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Geothermal Integration at Dublin Airport: A Flagship Project for Decarbonising Complex Infrastructure

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ABSTRACT

Dublin Airport has undertaken a large-scale geothermal feasibility study to explore the integration of ground source heating and cooling technologies into its energy intensive infrastructure. With a target to reduce Scope 1 carbon emissions by 51% by 2030, the project focuses on Zones 1 and 3 of the campus, which include Terminal 2 and several high demand piers. The initiative explores the potential deployment of a district-scale geothermal heat pump system of up to 10 MWth capacity, using a mix of open- and closed-loop systems across four test locations. This paper presents the methodology, scope, and impacts of the feasibility study, which includes subsurface characterisation, thermal response and pumping tests, and detailed system modelling. The study also addresses integration challenges within operational airport environments, such as maintaining service continuity and interfacing with existing BMS and HVAC systems. The work reflects growing momentum in applying geothermal to critical infrastructure and urban development. Dublin Airport is positioned as a strategic demonstration site where geothermal becomes a central pivot in an emerging low-carbon energy ecosystem supporting heating, cooling, and broader energy optimisation across the campus. By embedding geothermal early into master planning and coordinating across airport operations, engineering, and planning teams, this project offers valuable lessons for infrastructure owners, designers, and policymakers. As one of Ireland's most ambitious geothermal efforts to date, the study aims to set a new standard for renewable integration in the built environment and inform broader replication across airports, data centres, and industrial campuses.

1 INTRODUCTION

Dublin Airport plays a central role in Ireland's transport, logistics, and tourism sectors. Its operational energy demands are considerable, driven by heating, cooling, lighting, and baggage handling operations that must function continuously throughout the year. Recognising the importance of reducing carbon emissions from such critical infrastructure, Dublin Airport Authority (daa) has committed to a 51% reduction in Scope 1 greenhouse gas emissions by 2030, with net zero targeted by 2050 (daa, 2022). These targets align with the national Climate Action and Low Carbon Development Act and Ireland's broader commitment to the European Union's (EU's) decarbonisation agenda.

One of the most promising routes for achieving these targets is through the integration of renewable heating and cooling technologies, particularly geothermal systems. Ground Source Heat Pump (GSHP) technology enables buildings to draw thermal energy directly from the earth, which remains at a stable temperature year-round. Unlike air-source heat pump and chiller solutions, geothermal installations offer the option to deliver simultaneous heating and cooling at high efficiency even during peak demand, making geothermal particularly attractive for airport campuses, where reliability and performance are critical.

The Eastlands Area of Dublin Airport, a section of land earmarked for future development, presents a unique opportunity to integrate a large-scale geothermal system into the campus master plan. This area is currently underutilised and lies adjacent to major energy-consuming infrastructure within the scope of the geothermal feasibility. As such, the area represents an ideal location for test drilling, borehole installation, and integrated design of a geothermal heating and cooling system. Various other land areas within the Dublin Airport Campus are also available for test drilling and geothermal installations, with the benefit of being located closer to energy-consuming infrastructure and avoiding utility service corridors having to cross regional roads. The proposed system aims to deliver a thermal capacity of up to 10 MW_{th}, potentially making it the largest geothermal project of its kind in the Republic of Ireland (Geoserv, 2024).

Document Classification: Class 1 - General

2 CONSORTIUM EXPERTISE AND CONTRIBUTIONS

The feasibility study was undertaken by a consortium led by GeoServ and includes several expert organisations:

- **APEX Geophysics**: leading geophysical surveys (ERT, Seismic Refraction).
- **OPNBuildings**: lifecycle analysis (LCA), emissions benchmarking, ESG reporting.
- **GeoMAX**: Ground Penetrating Radar (GPR) and subsurface utility mapping.

Together, this consortium provides multidisciplinary coverage of all technical, environmental, operational, and regulatory challenges that occurred during the feasibility and are anticipated during potential implementation phases.

3 PROJECT CONTEXT AND SCOPE

3.1 Site Characteristics and Development Plans

The Eastlands Area is situated on the eastern side of the airport, encompassing undeveloped land identified for future expansion in the Dublin Airport Master plan. Its proximity to both terminals and other large buildings allows for an efficient thermal distribution network if geothermal systems are installed in advance of construction. Unlike retrofit projects, where underground services and structural constraints can impede drilling or network layout, greenfield developments such as Eastlands provide a clean slate for infrastructure integration.

