Thermal Energy Transition Playbook

Best Practices for Partners

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Practical Pathways for Energy Transition

This playbook highlights **practical pathways** for thermal energy transition across manufacturing operations.

The intent of sharing this playbook is to inspire action, share recommended solutions, and offer a starting point toward assessing options to reduce site energy use and associated operational GHG emissions.

1

Energy Transition Overview

Provide a clear understanding of heat and electricity decarbonisation basics, objectives and execution approach

2

Thermal Energy Transition Pathways

Potential decarbonisation pathways for thermal energy with implementation guidance for key technologies

3

Execution Approach and Ownership Model

Proposed approach to identify decarbonisation opportunities and move from intent to execution

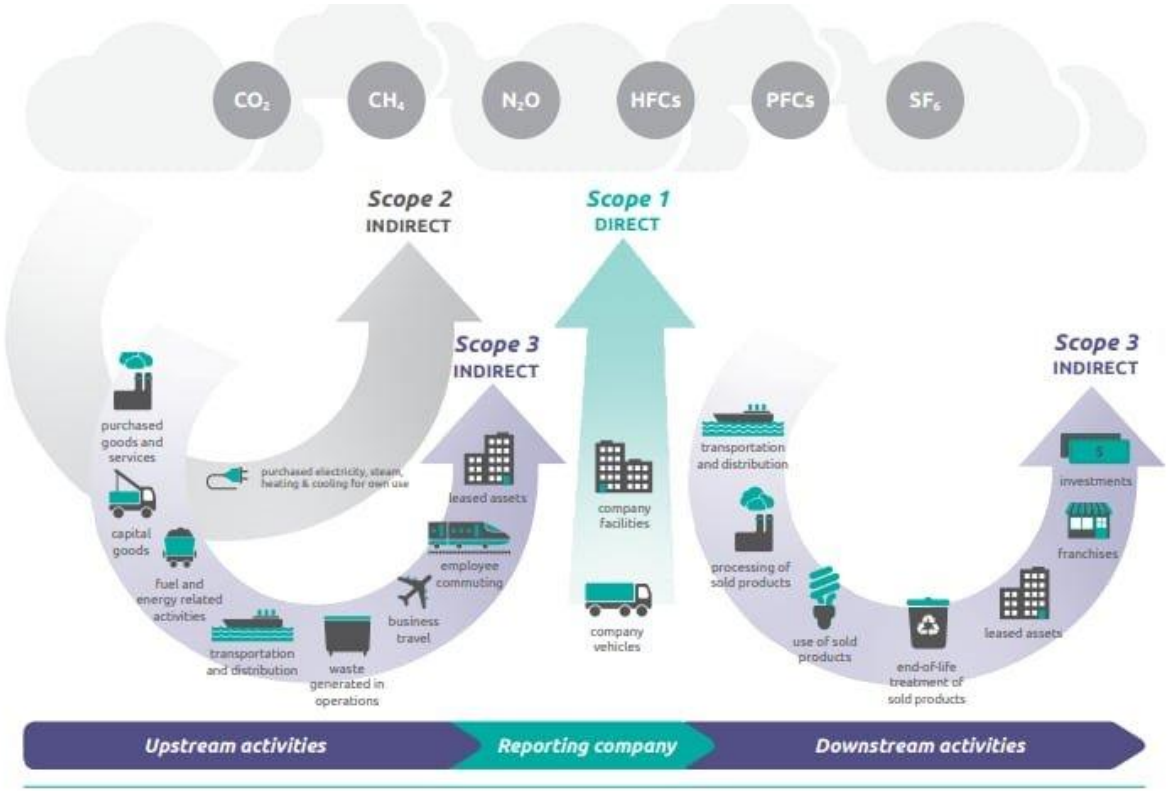
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Case Studies

Real examples of technologies implemented across Unilever facilities with lessons to replicate

Energy Transition Overview

Understanding Emissions Scopes (Scope 1, 2, and 3)



Scope 1: Direct emissions from sources owned or controlled by the organisation

- ***Stationary combustion: fuel burned onsite for heat/steam***
- Mobile combustion: fuel used in company-owned vehicles/equipment
- Process emissions: chemical/physical reactions inherent to manufacturing processes

Scope 2: ***Emissions from production of purchased electricity, heat, & steam***

Scope 3: Emissions from upstream and downstream value chain activities

Process emissions are industry- and company-specific, so this playbook doesn't address them directly. **The focus here is thermal and electrical energy transition - the lever that generally applies more consistently across industries.**

Source: GHG Protocol

Understanding Energy Types (Thermal and Electrical)

Thermal Energy

Fuel used to generate heat for manufacturing processes
E.g.: Boilers, furnaces, ovens, and hot air generators.

Majority Scope 1 Emissions: Generated on-site from fuel combustion

Electrical Energy

Electricity powers manufacturing processes, packaging lines
E.g.: Motors, compressors, and controls.

Majority Scope 2 Emissions: Purchased from the grid

Why is Energy Transition Important?



Commercial value upside: Can drive savings in energy costs and reduce exposure to fuel and power price volatilities



Sustainability expectations: Supports credible progress against net-zero or renewable energy commitments



Direct operational control: Direct impact from equipment and fuel changes which can enable decarbonisation without dependence on upstream supply chain readiness



Highest impact per facility: Heat and power systems typically deliver the biggest abatement potential per facility

Source: GHG Protocol

Key Considerations for End-to-End Energy Transition

Effective thermal decarbonisation often requires a **system-wide approach -** linking demand reduction, scalable solutions, and data enablement to deliver sustained end-to-end emissions reduction.



Ensure holistic view of emissions landscape

Take a holistic view across processes, utilities, and sites to ensure all major sources are systematically captured and addressed.



Enable with data, governance, and capability building

Establish robust data, performance tracking, and clear ownership to support decision-making and sustain progress at scale.



Embed energy efficiency as the foundation

Reduce energy demand at source through process optimization, improving the cost and effectiveness of downstream decarbonisation.



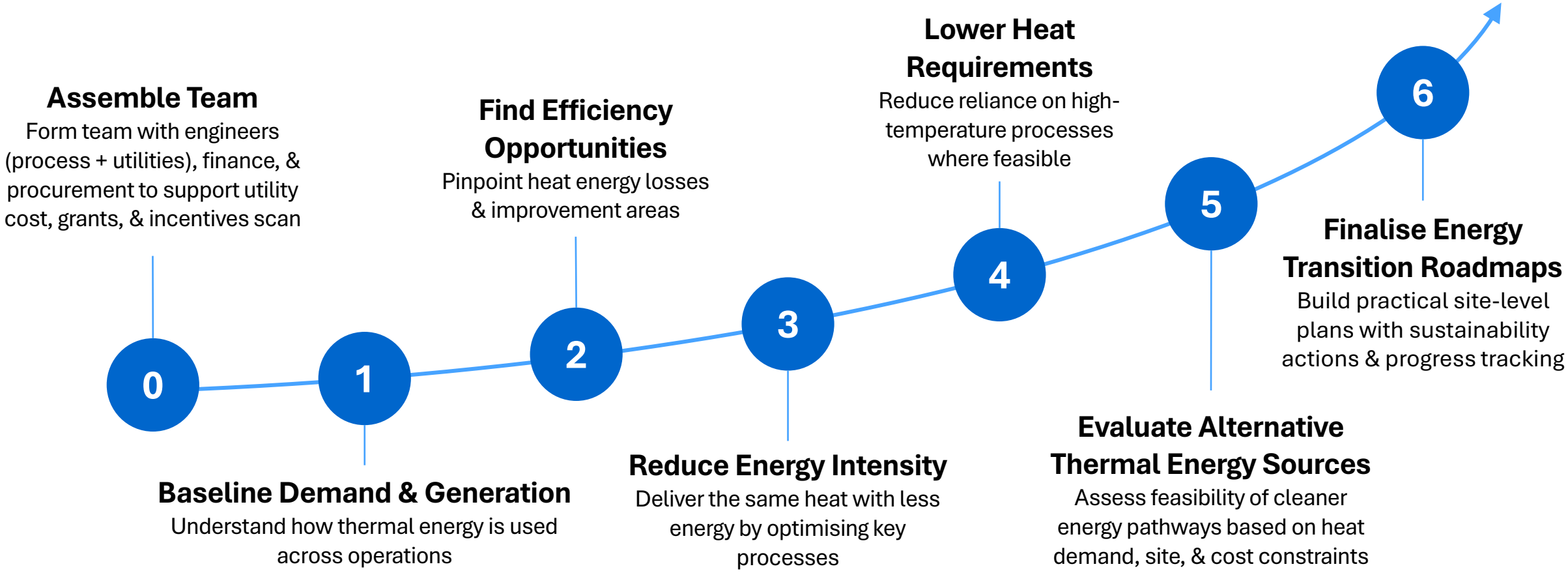
Select and standardise scalable solutions

