Institute for Physical AI @ John Bailey Institute · The Hall Lab & The Charlot Lab

ENERGY · DISCLOSURE · QUALIFICATION

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ENERGY · DISCLOSURE · QUALIFICATION

Where Is the Energy Reporting?

Embodied energy is measured in the research literature and is being standardised for the industrial arm. It is reported nowhere a buyer, an operator or a regulator can act on. The binding constraint is disclosure, not instrumentation, and that makes it a qualification problem before it is an engineering one.

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Instrument: when the computer becomes the load

3 claims of the background survey corrected against primary sources

1 crossover computed from published figures

4 quantities recorded as not located

the first Hall Lab report

Abstract. A humanoid that walks efficiently makes its computer the thing to argue about. Hold the compute module fixed at its published envelope and improve only the gait, from the best figure the earlier literature carried to one reported in 2026, and the computer's share of shift power roughly triples. Nothing about the brain changed; the term it competes with fell fourfold. That is a good problem, because it means the machines are getting good enough for the ledger to matter, and the ledger is the cheap part. Every quantity it needs is already measured somewhere: cost of transport for humanoids is published at 0.41 to 0.42, a physics-based electrical power model for a commercial humanoid arm was identified from 897 measured trajectories in June 2026, and an ISO Technical Specification for industrial robot energy consumption was due for completion this month. A survey compiled for

this track concluded the opposite on all three counts, and §2 corrects it against primary sources. What has not arrived is the report: a statement of a machine's energy per unit of work, at a stated grade of evidence, that a purchaser or an inspector can rely on. The constraint is disclosure, not instrumentation, which makes it closable by an obligation, a format and a qualified signature rather than by better sensors, and §7 says who would sign.

1. What is in scope, and what does this continue?

This report is about disclosure: what an autonomous system states about its own energy, at what grade of evidence, to whom, and on whose signature. It is not a survey of efficient hardware, and it proposes no mechanism.

It joins two lines of Institute work that have not previously met. The Charlot Lab holds the substrate case in *The Energy-First Turn* (TR-2026-25) and the receipt schema in *OER/1 and DRIFT/1* (EFA-RFC-001), whose composition rule is the relevant one here: a composed receipt takes the weakest grade among its parts, never the average.[1,2] It holds the task side in *Joules per Punch* (TR-2026-41), *What a Machine Spends Looking* (TR-2026-42) and *Six Ways a Body Cheats* (TR-2026-45). The Hall Lab brings the discipline that the rest of this depends on and that robotics does not yet have: what a system must demonstrate before it is permitted to operate, and who is trained to judge the demonstration.

An internal background survey compiled for this track supplied the starting questions. Its central claims did not survive checking, which is §2.

2. Is the problem measurement, or reporting?

The survey's position was that embodied energy is unmeasured. Three of its load-bearing claims were checked against primary sources in August 2026 and are wrong, in the same direction.

Survey claim	What the record shows

No humanoid cost of transport has been published, ever; the best measured full-size figure is DURUS at 1.61	Humanoid cost of transport is reported at **0.42** (DUKE, straight-knee with parallel linkage) and **0.41** (lower-limb structural optimisation), roughly four times better. A roller-skating gait reports a 63% reduction against bipedal walking[6,7]
No power figure exists for a commercial humanoid	A physics-based electrical power model for the Unitree G1 arm was identified in June 2026 from **897 measured trajectories**, R^2=0.933, validated to R^2=0.965 at unseen speeds, decomposed per joint into viscous friction, copper losses and Coulomb friction[8]
The ISO energy slot was planned in 2019 and abandoned; it is documented and open	An **ISO Technical Specification** for measuring industrial robot energy consumption, led by ABB with the Swedish Institute for Standardization and experts from eleven countries, was announced in January 2026 for completion in **August 2026**[9,10]

Corrected, the picture inverts. Energy is being measured, published, modelled per joint and standardised. What none of that produces is a **report**: a statement of a machine's energy per unit of work, at a declared grade of evidence, that a purchaser, an operator or an inspector can rely on and compare. A journal result is not a report, because it describes one machine under conditions its authors chose. A specification is not a report either, because it describes how to measure and not what any given machine measured.

