Electrification of Industrial Heat Guide

A Best Practice Approach to Electrifying your Thermal Energy Demands

27th February 2025

Report prepared for SEAI by:
Action Zero

Sustainable Energy Authority of Ireland
SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with the public, businesses, communities and the Government to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

SEAI is funded by the Government of Ireland through the Department of the Environment, Climate and Communications.

Executive Summary

This electrification of heat guide is primarily intended for industrial site leadership teams and facilities managers who are currently researching and planning their transition to alternative renewable sources of thermal energy, via electrification. The aim is:

- To provide a guide to support industry stakeholders in understanding the fundamentals of electrification of industrial heat and why it plays an important role in the National Climate Action Plan.
- To direct the reader to a best practice approach in terms of carrying out a Site Assessment at their industrial site including a thorough understanding of heat sinks, sources, regulatory considerations, design options and implementation options.
- To ensure that systems are optimally sized using a best practice approach, with thorough analysis of thermal sinks/sources, as the basis for capacity requirement for electrified heat on industrial sites. The need to avoid over-sizing of electrified thermal capacity is critical given increasing constraints on electricity grid capacity, and the cost associated with providing electrified thermal capacity.

> *"The need to avoid over-sizing of electrified thermal capacity is critical. Thorough analysis of thermal sinks/sources at the initial stages of the electrification process will ensure that systems are optimally sized."*

- To educate and build capacity among industry stakeholders to empower them to distinguish between different vendor solutions and critically analyse different heating system designs.

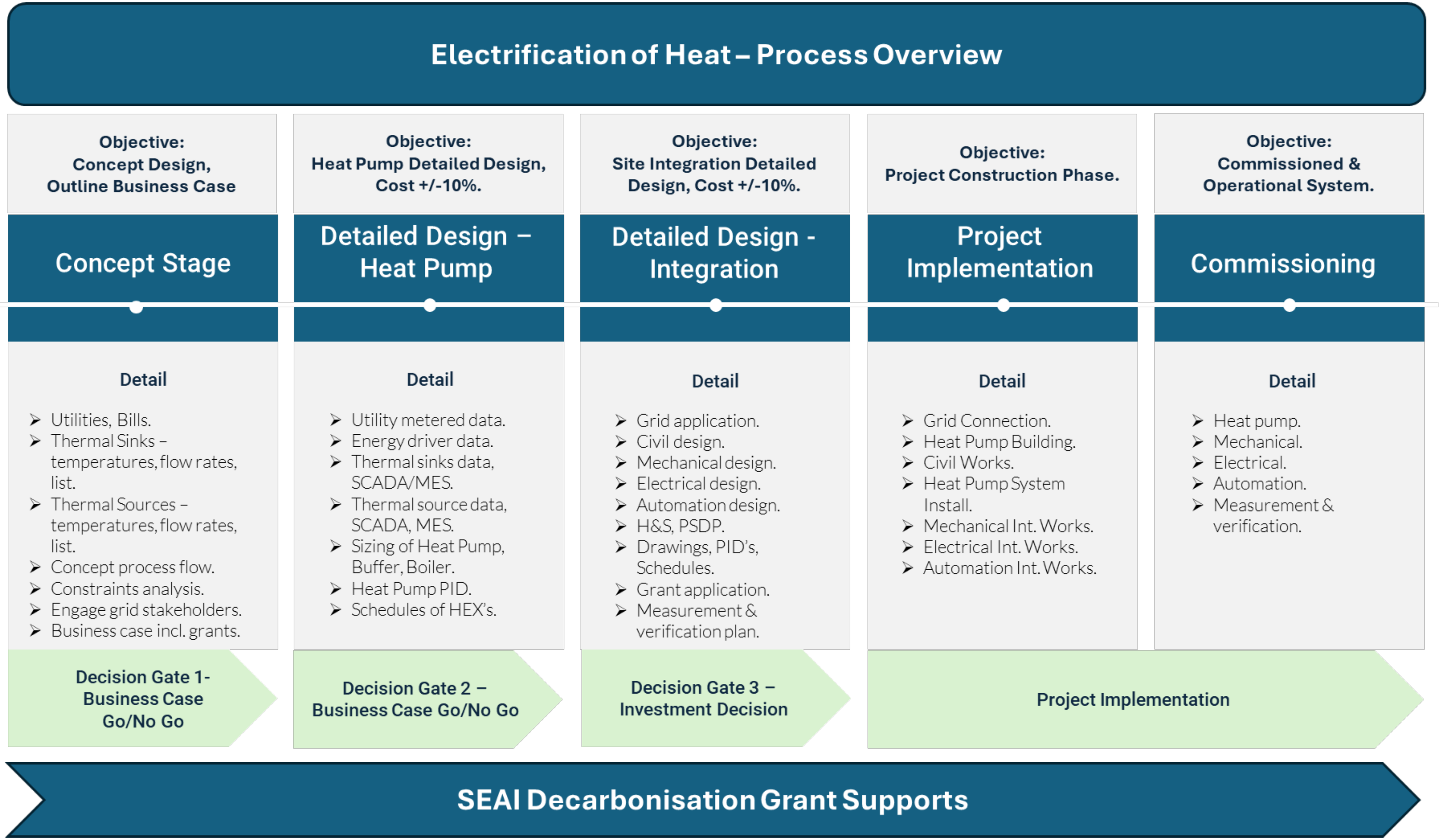
Electrification has been referenced in the "Roadmap for the Decarbonisation of Industrial Heat" (DETE, 2024), as the most viable alternative to fossil fuels in industrial applications where thermal end users demand temperatures <150°C.

Within this context, this guide sets out a best practice approach in how industrial sites can assess the most appropriate design and implementation options for electrification of heat, primarily via heat pump technology, and where technical or thermal process requirements dictate, electrification via electric boilers in conjunction with heat pumps. A phased process is outlined (from concept to commissioning), the foundational pillars of which include:

- Identifying, gathering and assessing relevant data streams required to inform thermal operational and design characteristics.
- Developing a comprehensive understanding of thermal sinks, thermal sources, and the interaction of both.
- Developing a concept design, flowing to detailed design, for electrification of heat, including thermal storage/buffering.
- Identifying and assessing constraints to electrification, with particular emphasis on electrical grid constraints. Early engagement with grid stakeholders is vital to the success of any project in this space, with long lead times to provisioning of grid capacity a key issue.

This approach provides a roadmap to developing, designing and delivering electrification of heat projects at industrial sites, taking in concept, detailed design of heat pump, site integration detailed design, commissioning, and also considerations in terms of robust O&M and ongoing performance monitoring of the system. The approach also aligns with relevant SEAI grant support programmes for the electrification of heat, primarily EXEED, but also the SSRH, and other relevant Enterprise Ireland and IDA grant supports. Figure 1 on the following page provides a summary graphical representation of the process.

Figure 1: Electrification of Heat Process Overview



Contents

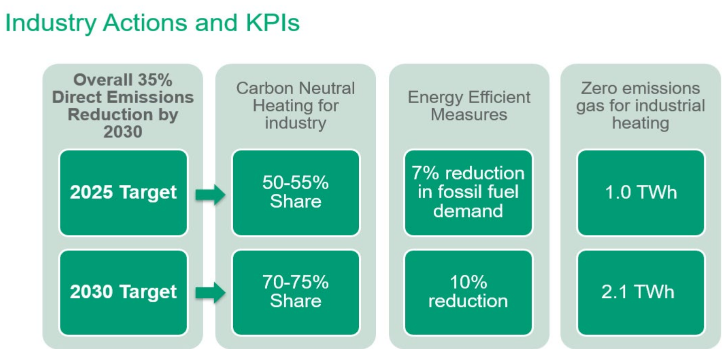
1. Introduction

The European Green Deal established an ambitious target of achieving net-zero climate neutral status within the European Union by 2050. This package also set an interim target to reduce net GHG emissions by at least 55% by 2030 compared to 1990 levels, with the goal of limiting global warming to 1.5ºC above pre-industrial levels in accordance with the Paris Agreement.

At a national level, each member state of the EU transposed the EU Directives associated with the EU Green Deal into its own National Law – the most relevant directive being the Energy Efficiency Directive, the Energy Performance of Buildings Directive and the Renewable Energy Directive. In Ireland, the Climate Action and Low Carbon Development (Amendment) Act was published in 2021. This Act sets out a legally binding commitment to emissions reduction, a 51% reduction in CO_2 emissions by 2030 and a net zero target by 2050.

A National Climate Action plan outlines targets for all sectors including Industry. The national targets for Industry as set out by the Climate Action Plan is highlighted in Figure 1. It is clear from the KPI's that it is direct emissions from fossil fuels (i.e. Scope 1 GHG emissions) that are the main driver of CO_2 emissions reduction in industry in Ireland.

Figure 2: Climate Action Plan Targets for Industry (DECC, 2024)



There are many alternative sources of industrial heat other than fossil fuels – biomass, biomethane, hydrogen and electrification. This guide focuses on the latter, electrification, which has been referenced in the "Roadmap for the Decarbonisation of Industrial Heat" (DETE, 2024), as the most viable alternative to fossil fuels in industrial applications where thermal end users demand temperatures <150°C (DETE, 2024).