The geothermal feasibility study covers five spatially distributed sites across the airport campus: Eastlands, Zone 1 (Terminal 2 and Pier 400), Zone 3 (Pier 100), Pier 500, and Cloghran Stud. These locations have been selected to assess geological variability and to support the future energy needs of Terminal 2, Pier 100, Pier 100 Mod, and Pier 500, which are included in the project's energy demand modelling.

The master planning of the Eastlands Area will include a mix of commercial, operational, and support facilities with heating and cooling demands that could be met through shared geothermal infrastructure. Integration of a geothermal collector field below the footprint of the proposed new developments in these areas provides a unique opportunity for deployment of a low carbon heating and cooling solution to address the main airport energy demand. Additionally, early planning enables the design of hydronic systems, pipe routing, and heat pump installation in conjunction with architects and civil engineers.

As a result of low yield during the pump test for the open-loop test borehole, the Purple Car Park was selected as an alternate location to drill a closed-loop borehole and undertake thermal response testing. This area is located closer to the Zone 1 buildings and is currently used for daa staff parking.

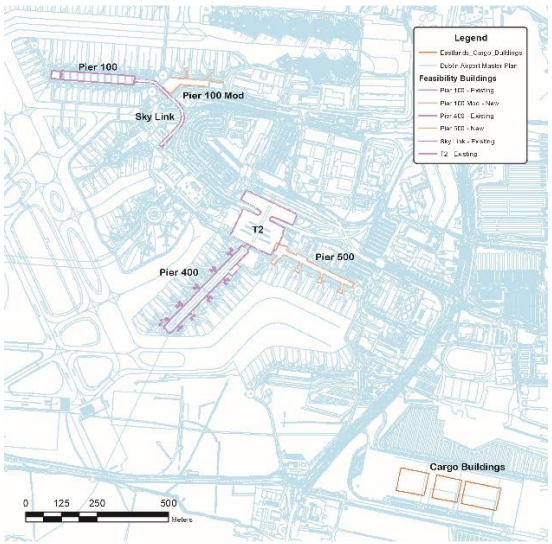


Figure 1. Project scope areas drawing

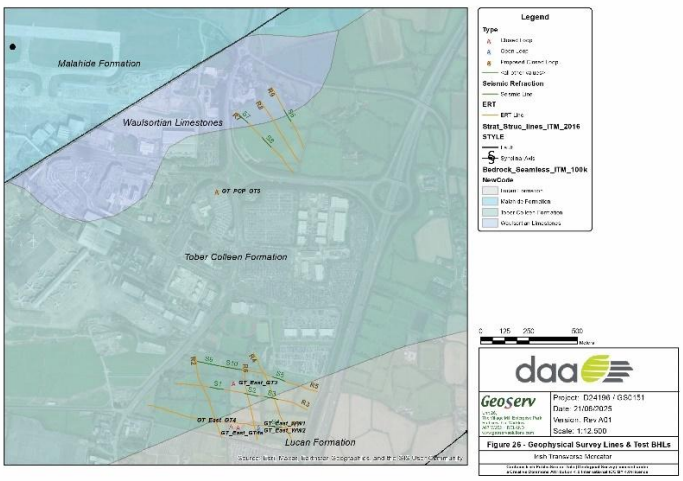


Figure 2. Dublin Airport campus solid bedrock geology map (Source: GSI)

3.2 Project Objectives and Rationale

The overarching aim of the project is to determine the technical, economic, and regulatory feasibility of installing a large-scale GSHP system at Dublin Airport to meet the energy demand of multiple facilities across Zones 1 and 3, while meeting key performance, resilience, and environmental criteria. Specific objectives of the study include:

- Understanding the current and future heating and cooling energy demands of the airport.
- Establishing the thermal properties of the subsurface and determining the geothermal potential of the site.
- Conducting high-resolution geophysical surveys to identify optimal drilling locations and avoid obstructions.
- Drilling five exploratory boreholes to depths of up to 200 metres and conducting thermal response tests (TRT) and pumping tests to determine in situ bedrock thermal properties and hydraulic properties of the aquifer. The number of exploratory boreholes was reduced from five to four during the feasibility study based on the drilling and pump test results from the other boreholes.
- Modelling potential system configurations, including vertical closed-loop and open-loop designs, and identifying the most suitable geothermal options.
- Developing a conceptual system layout compatible with the airport's mechanical systems, energy centres and Building Management System (BMS).
- Evaluating the cost, emissions reduction potential, and return on investment under different operational scenarios.
- Ensuring compliance with all regulatory requirements, including licensing, planning permission, and safety protocols (Geoserv, 2024).

