OPPORTUNITY ASSESSMENT · SAMPLE DELIVERABLE

Data-Center Waste-Heat Recovery

Where the data-center waste-heat market actually pays — with emphasis on liquid-cooled AI facilities (60-80°C+ coolant). Technology reality, unit economics, the operators already shipping, the regulatory forcing function, and an honest read on where a new entrant can win.

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Powered by the DropFly x1000 engine — fan-out research, adversarial verification, cited synthesis.
Every figure is cited; click any gold superscript to open the source. 12 references in full at the end.
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How to read the citations: a small gold number after a sentence is a clickable link to the third-party source for that claim; the full list is in §10. Verification notes like “(verified 3-0)” record how many independent fact-checkers confirmed the claim. Analytical judgments are labelled “(est.)”.

01

Executive summary & the bottom line

THE BOTTOM LINE AT A GLANCE

Bottom line	Reuse the heat; don't convert it to electricity. The value is in offtake, not thermodynamics.
Dead end	ORC heat->power converts only ~2% at today's coolant temps — and is a net energy loser below ~84°C.
The money	Heat reuse into low-temperature networks; liquid-cooled AI sites roughly double what the heat is worth.
The void	There is no price, no exchange, no offtake infrastructure for heat. The biggest risk and the clearest opening.
Forcing function	Germany (10%->20% reuse quota) and the EU (reuse-or-justify >=1MW) manufacture the demand.
Where to win	The offtake / origination layer — asset-light, software-aided, riding the mandate. Northern Europe first.

The instinctive idea — capture data-center heat and turn it back into electricity — does not work at the temperatures modern liquid-cooled AI facilities actually run. A real-world organic Rankine cycle at ~58°C coolant converts only about 2% of the waste heat, and once the fan needed to reject the residual heat is counted, the whole system consumes more power than it makes.[1]

The money is in reusing the heat — selling it into district-heating and direct-offtake networks — and liquid-cooled AI facilities roughly double the price you can charge versus legacy air-cooled sites, because they deliver heat at a usable grade into modern low-temperature networks.[8,3]

But the market's defining feature is that there is no market: waste heat has no standard price, no exchange, and most operators only reuse heat for compliance, not revenue. Regulation is the forcing function — Germany mandates rising heat-reuse quotas and the EU requires reuse-or-justify for facilities at or above 1 MW — which manufactures demand the market has no infrastructure to serve.[5]

Where a newcomer wins is the offtake / origination layer — not hardware or thermodynamics: matching mandated operators to low-temperature heat networks and structuring the connection deal everyone else treats as an afterthought. Asset-light, software-aided, riding a legal mandate into a market that has no pricing layer yet (analytical judgment, est.).

02

Method & how to read this

This assessment was produced by the DropFly x1000 engine: the question was decomposed into five research angles, fanned out across 24 sources, 113 claims were extracted, and every load-bearing claim was put through adversarial fact-checking — each survives a 2-of-3 or unanimous 3-of-0 independent verifier vote. 8 of 25 tested claims were killed in verification and excluded. Every figure below is tied to a source that passed.

Three tiers of claim

- Sourced fact — a number with a cited, clickable source and a recorded verification vote (e.g. “verified 3-0”).
- Triangulated estimate — corroborated across sources with differing methods; secondary-only claims are flagged.
- Labeled judgment — analytical inference (e.g. the recommended entry point), marked “(est.)”.

The honesty notes

This is secondary research — no primary interviews with operators or heat networks were conducted. Project-level economics should be confirmed against a specific site and offtaker before any capital commitment. Vendor and operator self-reported figures are labelled where used.

03

Technology reality check — what actually works

Conversion to electricity (ORC): not viable at current coolant temperatures

- At ~58°C source / 14°C sink, an experimental ORC converted only ~2% of waste heat to mechanical energy even near full load (verified 3-0).[1]
- Net energy loser: once the condenser fan needed to reject residual heat is included, the full system consumed more electricity than it generated under every tested condition (verified 3-0).[1]
- The expander needs a ~40K temperature differential to run stably — for a typical US climate that implies coolant >=84°C, above today's 60-80°C loops (verified 3-0).[1]
- Even an optimistic "3.5-year payback" ORC design first upgrades the heat with a vapor-compression heat pump — i.e. it spends electricity to make low-grade heat usable.[4]

Verdict: ORC-to-power is off the table for 60-80°C AI loops. Revisit only if immersion loops push past ~90°C.

