ADAPTIVE ELECTROMAGNETIC ENERGY OVERLAY

Technical Whitepaper, Engineering Requirements, Patent-Style Disclosure, Commercialization Framework, and Low-Voltage Reproducibility Test

Working name	AEEM
System role	Supplemental wireless-energy overlay; not a grid replacement
Development status	Pre-prototype research and validation framework
Safety posture	Low-voltage laboratory work first; no open-air high-power experiments

Purpose. *Formalize a cost-conscious, falsifiable path toward adaptive wireless power that supplements conventional infrastructure through short, authenticated, carefully controlled electromagnetic links.*

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1. Executive Summary

The formalized outcome is an adaptive electromagnetic energy overlay rather than an attempt to replace the electrical grid. The system uses existing generation, local storage, authenticated receivers, resonant magnetic coupling, phased arrays, time-reversal or channel-aware focusing, and passive or programmable field-shaping structures. Wireless transfer is used only where it creates more operational value than wire: moving equipment, sealed environments, temporary links, hard-to-wire gaps, microgrid balancing, resilience, and selected peak-load relief.

Core thesis. The strongest innovation is not a new atmospheric fuel or ion conductor. It is closed-loop field control: measure the real propagation channel, form energy only on demand, concentrate it at an authenticated receiver, suppress unintended fields, recover DC, and terminate immediately when conditions change.

Item	Definition / Requirement
Primary product	A modular wireless-energy router for equipment, buildings, campuses, microgrids, and critical infrastructure.
Best initial range	Centimeters to several meters; controlled tens-of-meters research only after short-range validation.
Best initial power	10-100 W tabletop/room-scale, followed by 1-10 kW industrial pilots.
Excluded early claims	Free energy, atmospheric ion generation, passive amplification, citywide open-air current, and complete grid replacement.
Commercial success criterion	Lower lifecycle cost or higher operational value than a wired alternative in at least one defined use case.
Scientific success criterion	Repeatable improvement in received DC power or field localization under fixed total source input, with complete uncertainty and safety reporting.

2. System Concept and Scope

2.1 Functional definition

AEEM is a distributed network of power nodes that senses local field conditions, demand, storage, occupancy, and link efficiency; then selects and controls the safest economically useful transfer path. **The atmosphere remains primarily a dielectric propagation medium, not a deliberately ionized conductor.**

- Powered anchor nodes provide energy from the grid, solar, batteries, generators, or other conventional sources.
- Receiver/storage nodes authenticate, rectify the received waveform, report delivered energy, and buffer it as DC.
- Passive or semi-passive field shapers alter phase, impedance, polarization, reflection, or local coupling without becoming full transmitters.

- Environmental reference nodes measure occupancy, geometry, temperature, humidity, pressure, interference, and local electric/magnetic fields.
- A supervisory controller chooses frequency, phase, amplitude, timing, polarization, route, and shutdown state.

2.2 Intended role

AEEM supplements existing infrastructure by selectively offloading difficult or high-value transfers. It does not carry every kilowatt-hour. The system should remain idle unless an authenticated receiver requests power and a safe, efficient route is verified.

3. Technology Selection

Method	Best range	Strength	Primary risk	Roadmap status	Decision
Resonant magnetic coupling	mm to meters	Mature, efficient at short range	Alignment, metal heating	Immediate	Core
Channel-aware phased arrays	meters to controlled tens of meters	Adaptive focusing/nulling	Complex sensing and synchronization	Research	Core research
Time-reversal / reciprocity control	Complex indoor paths	Uses measured multipath	Dynamic environments	Research	Core research
Programmable metasurfaces	Path-dependent	Potentially low-cost field shaping	Insertion loss and power handling	Research	Cost-reduction option
Directional microwave/rectenna	Controlled long links	High directionality	Exposure corridor and aperture cost	Later specialty	Conditional
Atmospheric ion conduction	Open air	Conceptually conductive	Corona, chemistry, low natural current	Exploratory only	Exclude from core
Vacuum/plasma beamline	Tube infrastructure	Particle energy transport	Pumps, radiation, physical conduit	Separate research	Exclude from product

4. Cost-Optimized Architecture

4.1 Node classes

Class A - Powered anchor: Active power electronics, transmitter/coil array, synchronization, sensing, and independent safety shutdown. Minimize count.

