STORY

added value of STORage in distribution sYstems

Deliverable 9.8
Replication Plan

Revision 1
Preparation date ..2020-11-23 (m67)
Due date 2020-10-31 (m66)
Lead contractor ....Prospex Institute
Dissemination level PU

Authors:
Leen Peeters ………………………TH!NK E
Arnor Van Leemputten …..……... TH!NK E
Lucija Rakocevic ………………... TH!NK E
Christiaan Carelsberg ………..…. Viessmann
Christophe Van den Eynden …... Viessmann
Andreas Tuerk …………………... Joanneum Research
Martin Watson ……………………. Prospex Institute

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

Table of Content

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

Disclaimer

The information in this document is provided without guarantee or warranty, that the content fits for any particular purpose. The user thereof uses the information at its sole risk and liability. The document reflects only the author's views and the Community is not liable for any use that may be made of the information contained therein

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

Executive Summary

The ambition to advance to a more renewable energy system poses challenges on the current energy infrastructure. These challenges are mainly due to more intermittent production that will increasingly become a combination of centralized and decentralized assets, along with changing behaviour at consumer level due to increased electrification. Storage is seen as a mean to overcome, at least partially, this mismatch. Together with behavioural change and improved energy management systems, storage is seen as a key technology in the energy transition.

The main objective of the STORY project is to answer the question: what is the added value that storage can bring to flexible, secure and sustainable energy systems? In order to assess this, the project had included small scale thermal and electrical storage as well as medium scale thermal and electric storage. The test environments were diverse in nature and included residential and industrial settings.

With the introduction of H2020, the emphasis was moved to replication and exploitation as means to support effective impact creation. Replication is the act of making or doing something again in the same way, whereas exploitation is the use of results for commercial purposes or in public policymaking.

STORY has advanced products, developed new tools that delivered business already during the project duration and led to a relevant number of commercial contracts. Moreover, STORY led to new ways of cooperation in the landscape of clustered EU funded projects and contributed substantially to the policy and regulatory developments in Flanders, Austria and at the European scale.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

1 Introduction

STORY was designed to deliver an answer to the question on when/where to install what type of storage, seen from a system-level perspective. Or in other words: **show the added value storage can bring for a flexible, secure and sustainable energy system for different stakeholders in different marketplaces.**

At the moment STORY was written, the Clean Energy Package was in an early design phase and little of its content was communicated to the wider public. To be more specific, the European Commission staff working document on Energy Technologies an Innovation[1] of May 2013 does mention energy storage once in the 57 pages document. The list of energy technologies that is given in the accompanying documents with regards to the focus on the EU policy, does not even include storage at that time[2]. The document further mentions storage in the form of electrochemical batteries to be occasionally deployed in electricity grids, mainly for short time action such as frequency control. Thermal storage is not mentioned. In 2015, the SET Plan mentions the aim to become competitive in the global battery sector mainly to drive e-mobility forward[3]. A Study for the ITRE Committee, i.e. the Industry, Research and Energy committee of the Directorate-General for internal policies, of 2015 briefly mentions the potential role of thermal storage and recalls the first Tesla home batteries to have been sent to US customers in 2015[4]. Since 2018, the landscape is changing and the European policy level puts high ambitions on the battery sector development.

---

[1] European Commission, Commission Staff Working Document JRC Scientific and Policy Reports R&D Investment in the Technologies of the European Strategic Energy Technology Plan, Brussels, 2.5.2013 SWD(2013) 157 final <https://ec.europa.eu/energy/sites/ener/files/swf_2013_0157_en.pdf >

[2] European Commission, Commission Staff Working Document Technology Assessment Accompanying the Document Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions Energy Technologies and Innovation, Brussels, 2.5. 2013 SWD(2013) 158 Brussels <https://ec.europa.eu/energy/sites/ener/files/swf_2013_0158_en.pdf >

[3] European Commission, Communication from the Commission Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, Brussels, 15.9.2015 C(2015) 6317 final < https://ec.europa.eu/energy/sites/ener/files/publication/Complete-A4-setplan.pdf>

[4] European Parliament, Directorate General for Internal Policies Policy Department A: Scientific and Economic Policy, Energy Storage: Which Market Designs and Regulatory Incentives Are Needed? Study for the ITRE Committee (2015)< https://www.europarl.europa.eu/RegData/etudes/STUD/2015/563469/IPOL_STU(2015)563469_EN.pdf >

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

These results, among others in a Strategic Action Plan on Batteries in 2019[5] and the financing of 1 million euro for the set-up of an attractive European R&I ecosystem on batteries. Aside from positioning papers and advocacy work, little effective policy work has been done with regards to thermal storage and its role in the future dynamic energy system.

The Clean Energy Package, and specifically the Recast of the Renewable Energy Directive (2018) and the Directive on the Internal Electricity Market (2019) have clarified elements which relate to storage, but mainly emphasize flexibility. However, a realistic view will be needed in the coming years with regards to the assessment of the actual value of flexibility and the robustness of business models building on this.

STORY has advanced products, developed new tools that deliver business already today and led to a relevant number of commercial contracts. STORY also led to new ways of cooperation in the landscape of EU funded projects. And additionally, STORY did substantially contribute to the policy and regulatory developments in specifically Flanders, as well as Austria & Slovenia and at the European scale.

The replication work conducted within the project has been led by THNK as task leader with support from PI. VIES contributed to the content of the general sections and reviewed intermediate versions of the deliverable. Additionally, all partners participated to the KER identification session ran by the META group in Belfast and many partners joined the Advisory Board meetings which focused on furthering replication within the project.

2 Replication and Exploitation

With the introduction of H2020, the emphasis was moved to replication and exploitation as a mean to support effective impact creation. Replication is the act of making or doing something again in the same way. Whereas exploitation is the use of results for commercial purposes or in public policymaking.

[5] European Commission, Report From the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank on the Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe, Brussels, 9.4.2019 COM (2019) 176 final <https://ec.europa.eu/commission/sites/beta-political/files/report-building-strategic-battery-value-chain-april2019_en.pdf>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

This deliverable was originally previewed to be a public document presenting a replication plan. The team has used the services provided by the EU and has cooperated closely with the company Meta to deliver a rather high-level replication plan. However, we believe there is substantial value in providing INEA with the effective overview of what this project has already achieved with regards to impact and how the different partners will move this forward. Such market projections are especially difficult in the current circumstances with a setback of economy due to the COVID-19 pandemic. Additionally, the nature of the outcomes of STORY prevents an easy and especially meaningful translation in expected market projections.

Therefore, this document will not present the replication and exploitation with the typical generic high-level approach. Instead, it will focus on effective achievements, already initiated business and near-future actions and expectations.

As STORY is an innovation action, not all tested and developed outcomes have resulted in successful outcomes from a potential commercial solution demonstration point of view. Innovation is cooperation, hence the report is therefore not partner-based. It is centred around the main contributions to impact.

3 Outlook of the storage market in Europe

3.1 General outlook

The ambition to advance to a more renewable energy system poses challenges on the current energy infrastructure. These challenges are mainly due to more intermittent production that will become more and more a combination of centralized and decentralized assets combined with changing behaviour at consumer level due to an increased electrification. Storage is seen as a mean to overcome, at least partially, this mismatch. Together with behaviour change and improved energy management systems, storage is seen as a one key technology in the energy transition.

The recent study on energy storage contribution to the security of the electricity supply in Europe[6] provides an outlook on the 2030 and 2050 scale with regards to the need for energy storage. While

[6] European Commission, Study on Energy Storage- Contribution to the Security of the electricity supply in Europe Final Report 2020 <https://op.europa.eu/en/publication-detail/-/publication/a6eba083-932e-11ea-aac4-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=37085&WT.ria_f=3608&WT.ria_ev=search>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

2050 is beyond our scope, the 2030 outlook is interesting to look into. According to the report, up to 108 GW of electricity storage will be needed for the EU-28 by 2030. This storage will, to a large extent, be delivered by pumped hydro as well as batteries. Electrolysers are not specifically needed, though, when they would be deployed before 2030, they could provide flexibility on all relevant timescales. What is specifically interesting in the assessment is the potential that demand-side response could bring. As stated by the report, in 2030, an optimal use of flexibility of electric vehicles and of decentralised space heating could reduce the need for stationary batteries by half (67 GW vs 34 GW).