So the question in this report's title is the correct one, and it is narrower than it looks. **The constraint is disclosure, not instrumentation.** That reframing decides everything after it, because instrumentation problems are solved by better sensors and disclosure problems are solved by an obligation, a format, and someone qualified to sign.

3. What does the industrial arm get that the body does not?

The asymmetry is now concrete and dated. The industrial arm is receiving a measurement standard this month. The humanoid is not, and neither is the embodied system that carries a learned policy.

The motivation stated for the industrial work applies with more force to the body than to the arm: internal studies reported that over 70% of a robot's carbon footprint arises from electricity during operation.[9] An arm bolted to a floor draws from a wall. A humanoid carries its supply,

which converts the same quantity into runtime, fleet size, swap infrastructure and thermal limits, and does so before it appears on any utility bill.

Two further asymmetries are worth stating because they show the direction of travel. China published a national standard system for humanoid robotics and embodied AI in March 2026, and the one robot energy-efficiency standard this review located, GB/T 40575-2021, covers industrial robots and was not extended to humanoids.[11] In the European Union, data-centre operators already report energy key performance indicators annually under an adopted delegated act, and an AI energy and emissions label is under exploration.[12,13] **The computer in a rack has a reporting obligation. The same computer strapped to a torso has none.**

4. Why does an efficient body promote the computer?

The two literatures are separate, and separating them hides a result that neither reports. Cost of transport is dimensionless and defined as CoT = P/(m·g·v), so locomotion power follows directly from a machine's mass and gait. Compute power for a current embodied platform is a published envelope: NVIDIA's Jetson Thor is specified at 40 to 130 W.[14]

Hold the computer fixed and improve only the legs. For a 35 kg machine at 1.2 m/s, with the computer unchanged at the middle of its envelope:

Cost of transport	Locomotion power	Compute share of walking power
1.61, DURUS, the figure the survey carried	663 W	6% at 40 W, 16% at 130 W
0.42, humanoids reported in 2026	173 W	**19% at 40 W, 43% at 130 W**
0.20, human walking, for reference	165 W at 70 kg	20% at 40 W, 44% at 130 W

Nothing about the computer improved. Its share of the bill roughly tripled, because the term it is being compared against fell by a factor of four. **Efficiency in the legs is what promotes the brain to a first-order term.**

This is the reason the omission stops being tidy. A ledger that prices actuation and omits compute was defensible while locomotion dominated by an order of magnitude. At the efficiencies being reported in 2026 it is not, and the machines are crossing that line now. The accompanying instrument lets a reader move the gait and watch the crossover, and reports the same figures.

The human row is worth reading twice. A human walks at 0.20 and runs perception, planning, control and lifelong learning on roughly 20 W.[15] A machine approaching that gait efficiency carries a computer drawing two to six times as much for a fraction of the function. The body is close to caught; the brain is not, and the closer the body gets the more that shows.

5. Why is the compute term a memory term?

The compute share above is not an arithmetic bill. The canonical figures put a DRAM fetch at roughly three orders of magnitude above a 16-bit add, and current mobile memory at 10 to 20 pJ per bit, which a vision-language-action policy pays every time it streams its weights.[16] Recent edge measurements attribute the dominant share of inference energy to decode rather than to perception, and note that output-length control is therefore the largest available saving.[17]

Two consequences follow for reporting. The first is that TOPS/W at peak utilisation is the wrong denominator for a bandwidth-bound workload at batch one, so a vendor number that a robot integrator can use would be joules per decision at deployment conditions; this review did not locate a datasheet publishing one. The second is that the energy of a decision is a property of the deployment, not of the chip, which means it cannot be inherited from a component datasheet and has to be measured on the machine. That is an argument for a receipt rather than a specification, which is what OER/1 already provides.[2]

6. What would a report actually have to contain?

A useful report is not a number. It is a number with a denominator, a grade, and a boundary.

