

UK Energy Storage Lab Project

Public Report

January 2020

Element Energy Ltd

Sarah Clements

Lisa Ruf



Department for
Business, Energy
& Industrial Strategy



This report provides detailed public information on the UK Energy Storage Lab project

Aim of report

- The primary purpose of this report is to provide detailed information on the UKESL project
- It is publicly available and can be shared with any interested parties
- All project partners and the Department for Business Energy and Industrial Strategy (BEIS) have access to the report
- The report is also available on Element Energy's website

Content

- Project mission statement and overview of project partners
- Introduction to the topic of battery repurposing and second life applications
- Key objectives of the project
- Description of the battery packs and modules; and new state of the art techniques for processing
- Use cases and market sizing
- Wider implications of the project

The UKESL project aims to demonstrate grading and sorting of end of life EV batteries, for the first time in the UK

UK Energy Storage Lab (UKESL) project





Project Mission: Reduce the cost of stationary energy storage by opening the UK's first facility for grading and sorting end of life Electric Vehicle (EV) batteries

Total Project Costs: £1.4m part funded by BEIS (£900K) as part of the 2017 Energy Storage Cost Reduction Competition



Department for
Business, Energy
& Industrial Strategy

There are 4 key partners involved in the UKESL project, each with different roles and responsibilities:

Partner	Description	Role in project
	Nissan Manufacturing UK (NMUK) is the UK's 2 nd largest auto manufacturer responsible for producing 4 different Nissan models	Lead beneficiary. Responsible for facility specification, handling the logistical operation and opening the facility
	Warwick Manufacturing Group's Energy Innovation Centre is the UK centre of excellence for battery research	Responsible for module characterisation and testing
	Ametek is a leading global manufacturer of electronic instruments and electrochemical devices used to test novel battery technologies	Work alongside WMG to develop process of grading battery modules. Provide necessary equipment
	Element Energy is a specialist low carbon energy consultancy with a reputation for ambitious and well managed projects	Project Manager. Responsible for overall project coordination and reporting & dissemination

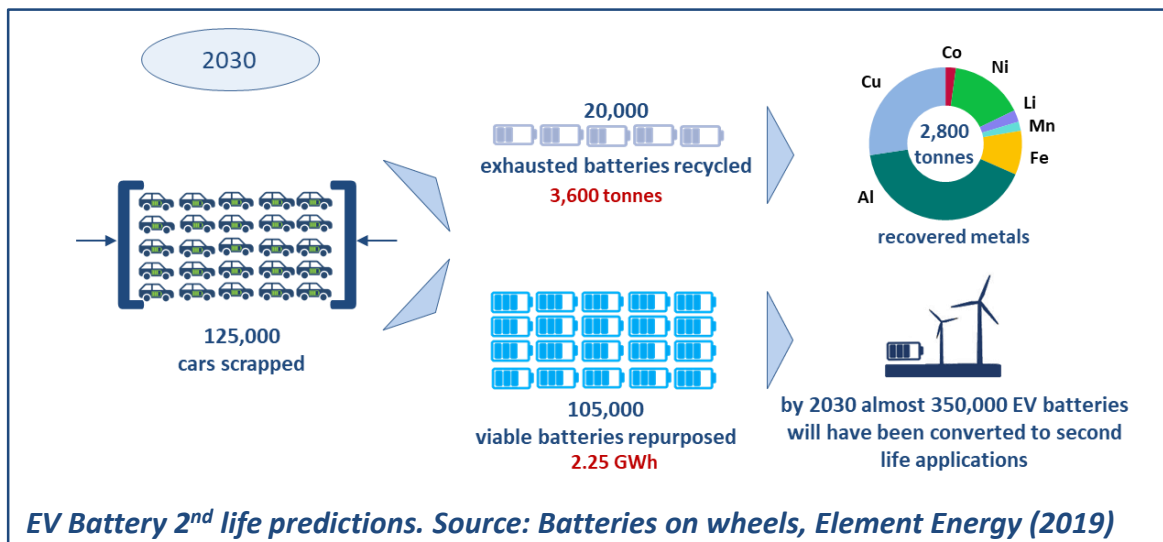
Battery repurposing is crucial to extending the life of EV batteries, for use in stationary storage applications

Why is battery repurposing needed?

