

— WAREHOUSE CLIMATE CONTROL

You stored the cigarettes. *The humidity ruined them.*

A humidity excursion you didn't see this morning is **finished product you can't ship next week**. The Karnot architecture — one AHU with hot & cold coils, a reversible R290 heat pump, and **iSTOR phase-change storage tanks** — holds the warehouse at **22 °C / 60% RH continuously**, year-round, regardless of outdoor weather. Engineered for the Philippine wet season.

APPLICATION

Warehouse Climate Control

Brief 41 · Edition 1 · 2026

DESIGN BASIS

Manila 0.4% · 33.5 °C DB

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Karnot Energy Solutions

Pangasinan · Region 1 · Philippines

— WHO WE ARE

The people behind *cleaner energy*.

We're **engineers, installers and problem-solvers** building natural-refrigerant technology that **cuts energy costs** and **protects the planet**.

OUR MISSION

Replace combustion. *Replace synthetics.*

Natural refrigerant systems that deliver **75% energy savings** — just as global regulations make them essential.

CO₂ · R290 · THE NEW STANDARD



OUR FOUNDER

Stuart Cox — *Founder & CEO*

Stuart brings **decades of hands-on experience** designing and delivering natural-refrigerant systems for the world's most demanding industries.

He previously founded **Likido Ltd** in Edinburgh and successfully **exited via acquisition to Dalrada Corporation (OTCQB: DFCO) in 2020**. His systems were selected for technology assessment by the **U.S. Department of Energy** and **Oak Ridge National Laboratory**. In 2023 he moved to **Pangasinan, Philippines**, to build Karnot.



RESEARCH ADVISOR

Prof. Zhibin Yu — *Chair of Energy Engineering*

Chair of Energy Engineering and Lead of the Energy Research Cluster at a UK university. **Royal Society Industrial Fellow (2023–2027)** — placing senior academics inside industrial R&D to accelerate translation. Brings deep expertise in thermal-system modelling, heat-pump performance characterisation and natural-refrigerant cycle analysis.



ENGINEERING ADVISOR

Andrew McCahey — *CEng MIMechE*

Chartered Mechanical Engineer (CEng) and Member of the Institution of Mechanical Engineers (MIMechE). Reviewing engineer on Karnot's **FLX phase-change-material module design**. Brings rigorous CIBSE/ASHRAE-grade design review and UK-standard mechanical-systems verification.

— PART I — THE OPPORTUNITY

Your existing AC plant is on a *phasedown clock*.

Most warehouse split systems were specified with **R32 or R410A**. Both are now mid-phasedown under **DENR DAO 2021-31** (Kigali codified into PH law). Refrigerant prices have already risen 3–5× since 2022. Service-call recharge cost is now the largest line on most facility HVAC contracts.

01 — THE GAS

GWP 2,088

R410A traps **2,088×** more heat than CO₂. R32 (the "bridge" replacement) is 675. **Karnot R290 is 3.**

02 — THE PRICE

3–5× since 2022

Wholesale R410A price **up 3–5× in four years** as Kigali quotas tighten. Recharge cost now dominates HVAC OPEX. Insurance premiums on F-gas-equipped facilities rising too.

03 — THE DEADLINE

–80% by 2047

Under DAO 2021-31 the Philippines has committed to a **10% HFC cut by 2029, 30% by 2035, 50% by 2040, 80% by 2047**. Equipment installed today must outlive the gas inside it.

2024

FREEZE

PH hits HFC consumption ceiling

2029

–10%

Virgin HFC supply tightens

2035

–30%

R410A becomes a financial liability

2040

–50%

Synthetic refrigerants near-eliminated

2047

–80%

Final phase-down target

— PART I — THE OPPORTUNITY (CONTINUED)

Why standard split AC *always fails for cigarette storage.*

The engineering reason your warehouse goes **over 65% RH** every wet season is structural — split AC is sized for sensible cooling, but a tropical warehouse load is mostly latent. Four ways the existing plant fails:

01 — SHR MISMATCH

Sized for sensible. Your load is latent.

A standard split AC has a Sensible Heat Ratio of **0.70–0.80** — 70-80% of capacity goes to cooling air, only 20-30% to removing moisture. Your warehouse needs SHR **0.40–0.50**. Specifying the wrong SHR is a fundamental engineering error.

