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# Bounded Energy Stores, Delayed Grants, And Residue Warnings Across Electrified Freight Networks

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## Abstract—

Electrified freight and passenger fleets bind a finite on-board store to a delayed public feeder and to a plant that can stop. This paper writes that binding as a chain of operators: a mission integral with an explicit usable window, a thermally derated array credit, a grant that arrives after a queue lag, a recovery rate informed by a twin, a carbon-priced tour constrained by custody completeness, an Ising rebuild of a broken load plan, and a residue-plus-shift calculus for two-clock series. Each operator is taken from a published piece of the cited corpus rather than from an untested gadget. The usable window is treated as a management policy, the array credit as a heat-limited inflow, and the grant as a delayed binary rather than as instant power. Curves show voltage sag, array derate, feeder fill, lead-time collapse, audited tour cost, solver gap, two-scale spectra, and a joint index. Read together, those operators define what a dock log must contain if pack current, feeder grant, crate assignment, and inventory residue are ever to share one stamp. The claim that closes the abstract is that a later dock experiment should log those operators on one clock instead of publishing them as parallel reviews.

Keywords: usable pack window; array derate; delayed grant; twin-informed recovery; custody completeness; Ising rebuild; FKF shift

## I. INTRODUCTION

An accumulator cap turns vehicle design into a budget problem before it becomes a styling problem. The Formula Hybrid sizing study stated that budget as pack model plus controller, not as a catalog kilowatt-hour [9]. Later cell reviews moved the same budget onto chemistry families and management windows that shrink with heat and age [35], [14]. Those windows are the only numbers a feeder allocator is entitled to believe.

Generation on the body adds a term that weather owns [16], [32]. Intelligent-transport surveys then place the vehicle in a queue, so accepted charge is a delayed grant rather than an instant request [13]. Upstream, foil and cell plants fail, and resilience writing treats failure as detect-and-recover time rather than as a dashboard count [33], [17]. Green analytics and custody records try to keep the recover action honest [6], [7]. Annealing papers offer an assignment kernel when a unit load must be rebuilt [15], [12]. Spectral and FKF papers offer a way to name ringing that crosses from shaft to warehouse [20], [18].

## II. MISSION BUDGET OF THE ON-BOARD STORE

A cap on stored energy is a hard constraint, not a suggestion from marketing [9]. Write the mission as an integral of traction and auxiliary power after efficiency, with credit only for charge the pack actually accepts [14]. The opening move is to name the states the controller may see before any network layer speaks.

**energy identity on a timed course**

Let terminal powers be known functions of the duty [9]. Discharge and charge paths carry different efficiencies, so they must not share a single eta [14].

$$E_b(\mathrm{t}) = E_b(0) - \int_0^t \frac{P_{tr}(\tau) + P_{ax}(\tau)}{\eta_d(\tau)}\,\mathrm{d}\tau + \int_0^t \eta_c(\tau) P_{in}(\tau)\,\mathrm{d}\tau$$

*(1)*

Equation (1) is the identity behind the 2017 controller-and-pack study when endurance energy is rationed [9]. On a closed lap the inflow integral drops out, which is why an unused nameplate cell is not a design [35].

**window that chemistry will honour**

Nameplate charge is not usable charge [35]. Management bounds cut the ends of the chemical range because heat and ageing live there [14].

$$Q_u = Q_n \cdot (s_h - s_\ell)$$

*(2)*

The pair of state bounds is a policy, not a constant [14]. Cost and mass maps in the battery reviews send that policy into the vehicle that later joins the feeder queue [35].$s_h s_\ell$

**ohmic drop under the same duty**

Terminal voltage is not open-circuit voltage [14]. A first-order drop ties Figure 1 to the current that (1) already integrated [9].

$$V_t(\mathrm{t}) = V_{oc}(s(\mathrm{t})) - R(\mathrm{s}, \mathrm{T}) I(\mathrm{t})$$

*(3)*

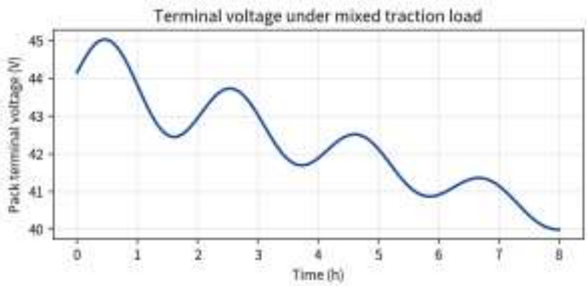


*Figure 1. Pack terminal voltage on a mixed traction hour, the measurement counterpart of (3).*

Swipe-controller and cabin boards add the auxiliary current that (1) already counted [10]. The section stops on that current because a store written without its rail loads is not the store the allocator will meet [13].