Deploy solutions that can be replicated across sites and regions, enabling consistent progress over time.

Together, these typically enable systematic Scope 1 & 2 decarbonisation at scale.

Thermal Energy Transition: Decarbonisation Approach

Framework for Thermal Heat Decarbonisation



Unilever has found that this approach leads to practical and phased decarbonisation actions aligned with site-level realities.

Step 1 & 2: Baseline Thermal Demand & Generation Profile

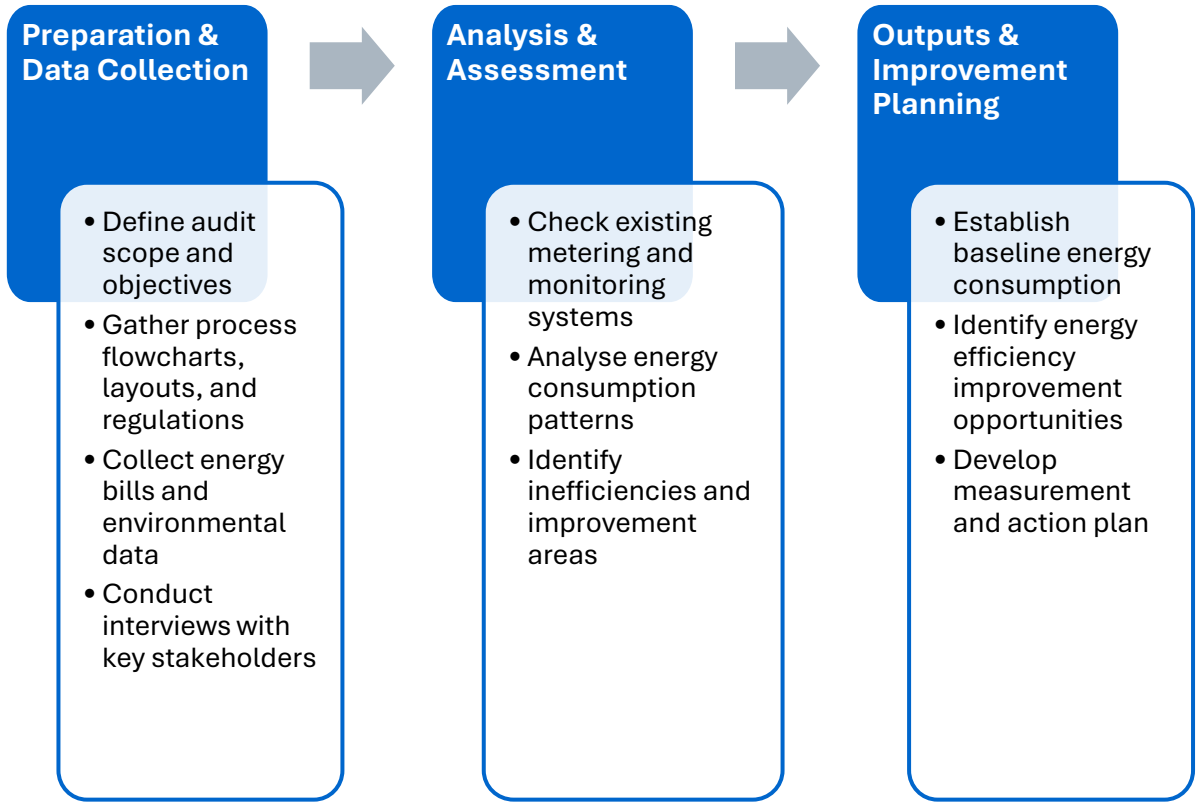
Baseline Thermal Demand

Understand how thermal energy is consumed across site operations, which processes use heat, at what temperatures, and how demand varies over time.

Baseline Generation Profiles

Capture current heat generation assets, including fuel types and operating capacity, to establish yearly and peak demand per energy stream.

Standard Auditing Process to establish baselines and find opportunities for thermal energy efficiency



Step 1 & 2: Thermal Heat Mapping

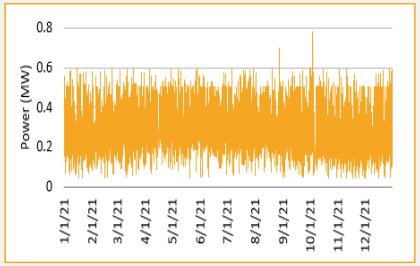
A. Data Collection

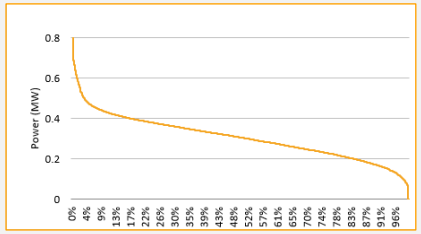
Collect generation and demand temperature profile data of all processes using thermal energy.

Example Processes:
- Tank Heating
- Cleaning in Place (CIP)
- Pasteurisation
- Building Heating
- Product Processes

Data can be checked via:
- Factory Energy Consumption Data
- Metering, Monitoring, & Targeting Software
- Internal Benchmarks
- Energy Assessments

Air Compressor load profile





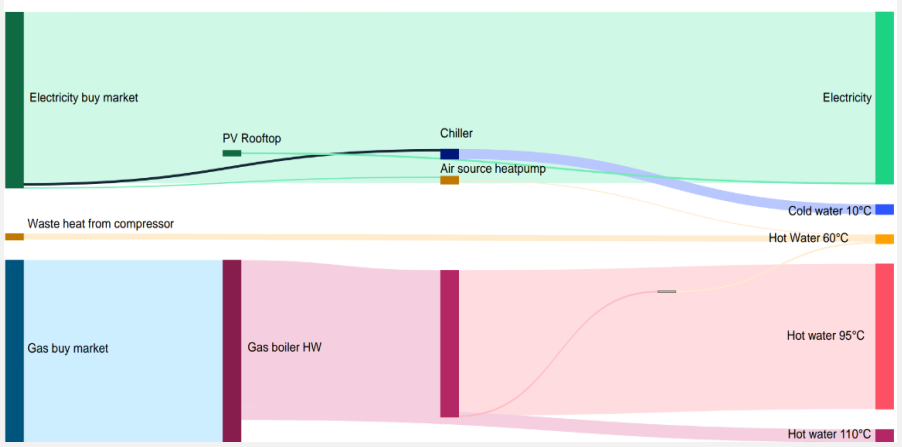
Yearly Demand (GWh/yr)	2.70
Peak Demand (MW)	0.75

Sample view of hourly load profile data

B. In Depth Analysis of Data

In depth data analysis (e.g. heat and mass balance) is undertaken to identify opportunities for energy efficiency and decarbonisation.