ASHRAE FUND. 2021 · MANILA 0.4% DESIGN

02 — SHORT-CYCLE COMPRESSOR

Temp setpoint hit, moisture continues to pour in.

The room hits 22 °C in 5 minutes (low sensible load). The thermostat is satisfied, the compressor cuts off — but moisture continues to enter through loading-bay doors, ventilation, and product respiration. **RH spikes to 75–80%. Mould in 3–6 days.**

ISO 3402 CEILING: 60% RH ± 3%

03 — ELECTRIC REHEAT WORKAROUND

The "fix" that's both illegal and ruinous.

When the split AC short-cycles on humidity, the lazy operator solution is to **add an electric resistance reheat coil** — overcool the air, then reheat it electrically. This is **explicitly forbidden under ASHRAE 90.1 §6.5.2.3** (simultaneous heating & cooling) and triples the energy bill. R290 with hot-gas reheat from recovered condenser heat is the only compliant answer.

ASHRAE 90.1 §6.5.2.3 · EXCEPTION 5 ONLY

04 — SPARES SCARCITY

8-week air-freight for parts.

The wave of low-cost imported split AC units shipped into PH facilities in 2014–2018 came from vendors that have since consolidated, renamed, or left the export market. **Spare parts now require 8–12 week air-freight** — and your humidity excursion can't wait three months.

KARNOT ANSWER: PANGASINAN PARTS DEPOT

— PART I — WHAT IT ACTUALLY COSTS

The humidity excursion you didn't see.

The product you can no longer ship.

A standard split AC failure **does not show up on the BMS dashboard**. The room is at 22 °C. Everything looks fine. The damage compounds silently in the bays — and shows up two weeks later in QA reject, customer complaint, or worse.

01 — FINISHED PRODUCT

Mould in 3–6 days at >65% RH.

Cigarettes go soft. Paper rehydrates and unwraps. Filters lose draw consistency. Once mould begins, the entire affected pallet is **unrecoverable** — destroyed at company cost, with chain-of-custody disposal paperwork. Industry literature documents **visible spoilage inside one week** of sustained over-humidity.

REFERENCE: ISO 3402 · INDUSTRY MOULD-ONSET LITERATURE

02 — DRY EXCURSION

Below 55% RH, the leaves crack.

Operators trying to control humidity by overcooling (16 °C) flip the failure mode. Tobacco shrinks, becomes brittle, falls out of the paper casing during manufacturing. **Production lines stop. Yield drops. Brand-spec consistency fails QC.** The same standard split AC causes both failure modes within the same week.

INDUSTRY QUALITY-CONTROL LITERATURE

03 — REGIONAL SUPPLY-CHAIN LOSS

12% post-harvest loss baseline.

PHilMech (Philippine Center for Postharvest Development) documents **average 12.7% storage loss on corn alone**; broader agricultural loss across PH supply chains routinely reaches **50%**. Inadequate warehouse HVAC is universally cited as the primary driver. Tobacco operators face the same physics.

SOURCE: PHILMECH 2025 POSTHARVEST JOURNAL VOL. 8 NO. 2

04 — DISCLOSURE LIABILITY

Refrigerant leak = Scope 1 emissions.

Existing R410A or R134a heat pumps in the warehouse plant are **direct Scope 1 emissions** under SEC PFRS S2 reporting. Annual leak rates of 5–10% are typical industry baseline. A single 100-TR R410A chiller leaking 8% per year generates the **CO₂e equivalent of a fleet of delivery trucks** — and most operators don't disclose it because they've never measured it.

SEC PFRS S2 · R410A GWP 2,088

— PART II — THE ANSWER

One AHU. Two coils.

Reversible R290 heat pump & iSTOR.

The Karnot architecture: a **fully inverter-controlled Air Handling Unit** with both a hot coil and a cold coil, fed by an **iHEAT R290 reversible heat pump**, buffered by **two iSTOR thermal batteries** (hot + cold, patented PCM), and powered by an **iVOLT solar + Li-ION** package on the warehouse roof. Continuous, stable conditions year-round — independent of grid events.

