

Case Study: Wavelet-Based Dispatch for an Off-Grid Holiday Park

Dr Stuart Woolley
Full Stack Energy

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1 The Problem

Riverside Holiday Park operates approximately 60 mobile homes and lodges across a rural site in western Ireland, with a clubhouse, laundry block, and small shop. The park has accumulated generation assets over several years: two micro-hydro turbines on an adjacent river, three small wind turbines, rooftop solar across twenty lodges, a communal ground-mounted solar array, seven battery storage units of varying sizes owned by different parties, a backup diesel generator, and a metered grid connection.

The site manager faces a practical question: how should all these assets be coordinated to minimise the electricity bill without expensive software, reliable internet, or a power systems engineer on staff?

The grid connection works, but at retail rates. The diesel is available but expensive and noisy — guests complain. The renewables are free but intermittent. The batteries could smooth things out, but nobody is coordinating them. The result is ad-hoc operation: batteries charge whenever there's excess solar, the diesel fires up when someone notices the grid import is too high, and money leaks through the cracks.

The standard industry solution — a MILP-based energy management system — requires commercial optimisation software, a server, a reliable internet connection to the cloud, and a consultant to configure it. For a holiday park, this is absurd. The annual electricity bill doesn't justify the tooling.

2 The Approach: Frequency Bands

Electricity demand at a holiday park has layers, like music. There is a steady hum that never changes — the security lights, the water pumps, the fridges in the shop. On top of that sits a daily rhythm — demand rises in the morning when everyone showers, drops when they go out, and peaks again in the evening when they cook and turn on the heating. And on top of that are sudden, unpredictable spikes — someone turns on a washing machine, or twenty kettles boil at once after a rain shower drives everyone indoors.

These layers operate at different speeds. The steady hum changes over days or weeks. The daily rhythm repeats every 24 hours. The spikes last minutes.

A mathematical technique called wavelet decomposition can separate a demand signal into these layers automatically, much as an audio equaliser splits music into bass, mid-range, and treble. The result is a set of *frequency bands*, each capturing a different speed of variation in the original signal:

- The *slow band* (approximation) captures the steady underlying demand — the baseload that barely changes from hour to hour.
- The *medium band* (mid-detail) captures the daily rise and fall — the predictable pattern of morning and evening peaks.
- The *fast band* (high-detail) captures the sudden spikes and dips — the unpredictable transients that come and go within minutes.

The insight behind this work is that different types of generator are good at different speeds. A grid connection or a hydro turbine handles the slow, steady demand. A diesel generator or a flexible grid contract handles the daily swing. Batteries handle the fast spikes — they can respond instantly, absorbing a sudden surge or filling a sudden gap.

By splitting the demand into frequency bands and handing each band to the right type of generator, the dispatch algorithm matches assets to the parts of the demand they are best suited to serve. No single asset tries to do everything; each does what it is good at.

3 The Fleet

Table 1: Riverside Holiday Park generation fleet. Wavelet band assignment determines which frequency component of the load signal each asset serves. Exogenous assets are subtracted from gross demand before decomposition.

Asset	Owner	Type	Capacity	Band
Grid import	Park	Baseload	100 kW max	Approximation
Diesel genset	Park	Backup	10–50 kW	None (gap-fill)
Communal battery x2	Park	Storage	5 kW / 13.5 kWh	Detail (high)
Lodge battery x5	Various	Storage	3 kW / 6 kWh	Detail (high)
Rooftop solar (20 lodges)	Various	PV	60 kW total	Exogenous
Ground-mount solar	Park	PV	25 kW	Exogenous
Micro-hydro x2	Park	Run-of-river	~12 kW each	Exogenous
Wind turbine x3	Park	Wind	10 kW each	Exogenous

Total renewable generation: ~145 kW peak. Battery storage: 57 kWh across 7 units. Grid: 100 kW. Diesel: 50 kW. 9 dispatchable assets, 3 exogenous sources. Peak demand: ~120 kW (summer evening, high occupancy). Overnight baseload: ~20 kW.

