Intelligente flexibiliteit door geïntegreerde hybride opslagtechnologieën

FLEXINet

Public Yearly Progress Report

Period covered

M13 (May 2022) – M24 (April 2023)

Reference number	MOOI32027
Project start	1 May 2021
Duration	4 years

Het project is uitgevoerd met Topsector Energie subsidie van het Ministerie van Economische Zaken en Klimaat, uitgevoerd door Rijksdienst voor Ondernemend Nederland. De specifieke subsidie voor dit project betreft MOOI-subsidie ronde 2020

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1 Summary of the principles and the objectives of FLEXINet and its cooperating parties (beneficiaries)

Project Title
Intelligent flexibility through integrated hybrid storage technologies (“FLEXINet”)

Objective
The objective of FLEXINet is to develop an integral smart system for the intelligent and integrated control and implementation of hybrid energy storage technologies in the built environment. The smart system will improve the flexibility and sustainability of energy supply (via solar PV) through underground power electronic conversion technology and by combining stationary lithium-ion battery storage, sea salt batteries, electric vehicle charging with vehicle-to-grid technology and thermal energy storage. FLEXINet integrated control strategy for hybrid energy storage will be validated in two living labs.

Outcome
FLEXINet follows a research model that consists of 4 layers: 1) Flexibility-enabling hardware, 2) Integration, conversion and smart control, 3) System flexibility and Living Labs, and 4) Social acceptance and Learning community. The hybrid energy storage technologies that are being developed in layer 1 will be integrated in arrangements for homes and utility buildings, to make the heat and cooling facilities more sustainable and to integrate renewable energy sources and electric vehicles. The smart solutions developed in layers 2 and 3 improve the flexibility and sustainability of electricity supplies by combining stationary battery storage, reused batteries, electric vehicle charging, vehicle-to-grid technology and flexible heat pumps and storage. We strive for the most complete, integrated and validated solution that is attractive to users who are further involved in layers 3 and 4. End-result of the project is an integral smart system for the intelligent and integrated control and implementation of hybrid energy storage technologies in the built environment.

Activities
FLEXINet consist of four interlinked layers. The activities belonging to the first layer of Flexibility-enabling hardware concern the development of innovative low-cost and high-energy battery chemistries and power electronics for hybrid energy storage systems, including the design, development and testing of prototypes. In the second layer the activities concern the design, integration and smart control of an underground heat storage system, the development of a life-extending battery optimization, the design and testing of a generic and open-source EMS platform and the development of intelligent hybrid EMS algorithms. Later these systems in the System flexibility and Living Labs layer lead to new services and revenue models for reliable networks. Here in this layer the demonstration, testing and validation of the FLEXINet solution is also done (TRL4-6). In the fourth layer, Social acceptance and learning community, the activities concern the investigation of social acceptance and knowledge dissemination. In this way, we offer a complete and integrated solution to exploit the potential flexibility of the built environment through hybrid energy storage systems.

2 Description of the activities performed, the results achieved per milestone, the bottlenecks and the perspective regarding application (<1 page)

Result	Activities performed, results achieved, bottlenecks and perspective
R1 - Innovative battery technology	Recoy procured two packs of K-STAR (K-STAR BluE H3 5.1 kWh incl. inverter based on Lithium Iron Phosphate (LFP) cells manufactured by CATL) that were delivered to VITO for parameterisation and testing/modelling and to Green Village for the eventual demo. VITO has used the packs to perform test at the battery pack and module level such as accelerated aging tests under varying conditions. Data obtained via this test program will be used in result 4 for the adaptation of the battery degradation model. The test program is running at the VITO Battery Test Lab and will continue to run at least until October 2023 in order to have sufficient degradation. The prototype LFP/Si cells cells of LeydenJar were found to be able to match upto and have a similar energy density as conventional NMC/Gr cells. Voltage curve for lithiation and de-lithiation of silicon has been developed by VITO. First 1,5 Ah cells created by LeydenJar. Test program to obtain battery cell degradation data for the LeydenJar NMC622-Si 0.2Ah cells has been completed successfully. Dr.Ten Seasalt battery cells of about 2,4 Ah were obtained with about 2 Ah stable (128 cells in box, 256 Ah or ~22 Ah/12V). dr.Ten has been investigating optimized electrodes: 1. Carbon powder coated carbon electrodes using nano carbon powder. 2. Zink-additive plated carbon. 3. Non-noble metal plated electrodes. 4. Improved carbon-catalyst air electrodes. Dr.Ten evaluated higher power charging of cells and observed that higher powers are possible as long as it is not under steady state battery conditions or at higher DOD values.
R2 - Power electronics for hybrid energy storage systems	Dr.Ten has demonstrated on lab level unidirectional solar to grid converter that enables improved dc tot dc peak shaving of solar energy with dc to ac conversion to off grid appliances and the grid. This uses existing inverter technology with an innovative new BMS- microcontroller-sensor system. They are also investigating how to use an MPPT-switch in the combination with a grid-tie inverter. Development of the multiport converter is ongoing (PRE) with research on the battery by (with Heliox), cooling (with TU Delft) but also the effect of the ground (like floating) on the underground solution. Besides we are looking to the installation and the possible risk of the implementation of such a system. TU Delft has selected two modules Dual Active Bridge converter for DCDC EV charging application. The design for the converter as well as modelling of the heat transfers in the soil using the heatpipes as passive cooling technique is being conducted using COMSOL. Further comparison of different cooling techniques will be carried out and suitable solution will be selected which will be cost effective, has low power consumption and will occupy less space.