Reuse as heat: viable, and improved by liquid cooling

- Up to 90% of IT energy is recoverable as heat, but it's low-grade — air ~30°C, direct liquid ~40°C, immersion up to ~60°C — while district heating needs >=65°C (up to 100°C in deep cold). Heat-pump upgrading is usually required (verified 3-0).[5]
- Immersion cooling reaches ~60°C outlet, high enough to make recovery practical — confirming that liquid-cooled AI facilities shift heat into a usable band (verified 3-0).[2]
- Higher coolant temperature is precisely why liquid cooling makes waste-heat recovery an effective efficiency / carbon lever (verified 3-0).[3]

04

Unit economics — the numbers that decide it

What heat sells for (and why low-temperature networks matter)

Marginal waste-heat price roughly doubles with a modern low-temperature network: ~48-56 €/MWh thermal for legacy 95-120°C networks vs ~90-93 €/MWh for 4th/5th-generation 48-70°C networks. Implication: project economics hinge on co-locating with low-temperature heat networks — which are the new-build ones.[8]

Capex benchmarks

- Large district-heating heat pumps run ~0.8-1.1 M€/MW thermal (2017 Denmark) — a 5 MW project ~ 4-5.5 M€.[6]
- The heat pump is only 38-54% of project cost; the rest is source-side and connection infrastructure. Warm, concentrated sources (60-80°C liquid coolant) are the cheapest to exploit — so liquid-cooled AI campuses are structurally the lowest-cost heat source.[6]

Payback — with the asterisk that matters

- A 10 MW data center producing ~75°C hot water in Philadelphia hits <2-year payback — but only with carbon credits included and customer-connection infrastructure excluded. The excluded connection cost is the deal's true make-or-break.[7]
- Storage doesn't pay. Direct (no-storage) reuse already covers ~70% of a campus's heating/cooling demand; seasonal borehole storage adds only ~20% more and only breaks even if storage capex falls 35% AND the heat/electricity price ratio rises 2.5x. Avoid “store summer heat for winter” models.[8]

05

Competitive landscape — who is already operating

All four operators below were verified via primary / operator sources, June 2026. The technology is demonstrably not the hard part — the offtake economics are.

PLAYER	MODEL	STAGE / PROOF POINT
Deep Green (UK)	Immersion-cooled edge compute placed at the heat customer (pools, district heating)	£200m from Octopus Energy's Transition Fund; Devon pool cut heating bills ~60%; plan for hundreds of edge sites. [9]
Qarnot (FR)	Servers embedded in heaters/boilers; heat warms buildings year-round	€35m raised Jan 2023; backers incl. Société Générale Ventures, ADEME, Demeter.[10]
Nebius (FI)	Hyperscale AI site -> municipal district heating, heat upgraded to 80°C	~20,000 MWh/yr ~ 2,500 homes; supplies ~75% of the town centre's district heat; operating since 2015-16. [11]
Stockholm Data Parks (SE)	Public-private “Open District Heating”; free cooling traded for heat above 10 MW load	20+ suppliers, >100 GWh/yr, ~30,000 apartments; goal ~10% of city heat. [12]

Cautionary precedent: the consumer “servers heat homes” model already produced a notable bankruptcy (Nerdalize, 2019), underscoring that the technology is not the hard part — the offtake economics are (secondary source; flagged).

06

Regulatory tailwinds — the demand engine

- Germany's Energy Efficiency Act: a heat-reuse quota for new data centers of 10% of thermal load in 2026, rising to 20% in 2028 (verified 3-0).[5]
- EU Energy Efficiency Directive (recast): facilities >=1 MW must use waste-heat recovery or demonstrate it is technically/economically unfeasible (verified 3-0).[5]

Together these create a population of operators legally obligated to reuse heat, feeding into a market with no pricing mechanism and no offtake infrastructure — a structural gap a new entrant can occupy.

07

Why ventures fail & the defensible opening

The three failure modes

- No price mechanism for heat. No exchange, no comps; supply and demand both vary seasonally; most reuse is compliance-driven, not revenue-driven.[5]
- Connection infrastructure is the silent project-killer — every favorable payback in the literature explicitly excludes it.[7]
- Seasonal mismatch — supply is year-round, demand is winter-heavy; storage to bridge it doesn't pencil.[8]

The defensible opening (analytical judgment, est.)

Sit in the gap the mandate creates. Be the heat-offtake originator / broker — match mandated operators to low-temperature networks and heat-hungry offtakers, and structure the connection financing and contracts that everyone treats as an afterthought. Asset-light, software-aided, riding a legal mandate into a market that has no pricing layer yet. Northern Europe first (heat-network density + binding mandate + low-temperature networks); the US lacks both for now.

08

Glossary of domain terms

Waste heat
The low-grade thermal energy a data center rejects to the environment; the raw material here.

ORC (Organic Rankine Cycle)
A heat-to-electricity engine using a low-boiling-point fluid; the path this report rules out at current temps.

District heating (DH)
A network distributing centrally-produced heat to buildings; the main offtake channel for reused heat.

