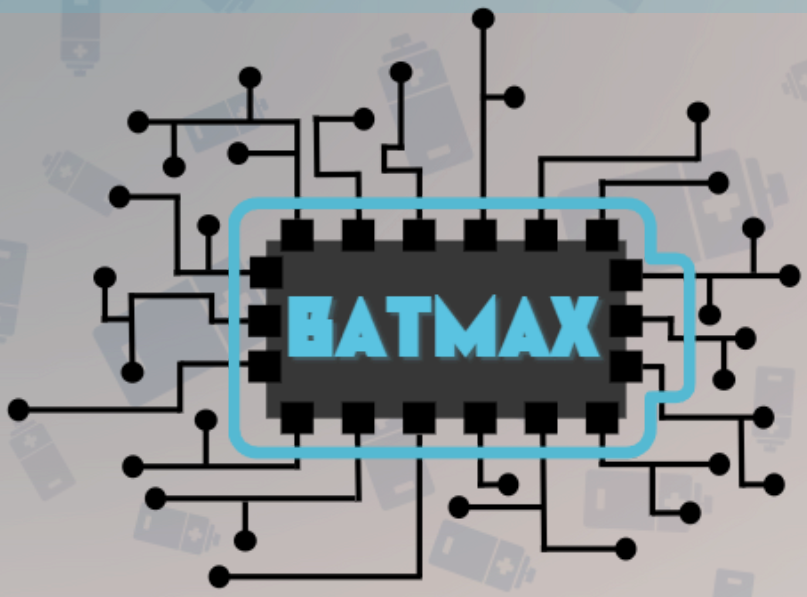
Issue 2 June 2024




# BATTERY MANAGEMENT BY MULTI-DOMAIN DIGITAL TWINS

# Project Newsletter

Developments within the BATMAX project are progressing full speed, reaching the end of the first year of the project. Use case definitions, requirements and reference cycles have been defined, functionalities, requirements and KPIs for BMS specified and requirements for BMS hardware, software and measurement data quality agreed upon together with the definition of IT and data management architecture.

In parallel, the Plan for the Dissemination, Exploitation and Communication of the project results was prepared containing detailed list of KPIs for all planned activities as well as the description of the results the BATMAX project inspires to generate.

## Contents

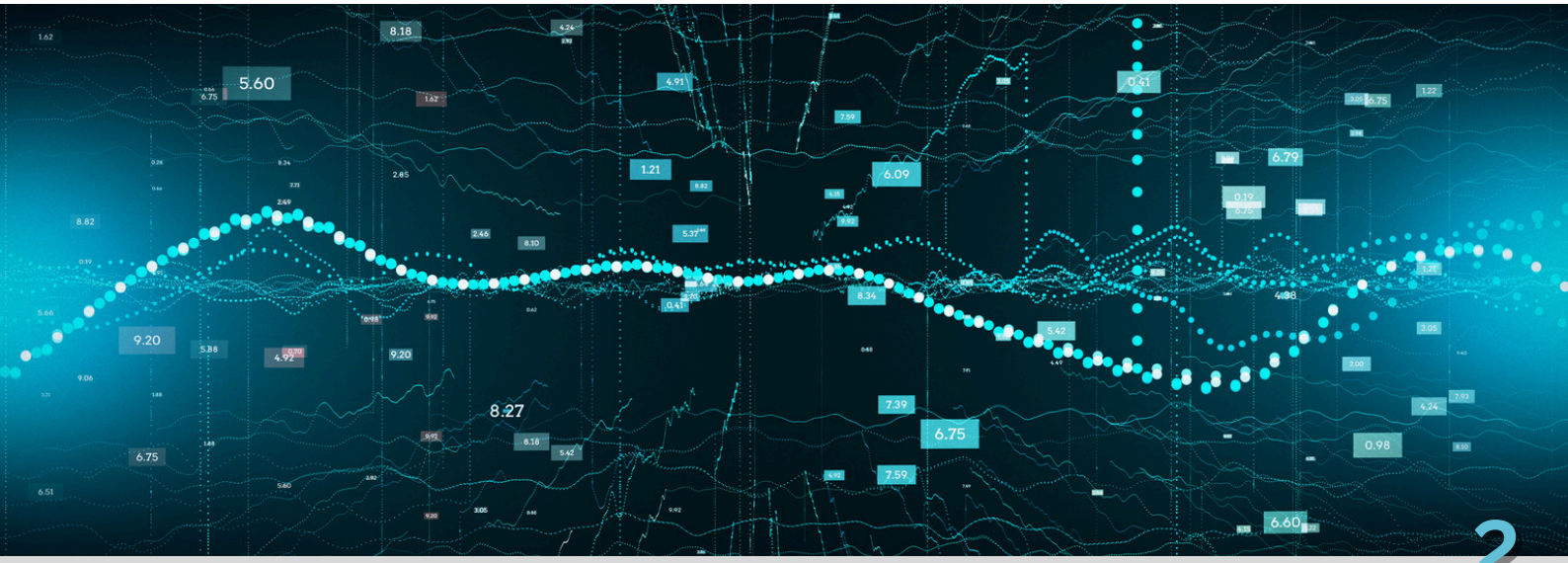
# Definition of IT and data management architecture

The role of data and data-driven methods is increasing rapidly in scientific development in various domains, including the development of next-generation batteries and battery management systems. Modelling and the use of machine learning algorithms and AI can provide new scientific results faster than plain traditional methods, but there are questions regarding the reliability of these results.

