LF EDGE

Building a Self-Sufficient Home: Edge AI for Smart Microgrid Energy Management With EdgeLake

How UC Santa Cruz students are using EdgeLake and on-site AI to give a residential microgrid a brain that never needs the cloud.

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At a Glance

Project
Edge AI for Smart Home Energy Management

Platform
LF Edge's EdgeLake Project

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Deployment Site
A live, instrumented residential microgrid (Los Gatos, CA)

Executive Summary

Homes are no longer just consumers of electricity. With rooftop solar, battery storage, and backup generation increasingly common, a house is becoming its own small power system, a microgrid. As climate-driven outages grow more frequent and the grid ages, that microgrid needs to understand and manage itself, especially when the power and the internet both go out at once.

A team of UC Santa Cruz students, working with LF Edge's EdgeLake platform, built and deployed a working system that does exactly that. It unifies data from solar, battery, and whole-home electrical monitoring; uses AI to figure out which appliances are running even when they have no smart connectivity of their own; and turns all of it into clear, explainable guidance for the homeowner, entirely on local hardware inside the house, with no dependency on the cloud or the internet.

The system is live today in a real home in the Los Gatos Mountains, where it has already validated appliance-detection accuracy across refrigerators, dishwashers, HVAC systems, washers, and dryers. It is also actively guiding operational decisions during outages, including which loads to shed and when to run deferrable appliances such as the dishwasher.

The Challenge

As homes take on more responsibility for producing and storing their own energy, they also take on the responsibility of managing it. During an outage, a homeowner needs to know more than just "how much power is left." They need to know what is using that power, whether it's essential, and how many hours remain before the battery runs out.

That kind of insight requires continuously monitoring the home's energy systems and reasoning about them in real time. But an energy-management system that only works when the cloud is reachable defeats its own purpose: the moments homeowners need it most (storms, wildfires, grid failures) are exactly when internet connectivity is least reliable.

The challenge, then, was to build a platform that could:

- Unify data from solar inverters, batteries, and panel-level electrical meters into one coherent picture of the home.
- Infer what ordinary, non-smart appliances are doing, without installing a sensor on every device.
- Turn that picture into clear, trustworthy, explainable recommendations.
- Do all of it locally, so the system keeps working when the grid, and the internet, do not.

The Approach

One local platform instead of many integrations

At the center of the system is EdgeLake, a lightweight software agent that runs on local hardware, anything from a Raspberry Pi to a mini PC. A home can start with a single node and add more only as it needs additional storage, processing power, or redundancy. Multiple EdgeLake nodes present the home's data, storage, and compute as one unified system: applications and AI agents query the home through a single API, without needing to know which device actually holds the data.

Without this layer, every battery, inverter, meter, and sensor would need its own custom integration and database, and a cloud-based version of that same complexity would add ongoing cost while making core functions dependent on an internet connection that may not survive the outage the system is meant to help with.

Three sources of ground truth

- Solar Assistant: measures solar production and battery charge directly from the inverter and battery system.
- Home Assistant: the local automation and control layer for connected devices, running entirely on the home network.
- An eGauge meter: a whole-home electrical meter reporting real power for every subpanel every six seconds, including the connection point to the utility grid. The instant that connection goes to zero, the system knows the home has gone "off-grid," without anyone telling it.

Teaching the system to see appliances it can't talk to

Most household devices, refrigerators, dishwashers, water heaters, have no smart connectivity at all. Rather than requiring a sensor on every appliance, the system uses a technique called Non-Intrusive Load Monitoring (NILM): it looks for each appliance's electrical "fingerprint" in the whole-home power signal and infers what's running from that pattern alone.

The models are trained on the home's own data, using its own appliances, not a generic dataset borrowed from someone else's house. This matters because two refrigerators can have very different power signatures depending on their compressor and wiring. As the home accumulates weeks and months of history, the models improve, and every prediction is checked against a set of physical and behavioral rules before it's trusted, so an AI that's confident and wrong gets caught before it misleads anyone.

Turning insight into decisions

A decision layer combines solar production, battery state, household demand, grid status, and inferred appliance activity into ranked, explainable recommendations, for example, which loads to shed to extend runway, or when to run a load because there is surplus solar to spend rather than save. Every recommendation comes with a reason a homeowner can read, question, and override.

Why It Has to Run at the Edge

A microgrid is most valuable exactly when the utility grid is down, which is also when a cloud connection is least dependable. By keeping measurement, inference, and decision-making local and at the edge, the system keeps working under the same conditions it exists to handle.

This also has a privacy dimension: appliance-level energy data can reveal occupancy, sleep schedules, and medical device use. Keeping that data inside the home isn't a policy choice that could change; it's a property of how the system is built. There is no cloud subscription, no required account, and no service that can be discontinued from under a homeowner who installed a system meant to last for decades.

Results to Date

In under a year, the project moved from an experimental data pipeline to a working system running continuously inside a real, lived-in home.

Live deployment: A working residential microgrid combining solar, battery storage, backup generation, and multiple monitored panels.

Data pipeline: End-to-end local flow from the whole-home meter through EdgeLake running across three nodes, at six-second resolution.

Appliance AI: Three neural network models (one per subpanel) trained on the home's own data and running locally, updating predictions every thirty seconds.

Validation: Refrigerator behavior confirmed four independent ways: a 37.9% duty cycle, ~13-minute average compressor run time, and ~33 cycles per day, consistent with the physical unit.

Dashboards: Real-time views combining generation, battery state, demand, appliance activity, and outage guidance with tiered load priorities.

The deployment also produced a key research finding: model accuracy depends heavily on how often an appliance runs. Frequently used loads (like refrigerators) are learned quickly; rarely used ones (like a dryer) need much more time. That finding directly shaped the project's approach of combining learned models with physics-based rules, rather than relying on AI alone.

> That convergence is the strongest evidence to date that the system is learning real appliance behavior, not fitting noise.

Real-World Resilience

When the power goes out

The home transitions to battery and solar automatically, with the generator held in reserve. The system detects this transition within seconds by watching the utility connection: no manual switch, no cloud confirmation needed. It then shifts its objective from routine monitoring to actively managing a limited energy budget, projecting battery runtime, identifying which loads are consuming it, and recommending what to defer or run based on real conditions, not guesswork.

When the internet goes out

The system keeps working. Every step, measurement, inference, and recommendation, happens on the home's internal network and never depends on an internet connection. The only thing that becomes slightly less precise is forward-looking weather and solar forecasting, which falls back gracefully to recent history and seasonal patterns rather than failing outright.

What's Next

The system is operational today, with EdgeLake unifying measurement, appliance inference, and decision support while Home Assistant provides the control path to household devices. Planned next steps include:

- Expanding Home Assistant integration to more devices.
- Gradually converting validated recommendations into safe, automated actions, with homeowners retaining control over priorities.
- Continuing to refine appliance models as more local history accumulates and as equipment changes.
- Translating system output into plain-language guidance: what happened, why it matters, what to do, and what it's worth.

Read the companion technical blog post which goes deeper into the architecture, the appliance-detection models, and the engineering behind this system.

Get Started with EdgeLake

EdgeLake empowers businesses to unlock the true potential of their edge data. By turning the edge into a virtual data lake, companies extract real-time insights from their distributed edge data without centralizing the data.

GitHub: github.com/EdgeLake

Web: lfedge.org/projects/edgelake