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Alex Hunter – CEO
Sherwood Limited (t/a Sherwood Power)
Wed 31st Aug 2022

Purchase Order number: 415000050819
Tender number: 5383/10/2021

Title: CO_2 and NO_X reduction at temperature controlled fast moving consumer goods [FMCG] distribution hubs, replacing red diesel with electricity to power auxiliary trailer refrigeration units [TRU]

SHERWOODPOWER
BALANCING ENERGY

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Contents:

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Project description & introduction:

The project forms part of the BEIS NZIP Industrial Fuel Switching competition supporting the following objectives:

- Demonstrate potential for industrial greenhouse gas emissions reduction via industrial fuel switching technologies for UK industry to reach Net Zero.
- Demonstrate the potential commercial viability of industrial fuel switching solutions.
- Gather evidence to inform future industrial decarbonisation policy making, such as supporting the delivery of the Industrial Decarbonisation Strategy, Industrial Energy Transformation Fund, and further understanding of hydrogen and electricity use in industry.
- Increase awareness of potential industrial fuel switching solutions and technologies, by collecting and disseminating findings across industry and investors.
- Strengthen supply chains and skills for industrial decarbonisation around the UK.

Through April to August 2022, Sherwood Power and team have investigated the feasibility of a fuel switching technology for cold storage hubs across the UK. The study is focused on retail cold storage, replacing red diesel-powered trailer refrigeration units [TRU] with electricity to reduce CO2, NOx and PM particle emissions.

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Project description & introduction:

When the TRUs are docked at a cold store depot without the tractor connected, the TRU refrigeration is powered by a built-in diesel engine to maintain the TRU temperature and prevent product spoiling.

Project Aims

The project aims to look at the feasibility of replacing the diesel motors with a docking station electrical connection (shore supply), so that when the TRUs are at the distribution hub, the TRU can remain refrigerated during the loading process, without polluting the local air. The project will explore ways to meet the additional electricity capacity to replace kWh diesel with kWh electricity, during loading and when standing at the parking bays awaiting dispatch. It will determine the peak electrical demand (kW) across 10 loading and 10 parking bays, quantify the additional site capacity (kW) and energy (kWh) required. Also identify operational opportunities through the switch to TRU electrification.

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Executive Summary:

Sherwood Power delivered the BEIS Industrial Fuel Switch feasibility project at a retail temperature-controlled depot ably assisted by our retail and project partners I C Consultants, Colehouse Communications, with a broad subcontract base including mechanical and electrical, IoT data acquisition, logistics management, refrigeration and trailer manufacturer and site facilities management. The project was delivered on time and within budget, a credit to the hard work from all involved.

Replacing diesel liters with kWh of electricity is not easy, while the infrastructure is in place for diesel distribution and bulk storage the same can not be said of the electricity distribution network. Replacing the TRU diesel use when docked requires a capacity increase of approximately **500 kW** and **10,400 MWh** of additional energy, representing **2,850 tCO_2e** of carbon savings (depending on the source of the electricity). The drive to Net Zero is placing unprecedented strain on the electricity network to increase the flow of electrons and become far more flexible, what is not clear; is the rate of investment in the network keeping pace with industries desire to reduce carbon emissions. In 2020, to meet the 2050 net Zero target, the National Infrastructure Commission advised government that the electricity networks required a minimum of £10 billion investment per year up to 2050. Due to the pace of change in June 2022 they revised their recommendation to £100 billion by 2025.

Clearly businesses who are exposed to fluctuating energy costs need to devise strategies to mitigate both future supply and cost risk. Securing local renewable generation to offset grid energy exposure, while reducing tCO_2e emissions, is one mechanism to achieve that.

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Project management and implementation:

Sherwood Power acted as project lead working closely with our retail partner:

Imperial Consultants were responsible for delivering demand profiles for the TRUs in a range of conditions and day profiles, to deliver annual energy usage and cost, correlating this information against know diesel usage and real time data capture from the sample bays. Assessment of the environmental impact through the consideration of the current and future scenarios. A review of the potential for on-site generation and storage to mitigate the impact of increased electrical capacity and energy demand.

Colehouse Communications were responsible for all aspects of project communication to internal and external stakeholders, internally they were specifically tasked with the design and delivery of driver engagement, working alongside Sherwood Power and the electrical contractor.

The mechanical and electrical subcontractor with Sherwood and assisted with all elements of electrical installation design, including the installation of all the data acquisition equipment, power charging equipment for the loading and parking bays and an overview of the connection to the TRUs.

IoT data acquisition subcontractor have organized the collection of all loading and parking bay equipment the specification and configuration of the hardware and software necessary to measure peak capacity and energy usage across the 20 bays.

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Project management and implementation:

Logistics management operations, shunters/drivers and training personnel were consulted and engaged from the start of the project, under an inclusive project delivery style, it was seen as a vital step to ensure buy in from all users and stakeholders who would be responsible for implementing the project. The logistics management and training department generously shared the existing standard operating procedures around safe trailer loading (lock and dock).

The TRU refrigeration provider gave valuable insights into the model type distribution across the fleet including the running and tested electrical load at start up, this has been measured in real time at the site, giving a granular insight to TRU performance. Further information was presented about the four controller types deployed across the fleet.

The TRU manufacturer helped with enhancing the design of the electrical connection point on the trailers along with useful input and practical demonstration of trailer parking assistance measures, which enhance the safe operation and use of the charging system.

Finally onsite facilities management, gave generously of their time and knowledge, helping with introductions to the broader team, site maps and infrastructure configuration.

To assist with delivery of the project it was broken into work packages, and managed online via Teamwork project management software, with bi-weekly project review meetings on Teams, site, subcontractor meetings and visits.

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Project deliverables and results:

Typical peak power kW for a TRU refrigeration unit ranges between 12 to 14 kW, at start up it has been measured up to 15.2 kW, typical running values are 3.4-7.8 kW. Due to the out of phase TRU load profiles the site would require an additional **200 kW** to cover the existing scenario and current measured results, however, to ensure enough head room for exceptionally busy periods a capacity increase of **500 kW** should be considered on top of the existing **1,500 kW**. Annual energy consumption increases by **13 GWh** the cost differential is between neutral and plus 2% depending on the prevailing diesel and electricity costs.

If the entire fleet is electrified, TRU and peak HGV charging demand could reach up to 7.5 MW (5-fold increase). With no on-site/local generation sourced nor storage installed, this would require a capacity upgrade of **6,000 MW.**

Carbon saving are dependent on the source of the replacement electricity (grid electricity due to the current generation mix comes with a carbon content of 0.211 kgCO_2e/kWh). Replacing TRU diesel offers a carbon saving opportunity of up to **3,079 tCO_2e** if all aspects of cold storage diesel use are electrified this rises to **16,548 tCO_2e** and if the current grid supplied electricity replaced with renewable sources **18,616 tCO_2e** per annum.

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Project conclusions:

The project would like to extend special thanks to the retailer's senior team who gave generously of their time. If the entire TRU fleet is electrified, then the required capacity increase is **500 kW.** If the If the entire TRU and HGV fleet is electrified, peak charging demand could reach up to **7.5 MW**. With no on-site generation or storage installed, this would require a capacity upgrade of **6.0 MW** (**5** times more than the existing **1.5 MW** connection).

All or part of the capacity increase can be met by installing on site renewable energy or accessing local renewable generation and implementing long duration electrical energy storage, improving breathing air quality, while reducing peak load demand required from the Distribution Network Operator (DNO) and avoiding costly network upgrade costs. The Free Air Battery (FAB) novel energy storage system (Appendix F) is important as it supports the efficient use of renewable energy and can in the future incorporate Carbon Capture Utilisation and Storage (CCUS).

The potential carbon savings are significant for this site alone, between **3,079** and **18,616 tCO_2e** per annum depending on the volume of diesel displaced and the choice of electricity generation used, there are **450** equivalent cold storage distribution sites throughout the UK leading to potential annual savings between **1.4** and **8.4 $MtCO_2e$**. (In line with the National Atmospheric Emissions Inventory which estimates all HGVs contribute **19.5 $MtCO_2e$**).