HOW IT WORKS

- **Fully inverter-controlled AHU** with hot & cold coils — the *same* machine handles both jobs from the *same* airstream
- **iHEAT R290 reversible heat pump** charges either the hot or cold loop, depending on what the AHU asks for
- **Two iSTOR thermal batteries** (hot & cold, patented PCM) buffer both loops — when the HP reverses, the “other” tank carries the load. **No interruption to the warehouse.**
- **iVOLT solar + Li-ION** on the warehouse roof powers the whole system — runs the day on solar, the night on battery, the diesel generator goes off the OPEX line entirely

THE TOPOLOGY



The iSTOR tanks decouple the heat pump from the AHU's instantaneous demand. When the HP is making hot water, the cold tank discharges to the cold coil — and vice versa. **Reversal is invisible to the warehouse.**

— PART II — WHAT KARNOT DELIVERS

From psychrometric audit to commissioning. *We run the project.*

A single contractor across the entire mechanical scope — survey, load calculation, design, installation, commissioning, performance verification.
One number to call. One throat to choke.

01 — AUDIT

Free site visit + ASHRAE block-load calc

One day on site with our engineers. Temperature/RH datalogging at multiple zone heights. Block-load calculation per ASHRAE Heat Balance Method (HBM). **Indicative pinch report and AHU + system sizing inside 14 days.** No procurement triggered.

FREE · NO OBLIGATION · 14-DAY TURNAROUND

02 — DESIGN

Mechanical package & compliance

Full AHU + iSTOR package — R290 plant sizing, PCM thermal storage modules, glycol distribution, BMS integration, structural review. **RA 11285 / DOE classification** support, EN 378 charge-limit verification, IPMVP Option B M&V plan included. BOI registration paperwork on request.

EN 378 · ASHRAE 90.1 · IPMVP · RA 11285

03 — INSTALL

Phased rollout · zero product disruption

Phased install warehouse-by-warehouse on a 12-month national programme. **The R290 heat pump sits outdoors** — no in-warehouse mechanical work and no flammable refrigerant inside the building envelope. **Witness-tested** per CIBSE Commissioning Code M.

SINGLE CONTRACTOR · 4 JURISDICTIONS

04 — SERVICE

Scheduled service & spare-parts depot

Quarterly service visits, refrigerant-leak inspection, performance audit. **PH-based parts depot** in Pangasinan — no 8-week air-freight wait for spares. **3-year warranty** on the heat-pump core. IPMVP-compliant sub-meter data feeds the M&V baseline.

ANNUAL SERVICE CONTRACT · 3-YEAR CORE WARRANTY

— PRODUCT 01 · IHEAT

iHEAT — the reversible *R290 heat pump.*

The thermodynamic engine of the architecture — *one machine charges both iSTORE tanks*, hot or cold, on demand.

Reversible R290 (propane) air-source heat pump in a sealed monobloc, sited outside the warehouse envelope. Heating COP 4.14–5.59. Cooling EER 3.51–4.16. Reverses between heating and cooling modes to charge whichever iSTORE tank is depleted — the AHU never sees the reversal because the other tank carries the load. Full DC inverter, smart controller, A+++ class, ambient operating range –25 °C to +45 °C.

REFRIGERANT · CHARGE

R290 0.55 kg · GWP 3 · EN 378 outdoor

HEATING COP / COOLING EER

4.14–5.59 / 3.51–4.16

CAPACITY LINE-UP

9.5 → 105 kW · 9 R290 + 4 R744 models

REVERSAL

On demand charges either iSTORE tank

BUILT FOR

Warehouse climate control · tobacco product storage · pharmaceutical conditioning · paper & packaging stores · cleanroom anterooms. **Pairs with iSTORE** for continuous AHU operation through reversal cycles.

— PRODUCT 02 · ISTOR

iSTOR — phase-change *thermal storage tanks.*

TWO TANKS · TWO TEMPERATURES

HOT TANK

44 °C

to AHU hot coil

COLD TANK

22 °C

to AHU cold coil

Patented PCM formulation — natural phase-change fluids, sourced in the Philippines. PH-manufactured tanks. No imported synthetic chemistry.

iSTOR PCM thermal storage

22 °C COLD TANK + 44 °C HOT TANK · NATURAL PCM · PH-BUILT

The reason the AHU never has to wait for the heat pump — *both temperatures are always available.*

Two iSTOR tanks sit in the loop — a 22 °C cold tank and a 44 °C hot tank, both filled with natural phase-change material sourced from PH suppliers. When the reversible R290 heat pump is making hot water for the AHU's hot coil, the **cold tank discharges into the cold coil**. When the heat pump reverses to make chilled water, the hot tank carries the heating load. The AHU sees continuous, stable conditions on both sides — the warehouse never sees the reversal.

