MDL Yield Parameter (Y):
Reproducibility Note for Battery Experiments and CAISO Grid Simulation

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Abstract

This note documents what was executed, which files were used, how the MDL controller was applied, and how the reported *MDL yield parameter* was computed for two executed embodiments: (i) controlled lithium-ion battery discharge experiments under fixed cutoff rules with two policies (baseline constant-current vs. MDL-governed multi-step current reduction), and (ii) a 24-hour CAISO OASIS real-data grid simulation comparing baseline (no curtailment) vs. single-layer MDL vs. dual-layer MDL. Yield is defined as a benefit-to-cost ratio under a declared embodiment contract. This document reports the computed yields under the declared definitions and provides a file-level reproduction recipe; it does not claim a universal constant across unrelated domains.

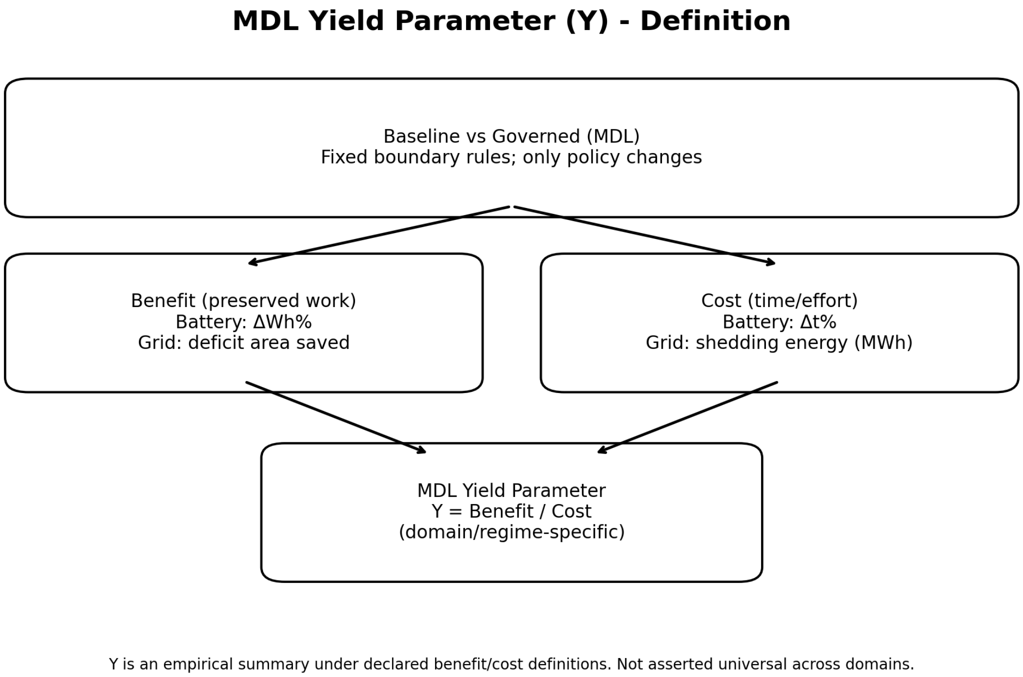
1 Scope and relationship to the MDL papers

This PDF is intended to ship alongside the downloadable CSV artifacts. It provides (a) a plain-language description of what was run, (b) the exact data files used, (c) the controller inputs/outputs, and (d) the yield calculations used to produce the reported numbers.

Non-claims. This note does **not** claim a new fundamental physical interaction and does **not** claim a numerically universal constant across all domains. It reports *domain/regime-specific* yield parameters under fixed boundary rules and fixed benefit/cost definitions.

2 Definition: MDL yield parameter (Y)

The MDL yield parameter is a compact summary computed from paired baseline vs. governed outcomes under fixed boundary rules.