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Learning:

It requires effort and persistence when changing long established working processes and operational procedures which are inexorably connected with human behavior. The project plan foresaw the need in this area but underestimated the amount of management time and effort it would take to coordinate and lead such a broad range of stakeholders, dealing with internal dynamics of various groups and pace of change. As the project continues it will require continual intervention from site trainers and management to embed an TRU electrical plug-in culture, made especially challenging as people join and leave the business. Project champions throughout the organization will help smooth the transition and lock in electric plug-in practices. There is an ongoing need to communicate and reinforce the benefits of TRU electrification.

Transport management require concise daily reports of electrification status, to quickly address any system issues and build robustness and resilience in it. Training new employees is vital to continued project success, building the demo rig not only helped with user engagement and ownership but is also a useful legacy training aid.

There is an ongoing plan to disseminate learning from the project through internal and external stakeholders, including but not limited to “The Cold Chain Federation”, trade press, via social media (LinkedIn and Twitter) as defined on the dissemination plan. Further internal monitoring, review and ongoing engagement is required to assure the long-term success of the feasibility study.

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Net Zero Innovation Portfolio - Industrial Fuel Switching Phase 1 - Dissemination plan

Audience	Key messages	Intended Outcomes	Timing	Content	Resource Implications	Channels	Owner	Evidence
Internal Project team	Project start - key objectives and outcomes	Buy in to project objectives and activity start	01/03/2022	PDF, infographic, Team Works plan	SP - 1 day, CC - 1 day	Team Works, Twitter, LinkedIn Group, email	SP	Read receipt, accept invite, join group, likes
External stake holders	Project start - key objectives and outcomes	Draw interest and study support from external actors	01/03/2022	PDF, infographic, Team Works plan	CC - 0.5 day	Team Works, Twitter, LinkedIn Group, email, MP, CI	CC	Read receipt, accept invite, join group, likes
Drivers and logistics personnel	Change of working practice benefits to the environment and personal health	Positive desire to engage with the project and make it a success	Mar-22	Driver survey, results circulation, flyers	SP - 1 day, CC - 1 day, ICON - 4 days	Establish special user group, links, twitter, Facebook, informal presentation	ICON	Number of charge points and energy used, damage, air quality improvement
Drivers and logistics personnel	Changing working methods makes life easier	Encourage adoption of new working practices by engagement in the solution process	Apr-22	Practical demonstrations, mock-ups, Infographics, feedback	SP - 2 day, ICON - 1 day, CC - 1	Video, face to face demo's, twitter, linkedIn, flyers	SP	Successful solution selection, feedback engagement with Q&A
Internal Project Team	Project progress update, on track, what has been achieved and what is still to be done, challenges	Focus on time used and remaining time to achieve outcomes - urgency	May-22	Feasibility project plan, work done v to do, reports, celebrate wins	SP - 2 day, ICON - 1 day, CC - 1, IPT - 1 day	Face to face or Video meeting with short presentations, Infographic	SP	On track, work to do understood and barriers managed
External stake holders	Project outcomes, successes, challenges, conclusions, recommendations and lessons learnt	Shared understanding of the challenges, successes proposed next steps	Jul-22	Written report, diagrams, charts, infographic, video, presentation	SP - 4 day, ICON - 3 day, CC - 1 day, ESH - 0.5 Day, MP - 1 day, CI - 0.5 day, EW - 2	Website, twitter, LinkedIn, email, campaign, press, Webinar, Presentation	SP	Number of organisations, clicks, downloads, webinar or presentation attendance

Key	Colehouse Communications (CC)	CC
	Sherwood Power (SP)	SP
	Internal Project team (IPT)	Sherwood Power, Supermarket - Property, Logistics, Imperial ICON, BEIS
	External Stake Holders (ESH)	Defra, Climate Change Committee, The Cold Chain Federation, Freight Transport Association, The Road Haulage Association, British Frozen Food Federation (BFFF) British Poultry Council (BPC), British Meat Processors Association (BMPA), Dairy UK, Chilled Foods Association (CFA)
	Media & Publications (MP)	Temperature Controlled Storage and Distribution (TCS&D), FoodChain, Transportation & Logistics, The Grocer, Food Safety News (FSN), Logistics Management, Cooling Post, Freight in the City, Commercial Motor, Motor Transport, Supply Chain Analysis (IGD), Reuters Events, Bloomberg NEF, CleanTechnica, Power Engineering,
	Consultant's and influencers (CI)	Energy Systems Catapult, Aurora Energy Research, Cornwall Insight
	Exhibitions and webinars (EW)	The Distributed Energy Show, NEPIC Meet the Members, BusinessGreen, The Energyst

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Outline budget and plan for phase 2

Reducing Distribution Network Operator (DNO) capacity demand from intensive industrial and business users is critical to meeting the Governments Net Zero 2050 challenge. If all industry were to increase capacity by 5 fold then the UK would need at a minimum 100 GW of additional generation and the existing grid would collapse, in energy terms the current 175 TWh would increase to 875 TWh.

Clearly providing all this electrical capacity and energy from the centre pushing out, down the UK's existing transmission and distribution lines would present serious engineering challenges (The National Infrastructure Commission state that £100 billion is required to be spent on the electricity grid by 2025 to meet the UK's 2050 Net Zero target) Carbon Trust and partners "Flexibility in Great Britain" state that flexibility can deliver savings of between £9.6 billion and £16.7 billion per annum to 2050 over a range of scenarios and "Flexibility is deployed more locally in 2050 and delivers significant value nationally. A large proportion of the flexibility across scenarios will be distributed sources deployed locally, closer to demand."

It is clear a complementary approach to increase demand is to generate electricity near to where it is used or even on-site via renewable means with long term storage smoothing out generation and demand peaks.

Outline budget and plan for phase 2

For large energy users this is equivalent to having a large store of potential energy bunkered on site (e.g. diesel stored in tanks) but replacing it with a clean environmental source. Building a Free Air Battery (FAB) on site (Appendix F) at industrial scale (1 to 100 MWh) supports the seamless integration of clean renewable energy (without 10% transmission and distribution losses) at the point of need. Beneficially this would free DNO capacity, to focus on the difficult challenge of providing additional energy to domestic clients (electric cars and heat pumps).

The DNO has confirmed that **5 MW** is the maximum that the current supply infrastructure could accommodate and at **10 MW** as it is outside the limits of the current connection capacity and requires significant redesign and development with the associated lead time. Working with the retailer, DNO, site M&E contractors the team would finalise the future timing of the client's electricity needs considering the current supply constraints and available infrastructure. The on-site distribution cables and infrastructure require significant upgrade to support the additional charging load. Drawing energy from local renewable generation sources while storing significant quantities of clean electrical energy on site is vital in the move away from diesel kW to electric kW.

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Outline budget and plan for phase 2

Initially Sherwood works with the retailer and project team to deliver a 1 MW over 4 hours (4 MWh) FAB commercial demonstrator. The projected project cost is £2.8m, including material (£2.1m) and development (£700k) cost, as client demand increases additional FAB energy (MWh) output can be easily retrofitted at 30% of the initial cost, while additional power (MW) at 25% of the original cost, making the storage extremely flexible and cost effective growing with client needs and avoiding a stranded asset.

The amortised cost to store electricity over the lifetime of the FAB asset is **4.5p/kWh** the equivalent lithium ion amortised installation cost **13.7p/kWh**. Operationally the FAB solution requires annual maintenance which is forecast at £4 to 5k. Compared to chemical battery equivalents FAB is a modular design, built from mature and reliable technologies, stores energy without capacity fade, is fully recyclable with zero emissions, cleans and filters ambient air during operation and has a minimum 30-year life (OEM warranties).

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Outline budget and plan for phase 2

The existing client operates 3% of the 450 UK cold storage distribution deports, leaving an initial addressable market segment of £4.8 billion, Data centres are our next target market a further £5 billion market in the UK following that the wider industrial market £72 billion and rising.

Without on-site generation and storage the client site is constrained to a maximum 5 MW supply capacity, insufficient to meet future need and hampering their Net Zero progress.

