SIX Sustainable Industry X | MOBILE WORK MACHINES

VALMET AUTOMOTIVE · SANDVIK · KALMAR · PONSSE · fortum · VTT · SITRA · VIRTUAL FINLAND

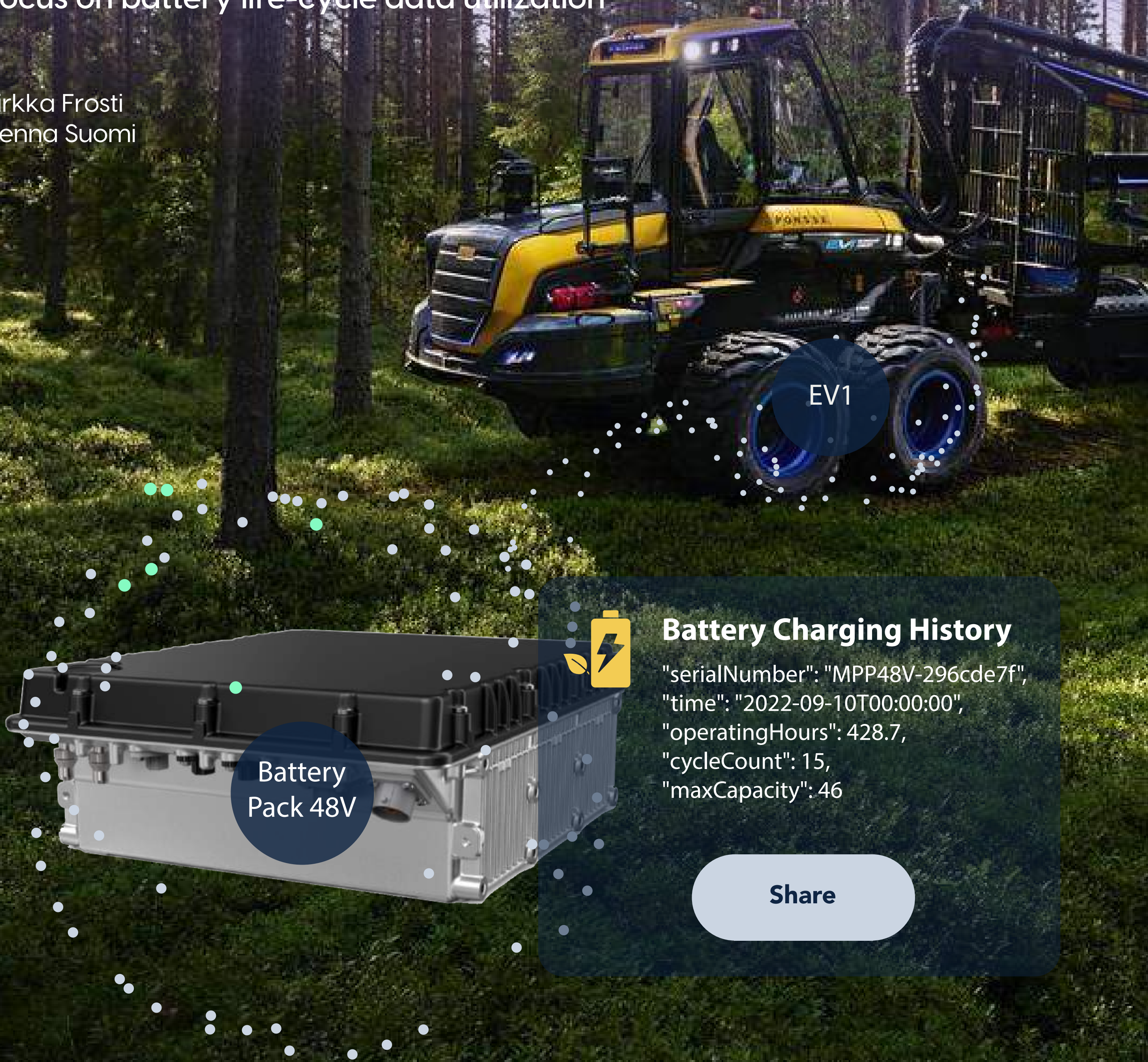
IOXIO

Case study 10.1.2023

Creating an industrial dataspace around the Mobile Work Machines

Focus on battery life-cycle data utilization

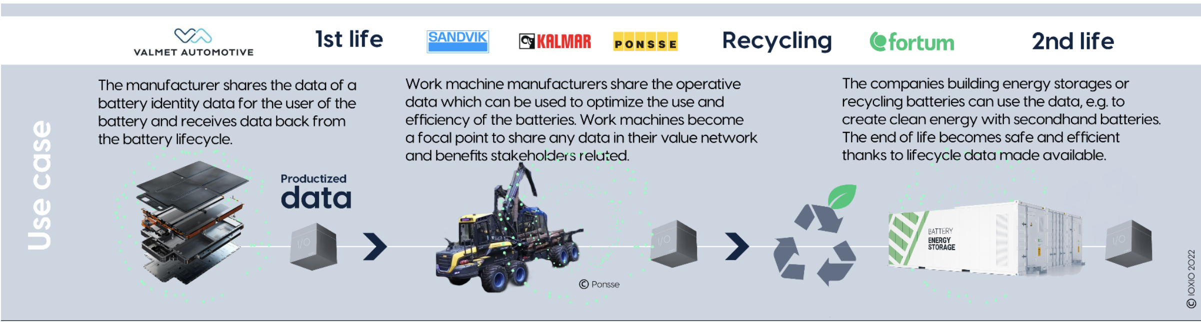
Pirkka Frosti
Henna Suomi



Executive summary

The global industries are facing growing demand for data, while legislation is promoting secure and efficient data usage. To effectively share data, maintain control, and stay ahead of competitors, companies must comply with regulatory, market, and investor demands to open their product data. The green transition, industrial digitalization, and economic competitiveness in Europe depend on data sharing. The manufacturers of machines and batteries have a crucial role in the green transition, but must ensure safe data sharing to improve the full product life cycle without compromising their business. Leading the digital transformation, Finnish and Swedish manufacturers aim to evaluate the benefits of data sharing to build smarter machines and batteries towards the SIX 2030 vision.

Dataspaces enable interoperable, semantic, secure, and decentralized data sharing and usage on the internet. Europe is at the forefront of making data sharing a reality to achieve digitalization goals for businesses. This applies to companies involved in manufacturing, operating, and recycling machines and batteries, as well as those providing the energy, components, and raw materials necessary. Secured data access, unique digital identities for machines and batteries, and the ability to carry product data throughout the battery life cycle are essential to address systemic challenges. Without data harmonization, trust between companies, consent-based sharing, and a business-driven legal framework, the data economy will falter. A proof-of-concept experiment was conducted to find practical solutions that enable the full life-cycle usage of data in demanding machine applications, second-life use in energy storage, and safe and efficient end-of-life recycling.



This report presents the key findings from a study of the market drivers, business value, and opportunities from sharing 1st life and recycling/2nd life battery data. With input from leading industry experts at Ponsse, Sandvik, Cargotec/Kalmar, Valmet Automotive, and Fortum, the first datasets were harmonized and the requirements for trust and control in data sharing were analyzed. The project resulted in concrete recommendations for building a production-grade dataspace for machines and batteries, based on European best practices and dataspace architecture**.**

The proof-of-concept demonstration showed how trusted industry data sharing can be achieved in practice. The project produced a first prototype data space that supports the use of existing systems, APIs, and software already in place for the participating companies. The IOXIO Dataspace SaaS was used in conjunction with the Virtual Finland Testbed to power the experiment. The first data products were semantically modeled on the dataspace, with demo APIs built for Valmet Automotive's battery data and machine operational test data sources built for Ponsse, Kalmar, and Sandvik. The decentralized data sources provided productized data for a showroom application as a data consumer on the dataspace. The data release was made possible through consent from the participating companies and adhered to fair data economy principles. The data was not copied into new platforms or silos, and the linked data was shown to span across various stages of the product's life. The dataspace established a secure framework for companies involved in manufacturing, owning, maintaining, operating, and recycling batteries to start sharing data, in line with the battery passport and European regulations**.**

This report offers insights into both business and technical barriers, as well as the development needs for full lifecycle battery data sharing. It includes recommendations for short-term and long-term development towards this goal.

Case description and aim

Aim – answers we are looking for

The future world is built every day with mobile machines. Finland is strong player in developing these solutions, and numerous companies representing the industry operate in our country. Many of these players have been recognized as leading players and trendsetters in their own application areas on a global level. Accordingly, the mobile machines industry forms one of the cornerstones of our well-being, being one of our most significant export industries in our country.

The mobile machines industry as we know it, is at the middle of the biggest change in its entire history. Driver for this change is widely discussed green and digital transition. For this reason, a number of Finnish companies joined their forces about two years ago. SIX Mobile Machines, an industry driven cluster, focused on smart mobile work machines was born. The cluster members are working towards the joint vision:

The best operating environment

In 2025, Finland has become known as the world's best place for developing mobile work machines and their key technologies and services

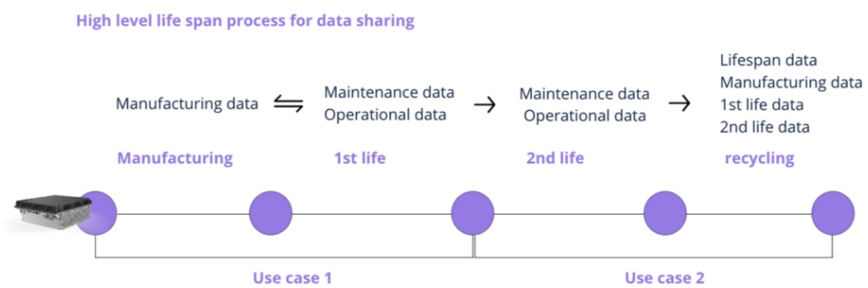
The future machine

The future mobile machine: It is not just sustainable. It is enabling totally new, unseen value over the value chain the machine is operating in.

One concrete step towards the vision, the SIX Mobile Machines roadmap contains the development of *data intensive life-cycle services enabling new value from data*. The key purpose of the experimentation was to demonstrate how an industrial dataspace, compatible with the Fair Data Economy as well as European level Data space design principles, can be build: what are the key building blocks and components needed and how they can in practice enable trusted data exchange and value creation for stakeholders on the battery life cycle.