To overcome these obstacles in the advantageous use of AI, current dogma recommends using such processes and methods that allow human users to comprehend and trust the results and output created by machine learning algorithms.

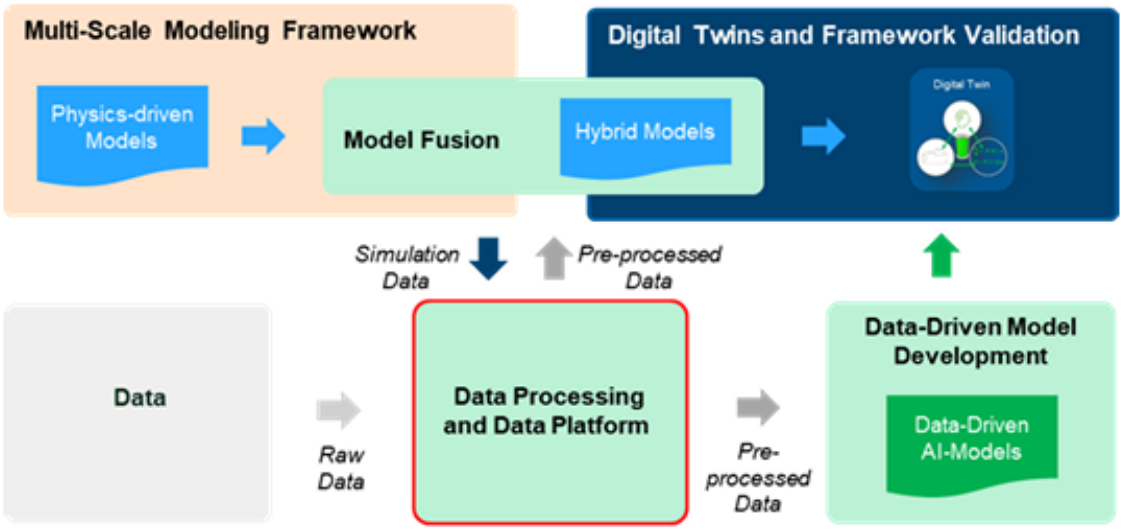
Explainable AI is used to describe an AI model, its expected impact, and potential biases. This can be achieved by the inclusion of physical and chemical knowledge in hybrid models or complementing data-driven models for improved explainability.

The project takes advantage of the latest EU initiatives regarding FAIR data sharing. One of the actions is the incorporation of the FAIR principle as a requirement in EU research calls. FAIR stands for Findable, Accessible, Interoperable, and Re-usable data. To create reliable research results utilizing modelling and AI, also the data used to train machine learning algorithms need to be open.



# Definition of IT and data management architecture

As a part of EU funded BATMAX project, a centralized data pre-processing and integration platform is decided to be utilized in the project, collecting, storing, and giving access to all data for project partners systematically. The BATMAX project, like many EU projects nowadays, relies heavily on data produced in the project, and used in the project by multiple partners. In the BATMAX project, this data includes battery characterization data from experimental activities and testing, reference data collected earlier from experimental setups, synthetic data produced with physics-based modelling, predicted data from machine learning algorithms and surrogate models, and live sensor data from prototype setups and from real-world field units.