1. **A unit of work.** Joules per task, per metre, or per unit moved. Watt-hours of battery capacity is a property of the pack, not of the machine, and hours of runtime is a property of the duty cycle somebody chose.
2. **The whole loop.** Locomotion, standing, sensing, decode and recovery, itemised. The crossover in §4 is exactly what a partial ledger hides.
3. **A grade of evidence.** Modelled, stand-in, or metered, kept permanently distinguishable, with a composed figure taking the weakest grade among its parts rather than the average.[2]
4. **The conditions.** Gait, speed, payload, ambient temperature and duty cycle, because each moves the answer and any of them can be chosen to flatter it.
5. **What was not measured.** Named, rather than omitted. An unstated exclusion is the difference between a report and an advertisement.

7. Who is qualified to sign it?

This is the question robotics has not asked, and the one aviation answers as a matter of routine. A maintenance release is not valid because a measurement was taken. It is valid because a named person holding a current qualification, working to a published method, attests to it and carries the consequence of being wrong.

Energy disclosure will arrive at the same requirement, and the reason is structural rather than cultural. Every quantity in §6 can be chosen to flatter: a gait, a payload, an ambient temperature, a duty cycle, a decision about what is in the boundary. A format alone does not survive that, because the incentive to select conditions is intrinsic and permanent. What survives it is a qualified signature and an audit trail, which is what OER/1's conformance ladder anticipates when it separates self-declared from wall-plug-metered from witnessed.[2]

The competency that has to exist, and this review did not locate a curriculum containing it, is the ability to read an energy claim adversarially: to ask what unit of work the denominator is, at what grade, under which conditions, with what excluded, and to refuse the claim when those cannot be answered. That is an examinable skill, it is close to what an aviation inspector already does for a different quantity, and it is the piece that decides whether any of the rest arrives.

8. What is this report careful not to claim?

It does not claim embodied energy goes unmeasured. §2 exists because the opposite is true, and because our own background survey had it wrong.

It does not claim the ISO Technical Specification excludes humanoids. Its published scope is industrial robots; this review did not locate a statement either way about humanoid applicability, and the specification's final text was not available to us at the time of writing.

It does not claim the crossover in §4 is a measurement. It is arithmetic on published inputs, and it inherits their conditions: one speed, one mass, a flat compute draw, no regeneration credited and no thermal derating. It is a statement about which term dominates, not a prediction of a machine's consumption.

It does not claim that a reporting obligation would by itself reduce energy. Measurement precedes markets; it does not substitute for them.

9. Searched for and not located

1. A datasheet, from any edge-compute vendor, publishing **joules per decision** at deployment batch size for a vision-language-action policy.
2. A humanoid manufacturer publishing cost of transport, a power curve, or energy per task for a shipping product.
3. A curriculum, in robotics or adjacent engineering education, teaching the adversarial reading of an energy claim described in §7.
4. A published energy report for any embodied system that itemises locomotion, standing, sensing and decode together for one machine over one shift.

10. Conclusions

1. The constraint is disclosure, not instrumentation. Cost of transport, per-joint power models and a measurement specification all exist in 2026; a usable report does not.
2. The industrial arm is receiving a measurement standard this month. The body, which carries its own supply and therefore converts joules into runtime and fleet size, is not.

3. Holding the computer fixed and improving only the gait raises the compute share of shift power roughly threefold between the older literature's best humanoid and a 2026 one. An efficient body promotes the computer to a first-order term.
4. A ledger that prices actuation and omits compute stops being adequate exactly as the machines become good, which is now.
5. A report requires a unit of work, the whole loop, a grade of evidence, the conditions, and the exclusions. Any of the five can be selected to flatter, which is why the sixth requirement is a qualified signature.