Experimentation scope and use cases

In the experimentation, the analysis of the data driven business value and new business models covered the entire life cycle of the battery. Starting from the manufacturing, containing the 1st and 2nd life use and operation until the recycling phase of the battery.



During the analysis phase numerous potential benefits of data exchange were identified in terms of bringing business value as well as sustainable use and operation of the battery.

Manufacturing and 1st life use

The electric mobile machine operator can benefit from the machine usage and charge cycles based on the battery manufacturing and maintenance data to optimize operator value in daily use. External data sources such weather data can feed additional insight regarding the conditions where the mobile work machine is operating. On the other hand, the feedback loop from the machines and their operational sites can provide an information back loop on the machines lifespan for improving the design and manufacturing of the batteries.

1st life, 2nd life and recycling use

Having data available from the battery manufacturing and the 1st life operations, e.g., the 1st life operator can monitor the battery performance and its forecasts better, identify when the battery is not performing in 1st life use and find optimal 2nd life use by sharing the battery and operational data to energy storage operators. The 2nd life operator knows how the battery has been charged, discharged and what were the operational conditions during the 1st life use. Safer and more efficient recycling is also made possible when the data can be shared towards the recycler from the battery manufacturing, 1st life and potential 2nd life use.

Members and their roles in the experimentation

SIX Sustainable Industry X	SIX Sustainable Industry X - a Finnish national initiative supercharging Finnish industry performance and sustainable growth through innovation and knowledge.
SIX Sustainable Industry X MOBILE WORK MACHINES	SIX Mobile Work Machines is an industry driven cluster, focused on smart mobile work machines. The cluster companies and research organizations as end users and business case owners in the experimentation.
SIX members:	
VALMET AUTOMOTIVE	Valmet Automotive is a Finnish manufacturer of electric vehicle battery systems, automotive kinematic systems for OEMs, and a leading vehicle contract manufacturer.
SANDVIK	A Swedish engineering company specializing in mining equipment manufacturing and machinery. 1st life use case machine manufacturer.
CARGOTEC	A Finnish company that makes cargo-handling machinery for ships, ports, terminals, and local distribution. 1st life use case machine manufacturer.
PONSSE	Manufactures, sells, and maintains cut-to-length forest machines such as forwarders and harvesters. 1st life use case machine manufacturer.
fortum	Finnish state-owned energy company. Expert in the battery recycling business. Also offers consultancy services for power plants and electric vehicle charging. In the experimentation the business owner for the recycling and 2nd life use cases.
VTT	As a leading research partner VTT coordinated the SIX cluster work and provided the latest research knowhow for the use of the experimentation.
Enablers:	
SITRA	The Finnish Innovation Fund Sitra funded the project. The experimentation utilized the fair data economy principles and fair data sharing rulebook developed with the support of Sitra.
VIRTUAL FINLAND	The Virtual Finland project under the Ministry of Foreign Affairs promotes the Finnish cross-border competitiveness and offered the national data economy testbed for the experimentation.
IOXIO	As the main dataspace technology partner IOXIO was responsible of the project execution, deliverables, and the implementation of the experimentation. IOXIO's architecture and concept as well as the Dataspace SaaS was used in the Virtual Finland Testbed to enable the semantic and secure sharing of productized data.

Deliverables

The proof-of-concept experimentation consisted of two parts:

1. The specification and identification of the battery life-cycle value network and understanding the data sharing needs, context and their value potential during the life cycle
2. A prototype trusted data exchange implementation to demonstrate the business value and data sharing solution in practice

The experimentation resulted in an end-to-end working prototype of trusted industry data exchange between industry stakeholders: Valmet Automotive, Sandvik, Cargotec/Kalmar and Ponsse. The prototype consisted of 1) the Virtual Finland testbed running on IOXIO Dataspace service and a juridical and governance framework based on Sitra's Rulebook for exchanging 2) standardized data sets, i.e. *data products*, 3) simulated battery and machine manufacturer APIs adjusted to data product definitions and 4) a showroom application to demonstrate the end user value of interoperable and trusted data exchange. between stakeholders.

Outcome and results

It is not a question that should we share the data around batteries and electrified work machines. It is now in the law and the new normal for the global business. The question is how you can do it, not to lose your data and control, and how to use it to fight global competitors going faster and faster towards digital with new business models and smarter products.

Identified key market drivers

EU regulation push and the European Data Act

The European Commission "Data Act" on harmonized rules on fair access to and use of data was published earlier this year to push Europe to create a harmonized framework for industrial, non-personal data sharing in the European Union. The proposed connected Data Governance Act aims to create sector-specific dataspaces to enable the sharing of data within a specific sector.

In Europe this is a significant driver to encourage and even mandate also industrial companies and governments to both share data but also ensure the safe and transparent use of data. For SIX and industrial manufacturing companies it has been seen both as a threat that would force manufacturing companies to open their product data to 3rd party use jeopardizing their capability to control how the data is used and most importantly used to drive value added service and after-market business leaving them as utilities. Provided that the regulation drives a positive digital single market for industry data to be used and shared much wider in the battery and machine business this also opens a wide avenue of new business for early adaptors and data driven manufacturers.

Electrification of heavy machinery

The electrification, autonomous operation, and digitalization of working machines are a growing trend among the heavy machinery and equipment segment. The sustainability drivers as well as the higher energy efficiency of electric vehicles, a lower lifetime operating costs and rapidly decreasing costs for electric power trains makes the electrification of movable work machines increasingly more attractive to operators, investors and thus manufacturers alike. The SIX consortium is working towards researching and developing the leading products and capabilities to offer hybrid and fully electrified solutions to their customers. The market dynamics are thus one of the leading drivers to ensure that future machines can be built and operated towards the climate neutrality and utilizing digitalization as much as possible to meet these goals.

Battery passport

New EU rules for design, production, and waste treatment for batteries enforces industry to adopt more stringent targets for waste collection, recycling efficiency and material recovery for the sake of improved sustainability and better use of natural resources. A carbon footprint declaration and label will be obligatory for EV batteries, LMT batteries and rechargeable industrial batteries with a capacity above 2kWh. The data is mandated to be made better available especially for the consumers to understand the impact.

Sustainability and the green transition

In Europe the European Green Deal aims to make Europe climate neutral by 2050, boost the economy through green technology, create sustainable industry and transport, and cut pollution. Supporting the decarbonisation of electricity systems, including the design of renewable-energy-friendly markets and regulatory frameworks it mandates the EV manufacturers to find more effective business models and ways to create competitive solutions that put the energy efficiency first. The US also aims to drive a similar change in the industry. Following the <1.5´C goal and net zero by 2050 global actions rely on rapid electrification of traffic and machinery.

Energy crisis in Europe and global economy

As the energy is more and more connected with democratic societal issues the European manufacturers should have an opportunity to benefit from the opportunity if they can meet the efficiency goals with the means of digitalization. The experienced shock to the economy by the pandemic and the Russia's offensive in Europe and our evident reliance to Chinese manufacturing puts a strain on the supply chains, capabilities to improve predictive maintenance, and most importantly to get everything we can out of the batteries and raw materials. The 2nd life use and circular use of material doesn't work without data and recycling is made much more efficient and sustainable with the increased quality and accuracy of data.

ESG – environmental, social and governance

"Companies are expanding the metrics they use to define success well beyond profit and sales. In response to growing concerns among their employees, customers, investors, and impacted communities, many firms are making themselves accountable for their Environmental, Social, and Governance (ESG) practices." MIT Sloan School of Economics The investors, shareholders, financial advisors, and regulators are learning the value of transparency and use of data to drive decisions behind investments and their portfolios. The sustainability, fair use of resources and labor especially around the chemicals and earth minerals used in the batteries and the provenance of the whole value chain the battery travels through its life cycle must be made visible and accessible with data.

Dataspace development

Besides the European Commission driving the data regulations many European States as well as public-private initiatives (e.g. Gaia-X and IDSA) around Europe are striving towards creating the building blocks for interoperable and trusted data sharing on the different domains. Catena-X represents and initiative around the industrial data sharing with a focus on the supply chain data exchange in manufacturing. Catena-X relies on the architecture developed in the International Data Spaces Association reference architecture which, however, is still lacking the methods and tools for enabling the contextual standardization and use of data. As a next step to align different dataspaces initiatives around Europe, the European Commission has started funding the Data spaces support center (launch in October 2022) which will explore the needs of dataspace initiatives, define common requirements and establish best practices to accelerate the formation of sovereign dataspaces as a key element of digital transformation at all levels.

Human centric and fair data economy

The Finnish Innovation Fund, Sitra, has long been promoting the human-centric, sovereign and fair use of data as a backlash for the US driven, uncontrolled use of people's data. The data sovereignty reaches up to the businesses as well and fairness in data sharing means that the interests of individuals, businesses and society are balanced. This is what is called as the fair data economy. Sitra is supporting and promoting the creation of dataspaces as a practical solution proposal for enabling the fair data economy to happen in practice. Sitra also

coordinates the [Gaia-X Hub in Finland](#)to support pan-European emergence of dataspaces in different business domains: current portfolio of working groups includes an own hub for industrial dataspace development.
Business value in data sharing

Value network – understanding the business ecosystem

The project conducted a [high-level analysis](#) of the real-world business value network around the battery and work machines to map out the key stakeholders as potential future members to join the SIX dataspace as data providers and data consumers benefitting from access to the refined data. The value network modelling is vital to understand the business relationships between the companies, machines, and the equipment they manufacture and operate as well as the sites where the actual value is delivered for the end customers. Relations and roles between various organizations and the physical assets and products can be identified providing the foundations for the both contextual semantic data sharing and the digital trust needed to safeguard and consent the data use in the dataspace.

The end customers benefit from the value delivered by the electrified machines but also carry the costs of operations and energy making them the main target for digitalization.