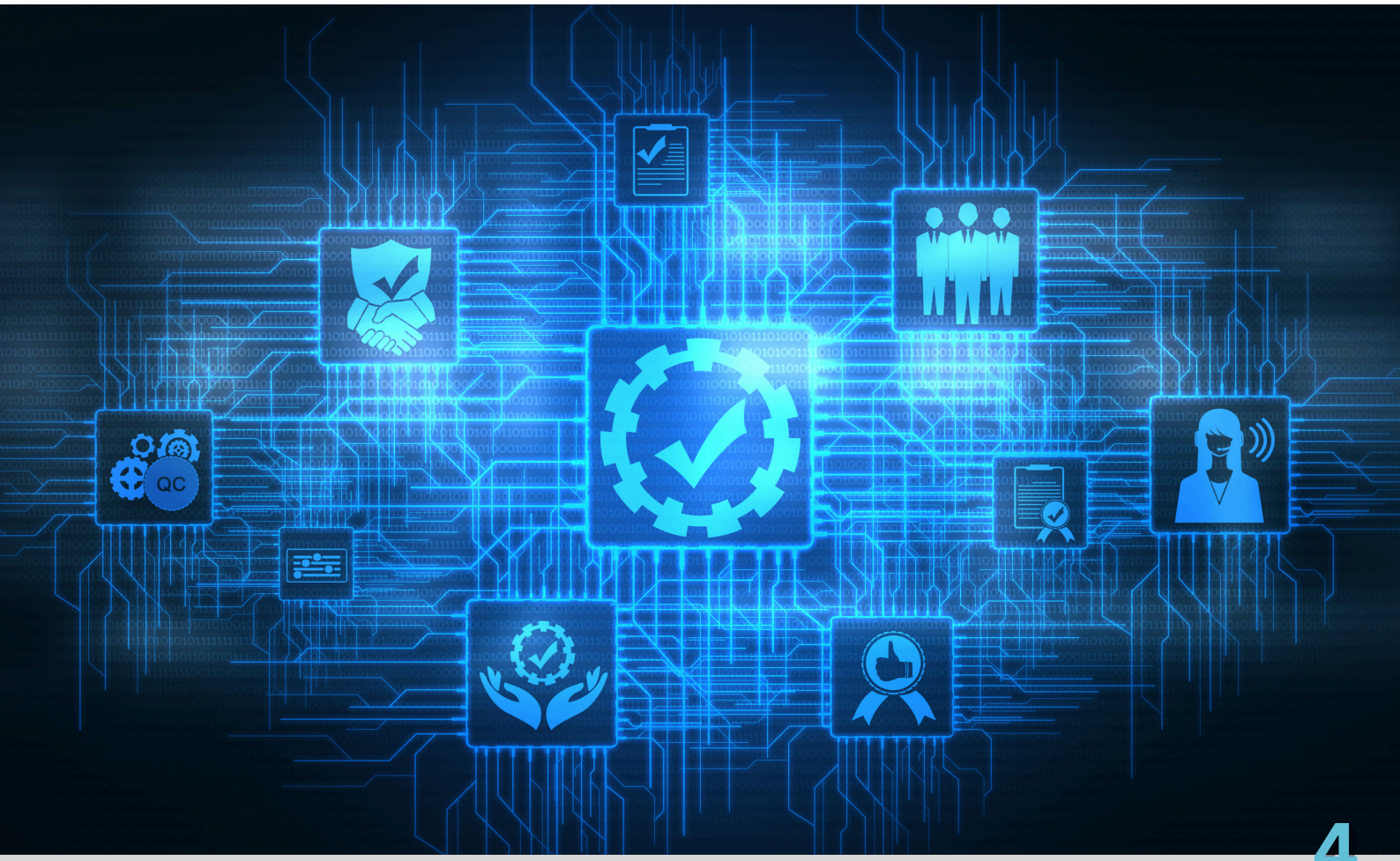

*Envisaged data flow in BATMAX and interaction with the model development frameworks.*

In the BATMAX project, the effort towards the generation of hybrid models, explainable AI, and their inclusion in battery digital twins with the incorporation of FAIR principles includes this public plan for the project data pre-processing and integration platform, its implementation and usage throughout the project and as a last activity of the project, publishing as much of the generated and used data as possible.

# Requirements for BMS hardware, software and measurement data quality

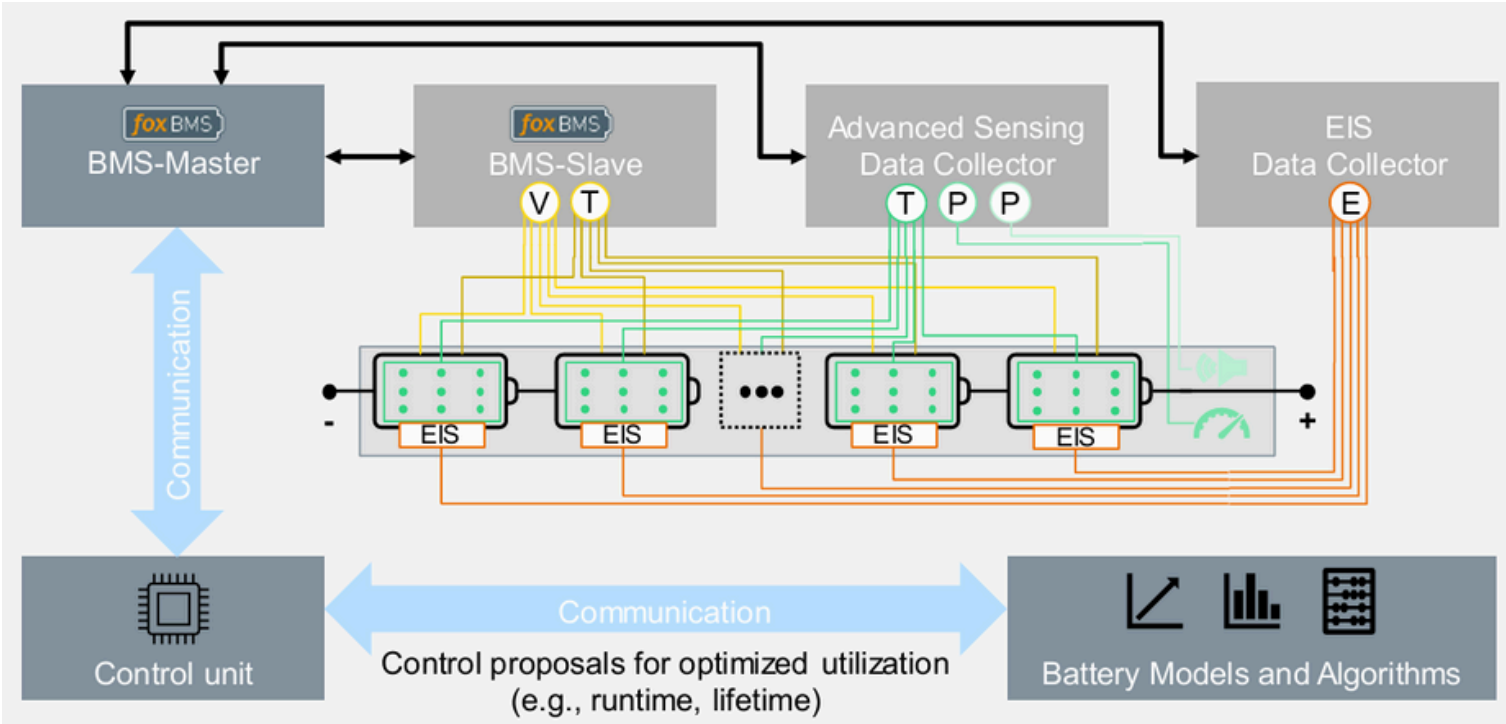
The technical specification of the battery management system (BMS) have been defined, together with the requirements for the data this BMS is going to produce.