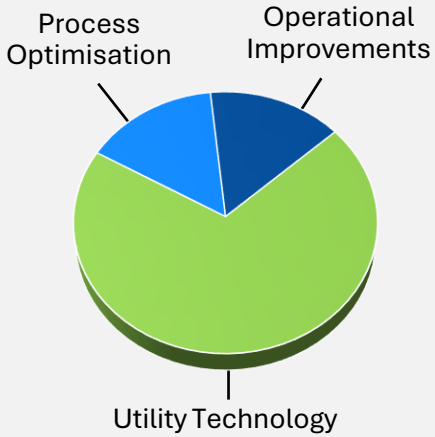
Sankey diagrams visualise energy flows across processes. They can highlight major loss points and enable prioritisation of high-impact efficiency and decarbonisation opportunities.



Sample Sankey diagram for energy flows

Thermal mapping is key to understanding where opportunities for efficiency and decarbonisation lie and their impact potential.

Sample View of Potential Efficiency Impact



Step 3 & 4: Lower Energy Intensity and Heat Requirements

Objective: Minimise steam and thermal energy per unit of production.

Reducing thermal demand through setpoint optimisation, process redesign, and heat recovery typically lowers fuel consumption and enables more cost-effective decarbonisation pathways.

Examples of energy efficiency processes. *The below list is not exhaustive.*

Optimise Utility Setpoints[1]

- Lower steam header pressure
- Optimise boiler blowdown
- Adjust temperature setpoints to process minimums
- Minimise excess air in combustion systems

Improve Process Heat Efficiency

- Redesign processes to reduce heat load
- Improve insulation on piping and vessels

Recover and Reuse Heat

- Waste heat recovery from exhausts and compressors
- Condensate return and flash steam recovery
- Improve heat integration across key processes

[1]*Optimisation of Utility setpoints must be executed in a controlled environment, phased and monitored manner. Facilities must ensure they have adequate risk assessment protocols in place before altering baseline operations*

Source: RTC Playbook for decarbonising Process Heat in Food and Beverage Sector

Step 5: Evaluate Alternative Thermal Energy Sources

*1. **Identify and evaluate cleaner fuel options** that can meet site heat requirements based on following parameters:*

Regulation

Flag any policy, legal, or compliance barriers that could block or delay adoption

Commodity Availability

Highlight supply chain or fuel availability constraints that may limit feasibility of technology adoption

Physical fit

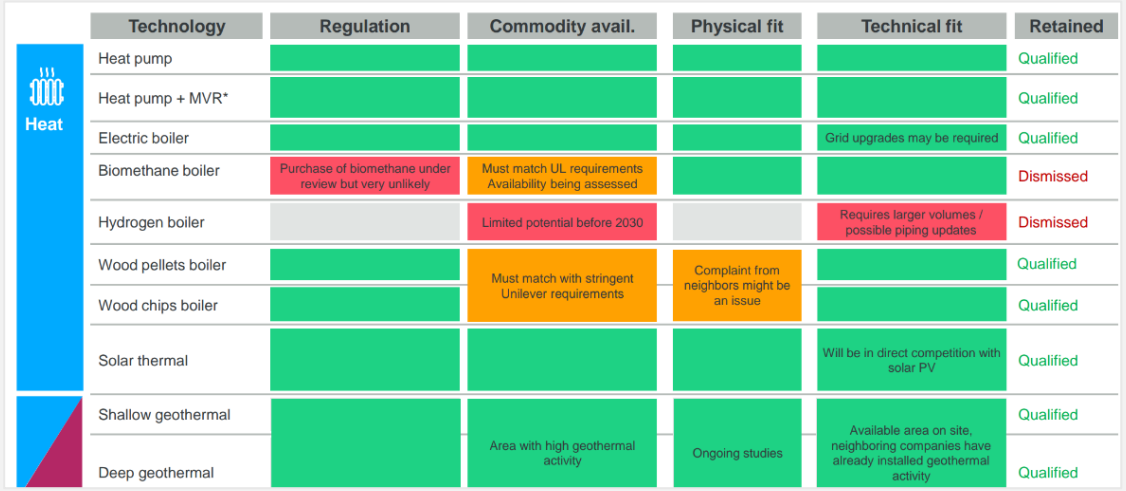
Note any physical constraints that differ site-to-site (e.g., spatial limitations, neighbour complaints)

Technical fit

Evaluate whether the technology is compatible with existing technical and operational setup

*2. **Create a technology evaluation matrix** to assess technology options across key parameters (regulation, commodity availability, physical fit, and technical fit) and identify qualified technologies.*

*3. **Secure leadership approval** to move from strategy to execution. Advance qualified technologies into detailed feasibility studies and proposal development.*



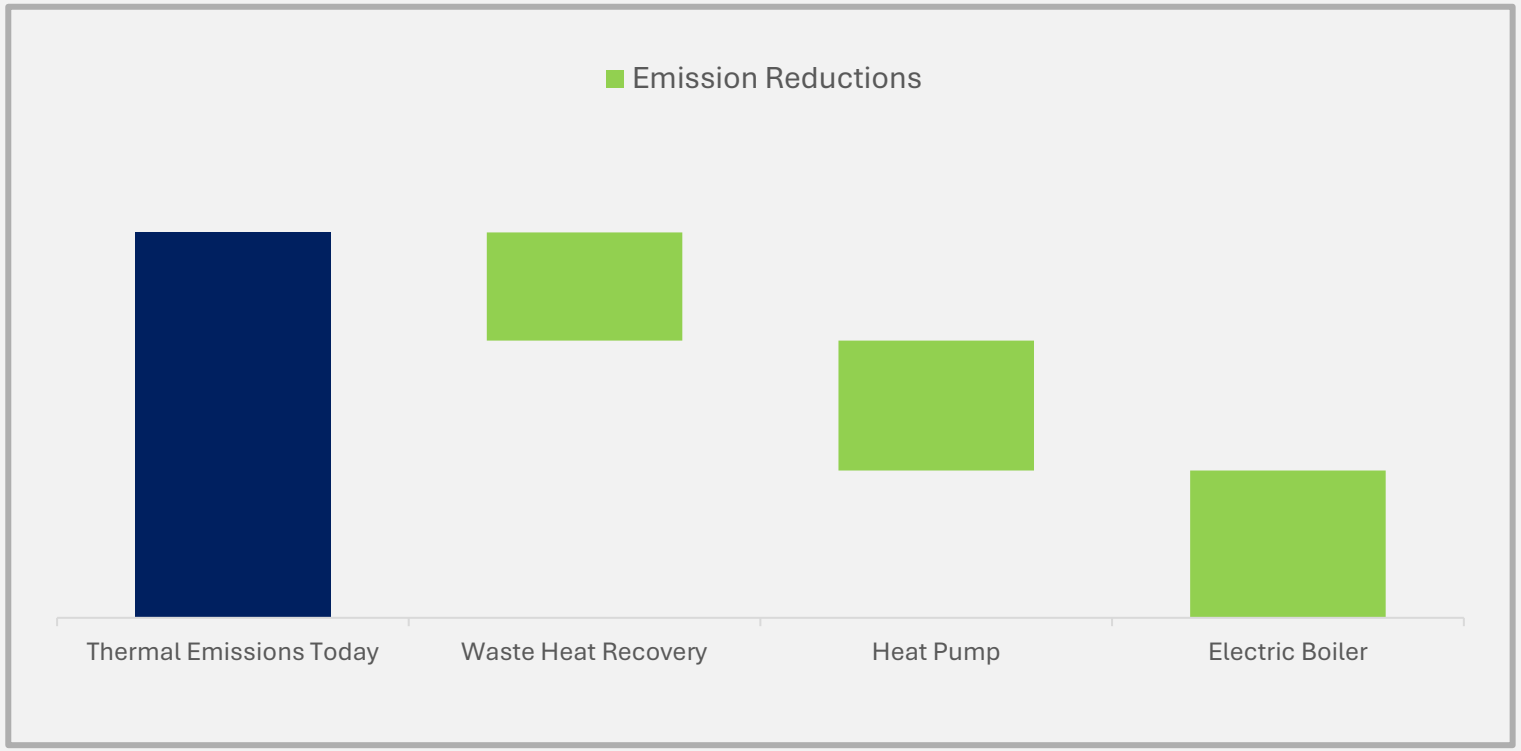
	Technology	Regulation	Commodity avail.	Physical fit	Technical fit	Retained
Heat	Heat pump					Qualified
	Heat pump + MVR*					Qualified
	Electric boiler				Grid upgrades may be required	Qualified
	Biomethane boiler	Purchase of biomethane under review but very unlikely	Must match UL requirements Availability being assessed			Dismissed
	Hydrogen boiler		Limited potential before 2030		Requires larger volumes / possible piping updates	Dismissed
	Wood pellets boiler		Must match with stringent Unilever requirements	Complaint from neighbors might be an issue		Qualified
	Wood chips boiler					Qualified
	Solar thermal				Will be in direct competition with solar PV	Qualified
	Shallow geothermal		Area with high geothermal activity	Ongoing studies	Available area on site, neighboring companies have already installed geothermal activity	Qualified
	Deep geothermal					Qualified