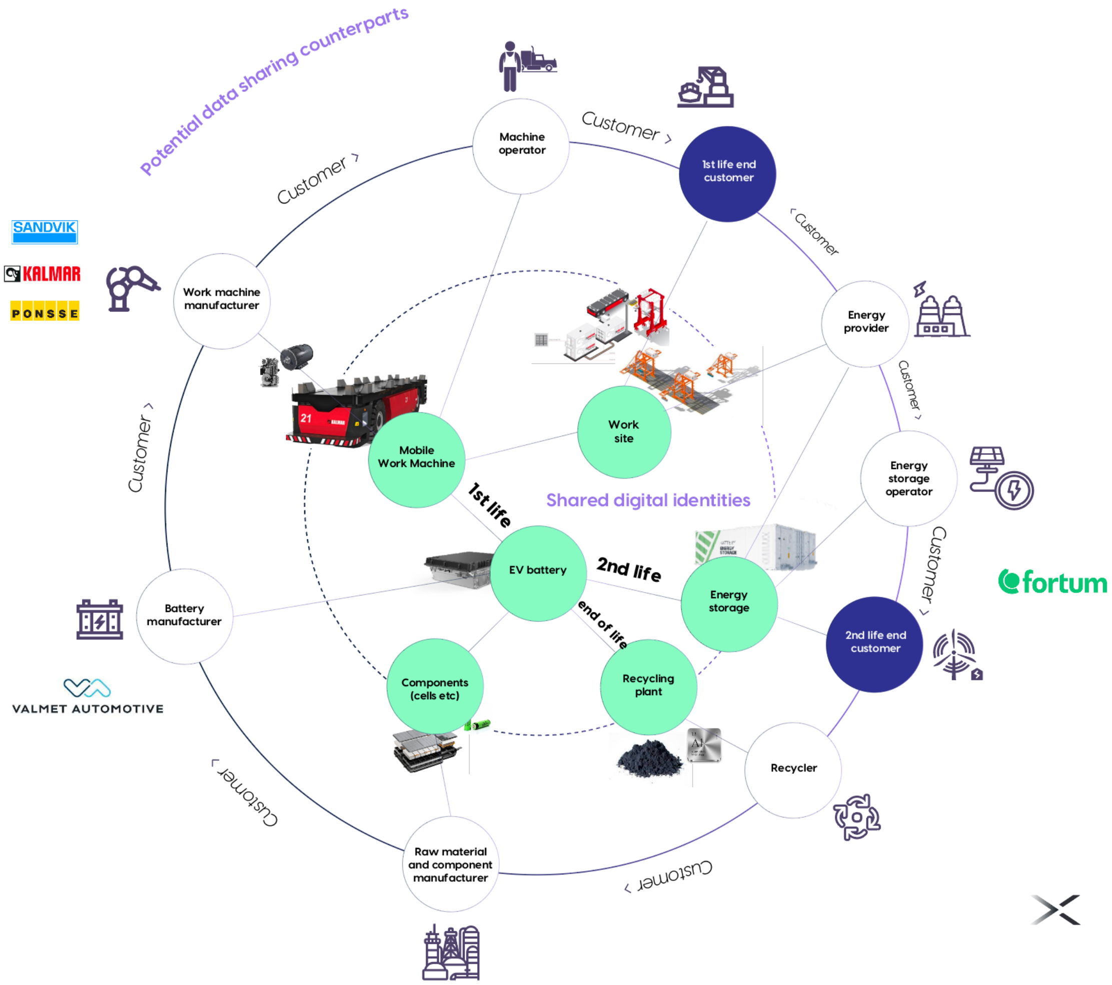


Figure 1. *Digital identities in which data can be linked and which create the context for trusted data sharing in the battery life cycle for achieving the identified business value for the battery industry stakeholders.*

In the production stage, the value network would be taken to much higher detail but already from the quick experimentation we can deduct that:

- the value chains are rather straightforward and follow the life cycle of the battery and the work machines and energy storages making it easy to understand also how the data would follow the money in these business relationships.
- the battery plays an important role as it is the key point that connects the various life-cycle ecosystems and business stakeholders that also act as data providers.
- the 1st and 2nd life end customers (in dark blue) drive the demand as they pay for the value delivered by the electrified machines but also for the energy used to power the machines. These are the key stakeholders that should benefit the most.
- the operators of the machinery and the energy storages play an important role as direct end customers for the machines. They are also the ones getting access to the data services and digital solutions offered by the manufacturers.
- energy providers play an interesting role in the data sharing as they can provide data considering the primary energy sources, sustainability and cost of the energy used.
- the sites are important as they create the physical context between the machines, operators and end users opening the door to connect the battery and machine performance to the end user value they deliver. This is the key when considering how the data can be used to cut down more lumber in a forest, dig more holes in a mine or load more containers in a harbor with as few energy and virgin raw material consumed as possible.

Identified key stakeholders in the experimentation

Manufacturing and recycling	**Other**
Battery manufacturer	Energy provider
Raw material and component manufacturer	
Recycler	
1st life use	**2nd life use**
Machine operator	Energy storage operator
Machine manufacturer	Energy storage manufacturer
1st life end customer	2nd life end customer

Other identified key identities in the experimentation

Manufacturing and recycling	**Other**
Battery	
Battery components (mainly packs and cells)	
Recycling plant	
1st life use	**2nd life use**
Movable work machine	Energy storage
Operating site	Operating site

The machine operators are the pivotal point for access to data as they own and operate the machines and batteries for the end customers.

Life-cycle data business models

Based on the value network and process modelling done in the experimentation the following first business opportunities were identified from the selected use cases.

Use case 1 – 1st Optimizing machine use based on battery data

- Optimize the machine usage and charge cycles based on the battery manufacturing and maintenance data to optimize operator value in daily use

- Design backloop from the machines and sites to the battery manufacturer
  - Design better performing and higher value batteries for customers based on real world information on the machine lifespan.
  - Enable second life use in energy storages based on battery and operational data shared.

Use case 2 – Optimizing sustainable secondary use of batteries and safe and efficient recycling

- Identify when the battery is not performing in the intended use (1st and 2nd life)
  - Having life-cycle data available for unique batteries makes it possible to better detect in advance when the battery is not going to perform within desired specs.
  - This makes it possible to replace the battery without disruptions to the operations and find the best further use for the unit, be it to send it to be recycled or to sell it for 2nd life use to, e.g., backup a cellular tower with solar charging.
- Discover the provenance and usage profile of a battery to optimize its new use
  - Find optimal 2nd life use by sharing the battery and operational data to energy storage operators. Currently the batteries are mostly discarded regardless of their unique condition and life left missing an opportunity to get more out of them in other use.
  - 2nd life operator knows how the battery has been charged, discharged and how the battery has been used in 1st life
- Ensure safe and efficient recycling of the batteries
  - The recycling plant needs to identify the possible hazardous units
  - There is currently no history data being passed and no channels to offer batteries for 2nd life use

Key findings from the brief data driven business analytics

The data driven means in practice the capability to allow contextual data to cross the steps in the value chain as the raw materials, components and energy connect with the machines and batteries in daily operations. Similarly, the capability to connect different stakeholders and their processes better together around the machines and their operating environment with data enables better automation towards efficiency and cost savings as well as formation of new ecosystem business models for improved revenues.

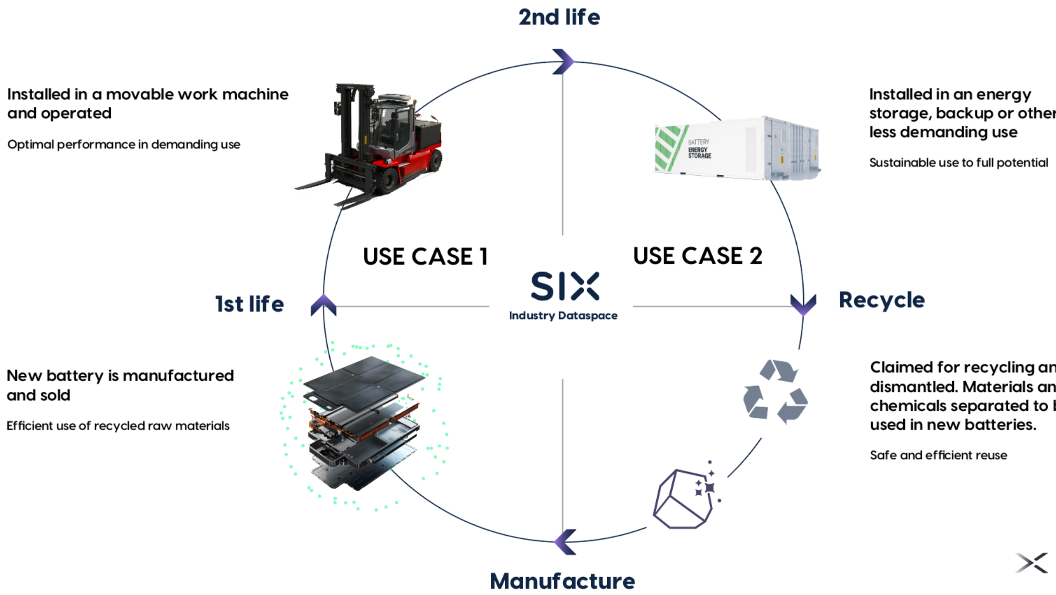


Figure 2. *The different use cases in the lifespan of the battery. The circular economy connects the recycling back to manufacturing. The different steps in the life cycle also possess the barriers for data flow as the ownership and access to data changes hands.*

Business is siloed and the new systemic scale business models are needed

The benefits can well be recognized by the stakeholders, yet the systemic business models are not mature yet to drive the full lifespan use of the batteries. The companies themselves are digital ready and highly technology oriented but the approach to data driven business is still rather traditional between the companies. The mindset is still rather focused on traditional supply chain and direct manufacturer to customer-oriented use of data. This results in low utilization of data and untapped potential in driving the end customer value or societal level sustainability efforts in practice on a daily level.

Building the connection between the machines, batteries, and the operational environment they operate in and especially the end users doing business with the help of the machinery would be the crucial step to drive revenues and build new data driven business on e.g., preventative maintenance, aftersales and much wider business services ranging from finance, insurance to new onsite charging infrastructure services etc.

The companies themselves are digital ready and highly technology oriented but the approach to data driven business is still rather traditional between the companies.