Class B - Field shaper: Passive resonator or programmable surface with low-power control. Maximize reuse of walls, roofs, poles, and existing structures.

Class C - Receiver/storage: Authenticated receiver, rectifier, DC regulation, local storage, temperature sensing, and optional relay capability.

Class D - Reference sensor: Field probes, occupancy sensing, environmental measurement, interference monitoring, and calibration.

4.2 Cost rules

1. Use wire whenever wire is cheaper, safer, and reliable; reserve wireless for gaps where it creates measurable value.
2. Prefer one active hop over multiple regenerated hops; every additional conversion must justify itself.
3. Use passive resonators or metasurfaces only when measured delivered energy per installed dollar improves.
4. Standardize receiver modules and communications before attempting district-scale infrastructure.
5. Use off-the-shelf power electronics and unlicensed/approved experimental bands only within applicable rules.
6. Design field-replaceable modules and log all energy input, delivered output, heat, and downtime.
7. Require local storage so wireless links can pause instantly without interrupting critical loads.

5. Engineering Requirements Specification

ID	Category	Requirement
SYS-001	SYS	The system shall operate as a supplemental power link and shall not be required for baseline life-safety power.
SYS-002	SYS	Every energy receiver shall be authenticated before power rises above a low verification level.
SYS-003	SYS	The system shall measure wall-plug input and recovered DC output with traceable instrumentation.
SYS-004	SYS	The controller shall preserve raw test data, calibration data, configuration, environmental measurements, and timestamps.
EM-001	EM	Transmit amplitude, phase, frequency, timing, and where applicable polarization shall be independently controllable or explicitly fixed and documented.
EM-002	EM	The system shall execute a low-power channel verification before every high-power transfer session.
EM-003	EM	The design shall characterize unintended electric and magnetic fields across the accessible test volume.
SAFE-001	SAFE	Initial prototypes shall be extra-low-voltage, current-limited, enclosed, and powered by certified USB or laboratory DC supplies.

SAFE-002	SAFE	No prototype shall use exposed mains voltage, intentional arcs, plasma channels, high-voltage Tesla coils, or homemade microwave sources.
SAFE-003	SAFE	Any abnormal temperature, object intrusion, receiver loss, communications loss, or sensor disagreement shall remove transmit power.
SAFE-004	SAFE	Human-exposure assessment shall follow the applicable frequency-range standard before scaling beyond low-power laboratory work.
CTRL-001	CTRL	The controller shall optimize delivered DC power subject to measured safety, temperature, and source-power constraints.
CTRL-002	CTRL	The controller shall prevent oscillatory target switching through hysteresis and minimum dwell times.
ECON-001	ECON	Each deployment stage shall compare lifecycle cost and delivered energy with a wired baseline.
GO-001	GO	Scale-up requires repeatable improvement across at least three independent builds or laboratories.

6. Control and Measurement Model

A transfer session follows a closed-loop sequence:

8. Receiver announces identity, state of charge, requested power, location or calibration signature, and thermal limit.
9. Source nodes transmit a low-power probe or receive a receiver pilot signal.
10. The controller estimates the channel and proposes one or more field configurations.
11. The system applies a low-power test state and measures received DC power plus stray-field probes.
12. Power increases only while all measured constraints remain satisfied.
13. The controller periodically rechecks the channel; movement or obstruction triggers a power reduction or shutdown.
14. All source energy, recovered energy, temperature, and configuration data are written to a test ledger.