HOT TANK · PHASE-CHANGE TEMP

44 °C **patented PCM** · feeds hot coil

COLD TANK · PHASE-CHANGE TEMP

22 °C **patented PCM** · feeds cold coil

STORAGE CAPACITY

33 → 80 kWh per tank · modular

SUPPLY CHAIN

PH-sourced natural fluids · BOI-eligible**BUILT FOR**

Any Karnot installation that needs **continuous AHU operation through reversible heat-pump cycles** — warehouse climate control, hospital sterile storage, F&B process plant, pharma conditioning rooms. Drives the “no interruption” promise.

— PRODUCT 05 · iVOLT

iVOLT — solar panels + inverter + Li-ION battery. *No more diesel generator.*



A complete electrical package — *solar panels, inverter, and lithium-ion battery* sized to power the AHU + iSTOR + iHEAT system through any grid event.

Warehouse roofs are some of the largest under-utilised solar surfaces in the country. iVOLT pairs a roof-mounted PV array with a Karnot inverter and a LiFePO4 lithium-ion battery, integrated directly with the iHEAT load. Solar runs the day, the battery runs the night, the grid is the backup — and the diesel generator goes off the OPEX line entirely. Aligns directly with corporate Climate Transition Plan targets on Scope 2 emissions reduction.

PV ARRAY
Roof-mount site-specific · sized to thermal load

INVERTER
Karnot grid-tied · battery-coupled

BATTERY
LiFePO4 Li-ION millisecond cutover · 20-yr life

DIESEL OFFSET
~600 L/wk per warehouse · ₱1.87M/yr saved

BUILT FOR
 Warehouse fleets with large roof-area-per-thermal-load ratio · operators with formal Climate Transition Plans · facilities exposed to yellow/red Luzon grid alerts in dry season.

WORKED CASE · UNNAMED CUSTOMER · 200 M² ZONE

One warehouse. *Eighty-nine percent off the bill.*

First-principles heat-load case study on a **200 m² tobacco-product warehouse zone** at 22 °C / 60% RH spec, currently cooled by 5 × 3 HP + 1 × 2 HP split AC running 24/7. Tariff: ₱14/kWh including 3-phase service premium. Customer name withheld; figures are independently calculated by ASHRAE Heat Balance Method.

FIG. 01 · ANNUAL ELECTRICITY COST PER ZONE (₱/YEAR · 200 M² ZONE · ₱14/KWH TARIFF)

