MAYOR OF LONDON

# GLA Roofs Designed to Cool

A Review of Reflective and Solar PV Roofs for London

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Kamal Chunchie Way
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enquiries 020 7983 4000
minicom 020 7983 4458

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## ACKNOWLEDGEMENTS & CONTRIBUTIONS

Metropolder BV, Rotterdam, Netherlands
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## MEMBERS OF THE PROJECT STEERING GROUP

**Annette Figueiredo** – Project Lead, Principal Programme & Policy Officer, Greater London Authority, Climate Change (Adaptation)

**Kristiina Yang** – Senior Policy & Programme Officer, Greater London Authority, Climate Change (Adaptation) & Green Infrastructure

## OTHER CONTRIBUTORS

**Johanna Sutton** – Principal Programme & Policy Officer, Greater London Authority, Climate Change (Mitigation)
**Kristen Guida** – Urban Resilience Manager, Greater London Authority, Fire and Resilience **Dan Bicknell** – Climate Adaptation Manager, Greater London Authority, Climate Adaptation, Environment & Energy
**James Lee** – Principal Policy Officer, Greater London Authority, Skills Strategy and Policy.
**Ruxanda Profir** – Senior Data Analyst, Greater London Authority

**Paul Hodgson** – Senior Manager, Greater London Authority, City Data
**Lizzie Botfield** – Senior Policy & Programme Officer, Greater London Authority, Green Infrastructure
**John Diver** – Senior Strategic Planner, Greater London Authority, Design, Heritage & Environment
**Katie Ferguson** – Consultant, Greater London Authority, Public Health
**Kosh Kar** – Development Lead, Greater London Authority, Infrastructure Co-ordination
**Holly Smith** – Project Manager (Surface Water Flooding), Greater London Authority
**Juliette Young –** Senior Policy and Programmes Officer, Greater London Authority
**Simon Wyke** – Climate Change Mitigation Manager, Greater London Authority
**Pete Daw** – Head of Climate Change, Greater London Authority
**Sarah Fletcher** – Principal Policy and Programme Officer, Greater London Authority
**Sally Frazer** – Policy and Programme Manager, Greater London Authority
**Rhianna Malcolm** – Energy Policy and Projects Officer, Greater London Authority
**Claire Jaimeson** – Climate Change Team, Greater London Authority
**Zahra Ali** – Senior Policy and Programmes Officer, Climate, Greater London Authority
**Helen Booth** - Copywriter, Greater London Authority
**Vivienne Lang** – Creative Services Manager, Greater London Authority
**Agnese Manfrin** – Content Designer, Greater London Authority

## EXTERNAL PEER REVIEWERS

**Clare Heaviside** – Natural Environment Research Council (NERC) Fellow & Associate Professor, UCL
**Anna Mavrogianni** – Associate Professor, Sustainable Building and Urban Design, UCL
**Anastasia Mylona** – Head of Research, Chartered Institution of Building Services Engineers
**Syed Ahmed** – Director, Energy for London

## SUPPLIER

ARUP

**Becci Taylor** – Project Director, Director, Arup, Buildings
**Doug Kingham** – Project Reviewer, Associate Director, Advisory Services
**Dimple Rana** – Project Manager, Associate, Arup, Technical Services
**Elliot Marsden** – Project Manager, Senior Consultant, Arup, Advisory Services
**Emma Boucher** – Project Team, Consultant, Arup, Climate Change
**Laetitia Lucy** – Project Team, Senior Consultant, Arup, Cities Planning & Design
**Lorena Cruz** - Project Team, Senior Consultant, Arup, Cities Planning & Design

**Paul Garbet** – Cost Consultant, Associate, Arup, Advisory Services
**Abi Hughes** – Assistant Quantity Surveyor, Arup, Advisory Services
**Nanayaa Ampoma** – Senior Planner, Arup, Cities Planning & Design
**Jake Hacker** – Environmental Physics, Associate, Arup, Technical Services
**Nabihah Ghufoor** – Environmental Physics, Engineer, Arup, Technical Services
**David Coningsby** – GIS Consultant, Arup, Digital Services
**Mandy Maas** – Senior Data scientist, Arup, Digital Hub
**Adam Jaffe** – Senior Engineer, Arup, Technical Services

## EXTERNAL ADVISORS & CONTRIBUTERS

**Helen Macintyre** – Senior Environmental Scientist, UK Health Security Agency
**Frisco Klapwijk** – Global Director, MetroPolder, Urban Climate Resilience
**Adam Freed** – Principal, Bloomberg Associates
**Lauren Racusin** – Manager, Bloomberg Associates
**Dr Ting Sun** – Lecturer in Climate & Meteorological Hazard Risks, UCL Institute for Risk & Disaster
**Snigdha Jain** – Director of Sustainability, Turley

# Contents

# Summary

Temperatures in London are increasing due to global climate change. This is worsened by London's urban heat island (UHI) effect which means the city is hotter than its rural surroundings. Cities are heating at twice the rate of global average warming (Resilient Cities Network, 2022).

As a result, there is growing pressure on London's buildings, infrastructure, services, and, above all, Londoners. Hotter temperatures are bad for health and cause discomfort exacerbating existing physical and mental health conditions. They will impact the city's vulnerable and 'at risk' people and critical infrastructure the most. Furthermore, as demand for cooling increases, increased heat may stress power supply networks and infrastructure systems. This is due to increasing electricity demand and higher summer peak loads combined with lower grid efficiency during hot weather (World Economic Forum, 2022). In turn, this will impact London's environment, society, and economy. It is important that we set an agenda and take action.

This report sets out how a 'Cool Roofs Retrofit Programme' for London could lead to a greener and cooler city and contribute to reducing health, economic, and social inequalities.

Cool roofs can contribute to both the adaptation and resilience of London. On a single-building scale, cool roofs can reduce overheating and energy use. Taken at a city-wide scale, cool roofs can help to reduce the UHI of London. Alongside other measures the city is taking to reduce the risk of overheating in London, a 'Cool Roofs Retrofit Programme' could make an important difference.

A London 'Cool Roofs Retrofit Programme' can also bring other co-benefits. These include building strong communities through increased health, comfort, and neighbourhood schemes, reducing social and health inequalities through prioritising the vulnerable, and providing opportunities to develop skills and job opportunities in retrofit. All key objectives for the city.

This report focuses on reflective and solar photovoltaic (PV) roofs. Its purpose is to establish the evidence base for installing cool roofs on existing buildings across London. This includes examining the environmental, social, and economic benefits of a London 'Cool Roofs Retrofit Programme' and distilling recommendations.

It takes a holistic view of considerations, opportunities, and barriers to set the context for future phases of programme delivery. This includes consideration of climate adaptation

though retrofit action which must also be incorporated when other improvements are being made to existing buildings.

**Building a case for London**

The report compiles the evidence bases for both reflective cool roofs and solar PV roofs by examining academic research, case studies, and specially commissioned research.

The evidence base shows the key benefits to London are:

- Reduction of overheating in buildings. Reflective roofs, in particular, have proved effective in reducing overheating in buildings in global cities, including New York, Toronto, and Madrid. Research and analysis show that reflective roofs can reduce summertime overheating in London. In addition, cool roofs are likely to reduce overall energy use in buildings that are air conditioned.

- Reduction in UHI effect. At a large scale, cool roofs (both reflective and solar PV) can help cool London’s wider microclimate by reducing build-up of heat in the built environment.

- Energy generation. The main benefit of solar PVs is generating electricity for both homes and other buildings, with potential for export of excess electricity to create income. If combined with battery storage, PVs can also reduce peak demand on the grid.

- Improving health and comfort of people. Lower urban and internal temperatures will reduce heat-related illnesses and deaths. Furthermore, a reduction in UHI can improve air quality further benefiting Londoners’ health.

- Creating skills for Londoners. A London ‘Cool Roofs Retrofit Programme’ could enable new engineering apprenticeships and skills development, especially for young Londoners. This could be supported through existing schemes, such as Skills Bootcamp for Londoners and Green Hubs.

- Reducing social inequalities. Prioritising cool roofs in the ‘riskiest’ or priority areas, where there is the greatest heat exposure and vulnerability to heat stress, will ensure that those most in need are helped. This report presents opportunity maps for cool roofs to inform London stakeholders on where cool roofs should be installed. This highlights areas where high exposure, vulnerability, and social inequalities overlap.

**A holistic approach**

A holistic systems approach is vital to ensure the success of a 'London Cool Roofs Retrofit Programme'. Therefore, the report has considered cool roof implementation factors related to context, barriers, and opportunities. These include:

- Cost
- Constructability
- Funding, partnerships, and commercial models
- Policy and planning
- Behaviour, engagement and communication
- Social value and skills development

Following investigation, the report has identified several Critical Success Factors (CSFs) which provide a direction of travel for the programme. These are 1) Strategic Fit and Business Needs, 2) Social, Economic and Environmental Value, 3) Supplier Capacity and Capability, 4) Affordability, and 5) Achievability.

The report has evaluated these factors against various building archetypes (residential, school, and commercial). These typologies were chosen to capture a suitable range of building types which can represent much of the city's building stock. Considerations that apply to these typologies could also be interpreted for other building types. For each archetype an assessment was carried out for the recommended technologies available for application within a cool roof retrofit programme, as shown in the table below.

| | **Archetype 1: House** | **Archetype 2: School** | **Archetype 3: Social Housing** | **Archetype 4: Commercial Office** |
|---|---|---|---|---|
| **Type** | Building Type: 1919-1944 semi-detached house, family home | Building Type: Late 20th Century School | Building Type: 1960-80 Social housing estate | Building Type: Commercial office |
| **Description** | Traditional pitched roof with plain clay tiles. Naturally ventilated. | Concrete construction with a flat roof. Naturally ventilated. | High-rise concrete construction with a flat roof. Naturally ventilated. | Medium rise concrete construction with flat roof. Mechanically ventilated. |
| **Reflective Roof** | Recommended (tiles) | Recommended (coating) | Recommended (coating) | Recommended (coating) |
| **Solar PV** | Recommended | Recommended | Recommended | Recommended |

As shown above, both cool roof technologies are recommended for the types of building the report has assessed. They have been recommended based on an investigation into their wider benefits, which are discussed in more detail in this report. The specific considerations and performance impact of cool roof retrofitting will vary depending on building type, retrofit option, occupants, and location. This assessment is intended as a starting point and the recommendations in this report discuss the next steps suggested to implement a comprehensive programme for London.

**Next Steps: Wins for London**

The evaluation of holistic considerations and success factors has helped to shape the report's recommendations. These provide short, medium, and long-term wins for London.

The below table summarises the recommendations and their suggested stakeholders who could progress them.

| **Wins** | | |
|---|---|---|
| **Short-term wins (suggested c 3 – 6 months)** | Stakeholder | Description |
| **Checklist for building owners** | Building owners and developers (e.g. homeowners, housing associations, private organisations Local Authorities) | Checklists to help stakeholders around decision making with key considerations for a cool roof retrofit. Sample checklist for a private homeowner in Appendix H. |
| **Organisational strategy** | GLA | Establish a GLA Cool Roof retrofit taskforce. |
| **Pilot project** | GLA, Consultant Team, Retrofit Installers and 1-2 local community stakeholders in higher-priority boroughs | Plan and implement pilot project to assess the potential for cool roof retrofits to reduce overheating, cool local UHI and to provide social equality (value) and skills development. |
| **Integration with and benefitting from existing programmes** | GLA | The GLA could engage with existing funding, partnership, and training programmes to develop implementation synergies and scope the "Cool Roofs Retrofit Programme". This could include programmes such as:<br><br>The Business Climate Challenge<br>Solar Together<br>London Energy Climate Fund |

| **Medium-term wins (suggested c. 6 – 12 months)** | Stakeholder | Description |
|---|---|---|
| **Consolidation and integration of cool roof workstreams** | GLA | Consolidation of all cool roof adjacent workstreams to support an integrated approach for cooling London. |
| **Development of business case** | GLA and Consultant Team | Developments to business case that factor in learnings from pilot project. |
| **Communication and behaviour engagement** | GLA to Homeowners, Housing Associations, Developers, Architects and Green Skills Hubs | Prepare and share communication material to a wider retrofit stakeholder audience. |
| **Develop training and apprenticeship programmes** | Training Institutions, Co-Ops, and Apprentices | Continue to engage with existing schemes as well as develop a comprehensive training and apprenticeship programme specifically for cool roofs. This can widen opportunities for Small and Medium Enterprises. |
| **Long-Term Wins (suggested c. 12 – 24 months+)** | Stakeholder | Description |
| **Planning policy** | GLA and UK Government | Promote and lobby updates to national policy to ensure that cool roof retrofitting is embedded into Permitted Development rights. Consider London planning policy or incentives to motivate or require 'Cool Roofs Retrofit' when other works occur. |
| **Funding** | GLA and UK Government | Promote and lobby updates to national policy to support new funding schemes for reflective roofs retrofitting.<br>Promote update to existing schemes eligibility rules to ensure that cool roof retrofit funding is available to wider stakeholders. |
| **London-wide adoption of cool roof implementation** | Homeowners, housing associations, developers, architects, and Green Skills Hubs | London-wide understanding and implementation of cool roof retrofits to reduce overheating and UHI and support skills development and social value. |

These recommendations will support a comprehensive plan for a London-wide 'Cool Roofs Retrofit Programme' to meet its objectives at scale. Completion of the short-term wins will inform medium- and long-term recommendations and, subsequently, an overall approach for a London-wide programme at scale.

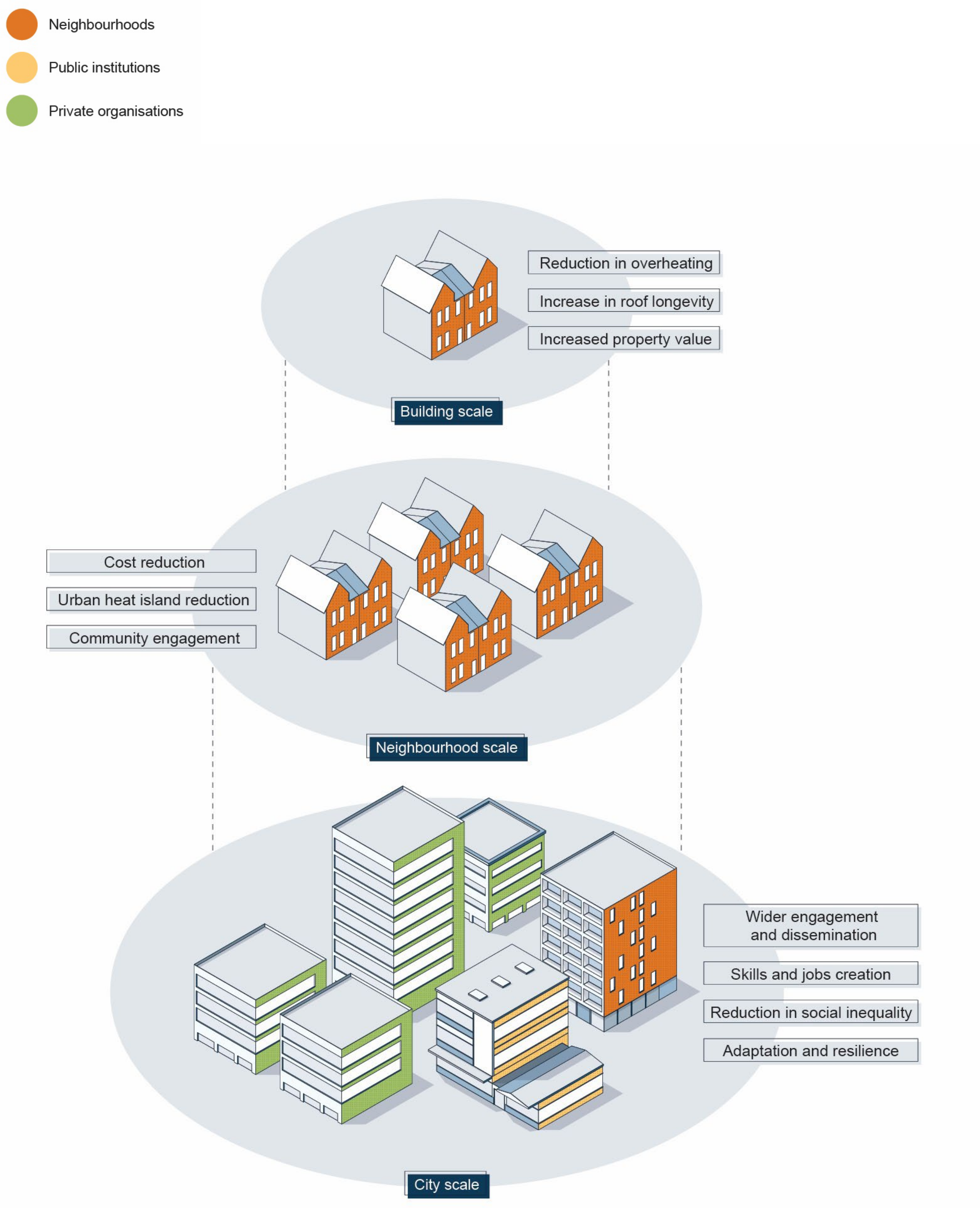


**Figure 1: Benefits of reflective roofs at different scales (Arup)**

# Introduction

London is growing. This is putting increasing pressure on the city's buildings, infrastructure, services and the environment. The impacts of climate change and of future increasing temperatures are adding to this problem. Most buildings that will be present in 2050 have already been constructed. As such, there is the need for an urgent change in both the pace and depth of retrofitting. This must incorporate climate adaptation and energy efficiency measures. Otherwise, these buildings will not remain fit for use.

A London 'Cool Roofs Retrofit Programme' can address some of the challenges the city is facing now and in the future. For buildings, cool roofs can reduce overheating and energy use (or even generate energy in the case of solar photovoltaics). And city-wide, this can help to reduce the urban heat island (UHI) of London. Cool roofs offer other benefits too, including building stronger communities, reducing social and health inequalities, and providing opportunities to build skills.

A programme to deliver cool roofs provides an opportunity to meet many of the mayor's commitments described in the Climate Action Plan (Mayor of London, 2018), Solar Action Plan (Mayor of London, 2018), and the London Recovery Programme (Mayor of London, 2020).

This report focuses on reflective and solar photovoltaics (PV) roofs. However, a "cool roof" may include other types of roof systems, such as green roofs. This report does not investigate green and other types of cool roofs. Where relevant, it does refer and make links to these to ensure an integrated approach. All cool roofs, alongside other interventions, can help to cool London in the face of rising temperatures due to climate change.

The report offers an overview of cool roof technologies for a wide audience. This may include building owners, developers, local councils, housing associations, professionals, the skills and education sectors, and the public.

It also establishes the evidence base for more cool roofs on existing buildings, including how this can benefit building owners, occupants, and the environment.

It considers the current context of London, and the requirement to act on existing climate and social inequalities. It also addresses how such a programme could be prioritised by identifying 'opportunity' areas with the largest potential and the largest need around these factors. The risk of heat-related mortality increases with factors such as ageing, social, and/or physical vulnerability (Kovats, 2008). Climate change will increase the frequency and the intensity of heat waves, and a range of measures, including improvements to housing, need to be developed to reduce health impacts.

The report takes a holistic, systems approach to a London 'Cool Roofs Retrofit Programme'. This considers its potential impact in environmental, social, and economic terms for Londoners to support a cleaner and greener city.

Crucially, this work is underpinned by careful investigation of case studies from the UK and globally. Since a reflective roofs programme does not exist in the UK and they have not been applied yet in a broad sense, it was not possible to gather any UK-based case studies on reflective roofs. However, London is in the fortunate position to benefit from lessons learned from similar examples in several other cities, and a few key examples are presented in the Case Studies section. Case studies of UK-based solar PVs have also been presented.

Overall, the work aims to support the development of a London 'Cool Roofs Retrofit Programme'. It will also make recommendations on policy changes vital to support cool roofs in London for both retrofit and new build projects.

# Context

**Background: The Challenge for London**

As a result of global climate change, temperatures in London are increasing. By 2050 average temperatures in London are projected to increase by 1.2°C for winter and 2.6°C for summer when compared with 1981-2010 (UKCP18, 2020)[1]. This will have an impact on health and comfort of people as well as the operation of the city. The UK Health Security Agency (UKHSA) reported 387 excess mortalities for London relating to heat periods in 2022 (UKHSA, 2022). In one week in August 2019, there were 108 excess deaths of people 65 or older (Public Health England, 2019). In the hot summer of 2018, 15% (3.6 million) of English homes had overheated living rooms and 19% (4.5 million) overheated bedrooms (K.J.Lomas, 2021). The most vulnerable in London, which includes the elderly, young, and those with chronic health conditions, are especially at risk (Public Health England, 2015). Minimising the effects of temperature on health requires both prevention of and adaptation to a changing climate—two of the key aims of COP26, in Glasgow (The Lancet, 2021).

As demand for cooling increases, there may be stresses on power supply networks and infrastructure systems due to increasing electricity demand and greater summer peak loads, consequently threatening London's sustainability.

In December 2018, the mayor declared a climate and ecological emergency and released one of the world's first climate action plans (Mayor of London, 2018) that was compatible with a 1.5°C degree pathway in support of the Paris Agreement (United Nations, 2015). Furthermore, in 2020, the mayor established a London Recovery Programme (Mayor of London, 2020) that aims to restore confidence in the city, minimise the impact on communities, and build back better the city's economy and society.

A programme to deliver cool roofs can provide an opportunity to meet many of the mayor's objectives, including:

- **Adaptation to climate change**, including reduction of overheating in buildings and reduction in London's UHI. This is discussed further in the *Benefits of Reflective Roofs (page 24)*.

- **Reduction in carbon emissions** through reduction in cooling demand in buildings through reflective roofs and energy production through solar PV. See *Benefits of Reflective Roofs (page 24)* and *Benefits of Solar PV (page 30)*.

[1] These changes have been estimated under a worst-case scenario (RCP8.5) and are shown as the central estimated of change that represents the 50% probability level

- **Alignment with the Green New Deal** on retrofitting of existing buildings and potential for jobs creation, connected neighbourhoods and volunteering. See *Making a Case for London (page 34).*

- **Contributing to building strong communities and reducing social and health inequalities** via engagement of the community through volunteering schemes and building community networks, and by ensuring that the benefits of cool roofs are delivered in the areas with the highest vulnerability. See *Cool Roofs Opportunities in London (page 17), Behaviour, Engagement and Communication (page 65) and Social Value and Skills Development (page 71).*

- **Providing opportunities to build skills.** The mayor's mission of 'Helping Londoners in good work' (Mayor of London, 2020) and the Skills Roadmap for London (Mayor of London, 2022) can both be supported by a 'Cool Roofs Retrofit Programme'. See *Social Value and Skills Development (page 71).*

## Cool Roofs in London – The Current Picture

*Solar Photovoltaics (PVs)*
Solar PVs are an established and reliable technology that has already seen wide-scale installation in London and in the UK. Solar PVs are considered cool roofs, on top of providing a source of clean energy, they absorb solar radiation and provide passive shading, reducing the heat gain into buildings and the environment.

In the UK, there has been considerable growth in the number of solar panels installed on UK homes. However, the solar industry has been increasingly challenged recently, most especially due to reductions in financial support through changes in government policies.

To achieve the Mayor's target of a net zero city by 2030, analysis conducted by Element Energy indicates that London would need 1,500 MW of solar power on our roofs by 2030 and 3,900 MW by 2050 (Element Energy, 2022). This is nearly double the amount outlined in the London Environment Strategy, which sought to achieve 2,000 MW of solar power by 2050. According to the Mayor's Solar Action Plan, and London Solar Opportunity Map, solar PV potential in London is strong. Under an ambitious scenario, solar PV installation could reach around 550 MW capacity by 2025, 850 MW capacity by 2030, and 2,000 MW capacity by 2050 (GLA, 2018). More recently, the government made clear its ambition to accelerate deployment of solar in the UK to a five-fold increase in solar capacity by 2035 (Solar Energy UK, 2022), equating to roughly 70 GW. This illustrates an even bigger potential for solar in London.

The Solar Action Plan (SAP) found that although the potential for solar PV is large, the economic potential has become less significant due to rising costs from low deployment and lack of funding support.

The SAP details several objectives to encourage solar PV uptake, including planning policy to encourage installation, supporting Londoners with retrofitting through funding and information, as well as a call on Government to set a national policy that supports solar PV. It should be noted that, since the document was published, the government has increased ambitions to deploy solar PV in the UK as stated above.

The Mayor has a range of actions already underway:

- **Solar Together London**: Phases one to three of the Mayor's successful group purchasing scheme Solar Together London supported 974 homes with high quality, competitively priced solar PV panels. The programme is now in the fourth phase, funded by the Green New Deal fund, and is pan-London for the first time. It now also allows residents to take up battery storage and electric vehicle charging points. Phase 4 has already delivered 1,041 installations of solar PV and retrofit battery storage with a further 400 booked in coming weeks. Phase 4 is well on track to reach a target of at least 1,100 by the time it closes. In February, the fifth phase of this programme launched. Over 3,500 households have accepted their offers and paid their survey deposits.

- **London Community Energy Fund**: To date, over 116 grant offers have been made through the London Community Energy fund through five rounds of funding since 2017, totalling over £1.4 million of grants. Buildings to have benefitted so far include schools, community centres, GP surgeries, churches, and sports centres. The majority of grants enable solar PV installations, alongside energy efficiency retrofit and renewable heating. If all of the projects that applied to the first four phases proceeded to installation, this would have saved over 2,500 tonnes of carbon a year and generated up to 8 MW of additional solar capacity. The Mayor launched the fifth round of the London Community Energy Fund on 1 October 2021. Applications have been assessed and offers of grant funding made to over 30 projects.

- The £6m **Local Energy Accelerator Programme** (launched in November 2020), continues transforming the way London generates, supplies, integrates, and uses clean local energy, including solar PV, in buildings and transport. The scheme provides funding for public and private organisations to utilise expertise from a framework of suppliers as well as additional capacity and capability via a Programme Delivery Unit. To date, about 1,160 tonnes CO2e per year are being saved. About £2.36m has now been committed to 16 projects which once installed should save about 7,000 tonnes CO2e in calendar year 2024, rising to about 20,000 tonnes CO2e by 2025. All private and public sector bodies, including NHS Trusts & housing associations, delivering low carbon, local energy projects in London, can now apply for fully funded support through the expanded LEA from 1st April.

- **Solar Skills London**, launched in June 21, aims to grow the capital's solar energy sector by creating career pathways for the next generation of solar experts, increasing the number of registered solar installers in London and helping create more green jobs. Solar Energy UK delivered the first phase of this initiative and the second phase, delivered by MCS and Solar Energy UK, was launched on 9 June 2022, alongside a new Solar Careers Hub. Phase 2 will focus on increasing the number of registered solar installers in London and engaging local authorities, schools, colleges and training providers as well as the private sector to promote the solar industry in London. The **London Solar Opportunity Map**, developed by the Mayor with UCL, helps London businesses and other organisations to identify opportunities to install solar panels on their property (a version of this map is presented in the next section).

- Through the **London Plan** requirements, over the previous mayoral term, over 36 MW of solar PV was deployed. In 2021, a further 10.3 MW was installed.

*Reflective roofs – Globally and in the UK*

Many cities around the world have delivered reflective roof programmes as a key component of a city's cooling and resilience strategy. These cities have typically been in warmer climates where the need for cooling interventions has been more urgent. In London, reflective roofs are yet to be deployed at scale, however, increasing temperatures make the case for reflective roofs more compelling. There have been several studies researching the potential benefits of reflective roofs in the UK and London climate. These are described and investigated further in this report.

*Other cool roofs*

Much has been done to encourage the implementation of green roofs in London, and this has resulted in increasing adoption over the last ten years. A 2008 report by the GLA on '*Living Roofs and Walls'* (Mayor of London, Design for London, 2008) investigated the benefits and potential for green roofs, including a review of barriers and policy changes that may be required. A further report that was published in 2019 ('Living Roofs and Walls from Policy to Practice') (GIC Ltd, 2019), measured the success of the Living Roofs and Walls policy that was included in the London Plan. A new 'Cools Roof Retrofit Programme' can build from what has already been attempted and achieved in London.

# Cool Roofs Opportunities in London

Opportunity areas have been identified which help prioritise where or the order in which cool roofs are implemented to ensure that the programme is directed toward the highest need and vulnerability. This aims to, more systemically, address a just transition and a reduction in social inequality.

## Reflective Roof Opportunity Map

Climate risk is a key consideration when prioritising reflective roofs in London. The GLA's London Climate Risk maps consist of a series of London-wide climate risk maps that have been produced to analyse climate exposure and vulnerability across Greater London (GLA, Bloomberg Associates, 2021). The Climate Risk Maps include a heat risk map that provides a suitable starting point to create the *reflective roofs opportunity map* presented in this section.

The existing heat risk map considers exposure and vulnerability to categorise heat risk[2] (Bloomberg Associates, 2021). Both have been described below:

- **Exposure** – this relates to the intensity of UHI in London. Factors, such as land surface temperature, tree canopy cover, and green and blue surface cover, provide an indication of where the UHI will be higher. Areas suffering from a higher exposure will be (relatively) more vulnerable and, consequently, have the highest need for UHI mitigation.

- **Vulnerability** – this relates to personal and social factors that affect a person's ability to cope with and respond to extreme events, such as heatwaves. Factors, such as age, income deprivation, social renting, and English non-proficiency are considered.

As a feature of this report's analysis, to produce the *reflective roofs opportunity map*, the following additional datasets have been combined with the heat risk map. These provide an indication of the impact and *effectiveness* that a reflective roof might have for improving UHI and for decreasing building overheating and energy usage. These have been described below:

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[2] London Climate Risk. A Spatial Analysis of Climate Risk Across Greater London: 2021 Methodology Report (see full citation in References) should be referred to for details on methodology.

- **Roof Reflectivity** – this provides the current reflectivity of rooftops and provides an indication of areas that currently have roofs with lower reflectivity and could, therefore, benefit the most from a reflective roof retrofit.

- **Building height-to-area ratio** – buildings with a lower height-to-area ratio are likely to benefit from a reflective roof if considering the roof area to building volume ratio, which have been deemed a higher priority. The impact on improving local UHI will be larger when there is a greater distribution of roofs closer to ground level, whereby UHI is most adversely impacting to people. The impact on overheating and energy usage will also be (relatively) larger for these buildings' typologies.

The underlying maps for these data sets are presented in Appendix C. Other data sources are presented in the Data Sources section of this report.

*Limitations*
It should be noted that an equal weighting has been applied to all the parameters presented in this map in line with the existing heat risk map. Therefore, there may be some vulnerability factors not accounted for in the map due to risk of double counting or lack of data. The heat exposure is based on the magnitude of London's UHI and does not account for the risk of overheating in buildings, which would require higher-resolution data on London's building stock. A more in-depth assessment would be required to adjust the weighting and include additional data sources, which may be next-phase development feature.

The *reflective roofs opportunity map* is shown in Figure 2.

