# SIF CoolDown Alpha

# D5.1: Ground Source Heat Pump passive cooling exploration vF

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# CoolDown is exploring strategies to reduce the impact of increased cooling demand on the grid

### Problem

- Whilst becoming ubiquitous in non-domestic settings, residential space cooling (SC) remains nascent in the UK.
- As the UK warms, cooling load from both sources will increase.
- The potential impact of this load on distribution networks is poorly understood, as is space cooling's capacity as a flexible load.

### Phase 1 (Discovery) progress

- Modelled cooling load growth in two substations. Extrapolated results across wider pool of ENWL.
- Did an initial CBA suggesting that the cumulative benefit of demand response for cooling technologies could be up to £57mn by 2050.
- Developed a longlist of potential commercial models for network SC DR in the UK and identified any barriers to deployment.

### Objectives of phase 2 (Alpha)

- Refine and improve building cooling load modelling done in discovery.
- Develop 4-6 commercial arrangements for cooling demand response to trial in Beta phase.
- **Explore the potential of ground source heat pump (GSHP) passive cooling to complement demand response programmes in minimising the network impact of increasing cooling demand.**

### The purpose of this report is to:

1. Define passive cooling and explain how GSHP passive cooling works.
2. Present high-level potential consumer and network benefits realised by wider adoption of GSHP passive cooling.
3. List potential barriers to the adoption of GSHP passive cooling in GB.
4. Recommend actions for DNOs, Ofgem and DESNZ to improve the uptake of passive cooling in GB, including via GSHPs.

# What is passive cooling and how does GSHP passive cooling work?

# Passive cooling strategies can complement cooling DR to reduce cooling's network impact

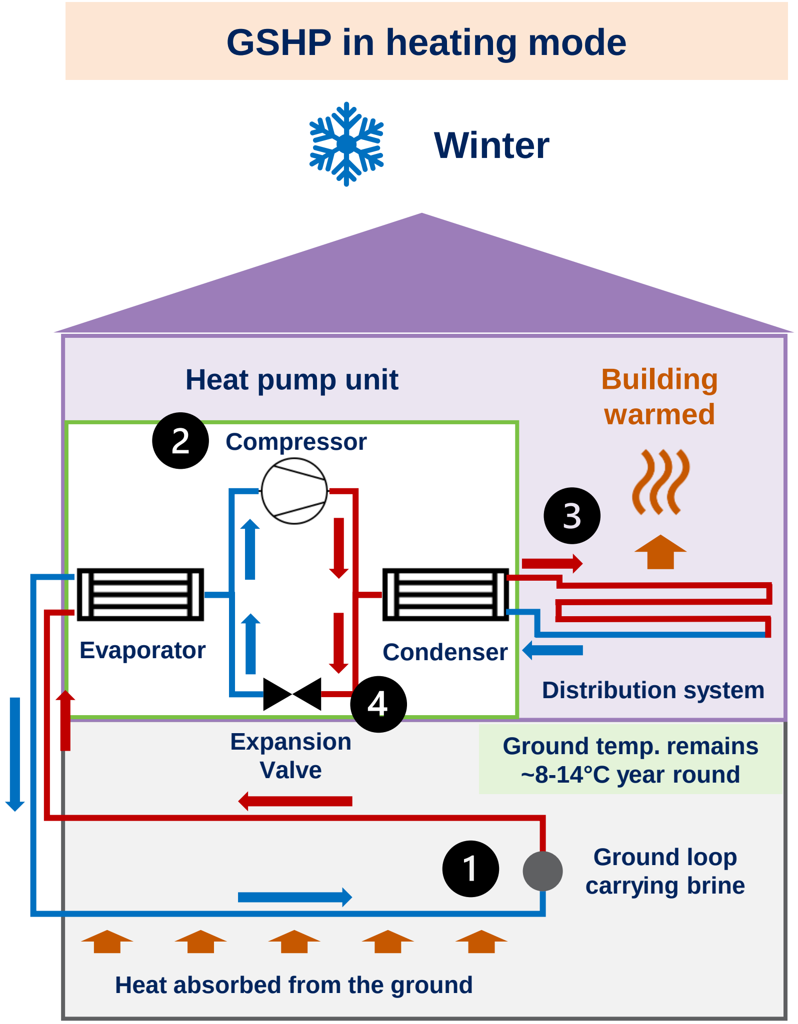
**Passive cooling is a building design approach that focusses on building heat dissipation during warm periods and improving building heat retention during cooler periods at low or no energy consumption. These could complement demand response strategies to minimise network impact of cooling.**

