science and Technology, Vol. 4 (2007) | 2007 |
| FZ Jülich | A review of standardising SOFC measurement and quality assurance at FZJ | Journal of Power Sources 171 (2007) | 2007 |
| JRC | The dynamics of the stationary fuel cell standardisation framework | Journal of Hydrogen Energy 36 (2011) | 2011 |
| JIS C 8841-2 | Small Solid Oxide Fuel Cell Systems – Part 2: General Safety Codes and Safety Testing Methods. Output less than 10kW | Japanese Standards Association Solid Oxide Fuel Cells | March 2011 |
| JIS C 8841-3 | Small Solid Oxide Fuel Cell Systems – Part 3: Performance Testing Methods and Environmental Testing methods. Output less than 10kW. | Japanese Standards Association Solid Oxide Fuel Cells | March 2011 |
| JIS C 8842 | Single cell and stack performance test methods for solid oxide fuel cells<br>Adopted from IEC 62282-7-2 | Japanese Standards Association Solid Oxide Fuel Cells | December 2013 |
| Plan No. 20132465-T-604 | Single cell/stack performance test methods for solid oxide fuel cells (SOFC). Adaptation from IEC 622282-7-2 | China<br>Fuel Cell Standards | Scheduled for completion by the end of 2015 |

# 3 Definitions / Terminology

The following tables give an overview of SOC nomenclatures and definitions, sorted by their underlying projects and institutions.

## *3.1 Projects "FCTESTNET" and "FCTES$^{QA}$"*

*Table 3: FCTESTNET definitions / terminology*

| **Document** | **Nomenclature** |
|---|---|
| WP2 Stationary Fuel Cell Systems: Test Programs and Test Modules | Discharge water; Electric efficiency; Emission characteristics; Fuel cell combined heat and power system; Fuel cell power system; Heat recovery efficiency; Higher heating value (HHV); Lower heating value (LHV); Overall Energy Recovery Efficiency; Overall energy efficiency; Oxidant consumption; Parasitic load; Recovered heat; Test run; Uncertainty; Waste heat |
| Terminology Document | (fuel cell) module; (fuel cell) stack; acceptance test; accesible; activation; activation polarization; air; air bleed; air inlet, primary; alkaline fuel cell (AFC); ambient status; anode; appliance, cogeneration; area (cell); area (electrode); area (GDL); area (MEA); area, catalyst; auxiliary power unit (APU); availability factor; back pressure; background noise level; baffle; balance-of-plant (BOP); barrier layer; base load; biological inputs (biological conditions); biomass; bipolar plate; black start; blowdown; blower; boost regulator; burner; capacity factor; catalyst; catalyst coated membrane (CCM); catalyst layer; catalyst loading; cathode; cell; ceramic; cermet; channel (related to flow field); chemical conditions; climatic conditions; coal gas; co-firing; coflow; cogeneration; cold start; cold state; combustion; combustion chamber; combustion products; compression; compressor; condensate (condensation); conditioning facility; controls; convection; coolant; coolant heat; counter flow; cross flow; current collector; current density; dead end; delamination; desulfurizer; dew point (of a gas); dicretionary downtime; diffusion; direct fuel cell; direct internal reforming; direct methanol fuel cell (DMFC); discharge water; distributed generation; drain; durability inputs; efficiency; efficiency, electrical; efficiency, heat recovery; efficiency, thermal; effluent; ejector; electro farming; electrode; electrolyte; electrolyte leakage; electrolyte loss; electrolyte matrix; electrolyte migration; electrolyte reservoir; electroosmotic drag; end plate; energy (net, gross, electrical, thermal, total); energy management system (EMS); environmental conditions; equivalence ratio; excess air; exhaust air; exhaust gas; exhaust gas cooler; exhaust gas system; exhaust gas turbine generator; exhaust heat; exhaust steam; exhaust steam system; external manifolding; external reforming; failure modes and effects analysis (FMEA); fan; filling (level); filter; flat plate cells; flow field; flow resistance; flow through; forced |