	DC Opportunities has built the first prototype of the battery storage converter along with the BMS board/software. The converter and the BMS are combined with 8kWh battery system for testing and development
R3 - Heat storage integration	This result focuses on the integration of heat storage. TU Delft modelled the Thermal Energy Storage System (TESS) within a household building. Buffer can start and stop charging based on external control signals, without compromising on meeting heat demand from the house. An MSc student from TU Delft made a study on the Vapour Heating Unit (VHU). There are no delays encountered so far.
R4 - Life-extending battery optimization	Adaptation of the battery degradation model for the LeydenJar NMC622-Si 0,2Ah cells and the KStar/CATL LFP cells is ongoing in VITO. Discussions have been held between Recoy and VITO – to assess the outcomes of the degradation model and how these results are best integrated in Recoy's optimization models The partners are defining the Use Cases for the deployment of the batteries for various cases and discussing with The Green Village on the location and installation aspects for the KStar battery.
R5 - Generic and open-source EMS platform	PRE has designed and produced a prototype of the controller. The controller is currently working on a V2G charger (to control solar input, ev charging, battery) for testing and validation. There is close collaboration with result 6 to connect the controller to the cloud. And looking at what setpoint of all assets they need for their model. Dr Ten has finished a bidirectional inverter system in the houses that is almost set at GV. Studies were made with the seasalt battery positioned between the solar panels and a standard inverter from SolarEdge and also about to a Victron inverter.
R6 - Intelligent Hybrid EMS	The first version of the mathematical formulation for the energy management system that includes empirical aging model, energy market participation, and electric vehicle charging requirements is implemented in Julia code. Li-ion battery models for the EMS are based on the modelling approach developed by VITO . TU Delft has done several measurement experiments to describe the sea salt battery, together with an MSc student, and two researchers from the Center for Research in Electrochemistry and Chemical Energy (CELEQ) from the University of Costa Rica, comparing the results with the measurements done by Dr. Ten. Discussions regarding the decision between different communication protocols/frameworks (OpenEMS or S2 or EEBus) were held. The control architecture has been approved based on the S2 protocol and a decentralized philosophy. All partners will implement their own Resource Manager to connect to the secondary controller which acts as a Customer Energy Manager, following S2 fashion.

R7 - New services and revenue models	Result 7 studies system flexibility through the integration of hybrid energy storage systems. The past months Emmett Green continuously developed its EMS system. This includes storage and heat, incorporates real market data. The preparatory work (input costs such as CAPEX for the possible FLEXINET assets) for the simulations is nearly finished. TUDelft has started the discussions regarding the optimization framework that will be used further in this Result to integrate the new services and revenue models.
R8 - Living labs	Result 8 focuses on Living Labs. During the last months TUD/GV has been working closely together with PRE, Recoy and DrTen on the specifications of the systems they are going to install for the demo. Communication protocols and hardware connections were defined and listed. Missing elements identified. These are now being solved. Dr Ten's Vapour heating system will not be tested with the same user as the Borg heat buffer, Recoy home battery, PRE battery and EV-charger and DrTens Seasalt battery.
R9 - Social acceptance	Result 9 focuses on social acceptance and energy justice. The last 12 months the factors contributing to social acceptance have been identified. Both trough literature review, interviews and first workshop with residents on the Green Village. The first pilot for co-creation workshops has taken place at the Green Village. This pilot was to test how to execute workshops regarding flexibility technologies, and to get some impressions on the factors contributing to social acceptance.
R10 - Learning Community and Dissemination	Workshops and other events were planned this year, including FLEXINet workshop "FlexBat meets FLEXINet". An internal workshop was organized on 4 April 2023 on Social Acceptance of Battery Innovations. Besides that, FLEXINet is part of the external learning community, which is the national learning community on System integration (mentioned above). A knowledge platform on the website of FLEXINet is being created to support learning. Here, an overview of Dutch projects on hybrid storage technologies is being offered. Project coordination is being done by the learning community manager of The Green Village. At The Green Village, most FLEXINet hybrid energy storage systems are being tested.