> ***Primary performance ratio:*** *end-to-end efficiency = recovered DC energy / total electrical source energy. Any claimed field-control gain must compare configurations under the same total source input, receiver load, geometry, frequency, and measurement interval.*

7. Patent-Style Invention Disclosure (Non-Legal Draft)

> ***Notice.*** *This section is an engineering disclosure and claim-outline aid, not a legal opinion, novelty search, or filed patent application.*

7.1 Working title

Adaptive Authenticated Electromagnetic Energy Routing System with Closed-Loop Field Localization and Safety-Constrained Power Delivery

7.2 Problem addressed

Conventional wireless-power systems typically optimize a single transmitter-receiver link and may not coordinate distributed sources, field-shaping structures, environmental sensing, receiver authentication, energy-deficit routing, and measured safety constraints as one closed-loop network.

7.3 Proposed inventive combination

- A plurality of spatially separated electromagnetic source nodes under a shared timing and control process.
- An authenticated receiver that transmits a pilot or reports channel and recovered-power measurements.
- Closed-loop adjustment of source amplitude, phase, frequency, timing, polarization, or impedance to maximize recovered DC under explicit field constraints.
- One or more passive or programmable field-shaping nodes selected dynamically for the active route.
- Occupancy or protected-zone sensing incorporated directly into the optimization objective.
- Energy routing based on receiver deficit, criticality, predicted demand, transfer efficiency, and safety penalty.
- Automatic fallback to a safe low-power or off state upon channel change, disagreement, or receiver loss.

7.4 Example independent-claim skeleton

A system comprising: multiple spatially separated electromagnetic transmit elements; a receiver configured to convert received electromagnetic energy to direct-current electrical energy; one or more sensors measuring a propagation condition or protected region; and a controller configured to authenticate the receiver, determine a transfer configuration from measured channel information, command the transmit elements to form a receiver-localized field, constrain a measured or predicted field within the protected region, and modify or terminate transmission in response to feedback from the receiver or sensors.

7.5 Candidate dependent-claim features

- Time-reversed or reciprocal-channel waveform generation.
- Programmable metasurface selection and phase-state control.
- Resonant magnetic relay selection based on measured coupling.
- Alternating carrier, polarization, or frequency based on environmental conditions.
- Receiver-side storage allowing immediate interruption of the wireless link.
- Weakest-node or highest-value-node scheduling with hysteresis.
- Measured null or reduced-field constraint in a moving protected volume.
- Distributed ledger of source energy, recovered energy, configuration, and safety state.

8. Commercialization and Investment Framework

8.1 Initial customer problem

The initial customer is not a city utility seeking full wireless replacement. It is an operator paying high cost for contacts, cables, downtime, maintenance, contamination control, movement constraints, or temporary wiring.

Item	Definition / Requirement
Warehouse/robotics	Contactless charging and reduced docking precision for autonomous equipment.
Industrial sealed systems	Power across barriers, rotating joints, wet zones, clean rooms, or corrosive environments.
Campuses/microgrids	Selective transfer across roads, courtyards, temporary structures, or resilience links.
Emergency/temporary infrastructure	Rapidly deployed links where trenching or overhead lines are impractical.
Critical facilities	Supplemental, interruptible transfer backed by local storage; never the sole life-safety supply.

8.2 Development budget gates

Item	Definition / Requirement
Gate 0 - Simulation and bench design	$25,000-$150,000; establish instrumentation, models, safety plan, and baseline.
Gate 1 - Tabletop reproducibility	$5,000-$50,000 professional laboratory version; the simplified home version is under roughly $150.
Gate 2 - Room-scale prototype	$250,000-$1 million; moving receiver, multipath, protected-zone sensing.
Gate 3 - Industrial pilot	$2-$10 million; 1-10 kW, multiple receivers, uptime and maintenance evidence.
Gate 4 - Multi-building overlay	$10-$50 million only after a positive lifecycle-cost case.