Recycling business is growing but 2nd life markets are not yet well established

Considering the readiness in Use Case 1 and 1st life-cycle services the secondary use business seems to be in its early incumbency. The energy storage business utilizing recycled batteries such as, e.g., the Finnish startup Cactos that uses old Tesla batteries in its energy storage units for industry scale solutions are emerging. However, the large-scale solutions to broker, collect and manage used battery markets are not present yet. The study identified a great opportunity to lower the cost of batteries in the 1st life use to improve their resale price on the secondary markets and similarly drive new sustainable business in offering energy storage services for new energy solutions. The market needs new stakeholders to start offering these services fueled by the battery passport and the life-cycle data which can be shared in a trusted and controlled manner.

Recycling business is improving and as the commodity prices as well as the recycling methods improve more business value can be found in recycling the batteries. Fortum has already invested in the state-of-the-art recycling facilities in Finland and capable to build processes to handle recycled batteries better with data.

Compared to consumer driven passenger transportation markets the heavy machinery business needs better matching solutions in data sharing built for B2B and industry with much stricter needs for reliability and security.

Companies are driven to build new value for data but lack the means to do so

The SIX consortium and the investments made by the companies testify the will for the industry to rapidly improve its capabilities to address especially the sustainability goals and embrace the opportunities the electrification could bring to the heavy machinery business. Compared to the consumer driven passenger transportation markets the machine lifespan, cost profile, application energy intensity, end customer requirements and demands for reliability and efficiency are much higher. The level of trust between companies and the data they share has stricter needs for control and security. The applications can be more tailored to customer specifications and the way they maintain and operate the machinery can differ greatly for each customer.

This means that the technologies used in data sharing must also meet the industry grade needs especially considering the data standardization, B2B authentication and API technologies and standards used by the companies. There are plenty of solutions available for intercompany data management, integrations and data sharing but very little yet exists that could create the semantic and trusted data sharing between the companies on the Internet. The dataspace technologies are prominent to address these needs.

Data itself and its semantics

Connecting semantic data to machines and batteries

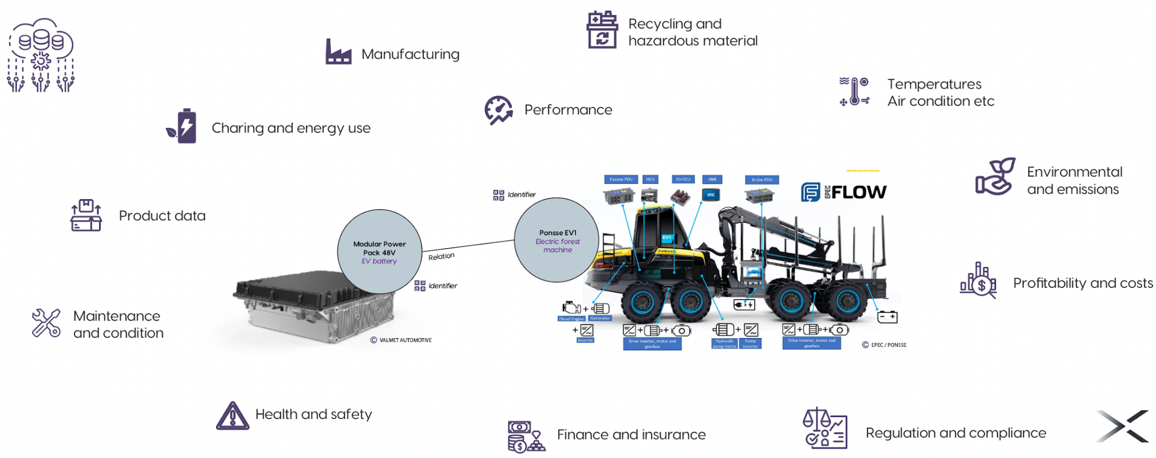


Figure 3. *The battery and machine digital identities are linked to productized data sets from various sources allowing to build rich applications for various use cases. The semantic standardization allows to refine the shared data that currently only meets when handled manually.*

Linked digital identities and unique identifiers makes the digital twins

The key business value for data is created by connecting different real-world stakeholders and their data together. The digital twins (digital identity + unique identifier + context) can be used to link data to create the semantic data models for data sharing in the dataspace. Data can be drilled down to smaller components to machine parts and components to battery cells and chemicals or connected to larger entities by crossing cross-domain data together. Using digital linked identities allows to contextually connect the data with the battery and link it first with the OEM manufacturer's machine and later connect it with the energy storage's rack or recycling plant process at the end of life. This makes it possible to link and carry the data for a specific battery along its entire life. Note that business level harmonization initiatives around digital twins are emerging already in many industries, see e.g. the example from the port logistics and maritime industry (TIC4.0) community which links to the delivery process of the mobile work machine vehicles in the global markets.

Semantic data products are needed for automated sharing

The data lacks standards and is not currently harmonized between companies resulting in poor interoperability and discoverability between systems. The novel Finnish addition to the European data economy is the capability to productize data developed by IOXIO to 1) add semantic structure for both the data inquiry and response, 2) trust controls for release of data only when allowed to do so and 3) the future capabilities of connecting the data market capabilities to the data being exchanged such as pricing and payment controls.

See the actual experimentation for data productization and examples created for the experimentation.

The life cycle of battery data

Information follows the real-world processes and value chains. To meet the set aims for life-cycle data sharing around batteries we need methodologies to contextually connect data to the time and the stage of the specific product's lifespan. This was done by modelling out the set use case processes and understanding how the 1st and 2nd life use cases flow from each stakeholders' perspective. Extracting the identities for each company, machine and component used in the processes made it also possible to model the data being exchanged between these entities in the real value chains thus providing the right contextual data categories.

Using the industry standard baseline, the data was structured and stored in the Testbed's data definitions as harmonized data products. For example, the battery charge cycle history data could be standardized into specific key-values datasets with appropriate industry agreed units defined and named as "Battery/BatteryChargingHistory". Any data provider wishing to publish their product data for the recyclers could map once their API with this data definition with the battery serial number as the inquiry parameter making it possible for others to discover and request the said data from the dataspace.

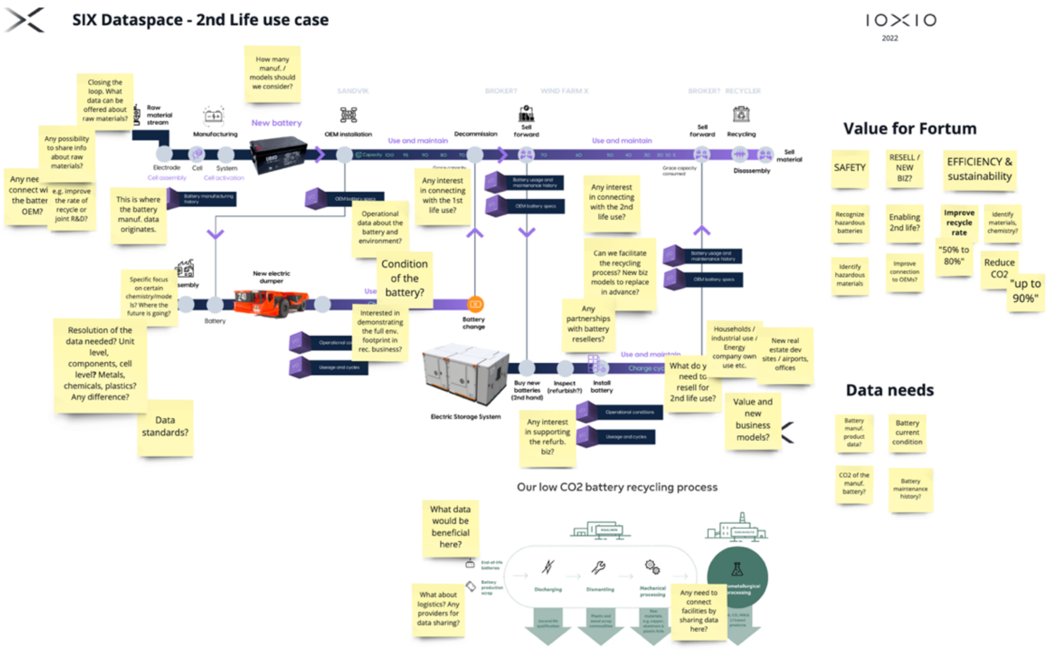


Figure 4. *The data products were modeled from different real-world processes. Contact points were used to discuss different business value achieved in each interaction provided that the different processes and stakeholders could share semantic data in each interaction.*

Controls for productized data sharing needed

The companies naturally were hesitant to share data openly with any 3rd party and are concerned about business-critical data being exposed without their control in the open Internet. The dataspace must enable companies to trust the data they use as well as the party they release their data for use. The data should not be copied rather than kept with the manufacturers and operators and only shared with their specific consent and under the trust framework described below in this chapter.

Anonymization and pseudonymized use of data should be enabled to disconnect the owners and operators of the batteries and machines from the battery data. The data being shared between the 1st and 2nd life cycle ecosystems must be shared so that no sensitive data is not made available without the companies' consent.

Using the proposed dataspace architecture and methods for consented and productized data sharing is believed to produce an adequate solution in the future.

The IOXIO Dataspace architecture used in the experimentation promotes the use of following components to ensure the secure exchange of data:

- Data product transfers
  - Following the common web API practices and subset of the OpenAPI 3.0 the data was harmonized to enable validation and control of the data being shared.
- Data product signatures
  - Providing the ability to verify the source of data product requests and responses via digital signatures ensures that the data is only shared between authenticated sources. JWT tokens signed with RSA keys available over JWKS for verification is proposed for production use.
- Authentication
  - The Dataspaces define the supported authentication method and all applications and data sources on the Dataspace must use this authentication method. All authentication happens over OpenID Connect, and we use the Authorization header in the Data Products.
- Data product encryption and confidentiality

  - Our goal is to provide public-private key encryption-based capabilities for Data Products in the future. Keys will be distributed over JWKS by applications and sources, and the Data Product definitions will likely be converted to a JSON Schema format for validation.
- Group (organization) verification
  - Applications and sources are assigned to groups in a Dataspace, and the groups are used for identifying the parties. Groups will define the JWKS signing domain for their requests and responses, and we can do traditional domain verification, and e.g. check Extended Validation certs on it for additional security and otherwise verify the group ownership.
- Consent protocol
  - Data Product consenting has been prototyped using a Consent Protocol IOXIO has developed based on OpenID Connect. It uses the JWT tokens, signed with RSA keys available over JWKS for verification. The protocol should give the necessary guarantees for identifying applications, data sources, and users, and that the consent has been granted.
- Rulebook for fair governance and use
  - Fair data rulebook developed by Sitra creates the needed legal and ethical framework for the SIX Dataspace. It helps the companies to control who can join the Dataspace and how they behave under the common rules.

