AEEM HOME NODE

Consumer Energy Optimization Whitepaper

A plug-in, measurement-first energy router designed to reduce household electricity cost now and become the standardized node layer for future wireless energy transfer.

Core commercial promise: measure first, automate second, prove savings continuously.

Version 1.0 | August 2026

1. Executive Summary

AEEM Home Node is a consumer energy-management platform built around a simple principle: a household cannot save money merely by inserting electronics between the wall and an appliance. Savings must come from measurable reductions in unnecessary consumption, better scheduling, reduced peak demand where tariffs reward it, and earlier detection of inefficient equipment.

The first product is therefore not a speculative wireless-power transmitter. It is a plug-through energy router that measures real power, switches loads safely, learns operating patterns, and coordinates appliances as a single household energy system. The same node standard can later host short-range resonant wireless receivers and other advanced energy-routing technologies.

Design goal	Whitepaper position
Immediate bill reduction	Primary objective
Whole-home grid replacement	Not an initial objective
Wireless power	Future node capability, not required for Version 1
Savings verification	Mandatory counterfactual measurement
Consumer installation	120 V plug-through products first
240 V major loads	Professionally installed modules

2. Why This Product Can Create Real Savings

A residential power-factor correction box, voltage manipulator, or passive 'energy saver' generally cannot create meaningful household savings when the utility bills primarily for real energy in kilowatt-hours. AEEM instead targets controllable behavior and equipment performance.

The U.S. Department of Energy has already demonstrated the economic importance of home energy-management systems. In one smart-panel project, a representative summer-day simulation reported 10.4% energy savings and 44.4% energy-cost savings under its tested pricing and control conditions. DOE separately describes smart-panel home energy management as a strategy to improve bill savings under time-of-use, real-time, and demand-charge rate structures.

ENERGY STAR reports that certified smart thermostats save about 8% of heating and cooling bills on average. That establishes an important precedent: automated control can create measurable savings without changing the fundamental energy source.

Water heating is another major controllable load. DOE notes that typical heat-pump water heaters can save roughly 60% of annual water-heating energy compared with conventional electric resistance systems. AEEM does not attempt to manufacture that efficiency advantage electronically; instead, it coordinates when the water heater runs and can recommend replacement when the economics justify it.

3. Product Architecture

3.1 AEEM Energy Valve - 120 V

A plug-through module placed between a standard outlet and an appliance. It measures voltage, current, real power, apparent power, power factor, temperature, runtime, standby behavior, and switching events. It can physically disconnect selected loads and report verified savings.

Subsystem	Function
Metering	True-RMS voltage/current and real-energy measurement
Switching	Rated relay or solid-state disconnect with fail-safe state
Controller	Local pattern learning and automation
Connectivity	Matter/Thread/Wi-Fi class communications
Protection	Overcurrent, overtemperature, surge, relay-weld detection
User interface	Simple saved-today / saved-month / projected-year view

3.2 AEEM Climate Node

A thermostat/HVAC companion that learns energy required per degree of conditioning rather than relying only on temperature schedules. It correlates compressor runtime and electrical demand with outdoor conditions, indoor temperature, humidity, occupancy, and recovery performance.

The Climate Node can identify patterns such as increasing compressor runtime for the same cooling result, excessive cycling, poor recovery after setback, or high cost during expensive tariff windows. It can recommend maintenance rather than silently allowing degradation to persist.

3.3 AEEM Water Node

A professionally installed controller for electric water heating. It treats the water tank as thermal storage: heat when electricity is cheap or rooftop solar is abundant, then reduce operation during expensive periods while maintaining user-defined comfort and sanitation constraints.

3.4 AEEM Home Controller

The controller coordinates all nodes. It may begin as software running on one Energy Valve or a small local hub. The control objective is whole-home cost rather than isolated appliance optimization.

The home becomes one energy system: measure -> predict -> prioritize -> switch -> verify.

