Low-Carbon Crematorium Procurement Study Summary Report

Contents

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1. Executive Summary

This document is an English-language summary of the procurement study, commissioned by Lutheran Church in Helsinki (Helsingin seurakuntayhtymä). The complete study is available in both Finnish and Swedish.

The sudy provides a comprehensive analysis of options for implementing a low-carbon crematorium in Helsinki. The project was initiated in response to two converging pressures: a steady and significant rise in cremation demand, and an organisational commitment to meet the Carbon Neutral Church 2030 goals.

The report explores existing and emerging cremation technologies, assesses environmental and economic implications, reviews applicable legislation, and considers cultural and theological dimensions.

Key conclusions include:

- The most suitable option is an electric cremation furnace with Best Available Technique (BAT)-compliant flue gas cleaning and heat recovery integrated into the district heating network.
- One-shift and two-shift operational models differ significantly in per-cremation costs, energy use, and emissions.
- Life-cycle cost analysis favours electric technology when heat recovery revenue and renewable electricity sourcing are considered.
- The system should be scalable, modular, and ready to trial future low-carbon methods (e.g., water cremation) if legislation changes.
- The procurement process should incorporate robust environmental performance requirements, clear operational capacity targets, and flexibility to integrate future innovations.

The recommended approach would enable Helsingin seurakuntayhtymä to eliminate fossil CO_2 emissions when paired with renewable electricity and to integrate heat recovery into local district heating networks, providing both environmental and potential financial benefits.

2. Background and Objectives

Helsingin seurakuntayhtymä operates two crematoria. Malmi has one and Honkanummi two cremation furnaces. In 2024, over 4,000 cremations were performed in these facilities. Demand is projected to rise due to demographic trends and changing funeral preferences. Nationally, cremation accounts for over 65% of burials and over 80% in Helsinki metropolitan area.

The main goal is to determine how Helsingin seurakuntayhtymä can procure a new crematorium or cremation furnace with the lowest possible carbon footprint and to provide procurement recommendations for the investment. The main goal breaks down into several sub-objectives:

Technical – Identify the most suitable cremation furnace technology and supporting systems, including energy source, flue gas cleaning, and heat recovery.

Environmental – Quantify life cycle greenhouse gas emissions and air pollutant reductions under different energy and operational scenarios.

Economic – Assess capital investment, operating and maintenance costs, and potential savings or revenues from efficiency gains and heat sales.

Regulatory – Ensure compliance with Finnish and EU environmental, health, safety, and building regulations, and anticipate upcoming changes.

Cultural and Social – Ensure that the proposed solution aligns with the values, traditions, and expectations of diverse religious and non-religious communities.

3. Cremation Furnace Technologies

Modern crematoria employ a range of furnace technologies, each with distinct implications for energy efficiency, environmental performance, operating costs, and maintenance requirements. In the Finnish and broader European context traditional fuel-fired furnaces still dominate.

3.1 Traditional Fuel-Fired Furnaces

These are the most common globally, typically configured as hot-start units that maintain a base temperature between cremations, reducing start-up fuel demand. Operating temperatures are 700–800 °C in the primary chamber and at least 850 °C in the afterburner chamber for a minimum of two seconds to ensure complete combustion of flue gases.

Fuels used:

Light Fuel Oil (LFO) – long-standing option, widely available, but high fossil CO_2 intensity (~39–74 kg per cremation depending on shift pattern).

Natural Gas (NG) – cleaner burning than LFO, with lower particulates and CO_2 emissions (~32–61 kg per cremation), but still fossil-based.

Advantages include established supply chains and familiar operational procedures. Disadvantages are high emissions, exposure to fossil fuel price volatility, and a larger flue gas volume, which increases the scale and cost of emission control equipment.

3.2 Biofuel-Fired Furnaces

Bio-oil (HVO) and biomethane are direct replacements for fossil LFO and NG, requiring minimal burner modifications. They offer near-zero fossil CO_2 emissions and can reduce life cycle greenhouse gas output by up to 90%. However, fuel prices are generally higher than fossil equivalents, which can raise annual operating costs.