In a first step, the basic requirements of the demonstrator application developed within this project are defined. This demonstrator application is one use-case through which the BATMAX project demonstrates its improvements and novel features on BMS and modelling level. In the second step the improvements and novel features of the BMS, the battery system, and battery cell sensorisation are described, that enable the BATMAX objectives (enhanced performance, safety, reliability, service life, lifetime cost of the battery system). Some of the objectives are directly related to BMS hardware or software and the accompanying sensorisation, while others rely on the data generated by the BMS to improved performance (e.g., battery modelling tasks).



# Requirements for BMS hardware, software and measurement data quality

Therefore, two coherent sets of requirements are collected and shown, namely the “Battery Management System Requirements”, and the “Battery Measurement Data Quality Requirements”.
The image below shows the BATMAX system demonstrator as well as the overall system architecture, including the BMS-Master, BMS-Slaves, the novel EIS- and mechanical property sensors. The requirements for all shown subcomponents (BMS-Master, BMS-Slave, the Advanced Sensing Module, and the EIS sensor) are defined in this deliverable. The requirements include important parameters, such as power consumption, mechanical properties and mountings, data rates and measurement accuracy.



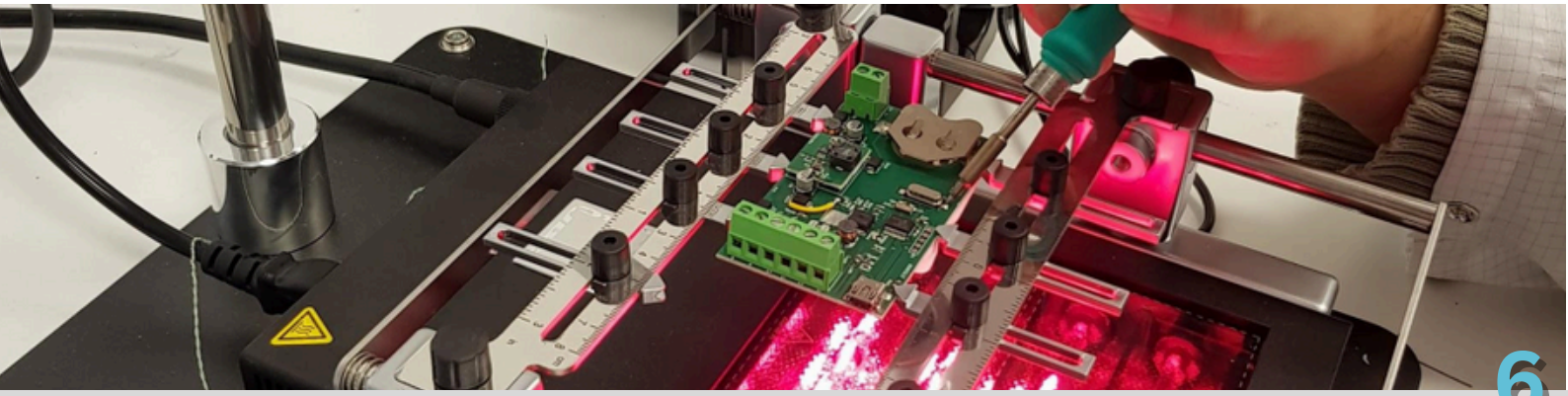

*The BATMAX system demonstrator application includes a battery module, a BMS derived from the open source BMS solution “foxBMS” (V=voltage) and novel battery sensors for electrochemical impedance spectroscopy and measurement (E) of e.g., the swell force (P), acoustic impedance (P), and detailed temperature distribution (T).*

# Key Exploitable Results

Key Exploitable results are the outputs generated by the project in order to create impact both on the short-term and on the long-term. BATMAX project aspires to achieve the following Key Exploitable Results:

1. Efficient parametrisation framework for physics-based models through cell lifetime
2. Methodology to produce accurate reduced-order, hybrid and AI-driven models from large amounts of synthetic, experimental and operational data
3. Development of new battery system sensorization and provision of drivers and IoT-native communication for secure data collection
4. Scalable and performance-optimised system-level digital twin architecture for BMS development, online diagnostics and operation optimisation
5. Exploration of emerging opportunities to improved battery utilisation through BATMAX innovations

The Key Exploitable Results will be defined and characterised throughout the project and commercial and non-commercial exploitation actions will be identified. The aim is to prepare viable and scalable exploitation plans for each consortium partner and for each project result by the end of the project which will serve as a basis for future utilisation of the results.