Sample Technology Evaluation Matrix (only for illustrative purposes)

Step 6: Finalise Energy Transition Roadmaps

Create costed roadmaps with decarbonisation initiatives aligned with operational and investment timelines.

Sample decarbonisation roadmap with a combination of thermal heat solutions; only for illustrative purposes



- **Waste heat recovery** (WHR) system captures and repurposes excess heat generated from industrial processes and utilities.
- **Heat pumps** will provide hot water for process heating and space heating.
- **Electric boilers** will provide trim steam heating and support seasonal loads. A new boiler house is factored into the CAPEX.

There is no 'one size fits all' approach to thermal decarbonisation; combining different technologies is often key

Thermal Energy Decarbonisation Technology Pathways

Scope 1 & 2 Decarbonisation Technology Overview

TRANSITIONAL TECHNOLOGIES

Biomass, Biomethane, Biodiesel

- **Can enable immediate emissions reductions** with drop-in or retrofit solutions
- **Often quick to adopt and scale**, as they build on existing assets
- A bridge solution alongside longer term electrification
- Return on Investment may be favourable where supply is abundant

Feedstock availability and cost may limit scalability in some markets

DEEP DECARBONISATION TECHNOLOGIES

Heat Pumps, Electric Boilers, Solar Thermal, Thermal Storage

- Can enable **near zero, long term emissions reduction** through electrification (no combustion)
- Transform energy generation and use, not just the fuel source
- May offer **efficiency and cost benefits** over time
- Leverage renewable electricity contracting

Often require capital investment and site-level redesign (utilities, heat integration)

EMERGING/FUTURE TECHNOLOGIES

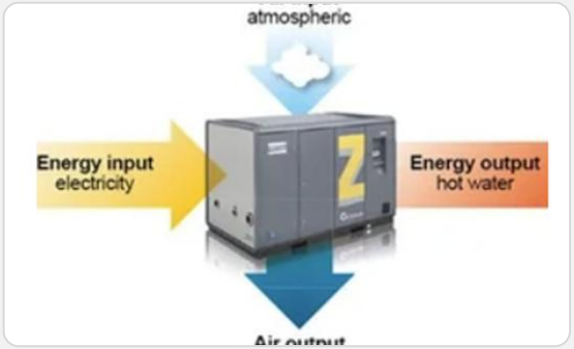
Hydrogen, Carbon Capture

- May address hard-to-abate processes where electrification or biofuels are not viable
- **Still maturing in cost, infrastructure, and supply**, limiting near-term deployment
- Often require **significant system changes and ecosystem buildout**

Potential for targeted pilots, limited feasibility for immediate implementation

Reflects Unilever's view; specific technology suitability should be assessed individually on a case-by-case basis

Thermal Energy Decarbonisation Technologies at a Glance



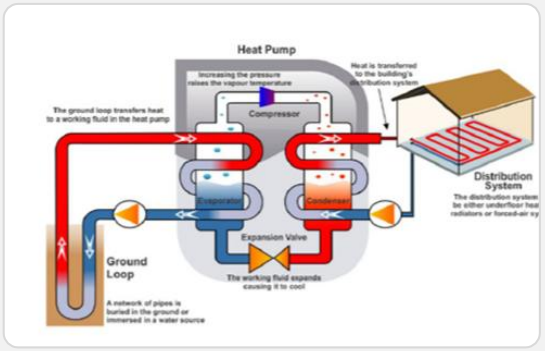
WASTE HEAT RECOVERY
Captures heat that would otherwise be wasted and reuses it for process heating



HEAT PUMPS
Systems that upgrade heat from lower to higher temperatures using electricity



SOLAR THERMAL
Converts sunlight into heat for water, space heating, or other processes.



GEOTHERMAL
Extracts natural heat from the earth via wells or ground loops for heating



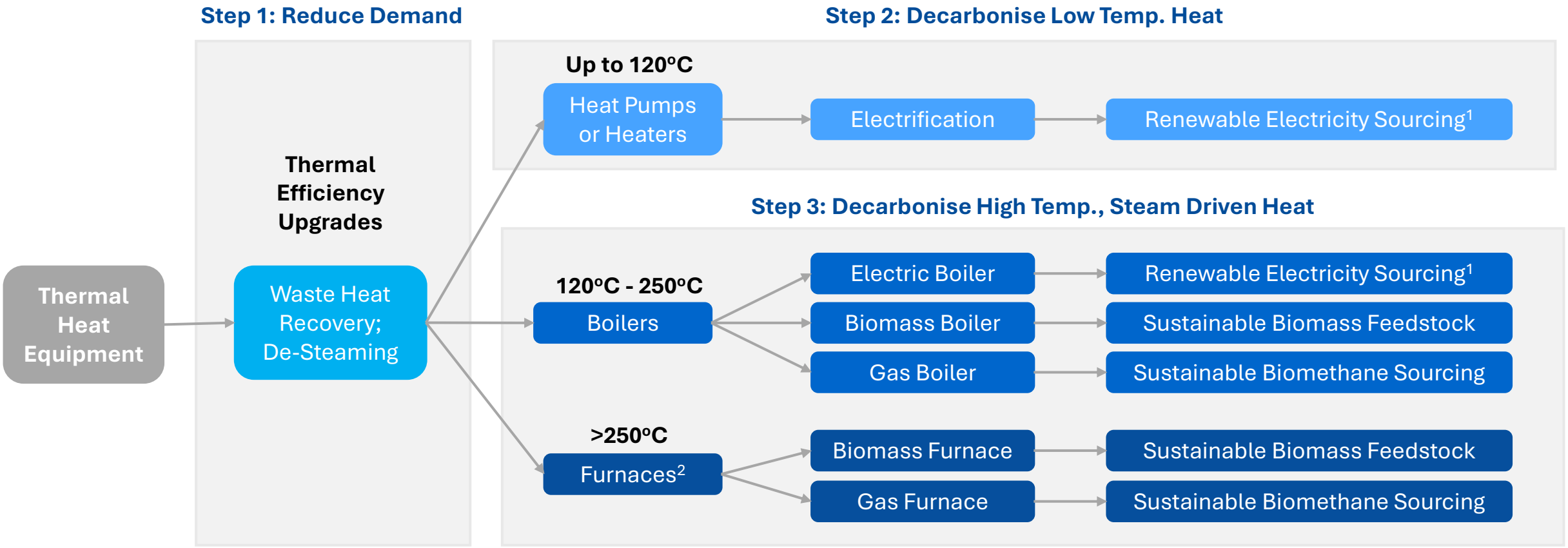
ELECTRIC BOILERS
Boilers that generate steam or hot water using electricity instead of fossil fuels