The European market outlook for residential batteries[7] dives specifically in the potential that home batteries could deliver. In 2019, less than 7% of residential PV was connected to battery storage, numbers largely impacted by the German market (66%). Next are Italy (12%), UK (5%), Austria (5%) and Switzerland (3%). Local policies and to a large extent also local subsidies influence these figures. In the UK also specific tariff structures offered by retailers are further impacting the market growth. The report makes forecasts including Low, Medium and High growth scenarios for the market of residential batteries in Europe. The Low Scenario forecasts additions of only 0.6 GWh in 2021, 0.7 GWh in 2022, 0.8 GWh in 2023, and 0.9 GWh in 2024. The High Scenario, increasing to 1.2 GWh in 2021,1.3 GWh in 2022, 1.6 GWh in 2023, and reaching 2 GWh in 2024.

[7] SolarPower Europe European Market Outlook for Residential Battery Storage 2020-2024 (SolarPower 2020) <https://mcusercontent.com/2702b812ce1f3e6da64933b9d/files/5a665f63-d8db-497a-98c6-a39567410614/2820_SPE_EU_Residential_Market_Outlook_07_mr.pdf?utm_source=Master+List&utm_campaign=74458b27ff-EMAIL_CAMPAIGN_9_27_2018_15_43_COPY_02&utm_medium=email&utm_term=0_c76dca7a55-74458b27ff-69144137&ct=t(EMAIL_CAMPAIGN_9_27_2018_15_43_COPY_02)&mc_cid=74458b27ff&mc_eid=f27f5ccb8c>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

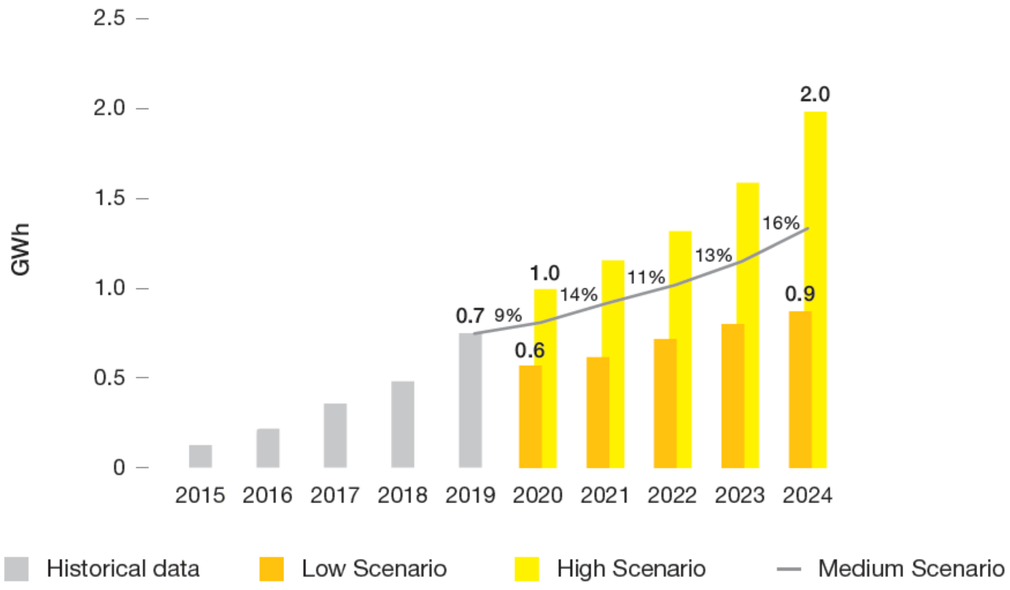

Figure 1: Expected growth for battery capacity in Europe, source: Solarpower Europe 2020.

Neighbourhood batteries are much less discussed in the outlooks. The earlier mentioned study on energy storage contribution to the security of the electricity supply in Europe does not mention neighbourhood or district batteries in its core, but provides some views on the policy and support schemes in the member state policy overviews. Aside from Austria and Belgium, neighbourhood electricity storage is not mentioned. The potential of district heating systems that could absorb excess renewable energy is mentioned extensively. This is not unexpected, due to the large thermal demand of the European building sector and the inertia in district heating systems that could be further increased by thermal storage.

An important view is put forward by IEA[8]. They emphasize the need for **flexibility to be at the core of policy design, rather than individual technologies**. The first step in a proper assessment is therefore to undertake a whole-system study of flexibility requirements that compares the case for storage against other options such as demand response, power plant retrofits, smart-grid measures that enhance electricity networks, and other technologies that raise overall flexibility.

[8] IEA, Energy Storage (IEA, 2020) <https://www.iea.org/reports/energy-storage>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

3.2 Barriers and obstacles as per recent literature

Barriers to wider storage uptake are mainly related to battery storage and less to thermal storage. Important barriers, as identified in studies[9,10, 11, 12,13], include the following:

- Missing uniform definition of storage in regulation and legislation.
- Lack of a system-based perspective;
- Lack of understanding from policy makers and local & regional public bodies;
- Unclarity with regards to permitting;
- Access to energy markets;
- Hesitance of network operators due to unclear regulation, especially ownership issues;
- Incoherent regulation on home batteries.

With regards to thermal storage, it is often a matter of behind the meter system optimisation or integrated as part of district heating systems. The potential of thermal electrical storage, as part of demand side management and aggregation services for electric resistance heating or heat pumps, is challenged by the unclear outlook of the acceptance of small scale assets to participate in this market in many Member States.

The overview below provides a high-level assessment of barriers and obstacles to battery implementation.

3.2.1 Missing uniform definition of storage

A uniform definition to energy storage, applicable throughout Europe, is not self-evident. Energy storage often includes conversion between energy carriers, eg. a battery stores the electrical energy

---

[9] European Commission Directorate-General for Energy, Working Paper: the future role and challenges of Energy Storage, <https://ec.europa.eu/energy/sites/ener/files/energy_storage.pdf >

[10] Eurobat, Battery Energy Storage in the EU: barriers, opportunities and benefits, (2016) <https://www.eurobat.org/images/news/publications/eurobat_batteryenergystorage_web.pdf >

[11] Dekker, Barriers for integration of energy storage in the current regulatory and market framework (2017) DNV GL <https://site.ieee.org/norway-pes/files/2017/04/Barriers-for-integration-of-energy-storage-in-the.pdf>

[12] Bhatnagar, et al., Market and policy barriers to energy storage deployment, A study for the Energy Storage System Program (2013) Sandia National Laboratories <https://www.sandia.gov/ess-ssl/publications/SAND2013-7606.pdf>

[13] US Department of Energy Office of Technology Transitions, Spotlight: Solving challenges in Energy Storage (2019) <https://www.energy.gov/sites/prod/files/2019/07/f64/2018-OTT-Energy-Storage-Spotlight.pdf>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

in a chemical form, a flywheel uses mechanical energy, and one could even use heat and convert it (back) to electricity. Aside from that, electricity could be stored for later use as another energy vector, which is the principle of power-to-gas.

The definition of energy storage therefore risks to intertwine with several other non-electricity related regulation and legislation. The implication of this is complexity in the integration of a uniform definition of storage at Member State level.

Consequently, no clear role on energy storage in an energy market is yet defined. Attempts such as avoidance of double taxation are a first step as also included in the Electricity Market Directive, but there is more to be clarified: e.g. clarification is also needed with regards to the operation of storage and under which categorisation of actors this should be seen, i.e. generators and/or consumers or a new category.

3.2.2 Lack of a system-based perspective

The business case of batteries, whether small scale residential batteries or neighbourhood batteries, is often seen from the push-perspective: i.e. conditions have to be created by the DSO, the regulator and policy to enable a viable business case. However, all of these actors have to take into account many elements and could or should not be favouring a particular technology but an aim. Furthermore, a grid operator has to choose the best available option when resolving a grid challenge.