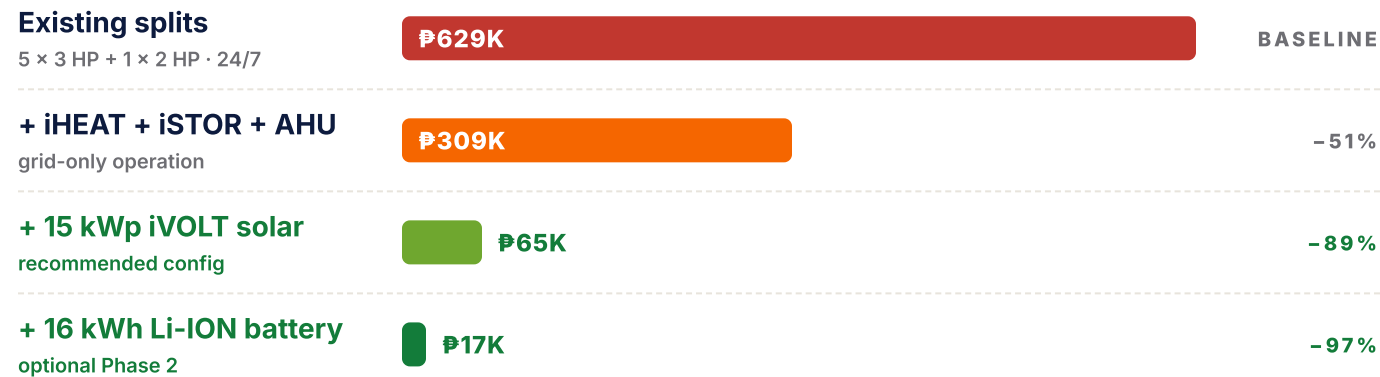
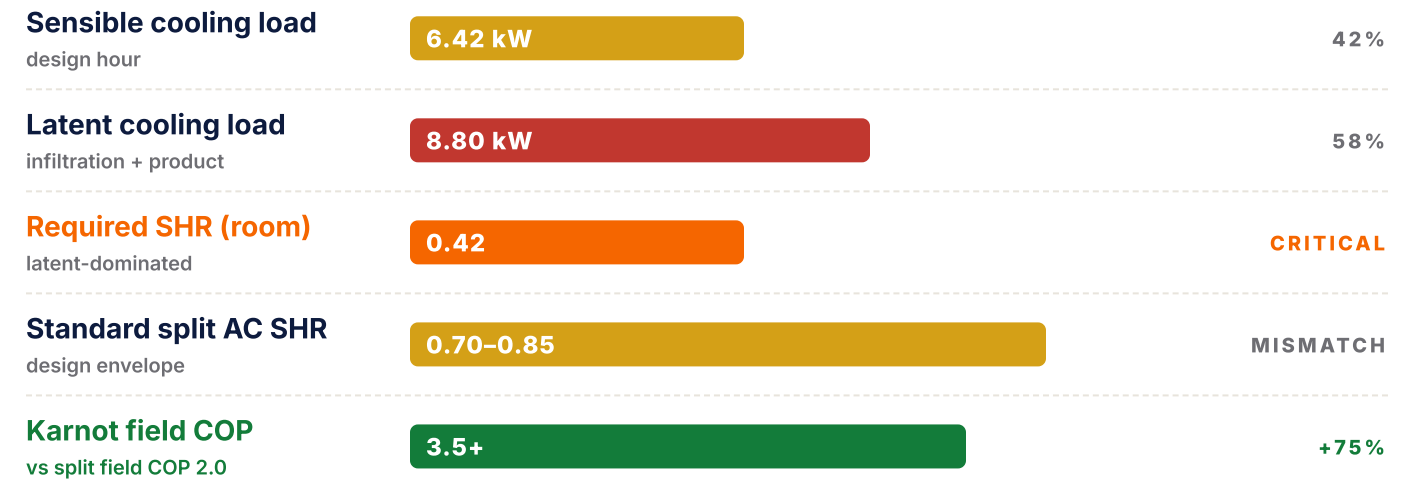


FIG. 02 · WHY THE EXISTING SPLITS CANNOT HOLD SPEC (LOAD PROFILE · 200 M² ZONE)



-89%

ELECTRICITY · ZONE BASIS

₱564K

ANNUAL SAVING · PER ZONE

28 t

CO₂ AVOIDED · PER ZONE / YR

2.9 yr

PAYBACK · NEW-BUILD BASIS

COMPLIANCE & MEASUREMENT

Bankable savings. *Verified to international standard.*

Modern corporate Climate Transition Plans require **independently verifiable** Scope 1 and Scope 2 reductions. Karnot designs the M&V protocol from day one — sub-metered, IPMVP-compliant, audit-ready.

01 — ENERGY STANDARD

ASHRAE 90.1 §6.5.2.3 Exception 5

100% recovered condenser heat drives the reheat coil. Compliant with the energy-code prohibition on simultaneous heating & cooling — qualifies under the dehumidification exception. **Electric reheat batteries (the lazy alternative) are illegal.**

ANSI/ASHRAE/IES 90.1-2022

02 — SAFETY

EN 378 / ASHRAE 15 / ISO 5149

R290 charge limits for direct-expansion in occupied spaces are strict (2.5 kg max). Karnot's **outdoor packaged unit + glycol distribution** architecture removes refrigerant from the warehouse envelope entirely — satisfying EN 378 Location Class III/IV without compromise.

IEC 60335-2-40 (7TH ED.) COMPLIANT

03 — M&V

IPMVP Option B · retrofit isolation

Dedicated **kWh sub-meters** on the dehumidifier feeds + continuous space RH/T datalogging. Mathematically isolates system boundaries and proves **litres-of-water-per-kWh**. Bankable for ESCO contracts and CECO reporting.

IPMVP VOL. 1 · EVO STANDARD

04 — PH STATUTORY

RA 11285 · DOE designated establishment

Energy Efficiency & Conservation Act compliance — DOE Type 1 / Type 2 facility classification, CECO appointment, DEOS portal reporting. **BOI fiscal incentive registration** may apply to the energy-efficiency capex; final package case-by-case.