The project budget includes all design, development and certification of the installation as well as specialist sub contract services. The outline plan following will be refined during the phase 2 application process, serving as a current guide to expected activities and timeframes. Additional time will be planned for team co-ordination and user engagement activities as a result of our learning from phase 1.

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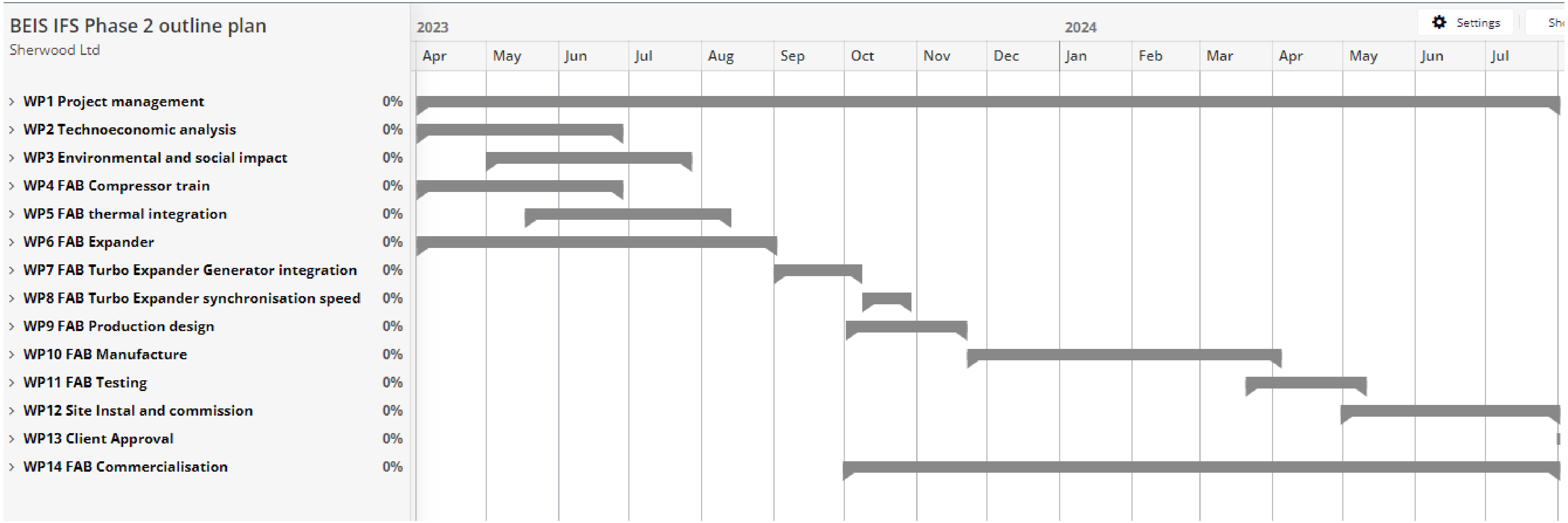

Appendix

Project Work Package (WP) update:

- **WP1 (1.1-1.63) – Project Management & Progress**
- **WP2 (2.0-2.6) – Dissemination plan (see appendix A)**
- **WP3 (3.1-3.5) - Driver & logistics electrification attitudes (see appendix B)**
- **WP4 (4.1-4.6) - TRU site electrification & data collection (see appendix C)**
- **WP5 (5.1-5.4) - Electrification Modelling Analysis (see appendix D)**
- **WP6 (6.1-6.3) - Environmental Impact assessment (see appendix E)**
- **WP7 (7.1-7.5) - Phase 2 demonstration technical risks (see appendix F)**
- **WP8 (8.1-8.8) - Market feasibility and project review (see appendix G)**

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Project WP update

- **WP1 (1.1-1.63) – Project Management & Progress:** Since project launch 22 meetings have been held – 7 more held in Aug with notes and actions and an extensive project team expanded to include multiple subcontractors. Stakeholder engagement has remained high throughout the project facilitating quick decision making and progress. The commitment of our retail partner of senior management time and input both on site, with sub-contractors and online has been a major factor in successful project delivery.
- **WP2 (2.0-2.6)** – **Dissemination plan (see appendix A):** Press release prepared and signed off by BEIS and our retail partner. Design finalised for project iconography and driver engagement; plug/unplug instruction (credit card size), distributed branded assets including site bay cont…

Project WP update, cont…..

- **WP2 (2.0-2.6) – Dissemination plan:** electrification signage and bays fitted with additional lighting. Internal communications were present at multiple positions focused on safe working practices, there is an opportunity to enhance the branding and provide additional information regarding energy efficiency. Retailer engagement on their future electrification plans for their assets and provisional capacity requirements agreed. Plans in place for dissemination of the final public report, to both internal and external stake holders. To assure the ongoing success of the diesel/electricity change it is important to have internal charging champions, looking at opportunities to reduce energy use and help identify additional training needs, (The demonstrator rig has been substantially revised as a training aid), management needs regular data available indicating the success of charging adoption.

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Project WP update cont…

- **WP3 (3.1-3.5) - Driver & logistics electrification attitudes (see appendix B):** As well as the driver engagement exercise with demo rig, formal surveys were completed at 2 sites, of management and users, summary findings included attitudes towards electrification, feedback on electric vehicles, infrastructure and the fridge controller setting. From the findings a SWOT analysis was undertaken to capture key messages. This greatly helped to inform the project team and assisted with awareness, engagement and adoption, feeding into **WP4 – TRU Site Electrification & Data Collection**
- **WP4 (4.1-4.6) - TRU site electrification & data collection (see appendix C):** loading and parking bay design finalised, including individual isolation switches, power light indicator, cont…

Project WP update cont…

- **WP4 (4.1-4.6) - TRU site electrification & data collection (see appendix C):** individual smart meter and quick release cable, 10 x loading and 10 x parking bays installed with ongoing data collection, position assistance guides on the parking bays are installed which are compatible with all trailer types, position of charging stands and cable length optimized for all trailer types, numerous site visits with the electrical contractor and our data acquisition and analysis partner, with assistance from logistics management, facilities management, trailer manufactures and the refrigeration manufacturer. The trailer manufacturer helped revise the connection point, the revised solutions makes it easier for the users to see and connect to the trailer socket. This attention to detail helps as a technology enabler.

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Project WP update cont…

- **WP5 (5.1-5.4)** - **Electrification Modelling Analysis (see appendix D):** Modelling analysis of current summer and winter load, future site generation requirements and strategy has been analysed and several scenarios proposed v increasing electrical capacity, initial projections of current and future load profiles are complete and have been refined along with the optimum storage size. The retailer has shared reports on their transport TRU strategy, further work on the modelling of onsite electricity supply mix, dispatch and control has been completed along with the positive impact that electrical energy storage can play in the mix. Site data has been interrogated to determine the frequency and time of TRU dispatch and return as well as the loading time and standing times at parking bays. cont……

Project WP update cont…

- **WP5 (5.1-5.4)** - **Electrification Modelling Analysis (see appendix D):** The operational data has been correlated against a register of rigids, trailers and tractors registered to the site and the type of fridge unit fitted. This leads to a hypothetical load profile which can be compared to real time data. On average a trailer can be on a loading bay for 5-6 hours and at a parking bay for 2-3 hours. Individual e-TRU average power demand is 3.4-7.8 kW and can peak at 15.2kW at startup. A typical summer day demand is about 100 kW but can go as high as 200 kW in busy periods. The increased e-TRU demand can not be considered in isolation, increased demand will also come from the tractor and rigid electrification. On an average summer day there are 124 tractor & 77 rigid journeys (201 total) tractors travel approx. 270 v 200 km for rigids

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Project WP update cont…

- **WP5 (5.1-5.4)** - **Electrification Modelling Analysis (see appendix D):**

- 99% of rigids can be charged with a combination of slow and fast chargers.
- Due to their short dwell times, 40% of tractors cannot be charged quickly enough to maintain their historical operating behavior, even using fast chargers.
- In later calculations we assume dwell times for currently “infeasible” tractors are increased so they can be charged using fast chargers. This will have significant operational impact for site.
- Peak charging demand in summer and winter reaches 7.44 MW and 7.51 MW respectively

Project WP update cont…

- **WP5 (5.1-5.4)** - **Electrification Modelling Analysis (see appendix D):**

- If the entire fleet is electrified, peak e-HGV charging demand could reach up to 7.5 MW. With no on-site generation or storage installed, this would require a capacity upgrade of **6,000 MW.**

- **WP6 (6.1-6.3) - Environmental Impact assessment (see appendix E):** Collection and analysis of baseline data complete, base carbon framework established additional impact of low carbon generation and storage to be considered.

