Renewable Energies:

An Action Plan for Responsible Grid Harmony

VERSION 3.1 - 30 January 2026

WHITE PAPER | ASSOCIATION ENVIRONNEMENT JUSTE

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EXECUTIVE SUMMARY

THE FIRM POWER MANDATE FOR UK GRID SOVEREIGNTY

A Blueprint for Stability, Affordability, and Industrial Independence

The United Kingdom's electricity system is entering a critical phase. While wind and solar capacity continue to expand, the physical volatility of intermittent generation is now imposing a systemic cost that current energy policy fails to address. The cost of balancing the grid has risen to over **£2.7 billion per year**, a burden borne ultimately by households and taxpayers.

This cost is not incidental. It is the direct result of a regulatory framework that evaluates generation in isolation—using plant-level metrics such as Levelised Cost of Electricity (LCOE)—while externalising the physical and economic consequences of intermittency to the national grid. The result is a system increasingly dependent on gas-fired balancing, oversized infrastructure, and emergency interventions, despite rising renewable capacity.

This White Paper proposes a corrective framework: **the Firm Power Mandate**.

The Firm Power Mandate requires that new wind and solar generation deliver predictable, stabilised output through integrated energy storage at the point of production. By aligning renewable generation with the operational realities of the grid—beginning with mandatory 15-minute output smoothing and progressing toward real-time stability—the mandate transforms volatile injection into usable, firm electricity.

The British Breakthrough: BATRI-Swansea Proves Sovereignty is Achievable

This proposal is not theoretical. **On 17th December 2024, Wales achieved a strategic breakthrough**: BATRI, in partnership with Swansea University and backed by Faraday Institution funding, produced **the first cylindrical sodium-ion cell made in the UK using fully UK-manufactured anode and cathode materials**.

Using composite carbon derived from Welsh coal, this industry-standard 18650 cell proves that battery supply chain sovereignty is not a future aspiration—it is current reality. Swansea is now emerging as a world-class sodium-ion innovation hub, demonstrating that the UK possesses the technical and industrial capabilities to establish complete strategic independence from Chinese battery supply chains.

The question is no longer "can we build sovereign battery capacity?" but "will we create the guaranteed demand to scale what BATRI has already proven possible?"

Central to this proposal is the strategic use of **Sodium-Ion (Na-Ion) battery technology** for stationary storage. Sodium-Ion systems are uniquely suited to grid applications: they rely on raw materials widely available in the UK and Europe (salt, carbon, aluminium), avoid critical mineral dependencies, offer a significantly longer operational life than lithium-based systems, and perform reliably in cold and variable climatic conditions. Weight, a limitation in transport, is irrelevant for static infrastructure and becomes an advantage in durability and safety.

Beyond grid stability, the Firm Power Mandate delivers three strategic outcomes:

- **Economic Stability**: By internalising balancing, profile, and infrastructure costs at the point of generation—consistent with emerging UNECE Full System Cost (FSC) standards—the mandate reduces long-term system costs by addressing the low Capacity Factor and restores price predictability for consumers and industry.
- **Sovereign Industrial Capacity**: Guaranteed demand for long-life, stationary storage enables domestic and European manufacturing. The UK has 15+ GW of solar and wind projects in connection queues; at mandated storage ratios, that represents 30+ GWh of battery demand—**thousands of manufacturing jobs in Wales and Northern England**, using Welsh carbon, UK salt, and European aluminium. BATRI has proven the technology works; policy must now create the market to scale it.
- **Territorial Preservation**: By prioritising renewable deployment on already anthropised surfaces—brownfield land, rooftops, industrial zones—the mandate protects agricultural land, biodiversity, food security, and landscape heritage from unnecessary industrialisation—a vital necessity in mitigating the 6th Extinction.

The choice facing policymakers is no longer between renewable energy and fossil fuels. It is between continuing a fragile system that socialises the cost of volatility, or establishing a firm, sovereign, and resilient electricity infrastructure fit for a decarbonised economy.