8.3 Investment thesis

Fund the control layer first. The defensible asset is the measured field-routing, authentication, safety, and energy-accounting platform. High-power infrastructure should be deferred until the same control architecture has demonstrated value at low and moderate power.

9. Simplified At-Home Reproducibility Test

> ***What this test can prove:*** *whether a passive resonant relay and controlled geometry can improve received DC power at a fixed low-voltage wireless-power setup. It cannot prove city-scale*

transmission, free energy, atmospheric-ion harvesting, human-safe high-power operation, or grid replacement.

9.1 Safety boundary

- Use only certified 5 V USB power or a current-limited bench supply set to 5 V and no more than 1 A.
- Do not open wall-powered chargers, microwave ovens, induction cooktops, RF amplifiers, or mains adapters.
- Do not use Tesla coils, flyback transformers, ignition coils, vacuum tubes, arcs, plasma, or exposed high voltage.
- Keep the setup away from implanted medical devices, magnetic cards, watches, and unknown metal objects.
- Stop immediately if any coil, capacitor, receiver, cable, or power supply becomes hot, smells abnormal, discolors, or behaves erratically.
- Operate for short measurement intervals on a nonflammable surface with adult supervision.

9.2 Test question and hypothesis

Question: At a fixed source voltage and fixed geometry, can an untethered passive resonant relay coil placed between a transmitter and receiver increase the receiver load power compared with the no-relay baseline?

Null hypothesis H0: The relay produces no repeatable increase beyond measurement uncertainty and normal positioning variation.

Alternative hypothesis H1: At one or more positions, the tuned relay increases median recovered DC power by at least 10% while source input remains within 5% of baseline.

9.3 Materials

Item	Definition / Requirement
Required	One low-power 5 V wireless power transmitter/receiver module pair rated around 1-5 W, with the transmitter and receiver coils exposed as low-voltage modules; use a reputable preassembled module.
Required	One USB power meter capable of voltage, current, and accumulated energy, or two digital multimeters used safely on the low-voltage DC side.
Required	A fixed resistive load appropriate for the receiver output, such as a USB electronic load set conservatively or a power resistor specified for the module output.
Required	Nonconductive ruler, cardboard/foam fixtures, tape, graph paper, and a thermometer or inexpensive contact temperature probe.
Relay option A	A second identical receiver coil/module left electrically unloaded. This is the simplest screening relay, though its electronics may detune it.
Relay option B	A preassembled passive resonant repeater coil made for the same wireless-power frequency. Do not improvise

	capacitor values unless you can verify their voltage and temperature ratings.
Optional	A second identical passive relay for comparing one-relay and two-relay configurations.

> ***Expected household cost:*** *approximately $40-$150 depending on meters and modules. Avoid ultra-cheap unmarked modules with no current rating or documentation.*

9.4 Fixture

Create a straight, repeatable axis using cardboard or foam supports. The transmitter and receiver coil centers must stay aligned and parallel. Mark distances at 5 mm increments. Keep all metal tools and phones at least 30 cm away during measurements.

5 V USB	→	TX module	air gap	RX module
USB meter		fixed	relay inserted here	fixed load
measure Vin, Iin			change one variable	measure Vout, Iout

9.5 Variables to hold constant

- Same USB supply, cable, transmitter, receiver, load, and meter.
- Same transmitter-receiver distance and coil orientation for each paired comparison.
- Same measurement duration, preferably 60 seconds after a 30-second settling period.
- Same room and surrounding objects.
- Same receiver load setting.
- Coil temperatures within 5 degrees C between compared trials; allow cooling if necessary.