- TRU diesel use represents 16% of all carbon emissions 3,079 tCO_2e out of 19,296 tCO_2e total. Electrifying TRUs would have a significant impact especially if adopted across all sites.

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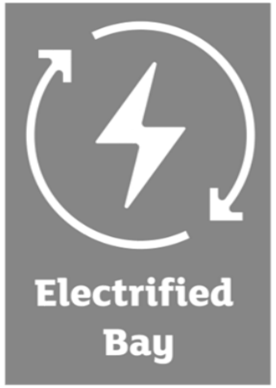
Project WP update cont…

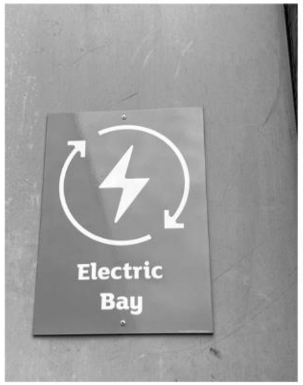
- **WP6 (6.1-6.3) - Environmental Impact assessment (see appendix E):** The carbon displacement factor depends on the source of the electricity, grid or other clean energy source. In the best case if diesel is replaced with 100% clean electricity the potential carbon savings are up to 16,548 tCO_2e for the trial site
- **WP7 (7.1-7.5) - Phase 2 demonstration technical risks:** Digital twin operational program has been validated against 20 separate test runs. Whole system operating parameters are set, synchronization time constrains considered (the system can synchronize in under 1 second and in milliseconds if required and options evaluated, cont…..

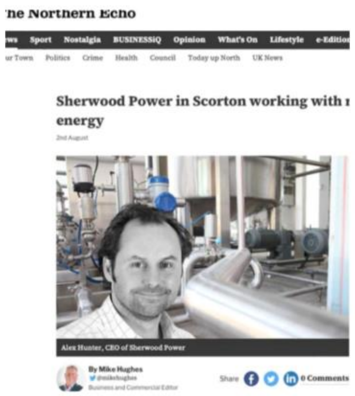
Project WP update cont…

- **WP7 (7.1-7.5) - Phase 2 demonstration technical risks:** optimum expander size and configuration determined to deliver a modular design capable of scaling to multiple power outputs based on a single expander generator configuration. Input costs and lead times have been collated and the techno-economic review and report finalised.
- **WP8 (8.1-8.8)** - **Market feasibility and project review:** Benchmarked against other compressed air energy storage systems, and competing long duration energy storage technologies including flow, gravity, liquid air types. Business model, BoM and OPEX assumptions have been validated under 3rd party review (chartered accountants), route to market has been agreed challenging assumptions. Regional social impact and wealth creation incorporated into business strategy

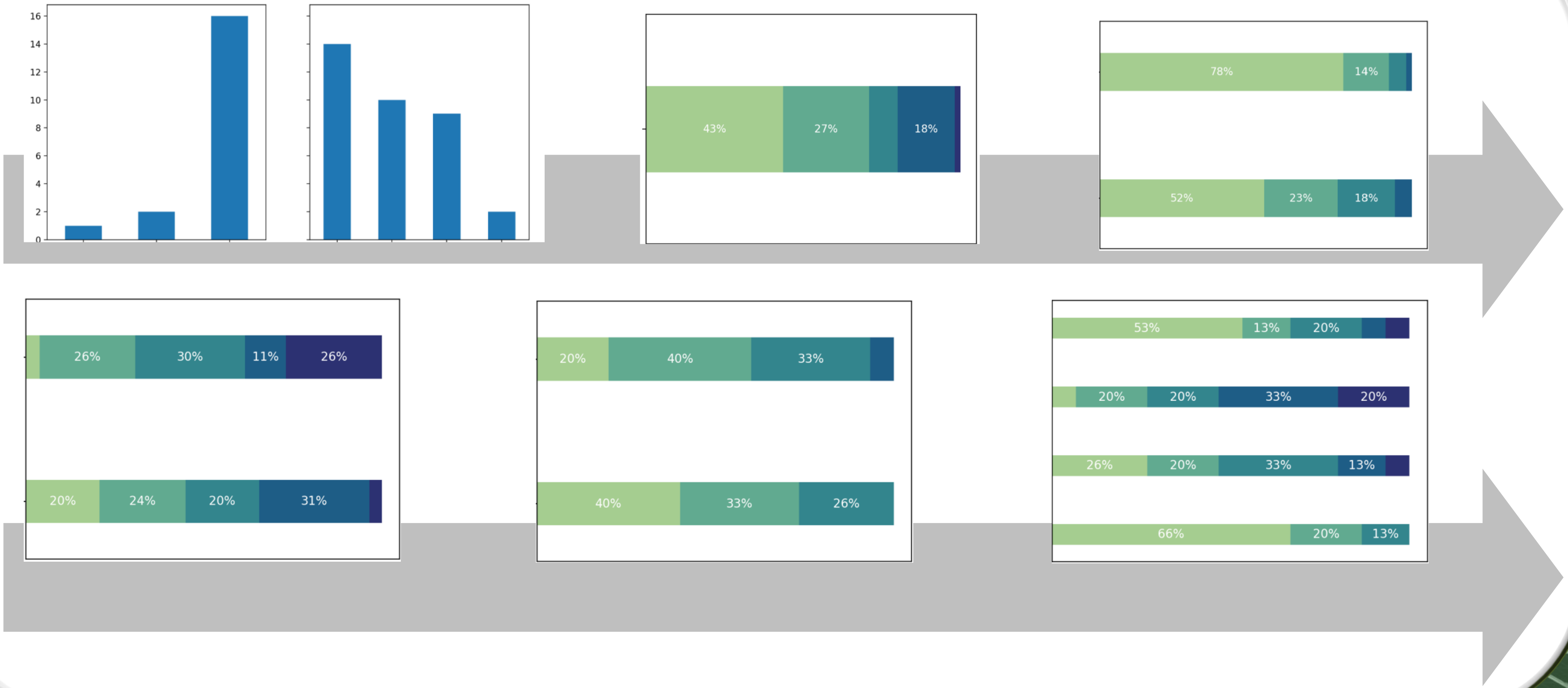
BEIS IFS report – Public - WP2: Dissemination plan (Appendix A)