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|---|---|
| | derating hours; forced outage; forced outage rate; fuel; fuel cell; fuel cell electric vehicle (FCEV); fuel cell hybrid electric vehicle (FCHEV); fuel cell system; fuel processing system; fuel utilization; full load current; functional inputs; gas cleanup; gas crossover (fuel); gas diffusion electrode; gas diffusion layer, gas diffusion medium; gas leakage; gas seal; gas turbine; gasket; gas-tightness; grid connected; grid isolated; gross power; hazards; heat exchanger; heating value (total); hot start; hot time; humidification; humidifier; hybrid fuel cell / battery system; hybrid fuel cell / gas turbine plant (hybrid plant); I2R Loss; idle power; idle time; impurities; indirect internal reforming; interconnect; intercooler; interface point; interlock; internal manifolding; IR Loss (Ohmic Polarization); islanding; isolated operation; joints; land (related to flow field); leakage current; levelized cost; load duration curve; load-following; location, hazardous (classified); low emission vehicle (LEV); lower flammability limit (LFL); manifold; mass activity; mass transport (or concentration ) loss; mean time between failures (MTBF); mean time between forced outrage (MTBFO); mean time to repair (MTR); mechanical inputs; membrane; membrane electrode assembly (MEA); microporous layer; mixed conductor; mode; module; molten carbonate fuel cell (MCFC); nernst potential; net power; noise level (power system); nominal capacity; non-repeat components; open circuit voltage; operating pressure; operating pressure, maximum (MOP); operation; operational conditions; operational requirements; opportunity fuels; output voltage; overpotential; overvoltage; oxidant processing system; oxidant utilization; oxygen-to-carbon ratio; parasitic load; partial oxidation; partial oxidation burner; perovskite; phosphoric acid fuel cell (PAFC); pilot; pitch; plant footprint; plant heat rate; poisoning; polarization; polarization curve; polymer electrolyte fuel cell (PEFC or PEMFC); porosity; power; power conditioning (system); power density; power factor; power plant; preferential oxidation (PROX); pressure gradient monitor; programmable controller; proton exchange membrane (PEM); purge; rated power; reaction rate; recirculation; recovered heat; redox couple; redox potential; reference conditions; reformate gas; reformer; reforming; relative humidity; reliability; reliability, assessed; repeat components; residential power plant; resistance (electrical); response time; reversible fuel cell; ripple current; roughness factor; rupture member; safeguarding; schedule outage duration; scheduled outage; separator plate; series connection; service factor; shield, radiation; shift conversion; short stack; shutdown; shutdown time; single cell test; sintering; solid electrolyte / solid oxide; solid oxide fuel cell (SOFC); sound level; specific activity; specific power; stack (cell) conditioning; stack end frame; stack life; stack test; stacking; standard conditions; standby (state); start-up energy; start-up time; stationary fuel cell power plants; steam bottoming cycle; steam reforming; steam-to-carbon ratio; stoichiometric ratio; stoichiometry; storage state; substack; synchronization; syngas; temperature; test; test for power output change; thermal management system; thermal stability; thermostat; time to full power; trigeneration; triple phase boundary; tubular cells; turbocharger; turbocompressor; turboexpander; valve; valve, control; valve, relief; vent; ventilation; ventilation system; vessel, pressure; vessel, unpressurized; |

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|---|---|
| | vibration level; voltage, harmonic; waste heat; waste water; water gas shift conversion; water treatment system; wet seal; working pressure, allowable; working temperature; zero emission vehicle (ZEV) |

## *3.2 International Electrotechnical Commission "IEC 62282"*

*Table 4: IEC 62282 definitions / terminology*

| **Document** | **Nomenclature** |
|---|---|
| IEC 62282-7-2: Single cell and stack test methods – Single cell and stack performance tests for solid oxide fuel cells (SOFC) | cell/stack assembly unit; active electrode area; current density; average cell voltage; normal temperature and pressure; anode gas; cathode gas; current collector; stable state; theoretical current; effective fuel utilization; effective oxygen utilization; maximum effective fuel utilization; minimum cell/stack assembly unit voltage; open circuit voltage (OCV); power density; total impedance; total resistance; stoichiometric ratio |
| IEC 62282-1 TS: Fuel Cell technologies Part 1: Terminology | air bleed; anode; active layer; area; cell area; electrode area; active area; effective area; electrochemical surface area; membrane electrode assembly (MEA) area; specific surface area; availability factor; axial load; balance of plant; base load operation; bipolar plate; bus bar; catalyst; catalyst coated membrane (CCM); catalyst coated substrate (CCS); catalyst layer; catalyst loading; catalyst poisoning; catalyst sintering; cathode; planar cell; single cell; tubular cell; clamping plate; compression end plate; conditioning; cross leakage; crossover; leakage current; rated current; current collector; current density; degradation rate; desulfurizer; efficiency; electrical efficiency; exergetic efficiency; heat recovery efficiency; overall energy or total thermal efficiency; overall exergy efficiency; electrocatalyst; electrocatalyst support; electrode; gas diffusion electrode; ribbed electrode; electrolyte; electrolyte leakage; electrolyte loss; electrolyte matrix; electrolyte migration; electrolyte reservoir; end plate; filling (level); co-flow; counter flow; cross flow; dead end flow; fuel cell; air breathing fuel cell; alkaline fuel cell; direct fuel cell; direct methanol fuel cell (DMFC); molten carbonate fuel cell (MCFC); phosphoric |