In addition, the behind-the-meter applications are mainly based on optimisation of self-consumption, where models for virtual power plants are emerging but not yet accepted in all European Member States.

3.2.3 Lack of understanding from policy makers and local & regional public bodies

One of the barriers to implementation is a lack of a clear understanding from policy and regulatory bodies. They are confronted with a lot of ideas and sometimes hypes, but cannot have all necessary expertise within their team to correctly and multi-disciplinary assess the proposed innovations or technologies[12].

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

3.2.4 Uncertainty with regards to permitting

The lack of a clear and uniform definition implies uncertainty on how to evaluate a storage system with regards to at least the following:

- Safety and environmental impact[14];
- Implementation in the public or private domain;
- Public health.

Though, the earlier referred Study on Energy Storage states: “In general, this legal obligation (the need for a licence) is not considered as a barrier to storage, as it was not highlighted by stakeholders, also considering that it generally only applies to larger scale facilities, while small installations are exempted.

Furthermore, the responsibility between stakeholders could be further clarified. Today the manufacturers are responsible for the modules, but the safety towards the end-consumers or clients is to be assured by the system integrators and installers[15].

3.2.5 Access to energy markets

Market barriers for storage are related to the size of the storage system, which is linked to the services or energy market products it can deliver. The size is also affected by whether it is connected to the distribution or transmission system. Also, connection characteristics and its operating conditions vary between those voltage levels.

Further distinction can be made between barriers to entry in a market and barriers to participate in such market, but they are often intertwined. Barriers comprise:

- market rules, regulation and legislation,
- minimum capacity and energy requirements,
- the lack of a clear definition of storage,
- the lack of standard tariff structures,

[14] Swantje Gars and Jan Knoefel, Stakeholder demands and regulatory framework for community energy storage with a focus on Germany (2020) 144 Energy Policy DOI: 10.1016/j.enpol.2020.111678 <https://www.sciencedirect.com/science/article/pii/S0301421520304079?via%3Dihub>

[15] Gerritsen et al., City-Zen D5.7-5.10-5.11-5.12-7.4, A Balanced Approach to the City of the Future (2019) <http://www.cityzen-smartcity.eu/wp-content/uploads/2019/12/city-zen_d5-7_d5-10_d5-11_d5-12_d7-4_cityzen_smart_grid.pdf >

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

- excessive pre-qualification requirements (such as with regards to certified metering, direct control and others),
- inappropriate market design parameters (for example a minimum bid size of several MWs).

Furthermore, limitations on local grid characteristics could partially hamper the potential contribution to the energy market.

3.2.6 Hesitance of network operators

Network operators are often hesitant towards implementing innovative solutions for which they lack experience. This is not unexpected, as they are responsible for a safe and secure power supply towards all customers and within limits described by regulation. New technologies, especially those not under their control, pose a risk. Even if this concerns known and proven technology, the interaction with the local system can cause issues and difficulties that are unclear and unknown to the network operators. Large network operators are typically an exception due to their large resource portfolio in testing and applying innovative solutions.

3.2.7 Incoherent regulation on home batteries

While home batteries generally only have a business case in maximising self-consumption and peak reduction, capacity limitations with regards to injections could apply to the sum of the storage capacity and the solar inverter capacity as a whole.

3.3 Identified R&D needs

A recent (2018) study in the frame of the Batstorm project, looked into the R&D needs for battery-based energy storage[16]. Some of the actions that where identified to be further researched/developed include:

- Develop advanced Battery Energy Management Systems and integrate them to General Energy Management Systems (GEMS);

[16] Jeroen Buscher et al, Support to R&D Strategy and accompanying measures for battery based energy storage, Roadmap for R&I and accpmpanying measures 2018 – 2027 and short term prioritisation (D10) (2018) <https://ec.europa.eu/energy/sites/ener/files/roadmap_for_ri_and_accompanying_measures_2018-2027.pdf>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

- Support for (large-scale) recycling and second life use through adaptation of regulation;
- Identifying and proposing best-practices on battery connection and pre-qualification requirements;
- Propose duty cycle testing standards and performance certification;
- Continue development of safety standards;
- *Create and maintain knowledge sharing platform → at least partially covered by the Batteries Europe consortium (tender ENER-2018-453-A7)*

While the above remain relevant, it is worth adding 3 others based on the STORY experience:

- Share failures and less successful tests and pilots and hence communicate correctly to enable the right policy being developed at the right moment and the further R&D needs to be correctly assessed;
- Collaborate and share internationally. The R&D needs of batteries are still enormous, whether it is related to technology, integration or grid interaction. Creating synergy and exchanging experiences would enable more resource efficient and faster advancements;
- Interoperability challenges that prevent a cost-effective integration of any type of storage.

3.4 The STORY-experience

While the different deliverables in STORY dive into the detailed outcomes, the following section briefly summarizes the experience gained throughout the project.

With regards to the thermal storage systems, no specific market or regulatory barriers were encountered. The main challenge was on their integration in the operational control. But the different pilots on batteries and especially the pilot with compressed air energy storage encountered multiple challenges and obstacles.

3.4.1 "Behind the meter"-batteries

In 2015, home batteries were all but common. Mercedes Energy was working on a stationary and stackable Li-Ion system, completely made in Germany and stopped after the first commercial batch was out. Tesla's first range of Powerwalls was just being finalized and when it was out, faced some technical-issues[17]. SMA was still working on resolving their supply interruption when switching from grid to offline and vice versa. Renault was using its experience to launch a second life for its car batteries as stationary storages. In Germany, Sonnen was working on improving its solution

[17] ITP Renewables, Reports, <https://batterytestcentre.com.au/reports/>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

but supplied only the German market as it was large, uniform and simple to address due to its uniform policies in this sector. Orison, a US-based kickstarter campaign folded in 2015 and is in 2020 not selling anything yet. They faced delivery issues, development issues and even the unexpected death of their young and bright CTO.

Going to slightly larger systems, the market was just emerging. As an example, an order at Samsung would take a delivery time of 1 year. One of their largest competitors had a single person for commissioning & maintenance for Europe and South-America. Another provider of batteries simply stated that any order below 100 000 batteries a year would not be considered. They lacked personnel and their order portfolio was filled with demands from car manufacturers. Even in 2018, the wait times remained high and the smaller car brands had to wait months to be supplied. Most Uninterrupted Power System (UPS) manufacturers could provide a solution for back-up, but not for full energy management of a building or site.

Regulations and legislations were absent in most Member States. Aside from some, national or regional insurance companies had no idea how to handle storage, and banks were looking at it as a potential basis for a new financial product. A hype to opt for batteries had been created among geeks and tech-lovers, even people who simply wanted to be as independent from the grid as possible. However, most end-consumers were sceptical with regards to safety, investment pay-back and comfort.

3.4.2 Neighbourhood batteries

At the start of STORY, neighbourhood batteries were an exception throughout Europe. Most Member States had no experience. A few offers where available on the market and several of them were used in private test set-ups, such as with Engie Lab. Typical system providers were Alfen and Younicos. Major battery or inverter developers were still finalizing their design and preparing for testing.

Regulation and market conditions were absent in many Member States, unless it was a high voltage connected storage, or a storage system serving for temporarily use such as a festival or construction site. In Austria, DSOs were assessing the potential of co-owning a neighbourhood battery with a commercial entity and using it jointly to optimise the return of investment.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

3.4.3 Compressed air energy storage

A compressed air energy storage (CAES) unit was previewed to be installed during STORY. However, although several offers had been received prior to proposal submission for the intended power (250 kW and capacity 92MWh), when contacting those potential providers once the project was started, they all pulled back. Mainly because they were not yet up to implementation tests in the actual intended environment. Consequently, a large number of companies was contacted, but no one was able to deliver the 250kW power CAES or anything near it. Siemens US was working in a much larger unit, LightSail Energy was working on a unit, but failed to deliver and closed business not long after going from 60 to 15 employees. One CAES at the scale of 250kW was being tested in London, with round-trip efficiencies close to 8%[18].