1.1 Purpose of Guide

This guide is primarily intended for industrial site leadership teams and facilities managers who are currently researching and planning their transition to alternative renewable sources of thermal energy. The aim is:

- To provide a guide to support industry stakeholders understand the fundamentals of electrification of industrial heat and why it plays an important role in the National Climate Action Plan.
- To direct the reader to a best practice approach in terms of carrying out a Site Assessment at their industrial site including a thorough understanding of heat sinks, sources, regulatory considerations, design options and implementation options.
- To educate and build capacity among industry stakeholders to empower them to distinguish between different vendor solutions and critically analyse different heating system designs.

1.2 Scope

This guide concentrates on industrial sites that currently use steam and hot water generated by traditional fossil fuel boilers and CHP systems for the provision of thermal energy to their industrial processes, clean-in-place (CIP) systems, Space Heating and Domestic Hot Water systems. It is assumed readers have a basic knowledge of how heat pump technology and electric boilers work.

1.3 Note on Electric Boilers

The guide focuses on the application of heat pump technology as the primary technology for electrification of heat in industrial settings. It is anticipated that in many cases, heat pumps will be deployed in addition to electric boilers as a means of delivering full decarbonisation. The use of electric boiler systems can and should be considered where technical considerations dictate, for example:

- Applications where a heat pump system can deliver partial decarbonisation of thermal processes in the first instance, with electric boilers integrated to deliver higher temperature/steam process heating requirements.
- Applications where the production process thermal requirements cannot be fully de-steamed.
- Applications requiring higher temperature process heat traditionally delivered via high pressure steam systems or other means.

It should be noted that both heat pumps, and in particular electric boilers, along with thermal storage, offer the potential for industrial sites to be active participants in the provision of flexible demand services to the electricity grid, offering much needed flexibility to the grid in terms of integration of variable renewable electricity, helping to mitigate the issue of curtailment/dispatch down and increasing renewable electricity penetration. Participation in such schemes can enhance the business case associated with electrification of industrial heat. Both Eirgrid and ESB Networks are actively developing schemes for this purpose.

1.4 District Heating

The role out of district heating networks is identified as one of the key objectives via the Climate Action Plan. At the time of writing, progress has been made via the first steps legislating for district heating networks, with a clear route to market expected for such projects in the near term. Depending on location, there may be viable options for industrial sites to access such networks, whether that be as a source for the network or as a sink/connected customer. There may be opportunities to utilise a mix of technology solutions to deliver site specific decarbonisation goals, via deployment of local heat pumps, electric boilers, and connection to district heat networks, as supporting solutions to deliver site objectives. A strategic view should be taken in terms of early-stage decarbonisation planning for the site, with consideration given to all solutions to identify the most technically and economically viable solution mix for the site in question.

2. Overview

2.1 What is the Electrification of Industrial Heat?

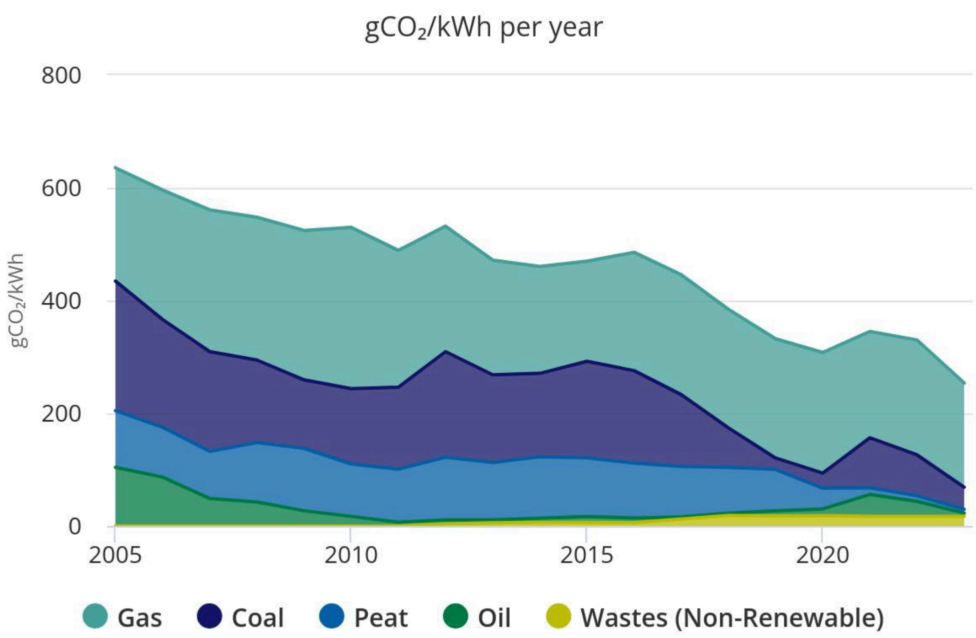
The Electrification of Industrial Heat is as simple as the wording suggests. It refers to the transition away from traditional fossil fuel boilers and/or CHP systems for the generation of Steam and/or Hot Water at your Industrial Site and a move to electric boilers and heat pump systems. According to the "Roadmap for The Decarbonisation of Industrial Heat", after energy efficiency steps have been implemented at an industrial site, emissions reductions will be sought through switching from fossil fuels. For industrial sites that have thermal end users at temperatures below 150°C, manufacturers should consider decarbonising all these low-medium grade heat requirements through electrification (DETE, 2024).

2.2 Why choose electrification of heat such as a heat pump or electric boiler?

The advantages of choosing electrification of heat technologies compared to other renewable alternatives (biomass, biomethane, hydrogen) include:

- Technology Readiness Level 8-11 for thermal end users with temperatures <140°C (IEA, 2022)).
- Both Energy Efficiency and Decarbonisation benefits to corporate targets.
- Large electrical demand that will promote further investment in Renewable Electricity Generation and Grid.
- Stable electrical demand from variable sources of Renewable Electricity Generation (wind, solar, etc.).
- Heat pumps most energy efficient compared to biogas, electric boilers and electrolysis/H2 (EHPA, 2023).
- Heat pumps most cost effective compared to biogas, electric boilers and electrolysis/H2 (EHPA, 2023).
- EU benefits such as indigenous industry, well-trained workforce, expansion of jobs/economy, energy security.

Figure 3: CO_2 emissions intensity of electricity (SEAI, 2024)



The carbon intensity of the national electricity grid has been reducing since 2005 as reflected in Figure 3 above. In 2023, Ireland generated 3.3 TWh less electricity from fossil fuels than in 2022, balanced by 3.0 TWh more electricity imported through international interconnectors and 1.0 TWh more renewable generation in Ireland. The renewable electricity target is commonly referred to as the RES-E target. Ireland's NECP 2021-2030 includes a planned RES-E of 70% in 2030, which will ensure that renewable electricity continues to form the backbone of our renewable energy use for the coming decade and beyond. Since 2021, Ireland's Climate Action Plan has included a target to increase the share of electricity generated from renewable sources up to 80% in 2030, further reducing the carbon emissions intensity of the national electricity grid.

2.3 Key differences between electric and fossil fuel heating systems

An electric heating system, especially heat pump technology, is different from gas or oil-fired equivalents, because it is comprised of multiple components such as compressor(s), condenser(s), evaporator(s), refrigerant line(s), thermal store(s) etc. The multiple components associated with a heat pump have the following implications:

- Overall system efficiency is related to the correct selection of individual components for the specific application
- The selection of components offers modularity and flexibility for a site
- There can be several different designs for the same application – customised designs by different vendors
- Technical complexity needs to be understood by Industry decision-makers to decipher different designs
- The requirement and availability of additional reliable power is fundamental
- Additional physical space to house the various components and hence link them through refrigerant piping and new heat exchangers/pipework.

Because of the multiple components and design configurations available, it is critical that industry stakeholders are educated on a best practice process when considering the electrification of heat at their industrial site.

2.4 Planning the transition from fossil fuel heating systems

This guide sets out a best practice approach to transitioning to the electrification of heat at your industrial site. This best practice approach is technology agnostic, i.e. it is simply a “process” of understanding your own site’s heat sinks and sources. This understanding is fundamental in evaluating any renewable heat alternative that you are considering for your facility. The latter part of this guide offers initial design considerations, financial life cycle costing and implementation options.

2.5 Communications

As with any change management project, the electrification of heat is a significant business transformation project in any industrial site. Hence, it is important that the project team responsible give careful consideration to engaging with stakeholders who could be affected by the project – both internal and external.

