HeatNEWS District Heat and Industrial Step-by-Step Guide

Empowering Industry: Flexibility in Heating for Ireland's Electricity Grid

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Introduction - What is demand side response / demand flexibility

Demand side response (DSR) refers to the reduction of electrical consumption in order to balance the electricity grid and keep it stable. When demand is high or generation is low, electrical consumption is reduced, instead of fossil fuel based dispatchable generation being increased. This process is represented graphically in Figure 1 below.

Electrical heating equipment (e.g. heat pumps, immersions, electric boilers, etc.) can be turned down or off in order to provide flexibility to the grid and for heat asset owners to earn benefits. These benefits are usually in the form of reduced electricity bills or explicit payments for being available to provide ancillary services[1] to the electricity grid.

The most common method of accessing these benefits is through the use of a smart meter in combination with time-of-use tariffs (i.e. 'smart' tariffs or 'Nightsaver' tariffs). Time-of-use tariffs allow operators to prioritise electricity use during times of the day when electricity is cheaper. This is particularly true for smaller consumers, e.g. domestic dwellings where the cost and complexity of engaging with and enabling these to operate in response to specific events can be more challenging than for larger installations. There is also a variety of further implicit and explicit flexibility markets that different customers can participate in. These are described in greater detail in Step 1 of this document.

Overview of the process

This section outlines the step-by-step process for large-scale heat asset owners (typically the industrial and district heating sectors) to follow in order to realise the benefits of operating your heating system in a more flexible way.

The first step identified is to familiarise yourself with the flexibility markets from which revenues can be earned. This will provide a good starting point from which to progress to the following steps and provide greater context when looking at the flexibility options open to you. It will inform what information is important to gather from manufacturers, operators, etc., which will facilitate valuable discussions with aggregators or others looking to procure flexibility services.

The second step is to carry out an assessment of your heating equipment to provide flexibility. This will provide an indication of the markets/services you may be able to participate in, as well as providing an opportunity to gather relevant data, such as manufacturer data, operational data, etc., which will inform the discussions you will have with flexibility product suppliers (aggregators, transmission system operator (TSO), distribution system operator (DSO), etc.)

The third step is to engage with the flexibility service provider. In many cases this will likely be an aggregator but if in case where the flexibility than can be provided exceeds 4MW[2] this could be EirGrid/SEMO. If this exceeds 10MW it has to be Eirgrid/SEMO. ESB Networks are also developing their own flexibility products and are more likely to engage with smaller market participants than EirGrid.

Step 4 is to make the changes necessary to allow the heat asset to provide the different forms of flexibility. For large-scale installations that focus on ancillary services which require a response time of less than 20 minutes, this change would take the form of an additional controller. For larger installations to take advantage of variable tariffs may only require a change to the control logic within their existing controls. However, an additional controller may be required for smaller installations alongside this.

The final step, Step 5, is where the savings/revenue earning potential of operating flexibly are realised.

[1] Also known as system service or in the Irish context DS3
[2] As per the Grid Code

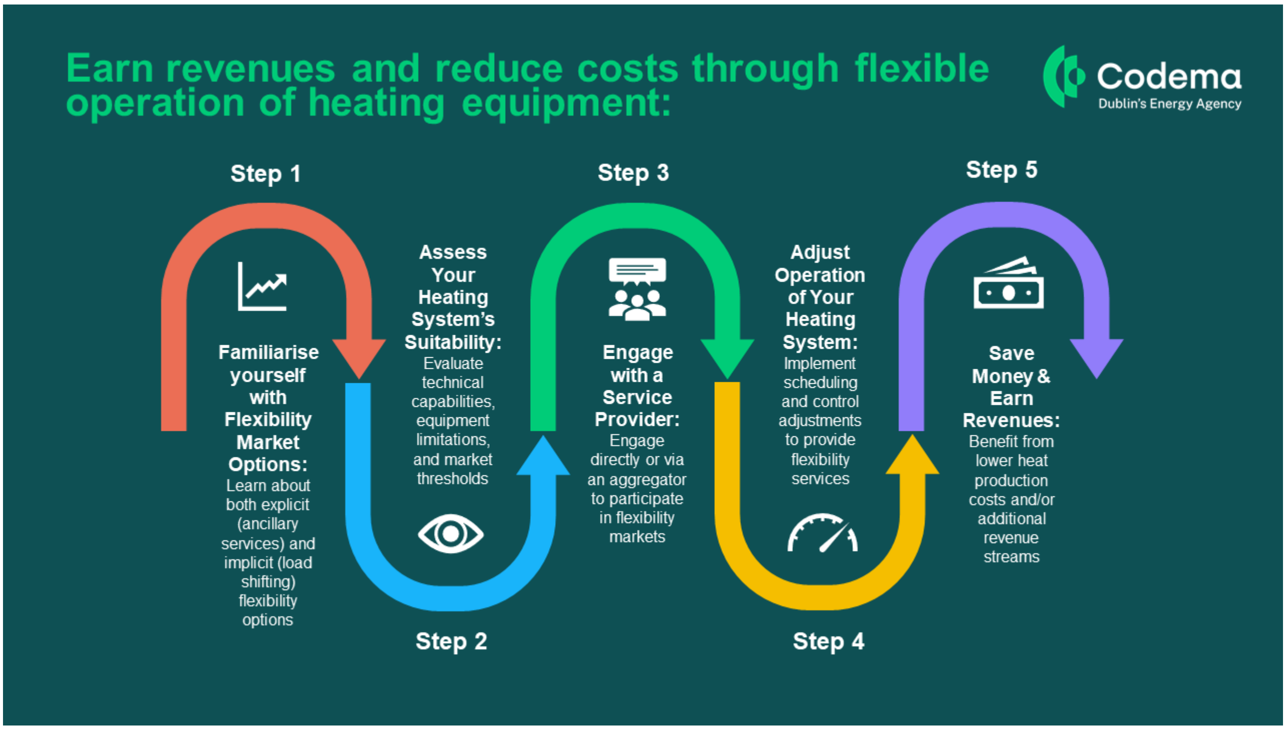

Figure 1: Step-by-step process for earning benefits from flexible operation of heating equipment

Step 1 - Familiarise yourself with your flexibility market options

Flexibility markets can be split into two main groups, called implicit and explicit flexibility markets. A definition of each type is provided in sections 1.1 and 1.2. A list of the implicit and explicit flexibility markets in Ireland is provided in Figure 2. The grey text in this figure indicates the service this particular market provides to the grid.

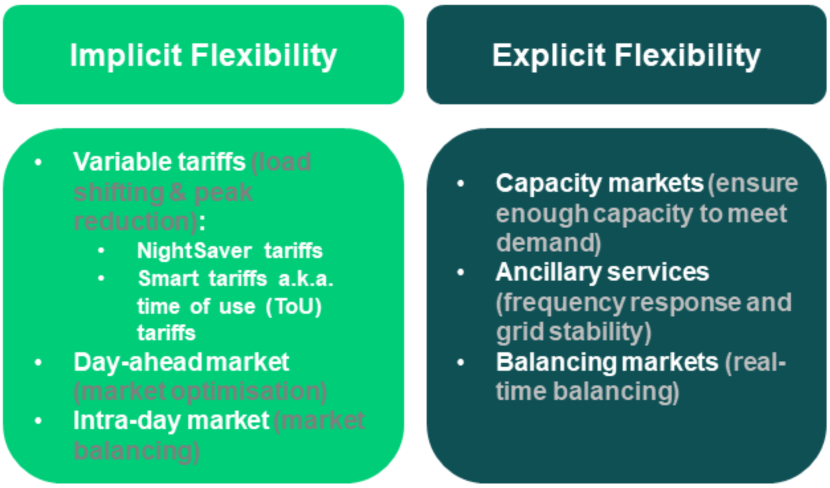

Figure 2: Summary of the current flexibility markets in Ireland

1.1 Implicit Flexibility Markets

Implicit flexibility markets use electricity price variations to encourage consumption during specific times, e.g. 'NightSaver' tariffs that offer lower prices at night, and smart tariffs (also known as Time-of-Use or ToU tariffs), which charge more during peak demand periods). These market options can apply to installations across a broad range of electricity customers, from small domestic customers up to large industrial customers, and rely on the consumer choosing to change the timing of their consumption in response to these price signals, such as heating their hot water tank at night when it is cheaper to do so.