BIOGENIC FUEL BOILERS
Boilers that generate steam or hot water from renewable fuels like biomass or biomethane

The list of technologies provided are not exhaustive

Execution Pathway: Key Thermal Energy Technologies



In Unilever's experience, process temperature is key to thermal heat decarbonisation. This pathway **prioritises efficiency upgrades first before identifying clean decarbonisation options based on alternate fuels.**

This pathway is not exhaustive; partners are recommended to assess their own operations holistically to determine the best pathway for specific contexts and site-level realities

[1]More details on renewable energy procurement available in the Electrical Energy Transition Playbook

[2]Electric furnaces are an additional option for high temp. decarbonisation but often come at a high cost; so, this playbook focuses on biomass and gas furnaces

Execution Pathway: Thermal Efficiency Upgrades - Deep Dive

Reduce thermal energy demand while maintaining production output by improving how heat is generated, distributed, and utilised across operations.

Examples of thermal efficiency upgrades. *The below list is not exhaustive.*

Setpoint Optimisation

- Reduce steam usage pressure
- Optimize boiler blowdown setpoints
- Lower de-aerator pressure setpoints

Process Optimisation

- Replace steam-heavy steps with lower-energy options
- Use low-temp. formulations
- Use pressing instead of heat where possible
- Ship concentrates; dilute on-site

Waste Heat Recovery

- Capture boiler exhaust heat
- Maximize condensate recovery
- Recover compressor waste heat

Example: At a site using steam for pasteurisation and hot water for cleaning, improving insulation and optimising operating schedules reduce heat losses. Captured condensate heat can also be reused to preheat cleaning water - lowering overall heat demand without impacting production volume or product quality.

Source: RTC Playbook for decarbonising Process Heat in Food and Beverage Sector

Execution Pathway: Heat Pumps – Deep Dive

A heat pump is used to **supply heat** in the **low-temperature** range **(typically up to 120°C)** by upgrading heat from sources such as **air or water using electricity and** delivering it to a **space or process** where it is needed.



High Efficiency
High coefficient of performance

Zero Combustion Operation
Reduces or sometimes even eliminates on-site fossil fuel combustion and related hazards

Lower Operating Cost
Can reduce exposure to fuel price volatility

Broad Applicability
Process heating, space heating, cooling

Decision Pathway for Low-Temperature Heat Pump Adoption

These questions are developed to determine which steps are applicable to your plant / business, depending upon how developed the plans for heat pump deployment are.

Have you optimised process heat requirements for the plant?

- ✓ → **Heat pump application identified?**
- ⊘ → **1 Complete optimisation steps:**
  1. Setpoint reduction
  2. De-steaming
  3. Waste heat recovery

Heat pump application identified?

- ✓ → **3 Heat pump evaluation and selection / OEM[1] engagement**
- ⊘ → **2 Complete thermal energy mapping:**
  1. List heat sources
  2. List heat sinks
  3. Run pinch assessment
  4. Identify potential

Note: *Optimum sizing of heat pump and buffer storage is the most important factor for business decisions.*

[1] *Original Equipment Manufacturer*

Source: *RTC Playbook for decarbonising Process Heat in Food and Beverage Sector*

Refer this for additional information on technologies

Execution Pathway: Electric Boilers – Deep Dive

An electric boiler is a system that **generates steam or hot water using electricity** instead of burning fossil fuels.
It uses electrical energy to heat water through resistance elements or electrode systems.



High Efficiency
Up to 99% of electrical energy is typically converted to steam (compared to fossil fuel boilers ~80%)

Higher Up Time
Generally fewer moving parts and no combustion system, requiring less maintenance

No on-site combustion emissions
Removes direct Scope 1 emissions, avoiding flue gases, NOx and particulate matter

Simple installation
Often requires less space as fuel storage or flue stacks are not required

Key Considerations for Electrification of Thermal Energy

Electrification (e.g., heat pumps, electric boilers) shifts emissions from fuel to electricity – typically delivering decarbonisation only when paired with low-carbon power and system readiness



Electrification shifts emissions, not eliminates them

Heat pumps and electric boilers move thermal emissions to electricity; **overall impact depends on grid carbon intensity and power sourcing**



Electrical infrastructure becomes a critical constraint

Electrification can significantly **increase load and peak demand**, requiring upgrades to site infrastructure, grid connection, and capacity planning



Secure low-carbon power to unlock full benefit

Decarbonisation depends on **access to renewable electricity** (on-site generation, PPAs, EACs[1]), not just switching equipment



Integrate with site-level system design

Electrification is usually most effective when combined with **heat integration, storage, and demand optimisation**

For detailed guidance on electrical decarbonisation pathways, refer to this playbook which explores more on efficiency upgrades, On-site solar PVs and Renewable Energy Contracts

Electrical Energy Transition Playbook

[1]*PPA – Power purchase agreement; EAC – Energy Attribute Certificate*

Technology Deep-dive: Biomass Boilers

A **biomass boiler** is a **renewable-fuel boiler** that burns materials like **wood chips or pellets** to generate steam or **hot water** for **industrial heating**, typically supporting **process temperatures** around **120-250°C**



Low-carbon heat solution
Provides a renewable alternative to coal or gas for process heat demands above 100 °C

Cost-effective transition
Capex is often comparable to coal boilers and converting existing assets is typically lower cost than new-build

Fuel cost advantage
Upfront costs may exceed gas boilers but, in some markets, biomass can deliver lower fuel costs than biomethane; partners should assess local pricing conditions

Energy security
Supports fuel resilience through stable, locally sourced biomass supply

Overview of Biogenic Boiler Options

Technology Deep-dive: Biomethane Boilers

A biomethane boiler is a standard natural-gas boiler fuelled by biomethane (renewable natural gas), an upgraded form of biogas that meets pipeline-quality specifications.



Low-carbon heat solution
Enables Scope 1 decarbonisation by replacing fossil natural gas with renewable, natural gas.

Drop-in Compatibility
Uses existing natural gas boiler assets with limited modifications, reducing retrofit complexity.

Faster Deployment
Implementation is primarily a fuel switch, so projects can often move quickly once supply is secured.

Operational reliability
Maintains existing boiler operation and control leading to lower disruptions in production

Overview of Biogenic Boiler Options

Approach to Biogenic Boiler Deployment

Assessment & Feasibility

1 Energy Assessment

- True demand
- Load profile
- Efficiency potential
- Temperature needs

2 Options Study

- Technology comparison
- Capex/Opex estimation
- Technical fit
- Site constraints

3 Fuel Review

- Supplier engagement
- Fuel type & volume
- Cost outlook
- Supply reliability

Evaluation & Selection

4 Equipment Scan

- Vendor options
- Performance range
- Cost comparison
- Lead times

5 Source Evaluation

- Storage needs
- Resilience factors
- Price sensitivity
- Pathway comparison

6 Strategy Selection

- Hybrid options
- Techno-economics
- Operational fit
- Final selection

Technology Deep-dive: Biomass Furnace

A biomass furnace is a renewable heat system that **combusts organic materials** such as wood chips or solid agri-waste **to generate hot air** for industrial processes; it typically supports process temperatures around 250-400°C.