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|---|---|
| | acid fuel cell (PAFC); polymer electrolyte fuel cell (PEFC); proton exchange membrane fuel cell (PEMFC); regenerative fuel cell; soild oxide fuel cell SOFC; solid polymer fuel cell SPFC; fuel cell / battery hybrid system; fuel cell / gas turbine system; fuel cell gas turbine hybrid system; fuel cell cogeneration system; fuel cell module; fuel cell power system; micro fuel cell power system; portable fuel cell power system; stationary fuel cell power system; fuel cell stack; fuel cell vehicle; fuel utilization; fuelling coupler; gas cleanup; gas diffusion anode; gas diffusion cathode; gas diffusion layer GDL; gas distribution plate; gas leakage; gas purge; gas seal; humidification; humidifier; interconnector; interface point; internal resistance; IR Loss (Ohmic Polarization); land (related to flow field); catalyst life (reformer); cell or stack life; manifold; mass activity; mass transport (or concentration ) loss; membrane electrode assembly (MEA); micro fuel cell power unit; no load voltage; non-repeat parts; constant current operation; constant power operation; constant voltage operation; full load operation; grid-connected operation; grid-independent or isolated operation; load following operation; standby operation; oxidant utilization; parasitic load; partial oxidation; poisoning; (fuel cell) polarization; activation polarization; ohmic polarization; concentration polarization; polarization curve; porosity; gross power; minimum power; net electrical power; rated power; specific power; pressure gradient monitor; differential cell pressure; maximum allowable differential working pressure; maximum allowable working pressure; maximum operating pressure; porous transport layer (PTL); purge; raw fuel; reactant recirculation; reformate gas; reformer; catalytic combustion type reformer; direct fired type reformer; reforming; external reforming; internal reforming; partial oxidation reforming (POX); steam reforming (SR); repeat part; roughness factor; safeguarding; separator plate; series connection; shift converter; short stack; shutdown; emergency shutdown; normal shutdown; scheduled shutdown; (mass) specific activity; stack; stack end frame; stack terminal; stacking; standard conditions; black start; cold start; hot start; warm start; start-up energy; cold state; operational state; passive state; pre-generation state; steady state; storage state; substack; acceptance test; freeze-thaw test; porcess and control test; routine test; single cell test; stack test; type test; thermal stability; three phase boundary; generating time; hot time; power response time; shutdown time; start-up time; forced ventilation; natural ventilation; minimum voltage; open circuit voltage (OCV); output voltage; waste water; water gas shift converter; water separator; wet seal |

## *3.3 Project "STACKTEST"*

*Table 5: STACKTEST definitions / terminology*

| **Document** | **Nomenclature** |
|---|---|
| Stacktest Master Document | fuel cell system; fuel processing system (FPS); oxidant processing system (OPS); conditioning; thermal management system (TMS); power distribution system (PDS); fuel cell stack |

## *3.4 Conclusion for SOC definitions and terminology*

The definitions & terminology for use in the test procedures to be drafted in WP3 shall be those of IEC 62282 where needed supplemented by the FCTESTNET Glossary to avoid repetition and to preserve consistency with international standards. Definitions missing in these documents may be defined during the drafting of the test procedures by the consortium. The project consortium consented that all definitions & terminology to appear in the Master document (StackTest approach) to be drafted in WP3.

# 4 Test Modules

The following table lists the SOC test modules as part of the test programs. The corresponding test specimen (cell/stack), operating mode (SOFC/SOEC/Other fuel cells) and the relevant test modules from the test matrix of WP3 (see deliverable D2.1) are assigned. For better comprehension of the following tables, the test matrix that was defined in deliverable D3.1 is shown in Table 6.