Creating scalable data ecosystems for sharing

As the data is still heavily stuck in industry silos the cross-sectoral data sharing rarely happens many of the processes around mines, loading docks, logging sites or factories still run on paper, pdfs and spreadsheets. The major opportunity for automation is lost.

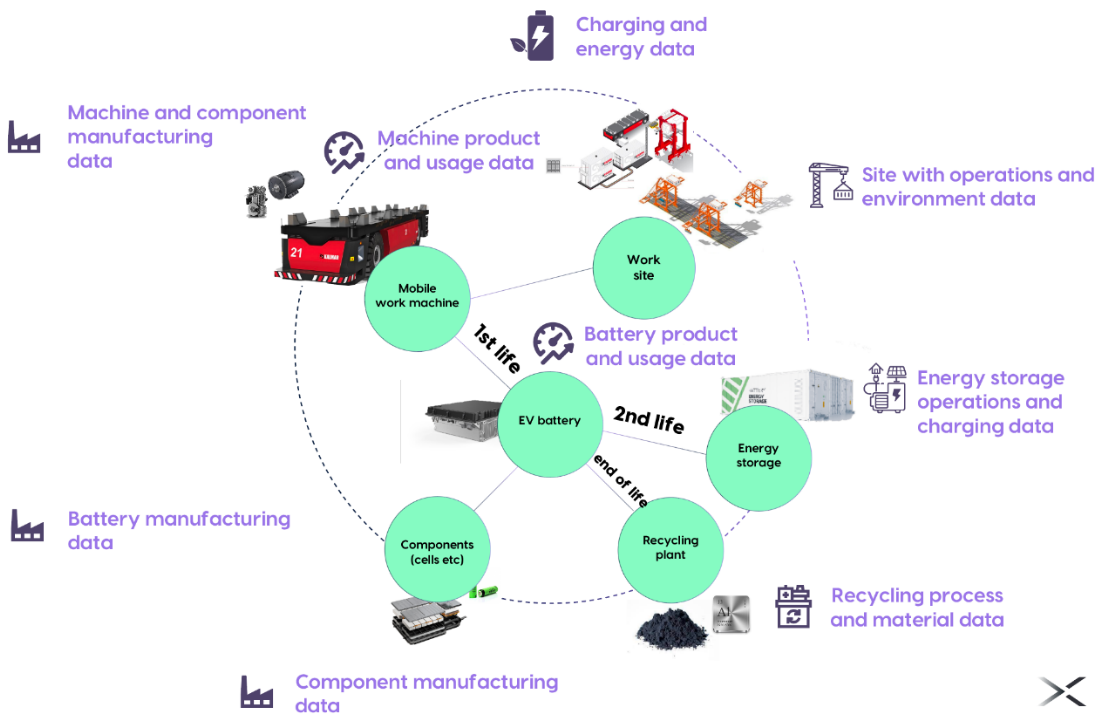


Figure 5. *Recognized first key domain for data around the digital twins based on the value network modeling.*

Based on the value network modeling illustrated earlier the data domains and the systemic information ecosystems can also be scaled to cover a wide variety of different data around the work machines. The data definitions can be made based on various data and industry standards enabling to easily harmonize and share any kind of cross-sectoral data in different contexts around the batteries.

The key value for data emerges when the design, manufacturing, maintenance, and logistics data of the heavy industries meet with the business data the customers have. Connecting euros and dollars to kWh and cubic meters of logged wood to charge cycles yields data that the customer can utilize when running their business using the electrified machinery. As the data is still heavily stuck in industry silos the cross-sectoral data sharing rarely happens many of the processes around mines, loading docks, logging sites or factories still run on paper. The major opportunity for automation is lost.

Key findings around the data shared

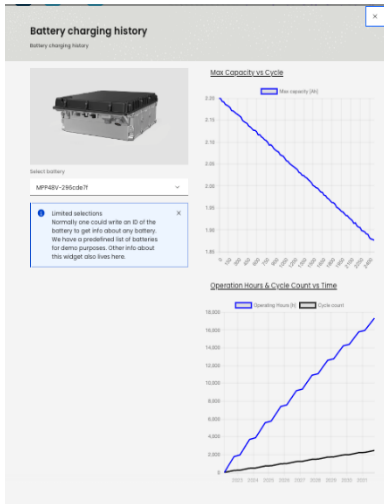
The data is there inside the companies yet the solution to safely and easily share it with the desired 3rd parties without heavy integrations and costly projects are needed.

- Data is still heavily siloed in companies' own systems and in industry silos
  - The utilization of data sharing between companies is rather low
- The data doesn't travel over the gaps in the life cycles yet
  - Sharing data between the manufacturers is increasing but the access to data for the customers let alone second life users is not possible today
- The data is not standardized preventing simple integrations and data discovery
  - APIs are built to each company's specifications
  - There are no common definitions for data exchange
- Battery passport is a good direction towards the first industry scale standards
  - The project started the discussions with international groups working on an industry wide data definition for the battery product data
  - The dataspace was recognized useful in getting the data into the passports
- The data does not go into component level
  - The APIs and proposed data models used in offering the data around the machines and batteries does not allow to drill down to component level data
  - The capability to connect and share data around the battery packs or even cells would help e.g. to better recognize which part of the battery is not performing and thus facilitate the repairs and reuse of the components
- Sustainability data is not widely in use nor available for API based sharing
  - Valmet Automotive has started to model the first carbon footprint data to be shared around the batteries they manufacture
  - The industries see the environmental and sustainability data as an important development topic. The 2nd life and recycling use case studies highlighted the benefits of demonstrating the lifespan value for cost vs. environmental impact for each battery.
  - The project studied the best ways to start with the standardization of at least CO2 equivalent data products for batteries and recognized that it needs more work among the industry stakeholders. Some sort of comparable index for each life-cycle step could be beneficial from the end users' perspective. The CO2 produced when manufacturing the battery should be understandable in comparison to the CO2 produced when powering the machine for an hour using a given primary energy in charging.
- Measuring the actual conditions of the battery has different options
  - Obviously one of the first important information for battery life-cycle use is to understand at each state what is the overall condition and state of the battery and how much life can it still be expected to have in each use.
  - This means comparing the actual performance received to the specifications the manufacturer provides for intended use and making it possible to read this data at any given point during the life cycle.
  - This data is well known at the machine level as the modern work machines and energy storage units can use the battery management systems capable of reading the charge cycles and voltages of the units. It can also be manually measured and read as needed by the operator or at the recycling plant. This information is not easily made available on a 3rd party APIs yet preventing the data to be easily carried with the passport or requested as a historical dataset later in life. Data is there but it's once again hard to get.
- The loopback is missing – especially from the circular economy point of view
  - As the life-cycle data for each unique battery is not yet made available it is hard for the battery and machine manufacturers to know how each unit has performed in terms of energy and charge cycles provided, costs incurred, and CO2 emitted.

    - Understanding this would help to design better performing and more sustainable batteries and machines but also recycle them in a way that maximizes the use of material so that less and less virgin material is used, and the solutions are built to minimize waste in all stages of life. This was one of the use case goals set for the experimentation to study.
- Cloud solutions and APIs are starting to emerge but are still quite rarely offered
    - The project participants are arguably leaders globally when it comes to adapting digital tools and solutions and very knowledgeable when it comes to data utilization.
    - The leading digital edge in the industry has been in the CAD and 3D modelling as well as the manufacturing process, OEM maintenance and vendor support digitalization and logistics automation.
    - The machines are highly intelligent and digital ready with CAN-bus and highly development engine, drive train and battery management systems and computers made ready. The newest machines have capabilities to share data also to the manufacturer's cloud that enables remote access to also for example to battery and charge cycle data.
    - Similarly, the energy storage solutions in the 2nd life use case are built with advanced battery management systems and are often connected to remote monitoring and cloud controls.
    - Naturally the first APIs capable of exchanging data outside of the organizations are thus built to support these functions and the closest stakeholders first.
    - The data is there inside the companies yet the solution to share it safely and easily with 3rd parties without heavy integrations and costly projects are needed.
- Operators are the blockers
    - Following on the previous points the ones who buy and own the machines are primarily offered the access to the manufacturer's current API and data services as direct customers.
    - Understandably it is difficult for the manufacturers to open any more business critical information about the battery use without jeopardizing customer sensitive information about where, how and by whom the machine is being used.
    - To this end allowing for example the recyclers or the end users running a warehouse with leased electric forklifts have contractual difficulties to be allowed to access the OEM data.
    - As this study proposes we need APIs, standardized datasets, and trust capabilities to allow these other stakeholders access to only the data they are allowed to have but in a way that makes it possible for them to use it in their own systems.
    - The dataspace architecture should cater exactly for these needs.
- Different user roles and access levels are needed
    - To allow ecosystems of data end users and different service providers on the battery's life cycle to connect with the right data we need the dataspace to also support the organization and role-based access and authorization solutions to control the data sharing.