11. The forcing function

The engineering change is available and dated. A specification for measuring robot energy reaches completion this month for the industrial arm.[9] Extending its method to a self-powered machine is not a research problem; it is a scope decision, and the parties who would have to make it are named and currently assembled.

What becomes possible once a machine can state its energy per unit of work at a declared grade is the thing every other party in this chain is currently unable to do. A purchaser can compare two machines on the quantity that decides whether a shift of work fits in a pack. An operator can size a fleet on evidence rather than on a vendor's runtime claim. An insurer and a regulator can price a duty cycle. A designer learns which term to attack, and §4 says that answer is already changing. And an instructor can set an examination, because reading an energy claim adversarially is a competency with a right answer.

None of that waits on a better battery or a more efficient actuator. It waits on a report, and on someone qualified to sign it.

References

1. Institute for Physical AI @ JBI, *The Energy-First Turn*, Technical Report TR-2026-25. `COMPANION REPORT, READ IN FULL`
2. Institute for Physical AI @ JBI, *OER/1 and DRIFT/1*, EFA-RFC-001, receipt schema and conformance ladder. `COMPANION SPECIFICATION, READ IN FULL`
3. Institute for Physical AI @ JBI, *Joules per Punch*, Technical Report TR-2026-41, actuation energetics on a humanoid. `COMPANION REPORT, READ IN FULL`

4. Institute for Physical AI @ JBI, *What a Machine Spends Looking*, Technical Report TR-2026-42, sensing as the third term of task energy. COMPANION REPORT, READ IN FULL
5. Institute for Physical AI @ JBI, *Six Ways a Body Cheats*, Technical Report TR-2026-45, mechanisms priced against the motor. COMPANION REPORT, READ IN FULL
6. Cost of transport reported for the DUKE humanoid (straight-knee configuration with parallel linkage) and for lower-limb structural optimisation, 2026. MEASURED, PEER-REVIEWED
7. SKATER: roller-skate locomotion for a humanoid, reporting a 63.34% reduction in cost of transport against bipedal walking, arXiv:2601.04948. MEASURED, PREPRINT
8. Identification of a physics-based electrical power consumption model for the Unitree G1 humanoid arm, arXiv:2606.15915, June 2026. MEASURED, 897 TRAJECTORIES, PREPRINT
9. ABB Robotics with the Swedish Institute for Standardization and experts from eleven countries, ISO Technical Specification for measuring industrial robot energy consumption, announced January 2026 for completion August 2026. REPORTED, INDUSTRY AND IFR PRESS
10. International Federation of Robotics, press release on the same standardisation effort. REPORTED, TRADE BODY
11. GB/T 40575-2021, *Guidelines of energy efficiency evaluation for industrial robots*; and China's national standard system for humanoid robotics and embodied AI, March 2026. REPORTED, NATIONAL STANDARD AND STATE MEDIA
12. European Commission delegated act establishing an EU scheme for rating the sustainability of data centres, with annual key-performance-indicator reporting. FILED, REGULATORY
13. Analyses of energy-efficiency requirements under the EU AI Act and an AI energy and emissions label under exploration. REPORTED, LEGAL AND POLICY ANALYSIS
14. NVIDIA Jetson Thor platform specification, 40 to 130 W envelope. REPORTED, VENDOR
15. Raichle and Gusnard, brain energy budget of approximately 20 W. MEASURED, PEER-REVIEWED
16. Horowitz, ISSCC 2014, energy per operation; and published LPDDR5/5X energy per bit. MEASURED, CANONICAL REFERENCE
17. *Seeing is Free, Speaking is Not: Uncovering the True Energy Bottleneck in Edge VLM Inference*, arXiv:2607.09520. MEASURED, PREPRINT