



DELIVERABLE D3.8

Report on Factory-acceptance testing of the SO-FREE prototype system

DISSEMINATION LEVEL: PUBLIC

*Grant Agreement no 101006667
Research and Innovation Actions (RIA) project
Granted by:
Fuel Cells and Hydrogen 2 Joint Undertaking (JU)*



Document Control Sheet

Project	SO-FREE Solid oxide fuel cell combined heat and power: Future-ready Energy		
Grant Agreement n.	101006667		
Document Title	Deliverable D3.8 Report on Factory-acceptance testing of the SO-FREE proto-type system		
Lead Beneficiary	ICI		
WP number	WP3		
Type	Report		
Dissemination level	Public		
	Version	Date	Description
	0.1	19/05/2026	
	DEF	22/05/2026	
	Date	22/05/2026	
	Number of pages		
	Archive name	D3.8	
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Executive Summary

This deliverable reports on the Factory Acceptance Testing activities carried out on the SO-FREE prototype system at ICI facilities. The SO-FREE prototype is a solid oxide fuel cell combined heat and power system designed to operate with hydrogen, methane and intermediate hydrogen/methane blends.

The FAT campaign was performed to verify the correct integration of the balance-of-plant, the operation of the control and safety systems, the thermal management strategy, and the multi-fuel capability of the prototype prior to shipment for further validation activities.

The testing activities confirmed stable operation of the system under hydrogen, methane and blended-fuel conditions. The campaign also demonstrated the correct operation of the anodic recirculation concept, methane bypass architecture, purge management and safety shutdown functions.

The FAT campaign focused on functional validation and operability assessment. Long-duration operation, endurance testing and detailed performance optimisation will be addressed in subsequent project activities.

1 Introduction

The SO-FREE project aims at the development and validation of a future-ready SOFC combined heat and power (CHP) system capable of operating with different fuels, including hydrogen, natural gas and intermediate blends.

Within WP3, ICI was responsible for the integration, construction, commissioning and functional validation of the prototype system.

The present deliverable summarizes the Factory-Acceptance Testing (FAT) activities carried out at ICI facilities before shipment of the system for further testing and validation activities.

The purpose of the FAT campaign was to verify:

- Correct integration of the balance-of-plant (BoP);
- Proper operation of the control and safety systems;
- Stable operation of the SOFC system under different operating conditions;
- Multi-fuel capability;
- Correct operation of thermal management and recirculation systems.

The activities described in this report focused on system functionality and operational verification. Long-duration optimization and endurance activities were planned for subsequent testing campaigns.



Figure 1 – SO-FREE prototype system integrated at ICI facilities.

2 SO-FREE Prototype System

The SO-FREE prototype system is a multi-fuel SOFC CHP system designed around a stack-agnostic architecture capable of operating with different SOFC stack technologies.

The system includes:

- SOFC stack module;
- Fuel processing and methane management section;
- Anodic off-gas recirculation loop;
- Thermal recovery and heat management system;
- Burner and reforming section;
- Safety architecture including SIS/ESD and purge management;
- Supervisory control system.

A key characteristic of the SO-FREE architecture is the capability to operate with:

- Pure hydrogen;
- Pure methane;
- Intermediate H₂/CH₄ blends.

The architecture also includes:

- Methane bypass management;
- Anodic recirculation for steam availability;
- Adaptive thermal management.

The prototype was fully integrated at ICI facilities, including:

- Mechanical integration;
- Electrical integration;
- Instrumentation installation;
- PLC and control logic implementation;
- Safety validation.