The Firm Power Mandate offers a practical, technically grounded path to achieve this transition—by ensuring that every new megawatt of renewable capacity strengthens the grid rather than destabilising it, while building a British battery manufacturing sector that transforms Welsh coal heritage into 21st-century industrial advantage.

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1. THE GREAT ELECTRICAL CONCERT: A PLEA FOR SYNERGY

A stable national grid requires a symphony of synchronised generation. Currently, wind and solar operate as unreliable "Soloists" who exit the stage without warning or change their tempo mid-measure.

We do not propose to stop the music; we propose to provide the integrated buffer that acts as the "Conductor." This serves two critical purposes:

- **Smoothing the Silence**: It allows the concert to continue without the expensive, carbon-heavy "gas-fired understudies" (spinning reserve) currently waiting in the wings.
- **Capping the "Forte"**: By absorbing excessive production peaks, storage prevents the system from playing too "loud" for the existing infrastructure. This eliminates the need for multi-billion-pound investments in an oversized grid built solely to handle rare peaks that the storage could otherwise "dampen" and deploy later.

True green energy must be **Firm Power**—it must be capable of holding its note without deafening the system or leaving it in silence.

2. THE PHYSICAL TRUTH: THE "SAWTOOTH" & THE RULE OF 8

Intermittency is compounded by extreme physical volatility—a high-frequency failure of stability driven by the fluid dynamics of wind and the radiative flux of solar.

The "Rule of 8" (Wind Power Law)

Wind power output is proportional to the cube of the wind speed. If the wind speed doubles, the power increases by **8 times** ($P \propto v^3$). Conversely, a small drop in wind speed causes a catastrophic collapse in power. This makes wind energy inherently violent for a grid built on a steady 50Hz frequency.

The "Cloud-Edge" Effect (Solar)

Solar output can collapse by 70%–80% in seconds during cloud transients, creating an instantaneous "step-change" that the grid cannot physically absorb without mechanical inertia.

The Frequency Crisis

The European synchronous grid must be maintained within ±0.1 Hz of 50 Hz. A deviation of just ±0.2 Hz triggers automatic load shedding (blackouts). Renewable fluctuations—shifting from 1 MW to 8 MW in seconds—can cause deviations of up to ±0.5 Hz. This is a **500% increase** over the safe operating margin, creating a cascading failure risk that currently mandates a permanent, fossil-fuel-based "spinning reserve."

The Fossil-Fuel Tether

Because these collapses (The Sawtooth) happen in seconds or minutes, the system operator is forced to keep gas-fired backup generation in "spinning reserve." This "phantom grid" of gas must be brought online rapidly to balance every collapse. Therefore, **unbuffered renewables do not replace gas; they mandate its continued use as a permanent crutch**.

Capacity Factor: The Hidden Performance Reality

Beyond volatility, the **Capacity Factor** reveals the true operational reality of renewable generation. In the UK:

- **Solar PV** delivers an average of just **10%** of its installed capacity—a 1 kW solar array produces only approximately 100 watts of continuous power during daylight hours, averaged across the year, effectively dropping to zero every night and during peak winter demand.
- **Onshore Wind** averages around **25%**
- **Offshore Wind** performs better at **38-40%**

This stark discrepancy between installed capacity and actual grid delivery underscores the critical need for integrated storage. The Capacity Factor is not just a technical metric; it represents the physical gap between renewable potential and grid reliability that the Firm Power Mandate seeks to bridge.

3. THE 15-MINUTE MANDATE: FROM REACTIVE TO PROACTIVE

We must move from "Blind Injection" to Guaranteed Power Profiles. Following the October 1, 2025 implementation of 15-minute Market Time Units (MTU) across Europe, the legal framework for stability already exists; we must now enforce its technical execution.