4 METHODOLOGY

4.1 Energy Demand Data Review

The feasibility study began with an assessment of current and future energy demand for key operational zones within the airport campus. This included Terminal 2, Pier 500, Pier 100, and Pier 100 Mod, which collectively represent some of the most energy-intensive and strategically important areas of the airport. Heating and cooling loads for these zones were modelled based on historical utility and monitoring data, current system performance, and projected growth linked to passenger numbers, building extensions, and system upgrades. This demand modelling provided the baseline against which geothermal supply scenarios were tested and ensured that system designs were scaled appropriately to meet both immediate operational needs and long-term decarbonisation targets.

4.2 Subsurface Data Review and Geological Assessment

The feasibility study followed with a desk-based review of geological, hydrogeological, and geotechnical data. This included data from the Geological Survey Ireland (GSI), previous borehole logs, aquifer vulnerability maps, and 3D geological models. Understanding the bedrock type, fracture zones, groundwater table, and soil conductivity is essential for evaluating the thermal potential of the ground (GSI, 2020).

4.3 Geophysical Surveying

Advanced geophysical methods were used to assess subsurface conditions. Electrical resistivity tomography (ERT) can reveal conductivity contrasts linked to lithology or water content, while seismic refraction (SR) offers high-resolution images of the overburden and shallow features. Combined, these techniques delivered a subsurface model that informed the borehole siting and collector array design.

4.4 Geothermal Test Drilling and Thermal Response Testing

Drilling four test boreholes to a depth of up to 200m was a key milestone in the project. The boreholes were used for either thermal response testing (TRT) or pumping/injection tests to evaluate both closed-loop and open-loop viability. The TRT measured effective thermal conductivity and borehole resistance, while open-loop testing assessed groundwater aquifer and hydraulic properties.

4.5 Conceptual System Design and Integration Modelling

The conceptual system design accounted for heat pump performance, collector layout, pipe routing, pressure losses, and integration with terminal plantrooms and energy centers.

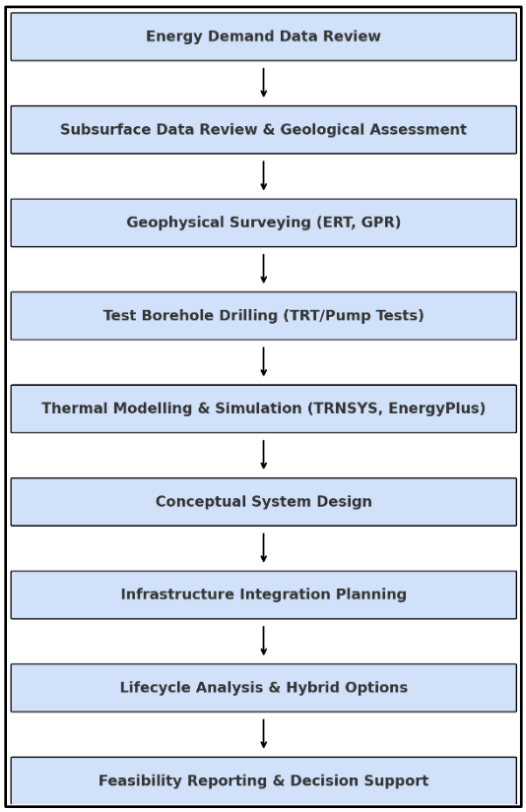


Figure 3. Feasibility workflow

5 INFRASTRUCTURE INTEGRATION AND TECHNICAL CHALLENGES

5.1 Challenges and Operational Integration

Airports represent some of the most complex infrastructural environments for the deployment of energy systems. Operational constraints, continuous public access, safety protocols, and buried service congestion make it difficult to schedule and execute intrusive works. Therefore, the geothermal system must be designed to minimise surface disruption and align with other scheduled works or utility upgrades (Atkins, 2022).

The design team coordinated closely with Dublin Airport's facilities and operations divisions to identify suitable installation windows, determine no-go zones for drilling, and plan staged construction that avoided peak travel periods. Interaction with project design teams for the development of the airport site formed a critical part of the study to determine the most suitable routes and methods of completion for the final geothermal design.

5.2 Interconnection with Mechanical Systems

The geothermal system will need to connect efficiently with existing HVAC systems or energy centres in Zones 1 and 3. This involves engineering considerations such as pipe lengths, heat exchanger sizing, pressure losses, and fluid flow rates. Hydraulic modelling ensured that the thermal delivery is balanced across all buildings and that control systems can manage seasonal demand variations.

