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INDUSTRIAL DECARBONIZATION
Beyond renewable electricity

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Photo by Stefan Els

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Acknowledgement

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PhD dissertation: *An outlook on the energy mix evolution at South African beverage manufacturers and opportunities for greater adoption of renewable energy solutions*

and beyond….

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SYNOPSIS

South African industry has embraced renewable electricity.

But renewable electricity alone will not get us to net zero:

It doesn't solve the heat problem;
Process heat is two-thirds of industrial energy use / ±35% of national energy use.

Objectives:

1. Frame why heat is the next renewable energy battleground;
2. Show you where the techno-economics actually land today — what wins, what doesn't, and what changes in the short to medium term;
3. Inform you of what we're doing at SU in this space and how we'd like to partner with with industry to progress the agenda of Industrial Decarbonization.

Renewable electricity in South Africa

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7.3 GW

REIPPPP solar + wind on grid

Of 13.4 GW procured — utility-scale

USD 29/MWh

Lowest REIPPPP bid

Bid window 5 (2021) — solar & wind

7.5 GW

Private rooftop PV (end 2025)

Industrial & commercial-led — tripled in 2 yrs

Source: Rozon, Owen & McGregor, Energies 18 (2025) 3241; REIPPPP IPP Office data.

Solar PV leads the way — but wind is in the mix

REIPPPP has procured **13.4 GW** of utility-scale solar + wind since 2011, attracting **USD 15 bn** in investment — 25% foreign.

In parallel, private "rooftop" PV — industry-driven — has tripled in two years and now **rivals REIPPPP capacity.**

Key drivers

- Rapidly increasing industrial electricity tariffs
- Load shedding made on-site generation a survival issue
- Rapid decreases in PV & BESS prices
- 1 MW unlicensed-generation cap lifted (2021); wheeling agreements matured
- Competitive REIPPPP bidding drove utility solar + wind tariffs below coal

https://shorturl.at/MG2rF

https://shorturl.at/OBXVP

The problem: Fossil-fuel heavy industrial process heat

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52%

of SA energy used by industry

More than households + transport combined

± 700 PJ/yr

industrial process heat in SA

Two-thirds of industrial energy — ≈200 TWhth

± 70% of low/med

of that heat is from coal boilers

Steam at 4–10 bar, 150–185 °C — the workhorse

How the heat is produced today

Heat source	Share	LCOH USD/MWh_{th}	Notes
Coal-fired steam boilers	~70%	**17–28**	*Cheap, ubiquitous — but carbon-heavy*
Pipeline gas (Sasol)	10–15%	**≈ 23**	*Limited to Gauteng / KZN corridors*
Heavy fuel oil	5–10%	**≈ 68**	*Coastal industry — exposed to oil-price swings*
Diesel (backup / peak)	3–5%	**≈ 140**	*Load-shedding driven — high cost, high CO_2*
Electricity (electro-boilers)	3–5%	**≈ 120**	*Carbon-heavy: grid factor ≈ 0.94 t CO_2e/MWh*

Where industry uses heat

LOW < 100 °C	**Washing · cleaning · drying · CIP** *Dairy, soft drinks, hospitals, hotels*
MEDIUM 100 – 200 °C	**Pasteurisation · distillation · dyeing · drying** *Beverages, pulp & paper, textiles, food*
HIGH > 200 °C	**Calcining · smelting · cracking · firing** *Cement, steel, glass, petrochemicals*

Coal locks in coal-era boilers. Grid electricity still emits ≈0.94 t CO_2e/MWh. Carbon-tax tightens 2026 — CBAM hits exports.

Five practical pathways to renewable heat

FOUNDATION

Energy efficiency

Heat recovery, insulation, process optimization. 20–30% savings before any capex on supply. Exposes the waste-heat streams that unlock #2.

LOW – MEDIUM

Heat pumps

COP 2–5. Upgrades waste heat from #1 to useful process temperatures. Game-changer with low-cost green electricity. LCOH USD 45–73/MWh_{th}.

LOW – HIGH

Bioenergy

Biomass, biogas, agricultural & municipal waste. Drop-in for existing combustion boilers — keeps the steam plant familiar. WC alone has 3 Mt/yr.