3.4.4 Non-technology specific experience

The uniform definition was not the main missing part. Three more relevant elements are:

- Missing basic understanding of the technology;
- Missing system-level perspective;
- Hesitance of network operators.

For thermal storage, there is no direct impact of the last one. For any of the other described forms of storage experimented with in STORY, the three listed elements where decisively important with regards to the connection, the operating conditions of the storage and even its accepted location.

3.4.4.1 Missing basic understanding of the technology

Novel technological solutions are often difficult to grasp for non-technical people. Civil servants that are directly or indirectly part of the permitting process often lack confidence and hold back the permitting procedure.

For the neighbourhood battery in Belgium, it took nearly 2 years to get a permit. The first step immediately showed that civil servants and local political staff at the municipality level are not trained nor used to work towards using the existing legislation to find a way to facilitate the new

[18] Chen, L., Zheng, T., Mei, S. *et al.* Review and prospect of compressed air energy storage system (2016) 4 J. Mod. Power Syst. Clean Energy, 529–541 https://doi.org/10.1007/s40565-016-0240-5 <https://link.springer.com/article/10.1007/s40565-016-0240-5#citeas>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

technology. At least a relevant part of that is related to a lack of understanding. A complex technology as a 3-phase connected battery that can contribute to resolving power quality dips, reduce harmonic variation and voltage swings presents a solution to a problem they were not aware of. Consequently, it is not seen as something they should resolve, nor can you expect them to evaluate the overall legislation to find a way to host the storage unit. At the level of the Flemish government, a single person is responsible for new technologies. However, the distrust from the local level towards the guidance of that person prevents a fast development. The main challenge is that the local level is the one providing the permit, and therefore feels responsible.

Even when a meeting was organized where the administrative staff of the Flemish level came to the municipality to explain that there was no issue, the local civil servant suggested to send a mail to the Flemish level to ask for confirmation of what the person from the Flemish level was saying on the table they jointly occupied.

3.4.4.2 Missing system-level perspective

All storage technologies tested in STORY had a direct or indirect impact on the grid. Direct through the immediate coupling of the storage with the grid, indirect when the storage impacts other electricity consuming devices. To understand the value of flexibility, a grid-level perspective and customer's business understanding are both needed.

The lack of such perspective leads to a minimisation of the value of storage and identifies it as an individual optimisation. Additionally, in the Bridge work on energy communities, this lack of system-view came up prominently when Member States and various stakeholders discussed tariff reductions for energy community members. It was assessed from the perspective of the community, not from the perspective of a cost-benefit analysis for the system.

3.4.4.3 Hesitance of network operators

Distribution network operators are responsible for the safe and reliable operation of their infrastructure. Adding an element that is new and might not be reliable yet, and more importantly one that they might not be able to control themselves is therefore not necessarily straightforward. It must be noted, however, that network operator's control actions may be possible although the ownership of the BESS infrastructure is elsewhere. The Slovenian case was therefore easier as the latter argument was avoided by having the distribution grid operator as project partner and pilot

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

owner. In the Belgian pilot, the open and constructive approach, combined with accepting their speed of decision making, resulted in acceptance and fruitful cooperation.

3.5 Contributions of STORY

STORY has delivered major contributions to several areas that include and go beyond the matter of storage in the distribution grid.

3.5.1 STORY-related contributions to overcoming the barriers

This document focuses on commercial replication or upscaling as well as inducing research focussing on advancing the R&D outcomes or expanding its application range.

3.5.1.1 Lack of understanding on storage

Several initiatives were induced and delivered to increase the knowledge on storage, what it is and what it is not as well from regulation and legislation, from technology and from business point of view.

In the frame of the commercial contract Smart Cities Information System, VITO and THNK delivered a number of solution booklets. Two were created based on the experience of STORY, i.e. the identification of the need for further explanations and the inclusion of STORY experiences: Batteries and PV[19] and the booklet on Energy Communities that is under final review by DG ENER.

Additionally, the province of Flemish-Brabant awarded THNK a 2-year contract to work on providing stakeholders the needed clarifications on what neighbourhood batteries are and how to evaluate them.

In the H2020 project COMPILE, UL collaborates with a large supplier, PETROL, on a neighbourhood battery for a weakly-connected community. PETROL uses this case to gain understanding in the possibilities for its business and gaining understanding in user-interaction.

[19] EU Smart Cities Information System, PV and Battery Solution Booklet, (2019) SCIS <https://smartcities-infosystem.eu/content/batteries-and-pv>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

B9 contributed significantly to clarifications on the added value that different types of storage could bring in reducing curtailment of renewables. The B9 model has now been validated by Ernst & Young and used to secure Northern Ireland Water board approval for an Outline Business Case to purchase an innovative 1MW membrane-free electrolyzer from a company called CPH2 in Doncaster. The Pre-Qualification Questionnaire was advertised in OJEU in week commencing 19/10/2020.

3.5.1.2 Development of advanced storage management solutions

While the above-mentioned R&D assessment focusses on batteries, there is still significant work to be done on both thermal and electric storage and specifically on its integration in control and energy management systems.

In the H2020 project EXCESS, VITO, JR, PI and VTT expand several of the solutions tested in STORY to a wider application area and further finetune the integration in the overall control. VITO will use the State of Charge measurements as developed in STORY for single building applications to the use as decentralized flexible assets in district heating system. VTT will advance its Model Predictive control with the experience of the Living Lab in STORY to optimise the use of measurement data and reduce calculation intensity and energy consumption of the control operation and data input. JR further expands its LCA expertise, serving the larger group of clients asking for such assessments. While the focus in STORY was on batteries and a minor effort included electric vehicles, EXCESS will enable the expansion and testing of PVT and BIPV.

In addition to EXCESS project, VTT continues the development and application of the MPC and optimisation strategies in several projects, involving different stakeholders that can use the learnings from STORY project in their business. These include a Lighthouse project on Smart Cities (SPARCS), an ecosystem co-operation in Espoo, Finland (Smart Otaniemi) and several H2020 projects. VTT has also started discussions with some companies on the storage as a service concept, using learnings from the market analyses in STORY.

VITO further expands the application of the SOC to large tanks connected to substations of district heating systems in the TEMPO H2020 project. The joint learnings feed into the commercial controller that VITO and the Swedish company NODA are jointly developing. The currently commercially available control is only focussing on peak shaving using buildings' thermal mass. The learnings on the SOC will substantially increase the potential and market value of the controller.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

VITO further integrates the learnings to expand the FLEXHARVESTER platform that will be launched spring 2021 in cooperation with Microsoft.

CENER has been working in STORY on advancing its microgrid control to a non-intrusive site optimisation control where the only controllable course is the battery. The control is currently being further expanded with more tariff setting options and enabling it to work in various regulatory contexts. CENER is working on finding investors and investments to commercialize the control.

ABB presented in STORY its PQPlus unit for both the Slovenian and Belgian pilot, though with different inverters. A first important improvement, based on the Slovenian pilot, that is now integrated in all new PQPlus products, is the new inverter platform with 3-level IGBT (Insulated-gate bipolar transistor) to reduce the noise generated by the old inverter platform. Next is the initiation of a new project, H2020 Muse Grid, where the focus will be on the auxiliary load consumption due to heating and cooling of the batteries (HVAC). Ongoing investigations as part of new H2020 project include thermal simulation, testing in new thermally upgraded pre-fabric concrete cubicle and soft-starter to limit start-up current.

Although the CAES pilot of B9 was not successful due to less advancements on the market as expected, the company continued to develop a more generic power-to-X control system as well as the architecture that goes around that control system. This control system has been further developed with EY to include these hydrogen and oxygen off-takes as well. It provided the basis for the above-mentioned business model validation model of B9.