The day-ahead (DAM) and intra-day (IDM) markets are also examples of implicit flexibility markets, as these use price signals that influence consumption. Demand side response units do not typically engage in these markets for a number of reasons. Firstly, these markets are structured around increasing generation of electricity rather than decreasing demand; i.e. generators bid into these markets, whereas demand side flexibility reacts to market conditions. Secondly, the value of engaging in the DAM and IDM markets is often lower than explicit flexibility markets and requires firm commitments that can be challenging for DSR actors to forecast and provide without a certain risk of underdelivery and the associated penalties. As a result, the potential for acting in the DAM and IDM markets is not covered in detail as part of this guide.

1.2 Explicit Flexibility Markets

Explicit flexibility (capacity market, ancillary services[3] and balancing markets) refers to when an electricity customer has an agreement in place to provide flexibility. There are different forms of agreements, such as an agreement to provide ancillary services to the transmission system operator (TSO) directly (only if electrical demand reduction of at least 4MW is possible), or an agreement with a demand side aggregator to provide system services. This market generally focuses on larger consumers due to the capacity thresholds for engaging in this market. However, these capacity thresholds can be overcome by aggregating multiple installations together, but this also adds complexity and costs, such as the additional costs of engaging with

[3] The ancillary services (i.e. system services) market in Ireland is known as DS3 (Delivering a Secure Sustainable Electricity System)

specific customers and installing additional controls that respond quickly to real-time system requirements of the grid. Participants in the balancing market also need to pre-qualify and demonstrate their flexibility prior to participation.

1.2.1 Capacity Market

The capacity market in Ireland is operated by SEMO. Its purpose is to ensure that there is enough demand flexibility or electricity generation to meet peak electricity demand. Participants in this market are paid to guarantee their availability to reduce demand when required during periods of peak demand or constraint. This guarantee is typically made a year in advance. It should be noted that payment is received to be available to turn down demand whether or not the need actually occurs. To participate in this market you can engage with a demand response aggregator or if your load reduction capacity is 10MW or above you can engage directly with SEMO and EirGrid.

1.2.2 System Ancillary Services

System ancillary services are services that are provided to ensure a stable and secure electricity grid. These include services like frequency response, grid balancing, etc. Traditionally, the need for these services was not significant due to traditional thermal power plants having less variability in their operation and the in-built inertia control of having heavy spinning turbines. As renewable generation is more variable, increased levels of renewable generation on the grid has resulted in a greater need for the provision of separate ancillary services.

Table 1: System Services/Ancillary Services (DS3) Descriptions

Ancillary service name	Description[4]
Fast Frequency Response (FFR)	Fast Frequency Response: In the event of a grid disturbance, your heating load is reduced rapidly, providing ultra-fast support to arrest frequency deviations and mitigate rate of change of frequency (RoCoF) with minimal disruption to your heating. The required response (0.15 seconds) time is often too fast for many heat assets to be able to provide this service.
Primary Operating Response (POR)	Primary Operating Reserve: When frequency falls, a brief reduction (for approximately 10 seconds) of your heating load is requested to help arrest the decline; the interruption is very short so that your heating is affected only momentarily. Unlikely to require any form of thermal energy storage (TES).
Secondary Operating Response (SOR)	Secondary Operating Reserve: Your heating load may be adjusted over 15–90 seconds following a disturbance to help restore frequency, with only a short-term, managed impact on your heating. For some systems a small amount of TES may be required to maintain supply.
Tertiary Operating Response 1 (TOR1)	Tertiary Operating Reserve 1: A further, planned load reduction from 90 seconds up to 5 minutes supports short-term grid recovery with a modest, scheduled curtailment of heating. For some systems a small amount of TES may be required to maintain supply.
Tertiary Operating Response 2 (TOR2)	Tertiary Operating Reserve 2: This service calls for a controlled reduction in your heating load between 5 and 20 minutes after an event, providing sustained support during longer disturbances. This would likely require some form of TES, although of very modest scale.
Replacement Reserve DeSynchronised (RRD)	Replacement Reserve (Desynchronised): If an event lasts longer, a pre-planned load reduction between 20 minutes and 1 hour “replaces” lost capacity, affecting your heating in a controlled, scheduled manner. This would typically require some form of TES for most heating applications.

[4] https://cms.eirgrid.ie/sites/default/files/publications/EirGrid-DS3-System-Services-_Regulated-Arrangements_draft.pdf

Ramping Margin 1 (RM1)	Ramping Margin 1: Over a 3-hour period (1 hour ramp + 2 hour sustainment), your heating load is gradually modulated to help the grid ramp up or down smoothly with minimal abrupt changes. This would typically require some form of TES for most heating applications.
Ramping Margin 3 (RM3)	Ramping Margin 3: Your heating load is adjusted over an 8-hour window (3 hour response + 5 hour sustainment) to help integrate variable renewables with a gradual, extended curtailment. This would typically require some form of TES for most heating applications.
Ramping Margin 8 (RM8)	Ramping Margin 8: For extended grid stress, your heating load undergoes a gradual, planned reduction over 16 hours (8 hour ramp, 8 hour sustainment) with very gradual changes. This would typically require some form of TES for most heating applications.

The figure below highlights the response times required for the different ancillary services in Ireland. For example, in the case of POR, your demand would need to reduce within 5 seconds of the event (in this case the event being the fall in grid frequency) and would be allowed to increase again 15 seconds after this event.

Figure 3: Response times for different ancillary services

The revenues earned for these services are based on an electricity consuming assets (a heat pump or electric boiler in this case) ability to be turned down, even if this demand reduction is not dispatched by the system operator. This means that you are paid for being able to respond, rather than earning revenues from an actual event occurring. This earning potential is based on the mega-watts of electricity demand reduction that is possible within the required response times for each system service. The revenues in €/MWh for the different ancillary services are set out in Table 2. A multiplier, known as a scalar, is applied to these prices based on the system non-synchronous penetration (SNSP). The SNSP is the percentage of wind and solar in the system at a given time. This means that demand that can be reduced during periods where renewable generation accounts for a high proportion of generation on the grid will earn higher revenues in €/MWh during these periods. The periods with the highest SNSP are typically pm to am. This

Table 2: Response time, downtime duration requirements and service prices and scalars for the various relevant ancillary services in Ireland

Ancillary Services	FFR	POR	SOR	TOR 1	TOR 2	RRD	RM1	RM3	RM8
Allowable capacity range ($MW_{electrical}$)[5]	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.0
Demand down speed	0.1 secs	5 secs	15 secs	90 secs	5 mins	20 mins	1 hr	3 hrs	8 hrs
Duration of down time	9.9 secs	10 secs	75 secs	3.5 mins	15 mins	40 mins	2 hrs	5 hrs	8 hrs
Demand up speed (secs)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Price (€/MWh)[6]	2.16	3.24	1.96	1.55	1.24	0.56	0.12	0.18	0.16
Scalar @ SNSP less than or equal to 60%[7]	1	1	1	1	1	1	1	1	1
Scalar @ SNSP greater than 60%	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Scalar @ SNSP greater than 70%	4	4	4	4	4	4	4	4	4

1.2.3 Balancing Market

This market provides real-time balancing of the grid by either reducing demand or absorbing surplus electricity. This market is closer to real-time and typically offers are made hours to seconds before delivery. Unlike DS3 and Capacity Markets, payments in the balancing market are based on actual dispatch events, rather than availability. To participate in the balancing market, heat production operators or partnering demand side aggregators need to register as a Demand Side Unit. For direct participation (without using an aggregator) you will need at least 4MW of load reduction capacity to engage with EirGrid and SEMO.

1.3 Future Flexibility Markets

A number of flexibility products are in development at both the TSO and DSO level. This section outlines some of the potential new markets that will become available in the coming years and provides some commentary on what these services are and the potential future role of large-scale heating assets and thermal storage in providing these services.

