Renewable Energies:

An Action Plan for Responsible Grid Harmony

WHITE PAPER | ASSOCIATION ENVIRONNEMENT JUSTE

*“Bien comprendre pour mieux décider” **

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.

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, supporting skilled employment and avoiding repeated dependence on foreign mineral monopolies.
- **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.

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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** ($P \propto v3$). 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%, while 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," Europe 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 and Batri** 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 **€50/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 European 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, Europe can avoid repeating the lithium dependency mistake.

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**.

- 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.

By moving away from **Non-Firm Volatile Energy** and mandating **Sodium-Ion integration**, we achieve more than just grid stability; we trigger a European 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 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 **"Bien comprendre pour mieux décider,"** 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.

GLOSSARY

***** *«Thorough understanding for better decisions»*

Rule of 8: The physical law where wind power is proportional to the cube of wind speed ($P \propto v3$). 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.

- **Gate 2 Requirement:** To secure a firm connection, projects must meet strict **Strategic Alignment Criteria**. Our proposal uses this to prioritise storage-backed "Firm Power" over volatile "Zombie" projects.

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.

11. REFERENCES & KEY LITERATURE

Regulatory & Policy Frameworks

- **UNECE (2025):** *Understanding the Full System Cost of Electricity (FSCOES): Beyond Plant-Level Metrics.* [Ref: UNECE-2025-SCBOE]. (Establishes the framework to replace LCOE with System-level accounting).

- **Ofgem (2025):** *Response to Balancing Costs in Winter 2024-25.* [Ref: Ofgem-27/11/2025]. (Verification of the £2.7 billion annual taxpayer burden for grid balancing).

- **National Energy System Operator (NESO) (2025):** *Annual Balancing Costs Report: 2024/25 Review and 2030 Projections.* (Analysis of the 17% volume increase in grid-stability interventions).

Technical & Academic Research

- **Mohammed, N. et al. (2025):** "*Grid-Forming Inverters: A Comparative Study of Control Strategies in Frequency and Time Domains.*" *IEEE Industrial Electronics Society.* [DOI: 10.1109/GFMI.2025.33]. (The primary technical evidence for **Synthetic Inertia** and Sodium-Ion grid stabilisation).

- **Batri & Swansea University (2025):** *Sovereign Battery Breakthrough: 18650 Sodium-Ion Cells from Welsh Anthracite.* (The strategic milestone for domestic coal-to-carbon anodes).

- **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 €50/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 €50/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 French and 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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