The Progressive Smoothing Strategy

To protect the grid, all generators must legally deliver their output through a precision smoothing window (Sandia Standard) with the following milestones:

- **Implementation in the first regulatory cycle**: Mandatory 15-minute MTU smoothing with a minimum 90% output stability requirement. Penalties must apply for deviations beyond ±5% of declared output.
- **The Evolutionary Pathway**: Within 3 years, the mandate must transition to a 5-minute smoothing window, reaching 1-minute real-time balancing by Year 5.

The Infrastructure Revolution

By mandating increasingly precise storage requirements at the source, we achieve:

- **Cost Reduction**: A projected 60% reduction in grid reinforcement costs.

- **Predictability**: A grid that is not just "balanced" by expensive gas, but mathematically engineered for stability.
- **Accountability**: Direct alignment between generator performance and national infrastructure investment.

4. RESPONSIBILITY TIERS: INTERNALISING SYSTEMIC COSTS

Following the "Polluter-Pays" principle, producers must internalise the costs of the stability they currently externalise to the public and the taxpayer. Responsibility is tiered to protect small-scale autonomy while mandating firmness from industrial players:

- **Micro-Residential (<10 kW)**: Exempted. To encourage local energy autonomy and reduce administrative barriers for households.
- **Small Commercial (10–250 kW)**: 1 kWh storage / 1 kW capacity. Standardising local buffering for businesses.
- **Industrial (250 kW–10 MW)**: 1.5 kWh / 1 kW capacity. Mandatory smoothing for medium-scale grid injection.
- **Utility Scale (>10 MW)**: 2–4 kWh storage / 1 kW capacity. Full-firmness requirements for high-impact generators.

Rationale and Adaptability

These storage requirements reflect the proportional grid impact of different generation scales. The specified ratios balance current technical feasibility with systemic stability needs.

To ensure ongoing relevance, these requirements will be subject to a **Biennial Technical Review**, allowing for legislative adjustments in response to technological advances, grid development, and emerging storage chemistry.

5. SODIUM-ION (Na-Ion): THE SOVEREIGN STORAGE SOLUTION

To achieve "Firm Power," the UK must transform its energy infrastructure strategically. Sodium-Ion technology represents more than a technological choice—it is a pathway to industrial sovereignty.

0V Safety Profile

Unlike Lithium-ion, Sodium-Ion offers significantly lower thermal runaway risk and zero-voltage shippability. This reduces logistical complexity and insurance overheads while providing enhanced safety margins.

Technological Validation

With global leaders like Faradion (UK) and CATL announcing cell specifications exceeding 160-175 Wh/kg and operational temperatures from -40°C to +70°C, Sodium-Ion has crossed from experimental to industrially viable technology.

The Coal-to-Carbon Revolution

Sodium-Ion replaces imported graphite with "Hard Carbon." Research from Swansea University demonstrates that domestic Anthracite coal can be converted into high-purity anode material, transforming a legacy industry into a high-tech future.

Economic Trajectory

While current cell-level costs are falling rapidly, projected reductions suggest potential grid-scale storage costs below £40/kWh within five years. This is not incremental improvement, but a structural economic shift.

Performance in Extreme Conditions

Maintaining 80-90% capacity retention at -20°C, Na-Ion ensures grid stability during challenging Dunkelflaute events—a critical advantage for UK energy systems over temperature-sensitive Lithium-ion.

Lifecycle and Repurposing Potential

Beyond initial grid deployment, Na-Ion's ultra-high cycle life enables a multi-generational infrastructure strategy. With potential for over 15,000 full cycles and modular design, these systems can transition through multiple use-cases—from primary grid service to distributed energy storage and local resilience networks. This transforms storage from a consumable asset into a long-term, adaptable infrastructure investment.

The Sovereign Imperative

The decisive question is no longer technical feasibility, but where value creation and industrial control will be located. By mandating domestic Na-Ion development, the UK can avoid repeating the lithium dependency mistake.