LOW – HIGH

Solar thermal energy

PTC, Fresnel, flat-plate. Direct solar-to-heat conversion. LCOH USD 38–70/MWh_{th} in SA. Mature in Europe; almost untapped here.

HIGH +

Green H_2 / CCS

For hard-to-abate, >400 °C processes. Not there yet but pilots and infrastructure decisions start now.

None of these are perfect — the right answer is almost always a hybrid system, optimized for a specific case.

Three phases for industrial decarbonization

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Decarbonising: Electricity Heat Both

PHASE 1
Foundation
Now → 2030

- Energy audits & EnMS
- Process & heat-recovery optimisation
- Fuel switching to lower-C alternatives
- PV self-generation + BESS
- Carbon-tax readiness (2026 reforms)

PATHWAYS IN PLAY

Quick wins. Year-1 RoI on PV: 17%. On BESS: 26%.

PHASE 2
Technological transition
2025 → 2040

- Scale-up renewable electricity (wheeling, PPAs)
- High-temperature heat pumps with waste-heat capture
- Solar thermal for steam (PTC, Fresnel)
- Thermal energy storage
- Hybrid PV + ST + HP architectures

PATHWAYS IN PLAY

Where most of our research effort sits today.

PHASE 3
Leadership
2035 →

- Full renewable heat & power integration
- Green hydrogen for >400 °C processes
- Carbon capture & utilisation
- Industrial symbiosis / district heat networks
- Synthetic fuels & negative-emissions tech

PATHWAYS IN PLAY

Hardest. But starts with pilots & infrastructure decisions now.

Adapted from Rozon, Owen & McGregor — Energies 18 (2025) 3241.

Economics: What wins today — and what will win by 2030

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Investment option	2020 Y1 RoI	2030 Y1 RoI	Capex (2020)	Capex (2030)	Status
PV vs grid electricity	**17%**	**45–50%**	USD 883/kWp	USD 490/kWp	✓ scaling
BESS vs peak tariffs+diesel	**26%**	**40–45%**	USD 430/kWh	USD 250/kWh	✓ scaling
Solar thermal vs HFO/diesel	**27%**	**45–55%**	USD 460/m²	USD 345/m²	ready
Solar thermal vs coal	**5–10%**	**10–15%**	USD 460/m²	USD 345/m²	needs policy
Heat pumps vs coal	**4%**	**10–15%**	USD 500/kWth	USD 375/kWth	needs cheap green e^-

KEY TAKEAWAYS

Today: PV, BESS and solar thermal energy vs liquid fuels are no-brainers. Solar thermal energy vs coal needs subsidies or carbon-tax teeth.
2030: ALL technologies cross the 10% Y1 ROI threshold; PV+BESS approach 50%. Carbon tax + CBAM tilt the field further.
Trigger: Cheap green electricity (<USD 70/MWh) unlocks heat pumps; coal above USD 150/tonne unlocks solar thermal.

Case study — Large soft-drink bottling plant

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200 ML/yr
soft-drink production
PET + Returnable Glass Bottles

3 057 MWh_{th}
annual process heat
avg 500 kW + 1 500 kW electricity

160 °C · 5.2 bar
medium-temp steam
washing · pasteurisation · CIP

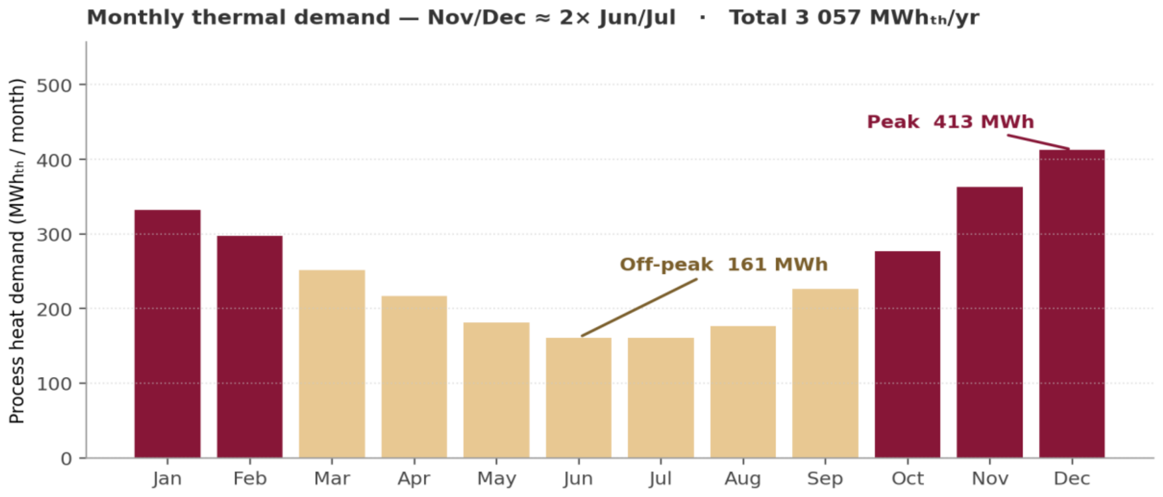
Nov/Dec ≈ 2× Jun/Jul
highly seasonal demand
12-24 h/day · 7 days/week