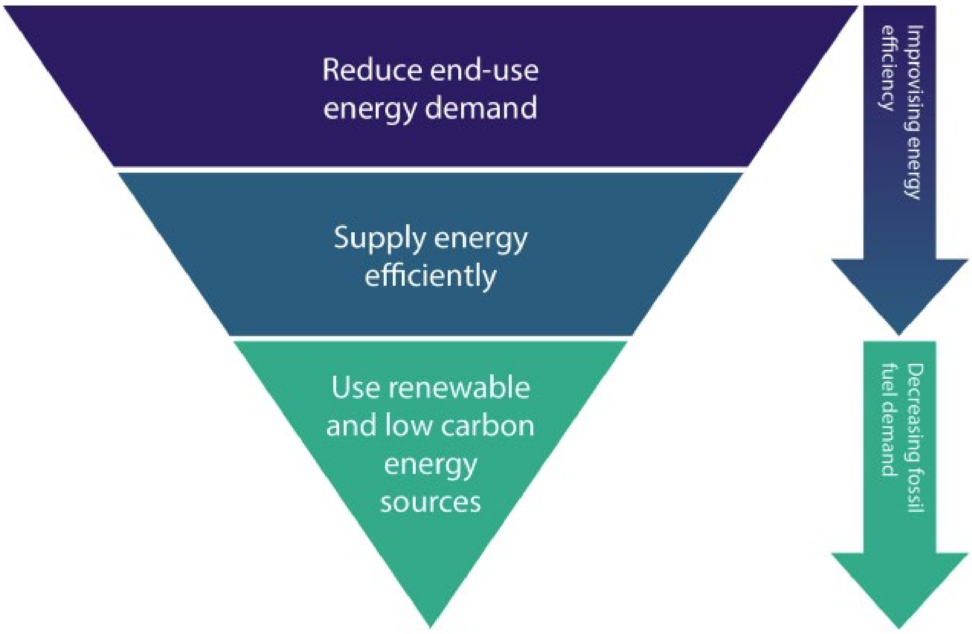
- The project team should make a communication plan at an early stage. The communication plan should list all the internal and external stakeholders who will need to be involved and/or informed about the prospective project, so that they can understand the relevant implications and input ideas/concerns. The communications plan should set out the nature and timing of communications and identify responsibilities of each project team member.
- Contact with the regulatory authorities at an early stage is important. The project team needs to understand the regulatory requirements and any legislation that may affect the project.
- Engagement with national authorities that may be able to support the project development stages of the project and provide grant support to a defined project at a later stage is critical at an early stage of the process.

- Early engagement with heat pump and electric boiler designers/vendors can provide the project team with information and options for the feasibility, detailed design, construction, and operation/maintenance stages of the project. Consultation with residents and adjacent business is also advisable.

2.6 Energy Efficiency First

All viable actions to minimise heat demand at the industrial site should be taken before sizing a heat pump or electric boiler. There is a synergy and perfect alignment between the best practice approach to the electrification of heat at your industrial site outlined in this guide and Stage 1 of the SEAI EXEED process.

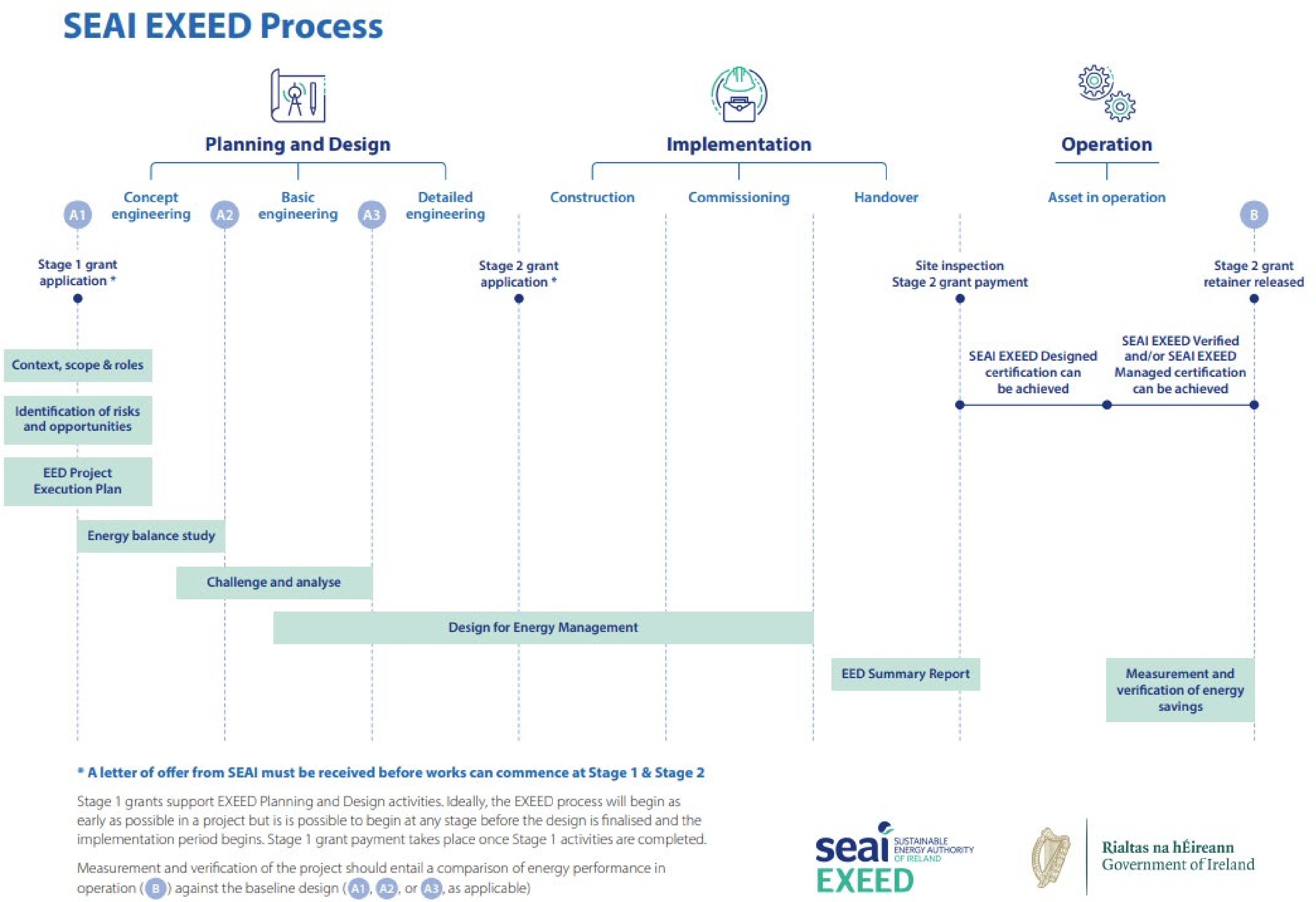
Figure 4: Energy Efficiency First



Excellence in Energy Efficiency Design (EXEED) is a two-stage process. It enables organisations to establish a systematic approach to design, construction and commissioning processes for new investments and upgrades to existing assets. Stage 1 is at the pre-investment design stage of the project and is 50% funded. Eligible expenditure includes the contracting of an EED Expert, Technical Feasibility Studies, Benchmarking, Specialist Consulting (such as heat pump or electric boiler experts), Concept Engineering Design Activities and Energy Modelling. Through this process, all thermal energy end users are challenged and analysed, with a list of energy efficiency first measures created and implemented to ideally contribute to the reduction of heat load at the facility in the first instance, followed by an installation of a new high efficiency alternative heating system such as heat pumps or electric boilers or a combination of both.

The overall value of the EXEED grant for Phase 1 (Pre-Investment Design) and Phase 2 (Implementation) is up to €3M at the time of writing (SEAI, 2024).

Figure 5: SEAI EXEED Process

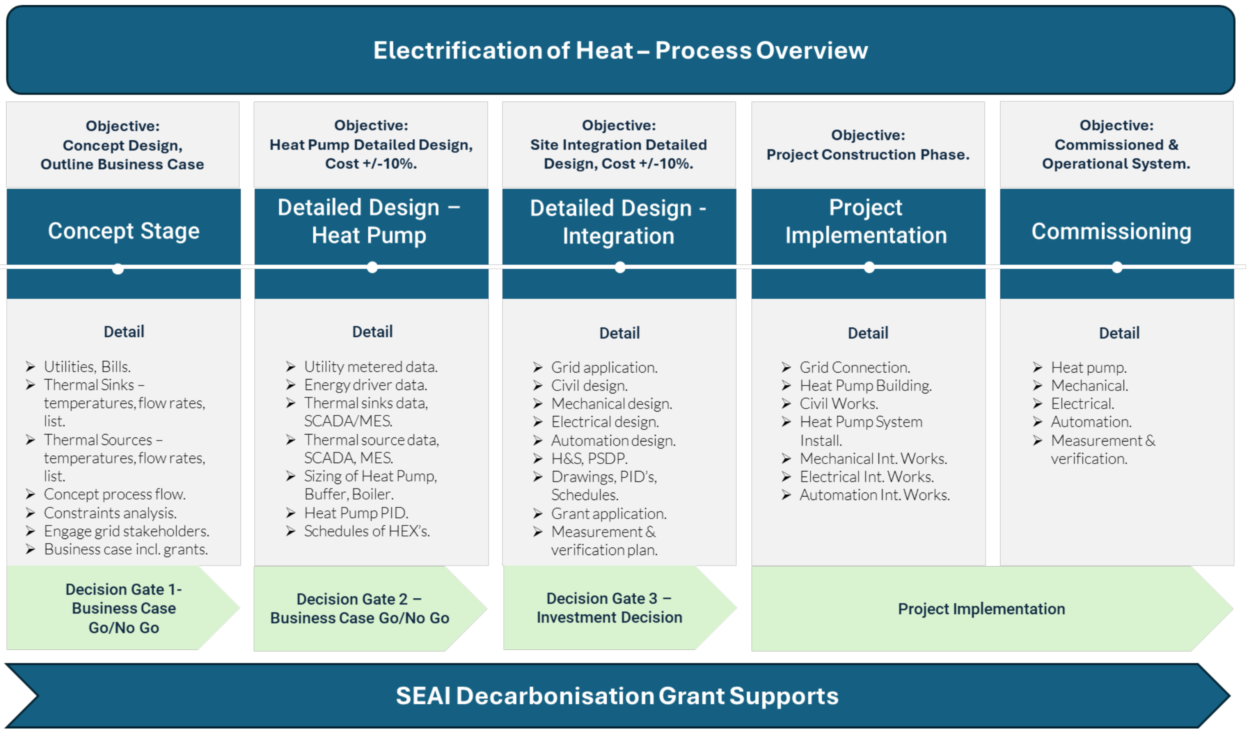


3. Electrification of Heat – Project Development Process

The project development process consists of the following phases;