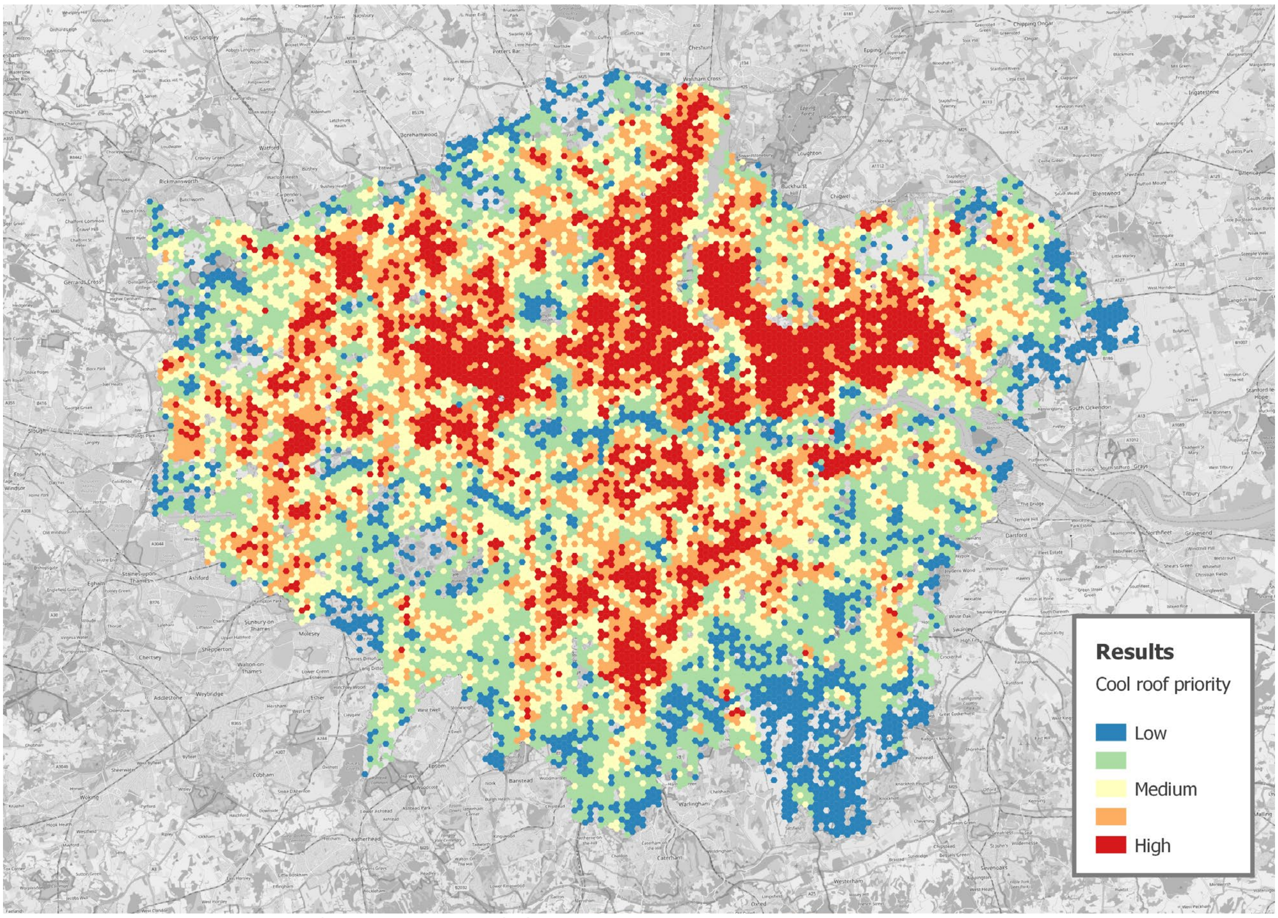
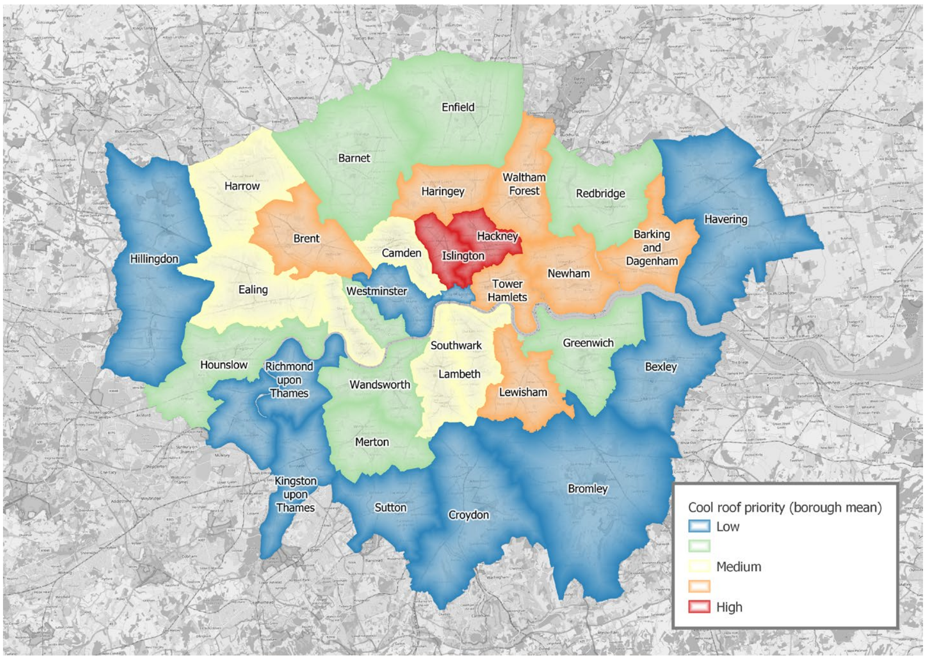



**Figure 2: London Reflective Roof Opportunity Heat Map**

*Using the map*

The data has been aggregated to borough level for comparison and for guiding local authorities and decision makers. The London boroughs have been ordered by highest opportunity using this data, with the top ten boroughs shown in Figure 3. For instance, boroughs closer to the centre of London, could be prioritised as they are likely to be at higher risk from heat exposure and have a higher density of vulnerable people compared to areas that are further away. The map also highlights neighbourhoods that are at highest risk. This could be helpful at a single-building level, whereby this data could be part of a checklist that building owners complete to assess the risk level of their building, and if investing in a cool roof would be beneficial. A Heat Vulnerability Index was developed by Columbia University for New York City that revealed high levels of overheating risk across the city. This study has helped drive the NYC Cool Roofs programme (see Case Study 8: New York Cool Roofs).




| | London Borough |
|---|---|
| 1 | Islington |
| 2 | Hackney |
| 3 | Brent |
| 4 | Tower Hamlets |
| 5 | Newham |
| 6 | Barking and Dagenham |
| 7 | Lewisham |
| 8 | Waltham Forest |
| 9 | Haringey |
| 10 | Ealing |

**Figure 3: London reflective roof opportunity by borough**

## Solar PV Opportunity Map

The 'London Solar Opportunity Map' published by the GLA (GLA, UCL Energy, 2020) can be used to prioritise PV implementation across London. The map presents the solar potential across the different rooftops of London by considering roof pitch to estimate the potential for PV energy generation. The solar potential has been categorised into low, medium, and high over a hex grid[3] to produce a different version of the existing solar opportunity map (Figure 4). This can also be aggregated by borough to compare the areas of London that have the largest solar potential (Figure 5). The central London boroughs present the greatest potential for solar PV, which may be related to the density of building and, therefore, the roof space in these areas.

The maps presented in this section offer direction to which areas a London 'Cool Roof Retrofit Programme' implementation plan could be prioritised. There are several other factors, not captured by these maps, which are important to consider prior to implementation. These are elaborated upon in the following sections.

[3] London was divided up into equally sized hexes of 350m to produce the hex grid. This allows data to be aggregated within each grid in order to layer up different data sources and produce an *opportunity map.*

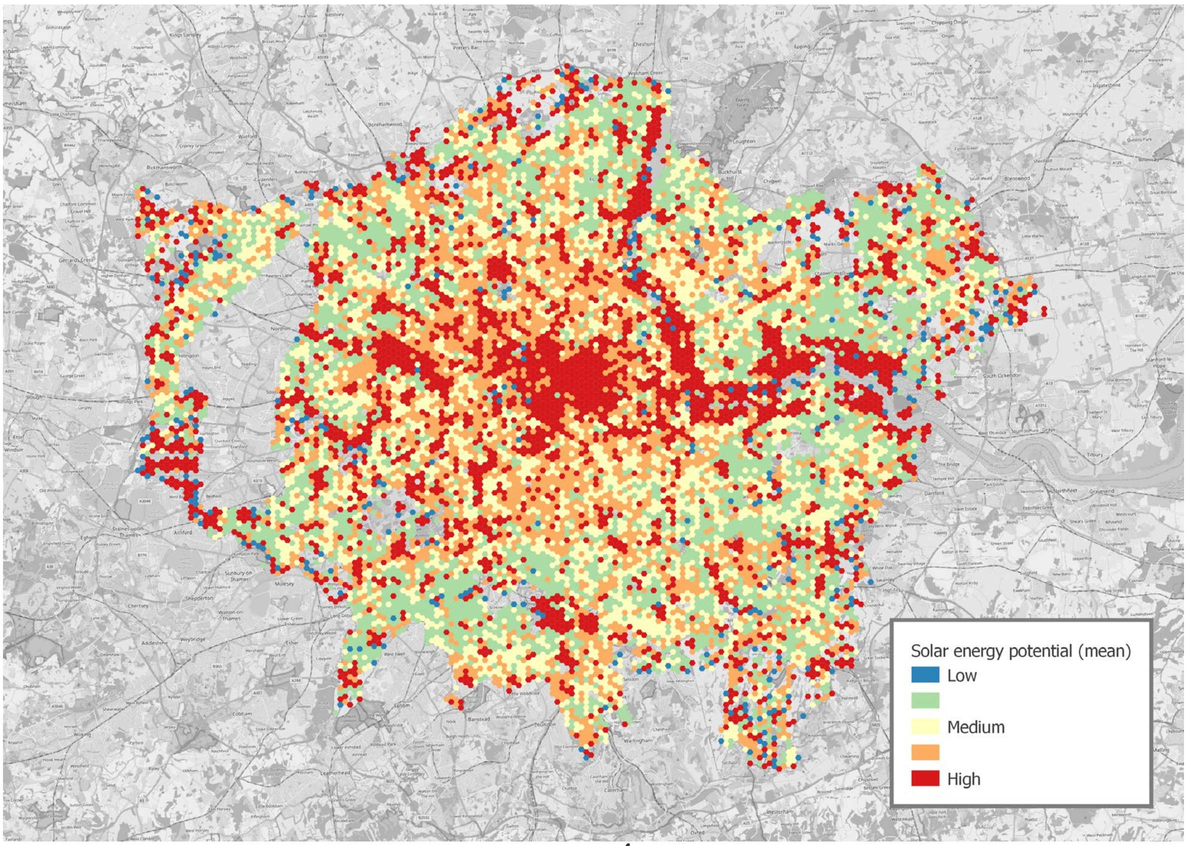
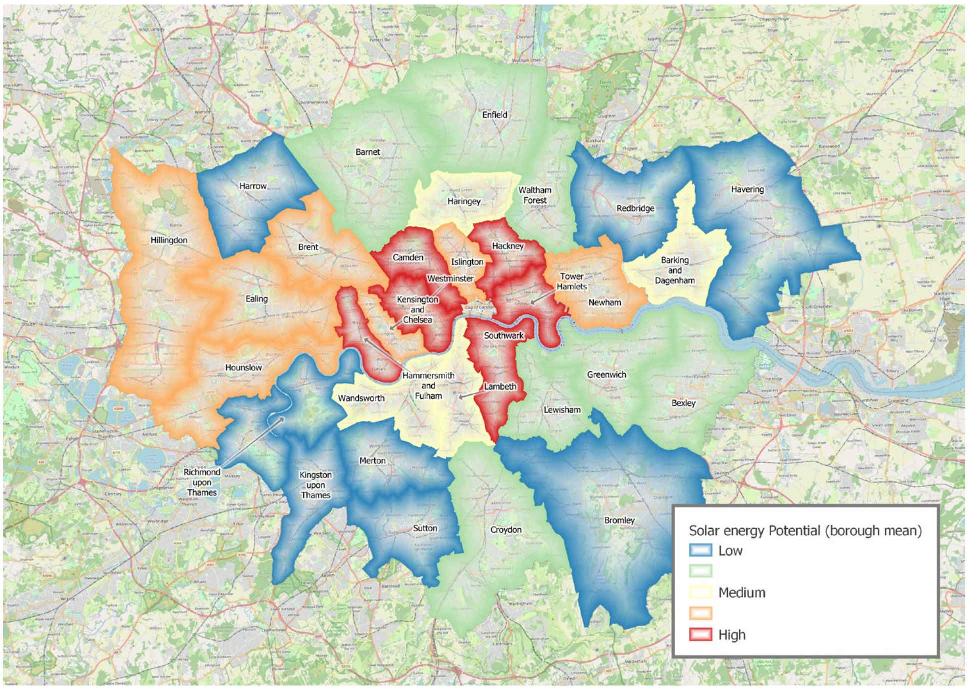



**Figure 4: London Solar Opportunity Map**[4]

[4] Note that missing data is due to gaps in Lidar data used to obtain this map. The data is aggregated to create the borough opportunity map so there may be some bias due to missing data.




| | **London Borough** |
|---|---|
| **1** | City of London |
| **2** | Westminster |
| **3** | Camden |
| **4** | Tower Hamlets |
| **5** | Southwark |
| **6** | Hackney |
| **7** | Hammersmith and Fulham |
| **8** | Islington |
| **9** | Hillingdon |
| **10** | Brent |

**Figure 5: London Solar Opportunity Map by Borough**

# Reflective Roofs

## Typologies

Reflective roofs are roofs that have a surface finish that reflects more (and absorbs less) solar radiation than a conventional roof.

The reflectivity of a roof can be described by the proportion of the sun's radiation that is reflected. A roof with a reflectivity of 0.1 is considered low, whereas a reflectivity of 0.6 or higher is considered high and can be described as a reflective roof.

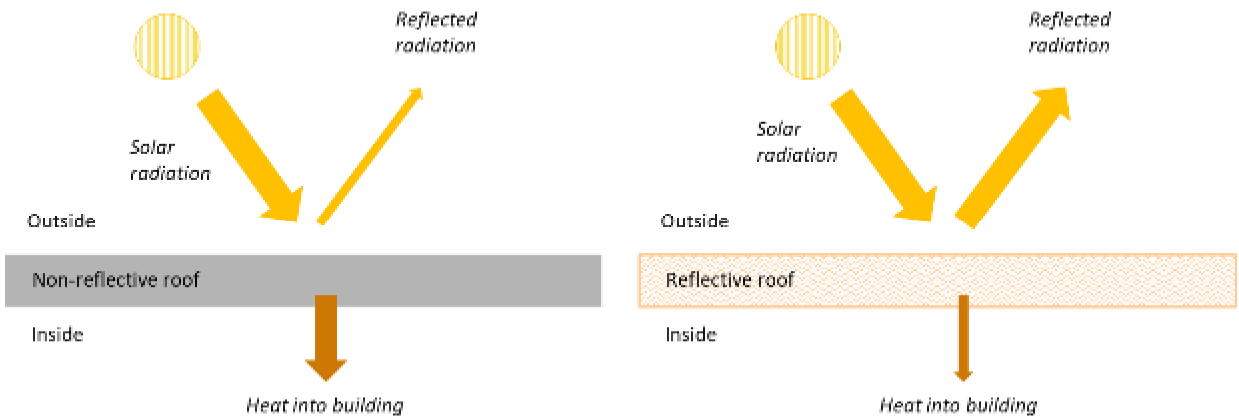



**Figure 6: reflective roof vs. non reflective roof**

There are two main types of reflective roof:

- **Flat roof** – deemed flat but with a minor incline to support drainage. This is typically defined as having no more than 5cm of vertical rise over a 30cm horizontal run, or an angle between 1° and 10°. Typically, a low-pitched roof is angled between 10° and 14°. Flat or low-pitched roofs are most found on commercial, industrial, warehouse, office, retail, and high-rise residential buildings in the UK.

- **Pitched roof** – defined as roofs with inclines greater than 5cm over a 30cm horizontal run. A high-pitched roof has an angle of 14° or more. These roofs are typically found on low- to medium-height residential buildings, Victorian schools, and some retail and commercial buildings.

The type of surface that can be applied to a roof to retrofit a reflective finish will depend on the roof typology.

*Low pitched and flat reflective roof materials*

Low-pitched roofs are comprised of built-up roofing or a membrane. Reflective roof options include coatings, single-ply membranes, foam roofs, built-up roofing (BUR) systems, and modified bitumen (Mod-bit). Appendix A provides descriptions of each reflective roof material and their effectiveness.

*High pitched reflective roof materials*

Although most existing reflective roof programmes have focused on the low-pitched roofing application, reflective roof options for high-pitched roofs are becoming increasingly available and the market for these materials is growing.

Alternative reflective roof techniques are used for higher pitched roofs because of their different structure and materials. Typically, these techniques are more aesthetically pleasing as high-pitched roofs account for approximately 40% of the external appearance of a building (GBA, 2020). As such, tiles, asphalt shingle, metal roofing, and shakes are the most common reflective roof materials used on high-pitched roofs. A description of the different high-pitched reflective roof material techniques is provided in Appendix A.

## Benefits of Reflective Roofs

Reflective roofs can provide several benefits when applied to London's building stock, which include positive impacts to building (overheating and energy demand) and UHI performance, as well as to occupant health and wellbeing.

The principal benefits of reflective roofs are:

- Reduction of overheating in buildings
- Reduction of energy demand in buildings
- Reduction in UHI

Other indirect benefits for people and the environment include:

- Health benefits
- Improving air quality
- Improving the longevity of roofs

These benefits and the evidence base for them are described in expanded detail within this chapter.

In addition, there are potential social and economic co-benefits benefits, such as skills and jobs creation, as well as neighbourhood cohesion, that are also discussed in the next chapter.

*Reduce overheating in buildings*

Compared to a conventional roof, a reflective roof absorbs less of the sun's radiation, therefore, less heat is transferred into the building below. This is most beneficial in the summer months when many buildings suffer from overheating during heatwaves.

The cooling impact of reflective roofs has been recorded in many cities globally that have adapted a 'Cool Roof Retrofit Programme'. For instance, an apartment complex with no cooling in Sacramento, California, found that adding a cool roof lowered peak air temperatures in the attic by 17-22°C (EPA, 2008). A New York-based study also identified that reflective roofs could reduce internal building temperatures (Solecki, 2015).

Significantly, a reduction of overheating in buildings is also possible in the UK climate. A study modelling a top floor office in London found that thermal comfort conditions can be improved for 25% of occupied hours by changing the reflectivity from 0.1 to 0.9 (Kolokotroni, 2013). Furthermore, a study carried out for this report (Arup, 2022) on cool roof construction corroborated that reflective roof construction could reduce heat gain through the roof (see Appendix D, Study 1). In London, where most houses (and flats) do not have air conditioning, this benefit is significant to ensure resilience and prevent adverse health issues. During the 2018 summer heatwave in London, with the peak temperature reaching above 35°C, a study carried out for this period showed that approximately 15% (3.6 million) of homes in England had overheated living rooms and that 19% (4.5 million) suffered from overheated bedrooms (Drury, 2021). Moreover, flats and small residential buildings in London and the Southeast were identified as particularly at risk to overheating (Drury, 2021). Therefore, a reduction in overheating will be become increasingly required as the climate warms.

*Reduce energy demand in buildings*

In the context of energy use, less heat absorbed into a building and, therefore, less overheating, will result in decreased energy demand for cooling in buildings that utilise air conditioning.

A paper by the 'School of Energy and Environment Studies' in India (Mohan Rawat, 2022), found that studies have shown that the average energy saving from reflective roof use reported across several analyses of temperate, tropical, hot-dry, and composite climatic zones was 32.8%, 35.7%, 15.0%, and 25.0%, respectively.

A reflective roof can also result in a reduction in peak energy demand during the hottest conditions. This means that during heatwaves a cool roof can help take pressure off energy systems which tend to run less efficiently during hot weather (World Economic Forum, 2022). In addition, a lower peak demand not only saves on total electrical use but can reduce demand fees that are charged to commercial and industrial users (Solecki, 2015).

In London, the reduction in energy use will vary depending on the type of building, reflective roof construction and its climate. London's climate is temperate with lower summer temperatures compared to other cities that have adopted reflective roofs.

The 'Global Cool Cities Alliance' has suggested that reflective roofs can be beneficial in temperate climates, such as London (Global Cool Cities Alliance, 2012). Several studies have corroborated this. For example, a study by University of Brunel and University of Loughborough of an open plan office in London identified that, although a reflective roof showed a heating load increase in winter, there was enough of a cooling load decrease to result in an overall reduction in energy demand by between 1 and 8.5% (Kolokotroni, 2013). Furthermore, modelling carried out by the University of Plymouth (Justin Halewood, 2008), indicated that reflective roofs help reduce internal temperatures and cooling energy use in the UK for the current and future climate.

There are concerns that there could be a winter heating penalty as a result of reflective roofs. This is because, during colder weather, solar radiation may provide heat to buildings. However, factors, such as lower sun angles in the winter, potential snow cover, as well as heating loads tending to be higher in the evening, support that the winter heating penalty is likely to be limited (Global Cool Cities Alliance, 2012). Furthermore, adding insulation and lowering operational temperatures can also act to mitigate the increase in heating demand, as was found by the University of Plymouth (Justin Halewood, 2010). A simple study carried out on cool roof constructions, demonstrates how insulation can limit any additional unwanted heat loss for average winter conditions for a reflective roof (see Appendix D, Study 1).

It is also important to consider the future climate when evaluating the energy benefits of reflective roofs. A study by University College London reviewing a typical London office, found that when considering a future climate change scenario, a reflective roof results in a reduction on the annual energy use (Gurdane Virka, 2014). This demonstrates that reflective roofs are likely to be an important consideration for future resilience as temperatures increase in London.

*Reduction in the UHI*

If implemented at a large scale, reflective roofs could be a measure for cooling London. Like many large cities, London experiences a UHI effect, which results in higher air temperatures than experienced in its rural surroundings. The UHI has several negative impacts which includes increased energy consumption (e.g. from increased demand on air conditioning), compromised human health and comfort (discussed below), and reduction in air quality (discussed below) and impaired water quality (EPA, 2021).

UHI is a result of several city factors, including the materiality of buildings. Dark or unreflective surfaces absorb the sun's radiation and heat up the roof surface, resulting in an increase in local air temperatures. Reflective roofs can mitigate this impact and lead to lower air temperatures.

A case study model of West Midlands has shown, for heatwave periods, reflective roofs could reduce city centre daytime air temperature by 0.5 °C on average, and up to a maximum of ~3 °C. Moreover, reflective roofs reduced average UHI by ~23% during a heatwave. The study also found that reflective roofs were most effective at reducing peak temperatures during the daytime and, therefore, have the potential to limit peak dangerous extreme temperatures during heatwaves (H.L. Macintyre, 2019).

A study carried out for this report (see Appendix D, Study 2) modelled the impact that varying all the roof reflectivities for an area of London could make to the local air temperature. The study predicted the air temperature during a July 2021 heatwave for non-reflective roofs (0.1 relativity) and reflective roofs (0.7). An average daily maximum difference of 0.23°C was predicted and, during the peak day of the heatwave a 1.1°C, lower temperature was predicted for the reflective roof. This would have an impact on health outcomes and cooling loads.

With temperatures in London projected to increase, and with more occurrences of heatwaves, reflective roofs are likely to be a key component of climate adaptation strategy.

*Health benefits*
Lower urban temperatures can have a direct health benefit to Londoners through the reduction of heat-related illnesses and deaths. The West Midlands study (H.L. Macintyre, 2019) identified that reflective roofs implemented across the whole city could potentially offset 18% of seasonal heat-related mortality associated with UHI, and result in reduced heat-related mortality associated with UHI by ~25% during a heatwave. It should be acknowledged that, in cooler periods, there are potential health benefits from heat absorbed through building surfaces that would be reduced by a reflective roof. This may be offset by combining cool roofs with improved roof insulation.

*Improving the air quality*
A reduction in UHI can also reduce the degradation of air quality by slowing down chemical reactions in the atmosphere and through a reduction in the production of smog (Jiachuan Yang, 2015).

In addition, reduced outdoor air temperatures will increase the possibility of using natural ventilation to provide summertime comfort instead of active cooling, which will also improve indoor air quality due to the high rates of ventilation. This reinforces the cooling hierarchy set out by the London Plan (Mayor of London, 2016).

*Improving the longevity of roofs*

A reflective roof will have higher regulated and, generally, lower surface temperatures compared to a conventional roof, which will extend its lifespan (Justin Halewood, 2010). Furthermore, reducing cooling loads can extend the lifespan of cooling equipment (Solecki, 2015).

# Solar PV Roofs

## Typologies

Solar electricity panels, also known as solar photovoltaics (PV), capture the sun's energy and convert it into electricity. A solar PV panel comprises of many cells made from layers of semi-conducting material, most commonly silicon, which are sandwiched between protective materials, such as glass and/or plastics to withstand external elements (EST, 2022). When light shines on the material, a flow of electricity is created.

Solar PV panels can be used individually or connected to form arrays. One or more arrays are then connected to the electricity grid as part of a complete solar PV system. The modular structure allows solar PV systems to be built to meet almost any electric power need, large or small.

Solar PV panels are typically mounted on rooftops but can be placed on the ground. In London, solar PV has the most potential on rooftops due to space limitations at ground level (GLA, 2018) and that shading is reduced. Solar PVs can also be combined with battery storage to retain energy for later use. This is an emerging option that provides additional incentive for building owners and will be an important part of grid balancing and storing of renewable energy further information on Solar PV technology is provided in Appendix B.

*Hybrid roofs*
Solar PV panels can be installed alongside other rooftop technologies, such as green roofs (see Case study 5). A mutual benefit can be gained from a hybrid roof, which defies common perception that different roof systems need to compete for roof space. There is evidence that solar PVs can work more efficiently when installed on a green roof (Bracha Y. Schindler, 2015). Furthermore, a green roof can regulate temperature fluctuations and improve conditions for solar PV efficiency (Mayor of London, Design for London, 2008). There is also evidence that combining solar PVs with reflective roofs can increase the energy yield of the PV. A study in Zurich showed a 3.4% increase in yield when the two technologies were combined (Giovan Battista Cavadini, 2021).

See Case Studies 4 and 5 for examples hybrid roofs.

## Benefits of Solar PVs

The principal benefits of Solar PV roofs are:

- Electricity generation
- Reduction in peak demand
- Decarbonisation
- Exported electricity
- Grid balancing and reducing demand (when combined with battery storage)

Aside from electricity generation, solar PV roofs can also indirectly provide:

- Reduction in UHI
- Reduction in overheating in buildings

These benefits and the evidence base for them is described in more detail in this chapter. As with reflective roofs, there will be social and economic co-benefits that are also described in the next section.

*Electricity generation*
The main benefit of solar PVs is the generation of electricity for both residential and non-residential buildings. It is estimated that solar PV in London has the potential to generate up to 50% of a household's annual electricity demand (EST, 2022), providing a strong incentive of reduced electricity costs. For individuals, the biggest benefit can be realised through lower electricity bills; once the initial upfront cost has been paid off or recouped. At the macro or city level, uptake and installation of solar PV systems can support energy demand across London.

*Reduction in peak demand*
When solar PVs are combined with battery storage, there is a potential to reduce peak demand in commercial and public sector buildings (GLA, 2018). This would be particularly important during a heatwave and may bring further financial benefit in the event of dynamic demand driven electricity tariffs.

*Decarbonisation*
PVs can contribute to London's grid decarbonisation targets. As solar electricity delivers low carbon and renewable energy, a home solar PV system could save approximately one tonne of carbon per year, depending on UK location (EST, 2022). A recent report by Element Energy identified that solar PV can be deployed under a range of scenarios to reduce energy demand of buildings and contribute to achieving London's net zero target for 2030 (Element Energy, 2022).

*Exported electricity*
With any solar PV system, there may be occasions when more electricity is generated than can be used on the building it is installed on. Therefore, surplus electricity can be exported back to the grid and used by somebody else. If there is an appropriate funding scheme in place, this may also result in an increased payback benefit for building owners. In the UK, the now defunct Feed-in-Tariff scheme provided payment for electricity generated and exported by the solar PV panels. As an alternative to a payback scheme, surplus electricity could be battery stored for usage at a later period.

*Long life span*
Solar PVs are an established and reliable technology and have a life expectancy of approximately 25 years or more (EST, 2022), however, the inverter is likely to require replacement during this period. Many inverters now contain online monitoring systems which can alert users of system failure.

Solar PV systems require some maintenance to ensure optimum performance. Typically, panels in the UK are tilted at approximately 15° (or more) and benefit from being cleaned by rainfall (EST, 2022), which can maximise optimal performance. Where panels are located near trees, regular monitoring should be undertaken to ensure that foliage does not overshadow the solar PV system as a small shadow can have a large impact on output.

*Reduction in UHI*
Installation of solar PVs at roof-level can modify the immediate environment, influence the amount of energy transferred to the atmosphere and the resulting UHI effect. Studies have shown that wide-scale deployment of solar PVs across urban areas in Los Angeles (Taha, 2013) and Paris (Masson, 2014) can cool the surrounding area by up to 0.2℃ during the day, depending on the efficiency and placement of the solar PVs. In both studies, there was a greater reduction in UHI at night.

Solar PVs modify the nature of the rooftop that can also influence the energy transfers to the local environment. Solar PVs reduce the storage of heat within the buildings by intercepting solar radiation (Masson, 2014), which reduces the UHI of the local surrounding area. Reflective roofs were shown to be more effective at cooling than solar PVs during the day, but this was reversed at night-time when solar PVs were more efficient at reducing UHI effect. Both technologies were shown to offer multiple benefits for cities by reducing summer cooling demand and by mitigating UHI. These results demonstrate how a strategy incorporating both reflective and solar PV roofs could maximise reductions in UHI, improve thermal comfort and reduce energy demand. As with reflective roofs, a reduction in UHI can also offer the indirect benefit of improving air quality.

*Reduction in overheating in buildings*

A study by researchers in San Diego demonstrated that the implementation of Solar PVs provides a shading effect on the roof beneath. The Solar PVs reduced the amount of heat reaching the roof, therefore, cooling the ceiling below the PV by up to 2.5°C when compared to portions of roof that had been exposed to direct sunlight (Dominguez, 2011).

These findings were confirmed by another study that reviewed the city-wide impacts of both reflective roofs and rooftop solar PVs on the near-surface air temperature (Salamanca, 2016). The study showed that the installation of both cool roof typologies resulted in the cooling of near-surface temperatures throughout the day.

# Making a case for London

## Introduction

To make a case for a London “Cool Roofs Retrofit Programme”, a wide range of relevant implementation considerations have been expanded upon within this section. The potential for a London ‘Cool Roof Retrofit Programme’ has been supported by research from global case studies and cities to collate what has been achieved, and how it has contributed to successful delivery. Furthermore, UK base data, funding, policy, and programme implications have also been referenced to develop a whole ‘systems’ understanding of the key considerations and the barriers pertaining to:

- Cost
- Constructability
- Funding, partnerships, and commercial approaches
- Planning and policy
- Behaviour, engagement, and communication
- Social value and skills development

A long list of opportunities is presented for each section. Some of these will be feasible for London and may be quick wins or short-term actions and others may be long-term and require more resources and careful planning. There may also be some opportunities that are considered unfeasible for a London “Cool Roofs Retrofit Programme” but have been discussed here for completion. The implementation recommendations in the next section discuss the specific short-, medium-, and long-term opportunities for London that should be explored further to support the framework for developing a ’Cool Roof Retrofit Programme’.

## London Building Stock

Building use, ownership, location, and structure (including roof construction type) are all important factors when considering the implementation potential of reflective or solar PV roofs. There is no single comprehensive source of information on the makeup of London’s building stock, however, some information is available that can inform decision making.

*Building usage*
Data obtained from the London Building Stock Model (GLA, UCL, 2022) on self-contained unit classifications demonstrates that approximately 94% of London’s building stock is residential (classed as domestic or domestic dominant). Of the remainder of building stock, less than 5% is non-domestic (i.e., commercial, industrial, public, etc.) and the remainder is unknown. However, when considering building footprint, which is typically a suitable

proxy of roof areas, residential buildings comprise 75% of London's total building footprint and non-residential uses comprise 20% of the total (with the remaining unknown).

*Building ownership*
Approximately 78% of London's residential buildings are in private ownership, with 51% owner-occupiers and 27% renters. Social renters make up 22% of London households (Department for Levelling Up, Housing and Communities, 2020).

In the UK, the majority (82%) of private sector residential buildings are houses or bungalows. The majority (55%) of social housing are houses and bungalows, whereas 43% consist of purpose-built flats (Department for Levelling Up, Housing and Communities, 2020).

Data on the ownership of properties is presented at Figure 7 for the top 20 property owners in London. Information of this nature can inform potential partnership opportunities for retrofitting at scale.

The statistics are summarised in Table 1.

**Table 1 – Summary of building type and ownership in London**

| Metric | Residential | Non-residential |
|---|---|---|
| Percentage of residential building stock in London | 94% | 5% |
| Percentage of London's building footprint | 75% | 20% |
| Private sector residential buildings | 78% | - |
| Public Sector residential buildings | 22% | - |
| Percentage private residential stock that is house and bungalow | 82% | - |
| Percentage public residential stock that is house and bungalow | 55% | - |
| Percentage public residential stock that is purpose built flat | 43% | - |

*Considerations*
Since most of London's building stock is residential and rented (both private and social), therefore making up almost half of the occupants, a London 'Cool Roof Retrofit

Programme' should engage and appeal to a range of stakeholders. This includes private homeowners, renters, property owners, and local authorities. The GLA could leverage their links to business which have been established through programmes such as the London Business Climate Leaders (GLA, 2022).

There are several private and public organisations that own large building portfolios. Engaging with these organisations will be crucial to delivering retrofit at scale.

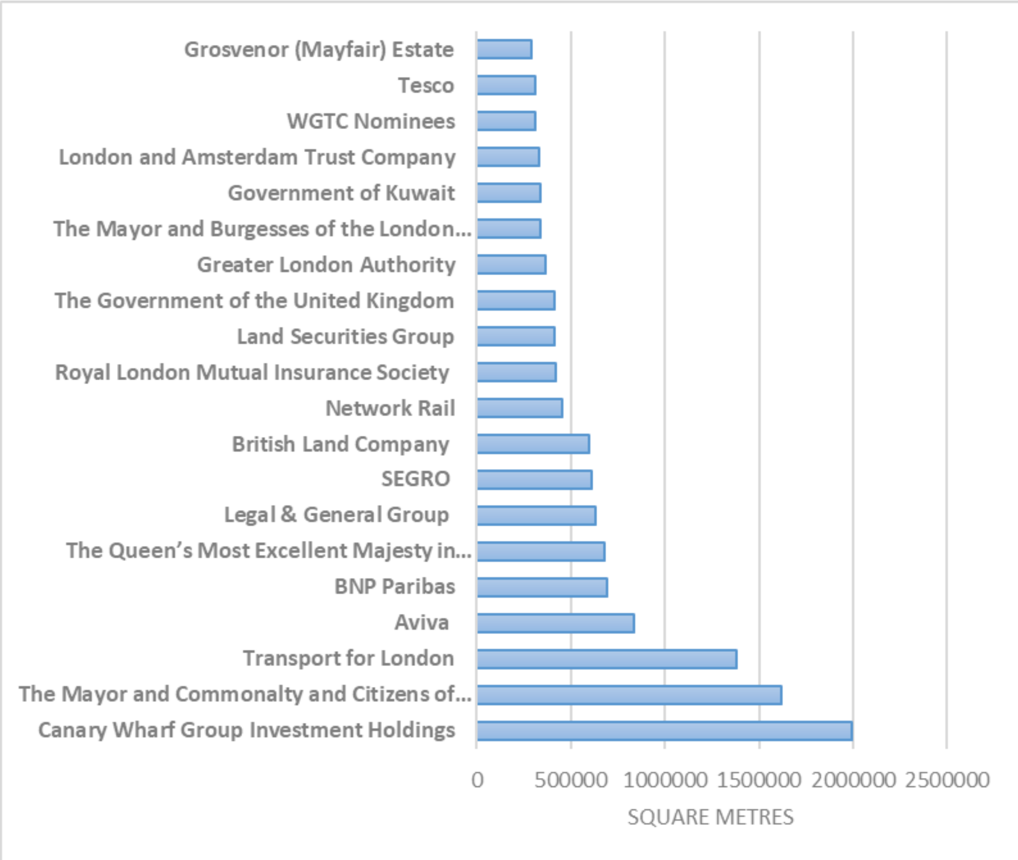
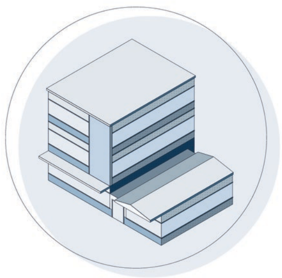



**Figure 7: Top property owners in London by area (Property Week, 2017)**

## Building Archetypes

Where relevant, building archetypes have been adopted as proxy representations when discussing both implementation considerations and recommendations. Four archetype options have been developed to examine considerations, such as cost and constructability, in greater detail. These typologies were chosen to capture a suitable range of building types which can represent much of the city's building stock. Considerations that apply to these typologies could be interpreted for other building types. However, it should be noted that there will be diversity within each defined archetype and that these are aimed to represent use-cases as a high level. The archetypes are presented in Table 2.

