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AMMONIA TO POWER

D6.6 1st Progress Activity Report

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August 2024

D6.6 1st Progress Activity Report

Project Acronym	AMON
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Type	HORIZON JU Research and Innovation Actions
Project Coordinator	Matteo Testi (FBK)
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Deliverable No.	D6.6
Dissemination Level	PU
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Lead beneficiary	1 (FBK)
Contributing beneficiary(ies)	-
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History of Changes

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2.0	25.09.2024	Second draft	Ilaria Alberti (FBK)
3.0	07.11.2024	Final	

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Introduction

This document aims at raising the awareness of the public on the activities done during the first reporting period of the AMON project, e.g. during the first 18 months.

This report starts with an overview of the overarching and specific objectives of AMON Project then passing to the description of the structure of the project, its partners and the activities planned to be implemented.

The last part is the central part of the report and describes the activities done in each Work Package, from January 2023 to June 2024.

01. AMON Objectives

The AMON project aims at developing a novel system for the utilization and conversion of Ammonia into electric power at high efficiency using a solid oxide fuel cell.

The project will deal with the design of the basic components of the system including the fuel cell, an ammonia burner, ammonia resistant heat exchangers, the engineering of the whole Balance of Plant, and validation of compliance with ammonia use for all the specific parts and components. Optionally, depending on system needs, an ammonia cracker and anode gas recirculation will be developed.

High-temperature electrolysers have demonstrated in several activities the capacity to reach high performances in lab scale prototypes and validation tests. The project will deal with the design of the basic components of the system including the fuel cell, the ammonia cracker, the ammonia burner and an anode gas recirculation, the engineering of the whole Balance of Plant, and the validation of compliance with ammonia use for all the specific parts and components.

For the development of the solid oxide fuel cell, a G8X cell from SolydEra will be utilized, first validated in a laboratory at the level of single cells, for electrochemical properties, degradation and post-mortem analysis, at the level of single repeating units for the validation of interconnects and sealing components, and at the level of stacks and stack modules.

An overall Ammonia fuel cell system will be engineered and manufactured to be tested in a relevant industrial environment. The final system will consist of an 8 kW stack module, with an ammonia cracker and a heat management system. It will aim at an overall electrical efficiency in the range of 70%. AMON will be supported alongside the engineering by horizontal strategic support on critical and open issues involving use of Ammonia with fuel cells, such as safety assessment, on techno-economic analysis, on modelling at multiscale and multiphysics levels, to consolidate, confirm and direct the engineering of the technology.

Despite the small pilot demonstration scale, AMON will propose scaled engineering for a system suitable to be applied in end uses such as ports, maritime environment, besides autonomous power systems. AMON will promote the use of Ammonia as a hydrogen carrier, to enhance the flexibility of the energy system.

Scientific Objectives

01. Design and develop a fuel cell stack module at a scale of 8 kWel, tested and qualified to convert ammonia into power, possibly using the internal reforming capacity of a solid oxide cell operating at high temperature and managing the power output through the control of the cell fuel utilization.
02. Qualify a system 100% tolerant to ammonia in all the components and related materials
03. Target 70% system electric efficiency
04. Qualify the system for at least 3000 hrs operation with demonstrated 90% availability in the operating hours and less than 3% degradation rate at nominal power condition measured over 1000 hours of continuous operation.

Economic and Social Objectives

01. Diversification and security of energy supply
02. Unlock wide markets potential and foster efficient conversion systems to decarbonize hard-to-abate sectors such as maritime, autonomous power systems, where volumetric density and long-term storage solutions are key requirements.
03. Raise industrial interest in ammonia and foster the development of new markets and new jobs.

02. Project structure

The AMON Project has an interdisciplinary consortium of 13 partners coordinated by Fondazione Bruno Kessler, through the Centre for Sustainable Energy. The Consortium includes:

FONDAZIONE BRUNO KESSLER	Fondazione Bruno Kessler, through the Center for Sustainable Energy. *Italy*	https://www.fbk.eu/en/ https://energy.fbk.eu/
SolydEra	SolydEra *Italy*	https://www.solydera.com/en/
ALFA LAVAL	Alfa Laval Technologies AB (*Sweden*), Alfa Laval Aalborg AS (*Denmark*), Alfa Laval SPA (*Italy*)	https://www.alfalaval.com/
SAPIO	SAPIO Produzione Idrogeno Ossigeno Srl *Italy*	https://www.grupposapio.it/en
kiwa	KIWA Nederland BV (*The Netherlands*) KIWA Cermet (*Italy*)	https://www.kiwa.com/en/
VTT	VTT Technical Research Centre of Finland *Finland*	https://www.vttresearch.com
DTU	Technical University of Denmark *Denmark*	https://www.dtu.dk/english/
EPFL	Ecole Polytechnique Fédérale De Lausanne *Switzerland*	https://www.epfl.ch/en/
EFCF Electrolyser Fuel Cell Forum est. 1994 www.EFCF.com	Electrolyser & Fuel Cell Forum *Switzerland*	https://www.efcf.com/
HSLU Hochschule Luzern	Fachhochschule Zentralschweiz Hochschule Luzern *Switzerland*	https://www.hslu.ch/en/

Each partner has a fundamental role in the project as each beneficiary brings its own expertise, know-how and infrastructure to achieve the results initially planned.