- EV uptake is predicted to rapidly increase in the next decade. There could be 20 million EVs on the road in Europe by 2030, and over 100 million by 2040¹
- The first wave of EVs ending service will hit in the early 2030s, which means there will be thousands of end of life batteries to be managed
- Batteries contain precious metals and require large amounts of energy to create, therefore it is important to recycle or repurpose them effectively



Nissan LEAF Battery Pack



Different end of life options for EV batteries:

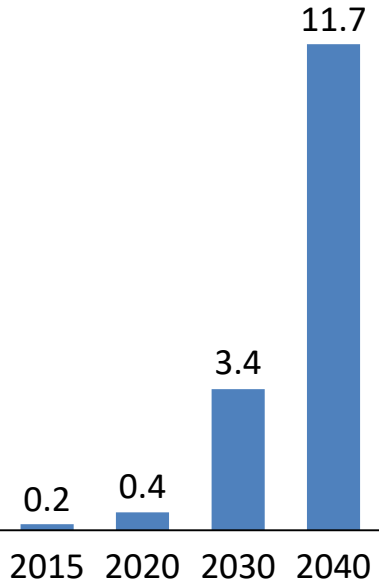
- 1) **Recycle the materials**
- 2) **Recondition** (mild degradation only) – replace degraded modules with new ones and reuse in EV applications
- 3) **Repurpose** – reassemble different packs for use in stationary energy storage as 2nd life applications

This project provides a link between the increasing supply of automotive battery packs and energy storage needs

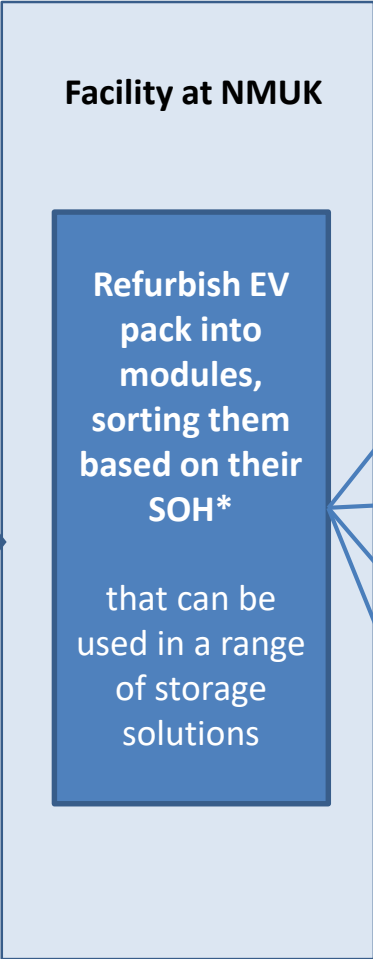
How does the project address this challenge?