3.3 Electric Furnaces

Electric cremators use resistance heating elements embedded in the refractory lining or arranged externally, transferring heat to the chamber without combustion. Air is supplied solely for the oxidation of the coffin and body, rather than for burning fuel, resulting in:

- Lower flue gas volume and temperature, reducing the size and complexity of flue gas treatment systems.
- Lower particulate, NO_x, and SO_2 emissions, easing compliance with BAT-AEL limits.
- Higher thermal efficiency, as there is no excess air heating requirement.
- Simplified maintenance — no fuel delivery, pumps, or burners.

The primary environmental advantage is the ability to run on renewable electricity, cutting fossil CO_2 emissions to zero. Even with the Finnish grid average, fossil emissions are extremely low (~2.7–3.3 t/year per furnace in modelled scenarios).

Operational considerations:

Cycle times are slightly longer (~2 h vs. ~1.5 h for fuel-fired), which marginally reduces daily throughput in a single-shift setup. With higher cremation capacity, cycle times may be reduced by increasing energy stored within the furnace structures.

Electrical connection capacity must be sufficient to handle peak load; for a single furnace, this can mean 300–400 kW installed power.

Energy costs are sensitive to electricity pricing, but potential integration with on-site solar or long-term renewable power purchase agreements can stabilise costs.

In two-shift operation, electric furnaces demonstrate the lowest energy use per cremation (30 kWh) and the most favourable environmental profile. When paired with high-efficiency heat recovery and renewable electricity sourcing, they represent the benchmark low-carbon solution currently available for cremation services.

Part list

POS	PART NUMBER
1	Automatic insert machine
2	Heat exchanger
3	Bypass valve
4	Injector
5	Dump cooler
6	Secondary heat exchanger
7	DFW 6000
8	Dust filter
9	AC filter
10	Spark arrestor
11	Spark arrestor container
12	Flue gas fan
13	Compressor
14	Expansion tank
15	Over pressure tank
16	Oil-water separator
17	Control panel

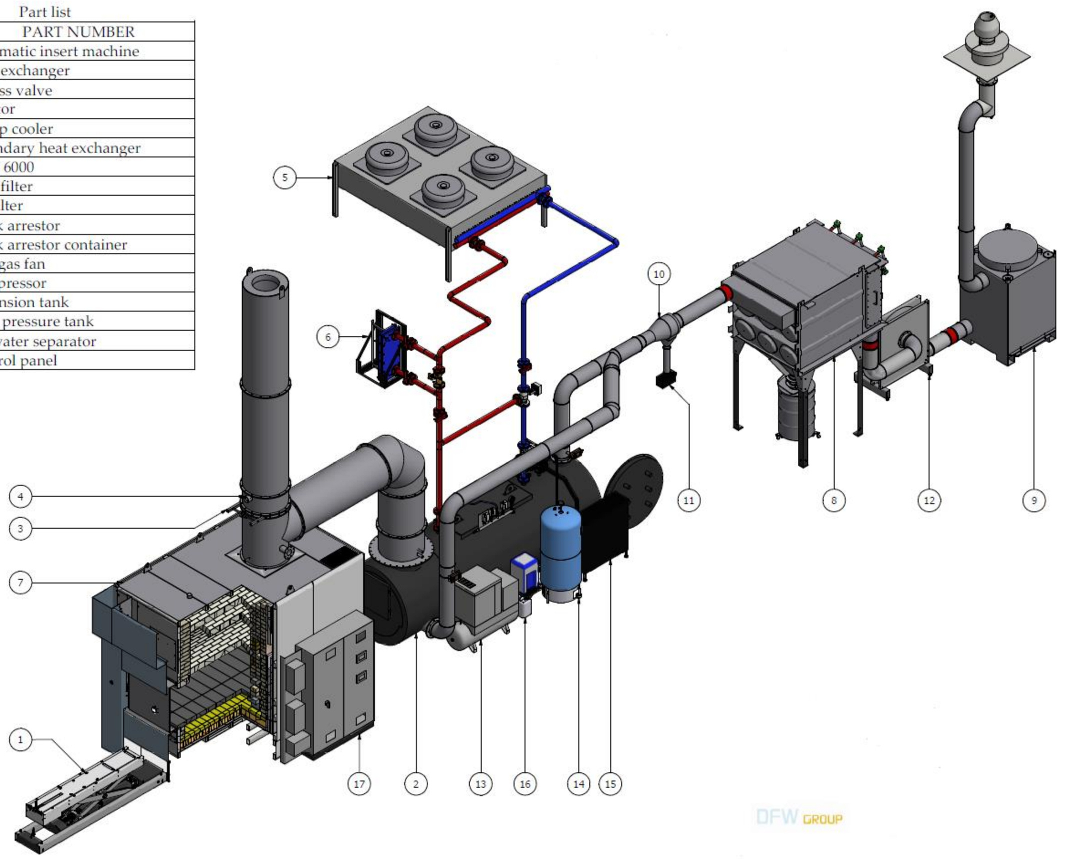

Figure 1 Electric cremation furnace with filtration and heat recovery system from Dutch equipment supplier DFW Europe.