# PESTEL analysis

A detailed market outlook was prepared for the BATMAX project in the framework of D8.1 Plan for Dissemination, Exploitation and Communication of Results (DEC Plan). The market outlook contained a thorough PESTEL (Political, Economic, Social, Technological, Environmental and Legal/Regulatory) analysis, identifying and analysing the different factors that influence the macro-environment.

The PESTEL analysis showed the evidence that there is a strong political force in the EU moving towards non-fossil based energy and net zero emissions targets thus enabling the drastic reduction of GHG emissions by 2030. This is already regulated by setting agreed targets in achieving abandonment of diesel/petrol internal combustion engines and replacement with electric motors and integrating energy storage within the electric grids in order to balance the fluctuation of energy production from RES.

To this end, it is evident that the Electric Vehicle market and the RES storage market are those markets most driving growth in the battery market. Managing the efficient operation of a battery (which is the objective of the BATMAX Project) will enhance both the range of EVs but also will extend the lifecycle of batteries thus reducing the price of EVs and RES storage.

# Market outlook

A detailed market outlook was also prepared and included in deliverable D8.1, describing the market drivers, market size, value and volume with special emphasis of the BMS market. Additionally, a market overview was also provided for the four use-case application areas where the BATMAX project strategically concentrates.

## Waterborne

## Non-road mobile machinery

## Heavy-duty vehicles

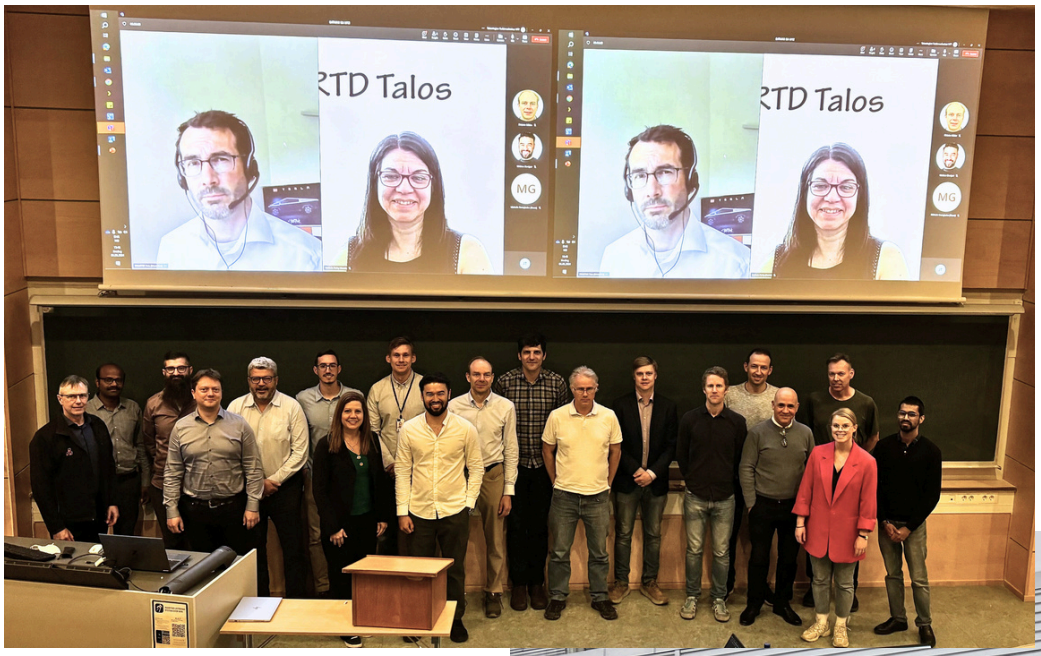
## Stationary Storage

The market analysis showed the enormous commercial potential that the BATMAX technology can have on the specific markets both in terms of current market size as well as the growing market trends in all these market segments.

Additionally, external factors, such as opportunities and threats were also identified and will be incorporated in the exploitation plans for the project results.

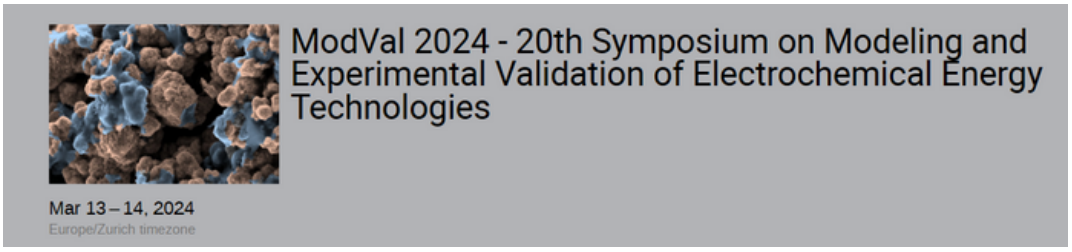
# M12 meeting

The M12 meeting took place in Trondheim, Norway on June 4-5th. The partners had the chance to present their progress in each Work Package and share their updates so far. A General assembly followed and a visit to the SINTEF labs concluded the first day. On the second day the participants headed to the RISE Fire Research Center where they had a RISE FRN presentation followed by lab visits.