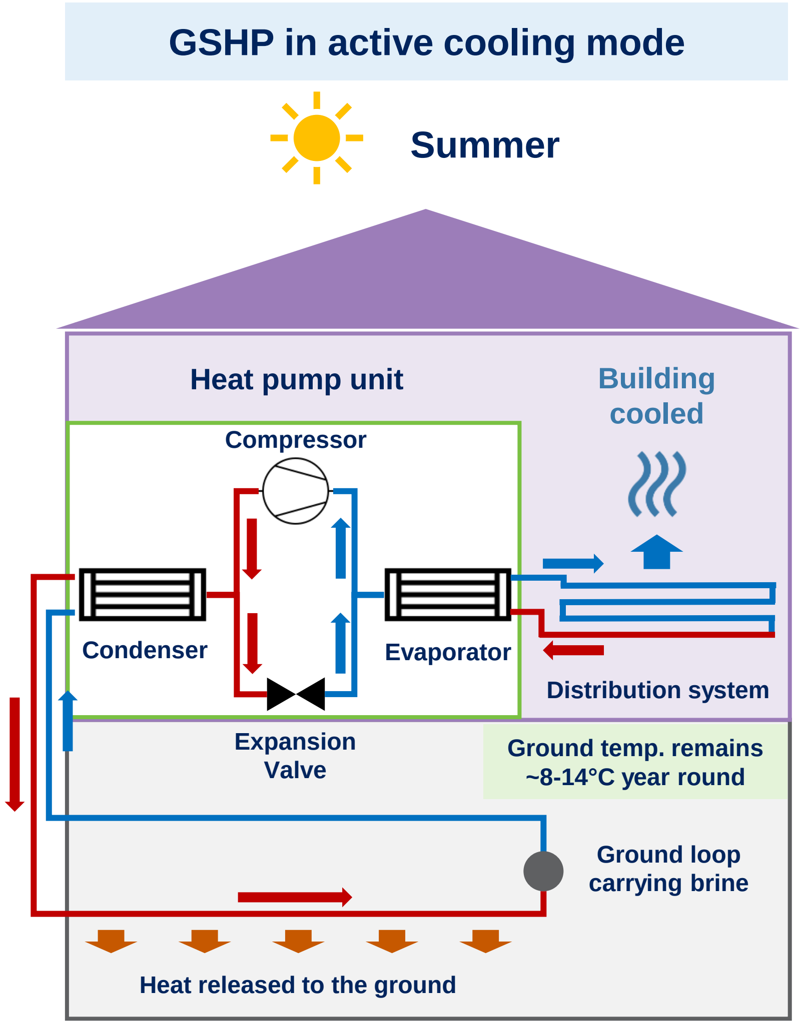
| Passive cooling strategies | Description | Ubiquity[1] | Ease of installation[2] | Pot. cooling demand red.[3] |
|---|---|---|---|---|
| GSHP passive cooling | • GSHP can provide passive cooling by transferring building heat to the significantly cooler nearby ground. | ○ | ◔ | ● |
| Shading devices | • Installing additional components to a window/façade to protect the building from direct sunlight, overheating and glare.<br>• Can be external (shutters, awnings, etc.) or internal (curtains, blinds, etc.). | ◕ | ◕ | ◑ |
| Green shading and roofing | • Positioning trees and vegetation strategically on the outside of a building to block out sunlight.<br>• This reduces the need for cooling and/or heating. | ◑ | ◑ | ◑ |
| Double glazing | • Improving insulation by using two glass panes separated by a layer of gas for windows instead of just one. | ◑ | ◑ | ◕ |
| Solar reflective window tints | • Using special films on windows to reduce the amount of solar irradiation and glare that enters a building. | ◔ | ◑ | ◑ |
| Natural ventilation | • Using natural airflow through building openings (windows, doors, etc.) to circulate fresh air and remove excess heat from buildings.<br>• Buildings can be designed to maximise this ventilation. | ● | ◕ | ◑ |
| Building fabric/material selection | • Using materials with high thermal mass, such as concrete or brick, to build buildings.<br>• These materials are better at maintaining internal building temperatures. | ◑ | ◑ | ◕ |



1 **Ubiquity:** How commonplace this passive cooling strategy is currently in the UK? 2 **Ease of installation:** Is installing this passive cooling measure disruptive/expensive?
3 **Potential cooling demand reduction:** What is the cooling demand reduction potential of this strategy, if adopted at scale?