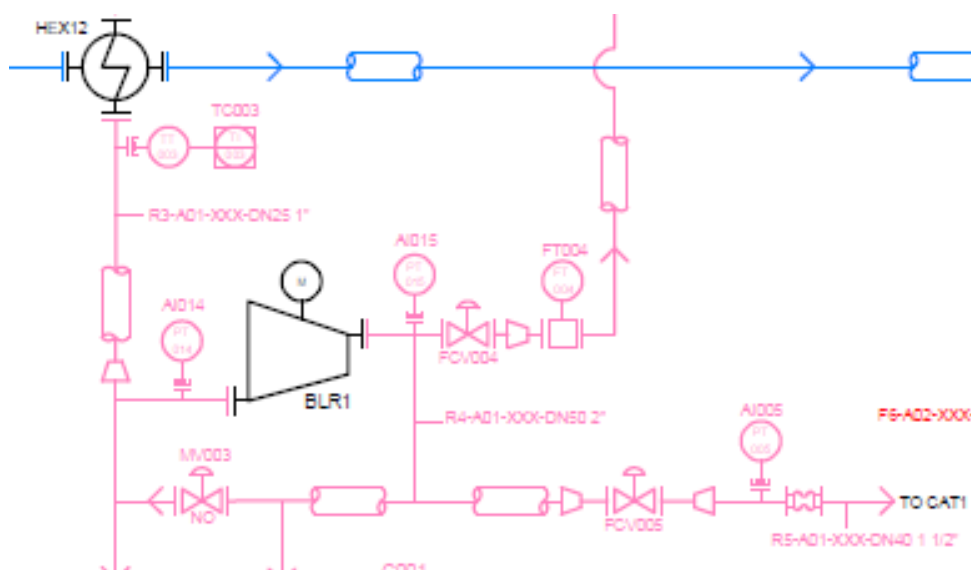


Figure 2 – ICI patented anodic recirculation architecture.

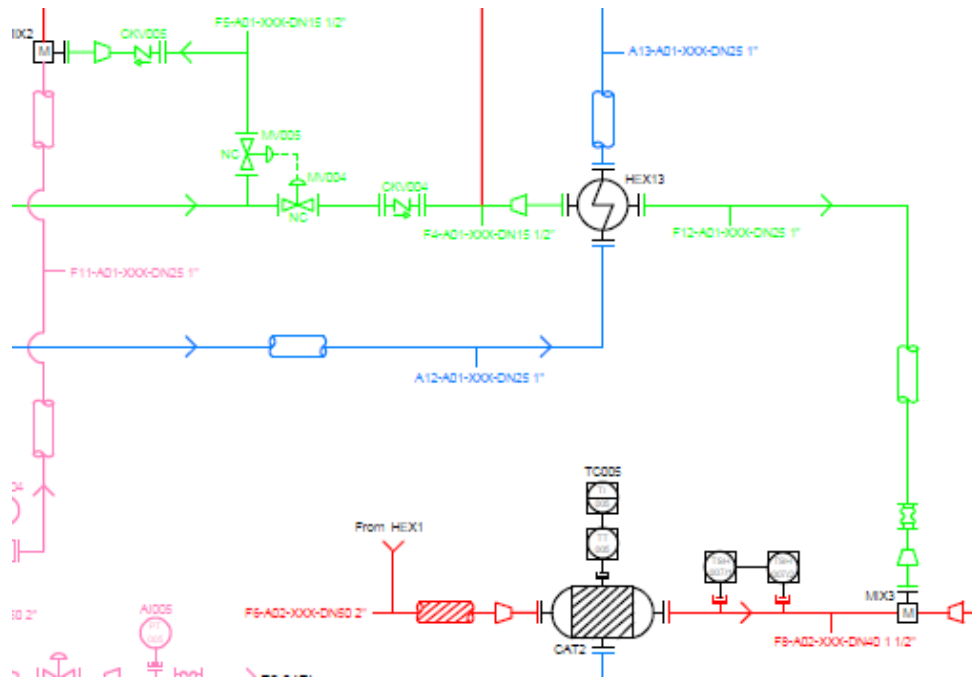


Figure 3 – ICI patented methane bypass architecture.

3 Factory-Acceptance Testing Activities

The FAT campaign included commissioning and operational verification activities performed with hydrogen, methane and intermediate hydrogen/methane blends. The campaign was designed to validate the integration, functionality and operability of the SO-FREE prototype system under controlled factory conditions.

The testing activities focused on the verification of the main system functions, including fuel supply and conditioning, thermal management, anodic recirculation, methane bypass operation, control logic, purge sequences and safety shutdown functions.

The FAT campaign was not intended to provide a full endurance assessment or final performance optimisation. These aspects will be addressed during subsequent long-duration testing and validation campaigns.

3.1 Preliminary checks

Before initiating system operation, a set of preliminary verification activities was completed to confirm the readiness of the prototype for the FAT campaign. These activities included:

- Leak testing;
- Instrumentation validation;
- Verification of sensors and actuators;
- Electrical checks;
- Validation of SIS/ESD functions;
- Purge sequence verification.

Following completion of these checks, the heat-up procedure was carried out and validated. The system successfully reached the required operating conditions, enabling the start of fuel-specific operational tests.

3.2 Hydrogen operation

Initial operational tests were performed using hydrogen as fuel. This testing phase was aimed at verifying system start-up, stable electrochemical operation, thermal control and shutdown procedures under hydrogen operation.

The hydrogen operation phase confirmed:

- Stable start-up and shutdown procedures;
- Stable electrical power production;
- Stable stack voltage behavior;
- Controlled thermal ramp-up;
- Correct operation of thermal management systems.