2.1 Battery yield (dimensionless %/%)

For paired battery runs (baseline R vs. governed M), we define:

$$Y_{\text{batt}} := \frac{\Delta Wh_{\%}}{\Delta t_{\%}}, \qquad \Delta Wh_{\%} = 100 \cdot \frac{Wh_M - Wh_R}{Wh_R}, \qquad \Delta t_{\%} = 100 \cdot \frac{t_M - t_R}{t_R}. \tag{1}$$

Interpretation: fractional delivered-energy gain per fractional runtime gain, under a fixed cutoff rule.

2.2 Grid yield (dimensionless MWh/MWh)

For the grid simulation, benefit is deficit-area saved and cost is total shedding energy:

$$Y_{\text{grid}} := \frac{\Delta A_{\text{deficit}}}{E_{\text{shed}}} = \frac{A_{\text{deficit}}^{\text{baseline}} - A_{\text{deficit}}^{\text{policy}}}{E_{\text{shed}}^{\text{policy}}}. \tag{2}$$

where $A_{\text{deficit}} := \sum_t \max(0, -\Delta_{\text{grid}}(t))\,\Delta t$ (MWh) and $E_{\text{shed}} := \sum_t u(t)\,\Delta t$ (MWh).

3 Executed embodiments and artifact list

3.1 Battery embodiment (experimental)

Boundary rule (fixed): terminate each run at the first time t_{cut} such that $V_{\text{pack}}(t) \leq V_{\text{cut}}$, where V_{cut} is fixed within each pack group across policies.

Policies:

- **R (baseline):** constant-current discharge to cutoff.

- **M (MDL-governed):** monotone multi-step "drop-down amps" schedule as $V(t)$ approaches cutoff, to avoid boundary violation while extending viability.

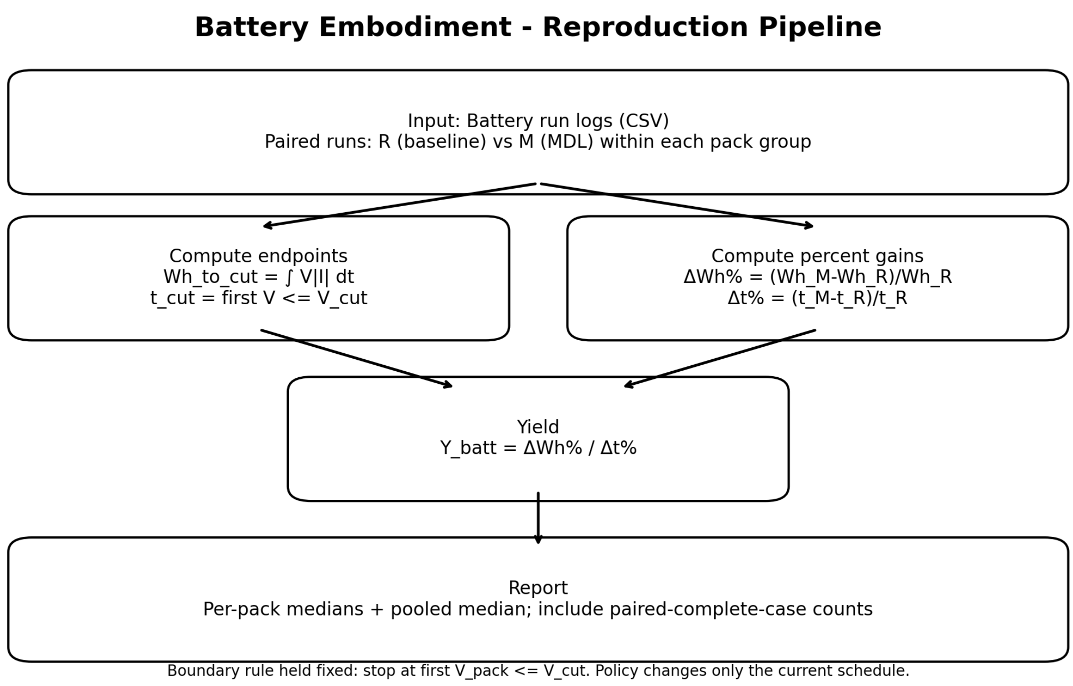
Primary endpoints:

$$Wh_{\text{to cut}} = \int_0^{t_{\text{cut}}} V(t)\,|I(t)|\,dt, \tag{3}$$

$$Ah_{\text{to cut}} = \int_0^{t_{\text{cut}}} |I(t)|\,dt. \tag{4}$$

Battery data files (as shipped):

- `Mena_Domiance_Law_battery Test.zip` (contains paired run logs; baseline runs labeled `Test_R_*` and governed runs labeled `Test_M_*`, organized by pack group).