The activities have been divided into Work Packages (WPs) and then subdivided in tasks. Each task has identified a leading partner and timeline, but all activities are connected with each other's. It becomes crucial the communication among partners and continuous exchanges on the state of art of the activities.

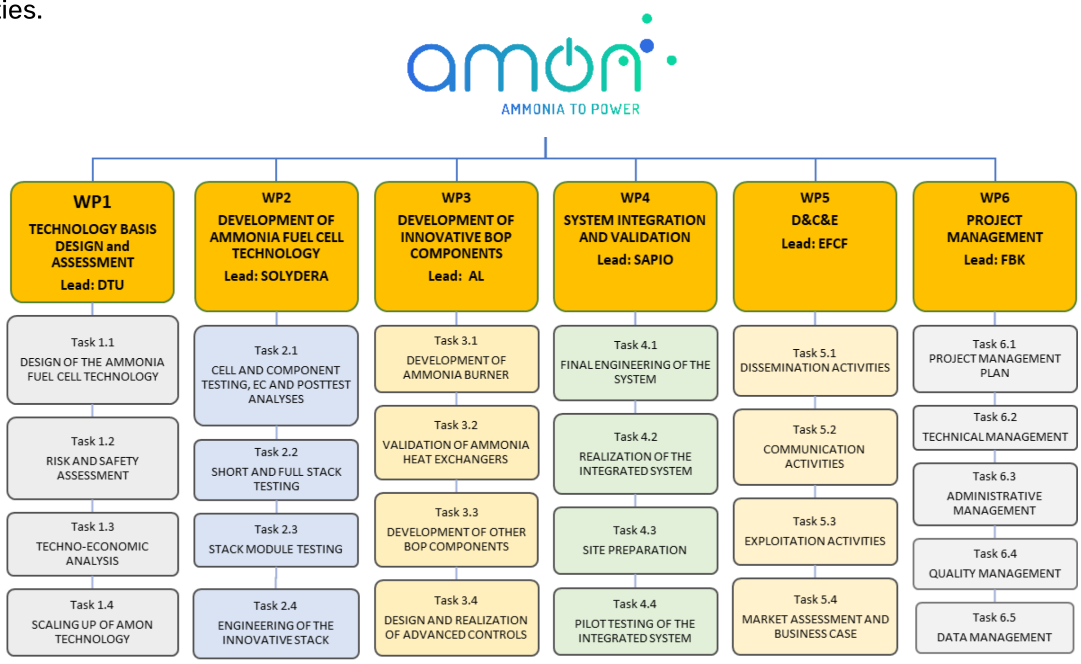

Figure 1. Structure of the activities of AMON Project

WP1 focuses on the early establishment of overall prototype system design to guide work in the other technical WPs. This includes different aspects: (i) the establishment of a high safety by pre-assessment, pre-certification and certification of ammonia based SOFC system; (ii) a techno-economic assessment of future upscaled ammonia based SOFC systems for end-users; (iii) establishment the long-term technical perspectives of the development of the technology.

WP2 aims at understanding electrochemical process contributions under operation with ammonia through the identification of degradation mechanisms in fuel cells and BoP components (including ammonia purity and degree of ammonia cracking) and the investigation of the effect of the operating parameters on stack performances. Last but not least, WP2 aims at developing SOC stack for operation with NH3.

WP3 will develop new advanced components using plate technology, bonding process and catalytic layers over the metallic surfaces. The activity will need also the development of a control strategy and logic of the AMON prototype. The final engineering of the integrated system is instead the objective of **WP4**, which will focus on the testing site preparation, safety perimeter definition and realisation, assembling and testing of the integrated system for the validation in a relevant environment.

WP5 and WP6 are the less technical work packages. **WP5** focuses on the communication, dissemination and exploitation of the results, while **WP6** relates to the proper management of the project.

03. Activities implemented per WPs

During the 1st reporting period (month 1 to month 18), the Consortium started the planned activities and progressed in the development of the AMON system. The main results achieved are listed below divided by Work Package:

Work Package 1 - Technology basis design and assessment

Leader: DTU

- A conceptual system design was developed. It both provides the targeted efficiency >70 % and a safe system without so-called nitriding.
- A multiscale multiphysics model concept was developed to more precisely foresee possible challenges and obtain designs to avoid these. This modelling approach
  - covers all the underlying physics within the stack including ammonia cracking, transport of mass, momentum, species, charges, and heat as well as the electrochemical reactions within the stack are represented in the 3D stack model.
  - considers nitriding on the steel layers of stack and nickel layers of cells as one of the main degradation mechanisms in ammonia-fueled SOFC system
  - allowed to design various system configurations for the ammonia-fueled SOFC system to investigate the system layout and different components on the performance and reliability of the system. Overall, DTU proposed 4 main system configurations with and without implementing anode off-gas recirculation (AOR) and ammonia external pre-cracker.
- Alfa Laval as one of the leaders in heat exchanger production, implemented more realistic data related to the heat exchanger integration and pressure drop and performed a detailed mass and energy balance for the final system layout.
- Alfa Laval also performed a load investigation on the final system layout by variation of load from the full load (100%) which equals 8 kW power production by the system to the part load (12.5%) that corresponds to 1 kW power production.
- The pre-assessment activities were performed in a series of workshops with the partners involved in the design of the system. In these workshops, review and completion of the system's risk assessment, mitigation actions to eliminate / reduce the severity of hazards or safeguarding were audited, and modifications on the system design to include mandatory components as defined by the product standard were made. In addition, the applicable legislation was identified and relevant standards for compliance of the system were chosen.