Direct high-temperature heat generation
Delivers controlled hot air/thermal energy for furnace-based operations

Fuel-flexible combustion system
Designed to handle diverse solid biomass fuels with stable combustion performance

Operational stability for continuous processes
Provides steady heat output with automated fuel feeding and combustion control

Technology Deep-dive: Gas Furnace

A gas furnace is a combustion-based heating system that can use renewable biomethane **to generate controlled hot air or thermal energy** for industrial processes



Precise temperature control
Enables accurate and responsive heat modulation, making it suitable for temperature consistency.

Clean and efficient combustion
Delivers uniform heat with minimal ash or residue, reducing maintenance

Compact and space-efficient design
Requires lower footprint compared to solid-fuel systems

High operational reliability
Provides stable and continuous heat output with automated control systems

Bio-energy Procurement: Generation and Fuel Contracts

Self-Generation

Biogas and Biomethane from Anaerobic Digestion



Produces biogas from organic waste

Onsite

Contracted Fuel Supply

Bio-diesel



Biodegradable fuel from biological sources

Fuel Supply Agreements

Biomethane



Blend-in substitute for natural gas

Distributed via Gas network or Direct Delivery

Biomass



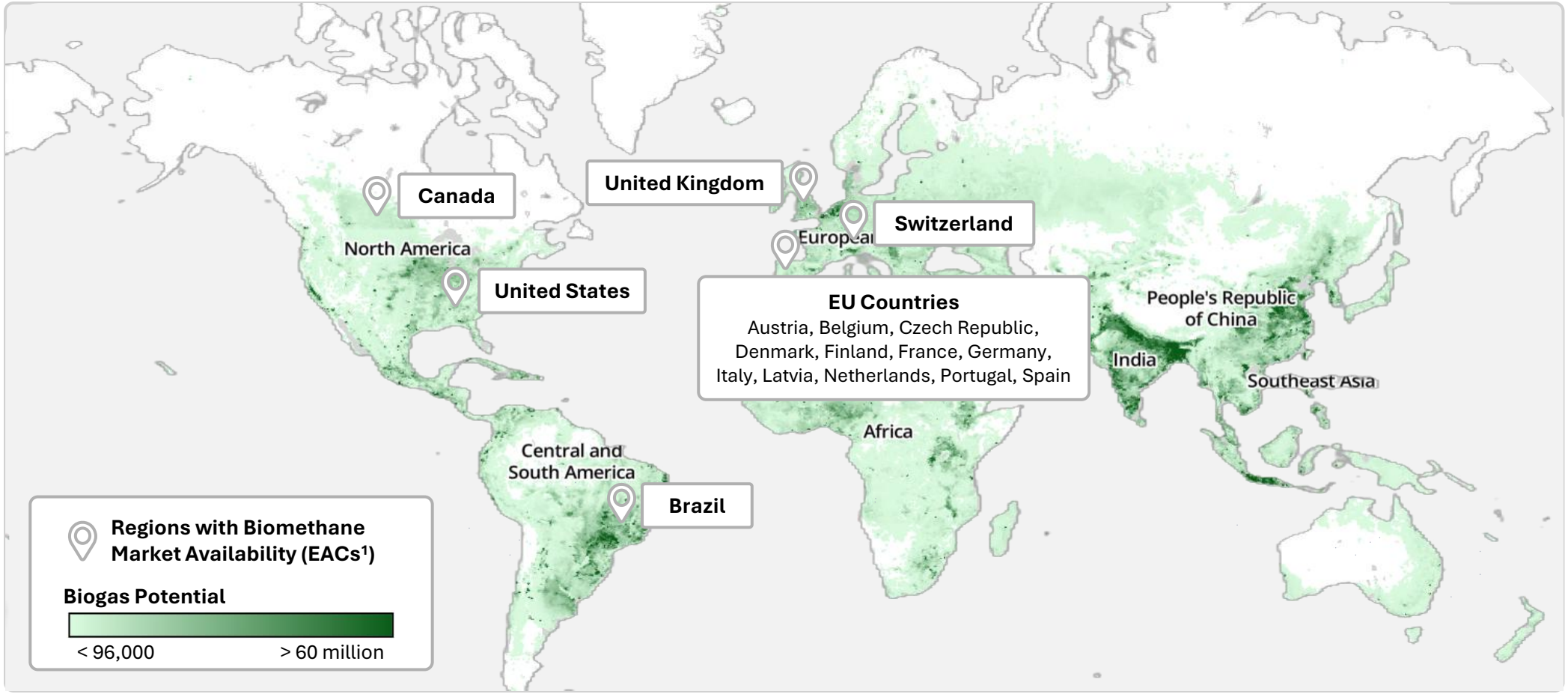
Uses solid agri-waste as boiler fuel

Fuel Supply Agreements

	Bio-diesel	Biomethane	Biomass
Best Suited When	Bio-diesel supply exists	Biomethane supply exists	Local Feedstock
Direct Infrastructure Change?	Low	Low	High
Current Technology Maturity	High	High	High
Supply Availability	Country-specific	Country-specific	Country-specific
Decarbonisation Impact	High	High	High
Backup boiler required?	No	No	Yes

Refer this for additional information on technologies

Bio-energy Procurement: Biogas & Biomethane Potential



Unilever has found market availability of biomethane EACs to be highest in North America, Western Europe, and Brazil

[1]*Energy attribute certificates*

Source: IEA Interactive map of global biogas and biomethane potential

Execution Guidance

Considerations for deployment in your organisation

Execution Guidance: Thermal Heat Decarbonisation

Ownership Structure
RACI definition; steering team formation (Ops., Eng., Finance); review cadence and stage-gate checkpoints

Executive Sponsorship
Executive sponsor identified; strategic alignment confirmed; success criteria defined

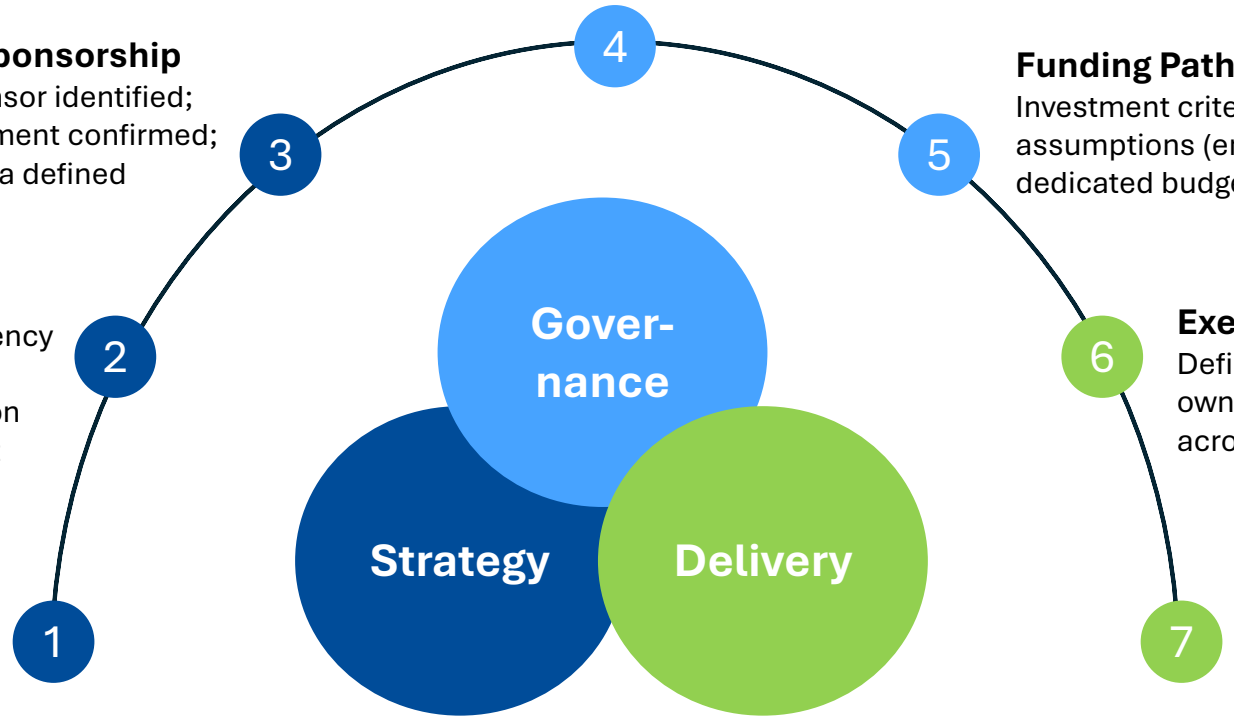
Funding Pathway
Investment criteria; Standardised assumptions (energy prices, downtime); dedicated budget/Capex pathway

Business Case Development
Estimation of potential savings, efficiency gains, emissions reduction, and investment needed; initial prioritisation of initiatives by feasibility, risk, impact

Execution
Defined milestones; site-level ownership; structured rollout across facilities/business units.