Electric vehicle market expanding fast

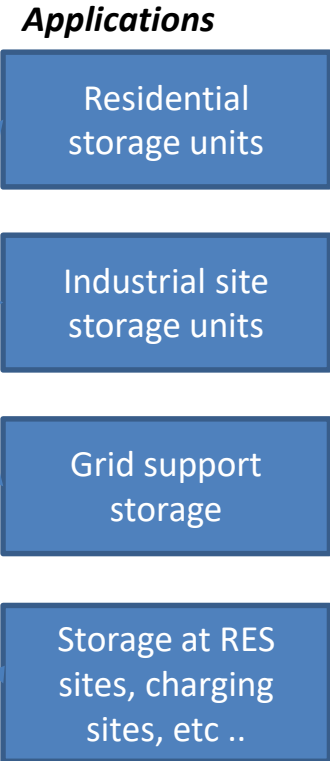
European annual sales, million¹



Source: **elementenergy**



The increasing energy storage need



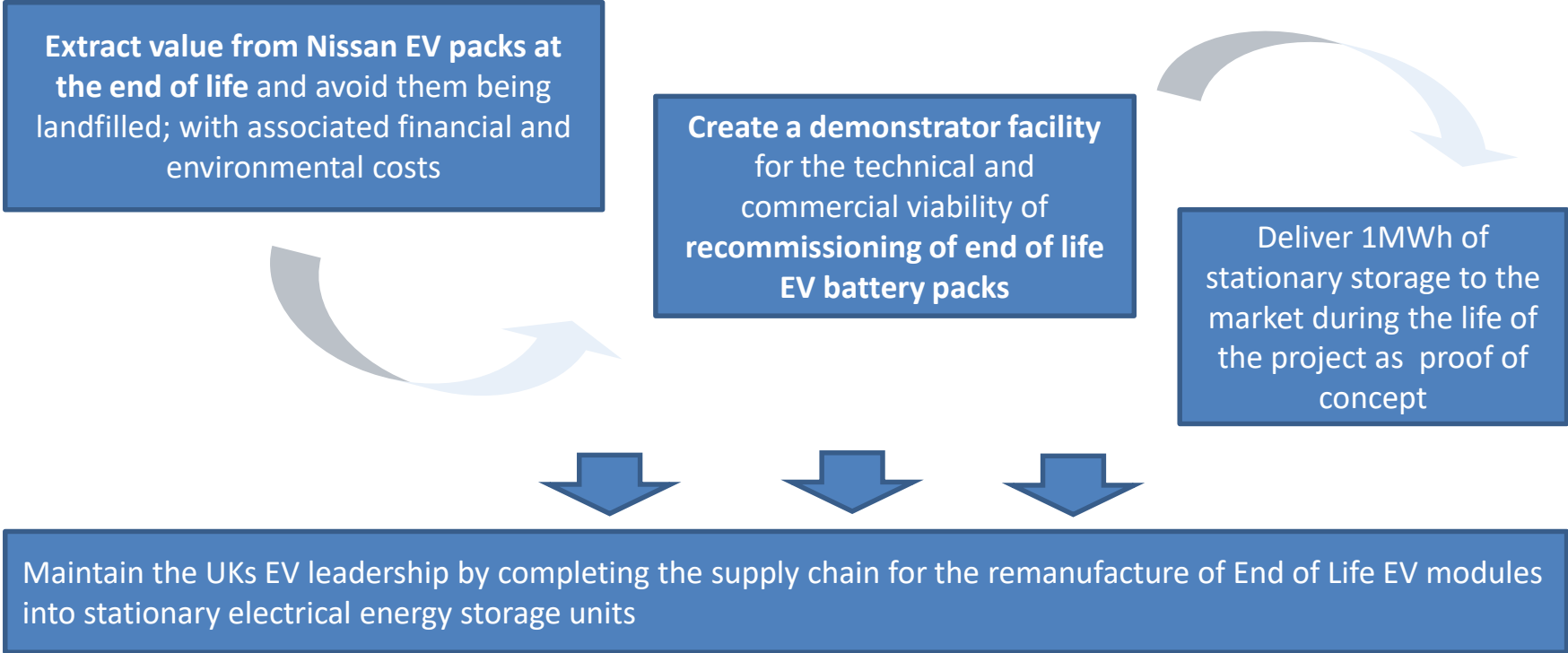
Increasing need for storage to support intermittent renewable generation and smarter use of the network/integration of new loads, including EVs

1 – Batteries on wheels, Element Energy (2019)

* State Of Health (SOH)

There are several key project objectives, most notably, extracting value from EV packs at the end of life and maintaining the UK's EV leadership

Key objectives



Comparable capabilities currently exist in the USA however the technology development is on-going and the economic and carbon cost of logistics are significant. This UKESL project seeks to bring this supply chain into the UK to supply domestic needs and those of Europe.