**Table 2 – Building Archetypes**

| Archetype 1: House | Archetype 2: School | Archetype 3: Social Housing | Archetype 4: Commercial Office |
|---|---|---|---|
| **Building Type**: 1919-1944 semi-detached house, family home | **Building Type**: Late 20th Century School | **Building Type:** 1960-80 Social housing estate | **Building Type:** Commercial office |
| **Construction**: Traditional pitched roof with plain clay tiles. Naturally ventilated. | **Construction**: Concrete construction with a flat roof. Naturally ventilated. | **Construction**: Medium-rise concrete construction with a flat roof. Naturally ventilated. | **Construction**: Medium rise concrete construction with flat roof. Mechanically ventilated. |
|  |  |  |  |

*Diversity*
These archetypes are representative of a portion of the London building stock and the considerations discussed for each will be applicable to a range of other types of buildings.

**Archetype 1: House**

A large portion of the London building stock is the housing typology with a pitched roof. Although this archetype has been selected for a specific period, other housing stock is similar enough that considerations such as cost, constructability, funding, and policy will be applicable. This type of building may suffer from overheating especially during a heatwave, on upper floors, although the level of overheating will depend on factors such as building materials, insulation, number of storeys, etc. A semi-detached house has been adopted for this archetype, and other types of housing such as terraced, detached or bungalow may differ in terms of cost and constructability considerations. Houses in London will not typically have air conditioning but will be equipped with heating measures. These types of buildings may also be converted to other types of uses such as flats, nurseries and/ or care homes, which could have implications on these considerations for a London “Cool Roofs Retrofit Programme.” For instance, building ownership would impact the decision making (see Behaviour, Engagement and Communication Section). Furthermore, a care home with vulnerable residents may be considered higher priority.

**Archetype 2: School**

The school building stock in London is considerably diverse in its construction type, therefore, constructability will differ for varying types of schools’ configurations. Despite this, some policy and funding considerations will remain applicable. Some schools will consist of a range of buildings, many of which will have pitched roofs. For this archetype, a cost has been considered, both for flat and pitched roof constructions of similar sizes. Schools have higher occupancy in term periods compared to other use types and may overheat even in the winter. Schools are typically closed during the hottest period in the summer, but the building may be used for a range of community activities. Typically, schools will not be air conditioned. This type of building may be representative of other similar concrete constructions, and these will have the same or similar implementation considerations. Children are considered as vulnerable and, therefore, there may be considerations that would apply to other buildings with vulnerable occupants. For instance, scaffolding would be required for undertaking building works for care homes and hospitals, as well as schools. For this project, a specific concrete construction has been considered, the GLA adaptation guide for schools “How London Schools and Early Years Settings can Adapt to Climate Change” provides further guidance on retrofit options including cool roofs for a range of school buildings (GLA, 2020).

**Archetype 3: Social Housing**

This building type is representative of a range of social housing projects from 1960s-1980s. These building types will not typically be air conditioned and may suffer from overheating on upper floors, especially during a heatwave. Some estates may comprise of a mixture of private and social housing, which will have implications on decision making. Furthermore, some social housing blocks will have pitched roofs and this diversity has been considered in the Cost section. It should be noted that a medium-rise social housing building (4-5 storeys) has been considered for this archetype. There may also be other high-rise social housing estates that will have similar considerations but may possess different cost implications.

**Archetype 4: Office**

The commercial building stock in London will vary considerably. This building type is a representation of a central London office that requires cooling all year. There will be competition for roof space with mechanical plant. Furthermore, some offices will consist of pitched roofs, and this diversity has been considered in the Cost section.

*Care homes*
The older population residing in care homes are at the highest risk of heat -related premature death (Greater London Authority, 2020). The GLA commissioned work to be undertaken on a ‘Care Home Overheating Audit’ pilot project which details evidence-based recommendations for reducing the occurrence of summertime indoor overheating and exposure to elevated temperatures in care home settings. Although this project uses a specific case, the findings can be applied to a range of care homes across London. The archetypes discussed in this report do not include care homes specifically, but the residential and school archetypes could be interpreted for care homes depending on the building type. The archetypes provide a range of implementation considerations that may also apply to care homes. The ‘Care Home Overheating Audit’ pilot project identified ‘high albedo surfaces’ as a measure that will be effective at keeping the heat out of buildings (rated medium to high effectiveness). This is particularly important for those aged over 65 years old, who are more likely to spend their time indoors particularly during the hottest time of the day. Cool roofs can help address the issue of overheating in care homes where the most vulnerable reside and there is an argument for making these types of buildings a priority.

## Cost

*Comparison of archetypes*
The cost of a cool roof retrofit intervention, whether it is a reflective roof or a solar PV roof, will vary widely across London's building stock. For this report, building archetypes have been used to produce hypothetical cost estimates to provide an indication of scale and return on investment (ROI).

This table provides a summary of the unit and total costs for applying different cool roof interventions on the selected building archetypes. This includes the cost of materials, installation, contractors, and overheads. These are presented for guidance with several assumptions made and noted. Further details of how these figures have been calculated have been presented in Appendix E .

**Table 3 – Summary of costs for cool roof interventions for different building archetypes**

| | House | School | Social Housing | Office |
|---|---|---|---|---|
| **Reflective coating** | - | *£89/m²* | *£13/m²* | *£13/m²* |
| | - | £134,000 | £19,000 | £30,000 |
| **Reflective Tiles** | *£125/m²* | *£177/m²* | *£125/m²* | *£299/m²* |
| | £11,000 | £301,000 | £212,000 | £837,000 |
| **Solar PV** | *£1,750/kW* | *£2,288/kW* | *£1,429/kW* | *£1,459/kW* |
| | £7,500 | £167,000 | £70,000 | £54,000 |

The lowest cost intervention is a reflective coating application. The price of installing a reflective roof will depend on several factors such as type of roof, size, complexity, and method of attachment (Global Cool Cities Alliance, 2012). A reflective coating is feasible for schools, social housing, offices, and any other building that consists of a flat or low-pitched roof. The typical unit cost £13/m$^2$ for a reflective coating. Special measures such as scaffolding may be needed. In buildings with vulnerable people, such as schools and care homes, this can increase the unit cost to £89/m$^2$.

For pitched roofs, costs are likely to be higher as the installation will be more labour intensive (roof retiling would be needed) and the cost of materials is likely higher. For the school archetype, for example, if the school roof is pitched, the cost would be more than double - with a unit price of £177/m$^2$. For the social housing and the office archetypes, the cost is also significantly higher if there is a pitched roof. Since reflective coatings or membranes are not possible for a pitched tiled roof, this type of intervention is the only viable and recommended option for much of London's housing stock. For a semi-detached house, the cost per unit is estimated at £125/m$^2$, with the total cost estimated at £11,000. This option would increase in feasibility if roof retiling is required for a building for other reasons (for example, if a general roof replacement or repair is already being carried out). In this instance, cool roof tiles could be incorporated as an additional good practice retrofit measure. Reflective tiles may also be more cost effective in conjunction with other retrofitting work so that savings can be made on high costs, such as scaffolding.

Over the last decade, solar PV prices have decreased globally, and this trend is expected to continue. The 'International Renewable Energy Agency' predicts that the global average cost for electricity generated by solar PV could decrease by up to 59% by 2025 - when compared to 2015 prices. Despite this, London has seen an increase by approximately 10% in the cost of solar PVs since 2016 due to low rates of deployment (GLA, 2018).

The upfront cost for installing solar PVs is approximately £4,000-6,000 for a typical family home in the UK (GLA, 2018). However, in London, the costs have been estimated as being higher. The total amount will be influenced by the size of array and roof access. Costs are also affected by whether a building owner chooses panels or tiles and whether these are selected as building-integrated panels or panels that fixed on top of the roof. Tiles are the most expensive system, whereas panels on top of the roof are deemed the cheapest option (EST, 2022).

Solar PVs may be a feasible option for pitched roofs, especially in cases where reflective tiles are not feasible. For instance, for a typical semi-detached house (archetype 1), a PV installation is estimated to cost £7,500 compared to £11,000 for reflective tiling. Solar PVs would also have a lower cost for non-residential buildings that are pitched.

*Return on investment*
Return on investment (ROI) may be important to consider when investing in a cool roof intervention. For reflective roofs on buildings, such as housing (both private and social) and certain public buildings like schools, it is difficult to determine a financial ROI only, as these archetypes are often without air conditioning. In these instances, the benefits of reflective roofs are not linked to monetary returns but rather in their impact on factors such as public health and wellbeing (see *Benefits of Reflective Roofs* section).

ROI has been estimated for the office archetype for a low insulation building and a high insulation building, both assumed to be air-conditioned. The numbers are based on the difference between a heating penalty in the winter and cooling reduction in the summer. Overall, there is an annual saving in energy costs for both types of roofs.

Approximate ROI periods for the office archetype with reflective roof are:

- Low insulation roof – 5-6 years
- High insulation roof – 15-16 years

These are approximations for guidance purposes, based on current prices for gas and electricity (gas assumed for heating and electricity for cooling) and assumptions on system efficiencies and roof construction (see Appendix E). There may, however, be significant variability on the return periods. Although there is a higher return period for an insulated building, the ROI calculation does not account for carbon savings for an insulated roof, which is a crucial consideration in line with the mayor's objectives. In addition, the calculation does not account for future projected increases in temperature, which would make cool roofs more compelling for both insulated and uninsulated buildings.

For solar PVs, an ROI has been estimated for the various buildings. Approximate ROI periods for solar PV installations have been calculated as follows:

- Semi-detached house – 7 years
- School – 4-5 years
- Social housing – 5-6 years
- Office – 2-3 years

As described above, these estimates are provided for guidance purposes only, and there will be considerable diversity associated with a specific building that will need to be evaluated in greater detail prior to installation (see Appendix E for details on assumptions). Moreover, a detailed ROI estimate would need be carried out prior to carrying out a project, which many suppliers already offer. Importantly, these figures do not account for any payback or rebate schemes for surplus energy generated, which could result in shorter payback periods.

*Considerations*
Some additional considerations not included in the cost estimates but may impact decision making include:

- **Maintenance.** The cost estimates provided only consider the initial investment for a reflective or solar PV roof. Maintenance costs should also be considered as part of any project. Maintenance associated with roof type is described in the next section (Constructability).

- **Property value.** The added value to property has not been considered (there is no current data for cool roofs, but PV may be easier to value when output is quantified). For private housing and commercial building owners, in particular, this may be a growing co-benefit of cool roof retrofitting.

- **Cost benefits from not installing air-conditioning**. Currently, a substantial proportion of the UK's non-commercial building stock is not air conditioned. As temperatures in London continue to rise, with more heatwaves occurring in the summer, residential cooling is becoming more prevalent with an increase in sales of cooling systems seen over the recent years (BEIS, 2021). Cool roofs are one measure that can successfully reduce overheating and save building owners from costly investments into installing and running cooling systems.

- **Diversity.** The archetypes will not be representative of all buildings and provide high level guidance only based on assumptions (as described). They also represent a moment in time, and inflation or economies of scale could influence costs, positively or negatively[5]. This could be considered in greater detail when evaluating the feasibility of a focused intervention.

*Barriers*
Cost barriers include:

- **Scaffolding and access**. Across the various archetypes, the requirement for scaffolding and access can make interventions unfeasible. There may be an indirect cost from scaffolding for a commercial property, such as loss of business for retail or hospitality. With the cost of scaffolding being the majority of a project's total costs, it is advised that wider additional refurbishment works, where possible, are considered to maximise the value and utility of scaffolding access.

- **Solar Reflective versus Solar PV**. An obvious difference in this cost consideration exercise is the high capex and high potential return on investment / savings associated with solar PVs. Whereas, with reflective roofs, such as through a coating application, the likely lower intervention cost has a low and/or difficult-to-measure return on investment / savings.

- **Hidden costs.** There could be hidden costs to construction which may not be apparent from the onset. For instance, the discovery of asbestos or structural issues which could add to the total cost. Even if these are unlikely, some consideration may be needed depending on the type of building.

*Opportunities*
There are several opportunities that could be explored either by individuals or as part of a London 'Cool Roofs Retrofit Programme.' These are discussed below and specific recommendations for next steps are presented later in the report.

[5] A combination of professional judgement and cited cost sources have been used to estimate the cost of material, labour, and scaffolding costs for the various interventions. There will be diversity on all these costs in reality. Please see E for details.

- **Aligning a London 'Cool Roof Retrofit Programme' with wider works.** Align proposed reflective intervention with wider planned building refurbishment works to decrease cost of installation, such as for scaffolding. For instance, climate adaptation measures such Building Renovation Passports could provide a roadmap for retrofit that a cool roof could be tied into for efficiency (Green Finance Institute, 2021).

- **Promote potential asset value enhancement through a London 'Cool Roof Retrofit Programme.'** Prepare and deliver communication and engagement material to residential and commercial property owners that demonstrates, with empirical data, the value enhancement created through cool roof retrofit activities.

- **Cost Reduction through Economies of Scale.** There are likely cost benefits to projects that are carried out at scale, and from the impacts of a growing market (as long as supply chain growth is incentivised alongside demand). For instance, the current 'Solar Together Programme' in London (iChoosr, 2022) is a group buying scheme that promises competitive pricing on solar PVs (see *Funding* section for more details). This is not covered in this analysis but could be adapted by a London 'Cool Roof Retrofit Programme.'

## Constructability

The constructability of a retrofitting measure depends on the building structure, roof construction, and its condition. Since London's building stock varies significantly in terms of type, condition, and age of structure, there are a myriad of variables to consider. As such, this section focuses on the main considerations for both pitched and flat roofs.

Data from the London Solar Opportunity Map shows that about 6% of London's roofs are flat (less than 10° pitch), 6% are low pitched (10°-14° pitch) and the remaining 88% are pitched (above 14°).

*Low pitched or flat reflective roof (untiled)*
For low pitched roofs, a reflective coating or single ply membrane is usually considered.

| | In London, low pitched or flat roofs include a large proportion of the social housing stock are concrete structures as well as a proportion of commercial and industrial buildings. |
|---|---|
| **Ease of construction** | A reflective coating or membrane can be applied directly on a flat roof over existing materials. Good installation is essential to ensure that there is no peeling or flaking (EPA, 2008). A reflective coating can be relatively easy to implement with technical assistance, for instance, the NYC Cool Roofs programme consisted of predominantly flat coated reflective roofs and was a largely voluntary effort. Skills and training may be required to coordinate, supervise, and provide technical support to projects. |
| **Time and disturbance** | Most flat roofs should be accessible without the need for specific measures during construction (e.g., scaffolding). This means there should be little disturbance and time required. |
| **Structural** | A reflective roof coating or membrane will not add any additional structural load to a roof. Flats roofs should, in general, be accessible for maintenance. |
| **Maintenance** | Roofs will inevitably collect dirt and particulates over time and will need to be cleaned to maintain their optimum reflectivity levels. Coatings will also need to be refreshed every 10-15 years (Justin Halewood, 2010). Note that a reflective roof will still likely provide some benefit even if they are not maintained. |

*High pitched reflective roof (tiled)*

For a high-pitched roof, reflective tiles or asphalt shingles are most suitable as a reflective roof.

| | Much of London's building stock consists of pitched roofs. Coatings or membranes are not suited to pitched roofs, therefore, replacing existing roof tiles is the most suitable option. |
|---|---|
| **Ease of construction** | Installation will entail replacing existing roof tiles or asphalt shingles which can be time consuming. Retiling would usually be done by a professional. Scaffolding will be expected to provide safe access to pitched roofs. |
| **Time and disturbance** | The time taken will depend on the size of the building, design, and condition of the roof. The condition of the roof structure will influence the disturbance factor, but typically it would be significant, and scaffolding would usually be required. As such, this type of retrofit measure would only be sensibly undertaken if the roof or tiles were already in need of replacement. |
| **Structural** | The condition of the roof will need to be checked to ensure that it can withstand removal of existing tiles and retiling and if the roof is walkable for works to be carried out. This will be especially important for older buildings. New tiles will need to be the same weight and size as the existing tiles to ensure there is no additional structural load. If tiles are heavier then structural checks will need to be completed to confirm the roof can withstand the additional load. |
| **Maintenance** | Manufacturers warranties will need to be checked for specific lifespans of products. To an extent a pitched roof may be easier to maintain as rainwater is likely to wash away any dirt and debris, but some maintenance may be needed if build up occurs. |

*Solar PVs*

Solar PV panels can be installed on pitched roofs by being fastened to the roof structure or the tiles. For a flat roof, solar PV panels will need to be mounted on a support structure to ensure there is an adequate incline. Roof orientation and level of shade on the roof will be factors to how much energy can be generated by a particular roof (Solar Together, 2021).

| | |
|---|---|
| **Ease of construction** | Solar PV installation will require a professional. |
| **Time and disturbance** | The time taken will depend on the type of building. A domestic building with a pitched roof will require typically 1-2 days for installation with the requirement of a scaffold. Commercial projects will vary depending on size, location, and type of building. |
| **Structural** | Solar PV panels will add additional loading to the roof structure. For pitched roofs, the rafter sizing and spacing and the impact of the permanent loading will need to be considered. The age and condition of the roof will need to be checked, and in some cases, reinforcements may be needed. For residential projects solar PV companies will usually offer a full service where such checks are carried out. The impact of structural loading will also need to be assessed for flat roofs. Installation may require scaffolding if there is no direct access to roofs. |
| **Maintenance** | PV panels that are tilted 15° or more will benefit from being cleaned by rainfall (SolarTherm UK, 2022). Some maintenance such as occasional cleaning may be required. Guidance for maintaining the performance of a solar PV system is often provided during construction works. This should include details of the main inverter fault signals and any troubleshooting guidance. Often this can be demonstrated at the time of installation. |
| **Compatibility** | Checking roof compatibility for solar PV installation is recommended as some shingle materials are not as compatible with solar panels and may require additional steps for sealing the solar PV system during installation. Roofs made of wood, shingle, clay, slate, and terracotta are particularly vulnerable to damage and leaks during installation and may warrant replacement of parts of the roof to better support a solar PV system. |

*Considerations*

Specific constructability considerations for reflective roofs and solar PVs have been discussed for both pitched and flat roofs. As noted, London’s building stock is vast and diverse and, therefore, it is not possible to list all possible constructability considerations. For instance, there may be issues relating to older buildings, less common roofs, and building structure, as well as less accessible locations, which will need to be assessed. This will require consideration a project-by-project basis and may require professional advice.

Several additional factors that should be considered for any given project or large-scale implementation plan include:

- **Potential glare to surroundings:** For reflective roofs, some consideration should be taken of the surroundings to ensure there are no adverse glare effects to surrounding receptors. Both discomfort glare and disability glare (when a bright source of light impairs the vision of other objects) should be avoided. Guidance such as "Site layout planning for daylight and sunlight" published by the BRE can be referred to for further information (Paul J Littlefair, 2022). In a situation where a low-rise building may impact taller neighbouring buildings, a mitigation could be to install a cool-coloured roof, as it will reflect more *non-visible* solar radiation, reducing glare (Berkeley Lab, 2022).

- **Competition for Roof Space:** There may be competition for roof space with other features such as plant on commercial buildings. There could even be competition from different roof systems such as reflective roofs, solar PVs, green roofs, and blue roofs. In some instances, these technologies could be combined for co-benefits; whilst in other cases the individual benefits and returns will need to be weighed up. Building owners need to be provided with the right information to aid decision making.

- **Materials:** There needs to be sufficient supply of materials to meet demand if uptake increases. The supply chain will need to be considered especially for materials that are currently not widely used in the UK, such as reflective tiles.

- **Warranty:** A warranty or guarantee from a provider or manufacturer will help protect against any issues for building owners post maintenance.

*Opportunities*
These opportunities may be explored by individuals or as part of a London 'Cool Roofs Retrofit Programme.' Specific recommendations for next steps are presented later in the report.

- **Scalability:** Being able to implement both reflective roofs and solar PV roofs at scale will have advantages. For reflective roofs, large scale installations are necessary for them to have a beneficial impact on the UHI effect. There may also be cost benefits from neighbourhood wide projects; for example, the 'Solar Together' programme incentivises this through more competitive prices on solar PVs (See Funding, Partnerships and Commercial Models Section). Efficient scalability will require an element of repetition which may direct what type of buildings should be prioritised. For instance, it may be efficient to install solar PVs on residential building with a pitched roof at a large scale first. Other measures to encourage scalability could be through less interfaces during the procurement process. An example of this would be a property owner or local council facilitating a project that would include several of their buildings.

- **Prioritising 'Do-It-Yourself' Construction:** Coated reflective roofs are relatively easy to implement and, although they will require some technical support, there is a potential to provide training to building owners and even volunteers to enable do-it-yourself projects. This could help facilitate larger uptake and increased scalability of projects.

- **No regrets climate interventions:** All new roof maintenance and replacement projects could be required to be cool roofs unless there is justification for them not to be. Incorporating cool roofs into existing projects would increase constructability and cost savings. See Case Study 7 for how similar policy changes were implemented in Toronto.

- **Integration**: Including a cool roof, whether reflective or solar PV, as part of a larger retrofit project would help increase ease of construction. The cost, time and disturbance associated with a cool roof should not add to a larger construction project and can help overcome barriers.

## Funding, Partnerships and Commercial Models

There are several London-focused and national initiatives aimed at encouraging energy efficient measures, retrofit, and installation of solar PV systems for individuals, social housing, communities, and local authorities. The current funds are presented in this section. Although there are several schemes that apply to Solar PVs there is not yet any support for reflective roofs. Funding programmes and initiatives for reflective roofs in other cities are also discussed and may provide some inspiration for a London specific "Cool Roof Retrofit Programme."

*Current funds, initiatives, and partnerships in London and the UK*

### Households

The following are current schemes for homeowners and tenants. Government funding like the 'Green Deal' and 'Feed-in-Tariffs' have been replaced by the Smart Export Guarantee (SEG) to incentivise solar PVs. Furthermore, schemes like Solar Together can provide cost effectiveness and incentive for community partnering. There is currently no funding or support for reflective roofs, however there may be opportunities if schemes like the Home Upgrade Grant (HUG) or VAT removal could be extended.

| Option | Type | Details |
|---|---|---|
| Solar Together (running since 2018) | Incentive (London) | Solar Together is an initiative run by the Greater London Authority for householders and small businesses. The aim of the initiative is to provide highly competitive solar PV panel prices through a group-buying reverse solar auction. |
| Smart Export Guarantee (SEG) | Funding (National) | The Smart Export Guarantee (SEG) provides support to small-scale renewable energy generators, consisting of individuals who have renewable technologies installed in their homes (e.g., solar PV) for the electricity they export to the grid (Ofgem, 2020). The savings from solar PV with the SEG are considerably higher than without it (EST, 2022). |
| Home Upgrade Grant (HUG)/ sustainable Warmth | Funding (National) | This strategy is designed to ensure that people in fuel poverty have access to affordable, low-carbon warmth as we transition to net zero and work toward our fuel poverty target (BEIS, 2021). |
| The Value Added Tax (Installation of Energy-Saving Materials) Order 2022 | Subsidy (National) | VAT has been removed on solar panels, heat pumps, insulation and other materials that can be used to make homes more energy efficient, as of 1st April 2022. |

## Social housing

The following schemes are specifically targeted at social housing to encourage the implementation of energy efficiency measures. The RE:NEW project was applied to solar PV installations across London. This project was superseded by the **Retrofit Accelerator – Homes** programme which launched in February 2020. As with the funds available to homeowners, there is currently no scheme that applies specifically to reflective roofs but there could be an opportunity to extend the criteria of existing schemes to include these measures.

| Option | Type | Details |
|---|---|---|
| RE: Retrofit Accelerator – Homes | Funding and support (London) | Retrofit Accelerator – Homes is a technical assistance programme. It provides London boroughs with the technical expertise they need to kick-start 'whole-house' retrofit projects across the capital. The programme helps social housing landlords cut carbon and reduce energy bills by drastically improving the energy efficiency of their homes through a 'whole-house' approach, tackling 'building fabric', heating systems and installation of renewable energy holistically.<br>The programme also helps build a network of suppliers and opportunities to accelerate the much-needed retrofitting of private homes.<br>Solar PV, where appropriate and feasible, is one of the measures that the Retrofit Accelerator -Homes Programme uses. |
| Social Housing Decarbonisation Fund | Funding (National) | Registered providers of social housing (including private and local authority providers) can apply the Social Housing Decarbonisation Fund (SHDF) to support the installation of energy performance measures in social homes in England.<br><br>The SHDF will upgrade a significant amount of social housing stock to an Energy Performance Certificate (EPC) rating of C. |

## Communities

The following schemes that can support communities, organisations, and local authorities with Solar PVs and energy efficiency or low carbon measures. There is a potential to link a "Cool Roofs Retrofit Programme" for London with some of these schemes as they may be broad enough to apply to both solar PVs and reflective roofs.

| Option | Type | Details |
|---|---|---|
| Future Neighbourhoods 2030 | Funding (London) | To help support a green recovery from the COVID-19 pandemic, the mayor has launched a new funding programme called Future Neighbourhoods 2030. It aims to tackle some of London's defining environmental challenges, including the climate emergency and toxic air quality, whilst creating jobs, developing skills, and supporting a just transition to a low carbon circular economy. £3 million is being made available for the first phase of the programme. A further £4.5million is |

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| | | expected to be made available for the second phase, subject to further decision making and budget process. |
| London Community Energy Fund in October (2017-ongoing) | Funding (London) | This fund offers grants to support the development of community solar projects (GLA, 2018). The fourth phase of LCEF supported project development and provided capital grants to help get projects over the line and completed. (Greater London Authority, 2022). |
| Energy Leap | Funding/ partnership (London) | The Energy Leap Project is part of the Mayor's Energy for Londoners programme. It provides match funding for project partners on small scale trials to deliver the first net zero energy retrofits in London. |
| Carbon Offset Funds | Funding (London) | A scheme whereby Local Planning Authorities (LPA) can raise money which can be ringfenced for spending on carbon saving projects. Contributions are made to the fund in cases where a new development cannot achieve zero carbon; the remaining emissions are offset by making a cash-in-lieu contribution to the LPA.<br>The funds are set aside to "reduce energy demand in existing buildings, including through energy efficiency measures and improving monitoring and operation" and thus have the potential to be used for cool roof retrofit |
| 24/7 Solar project (2019) | Partnership (London) | The 24/7 Solar project, which was part funded by National Energy Action (NEA), is being led by Camden Council working in partnership with Islington and Waltham Forest councils. The project installed and compared the performance of batteries in 41 properties across three London boroughs. The project aims to significantly reduce household electricity bills and will be monitored and verified through robust evaluation. |
| Community Solar | Partnership (London) | Community energy groups are usually local residents who come together to generate, own, manage, or reduce consumption of energy. In London, these groups currently own and operate at least 750 kW of solar PV situated on churches, social housing blocks and schools. These have often been financed through the purchase of shares by members of the community (GLA, 2018).<br>Organisations like Repowering have successfully empowered communities to fund, install and manage their own clean, local energy. See Case Study 1: Repowering UK for further information. |
| RE: FIT<br><br>RE: FIT 4 (until 2024) | Partnership (London) | The Re:fit programme is a procurement initiative for public bodies wishing to implement energy efficiency measures and local energy generation projects on their assets, with support to assist you in the development and delivery of the schemes. Re:fit 4 has been procured and run by a partnership of the Greater London Authority and Local Partnerships (Local Partnerships, 2022) |
| Local energy Accelerator (2020) | Fund (London) | Local Energy Accelerator (LEA) is a £6m programme providing expertise and support to organisations to develop clean and locally generated energy projects. Projects will include district energy networks that use renewable heat sources (including river water and waste heat from London Underground), and energy technologies such as heat pumps, solar panels, batteries, and smart electric vehicle charging to |

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|---|---|---|
| | | transform the way London generates, supplies, and uses clean local energy in buildings and transport. LEA will focus on helping projects that are in their final stages and would benefit from support to deliver carbon savings (Mayor of London , 2022). |

*Approaches in other cities*

Cool Roofs schemes across cities globally have adopted a range of funding, partnership, and commercial approaches to facilitate their implementation. These models could be considered in the context of London to explore how they could be adopted for reflective roof or solar PV programmes.

### Rebate programmes and incentive schemes

Several cities in the USA have launched rebate programmes for both commercial and residential building owners to incentivise cool roof uptake. In Austin, Texas, commercial buildings can apply for a rebate per square meter of reflective roof installed as long as conditions such as warranty of installation and materials is provided. In addition, building owners of multifamily buildings (housing estates, apartment blocks) can also apply for rebates. The scheme is operated through Austin Energy and goes beyond just reflective roofs; rebates are offered across a range of energy saving measures such as insulation and window treatments (Austin Energy, 2022).

Other cities, such as Los Angeles, have performance-based rebate programmes which offer a rebate based on your actual energy savings. For building owners this includes an incentive scheme for solar PVs which takes care of upfront cost and installation as well as providing a monthly credit on bills.

Tax rebates have also been used for some schemes. In Chicago, there is a stormwater retention scheme that offers 1% property tax break for each centimetre of stormwater re-use. This type of scheme could work in the case of hybrid roofs.

### Partnerships, corporate sponsorship, and volunteering

The New York City ‘NYC Cool Roofs Programme’ was launched as a partnership between NYC Department of Small Business Services, its Workforce1 Industrial & Transportation Career Center, the Mayor’s Office of Sustainability, the Mayor’s Office of Resiliency, and The HOPE Programme (NYC Business, 2022). Partnerships between these various organisations has allowed the programme to launch a training and work experience scheme, assemble volunteers, and ensure that installations are provided by the city at no-cost to non-profit organisations.

In addition, other partnerships that co-operate with sponsors have also been essential to the success of the programme. In 2017, Fordham University located in the Bronx, launched a plan to coat six of its buildings, adding an additional 81,000 $ft^2$ (about 7,500 $m^2$) of reflective roof area. The university also planned to engage with a mix of building owners in the neighbourhood to increase awareness and visibility of the programme (OneNYC, 2017).

The ‘NYC Cool Roofs’ programme is also a largely volunteer-based programme. Both individuals and corporate sponsors can sign up to volunteer to help install reflective roofs. Businesses and employees can also sponsor a corporate volunteer day as a team building experience.

Some cities have used partnerships to launch initiatives such as competitions to incentivise implementation. For instance, the ‘Philadelphia Coolest Block Contest’ was a collaboration between the ‘Mayor’s Office of Sustainability,’ a non-profit implementing agent (Energy Coordinating Agency), and a cool material manufacturer (The Dow Chemical Company). Residential blocks with the highest reflective roof sign up rates have a chance of getting their installations costs reimbursed (Global Cool Cities Alliance, 2012). Barcelona has also used a competition to encourage creativity in green roofs. Winners receive a subsidy that helps pay back 75% of the cost. These two examples could be used as a template for a similar initiative in London in order to drive the adoption of reflective roofs (Ajuntment de Barcelona, 2017).

*Barriers*
The following barriers intersect with cost considerations and are discussed in this section as they highlight the importance of funding and partnership schemes to make cool roofs feasible for different stakeholders.

- **No support for upfront costs:** Initiatives such as the ‘Green Deal,’ ‘Feed-in Tariffs,’ and ‘Solar Together’ still require the majority of upfront costs to be provided by the building owner. Building owners will need to be convinced of the benefits and return on investment.

- **Reduction in PV incentives for homeowners and businesses:** low uptake could be in part due to reductions in financial support following changes in government policies such as the ‘FiT,’ as well as increased business rates for commercial buildings with solar PV panels, both of which have weakened the financial business case for installing solar PVs on commercial buildings. Maximising the use of incentives to increase deployment rates is likely to provide more competitive solar PV prices, thus leading to further increases in deployment.

- **Lack of incentives for tenants and property owners**: In London, 49% of households are either private or social renters (Department for Levelling Up, Housing and Communities, 2020); addressing buildings within this sector must also be an important element. Current initiatives may not be attractive to property owners of housing stock within the rental market. Property owners and tenants are unlikely to wish to invest in these systems due to their large upfront costs and lack of direct and lasting benefit to themselves. The average tenancy duration in London is 22 months (Kinleigh Folkard & Hayward, 2020), and so the majority of tenants would not see the financial benefit themselves if they were to pay the upfront costs. Having said that, some landlords might be willing to invest, particularly as the energy efficiency of a home rises up the ‘wish list’ of prospective tenants; Kinleigh Folkard & Hayward found that 43% of tenants believe that ‘Good energy efficiency’ is a more important consideration than it was in their previous property search (Kinleigh Folkard & Hayward, 2020).

- **Need flexibility in current national funding schemes**: National funds such as the ‘Green Homes Grant’ or the ‘Homes Upgrade Grant’ are not currently relevant to reflective roofs and solar PVs. The GLA would need to influence national policy to extend the scope of these grants, which would be challenging.

- **Other funding options may be needed**: The *Local Partnership Domestic Handbook* (Local Partnerships, 2021) presents an in-depth account of possible funding options for domestic retrofit. The report states that public funding is unlikely to entirely fund the cost of retrofitting the UK’s housing stock and a form of private financing is likely to be needed.

*Opportunities*
Funds, partnerships, and commercial models introduced by other cities for cool roof programmes, as well as existing schemes in the UK and London, highlight opportunities that individuals, a London “Cool Roof Retrofit Programme” and the GLA could explore further. A “long-list” of possibilities is discussed in this section, however specific recommendations are discussed later in the report.