A critical design decision: the diesel generator is assigned to no wavelet band. It is never dispatched by the wavelet algorithm directly — only committed by the merit-order gap-filler when all other assets are exhausted. At EUR 350/MWh plus EUR 15 startup cost, it is economically the last resort. This prevents the wavelet’s oscillating detail bands from triggering unnecessary diesel starts, which was the primary failure mode in early testing.

4 Demand Patterns

The park’s demand has textbook multi-scale structure — exactly the spectral profile where wavelet decomposition excels:

- *Baseload* (security, pumps, fridges): ~20 kW, always on
- *Morning peak* (showers, kettles): 07:00–09:00 weekdays, 08:00–11:00 weekends, 45–55 kW
- *Evening peak* (cooking, heating, entertainment): 17:00–22:00, 60–70 kW
- *Changeover spikes* (laundry): Saturday and Monday mornings, +15 kW
- *Weekend amplification*: higher occupancy, later mornings, more evening activity

This is a clean diurnal signal with weekly modulation — rich in the multi-scale structure that the approximation and detail bands separate effectively. Unlike a national grid dominated by wind variability, the holiday park’s demand is the signal, not the residual after subtracting renewables.

The net load (demand minus solar, hydro, and wind) ranges from –86 kW (midday solar surplus) to +78 kW (evening peak), with 58% of intervals showing excess generation. The park is a net exporter in summer — the batteries’ job is to shift that surplus from midday to evening.

5 Results

Riverside is on a standard Irish day/night tariff.

Table 2: Irish time-of-use electricity tariff applied to grid import.

Period	Hours	Rate (c/kWh)	Rate (EUR/MWh)
Peak	17:00–19:00	35	350
Daytime	09:00–17:00, 19:00–23:00	21	210
Night	23:00–09:00	12	120

The tariff structure is known to the dispatch algorithm and declared in the plant configuration.

5.1 14-Day Benchmark (Summer Peak Season, 80% Occupancy)

Table 3: Dispatch comparison over 14 days at 80% occupancy with Irish ToU tariff. All methods achieve zero unserved energy and zero diesel starts. Cost differences arise from grid import timing and battery arbitrage efficiency.

Method	Cost (EUR)	Starts	ENS (kWh)	Wall Time
Wavelet (cost-weighted)	869	22	0	0.9 ms
Wavelet (reactive)	906	22	0	1.1 ms
Priority list	840	125	0	0.8 ms
DP (optimal)	690	45	0	7,798 ms

Reactive wavelet dispatch (EUR 906) assigns battery charge/discharge based on the detail band signal — the load’s fast-frequency component. It is oblivious to the tariff. The batteries cycle in response to load structure, not price structure.

Cost-weighted wavelet dispatch (EUR 869) multiplies the detail band by a normalised price signal: $d_1(t) \times p(t)$. This produces a cost signal rather than a power signal — large when fast demand coincides with peak pricing. The gap-filler is also reordered: during peak hours, batteries discharge first to avoid expensive grid import; during surplus intervals (negative net load), batteries charge from free renewable energy. This uses two known inputs (the wavelet decomposition and the published tariff schedule) to make better decisions.

Priority list (EUR 840) never uses batteries at all. Its low cost comes from simplicity — no round-trip efficiency losses. It beats the reactive wavelet approach by avoiding unnecessary battery cycling.

DP (EUR 690) achieves the lowest cost through perfect foresight: it knows the entire load profile and optimally times every battery charge and discharge. No causal method can match this. DP takes 7.8 seconds on an Apple M-series workstation. On the ARM Cortex-A72 in a Raspberry Pi 4, expect 10–20x longer — over a minute per dispatch run, assuming it fits in memory. Add a few more lodges with batteries and the 2^M state space doubles with each new asset.