1. Concept Stage – the objective of which is to develop a concept design for the project and present an outline business case.
2. Detailed Design Stage –
    a. Heat Pump Design – the objective of which is to develop a detailed design for the heat pump, costed to +/-10%, with a more detailed business case.
    b. Integration Design – the objective of which is to develop detailed design for integration of the heat pump with site systems, costed to +/-10%, with full project financial model presented for investment decision.
3. Project Implementation – the objective of which is to successfully deliver the project.
4. Commissioning – the objective of which is to handover a fully tested and operational system to the end user.

Figure 6: Analysis of Thermal Sinks/Sources within Overall Process



3.1 Concept Stage

The objective of the concept stage is to complete a provisional technical and financial assessment for deployment of an electrification of heat project. A concept report and business case should be developed and presented to the client, enabling a decision to be made to progress the project to detailed design stage.

Activities completed during the concept stage include:

- Gathering and analysis of energy and cost data from utility bills.

- Gathering and documentation of thermal sink data, with temperature and flow rates listed per user.
- Gathering and documentation of thermal source data, with temperature and flow rates listed per source.
- Development of system concept design and process flow diagram.
- Development of system energy balance.
- A preliminary assessment of project constraints, such as grid capacity, environmental, noise etc.
- Preliminary engagement with electricity grid stakeholders should additional electrical capacity be required from the Distribution System Operator.
- Development of outline business case via a financial assessment including outline costs and consideration of relevant grant supports and incentives.

Initial Site Inspection

An initial site inspection and discussion with internal members of the team should review the:

- Overall site layout
- Existing plant room, the thermal distribution network and the thermal sinks
- Existing waste heat streams and potential sources of waste heat.
- Site electrical capacity and the spare electrical capacity availability
- Physical location and proximation of plant room, waste heat source and electrical distribution room
- Available space for new technology, i.e. containerised heat pump components, outdoor evaporator fans etc.

3.2 Detailed Design – Heat Pump

This phase of the project development process will focus on the following:

- Gathering and analysis of utility metered data.
- Gathering and analysis energy driver data.
- Gathering and analysis of data on thermal sinks from site SCADA/MES systems.
- Gathering and analysis of data on thermal sources from site SCADA/MES systems.
- Sizing of the heat pump, thermal storage/buffers, and back up boilers.

Right sizing capacity is one of the key critical success factors for any project – scarcity/cost in terms of electricity grid capacity, cost of heat pump capacity if oversized/underutilised, and potential impact in terms of plant operational efficiency are key considerations here. This should be addressed via the comprehensive sink/source analysis and developing a clear understanding of thermal capacity needs driven by site thermal data rather than just existing thermal plant nameplate capacities.

- Development of the heat pump PID.
- Development of heat exchanger schedules.
- Drafting of system specifications.

Importance of Thermal Sink/Source Analysis

The most important step within the electrification of heat process, is to complete a detailed site assessment of thermal sinks/sources using data and evidence collected on site. Designers will use this to understand the current industrial thermal energy profile and availability of thermal energy as a source at the site for a period of at least 12 months.

This is not a high-level feasibility study that results in a basic concept, with high level costs and paybacks. This assessment requires thorough data collection, data analysis and data representation/reporting to gain a complete understanding of how each individual process that requires thermal energy at the industrial site operates i.e. temperature(s) and magnitude (kWh), when this demand occurs, and how often over the assessment period. It also offers Designers an opportunity to understand the various sources of waste heat available at the site and how the two, i.e. the sinks and the sources, relate from a timing and heat quantification perspective. **The more time and due diligence spent at this first stage - the site assessment of thermal sinks/sources - is without doubt the most important time spent within the entire design process as it provides a solid foundation for making decisions on technology selections, component selections and component configurations thereafter.** This step in the process aligns with the planning and design approach of EXEED, as detailed in Figure 5: SEAI EXEED Process.

This section provides guidance on how to undertake this site assessment and what it includes, such as:

- Choosing a suitably qualified person(s) to undertake the assessment study and the steps to be taken
- Assessing the thermal energy consumption of sinks and sources
- Reviewing how regulations might restrict the project or make it unfeasible
- Considering preliminary design and size options and establishing an initial outline of the system
- Conducting an initial review of capital and operating costs, revenues and savings – financial viability Considering implementation options for system ownership and responsibility for detailed design and installation

Conducting this site assessment of thermal sinks / sources

As stated previously, this site assessment is without doubt the most important time spent within the entire design process as it provides a solid foundation for making decision on technology selections, component selections and component configurations thereafter. Hence it is important that the right "team" is selected to participate in this assessment.

Who should conduct the assessment study?

It is recommended that a project team of stakeholders is set up to engage with this assessment study given the importance of the data that needs to be collected for a high-quality assessment of thermal sinks and sources. This team will include in-house expertise i.e. production/maintenance fitters, operations/production managers, energy managers, in-house process control engineers, utility/facilities managers, project engineers. External to the organisation, the team will include a heat pump specialist and an independent energy consultant. The value of team engagement, internal-external stakeholder feedback and two-way communication is critical to ensure that the assessment carried out is a true representation of the site's thermal energy consumption profile.

This team approach is also an essential aspect in the Phase 1 stage of the SEAI EXEED process. Traditionally, facilities may have chosen between using "in-house", "consultants" or "vendors" to complete this type of assessment. This guide advocates on the value of a "team" approach with all three types participating in the team and contributing to the assessment.

Assessment of Thermal Sinks/Sources

The assessment of thermal sinks/sources can be broken down into 3 phases:

- Top-Down Assessment (utility data, regression analysis, identification of factors that drive site thermal energy)
- Bottom-Up Assessment (identification of thermal sinks, i.e. process heat, HVAC, CIP, DHW etc.)
- Bottom-Up Assessment (identification of thermal sources, i.e. waste heat from cooling towers, chillers etc.)

As the assessment progresses, the optimum end result is an overlay of the data from each of the three assessments not only for the purpose of sanity checking but also for the understanding of the relationship between the thermal sinks demand and the availability of the thermal source at that specific time.

Top-Down Assessment

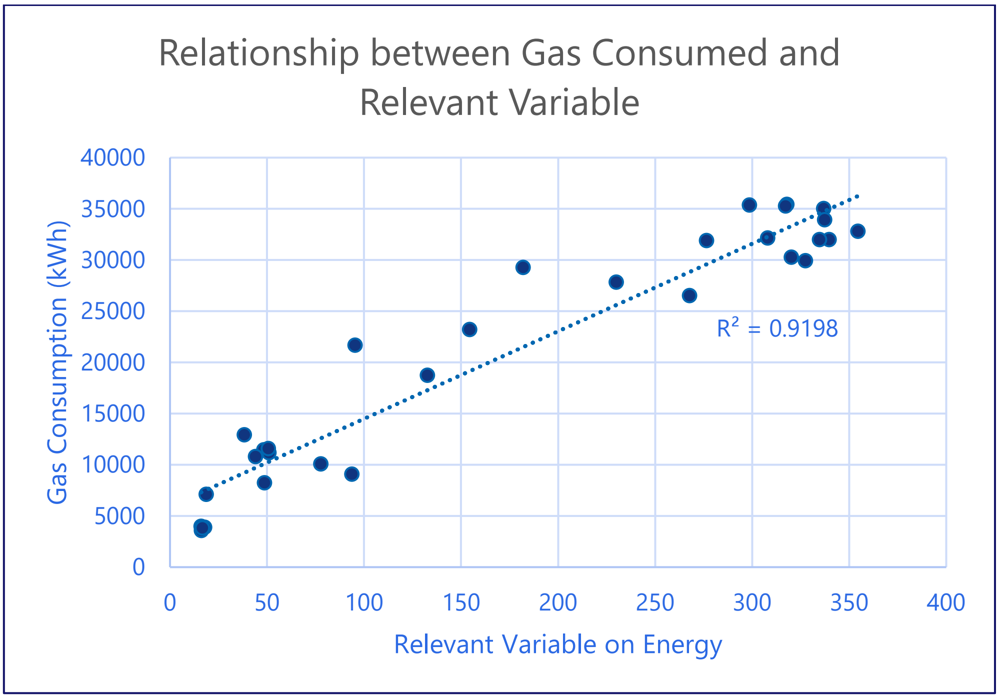
Data Source:

- Utility data (thermal) for at least 12 months, ideally at minute intervals or worst-case hourly intervals.
- Heat/Steam meter data for the same measurement period, ideally at the same interval
- Factors that influence thermal energy use for the same measurement period, at available measurement intervals. This could include production units, water consumption, weather (Temperature, %RH) etc.