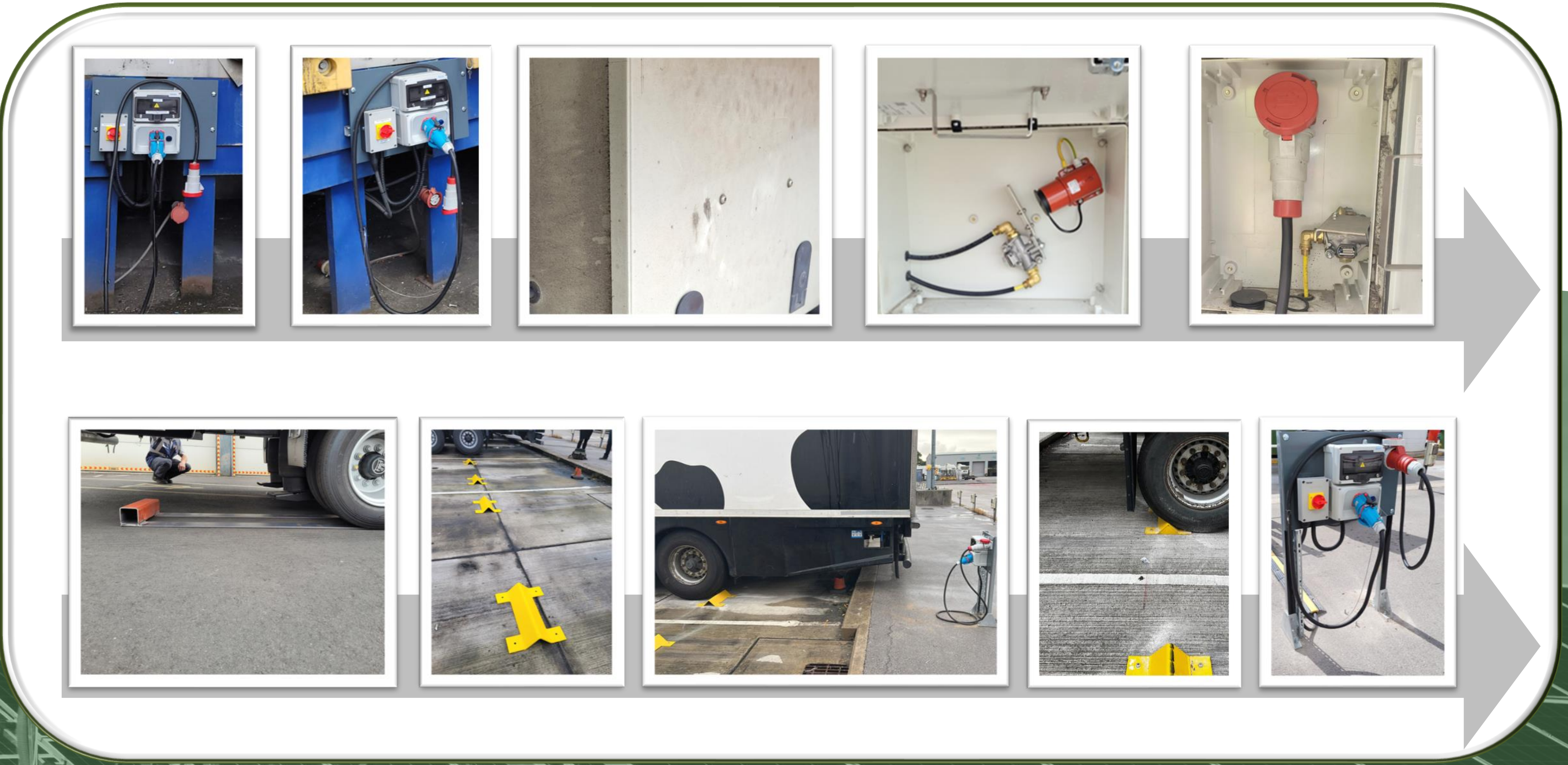




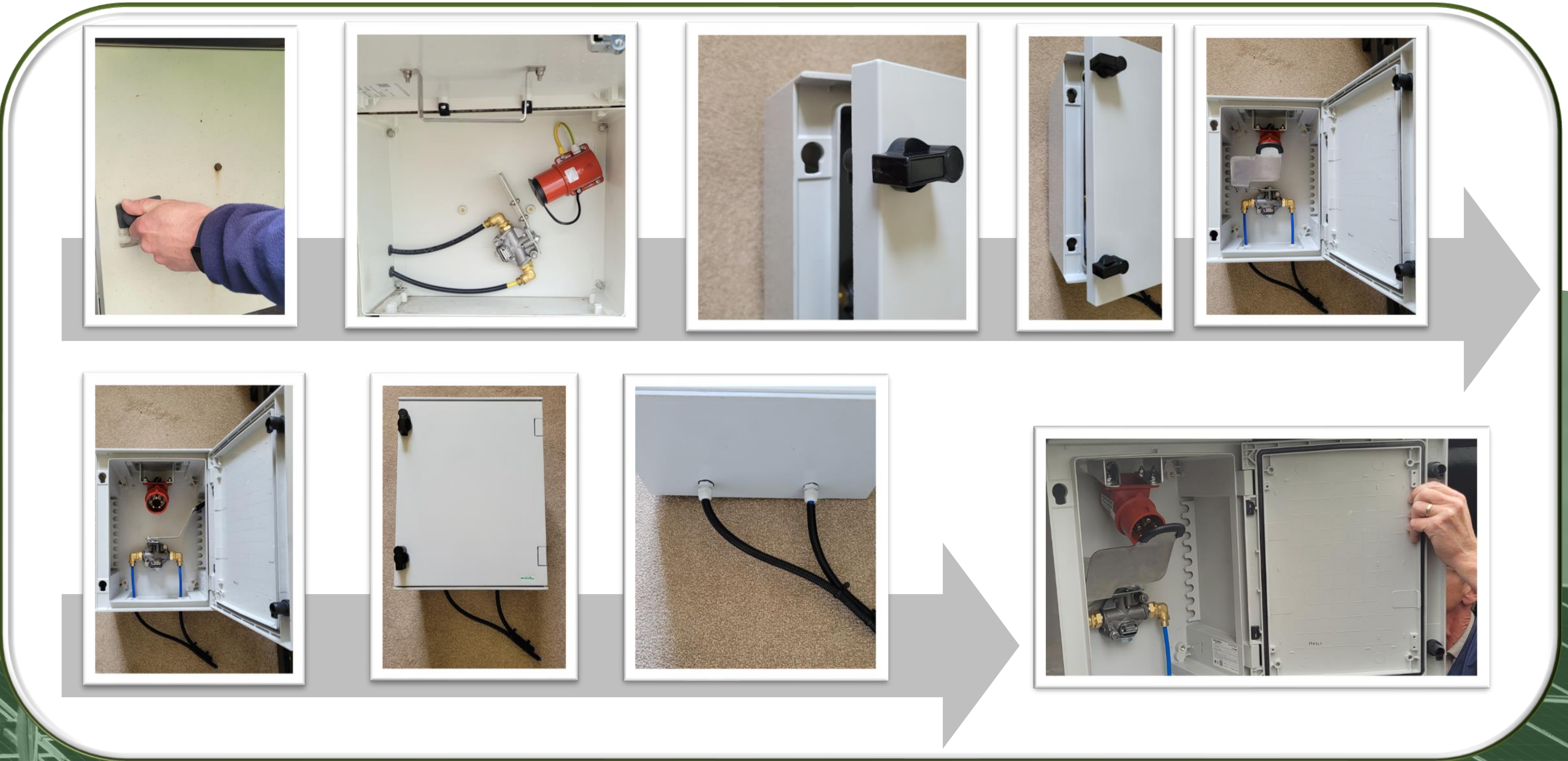
BEIS IFS report – Public - WP3: Driver & logistics electrification attitudes (appendix B)



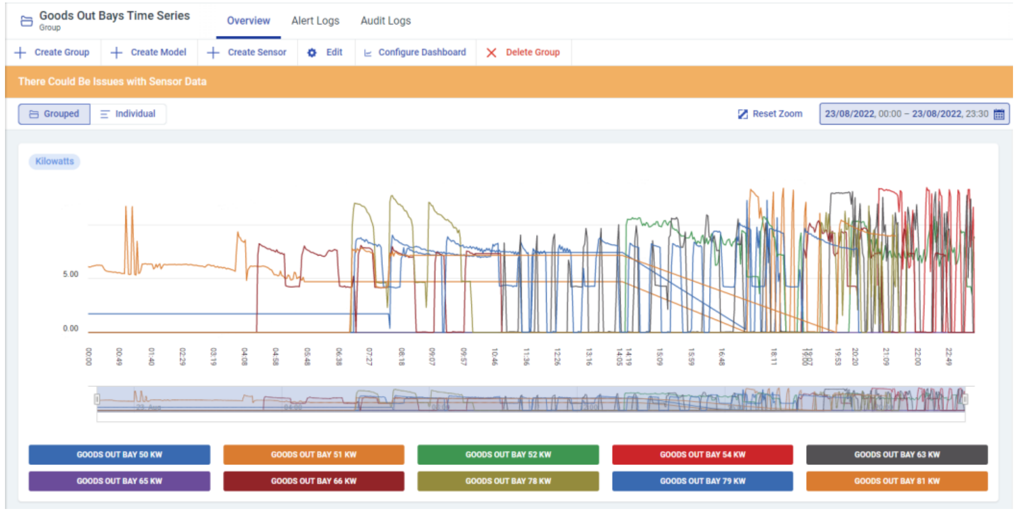
BEIS IFS report – Public - WP4: TRU site electrification & data collection (appendix C)