Baselining & Opportunity Research
Energy, emissions, and cost baseline; hotspot identification; secondary research on peer practices, tech. maturity, regional energy landscape, and national strategy

Performance Measurement
Actual vs. forecast energy, cost, and CO_2 impact; quarterly reports; reinvestment of savings



Research → Business Case → Governance → Execution → Verification

Partner decarbonisation can be supported by streamlined governance - clear ownership, predictable funding, structured execution, and verified impact.

Execution Guidance: Deep Dive

Strategy

Energy Baseline | *Business Case* | *Executive Sponsorship*

Key Activities
- Baseline energy & identify hotspots
- Screen technical levers
- Develop approx. savings & Capex range
- Prioritise 2–3 scalable initiatives

Key Stakeholders
- **Engineering** → Baseline data & feasibility
- **Sustainability** → Target alignment, benchmarking, sourcing guardrails
- **Commercial Leads** → Strategic positioning
- **Finance** → Assumption validation

Governance

Ownership Structure | *Capital Pathway*

Key Activities
- Build detailed ROI model
- Validate technical & operational feasibility
- Define accountable project owner
- Align funding structure

Key Stakeholders
- **Executive Sponsor** (COO / CFO / Business Head)
- **Finance** → NPV, IRR, sensitivity validation
- **Operations Leadership** → Deployment readiness
- **Procurement** → Vendor & contracting strategy

Delivery

Execution Plan | *Performance & Results Tracking*

Key Activities
- Execute defined milestones
- Monitor actual vs. forecast savings
- Conduct variance analysis
- Capture lessons & scale plan

Key Stakeholders
- **Project Management** → Delivery accountability
- **Engineering** → Technical execution
- **Finance** → Savings verification
- **Sustainability** → Impact tracking

Gate 1 – Concept Approval

Gate Criteria
- Clear problem statement (cost/intensity gap)
- Ranked short list of initiatives
- Rough savings & Capex range
- Strategic relevance (cost, resilience, ESG)

Gate 2 – Investment Approval

Gate Criteria
- Validated ROI model (incl. sensitivity)
- Defined funding structure
- Risk & implementation plan
- Accountable owner assigned

Gate 3 – Performance Validation

Gate Criteria
- Verified savings vs. forecast
- Variance explanation
- Implementation learnings
- Scale-up recommendation

Detailed business case development authorized → Capital approved & governance structure formalized → Replication across sites approved

Join the Renewable Thermal Collaborative

RENEWABLE® THERMAL COLLABORATIVE

The RTC is a U.S.-headquartered, global nonprofit with 130+ members dedicated to decarbonising industrial thermal energy use with renewable solutions

THE RTC'S KEY GOALS

Create a community of 100+ members committed to its goals by 2030

Accelerate the adoption of renewable thermal solutions globally

30% industrial thermal emission cuts by 2030; full decarbonisation by 2050

RTC Members and Solutions Providers work together to

- Address market barriers for renewable thermal technologies & improve the marketplace and financing for heat solutions
- Engage in peer-to-peer learning and case study development

The RTC can help companies with renewable thermal deployment through:

- Educational workstreams covering topics like electrification, geothermal, industrial heat pumps, renewable natural gas/biomethane, market-based accounting, solar thermal, thermal energy storage, policy, and more
- Monthly community calls between members and solutions providers facilitating peer learning

Partners may wish to consider joining the Renewable Thermal Collaborative; it can help support thermal decarbonisation efforts[1]

[1]**Membership fees are required;** *Source:* RTC

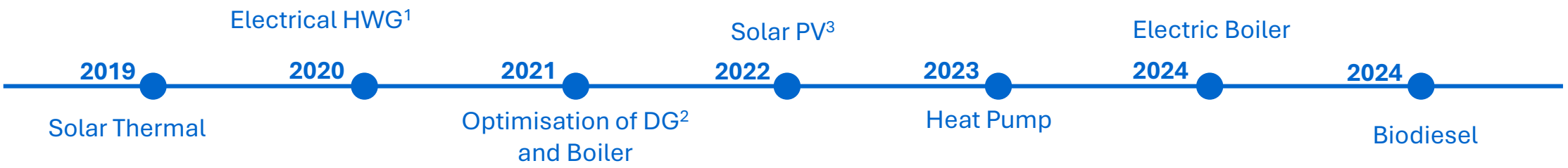
Unilever

Case Studies

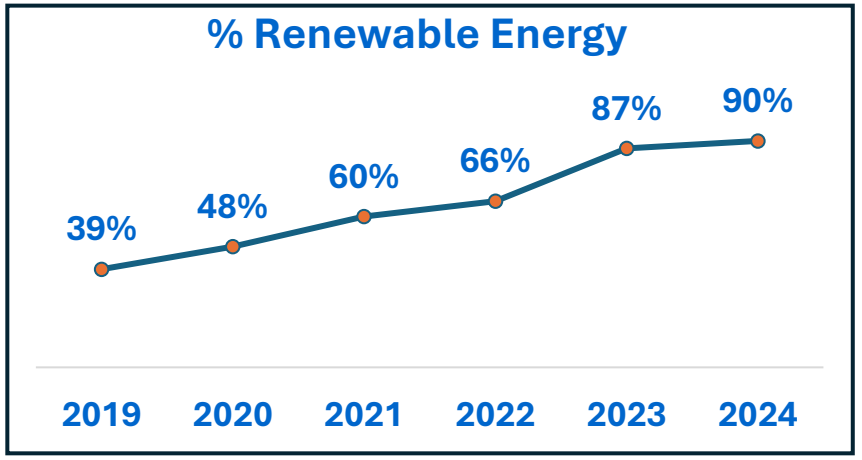
Decarbonisation of Unilever's Factory in South Asia

Combining on-site solar, waste heat recovery, thermal electrification, and biodiesel to implement 90%+ renewable energy across manufacturing processes resulted in **98% emission reduction** and **~40% reduction in steam costs**

Decarbonisation Projects Deployed Over the Years (2019 – 2024)









(1) HWG = Hot Water Generator, (2) DG = Diesel Generator, (3) PV = Photovoltaic

Decarbonisation of Unilever's Factory in the Philippines

Leveraging solar power, geothermal energy, and electrification of key equipment to achieve a more sustainable manufacturing facility with 100% renewable energy