### Funding Schemes
There are opportunities for several programmes in London to be extended or developed further. These are opportunities that would need to be lead at a city level by the GLA but could be integrated as part of a London “Cool Roofs Retrofit Programme” as seen in other cities.

- **Extending Current Schemes:** For solar PVs, there is an opportunity for the GLA to go further to provide more support and incentive. For instance, supporting with upfront costs and installation, will encourage greater uptake due to expected energy savings at a lower capital expense upfront. A neighbourhood scheme could be introduced to encourage building owners to sign up for cool roof retrofit at scale. This would promote interventions at scale that may result in wider benefits, such as reducing UHI in London. More guidance could also be provided to Local Authorities on allocating carbon offset funds for retrofitting existing buildings with reflective roofs and solar PVs.

- **Rebate Scheme or Pay Back Scheme:** Reflective roofs could also be incentivised through a rebate scheme, similar to schemes identified in other cities. This could be applied to both commercial and residential buildings and could provide a rebate based on either type and amount of installation or the energy saving potential. Funds, partnerships, and commercial models introduced by other cities for cool roof programmes as well as existing schemes in the UK and London highlight opportunities that a “Cool Roofs Retrofit Programme” could tap into. Furthermore, a rebate scheme could be holistic and include a number of retrofit measures.

- **Lobbying for national funding schemes to extend to cool roofs**: Existing grants (such as ‘the ‘Homes Upgrade Grant,’ or removal of VAT from cool roof materials such as coatings and tiles) could be extended to include cool roofs. This would encourage building owners to think holistically about retrofitting and go beyond reflective roofs or solar PVs, thus ensuring that as many energy saving measures as possible are considered.

### Partnership Schemes

The following partnership opportunities could be considered as part of a London “Cool Roofs Retrofit Programme.”

- **Engage with the private sector and community organisations** to help bring together a voluntary programme, as demonstrated by the ‘New York City Cool Roofs’ project.

- **Engage with community solar projects** and provide support toward fund raising.

- **Partner with public institutions**, such as schools, care homes, other critical infrastructure; and universities, to create lead by example programmes. Institutions lead by retrofitting their own buildings and set an example to the local community who they in turn support through dissemination and engagement. Further details on how community engagement can take shape is discussed in the ‘Behaviour, Engagement and Communication’ section. A London “Cool Roofs Retrofit Programme” could tap into the London Anchor Institutions’ Network which currently has the mandate to focus on three of London’s recovery missions - helping Londoners into good work, a new deal for young people, and a Green New Deal (London Anchor Institutions' Network, 2021). All targets that can be furthered by a “Cool Roofs Retrofit Programme”

- **Grow partnerships** through co-operative organisations where the skills could be included as part of whole house retrofit.

- **Partnering with the Future Neighbourhoods 2030 programme**: There is a potential to link with boroughs and neighbourhoods that have successfully secured funding from the scheme. A London “Cool Roofs Retrofit Programme” could be incorporated as part of the measures being implemented by these areas.

### Additional options

- **Other financial incentives:** There is potential to provide other types of financial incentives which could encourage retrofit of cool roofs in common with energy efficiency led retrofit. These do not currently exist in the private sector but could be considered at a London level. For residential buildings, the Construction Leadership council has proposed a Stamp Duty Rebate for homes with high energy performance, reduced VAT on ‘retrofit-led-renovation’, Government grants for low-income households, low interest loans, or ‘help to fix’ schemes (Construction Leadership Council, n.d.). These types of incentives may need to be supported by national policy. The idea of ‘green mortgages’ could also be mainstreamed, whereby people extend their mortgage at low interest rates to carry out upgrades to their home to make them more energy efficient.

- **Emerging Green Finance:** *Financing energy efficient buildings: the path to retrofit at scale published by the Green Financing Institute* (Green Finance Institute, 2020) details developing market solutions to scale up the finance needed to retrofit UK homes. The report discusses 21 scalable demonstrator projects, designed to overcome the barriers to mobilising capital towards the social rented, private-rented, and owner-occupied residential sectors. Demonstrators include tenancy agreements, lending products, saving and investment products and energy saving products which could all relate to reflective roofs and solar PVs. Green financing options are becoming a tangible for London and can include:

    - The Mayor’s Green Finance London Programme is being developed to catalyse the flow of finance into climate related projects. The development of his Financing Facility, the first phase being the Green Bond programme, will allow for a range of large climate related projects or portfolios of projects to access finance for their delivery but this is finance and not funding so projects will need to be able to evidence a clear revenue stream that can be used to pay back the investment and related interest. There is the opportunity to combine reflective roof and PV on buildings in to one offer that would potentially allow their financing as the revenue streams and/or savings from the electricity generated by the PV could be used to help pay back the costs of the reflective roof.
    - The 3Ci, of which London Councils is a partner, is another potential source of funding as they are looking to develop a national database of area-based Net Zero investment opportunities in pursuit of Net Zero 2030. The GLA and London Councils are working together to develop a regional pipeline of net zero projects that can be used to raise finance and funding from the public and private sector to support their delivery.
    - In each of these cases a portfolio of buildings having reflective roofs and PV installed would need to be aggregated together to be able to access these programmes.
    - In addition, the London Sustainable Development Commission (LSDC) is carrying out ‘Green Finance’ work (London Sustainable Development Commission, 2020) that examining how London can unlock investment need to deliver environmental activity at scale. Green finance provides a powerful opportunity to scale retrofit in London. Although these products do not currently exist, they are emerging models that can become tangible solutions for financing in the future.

## Policy and Planning

*Considerations*

The success of any cool roof initiative needs to be partnered with supporting planning policy or consenting mechanisms that can reduce the burden on the planning system and do not hold up development. It is also important to ensure that those wishing to install these systems are clear as to their ability to do so under the planning system. It is therefore essential to understand whether both reflective roofs and solar PV roofs require planning permission or otherwise under the Town and Country Planning Act (1990). The below discussion provides a summary of existing planning legislation and makes recommendations on how best to address any shortcomings within the current framework.

While the 'National Planning Policy Framework' (Ministry of Housing, Communities and Local Government, 2021) makes references to some cooling, there are no specific references within the policy itself. Several local authority development frameworks have sought to support the delivery of solar PV panels and green roofs.

Specific to London, the London Plan 2021 places great importance on the provision of cool roofs especially in major schemes. There are several policies governing the provision of greening and cooling systems. However, these policies are triggered at application stage. What is needed is more simplified legislation that allows the development of these systems without the need for planning permission.

### Current London and UK Planning Policy and Legislation

**Solar PV Panels**

The Town and Country Planning (General Permitted Development) (England) Order (2015): Schedule 2, Part 14, Class A (Renewal Energy) allows for the installation of solar PV panels to domestic buildings including houses and flats without the need for planning permission. However, it does not extend to commercial property, which have no existing 'Permitted Development' rights, and any installation of solar panels would require planning permission. The legislation also includes certain limitations and does not allow for installation on a Listed building and within a Conservation Area.

An Article 4 Directive provides additional planning control in a particular location. This means that although there may be some existing 'Permitted Development' rights, there are Article 4 Directives in place at a local authority level which further restrict or remove these rights. This can mean that solar PV panels could not be installed in these areas without planning permission. Therefore, any suggested full-scale programme of installation would necessarily require a local understanding and approach.

**Reflective Roofs – Painting**

The Town and Country Planning (General Permitted Development) (England) Order (2015): Schedule 2, Part 2 Class C (exterior painting) specifically allows the painting of the exterior of a building. However further clarification could be provided nationally through the updating of the wording under Class C to specifically refer to the painting of roofs. Currently reflective roof retrofit schemes may require planning permission depending on interpretation. This power can also be limited by 'Article 4 Directives' and other planning designation such as listed buildings which require consent for all work. In such cases planning and listed building permissions would be required placing a further burden on time and cost for reflective roofs.

**Green and Brown Roofs**

There are currently no 'Permitted Development' rights or other form of deemed planning consents for these forms of roofs. As such all new green and brown roofs would require planning permission.

The London Plan 2021 and local authority planning policy frameworks support the delivery of green and brown roofs.

**London Plan**

Policy 'SI 4 Managing Heat Risk' in the London Plan 2021 stipulates that major development proposals should reduce potential overheating and reliance on air conditioning systems. This should be demonstrated with respect to a six-part cooling hierarchy of which the first point refers to reducing the amount of heat entering a building in the summer through orientation, shading, high albedo materials, fenestration, insulation, and the provision of green infrastructure (roofs and walls).

**Heritage**

Under the Planning (Listed Buildings and Conservation Areas) Act 1990, local authorities are required to preserve or enhance buildings of historic importance. There are also no Permitted Development rights allowing the exterior changes to a Listed Buildings. Therefore, both planning permission and listed building consent would be required for any cool roof works. As such, the need for planning permission would further slow down any comprehensive upgrading works of these buildings (locally or nationally). There is also a greater risk of refusal at the local level if authorities feel the proposed cool roof system, would compromise the historic integrity or key features of the buildings. It may be that as more sensitive cool roof systems emerge, one with less of an impact on the appearance of a building could be adopted.

Given the importance of these buildings, it is also unlikely that the Government would want to forego the protection of these buildings. Therefore, it is unlikely any Permitted Development rights could be successfully lobbied.

## International responses to planning policy and cooling

The review of current London and UK planning policy demonstrates the need for planning rules to be further relaxed to encourage the uptake of both reflective and solar PV roofs by private individuals and organisations. Internationally, there are a number of cities that have introduced incentives through policy and legislative changes to address the need to encourage the move to cool roofs. These examples demonstrate that policy responses are wide and varying with the most successful being driven by government projects.

At least nine cities in the USA have mandatory policies for reflective roofs including Los Angeles, New York, Houston, and Chicago. This includes legislation for procurement policies for publicly owned buildings to adopt reflective roofs. Los Angeles passed a cool roof ordinance in December 2013 requiring all new residences or existing residences undergoing roof renovations to install reflective roof products (CoolCalifornia.org, n.d.) New York City's building codes require existing buildings, which replace or renovate 50% or more of their roof surface, to add reflective roofing materials (C40, 2021). This is a similar approach to that taken under the London Plan 2021, whereby major developments (schemes that are above 1000sqm or propose 10 residential units or above) within London, must make provisions for renewable energy systems, such as photovoltaic panels. It also requires that all developments maximise opportunities for on-site electricity, heat production and urban greening, all aimed at carbon reduction and urban cooling (see Policies SI 2, SI 3).

California even has state-wide policy, outlined in the state's Building Energy Efficiency Standards Title 24. This applies to any areas that fall outside of local city policies and requires commercial and residential properties to have a roof that meets a certain solar reflectance criterion (Cool Roof Rating Council, 2022).

Many of the policies in the USA and other cities globally link directly to a funding or incentive scheme. For instance, in the City of Toronto (Canada) an Eco-Roof Incentive programme was created in 2009. Toronto introduced a bylaw which sets out a graduated green roof requirement for new development. Exemptions or variations under the bylaw are subject to a cash-in-lieu payment which is directed to the Eco-Roof programme. The programme applies to both green and cool (reflective) roofs and provides rebate incentives on installations (C40, 2021). Greater details of funding measures can be viewed within in the *Funding* section.

*Opportunities*

What the most successful international responses illustrate is that a partnership of legislation and incentive is required. Unlike several international examples, London has large numbers of historic buildings that are protected. Therefore, a bespoke approach may be required. There are clear planning policy limitations and disconnections in approach, and a London “Cool Roofs Retrofit Programme” could provide the GLA with a backdrop to address these:

- **Lobby on a national level for an update to national policy** to include reflective roofs or solar PVs under ‘Permitted Development,’ as well as updates to local planning authority policy. A similar approach was applied to the installation of electrical charging points. The benefits from clearer national planning legislation would more readily enable installation without planning permission.

- **Replacement roofs and refurbishment** to avoid designing in hot roofs to home improvements or extensions, there could be a policy update that all new or replacement residential roofs are designed to be cool, unless there is a mitigating factor. Optimisation of the holistic retrofit at scale approach to embrace climate adaptation alongside mitigation

- **A national drive** to highlight the importance of cool roofs and their benefits, to encourage building owners to take action as independent or holistic projects

Despite several local authorities encouraging cool roofs, in partnership with the Greater London Authority, the most successful driving force exists from national government level – as demonstrated by the use of planning instruments, such as ‘Permitted Development’ and other directives.

## Behaviour, Engagement and Communication

The most successful cool roof programmes have employed effective initiatives to engage with stakeholders. This means getting everyone on board, including building owners, partners, and the general public. One key to success is to identify early on who the engagement audience is by understanding who owns the roof to be targeted and who is likely to benefit from the cooling provided.

*Considerations*

### Building owners

Ensuring that decision makers have a high-level understanding of different options, benefits, and costs is crucial.

When communicating the benefits of cool roofs with building owners, it is important to account for different motivations and types of audiences to maximise engagement and tailor the message. The UK Green Building Council (UKGBC) Retrofit Playbook sets out steps for defining your audience and the best way to appeal to different psychological types (UK Green Building Council, 2021). This approach can be used to develop an engagement plan and tailor the message to suit tenure types, life stages or ‘trigger points,’ and psychological responses of differing character types. For public and residential buildings, the ‘RESILIO’ project in the Netherlands found that ‘bringing the roof down to street level’ was effective in engaging the public with the project above them, using photography, installation time-lapse footage, and a living model of the roof itself used in engagement sessions (RESILIO, 2022).

One of the biggest drivers for retrofitting is the associated reductions in energy bills, improved air quality and more stable thermal comfort (GLA, 2022). Communicating these benefits could be a good way to promote the implementation of cool roofs.

The importance of post-implementation engagement is crucial for some end use typologies. In particular, the maintenance and potential automation processes for cool roofs on commercial and public buildings (for example, schools and care homes) should be clearly explained to end users to maximise the efficiency of the systems and overcome any barriers for implementation. Systems should be simple to use and easy to maintain to maximise optimal performance.

In London, some schools have installed solar PV panels to demonstrate the benefits of renewable energy and engage with students on important topics such as climate change, science, and engineering (GLA, 2018).

### Partners

Engaging a range of other stakeholders is also important. This includes industry professions, local contractors, energy companies, manufacturers, and local authorities.

These stakeholders can all be potential cool roof champions that can help drive a programme forward and provide knowledge, skills and even funding.

The development of skills is a key part of this to ensure development of the supply chain. This will require policy signalling to drive capacity building alongside continued engagement with co-operative retrofit organisations, such as RetrofitWorks (RetrofitWorks', 2022) and the provision of free or supported training.

Recent work by water companies giving out shower heads and shower timers to reduce water consumption has increased understanding of water usage in homes and how to save money on water bills by introducing water saving measures. The power of dissemination and providing free samples to incentivise building owners to implement retrofitting actions has increased general understanding of water saving benefits which has resulted in environmental benefits (GLA, 2022).

The 'Cool Roofs Programme' developed in Telangana, India which aims to install 303.3 square kilometres of reflective roofs over a ten-year period up to 2030 has a phased approach. This approach will target commercial, government, and public buildings first with the residential segment happening later. The aim is that the implementation of reflective roofs on commercial building will be mandated through new code which will ensure adoption in new construction in the short term. The rationale is that the benefits realised from the commercial sector will encourage uptake in residential buildings by providing showcasing the benefits of implementation (Telangana, 2019).

The 'MetroPolder' roof is a concept that integrates a green (living) roof with a blue (water drainage system) roof (MetroPolder, 2022). An interview with MetroPolder revealed that when considering blue roof infrastructure, developers can often be persuaded to fund a blue roof when the costs associated with water operating expenses are taken into consideration. For example, capturing water on the roof and using this as grey water in the building below can represent a cost saving in the long run. Similarly for a reflective roof, if the costs associated with cooling is clearly demonstrated to be offset then people may be incentivised to implement this measure.

*Barriers*
In the 'Retrofit Playbook' publication, which focuses on energy efficiency, the 'UK Green Buildings Council' (UKGBC) (UK Green Building Council, 2021) identified several barriers to residents when considering retrofit projects. Whilst this report did not look at cool roofs, the barriers identified may also influence the uptake of cool roofs. These include.

- the hassle factor of getting the works completed,
- lack of knowledge around the benefits of implementation,
- the cost versus the perceived value, and

- a lack of trust in tradespeople and the quality of workmanship.

The barriers identified in the UKGBC report are supported by the outputs from a research study (GLA, 2022) looking at retrofitting across London. It was found that Londoners are aware of the correlation between energy use and climate change, but do not automatically connect energy usage or retrofitting as a solution to benefit the environment. These views are underpinned by a lack of understanding of what retrofitting is; 46% of those who participated in the study had not heard of the term ‘retrofitting’ whilst only 30% understood what it is (GLA, 2022). Despite this, most participants are undertaking at least some retrofitting measures, such as using energy efficient light bulbs.

45% of participants identified the biggest barrier to retrofitting as upfront cost. However, this is influenced by tenure (GLA, 2022). For those who rent, the biggest barrier is being restricted by the changes they can make to their residence. Whilst cost may be a barrier, the findings of the study highlighted that there is a general lack of knowledge about the cost of retrofitting and the potential savings that could be realised. This is reinforced by the lack of a centralised hub of reliable information about retrofit options and certified providers to support uptake. A clear strategy or engagement plan that focuses on education could be developed. Consolidating all the relevant information into one place will increase clarity of the benefits of retrofitting and provide building owners with all the available options for their homes and budgets.

When retrofitting was explained, respondents of the study were receptive to retrofitting as it is the ‘right’ thing to do, however domestic energy is not yet associated with being bad for the environment in comparison to other activities such as single use plastic and combustion engine car usage. As a result, people were not proactively changing their behaviour to reduce their energy usage. This conclusion may already be out of date given the recent rise in energy prices driving more awareness of issues around energy use and carbon emissions. A similar thing may occur with climate adaptation retrofit such as cool roofs as climate change starts to have greater impact on our lives.

Low levels of social cohesion, highly transient populations, and high poverty rates could limit engagement with initiatives as a resident’s key concerns may centre around affordability and financial uncertainties. Communication may also be stunted if certain areas are not represented by neighbourhood organisations or local communities.

It requires time and effort to engage with and encourage individuals to understand the benefits of cool roof technologies and implement these practices into their homes. Lack of trust between residents, property owners, and local government may present additional barriers for engagement and communication. In these situations, partnering with community-based organisations is key to sharing information and building trust.

Promoting cool roof retrofit has a different set of values to communicate compared to more focused decarbonisation actions, in particular the wider public health benefits from the

UHI. This has similarities to decarbonisation's wider benefits but without the personal financial benefit of lower fuel bills in most home interventions. People worried about costs need to understand why they should invest. Messaging should strongly convey the non-monetary benefits such as personal comfort and mitigation of health risk for vulnerable people from overheating homes.

*Opportunities*
There are several opportunities to engage with the public, communicate the benefits of cool roofs, and overcome barriers. These could include:

- Awareness-raising campaigns to highlight the benefits of cool roofs, as well as to partner with local authorities or associations to increase reach into the local community.
- Distributing flyers and posters to spread the message.
- Using adverts, such as billboards, distributed across the city.
- Presenting the initiative at trade shows and conferences.
- Developing a website and associated social media to support any initiatives and providing the public with general knowledge on cool roofs.
- Preparing a 'how to' manual for self-installing reflective roofs, or how to ask for them alongside other home improvement works.
- Demonstration projects.

Marketing and outreach strategies provide a valuable tool for implementing the engagement approaches outlined above. For further details on where a successful marketing and outreach strategy was implemented, please see the 'NYC Cool Roofs' case study.

Awareness generation could be undertaken through focused events on the benefits of reflective roofs and solar PVs as well as how they are installed. Specifically targeting building owners and industry professionals can encourage uptake of cool roof installations.

Furthermore, developing a steering group or leadership committee of key stakeholders is an effective way to bring together different groups to build local support and capacity for effective implementation. It can also provide a point of contact for decision makers (R20, 2012). The transition to cool materials can be accelerated in cities where leadership prioritises and actively promotes the concept of cool approaches. Support is needed from the top levels of government to ensure buy-in and champion the effectiveness of reflective roofs as a mitigation and adaptation strategy.

## Engagement approach

One approach to communicate and engage with residents is the ‘Diffusion of Innovations’ theory (Rogers, 2003), which considers how different groups of people respond to new innovations. It identifies where groups of people should be prioritised for engagement to maximise the uptake of a cool roof initiative. Stakeholder mapping and demographic studies could be undertaken to understand which community groups might fall into the ‘innovator’ or ‘early adopter’ categories.

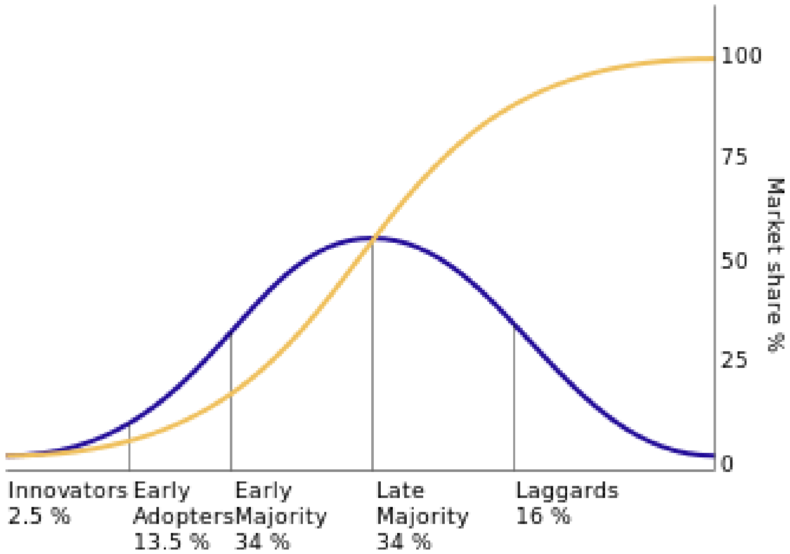


**Figure 8: Diffusion of innovations model (yellow=market saturation; blue=take up levels by group) (Source: Wikipedia)**

Another approach maps the social structure of the neighbourhood, by tapping into local knowledge through local government, residents’ initiatives, and neighbourhood organisations. The ‘RESILIO’ project made use of this approach to gain insight into local residents’ motivation and to understand which existing initiatives were most successful with respect to communication and engagement (RESILIO, 2022).

The ‘Community Energy London Programme’ (CEL, 2016) is an example of an organisation that could support engagement across London. It was established to encourage knowledge sharing for renewable energy support groups. The CEL holds many events to expand its engagement and to reach greater networks of people.

Lastly, short street surveys could support this approach, offering further insight into residents’ concerns and their willingness to act. Cumulatively, this information can support the development of a participation strategy for different areas across neighbourhoods in the city. For the ‘RESILIO’ project, this was the initial idea, however, only social housing owned by housing corporations was included in the research project. Therefore, the process was carried out as a ‘learning-by-doing’ project. The project continuously evaluated the tools and activities undertaken to adapt and improve the approach (RESILIO, 2022).

### Participation approach

Organising participation activities presents a unique approach to engaging with the public and to reaching diverse audiences. The ‘RESILIO’ project instigated several activities to engage with local neighbourhoods through active participation (RESILIO, 2022). This included:

- Information meetings.
- Attending local markets and festivals with a ‘roof bike’ to demonstrate a working blue-green roof that was installed on the bike.
- Creative workshops with children.
- Neighbourhood stories where residents would share their personal accounts.
- Events to celebrate the completion of the roof system.

Several worthwhile outcomes of these participation activities were identified and could be used to support initiatives in other cities:

- Early engagement is key for developing meaningful connections with residents and maximising local support to succeed.
- Identifying aspects of the decision-making process where residents can be involved as this will increase interest and commitment to the cause.
- Visual aids provide a powerful tool to communicate the concept and raise awareness among the general public.
- To facilitate cooperation, partnering with local organisations and initiatives and catalyse uptake as they are already considered to be trustworthy.

## Social Value and Skills Development

*Considerations*
Cool roofs will become an important tool to secure comfortable, low carbon, urban environments, noticeably improving human health and comfort as identified in the '*Benefits'* sections above. Teachers at a school in Florida, noticed improved comfort levels in classrooms following the installation of reflective roofs (EPA, 2008). From a retrofit perspective, therefore, its key to understand the relationship between buildings and the people making use of it (Tjorring & Gausset, 2018).

Buildings are not simply physical constructions; they are also places where people dwell and serve as frameworks for social interactions. Encouraging retrofit interventions amongst homeowners requires understanding the personal and family contexts that drive (or hinder) retrofit interventions, which often weigh more than energy savings or financial considerations themselves (Tjorring & Gausset, 2018; Judson & Maller, 2014). These include:

- Household practices and everyday routines, particularly those that have considerable energy consumption and GHG emission implications (for example, thermal comfort).
- Homeowners' capacity and willingness to undertake retrofit/renovations (for example, family finances, life milestones that influence housing renovation decisions).
- Flexible timeframes that accommodate personal circumstances, as opposed to one-time investments.
- House retrofits as investments for improved social relations and family life.
- Cultural ideas about ideal homes (for example, preferences towards renovations that enhance homes' appearances).

## Fuel Poverty

Although London saw a reduction in fuel poverty rates from 15.2% to 11.5% in 2020, the average fuel poverty gap increased from £178 to £188 in real terms (BEIS, 2022). Furthermore, increasing inflation and energy costs this year has triggered a cost-of-living crisis across the UK. A London 'Cool Roof Retrofit Programme' could address some of the challenges faced by fuel poor households in London. The 'Million Cool Roofs' project installed reflective roofs on houses in Mexico. The project improved thermal comfort in homes benefitting low-income families by providing a passive cooling mechanism that did not require the need for mechanical cooling which is unachievable for families who are suffering from fuel poverty. Further information can be found in Case Study 6: Million Cool Roofs.

**Social Inequality**

In addition to fuel poverty, a London “Cool Roofs Retrofit Programme” provides an opportunity to address a number of different social inequalities. The reflective roofs opportunity maps presented earlier in the report show areas that could be prioritised to ensure that retrofit reaches the vulnerable and those in need first. Currently the reflective roofs opportunity map includes social factors such as income deprivation, English non-proficiency, elderly people, social renters, and young people. This is a start, but other social factors could also be incorporated through an application or checklist process as part of a “Cool Roofs Retrofit Programme.” For instance, ‘NYC Cool Roofs’ offers cool roof installations at no cost or low cost to select buildings, with priority given to non-profits and affordable housing. Individual or organisation can apply through an online form (NYC Business, 2022).

**Skills Development through Green Hubs**

Cool roofs initiatives can include skills development components to train existing and future workforce. In the UK alone, energy retrofit programmes are estimated to generate a demand for 230,000 trained workers by 2030 (Green Jobs Taskforce, 2021) The ‘NYCCool Neighbourhoods’ programme provides a 10-week training and work experience programme for installing reflective rooftops. This process supported skills development for apprentices as well as providing them with the skills and connections to attain permanent employment opportunities (see Case Study 8: New York cool Roofs). A similar scheme in Brixton, London, installing solar power for estate residents, has created engineering apprenticeships for local young people through grants as part of the scheme (Repowering, 2019). The Skills Bootcamps for Londoners is a new programme intended to deliver flexible higher-level skills training provision based on ‘in-demand’ skills needs, bringing participants closer to good jobs (Mayor of London, 2022)

In addition, London has a network of already-established ‘Green Hubs’ that promote skills development and apprenticeships across various several London boroughs. Several of these hubs have been represented for reference in the table below. “Cool Roofs Retrofit Programmes” can use opportunities like ‘Skills Bootcamps’ for Londoners, partnering with Green Hubs and other local schemes to integrate skills development and training as a key part of the implementation plan.

**Table 4 – Summary of Green Hub schemes in London**

| Green Hub | Sector | Sub-Sector | Geography |
|---|---|---|---|
| **London & Southeast Education Group** | **Multiple** | Green construction, green spaces, and resilience: Photovoltaics, heat pumps, EV charging, | Local London (9 London boroughs) |

| Green Hub | Sector | Sub-Sector | Geography |
|---|---|---|---|
| | | data analytics and smart communication | |
| **London South Bank University (LSBU)** | **Green** | Green construction and retrofit: waste, recycling, circular economy, water management, green energy (from waste), EV charging and green infrastructure and green transport | Lambeth, Southwark, and Lewisham |
| **Evolve Learning Group & West London College** | **Green** | Energy efficiency: retrofit, insulation, renewables, and circular economy | West London sub-region |
| **South London Partnership (SLP)** | **Green** | Primary focus on Green Construction | SLP sub-region and Wandsworth |
| **Capital City College Group** | **Green** | New build, retrofit and EV installation | Hariney, Enfield, Waltham Forest, Barnet, Barking & Dagenham, Islington, Hackney, Camden, Newham, Redbridge, and Tower Hamlets |

**Skills Bootcamps for Londoners**

As an additional resource for retrofit skills development, the GLA's 'Skills Bootcamps Programme' (2023-2023) aims to deliver flexible skills training based on sector/employer 'in-demand' skills needs. The programme aims to support employers and regions to match skills shortages with training opportunities for participating individuals and with guaranteed job interviews (GLA, 2022).

*Barriers*
The retrofit market is one that is developing and faces considerable obstacles that hamper the supply of these services, including the lack of skills and capabilities in the local workforce and firms' disinterest in offering a suite of energy retrofit solutions (Brocklehurst, et al., 2021). Retrofit policies across the world have often been short-lived and failed to account for the time and skills that need to be invested in developing market capacity and

creating high volumes of work for risk-averse construction firms (Brocklehurst, et al., 2021).

The availability of skilled professionals has been identified as one of the biggest challenges to the delivery of energy-efficiency retrofit projects (Gross, et al., 2020; Green Jobs Taskforce, 2021). Workers' upskilling and labour mobility in micro-enterprises (companies with 7 employees or fewer) is particularly important (Simpson, et al., 2021; Green Jobs Taskforce, 2021), especially since these enterprises comprise around 92% of construction firms (ONS, 2018) and 77% of total construction workforce in the UK (BEIS, 2019). On-site learning opportunities, peer-to-peer knowledge-exchange and informal information-sharing networks have been identified as key activities to increase workforce capability and accelerate uptake of retrofit initiatives (Simpson, et al., 2021).

*Opportunities*
The following opportunities could be adapted by a London "Cool Roofs Retrofit Programme" to ensure that social value and skills development is integrated effectively in the programme and is seen as a crucial co-benefit.

- **Self-construction:** Other cool roofs initiatives have also focused on developing self-construction skills to cut implementation costs and increase the uptake of retrofit projects by lower-income homeowners and tenants. A self-construction delivery model was trialled as part of the 'Million Cool Roofs' project. The project team in conjunction with the federal government and local partners provide the community with training, tool kits and materials for construction (Jaffe, 2022). This model is supported by the legal framework in Mexico which has a self-construction skills programme that provides further training through a series of online videos (Jaffe, 2022). Initiatives like community energy groups have also been identified as key sources of skills, experience, and local knowledge for the delivery of solar projects in London (GLA, 2018).

- **Integration:** Successful retrofit interventions have in common high integration across roles played by contractors, which are traditionally separate and fragmented in the repair, renovation, and maintenance supply chains (Brown, et al., 2018; Brown, et al., 2019). MetroPolder have been able to partner with local suppliers and landscaping firms, in the USA and France for example, who they were then able to train over two days and recommend on future projects (MetroPolder, 2022). However, there is little evidence of mature retrofit supply chains in the UK, with most supply chains showing high levels of fragmentation (Brocklehurst, et al., 2021). Indeed, one of the reasons cited by some in the industry for the failure of the 'Green Home Grants' scheme was the complexity of getting building firms accredited in time (Harvey, 2020).

- **Reduce fragmentation:** Typically, implementation programmes are weakened by high fragmentation. In order to ensure successful cool roof retrofit implementation, the programme should have a strong integration across roles played by contractors and their supply chains included in the repair, renovation / retrofit and maintenance stages, which is essential for knowledge-transfer and skills development. Cool roof initiatives can further incentivise the creation of supply chain networks and trust relationships, which are essential for knowledge-transfer and skills development (Simpson, et al., 2021). For example, the willingness of intermediaries in the building process (e.g., advisers and installers) to innovate can potentially influence the use of new technologies throughout the supply chain at different stages of the retrofit intervention (Owen & Mitchell, 2015).

- **Growth in retrofit markets:** The creation of cool roof initiatives can also support the growth of climate adaptation and energy-efficiency retrofit markets, creation of new jobs and development of new skills over the next decades. As with the New York 'cool neighbourhoods' programme, any cool roof initiative for London should support the development of apprentices, and further support with the skills and pathway toward permanent employment opportunities.

- **Training and apprenticeships:** A "Cool Roofs Retrofit Programme" should enable engineering apprenticeships and skills development for local young people, supported through scheme grants and available funding such as the 'Skills Bootcamp' for Londoners and 'Green Hubs'. Furthermore, a strategy should consider the roles of training providers, accreditation, and trade bodies to support local ambitions and mobilise the supply chain (UKGBC, 2021). A robust and compelling strategy will be essential for engaging, recruiting, and training a skilled supply chain.

# Implementation Recommendations

## Introduction

This section of the report presents the potential for implementing a London 'Cool Roof Retrofit Programme', which has been informed by GLA and external stakeholder engagement, literature, and technical reviews, as well as by relevant experience discussed in detail in the previous section. It includes initial trajectory recommendations, which have been informed by a 'Critical Success Factor 'assessment as well as through consideration of the Management Case model both described by the Government 'The Green Book' methodology. Recommendations are made for where and how stakeholders may progress a 'Cool Roof Retrofit Programme' in London.

The implementation recommendations section of this report considers:

- The 'Critical Success Factors' assessment undertaken.
- Management Case considerations relevant to progressing a high-level implementation strategy.
- Recommendations for next steps that could be taken by the GLA and relevant retrofit stakeholders based on research and engagement. This is presented as short-, medium- and long-term wins.