The control algorithms developed by UL for BESS integration and optimal control in the STORY demo site in Suha village were integrated in the EG SCADA provider Sipronika. These algorithms are now part of the SCADA solution being offered commercially to further SCADA clients to support their BESS integration by Sipronika, supported by UL. UL is also in discussions with the company ELPROS delivering WAMAS systems worldwide for integration of such algorithm to their platform.

To boost utilization of BESS in electrical networks, it is also necessary to develop technical solutions for utilizing stacked business models and service solutions. Also, optimization solutions for serving different stakeholders with the same infrastructure may be necessary.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

3.5.1.3 Continued development of safety standards

Two contributions were delivered in the area of safety and improved procedures for safety. Firstly, ABB developed internal procedures for factory tests and site tests of BESS as part of STORY. This is now included in the operating mode of ABB when BESS units are ordered and delivered.

Additionally, for home batteries, THNK was awarded a contract that focuses specifically on the safety aspects of batteries. It includes the ventilation requirements, the wiring and certification and insurance of a house with home batteries. The Belgian explosion safety company Adinex was engaged to evaluate the behaviour of a battery that is in a building on fire. Both lead acid and Li-Ion (Li-FePO4) were tested. The results will be handed over to the government, emphasizing the need for a larger and multi-stakeholder view on the positions and requirements with regards to the roll-out of home batteries.

3.5.1.4 Collaborate and share internationally

Bridge was initiated by STORY. Its concept was included in the proposal and in collaboration with DG ENER it was picked up and soon outgrew the STORY context. The success of Bridge depends on the effort and dedication of people contributing to it. THNK, JR, UL, UCL, VITO and PI were contributing to different working groups, taking up coordinating roles in both content and dissemination work.

The success of the Bridge approach has led to the set-up of a similar collaboration between the Lighthouse Projects. Bridge enabled exchanges at high-level, contributions to the Clean Energy Package as well as its transposition at Member States level through the taskforce Energy Communities where THNK, JR and VITO delivered a well-appreciated training to the Council of European Energy Regulators.

Although not international as such, the work within the Taskforce LEC resulted in a further uptake project (ROLECS) with THNK, VITO and 28 other organisations and companies. This project is the largest funded R&D project ever in Flanders, both in terms of partnership as in budget. JR was awarded 3 commercial contracts based on its expertise on energy communities gained through the taskforce.

Bridge enabled a lot of partners to increase their visibility nationally and internationally. The H2020 CSA project DECIDE as well as the before mentioned project COMPILE are clear

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

examples of this. In the former, JR, PI and THNK will further work on the transposition of the clean energy package with regards to energy communities in different Member States with a focus on end-consumer categorisation and linked communication. The UL-coordinated H2020 project COMPILE (where JR is also a partner) focussing on community-based solutions for energy islands is directly drawing-upon and contributing to the cooperation in LEC TF, further deploying and replicating the technical and regulatory knowledge stemming from STORY and continuing the work of the Bridge Taskforce Local Energy Communities.

The work in the Business Model Working Group of Bridge (coordinated by THNK in the first 3 years, participation of VLER and UL) has further enabled UL to actively participate in the regulatory design process in Slovenia and by expanding cooperation with the Slovenian TSO ELES (2 commercial contracts and H2020 BD4NRG) and two other DSOs, Elektro Celje (H2020 X-FLEX) and Elektro Ljubljana (H2020 BD4NRG) as well as a cooperation with RESCOOP in the H2020 RESCoopVPP.

3.5.1.5 Interoperability

Interoperability was one of the aspects considered in STORY. Several partners have leveraged their impacts through participation in the DT-ICT10 call for proposals. Partners VTT, THNK and ABB were participating in 2 consortia. Interconnect was selected, with contributions of ABB and THNK. The project (over 30 million euro) has kicked off in fall 2019 and aims to deliver effective leading contributions to standardization.

Additionally, in summer 2020, THNK, SWECO and EY won a contract with regards to the preparation of standardization in the field of V2G and smart charging. The experience of STORY and the network of Bridge are highly relevant to feed into this work.

Former Actility, now Flexcity, has applied its interoperability experience gained through the various devices it had to interact with to develop a low-cost device that enables the valorisation of lower power flexibility.

In STORY BaseN demonstrated that external models are easily integrated to the BaseN system. STORY helped this in testing how to best integrate models and how to pass control commands back, and to demonstrate that this is easily doable with the BaseN platform. As a result, in 2021 already one commercial project is scheduled where this knowledge is leveraged.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

3.5.2 Other contributions of STORY

The advisory board of STORY was highly impactful. The interactions resulted in to several site visits to various pilot sites and enabled direct discussions with European regulators and distribution grid operators.

Furthermore, several of the presentations and considerations have resulted in a wider exploitation. Some examples include:

- In Belgium, the DSO Fluvius, developed a special procedure for connecting neighbourhood batteries specifically for the BESS of ABB and THNK;
- THNK was asked to revise the ASSET report on energy communities by DG ENER;
- JR impacts the development of the transposition of energy communities by the Austrian regulator;
- JR won two contracts based on the improved LCA assessment of batteries;
- UL supports the Slovenian Energy Regulatory Agency in the public consultation process regarding Flexibility market implementation, drawing upon the large-scale evaluation methodology of STORY.
- BaseN won a contract for a TSO/DSO in Rwanda, Africa, based on its unique experience to couple with the SCADA platform of EG;
- UCL has initiated a new course for bachelor students on digital twins;
- UCL further launched an internal project to use the concept of digital twins to support resource planning within the campus. 2 additional projects are in the final stage of evaluation
- VIES improved the design of the fuel cell to anticipate low power quality and voltage swings.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

4 BRIDGE: a major replicator by STORY

4.1 Context

At the stage of preparation of the project, cooperation between projects was limited: there were several projects with deliverables describing the regulatory framework in specific Member States or assessing the potential business models. All projects had their newsletter and all were trying to get the attention of as many high level stakeholders as possible.

STORY aimed to be different and lay the foundations for cooperation over project boundaries. Once STORY was accepted for funding, THNK had various discussions with prof. Dr. Ir. Jean-Marie Bemtgen who was policy officer at DG ENER. Mr. Bemtgen developed the concept of this cooperation internally within DG ENER and the first meeting with all LCE6-10 projects was prepared by PI, THNK and DG ENER.

Today, Bridge is a sound cooperation board which is now supported in its operation by a commercial contract under the supervision of INEA and DG ENER, following support under a previous CSA. All Smart Grid related projects under INEA are obliged to contribute to Bridge and cooperate to deliver joint policy supporting input. A common newsletter and a joint website are the visible outcomes of this cooperation.

Though the quality of the output is strongly dependent on the effective input of the people volunteering to contribute to a specific working group or taskforce, STORY has been a leading contributor.

4.2 Replication of the Bridge concept

The concept of Bridge has been copied to enhance cooperation among the Lighthouse projects. INEA recently awarded the contract to support and coordinate the ongoing Smart Cities and Communities Lighthouse Project Group. Similar to the projects under Bridge, all Smart Cities & communities Lighthouse projects have to allocate a certain percentage of their funding for this cooperation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

4.3 Bridge as an accelerator for STORY partners

Today, several STORY partners (VITO, UCL, PI, UL, JR, THNK) contribute to Bridge, i.e. delivering input or contributing to reports. UL takes a more prominent role in the Business Model working group. PI is active in the Customer Engagement working group.

THNK is leading the taskforce Local Energy Communities in which JR and VITO deliver major contributions. The work in this LEC Taskforce includes close interactions with different European regulators and policy makers. It has consequently led to trainings for CEER, i.e. the Council of European Energy Regulators. Additionally, the work has led to visibility and additional exploitation opportunities for JR, UL, VITO and THNK.

THNK, JR, UL and VITO have been awarded several commercial and funded projects following their work in Bridge. Also, they together influenced policy & regulatory developments in their respective Member States and in several others.

5 Storage devices

5.1 Context

The main objective of STORY is answering the question on the added value storage can bring to a flexible, secure and sustainable energy systems. In order to assess that, the project had included small scale thermal and electrical storage as well as medium scale thermal and electric storage. The test environments were diverse in nature and included residential and industrial settings. A few important observations are worth emphasizing and will be mentioned below.