5B. THE BATRI BREAKTHROUGH—BRITISH BATTERY SOVEREIGNTY

On 17th December 2024, Wales achieved a strategic milestone that repositions the UK in global energy storage: **BATRI, in partnership with Swansea University and funded by the Faraday Institution, produced the first cylindrical sodium-ion cell made in the UK using fully UK-manufactured anode and cathode materials.**

What Makes This Achievement Transformative

1. The 100% Sovereign Supply Chain

Unlike lithium-ion batteries, which require:

- Lithium from Australia/Chile (controlled processing in China)
- Cobalt from Congo (refined in China)
- Graphite from China

- Cell manufacturing in Asia

BATRI's Na-ion cell uses:

- ✅ **Composite carbon derived from Welsh coal** (domestic resource transformed)
- ✅ Salt (UK/European sources)
- ✅ Aluminium (European supply chains)
- ✅ Assembly in Wales (British manufacturing)

2. From Coal Heritage to Battery Future

The collaboration between BATRI and Swansea University demonstrates how Wales' coal mining heritage—once seen as obsolete—becomes strategic infrastructure for the 21st century. Welsh anthracite, when processed into composite carbon, provides superior anode material for Na-ion batteries. This creates:

- High-skilled jobs in former mining regions
- Industrial continuity and pride
- Elimination of foreign mineral dependencies
- Environmental valorisation of a historic resource

As **Dr Stephen Hughes, CTO of BATRI**, states: *"We're unlocking a sodium-ion ecosystem that starts in Wales and is aiming to reach global markets. The need for safe, robust, and cost-effective alternatives to lead-acid and lower performance lithium-ion is enormous, particularly in applications where resilience, sustainability, and supply-chain security are critical."*

3. Industry-Standard Format (18650)

The choice of the cylindrical 18650 format—the same used in millions of existing industrial applications—is not incidental. It enables:

- Immediate integration into existing systems
- Compatibility with established production lines
- Modularity and scalability (battery packs can use thousands of 18650 cells)
- Reduced industrial adoption risk

4. Swansea: Emerging as a Sodium-Ion Powerhouse

As **Professor Serena Margadonna** notes: *"Swansea is quickly becoming a focal point for sodium-ion innovation, and this achievement shows what can be delivered when academia and industry collaborate with urgency and purpose."*

Councillor Rob Stewart, Swansea Council Leader, confirms: *"This milestone strengthens Swansea's position as one of the UK's most exciting locations for advanced energy innovation. The growing sodium-ion hub here is already attracting significant inward investment, supporting new skilled jobs and creating real momentum for the regional economy."*

The Strategic Significance

The BATRI-Swansea achievement demonstrates three critical realities:

Technical Maturity: Sodium-ion technology has progressed from laboratory research to functional, industry-standard cells ready for commercial deployment.

Manufacturing Capability: UK facilities, academic partnerships, and domestic supply chains can produce competitive battery technology without relying on imported components or foreign expertise.

Scalability Pathway: With proven cell design in the widely-used 18650 format, the transition from pilot production to industrial-scale manufacturing becomes a question of market demand rather than technical feasibility.

Industrial Partnership: AceOn Group

BATRI is collaborating with **AceOn Group** to integrate UK-made Na-ion cells into swappable packs, including as part of the **StamiNa Ayrton Challenge on Energy Storage project**.

Mark Thompson, CEO of AceOn Group, explains: *"Sodium-ion is rapidly becoming a crucial technology for the applications we serve—from mobility and industrial power to stationary storage in harsh environments. Batri's UK-made 18650 breakthrough, backed by Swansea's world-class materials science, shows the UK can lead in safe, robust alternatives to lead-acid and entry-grade lithium."*

The Policy Opportunity

Our **Firm Power Mandate** creates the guaranteed market BATRI needs to scale from pilot production to industrial manufacturing. Without mandated storage requirements, BATRI competes against subsidised Chinese imports in a voluntary market. With the mandate, every new wind and solar project becomes a customer for British battery manufacturing.