## Critical Success Factor Assessment

The identification of 'Critical Success Factors' is made in order to evaluate or appraise a long list of potential options. Critical success factors are a list of holistic factors that consider the benefits, barriers, and success of potential implementation options. This is a typical consideration for business case (implementation plan) development and, in this context and at a high level, assesses the factors relevant to implementing cool roof options successfully.

*Primary archetype and technology recommendation*

The primary recommended models and contexts for implementation include solar PV and reflective roofs within the residential, school, and commercial archetypes in London - as suggested by the scored CSF options matrix for recommended archetypes and cool roof technologies in London (as referenced with associated supporting analyses in Appendix F).

### Reflective roof

For the implementation of cool roofs through reflective roof retrofitting, it is recommended that this programme delivery is piloted and understood within the office and residential archetypes, as these options currently demonstrate highest scoring against the CSFs. It is assumed that these are viable intervention options that can be self-funded by residential and commercial building owners, access requirements are available, and that there will be a subsequent benefit to UHI and cooling load. This research demonstrates that the most beneficial application of solar reflective retrofit is flat roofs on commercial buildings (with cooling).

Acknowledging that the reflective roof opportunity map identifies buildings with a lower height-to-area ratio, top-floor flats in high-rise blocks are also often identified as high risk for overheating and there should be consideration for targeted interventions in these contexts.

It is recommended that additional funding and finance options, as well as partnerships and skills development opportunities, as described above are promoted and lobbied to increase viability for more archetype options in these sectors. This is further referenced in the below ‘recommended next steps’ section of this report.

### Solar PV

For the continued implementation of solar PV retrofitting across London, it is recommended that continued adoption by the residential sector is promoted and prioritised, and that continued consideration for programmes, such as ‘Solar Together,’ are to be progressed.

Additional funding or finance support options could be established to assist homeowners with upfront installation costs. For commercial (and other non-residential) building types planning policy may need to be reconsidered to encourage wider deployment.

In addition, where suitable, Solar PV may be combined with reflective roofs to combine benefits. There could be edits to existing funding and finance schemes to incorporate and encourage this.

*Consideration for other passive cooling strategies*

As described in the next step recommendations, it is suggested that consideration be made for the wider available passive-cooling retrofit implementation strategies available. This could set out the passive cooling strategies available, their respective costs versus benefits, make recommendations for how to implement them individually and, significantly, describe opportunities to retrofit multiple strategies together in a highest-and-best use hybrid scenario. This would support decision makers with a clearer model for how best to prioritise the appropriate strategies for the relevant building context.

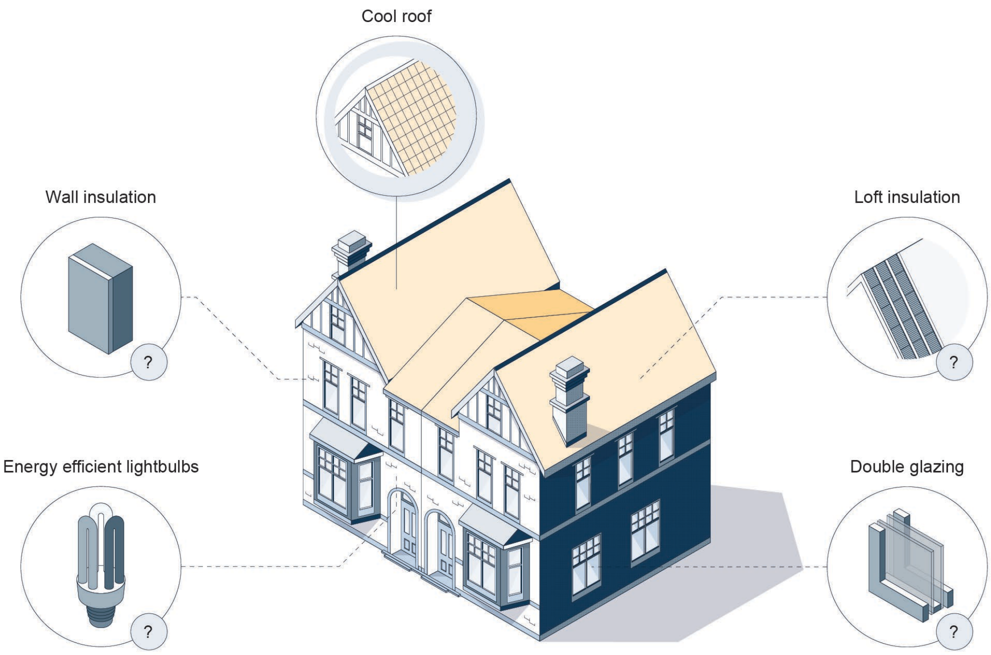


**Figure 9: Integrating cool roofs with other passive cooling and retrofit strategies (Arup)**

## Management Case Considerations

This report references short-, medium- and long-term wins as recommendation outputs. However, when developing the business case for an implementation or delivery set of options, it is typically structured, as per the government-stipulated ‘Green Book’ process, into five cases. Referred to as ‘The Five Case Model,’ these cases include the Strategic Case, Economic Case, Commercial Case, Financial Case and Management Case. This five-case model provides a framework, which, if applied correctly, considers the various features pertinent to any spending or investment proposal.

Within this report, several considerations have been made for the management case dimension of this five-case model for a potential cool roof implementation programme. The purpose of the management case is to test the deliverability of the proposed options, including timescales and change management required. At this early strategic stage, management case commentary is represented in the document’s appendices and covers high-level recommendations on risk management, project organisation and governance.

The findings of this report should be reviewed by the taskforce and/or project team leading the analyses at the next phase and potential future implementation. Furthermore, as a recommendation, the project team should develop, agree, and establish project governance and project roles prior to further work stages being undertaken.

## Recommended Next Steps

The below next steps recommend the decisions and actions that could be taken by the GLA and other retrofit stakeholders to progress a London “Cool Roofs Retrofit Programme”, as well as to evaluate further implementation possibilities for the Cool Roof technologies and models proposed in this report. These opportunities have been organised into short-, medium-, and long-terms wins and are summarised in Table 5.

**Table 55 – Short-, medium-, and long-term wins for a "Cool Roofs Retrofit Programme"**

| **Wins** | | |
|---|---|---|
| **Short-term wins (suggested c 3 – 6 months)** | Stakeholder | Description |
| **Checklist for building owners** | Building owners and Developers (e.g. homeowners, housing associations, developers, Local Authorities) | Checklists to help stakeholders around decision making with key considerations for a cool roof retrofit. Sample checklist for a private homeowner in Appendix H |
| **Organisational strategy** | GLA | Establish a GLA Cool Roof retrofit taskforce |
| **Pilot Project** | GLA, Consultant Team, Retrofit Installers and 1-2 local | Plan and implement pilot project to assess the potential for cool roof retrofits to reduce |

| | | |
|---|---|---|
| | community stakeholders in higher-priority boroughs | overheating, cool local UHI and to provide social equality (value) and skills development |
| **Integration with and benefitting from existing programmes** | GLA | The GLA could engage with existing funding, partnership, and training programmes to develop implementation synergies and scope the “Cool Roofs Retrofit Programme”. This could include programmes such as:<br><br>The Business Climate Challenge<br>Solar Together<br>London Energy Climate Fund |
| **Medium-term wins (suggested c. 6 – 12 months)** | Stakeholder | Description |
| **Consolidation and integration of cool roof workstreams** | GLA | Consolidation of all cool roof adjacent workstreams to support an integrated approach for cooling London |
| **Development of business case** | GLA and Consultant Team | Developments to business case that factor in learnings from pilot project |
| **Communication and behaviour engagement** | GLA to Homeowners, Housing Associations, Developers, Architects and Green Skills Hubs | Prepare and share communication material to a wider retrofit stakeholder audience |
| **Develop training and apprenticeship programmes** | Training Institutions, Co-Ops, and Apprentices | Continue to engage with existing schemes as well as develop a comprehensive training and apprenticeship programme specifically for cool roofs. This can widen opportunities for Small and Medium Enterprises. |
| **Long-Term Wins (suggested c. 12 – 24 months+)** | Stakeholder | Description |
| **Planning policy** | GLA and UK Government | Promote and lobby updates to national policy to ensure that cool roof retrofitting is embedded into Permitted Development rights. Consider London planning policy or incentives to motivate or require ‘Cool Roofs Retrofit’ when other works occur. |
| **Funding** | GLA and UK Government | Promote and lobby updates to national policy to support new funding schemes for reflective roofs retrofitting |

| | | |
|---|---|---|
| | | Promote update to existing schemes eligibility rules to ensure that cool roof retrofit funding is available to wider stakeholders |
| **London-wide adoption of cool roof implementation** | Homeowners, housing associations, developers, architects, and Green Skills Hubs | London-wide understanding and implementation of cool roof retrofits to reduce overheating and UHI and support skills development and social value |

*Short-term wins:*

### Check lists for building owners

Stakeholders: Building owners and Developers (e.g. homeowners, housing associations, developers, Local Authorities)

A set of check lists to aid decision making should be created for different types of building owners. This would help individuals and organisations to think about the key considerations for a cool roof retrofit and if their building will benefit from the intervention. A sample check list for a residential cool roof retrofit is provided in Appendix H. There is an opportunity to extend the checklists so that they apply to a wider roadmap of climate adaptation and retrofit measures. Both the Building Renovation Passport (Green Finance Institute, 2021) and London Energy Transformation Initiative (LETI) provide guidance on whole building retrofit.

### Organisational strategy

Stakeholders: GLA

Organisationally, as per the requirements stipulated within the management case considerations, it is recommended that the GLA:

- Establish ‘Greater London Authority (GLA) Cool Roof Retrofit Taskforce’ that is responsible for agreeing and delivering the vision, mission, and long-term objectives of the programme. This taskforce will also be responsible for ensuring alignment of any cool roof activities with the wider retrofitting efforts and programmes promoted by the GLA.
- The taskforce could include Londoners from a diverse pool working and living in London as well as other key agencies and partners such as the local authorities, public institutions, private and commercial organisations.
- Ensure that this ‘Taskforce’ continues to engage in workshop, round table and Local Authority environments with wider stakeholders involved in the design, funding, implementation, monitoring, and maintenance retrofit stages. Many of these stakeholders have been engaged during the technical literature phase of this report.

### Pilot project

Stakeholders: GLA, consultant team, retrofit installers (including support from Green Skills Hubs) and 1-2 local community stakeholders in higher-priority boroughs. The reflective roofs opportunity map can inform neighbourhoods and boroughs for a pilot scheme.

It is recommended that the GLA progress with a pilot project for planning, testing, and understanding the implications and potential benefits of a London 'Cool Roof Retrofitting' programme within a measurable and contained project scope. This is recommended as a next step to further develop a full-scale delivery plan and test and assess the practicalities of wider implementation.

Some considerations for implementing a pilot scheme include:

- Piloting at borough or neighbourhood level. This would entail engaging a range of stakeholder such as the local authority, public institutions, private and commercial organisations, and local residents.
- Partnering with suppliers, contractors, and cooperatives to explore supply chain and cost options (i.e., benefits from economies of scale).
- Explore how the pilot scheme can be integrated into existing funding schemes and mechanisms.
- Integrating with existing retrofit projects: Existing projects can be reviewed to determine whether a cool roofs component could be added to the project's scope. For example, projects that are undergoing a comprehensive series of improvement and upgrade works that could include improvements to the roof. Adding a cool roofs component to the scope of works for the project would be a "quick win" that would be relatively cost effective. For instance, a cool roof coating could be applied while scaffolding has already been erected for other building measures.
- Visiting existing retrofit projects: It is also suggested that members of the GLA visit neighbourhoods that have implemented cool and reflective roof strategies to learn first-hand about the successes and lessons learnt.

### Integration with existing schemes

Stakeholders: GLA, existing schemes

The GLA could take advantage of and integrate with existing funding, partnership and training schemes to develop implementation synergies and the wider scope of a London "Cool Roofs Retrofit Programme".

This can include (but need not be limited to):

- 'Skills Bootcamp for Londoners' and 'Green Hubs' to ensure that developing skills and training are a key outcome of cool roof implementation.
- Partnering with existing programmes such as The Business Climate Challenge, Solar Together and London Energy Climate Fund

- Anchor institutions to develop partnerships across different industries. This can be integrated into a pilot programme.
- Funding schemes such as Future Neighbourhood, Carbon Offset Funds, The Business Climate Challenge, Solar Together and London Energy Climate Fund as well as London's developing Green Finance mechanisms which can all help kick start the programme.

Furthermore, the GLA's social policy unit and stakeholder engagement teams could be involved to help with stakeholder engagement across a diverse pool of people. This will help ensure there is an inclusive discussion for developing and shaping a London "Cool Roofs Retrofit Programme".

*Medium-term wins:*

### Consolidation and integration of cool roofs projects and workstreams

Stakeholders: GLA

It is recommended that there is a consolidated study that assesses the integration of the mayor's energy and adjacent interventions, such as PV, reflective roofs, and green roofs. This would intend to be an overarching study that encompasses all workstreams and support a wider integration approach for cooling London. Appendix I discusses how "working in an integrated way" can be progressed.

### Communication and behaviour engagement

Stakeholders: GLA, Homeowners, Housing Associations, Developers, Architects, Green Skills Hubs

It is recommended that the GLA:

- Develop and approve a communication strategy for disseminating material. It should focus on the higher-priority locations and stakeholders described in this report (the cool roof opportunity maps can be used to inform this process and as dissemination material) and to property owners or entities with the authority/remit to implement cool roof measures specifically. Furthermore, there should be a specific focus on commercial activity districts, boroughs, neighbourhood forums, etc.
- Target a wide retrofit stakeholder base, prepare and disseminate communication material that demonstrates the technical evidence base for retrofitting cool roofs with reflective applications. This should prioritise demonstrating the benefits shared in this report and ensure that the cost-benefit messaging is underpinned by creation of medium-to-long term performance, sustainability, and potential asset value enhancements.

- Target property owners, develop and disseminate communication material that demonstrates opportunities for 'self-construction' and how works can and cannot be implemented without the need for planning and Permitted Development rights.
- Included in this material, provide explanations and recommendations of available funding sources, rebates and schemes, supplier contacts, etc.

Input from consultants and partners with the relevant skills and experience may need to be engaged to develop a successful programme.

### Develop training and apprenticeship programmes

Stakeholders: GLA, Training Institutions, Co-Ops, and Apprentices

Providing opportunities to build skills for Londoners should be integrated into a "Cool Roofs Retrofit Programme." This can be progressed in the short term through partnering and integration with existing schemes such as 'Skills Bootcamp for Londoners', 'Green Skills Hubs' and 'Solar Skills London'. A pilot scheme would also provide an opportunity to engage across the supply chain and test out a training programme. Engaging with small and medium enterprises (SMEs) at this stage can also widen opportunities. In the medium term, a comprehensive programme can be developed for cool roof retrofit that can be implemented across the city.

*Long-term wins:*

### Planning policy and funding

Stakeholders: GLA and UK Government

It is recommended that the GLA:

- Adopt policy within the future London Plan specifically aimed at accommodating cool roofs retrofitting. This could be incorporated as part of policies aimed at heat risk in buildings as well as reducing UHI at a city level.
- Lobby boroughs to incorporate cool roof policy into local plans.
- The Greater London Authority may wish to provide funding itself through grants or lobby for updates to scheme/rebate eligibility rules to ensure that cool roof retrofit funding is available to wider stakeholders.
- Consider London planning policy or incentives to motivate or require "Cool Roofs Retrofit" when other works occur. This will encourage an integrated approach to retrofit.

### London-Wide Adoption of cool roof Implementation

Undertaking the short- and medium-term recommendations will provide a strong foundation for formulating and implementing a London-wide "Cool Roofs Retrofit Programme". Lessons learned from the pilot programme and associated activities will help to shape the programme and as such the 'Critical Success Factors' should be detailed and updated appropriately prior to wider implementation. As with the pilot scheme a London - wide programme should address the considerations outlined in this report including:

- Setting tangible goals for making London greener and cooler –a “Cool Roofs Retrofit Programme” will reduce the UHI and overheating in buildings – the programme should consider how will this be assessed and measured.
- Engaging and partnering with different stakeholders which includes public institutions, private and commercial organisations (including the supply chain stakeholders) and the public.
- Putting in place the funding mechanisms required for implementation. This will include linking with existing schemes and programme across London and the UK.
- Contributing to building strong communities and reducing social inequalities
- Providing opportunities to build skills for Londoners and accelerating job creation.

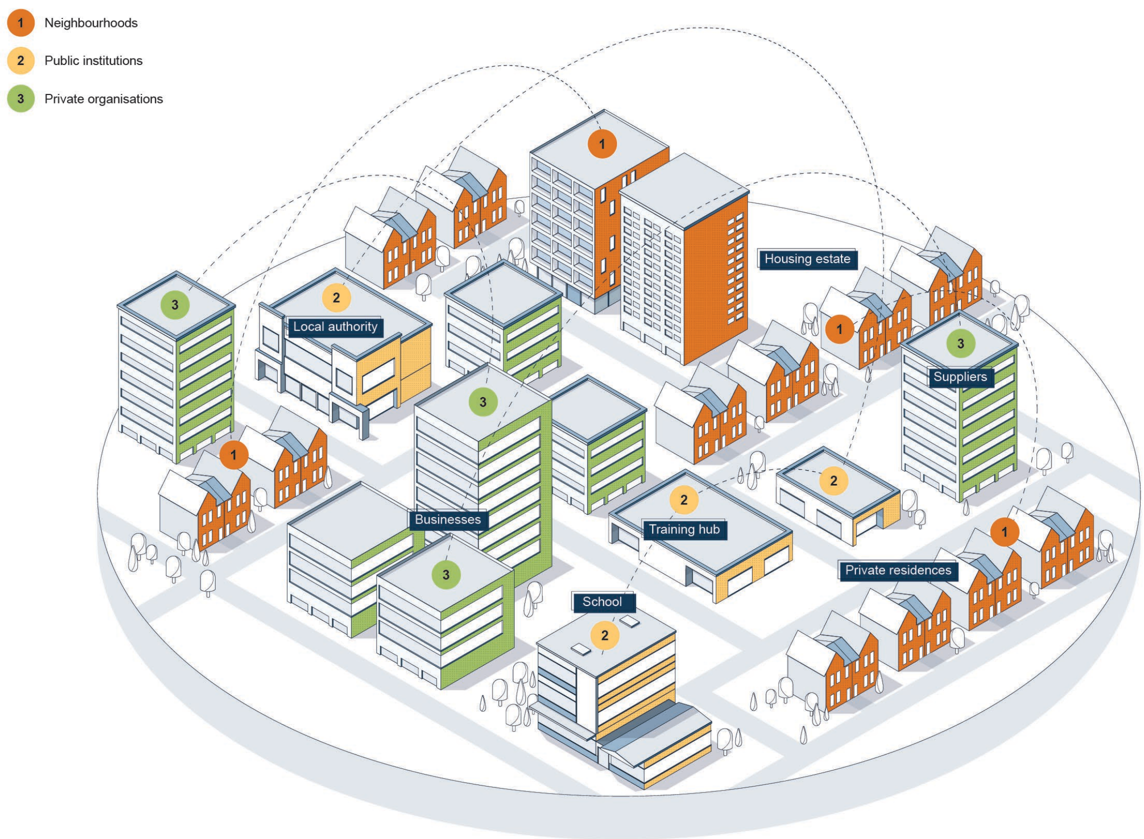


**Figure 10: Integration across a range of stakeholders for successful implementation (Arup)**

# Conclusion

This report has established an evidence base for both reflective cool roofs and solar PV (cool) roofs. Both roof systems can provide benefits for the individual buildings owners as well as contribute to London's wider goals on climate action and recovery from the Covid-19 pandemic.

The evidence base has shown the key benefits to London are:

- Reduction of overheating in buildings: Reflective roofs, in particular, have shown to be effective in reducing overheating in buildings in cities around the world, including New York, Toronto, and Madrid. Research and analysis demonstrate that reflective roofs have the potential to reduce summertime overheating in London. Furthermore, in airconditioned buildings, reflective roofs can also support the reduction of overall energy use.
- Reduction in UHI effect: If implemented at a large scale, cool roofs (both reflective and solar PV) have the potential to cool the wider city though reducing the build-up of heat in the built environment.
- Energy generation: The main benefit of solar PVs is the generation of electricity for both residential and non-residential buildings with potential for export of excess to generate income. If combined with battery storage, PVs can also reduce peak demand on the grid.
- Increase in health and occupancy comfort: Lower urban external and internal temperatures will reduce heat-related illnesses and deaths. In addition, a reduction in UHI can reduce the degradation of air quality, further benefiting the health of Londoners.
- Creating skills for Londoners. A London "Cool Roofs Retrofit Programme" could enable engineering apprenticeships and skills development, especially for young Londoners. This could be supported through existing schemes, such as the Skills Bootcamp for Londoners and Green Hubs.
- Reducing social inequalities: Prioritising cool roofs in the 'riskiest' areas will ensure that interventions benefit those that need it the most first. The opportunity maps for cool roofs, as presented in this report, highlight the areas where high exposure, vulnerability, and social inequality overlap, informing where London needs to prioritise cool roofs interventions.

Given London's diverse building stock and generally temperate (although warming) climate, the building-specific performance impact of reflective cool roof or solar PV retrofitting will vary depending on the type of building, roof type and location, as well as other criteria such as roof insulation. We strongly advise combining the reduction of heat gains though roofs with opportunities to minimise heat loss though insulation.

When assessing climate risk, consideration could be made for the reflective roof opportunity map that presents areas with high heat risk (i.e., high exposure and vulnerability) and those with the potential to benefit most from a cool roofs implementation programme. Furthermore, the Solar PV opportunity map present areas that have the largest potential for yield and that can be prioritized.

The considerations set out in this report have been compiled through a combination of stakeholder engagement and interviews (with GLA and external partners), literature review, project-specific analysis as well as investigation of several case studies. A holistic, systems approach has been taken that reviews several interlinked factors and the considerations, barriers, and opportunities that could be addressed and explored for the successful establishment of a London ‘Cool Roof Retrofit Programme’ implementation plan and business case. This includes factors such as cost, constructability, funding, partnerships and commercial approaches, policy and planning, behaviour, engagement and communication, as well as considering social value and opportunities for skills development.

The report sets out recommendations on potential delivery model options by making use of a ‘Critical Success Factors’ (CSF) assessment and making reference to the ‘Management Case Model’ as per UK government’s ‘The Green Book’ methodology, to shape an initial business case for different contexts or options. This CSF analysis considers 1) Strategic Fit and Business Needs, 2) Social, Economic and Environmental Value, 3) Supplier Capacity and Capability, 4) Affordability, and 5) Achievability factors, and demonstrates initial recommended models and contexts for implementation of solar PV and reflective roofs within the residential, school, and commercial archetypes in London.

Recommendations have been discussed in the *Next Steps* section of the report, but specific focus should be directed towards several areas that have been identified, as short-term wins:

- **Progress a cool roof implementation check list** for building owners to assess the feasibility and benefit of a cool roof retrofit. An example for a residential building has been provided in the appendices. A comprehensive checklist for additional building types to support decision making would be recommended and would support a wider engagement and dissemination programme. It is recommended that this assessment would be ideal to influence building owners considering other retrofit activities already, as well as key typologies where cooling is a driver.

- **Develop an organisational Strategy**: The GLA could establish a London ‘Cool Roof Retrofit’ task force that is responsible for agreeing and delivering the vision, mission, and long-term objectives of this programme. This task force would be well placed to influence other activities to incorporate cool roofs

- **Plan and construct a pilot programme**: It is recommended that a pilot project is pursued to study this evidence base within a contained stakeholder team and building (portfolio of buildings) environment. Specifically, this is recommended for reflective roof retrofit, which is new in the London context. A pilot programme would be crucial to test and develop the practicalities of delivery, such as establishing a supply chain, developing skills, and engaging stakeholders. A pilot scheme should not only test reflective roof retrofit, as a standalone measure, but how it can be integrated into a wider programme that includes reducing energy consumption, skills development, training, and public engagement.

- **Integrate with existing programmes:** The GLA could take advantage of existing funding, partnership, and training schemes, and integrate with them to develop the implementation synergies and scope of a London "Cool Roofs Retrofit Programme."

The carrying out of the short-term recommendations or 'wins' will provide the groundwork for the medium- and long-term recommendations that include developing a more comprehensive programme that can be deployed across London at scale.

# Case Studies

# Case Study 1: Repowering UK

**Description of the intervention:**
Repowering develops community-owned rooftop solar PV projects to provide Londoners with the opportunity to benefit from and participate in the transition to a low-carbon society. Repowering aims to empower communities to create local, renewable energy solutions that provide environmental, financial, and social benefits for the local community. They have worked with Local Authority partners, such as the Royal Borough of Kensington and Chelsea, City of London, Hackney Council and Lambeth Council.

**Key drivers:**
Repowering believes that gaining support from residents and encouraging them to take proactive steps to tackle the climate emergency are crucial to enacting change and building sustainable communities. Community engagement is, therefore, key to the success of the solar PV projects by ensuring that there is sufficient time to engage with urban communities to better understand their needs and to build meaningful relationships.

**Planning and design:**
Repowering initiates each project by working with relevant local authorities to identify buildings that are suitable to host a solar PV installation. Repowering then attends local community events and engages with residents for a six-to-nine-month period to establish relationships and collaborations with local groups. The local community is then assisted in setting up a Community Benefit Society that will own and manage the installation.

The next step includes carrying out a technical feasibility study. Once this study has been undertaken and the case for solar PVs has been confirmed, funding can begin. Contractual arrangements for installation of the solar PV system are managed by Repowering and the solar PV system is installed by Ecolution, Repowering's installation partner. Repowering has successfully negotiated planning fees for all of its solar PV installations.

For the programme of works that have already been completed, only solar PV panels have been installed. Plans for further solar PV installations are targeting inclusion of low-carbon heat and energy-efficiency technologies on suitable sites.

**Costs and commercial model:**
For each project, a 'Community Benefit Society' is created. This is a legal entity with the purpose to serve the broader interests of the community. Anyone can become a member of the society by purchasing shares. These shares raise the funds needed to purchase solar PV panels. The electricity generated by the solar PV system, is then sold back to the

building where the panels are located to generate a revenue stream. Shareholders receive a return on investment of approximately 3-4% each year. Once administrative and maintenance costs and investor returns are funded, remaining funds are set aside in a 'Community Fund'.

The 'Community Fund' accrues revenue over the lifetime of the project and is distributed by the Community Benefit Society to develop solutions to local problems. Thus far, across all projects, £196,000 has been raised. The money has been used to install energy efficiency measures for people living in fuel poverty, create youth training activities and help neighbours reduce energy costs by completing energy audits.

At present, seven community buildings across London have been involved in the Repowering scheme, with £710,530 in capital raised to install solar PV systems. Grant funding was used to pay for the feasibility studies of the projects and all remaining costs were financed through the community benefit society model.

**Outcomes:**
The 'Repowering' projects have shown that switching to renewable energy sources has reduced carbon emissions, by approximately 114 tonnes of greenhouse gas emissions each year and they also claim that there have been improvements in local air quality. The financial benefits include lower energy bills for the buildings where panels are installed and the return on investment for the shareholders.

Repowering also plays a key role in local skills development and contributing to education of the local community in terms of climate change and engineering. Funds from the Community Fund offer support to those living in fuel poverty and each project empowers the community to make decisions of how they wish to operate.

**Barriers faced:**
Opportunities for integrating circular economy principles were considered during project design, however, the lack of warranty arrangements associated with using second hand solar PV panels meant that it was not possible to finance the project successfully.

The largest challenges to the projects have been sourcing affordable costs for roof access during the installation process and managing shading.

**Significance to community:**
Since 2011, 'Repowering' have been supporting communities to fund, install and manage their own clean, local energy. The initiative strives to build resilient communities and promote technological innovation. 'Repowering' has installed a total of 670 kWp solar capacity saving 114 tonnes of greenhouse gas emissions each year.

'Repowering' supports education and training programmes to provide job skills and educational experiences for children and young adults. Their youth training programme supports young people to join the green economy and provides skills from technical feasibility analysis and solar PV panel making to teamwork and community engagement. Furthermore, Repowering has a reskilling and mentoring scheme, providing paid work experience opportunities to adults who want to learn new skills and find employment in the renewable energy sector. To date, repowering has supported the skills development of 123 paid interns. Other programmes include the 'ReCreate' programme which engaged with primary schools to talk about the local and global effects of climate change as well as sharing technological and social solutions. The programme aims to help students feel positive about the future and encourage them to create positive change.

**Further information**
- https://carboncopy.eco/initiatives/repowering
- https://www.repowering.org.uk/
- https://ashden.org/winners/repowering-london/

# Case Study 2: Residential PV 1

| | |
|---|---|
| Location: | London Borough of Redbridge |
| Roof area and building dimensions: | 1930's Semi- detached house |
| Client name: | Private |
| Development type: | Residential retrofit |
| Date completed: | 2011 |
| System supplier: | Local supplier |

**Description of the intervention:**
PV installation for a 1930's semi-detached family home in 2011. Twelve PV panels were installed to the south side of the roof along with brackets and an inverter fitted in the loft space.

**Key drivers:**
The homeowner heard about the solar panel scheme from leaflets posted in shops when they were renovating their house. The intervention was carried out in 2011 when incentives were high due to the pay back scheme in place at the time. The tariff offered £55p per kWh generation as well as pay back for supplying surplus to the grid. A payback period of 8-10 years was estimated.
They had the investment capital available.

**Planning and design:**
The homeowner shopped around and got quotes from several local suppliers which also helped them understand the process. They went with the cheapest supplier although a key driver for selection was the time for the fit out to be completed as the government scheme was running out relatively quickly.

The time from quote to installation was three weeks with the actual installation taking 2-3 days. Scaffolding had to be erected for installation which was included in the price and did not cause too much disturbance. The roof was checked for suitability by the contractor, they checked the structure including a check of the joists by going into the loft. The supplier organised the sign-up to the government scheme.

No planning permission is required for solar PVs to residential developments.

**Maintenance:**
The panels are guaranteed for 25 years. There is little cleaning required as a special coating on the panels means the rain washes away much of the dirt. The panels are sometimes washed with a hose pipe or jet wash. Electricity generation does not seem to have deteriorated.

**Costs and commercial model:**
The solar panels and PV installation cost £10,000 which was self- funded.

**Outcomes:**
The payback period was shorter than expected and return on investment was met after seven years. The Fee-In-Tarif scheme is still going although the payback has reduced compared to the original scheme. The family continue to benefit from the installation with their electricity being paid for by the solar PVs.

In addition, the homeowner has invested in both insulation and electric cars since the PV intervention resulting in co-benefits such as renewable fuel for the cars and energy efficiency.

**Barriers faced:**
Although there were no real barriers for this project it has highlighted some potential barriers that other homeowners may face currently:

- Lack of capital to invest in solar PVs. There are no grants or aid available and although costs are lower now, they are still high enough to present a barrier for many.

- End of government Feed-In-Tarif scheme means less of an incentive. Batteries can help with this and is probably something the family may have considered if they had known it was an option.

- Lack of clear information. Although they heard about the scheme through leaflets in shops the information may not be clear for all homeowners. This includes how solar PVs work as a system and how it can help homeowners reduce costs including an understanding of their own consumption. The environmental benefit to the wider community is also not clear and needs to be conveyed in plain language. Many of their neighbours have asked them about solar PVs to help understand their options.

**Significance to community:**
There has not been significant, the homeowner estimated that uptake in their community, has been about 10 houses out of 10,000 (anecdotally). There are roughly 970,000 UK homes with solar panels which is about 3.3% (The Eco Experts, 2022).

# Case Study 3: Residential PV 2

| | |
|---|---|
| Location: | Beaconsfield |
| Roof area and building dimensions: | Not available |
| Client name: | Private |
| Development type: | Residential retrofit |
| Date completed: | 2019 |
| System supplier: | Local supplier |

**Description of the intervention:**
PV installation on a pitched tiled roof of a 1950's detached family home. 9 solar panels installed with an immersion controller which allows access energy to be diverted to the hot water storage.

**Key drivers:**
The building owner is an electrical engineer and was curious about exploring PVs, they were further encouraged after talking to a friend who had installed PV's. The homeowner was interested in offsetting their consumptions by having an immediate access to renewables on site. Was not driven by a finite payback.

**Planning and design:**
The homeowner shopped around and got quotes from several local suppliers but designed the system layout themselves including the internal cabling route. They went with the best quote rather than any payback incentives. The quality of the components was of interested.

The installers visited a week prior to installation to erect the scaffolding. The install took two days, but the scaffolding was kept up for a further week in case there were any issues.

**Maintenance:**
Just hoses down the panels once a year to remove any sediment

**Costs and commercial model:**
The solar panels and PV installation cost was just over £6000 and was self- funded. The scaffolding was about a third of the cost.

**Outcomes:**
The PV panels combined with the access energy diverted to the immersion heater for hot water has resulted in big savings. No gas is used for heating for six months of the year, the cost savings have proved to be greater than anticipated.
An app is provided to see a how much energy is produced and when access heat can be diverted to the immersion heater. The homeowner keen to optimise the household's energy use by operating appliance such as dishwashers during peak solar hours.
Some broken tiles were fixed when scaffolding was erected resulting in a small co-benefit.

**Barriers faced:**
No real barrier faced, once everything was installed nothing more had to be considered.

**Significance to community:**
There has not been significant although a few people asked about the installation when it was happening

**Other considerations**
Selling back to the grid had been considered but since there was no smart meter had not considered this at the time of installation. This may be an option that is explored later if there are likely to be savings.

They had also considered a battery installation but found that it did not make economic sense since the access energy was limited. More PVs would be needed to make a battery more feasible; they have considered installing more panels on the shed but not sure about structural integrity.

The app has resulted in some behaviour changes in terms of energy consumption.
Has recently seen that Buckinghamshire County council will offer a bulk buy scheme and will ask companies to tender. This was not available at the time.