*Table 6: Test matrix*

| Generic Test Modules | | Applications | | | |
|---|---|---|---|---|---|
| | | Stationary<br><br>SOFC-µCHP | Mobile<br><br>SOFC-APU | SOEC for $H_2$ production *power-to-gas* | Combined SOFC/SOEC for electricity storage *power-to-gas-to-power* |
| TM01 | Leakage test | x | x | x | x |
| TM02 | Start-up | x | x | x | x |
| TM03 | Current-voltage characteristics | x | x | x | x |
| TM04 | Electrochemical impedance spectroscopy | x | x | x | x |
| TM05 | Current interruption | x | x | x | x |
| TM06 | Cyclic voltammetry | - | - | - | - |
| TM07 | Lambda sensitivity | x | x | x | x |

| | | | | | |
|---|---|---|---|---|---|
| TM08 | Reactant gas composition | x | x | - | - |
| TM09 | Temperature sensitivity | x | x | x | x |
| TM10 | Pressure sensitivity | - | - | x | x |
| TM11 | Mechanical load sensitivity | x | x | x | x |
| TM12 | Endurance test under constant current | x | x | x | x |
| TM13 | Endurance test under varying current | x | x | x | x |
| TM14 | Thermal cycling | x | x | x | x |
| TM15 | Redox cycling | x | x | x | x |
| TM16 | Shut-down | x | x | x | x |
| TM17 | Vibration test | - | x | - | - |
| TM18 | Emergency Stop | x | x | x | x |

## *4.1 Project "FCTES$^{QA}$"*

*Table 7: FCTESQA test modules*

| Project document | Test Module | Single Cell | Stack | SOFC | SOEC | Other fuel cells | Relevant for Test Matrix |
|---|---|---|---|---|---|---|---|
| Single Cell Performance and Endurance Test Modules | Light Duty Test Module with Hydrogen | x | | x | | | TM08, TM12, TM13 |
| | Light Duty Test Module with ISR Methane | x | | x | | | TM08, TM12, TM14 |
| | Light Duty Test Module with ESR Methane or Diesel | x | | x | | | TM07, TM08, TM12, TM15 |
| | Light Duty Test Module with POX or ATR Diesel | x | | x | | | TM07, TM08, TM12, TM16 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Heavy Duty Test Module with Hydrogen | x | | x | | | TM07, TM08, TM12, TM17 |
| | Heavy Duty Test Module with ISR Methane | x | | x | | | TM07, TM08, TM12 |
| | Heavy Duty Test Module with ESR Methane or Diesel | x | | x | | | TM07, TM08, TM12 |
| | Heavy Duty Test Module with POX or ATR Diesel | x | | x | | | TM07, TM08, TM12 |
| Testing the voltage and power as function of current density (Single Cell) | Polarisation curve for a SOFC single cell | x | | x | | | TM03, TM07, TM08, TM09, TM10, TM13 |
| SOFC Stacks Performance and Endurance Test Modules | Heavy Duty Test Module with Hydrogen | | x | x | | | TM07, TM08, TM12 |
| | Heavy Duty Test Module with ISR Methane | | x | x | | | TM07, TM08, TM12 |
| | Heavy Duty Test Module with ESR Methane or Diesel | | x | x | | | TM07, TM08, TM12 |
| | Heavy Duty Test Module with POX or ATR Diesel | | x | x | | | TM07, TM08, TM12 |
| Testing voltage and power as function of current density (SOFC Stack) | Polarisation curve for a SOFC Stack | | x | x | | | TM03, TM07, TM08, TM09, TM10, TM13 |

## 4.2 Project "FCTESTNET"

*Table 8: FCTESTNET test modules*

| Project document | Module | Single Cell | Stack | SOFC | SOEC | Other fuel cells | Relevant for Test Matrix |
|---|---|---|---|---|---|---|---|
| WP2 Stationary Fuel Cell Systems: Test Programs and Test Modules | Normal Efficiency Test under constant Load | x | x | x | | | TM03, TM08, TM12 |
| | Testing of Thermal Load Following for Stationary Fuel Cell Systems | x | x | x | | | TM14 |
| | Testing of Electrical Load Following for Stationary Fuel Cell Systems | x | x | x | | | |
| | Behavior of Stationary Fuel Cell Systems upon Start-Stop Cycles | x | x | x | | | TM02, TM05, TM13, TM16, TM18 |