5.2 Storage: STORY experience

5.2.1 Home batteries: experiences

Home batteries are installed in residential premises, often by electricians who consider it to be an attractive new business. Though, in STORY, the following issues were encountered:

- Concern of home owners with regards to safety;
- Unclear regulation on ventilation;
- Single phase systems in 3-phase set-ups;
- No business case;
- Mismatch between system design considerations and effective use;

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

- Development issues with control.

The safety aspects of home batteries have not been thoroughly assessed. Firefighters have no idea whether a battery is present, where it is located, what type it is (and hence how it has to be handled) and whether it is the cause of the fire or it has taken fire due to extreme conditions around the device. Additionally, homeowners remember the news items that included battery fires, but not the nuances, the circumstances nor the technology used. THNK had several talks to the homeowners and their insurance brokers to discuss the installations. Assessment and evaluation of the home electrical system was done prior to any works and after the installation of the batteries. It was mainly because some extra effort was done in resolving minor safety issues that were already present, that enough “negotiation” margin was created to move to a smooth installation.

The regulation on ventilation for lead acid batteries is not accessible, electricians are not aware of it and certifiers for electrical installations do not verify it. Consequently, ventilation rates are often too low. This is the case for home batteries as well as for batteries in larger facilities.

Throughout the course of the STORY projects, THNK dived into several installations to follow the uptake of home batteries. Information days on SMAs new solar-battery system enabled the discussion on installations with a broad range of installers. It was clear that simple aspects as how to safely connect a single-phase battery in a 3-phase installation, were never their concern. Also, the fact that there is currently no business case did not prevent them from trying to sell small home batteries to end-consumers. The business case will improve with the disappearance of net-metering and the implementation of capacity-based tariffing. However, it remains tight and allows only the cheapest installations to break-even.

In Belgium, the experience of the STORY pilot was used to delay by a year the allocation of subsidies for home batteries in order to gain experience with the systems. Different demonstration projects were launched which showed even round-trip efficiencies of 30% for some systems.

Several of the batteries and battery management systems and interaction control with the building showed development issues. The modules provided by Mercedes Energy were the first commercial batteries of a modular and literally stackable battery system. Technical challenges and non-robust design resulted in a bad contact between 2 modules. As a consequence, 1 of the 2 modules had to be sent back. It took over two months before a new module arrived. The main problem was that the new module was from another batch and had an upgraded software. The manual is clear on not connecting modules with various software versions. Technicians were only available after weeks

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

and their visit had to be prepared with providing them data from the modules. Data that could only be extracted when connecting the modules and activating them.

The sizing of the battery was at 2.5 kW and anything on the line that was above this value would stop the module and require a manual restart. Mercedes stopped the production[20], indirectly confirming that the product was not well-designed and not ready for commercial launch. Today, this battery is not in their product list anymore[21].

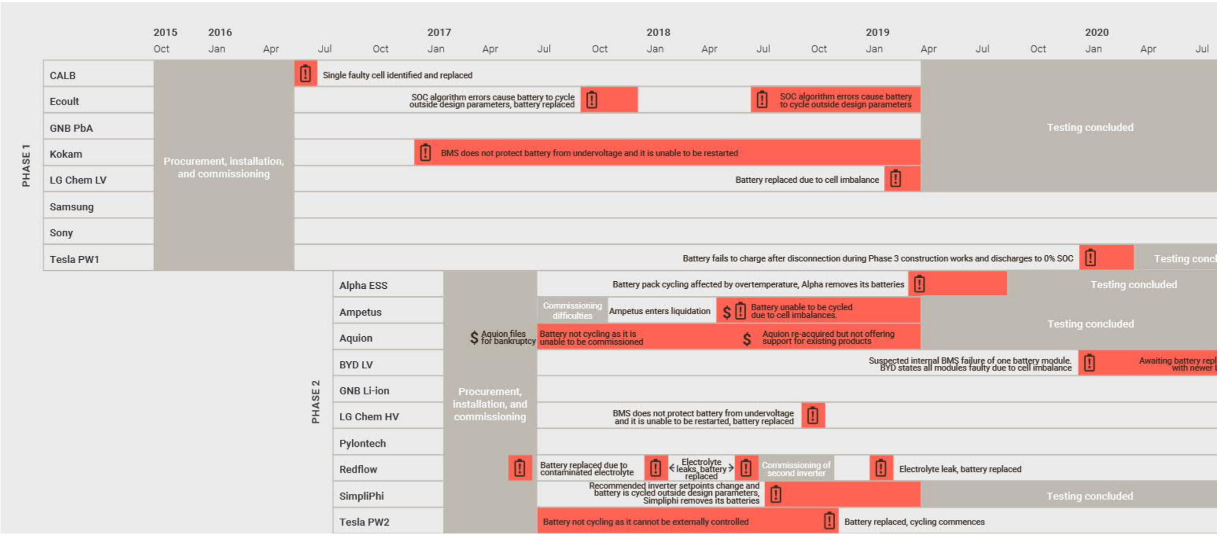

Figure 2: recent overview of performance and issues with different Li-Ion batteries, as per [22].

It is interesting to see is that many of the commercially available storage devices face similar challenges: technical, support & logistics. The Australian battery test centre provides monthly reports[22] on a broad range of commercially available Li-Ion batteries. An extract of issues is provided in Figure 2.

---

[20] Fred Lambert, 'Mercedes-Benz kills its 'Tesla Powerwall kill' energy storage device (Electrek, 2018) <https://electrek.co/2018/04/30/mercedes-benz-kills-tesla-powerwall-killer-energy-storage-device/>

[21]Mercedes Benz, 'Mercedes-Benz Energy Storage A key Component for large-scale energy storage solutions' <https://www.mercedes-benz.com/content/dam/brandhub/mercedes-benz-energy/business-segments/downloads/20171107_MBE_FL_Salesfolder_grid_4s_EN_Ansicht.pdf >

[22]ITP, Public Report 9 Lithium-ion Battery Testing, (2020) ITP Renewables <https://batterytestcentre.com.au/wp-content/uploads/BatteryTestingReport9Sept2020.pdf>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

The lead-acid battery set-up worked much better, though missed an alarm to check the grid-connection when the SOC dropped and the grid-supply remained unavailable. As a consequence, the battery discharged to a too low value and damage was done to the batteries.

5.2.2 Tailored batteries for industrial clients: experiences

Two pilot sites were selected to include larger batteries, but still in a behind-the-meter application. The experience with the Spanish site has been described above, with substantial delays (1 year) with Samsung and then again slow logistics with Saft. Additionally, during operation the battery had some technical and IT-issues that could not be resolved by CENER as they were caused by internal issues in the SAFT BMS as well as time delays in the communication between PV inverter and battery system. Furthermore, their limited technical support, combined with their hesitance to admit it to be their responsibility, caused several periods of operation-interruption. The Spanish regulation was changed during the pilot operation making grid exchange possible and storage more favourable. There was a high interest in the pilot.

The battery system for the Beneens pilot was less challenging on the technical side. The main problem was the absence of installers for this size of battery. A novel company was set-up meanwhile, building on experience of three people that came together based on the home battery installation pilot in Oud-Heverlee. After the launch of the company, the ordering and installation followed soon after a measurement campaign. Minor technical issues came up but, overall, no major outages occurred. The chosen technology was lead-acid and the whole BMS and monitoring system was built on Studer equipment, selected for its robust operation and good back-up service. Important to note is that such battery set-ups are generally installed in already operational facilities. Consequently, the wiring has changed compared to the original and documented approach and certification is outdated due to these changes. Also, the interaction with the Building Energy Management System (BEMS) or the exchange of signals with on-side devices is not always straightforward. This again often relates to a tailor-made and undocumented BEMS

5.2.3 Grid-connected batteries: experiences

STORY started with the one of the world’s largest battery manufacturers at that moment, i.e. Enersys. They had a solid design for a moveable lead-acid-based BESS, designed to be modular in size and simple and adaptable in operation. The intention further was that it would be easy to interface with it. An important break-though would be embedded in the software, namely an

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

algorithm to operate the battery ensuring an optimisation its lifetime. That aspect is important due to the typically lower number of cycles of a lead-acid compared to a Li-Ion battery. While the battery packs were ready, the failures and delays of the subcontracted software manufacturer were taking unacceptable proportions and the project had to be cancelled.