# Case Study 4: Biosolar Roof, London Olympic Park

**Description of the intervention:**
The Olympic Media Centre, which was later converted to commercial office space was designed with a biosolar roof. A biosolar roof, generates solar power for a building whilst simultaneously offering a green habitat that contributes to cooling the city, improving air quality, and storing storm water. Solar PVs are most efficient when the ambient temperature is approximately 25℃. Beyond this temperature, energy generation decreases steadily. Crystalline silicon solar PV panels typically lose 0.5% per degree in efficiency above 25℃. A green roof, therefore, acts as a natural cooling mechanism to maintain the solar PV's efficiency.

**Key drivers:**
The impacts of climate change are being felt in cities across the world, including severe overheating, poor air quality and increased water pollution. These impacts are negatively affecting people's health and wellbeing, biodiversity, and economic activity. In addition, as

cities continue to densify, space at ground level is becoming increasingly limited. Advancements in technology have demonstrated that buildings can generate their own energy through renewable sources. In addition, green roofs have successfully supported pollinators and contributed to improved biodiversity. Roofs are, therefore, seen as one of the only locations where biodiversity measures and energy plants can be implemented. To maximise both the ecological and energy benefits, biosolar roofs are becoming more desirable.

**Outcomes:**
Biosolar roofs create a symbiotic relationship between the green roof and the solar PV technologies. Studies have shown that the cooling from the green roofs increases the efficiency of the solar PV panels because it reduces overheating. Furthermore, the solar PV panels can enhance the biodiversity potential of the roof, by providing a more varied habitat for a greater number of species.
Other benefits of biosolar roofs include, reducing energy demand and the associated operational energy costs of a building, improving the local aesthetic for residents or office workers overlooking building roofs and a reduced reliance on the electricity grid.

**Barriers faced:**
The integration of green roof and solar PV technologies requires skill and understanding. Biosolar roof design that do not perform well are typically a result of lack of understanding and the assumption that solar PV panels require more technical input than green roof. This can lead to increased shading of the solar PV panels reducing their energy generation potential. With the correct information and design approach, solar PV and green roofs can improve the performance of both elements.

**Further information**

- https://iale.uk/dusty-gedge/news/7999
- https://livingroofs.org/green-roof-solar-boost-push-biosolar/
- https://livingroofs.org/introduction-types-green-roof/biosolar-green-roofs-solar-green-roofs/
- https://livingroofs.org/how-london-could-becoming-the-green-roof-capital-of-the-world/

# Case Study 5: MetroPolder Roof

| | |
|---|---|
| Location: | Benno Premselahuis, Amsterdam, Netherlands |
| Roof area and building dimensions: | 450 m2; 9 floors with 4th floor roof garden; base black bitumen; mixture of gravel, planting, solar PV, and reflective surfaces on top of a MetroPolder blue roof; 32,640L water retention capacity |
| Client name: | Amsterdam University of Applied Sciences (AUAS) |
| Development type: | Retrofit; education |
| Date completed: | June 2020 |
| System supplier: | MetroPolder |

**Description of the intervention:**
This roof was installed as part of the RESILIO programme, which is a collaboration between the City of Amsterdam, Waternet, MetroPolder Company, Rooftop Revolution, Amsterdam University of Applied Sciences (AUAS), Vrije Universiteit Amsterdam (VU), Stadgenoot, de Alliantie and Lieven de Key. The 5-year ‘RESILIO’ programme seeks to

develop a network of smart blue roofs which store water to reduce flooding, improve building insulation and regulate micro-climates. When combined with other roof coverings, these roofs can also provide opportunities for planting to encourage biodiversity and can be used recreationally.

The technology for the smart blue roofs has been developed by the ‘MetroPolder Company’ and uses a system of sensors to measure the volume of rainwater in reservoir, and valves to either retain the water, or release it at a steady rate to prevent overflowing the city drains during high rainfall events.

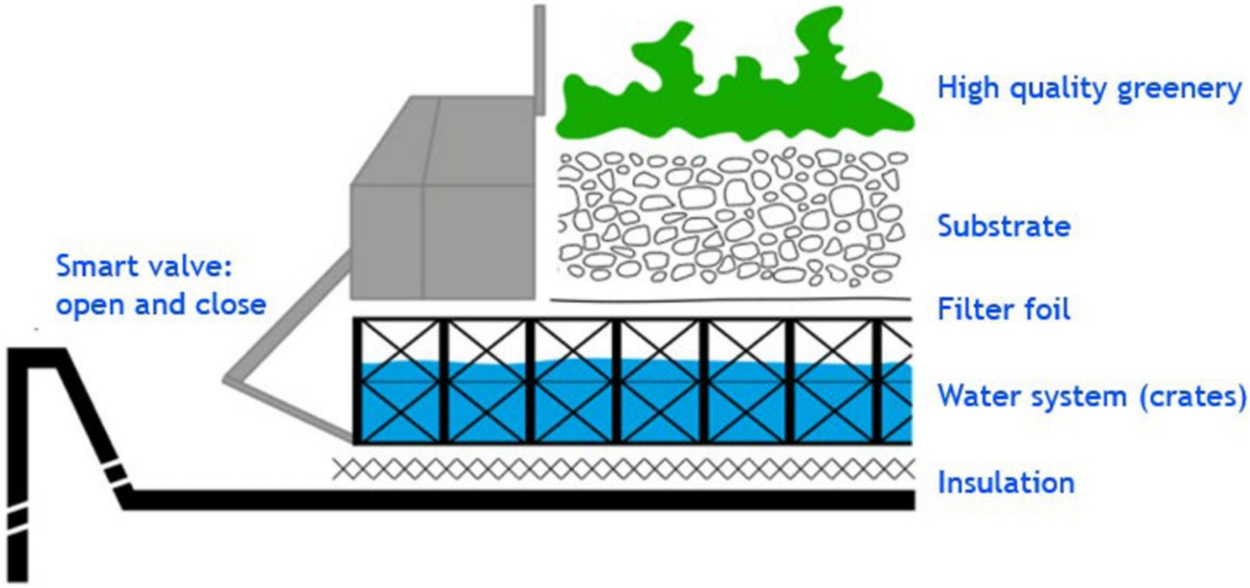


**Figure 11: The MetroPolder roof system**

This roof was constructed as a demonstrator project at AUAS to study the effects of different roof coverings. As well as the ‘MetroPolder’ smart blue roof, other roof types are being studied:

- Traditional grey layer (bitumen)
- Grey layer (bitumen) with a blue and a green layer on top
- Blue layer with white gravel
- Blue layer with native plants

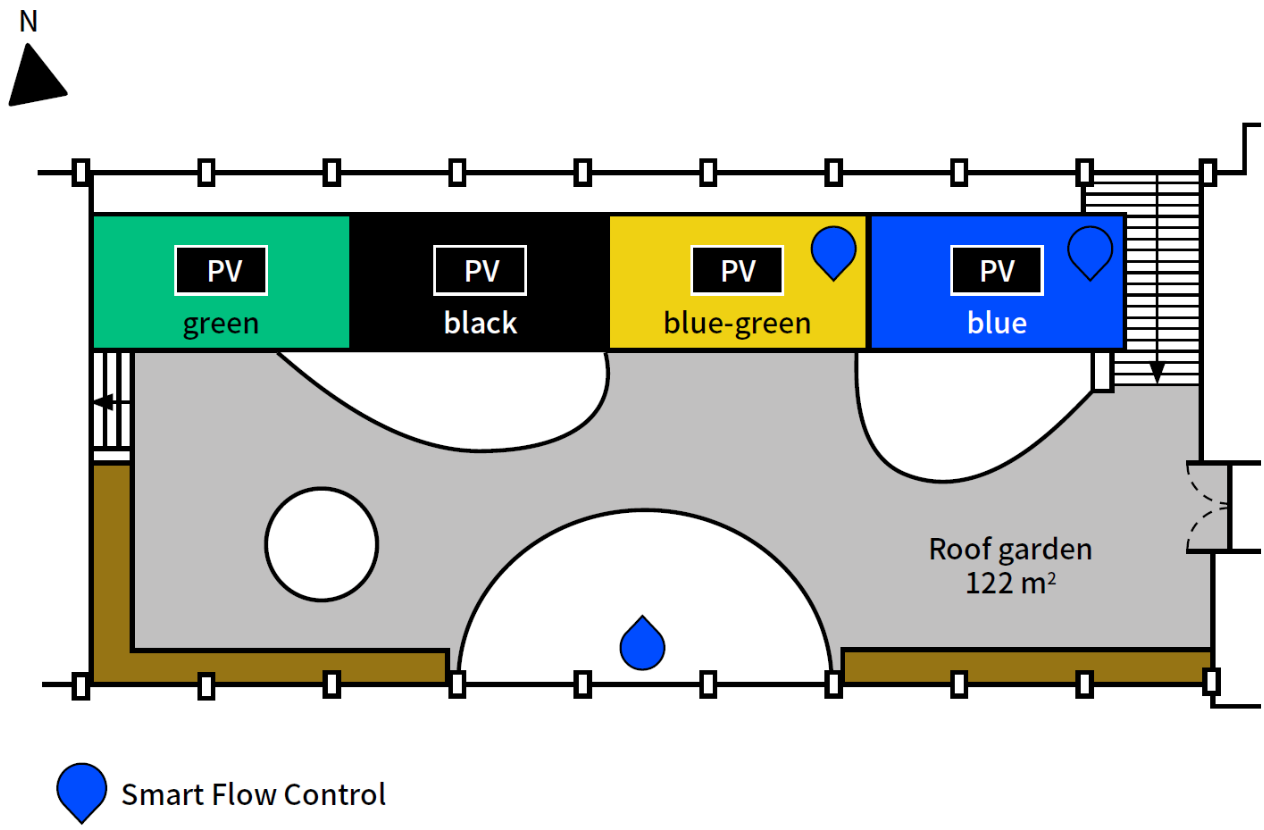


**Figure 12: Layout of the roof at Innovation Lab Benno Premselahuis**

**Key drivers:**
The roof was designed as a demonstrator project to test the effectiveness of different roof coverings, and new smart blue-green roofs; because of this, the roof had to be able to be accessed by students, as well as maintenance personnel, to assess the results. Blue-green roofs are being explored particularly in The Netherlands due to heavy rainfall putting increasing pressure on the city's main drains. Some 96 areas in the capital are highly vulnerable to flood damage from extreme rainfall.

**Planning and design:**
The university building had already been built, and designed for a green roof, when 'MetroPolder' became involved as part of their 'RESILIO' programme. Instead of simply a green roof, the team decided on a blue-green roof, incorporating the sensors and weir-system technology developed by 'MetroPolder'. This meant that they were able to re-use some of the green-roof materials that had previously been installed. The installation of the blue roof layer, with its sensors and smart valves, was carried out by specialist 'MetroPolder' staff, whilst the planting on top was done by another roof garden company. The installation took a total of 3 weeks.

**Costs and commercial model:**
The estimated cost of the roof was €150,000, which was met in part by the University, but was also subsidised by the 'RESILIO' programme. This 'RESILIO' programme is co-

financed by the European Regional Development Fund through the Urban Innovative Actions Initiative, with just over €4.8m granted so far.

**Outcomes:**
Of the four roof-types tested, the smart blue-green roof has proved to be the most successful in regulating the air temperature. Figure 13 shows how the black bitumen roof heats up the most (up to 55 °C), whilst the green roof reaches a maximum of over 30 °C. The blue roof and the blue-green roof stay below 30 °C but it is the smart BG roof shows the best performance.

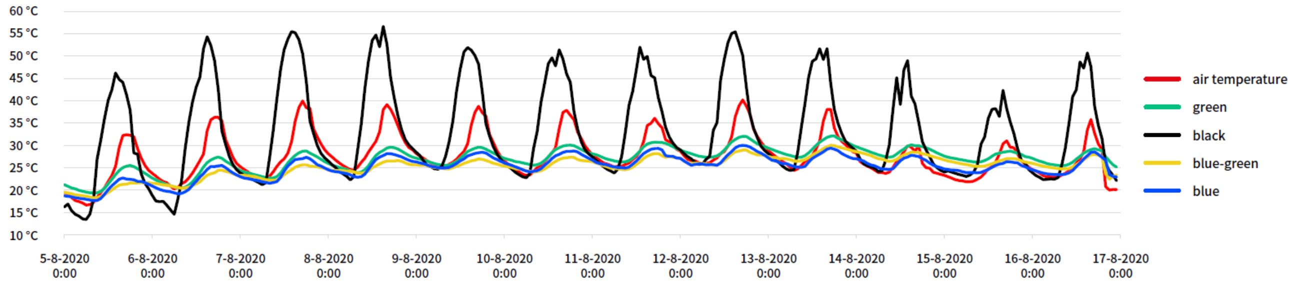


**Figure 13: Temperatures (°C) of the different underlying surfaces of the solar PV panels from the various roof types at Innovation Lab Benno Premselahuis**

The blue green roof, as expected, demonstrated the greatest potential for evaporation, and its cooling effect will result in lower indoor temperatures during hot summers.
These early-stage and small-scale research panels did not provide much evidence yet on the energy performance of the solar PV panels, and more findings will be available from other larger roofs as part of the RESILIO programme.
'RESILIO's' early-stage ecology research suggests positive outcomes on biodiversity with the smart blue-green roofs, though more comprehensive results will be available as the programme winds down.

**Barriers faced:**
The 'RESILIO' programme as a whole took a while to implement, particularly in terms of setting up appropriate and effective governance and project management systems. The planning of the 'AUAS' roof was the project phase that took the longest, but as mentioned earlier, the installation was relatively quick.
An early 'RESILIO' programme report has suggested that the retrofitting of existing rooftops is, as expected, more complex and therefore costly compared to new builds, the business case they wrote also made the argument that in-action, and resulting damage from flood events, could be far more costly.

**Significance to community:**
One of the main goals of the 'RESILIO' project was to raise awareness of blue-green roofs and their role in climate adaptation, so that if and when blue-green roofs are rolled out more widely, there is a sufficient level of public support and buy-in. The participation

processes used therefore extended beyond the immediate users of the buildings in the programme, and into the wider neighbourhoods. Covid-19 prevented the programme from carrying out the engagement as originally planned, but many events still took place. Key findings included:

- Be present in the neighbourhood as early as possible

- Engage with local people through existing local area organisations/initiatives

- Design the programme so that residents can have a meaningful way in decisions about the design of the project (e.g., choice of plants, access to the roof, planning).

The impact of the roof at the University on the students has been highly beneficial from a research perspective, and students from other universities have also been able to use the roof for their studies. A screen in the foyer of the building shows the data dashboard of the roof, indicating performance. Further, data from the entire ‘RESILIO’ programme has been able to accurately measure meteorological events, which has been shared with the national weather office.

**Further information:**

- https://metropolder.com/en/
- https://uia-initiative.eu/sites/default/files/2022-03/A%20roof%20journey%20-%20RESILIO%20final%20report.pdf
- https://uia-initiative.eu/sites/default/files/2020-06/Amsterdam_Resilio_Journal%201.pdf
- https://uia-initiative.eu/sites/default/files/2021-08/RESILIO%20-%20DSS%20Infographic%20-%20EN%20-%20DEF%20RGB.pdf
- https://www.uia-initiative.eu/en/news/resilios-first-research-roof-has-opened

# Case Study 6: Million Cool Roofs

| | |
|---|---|
| Location: | Totolapan, Mexico |
| Roof area and building dimensions: | The homes in Totolapan have a roof area of approximately 50m2 and building dimensions of 7m x 6m x 3m |
| Client name: | Community of Totolapan, Mexico. |
| Development type: | Retrofit; residential use. |
| Date completed: | July 2021 |
| System supplier: | Self-construction with support from Échale and Arup |

**Description of the intervention:**
Arup has been working in collaboration with the non-profits 'Échale' and 'New Story' to provide access to affordable and sustainable cooling for low-income families in Mexico who are suffering from heat stress (Arup, 2021). 'Échale' is the largest social housing constructor in Mexico and 'New Story' is a non-profit founded to provide innovative solutions to homelessness in Latin America.

In 2019, Arup, 'Échale' and 'New Story' jointly prepared a submission for the 'Million Cool Roofs Challenge' (Jaffe, 2022). The 'Million Cool Roofs Challenge' is a global competition to award grants to ten teams for rapid deployment of solar-reflective roofs projects in developing countries. The intervention involved retrofitting 27 homes in the community of

Totolapan, in addition to multiple new homes with reflective roofs in two more communities in Mexico.

In the case of Totolapan, 'Échale' had built the 27 homes less than three years ago and had built strong links with the community (Jaffe, 2022). 'Échale' proposed to the community in Totolapan, to switch to reflective roofs, as the roofs were initially built with a concrete slab with a red waterproofing layer. Following the intervention, the roofs were painted with a highly reflective, waterproof, durable, and low-cost white reflective paint (Arup, Échale, n.d.).

**Key drivers:**
Community members had previously shared with 'Échale' and 'New Story' that temperatures inside their houses were too high (Arup, 2021). Families reported health issues, difficulties to sleep, thirst and difficulty to focus (Jaffe, 2022). The homes included in the study were owned by low-income families, therefore all cooling strategies needed to be passive. None of the homes were air-conditioned.
Moreover, the legal framework in Mexico has provisions that support self-construction in the country. The project was supported by the federal government's Territorial Development Secretariat through its self-construction skills programme "Decide y Construye," sharing a series of online video-trainings (Jaffe, 2022).

**Costs and commercial model:**
Total retrofit cost per roof was USD$250 approx. The entire retrofit costs were subsidised through a grant awarded by the 'Million Cool Roofs Challenge' for USD$125,000 grant and an additional grant for USD$330,000 awarded by the 'Arup Community Engagement Global Challenge' (Arup, 2021).

As means to minimise labour costs, the team trialled a self-construction delivery mode. With support from the federal government and local partners, the team provided to the community training, toolkits, and materials for construction (Jaffe, 2022). Arup, 'Échale' and 'New Story' partnered with 'Cemex', a local building materials company, to distribute prepaid cards that could be spent at local suppliers to purchase materials to install reflective roofs themselves (Arup, 2021).

The use of new materials brought cost savings for families and constructors as 'Échale' (Arup, Échale, n.d.). Although the price per bucket for the white reflective paint has a higher price than the red one, it covers a larger surface area and provides 15% upfront savings. The reflective paint also has larger lifespan, which increases overall savings to 50%.

**Outcomes**:
Temperature measurements in homes with reflective roofs experienced on average a decrease of 1$^{o}$C to 3$^{o}$C during the summer months. Arup's modelling predictions show

close correlation with the measured data following reflective roofs interventions across multiple communities:

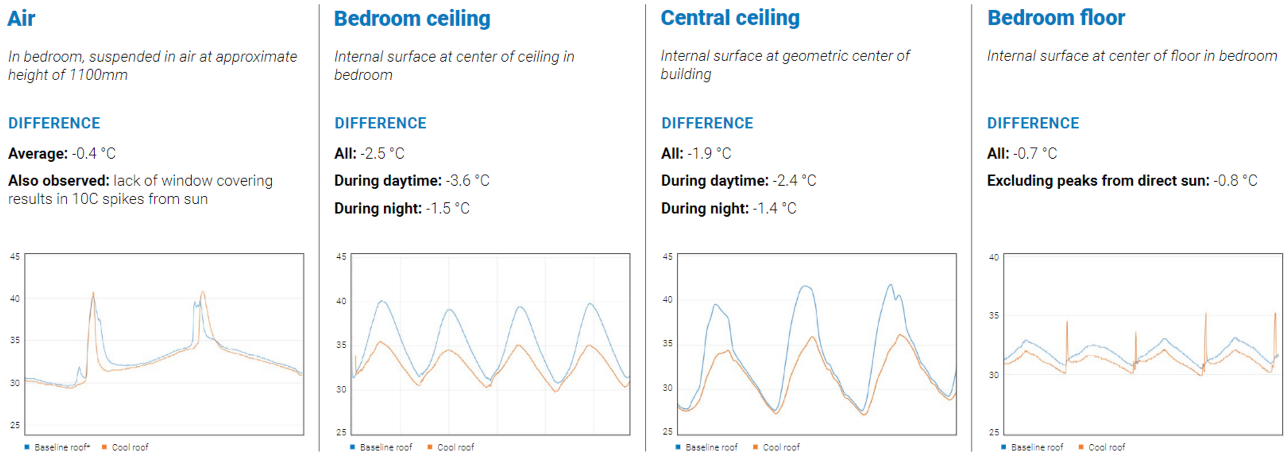


**Figure 14: Impact of reflective roofs on cooling modelled (Source: Arup)**

**Barriers faced:**
While the community was very receptive, the community still raised a concern on whether the intervention was going to make a difference. However, 'Échale' had built a relationship based on trust which facilitated the engagement with the community and the implementation of the project (Jaffe, 2022).

The community also reported some difficulties with the distribution of the materials for self-construction. Since the materials were distributed by a local supplier that was a 25-30 minutes' drive from Totolapan, getting the supplies generally took a long time and particularly one family had difficulties to pick up the supplies (Jaffe, 2022).

Moreover, the materials used by Échale are expected to last for 5 years and building owners would need to provide regular maintenance to the roofs due to the humidity of the area (Jaffe, 2022). This is particularly problematic for families that reported having financial hardships and would need ongoing help to fund regular maintenance.

Moreover, the materials used by Échale are expected to last for 5 years and building owners would need to provide regular maintenance to the roofs due to the humidity of the area (Jaffe, 2022). This is particularly problematic for families that reported having financial hardships and would need ongoing help to fund regular maintenance.

**Significance to community:**
The main benefit of the cool roofs project is that it will serve low-income families who often have no provision for mechanical cooling (Jaffe, 2022). Ownership of social housing built by 'Échale' is passed onto each family, and thus the retrofit interventions will directly benefit building owners in the community.

Similarly, the reflective roofs intervention also benefitted economically small stores that participated in the network of local suppliers. Stores were previously informed of the materials needed for the intervention and all the funds provided to the community for the purchase of construction materials were funnelled through these local suppliers (Jaffe, 2022).

The socialisation of this intervention's results raised awareness amongst the public sector and non-profit organisations in Mexico, who were initially sceptical of reflective roofs retrofit interventions (Jaffe, 2022). Today, there are nascent government programmes aiming to subsidise similar retrofit programmes in Mexico.

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**Further information:**

- https://www.arup.com/projects/million-cool-roofs-challenge
- https://decide-construye-autodiagnostico.ruv.org.mx/videos/4
- https://www.youtube.com/watch?v=Cfsif5atYpM

# Case Study 7: Toronto Cool Roofs

| | |
|---|---|
| Location: | Bayview Campus, 2075 Bayview Avenue, Toronto, Canada |
| Roof area and building dimensions: | 8,882 m2; roof area for 8 buildings across the campus, 7 constructed in 1940s and 1 constructed in 1980s |
| Client name: | Sunnybrook Health Sciences Centre |
| Development type: | Retrofit; hospital |
| Date completed: | 2016 |
| System supplier: | The Rock-ItTM Roof Surfacing System |

**Description of the intervention:**
This roof was installed as part of the 'Toronto Eco-Roof Incentive Programme', which was launched in 2009 by Toronto's city government. The 'Toronto Eco-Roof Incentive Programme' was created as a pilot project in parallel to a 'Green Roof Bylaw' for new construction which was the first of its kind in North America. The 'Eco-Roof Incentive Programme' provides funding to retrofit existing roofs and is open to schools, non-profit buildings, and buildings less than 2,000m2. The programme's success is partly due to its funding stream and substantial grants.

In 2010, legislation to mandate and support cooling and absorbent green roofs came into effect for most building types. This legislation was extended to new industrial development in 2012. The bylaw established a graduated green roof requirement ranging from 20% to 60% coverage for all residential, commercial, and institutional buildings with a minimum floor area of 2,000 m2. Industrial building owners also had the option to choose between at 10% green roof and a 100% reflective roof.

**Key drivers:**
The 'Sunnybrook Health Sciences Centre' is dedicated to maximising the health and comfort of its patients and employees and reducing the environmental impacts from its operations. Reflective roofing was identified as one option to achieve the campus's objectives within fiscal constraints.

**Planning and design:**
Existing roofing systems on several building wings had reached end of life. The seven 1940s building wings requiring replacement comprise a combination of acute care and office spaces. Air-conditioning requirements are met through a combination of window-mounted air-conditioning units and roof-top units. The 1980s building comprises further offices and chronic veteran care. This building is conditioned by air handlers connected to the 'Central Utility Plant' for chilled water and steam.

The retrofit works were tendered out, in alignment with Ontario's 'Broader Public Sector Supply Chain Guideline', to five pre-qualified roofing contractors in multiple phases over several years. The 'Rock-It™ Roof Surfacing System' was selected for installation. This system utilizes white calcite gravel embedded in a cold-applied, low-solvent white adhesive to provide the benefits of a highly reflective roof with the durability of a built-up roof.

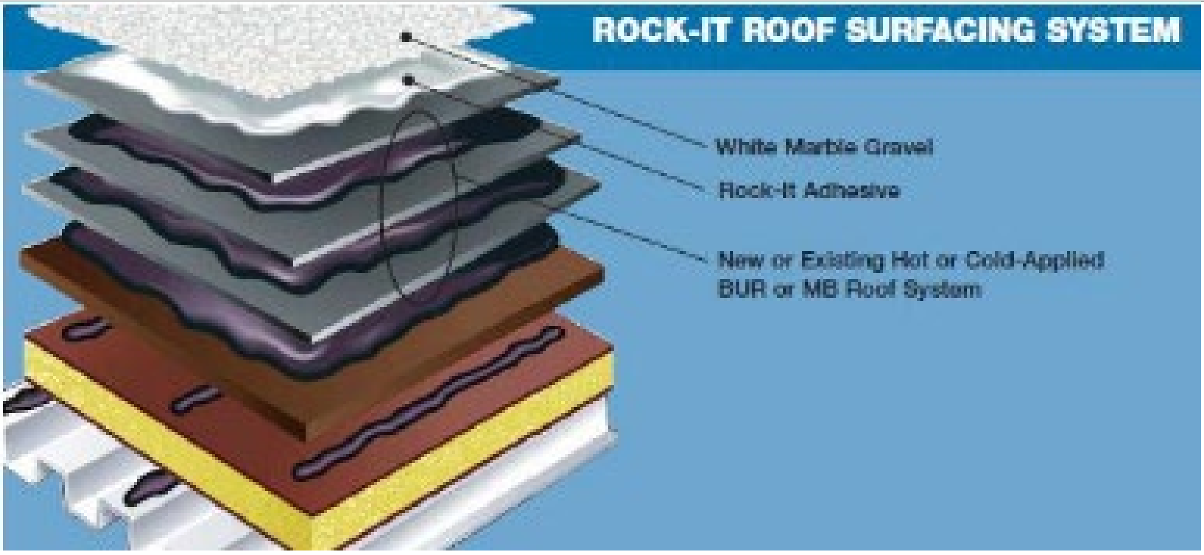


**Figure 15: Visual depiction on components of a cool roof system (Image credit: Tremco)**

**Costs and commercial model:**
The total cost of the roof was $2,758,521, which was met in part by the Hospital, but was also subsidised by the Eco-Roof Incentive programme. The programme offers grants of $100 per square metre for green roofs and $5 per square metre for reflective roofs. The Eco-Roof Incentive Programme funding received was $44,410.

**Outcomes:**
The installation of reflective roofs on several buildings across the 'Bayview Campus' reduced heat build-up on the roof surface reducing air-conditioning needs and extending the lifetime of the roofs. In turn, this reduced the UHI effect at the 'Bayview Campus' and improved comfort for patients and employees.

The use of the 'Rock-It™ Roof Surfacing Systems' resulted in low odour and no fire risks during roof application which was a critical requirement given the existing end use of the Bayview Campus which remained in operation during the retrofit works.

**Barriers faced:**
The higher than typical costs associated with the 'Sunnybrook Retrofit Project' were a result of several factors including the ten staging areas, extensive scaffolding, and multiple material lifts for the different roof areas, the removal of existing poured light concrete

layers and coal tar pitch, along with additional works to upgrade vapour barriers and insulation.

There was limited workspace and increased need for membrane and metal cladding due to the high perimeter walls. The site was also the location of a hospital, and their safety was paramount given the sensitive receptors identified.

**Significance to community:**
In its first decade of operation the ‘Toronto Eco-Roof Incentive Programme’ has enabled the installation of over 350 reflective roofs and more than 70 green roofs across the city. This equates to the creation of around 806,795.7 m2 in eco-friendly roofs, reduced greenhouse gas emissions by 298 tonnes per year and produced 1,593,495 kWh in energy each year (Bradford, 2019). The programme also supports Toronto’s climate change goals to reduce greenhouse gas emissions by 80% from 1990 levels.

The ‘Eco-Roof Incentive Programme’ and the ‘Green Roof Bylaw’ is responsible for increasing green space across the city, promoting green roofs and incentivising reflective roof construction on private buildings. It is estimated that the greening of 5% of the city’s area via green and reflective roofs has lowered citywide temperatures by an estimated 1.5℃ to 2℃, with a larger temperature reduction in high density areas of up to 4℃ to 5℃ roof surface cooling.

**Further information**

- Eco-Roof Institutional case study
- http://mediaedgedigital.com/supplierinsights/crca/torontos-eco-roof-incentive-program-10-years-later/
- https://qspace.library.queensu.ca/bitstream/handle/1974/22020/Lee_Joanne_201708_MPL.pdf?sequence=1
- https://developingresilience.uli.org/case/toronto-green-roof-bylaw-and-eco-roof-incentive-program/

# Case Study 8: New York Cool Roofs

| | |
|---|---|
| Location: | New York City, USA |
| Roof area and building dimensions: | 6,730,299 ft2 of roof space coated with reflective paint |
| Client name: | The City of New York |
| Development type: | Retrofit, Multiple |
| Date completed: | Ongoing |

**Description of the intervention:**
The New York City 'NYC °Cool Roofs' programme was launched in 2009 as part of the 'Cool Neighbourhoods Project', set up by the 'New York City Mayor's Office of Recovery and Resiliency'. The goal was to coat one million ft2 of rooftops each year with a reflective white coating.

The 'NYC °Cool Roofs Programme' initiative provides New Yorkers with paid training and work experience installing energy-saving reflective roofs and is supported by the partnership between the New York City Department of Small Business Services, its Workforce1 'Industrial and Transportation Career Center', the 'Mayor's Office of Sustainability and Office of Resiliency' and the HOPE programme.

**Key drivers**:
New York City is more vulnerable to heat than rural and suburban areas. Temperatures in the city can be much higher than the surrounding rural areas due to the high amounts of

dark impervious surface, dense population, and low levels of vegetation. This is referred to as the UHI effect. The UHI effect results in greater summertime energy demand, increased air-conditioned costs, air pollution and higher greenhouse gas emissions associated with the additional cooling loads. This has a negative impact on the quality of life of New York's residents.

The findings of a 'Heat Vulnerability Index' developed by Columbia University revealed high levels of overheating risk across the city. As a result, the 'Cool Neighbourhoods' programme was set up. The programme was developed to protect New Yorkers during hot weather, mitigate the UHI effect and protect against the worst effects of rising temperatures from climate change.

**Costs and commercial model:**
Two programme models were developed for the 'NYC °Cool Roofs' programme. From 2009 to 2014, The NYC Department for Buildings supported a voluntary program to engage volunteers to coat rooftops with a white reflective coating that was funded via city investment corporate sponsorships. Then from 2015, the 'NYC Department of Small Business Services' used a full city investment funding model to offer workforce development; supporting local jobseekers through paid and transitional work-based learning to install reflective roofs.

In 2017, the 'NYC °Cool Roofs Programme Strategic Implementation Plan' launched to improve the impact of the existing programme by undertaking $2.6 million dollars' worth of new projects that will mitigate the UHI effect in heat vulnerable neighbourhoods.

The reflective roof installations are provided to affordable and supportive housing organisations, select cooperatively owned house, and select organisations providing public, cultural or community services at no cost. Low-cost installation options and technical assistance is also available for other privately owned buildings. In this instance, the building owner would cover the cost of the coating, which is provided at a discounted rate through vendors participating in the 'NYC °Cool Roofs' Programme. Then the NYC °CoolRoofs Programme would provide the labour, technical assistance, and materials (e.g., paint brushes, rollers, gloves, etc.) at no extra charge.

**Outcomes:**
Between 2009 and 2016 the City of New York invested over $4 million in the 'NYC °Cool Roofs' programme. During this time more than 6.7 million ft2 of rooftop space has been coated with white reflective paint. This contributed to lower cooling costs and is estimated to have reduced an estimated 2,680 metric tons of carbon dioxide equivalent emissions across the city (OneNYC, 2017). The 'NYC °Cool Roofs' programme contributes to New York City's goal to reduce carbon emissions by 80% before 2050, contributing to city-wide greenhouse gas reduction targets (OneNYC, 2017).

By painting roofs across the city with a white reflective paint there has been a reduction in roof temperature and a simultaneous reduction in internal building temperature. The installation of a reflective roof can lower a buildings air-conditioning cost by 10-30% whilst achieving up to 30% reduction in winter heating costs. This has contributed to a reduction in the UHI effect across the city, leading to cooler temperatures and improving air quality in the neighbourhood. Reflective roofs can also extend the lifespan of rooftops by providing a protective covering and reducing the demand for building cooling equipment therefore increasing the lifetime of the assets and improving thermal comfort of building users (OneNYC, 2017).

The programme offers a ten-week training and work experience opportunity for job seekers. Each year 70 participants are enrolled onto the training course which also connects them to permanent employment opportunities upon completion. 5,034 volunteers have been engaged with the project between 2009 and 2016. The programme has provided wages and job training to job seekers in the local community.

**Significance to community:**
The 'NYC °Cool Roofs Programme' undertook an extensive marketing campaign to maximise its engagement across the city and target as many people as possible. The marketing campaign also allowed them to cross promote other opportunities offered by NYC such as green roofs and the tree planting scheme. The programme offered different installation options for building owners to meet different budgets and provided guidelines enabling individuals to install their own reflective roof.