First data product definitions used

The first data products identified to create value on the battery life-cycle path and to serve especially the data needs of the 1st life machines operator but also partly the basic data needs on the on the 2nd life and recycling use we selected in the experimentation as follows:



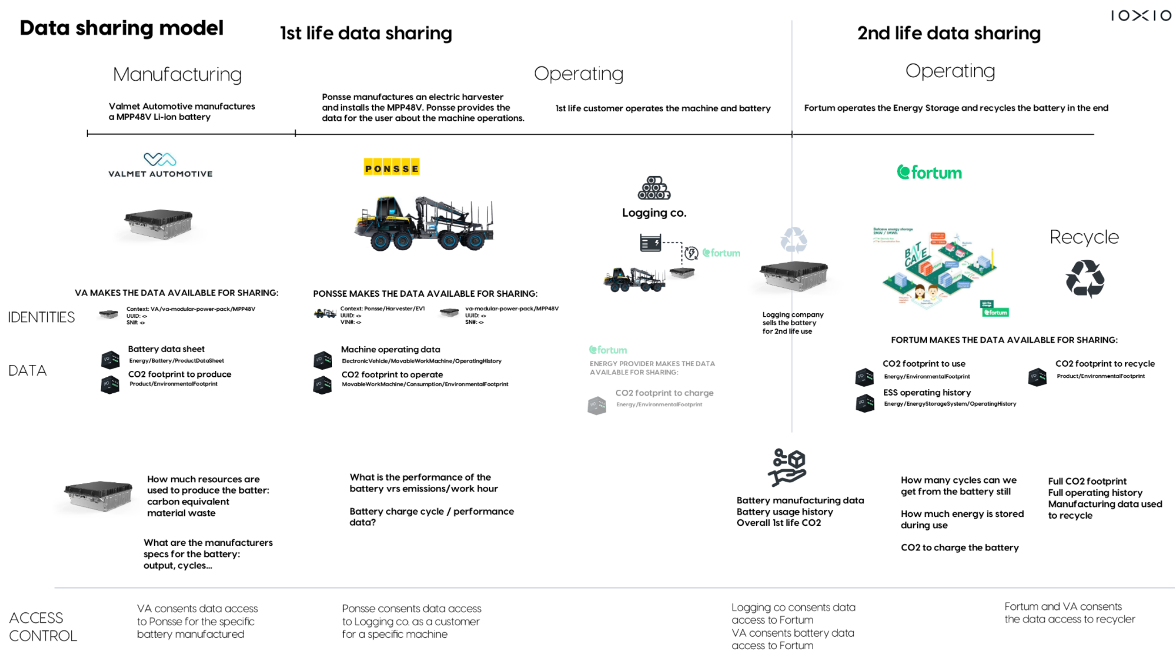
Battery product data sheet
Basic manufacturing details which summarize its performance technical characteristics, materials and use cases of the battery.

Battery Environmental footprint
Environmental footprint measures of the battery after the manufacturing phase of the battery. As the first properties the environmental footprint data product contains the amount of carbon dioxide equivalents and material waste generating the manufacturing.

Battery charging history
Battery charging history shows the history of the operating hours, cycle count for the battery as well as the maximum capacity measured in a specific time span.

Weather metric current
The current weather conditions containing temperature, humidity, and air quality on the site where the electronic mobile work machine is operating.

By using the charging history data from the machine manufacturer APIs, the overall and current performance of the battery can be analyzed better and with the help of e.g. some external data sources like the weather data it can significantly help with decision making for the 2nd life use, for example.



Dataspace solution proposal

Dataspaces represent a new type of integration ecosystem and a set of both business, governance, and technical solutions to overcome challenges with the current data integration systems. Dataspaces gives the tools and capabilities to make especially the cross-organizational data exchange easy and scalable which with the legacy integration solutions is challenging and costly. Therefore, dataspaces hold the great promise to fulfill the future business and sustainability operation needs with data in the industry businesses.

The IOXIO Dataspace SaaS governance model and technical architecture are based on the rulebook and open architecture work lead by Sitra in its fair data economy projects. The architecture itself emphasizes the use of currently and widely used Internet standards and not creating any new technology stack components where isn't necessary. As the key component, the IOXIO Dataspace SaaS inherently supports *data products* and their contextual definitions as well as out-of-the box tools for business and technical users for managing the semantic definitions that both humans and machines can understand. Data products also create the base for the consenting, i.e. which gives the control of who can use the shared data and for what purpose. You can read more about the current the open architecture, dataspace integration guides and available tools on the Virtual Finland testbed site.

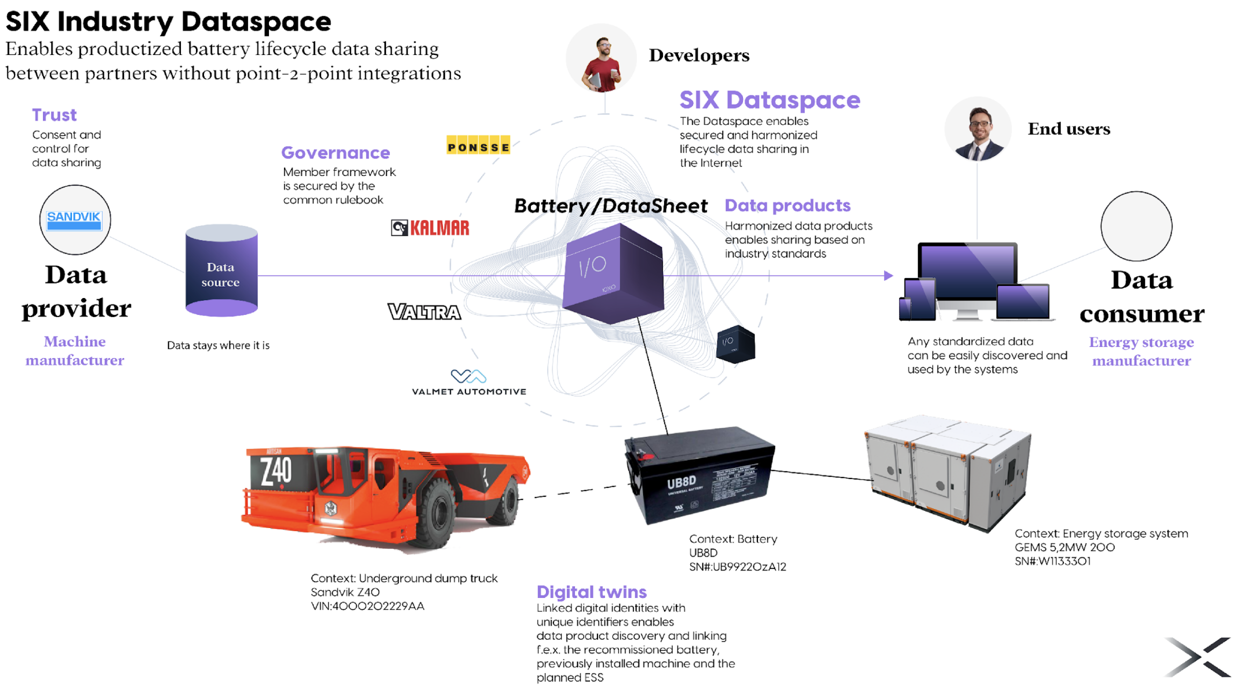


Figure 6. *The components of the IOXIO dataspace solution adapted to the use case in the experimentation.*

Note! The image is illustrative only and the use case is not correct in detail.

The key capabilities that the dataspace should support

- Open architecture and open standards built on commonly available Internet standards
- Semantic interoperability for data
    - Data productization enables the packaging the data behind the APIs so that both the semantic interoperability and universal controls for data sharing and discovery can be technically offered
- Digital identities and digital twins
    - Minimum level requirement is the standardization of common unique identifiers so that the data can be linked to specific products and machines both in internal enterprise solutions as well as towards the dataspace when sharing data
- Trust and consenting for data sharing
    - Authentication, cryptographic signatures, consents and other previously listed trust capabilities are required
- Ethical and legal framework – the rulebook
    - The companies must be able to agree how the dataspace is governed and what are the terms in offering and consuming data on it. Rulebooks offer both the business as well as the technical framework to do so
- Developer and end user services
    - Certain tools are needed for the data providers and application developers to be able to integrate and use their software on the data space.
    - End users maybe wished to have tools to grant and manage for example their consents for data sharing and perhaps enroll and authenticate themselves in different applications. This requires certain applications to be built just for them.
- Dataspace core capabilities for data sharing
    - The dataspace architecture points out the key centralized capabilities the dataspace has for productized data discovery, definitions management and use, transfer, and traffic monitoring.
    - The productizers (close to connectors in IDSA) are required as decentralized components to integrate data sources once with the dataspace with added capabilities for semantic interoperability and trust for data release.

Quick implementation test on the Testbed

The Virtual Finland testbed running on the IOXIO Dataspace SaaS service was used as the enabler of the trusted data exchange experimentation in the battery life-cycle use case. The quick implementation test lasting three months during the autumn 2022 resulted four key results to proof the business value for the future.

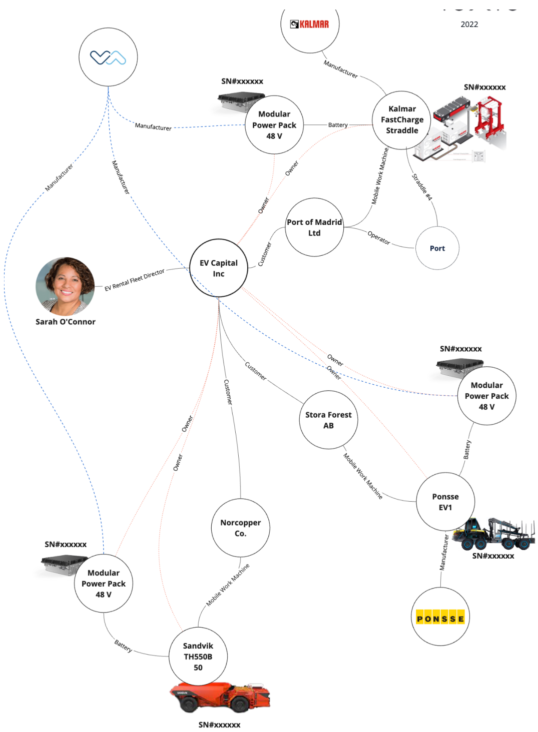
The use case demonstrated how the battery and machine life-cycle data can be shared semantically in a data sharing ecosystem with scalable partners, data sources and software using the data

A simple end user environment was modelled on the Testbed with data products defined for specific Valmet Automotive 48V Modular Power Pack battery system and Ponsse's and Sandvik's work machines.

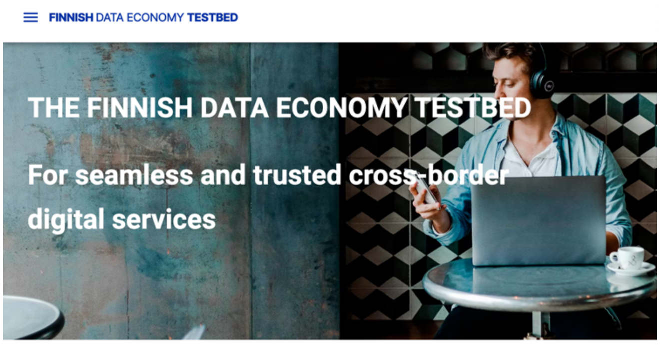
The first data product definitions were made with Valmet Automotive and Ponsse, Cargotec/Kalmar and Sandvik experts to create the first scalable data models to be shared in the experimentation. IOXIO data standardization experts then took them as open standards on the Testbed to be used by different APIs.