[5] https://cms.eirgrid.ie/sites/default/files/publications/DS3-SS-Protocol-v3.0-tracked.pdf - The proposals to lower the performance monitoring threshold for POR, SOR and TOR1 from 1 MW to 0.5 MW are supported by industry, while the suggested reduction for FFR (to 0.2 MW) was not adopted. Hence FFR is set at 0.5 MW.

[6] https://www.semcommittee.com/publications/sem-23-020-system-services-tariffs-rate-review-decision-letter

[7] https://cms.eirgrid.ie/sites/default/files/publications/DS3-SS-Protocol-v4.1-October-2024.pdf

1.3.1 Future Arrangements for System Services (FASS) and Day-Ahead System Services Auction (DASSA)

The current DS3 ancillary services market is due to run until December 2026[8]. Following this, a new market arrangement called DASSA will start operation in January 2027. This market is expected to include 24 flexibility products (compared with the current 14 flexibility products in DS3 - eight of which are suitable for demand response). This will also include demand-up products where consumers can get paid for increasing demand when required, while the current DS3 system only facilitates demand reductions. These demand-up products could be particularly of interest for equipment such as electric boilers with TES that have the ability to absorb large quantities of electricity within seconds. This new market will take the form of an hourly auction and is expected to increase competitiveness across multiple different technologies that cover a broader range of storage durations. Thermal storage has a very broad duration range, from seconds to months, which can cost-effectively cater to these new flexibility products.

In the case of the ancillary services market, it can be assumed that any installation / controller installed to provide services to the current DS3 market will also be compatible for providing services under this new DASSA/FASS market.

1.3.2 ESB Networks Flexibility Product

ESB Networks are currently in the process of developing their own local Demand Flexibility Product[9], which is designed to manage local congestion on the grid. This will allow flexible assets to reduce or shift the time of their demand in response to signals from ESB Networks. This product will contract flexible service providers (FSPs) to operate within an 'operating envelope' that ESB sets for each day. This envelope sets out the range of allowable power consumption based on local network needs.

The product includes long-term contracts (up to 15 years), performance-based payments and financial incentives to ensure that providers deliver flexibility reliably. In cases where the FSP operation deviates from the 'operating envelope' in order to take advantage of opportunities in other markets, a technoeconomic 'sharing factor' will determine how much of their external market earnings they can keep. The first tenders for the DFP are expected in 2025, with a goal of contracting 500 MW of flexibility capacity by 2030.

For more in-depth details of this product, please engage with ESB Networks, who are very open to having discussions with large heat installations (particularly those with substantial thermal storage) to provide local flexibility in areas where it is required. It is worth noting that, as this product evolves, it may look to address different technical characteristics, where certain locations may also focus more on consuming excess renewable energy (demand up) rather than addressing congestion due to high demand, or may be smaller in scale, addressing congestion at lower voltages of the electricity network, or directly connected with new demand connections.

Step 2 - Assessing your heating system's suitability for providing flexibility

The operational characteristics of each heating asset have been assessed in order to determine their technical suitability for providing the various flexibility services. This assessment is summarised inTable 3 to act as a quick means for both asset owners and demand response aggregators to identify suitable flexibility markets for installed or planned heat production equipment. It should be noted that this table only considers the response speed and the scale (electrical input in MW) of the heat asset itself. The allowable duration of downtime for each installation will vary with the demand during that period and the thermal storage capacity (in MWh), and is not being considered in this table. Any installation that is marked with an orange 'a' in the

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[8] https://cms.eirgrid.ie/sites/default/files/publications/SOEF-Markets-FASS-DS3-System-Services-Tariffs-FASS-The-Gap-Consultation-Paper-January-2025.pdf

[9] ESB Networks demand flexibility product proposal consultation document 22nd October 2024 - https://esbnetworksprdsastd01.blob.core.windows.net/media/docs/default-source/publications/demand_flexibility_product_proposal_consultation.pdf?sfvrsn=4eafb605_0

table indicates the likely need for aggregation of multiple installations to provide the required capacity to provide this service. It should be noted that for smaller installations (of less than 200kW flexible electrical load for individual sites or less than 100kW for a site that is part of a group of sites with the same owner[10]), the cost, time and effort required to aggregate them for ancillary services can present a significant challenge.

It can be seen from this table that none of these heat production units have the 0.15 second response time required to provide FFR services. Following discussions with multiple manufacturers, the response time of large-scale heat pumps is expected to be anywhere from 30 seconds to 5 minutes and will vary based on compressor type, refrigerant used, the type of operation used for reducing demand (e.g. turning the heat pump fully off versus turning the demand down to a part-load condition. It was noted by demand response aggregators that chillers, which provide cooling, have been used for fast-acting demand response (faster than the 30 second lower range provided by manufacturers) for decades. As chillers and heat pumps are extremely similar pieces of equipment, it is likely that the response times for heat pumps will reduce in the future as their flexible operation becomes more widely adopted and understood. The phone symbol (📞) in the table indicates that asset owners should contact their heat pump manufacturer in order to find where within this likely range the response time for their specific heat pump lies.

It should also be noted that this table does not consider the potential impact of on/off cycles on the lifespan and maintenance requirement of these installations, but is something that may be considered. However, based on conversations with manufacturers, in general, 3-4 on/off events per hour would still keep the heat pump within the manufacturer’s warranty, and many of the ancillary services currently have events that only occur this many times per year. Electric boilers are also highly resilient to regular on/off events.

It is important to note that, in order for demand to be turned down, it must first exist; i.e. heating equipment must be producing heat/consuming electricity in order for it to be turned down to provide these services. In the case of electric boilers, in many cases these may be used as backup and therefore may not be in a position to be turned down to provide these services. Future developments in the flexibility markets where turning up demand will also be allowed for providing ancillary services represents a real opportunity for this fast-acting dispatchable demand, especially when paired with TES.

The table below provides a general indication of the suitability of heat pumps and electric boilers to provide various services. In general, electric boilers are well suited to fast reductions in load. A breaker switch can be used to quickly cut power to the boiler without any significant impact or damage to the boiler itself. From discussions with manufacturers and electric boiler operators, these boilers can be switched off in less than 1 second, but don’t quite achieve the 0.15 seconds response time.

Table 3: Heat production equipment typical suitability for providing ancillary services

[10] Based on discussions with demand response industry experts

Ancillary Services		FFR	POR	SOR	TOR 1	TOR 2	RRD	RM1	RM3	RM8
District heating and Industrial	Heat pump	✗	☎	☎	☎	✓	✓	✓	✓	✓
	Electric boiler	✗	✓	✓	✓	✓	✓	✓	✓	✓
Commercial[11]	Heat pump	✗	☎	☎	☎	a	a	a	a	a
	Electric boiler	✗	a	a	a	a	a	a	a	a
Domestic	Heat pump	✗	☎	☎	☎	a	a	a	a	a
	Immersion	✗	a	a	a	a	a	a	a	a

2.1 What controls or operational changes can I make to deliver flexibility

Flexibility can be delivered by changing the operation/controls of your heat production equipment in a number of different ways. This includes:

- Reducing heat output either by turning down or turning off heat production (limited by the turndown ratio of the plant if owner/operator/manufacturer wants on/off events to be avoided and by the amount of thermal storage installed to avoid undesired disruption to your heat supply),
- Reducing output temperature (limited by minimum temperature end use requirements at different times).

For more in depth discussion on control requirements and controller costs see section 4.1

2.2 What are my thermal storage options

2.2.1 Reasons for using thermal energy storage

Before exploring thermal storage options, it is important to first highlight the key reasons for incorporating Thermal Energy Storage (TES) into your heating system. TES offers four main benefits:

1. Allows your heating equipment to operate at the load condition that is most efficient, independently of heat demand. This allows maximum efficiency/COP of heat pumps to be attained and removes the need to run less efficient equipment such as boilers during periods where demand is outside of the operational range of more efficient heat production equipment
2. Allows electricity consumption to be moved to periods where electricity is cheaper, thereby reducing the cost of heat production
3. Allows heat production to be interrupted without any interruption to heat supply, which enables provision of flexibility services without negatively impacting your primary business and also acts as a backup heat supply if there is an outage of heat production due to maintenance or malfunctioning equipment

[11] The expected heat capacity of commercial heat pumps is assumed to be 45kW to 1MW, in line with the SEAI Heat Pump Implementation Guide. This can be converted to electrical input using the appropriate CoP.