The Numbers:

- UK has 15+ GW of solar/wind in connection queues
- At 2 kWh storage per kW (utility-scale requirement), that's 30+ GWh of storage demand
- 30 GWh = **thousands of manufacturing jobs** in Wales and Northern England
- Supply chain: Welsh carbon, UK salt, European aluminium, British assembly

The Choice:
Import Chinese lithium batteries, or scale British sodium-ion production. BATRI has given us the second option. Policy must now create the demand.

6. THE ECONOMIC REVOLUTION: FULL SYSTEM COST (FSC)

Traditional Levelised Cost of Electricity (LCOE) is a deceptive metric that obscures the true economic burden on consumers. It measures the cost of a generator in isolation, failing to capture the massive "hidden" expenses required to make that volatile power usable by a modern society.

The UNECE Mandate

Per the UNECE Report GECES-21/2025/INF.2 (Sept 2025), we must transition to Full System Cost (FSC) accounting. This comprehensively tracks the three pillars of systemic expense:

- **Balancing Costs**: The expense of maintaining grid stability through carbon-heavy "spinning reserves" and emergency rapid-response generation when the "Soloists" leave the stage unexpectedly.
- **Profile Costs**: The economic penalties arising from the "Sawtooth" nature of renewable generation, where over-production leads to negative prices and under-production leads to extreme price spikes.
- **Grid Infrastructure Costs**: The multi-billion-pound investments required to reinforce and "over-size" the grid to handle rare peaks that storage could otherwise mitigate.

Systemic Transparency

Under FSC, energy projects must internalise these costs at the source. By mandating Sodium-Ion storage, we convert "Variable" energy into "Firm" energy, effectively collapsing the FSC back toward the LCOE. This ends the practice of externalising systemic instability to the taxpayer.

The Result

Moving to a storage-backed grid shifts the nation from a "volatile price" model to a **Predictable Cost Basis**. This does not just lower household bills; it provides the long-term price stability that energy-intensive industries (such as steel and aluminium smelting) require to remain and grow within our borders.

7. REGULATORY GATEKEEPER: THE CONNECTION ULTIMATUM

The current connection queue is a "graveyard" of stagnant projects that threaten systemic stability. We must transform the grid from an open-access dumping ground into a high-standard, Firm Power network.

No Storage = No Connection

To protect national infrastructure, grid access must be contingent on technical compliance. Projects that cannot guarantee a "Firm" output profile are technically incomplete and should be denied connection until they integrate the necessary smoothing buffers.

Regulatory Alignment: Under the TMO4+ "Ready and Needed" framework, unbuffered projects fail the "Strategic Alignment" test and should be denied a Gate 2 firm connection offer.

The "Grid-Ready" Fast-Track

Compliant projects—those that internalise their own stability costs—must be granted **Immediate Priority Access**. Because these projects do not require the multi-billion-pound grid reinforcements that "Variable" projects demand, they can be integrated into the existing infrastructure today.

Regulatory Alignment: By providing a "Zero-Net-Impact" profile, these projects satisfy the "System Need" criteria, allowing them to bypass the years-long delays caused by the national grid's thermal and frequency constraints.

Clearing the "Zombies"

By mandating storage, the regulator can instantly filter out speculative, "grid-toxic" projects that are currently clogging the queue. This unlocks space for professional, stable, and high-fidelity energy providers.

Regulatory Alignment: This mandate acts as a "Readiness Milestone" that "zombie" projects cannot meet, effectively purging the 2026 queue of speculative capacity and making room for high-fidelity generators.

The Policy Shift

We move from a system that rewards "Capacity on Paper" to a system that rewards "Stability on the Wire."

8. TERRITORIAL INTEGRITY: THE LAND-USE HIERARCHY

Industrialising Grade 1, 2, and 3a agricultural land—the UK's "Best and Most Versatile" (BMV) soil—is a strategic error that threatens national food autonomy. We must transition to a "Brownfield First" mandate.

The Anthropised Priority

Energy deployment must be directed toward surfaces that are already anthropised or artificialised: industrial rooftops, former brownfields, car parks, and transport corridors. This preserves the "living skin" of our farmland for its primary purpose: feeding the nation, and our heritage landscapes.