2023

- Solar powered lighting

2024

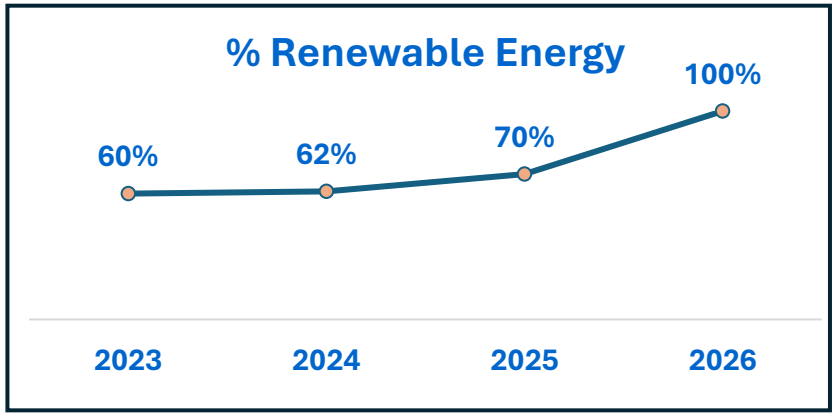
- 100% renewable electricity from geothermal
- Shift from diesel to electric forklifts
- Solar powered RMPM[1] warehouse and forklift battery charger
- Circular economy for water: reuse of water from RO[2] plant for ETP[3] water use

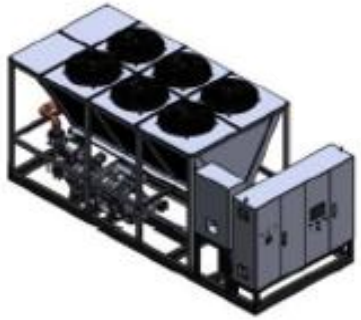
2025

- Convert diesel fired boilers to electric steam boilers
- Heat pumps for hot process water











(1) RMPM = Raw and Packaging Materials, (2) RO = Reverse Osmosis, (3) ETP = Effluent Treatment Plant

Additional Information

Technology Deep-dive: Heat Pumps Key Considerations

This is a non-exhaustive technical checklist to assess feasibility, cost, and integration risks for heat pump deployment

Heat demand & temperature: Required load and temperature range

Heat source availability: Source temperature, stability, proximity

System integration: Compatibility with existing systems

Electricity cost & supply: Tariffs and power sourcing

Thermal storage: Load balancing, peak shifting, demand variability

Space requirements: Footprint, access, installation constraints

Design parameters: Flow rates, sizing, water quality, temperature consistency.

Heat Pump Decision Tree

Technology Deep-dive: Applicability of Heat pumps

Low-temperature waste heat can be upgraded and reused across multiple on-site heating applications

Waste Heat Sources

- **Process cooling water**
- **Refrigeration condensers**
- **Air compressor cooling**
- **Chilled water return**
- **Wastewater treatment**
- **Other low-grade heat (<40 °C)**

Typical Heat Pump Applications

Process Water Heating	Water heating for **production**, **formulation**, & **auxiliary processes**
Cleaning & Washing Systems	**CIP**[1], **equipment washing**, & **hygiene hot water** needs
Preheating Applications	**Reactor feed**, **pasteurisation**, & boiler **feedwater preheating**
Space Heating	**Low-temperature heating** for **manufacturing** & **support spaces**

[1]Cleaning in Place

Heat Pump Decision Tree

Technology Deep-dive: Electric Boilers Key Consideration & Success Factors

Key Technical Considerations

Electrical Capacity Availability: Electric boilers significantly increase site power demand

Operating cost comparison: Long term electricity costs vs. current fuel costs

System integration: Compatibility with existing systems

Success Factors

Access to renewable electricity: 100% abatement potential when powered by renewable electricity

Supportive National grid transition: Countries with strong policy support for renewable electricity improves viability of electrification

Technology Deep-dive: Approach to Electric Boiler Deployment

A. Pre installation Requirements

Access Requirements

- Heating capacity
- Operating profile
- Setpoint requirement
- Role definition
- Hot-water case

Selection of equipment

- Boiler capacity sizing
- Electrical input check
- Pressure/temperature rating
- Turndown requirement
- Controls requirement

Adapt existing infrastructure

- Transformer and Voltage readiness
- Switchgear upgrade trigger
- Peak demand charges
- Feedwater systems

B. Install and commission the boilers

After installation, boilers are typically commissioned through start-up, functional testing, and performance verification against design specifications. Operating schedules should then align heat demand with renewable electricity availability and pricing.

Technology Deep-dive: Biogenic Boilers Key Considerations & Success Factors

Key Technical Considerations

- **Fuel availability and quality:** Confirm reliable supply and consistent specifications
- **Site readiness and compliance:** Assess space and infrastructure needs plus permitting
- **Cost and carbon integrity:** Validate total cost (Fuel + Logistics + Operations & Maintenance)

Success Factors

- **Right-fit design and controls:** Size to the optimized load, build in redundancy where needed
- **Robust fuel contracting and quality assurance:** Secure long-term supply agreements
- **Strong operations and maintenance discipline:** Operator training, and performance tracking

Overview of Biogenic Boiler Options

Tools Available for Energy and Technology Assessments

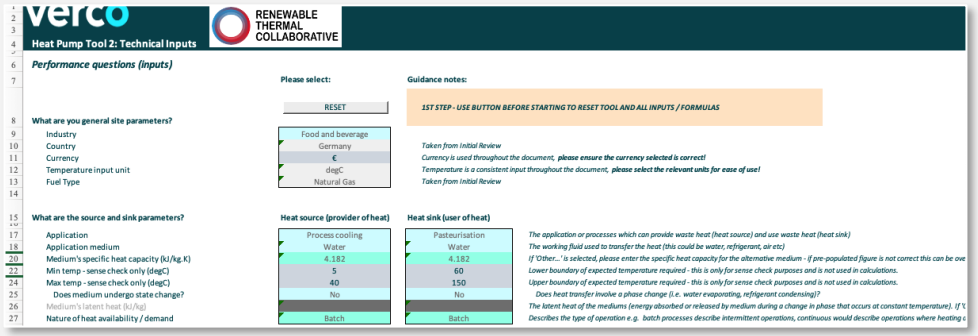
GOOGLE, ENERGY ASSESSMENT TOOL

Online self-service platform to help manufacturing facilities identify energy saving opportunities and conduct preliminary energy assessments



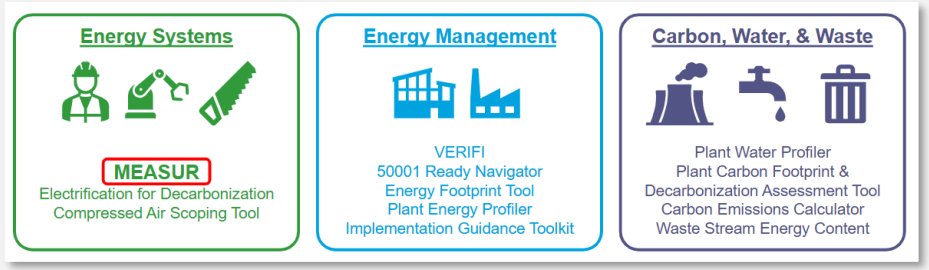
RTC[1], HEAT PUMP DECISION TOOL

Excel tool to help assess applicable heat pump technologies, evaluate technical and commercial viability, and identify heat pump suppliers



[1]Renewable Thermal Collaborative

UNITED STATES DEPT. OF ENERGY TOOLS



ENERGY FOOTPRINT TOOL (GUIDE, TOOL)

Excel tool to help plant managers establish a baseline of energy consumption and track annual progress of intensity improvements, energy savings, etc.

MEASUR

Online software tool to help model manufacturing energy use and generation, quantify savings opportunities, and create visualisations for project pitches

TECHTEST

Excel tool that integrates Life Cycle Assessment (LCA) and techno-economic analysis methods to estimate potential energy and cost impacts of new technology

Renewable Thermal Collaborative Heat Pump Tool – Additional Images