# GSHPs enable efficient heat transfer between the building and ground to provide heating/cooling




## How does a GSHP work?

**Heating**

1. A water/refrigerant fluid (often referred to as brine) is circulated through the ground loop, absorbing thermal energy from the ground and circulating it back to the heat pump.
2. The compressor inside the heat pump increases the temperature and passes it to the condenser.
3. The condenser facilitates exchanges this heat with the distribution system, which dissipates the heat to the house.
4. The fluid is then passed through an expansion valve which cools it before it repeats the circuit all over again.

**Active cooling**

Requires the direction of flow to be swapped so heat energy from the building is absorbed and released to the ground.

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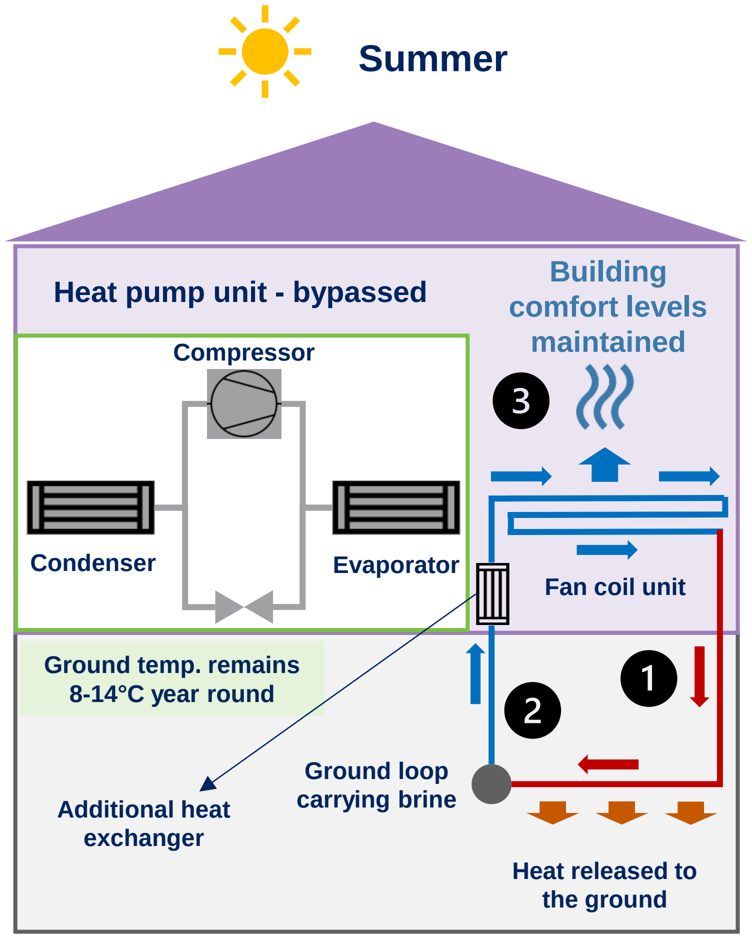
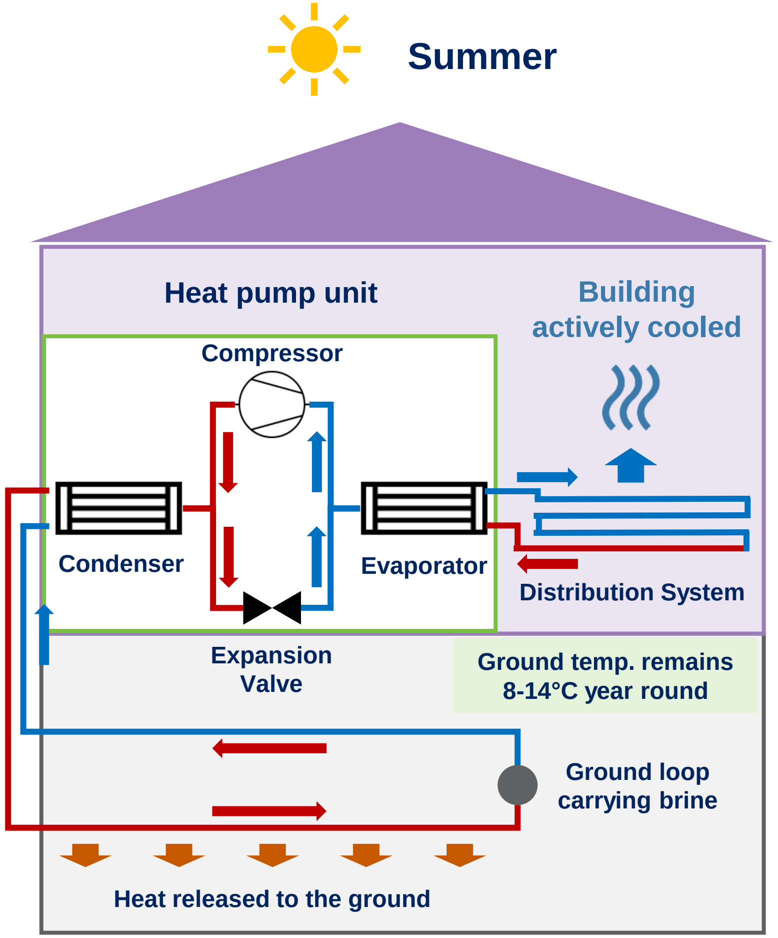
# GSHPs can cool buildings through active or passive cooling