9.6 Procedure

15. Inspect all modules for damage. Set the transmitter-receiver spacing to a distance where the receiver operates reliably but is not at maximum output; usually this is near the edge of its comfortable range.
16. Baseline trial: operate without a relay. After 30 seconds of settling, record source voltage, source current, receiver voltage, receiver current, and temperatures. Continue for 60 seconds.
17. Repeat the baseline five times, removing and reinstalling the receiver each time to capture positioning variation.
18. Insert the passive relay exactly halfway between the transmitter and receiver, parallel and coaxial. Do not connect it to a power supply or load.
19. Repeat five trials using the same settling and measurement intervals.
20. Move the relay in 5 mm increments along the axis. At each position, collect at least three trials. If practical, test small lateral offsets and angular rotations.
21. Randomize the order of relay-present and relay-absent trials or have another person conceal the condition from the recorder to reduce expectation bias.
22. Repeat the best apparent configuration on a different day after fully rebuilding the fixture.
23. Optionally repeat with a second identical transmitter/receiver module set to test build-to-build reproducibility.

9.7 Calculations

For each trial calculate:

- Source input power: Pin = Vin × Iin.
- Recovered receiver power: Pout = Vout × Iout.
- End-to-end efficiency: eta = Pout / Pin.
- Relay gain relative to paired baseline: G = (Pout,relay - Pout,baseline) / Pout,baseline × 100%.
- Also report source-power change; an apparent receiver gain caused only by higher transmitter input is not a field-control gain.

Trial	Relay?	TX-RX mm	Relay pos. mm	Vin V	Iin A	Pin W	Vout V	Iout A	Pout W	eta %	Max temp C

9.8 Pass/fail criteria

- PASS - screening result: median Pout with the relay is at least 10% above the paired no-relay median, the improvement exceeds two times the observed baseline trial-to-trial spread, and Pin changes by no more than 5%.
- PASS - reproducibility: the result repeats after fixture reconstruction and with a second module set or independent tester.
- INCONCLUSIVE: improvement is smaller than 10%, source power changes materially, or result depends on sub-millimeter placement that cannot be repeated.
- FAIL for the tested configuration: no repeatable gain, efficiency declines, thermal rise increases materially, or receiver regulation makes output measurements meaningless.
- Any positive result supports only the specific low-power relay geometry. It does not establish net energy creation; the correct interpretation is changed coupling or impedance.

9.9 Controls that prevent false positives

- Use a fixed resistive/electronic load rather than an LED brightness judgment.
- Measure both source input and receiver output.
- Repeat trials and report all data, including failures.
- Use a sham object of similar size made from cardboard to test whether simple spacing changes explain the effect.
- Test the relay rotated 90 degrees; a true resonant-coupling effect should be strongly orientation-dependent.
- Check whether the receiver voltage regulator is saturating; if output is clamped, increase the load safely or measure current/energy instead.
- Photograph the fixture with a ruler visible and publish exact module model numbers.

10. Professional Follow-On Experiment

After the home test, the next meaningful experiment is a four-channel synchronized low-power source array with calibrated three-axis field probes. Its purpose is to test whether closed-loop control can increase receiver power while reducing field magnitude in a separate protected zone under fixed total input power.

Item	Definition / Requirement
Independent variable	Source phase/amplitude state; optional passive surface state.
Dependent variables	Recovered DC power, source input, electric/magnetic field maps, temperatures, and shutdown latency.
Baseline	One transmitter or equal-phase array under the same total electrical input.
Primary success	At least 20% higher recovered DC power than baseline plus at least 6 dB field reduction in a predefined protected region.
Replication	Three independent builds or laboratories with shared raw data and calibration files.
Scale limit	Do not advance to kilowatt levels until exposure assessment and independent safety review are complete.