RA 11285 · DOE-EUMB · BOI-SIPP

— THE FREE TOOLS WE GIVE YOU

Run your own numbers. *No sign-up. No email gate.*

Six **live calculators** on karnot.com — built for the engineer, the CFO and the sustainability officer to use in the same conversation. Indicative output in under three minutes.

01 — RECOMMENDED FOR WAREHOUSES

Warehouse Dehumidification Sizer

m² + RH target + outdoor design in. Recommended Karnot DOAS unit size, projected litres/kWh, indicative payback period and CO₂ avoided per year.

karnot.com/applications/warehouse-climate-control-calculator

02 — COMPLIANCE

RA 11285 DOE Classification

Determines your facility's tier under the Energy Efficiency & Conservation Act. Triggers CECO/CEM appointment, mandatory audits and DEOS portal reporting.

karnot.com/compliance#doe

03 — CARBON

SEC PFRS S2 Carbon & F-Gas

Scope 1 + Scope 2 calculator including the F-gas refrigerant leak liability that most facility operators under-report. Built for SEC climate disclosures and corporate Climate Transition Plans.

karnot.com/compliance#sec-pfrs

04 — F-GAS RISK

Refrigerant Carbon Calculator

CO₂e impact of refrigerant leaks. R290 vs CO₂ vs R32 vs R410A vs R134a vs R404A. PFAS classification & Kigali phasedown timeline overlay.

karnot.com/engineering-hub/refrigerant-carbon

05 — PINCH

Pinch Analysis Tool

Identifies heat-recovery opportunities across the warehouse thermal load — process heat that can be recovered to reheat the dehumidifier supply air, eliminating waste.

karnot.com/engineering-hub/pinch-analysis

06 — RETROFIT ROI

Boiler / AC Retrofit ROI

Quick comparison: existing R410A split AC vs Karnot iHEAT-DOAS. Drops out a year-1 cost delta, 10-year NPV, and refrigerant-recharge avoidance — share-able single page.

karnot.com/engineering-hub/hot-water-opex

— THE COMMERCIAL MODEL

Capital purchase. *Three-year payback per zone.*

Karnot equipment is sold outright with a **3-year warranty on the heat-pump core**. Energy-efficiency capex may qualify for **BOI incentives under RA 11285** — Karnot supports the registration paperwork. Per-zone payback figures shown are from the worked 200 m² case study.

01 · PER-WAREHOUSE PAYBACK

From day one, the bill drops.

NEW-BUILD INSTALL

2.9 yr

net of avoided split-AC capex

RETROFIT INSTALL

3.7 yr

gross capex basis · per zone

HEAT-PUMP WARRANTY

3 yr

on the heat-pump core

ASSET LIFE

15–20 yr

No phasedown clock on R290

02 · PER-ZONE ROLLOUT · ~6 MONTHS

Single zone. Single contractor.

Karnot delivers the whole stack — survey, design, BOI registration, install, commissioning, M&V — under one contract per zone. **All-new mechanical install**, no retrofit dependency. Replicate across the fleet at customer's pace.

- **Mo 1:** Site survey, ASHRAE block-load calculation, BOI paperwork
- **Mo 2–3:** Mechanical & electrical design package · client review · long-lead procurement
- **Mo 4–5:** Install AHU + iSTOR + iHEAT outdoor unit · commissioning · witness testing
- **Mo 6:** iVOLT solar PV (where roof permits) · final M&V baseline · handover

Specific BOI incentives subject to BOI approval — verify with your tax adviser before commitment.

— NEXT STEP · A FREE PINCH STUDY

Thank you.

Now let's run your numbers.

Every Karnot project starts with a **pinch study** and a conversation. **Walk us through your plant room** — kitchens, laundry, pool plant, chillers — and we'll come back inside two weeks with an indicative system, payback under both commercial models, and the CO₂ you'd avoid. **No procurement triggered. No obligation.**

01 · FOUNDER & CEO

Stuart Cox

Direct line for site visits, pinch studies and bespoke quotes

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02 · THE COMPANY

Karnot Energy Solutions Inc.

SEC-registered · BOI-SIPP · Engineering · Compliance · Carbon · IP

karnot.com

03 · THE MARKETS

PH · UK · US · CA

Four jurisdictions · One stack · Built for the tropics · Shipping today

karnot.com/applications/warehouse-climate-control