Load-side compatibility is also essential, ensuring that terminal systems can accept low-grade heat for both space heating and cooling. Where necessary, auxiliary heat pumps or booster systems may be installed to achieve temperature lift.

5.3 Risk and Contingency Planning

A comprehensive risk management framework was adopted to address potential barriers. Key risks included drilling failures, poor thermal performance, lower aquifer yields, and cost overruns. Each of these was mapped, with corresponding mitigation strategies.

The phased nature of the feasibility study allowed for continuous review and redesign if findings suggested poor performance or unanticipated site constraints. Stakeholder engagement and early consultation with licensing authorities was also considered. The four-borehole approach provided contingency and data diversity to de-risk investment decisions.

6 POLICY CONTEXT AND MARKET DRIVERS

Ireland's Climate Action Plan (2021) and the Climate Act 2021 have created strong policy drivers for renewable heating technologies. In tandem, the EU's Fit for 55 package sets binding targets to cut emissions by at least 55% by 2030. Geothermal systems are identified as core enablers of renewable heat in multiple policy documents, including the Department of the Environment, Climate and Communications' (DECC's) 2020 Geothermal Roadmap and the European Geothermal Energy Council's (EGEC's) Geothermal Manifesto (DECC, 2020; EGEC, 2024).

At the European level, geothermal energy is increasingly seen as a versatile, resilient, and base-load renewable. The European Technology and Innovation Platform for Deep Geothermal (ETIP-DG) and the European Green Deal identify geothermal as key to achieving energy sovereignty and net-zero industry. They call for improved permitting processes, digital geological data, and financial risk guarantees to unlock project development across member states (ETIP-Geothermal, 2024).

The daa's project aligns with these principles and may become a reference site in policy discussions around scaling geothermal solutions in other transport and public infrastructure settings.

7 OUTCOMES AND IMPACT

The feasibility study for the Dublin Airport geothermal project generated a suite of technical, economic, and strategic insights with implications beyond the immediate site. At the most practical level, it determined the viability of deploying up to 10 MW_{th} of geothermal solutions across Zones 1 and 3. The outcome was a detailed understanding of ground conditions, system sizing, projected performance, and cost-benefit dynamics, guiding daa's decision-making for capital investment. The project also provides a valuable demonstration of early-stage integration of geothermal into large-scale public infrastructure, which is relatively rare in Ireland.

Beyond its technical and economic merits, the project's eventual deployment will have significant strategic impacts. It positions Dublin Airport as a testbed for institutional and infrastructural transformation, advancing the concept of the airport as an energy ecosystem. Within this system, geothermal becomes the anchor technology—supporting load balancing, carbon reduction, and eventual integration with district-scale systems such as energy storage, solar Photovoltaic (PV), and smart controls.

This vision aligns closely with the insights from Palmer et al. (2023), who argue in the *Pivoting the Geoenergy Nexuses* report that critical infrastructures such as airports can become "market-making spaces" where new technologies and business models are normalised. Geothermal deployment at Dublin Airport demonstrates this potential, providing proof-of-concept for planners, engineers, policymakers, and financiers who are seeking replicable low-carbon solutions.

The project also catalysed capacity building within the Irish geothermal sector. By advancing technical practices (e.g., TRT testing, pumping tests, DTS measurements and LCA modelling), coordinating multiple stakeholder engagements, and applying national and EU standards, it strengthened the competencies and confidence of consultants, contractors, and regulators alike. Importantly, it also generated institutional learning within the daa itself, preparing the organisation for a broader role in Ireland's climate transition.

The feasibility study demonstrated that subsurface conditions support both Shallow Closed Loop and Deep Closed Loop systems at Dublin Airport for the Zones 1 and 3 existing and future buildings.

There are opportunities for a plug-and-play shallow closed loop geothermal solution at Terminal 2 consisting of 224 no. boreholes at 224m depth for heating and cooling, with estimated annual energy savings of €656k. Free cooling benefits of 73% by year 10 are available based on demand-side adjustments such as moving to dynamic demand-based chilled water flow temperatures modulating upwards.