Data Analysis and Representation:

- Annual Fuel Consumption profile (monthly, weekly, daily) using utility data
- Annual Fuel and Heat Demand profile (monthly, weekly, daily) using heat/steam metered data
- Peak Fuel Input and Peak Heat Load – the maximum rate at which the fuel and heat is required in kilowatts (kW)
- Variation in Peak Fuel Input and Peak Heat Load over time (Month, Week, Day, Hour, Minute)
- Regression analysis of fuel consumption and factors of influence

Figure 7: Example of Top-Down Regression Analysis (ActionZero 2024)



Critical Reflection and Sanity Checking:

It is important to obtain the most accurate information available relating to thermal energy consumption and more important to continuously carry out "sanity" checks on the data. For example:

- When relying on metered utility data represented on an onsite Energy Management Information System (EMIS), compare the metered interval data with the billed data to be confident the data is good quality.

- If data from heat meters and steam meters are available, check that the overlay of the data from these meters is below that of the metered utility data. This indicates the losses associated with the combustion boiler.
- If data from heat meters and steam meters are not available, or is not accurate from a data quality perspective, theoretical efficiencies can be used to superimpose a “theoretical heat” trend line under the metered utility data.
- The rating plate on the boilers can be recorded, as a sanity check only, against the peak fuel input and peak heat load demonstrated in the data.
- If a satisfactory correlation is found between thermal energy consumption and a factor(s) of influence using regression analysis, this “equation of the line” can be used as both an energy baseline (to demonstrate savings into the future for grant purposes) and as a method of modelling future expansion at the site and how this might impact design decisions on heat load etc.

Bottom-Up Assessment (Identification of Thermal Sinks)

At this stage of the assessment, a list of all thermal sinks should be generated. This list can be generated as a table with the following suggested entries (Table 1):

Table 1: Identification of Thermal Sinks

Process	Product	Heat Exchanger Tag	Design Flow (kg/hr)	Design Tin / Tout (°C)	Design Heat (kW)
HVAC	STEAM / LPHW	AHU HEX	25,000	60 / 80	600
DHW	STEAM / LPHW	DHW HEX	43,000	55 / 65	500
CIP	STEAM / CAUSTIC	CIP1 HEX	27,000	60 / 75	470
PROCESS “X”	STEAM / PRODUCT	X HEX	13,000	66 / 80	169
PROCESS “Y”	Etc.				
				Total:	

Note, the data required to complete this table is available on name plate data, model/serial numbers of heat exchangers and support from the internal members of the project team.

This list serves only as a “complete” list of all thermal end users on site and highlights how many thermal end users require heat at temperatures <150°C and within the range of heat pump technology. A word of caution associated with this data is the acknowledgement of the term “design” in the data, the design heat “kW” calculated is based on design conditions not actual conditions, and the sum of the thermal end users likely exceeds peak heat demand demonstrated in the top-down analysis outlined above, because it is likely that not all heat exchangers are operating at design conditions or at the same time. This highlights the importance of the next data collection and data analysis stage which is based on operating conditions.

Data Source Operational Data:

- PID Drawings for Each Thermal End User (to identify tag no. of relevant temperature sensors, flow meters, steam valves)
- MES/Scada Front End Graphic Screen Shots for Each Thermal End User (to compare tag no. of relevant temperature sensors, flow meters, steam valves and identify what variables can be trended)
- BMS Front End Graphic Screen Shots for Each Thermal End User (to compare tag no. of relevant temperature sensors, flow meters, steam valves and identify what variables can be trended)

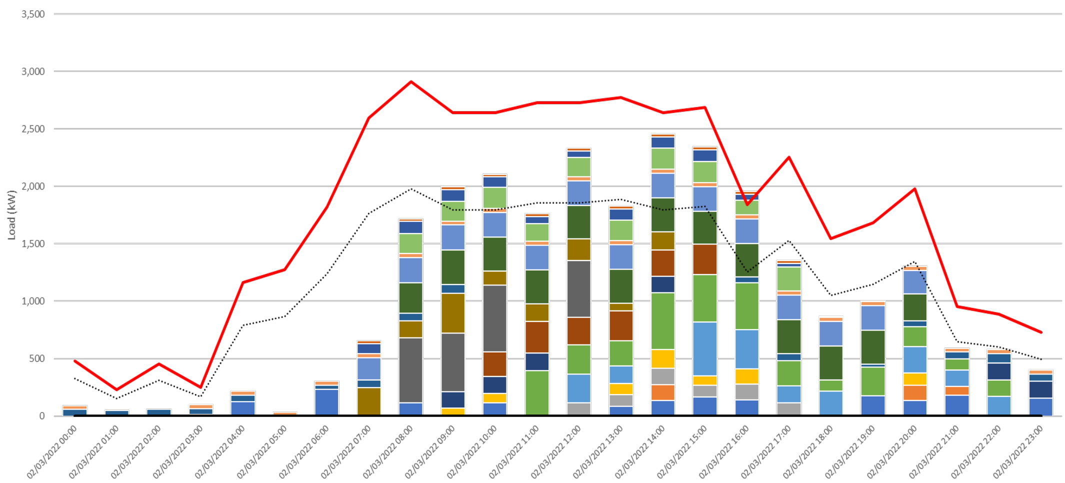
- Trend data of steam valve position, temperature in / temperature out, set temperature and flow at minute intervals (or as low an interval as is available) for the same time period as the top-down analysis.

Data Analysis and Representation:

For each thermal end user, the following analysis can be carried out:

- Heat Demand profile (monthly, weekly, daily, hourly, minute) using sensible and latent heating calculations
- Comparison of design setpoint temperatures versus actual temperatures
- Identification of multiple setpoint temperatures associated with a single thermal end user
- Demonstration of patterns in thermal demand
- Representation of sudden "spikes" or increases in thermal demand, i.e. frequency and magnitude
- Identification of the thermal base load
- Identification of how significant the thermal end user is in terms of kWh compared to overall utility consumption

Figure 8: Example of Bottom-Up Thermal Sink Analysis (ActionZero 2024)



Ultimately, each thermal end user is overlayed on each other and, hence, the following analysis can be carried out:

- Heat Demand Profile (monthly, weekly, daily, hourly, minute)
- Understanding of the thermal sequencing of heat demand on site
- Demonstration of patterns in thermal demand
- Representation of sudden "spikes" or increases in thermal demand.
- Identification of the thermal base load
- Potential "grouping" of thermal end users by actual temperature required
- Comparison of the combined thermal end user demand with the utility/ heat profile from the top-down analysis.

Critical Reflection and Sanity Checking:

It is important to obtain the most accurate information available relating to thermal energy consumption and more important to continuously carry out "sanity" checks on the data. For example:

- It is likely that the three variables (temperature in/out and flow) will not be available for trending for every heat exchanger. In this instance, a judgement call can be made as a team as to how significant this

thermal end user will be in the overall design – for example, how large is it in terms of heat demand (kW), how often does it operate. If significant, temporary metering should be installed to record flow and temperatures in/out. If not significant, the internal project team members can offer suggestions for flow and temperature or a decision to use "design" data can be made as the default.
- The purpose of recording the steam valve position at the heat exchanger, gives an indication of when that heat exchanger is operating and consuming thermal energy. However, a steam valve may become "stuck" in the open position – hence a sanity check against temperatures and flow is also a useful exercise to filter inaccurate representations of thermal demand.
- The operational data for each thermal end user should be compared with the corresponding design data to check for any anomalies or data quality issues with the operational data collected.

Bottom-Up Assessment (Identification of Thermal Sources)

Similarly, and as important, if not the most important, the availability and quantification of an onsite waste heat source needs to be analysed. Hence, a list of all thermal sources should be generated. This list can be generated as a table with the following suggested entries (Table 2):

Table 2: Identification of Thermal Sources

Process	Product	Design Flow (kg/hr)	Design Tout (°C)	Design Heat (kW)
Cooling Tower	Water	25,000	40 / 20	570
Air Cooled Chiller	Water	43,000	12 / 6	250
Effluent Treatment	Water	27,000	25 / 15	300
PROCESS "X" Waste Heat	Product	13,000	80 / 40	500
PROCESS "Y" Waste Heat	Etc.			
			Total:	

Note, the data required to complete this table is available on name plate data and support from the internal members of the project team. This list serves as a "complete" list of all potential thermal sources on site for further investigation. The key factor to consider when evaluating the potential sources of thermal energy on site, is the available quantity of heat (kW) and the availability of this heat in terms of time. This highlights the importance of the next data collection and data analysis stage which is based on operating conditions.