4. Allows a greater contribution from heat production equipment to total heat demand without the need to increase the installed heat production capacity, keeping the cost of the heat production equipment low

2.2.2 Types of thermal energy storage

There are many different types of thermal energy storage. The use of thermal storage can allow participation in a wide array of grid service markets, particularly where the duration times are longer or for applications where interruption to heat supply can cause issues. It also greatly improves the benefits from implicit flexibility to allow demand to be moved to periods when electricity is cheap. This has a potential added benefit of moving demand into periods when system non-synchronous penetration (SNSP) is greater and therefore the revenue-earning potential from providing system services is increased. Aside from the benefits of TES to maximise returns from both implicit and explicit flexibility markets, it should also be noted that TES will allow your heat asset to operate in a condition that allows efficiency to be maximised, avoiding part-load conditions where efficiencies can be lower. The table below provides an overview of the different forms of thermal energy storage explored as part of the HeatNEWS project.

Table 4: Typical characteristics of different TES installations (temperature, cost, storage duration, space requirement)

TES Option	Temperature range (°C)	Typical cost range (€/kWh)	Typical duration range	Typical space requirement (m2/MWh)
Large-scale tank	35-120	3-35	mins-days	2-7
Domestic cylinder	35-85	60-400	mins-hours	20-100
Phase-change material	15-200	300-1,200	mins-days	1-2
Pit storage	35-90	0.1-10	weeks-months	5-15
Aquifer storage	15-90	1.3-5	weeks-months	negligible
Borehole	15-90	1-10	weeks-months	0.3-5 (during installation phase)
Molten salt	200-800	10-100	secs-days	2-4
Thermo-chemical material	150-550	20-80	days-months	0.2-1
Sand battery	200-600	5-20	hours-weeks	1-3
Hydrogen storage (for comparison)	N/A	11,000	hours-months	negligible (underground)
Battery storage (for comparison)	N/A	600-1,000	secs-days	35-45

The figures above have been developed by Codema to help heat asset owners to select the appropriate thermal energy storage technology for their application. These figures look at the typical operational and technical characteristics of the different types of thermal energy storage.

Figure 4 below outlines the typical temperature and storage duration ranges for the different forms of TES. The graph also includes typical temperature ranges for different applications, such as building heat demands (space heating and hot water), process heating, and power generation. It should be noted that approximately 40% of process heat demand in Ireland will require less than 150°C[12]. Given the profile of

[12] Based on figures from the SEAI national heat study - https://www.seai.ie/sites/default/files/publications/Heating-and-Cooling-in-Ireland-Today.pdf

large industrial heat users in Ireland (dairy, pharmaceutical, food and beverage industries, etc.), it is likely that a significant proportion of industrial heat demand in Ireland will be below 200°C (i.e. for evaporators, drying, sterilisation, CIPs systems, autoclaves, brewing etc.), but exact figures on this are not currently available. The minimum temperature for power generation is indicated as being 75°C for organic rankine cycle (ORC) engines; however, a temperature in excess of 120°C is preferred by industry to achieve reasonable efficiencies. This 120°C figure has been included in Figure 4 below. It is also worth noting that steam turbines will typically use steam in the 400°C - 600°C range[13].

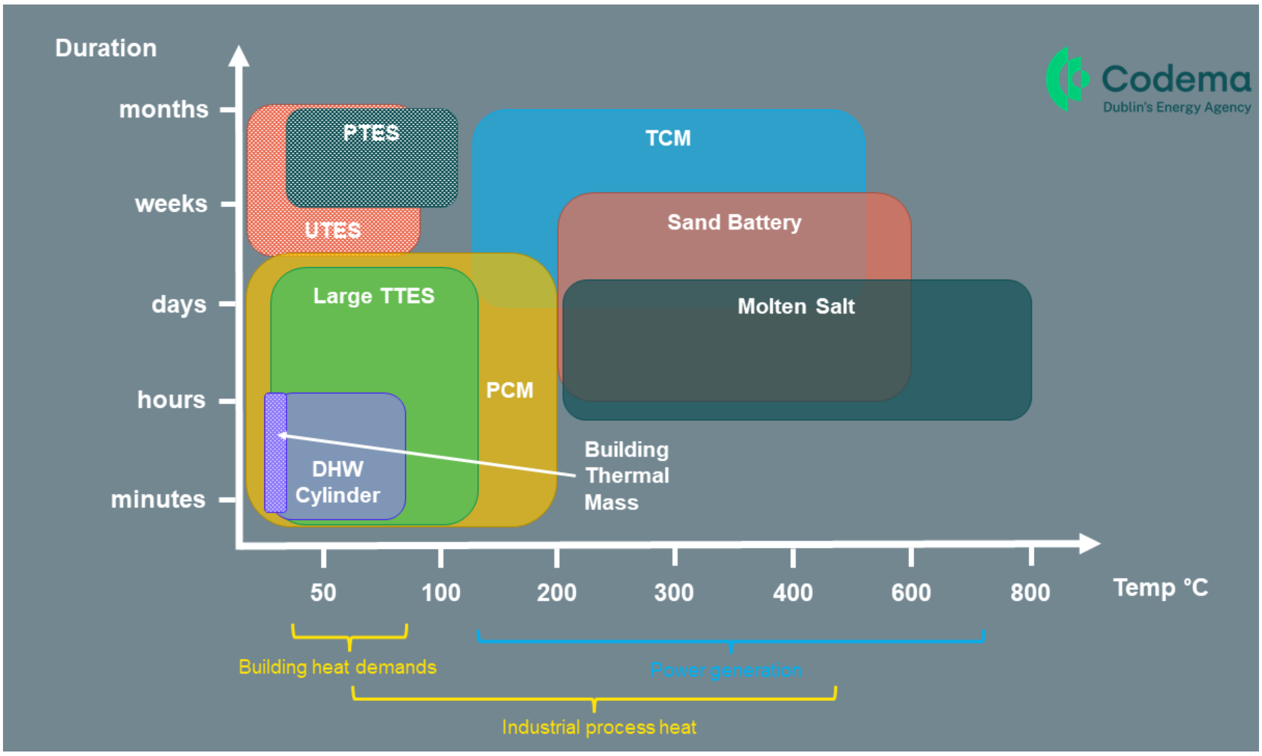

Figure 4: Typical temperature and duration ranges for thermal energy storage technologies

Figure 5 below outlines the typical cost and space requirements for the different forms of TES. It should be noted that the cost of the building thermal mass storage is considered zero, as this will already exist for the purpose of providing shelter to the building occupants. However, there may be a cost of upgrading controls that is not considered in this graph. There may be other forms of storage that already exist in a heating system, such as tank storage in an existing building, which could also be considered to have zero cost, but for the purpose of this graph it is assumed that these installations are new and require an upfront investment.