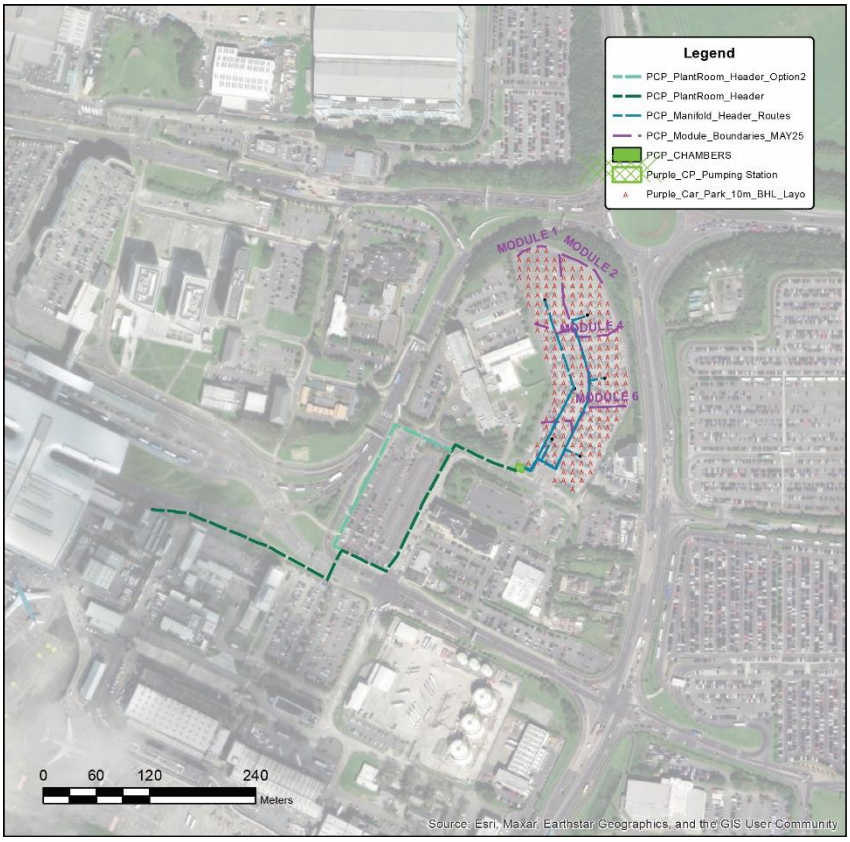


Figure 4. Geothermal Collector and Service Corridor for Terminal 2 / Pier 400

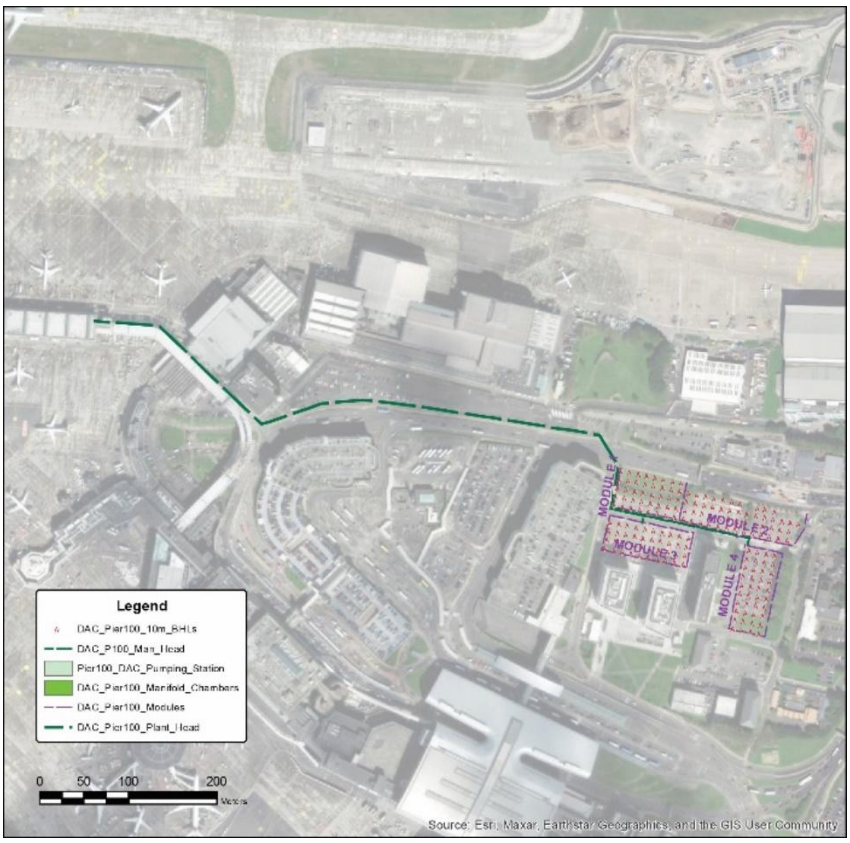


Figure 5. Geothermal Collector and Service Corridor for Pier 100

Pier 100 is the next stage – expanding geothermal to scalable infrastructure. At Pier 100, two proposed options were developed, with 168 no. shallow closed loop boreholes at 203m depth recommended due to the benefits of free cooling over time (i.e., 62% by year 10) based on a similar approach as Terminal 2 and estimated annual

energy savings of €232k. Prior to full deployment, additional energy load analysis and data monitoring will be necessary to optimise the integration of geothermal with Pier 100's heating and cooling systems.