5.2 What the Cost Weighting Achieves

The cost-weighted approach saves EUR 37 over reactive dispatch (4% reduction). The improvement comes from three mechanisms:

1. During the 35c/kWh peak window, the gap-filler discharges batteries before importing from the grid, displacing the most expensive kWh.
2. When net load is negative (free renewable surplus), batteries charge regardless of the detail band signal — storing energy that costs nothing.
3. During cheap overnight hours, batteries idle and let the 12c grid handle the load rather than wasting cycles.

The remaining EUR 29 gap to priority list is battery round-trip losses: each kWh cycled through 90% efficient batteries loses 10%. The arbitrage gain must exceed this loss to be worthwhile. At the current peak/off-peak spread (35c vs 12c = 23c), the net gain per kWh shifted is approximately 19.5c after losses — positive, but the volume is limited by the 57 kWh battery fleet cycling once per day.

5.3 The Diesel Stays Off

In all scenarios, the diesel generator was never started. The wavelet dispatch coordinates the existing renewables and batteries well enough that the backup generator — with its noise, fuel cost, and maintenance burden — is genuinely redundant during normal operation. It remains available for grid outages, but the dispatch algorithm never needs it.

6 Capacity Planning: Growing the Park

The wavelet decomposition provides a diagnostic tool beyond dispatch. By examining how the band signals change as occupancy increases, the park manager can identify which type of asset to invest in next.

6.1 Band Saturation Analysis

Table 4: Wavelet band statistics at three occupancy levels. The approximation band mean crossing zero indicates the transition from net exporter to net importer. Detail band stddev indicates transient intensity relative to battery capacity (25 kW total discharge).

Scenario	Approx Mean	Approx Max	Detail 1 Stddev	Grid Cost (14d)
80% occupancy	-2.9 kW	60 kW	6.5 kW	EUR 869
95% occupancy	+1.0 kW	70 kW	6.9 kW	EUR 1,010 est.
120% occupancy	+5.2 kW	85 kW	7.5 kW	EUR 1,330 est.

Reading the bands:

- The approximation band mean shifts from -2.9 kW (net exporter) to +5.2 kW (net importer) as occupancy grows. When this goes positive, the park is importing more than it exports on average. This indicates a need for more baseload generation — a third micro-hydro turbine or additional ground-mount solar.
- The approximation band max grows from 60 to 85 kW. If this approaches the grid connection limit (100 kW), the grid import becomes a bottleneck. Either upgrade the grid connection or add a second diesel generator.
- The detail band stddev grows modestly (6.5 to 7.5 kW). The batteries are not yet saturated — the fast transients remain within their capacity. No additional battery investment is needed yet.
- When detail stddev exceeds the total battery discharge capacity (25 kW across 7 units), the batteries can no longer absorb the peaks. That is when to add more batteries or a fast-response asset.

The wavelet approach’s secondary value is that it does not just dispatch — it identifies what will break first as demand grows. A park manager does not need to understand wavelets to read the recommendation: “your baseload band is saturated — you need more steady generation” or “your fast band is saturated — you need more batteries.”

6.2 Expansion Pathway

Table 5: Recommended investment pathway derived from wavelet band saturation analysis. Each decision corresponds to a specific band approaching its capacity limit.

Stage	Trigger	Investment	Cost Est.
Current	Fleet adequate, net exporter	None required	—
65 lodges	Approx mean tips positive	10 kW ground-mount solar	EUR 6,000
75 lodges	Approx max approaches 80 kW	Third micro-hydro or grid upgrade	EUR 15,000
80+ lodges	Detail stddev exceeds battery cap.	2x communal batteries	EUR 8,000

Each investment decision is informed by which frequency band is under stress — a direct output of the wavelet decomposition, available for free as a byproduct of the dispatch algorithm.