EV battery packs are made up of 192 component lithium ion cells which are grouped together to form modules and then packs

Information on battery pack components and grading for State Of Health (SOH) assessment

- Electric Vehicle batteries are made up of cells, which are grouped to form modules, and modules are then grouped to form battery packs
- Overtime, as the batteries are used to power the vehicle, the cells degrade
- This degradation of cells happens at different rates – therefore some cells / modules will have good State of Health (SOH), despite the battery no longer being fit for use in vehicle applications
- Understanding the SOH at these packs and module makes it possible to determine which modules can be repurposed for second life applications. Modules with a SOH of > 65% are deemed sufficient for use in energy storage applications and modules with lower SOH can be used in other specific applications
- Those that do not have sufficient high SOH readings will be recycled
- Within the UKESL project new grading techniques have been developed for both pack-level and module-level SOH assessment



Determining a used battery's state of health involves comparing it's remaining battery capacity to the capacity of a brand new battery

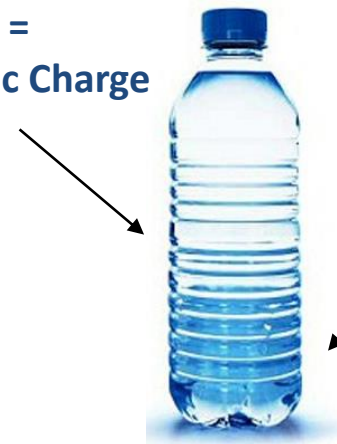
What does battery grading actually involve?

- Battery State of Health (SOH) is a measure of the battery's ability to store and deliver electrical energy, compared to a brand new battery
- Determining a battery's state of health can be achieved by a variety of measurements – such as internal resistance, remaining capacity and charge and discharge cycles
- Evaluating the remaining capacity involves charging the battery until it is fully charged to see how much charge the battery can hold
- This value is compared to the original battery capacity (when new) to determine the SOH
- For example the Generation 1 Nissan LEAF has a new battery capacity of 24 kWh. So if the used battery has a capacity of 17 kWh, the SOH is 70%

Filling up a water bottle can be used as an analogy for determining SOH:

- A standard plastic water bottle holds 100ml of water.
- A used plastic water bottle can get damaged and crumpled, and so cannot hold as much water as the new bottle.
- Filling up the water bottle after it has been used for a couple of months you may find that the water bottle only holds 70ml of water.
- The bottle can only hold 70% of its original capacity. That would translate as a SOH grading of 70%.

**Water =
Electric Charge**



**Bottle =
Battery**

The new grading methodology developed by the project partners supports processes suitable for the mass manufacturing environment

Stage 1 - Battery Pack Grading



Battery Pack graded using Bitrode cycler



- A methodology was developed to test complete packs for suitability in 2nd life applications with a test program using a Bitrode cycler
- The facility set up for the testing currently has a maximum potential throughput of 6 packs/day
- The grading approach involves 2 tests :
 - Characterisation test – provide readouts of the internal resistance (Ri) & the remaining capacity (as a measure of voltage or SOH)
 - Power test – Ability to charge and discharge
- The graded battery packs with appropriate SOH are used in second life applications directly or are disassembled and sent for individual module testing (for applications that require modules)

Stage 2 - Battery Module Grading



Battery Module graded using EIS technique



- A new state of the art module testing technique developed by WMG, involving Electrochemical Impedance Spectroscopy (EIS) to determine module SOH
- The test currently uses the Bitrode module cyclers
- This technique is expected to reduce the grading time from 3 hours to < 15 minutes

*Further developments are underway as an extension to the project's original scope: **Tooling to do EIS testing at module level is being developed by Ametek.** The newly developed module cyclers will have on board EIS testing channels for multigrading up to 50 modules (compared to 2 for the Bitrode)*

Second life batteries provide reliable and convenient energy storage options to a range of end customers

There are 3 key customer types for energy storage:



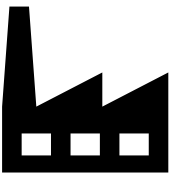
1) Roaming Customers

- Those customers who require an energy supply when on the move
- Nissan has already presented a concept made with two second life modules (700Wh) and 1kW power that will allow customers to have access to electricity when outdoors