## GSHP in passive cooling mode




## GSHP in active cooling mode




## How does a GSHP work in Passive Cooling mode?

1. The water/refrigerant fluid (often referred to as brine) is circulated through the ground loop directly, bypassing the heat pump completely.
2. The fluid is cooled by the lower temperature of the ground before being circulated to a heat exchanger which further reduces the temperature, providing chilled water.
3. The chilled water is then circulated through the distribution system, maintaining building comfort levels on hot summer days.

**Comparison to active cooling**

- Electricity is only needed to run the circulation pumps, heat exchanger and fan coil unit.
- GSHP passive cooling, therefore, represents a **cost-effective and low-energy solution to maintaining building comfort on hot days**



1 Union Road substation cooling load projections from CoolDown discovery phase, adjusted to account for new-build homes.

# Consumer and network benefits of GSHP passive cooling

# GSHP passive cooling can offer customer and network benefits, primarily in new build homes

**GSHP passive cooling of a building can save up to 80% of electricity costs related to space cooling compared to traditional air conditioning (AC) and active cooling technologies. However, its installation can be disruptive and capital intensive, especially if retrofitted into existing buildings.**

## Benefits of GSHP passive cooling systems

- Approximately five times less electricity consumption relative to active cooling technologies, resulting in large cost savings for customers.
- Improved heating efficiency in the winter from running the passive cooling system in summer can lower running costs by ~£11 per year[1] for every 1°C rise in soil temperature.
- Can be easily installed, without much disruption, in new build properties already installing a GSHP and commercial buildings with existing cooling distribution systems.
- Reduced peak demand resulting from increase future cooling load on the networks, potentially resulting in network reinforcement deferral/avoidance savings.

## Disadvantages of GSHP passive cooling systems

- Additional capital investment (~£500 extra[2]) and disruption in existing homes from installation of an additional heat exchanger, controls and pipework.
- Current heat distribution systems in most existing UK buildings (radiators and underfloor heating) are not suited for cooling and will need to be supplemented by fan coil units.
- Not as effective as active cooling technologies for lower desired temperatures. Passive cooling struggles to reach set points below 21°C, especially in larger buildings.
- Possible interference between heating and cooling control systems if detached, resulting in heating being turned on if the cooling set point is below a certain threshold.



1 Compared to a home powered by a GSHP without passive cooling units. Kensa Heat Pumps.
2 Interviews with Kensa Heat Pumps and Sero.

# Case study: Kensa Heat Pumps and Sero passive cooling trial in a newbuild property

**During the July 2022 heatwave, Kensa Heat Pumps trialed a passive cooling unit in the main living space of newbuild property in partnership with Sero. The system was able to maintain an internal temperature set-point of 21°C at low running costs even when external temperatures reached 32°C, demonstrating the effectiveness of passive cooling at maintaining building comfort levels.**

## Key findings from the trial

**Over 5x less power consumption than AC:** The system had a total power rating of ~0.12kW.

**>5x reduced daily running costs and carbon emissions:** £0.28 vs £1.53. 0.20kg$CO_2$ vs 1.13kg$CO_2$.

**Significant levels of cooling achievable:** Room temperatures of 16°C were achievable at maximum power.

**Significant levels of comfort achievable:** The main living space was 5°C cooler than the control room during operation.