The Storage Enabler

Traditionally, these urban/industrial sites were rejected because the local grid was "too weak" to handle the surges of a large solar array. Integrated Sodium-Ion storage solves this; it acts as a **Shock Absorber**, allowing these sites to connect to the "edge" of the grid without causing localised failures or requiring expensive new cabling.

The "Swiss Knife" Asset

These storage units are not passive batteries; they are multi-functional infrastructure. A storage-backed solar roof on a warehouse can:

1. **Buffer the Grid**: Providing the "Firm Power" profiles discussed in Section 3.
2. **Power Ultra-Fast EV Charging**: Providing the high-current "boost" needed for rapid charging in areas where the grid cannot currently support it.
3. **Support Local Industry**: Providing a "behind-the-meter" reserve that protects local businesses from peak-price spikes.

The Vision

We move away from the "Solar Plantation" model that consumes our countryside, toward a **Distributed Energy Fabric** where every warehouse, car park, and brownfield becomes a high-fidelity power station.

9. STRATEGIC SUMMARY: THE TRIPLE STABILITY

Grid Stability

- Eliminates "Sawtooth" shocks via local smoothing; provides Synthetic Inertia (Grid-Forming inverters) to replace lost mechanical inertia from retired fossil-fuel plants.
- Mitigates the **£2.7bn annual Systemic Balancing Burden** by eliminating structural economic inefficiencies. Transforms grid management from a reactive, high-cost compensation model to a proactive, stable infrastructure strategy.

Economic Stability

- Fully aligns physical generation with the 15-minute Market Time Unit (MTU) law and UNECE Full System Cost (FSC) transparency standards.
- Provides **Predictable Pricing** for the market; de-risks capital investment by shifting from volatile "spot" prices to a stable, industrial cost basis.

Sovereign Stability

- Utilises a 100% domestic and regional supply chain by leveraging Salt, Welsh Carbon (Anthracite), and European Aluminium.
- **Demonstrates proven industrial capability**: On 17th December 2024, BATRI (Wales) and Swansea University produced the first Na-Ion 18650 cell using 100% British materials, validating that complete supply chain sovereignty is operational

reality, not theoretical aspiration. Swansea is emerging as a world-class sodium-ion innovation hub.

- Protects **National Food Autonomy** by prioritising energy deployment on anthropised land; rebuilds the industrial base through high-skilled domestic manufacturing.

Summary of Impact

The implementation of the Firm Power Mandate ensures that every megawatt of renewable energy added to the system is an asset to stability, not a liability to the taxpayer. By internalising the cost of intermittency at the point of generation, we move from a fragile, weather-dependent grid to a **Sovereign-Secure infrastructure** that can power the 21st-century economy.

10. CONCLUSION: FROM VOLATILE INJECTION TO SOVEREIGN FIRMNESS

The transition to a carbon-neutral economy can no longer rely on the accounting fictions of the past decade. A secure, decarbonised grid is a systemic impossibility without a mandatory, integrated storage buffer that internalises the costs of intermittency.

The industrial foundation already exists: **BATRI's 100% British Na-ion battery (17th December 2024)** proves sovereign manufacturing is viable today. The supply chain is domestic: Welsh anthracite for anodes, UK salt for cathodes, European aluminium for current collectors. The academic expertise is ready: Swansea, now recognised as a sodium-ion hub, possesses the research capacity. The industrial partnership works: AceOn Group is already integrating these cells into commercial systems.

What's missing is guaranteed demand—and that's exactly what the Firm Power Mandate provides. The UK can choose: perpetual dependency on Chinese supply chains, or scaling sovereign capacity that's already proven.

By moving away from Non-Firm Volatile Energy and mandating Sodium-Ion integration, we achieve more than just grid stability; we trigger a **British Industrial Renaissance**. This policy provides the guaranteed domestic demand required to rebuild our Aluminium, Salt, and Hard-Carbon supply chains—securing thousands of high-skill manufacturing jobs in Wales and Northern England, and ending our strategic dependency on foreign mineral monopolies.