[13] Based on information from Wärtsilä, which aligns with figures from the BEIS CHP study (2021) https://assets.publishing.service.gov.uk/media/602a7b6bd3bf7f031e1bdcdd/Part_2_CHP_Technologies_BEIS_v03.pdf

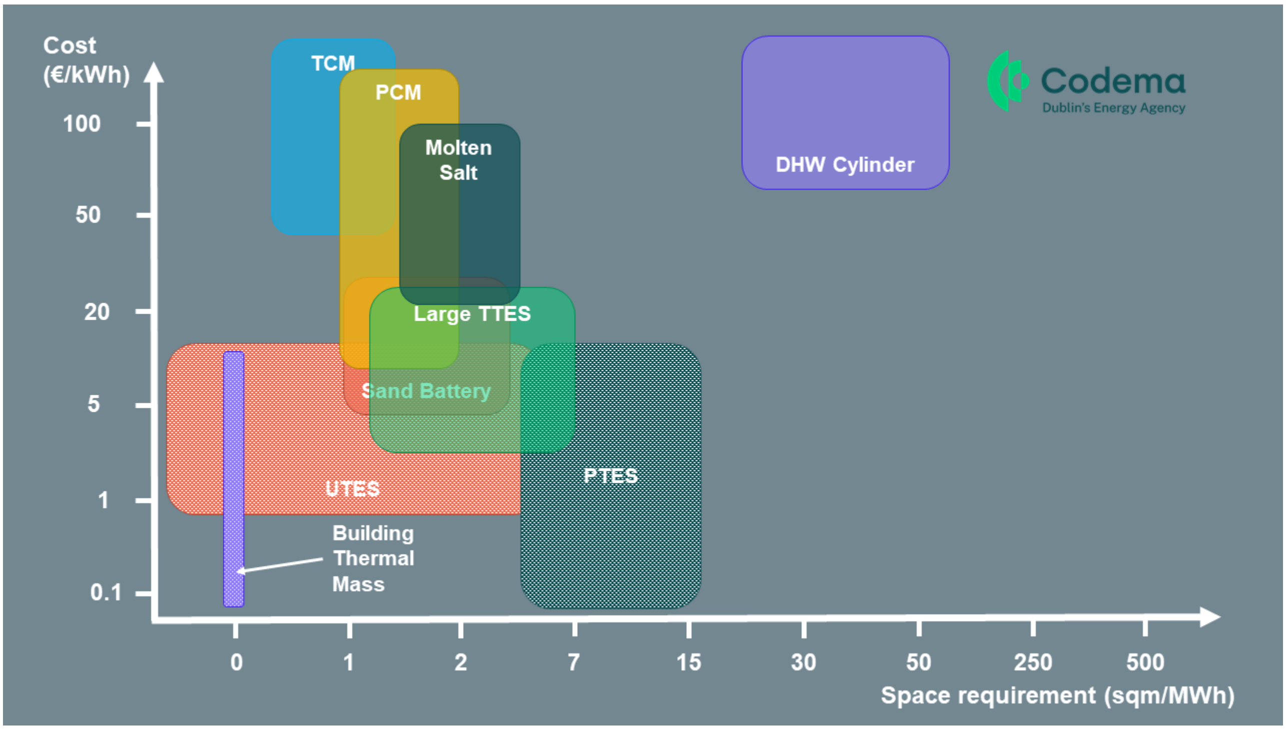

Figure 5: Cost - Typical cost and space requirement graph for thermal energy storage technologies

2.2.3 Engaging with TES manufacturers

The diagrams in the previous section provide an indication of the thermal storage technologies that may best suit your application. Following this step, you will need to engage with manufacturers/suppliers of these storage units in order to ensure that the installation matches your exact requirements and to determine the specific cost for you to install this on your site.

In order to facilitate discussions with these manufacturers, Codema has set out a list of questions that these manufacturers are likely to ask in order to determine the best solution and to provide an accurate quote for the installation of your TES. This also includes some background as to why these questions are important and what needs to be considered to answer them.

Table 5: Typical questions a TES manufacturer will ask

Question	Important considerations
What size of TES is required?	The optimum size of TES in MWh would typically be determined by some modelling of your heating system. This model would also take into account important factors such as variable electricity rates, operating temperatures, demand profiles, heat production efficiency (including at part load) and turndown ratios.
Pressurised storage or not?	There are three main considerations when it comes to deciding if your TES will be pressurised or not. The first of these is space availability - if you have limited space then you may consider a pressurised vessel, which takes up less space than an unpressurised/atmospheric pressure vessel. The second consideration is cost, as pressurised vessels are more expensive. The third consideration is heat losses, as pressurised TES allows for direct connection to the system (with no hydraulic break) these results in higher efficiencies.

Operating temperatures required?	The supply temperature required for your specific heating application will inform the top temperature for your TES and indicate which form of TES may be best suited to your application. The difference between the flow and return temperatures (commonly referred to as the delta-T) of your system will define the volume of storage medium required to provide the required MWh of storage. Certain storage media, such as PCM, also have challenges in providing a large delta-T and may be less united for systems that require this or may need different hydraulic arrangements for their use. You may also consider storing heat at a higher temperature than your primary heat production equipment would normally deliver to maximise the MWh storage capacity for a given volume of TES.
What space is available?	Different types of TES that use different storage media have different energy densities. Certain types of TES, such as PCM, can also fit into different footprints such as rectangular footprints, which can facilitate better utilisation of floor space, as opposed to more traditional tank storage, which is usually circular.
What filling level is suitable?	This is typically in the 85%-95% range.
Is transport to site required?	

2.2.4 Funding TES Installations

Thermal energy storage can be funded in a number of ways, depending on the capital you have available. If you have the funds available, purchasing the TES up-front secures all the savings/benefits for your business. If you don't have the capital available, you may look at possible grant or third-party funding to allow you to install your TES. In the case of grant funding, this would likely be available based on the carbon saving/energy efficiency potential and would be unlikely to cover the full cost. In terms of third-party funding, the payback for the third party may take the form of sharing savings with an Energy Services Company (ESCo).

Outside of the more traditional means of funding TES, an alternative funding model was explored as part of this study. This alternative model explored whether demand response aggregators could provide the capital to install the TES, and in turn they would earn a greater share of revenues from providing flexibility services. All the demand response aggregators engaged in relation to this model were open to this potential funding model for TES.

2.2.5 Space efficiency of thermal storage

For comparison, the relative land use and cost per MWh of large-scale tank thermal energy storage (TTES), pit thermal energy storage (PTES) and battery energy storage systems (BESS) are shown in figure 6 below. This highlights in real terms what the space saving potential of TES would be for a 200MWh installation. This is particularly relevant for sites with limited space and for fulfilling utility-scale storage needs in locations where land costs and space availability are important concerns.

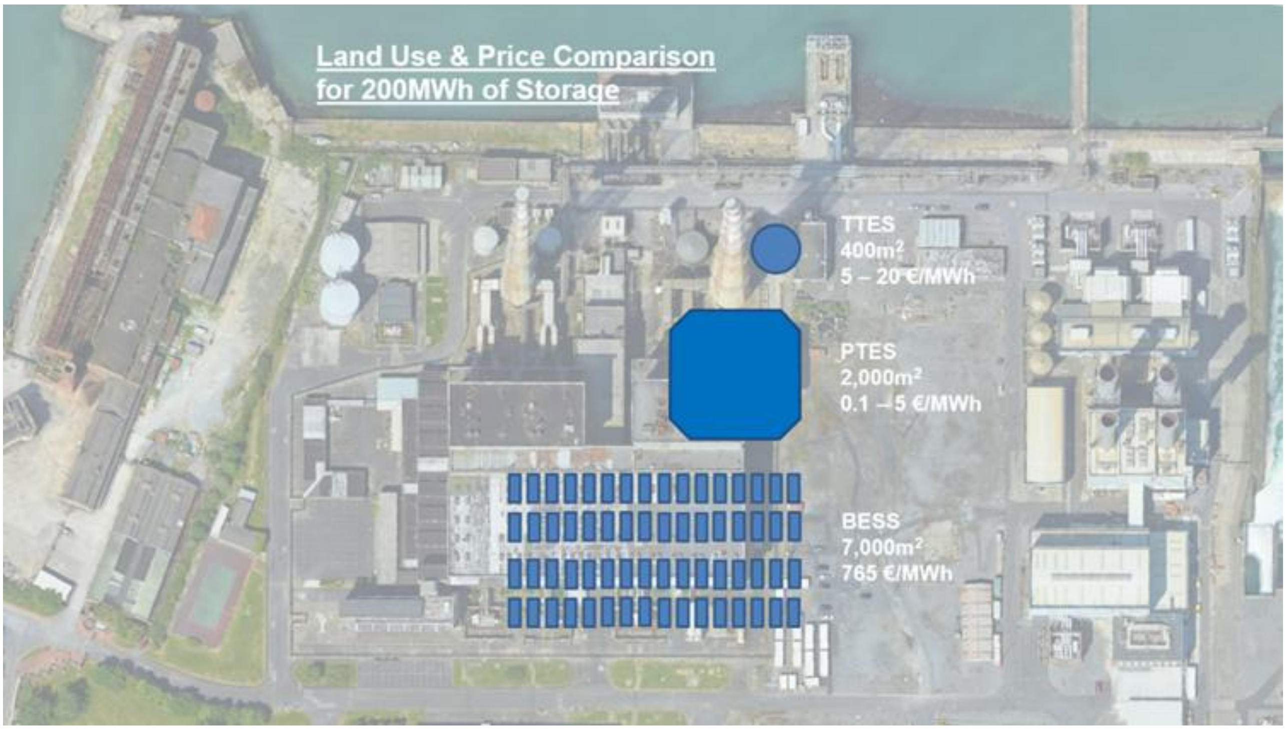

Figure 6: Energy storage comparison on cost and land use for TTES, PTES and BESS[14]