## 4.3 International Electrotechnical Commission "IEC 62282-7-2"

*Table 9: IEC 62282-7-2 test modules*

| Project document | Module | Single Cell | Stack | SOFC | SOEC | Other fuel cells | Relevant for Test Matrix |
|---|---|---|---|---|---|---|---|
| IEC 62282-7-2: Single cell and stack test methods – Single cell and stack performance tests for solid oxide fuel cells (SOFC) | rated power test | x | x | x | | | |
| | current-voltage characteristics test | x | x | x | | | TM03 |
| | effective fuel utilization dependency test | x | x | x | | | TM12 |
| | long term durability test | x | x | x | | | TM08, TM12, TM13 |
| | thermal cycling durability test | x | x | x | | | TM14 |
| | internal reforming performance test | x | x | x | | | TM08 |
| | resistance components identification test | x | x | x | | | TM04, TM05 |

## 4.4 Project "METSOFC"

*Table 10: METSOFC test modules*

| Project document | Module | Single Cell | Stack | SOFC | SOEC | Other fuel cells | Relevant for Test Matrix |
|---|---|---|---|---|---|---|---|
| Final Report | Single Cell Testing - Long Term and Cycling Stability | x | | x | | | |
| | Performance test | | x | x | | | |
| | Load Variation Test | | x | x | | | TM11 |
| | Thermo Cycle Test | | x | x | | | TM14 |
| | H2S Poisoning Test | | x | x | | | TM08 |
| | Stack Vibration Test | | x | x | | | TM17 |

## 4.5 Project "STACKTEST"

*Table 11: STACKTEST test modules*

| Project document | Module | Single Cell | Stack | SOFC | SOEC | Other fuel cells | Relevant for Test Matrix |
|---|---|---|---|---|---|---|---|
| Test Module Drafts WP2 | Humidity Sensitivity | | x | | | x (PEM) | TM08, TM11 |
| | Temperature Sensitivity | | x | | | x (PEM) | TM09 |
| | Pressure Sensitivity | | x | | | x (PEM) | TM10 |
| | Lambda Sensitivity | | x | | | x (PEM) | TM07 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fuel/Oxidant Composition (CO sensitivity) | | x | | | x (PEM) | TM08 |
| | Freeze Start | | x | | | x (PEM) | TM09 |
| | Continuous operation at constant load | | x | | | x (PEM) | TM12 |
| | Polarization Curve | | x | | | x (PEM) | TM03 |
| | Impact of ambient conditions to PEMFC stack performances | | x | | | x (PEM) | |
| | Electrochemical Methods | | x | | | x (PEM) | TM04 |
| | Dead End Operating Conditions | | x | | | x (PEM) | |
| Test Module Drafts WP3 | Steady State | | x | | | x (PEM) | TM12 |
| | Load Cycling | | x | | | x (PEM) | TM11 |
| | Start/stop | | x | | | x (PEM) | TM02, TM16, TM18 |
| Test Module Drafts WP4 | Gas Leakage Test | | x | | | x (PEM) | TM01 |
| | Vibration | | x | | | x (PEM) | TM17 |
| | Allowable Working Pressure | | x | | | x (PEM) | TM10 |
| | Short-time rated current | | x | | | x (PEM) | |
| | Dielectric Strength Test | | x | | | x (PEM) | |
| | Excess temperature test | | x | | | x (PEM) | TM09 |

## 4.6 Testcenter for brint og brændselsceller

*Table 12: Testcenter for brint og brændselsceller test modules*

| Project document | Module | Single Cell | Stack | SOFC | SOEC | Other fuel cells | Relevant for Test Matrix |
|---|---|---|---|---|---|---|---|
| Delrapport DGC1: Accelerated lifetime testing and standardization of SOFC systems | Not specified | | x | x | | | TM12 |

## 4.7 US Fuel Cell Council's SOFC Focus Group

*Table 13: US Fuel Cell Council's SOFC Focus Group test modules*

| Project document | Module | Single Cell | Stack | SOFC | SOEC | Other fuel cells | Relevant for Test Matrix |
|---|---|---|---|---|---|---|---|
| Introduction to Solid Oxide Fuel Cell Button Cell Testing | Not specified | x | | x | | | TM03, TM04 |