3.2 Grid embodiment (CAISO real-data simulation)

Inputs: CAISO OASIS system totals over a fixed 24-hour window.

Potential and load:

$$P_{\text{grid}}(t) = ISO\_TOT\_GEN\_MW(t) + ISO\_TOT\_IMP\_MW(t) - ISO\_TOT\_EXP\_MW(t), \tag{5}$$

$$L_{\text{grid}}(t) = ISO\_TOT\_LOAD\_MW(t), \tag{6}$$

$$L_{\text{eff}}(t) = L_{\text{grid}}(t) - u(t), \tag{7}$$

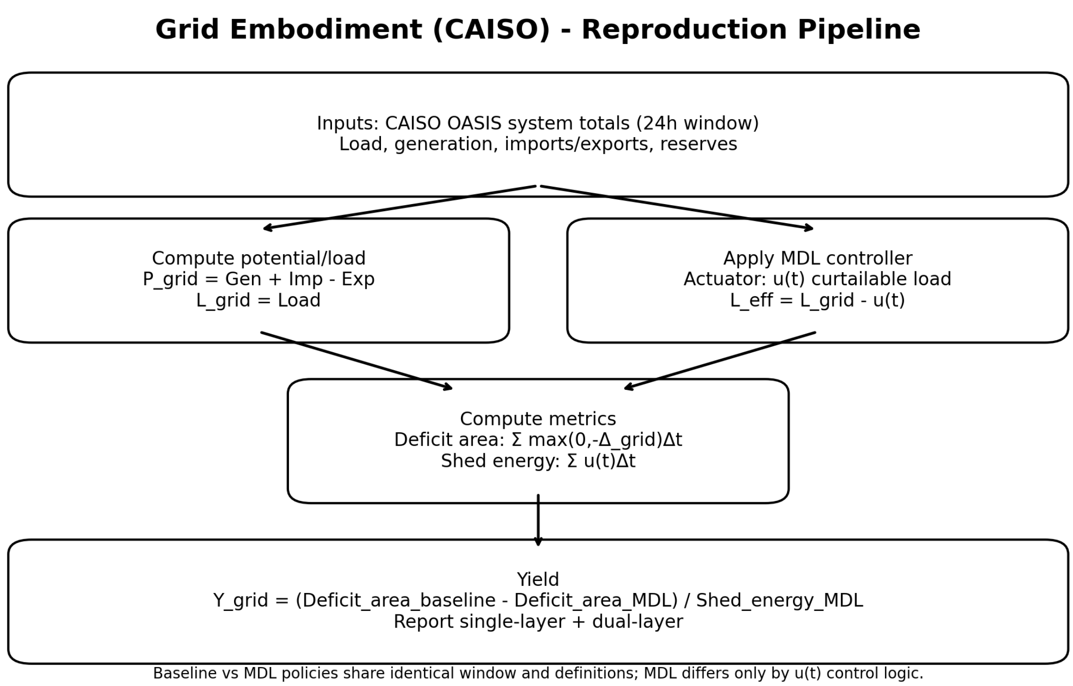
$$\Delta_{\text{grid}}(t) = P_{\text{grid}}(t) - L_{\text{eff}}(t). \tag{8}$$

Policies:

- **Baseline:** $u(t) = 0$.
- **MDL single-layer:** controller acts on $\Delta_\star(t) = \Delta_{\text{grid}}(t)$.
- **MDL dual-layer:** controller acts on $\Delta_\star(t) = \Delta_{\text{true}}(t) = \Delta_{\text{grid}}(t)\, g(t)$, where $g(t)$ is a reserve-admissibility gate.