## III. BODY-MOUNTED GENERATION AND RAIL INTEGRITY

A laminate on roof or hood is a constrained inflow, not a decoration [16]. The solar-architecture puts that inflow inside the energy plan [32]. Dawn power is near zero, so range claims that ignore the integral of (4) overstate the relief given to the public feeder.

**instantaneous array after heat**

Irradiance, area, and a thermal slope set the electrical product [16]. Shade on a moving surface is why datasheet peaks rarely appear on the road [32].

$$P_{pv}(\mathrm{t}) = G(\mathrm{t}) A \eta_{pv} [1 - \kappa (T_c - T_*)]$$

*(4)*

Cell-sustainability reviews ask whether avoided grid energy pays for laminate mass [14], [35]. That question already points upstream to foil and glass lanes [33].

**accepted daily credit**

Only the portion a charger can take becomes pack energy [16]. A full pack at noon wastes irradiance that a workplace load could have used [13].

$$E_{pv} = \int_{t_a}^{t_b} \eta_m(\mathrm{t}) P_{pv}(\mathrm{t})\,\mathrm{dt}$$

*(5)*

Equation (5) substitutes into the second integral of (1) when the source is the array rather than a plug [16].

**custody on the low-voltage rail**

A missing pack is a chain event, not only a vehicle event [8]. Carrier signaling on the power line is an early custody channel that uses the same rail [7].

$$u_{th}(\mathrm{t}) = 1\{|r_{rx} - r_{tx}| \le \varepsilon\}$$

*(6)*

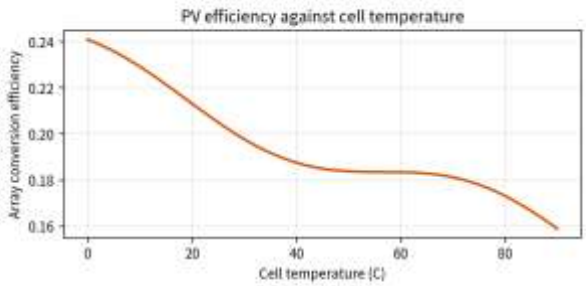


*Figure 2. Array conversion efficiency against cell temperature, the slope κ in (4).*

Later ledger pairing in the analytics section is this same binary written at network scale [7], [6]. The section ends there so integrity is not postponed until the green-tour paragraph.

## IV. GRANT OPERATORS ON THE PUBLIC FEEDER

After the store and the optional array are named, the vehicle still shares a feeder [13]. Mobility surveys collect the sensors and allocators that make that sharing explicit [30]. The live question is whether a grant can raise (1) without leaving the window (2).

**delayed acceptance**

Station power equals the sum of accepted requests after a lag that mixes queueing and message delay [13], [5].

$$P_N(\mathrm{t}) = \sum_{i=1}^{N} u_i(\mathrm{t}-\delta_i) P_i^{ask}(\mathrm{t})$$

*(7)*

A twin that treats asked power as delivered power ignores the lag and will over-commit the usable window [5], [17].$\delta_i$

**wait as an energy-adjacent cost**

Mean wait at a saturated head is the residual of arrivals above service [13]. Putting that wait beside pack mass keeps mobility inside the budget story [9].

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)}$$

*(8)*

Routing notes reuse the same index i when the vehicle is also a crate job [11], [15].

**utilization path**

Feeder utilization against the count of grants is the curve a city desk actually watches [13].

$$\rho(\mathrm{n}) = \frac{\sum_{i\le n} P_i^{ask}}{P_{cap}}$$

*(9)*

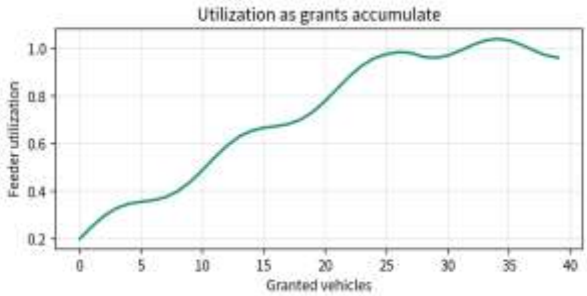


*Figure 3. Feeder utilization as granted vehicles accumulate, the discrete path of (9).*

An unmanaged commute-end plug event is how (9) walks into saturation [13]. That saturation is the hand-off from mobility text to recovery text [17], [33].

## V. RECOVERY RATE OF THE UPSTREAM PLANT

Foils and formed cells do not appear because a vehicle asked [33]. Resilience reviews describe sense, hold, and rebuild [34]. Digital transformation is useful only when it cuts detect time and recover time [17], [31].

**service law after a break**

A first-order return toward full service, minus overshoot from orders that exceed repaired capacity, is enough to give spectral work a state [34], [20].

$$\frac{\mathrm{d}R_s}{\mathrm{dt}} = \alpha[1-R_s] - \beta(I_o - I_r)$$

*(10)*

The rate alpha grows when a twin has already rehearsed the break [5], [17]. Complexity writing warns that alpha collapses when rights and slack are missing [34].