Work package 2 – Development of the Ammonia Fuel Cell technology

Leader: SE

- Single cell testing has been implemented at EPFL to set a benchmark for the future testing of improved cells. The tests were done with ammonia (NH_3), a mixture of 75% H_2 and 25% N_2 mimicking fully cracked ammonia, and pure H_2 for comparison. Each test lasted 1000h in steady polarization at 0.5 A/cm2 and 750°C. Periodic V-I and EIS characterization were carried out every 100 h to check the evolution of the performance with time. Post-test examination of the tested cells using SEM and EDX are on-going.
- Single repeating unit test setup for testing ammonia-fueled SOFC has been implemented by DTU. The primary goal is to conduct the test under conditions that more closely resemble those of an SOFC stack, rather than a single-cell test by having the interconnects and contact

components. Additionally, the long-term goal is to identify a solution to prevent nitriding degradation in the steel components of the stack and the nickel layers of the cell.

- Testing protocols for ammonia-fuelled SOFC were defined to establish common procedures and tests conducted during the project, presenting different thermal stabilization criteria and the design of the experiment. In this activity performed by FBK, the Joint Research Center of the European Commission was involved to harmonize processes and procedures.
- Experimental and numerical investigation of ammonia cracking has been carried out as understanding the ammonia cracking rate is crucial for developing the external cracker and it is important to understand the internal cracking of Ammonia in direct ammonia-fuelled SOFCs. DTU has measured the cracking kinetics on the catalyst in the ammonia cracker rather than on the steel components.
- VTT testing facility has been prepared with an upgrade process for upcoming stack module testing. An upgrade process has had three focus areas; enlarge the ammonia storage, upgrade existing testing platform to be compatible with SolydEra's 8-kW stack module, and upgrade safety measures for expanded ammonia usage.

Work package 3 – Development of the innovative BoP components

Leader: ALSW

High temperature tolerant low pressure drop heat exchanger has been developed by ALSW.

Technology for coating stainless steel with high surface area metal oxide has been developed and currently being optimized to apply washcoat.

A static MATLAB model has been developed and based on that a P&I diagram has been proposed.

Health and safety aspects have been incorporated in the P&I diagram.

Sourcing discussions have been initiated for unique components.

Work package 4 – System integration and validation

Leader: SAPIO

P&ID was prepared based on the control philosophy, equipment, previous project, and preliminary PFD of the overall system provided by ALDK.

Based on the pressure-drop available for heat exchanger and sizing, Alfa Laval investigated different types of heat exchangers.

A technical scouting for selection of equipment in the anode recirculation system was performed by ALIT according to specific data and requirements of the project.

Work package 5 – Dissemination, Communication and Exploitation

Leader: EFCF

Numerous activities were implemented with regards to communication and dissemination to lay the basis for a proper communication strategy and tools.

- Visual identity and logo of the AMON project

- Creation of a communication toolkit consisting of templates (Word, PowerPoint, Poster), flyer, GIF, package of illustrations and icons and roll-up
- Design, launch and active management of the project website activated under the domain www.amon-project.eu
- Design, launch and active management of the social media channels (X.com and LinkedIn): https://www.linkedin.com/company/amon-project-eu/ and https://x.com/AmonProjectEU
- Definition of the Dissemination, Communication and Exploitation Plan
- Active presence of AMON at several conferences, fairs and workshops. AMON is meanwhile very well known in the FCH community and in active exchange with relevant familiar projects. Due to fruitful collaborations has AMON already achieve some awareness in the field of end users, ammonia stakeholders and in the maritime sector.
- In task 5.4, Literature review and preparation of expert interviews for the market assessment and Concept and development of a modelling framework for business case evaluation were carried out.
- Significant progress has been made towards having the AMON project as part of a standardization process.

Work package 6 – Project Management

Leader: FBK

During the first months of the project, the basis were laid for a proper management and coordination among partners:

- The project Management body and structure were set up and a detailed implementation plan was prepared
- The project management has been continuous and smooth
- A common shared space was created by FBK on MS Teams / SharePoint.
- 1 kick off meeting and 2 project meetings were performed till M18
- Every month a general call was set up to follow the progress of the project, WPs calls were set up by WP Leaders ad hoc.
- Five members of the End-User Advisory Board were selected.

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FBK
Fondazione Bruno Kessler
(Italy)

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(Italy)

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(Switzerland)

Amon – Ammonia to power

Coordinator Contacts:

Matteo Testi testi@fbk.eu

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