Processes requiring heat

Process	Temperature	Use
Bottle washing (RGB)	75-80 °C	Hot water + caustic
Pasteurisation	75-85 °C	Tunnel pasteurisers
Sterilisation (CIP/SIP)	120-150 °C	Steam injection
Cleaning-in-place (CIP)	60-90 °C	Hot loops
Process steam supply	160 °C	Boiler header

0.2 kWh of process heat + 1.5 kWh of electricity per litre produced

Demand profile · seasonal



TODAY: HEAT SOURCED FROM COAL / HFO BOILERS
The displacement target — full thermal load (3 057 MWh_{th}) is on the table.

https://shorturl.at/xBEE9

https://shorturl.at/WqkKH

Case study: Renewable energy interventions

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OPTION 1
Solar Thermal (PTC + storage)

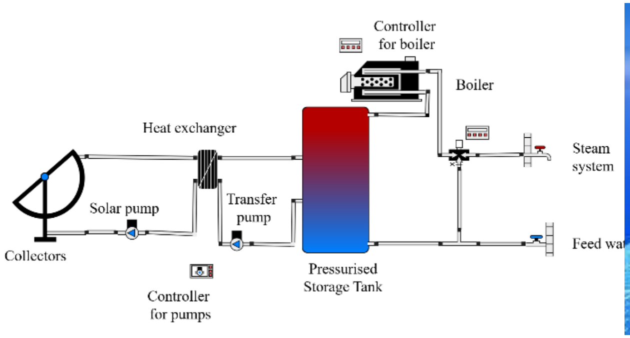
Direct solar-to-heat — collectors produce pressurised hot fluid that drives steam generation, with thermal storage smoothing intermittency.

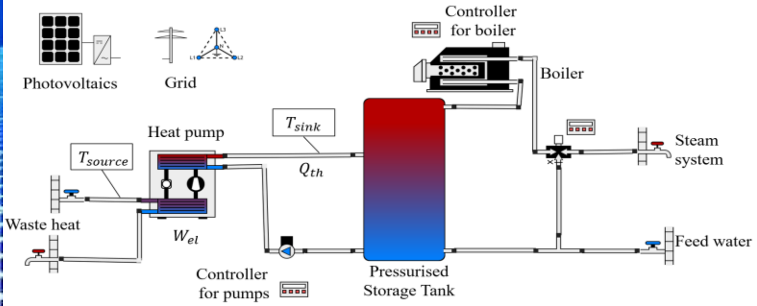
- **COLLECTOR** Parabolic Trough Collector (PTC), single-axis tracking
- **STORAGE** Pressurised thermal storage — extends solar fraction to ~50 %
- **BACK-UP** Existing coal / HFO boiler retained for top-up & no-sun periods
- **OPERATES** Daylight + storage discharge · ≈ 8-14 h/day depending on season
- **FOOTPRINT** Large — collector field sized in m² per kW_{th} peak
- **CAPEX DRIVER** USD 460/m² today → USD 345/m² by 2030
- **METHOD** Quasi-dynamic Polysun · Scenocalc data · VDI 6002 LCOH

OPTION 2
PV-assisted High-Temp Heat Pump

Compressor lifts low-grade waste heat to 140-160 °C steam — driven by rooftop PV with grid / wheeled-PPA top-up.