The following summarises the preliminary designs that were developed for future infrastructure builds at Dublin Airport based on subsurface geology, thermal conductivity parameters, and energy demand data:

- Pier 500: shallow closed loop; 110 boreholes at 210m depth;
- Pier 100 Mod: shallow closed loop; 42 boreholes at 195m depth; and
- 3 no. Cargo Buildings: shallow closed loop; 60 boreholes per building at 200m depth.

Each geothermal collector layout for these future buildings was designed on the basis of limiting the extent of the collector to below the proposed footprint and immediate surrounding area as much as possible.

8 INSTITUTIONAL AND ECOSYSTEM PERSPECTIVES ON GEOTHERMAL DEPLOYMENT

The geothermal feasibility study at Dublin Airport was not only a technical and strategic exercise, but also a manifestation of broader institutional and market-shaping dynamics that underpin the geothermal energy market transition. Drawing on Ireland et al. (2025), the project can be understood as part of an evolving process of collective vision-making - a coordinated effort among public, private, and civic actors to stabilise expectations, construct shared narratives, and embed geothermal within the infrastructural imagination of the Irish energy system. As Geels (2005) and DiMaggio & Powell (1983) highlight, such alignment processes are central to the institutionalisation of emerging technologies, where legitimacy is built not only through performance but through symbolic conformance and normative framing.

Crucial to this process is what Ireland et al. identify as social flow maintenance work - the proactive and often invisible labour of keeping momentum in complex, uncertain, and multi-actor transition processes. This involves bridging operational silos, smoothing regulatory pathways, and maintaining narrative and procedural coherence across organisational and temporal boundaries. Mintzberg's (1979) insights on strategic structuring and Ready & Conger's (2007) emphasis on collective leadership capacities echo here, as the success of infrastructural innovation depends not solely on technical capability but on institutional fluency and adaptive coordination.

The daa's leadership in convening this feasibility study demonstrates what ecosystem theorists such as Adner (2017), Foss et al. (2023), and Kuan & West (2023) describe as ecosystem orchestration - the deliberate shaping of an environment where diverse actors can coalesce around mutual dependencies and shared outcomes. In line with this, the study shows how strategic infrastructural nodes, such as airports, can serve as institutional accelerators, imprinting the built environment with new technological trajectories and embedding renewable energy transitions within core public functions.

By situating geothermal energy at the heart of a high-visibility, operationally intensive site like Dublin Airport, the project also responds to the governance dilemmas outlined in Palmer et al. (2023), who argue that geothermal's advancement depends not only on technical standards and capital flows, but on strategic imagineers and demonstration spaces that enable market actors to believe, coordinate, and act.

The feasibility study, therefore, is more than an appraisal, it is a performative act of institutional market-making. It constructs geothermal as a credible, integrated, and forward-compatible infrastructure option, while catalysing capacity-building, stakeholder alignment, and sectoral legitimacy. It is a key moment in the collective effort to "normalise geothermal" as both a technical solution and a socio-political project within Ireland's evolving climate and infrastructure regime.

9 LIFE CYCLE ANALYSIS AND HYBRID SYSTEM CONSIDERATIONS

A lifecycle analysis (LCA) was embedded within the geothermal feasibility study, led by OPN Buildings using their advanced Net Zero Platform. This analysis evaluated the long-term operational performance of the proposed geothermal systems, focusing on metrics such as projected carbon savings, lifecycle energy costs, and environmental, social, and governance (ESG) compliance. By simulating cost-benefit outcomes under different energy pricing scenarios and operational configurations, the LCA provided daa with a robust evidence base for investment decisions. In parallel, the study explored the technical and economic viability of hybrid system architectures that combine multiple renewable technologies to enhance resilience and scalability. These configurations include closed-loop GSHP fields, open-loop groundwater systems where hydrogeological conditions permit, and borehole thermal energy storage (BTES) to support seasonal heat balancing. Integration opportunities with complementary technologies such as PV arrays were also evaluated to create a flexible, modular energy system. This holistic and portfolio driven approach ensures that geothermal deployment can

adapt to the evolving energy needs of the airport campus while maximising decarbonisation outcomes and aligning with daa's long-term masterplan for sustainable infrastructure development.