Data Source Operational Data:

- PID Drawings for Each Thermal Source (Identify relevant temperature sensors, flow meters, etc.)
- MES / Scada Front End Graphic Screen Shots for Each Thermal Source (temperature sensors, flow meters and identify what variables can be trended)
- BMS Front End Graphic Screen Shots for Each Thermal Source (temperature sensors, flow meters, steam valves and identify what variables can be trended)
- Trend data temperature in / temperature out and flow at minute intervals (or as low an interval as is available) for the same period as the top-down analysis of sinks and the bottom-up analysis of sinks above.

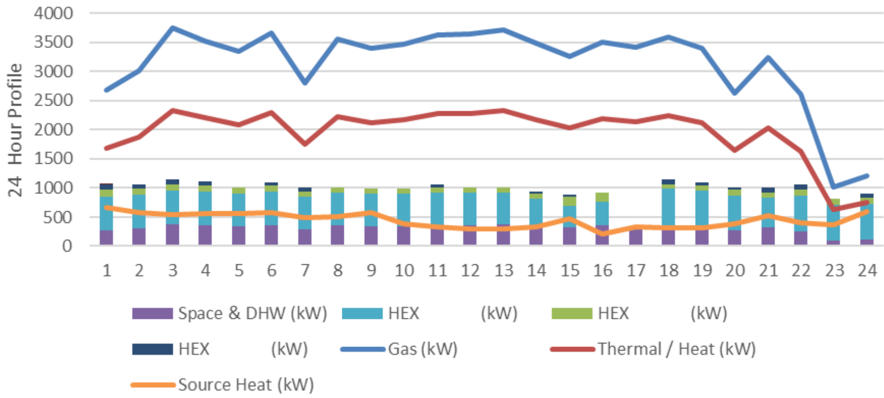
Data Analysis and Representation:

For each thermal source, the following analysis can be carried out:

- Waste heat Availability profile (monthly, weekly, daily, hourly, minute) using sensible heating calculations
- Comparison of different waste heat sources in terms of quantification of heat (kW) and availability (time)
- Demonstration of patterns in thermal source availability
- Representation of sudden "spikes" or "troughs" in individual thermal source availability (i.e. production start-up)

Depending on the size of the site, it is likely that there will be at least one source that is the most significant source of waste heat and has the most potential in terms of availability as a source for a heat pump system.

As a final step, the most appropriate source(s) is selected and combined with the top-down analysis and the bottom-up thermal sink analysis to demonstrate the demand for heat at any given time and the availability of waste heat that can be utilised as a source of a heat pump system at that same time. A typical representation of this is outlined in Figure 9: Representation of Utility Analysis, Heat Sink Analysis and Heat Source Analysis (ActionZero, 2024)



As outlined in Figure 9, this is a 24-hour profile of one day at an industrial site. The gas demand ranges from 1.5-3.6MW. An efficiency of 63% is applied to this steam boiler (because of data quality issues found with the steam metering system on site). Hence, the theoretical heat load, represented by the red line, ranges from 900-2.1MWth. This serves as a sanity check for the thermal end users (sinks).

Four thermal end users (sinks) are represented on this graph. Most thermal end users run 24 hours of this specific day. The thermal demand ranges from 300-1100kWth in any given hour of that day. This is below the theoretical heat trend and hence passes any critical reflection or sanity check. There is a constant availability of source at this site, which ranges from 300-600kWth. This analysis tells us that waste heat, although available is not sufficient to meet all the thermal demands at this site, hence additional sources of energy will have to be considered in the design phase of the project. An additional source of thermal energy could be "air" or "thermal storage" or "electric boiler" or "existing boiler".

Critical Reflection and Sanity Checking:

It is important to note that the representation above is representative of 1 day only. This analysis needs to be repeated for a sample of days, weeks, months etc. The most relevant sample or sampling period can be decided as a team with internal and external stakeholders.

Regulatory Review – Planning Permission, Local Air Quality, Refrigerants and Electrical Capacity

An early review of regulations is needed to identify possible regulatory barriers which may inhibit progress on an electrification of heat project.

Planning Permission

The need to obtain planning permission may arise, for example, if:

- New buildings, such as boiler house is required
- The evaporator fans are going to be particularly visible, i.e. height restrictions
- Existing vehicular access is required to be altered to make space for the new plant
- Internally, new mezzanine floors are required to locate new heat exchangers
- Noise restrictions are an existing condition of planning at the specific location of the new plant

The project team should liaise with their local authorities planning section to assess what planning requirements are relevant to a potential electrification of heat project.

Local Air Quality Regulations

In line with the EPA's ongoing remit of monitoring industrial sites, an early review of regulations with the EPA is needed to identify potential issues associated with an electrification of heat project. Some of the issues that could arise, include for example the scope of existing licensing agreements in place and the enforcement of Restriction of Hazardous Substances (RoHS), i.e. choice of refrigerant in a heat pump system.

As well as the identification of potential issues, the EPA could be used as a resource to provide advice and guidance to industry and the public on the environmental benefits of the project – which include a reduction in particulate matter and emissions from the burning of fossil fuels on site.

F-Gas Regulations – Choice of Refrigerant

In response to the European Climate Law, and the need for stronger climate action, the European Commission adopted the F-gas Regulation (EU) 2024/573 on the 7th February 2024 and started to apply it on the 11th March 2024. The key measures of the new F-gas Regulation are:

- Reducing hydrofluorocarbons – the quota system generates a steeper reduction in the amounts that importers and producers may place on the EU market, and in 2050, HFCs will be phased out in the EU.
- Stricter rules to prevent emissions – the regulation covers additional equipment and gases, expanding measures to prevent leakage during transportation, installation, servicing and disposal of equipment and products.
- Facilitate better monitoring – more digitalisation and electronic automation of custom control will allow enhanced enforcement and monitoring in the member states and combat illegal trade.
- Capping EU production of HFCs – starting in 2025, producers will receive rights equivalent to 60% of their average annual production from 2011 to 2013. This rate will decline to 15% by 2036.

Hence industrial sites should really be considering natural refrigerants such as R717 Ammonia with 0GWP, R744 CO2 with 1 GWP or R290 Propane with 3 GWP, where technically feasible based on system characteristics and site health & safety considerations.

Electrical Capacity – Grid Connection

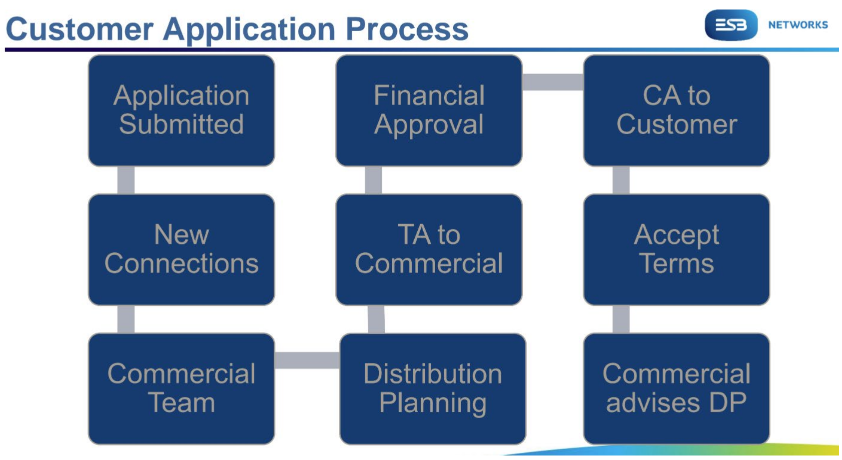
One of the most important early engagement conversations to have, is with the distribution system operator, ESB Networks, regarding available spare electrical capacity in the vicinity of the industrial

site (if additional capacity is not available on site). Should there be a scarcity of grid capacity, this can be factored into the design process and potentially managed via thermal storage, load shifting etc.

Because of the different seasonal efficiencies associated with an electric boiler and an electric heat pump, electric heat pump technology will, for the same heat load, require less additional electrical capacity, due to the fundamental operating principle of the technology itself.

Maximum Import Capacity (MIC) is the maximum electricity demand level that can be catered for by an industrial site's connection to the electricity grid network. When applying for a new connection, the industrial site needs to specify the maximum electricity demand level that it requires. This level is then written into a connection agreement as the MIC. ESB networks then design the network to provide a connection method in accordance with the agreed MIC. The cost and the timeline associated with such a connection method will vary depending on the complexity of the design/upgrade work required.

Figure 10: DSO Customer Application Process (ESB Networks 2024)



With increasing levels of renewable electricity development on the supply side, and increasing electrification on the demand side, demands on electricity system operators in Ireland are increasing exponentially. Should additional grid capacity be required to enable electrification of industrial heat, customers can potentially face timelines running between 18-months and 5-years to energisation, depending on local grid considerations and customer requirements. It is crucial that engagement with grid stakeholders happens as early as possible in the process.