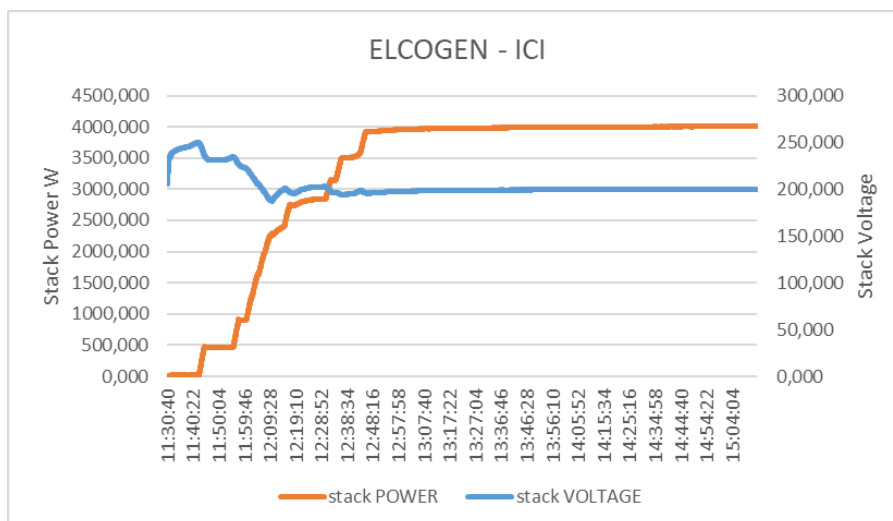


Figure 4 – Hydrogen operation during FAT activities.

The results confirmed that the prototype system was able to operate under hydrogen conditions in a stable and controlled manner during the FAT campaign.

3.3 Hydrogen and methane blend operation

Additional operational tests were performed using different hydrogen/methane fuel blends. This phase was aimed at verifying the capability of the prototype system to manage variations in fuel composition while maintaining stable electrical and thermal operation.

The tests demonstrated:

- Stable transition between operating conditions;

- Correct control adaptation during fuel changes;
- Stable thermal behavior;
- Stable stack voltage and current;
- Proper fuel management.

The operation confirmed the capability of the system to adapt to different fuel compositions.

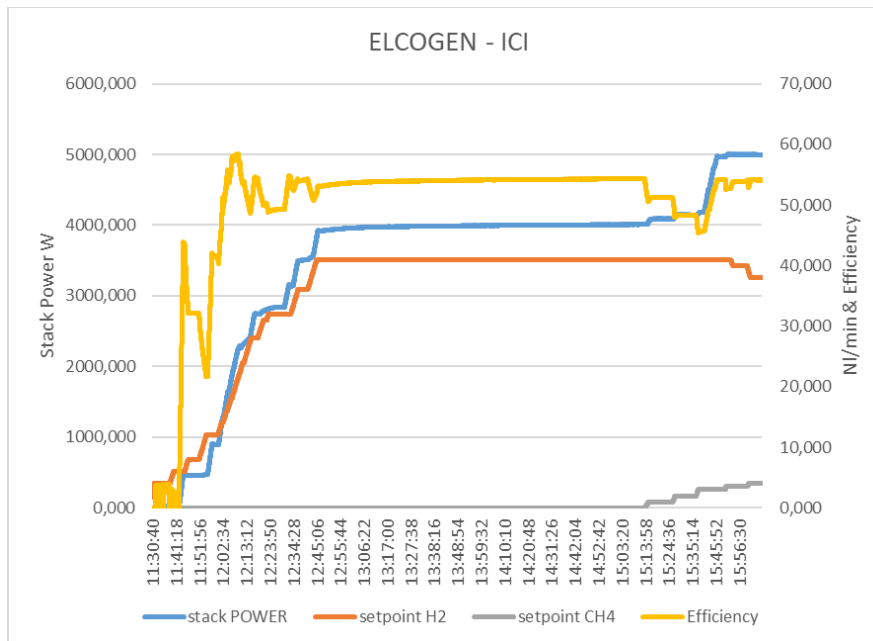


Figure 5 – Operation with hydrogen and methane blends during FAT activities.

3.4 Methane operation

Further operational tests were conducted using methane as fuel. This phase was aimed at verifying the correct operation of the fuel processing section, reforming management, anodic recirculation loop and methane bypass architecture.

The activities verified:

- Correct reforming management;
- Stable operation of the anodic recirculation loop;
- Correct methane bypass operation;
- Stable temperature profiles;
- Stable electrical behavior.