**Relatively rapid rate of cooling:** Room temperature could be reduced from 23.5°C to 21°C in 45 minutes.

**Highlights from Sero and Kensa interviews:**

GSHP Passive cooling:

- Is an **easier solution for new-builds** as access and routing for the additional pipework to retrofit passive cooling units may prove challenging.
- Could work for larger domestic and commercial buildings, but **no trials have been conducted** in them.
- is a **comfort cooling solution**. It cannot guarantee a set point below 21°C but will provide comfort on hot summer days.

**Assumptions made in this trial[1]:**

- Electricity cost = £0.22/kWh (August 2024).
- Grid carbon intensity = 0.16kg/kWh (2023 avg).
- Air-conditioning power requirement based on market research of 6 AC units with a rated power of <2kW.
- Air-conditioning unit assumed to run at same hours as passive cooling unit.

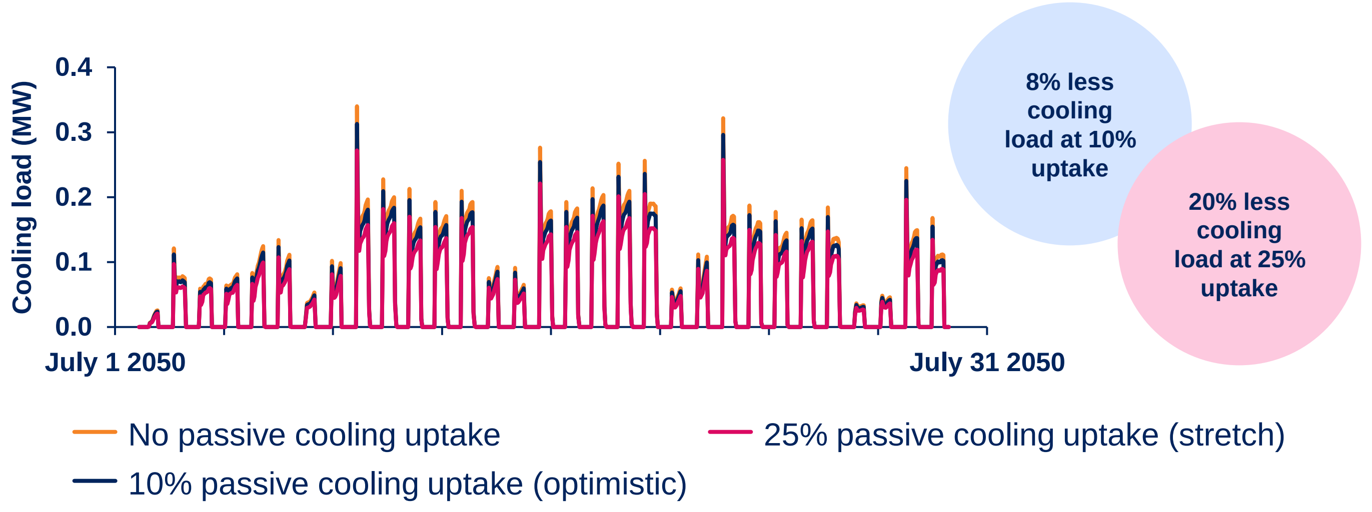


[1] The numbers presented and assumptions made are from the Kensa Heat Pumps x Sero passive cooling demonstrator in 2022.

# GSHP passive cooling could provide similar benefits to cooling DR if uptake is significant

**Cooling DR could reduce peak summer demand by ~1% ENWL wide[1]. GSHP passive cooling could provide similar substation and network level benefits depending on uptake. However, the barriers to adoption of GSHP passive cooling are significant - a 10% uptake by 2050 is optimistic.**

**GSHP passive cooling uptake's potential impact on a summer peaking substation's[2] cooling load in July 2050**




- The uptake of passive cooling is expected to be limited by barriers detailed in the next section. This limits the achievable cooling peak reduction and associated benefits.
- Given these barriers, a 10% uptake of GSHP passive cooling to replace AC demand is optimistic. 25% uptake is a stretch, shown for comparison.