- **SOURCE HEAT** Refrigeration equipment (NH_3) + PET blow-mould exhaust · 20-60 °C
- **SINK** Saturated steam at 140-160 °C feeding existing header
- **COP** 2.5-3.5 — strongly depends on waste-heat source temperature
- **REFRIGERANT** R365mfc / R1233zd-E / n-pentane — high-boiling-point fluids
- **POWER INPUT** Rooftop PV first, grid / wheeled green PPA top-up · 624 kW peak HP
- **FOOTPRINT** Compact — HP skid + rooftop PV ≈ 400 kWp · no field needed
- **METHOD** Polysun model · Chemcad-derived COP curves · co-published 2024





Results — head-to-head

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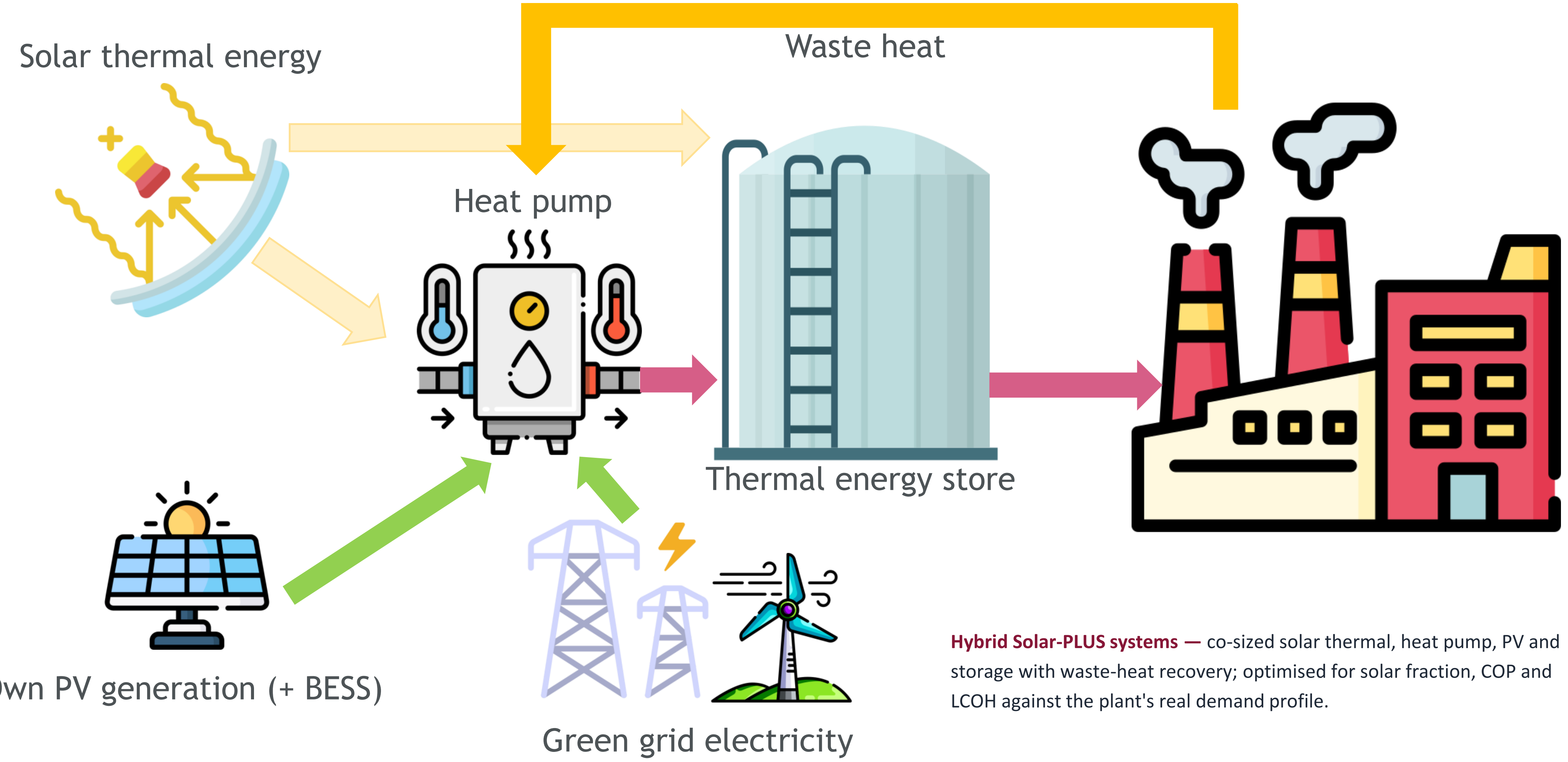
BASELINE Coal / HFO boiler	OPTION 1 Solar Thermal (PTC + storage)	OPTION 2 PV-assisted HT Heat Pump
LCOH		
USD 11-20 /MWh_{th}	USD 38-70 /MWh_{th}	USD 50-73 /MWh_{th} · ≈ 50 with 60 °C waste heat
CO_2 INTENSITY		
942 kg /MWh_{th}	≈ 330 kg /MWh_{th} · ~65 % cut vs coal	≤ 180 kg /MWh_{th} · 80 %+ cut once grid decarbonises
RENEWABLE FRACTION		
— fossil baseline	Up to 50 % solar fraction with storage	70-100 % electricity-driven · scales with green e^-
YEAR-1 ROI · 2026		
— reference	5 - 10 % vs coal 27% vs HFO	4 % vs coal electricity > USD 70/MWh
YEAR-1 ROI · 2030		
— reference	10 - 15 % vs coal 45 - 55 % vs HFO	10-15 % vs coal electricity < USD 50/MWh
UNLOCKED BY		
no carbon tax status quo today	Coal > USD 150/t or CBAM-driven carbon pricing	Green e^- < USD 70/MWh + waste heat ≥ 30-60 °C