2.2.6 Resource efficiency of thermal storage

An area that should also be considered is the relative resource efficiency of typical thermal storage (tank storage) when compared to other forms of storage such as batteries. Figure 7 below provides an indication of the overall breakdown of materials used in large-scale tank thermal energy storage and Lithium Iron Phosphate (LFP) battery energy storage systems. The overall weight of materials per MWh of storage capacity for the BESS system is approximately three times greater than that of the TTES (approximately 9tonnes/MWh for BESS, compared with 3tonnes/MWh for the TTES[15]). It can be seen that the majority of the materials used for the BESS system are metals (steel, aluminium, copper) and rare earth minerals (lithium, graphite), which together make up 61% of the total weight of the BESS. The TTES consists predominantly of water, which makes up 94% of its final weight. The main material used in the TTES construction is steel which accounts for 4% of the final weight. It is worth noting that many BESS systems are modular and therefore will have a similar proportion of materials as they scale above the indicative 5MWh unit shown. The thermal energy storage tank will have a reducing proportion of materials as it increases in size due to the non-linear relationship between the volume of the tank and its surface area -i.e. proportionally more volume for a given increase in surface area. This is mitigated somewhat by the requirement to increase the thickness of steel for the tank if using similar height to diameter ratios, so therefore larger tanks tend to have a lower height to diameter ratio to smaller tanks.

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[14] RDD funded Poolbeg Sector Integration Study - https://www.codema.ie/wp-content/uploads/2024/09/Poolbeg_Sector_Integration_RDD_Final_Report.pdf

[15] Excluding the weight of the water in the TTES which is not considered a construction material

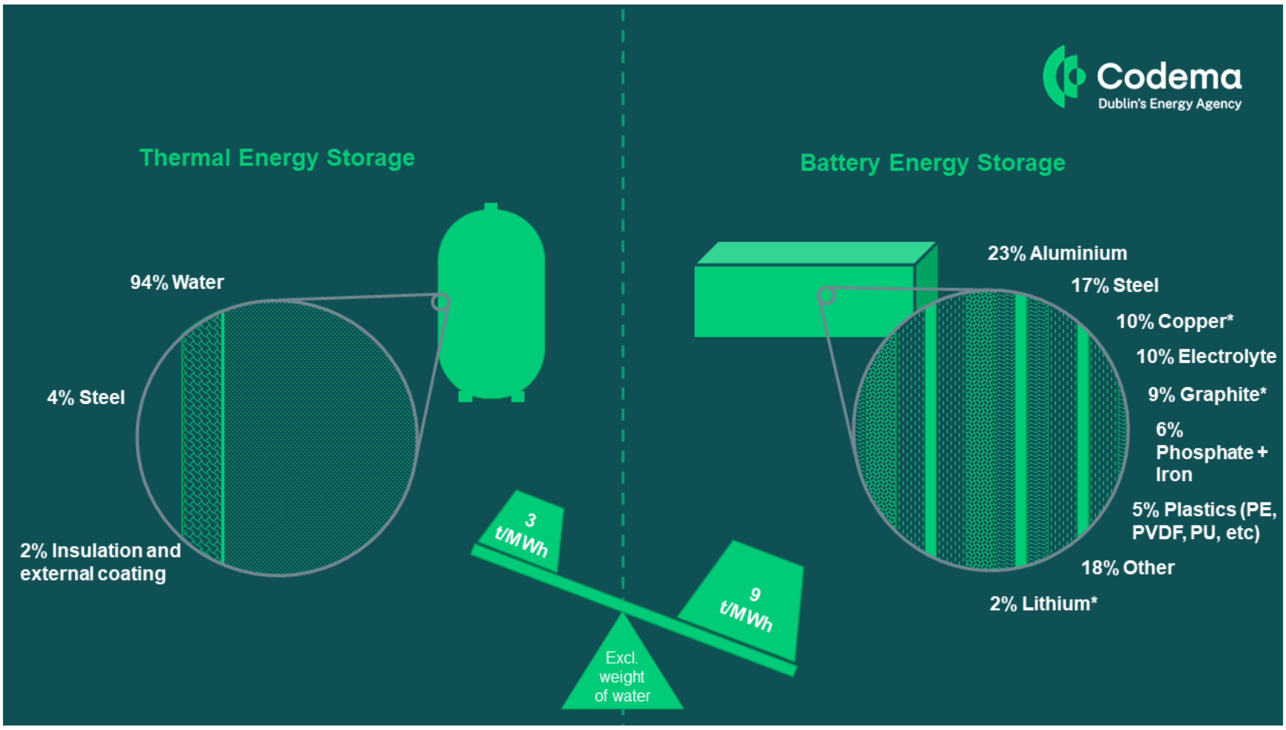


Figure 7: Resource efficiency comparison[16] for large-scale energy storage (TTES[17] and BESS[18] at 5MWh scale)

The embodied carbon associated with the extraction and transportation of these materials is also to be considered. While the total total carbon impact of using these materials is not calculated in this analysis, the map below provides an indication of the likely embodied carbon impact of these materials for their transportation alone.

[16] Based on published LFP battery material studies (e.g., EU JRC, Fraunhofer ISE, and CATL system data)
[17] TTES weight based on dimensions of a 200m^3 tank for TDHS, wall thickness from: https://eurotankworks.com/storage-tanks/vertical-storage-tanks/vertical-tank-vol-200/
[18] Weight of 5MWh BESS from: https://www.chintpowersystems.com/wp-content/uploads/2024/03/CPS-5-MWh-BESS-Datasheet-3-15-2024.pdf

Step 3 - Engage with service provider

This section of the guide indicates how a large-scale heat asset owner can engage best with both the implicit and explicit flexibility markets.

3.1 Engaging with the implicit flexibility market

In order to take advantage of potential savings from implicit flexibility services, you will need a smart meter and to engage with electricity suppliers to find a tariff structure that minimises your electricity bills. You will also need to have the ability to control your heat assets, in order to schedule heat production for times when electricity is cheaper and minimise heat production during times when prices are high. Thermal energy storage will allow much greater ability to move electrical consumption to off-peak periods without causing disruption to heat supply. The indicative savings under varying forms of smart tariff are provided in Step 5.

In order to explore variable tariffs for large-scale consumers you can engage directly with electricity suppliers (Electric Ireland, SSE Airtricity, Bord Gáis Energy, Energia, etc.) to understand the different electricity plans that may be best suited to your organisation based on your demand profile, desired price stability (fixed rate contracts, price indexing), generation mix, etc. To compare across multiple suppliers you may also wish to engage with an energy broker such as utilityfair.ie, cost.ie, procure.ie, energybroker.ie or utilitybrokersireland.com.

3.2 Engaging with the explicit flexibility market

In order to earn revenues from providing explicit flexibility services, you must first determine whether or not you can feasibly engage with the markets directly or require the support of a demand response aggregator. The revenue from these services can be slightly higher when you engage directly with Eirgrid/SEMO, but also means that you will be taking responsibility for providing these services, registering with SEM, installing the required equipment to communicate with the market and will undertake the compliance testing yourself. The decision tree in Figure 8 below will help heat asset owners to decide how to engage with these explicit flexibility markets. It should be noted that for smaller installations (of less than 200kW flexible electrical load for individual sites or less than 100kW for a site that is part of a group of sites with the same owner[19]), the cost, time and effort required to aggregate them can present a significant challenge to demand side aggregators.