ABB came on board to replace Enersys. The first BESS was placed in the demonstration site in Slovenia. There were a number of technical issues that initiated a series of interruptions in the operation. Several assessments and site visits were undertaken. The issues were resolved after developing and implementing a new inverter platform with 3-level IGBT (Insulated-gate bipolar transistor) to reduce the noise generated by the old inverter platform. The BESS was the first grid-connected BESS in Slovenia and the pilot was managed by the DSO in the area who had previously been part of a European R&D project. The end-consumers were used to it and there was a relation of mutual respect and trust between the nearby end-consumers and the DSO, EG. The BESS was planned to be moved to the headquarters of EG, but several delays to resolve the technical issues prevented that.

The BESS in Belgium was an interesting and intensive journey. There was no legislation on urban planning that could be used, no legal nor regulatory framework discussing connection of batteries to the grid, no tariffing framework nor had suppliers anything in place. The main challenge was in the lack of understanding from various public servants. It took several months to have the technical concept understood by the relevant public servants at local and provincial level. The Regional, i.e. Flemish, expert on integration of novel technologies in the urban landscape had to intervene and one of his colleague even joined a meeting at the municipality. Lawyers were further engaged to provide support and assistance in a potential grey zone of the legislation that could be used.

In order to ease the process of the identification of the location, THNK bought an empty lot previewed to be used for a building. When, finally, all agreed that that piece could be used and accepted the proposed architectural design, an unexpected hurdle came up. The piece of land, as the public servant of nature protection claimed, was a unique lynchet with also on the back side of the land unique plants that could not be touched. His claims where not aligned with building regulation and the lynchet claim was clearly wrong, but he filed an official claim against the permit that was meanwhile delivered. Such claim leveraged the discussion to the provincial level. The lynchet statement was even considered invalid by his own colleagues as well as by a senior researcher and expert on the topic, dr. Dirk Goossens of KULeuven. The counterparty did not even show up during the case defence, confirming that he mainly intended to (and succeeded in) delaying the process. Meanwhile, the further discussion and search for a back-up plan had

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

continued and the Flemish department on building permits had by then agreed that no special permit is needed for a grid-connected BESS and it can be installed on private property. Hence, the parking lot of a nearby resident was rented for the duration of the test.

Parallel to the process of permission for placing the BESS in the urban area, the discussion and connection requirements with the DSO took place. From an initial resistance to an effective approval, the process took over 6 months, but the final result was highly relevant: an addendum to a standard connection contract was developed specifically for BESS units. That implies that for any next BESS to be connected, the conditions and requirements are clear. Regulation on tariffing was missing, but the decision was taken to first assess the potential and only afterwards discuss with the regulator. So the final part needed was a contract with a supplier. Also there, none of them had a contract proposal ready for a BESS. The larger suppliers such as Engie and EDF could not provide us a solution as the logic of a client who only buys to “store and inject again” did not fit in their standard contracts. A small supplier was the easiest and fasted way forward.

On the technical part, the BESS in Belgium mainly faced issues with regards to over-voltages. Also, the inverter certification came with more delay due to the COVID-19 lock-down. Finally, near the end of the pilot LG called back the batch of batteries used in the Oud-Heverlee BESS for replacement.

5.2.4 Thermal storage

The thermal storage units where less of a challenge. The large sizes were not standard, but that did not lead to substantial costs nor long delivery times. An important, though mainly research related point, was the failure with regards to the thermal sensors in the underground storage tanks. Sensors were not easy to reach, nor to replace. The zone above the sensors had a rather high humidity and was completely encapsulated by insulation, avoiding any air recirculation. The failures started soon and eventually the majority of sensors dropped out. Though, the method VITO developed using the data of these tanks, is based on a limited number of sensors to be able to predict the State of Charge (SOC) of a thermal storage tank.

5.2.5 CAES: experiences

The status with regards to the CAES has been briefly explained above and is further documented in D6.1. The main challenge was related to the heat exchanger being more challenging in design

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

and substantially underperforming in real-life tests. While the development was continued aside from STORY, the pilot itself was stopped due to the substantial delays and the R&D challenges still remaining.

5.3 The acceleration potential for STORY partners

The different experiments have led to substantial replication and valorisation opportunities for the engaged STORY partners. THNK has received multiple commercial contracts for optimal sizing of PV-battery combinations based on the calculation tool designed for the home battery demonstration, such requests are now a regular activity within the company providing recurrent income. Additionally, a project was awarded by the Flemish government in which the safety aspects, including explosion safety, ventilation requirements and wiring were tested and feedback was provided to the Flemish government and the insurance and certification bodies with regards to the safe implementation of home batteries. THNK was further co-initiator of a new company, that sizes, implements and manages battery systems for SMEs.

B9 continued the work on the different aspects of the CAES. They modified the design to work as a true liquid piston and are currently cooperating with Queens University, Belfast. A PhD student of Queens University developed predictive models that are currently being validated with the set-up. B9 has further been approached by Envision Digital from Singapore/ China to further elaborate the system through the use of their new AIoT techniques. Negotiations are ongoing. Additionally, the control system and associated techno-economic model of B9 with additions of EY has been used to satisfy the Board of Directors at NI Water of the outline business case for a 1MW demonstrator electrolyser project that has now been funded by government at £4.8m. The model focuses on using H2 in the transport sector. The next step will be to further develop the model to cover power-to-gas projects for 20 vol% injection of H_2 into natural gas distribution networks.

VITO has presented the results of the SOC assessment methodology in the final event of STORY and is invited by the European Heat Pump Association to present it to their members in spring. In addition, the results are already being integrated in the STORM controller that VITO co-owns and co-develops with the Swedish company NODA. Furthermore, the work will be integrated in 2021 in the Flexharvester platform that VITO develops in cooperation with Microsoft. The expertise is further applied in EXCESS and TEMPO to bring two additional use cases to ensure robustness of the STORM and Flexharvester control, i.e. the use of small scale domestic heat storages connected to a district heating system (EXCESS) and the use of larger scale storage units connected to a district heating substation (TEMPO).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

The work of JR focussed on the LCA impact of batteries. Two commercial contracts have been initiated recently on this aspect. Additionally, a PhD student started at JR to further develop and finetune the LCA on batteries.
The work of CENER will be considered in the next chapter below.

6 Microgrids, Energy communities and flexibility

6.1 Microgrid-level control

The integration of a flexible asset in a lab or factory could be done in multiple ways. However, the use of such a control in a lab or factory is not self-evident and measurement of all assets is not possible and/or economically feasible. The Living Lab pilot was a good example. The developed Model Predictive Control (MPC) developed by VTT requires an amount of data that could only be collected accurately in case of operating pumps every hour for about 5 minutes. Such operation would immediately make the control inefficient given the size of RES installed compared to the load. During the project the load increased drastically, due to the addition of another electric car, increasing the instantaneous self-consumption at site level. Consequently, there was no longer a benefit of the MPC against the energy cost of additional measurement for the MPC. Simulations have shown that using the MPC starts to make sense for PV size that are double than the existing one, considering the current load of the site. In the case of the factory in Spain, the decision was made to not intervene with the normal operation of the factory in order to not impact the processes of operation that were in place. Instead CENER opted for a smart approach where the control takes all non-battery assets and their consumption or injection as a given and uses the flexibility of the battery to optimise the microgrid operation.