BOTTOM LINE · Both technologies clear 10 % Y1-RoI by 2030. Solar thermal: capex stability + 50 % solar fraction. HTHP: deeper CO_2 cut + smaller footprint.

Next research focus: hybrid "solar PLUS" systems (medium temperature process heat)



Hybrid Solar-PLUS systems — co-sized solar thermal, heat pump, PV and storage with waste-heat recovery; optimised for solar fraction, COP and LCOH against the plant's real demand profile.

What we bring — research, implementation, technical capacity

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STERG

Solar Thermal Energy Research Group

Department of Mechanical & Mechatronic Engineering

- Concentrating collector R&D (PTC, towers, Fresnel)
- Receivers, secondary reflectors, thermal storage
- Hybrid PV + ST + HP system modelling
- Polysun / TRNSYS techno-economic analysis
- MEng & PhD graduates

CRSES

Centre for Renewable & Sustainable Energy Studies

Faculty of Engineering — interdisciplinary

- Established 2007 — 20 short courses on RE systems
- Advisory services for PCC, SANEDI, DSTI
- Industrial energy transition consulting
- SOLTRAIN scientific co-ordinator (Cape provinces)

Hub & Spoke

Wind & Solar R&D flagship

DSTI multi-university programme

- 20-year track record — managed by CRSES
- PV, wind, solar thermal, storage spokes across SA
- Pipeline of demonstrators with industrial partners
- Renewable energy focused graduates (MEng & PhD)

How to work with us

Consult / Advisory

DAYS TO WEEKS

Plant audit, techno-economic scoping, vendor evaluation, carbon-tax modelling. Direct CRSES advisory engagement.

MEng / PhD projects

1–4 YEARS

Embed a student in your problem. You contribute data + a funding*; we deliver thesis-quality analysis and a hire-ready graduate.

Demonstration pilots

12–24 MONTHS

Co-funded pilot at your site via UK PACT, EUROGIA2030, NRF, or DSTI. You bring the plant; we bring the technology and the grant route.

Training / Short courses

DAYS

CRSES short courses for your engineers — 20 modules. On-site delivery available. Up-skill your team while you de-risk.

Localisation R&D

2–5 YEARS

Co-develop locally manufactured collectors, receivers, heat pumps with SA SMEs. DSTI funding routes.

Standards / Policy

ONGOING

Joint contributions to SANS standards, PCC submissions, IEA SHC reporting. Shape the regulatory environment that impacts your investments.

Questions, conversations, and contacts

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Thank you.

Let's continue the conversation.

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