[19] Based on discussions with demand response industry experts

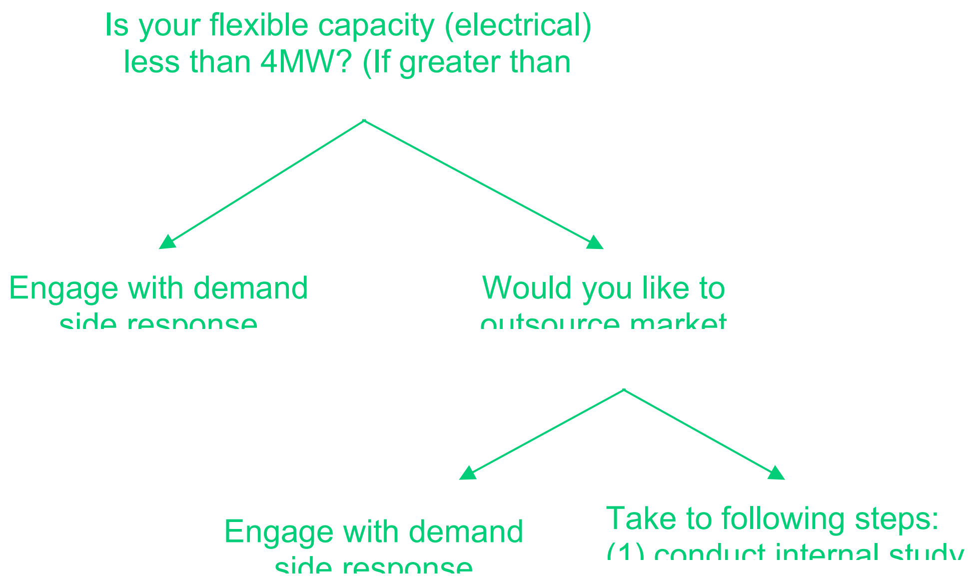


Figure 8: Explicit flexibility market participation decision tree

3.3 Demand response aggregators in Ireland

There are a number of demand response aggregators currently active in the Irish market. These aggregators can help heat asset owners of a certain scale to provide flexibility to the grid and earn revenues from doing so. Contact details for these aggregators are provided below. It should be noted that this may not be an exhaustive list, but does represent organisations who are known to support large-scale heating systems in providing flexibility services.

Table 6: Contact details of demand response aggregators in Ireland

Demand response aggregator	Website	Email	Phone
Demand response association of Ireland	https://thedrai.ie/	info@thedrai.ie	
EnelX	https://www.enelx.com/ie/en/demand-response	enelxireland@enel.com	
GridBeyond	https://gridbeyond.com/our-technology/	service@gridbeyond.com	015240736
Viotas	https://viotas.com/	info@viotas.com	061598000

Step 4 - Adjust operation of your heating system

4.1 Controls and scheduling

Flexibility can be delivered by changing the operation/controls of your heating equipment in a number of different ways. These include:

- Reducing heat output either by turning down or turning off heat production (limited by the turndown ratio of the plant if the owner/operator/manufacturer wants on/off events to be avoided and by the amount of thermal storage installed to avoid undesired disruption to your heat supply),
- Reducing output temperature (limited by minimum temperature end use requirements at different times).

For all DS3 services that require a response time that is faster than 20 minutes, the reduction in electricity demand will need to be controlled through an automatic controller. Services that require slower response times can be controlled manually. The cost of the automatic controller required to provide the faster frequency response is expected to be in the €2,500 - €25,000 range[20]. This cost is generally subtracted from the potential revenues when working with demand side aggregators to avoid upfront costs for the heat asset owner. While the cost of these controls is relatively small compared to the revenue earning potential for large asset owners, for smaller installations at a domestic scale, where the revenues are lower, providing these services may be less attractive.

When it comes to implicit flexibility, the control logic can be quite easily changed to reflect standard ‘smart’ or ‘NightSaver’ tariffs, as these are set around a specific time of day that is repeated across the year.

With greater access to more dynamic implicit flexibility markets (such as the planned DASSA scheme or through access to wholesale market prices) likely in the future tools which can help optimise the operation of the heating plant will become more prevalent. Such systems are already in use in countries such as Denmark with platforms such as energyTRADE[21] are used to plan heat production operations and take full advantage of the TES assets on site.

[20] Based on discussions with demand side response aggregators
[21] https://www.emd-international.com/software/energytrade

Step 5 - Save money, earn revenues and reduce carbon emissions

To outline the potential opportunities for heat asset owners, this section indicates the money-saving, revenue-earning and carbon reduction potential for district and industrial heating equipment operators when they adopt thermal storage. A breakdown between the implicit and explicit savings/revenues can be found in the full technical report which accompanies this guide.

5.1 Implicit flexibility - variable electricity price tariffs

The cost savings from implicit flexibility in this section come from the modelling of various electricity tariffs (smart tariff, nightsaver tariff and flat rate). The potential to reduce costs from participation in the day-ahead market and Intra-day markets are not considered as these markets are designed more for generators rather than demand side response and therefore are a more difficult and uncertain means of reducing costs for heat asset owners.

Table 7 and 8 provide indicative percentage savings in electricity costs for heat networks and industrial sites respectively compared with a no TES scenario. This table shows that the savings increase with each increase in TES capacity, however, this also shows that the cost reductions for TES of 8 and 12 hours are much lower for the same increase in TES size. This is reflected in the financial results where the 4 hour TES option was found to be the optimal size.

Table 7: Indicative reduction in electricity spend from TES for district heating networks

TES size (hours)	4 hours TES	8 hours TES	12 hours TES
Standard smart tariff	33.5%	40.0%	40.3%
Nightsaver tariff	33.3%	40.6%	40.9%
Flat rate	19.9%	20.2%	20.1%

It can be seen in table 8 that the electricity cost saving for industrial sites. The main reason for this difference is that the industrial heat demand profiles[22] used in this analysis have a larger proportion of their demand at night.

Table 8: Indicative reduction in electricity spend from TES for industrial sites

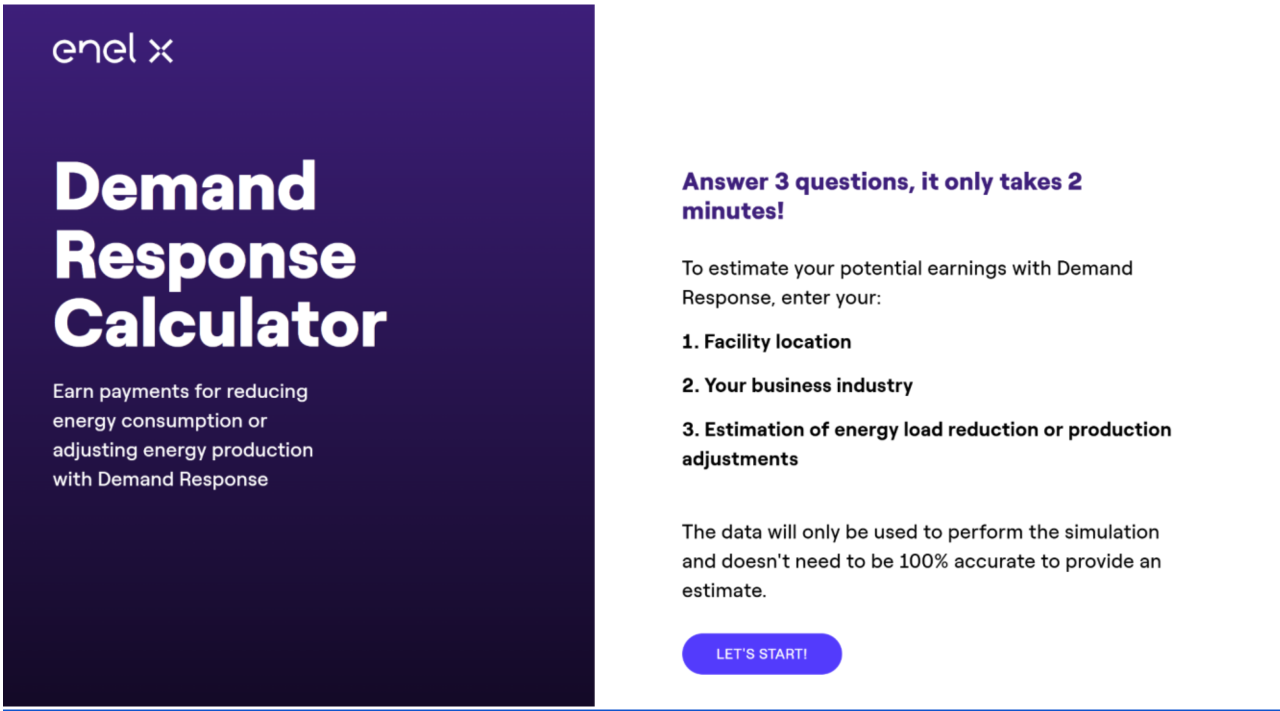
TES size (hours)	4 hours TES	8 hours TES	12 hours TES
Standard smart tariff	16.8%	22.2%	22.1%
Nightsaver tariff	16.6%	22.6%	22.5%
Flat rate	-0.1%	-0.2%	-0.3%