6.2 Energy Communities & flexibility

The typical approach in managing the energy flows and interactions in an energy community is the integration of a community platform in which all data on consumption and injection of connected users/loads or generators could be uploaded and a decision making algorithm determines the next step. For a community, such a platform is expensive and cumbersome: all connected users have to give consent. Consequently, it is – aside from an expensive hardware & software solution - a resource intensive solution in the aspect of user interaction.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

The approach taken for the neighbourhood BESS was therefore a smart voltage-based control. Due to the characteristics of the line, being undersized, the voltage on the 3 phases was a good indicator of the activity in the neighbourhood. The self-learning model showed to be accurate in predicting the next day such that the BESS operation was supporting the grid. Services to a TSO level were not relevant, due to the limits of the cable. Aside from the BESS, smart car charging was applied. The same logic was selected, i.e. voltage-based where voltage was measured at the point where the flexible asset was connected. Though building on previous experience with testing of various car chargers, the choice was made to not interrupt charging or not prevent charging to start at a certain moment. The adaptation was limited to the current and hence the available power for charging. Little experience was gained, as the charger software was ready when the first COVID-19 lock-down was announced. Teleworking and limited contacts remained the standard and hence interventions on site were not preferred, nor were people using their vehicles.

6.3 The acceleration potential for STORY partners

CENER developed an innovative algorithm for managing microgrids using the flexibility of the battery to optimise the interaction with the grid. The battery operation management is focused on operational cost reduction for site as well as extension of lifetime of the battery. The non-intrusive site optimisation approach is a considerable advantage. CENER is looking at different options for valorisation and has talked to different investors for the launch of a company. Decisions have not been taken yet. Important for the continuation of the Exkal demonstration is furthermore the commercial agreement between the 2 partners to enable CENER to continue maintaining and updating the control. CENER was further awarded a commercial contract to use the control for a windfarm with battery, where participation in the flexibility market is envisaged.

VTT, partner in EXCESS, will further advance the MPC with assets similar to the Living Lab. The lessons learned on the STORY pilot are used to increase the energy efficiency of the control.

THNK has used the experience with the voltage control in the interactions with policy makers at different levels, mainly to enable out-of-the-box thinking before advancing to advanced flexibility market concepts at DSO level.

THNK further used its expertise on energy communities to expand the battery-PV-sizing optimisation tool to a community-level tool. The latter has been applied in 3 commercial contracts and is now being used in a just awarded contract. Furthermore, the expertise on interoperability from the lab and the chargers, as well as the knowledge on EV-charging, has enabled the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

consortium EY-SWECO and THNK to win a commercial contract for DG ENER on the V2G and smart car charging.

UCL has delivered the first assessment of a digital twin to operate a complicated multi-energy system such as the Living Lab. That experience is now integrated in a course for bachelors students. Furthermore, the expertise is used in an internal project at UCL applying the digital twin learnings to manufacturing and shipping. Another already awarded internal project is on planning of personnel at the university college and finally two more projects to further broaden the concept are submitted for approval.

7 Cross-silo platforms

A single platform was used in STORY to collect and exchange all measurement data. This platform had to overcome a substantial amount of interoperability challenges and work with conversions as well as with different timesteps. All data was to be automatically processed to deliver the defined KPIs. BaseN managed to set-up such platform, maximally using the already available tools and platform at BaseN to increase the valorisation potential.

Important to mention is that GDPR was not yet in place at the start of STORY. Though, throughout the duration of STORY compliance with the new legislation had to be guaranteed. Hence, data collection, handling and visibility to different users of the platform had to be adapted. The needed security and protections were built in to enable this.

7.1 The acceleration potential for STORY partners

The proven experience showed to be valuable for a small company as BaseN to win contracts for large companies and distribution system operators (DSOs). Based on the experience with the pilot in Slovenia, BaseN was able to receive a contract for a local DSO on coupling with its SCADA. The decisive element was such proven previous experience. This experience further lead to a pilot project in Africa, where BaseN will monitor grid related parameters, process them and visualize them. The pilot was successful and will be further upscaled in 2021.

Additionally, the integration of Machine Learning (ML) in the BaseN platform, as was done in STORY was an important asset. STORY helped in enabling a testing environment to learn how to best integrate external and internal models and how to pass control commands back, and to demonstrate that this is easily doable with BaseN platform. Already one commercial project where

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

this will be applied is starting early 2021. The sessions with Advisory board helped a lot in marketing messages, providing BaseN good feedback on what parts to concentrate on and what parts should be skipped in the message.

BaseN is also successfully applying the device driver design/solution from UCL. It facilitates interoperability and counteracts vendor lock-in. In research, device drivers are used to shield the research set-ups from the ugly industrial reality. But it also works in commercial settings.

Applying the device driver solution also reveals whether a smart equipment vendor nudges/forces their users (integrators) to use features that cause lock-in. Thus, using device drivers results in exposing such bad habits. An example is “asynchronous events (coming soon)” in a product manual, forcing to invest heavily in coding using a vendor-proprietary programming language/tool (in which asynchronous event are handled already). This investment cannot be used except with this vendors equipment.

The negative effects of lock-in are not to be underestimated. In particular, they block the emergence of markets for smart services that need to interoperate with (almost) all vendors to flourish. If they need to develop and support a lot of different versions (one for every vendor), there is no viable market. In addition, those vendor-specific programming tools often force the innovative player to disclose too much.

UCL’s research, benefiting from STORY, will be focusing on a systematic approach for design to cooperate with other systems without lock-in.

8 Overview of replication activities

8.1 Continuous stakeholder interactions

STORY had an extensive exchange with stakeholders over the lifetime of the project that will continue after the project end. The demonstration in Oud-Heverlee was set up as a living lab, where the installed technologies and gained insight were regularly showcased to market actors, or policy makers.

Also, the demonstration in Slovenia, the country’s first community battery, facilitated replication, the demo leader, Elektro Gorejnska, had more than 10 visits by Slovenian stakeholders, including the Presidents of Finland and Slovenia, and serves as point of information for other actors that plan such batteries in Slovenia.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

Structured stakeholder engagements focused on replication were organised at two levels. First, STORY aimed to engage stakeholders around key issues and topics relevant to energy storage. A total of eight stakeholder events were delivered between 2015 and 2020 on smart girds, business planning and business canvases for storage, local energy communities and community batteries. These events were characterised by high levels of participation and interaction to ensure that stakeholders were able to engage in a dialogue with the STORY partners to address problems and co-develop solutions. For a full report on these stakeholder events please see D9.6 Summarizing Report on the Stakeholders Workshops.

The second level of structured stakeholder engagement was organised through the Advisory Board meetings. The STORY project broke with the traditional format for Advisory Board meetings and focused instead on engaging companies, investors and potential ‘users’ of storage technology. In the Advisory Board meetings, stakeholders were encouraged to adopt a critical frame of reference with a focus on replication and what STORY partners had to achieve in order to bring storage technologies to the market.

The focus of each Advisory Board meeting changed as the STORY technologies developed and became more mature. This also meant that the stakeholders changed as we sought to engage relevant businesses and investors. The first Advisory Board in 2016 looked at the potential of all the demonstration sites in STORY and the likely markets and business opportunities. The second Advisory Board visited two demonstration sites in Belgium and also contained a dedicated session on proposed EU legislation and how this might provide business opportunities for STORY technology. The third Advisory Board focused on the development of business canvasses for STORY demonstrations and the likely growth markets and business sectors of highest potential. The fourth Advisory Board involved four partners pitching their products and services developed in STORY and getting feedback on the business model, value proposition, pricing, service contracts, market segments etc. For more detail on the Advisory Boards please see D9.7 Specific Deployment Oriented Reports.

8.2 Sharing of lessons learned

Replication is facilitated in STORY by sharing the large range of lessons gained in the demonstrations with market actors, policymakers and the wider public. These include technological and non-technological issues and barriers such as lessons related to communication and control or improved customer engagement. STORY lessons were first presented in Sustainable Places Conference 2019 (with a related paper in the proceedings) and in the EU utility week 2019,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

where STORY received the best presentation award in an EC-organized event. STORY lessons were shared at the project's final event, and will further be disseminated in an upcoming policy brief and an academic publication.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426