# Latest events

## Presentation at ModVal 2024




On March 13-14th, in Baden, Switzerland, **Xavier Raynaud** and **August Johansson** of SINTEF attended **ModVal 2024**, the **20th Symposium on Modeling and Validation of Electrochemical Energy Technologies** and presented the new optimization and parameterization capabilities of BattMo.

## BattMo v0.3.0

On February 2024, X. Raynaud, A. Johansson, H. Møll Nilsen, F. Watson, S. Clark of SINTEF, published on GitHub about BattMo in a scientific publication titled **BattMo v0.3.0**.
BattMo is a framework for continuum modelling of electrochemical devices.

## The BMS Alliance

In April 2024, **The BMS Alliance** was established, uniting four groundbreaking projects funded by Horizon Europe: the **BATMAX project, ENERGETIC project, NEXTBMS project, and Nemo project**.
These projects, all granted in the same call, will collaborate on **Battery Management Systems** to revolutionize the future of energy storage.
The aim of the clustering is to align the communication and dissemination activities among the projects.


## The BMS Alliance - Sister projects

energetic

ENERGETIC project, funded by the EU Horizon Europe program, aims at developing the next generation BMS for optimising batteries' systems utilisation in the first (transport) and the second life (stationary) in a path towards more reliable, powerful, and safer operations. It contributes to the field of translational enhanced sensing technologies, exploiting multiple AI models, supported by Edge and Cloud computing. ENERGETIC will monitor and predict the remaining useful life of a Li-ion battery through a digital twin.

## The BMS Alliance - Sister projects

NEMO

The NEMO project aims to deliver next-generation BMS by combining cutting-edge hardware and software concepts. These concepts exploit a wide range of sensor information acquired at high frequencies, along with dedicated electrochemical impedance spectroscopy (EIS) sensors. This comprehensive approach enables the identification of different electrochemical processes inside the battery cells and tracks their evolution over time. Combinations of coupled physics-based and data-driven approaches are also planned. With every individual cell monitored, controlled, and studied, NEMO will provide solutions that significantly extend battery life and enhance system safety for automotive and stationary applications over the long term.

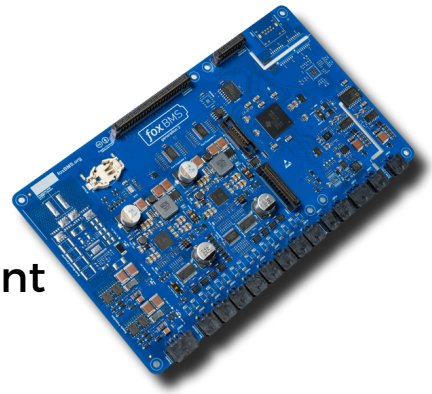

NEXTBMS will develop an advanced battery management systems (BMS) built on fundamental knowledge and experience with the physicochemical processes of lithium-ion batteries, which will enable the significant enhancement of current modelling approaches, including the readiness for upcoming lithium (Li) battery material developments. These modelling approaches will be further improved by optimising sensors and measurement techniques to meet modelling needs (and optimising models based on physical sensor data) and the physical cell configurations to form a framework that supports improving the battery state prediction and -control. By solving these challenges, NEXTBMS will ensure that the next generation of BMSs will enable higher performance, safety, and longer lifetime of the battery cells for an overall optimal utilisation of the battery system.

# Meet the project partners

## Fraunhofer IISB

Fraunhofer IISB

The Fraunhofer Institute for Integrated Systems and Device Technology IISB as part of the Fraunhofer-Gesellschaft conducts applied research and development for industry as well as public authorities in the field of electronic systems for application in, e.g., electric mobility, aerospace, Industry 4.0, power grids or energy technology. In this context, the institute uniquely covers the entire value chain - from basic materials to complete power electronic systems.



The department “Intelligent Energy Systems” develops the technologies for the digitalization of the power electronic and energy conversion in the transportation and energy domains. The department integrates these technologies in interconnected intelligent energy systems, building the “Cognitive Power Electronics” ecosystem initiated at the Fraunhofer IISB.

In the research area “Battery Systems” we work on innovative solutions for lithium-ion-based electrical energy storage systems for stationary and mobile applications. The activities range from the development of battery management systems (e.g., BMS platform foxBMS®), algorithms for battery state estimations and predictions, up to the design of full-custom battery systems, e.g., for large applications like racing cars, and submarine exploration robots.

In the research area “Data Analytics” we take an application-oriented approach that includes system analysis, conception, data collection, filtering, clustering, and finally the development and implementation of intelligent algorithms in industrial processes or in embedded systems.

## Role in BATMAX:

Fraunhofer IISB

FHG provides excellence in applied research in the fields of battery management systems and data analytics for the implementation of the digital twin. As a key element to the project, FHG supplies the foxBMS® platform with IoT interfaces and the integration of interoperable algorithms on the BMS. In the course of the project, the foxBMS® platform enables further sensorisation, standardized, IOT interfacing, and execution of algorithms. Data analytics methods are supplied to enable concise data aggregation, data-based prediction of relevant battery states (SOX), and their usage and implementation with the digital twin.