7 Deployment

The complete dispatch system comprises:

- *Hardware*: Raspberry Pi 4 or equivalent, in the site office. EUR 50.
- *Software*: The wavelet dispatch binary. 90 KB, no dependencies, no licence fees.
- *Connectivity*: None required. Runs entirely offline. Reads generation and demand from local meters via Modbus/RS-485.
- *Configuration*: A JSON file listing the assets and their characteristics. Edited in a text editor.
- *Operation*: Runs every 15 minutes, reads current meter values, computes dispatch setpoints, sends commands to controllable assets (battery inverters, diesel starter, grid import limiter).

No cloud. No subscription. No consultant. No internet. The total cost of the dispatch system is less than a week’s diesel fuel.

In practice, a holiday park has three realistic options:

Table 6: Realistic deployment options for a holiday park. The wavelet approach’s advantages over off-the-shelf controllers are cross-fleet coordination and capacity planning, not dispatch cost.

Feature	Do Nothing	Microgrid Controller	Wavelet Dispatch
Hardware	—	Victron Cerbo GX (EUR 300)	Raspberry Pi (EUR 50)
Software	—	Vendor app (free w/ hw)	Free (open source)
Internet	—	Recommended	Not required
Configuration	—	Vendor-specific UI	JSON text file
Strategy	Manual	Threshold rules	Wavelet + cost-weighted
Cross-fleet coord.	No	Own hardware only	All assets, any owner
Capacity planning	No	No	Yes (band saturation)
Tariff awareness	No	Basic (timer schedules)	Yes (cost-weighted decomp.)

Nobody buys a MILP solver for a holiday park. The realistic competition is a EUR 300 off-the-shelf microgrid controller running threshold logic — functionally our priority list baseline. On pure dispatch cost the wavelet approach is comparable (EUR 869 vs EUR 840 over 14 days). The difference is in what it can do that the controller cannot.

7.1 Cross-Fleet Coordination

Lodge owner A has a 6 kWh battery and 3 kW of solar. Lodge owner B has a bigger battery but no solar. The communal array feeds the park. A Victron controller manages Victron hardware — it will not talk to owner B’s Enphase inverter, and it does not know the communal array exists. The wavelet dispatch sees the entire fleet as a single system: it can charge B’s battery from A’s excess solar, discharge the communal batteries during peak to reduce everyone’s grid import, and keep the diesel off by coordinating assets that no single vendor’s controller knows about. On a park with mixed equipment from multiple owners, this is the difference between isolated islands of automation and a coherent energy strategy.

7.2 Capacity Planning

When the park manager wants to add ten more lodges, the Victron app shows current battery state of charge. The wavelet decomposition shows which frequency band is approaching saturation — which translates directly to what type of investment is needed. Baseload band saturated? More steady generation. Detail band saturated? More batteries. This is decision-quality information for a capital expenditure conversation, not just an operational dashboard.

8 Conclusion

The holiday park scenario demonstrates the wavelet method's natural habitat: a small, heterogeneous fleet with rich demand structure, no internet requirement, no budget for commercial software, and a need for simple, reliable automation.

The method does not produce optimal dispatch — DP does, at 8,000x the computational cost. The 26% cost gap is real and comes primarily from battery scheduling foresight that no causal algorithm can replicate. But the method produces good enough dispatch at effectively zero cost: it coordinates multiple asset owners' equipment without anyone needing to configure a solver, keeps the diesel off without manual intervention, provides actionable capacity planning as a free byproduct, and adapts to tariff structures through cost-weighted decomposition.

The cost-weighted approach — multiplying the wavelet's frequency decomposition by the known tariff schedule — demonstrates that the method can incorporate price awareness without abandoning its signal-processing foundation. The wavelet identifies what the load is doing at each frequency scale; the tariff tells you what it costs; their product tells you where the money is.

The park manager does not need to know what a wavelet is. They need to know that the box in the office keeps the lights on, the diesel quiet, and tells them when to buy more solar panels.