3.3 Emerging Alternatives

Several countries have introduced or are trialling alternatives to flame cremation. These options show promising environmental performance but require legislative change and cultural acceptance as Finnish law currently permits only burial and flame cremation.

Water cremation (alkaline hydrolysis) – Uses water and alkali under heat and pressure to break down remains. The process has lower energy use and emissions than flame cremation. Alkaline hydrolysis is a legal burial method in Ireland, South Africa, Australia, several states in Canada and the United States, and Mexico.

Cryomation – Freezes remains in liquid nitrogen, then shatters them for burial as a dry powder. The process has extremely low emissions: Cryomation has not yet been commercialized in any country, and no operational plant has been built.

Human composting (NOR) – Controlled decomposition into soil over several weeks. Low emissions but the most significant environmental disadvantage of composting is related to the use of dry bulking material. Human composting is legal only in some States in USA.

4. Energy Consumption and Operating Cost Modelling

Energy and cost modelling was performed for both one-shift and two-shift operational scenarios, based on reference furnace capacities defined in the technical review. In the one-shift scenario, an electric furnace is assumed to perform 1,150 cremations annually, while a fuel-powered furnace completes 1,380 cremations. In the two-shift scenario, these figures increase to 2,300 cremations for the electric furnace and 2,760 for the fuel-powered furnace. For each fuel type, the specific energy requirement per cremation was calculated and multiplied by the annual cremation count to estimate the total yearly energy consumption. Fuel and electricity prices were based on 2025 market averages, with no price escalation applied in the base case.

Table 1 Annual Energy Use, Cost, and Fossil CO_2 Emissions (per furnace)

Fuel type	Shift model	Annual capacity (cremations)	Energy use per cremation (kWh)	Annual energy use (MWh)	Annual fuel and electricity cost (€)	Annual fossil CO_2-eq. emissions (t)
Light fuel oil	1 shift	1,380	324	447	46,100	103
	2 shifts	2,760	173	449	48,700	108
Bio-oil (HVO)	1 shift	1,380	324	447	64,200	1.4
	2 shifts	2,760	173	449	67,500	1.9
Natural gas	1 shift	1,380	324	447	39,200	83
	2 shifts	2,760	173	449	42,100	87
Biomethane	1 shift	1,380	324	447	57,000	1.4
	2 shifts	2,760	173	449	60,600	1.9
Electric (grid avg.)	1 shift	1,150	76	88	8,800	3.3
	2 shifts	2,300	30	77	7,100	2.7
Electric (renewable)	1 shift	1,150	76	88	9,500	0.0
	2 shifts	2,300	30	77	7,700	0.0

Two-shift operation is estimated to double the annual capacity while increasing total energy usage only slightly on fuel using furnaces. With fuel-powered furnaces the requirement of energy from fuels is reduced with higher capacity, but the amount of electricity used to power ie. air circulation is increasing. Using electricity powered furnaces reduces energy usage by reducing the amount of waste heat and increasing recoverable amount of heat improves energy efficiency and reduces emissions per cremation.

CO_2 emissions can be compared per cremation instead of annual amounts. In this comparison they are reduced substantially when moving from one-shift to two-shift operation due to reduced start-up cycles and more efficient use of furnace heat retention:

- Light fuel oil: from ~75 kg CO_2-eq. to ~39 kg CO_2-eq. per cremation (–48%)
- Natural gas: from ~61 kg CO_2-eq. to ~32 kg CO_2-eq. per cremation (–47%)
- Electric (grid average): from ~2.7 kg CO_2-eq. to ~1 kg CO_2-eq. per cremation (–60%)
- Biofuels and renewable electricity: per-cremation fossil CO_2-eq is already near zero in both shift models.