Grid data files (as shipped):

- `baseline.csv`, `mdl_single.csv`, `mdl_dual.csv` (time-aligned series)
- `metrics.csv` (summary metrics table, including deficit area and shedding energy)
- CAISO OASIS archives (as-downloaded ZIPs) used to generate the above CSVs.



4 Computed yields (what we found)

4.1 Battery yields

Using median percent gains by pack group and pooled medians, Table 1 reports Y_{batt}.

4.2 Grid yields

Using the 24-hour CAISO window summary totals:

- $A_{\text{deficit}}^{\text{baseline}} = 18318.12$ MWh.
- Single-layer: $A_{\text{deficit}}^{\text{single}} = 603.62$ MWh, $E_{\text{shed}}^{\text{single}} = 18852.76$ MWh.
- Dual-layer: $A_{\text{deficit}}^{\text{dual}} = 1584.53$ MWh, $E_{\text{shed}}^{\text{dual}} = 17786.78$ MWh.

Table 1: Battery embodiment: MDL yield parameter $Y_{\mathrm{batt}} = \Delta Wh_{\%}/\Delta t_{\%}$ computed from median percent gains under the fixed cutoff rule.

Pack group	$\Delta Wh_{\%}$	$\Delta t_{\%}$	Y_{batt}
DCB205 (5Ah)	+4.31%	+55.0%	0.078
KB224-03 (2Ah)	+9.05%	+81.4%	0.111
R840040_A (4Ah)	+6.04%	+63.9%	0.094
R840040_B (4Ah)	+5.97%	+64.5%	0.092
Pooled medians (all runs)	**+5.82%**	**+63.38%**	**0.091**

Computed values.

$$Y_{\mathrm{grid}}^{\mathrm{single}} = \frac{18318.12 - 603.62}{18852.76} = 0.9396, \tag{9}$$

$$Y_{\mathrm{grid}}^{\mathrm{dual}} = \frac{18318.12 - 1584.53}{17786.78} = 0.9408. \tag{10}$$

5 Reproduction steps (minimum)

5.1 Battery (from the run logs)

1. Unzip `Mena_Domiance_Law_battery Test.zip`.
2. Pair runs within each pack group by matching baseline `Test_R_*` files to governed `Test_M_*` files by run index.
3. For each file, compute t_{cut} as the first sample where $V_{\mathrm{pack}} \leq V_{\mathrm{cut}}$.
4. Compute $Wh_{\text{to cut}}$ and $Ah_{\text{to cut}}$ by numerical integration/summation to t_{cut}.
5. Compute $\Delta Wh_{\%}$ and $\Delta t_{\%}$ and form Y_{batt}.
6. Report medians by pack group and pooled medians across all pairs.

5.2 Grid (from the CSV outputs)

1. Load `baseline.csv`, `mdl_single.csv`, `mdl_dual.csv` and verify alignment to a 24-point hourly grid.
2. Compute A_{deficit} for each policy: $\sum_t \max(0, -\Delta_{\mathrm{grid}}(t))\Delta t$.
3. Compute E_{shed} for each MDL policy: $\sum_t u(t)\Delta t$.
4. Compute $Y_{\mathrm{grid}} = (A_{\mathrm{deficit}}^{\mathrm{baseline}} - A_{\mathrm{deficit}}^{\mathrm{policy}})/E_{\mathrm{shed}}^{\mathrm{policy}}$.

6 Novelty (what is new here)

The novelty is not the arithmetic identity $\Delta = Potential - Load$. The novelty is the use of fixed boundary rules and paired baseline vs governed trajectories to produce a reproducible, embodiment-level yield summary (Y) for viability-governed control. Under fixed definitions, Y is stable within an embodiment (battery and grid), while differing across embodiments as expected.

7 Limitations

- Yield values depend on the declared benefit and cost definitions. Changing definitions changes Y.
- The grid embodiment is a system-balance simulation and does not include network constraints (line limits, topology, N-1).
- This document reports reproducible within-domain yields; it does not claim numerical universality across domains.