Heat Pump Sizing and Design Options (thermal stores, integration etc.)

A more detailed system design, building on the concept stage, needs to be developed. The data that feeds into this decision was generated at the initial assessment of sinks and sources on site. Hence, to reiterate, it is important that a generous amount of time, resources and good quality data is utilised in this assessment.

Sizing and Additional Generation

The required heat capacity (kW) of the new heating system will not necessarily be the same as the existing fossil-fuelled boiler plant (and may be significantly less). Fossil-fuelled boilers are traditionally sized based on peak heat demand plus some contingency (which can be significant). In addition, it is important to consider that the heat demands may have changed since the original fossil-fuel system was specified.

Step 1:

Review the list of thermal end users (or heat sinks) that require heat <150°C and the number of thermal end users that require heat >150°C that was created at the outset of the thermal sinks / sources assessment.

Step 2:

Focus on the heat sinks that require heat <150°C and the trend data that is represented in the assessment of thermal sinks/sources. Due to the high efficiency of water-based heat pump technology, the first opportunity to quantify, is how much of this heat demand can be supplied from a waste heat source on site.

This will be different depending on each site. For example, in the representation in Figure 2, only 40-50% of the heat demand represented in the graph could be met by the waste heat source available on site. This once again demonstrates the importance of the initial assessment of sinks and sources at the start of the project design phase.

Each site will be different depending on their processes. In some industrial sites, there may be enough waste heat source to supply all the heat required for all the heat sinks <150°C and in other sites, there may only be enough waste heat source to supply a certain percentage of the heat sinks with temperatures <150°C.

Step 3:

Assess whether there is excess waste heat available. It is possible that in some sites, the availability of waste heat occurs when there is no demand for the heat at the heat sinks <150°C. In this scenario, waste heat can be stored in thermal stores at a specified temperature. This then acts as a thermal battery or a high-grade source of thermal energy when the demand is required. This excess waste heat will be evident at the end of the initial assessment of sinks and sources.

Step 4:

Understand how the remaining demand <150°C will be met on site. For example, if an industrial site has enough waste heat source available to meet all of the heat demand <150°C, the design concept is very straight forward with a 100% water-sourced heat pump being the solution. However, there is also a likely scenario in industry, where there is not enough waste heat source available to meet all the heat demands <150°C or not enough waste heat available at the right time. In this instance, an additional source of heat will be required. This could take the form of "air" to form a dual-source heat pump (with efficiencies ~280% for the air-component depending on the application) or an electric boiler (with efficiencies ~99%).

Step 5:

Using the graphical representations for the heat sinks <150°C and comparing it to the utility consumption and theoretical heat consumption will provide an estimated size of the load that requires temperatures >150°C assuming all other loads <150°C have been included in the representation / calculation. In this instance, for the heat that requires temperatures >150°C, an electric boiler can be specified. In some instances, this heat load, i.e. the generation of steam for a specific process may be very small in terms of kW and is a very straightforward decision to make. The sizing estimate can be compared with end user specification data as a sanity check.

3.3 Detailed Design - Integration

This phase will focus on establishing detailed design for integration with site systems, to include the following:

- Development of project civil works design.
- Development of mechanical system design.

- Development of electrical system design.
- Development of control & automation design.
- Completion of application for grid capacity (if required).
- Definition of H&S requirements including PSDP, PSCS.
- Drafting of integration design drawing and specification packs.
- Drafting PID's, schedules for HX's, BOM's.
- Completion of relevant grant applications.
- Development of measurement & verification (M&V) plan.
- Development of a project implementation plan, resourcing plan and stakeholder matrix.

Integration Considerations

Depending on the temperature of the thermal end user (heat sink), the electrification of heat system will be integrated as supplementary technology. It is recommended that in the initial years of implementation, the fossil fuel boiler remains in situ as a back-up technology. The following points highlight different integration approaches:

- When integrating a heat pump into existing LPHW systems, for example HVAC or DHW circuits, the LPHW flow and return from the heat pump system can be integrated into the return of the existing LPHW system, raising the return water temperature to keep the existing fossil fuel boiler from firing.
- When integrating a heat pump into existing process thermal end users, for example processes requiring 80°C, a new heat exchanger will be introduced adjacent to the existing steam heat exchanger. This new heat exchanger will be supplied with a temperature of 82°C (in this example) on the waterside of the heat exchanger and will raise the temperature on the product-side of the heat exchanger prior to the existing temperature sensor that controls the steam valve position detecting a heat demand, hence keeping the valve shut.
- As part of the design, and assessment of heat sinks/sources, it may be found that there are intermittent spikes in demand for certain end users at certain temperatures. In this instance, a good design consideration is to group the heat sinks that share the same temperatures together, and design thermal buffers which store the water at the specific temperatures. This buffer then supplies the number of heat exchangers that has that same temperature demand.
- When integrating an electric boiler (for steam generation) or hot water production, the location of the boiler will depend on its size (kW) and physical size. If it is quantified that the need for steam is quite low at the industrial site, local electric steam boilers can be installed at the point of use. If a large electric boiler is to be installed, the existing systems mechanical schematics and O&M manuals should be examined, and its integration designed by a specialist industrial / building services engineer.

3.4 Financial Assessment

A financial assessment should be conducted, preferably comparing electrification of heat systems with other potential renewable heating alternatives. The preliminary financial assessment can be completed at concept stage and establish if there is a commercial case for installation of such a system, with a more detailed assessment completed as part of the detailed design process. It is recommended to carry out a financial assessment over the whole lifetime of the system (e.g. over a 25-year period). While standard techniques such as calculating the return on investment (ROI) or simple payback are appropriate for the preliminary financial assessment, more detailed analysis including Life Cycle Cost Assessment (LCCA), Net Present Value (NPV) and internal rate of return (IRR) should be used to assess viability at design stage, ultimately enabling an investment decision to be made.

Among the costs to be included in the calculation are:

- Capital costs – schedule of components required for the heat pump system electric boiler system for transparency of the full list of materials and associated labour, allowing the site's decision makers to be able to distinguish between different vendor offerings and prices.
- Maintenance costs – schedule of maintenance intervals, tasks that will be required and at what frequency as well as operational extras such as ongoing performance monitoring, i.e. real time recording of data, the associated hardware (sensors, meters etc.) and software.
- Electricity costs – established through discussion with energy manager or utility provider.
- Efficiency – seasonal coefficient of performance and boiler efficiency to compare the utility energy required of the electric heating system.

Understanding heat pump seasonal coefficient of performance is an extremely important differentiating factor between different vendors and systems specified. Standard testing assumes certain outdoor air conditions and certain supply temperatures. Installing a heat pump system operating at temperatures higher than standard testing and incorrect assumptions on waste heat source availability will result in operating efficiencies that do not reflect standard testing results. For example, specifying a water-sourced heat pump instead of a dual-sourced heat pump system would be a more economic option, but not necessarily the correct one if the aim is to decarbonise the industrial site.

Savings and income streams include:

- Savings in fuel costs of the existing fuel displaced by the electrification of the heating system including annual increases in carbon taxes that are being implemented by the Irish Government.
- Government incentive payments (such as SEAI EXEED, SEAI SSRH, IDA/Enterprise Ireland, SEAI Accelerated Capital Allowance).
- Utility payments (such as the Obligated Parties, EEOS scheme administered by SEAI).
- Avoided costs (such as reduced maintenance of steam distribution network, standard boiler replacement).

Non-financial savings to re-emphasize:

- Efficiency gains - for example a 60% industrial steam boiler and steam distribution system to 450% heat pump and HW distribution system so energy efficiency gains in "kWh" reduction towards 2030 and 2050 targets.
- CO_2 reductions of up to 100% depending on the scope of the project, hence meeting decarbonisation 2030 and 2050 targets.

3.5 Project Implementation

It is unlikely that any industrial site will have their own experienced in-house design, installation and commissioning team for an electrification of heat project. However, every industrial site will have experienced in-house staff in facilities, maintenance and project management and familiarity with standard refrigeration technology such as chillers, compressors etc. Hence the team approach, as recommended by the SEAI EXEED process, is the method by which an electrification of heat project should be implemented.

This team builds upon the value of the knowledge the in-house team have acquired from working at the site and draws in the expertise of external stakeholders such as a consulting design engineer, a technology specialist engineer, process control specialists and the relevant contractors (civils, mechanical, electrical and automation contractors). The advantage of this approach is that there is less risk for an internal project manager and the design (if carried out as suggested in this guide) is not influenced by vendor bias. For example, specifying packaged units available commercially without understanding the thermal sink/source profiles on site, will not occur. The disadvantage is the cost of the professional fees for all the external stakeholders as well as the potential lack of clarity on the interface between the design consultant, the technology specialist and the contractor which may increase contract cost. There is also a risk of lack of ownership of errors without clearly communicated roles and responsibilities.

Turnkey models where external stakeholders on the “team” take responsibility for design, installation and commissioning carries the least risk for the site and if energy performance clauses are included in the contract, will produce a system specific to the site’s requirements. The disadvantage of this approach is that it is the most expensive option due to the contractual relationship between the design consultant, the technology specialist and the list of contractors required to implement the project.