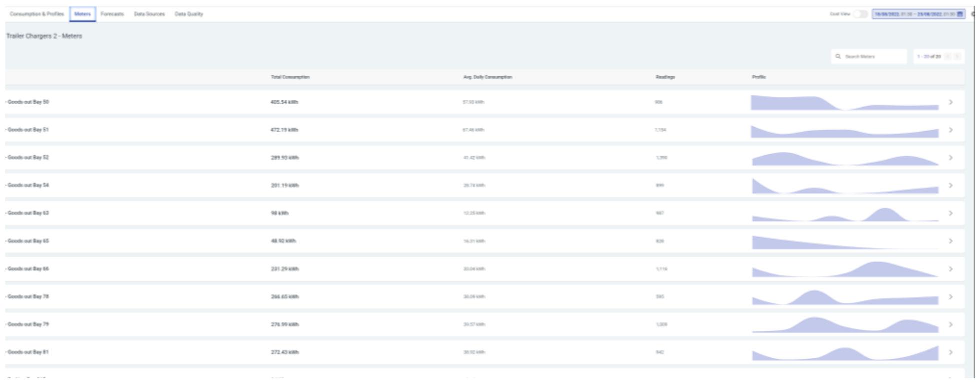


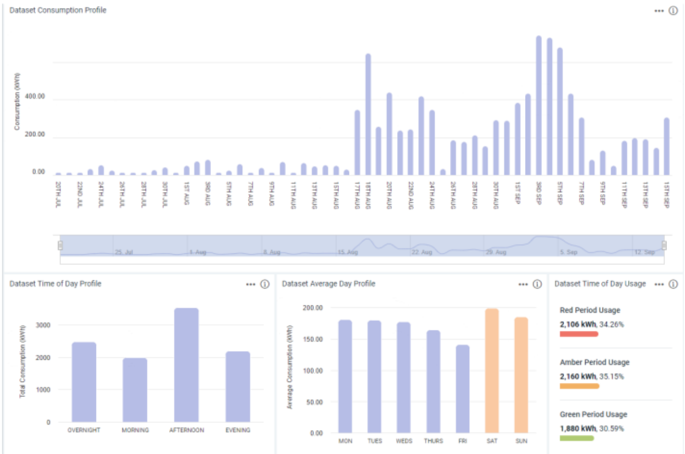
Project report #3 - WP4: TRU site electrification & data collection (appendix C)



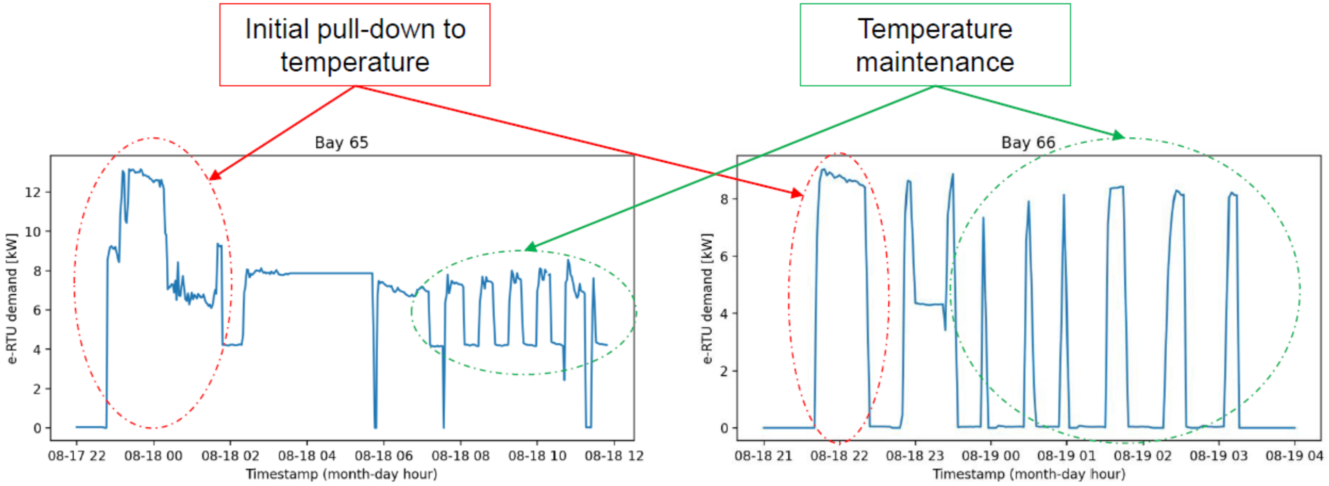
BEIS IFS report – Public - WP4: TRU site electrification & data collection (appendix C)

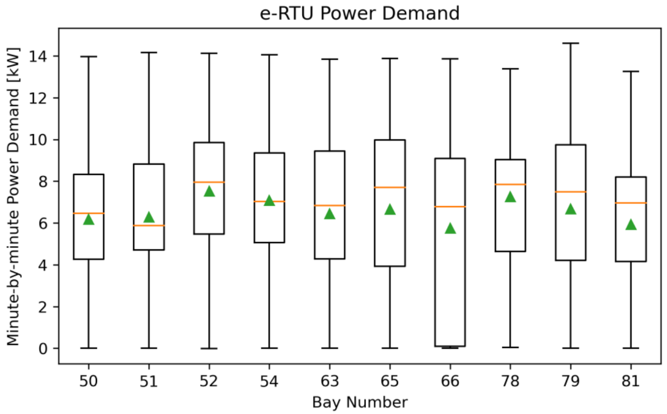


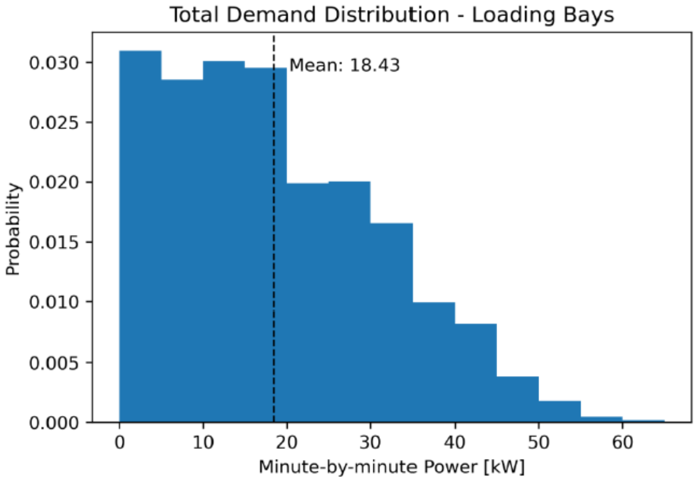


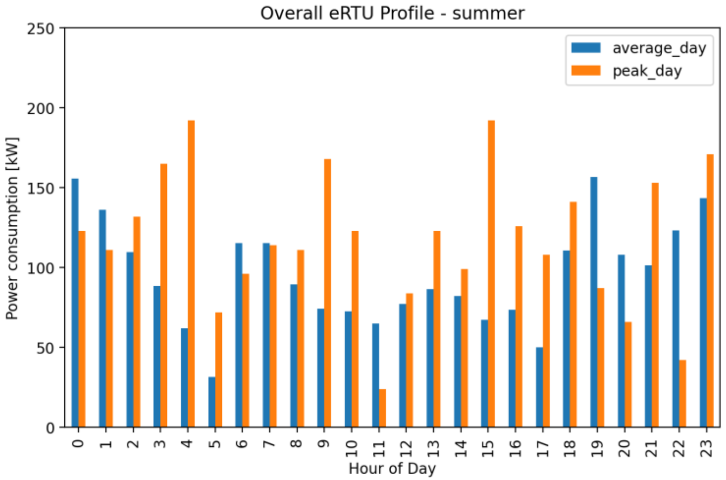


BEIS IFS report – Public - WP5: Electrification Modelling Analysis (appendix D)