IOXIO developed a sample data sources and APIs in the cloud matching to Ponsse and Sandvik machine data and Valmet Automotive battery data. The data was synthetic but standardized to meet the production grade structured data. These were registered on the developer portal on the Testbed and made available for other stakeholders to request.

Open architecture data productizers were built to connect the APIs with the Testbed and to enable data access for the developed showroom application. The productizers also demonstrated the capability to consent the exchange as well as to authenticate the data providers and data consumers in the dataspace.



Note! The image is illustrative only.



The products were given a digital identifier to make the contextual data sharing possible around unique digital twins. This would open the possibilities to link the data products with any existing system and to design environment used in the manufacturing and operations.

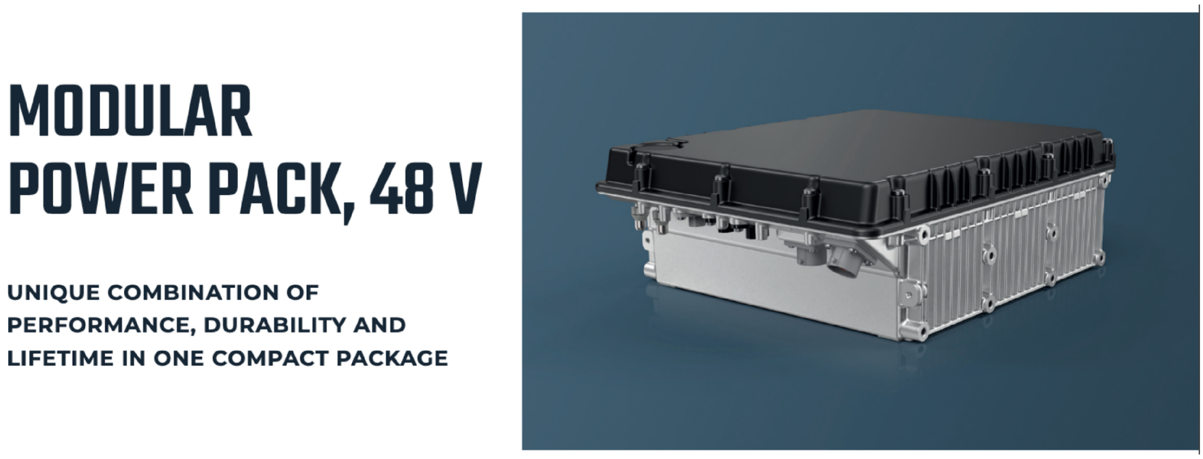


Figure 7. *Valmet Automotive's Modular Power Pack 48V battery system is used in the new Ponsse EV1 electric forest machine technology concept. It provides a great example for future-oriented data use and smart batteries and was used to model the shared data in the first use cases. Image by Valmet Automotive.*

User interface used to visualize data being shared

IOXIO created a Showroom example application registered on the Testbed to demonstrate how the productized data can be used in any web application or system capable of discovering and accessing data from the connected data sources in the dataspace.

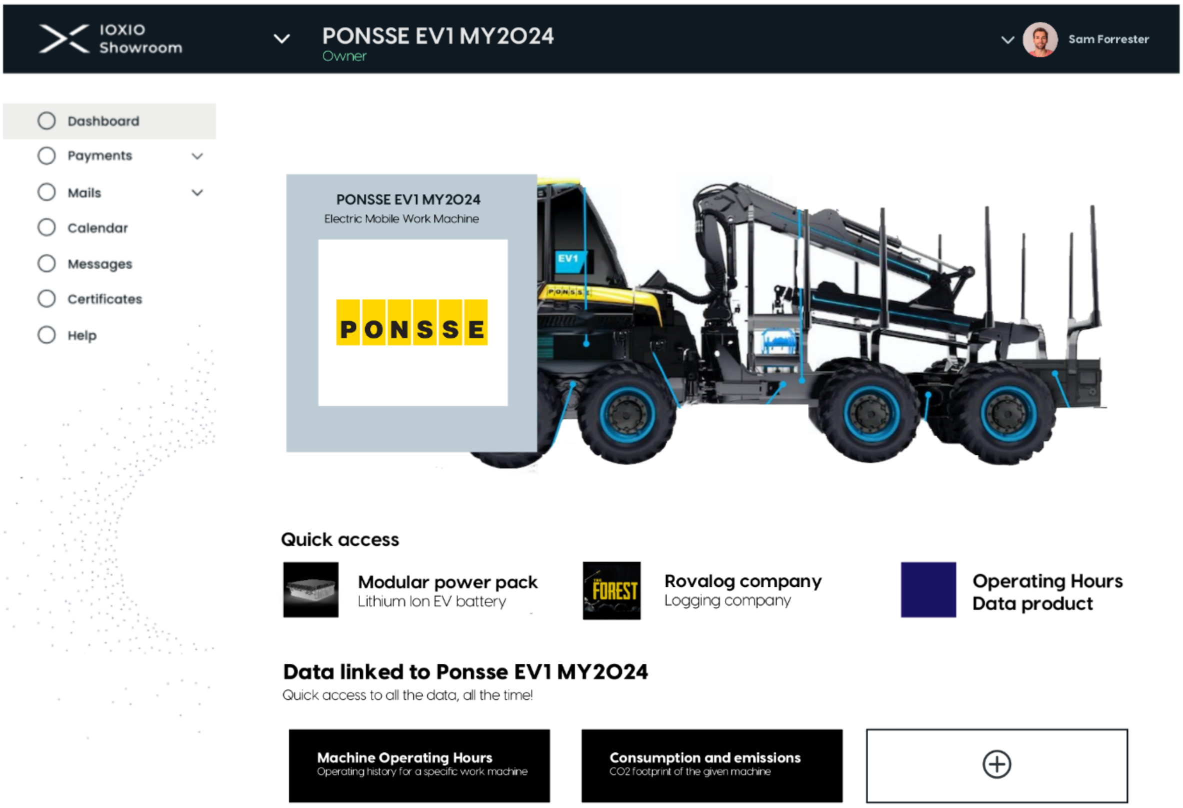


Figure 8 . *IOXIO built a showroom application connected to the Testbed to demonstrate how the digital identities can be linked with role-based controls and how the productized data can be shared between companies from the decentralized data sources made for Valmet Automotive, Ponsse and Sandvik.*

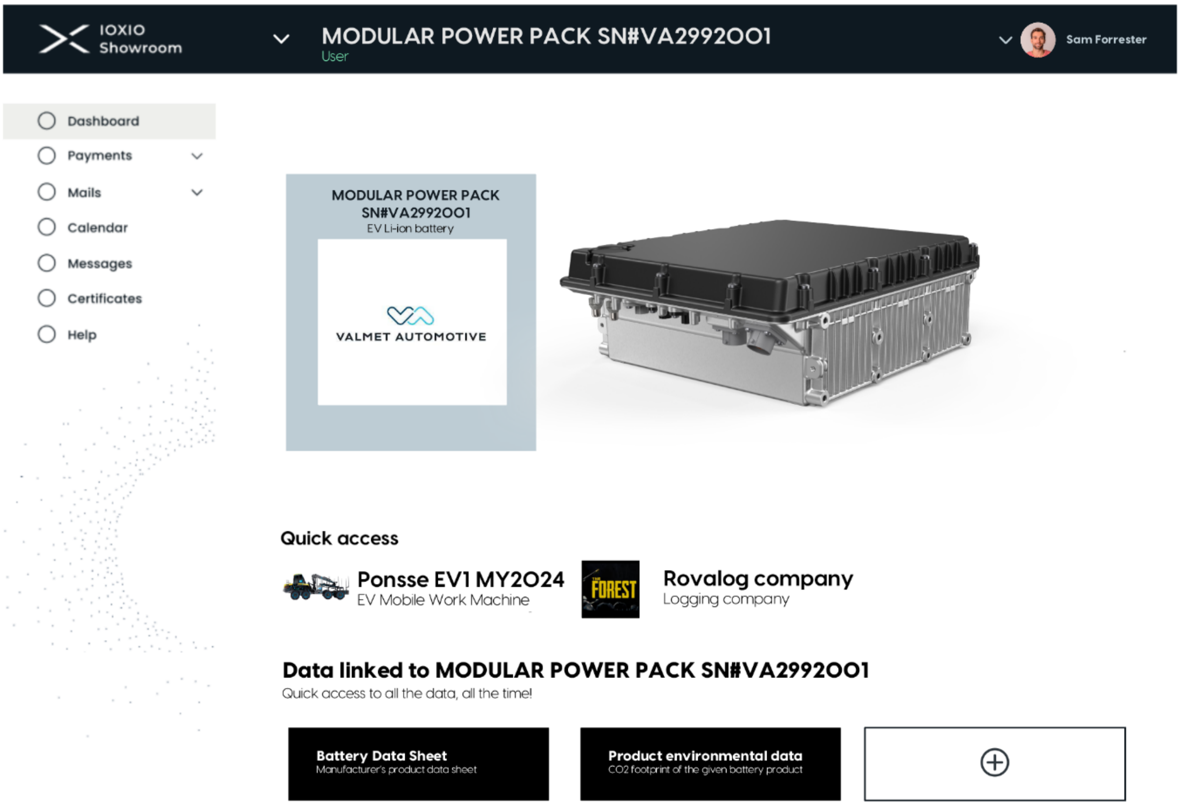


Figure 9. *The batteries can be linked to machines and data products allowing unique products to connect also with energy storage systems and recycling facilities in different stages of their life. The data follows the products and is linked from the controlled data sources.*

The showroom demo application demonstrates an example business case how Sandvik, Kalmar and Ponsse mobile machine fleet using Valmet Automotive's electric vehicle battery systems can be better managed by exchanging data in a trusted manner between stakeholders along the battery life cycle.