The 'NYC °Cool Roofs Programme' brings many benefits to the community, it reduced building energy consumption and subsequently saves money for residents and building owners, it lowers ambient air temperatures across the city improving thermal comfort, it has contributed to city wide greenhouse gas reduction goals, and it provides social value in terms of job training and providing a source of income to job seekers.

**Further information**
- https://www1.nyc.gov/nycbusiness/article/nyc-coolroofs
- https://www1.nyc.gov/site/sbs/about/pr20170403-rooftops.page
- https://www1.nyc.gov/site/sbs/businesses/coolroofs-contact.page
  https://www1.nyc.gov/assets/orr/pdf/Cool_Neighborhoods_NYC_Report.pdf
- https://coolroofs.org/documents/NYC_CoolRoofs_6-14-17_Presentation.pdf

# Appendices

## Appendix A – Reflective Roofs

*Low pitched and flat reflective roof materials*
The following section describes the different types of reflective roof materials that can be applied to low-pitched or flat roofs.

### Reflective roof coatings

Reflective roof coatings are surface treatments which are best applied to low-pitched roofs in a good condition. The coatings have the consistency of thick paint and contain additives to improve their adhesion, durability and longevity whilst simultaneously reducing the growth of bacteria (EPA, 2008). Reflective roof coatings can be applied to various existing surfaces including asphalt capsheet, gravel metal and single-ply materials.

There are two main types of reflective roof coatings: elastomeric and cementitious. Both types have a solar reflectance of at least 0.65 when new and emit at least 80% of the heat it absorbs (EPA, 2008). Elastomeric coatings provide a waterproof membrane whereas cementitious coatings are pervious and rely on underlying roofing material for waterproofing.

White roof coatings are made from opaque and reflective polymeric materials that are combined with various types of white pigment. Depending on the white roof coating's thickness they have a solar reflectance of between 0.7 and 0.8, thus keeping surface temperatures close to ambient temperatures. Pigmented coatings are less efficient than white coatings, with a solar reflectance of around 0.2; however, these coatings are sometimes preferable in the residential sector where requirements for more aesthetically pleasing options are wanted. Glare from a bright white or silvery roof on a low-rise building poses risks to taller neighbouring buildings and could disturb occupants. Under these circumstances pigmented or cool-coloured coatings may be more appropriate for the low-rise building.

Researchers at Purdue University have recently developed a new coating that can reflect over 95% of sunlight (Irving, 2020). The paint is comprised of a variety of particle sizes which help to scatter more sunlight, and calcium carbonate fillers are used which are more abundant, cheaper, and absorb less ultra-violet light that other cooling coatings already on the market. When testing the material, they found that under direct sunlight the surface with the new coating remained 1.7°C cooler than the ambient temperature (Irving, 2020). This new coating is compatible with the existing manufacturing process for commercial coatings and is thought to be cost competitive. The next step is to understand its viability in long term outdoor applications.

### Roofing membranes

Roofing membranes are made from fibreglass, felt or polyester and attached with flexible polymeric materials such as asphalt, synthetic rubber, or synthetic polymers like polyvinyl chloride. They are then covered with a pigment to increase solar reflectance or with roofing gravel. Single-ply membranes are strong, flexible, and waterproof, come in black or white, can be easily repaired and are suitable in multiple climates.

Single-ply thermoplastic membranes consist of prefabricated flexible sheets made from plastic polymers. This sheet is applied as a single layer to a low-pitched or flat roof and secured in place with seams sealed by gluing, taping, or heat-welding. Membranes are made from polyvinyl chloride or thermoplastic polyolefin. They are white in colour, although pigments can be added if required.

Black single-ply membranes have a solar reflectance of around 0.05, when a white single-ply membrane is used solar reflectance increases to 0.7 to 0.8. When pigments are added solar reflectance reduces to around 0.4 to 0.60 (R20, 2012).

Single-ply roofing membranes can be directly installed onto an approved roofing substrate, which can reduce installation times when compared with built-up roofing systems, reduce material costs, and allow for easier installation.

### Foam roof

A foam roof is typically made from two liquid chemicals which mix to form a solid, flexible, and lightweight substance which attaches seamlessly to a roof. The material creates minimal waste and needs limited maintenance over its lifecycle. Foam roofs also provide insulation benefits, but are highly susceptible to mechanical, moisture and ultraviolet damage, and therefore require a protective coating. Foam roofs can be installed over existing roofs, making them a cheaper option that is efficient to implement.

### Built-up roofing (BUR)

Built-up roofing (BUR) systems are made from multiple layers comprising a base sheet, fabric reinforcement layers and a protective surface layer. Built-up roof cooling strategies can vary between building types. Some BUR systems will contain reflective materials embedded into asphalt or coal tar to reflect sunlight whilst others will have a mineral-surfaced layer containing reflective mineral granules or applied coatings.

Traditional BUR systems comprised of dark gravel have a solar reflectance of 0.1 to 0.15, when white gravel is used, this is increased to a solar reflectance between 0.3 and 0.5. For BUR systems that include a white smooth coating, solar reflectance can be increased by up to 0.75 to 0.85 (R20, 2012).

The benefits of BUR systems include low maintenance long term durability, water proofing and fire protection. These systems are also easy to repair and are less costly than other roofing systems.

### Modified bitumen reflective roofs

Modified bitumen reflective roofs, more commonly referred to as Mod-Bit, are like a BUR system but have a higher degree of elasticity. They are typically asphalt based and are suitable in both cold and warm climates.

The high degree of elasticity means that this type of roof does not become brittle in cold environments and is less likely to crack and create leaks. Mod-Bit systems are waterproof, hard-wearing, and easy to repair and maintain.

This roof type can be installed in four ways; cold-applied, hot-mopped, torch-applied or secured with self-adhesives. The solar reflectance for Mod-Bit systems is approximately 0.6 to 0.75 (R20, 2012).

*High pitched reflective roof materials*

Reflective roof materials for high pitched roofs are described in the following section below.

### Tiles

“Cool coloured” tiles which contain pigments to reflect solar energy in the infrared spectrum. These cool coloured tiles (25-70%) can in some cases double the solar reflectance to between 0.25 and 0.7 when compared with traditional tiles which have a solar reflectance of between 0.1 and 0.3. The diagram below shows how the solar reflectance of different coloured roof materials can change when treated with reflective coatings.

Cool coloured roof tiles can reduce energy bills associated with air-conditioning systems, lower roof maintenance costs and extend the lifetime of the roof. Coloured roof tiles can also overcome any concerns around altering the aesthetic of the building or change local heritage.

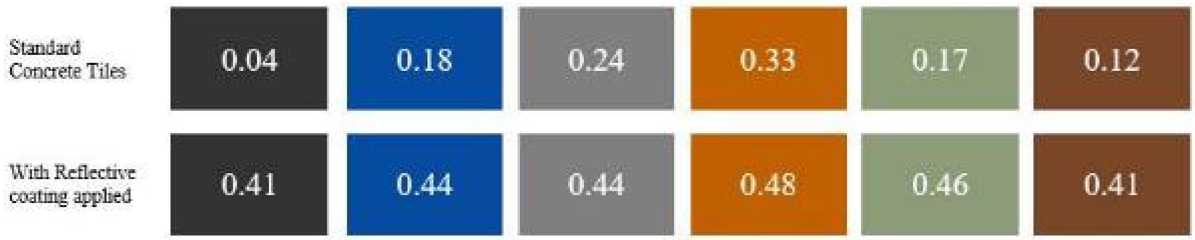


**Figure 16: Solar Reflectance (SR) values for different coloured concrete roof tiles with and without a reflective coating. (Source: adapted from A Practical Guide to Cool Roofs and Cool Pavements)**

## Metal roofing

Cool coloured metal roofing materials also use infrared-reflecting pigments and have a long life and high durability. Solar reflectance's for cool-coloured metal roofing products range from 0.2 to 0.9. Another option is aluminium roof coatings which is an asphalt-like resin containing aluminium leafing flakes. The majority of these coatings provide a solar reflectance of at least 0.5 and can exceed 0.7 for some brands (GBA, 2020).

The benefits of metal roofing include a wide variety of colour ranges and styles, long lifetimes, and good durability.

## Asphalt

Asphalt shingles are composed of asphalt mats made from organic felts or fibreglass. Their solar reflectance is relatively low; with white asphalt shingles having a solar reflectance of around 0.3 and other colours have even lower reflectance's.

Asphalt shingles are widely used in the residential sector because they are cost effective and easy to install. They also have a long-life expectancy and are available in a wider range of colours and textures which is advantageous on high pitched roofs where the roof can be seen from the ground. It is not recommended to use cool coatings over existing asphalt shingles. This technique can inhibit drying after rain or dew accumulation, letting water to condense and gather under the asphalt shingles, generating moisture and resulting in water damage

In addition, asphalt shingles are recyclable at their end of useful life. Other benefits include their availability on the construction sector market, their thermal performance, multi-layer protection, good durability, and strong tensile strength.

## Appendix B – Solar Photovoltaic Roofs

Solar PV panels are typically constructed in three ways, which also differ in efficiency, appearance, and cost (CSE, 2013):

- Monocrystalline: made of thin slices of silicon, cut from a single crystal
- Polycrystalline: made from thin slices of silicon, cut from a block of crystals
- Hybrid: combining crystalline cells with a thin layer of silicon on a glass or metal base. This construction tends to be the most efficient.

Solar PV technology is rapidly improving. For example, higher-efficiency panels being developed by Oxford PV may be available on the market in the next few years (see case study below).

*Case Study: High-efficiency solar PV*
Solar PVs have seen considerable technical development over the last ten years with a number of companies innovating in this sector.

One example is Oxford PV, who are developing high efficiency solar panels that hold much promise for the sector. Highly efficient solar panels can produce the same amount of energy with less roof space or less land. They provide an advantage for installation on urban rooftops to power homes and businesses.

**Figure 17: Oxford PV**

### Technological context

Today, the mainstream solar conversion technology – silicon – is reaching its practical efficiency limit of 26%. Most panels today convert just 15–20% of sunlight into electricity. Oxford PV’s perovskite-on-silicon tandem solar cell technology will help solar PV to break through its current performance barrier. Commercial solar cells, with an efficiency of 27% could go on the market by 2023.

### Impact

Systems with Oxford PV´s tandem technology will enable homes and businesses to generate 20% more electricity and to lower their energy costs. The 20% extra electricity will directly reduce energy bills, reduce society’s reliance on fossil fuels, and improve energy security.

## Appendix C – Data Maps

The following maps present the data added to the London climate Vulnerability map for heart risk to create the reflective roof opportunity map.

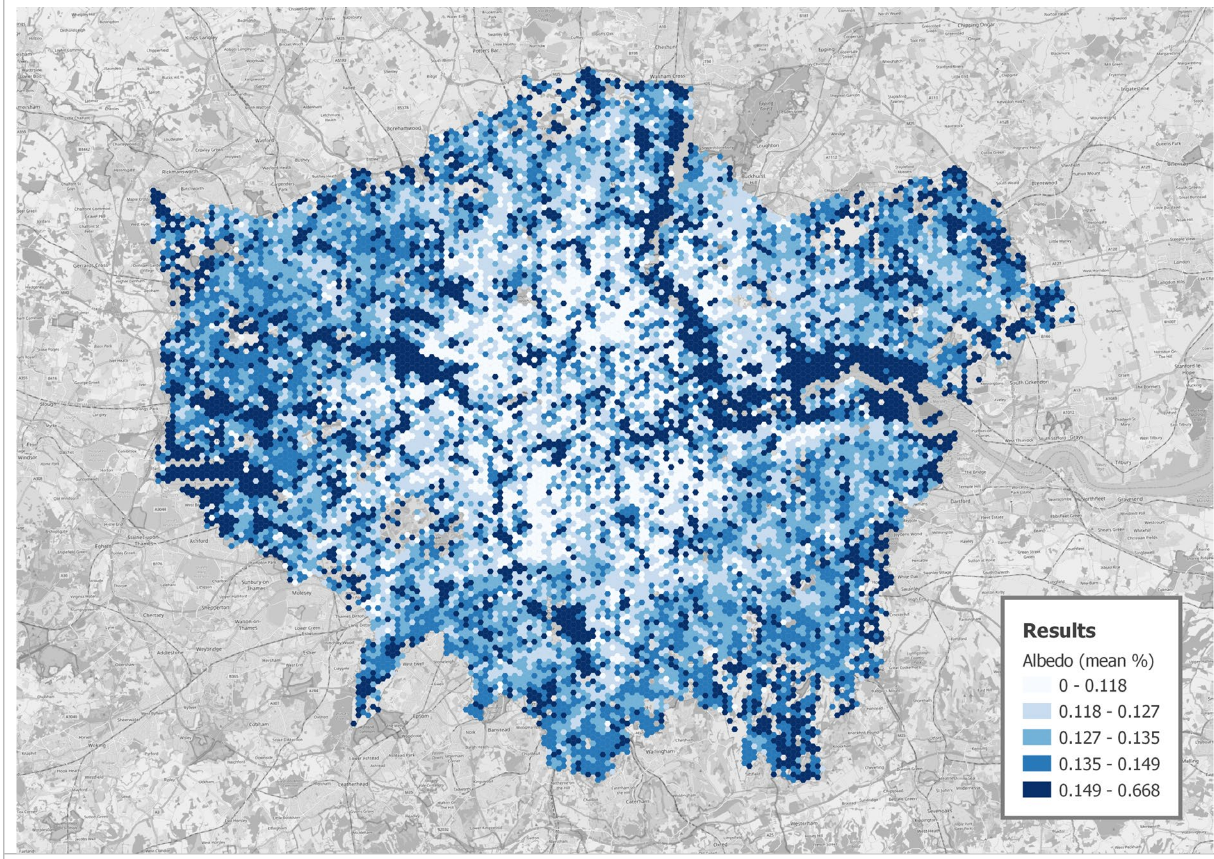


**Figure 18: London roof albedo map. Data aggregated for 350m hex grid (Arup)**

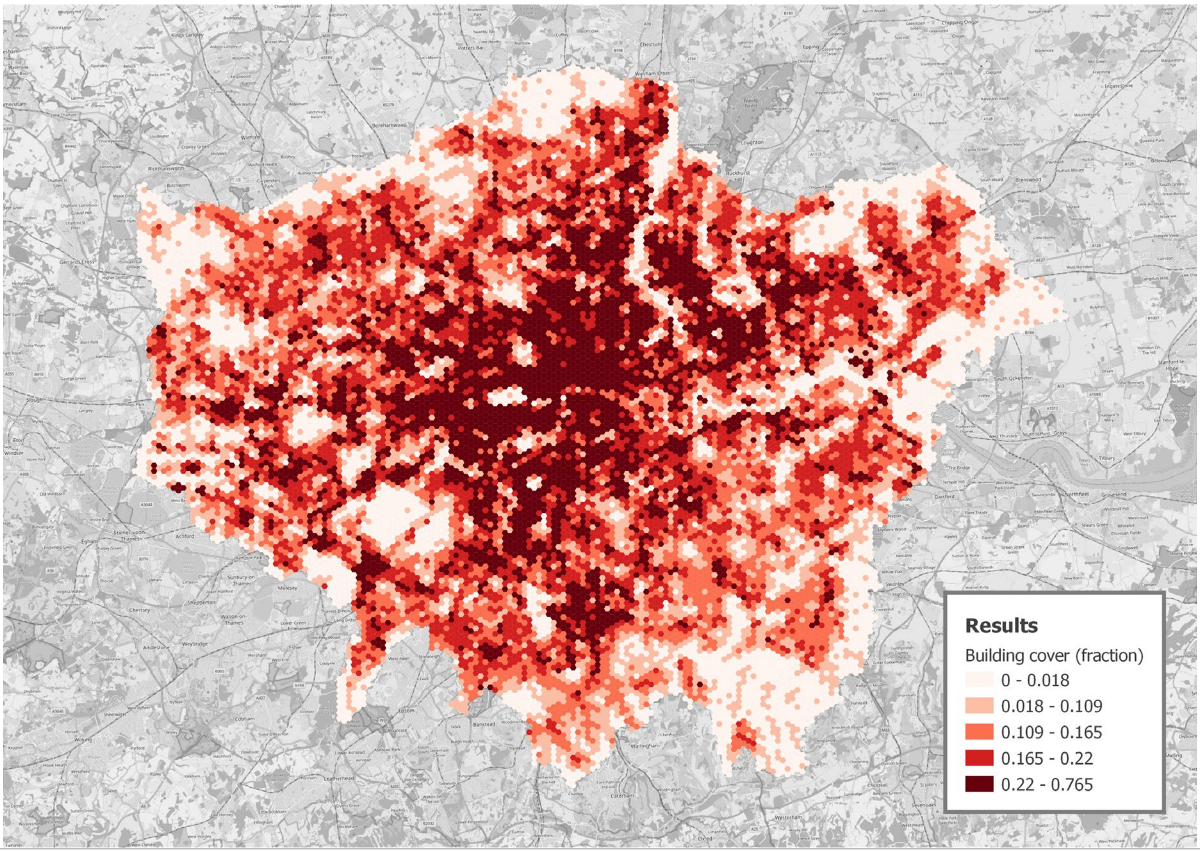


**Figure 19: London building cover map. Data aggregated for 350m hex grid (Arup)**

# Appendix D – Technical Studies

*Study 1: A study in overheating in homes*

A simple mathematical model was developed for this report that allows us to understand the impact of changing both the roof reflectivity and level of insulation. Only the heat transfer through the roof fabric is examined here and the space under the roof (whether it is a loft or room) is assumed to be outside temperature in the summer and heated to 20°C in the winter.

## Model Inputs

The reflectivity and level of insulation of the roof construction were varied, and the impact on heat gain or loss tested for a peak summer and an average winter.

## Results

| ***Input*** | ***Summer*** | ***Winter*** |
|---|---|---|
| ***Reflectivity range*** | *0.04 (a non-reflective roof such as dark slate) to 0.7 (reflective roof coating or tiles).* | *0.04 (a non-reflective roof such as dark slate) to 0.7 (reflective roof coating or tiles).* |
| ***Insulation level*** | *High, medium, low** | *High, medium, low** |
| ***Internal temperature*** | *set to outside temperature (assumed to not have a big impact)* | maintained at 20°C. |

The results indicate that in the summer a reflective roof can help reduce heat gain into a building. As reflectivity increases the heat gain decreases. Cool roofs can still provide benefits when insulated, although the benefits decrease.

For an average winter condition, the results indicate that a higher reflectivity could result in more heat loss for an uninsulated construction. However, with insulation, there is little difference in winter heat loss for different reflectivity's. This indicates that insulation can be beneficial when combined with a reflective roof in avoiding adverse winter heat loss.

The study shows that a reflective roof can result in decreased heat gains during high temperature. A roof with insulation will still see some benefit and will have the added advantage of limiting adverse heat loss in the winter.

## Limitations

This study only considers hypothetical roof constructions and does not account for other aspects of a building that may also have an impact such as thermal mass, ventilation, walls etc.

* Insulation levels represent the following U-values: high insulation = 0.18 W/m2 K (Building Regulations 2022), medium/some insulation = 1.0 W/m2 K and low/uninsulated = 2.4 W/m2 K

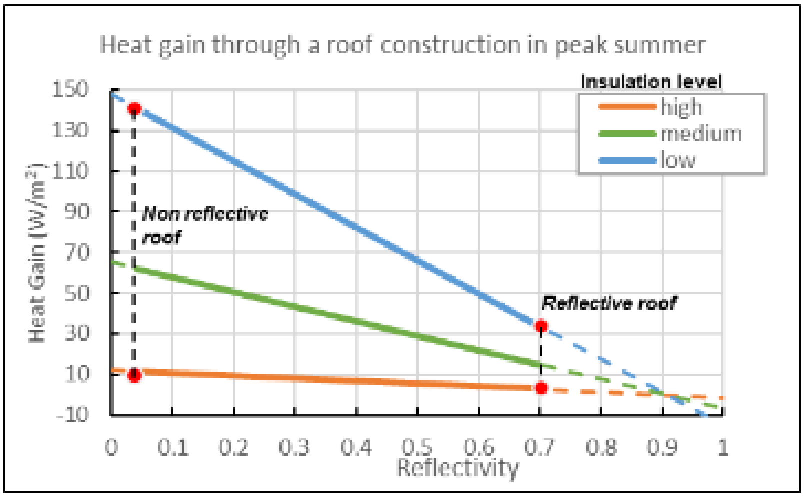


**Figure 18: Heat gain through a roof construction in peak summer**

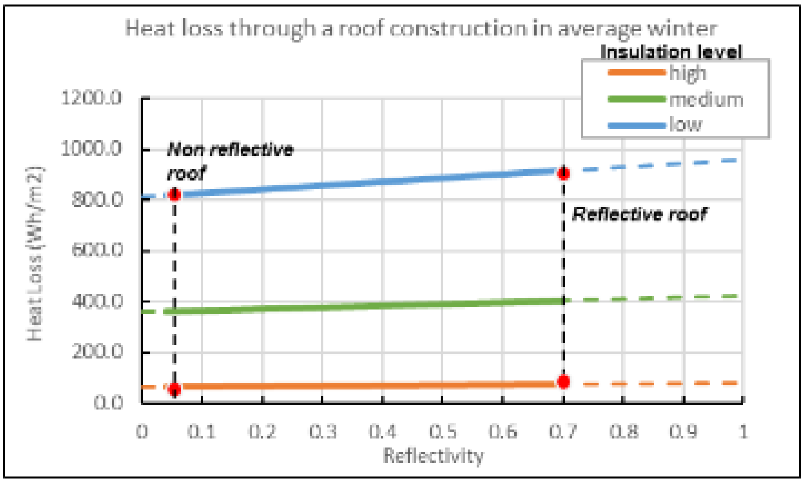


**Figure 19: Heat loss through a roof construction in average winter**

*Study 2: the impact of reflective roofs on UHI in London*

A model was carried out to assess the impact that retrofitting with reflective roofs could have on the UHI of London.

## Methodology

The assessment was carried out using the Surface Urban Energy and Water Balance Scheme (SUEWS) which is a model developed by the University of Reading (Sun, 2019). The model takes in as input a number of different parameters that have an influence on UHI including surface cover, building height, and building reflectivity. The impact that reflective roofs could have on air temperature can be tested by varying the reflective (or albedo) of the roof while keeping all the other parameters the same.

The model was run for July 2021 which had a heatwave in the middle of the month (19-24th July) when temperatures were in the mid-30s°C.

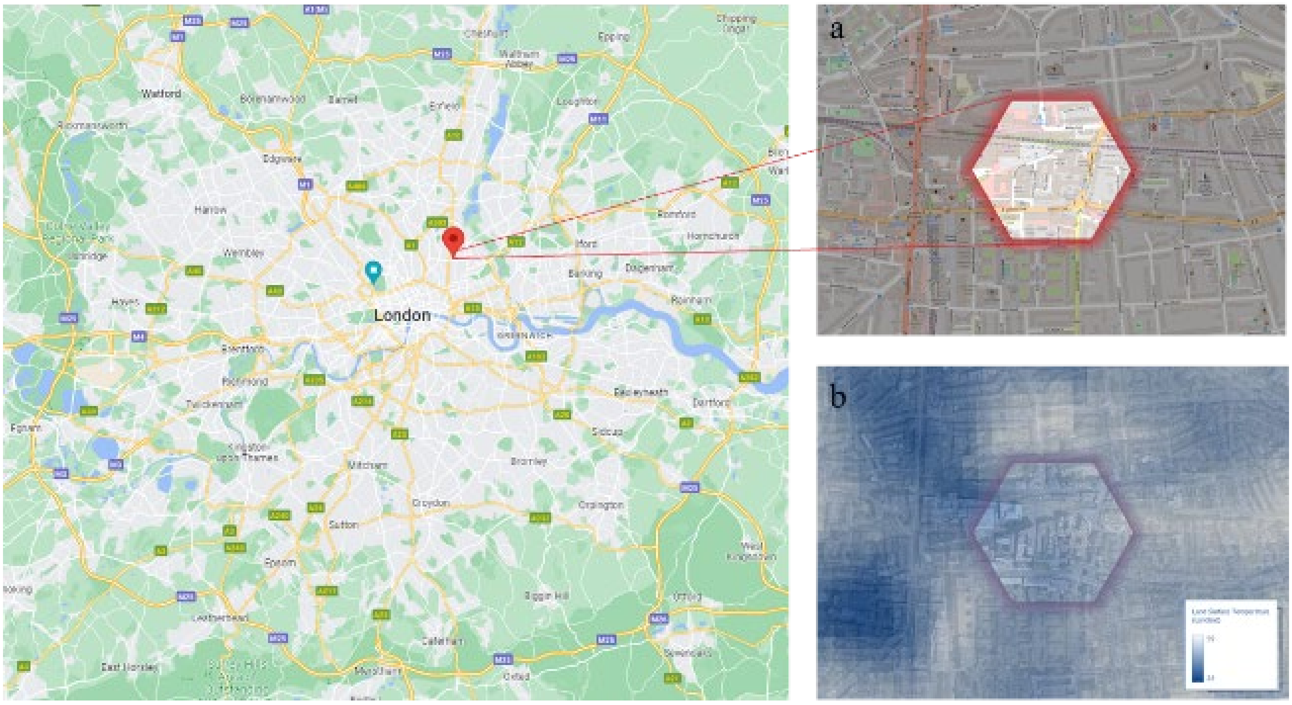


**Figure 20: Map of London with highlighted sections showing land surface temperature for reflective vs non-reflective roofs (Google maps and Open Street Map)**

The assessment was carried out for an area that is relatively hot (determined through land surface temperature data) and in a higher-priority borough (determined from the reflective roof opportunity map). This A 350m hex was selected for the assessment (see figure). The reflectivity of the building roofs was varied for this area in the model from 0.1 (a non-reflective roof) to 0.9 (a very reflective roof) with air temperature compared for each scenario.

## Results

The graph shows the predicted air temperature during July 2021 for the different roof reflectivity's. A high reflectivity resulted in up to 1.1°C lower air temperatures compared to a non-reflective roof. Consistently lower temperatures were predicted for reflective roofs during the course of the heat wave. Across the whole month, higher reflectivity's were predicted to result in an average daily maximum difference of 0.23°C, compared to having non reflective roofs.

The study indicates that cool reflective roofs can have the benefit of reducing the UHI effect in London consistent with other cities.

See Data Sources section for a list of input data for the assessment.

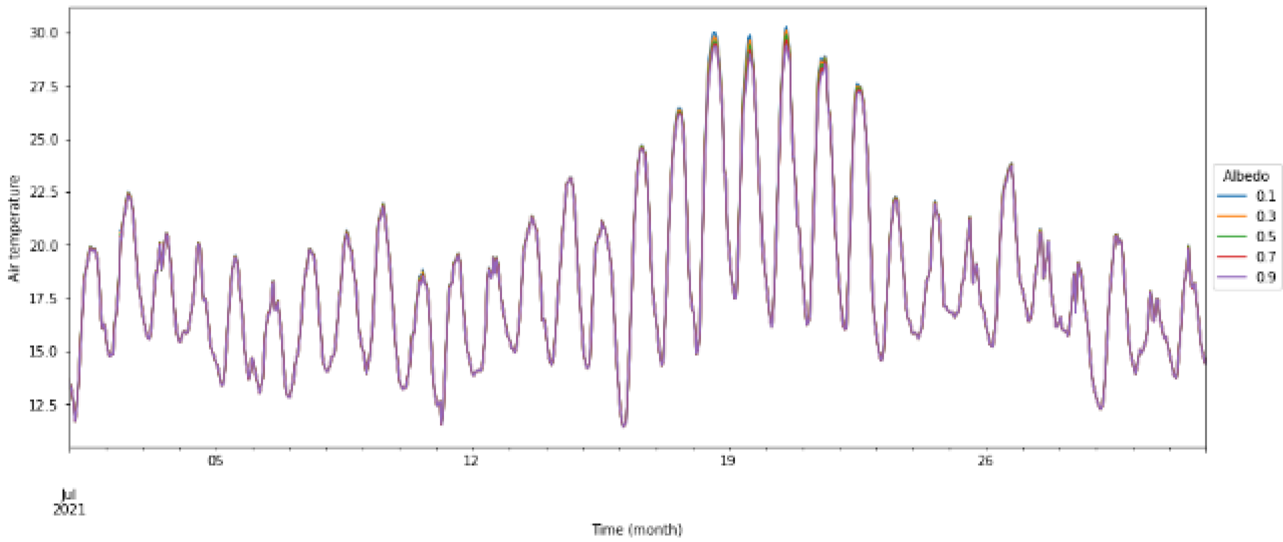


**Figure 21: Graph showing the fluctuation in air temperature over time (Arup)**

## Appendix E – Cost and ROI for Reflective Roofs and Solar PVs

*Cost Estimates*

The following tables detail the cost estimate calculations carried out for the building archetypes.

### Reflective roofs

**Table 6 6– Estimated costs for a reflective roof (coating) in London**

| | School | Social Housing | Office |
|---|---|---|---|
| Building Type | Low rise (1- 2 storeys) Concrete construction, flat roof | High rise, concrete construction, flat roof | Medium rise concrete construction, flat roof |
| Roof Type | Reflective coating | Reflective coating | Reflective coating |
| Total flat roof area ($m^2$) | 1,520 | 1,500 | 2,400 |
| Cost per Unit (£/$m^2$) [1] | 89[2] | 13[3] | 13[3] |
| Total Cost (£) | 134,000 | 19,000 | 30,000 |

*Notes*

[1] Costs include the material and labour costs of applying reflective paint coat and are inclusive of contractor preliminaries at 15% and OH&P's (overheads and profit) at 8%. Other costs associated with the works, including professional fees and inflation, have been excluded.

[2] Scaffolding to the façade of the school has been included for safety purposes.

[3] It is assumed the roof is flat and access is assumed to be feasible from existing roof access with an existing safety rail / parapet to the perimeter.

**Table 7 7– Estimated costs for a reflective tile in London**

| | House | School | Social Housing | Office |
|---|---|---|---|---|
| Building Type | Semi-detached with tiled pitched roof (45°) | Low rise (1- 2 storeys) pitched roof (30°) | 4-5 storeys, pitched roof (30°) | Approx. 4-5 storeys, pitched roof |
| Roof Type | Reflective tiles | Reflective tiles | Reflective tiles | Reflective tiles |
| Total pitched roof area ($m^2$) | 88 | 1500 | 1,700 | 2,800 |

| | | | | |
|---|---|---|---|---|
| Cost per Unit (£/m²) [1] | 125 | 177 | 125 | 299 |
| Total Cost (£) | 11,000 | 301,000 | 212,000 | 837,000 |

| |
|---|
| *Notes* |
| [1] Costs include the material and labour costs of removing existing tiles and replacement with lighter coloured roof tiles. Works are for replacement of tiles only, excluding any structural works. Costs are inclusive of contractor preliminaries at 15% and OH&P's at 8%. Scaffolding to the perimeter of an assumed pitched roof is included. |
| [2] Note that the cost for a reflective tile is that same as that for a normal roof tile. There was no data available for a specifically reflective tile as supply chains have not been established in the UK. According to the US Department of Energy (U.S. Department of Energy, n.d.), Cool roofing products usually cost no more than comparable conventional roofing products. |

## Solar PVs

**Table 88 – Estimated costs for a Solar PV in London**

| | House | School | Social Housing | Office |
|---|---|---|---|---|
| Building Type | Semi-detached with tiled pitched roof (45°) | Low rise (1- 2 storeys) Concrete construction, flat roof | High rise, concrete construction, flat roof | Approx. 4-5 storeys, concrete construction, flat roof |
| Roof Type | Solar PV | Solar PV | Solar PV | Solar PV |
| Total Pitched roof area (kW) | 88 | 321 | 1,700 | 2,800 |
| Solar Potential (kW) [1] | 4 | 73 | 49 | 37 |
| Cost per Unit (£/kW) [2] | 1,750[3] | 2,288[4] | 1,429[5] | 1,459[5] |
| Total Cost (£) | 7,500 | 167,000 | 70,000 | 54,000 |
| Years until ROI | 7 | 5 | 6 | 3 |
| ROI / Year | c. 14% | c. 20% | c. 17% | c. 33% |
| Supply Cost as a % of Total Return | 64% | 44% | 50% | 28% |

*Notes*

[1] Solar PV outputs based on the Mayor of London Solar Action Plan and Mayor of London Solar Opportunity Map

[2] Costs include the material and labour costs of polycrystalline solar PV panels and costs associated with preliminaries, contractor OH&P and testing and commissioning are included. It is assumed that the current electrical system can accept PV integration. Battery storage has been excluded. An allowance has been made for BWIC (builders work in connection) as well as testing and commissioning.

[3] Scaffolding to one side of an assumed pitched roof is included.

[4] An allowance has been made for cranage equipment for 2 weeks to lift solar PV panels onto the roof.

[5] An allowance has been made for extension of DC cabling through existing risers to a ground floor plant room. An allowance has been made for cranage equipment for 2 weeks to lift solar PV panels onto the roof.