2) Home Storage Customers

- Batteries enable customers with solar panels to store the energy generated for use when they need it (so the electricity doesn't get wasted)
- Nissan has been working since 2016 on second life battery residential solutions (e.g. xStorage Home with EATON)



3) Business Customers

- Industries with large energy consumption can utilise batteries to store energy from the grid when it is cheapest (overnight) and then utilise it within the day
- A good example is the ESS project in the Johan Cruijff Arena (2.8MWh) in Amsterdam which uses a mix of new batteries and second life batteries
- Within business, a critical end user is the electricity network. The inclusion of 2nd life batteries on the electricity grid means that more intermittent renewable energy capacity, e.g. wind and solar, can be stored and injected into the grid
- This allows renewable energy generated at times of high production to be stored for use at times of high demand, i.e. at peak times in the morning and evening



Wider benefits include both environmental – increased renewable energy, and economic – reduced cost

Environmental benefits

Economic benefits

There are several wider benefits of the UKESL battery grading facility

Reduced CO2 emissions



Reusing batteries for other applications means that less manufacturing energy is required, so less emissions released

Reduced cost of battery storage

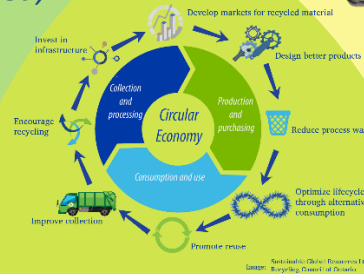


30% reduction of costs for modules to be used in stationary storage are expected from this pilot facility

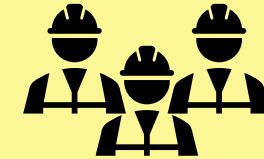
Enabling increased renewable energy on the grid



Battery storage enables increased intermittent renewable energy sources to be used without putting security of electricity supply at risk



Part of the circular economy
Modules/Cells have the potential to be reused several times before they are recycled or disposed of



Creation of jobs

During the project (pilot line) 2 direct jobs were created. In the future, with the deployment of the second life grading more jobs could be created

Less rare metals mined

Less raw materials are required for the manufacturing of batteries as they are reused



Reduced cost of recycling



Less recycling of materials is required as the modules are used in second life applications

The UKESL project has several key achievements – notably it's the first time battery grading has been demonstrated outside of the lab

Key achievements

- This is the first time that pack grading methodology has been demonstrated for volume manufacturing outside of the laboratory environment – ‘first of a kind grading facility in the UK for end of life battery packs’
- The project successfully graded 1 MWh of Generation 1 Nissan LEAF battery packs as a proof of concept
- This was possible thanks to the development of a safe, robust and fast grading testing methodology for Lithium-ion battery packs by WMG, suitable for production environment
- Additionally, novel algorithms for battery modules were developed by WMG for use in specialist equipment supplied by AMETEK. This methodology reduced grading time from four hours to less than five minutes per module, with a proven accuracy of $\pm 3.2\%$ in State of Health
- Newly developed tooling for module processing will enable delivery at scale with EIS testing channels for multigrading up to 50 modules (compared to 2 for the Bitrode)
- Commercialisation above and beyond the project is being developed by Ametek – with the launch of their new product in 2020



Each of the partners will engage in further exploitation, helping to develop the second life battery sector

Further exploitation



- Ramp-up scale of grading facility so that more packs can be processed
- Nissan hopes to re-use the vast majority of packs currently assembled in EVs in Europe
- Potentially integrate module grading technique once fully certified
- Second life batteries provide reliable and convenient energy storage options to a range of end customers



- Publishing of Academic Papers on the methodologies developed throughout the project, which will help to advance learnings in the sector
- Funding an Engineering Doctorate programme with AMETEK to continue algorithm development for other battery cells



- AMETEK have registered a patent for the integration of WMG's grading algorithm into AMETEK machines
- The new grading process and the methodology in the patent will be applicable to other OEM battery modules
- AMETEK will announce commercialisation of prototype at ECS show in October to generate interest for 2020 commercial sales



- Exploit key learnings of battery equipment and storage/state of health requirements in other strategic consultancy work going forwards