## 4.8 FZ Jülich

*Table 14: FZ Jülich test modules*

| Project document | Module | Single Cell | Stack | SOFC | SOEC | Other fuel cells | Relevant for Test Matrix |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Quality Assurance and Solid Oxide Fuel Cell Testing at Forschungs-zentrum Juelich | Not specified | **x** | | **x** | | | TM03, TM07, TM09 |
| A review of standardising SOFC measurement and quality assurance at FZJ | Not specified | **x** | | **x** | | | TM03 |

## 4.9 Test Modules Conclusion

Figure 1 shows the number of relevant documents for each test module of the test matrix and the operating mode.

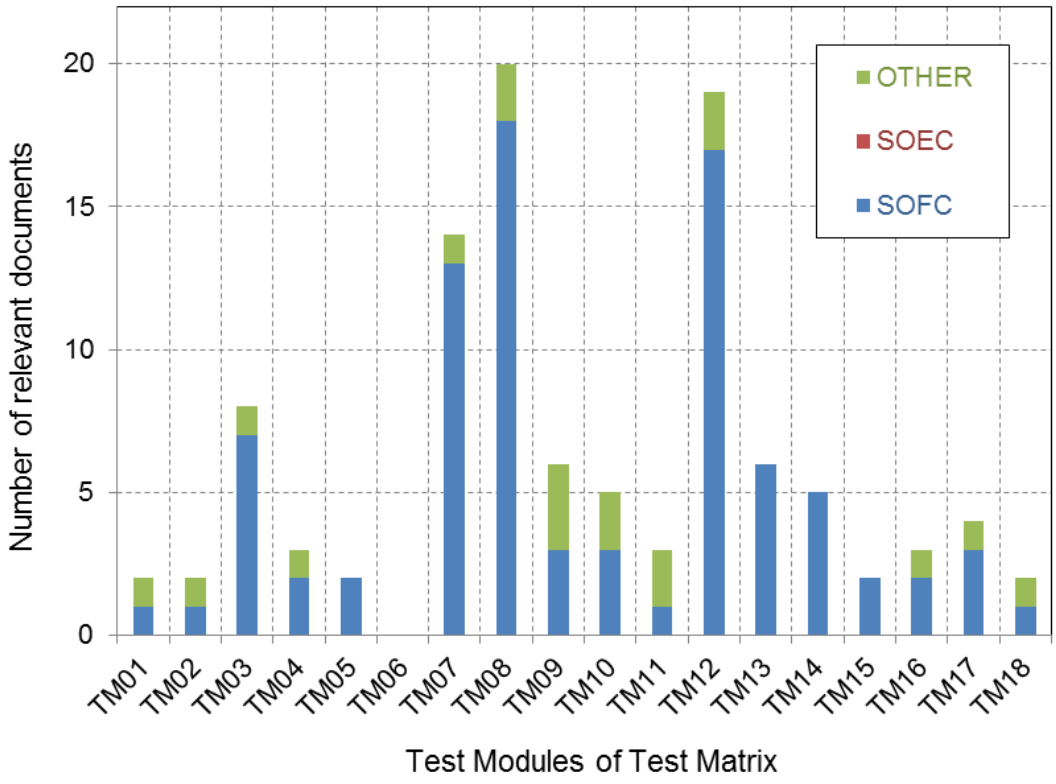


*Figure 1: Number of relevant documents for each test module*

Based on the available test procedures generic test procedures for SOC stacks for performance and durability / endurance under steady-state & dynamic operation (load & thermal cycling) of SOFC, SOEC and combined SOFC/SOEC operation should be drafted in WP3 followed by their experimental validation and finally revision. The basis for these drafts that was found in the investigated literature already offers a large number of tests for reactant gas compositions, lambda sensitivity and cell/stack endurance whereas other modules can hardly be found. Individual modules may be defined for the different test methods and parameter variations. Also, specific test procedures should be drafted for SOC systems when operated in SOFC, SOEC or combined mode for performance and durability with load cycles applied to the specific application (APU, CHP, etc.). So far, most of the modules refer only to SOFC testing. The lack of SOEC test modules shows that the development of test programs for electrolysis mode needs the most effort within the present project.

The consortium consented that the Stacktest approach of a Master document to which individual test modules are annexed should be followed.