11. Roadmap, Decision Gates, and Estimated Odds

Stage	Target	Indicative cost	Go criterion	Estimated success chance
Home screening	Passive relay coupling	\$40-\$150	Repeatable measured gain	60-85% chance of finding some geometry-dependent effect; not necessarily useful
Tabletop lab	Controlled focusing and null	\$5k-\$50k	Gain under fixed input and mapped stray fields	80-95%
Room-scale	10-100 W moving receiver	\$250k-\$1M	Stable authenticated operation	70-90%
Industrial pilot	1-10 kW	\$2M-\$10M	Positive lifecycle value	50-75%
Campus overlay	Selective links	\$10M-\$50M	Measured peak/resilience benefit	35-60%
District overlay	Supplemental utility role	\$50M+	Regulatory and economic case	20-45%

12. Principal Risks and Mitigations

Item	Definition / Requirement
Efficiency	Wireless transfer may not beat wire. Mitigation: Target high-value gaps; measure full wall-plug efficiency; terminate low-value branches.
Safety and exposure	Field localization may fail around people or metal. Mitigation: Start at extra-low power; calibrated mapping; independent shutdown; standards-based assessment.
Interference	Power waveforms may disturb communications/electronics. Mitigation: Frequency planning, shielding, EMC testing, and controlled environments.
Control instability	Multipath and movement can detune the link. Mitigation: Continuous pilot feedback, conservative ramping, hysteresis, and local storage.
Metasurface losses	A field shaper may cost more energy than it saves. Mitigation: Require measured net gain and lifecycle-cost benefit before deployment.
Overclaiming	Laboratory coupling improvement may be mistaken for energy creation. Mitigation: Complete input/output accounting, explicit limitations, independent replication.
Regulation	High-power public deployment may be unacceptable. Mitigation: Focus first on enclosed industrial sites and existing standards pathways.

13. Technical Basis and Selected Sources

These sources establish demonstrated power beaming, programmable field-shaping research, and the exposure-assessment framework. They do not validate all proposed AEEM features as a complete commercial system.

- **IEEE/IEC 63184-2025:** Assessment methods for human exposure to fields from wireless power transfer systems, 3 kHz to 30 MHz. Source
- **IEEE P63480:** Exposure-compliance assessment methods for WPT systems from 30 MHz to 300 GHz. Source
- **ICNIRP RF Guidelines 2020:** Human exposure guidance for RF electromagnetic fields from 100 kHz to 300 GHz. Source
- **U.S. Naval Research Laboratory SCOPE-M:** Reported 1.6 kW terrestrial microwave power transmission over 1 km. Source
- **Li et al., Nature Communications (2024):** Intelligent wireless power transfer using a compact programmable metasurface; reported low-cost/selective concepts and approximately 3% best RF-to-RF efficiency in that framework. Source
- **Ranaweera et al., Scientific Reports (2019):** Active metasurface field localization for wireless power transfer and reduction of leakage into unintended regions. Source

14. Formal Conclusion

Proceed with AEEM as a staged, supplemental, safety-constrained field-control platform. The immediate objective is not citywide wireless power. It is to demonstrate that controlled resonant relays and distributed source states can improve useful receiver delivery or reduce unintended fields under fixed total input, then identify a niche where that improvement creates lifecycle value.

The low-voltage at-home test provides a transparent first screen. A positive result advances the relay branch to calibrated laboratory testing; a negative result is equally useful because it prevents unnecessary scale-up. Atmospheric ions, vacuum beams, geomagnetic anomalies, and city-scale power transmission remain separate exploratory branches unless quantitative evidence shows an advantage over established electromagnetic methods.

Appendix A. Reproducibility Publication Checklist

- Exact module manufacturer/model and rated input/output.
- Circuit diagram or clear wiring photograph.
- Coil outside/inside diameter, turns if known, and orientation.
- Transmitter-receiver and relay distances with uncertainty.
- Load type and setting.
- Meter model, range, resolution, and calibration status.
- Raw trial-by-trial Vin, Iin, Vout, Iout, time, and temperature.
- All excluded trials with reasons stated before analysis.
- Photographs of baseline, relay, sham, and 90-degree control conditions.
- Analysis spreadsheet and formulas.
- Explicit statement that no net-energy claim is made.