3 Description of FLEXINet's contribution to the objectives of the subsidy scheme (MOOI)

Main innovation theme	Innovation theme (Innovatiethema)	Results
1. Further development of natural gas-free arrangements and supporting processes/services	1. Development of integral arrangements for renovation	2,3
	4. Smart energy use in/between buildings by users, smart grid	5,6, 7,10
2. Making the (collective) heat and cold supply more sustainable	5. Collective heat and cold supply	3
3. Solutions for a reliable, affordable and fair electricity supply	6. Flexibility of/for the energy system (in the built environment)	1-10
	7. System design for the electricity system in the built environment	5,6,8,10
	8. Local flexibility for the overall electricity system	6,7.9

(1) Further development of natural gas-free arrangements and supporting processes/services.

- Intelligent and integrated energy management hardware and control – FLEXInet will develop intelligent and integrated control algorithms to increase the flexibility of electricity

and heat supply through hybrid energy storage and develop a hardware controller to interface with various power generation/conversion devices. The EMS will implement a multi-objective optimization to reduce/eradicate the use of natural gas by using heat pumps with thermal storage and solar collectors, increase the use of renewables, improve grid integration and offer ancillary services *Results: Algorithms, Controller (product) demonstration*

- (Underground) power conversion cabinet - Space is often a challenge for the placement of batteries and hardware. We develop the FLEXGRID-PLUS solution, an invisible (underground) box that contains the batteries, power electronics including solar MPPT converter, inverters, and EV chargers for controlling the hybrid storage system. We also develop power electronics for the efficient use of discarded traction batteries that get a second life as a stationary energy storage system and to connect sea-salt batteries to the grid. *Results: FLEXGRID-PLUS (product), demonstration*

(2) Making the (collective) heat and cold supply more sustainable

- More sustainable heat supply through thermal storage, heat pipes and heat pumps - FLEXInet will develop an underground heat buffer connected through flexible heat pumps and heat pipes. The buffer works with an intelligently controlled weather and demand forecasting model to control the behavior of the connected energy sources. We will also develop sea salt based vapor heating unit as a means to reduce the use of natural gas, *Results: Algorithms, thermal buffer (product), vapor heat unit (product), demonstration*

- Social acceptance and experience of flexibility - We investigate social factors and draw up a business case for the investment and financing and build a cooperative neighbourhood organization as a basis and management organization for the hybrid storage facilities. The basis for the business case is an investigation into the circumstances under which users in the neighborhoods want to make flexibility available in which both financial and non-financial costs and benefits are considered. *Results: Social factors and optimization of willingness to participate, business model*

(3) Smart solutions for the reliability, affordability and fairness of electricity supply

- Novel energy storage technologies - to increase the flexibility of hybrid energy storage, we will improve sea-salt batteries technology; develop silicon anodes to increase the energy density of lithium-ion batteries; study the ageing behaviour and develop optimization algorithms to improve lifetime of Li-ion cells. *Results: sea-salt battery (product), silicon anodes (product), Algorithms, demonstration*

- New services and revenue models for hybrid storage. We evaluate the possibility of using demand management to enable the aforementioned storage technologies to reinforce each other. We will also design transactional energy solutions, based on peer-*to-peer* delivery, through the potential complementary effect of using hybrid storage technologies. Finally, we determine guidelines and requirements for the provision of additional services to the grid (DSOs/TSOs) through hybrid energy storage in the built environment. *Results: Algorithms, simulations, guidelines, business models*

- Learning community and dissemination - As an integral part of the project, we ensure an adequate link between innovative technologies that support the energy transition and the knowledge and skills needed to implement these technologies in practice. *Results: Information, training materials, guidelines*

4 Spin off inside and outside the sector

Not applicable for now

5 Overview of project's open access (public) publications and where to find/obtain them

Project website - https://www.tudelft.nl/en/flexinet

Dissemination

Geraedts, M., Alpízar-Castillo, J., Ramírez-Elizondo, L., & Bauer, P. (2022, June). Optimal Sizing of a Community Level Thermal Energy Storage System. In *2022 IEEE 21st Mediterranean Electrotechnical Conference (MELECON)* (pp. 52-57). IEEE.
Alpízar-Castillo, J., Ramirez-Elizondo, L., & Bauer, P. (2022). Assessing the Role of Energy Storage in Multiple Energy Carriers toward Providing Ancillary Services: A Review. *Energies*, *16*(1), 379.
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https://topsectorenergie.nl/agenda/flexbat-meets-flexinet-adding-intelligent-flexibility-distribution-grid
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SYSTEM INTEGRATION LUNCH LECTURE, 14 February 2022
https://www.thegreenvillage.org/event/flexinet-lunchlezing/

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