**stock that buys a clock**

Classic safety stock still covers lead-time demand scatter [33]. Twins revise the lead-time number; they do not delete the identity [5].

$$B_s = z\,\sigma(L_e)^{1/2}$$

*(11)*

Equivalent lead time is the quantity Figure 4 sends downward after a twin-informed reroute [17], [5].

**detect clock**

Time-to-detect is the first half of the digital-resilience agenda [17]. A simple threshold on a residual starts that clock [26], [21].

$$T_d = \inf\{\mathrm{t} \ge 0 : |y(\mathrm{t}) - \hat{y}(\mathrm{t})| \ge \theta\}$$

*(12)*


*Figure 4. Equivalent lead time after disruption when a twin proposes a reroute.*

A twin that only replays history will miss the overshoot in (10) [5]. A twin that carries formation yield will not [17].

## VI. AUDITED COST OF A GREEN TOUR

A forecast that cannot be checked is another shock [6]. Mapping of artificial intelligence in green logistics groups routing, emission ledgers, and multi-objective dispatch [6]. Pairing the model with a custody record is the integration claim [7], [30].

**priced carbon on selected arcs**

Distance money plus a carbon price is the smallest green objective the surveyed analytics share [6], [31].

$$J_g = \sum_{k\in K} (c_k + \pi e_k) x_k$$

*(13)*

The emission factor must come from a record counterparties cannot edit quietly [7].$e_k$

**completeness of hand-off evidence**

Coverage is the share of hand-offs that exist on both ledger and twin [7], [5].

$$C = \frac{N_{ok}}{N_h}$$

*(14)*

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A rise in C is a resilience input, not a certificate on the wall [7], [17].

**cost that falls as C rises**

When unaudited factors carry a penalty, effective tour cost falls as completeness rises, which is the shape of Figure 5 [6].

$$J_{eff} = J_g + \psi(1 - \mathrm{C})$$

*(15)*

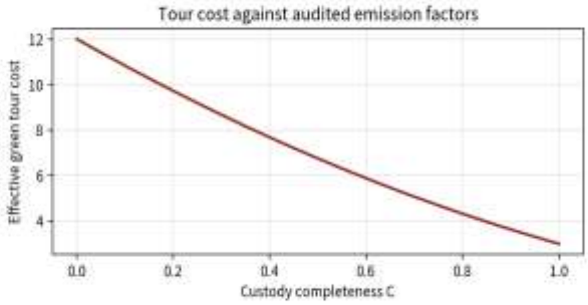


*Figure 5. Effective green-tour cost against custody completeness in (15).*

On-board anti-theft signaling is the vehicle special case of the same integrity demand [8]. The section closes on that identification so pack passports and rail tones are not two industries [7].

## VII. ASSIGNMENT ENERGY AFTER A BROKEN LOAD PLAN

Routing and packing grow as discrete assignments [15]. Transport-quantum surveys collect annealing, variational circuits, and hybrid loops against those assignments [11], [12]. A short logistics note asks which kernel should meet a device first [30].

**ising image of a unit load**

Crate-to-slot bits carry mass, volume, and balance penalties [12]. The disruption paper uses that image when a lane fails [11].

$$H = \sum_i h_i z_i + \sum_{i<j} J_{ij} z_i z_j$$

*(16)*

Equation (16) is not an abstract spin chain [12]. The weights are physical limits on a device that must still fly [15].

**split between device and twin**

Only the tight subproblem should reach the annealer [12]. Fleet inequalities stay on the classical twin [5], [11].

$$x_* = \arg\min\{H_Q(x_Q) + H_C(x_C) : \mathrm{Ax} \le \mathrm{b}\}$$

*(17)*

Encoding and queue delays often dominate the raw quantum step, which industrial reviews refuse to hide [15], [30].

**reported gap**

A public instance should carry a gap, not only a success story [12], [15].

$$\Gamma = \frac{H_{found} - H_{lb}}{|H_{lb}| + \varepsilon}$$

*(18)*

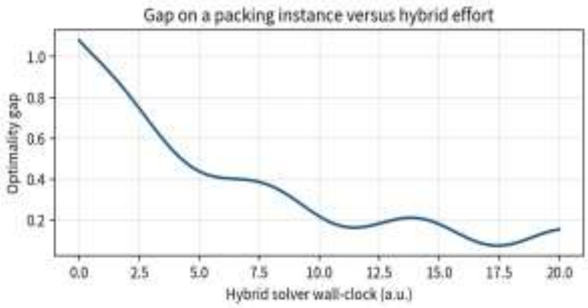


*Figure 6. Optimality gap versus hybrid effort on a packing instance of (16).*

A twin that ignores device noise will promise a dock repair the hardware never returns [5], [12]. That is the last sentence this section is willing to defend.