## Meet the Team

### Dr. Georg Roeder

Dr. Georg Roeder, senior researcher at Fraunhofer IISB, department of Intelligent Energy Systems, expert in data analytics and machine learning (Leader WP 3).

### Dr. Martin Schellenberger

Dr. Martin Schellenberger, group manager “Data Analytics” at Fraunhofer IISB, department of Intelligent Energy Systems, expert in application of data analytics (contact for data analytics and AI)

# Meet the Team

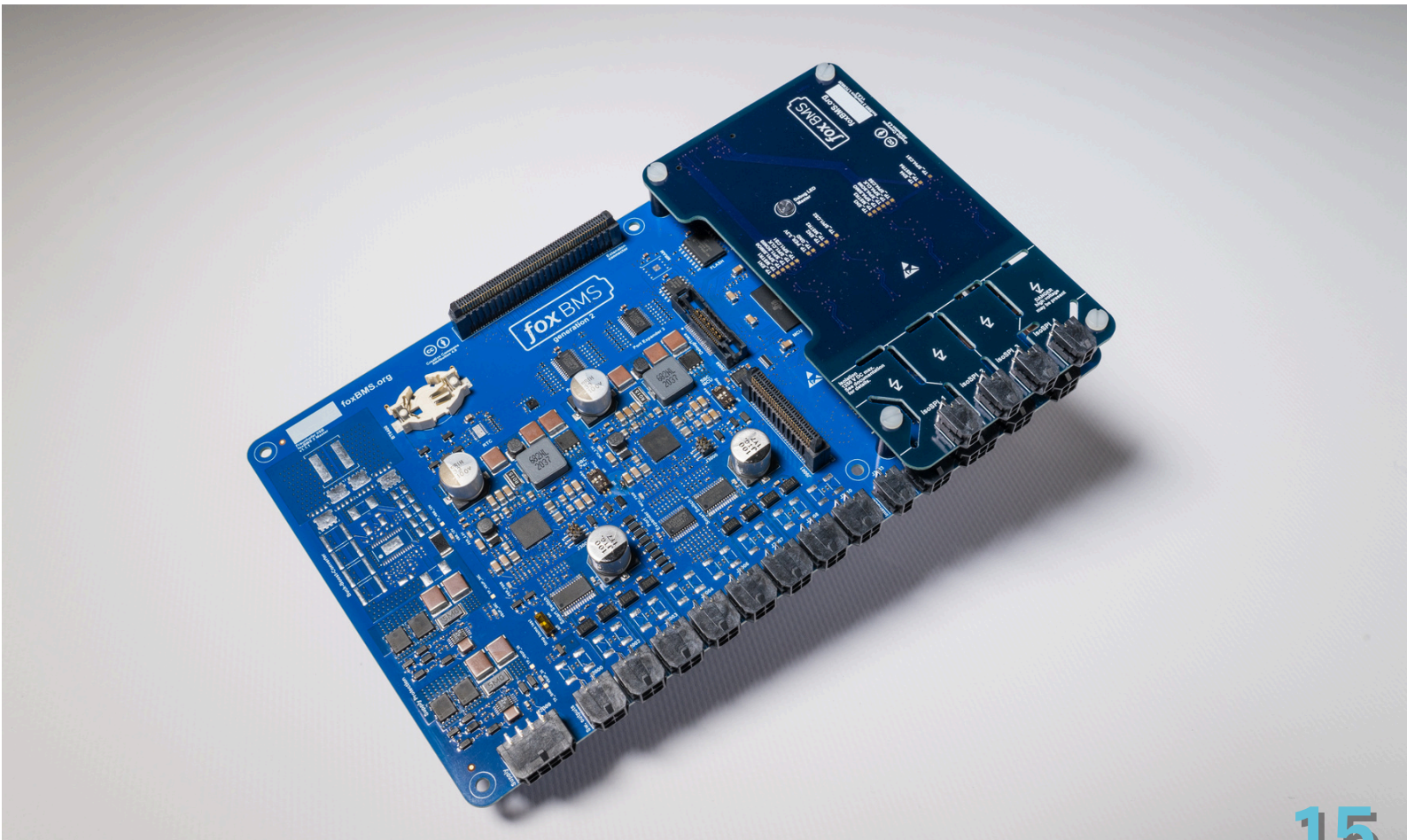
## Radu Schwarz

Radu Schwarz, group manager “Battery Systems” at Fraunhofer IISB, department of Intelligent Energy Systems, expert in BMS electronics (Fraunhofer IISB main contact for BATMAX).

## Stefan Waldhör

Stefan Waldhör, senior engineer at Fraunhofer IISB, department of Intelligent Energy Systems, expert in BMS software and battery system integration (Leader WP 5)

Fraunhofer IISB



# Meet the project partners

## EDF

Electricité de France (EDF) is a French public electricity production and supply company, 99.98% owned by the French state. The company is the leading producer and supplier of electricity in France and Europe and one of the mondial leaders. EDF's raison d'être is to build a net zero energy future with electricity and innovative solutions and services, to help save the planet and drive wellbeing and economic development.

## Role in BATMAX:

EDF R&D contributes as end user. EDF is directly involved in Work Package 1- Coordination and Management, Work Package 7- Applications, requirements and use cases and Work Package 8- Dissemination, communication and exploitation .