Key results from the experimentation

1. Battery and machine data can be structured and standardized

Open data definitions for the battery 1st life use cases were defined and made available on the testbed. First try outs were done using four different data product definitions:

- Battery product data sheet
- Battery Environmental Footprint
- Battery charging history
- Weather data

2. Dataspace around mobile work machine data sharing can be built

Prototype Dataspace was set up and maintained for building and testing easy integrations towards applications and data sources for exchanging data in a trusted manner. The self-service tools and guides of the dataspace serve both battery and mobile machine manufacturers as well as any third party to build integrations easily. The Virtual Finland testbed rulebook applied from Sitra's data economy rulebook exists and works as an example contract and governance framework for applying to any data exchange needs between the industry partners willing to setup their own dataspace.

3. The standardized data can be shared between stakeholders in the Internet
Demo data sources simulating the existing APIs of the battery and mobile machine manufacturers ERP and similar IT systems were built and connected to the dataspace. They demonstrate how any current API can be adjusted to the data product definitions and the data from the existing APIs to be linked and shared in an easy but controlled manner to other parties in the same dataspace.

4. Value for the business users can be demonstrated
As part of the IOXIO showroom, a use case around mobile work machine leasing company was built to demonstrate how digital twins and exchanging data products around them can help business managers of a leasing company to better understand how their fleet of work machines is performing and how they are used in a most valuable and sustainable way and how the data can help in better decision making during the mobile work machine and connected battery life cycle.

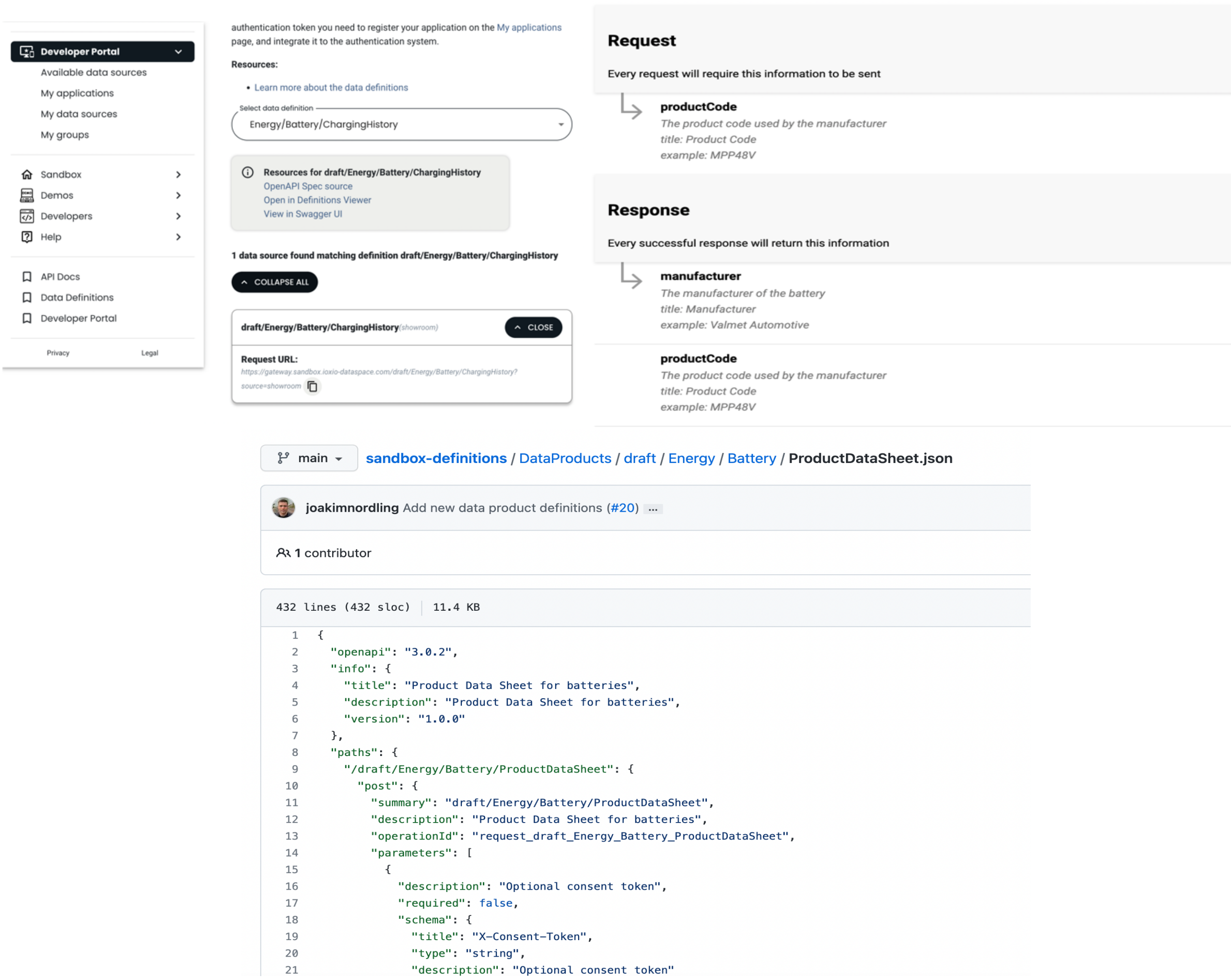


Figure 10. *The actual productized data was defined and shared using the OpenAPI3.0 standards. The main addition on the IOXIO Dataspace and Sitra's fair data economy work was the introduction of standardized input query parameter that makes the semantic data discovery as well as data sharing possible in the dataspace. Both input and output values are standardized for each data product. This capability is still lacking from the European dataspace initiatives, e.g. IDSA and Gaia-X.*

Conclusions and recommendations

Dataspaces seem prominent to help share data around battery and machine life cycles

The project achieved the set main goals to evaluate how SIX consortium set business cases could benefit from semantic and trusted data sharing made possible by European dataspace architectures and patterns. The project also connected with European consortiums such as IDSA and Catena-X for further validation. The conducted practical experiment and this report provides concrete means for SIX to continue discussions between Finland and Germany to deepen the collaboration further towards production use within industry partners.

The value network and process driven modelling was used to gather the understanding on how to create scalable data ecosystems around batteries and work machines with Valmet Automotive as the battery system supplier and Ponsse, Sandvik and Cargotec/Kalmar as experts in work machine data. The project gathered common understanding of the first data that could be standardized and shared. The work also demonstrated the capabilities and building blocks needed to build the functioning data space based on the identified industry requirements. The conclusion is that the proposed methodologies could be used to build a scalable data ecosystem around the work machines for different business use cases, data sharing partners and data providers towards full scale global data sharing use.

The first data space architectures and data sharing technologies provided by IOXIO were put to test in on the cross-border data space offered by the Ministry of Foreign affairs. SIX consortium members defined the data and API specifications to be validated in the experimentation. The Proof of Concept delivered the concrete examples on how the technologies, architectures and the juridical framework would work. They proved to work especially in enabling the semantic interoperability and decentralized sharing of data where the companies can retain the control over the data they share. It should be noted that the trust capabilities were not put to full scale test, and we conducted the first experimentation with synthetic data without real production APIs used. The technologies should put through more exhaustive tests next.

There is work still left to do both in the business development and technical readiness. The report describes the findings in both terms of business and data. Yet as a main conclusion there were no final showstoppers found that couldn't be solved. The readiness for data sharing is high with the companies, SIX already promotes the common business model development and data space technologies deliver adequate solutions to move forward.

There is a strong demand for industry to open data

The market drivers seem to all push towards more open access for data especially in Europe fuelled by the European Commission's data strategy and regulation and globally by the green shift towards more transparency for data for the sake of sustainability and efficiency. The battery passport regulation and the EU Data Act sets concrete deadlines for companies to open product data and promote the 3rd party use of battery and machine data. The dataspaces could help retain the control of their data with the manufacturers yet provide ways to create new digital business by enabling consented and standardized access to battery data.

The SIX industry use cases could scale out to industry scale solution

The use cases set for 1st and 2nd life stages have both traction and commonly identified new business opportunities amongst the different stakeholders. Provided that the data can be securely and easily made available there seems to be good grounds for common development that supports the SIX consortium long term targets.

Enabling the life cycle use of data around the electric work machines and their batteries seem feasible given that we solve the key business and technical barriers that still exist. The study concludes that the data and the understanding on how to use it is there. We are still mainly missing APIs for 3rd party data access the companies can better control, first business models to better support battery reuse and recycling data sharing, common semantic definitions for the life-cycle data. The first production grade dataspaces should be built among the companies to provide the needed capabilities to share the data in everyday business.

Suggested next steps

- Publish the first results of this work with Sitra regarding the 1st life results and the experimentation so far
  - Agree about the common communication plan
  - Create a short video and case web site to help communication
  - Consider opportunities to speak about the case also in the international industry events
- Capabilities have been tested and demonstrated, next innovate around data business models and value
  - Merge business and demo tracks within the SIX consortia
  - Common data innovation workshop(s) recommended next to plan how the tech track could support more concrete business case development
- Consider establishing SIX industry data space first as a consortium owned testbed
  - Move in stages by creating the first own SIX testbed to allow further experimentations and widening the use cases by introducing real industry APIs, battery passport tags and software to test out the real-world life-cycle data sharing around real batteries and machines
  - Create a plan towards SIX production grade dataspace to support companies to rapidly develop the data sharing capabilities also requested by the EC regulation and the battery passport till the end of 2024
- Continue improving the data product definitions and link e.g. to the Battery passport standardization
  - Feedback welcome on the common first standards
  - Consider how to extend them to better cover partner needs
    - how to better support business use cases and e.g. CO2 foot print
  - As summarized in this report, the market drivers for data sharing of companies and technical proposals around dataspaces are many. The key thing, however, is not to lose the track on the data semantics and the definitions of *data products* which creates the baseline why, how and to whom the data will be shared.
- Participate and start influencing the international battery passport development
- Support any party willing to test out and experiment data sharing with their own test APIs
  - Discussions ongoing with Ponsse, Sandvik and Cargotec/Kalmar to move forward in practical experimentations and support companies own API development
- Continue evaluating the 2nd life data needs and business models
  - Ongoing track with Fortum, everybody is welcome to join
  - Recommended to join the 1st and 2nd use case tracks together to cover whole lifespan
- Tighten the collaboration towards the European initiatives, especially regarding the standardization initiatives, e.g. battery passport modeling
  - Consider joining the Catena-X consortium and present the results of the SIX work and this data space experimentation as a concrete way forward