4. Savings Mechanisms

Mode	What it does	When it saves
Ghost Load	Disconnects unnecessary standby loads	Always, if standby use is material
Schedule Shift	Moves flexible loads to cheaper tariff windows	Time-of-use / dynamic rates
Peak Guard	Prevents simultaneous flexible high loads	Demand charges or constrained service
Climate Optimize	Minimizes energy cost per useful degree of conditioning	Most electrically heated/cooled homes
Fault Watch	Detects rising energy per completed task or HVAC output	Degrading equipment
Solar Capture	Runs flexible loads when local solar would otherwise export	Solar homes
EV Coordinate	Varies charging around household demand and tariff	EV homes

5. Control Logic

The system should not simply charge or run the 'weakest' load. It should calculate the most economically useful action from measured state, user priority, forecast demand, appliance constraints, and tariff.

A practical decision score can be expressed conceptually as:

Priority = (Energy Need x User Criticality x Forecast Benefit) / (Energy Cost + Wear Penalty + Comfort Penalty)

The controller then tests actions against hard constraints: refrigerator uptime, medical-device exclusions, HVAC anti-short-cycle timing, water-temperature limits, relay ratings, and user overrides.

6. Verified Savings, Not Marketing Savings

The central differentiator should be a defensible counterfactual. Every node records what the connected load historically consumed under comparable conditions, what it consumed after optimization, and which control action produced the difference.

Metric	Required treatment
Energy saved	Measured kWh reduction against weather/time/use-adjusted baseline

Bill saved	Actual tariff applied to measured load shift/reduction
Avoided peak	Measured kW reduction during tariff-defined peak interval
Equipment anomaly	Change in energy per cycle, runtime, or delivered HVAC effect
Uncertainty	Displayed when baseline confidence is insufficient

AEEM should refuse to claim savings when the data cannot support the claim. That restraint is commercially valuable because it separates the product from plug-in 'electricity saver' devices that make physically implausible promises.

7. Consumer Savings Target

A fixed percentage should not be promised before field trials. The engineering target should be a minimum 5% whole-home electricity-cost reduction in suitable homes, with 10-15% as a design target for homes that combine electric HVAC, electric water heating, meaningful flexible loads, EV charging, solar, or time-varying tariffs.

Already-efficient homes on flat-rate electricity may save much less. Homes with poor scheduling, aging HVAC, electric resistance water heating, high standby consumption, or dynamic pricing may save substantially more in dollars.

Household profile	Expected opportunity
Flat rate, efficient appliances, gas heat/water	Low - mainly standby/fault detection
Electric HVAC + flat rate	Moderate - climate optimization and fault detection
Electric HVAC + TOU rate	Moderate to high - control + shifting
Electric water heater + EV	High flexibility opportunity
Solar + EV + electric water heat	High - self-consumption and coordinated scheduling
Demand-charge residential tariff	Potentially very high bill impact from peak control

8. Hardware Classes and Cost Targets

Product	Target role	Estimated mass-market retail target
Energy Valve 15 A	Plug loads	$79-$149
Energy Valve 20 A	Larger 120 V loads	$99-$179

Climate Node	HVAC optimization/diagnostics	$149-$299
Water Node	240 V water heater control	$199-$399 + installation
EV/High-Load Node	240 V load coordination	$249-$499 + installation
Home Controller	Optional dedicated hub	$99-$199

8.1 120 V BOM Target

Component group	Target BOM
Metering IC + current sensing	$4-$8
MCU / radio	$4-$8
Relay / switching	$3-$8
Isolated low-voltage supply	$3-$5
Protection / thermal sensing	$2-$4
PCB	$3-$6
Enclosure / connectors	$5-$10
Miscellaneous	$3-$5
Target electronics BOM	$27-$54

9. Safety and Certification

The consumer product must be designed as an appliance-control system, not an experimental high-voltage platform. Mains switching, creepage/clearance, flame-retardant enclosure, thermal behavior, relay failure, surge immunity, cybersecurity, and fail-safe control must be addressed before sale.