# Meet the Team

## Dr. Laurent Torcheux

Dr. Laurent Torcheux, EDF Group expert/Fellow and senior researcher at EDF R&D, Electrical Equipment Laboratory. Working on electrochemical batteries since 1995, Expert in battery technologies, ageing & safety studies. Technical contributor to the BATMAX project.

## Researchers involved in the project at EDF R&D

## Dr. Antonella Cristiano-Tassi

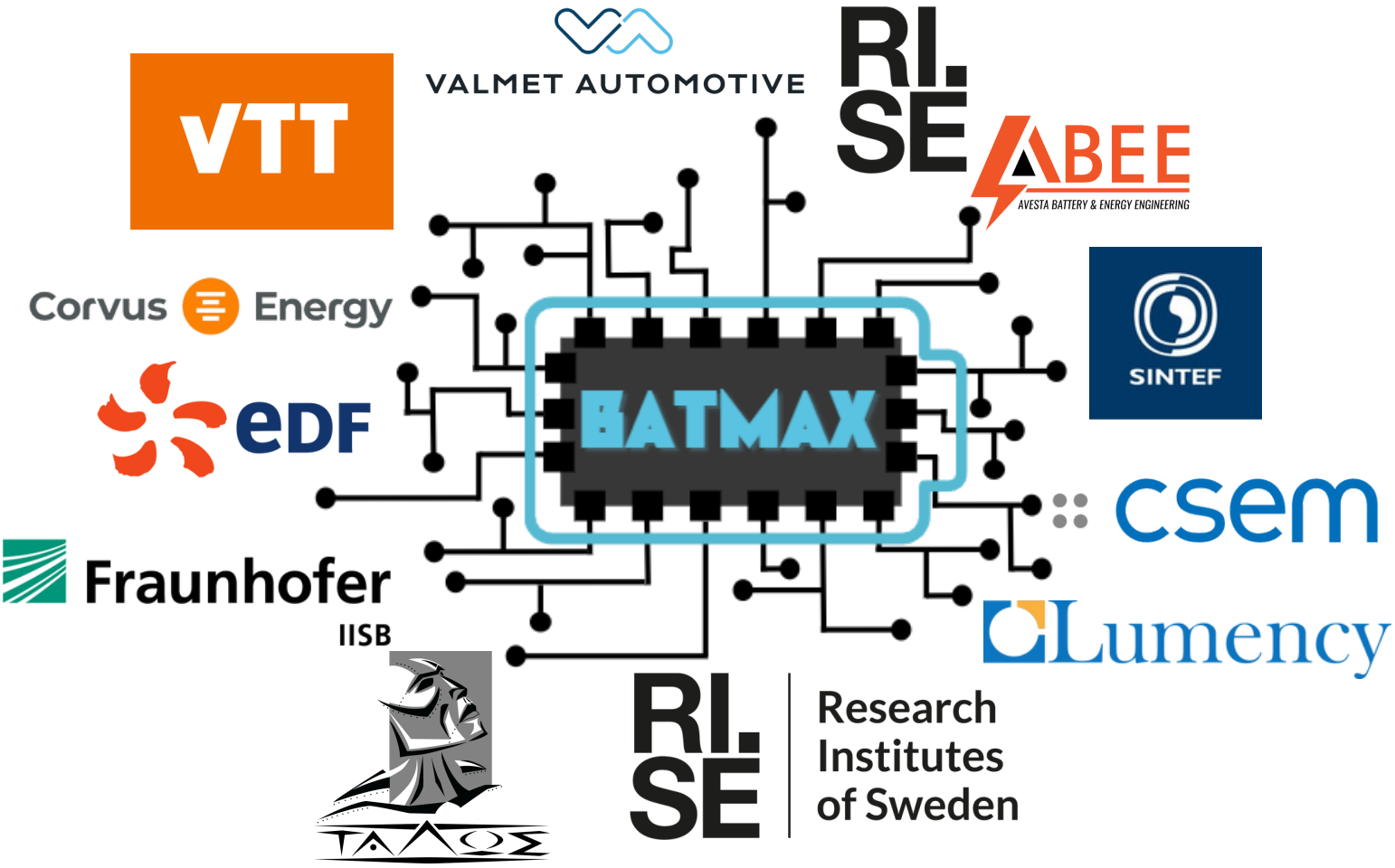
Dr. Antonella Cristiano-Tassi, Research Scientist at EDF R&D, Electrical Equipment Laboratory. Researcher in Battery Technologies for stationary applications. Leader of BATMAX project for EDF team.

## Renaud Guyot

Renaud Guyot, Project manager at EDF R&D, Electrical Equipment Laboratory. Researcher in Battery Technologies and Battery Ageing modeling. Technical contributor to the BATMAX project.

## Pierre Horsin

Pierre Horsin, engineer at EDF R&D, Electrical Equipment Laboratory. Researcher in stationary storage applications. Technical contributor to the BATMAX project.




# Connect:

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GRANT AGREEMENT: 101104013

Project funded by:

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
**State Secretariat for Education, Research and Innovation SERI**

This work was supported by the Swiss State Secretariat for Education, Research and Innovation (SERI)