## Network impact of GSHP passive cooling

**Substation level**

- A 10% uptake of GSHP passive cooling, replacing AC demand, could reduce **summer peak cooling demand by 8%** in **2050[3]**. This is similar to the **~9-15% decrease in peak load achieved by cooling DR** in >50% of substations modelled in WP2[4].

**ENWL network level**

- The **total AC demand** only accounts for **~25% of total network load[1] in summer in 2050.**
- A 10% uptake of GSHP passive cooling would potentially reduce **peak summer demand by ~2% network-wide in 2050.** This is **similar to the ~1% summer peak demand reduction achievable by cooling DR[1]** in 2050.

Either method could therefore offer **reinforcement deferral benefits for summer peaking substations**, whose peak demand is driven by cooling demand. Passive cooling has a narrower potential penetration than DR, however, limiting its **achievable** relative benefits.


[1] Refer to WP3 – Network impact of SC – outputs for more details on this; [2] Refer to appendix for methodology behind this; [3] Assuming GSHP passive cooling uses 5x less power than equivalent AC; [4] Refer to WP2 – Modelling SC uptake and DR – outputs for more details

# Barriers to widespread adoption of GSHP passive cooling

# Barriers to adoption of GSHP passive cooling

**High costs, regulatory barriers, and the need for additional retrofit work in existing homes/buildings all limit the potential for GSHP passive cooling to deliver widespread benefits.**

| | Barrier to widespread adoption | Impact of barrier | Type of barrier |
|---|---|---|---|
| 1 | **Incompatible with the heating distribution systems (radiators) in existing homes**. Fan coil units, a separate circulation and control system, an additional pump and a heat exchanger all need to be installed to enable passive cooling. | • Installing passive cooling in existing homes is disruptive and expensive, disincentivising residents from doing so. | Technical |
| 2 | **Technology is yet to be proven at scale.** There have only been a few small-scale, individual house level trials of GSHP passive cooling in the UK. | • Poor GSHP passive cooling uptake due to low confidence in the efficacy of the technology. | Technical |
| 3 | **GSHP uptake is low for heating, even in new builds.** This is because of the large capital costs associated with the boreholes, disparity between electricity and gas prices and the Standard Assessment Procedure (SAP) calculation and EPC methodology focussing energy costs rather than energy efficiency. | • Poor uptake of GSHPs as a replacement for gas boilers.<br>• Energy consumers may prefer cheaper, less efficient alternative heating technologies (Air source heat pumps). | Economic |
| 4 | **Limited understanding of the factors impacting building comfort amongst developers and building tenants.** Developers follow an internal temperature driven assessment of building comfort instead of considering factors such as air movement, humidity, evaporation, etc. | • Developers choose to install active cooling in buildings instead of, or along with, passive cooling measures. | Behavioural |

# Policy change recommendations to support widespread adoption of GSHP passive cooling

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# Suitability matrix for passive cooling measures by building type

**The following matrix rates the suitability of passive cooling strategies by building type based on the following factors:**
**1) Ease of installation, accounting for cost and level of disruption needed.**
**2) Effectiveness of solution in maintaining building comfort levels.**

| | Building type | | | |
|---|---|---|---|---|
| **Passive cooling measures** | **Residential new-builds** | **Commercial new builds** | **Residential existing** | **Commercial existing** |
| GSHP passive cooling | High priority measure | Medium priority measures | Unsuitable | Medium priority measures |
| Shading devices | Medium priority measures | Medium priority measures | High priority measure | High priority measure |
| Green shading and roofing | Medium priority measures | Low priority measures | Low priority measures | Low priority measures |
| Double glazing | High priority measure | High priority measure | High priority measure | High priority measure |
| Solar reflective window tints | Low priority measures | Low priority measures | Low priority measures | Low priority measures |
| Natural ventilation | High priority measure | High priority measure | Medium priority measures | Medium priority measures |
| Building fabric/material selection | First choice measure | First choice measure | Unsuitable | Unsuitable |

**GSHP passive cooling suitability:**

1. High priority in **residential new builds** as it can be installed during building.
2. Unsuitable in **existing residential buildings** due to incompatible heat distribution systems and insufficient space.
3. Medium priority in **commercials** due to compatible heat distribution systems.