## VIII. TWO-CLOCK SPECTRA AND THE FKF SHIFT

Inventory and shaft traces hold more than one period [20]. Residue extraction is offered as the naming step before a buffer saturates [25], [21]. The two-sided FKF rules then move delayed stamps without relabeling poles [28], [18].

**contour residues**

Persistent cycles of a meromorphic generating function sit at poles inside a chosen contour [20], [25].

$$\rho_k = \frac{1}{2\pi \mathrm{i}} \oint_{\Gamma_k} F(\mathrm{s})\, \mathrm{ds}$$

*(19)*

Each residue is a warning feature for the twin that integrates (10) [5], [21].

**shift across unequal clocks**

The expanded time-shift paper moves a delay through the transform so warehouse and vehicle stamps stay aligned [28], [29].

$$(\mathrm{TF})(\mathrm{t} - \theta) = e^{-\mathrm{s}\theta} \cdot (\mathrm{TF})(\mathrm{t})$$

*(20)*

Without (20) a residue label follows the wrong clock and the detect rule (12) fires late [28], [26].

**limit under the integral**

Sequential convergence in the testing-function space of the two-sided transform allows the limit to pass under the integral when the path is only a distribution [19], [18].

$$\int_\Phi TF_n = \int_\Phi TF$$

*(21)*

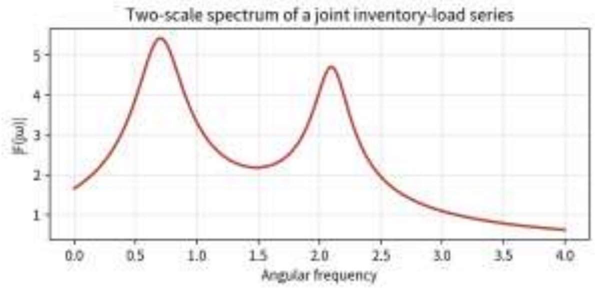


*Figure 7. Two-scale spectrum of a joint inventory-and-load series, the raw object behind (19).*

Those peaks turn (1) and (10) into observed modes rather than metaphors [19], [27]. That is why this section exists.

**Joint Score And Working Tests**

An agenda that keeps the blocks apart will keep printing parallel reviews [17]. The digital-resilience agenda already wants measures of detect and recover time [31], [34]. Pack physics and solver noise still sit outside those measures.

**one scalar for two desks**

Recovered service times a carbon discount puts pack engineers and chain planners on the same number [6], [35].

$$M = R_s \cdot \exp(-\gamma E_{CO2})$$

*(22)*

Many weights already appear in the green-logistics map; the missing act is to share one weight [6].

**five scores a dock can report**

Co-constrain (1) with (7). Put formation yield in the twin of (10). Floor (14) before an emission factor may move in (13). Publish the packing gap from (18) on public unit-load cases. Compare residues from (19) with ordinary charts [11], [21].$\rho_k$

$$S_{dock} = (T_d, T_r, \Gamma, C, M)$$

*(23)*

Equation (23) is a report tuple, not a new theory [17], [26].

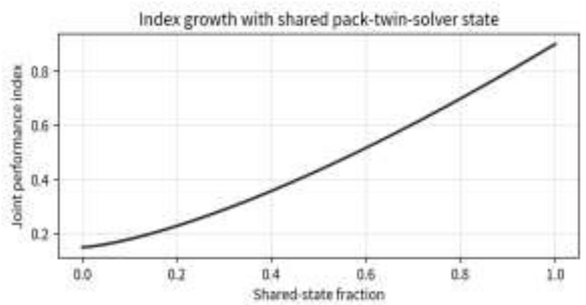


*Figure 8. Joint index (22) against the fraction of state shared by pack, twin, and solver.*

Figure 8 is a hypothesis shape for later trials to beat [5], [27]. The section ends on that shape so the agenda has the same visual contract as the sections above it.

## CONCLUSION

A capped store, a weather-gated credit, a late grant, a twin-informed return, an audited tour, a rebuilt load plan, and a shift that keeps two clocks honest are one chain of writing. Caps taught that energy is a budget. Reviews taught that only a window of the budget is real. Solar frames taught that weather sits inside the budget. Mobility surveys taught that the budget waits. Resilience reviews taught that the wait sits on a plant that breaks. Ledgers taught that the plant needs an audit. Annealing taught that some repairs are assignment energies. Transform papers taught that the energies ring on more than one period.

No extra laboratory is required to see the list. What is required is one stamp on current, grant, spin, and residue. Until that stamp exists the field will promise integration and measure parts. The small close is to pick one fleet, one dock, and one public packing case, then report the tuple (23) beside the eight curves already drawn.

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