The choice is no longer between "green" and "fossil." The choice is between a fragile, expensive grid perpetually dependent on gas-fired balancing, or a resilient, sovereign system built on **Firm Generation**.

In the spirit of "Thorough understanding for better decisions," we call on legislators to move beyond speculative "capacity on paper" and enact this Firm Power Mandate immediately. The stability of our economy and the integrity of our land depend upon it.

BATRI has shown us it can be done. Policy must now scale what Wales has already achieved.

GLOSSARY

Rule of 8: The physical law where wind power is proportional to the cube of wind speed ($P \propto v^3$). A doubling of wind speed results in an eight-fold increase in power, creating the extreme volatility that necessitates storage buffers.

MTU (Market Time Unit): The 15-minute block used for electricity trading (standardised Oct 2025). This is the "temporal heartbeat" of the grid; our mandate ensures renewable production matches this reality.

Firm Power: Electricity that is guaranteed to be available at a specific time and duration. Unlike "intermittent" power, Firm Power provides the reliability required for industrial and sovereign stability.

Sawtooth Profile: The erratic, jagged output of unbuffered renewables that forces the grid to "chase" the load, leading to high balancing costs and mechanical wear on infrastructure.

Synthetic Inertia (Grid-Forming): The digital replacement for the physical "Spinning Reserves" of old fossil-fuel turbines. Sodium-Ion inverters provide this instantly, stabilising the grid frequency (50Hz) without burning gas.

TMO4.2 (Gate 2) – "The Connection Ultimatum": The definitive grid connection reform package implemented in 2025/2026. It replaces the legacy "first-come, first-served" system with a "First-Ready, First-Connected" model.

Full System Cost (FSC): A "Truth-in-Accounting" metric (aligned with UNECE 2025 standards) that includes the costs of balancing, backup, and grid reinforcement. It replaces the outdated LCOE (Levelised Cost of Energy), which ignores the cost of intermittency.

0V Safety (Zero-Volt Transport): A unique chemical property of Sodium-Ion that allows cells to be fully discharged to zero volts for shipping and maintenance. This eliminates fire risk during transit and reduces insurance premiums by 30-40%.

Hard Carbon Anode: The negative electrode in a Sodium-Ion battery. By utilising domestic Anthracite coal or biomass to create this carbon, we ensure a 100% sovereign supply chain independent of foreign graphite.

Dunkelflaute: A period of "dark wind lulls" (low wind, low sun) common in European winters. Our mandate ensures that Sodium-Ion buffers—which retain 90% capacity at -20°C—protect the grid during these critical events.

BATRI (Wales): British company that, in collaboration with Swansea University and funded by the Faraday Institution, produced on 17th December 2024 the first cylindrical sodium-ion cell in 18650 format using 100% UK-manufactured anode and cathode materials. Key innovation: use of composite carbon derived from Welsh coal for anodes, transforming a heritage resource into a strategic component for 21st-century batteries.

18650 Format: Standard cylindrical battery cell format (18mm diameter, 65mm length) widely used in industry. BATRI's choice of this format enables immediate integration into existing systems and rapid industrial scalability.

Swansea Sodium-Ion Hub: Emerging innovation cluster in Wales, centred on Swansea University, BATRI, and their industrial partners. Recognised as a UK centre of excellence for sodium-ion research, materials development, and cell engineering.

Faraday Institution: UK battery research organisation, funded by UK Research and Innovation (UKRI), which provided the Sprint funding that accelerated development of the BATRI-Swansea cell.

11. REFERENCES & KEY LITERATURE

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- **Faraday Institution**: Sprint Funding Programme - Sodium-Ion Cell Development. (Funding acceleration of development, testing, and integration of British materials into a commercial cylindrical cell format).
- **Journal of Energy Storage (2026)**: Sodium-ion battery cost projections and their impact on the global energy system transition until 2050. [Ref: 146:119861]. (Source for the 40-year lifecycle and £40/kWh cost floor).