5.2 Explicit flexibility - assess your own revenue potential from flexibility service agreements

EnelX has an online demand response calculator tool that can indicate the potential revenues from the Capacity Market and the DS3 market based on the location, your business/industry type and potential

[22] Based on a combination of data from 6 industrial heat users and generic industrial heat demand profiles from industry

electrical load reduction. The link to this tool can be found here[23]. A screenshot of this tool can be seen below. It is also important to note that while DS3 is only set to remain in place until the end of 2026, under the new FASS/DASSA system, similar services and saving opportunities will remain.



5.3 Total operational cost savings from TES

5.3.1 Cost savings for DH networks

Table 9 below provides indicative cost reduction potential of TES installations for DH network operators, compared with a network with no TES using a nightsaver tariff. This percentage reduction in electricity spend includes cost reductions from greater use of low-cost electricity (implicit flexibility) and revenues from provision of demand response services (explicit flexibility). The hours of storage refer to the equivalent number of hours for which the main heat plant (likely a heat pump) would operate at full capacity to fill the TES. This was chosen to present the results in a more intuitive way that can be applied across projects of varying scales. This table shows that the cost reductions for TES of 8 and 12 hours are much lower for the same increase in TES size. The negligible change in the savings across the flat rate tariff options is due to the fact that these cost reductions come entirely from maximising the use of the efficient heating plant which was achieved in full by smaller TES installations.

Table 9: Indicative total cost reductions[24] from TES for district heating networks using different electricity tariffs

	4 hours TES	8 hours TES	12 hours TES
Standard smart tariff	38.1%	44.5%	44.8%
Nightsaver tariff	37.9%	45.1%	45.5%

[23] https://www.enelx.com/ie/en/demand-response/demand-response-calculator
[24] Cost reductions from installing TES include both implicit savings (predominantly from load shifting but also avoided use of less efficient heat production equipment when demand is outside of the range of the main efficient heating plant and explicit revenues from providing flexibility services to the grid (DS3 and capacity markets). Note that the additional benefits of avoided part-load operation inefficiencies are not included due to lack of real-world data around HP performance curves

Flat rate	26.1%	26.1%	26.1%

While the table above shows the cost savings and revenue impact (as a percentage of original electricity spend), the financial analysis also considers the capital cost of the TES to determine the most viable option. It can be seen from the figures presented below that the installation of TES is highly beneficial from a financial perspective with very high returns and very short payback periods for district heating networks. The optimal combination of electricity tariff and TES size is to use the standard smart tariff with 4hours TES which gives an IRR of 61.5% over 25 years and has a simple (non-discounted) payback of 1.6 years.

Table 10: Financial analysis[25] results for district heating

Tariff	TES size (hours)	4	8	12
SST	Simple payback (years)	1.6	2.7	4.1
	IRR (25-year)	61.5%	35.5%	23.4%
NST	Simple payback (years)	1.6	2.7	4.0
	IRR (25-year)	61.2%	36.0%	23.8%
Flat	Simple payback (years)	2.3	4.6	7.0
	IRR (25-year)	41.9%	20.4%	12.6%

5.3.2 Cost savings for industrial sites

Table 11 below provides indicative cost reduction potential of TES installations for industrial heat customers, compared with the same industrial heat demand[26] with no TES using a nightsaver tariff. The hours of storage refer to the equivalent number of hours for which the main heat plant (likely a heat pump) would operate at full capacity to fill the TES. This was chosen to present the results in a more intuitive way that can be applied across projects of varying scales. This table shows that the cost reductions for TES of 8 and 12 hours are much lower for the same increase in TES size. The negligible change in the savings across the flat rate tariff options is due to the fact that these cost reductions come entirely from maximising the use of the efficient heating plant which was achieved in full by smaller TES installations.

Table 11: Indicative total cost reductions[27] from TES for industrial sites using different electricity tariffs

	4 hours TES	8 hours TES	12 hours TES
Standard smart tariff	22.5%	27.9%	27.8%
Nightsaver tariff	22.3%	28.4%	28.3%
Flat rate	7.3%	7.2%	7.1%

[25] Discount rate of 4% used for this analysis
[26] This demand profile is based on known hourly heat demand profiles for large industrial sites in Ireland
[27] Cost reductions from installing TES include both implicit savings (predominantly from load shifting but also avoided use of less efficient heat production equipment when demand is outside of the range of the main efficient heating plant and explicit revenues from providing flexibility services to the grid (DS3 and capacity markets). Note that the additional benefits of avoided part-load operation inefficiencies are not included due to lack of real-world data around HP performance curves

While the table above shows the cost savings and revenue impact (as a percentage of original electricity spend), the financial analysis also considers the capital cost of the TES to determine the most viable option. It can be seen from the figures presented below that the installation of TES is highly beneficial from a financial perspective with very high returns and very short payback periods for industrial sites. The optimal combination of electricity tariff and TES size is to use the standard smart tariff with 4hours TES which gives an IRR of 42.0% over 25 years and has a simple (non-discounted) payback of 2.3 years. The only scenarios where the use of TES is not feasible is where a flat electricity rate is being used and the TES size is too large for the application (i.e. 8 hours or 12 hours of storage).

Table 12: Financial analysis results for industrial sites

Tariff	TES size (hours)	4	8	12
SST	Simple payback (years)	2.3	3.7	5.6
	IRR (25-year)	42.0%	25.6%	16.3%
NST	Simple payback (years)	2.3	3.7	5.5
	IRR (25-year)	41.7%	26.1%	16.7%
Flat	Simple payback (years)	7.2	14.6	22.0
	IRR (25-year)	12.2%	3.2%	-0.9%

5.4 Grid connection and Maximum Import Capacity benefits

Aside from the revenues received from providing explicit and implicit flexibility services to the grid, there are also benefits in terms of the grid connection itself. These have not been included in the total costs savings above due to their site-specific nature but are as follows:

- Reduced MIC and the associated charges - this MIC charge is driven by the maximum electrical demand required. TES allows the electrical demand associated with the heat production to move to periods where it doesn’t coincide with other on-site electrical demands therefore reducing the site peak electrical demand. This reduction in MIC reduces associated charges such as DUoS, TUoS etc.
- Timed/flexible connection - New connection types where the consumer agrees to consume power outside of certain periods in order to reduce stress on the grid and in return get lower charges for their connection

Abbreviations

BESS	Battery Energy Storage System
DAM	Day-Ahead Market
DSR	Demand Side Response
DS3	Delivering a Secure Sustainable Electricity System
DSO	Distribution System Operator
ESBN	Electricity Supply Board Networks (Ireland's DSO)
ESCo	Energy Service Company
FASS	Future Arrangements for System Services
FSP	Flexibility Service Provider
IDM	Intra-Day Market
MIC	Maximum Import Capacity
NST	Night-Saver Tariff
PTES	Pit Thermal Energy Storage
RoCoF	Rate of Change of Frequency
SEMC	Single Energy Market Committee
SEMO	Single Electricity Market Operator
SNSP	System Non-Synchronous Penetration
SST	Standard Smart Tariff
ToU	Time of Use (electricity tariff)
TSO	Transmission System Operator
TTES	Tank Thermal Energy Storage

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