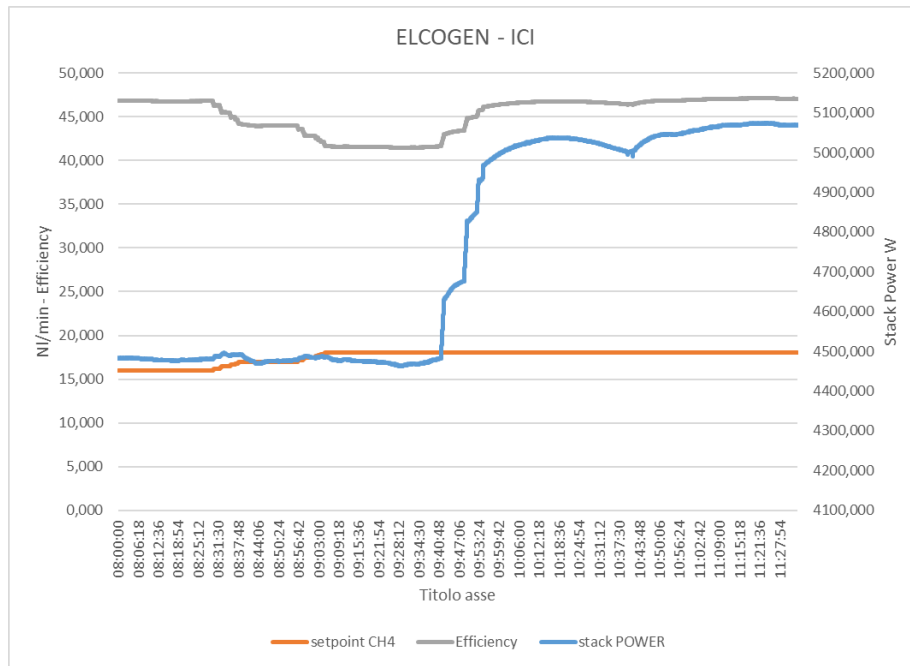


Figure 6 – Methane operation during FAT activities.

Overall, the FAT activities confirmed the correct operation of the main prototype functions, including thermal management, multi-fuel control strategy, fuel conditioning architecture, purge management and safety systems.

4 Main Results Achieved

Table 1 summarizes the main results achieved during the FAT campaign.

Parameter	Result
Fuel tested	H2, CH4, H2/CH4 blends
Stack technology tested	ELCOGEN
Maximum power achieved	>5 kWe
Electrical efficiency (H2)	~50% LHV
Electrical efficiency (CH4)	~56% LHV
Fuel switching capability	Successfully demonstrated
Thermal management	Stable
Stack voltage behavior	Stable
Safety shutdown functions	Successfully validated
Recirculation concept	Successfully validated
Methane bypass concept	Successfully validated

The tests confirmed stable multi-fuel operation and correct integration of the main balance-of-plant systems.

The system also demonstrated:

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 101006667. The JU receives support from the European Union’s Horizon 2020 research and innovation program and Italy, Austria, Finland, Germany, Poland, Netherlands, United Kingdom.

- Stable operation during load changes;
- Controlled thermal transients;
- Correct purge and safety sequences;
- Proper interaction between reforming and stack thermal behavior.

The FAT campaign mainly focused on validation of functionality and operability. System optimization activities are planned for subsequent endurance campaigns. Consequently, additional performance improvements are expected after optimization of operating parameters and long-duration tuning activities.

5 Operational Observations

The FAT campaign provided valuable operational experience regarding industrial integration of SOFC systems.

Particular attention was dedicated to:

- Thermal integration;
- Fuel flexibility;
- Safety architecture;
- Anodic recirculation management.

The activities highlighted the importance of:

- Careful thermal management;
- Robust auxiliary components;
- Controlled operating transients;
- Proper integration between stack and balance-of-plant.

The FAT activities highlighted the importance of thermal integration, fuel flexibility and proper interaction between stack and balance-of-plant systems.

The tests demonstrated stable operation during load changes, controlled thermal transients and correct interaction between reforming and stack thermal behavior.

6 Conclusions

The Factory-Acceptance Testing activities successfully demonstrated the operability and integration of the SO-FREE prototype system.

The tests confirmed:

- Stable operation with hydrogen, methane and fuel blends;
- Correct operation of the control and safety architecture;
- Proper thermal management;
- Successful operation of the methane bypass and anodic recirculation concepts;
- Stable interaction between stack and balance-of-plant.

The activities validated the multi-fuel architecture of the SO-FREE system and confirmed the feasibility of the stack-integrated CHP concept developed within the project.

The experience gained during the FAT campaign provided important information for the following endurance and validation activities planned in the project.

The FAT campaign was focused on validation of system operability and architecture, rather than on optimization of system performance.

Further optimization activities are planned for the following endurance campaigns, therefore additional improvements in operating parameters and system performance are expected during subsequent testing activities.