The LCA identified a cumulative 6,625 tCO_2e reduction for Terminal 2 and Pier 400, representing 125% of the Airport's 2030 scope 1 target, when apportioned on a pro rata basis to Terminal 2. It identified a further cumulative 1,970 tCO_2e reduction for Pier 100, representing 133% of the Airport's 2030 scope 1 target, when apportioned on a pro rata basis to Pier 100.

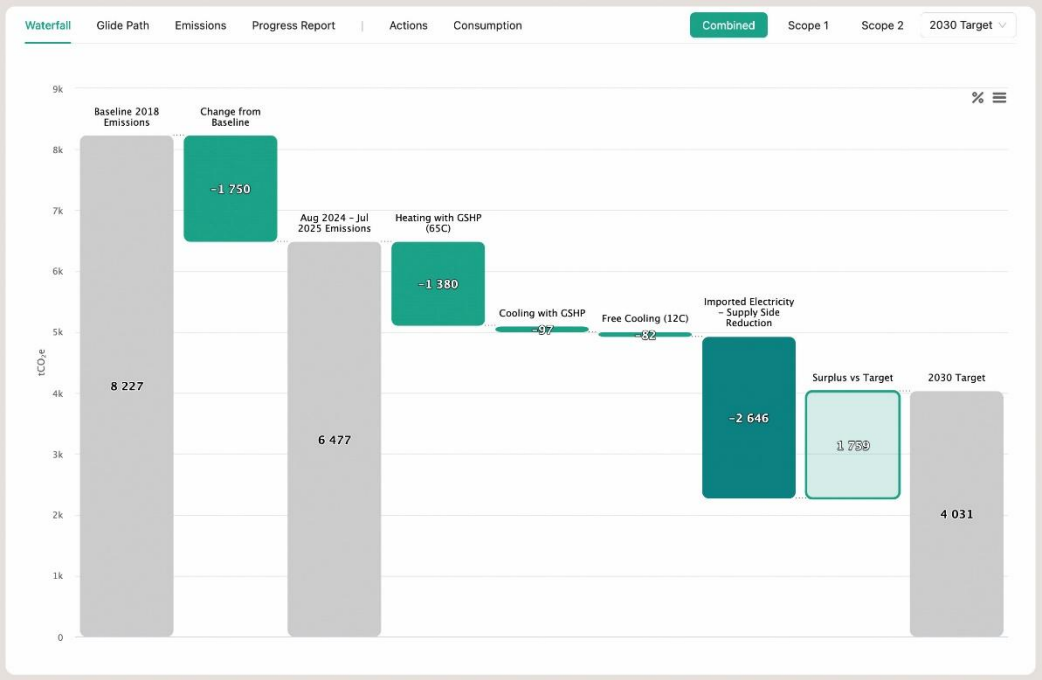


Figure 6. Terminal 2 / Pier 400 Shallow Closed Loop Carbon Emissions Pathway to 2030 (Source: www.opnbuildings.com)