Industrial Benchmarks

- **Faradion Limited (2024/25)**: Sodium-ion Technology: The Next Generation of Energy Storage. (Global benchmark for 0% Voltage Safety and commercial patent-holding).
- **CATL (2025)**: Technical White Paper: The NaXTRA Series and the Path to £40/kWh Storage. (Validating energy density targets of 160 Wh/kg).

- **IRENA (2025)**: Innovation Outlook: Sodium-Ion Batteries. (Global analysis of supply chain resilience).

APPENDIX A: THE SOVEREIGN DNS PROTOCOL (GRID SECURITY)

Purpose: To ensure every Sodium-Ion battery and grid-controller remains unhackable, high-speed, and autonomous from foreign digital influence.

1. Resolver Strategy: DNS4EU (Sovereign EU)

- **Recommendation**: Migration to the EU DNS4EU consortium infrastructure.
- **Strategic Rationale**: This replaces dependency on US-based resolvers (like Google or Cloudflare). By routing grid-control traffic through sovereign European infrastructure, we ensure that metadata and operational commands stay strictly under European jurisdiction and are protected from extra-territorial data laws.

2. Security Protocol: DNSSEC (Algorithm 13/15)

- **Recommendation**: Mandatory use of digital signatures via ECDSAP256.
- **Strategic Rationale**: This prevents "Cache Poisoning" and "Man-in-the-Middle" attacks. It ensures that a Sodium-Ion battery unit only accepts commands—such as a request to discharge during a frequency drop—from a verified, authentic grid operator.

3. Latency Target: Edge Resolution (< 20ms)

- **Recommendation**: Deployment of localised DNS servers in UK regions.
- **Strategic Rationale**: Grid stability requires sub-second response times. High-speed "Edge" resolution is critical for the 15-minute smoothing mandate; any delay in DNS lookups could result in a battery failing to catch a "Sawtooth" spike in time.

4. Record Type: IPv6 Preferred (A/AAAA)

- **Recommendation**: Native IPv6 implementation for all grid-connected assets.
- **Strategic Rationale**: We are moving toward a "Distributed Energy Fabric" with billions of IoT devices. IPv6 provides the massive, unique address space required for a nationwide fleet of batteries, ensuring every unit is uniquely reachable and manageable without complex, insecure workarounds.

5. Redundancy: Triple-Anycast

- **Recommendation**: Distribution of DNS records across three separate physical networks.

- **Strategic Rationale**: This provides "Grid Resilience." By using an Anycast strategy, if one physical network is attacked or fails, the grid's "digital map" remains instantly available via the other two, preventing a localised internet outage from taking down national energy storage.

6. Privacy & Tunnelling: DNS-over-HTTPS (DoH)

- **Recommendation**: Fully encrypted request paths for all telemetry data.
- **Strategic Rationale**: DoH encrypts the communication between the battery and the resolver. This prevents third parties or hostile actors from "sniffing" traffic to see when a battery is charging or discharging, effectively protecting industrial secrets and national energy usage patterns.

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Published by
Association Environnement Juste
Association loi 1901 – Registered in France
Registered number: W461002451

Registered office
La Mairie, 1 Place des Consuls
46800 Montcuq-en-Quercy-Blanc
France

Correspondence address
330 Chemin de Vidalot
46800 Montcuq-en-Quercy-Blanc
France

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Direct Access: Full Document Available at
https://www.environnement-juste.fr/wp-content/uploads/2026/01/Firm_Power_Mandate_UK_AEJ_TA_20260130_v3.1.pdf

Author and principal contributor
Tim Abady

Direct contact
tim.abady@environnement-juste.fr
+33 6 60 55 66 64

VERSION 3.1 - 30 January 2026
Revision incorporating BATRI-Swansea breakthrough (17th December 2024) and verified UK grid data