Version 1 should contain no exposed high voltage, no Tesla-coil circuitry, no plasma generation, and no intentional high-power RF power beaming. Future wireless-energy modules should be treated as separately certified subsystems.

Failure case	Required response
Loss of network	Local safe operating policy continues
Controller crash	Critical loads remain energized unless specifically

	designed otherwise
Relay weld	Detect mismatch between command and measured current
Overtemperature	Disconnect load and alert
Unexpected current	Immediate protective shutdown within hardware limits
Medical / life-safety load	Default exclude from automatic shedding

10. Development Roadmap

Phase	Scope	Gate
0	Bench metering + relay prototype	Accurate energy measurement and safe switching
1	5-20 homes	Reliable baseline and automation; no nuisance failures
2	100-home beta	Measured bill reduction by household type
3	Climate + water integration	Savings materially exceed plug-only system
4	Utility / TOU integration	Demonstrable peak and tariff optimization
5	Short-range wireless receiver option	Adds value without degrading efficiency or safety

11. Relationship to the AEEM Wireless Mesh

The Home Node is strategically important even if long-range wireless power never becomes economical. It creates the authentication, measurement, routing, synchronization, occupancy, and demand-control layer that any future electromagnetic power network would require.

Generation 1 remains wired on both sides. Generation 2 adds short-range resonant receiving. Generation 3 may add room-scale energy routing where safe and efficient. The product is therefore commercially useful before the speculative research branch succeeds.

Generation	Energy path

Gen 1	Wired source -> smart node -> wired appliance
Gen 2	Wired source -> local resonant transmitter -> authenticated receiver -> appliance
Gen 3	Multiple local anchors -> adaptive short-range field routing -> receiver
Gen 4	Building / microgrid overlay where economics and safety justify it

12. Commercial Positioning

The product should not be marketed as free energy, a power-factor saver, or a device that somehow produces additional electricity. The consumer-facing value proposition is straightforward:

Plug it in. It learns where your home wastes electricity and automatically stops buying electricity when you do not need it.

The app should emphasize dollars rather than electromagnetic theory. The advanced field-control research remains part of the platform roadmap, while the first product succeeds or fails on verified household savings.

13. Go / No-Go Criteria

Continue if...	**Redesign or stop if...**
Metering error is low enough to support savings claims	Savings are smaller than device self-consumption / ownership cost
Automation saves >=5% in a meaningful target segment	Users disable controls due to comfort or nuisance
HVAC diagnostics find actionable degradation	False alarms dominate
Hardware can retail below practical payback threshold	Certification/manufacturing cost destroys payback
Savings remain after weather and occupancy adjustment	Apparent savings disappear under controlled analysis

14. Reference Evidence

- U.S. Department of Energy / NREL - Smart Electrical Panel-Based Home Energy Management System (2023). A representative summer-day evaluation reported 10.4% energy savings and 44.4% energy-cost savings under its tested control and pricing conditions.

- U.S. Department of Energy - Smart Electrical Panel-Based Home Energy Management System. DOE describes HEMS as a means to improve utility-bill savings under time-of-use, real-time-pricing, and demand-charge plans.
- ENERGY STAR - Smart Thermostats FAQs. Certified smart thermostats save approximately 8% of heating and cooling bills on average.
- U.S. Department of Energy - Heat Pump Water Heaters Achieve Significant Peak Reduction and Energy Savings. DOE notes typical HPWHs can save about 60% of annual water-heating energy compared with conventional resistance water heating.

15. Formal Outcome

AEEM Home Node should be developed first as a measurement-first residential energy router. Its immediate purpose is to reduce unnecessary consumption, shift flexible demand, coordinate major electric loads, and expose inefficient equipment before it silently wastes energy.

This is the lowest-cost, highest-probability consumer path emerging from the broader AEEM research. It creates a useful product now while establishing the standardized node layer required for later electromagnetic power-routing experiments.