Results show that operational optimisation—specifically adopting a two-shift model—can significantly improve the environmental performance of any technology per cremation, but the greatest absolute reductions in fossil CO_2 come from transitioning to renewable energy sources.

5. Life-Cycle Cost Assessment (LCCA)

The life-cycle cost analysis in this study evaluates the total cost of owning and operating a single cremation furnace for 25,000 cremations. The number of operational years depends on the annual number of cremations. The assessment encompasses the full financial picture, including capital expenditure, annual operating costs, scheduled mid-life refurbishments, and end-of-life decommissioning.

Capital costs vary slightly between technologies. An electric cremation furnace equipped with BAT-level flue gas cleaning and a high-efficiency heat recovery system is estimated to cost €1.0–1.2 million (installed). Fuel-fired furnaces operating on light fuel oil, natural gas, or biofuels are slightly less expensive—€0.9–1.1 million—but require larger flue gas cleaning units due to higher exhaust volumes.

Operating costs are influenced by both the specific energy requirement per cremation and the prevailing price of the selected energy source. Bio-oil and biomethane exhibit the highest annual fuel costs, are more vulnerable to price volatility, and may face supply constraints. Light fuel oil and natural gas are cheaper per energy unit but result in a significant fossil CO_2 footprint over the asset's lifetime. In contrast, bio-oils and biomethane can reduce fossil CO_2 emissions to near zero, albeit at a higher cost.

Electric furnaces demonstrate the lowest total energy requirement per cremation and eliminate the need for all fuel-handling infrastructure, except for backup power systems, which are required for all furnace types and are therefore excluded from this comparison. Unlike fuel-fired systems, electric furnaces do not require fuel burners, pumps, or storage units, which are not assessed in this study. The presence of additional machinery in fuel-powered systems also increases maintenance needs and associated costs.

Table 2 Annual cremations during the life cycle (LC), LC length in years, total costs during the LC and fossil CO_2-eq. produced from energy sources during the LC.

Fuel type	Shift model	Annual cremations	LC length (years)	Total LC costs (M€/ LC)	Energy usage per LC (MWh/LC)	Fossil CO_2-eq. over LC (t CO_2-eq./LC)
Light fuel oil	1 shift	1,380	18,1	7,5	8101	1512
	2 shifts	2,760	9,1	3,9	4335	792
Bio-oil (HVO)	1 shift	1,380	18,1	7,8	8101	25
	2 shifts	2,760	9,1	4,1	4335	17
Natural gas	1 shift	1,380	18,1	7,6	8101	1863
	2 shifts	2,760	9,1	4,0	4335	975
Biomethane	1 shift	1,380	18,1	7,9	8101	25
	2 shifts	2,760	9,1	4,2	4335	17
Electric (grid avg.)	1 shift	1,150	21,7	5,6	1904	72
	2 shifts	2,300	10,9	3,5	762	29
Electric (renewable)	1 shift	1,150	21,7	5,6	1904	0
	2 shifts	2,300	10,9	3,5	762	0

The life cycle of the electric furnace is slightly longer in years, as the number of cremations per year is lower due to longer cremation times. Total costs are higher when using renewable energy sources, though the difference with renewable electricity is relatively small. Significant cost differences arise when comparing one-shift and two-shift utilisation rates, with costs decreasing as cremation capacity increases. Total energy consumption also decreases considerably under the same conditions as energy costs. Fossil CO_2-equivalent emissions are reduced to nearly zero with the use of renewable energy sources. In the case of renewable electricity, emissions can be reduced to zero from the perspective of energy consumption.

When all factors are considered, the electric furnace option achieves the lowest Global Warming Potential (GWP) impacts and the lowest total costs, particularly under a two-shift utilisation scenario. Bio-oil and natural gas remain competitive alternatives, although they entail higher operational costs. For both electricity- and fuel-powered systems, increasing the utilisation rate further reduces the cost per cremation, with more substantial savings observed in the electricity-powered option.

6. Heat Recovery & ORC

Heat recovery from cremation furnaces offers both environmental and economic benefits by capturing residual thermal energy from flue gases and allowing it to be used for secondary purposes, such as heating the crematoria, chapel, and possibly even local district heating network. In BAT-compliant systems, heat is recovered via a heat exchanger placed downstream of the afterburner and upstream of the flue gas cleaning unit. This setup ensures that heat is extracted without compromising emission control or flue gas cleaning equipment’s performance. If heat is not used within district heating or other purposes it must be removed from the energy system by cooling and condensation system, which increases costs due to its energy requirement and does not provide any additional benefits from the energy recovered.