Implementing this type of project through an ESCO (Energy Services Company) is suitable where the site is unable or does not wish to provide the capital investment and/or any responsibility for the ongoing operation / maintenance of the new electric heating system. In this instance, the ESCO takes ownership of the plant, and takes responsibility for its operating and maintenance and is penalised for any subsequent downtime other than planned maintenance at a rate specified in the contract. The ESCO contract is a specified term in years, and often the overall CAPEX is repaid based on demonstrated savings (in kWh) annually. Essentially, this financial arrangement is a loan with specified monetary repayments over the term of the arrangement subject to meeting conditions of energy performance, operation and maintenance. This is the most expensive form of implementation option.

3.6 Commissioning

The goal of the commissioning process is to verify and prove that the system is installed and operating according to the criteria in the design and engineering documentation.

Project commissioning activities will run across the following:

- Heat Pump/heat generation plant.
- Mechanical systems.
- Electrical systems.
- Control & automation.
- Formalised and documented commissioning procedures, testing and commissioning certificates for inclusion in the handover pack.

A comprehensive commissioning plan should detail how the system will progress from run testing through to full operation and handover of the asset to the client, with due care and attention given to avoiding/minimising disruption to client operations, a risk rating applied to commissioning and on-boarding of each thermal user to the system, and appropriate steps taken to manage said risk – this should include a prioritised list of on-boarding thermal loads to the system from lowest to highest risk, and include management of the commissioning process around the risk associated with each thermal user.

Commissioning reports and certificates should detail the commissioning requirements, process, documentation, results, compliance with acceptance criteria and actions taken to rectify any identified deficiencies.

3.7 Operation & Maintenance and Performance Monitoring

Ongoing O&M of the system should be given careful consideration. Within this context, the key objectives for an effective O&M plan are:

- Maximise reliability.
- Maximise longevity.
- Maximise performance

    - Delivery capacity,
    - Delivery temperature,
    - Efficiency.

There are some key characteristics that will determine the maintenance requirements for a heat pump system, including the plant operating hours, system operating pressures, system pressure differential, compressor(s) rotating speed, frequency of start/stops, among others.

For compressor systems, manufacturer guidance should be sought on service intervals and specific service requirements, based on your system design/operating characteristics. For heat exchangers, routine checks on operating conditions vs design conditions should be completed (access to commissioning data is important), temperature and flow profiles should be monitored against design conditions to assess trends.

Where O&M is outsourced to a contractor, a number of factors should be considered:

- Service intervals and service kits.
    - What service interval is required and what work is being done during each planned visit?
- System technical parameters.
    - Is the O&M service level agreement (SLA) in line with manufacturer guidelines for operating conditions?
- Understand the risks in an outage event.
    - What is the nature of the processes supplied by the heat pump?
    - What level of system redundancy is available?
    - Is the system remotely monitored?

All the above will help inform service level requirements for O&M.

Additional consideration should be given to key parameter monitoring from the perspective of O&M and ongoing system performance monitoring. These elements are interconnected with metering and measurement & verification, which will be a key requirement of any project grant supports.

Glossary

Buffer Tank	The purpose of a buffer tank is to decouple the operation of the heat pump from the heat load in the site, to meet thermal demand at the site and to optimise heat pump operation. The buffer tank meets the heat load in the system and the heat pump turns on and off in a controlled manner to ensure that the buffer is kept sufficiently charged while reducing the number of stop-start cycles. This reduces wear and improves efficiency.
Clean in Place	Clean-in-place (CIP) is an automated method of cleaning the interior surfaces of pipes, vessels, equipment, filters and associated fittings, without major disassembly. CIP is commonly used for equipment such as piping, tanks, and fillers.
Combined Heat and Power	Also known as "Cogeneration", Combined Heat and Power (CHP) is the use of a heat engine or power station to generate electricity and useful heat at the same time.
Compressor	In the context of a heat pump system, a compressor pumps the refrigerant between two heat exchangers. In one heat exchanger, the evaporator, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed and moves to the heat exchanger, the condenser, where it condenses at high pressure.
Condenser	In the context of a heat pump system, the condenser is the heat exchanger, that receives high pressure refrigerant in the form of a gas and rejects its associated heat to the heat distribution system. In doing so, the refrigerant gas cools, condenses and changes state to a liquid.
Electric Boiler	An electric boiler is a device that uses electrical energy to boil water, serving as an alternative to traditional gas or oil boilers. It generates steam using electricity, rather than combustion of a fuel source and can be used as a direct replacement for fossil fuel boilers in industry, hospitals etc.
Evaporator	In the context of a heat pump system, the evaporator is the heat exchanger, that receives low pressure refrigerant in the form of a liquid and absorbs heat from a source, albeit waste heat, air, ground etc. In doing so, the refrigerant liquid heats up, evaporates and changes state to a gas.
Heat Pump	A heat pump is a sealed loop that contains a refrigerant gas. It uses an electrically driven compressor to compress the gas, taking it from a low temperature and pressure to a higher temperature and pressure. One of the main factors that effects heat pump system efficiency is the difference between the mean temperature in the evaporator and the temperature in the condenser.
Maximum Import Capacity	Maximum Import Capacity (MIC) is the upper limit on the total electrical demand you can place on the network system. For large energy consuming organisations, understanding and assessing MIC is paramount before embarking on any electrification journey.

Obligated Parties	Energy suppliers and distributors that sell more than 400GWh of energy per year are Obligated Parties under the Energy Efficiency Obligation Scheme. All Obligated Parties are set annual targets based on their sales volumes. Each Obligated Parties' target is divided into three sectors: 85% for cross-sector, 10% for residential and 5% for energy poverty.
Refrigerant	A refrigerant is a working fluid used in the refrigeration cycle of air conditioning systems and heat pumps where in most cases they undergo a repeated phase transition from a liquid to a gas and back again. Refrigerants are heavily regulated because of their toxicity and flammability and the contribution of CFC and HCFC refrigerants to ozone depletion and that of HFC refrigerants to climate change.
Scope 1 GHG Emissions	Scope 1 emissions are direct greenhouse (GHG) emissions that occur from sources that are controlled or owned by an organisation (e.g. emissions associated with fuel combustion in boilers, furnaces, vehicles)
Technology Readiness Level	Technology readiness levels (TRLs) are a method for estimating the maturity of technologies. TRLs enable consistent and uniform discussions of technical maturity across different types of technology. TRL is determined during a technology readiness assessment (TRA) that examines program concepts, technology requirements and demonstrated technology capabilities. TRLs are based on a scale from 1 to 9 with 9 being the most mature.
Thermal End User	A thermal end user is the ultimate end user of the thermal energy. It is important to understand the complete list of thermal end users in a facility, as well as the thermal properties and conditions these end users operate at, i.e. set temperature, flow etc.
Thermal Sink	A thermal sink absorbs heat from a distribution system. It is analogous to a thermal end user described above.
Thermal Source	A thermal source supplies heat to a system. In the context of an industrial heat pump system, the thermal source may be a waste heat source from a cooling tower, an existing air-cooled chiller, a specific process or could be the air, ground, river etc.
Thermal Store	Thermal stores are used to store the heat generated by heat pumps or electric boilers for later use. While, like buffer tanks, they reduce the number of stop-start cycles, thermal stores generally operate on a longer time frame and tend to be significantly larger than a tank simply used as a buffer.

References

Sustainability Legislation and Policy

Climate Action and Low Carbon Development Act 2021 Climate Action and Low Carbon Development (Amendment) Act 2021 (irishstatutebook.ie) (Ireland, 2024)

Climate Action Plan 2024 (CAP24) is the third annual update to Ireland's Climate Action Plan gov - Climate Action Plan 2024 (www.gov.ie) (DECC, 2024)

The European Green Deal is a growth strategy that aims to make the EU climate-neutral by 2050 and protect the environment. The European Green Deal - European Commission (europa.eu) (EU, 2024)

The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. The Paris Agreement | UNFCCC (United Nations, 2024)

The Roadmap for the Decarbonisation of Industrial Heat is a concise policy document designed to translate the policies in the Climate Action Plans and EU regulations into a clear and coherent decarbonisation pathway for businesses Roadmap for the Decarbonisation of Industrial Heat - DETE (enterprise.gov.ie) (DETE, 2024)

General References

The Future of Heat Pumps – World Energy Outlook Special Report The Future of Heat Pumps (iea.blob.core.windows.net) (IEA, 2022)

National Programmes / Initiatives

Capital Investment for Decarbonisation Processes | Enterprise Ireland (enterprise-ireland.com) (Enterprise Ireland, 2024)

Energy Efficiency Obligation Scheme (EEOS) | Business Grants | SEAI (SEAI, 2024)

EXEED Certified Program | Business & Public Sector | SEAI (SEAI, 2024)

Support Scheme for Renewable Heat | Business Grants | SEAI (SEAI, 2024)

Sustainable Energy Authority of Ireland

Three Park
Place Hatch
Street Upper
Dublin 2
Ireland
D02 FX65

w: www.seai.ie
e: info@seai.ie
t: 01 8082100