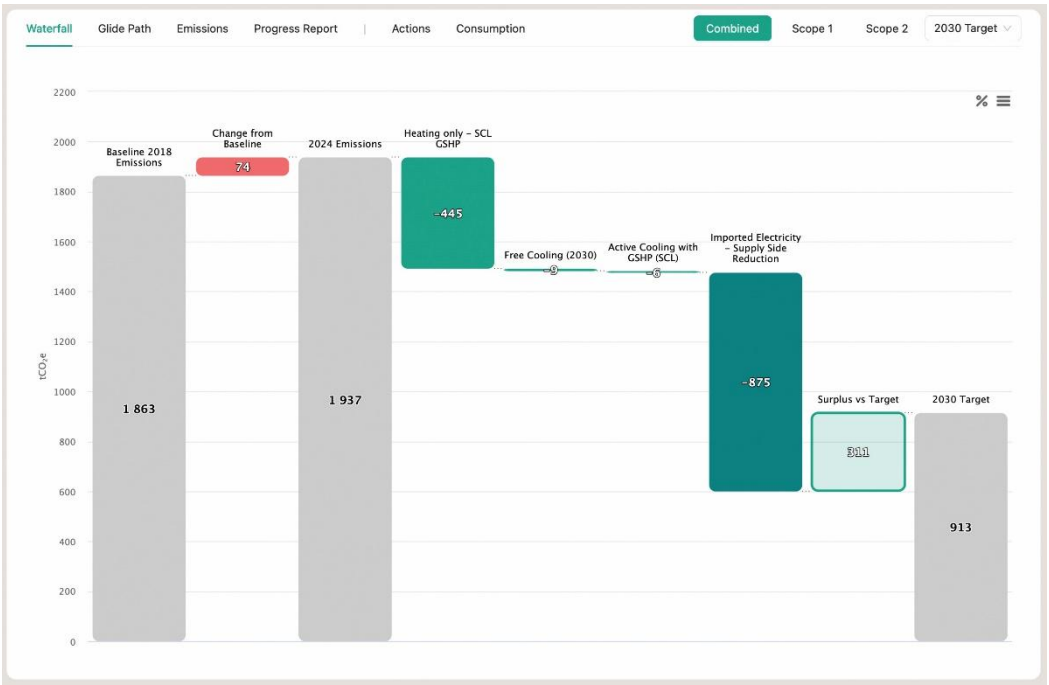


Figure 7. Pier 100 Shallow Closed Loop Carbon Emissions Pathway to 2030 (Source: www.opnbuildings.com)

Other technologies such as air source heat pumps face severe performance drop-offs in extreme temperatures, draw the most power when the grid is already under strain, require more frequent maintenance with shorter lifespans and cannot store energy. A geothermal battery, by contract, stores heat rejected from the building in

the ground year-round, ready for use when heating is needed. Offering steady performance, flattening peaks, and avoiding costly efficiency drops when demand is highest. This is not just an alternative; it is a value-driven commitment that will propel daa as a leader in renewable energy infrastructure. For daa, there is no other technology that delivers the same resilience, stability, low carbon, low-cost performance for every stage of expansion, long-term savings, and security for the next one hundred years.

For Dublin Airport, geothermal is not an incremental improvement – it's transformational. These gains lock in resilience, cost stability, and regulatory compliance long before deadlines.

10 CONCLUSIONS

The Dublin Airport geothermal feasibility study represents more than a technical or economic appraisal; it marks a pivotal institutional and infrastructural inflection point in Ireland's energy transition. By integrating geothermal energy into one of the country's most operationally demanding public campuses, the daa and its partners are helping to reposition geothermal as a core enabler of decarbonisation, energy security, and infrastructural resilience.

This project exemplifies how technically sound, policy-aligned, and socially embedded geothermal solutions can be realised through ecosystem coordination and visionary planning. It demonstrates the capacity of critical infrastructures, i.e. airports, to serve as institutional accelerators, market-making arenas, and flagship testbeds for climate innovation. The geothermal system at Dublin Airport is not conceived as a standalone intervention, but as an anchor technology within a broader, evolving energy ecosystem that supports hybrid systems, smart controls, seasonal balancing, and long-term campus adaptability.

The feasibility study's technical outputs - geophysical characterisation, borehole data, system modelling - will inform design and investment decisions. But perhaps more critically, the project performs an institutional function: it constructs and validates the conditions under which geothermal energy becomes thinkable, fundable, and replicable at scale.

Crucially, this work reflects a maturing policy, regulatory, and strategic environment for geothermal in Ireland. It aligns with EU decarbonisation objectives and national climate mandates, while cultivating organisational capacities and public-sector leadership in renewable heating and cooling. The daa, through this study, is not only testing a system, but also scripting a future for Irish geothermal.

Following completion of the feasibility study, the daa are currently undertaking a comparative assessment of geothermal and air-source heat pump (ASHP) solutions to determine the optimal long-term decarbonisation pathway for the airport. A final decision on the preferred technology and delivery approach is expected in the coming months. Should geothermal be selected, the next phase would include detailed design, phased implementation, and the establishment of a monitoring and verification programme to track system performance, carbon savings, and operational efficiency. Regardless of the outcome, the work undertaken at Dublin Airport already provides a robust technical and institutional foundation for future geothermal integration across Ireland's transport and infrastructure sectors. The findings are being used to inform early scoping discussions at other strategic sites such as Cork and Belfast City airports, helping to shape a consistent evidence base for national decision-making around low-carbon heating and cooling infrastructure.

The next steps - implementation, monitoring, reporting and scaling - will determine whether geothermal can move from margin to mainstream in Ireland's infrastructure landscape. This project has laid a strong foundation. What follows could define a generational shift in how heating and cooling is delivered, governed, and imagined.

Acknowledgements

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