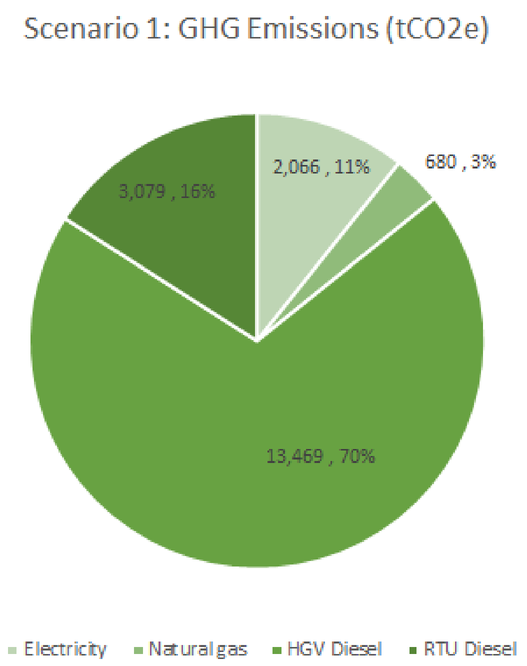


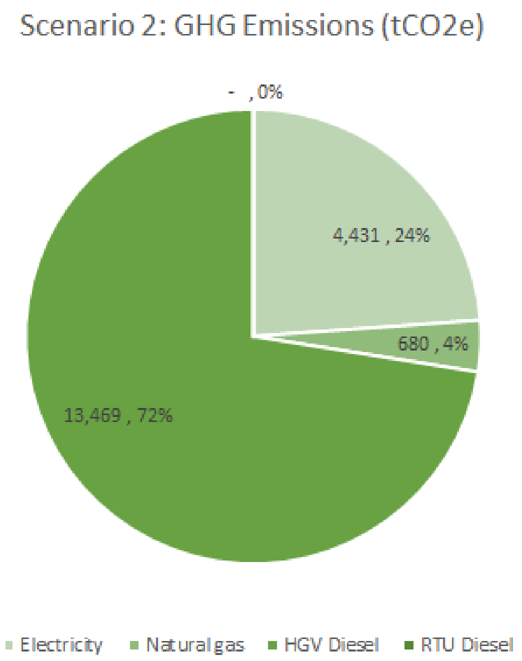


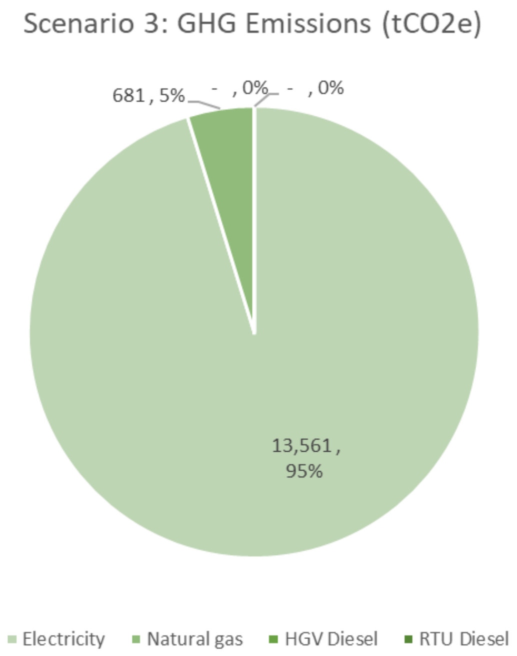
An individual e-TRU, average power demand ranges **between 3.4 –7.8 kW** and can peak at **15.2 kW** during intensive periods (e.g., initial temperature pull-down, defrost periods etc).

BEIS IFS report – Public – WP7: Environmental Impact assessment (appendix E):

- Scenario 1: Business as usual (BAU)Determine baseline performance for FY 2022-23
- Scenario 2: TRUs ALL electric, no diesel use for TRUs
  - Primary energy efficiency gains in e-TRUs
  - Outline “new” performance in terms of energy use, costs, and emissions
- Scenario 3: TRUs and HGVs ALL electric, no diesel use for HGVs
  - Primary energy efficiency gains in e-TRUs and e-HGVs
  - Outline “new” performance in terms of energy use, costs, and emissions







BEIS IFS report – Public - WP7- Phase 2 demonstration technical risks (appendix F)

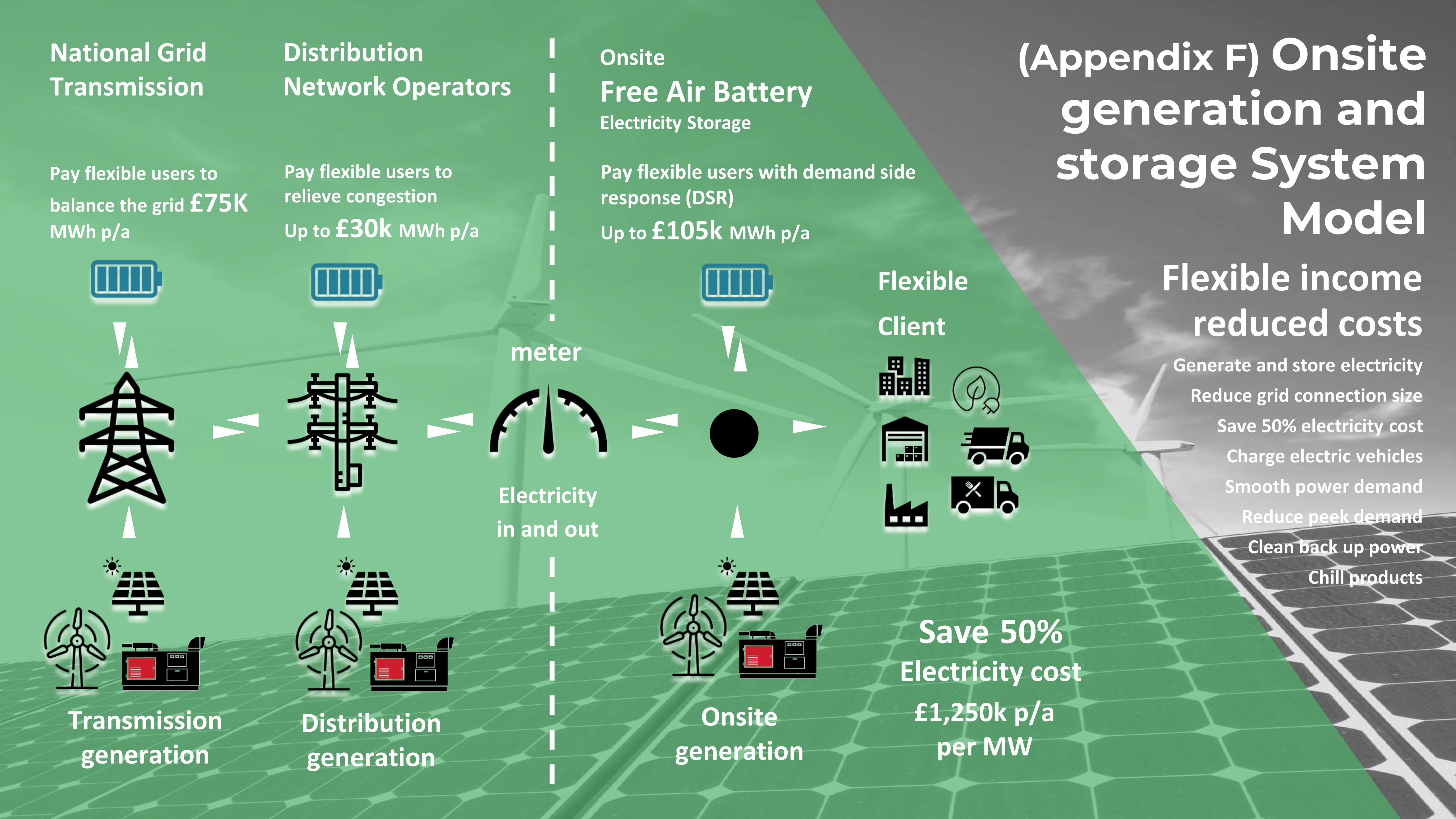
The following two slides show a typical configuration for the on-site generation and storage solution, where a range of generation assets, combined heat and power (CHP) solar and wind, are managed together with onsite energy storage through a central control module.