In the base case for Helsingin seurakuntayhtymä, recovered heat is intended for integration into the local district heating network. The analysis shows that in one-shift operation, the annual amount of recoverable heat is significantly lower compared to two-shift operation due to reduced furnace utilisation and greater heat losses during cooldown periods. In a two-shift scenario, the higher throughput increases the volume of flue gases available for recovery, thereby improving the cost-effectiveness of the heat recovery system investment. Additionally, the recovered heat could potentially be sold to the local district heating network, generating additional revenue. In such cases, the recovered energy may also indirectly reduce CO_2 emissions from the district heating provider and lower the overall environmental footprint of the network.

6.1 Organic Rankine Cycle (ORC) Option

An alternative or complementary use for recovered heat is the Organic Rankine Cycle system, which converts low-to-medium temperature waste heat into electricity. In an ORC system, a working fluid with a low boiling point (often an organic compound such as a refrigerant) is vaporised using the recovered heat. The vapour drives a turbine connected to a generator, producing electricity.

For crematorium applications, the available flue gas temperature after the afterburner and heat recovery system typically ranges between 130–320 °C, which is suitable for integration with an Organic Rankine Cycle (ORC) system. However, practical electricity yields from ORC systems in this context remain modest due to the intermittent operation of the furnace and fluctuating heat output. With higher utilization rates—or when multiple cremation furnaces are combined with adequately sized thermal storage systems—it is possible to operate the ORC unit with a high-capacity factor.

Based on the operational profile modelled in this study, an ORC system could generate approximately 60 MWh of electricity annually under a two-shift operating schedule, sufficient to offset part of the crematorium's own electricity consumption. Economic viability for ORC depends on electricity prices and capital cost. While the operational costs of the ORC unit are relatively high (estimated at €7,000 per year), this is estimated to reduce the profitability of the system by current prices by roughly 50 % or more.

While an ORC system significantly reduces the energy demand and associated costs of cooling and condensation systems, the payback period for a dedicated ORC unit serving a single furnace—whether in one- or two-shift operation—is generally not economically viable. However, when applied to systems with multiple cremation furnaces, ORC technology may offer an effective solution for utilising recovered heat. A single ORC unit with a 20-kW electricity production capacity can be estimated to handle the excess heat generated by up to three furnaces operating under a one-shift schedule. Nonetheless, the economic attractiveness of ORC systems could improve if electricity prices increase or grid feed-in tariffs become more favourable.

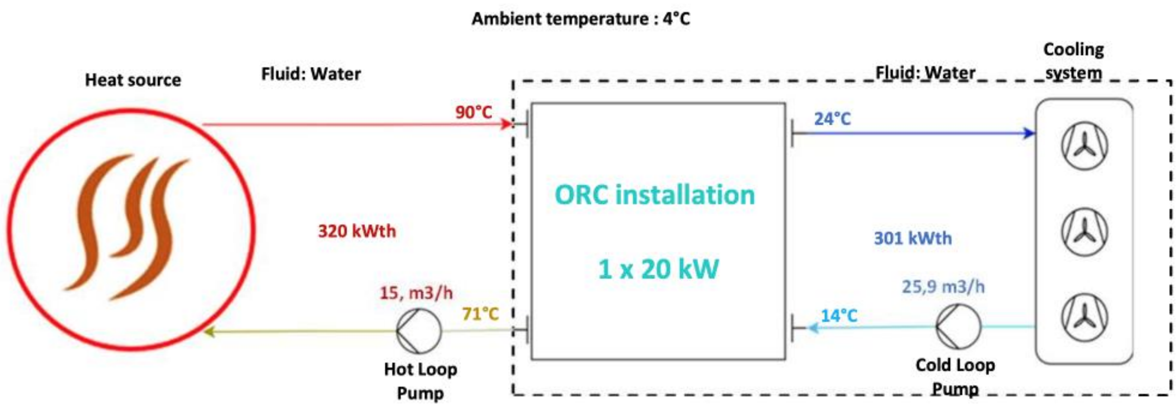

Figure 2 The principle of the ORC process for converting heat from three cremation furnaces into electricity.