- **Unsuitable**
- **Low priority measures**
- **Medium priority measures**
- **High priority measure**
- **First choice measure**

# Recommendations to support GSHP passive cooling uptake across GB

**There should be more focus on the viability of GSHP passive cooling as a mechanism to unlock potential network benefits across GB. If viable, there should be stronger policy and regulatory signals to support the rollout of GSHP and GSHP passive cooling. These recommendations are based on interviews and research undertaken for this report.**

| | Recommendation | Responsible | Outcome | DNO action |
|---|---|---|---|---|
| **1** | Provide support and funding for larger-scale trials of GSHP passive cooling in commercial buildings and new-build residentials. | DESNZ/Ofgem | Improved confidence in and awareness of the benefits of GSHP passive cooling, positively impacting uptake rates. | Consider potential innovation projects for larger scale GSHP passive cooling trials to understand benefits at a substation level. |
| **2** | Mandate a passive first building design approach for development proposals to reduce potential overheating and reliance on AC systems. | Local Authorities | Passive cooling measures, including via GSHPs, will be adopted in more new builds in the UK, minimising the rise in cooling demand and associated network impacts. | Actively support adoption of a passive-first building cooling design strategy, particularly in constrained regions of the network. |
| **3** | Educate developers and consumers on factors impacting building comfort and the ability of passive cooling measures to maintain building comfort on hot summer days. | DNOs/DESNZ/ Ofgem/Local Authorities | More developers will install passive cooling measures, including GSHP passive cooling, instead of active cooling technologies. | Actively communicate the benefits of passive cooling, including via GSHPs, to consumers, developers and policymakers. |
| **4** | Mandate an expanded role for DNOs to deliver energy efficiency in the ED3 period where it can deliver greatest value to the network. | Ofgem | DNOs may actively support uptake of passive cooling measures. | Explore the implications of this for their ED3 plans. |
| **5** | Refresh the SAP calculation and EPC methodology to better reflect the energy efficiency benefits attainable from installing heat pumps. | DESNZ | Developers are better incentivised from a reporting perspective to install GSHPs with passive cooling. | Support changes if they are designed to reduce network load from new builds. |
| **6** | Update the Boiler Upgrade scheme (BUS) to a tiered grant framework. Heat pumps with a higher coefficient of performances (CoP) to receive greater grant than those with lower CoPs. | DESNZ | Energy consumers are better incentivised to install GSHPs over air source heat pumps. | No action required. |

# Appendix: substation and network impact methodology

# Method to estimate the impact of GSHP passive cooling uptake on peak summer cooling demand

**This slide presents the methodology and assumptions adopted to understand the impact of varying levels of GSHP passive cooling uptake on:**

- **The predicted cooling load of a summer peak substation in ENWL's license area**
- **The impact of a100% uptake of GSHP passive cooling across ENWL's network.**

| | Method | Assumptions made | Limitations |
|---|---|---|---|
| | **Substation level impact of varying levels of GSHP passive cooling uptake** | | |
| **1** | Add on the impact of predicted cooling uptake amongst new builds in 2050 on the cooling load projections at Union road substation modelled in the discovery phase | • The increase in number of domestic buildings at this substation is proportional to the increase in the number of new homes across the UK by 2050[1].<br>• No new commercial buildings at this substation in 2050.<br>• All buildings connected at this substation have the same cooling load.<br>• 66% of all new and existing buildings connected to this substation will would install AC by 2050. | • The growth in number of domestic buildings may not be equal everywhere across the UK.<br>• There may be new commercial buildings at this substation in 2050, not accounted for in this approach.<br>• The different buildings will have different levels of cooling load. |
| **2** | Proportionately apply a 5x cooling load reduction factor based on the GSHP passive cooling uptake rate being modelled. | • GSHP passive cooling uses 5x less electricity than equivalent AC. | • This is based on small-scale UK trials of GSHP passive cooling in individual homes.<br>• This figure may vary for larger domestic and commercial buildings. |
| | **Network level impact of a 50% uptake of GSHP passive cooling** | | |
| **3** | Apply a 5x reduction on 10% of the total 2050 AC demand, obtained from ENW's 2023 DFES[2]. | • GSHP passive cooling uses 5x less electricity than equivalent AC. | • This is based on small-scale UK trials of GSHP passive cooling in individual homes.<br>• This figure may vary for larger domestic and commercial buildings. |



1 ~9 million new homes in UK by 2050.

2 ENW DFES 2023 workbook – Best View Scenario