Low-temperature network (4GDH/5GDH)
4th/5th-generation district heating running at ~48-70°C — where reused data-center heat is worth the most.

Heat pump
Equipment that upgrades low-grade heat to a usable temperature; the single largest capex line item.

Immersion cooling
Submerging servers in dielectric fluid; reaches ~60°C outlet, high enough to make recovery practical.

Coolant grade
The temperature of the heat-carrying loop; higher grade (liquid/immersion) = more valuable, cheaper to reuse.

PUE
Power Usage Effectiveness — total facility power / IT power; the standard data-center efficiency metric.

Offtake / offtaker
The contracted buyer of the heat (a utility, district network, or heat-hungry industry).

Origination
Sourcing and structuring offtake deals — the asset-light layer this report identifies as the opening.

09

What this assessment did not do

- Zero primary research — no interviews with operators, heat networks, or municipalities; this is a secondary-source synthesis.
- No site-specific model — project economics depend heavily on the specific climate, coolant grade, network temperature, and connection distance, none modelled here.
- Regulatory scope limited to Germany and the EU as the leading forcing functions; other jurisdictions not assessed.
- One competitive precedent (Nerdalize) is a flagged secondary source, not independently verified to the same standard as the operators table.

This is a validation-stage opportunity assessment, not investment advice. Figures reflect verified public sources as of June 2026; project-level economics should be confirmed against a specific site and offtaker before capital commitment.

10

References

The 12 sources that directly support claims in this report, grouped by theme. Every entry is clickable — the gold superscripts throughout link here and out to the original source.

Technology & thermodynamics

1 Experimental Lessons of an Organic Rankine Cycle for data-center waste-heat recovery (~2% conversion; net energy loser; ~40K differential needed)
Vertiv (white paper) — https://www.vertiv.com/en-us/about/news-and-insights/articles/white-papers/experimental-lessons-of-organic-rankine-c

2 Immersion-cooling outlet temperatures (~60°C) & district-heating-vs-ORC siting
Applied Thermal Engineering (ScienceDirect) — https://www.sciencedirect.com/science/article/pii/S1359431124001479

3 Coolant temperature & waste-heat recovery effectiveness
Journal of Cleaner Production (ScienceDirect) — https://www.sciencedirect.com/science/article/pii/S0959652624033213

4 Dual-loop ORC techno-economics (heat-pump upgrading required)
Applied Thermal Engineering (ScienceDirect) — https://www.sciencedirect.com/science/article/pii/S1359431116326114

5 Heat reuse: a management primer (recoverable grades; Germany EnEfG quota; EU EED >=1MW reuse-or-justify; no pricing mechanism)
Uptime Institute — https://uptimeinstitute.com/resources/research-and-reports/heat-reuse-a-management-primer

Unit economics

6 Allocation of investment costs for large-scale heat pumps (0.8-1.1 M€/MW; heat pump 38-54% of project cost)
DTU / Pieper et al. (Energy Procedia) — https://www.sciencedirect.com/science/article/pii/S1876610218302613

7 Data Center Waste Heat Reuse: An Investment Analysis (10MW Philadelphia <2-yr payback with carbon credits, excl. connection)
ASME J. Eng. Sustainable Bldgs & Cities — https://asmedigitalcollection.asme.org/sustainablebuildings/article/6/1/011002/1210426/Data-Center-Waste-Heat-Reuse-

8 Göttingen waste-heat pricing & storage economics (~48-56 vs ~90-93 €/MWh; storage doesn't pay)
Energy Conversion & Management (ScienceDirect) — https://www.sciencedirect.com/science/article/pii/S0196890425003796

Operators in market

9 Octopus Energy invests £200m in waste-heat data-center business Deep Green (Devon pool heating bill cut ~60%)
DatacenterDynamics — https://www.datacenterdynamics.com/en/news/octopus-energy-invests-200m-in-waste-heat-data-center-business-deep-green

10 Reclaiming data-centre waste heat nets Qarnot €35 million (Jan 2023; Société Générale, ADEME, Demeter)
Tech.eu — https://tech.eu/2023/01/11/reclaiming-data-centre-waste-heat-nets-qarnot-eur35-million/

11 Turning heat into a resource — Mäntsälä supplies ~75% of town-centre district heat (~20,000-25,000 MWh/yr ~ 2,500 homes)
Nebius (sustainability) — https://nebius.com/sustainability/turning-heat-into-a-resource

12 Stockholm — heat recovery from data centres (Open District Heating; 20+ suppliers, >100 GWh/yr, ~30,000 apartments)
EU Covenant of Mayors — https://eu-mayors.ec.europa.eu/en/news/stockholm-sweden-heat-recovery-data-centres