Integration Considerations

When designing the new crematorium, space should be allocated and connection points prepared for either or both heat recovery and ORC systems. This futureproofing will allow Helsingin seurakuntayhtymä to adapt to market changes and regulatory developments without costly retrofits. The procurement specification should explicitly require thermal energy metering and control systems to manage both heat export and potential electricity generation efficiently.

7. Conclusions

The study concludes that an electric cremation furnace equipped with BAT-level flue gas cleaning and high-efficiency heat recovery is the most suitable solution for Helsingin seurakuntayhtymä, both from an environmental and operational perspective. When powered by certified renewable electricity, this technology can remove fossil CO_2-eq. emissions from the energy usage while meeting or exceeding all emission control standards for particulates, NO_x, SO_2, and mercury.

Two-shift operation significantly improves utilisation, reduces per-cremation energy use, and increases the amount of recoverable heat. When integrated into the district heating network, recovered heat generates both financial revenue and measurable climate benefits through carbon handprint—the positive climate impact of displacing fossil-based heat production elsewhere in the energy system.

Shifting to renewable electricity or sustainable biofuels can reduce fossil CO_2 emissions by over 95–100% compared to fossil-based fuels. Higher utilisation rates (two-shift models) further lower emissions per cremation and improve environmental performance. The fuel type and operational model significantly influence the total fossil CO_2-equivalent emissions over the furnace's life cycle (LC). Among the assessed options, renewable electricity yields zero fossil emissions, making it the cleanest energy source from a climate perspective. Switching utilization rates from one- to two-shift utilization rate reduces emissions especially when using fossil fuel types, ie. with light fuel oil this reduces emissions from 25 000 cremations by up to 920 tonnes per LC.

By designing the system for both high operational efficiency and maximum integration of recovered heat, it is possible to ensure that the new crematorium does not only minimise its own climate impact (carbon footprint) but also actively contributes to reducing emissions in the wider community energy system (carbon handprint). This dual benefit strengthens the case for selecting the electric BAT solution and for prioritising robust, scalable heat recovery capability from the outset.

Preferences may differ among religious communities, with some faiths favouring cremation and others requiring burial, but cremation is widely accepted in Finland, including within the Lutheran Church. Introducing new technologies such as water cremation requires dialogue and changes in the current burial laws. Public acceptance depends on transparency, environmental responsibility, and respect for the deceased. Engagement with stakeholders can build trust and ensure smooth adoption of innovations.

7.1 Recommendations

The procurement specification should prioritise:

1. **Technology Choice** – Select an electric furnace designed for high utilisation rates, with modular BAT-compliant flue gas cleaning and integrated heat recovery.
2. **Renewable Energy Supply** – Secure long-term contracts for renewable energy sources with Guarantees of Origin; assess opportunities for investments such as on-site solar generation.
3. **Heat Recovery Design** – Integrate with the local district heating network; ensure operational flexibility for seasonal adjustments when the district heating network is not capable of receiving excess energy.
4. **Operational Flexibility** – Design for both one-shift and two-shift operation; enable easy capacity expansion. Higher utilization rate reduces costs and environmental releases.
5. **Environmental Compliance** – Require continuous monitoring capability and readiness to meet tighter emission limits in the future. Easier to reach with electric furnace types due to not having need to burn fuels.
6. **Economic Optimisation** – Include life-cycle cost evaluation in procurement scoring, considering heat recovery and minimize environmental releases to avoid issues with upcoming changes in environmental permits.
7. **Stakeholder Engagement** – Maintain ongoing dialogue with funeral service providers, religious communities, and environmental authorities to ensure acceptance.

7.2 Strategic Outlook

The crematorium sector is expected to evolve in both technology and regulation. Helsingin seurakuntayhtymä can position itself as a national leader by making the new facility a platform for innovation.

Key strategic actions include:

- Aligning the project with broader municipal and parish sustainability programmes, including integration with other energy efficiency initiatives.
- Using the facility as a demonstration site for advanced environmental monitoring, sharing data with national and international networks.
- Communicating environmental benefits clearly to the public, reinforcing the organisation's role as a climate-conscious service provider.
- Ensuring design resilience to accommodate shifts in cremation volumes, energy market conditions, and regulatory requirements.