It is a hybrid system to reduce the capacity demand requirement on the local distribution grid while allowing the client to electrify equipment and services replacing diesel.

The solution provides additional headroom for the DNO to apply to other clients without costly reinforcement measures

The second slide shows the FAB system each of the component parts, turbo expander generator (kW system power), storage cylinders (system run time kWh) and air compressors (system charge time) are proven technologies available from multiple vendors worldwide.

The 99% heat capture within the compressor train is patented and delivered using hydraulic compression, again using existing hydraulic pumping technology and compression cylinders.


(Appendix F) Onsite generation and storage System Model
Flexible income reduced costs
Generate and store electricity
Reduce grid connection size
Save 50% electricity cost
Charge electric vehicles
Smooth power demand
Reduce peek demand
Clean back up power
Chill products
National Grid Transmission
Pay flexible users to balance the grid £75K MWh p/a
Distribution Network Operators
Pay flexible users to relieve congestion
Up to £30k MWh p/a
Onsite
Free Air Battery
Electricity Storage
Pay flexible users with demand side response (DSR)
Up to £105k MWh p/a
Flexible
Client
meter
Electricity in and out
Transmission generation
Distribution generation
Onsite generation
Save 50%
Electricity cost
£1,250k p/a
per MW

How it works (appendix F)

Patent Filed

WHY IS OUR TECH DIFFERENT?

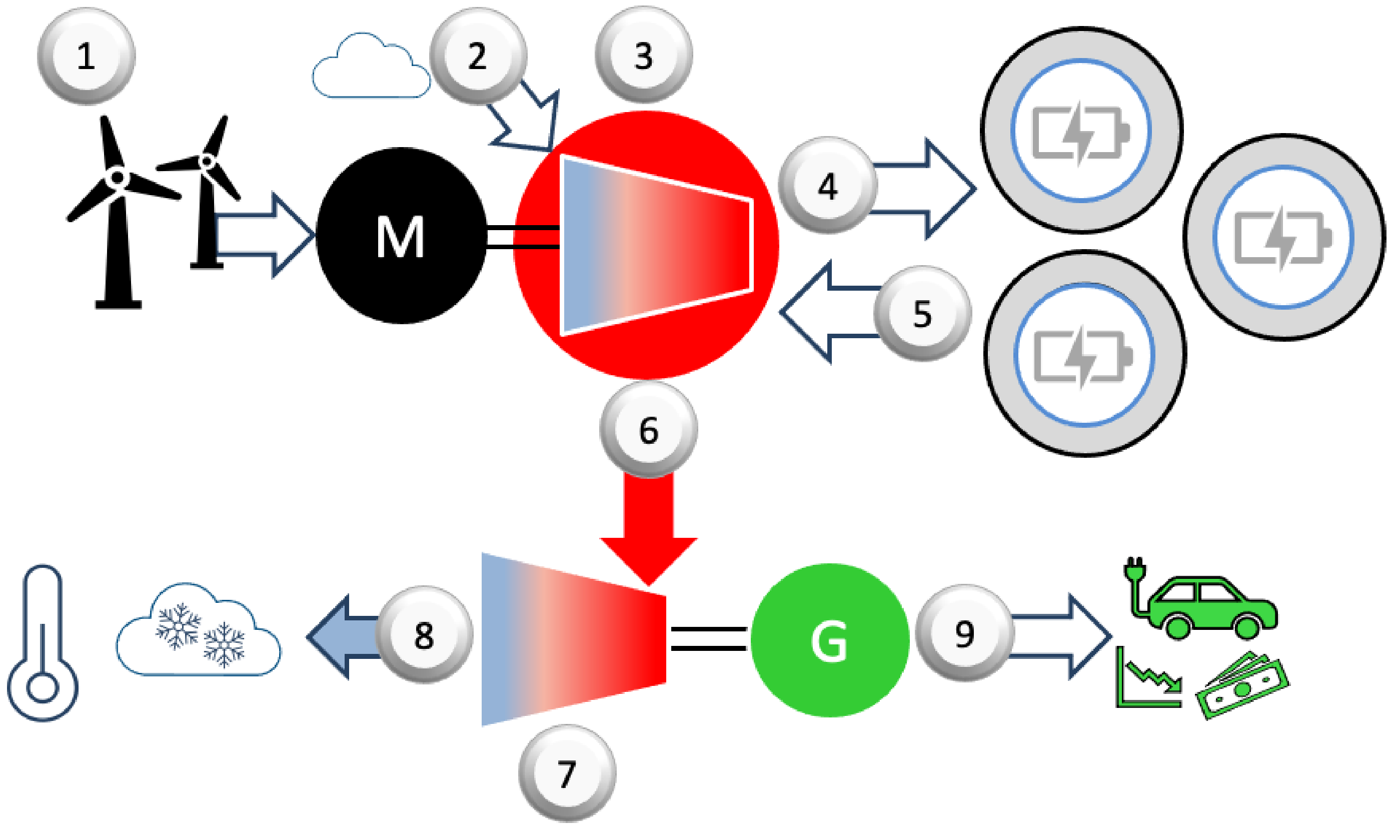
PATENT - 99% HEAT CAPTURE usually lost to atmosphere

Energy Storage

1. Cheap renewable electricity drives the compressors
2. Air enters and is compressed
3. Compression heat retained
4. Compressed air stored

Energy Supply

5. Stored energy released
6. Stored heat energises air
7. Hot air drives expander generator to make electricity
8. Cool clean refrigeration air
9. Revenue or cost avoidance



BEIS IFS report – Public – WP8 - Market feasibility and project review (see appendix G)

Sherwood Power stores excess wind and solar electricity, releasing it during peak demand to balance the grid and reduce business consumer cost.

Sherwood Power is developing embedded Electrical Energy Storage (EES) for the food cold storage supply chain, with a patented Free Air Battery (FAB) using compressed air to absorb excess renewable electricity, then dispatching it either to reduce business cost by managing customer demand or selling it later during a high margin period, through National Grid's (NG) balancing market.

Sherwood's core technology, has been validated at Imperial College London, use a column of water (liquid piston) to compress air, simultaneously extracting 99% of the heat energy. The heat energy is retained in the insulated water column and compressed air is stored in gas cylinders. When electricity is required, the compressed air is released, during expansion it is further energised collecting heat from the store maximising efficiency to drive a turbo expander generator. Sherwood's innovation lies in maximising the storage efficiency through heat energy capture.

BEIS IFS report – Public – WP8 - Market feasibility and project review (see appendix G)

The combined effect of reduced electricity demand due to COVID-19 coupled with increasing wind, solar generation and wholesale gas prices is causing balancing costs to surge. Balancing costs are incurred by NG to cover the costs associated with volatility in both supply and demand, for example in turning generation resource on or off, placing higher loads on switching and transmission equipment. NG balancing costs are passed on directly to consumers and make up part of the 55% non-electricity costs charged to businesses, eroding UK competitive advantage.

Sherwood Power FAB is optimised for EES over 1 to 10 hours or days or weeks and months with 1 to 100 MW power ranges (1 to 20,000 MWh+). More importantly, it is designed to sit primarily “behind the meter”, i.e. under the control of the company/organisation with the need for low-cost, environmentally generated electrical power. Use of the Sherwood FAB becomes a “distributed” decision, where balancing the grid through intelligent demand flexibility is rewarded by NG, to maximise take up of cheaper renewable energy. With the lowest **installed capital cost per kilowatt hour <£308/kWh and 4.5p/kWh produced**, it is patented, a modular design, built from mature and reliable technologies, stores power without loss, is fully recyclable with zero emissions, cleans and filters ambient air during operation and has a minimum 30-year life (OEM warranties).