*Return on Investment*

The following charts present the return-on-investment (RIO) calculations for reflective roofs (for office archetype with reflective coating only) and Solar PVs (all archetypes)

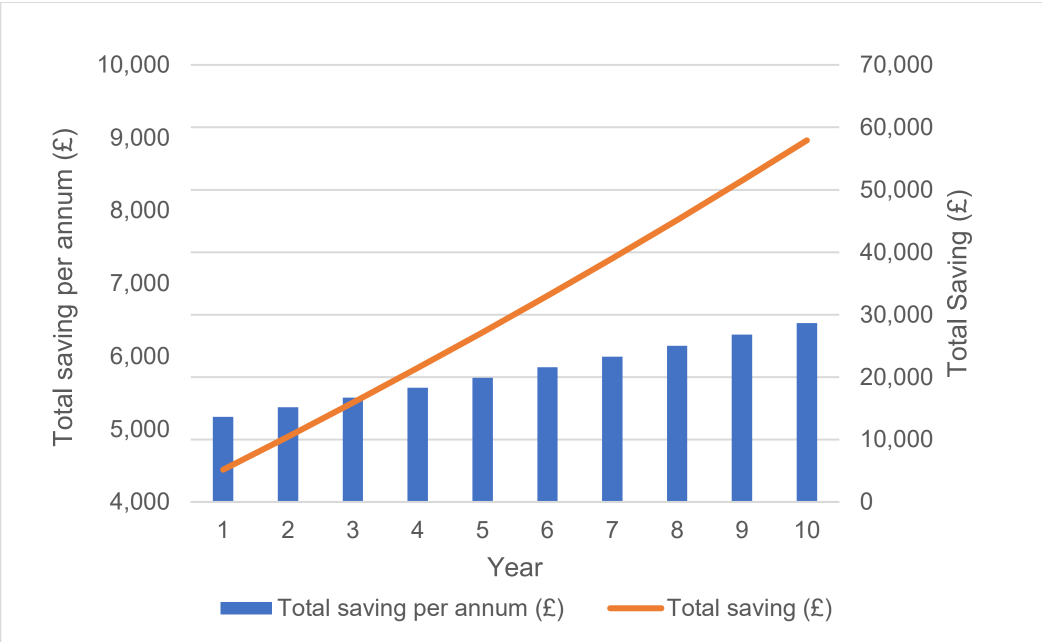


**Figure 22**: **ROI for reflective roof on an office building in London (with a low insulation roof) (Arup)**

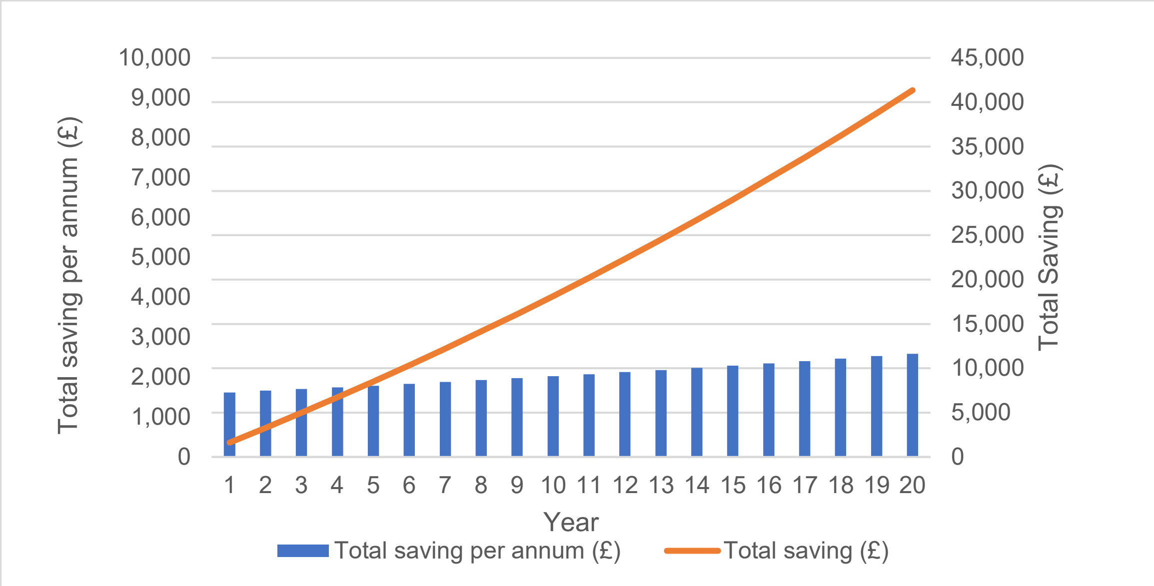


**Figure 23: ROI for reflective roof on an office building in London (with a well-insulated roof) (Arup)**

An inflationary rate of 2.5% has been applied to energy costs per annum. This is an assumption and will require verification and future adjustments. No adjustment has been made for NPV. Heating is assumed to be gas fuelled and cooling has been assumed to be electric.

Gas rate obtained from businessenergy.com (Businessenergy.com, 2022)

Electricity rate obtained from EDF Energy (EDF Energy, 2022)

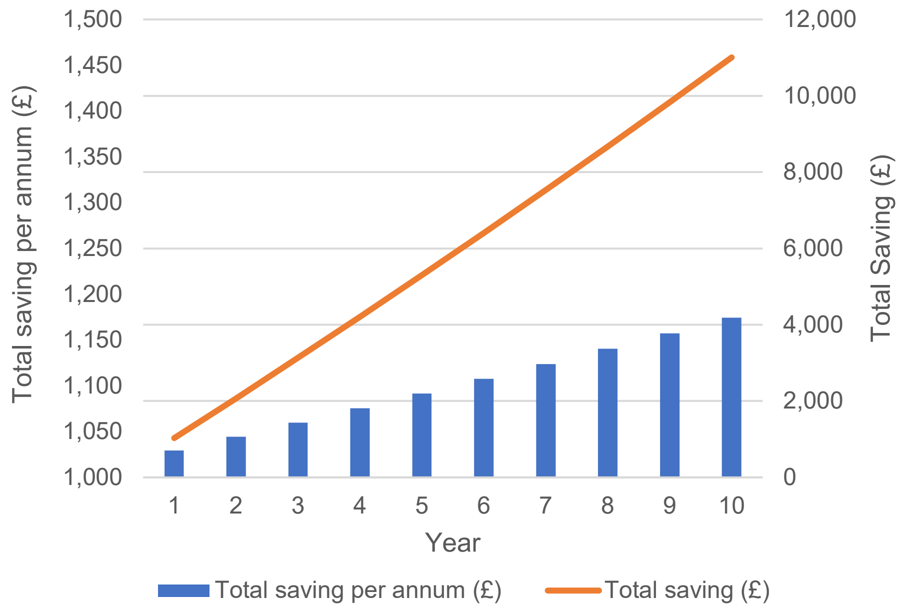


**Figure 24**: **ROI for PV on semi-detached house in London (Arup)**

It has been assumed 50% of residential buildings will be orientated south facing PV panels, 25% will be orientated west facing and 25% orientated east facing. A 1% reduction in efficiency per annum has been assumed. An inflation rate of 2.5% has been applied to energy costs per annum. Roof properties are those described Table 8 for a house.

Domestic energy rate of 0.28 £/kW obtained from British Gas (British Gas, 2022)

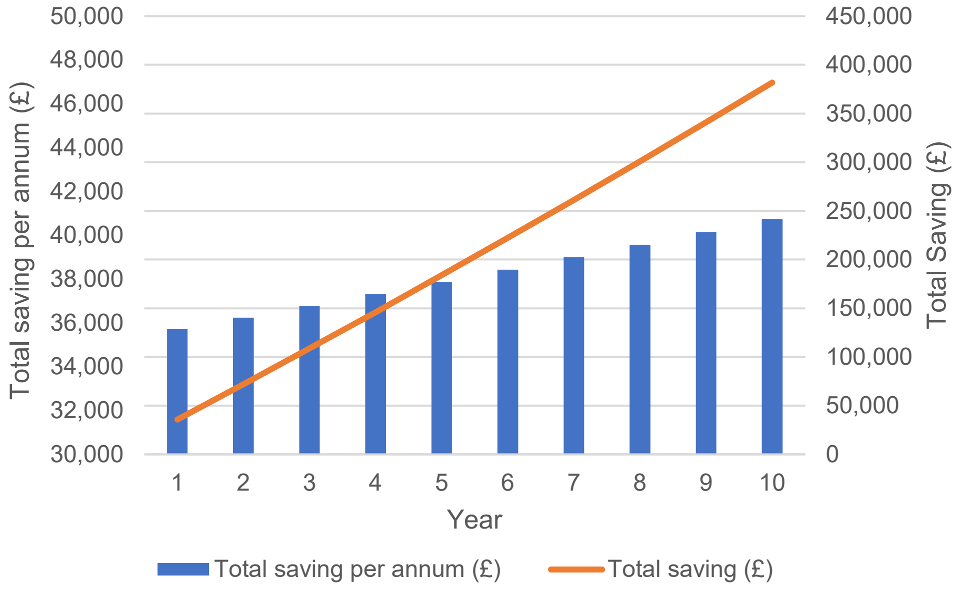


**Figure 75**: **ROI for PV on school in London (Arup)**

As a non-domestic building, business rates have been applied. PV panels are assumed to be orientated south facing. A 15° mounted slope has been assumed. A 1% reduction in efficiency per annum has been assumed. An inflationary rate of 2.5% has been applied to energy costs per annum. Roof properties are those described in Table 8 for a school.

Gas rate of 0.51 £/kW obtained from businessenergy.com (Businessenergy.com, 2022)

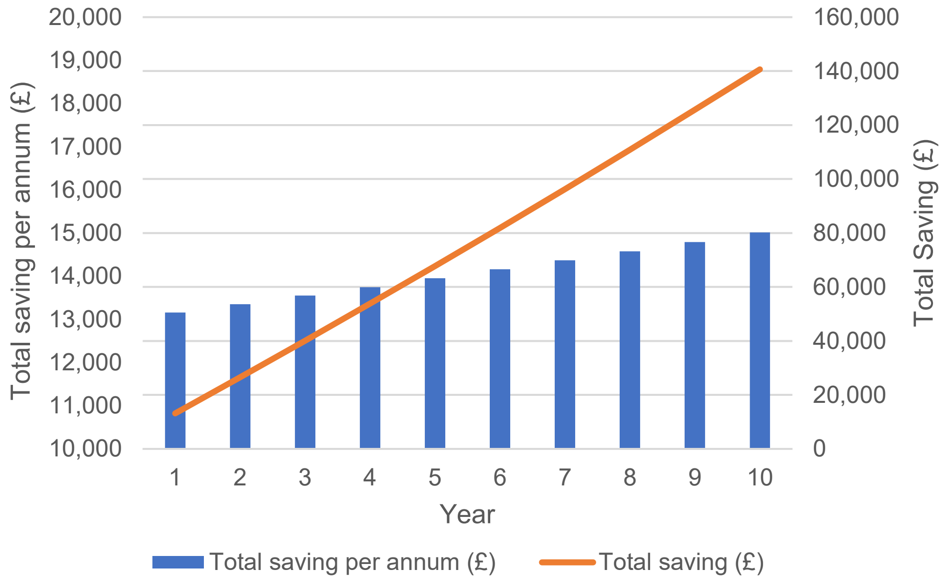


**Figure 268**: **ROI for PV for social housing in London (Arup)**

As a domestic building, domestic rates have been applied. PV panels are assumed to be orientated south facing. A 15° mounted slope has been assumed. A 1% reduction in efficiency per annum has been assumed. An inflation rate of 2.5% has been applied to energy costs per annum. Roof properties are those described in Table 7for a social housing.

Domestic energy rate of 0.28 £/kW obtained from British Gas (British Gas, 2022)

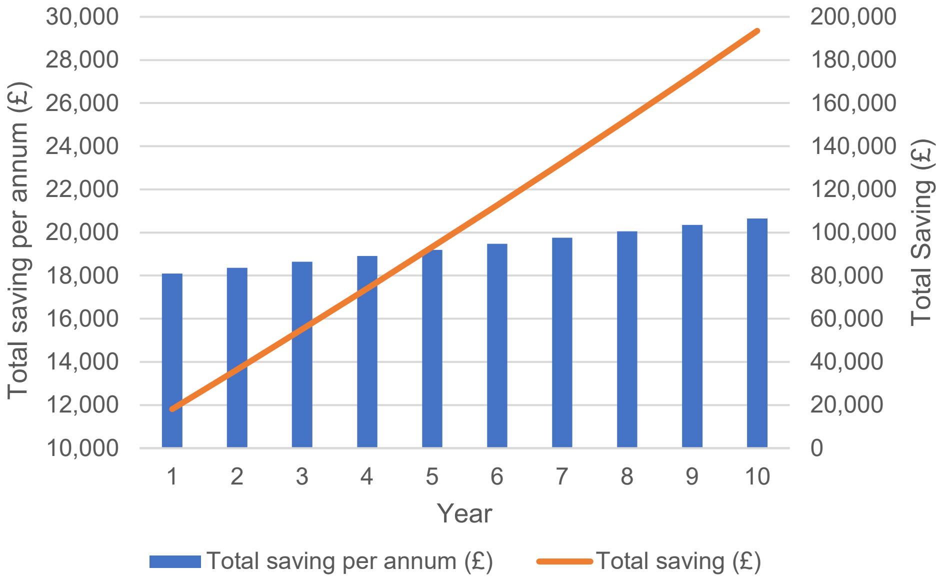


**Figure 27**: **ROI for PV an office building in London (Arup)**

PV panels are assumed to be orientated south facing. A 15° mounted slope has been assumed. A 1% reduction in efficiency per annum has been assumed. An inflation rate of 2.5% has been applied to energy costs per annum. Roof properties are those described in Table 7 for an office.

Gas rate of 0.51 £/kW obtained from businessenergy.com (Businessenergy.com, 2022)

## Appendix F – Critical Success Factor Supporting Analysis

*Critical Success Factor assessment*

### Long-list assessment

As prescribed by 'The Green Book' methodology, in order to develop a rational for intervention, a long list of potential options to achieve the project objectives is generated. This list is then filtered down into a suitable shortlist for more detailed cost benefit and/or cost effectiveness analysis. The identification of 'Critical Success Factors' is made in order to evaluate or appraise a long list of potential options. Critical success factors are a list of holistic factors that consider the benefits, barriers, and success of potential implementation options. This is a typical consideration for business case (implementation plan) development and, in this context and at a high level, assesses the factors relevant to implementing cool roof options successfully.

At this early outline stage, an indicative comparative matrix (CSFs) was established to assess the opportunities to implement cool roof retrofit activities for different building archetypes (long list) in London. These generic archetypes, which have been described in the section '*Building Archetypes,'* represent a broad range of building types across London and have been used as a proxy for testing implementation opportunities. Archetypes were evaluated against the 'Critical Success Factors' (CSFs), considering the potential to implement cool roofs in different contexts. The objective of this high-level scoring assessment is to highlight the archetypes and cool roof implementation technologies to prioritise for future understanding and development.

### Critical Success Factors

The CSFs include the fundamental success criteria relating to affordability, deliverability, compliance, and risk, and have been formulated and given a hierarchy through workshop and stakeholder engagement with the GLA.

In a developed business case or implementation plan analysis, the CSFs are deemed crucial metrics, not simply desirable, and any proposed option that 'fails' to meet a CSF is recommended not to be taken forward for further consideration. However, at this early stage of a cool roof implementation programme, it is recommended that any proposed archetype interventions with a low CSF scoring may need to be reconsidered with potential alternative options proposed. Therefore, it is not suggested that these options are disregarded but that they may require further technical enquiry or evaluation in the next project phases.

## Critical Success Factors output matrix

The table below assesses the recommended solar reflective and solar PV technologies against the critical success factors for each of the building archetypes. Each technology's CSF score per archetype is totalled at the base of the table. This informs the high-level long list recommendation for which primary technology to consider for deeper inquiry and wider adoption, and which secondary technology may also be considered further for implementation. Where the technology is presented in grey fill and unscored, it is deemed an unviable implementation technology and is not currently recommended for the scope of this delivery plan. Further research into how the two primary and secondary technologies may be implemented together in hybrid is recommended as a next step, as this currently falls outside of this report's scope.

Additional 'Critical Success Factor' supporting commentary and two example scoring assessments for 'CSF 4 – Affordability' and 'CSF 5 – Achievability' have been provided in Appendix G. Further assessment sheets for the remaining CSFs scores can be provided separately, if requested. This provides a high-level description per score to validate the score selected. Importantly, the scores are indicative and can also be based on option potential or opportunity. For example, higher scores may be suggestive of potential not yet achieved but which may be realistically achieved in latter implementation consideration stages. It is recommended that this high-level analysis is developed further as more option and archetype specificity is available, such as through a potential pilot programme.

## Recommended archety*pe technologies*

**Table 9 – critical success factors output summary matrix**

| | | Archetype 1 | | | Archetype 2 | | | Archetype 3 | | | Archetype 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | House | | | School | | | Social Housing | | | Office | | |
| **No** | **Critical Success Factors** | **RP** | **RT** | **SP** | **RP** | **RT** | **SP** | **RP** | **RT** | **SP** | **RP** | **RT** | **SP** |
| 1 | Strategic Fit and Business Needs | | 3 | 4 | 3 | | 4 | 3 | | 4 | 3 | | 4 |
| 2 | Social, Economic and Environmental Value | | 2 | 3 | 2 | | 3 | 2 | | 4 | 2 | | 4 |
| 3 | Supplier Capacity and Capability | | 2 | 3 | 3 | | 4 | 3 | | 4 | 3 | | 4 |
| 4 | Affordability | | 2 | 3 | 2 | | 3 | 2 | | 3 | 3 | | 4 |
| 5 | Achievability | | 3 | 3 | 3 | | 2 | 3 | | 2 | 4 | | 3 |
| | | | | | | | | | | | | | |
| | | | 12 | 16 | 13 | | 16 | 13 | | 17 | 15 | | 19 |

*Notes*

[1] Key: RP = Reflective Paint, RT = Reflective Tile/Panel, SP = Solar PV

[2] Reflective paint or coating may be considered for a house typology with an extensive flat roof. Therefore, this was not considered in this pitched-roof house archetype

As an output from the above, the table below prioritises the recommended technologies per archetype. Ordered from green to amber, the green column describes the primary implementation technology recommended to be considered further, whereas the amber row describes the least viable technology for implementation, but which requires further analysis regarding implementation.

**Table 1010 – Recommended archetype technology**

<table>
<tr><th></th><th></th><th colspan="3">Archetype 1</th><th colspan="3">Archetype 2</th><th colspan="3">Archetype 3</th><th colspan="3">Archetype 4</th></tr>
<tr><th></th><th></th><th colspan="3">House</th><th colspan="3">School</th><th colspan="3">Social Housing</th><th colspan="3">Office</th></tr>
<tr><th>No</th><th>Critical Success Factors</th><th>RP</th><th>RT</th><th>SP</th><th>RP</th><th>RT</th><th>SP</th><th>RP</th><th>RT</th><th>SP</th><th>RP</th><th>RT</th><th>SP</th></tr>
<tr><td>1</td><td>Strategic Fit and Business Needs</td><td rowspan="5"></td><td rowspan="5">Recommended</td><td rowspan="5">Recommended</td><td rowspan="5">Recommended</td><td rowspan="5"></td><td rowspan="5">Recommended</td><td rowspan="5">Recommended</td><td rowspan="5"></td><td rowspan="5">Recommended</td><td rowspan="5">Recommended</td><td rowspan="5"></td><td rowspan="5">Recommended</td></tr>
<tr><td>2</td><td>Social, Economic and Environmental Value</td></tr>
<tr><td>3</td><td>Supplier Capacity and Capability</td></tr>
<tr><td>4</td><td>Potential Affordability</td></tr>
<tr><td>5</td><td>Potential Achievability</td></tr>
</table>

*Notes*

[1] Key: RP = Reflective Paint, RT = Reflective Tile/Panel, SP = Solar PV

[2] Reflective paint or coating may be considered for a house typology with an extensive flat roof. Therefore, this was not considered in this pitched-roof house archetype

## Critical Success Sactors scoring system

The below rating system has been used to classify the CSFs against the archetype options.

**Table 11 – Critical Success Factors Scoring System**

| Rating | Score | Note |
|---|---|---|
| | 5 | Fully meets objective / CSF |
| | 4 | Largely meets objective / CSF |
| | 3 | Partially meets objective / CSF |
| | 2 | Neutral impact |

| Rating | Score | Note |
|---|---|---|
| | 1 | Risk to objective / CSF being met |
| | 0 | Completely fails to meet objective / CSF |

## Critical Success Factors description and scoring methodology

The table below presents the selected CSFs and describes how these factors have been translated into a wider list of considerations for evaluating a potential 'long list' of cool roof delivery models. The table lists the selected CSFs providing a description and explanation of the scoring methodology.

These factors would also be described as project constraints, which are external considerations that define the limits within which an implementation plan can be delivered.

**Table 12 – Critical Success Factors summary**

| No. | Critical Success Factors | Description | Considerations | Scoring Methodology |
|---|---|---|---|---|
| 1 | Strategic Fit and Business Needs | How well the option:<br>Meets the agreed spending objectives, related business needs and service requirements, and<br>Provides holistic fit and synergies with other strategies, programmes, and projects | **Compatibility with other GLA Workstreams –** The compatibility of the proposed reflective solution to other existing GLA workstreams and retrofit workstreams, as well as assesses that the intervention complies with the Mayor's Climate Action Plan and Mayor's London Recovery Programme | **0** = Disconnected from existing GLA workstreams and the Mayor's Climate Programmes<br>**5** = Strongly aligns / connects with existing GLA workstreams and the Mayor's Climate Programmes |
| 2 | Social, Economic and Environmental Value<br><br>*'The Green Book' guidance denotes this as 'Potential* | How well the option:<br>Optimises social value (social, economic, and environmental), in terms of the potential costs, benefits and risks | **Performance and Benefits –** Assesses the performance of the proposed reflective solution. Considers energy production, cooling reduction and UHI energy produced by the proposed reflective solution | **0** = Low performance benefits, within a lower-priority zone in London, Will provide no social value and skills development, produces significant waste that may be difficult to recycle / re-purpose. High embodied carbon. |

| No. | Critical Success Factors | Description | Considerations | Scoring Methodology |
|---|---|---|---|---|
| | *Value for Money'* | | **Location Opportunity –** Assesses whether the proposed reflective solution's building location is within a higher-priority zone, regarding environmental and social factors<br>**Social Value and Skills Development –** Assesses the social value and skills created by the proposed reflective solution<br>**Waste –** Assesses the waste generated through implementing the reflective roof technology | **5** = High performance benefits. Produces energy. Reduces cooling and UHI, within a higher-priority zone in London, Significant social value impacts and skills development, produces minimal waste and easy to recycle / re-purpose. |
| 3 | Supplier Capacity and Capability | How well the option:<br>Matches the ability of potential suppliers to deliver the required services, and<br>Is likely to be attractive to the supply side | **Partnerships –** Assesses the partnership value and opportunities of the proposed reflective solution<br>**Behaviour, Engagement and Communication –** Assesses the engagement and communication opportunities created by the proposed reflective solution | **0** = Partnerships with externals stakeholders not available, highly difficult to communicate and encourage behaviour change toward reflective solutions<br>**5** = Significant opportunities to partner with externals stakeholders to implement the reflective solutions, Easy to communicate and encourage behaviour change toward reflective solutions |
| 4 | Affordability<br><br>*'The Green Book' guidance denotes this as 'Potential Affordability'* | How well the option:<br>Can be funded from available sources of finance, and<br>Aligns with sourcing constraints | **Cost –** The **c**ost of the proposed reflective solution<br>**Funding –** Availability of (public and/or private) funding sources for implementing the proposed reflective solutions | **0** = High cost of construction (CapEx) and Maintenance (OpEx), No funding available, No ROI<br>**5** = Low cost of construction (CapEx) and Maintenance (OpEx), Private and Public funding sources |

| No. | Critical Success Factors | Description | Considerations | Scoring Methodology |
|---|---|---|---|---|
| | | | **Payback / ROI / NPV –** The return on investment of the proposed reflective solution | widely available / budgeted for, High ROI |
| 5 | Achievability<br><br>*'The Green Book' guidance denotes this as 'Potential Achievability'* | How well the option:<br>Is likely to be delivered, given the organisation's ability to respond to the changes required, and<br>Matches the level of available skills required for successful delivery | **Constructability – T**he ease or difficulty of constructing the proposed reflective solution. Considers Ease of construction, time and disturbance, structure, and maintenance.<br>**Planning –** The planning limitations / opportunities of the proposed reflective solution | **0** = High-pitched roof. Substantial scaffolding/access required. Long installation period. Existing structure does cannot accommodate added load. Requires significant maintenance., Prohibited, for example, List Building Status. Planning required<br>**5** = Flat or low-pitched roof. Minimal scaffolding/access required. Short installation period. Existing structure can accommodate added load. Requires minimal maintenance, Works permitted without planning approval or under Permitted Development rights |

# Appendix G – CSF Scoring Samples

## Table 13 – Critical Success Factors Descriptions and Scoring

*CSF 4 (Affordability) – Funding*

| **CSF 4** | **Funding (as per 'Affordability' CSF)** |
|---|---|
| **Archetype 1** | **House** |
| Reflective Paint | |
| Reflective Tile | **2** |
| Solar PV | **3** – Acknowledges support of funding schemes, such as 'Solar Together' |
| **Archetype 2** | **Late 20th Century School** |
| Reflective Paint | **2** – Private funding potentially available through school's planned maintenance / OpEx budget |
| Reflective Tile | |
| Solar PV | **3** – Acknowledges support of funding schemes, such as 'Solar Together' |
| **Archetype 3** | **Social Housing** |
| Reflective Paint | **2** – Private funding potentially available through council's planned maintenance / OpEx budget |
| Reflective Tile | |
| Solar PV | **3** – Acknowledges support of funding schemes, such as 'Solar Together' |
| **Archetype 4** | **Commercial Office** |
| Reflective Paint | 3 – Private funding likely available through building owner's planned maintenance / OpEx budget |
| Reflective Tile | |
| Solar PV | **4** – Acknowledges support of funding schemes, such as 'Solar Together' |

*CSF 5 (Achievability) – Constructability*

| CSF 5 | Constructability |
|---|---|
| **Archetype 1** | **House** |
| Reflective Paint | |
| Reflective Tile | **3** – More difficult to install. Requires professional contractor. Longer lead time. Scaffold likely required. |
| Solar PV | **3** – More difficult to install. Requires professional contractor. Longer lead time. Scaffold likely required. May require strengthening of roof structure for increased loading. |
| **Archetype 2** | **Late 20th Century School** |
| Reflective Paint | **3** – Relatively easy and fast to install, with minimal maintenance required. |
| Reflective Tile | |
| Solar PV | **2** – More difficult to install. Requires professional contractor. Longer lead time. May require strengthening of roof structure for increased loading. |
| **Archetype 3** | **Social Housing** |
| Reflective Paint | **2** – Relatively easy and fast to install, with minimal maintenance required. |
| Reflective Tile | |
| Solar PV | **4** – Easier to install. Requires professional contractor. Assumes access to roof. Scaffold likely not required. Roof structure can withstand additional load. |
| **Archetype 4** | **Commercial Office** |
| Reflective Paint | **4** – Relatively easy and fast to install, with minimal maintenance required. |
| Reflective Tile | |
| Solar PV | **3** – Easier to install. Requires professional contractor. Assumes access to roof. Scaffold likely not required. Roof structure can withstand additional load. |

## Appendix G – High-Level Checklist for Residential Retrofit

*Sample Checklist – Private Homeowner*

Please refer to the GLA's guidance on implementing Cool (Solar Reflective) Roofs for residential homes across London

| No. | Question |
|---|---|
| | **Property Ownership** |
| | Who owns the property? Do you have the rights to conduct works? If not, then have you sought permission from the property owner? |
| | If you are a property owner, then do you need to consult the tenants or leaseholders? |
| | **Establishing Priorities** |
| | Does your property experience any of the following?<br>• Overheating<br>• High cooling bills (if air conditioned) |
| | Is the building in a higher-priority area (see Opportunity Heat map)? |
| | **Building type and selecting an intervention** |
| | What type of property do you have? What type of roof is there? |
| | Are you aware of the costs and benefits of implementing a reflective roof? Please refer to X for guidance |
| | Are you aware of the type of reflective roof that will be suitable? |
| | If considering reflective tiles/panels or Solar PV, will your roof structure support the cool roof intervention? Refer to the Constructability section of "xxx" for guidance. |
| | Has the need for scaffold and edge protection been considered? Refer to the Constructability section of "xxx" for guidance. |
| | **Delivery** |
| | Have you considered the planning implications of this intervention? Please refer to X for guidance. |
| | Do you have budget available for a reflective roof retrofit? |

| No. | Question |
|---|---|
| | Are you aware of any other cool roof solar reflective interventions that have been carried out in your neighbourhood or borough? Is there an existing neighbourhood scheme that you could tap into? |
| | What funding options are available? For example, are their group-wide deals that are available? Please refer to X for guidance. |
| | Do you have a list of accredited retrofit installers that may assist with this intervention? Please refer to X for guidance. |
| | **Retrofit integration** |
| | Could the roof retrofit be integrated into a whole house retrofit plan? |
| | If you are not undertaking a whole house retrofit, then could you incorporate any other measures? |

## Appendix I – Working in an Integrated Way

The 'Roofs Designed to Cool' project has focused on reflective and solar PV roofs, however cool roofs encompass a range of different options, which includes green roofs. There is an opportunity to consolidate work that has been done so far on different roof systems and develop a holistic programme. This could entail:

- A decision-making tool aimed at building owners and tenant to allow them to assess the different options available and what benefits and returns they may achieve on investment. This could be in the form of a more detailed check list which could vary by building type. A more developed version of this tool could also assist building owners to understand barriers and drawbacks (e.g., Potential winter energy penalty of cool roofs) and how this may encourage or discourage implementation in certain contexts.
- Consolidated data maps. There are currently several different data maps such as the green roofs map, solar opportunity map, London building shock map. The GLA, local authorities and the public will be able to gain a bigger picture understanding of projects which relate to the green agenda and the potential for what is possible still.

Beyond cool roofs, there is also the potential to further extend the work to incorporate a wider range of retrofit measures. For instance, if the focus was on residential buildings, this may include interventions such as insulation, double glazing, heat pumps, etc. detailed in a check list which allows better decision making. Combining different energy efficient retrofit measures can have cost and time saving benefits as well as other co-benefits such as energy efficiency. Homeowners may be encouraged to approach retrofit holistically if there is alignment across different programs. Some schemes that can be linked include:

- Solar Action plan
- Retrofit Accelerator

Additionally, there is a potential for cross-linking and integration with other schemes and programmes in London. For instance, there could be integration of workstreams that address overheating and air quality in London, namely:

- Cool Spaces London
- Green infrastructure
- Mayor's Air Quality Fund
- Schools Adaptation Plan
- London Climate Vulnerability Map

Through better integration, an overarching programme can be developed that can address the issues of overheating and air quality in London across multiple fronts through both adaptation and mitigation strategies. Linking with other cities that have taken such an approach would also facilitate a successful programme which can benefit from the skills, knowledge and lessons learned by others. For instance, the New York City's Cool Neighbourhoods NYC programme is one such example where London can make links.

## Appendix J – Management Case Supporting Commentary

The below sections provide further supporting commentary to the Management Case component of a five-case business case analysing the potential for a cool roof implementation plan.

*Programme*

Following this strategic phase, it is recommended in determining next steps, a developed timeline of cool roof intervention programmes (and potential projects) is set out to align stakeholders and key activities.

*Governance structure and project organisation*

The project organisation and governance structure for any future analyses and implementation workstreams will need to be developed to support the successful delivery of projects by ensuring that:

- The need for a project and the investment in resources required to implement it, must be developed within a clearly defined business case to ensure that there is a direct and clear connection between the parameters that define a capital project or programme and the commercial/social outcomes and benefits realised.
- The governance structure establishes a defined hierarchy of responsibility, with appropriate delegation of authority to enable lean project organisation that supports timely decision-making.
- The integrated implementation project team, including the whole ‘client’ team, project manager and wider delivery team of consultants, contractors and other suppliers must structure themselves into a virtual organisation with aligned and shared working practices and effective communication methods.
- An Investment Decision Maker (IDM) and the business criteria for making the investment decisions is defined clearly.
- A named individual with sufficient seniority within the implementation stakeholder is allocated to the role of Senior Responsible Owner (SRO). The SRO is to be accountable to the IDM for the successful delivery of the project or programmes and is empowered with the executive authority and resources to function.
- A named individual is allocated as the Project Champion who has sufficient knowledge of and experience around the intended Cool Roof implementation outcomes and benefits

*Risk Register*

As per the Government’s Green Book guidance, the management case is concerned with planning the practical arrangements for delivery or implementation. It identifies the organisation(s) responsible for implementation, when agreed milestones will be achieved and when the implementation will be achieved. It is required to demonstrate that a preferred option can be delivered successfully and includes the provision and management of the required resources for implementation. As part of the management dimension, a risk register is assembled. A high-level risk register in tabular form, still requiring further development in later project implementation stages, has been shown below.

| # | Identified During | Risk Title | Description | Probability | Impact | Risk Level |
|---|---|---|---|---|---|---|
| 1 | Report Compilation | **Non-Performance** | Risk that intervention fails to provide any cooling benefit or that performance is inconclusive. Risk that benefits to individuals could be minimal to warrant change | 2 | 4 | 8 |
| 2 | Report Compilation | **Cost** | Risk that, unless implemented with other retrofit strategies, interventions are too expensive | 2 | 4 | 12 |
| 3 | Project Inception | **Stakeholder Engagement** | Risk that stakeholders in a pilot project or in wider implementation fail to adopt or engage with suggested measures | 3 | 4 | 12 |
| 4 | Project Inception | **Material and Labour (Skills) Supply** | Risk of failure of suppliers to provide appropriate products and / or lack of availability of labour to install interventions | 2 | 4 | 8 |
| 5 | Report Compilation | **Funding** | Risk that necessary funding is not available | 2 | 4 | 8 |

*Management case (business case) next steps*

As this study has focussed on a technical evidence base for Cool Roofs' potential implementation, it is recommended that specific project organisation, governance structures, roles and processes required are further developed as required within the management case as required for a Strategic Outline Case stage, according to The Green Book methodology.

# Glossary

| | |
|---|---|
| **Capex** | Capital expenditures (Capex) are funds used by a company to acquire, upgrade, and maintain physical assets such as property, buildings, or equipment |
| **Cool roof** | A cool roof describes any roof that can stay cool in the summer by minimising solar absorption and maximising the amount of heat that is released or emitted from the roof. The cool roofs covered by this document are solar PV and reflective roofs |
| **Critical Success Factor** | Is an element that is necessary for a product or organisation to achieve its mission |
| **Materiality** | The concept or application of various materials or substances in the design of a building |
| **OpEx** | Operating expense (OpEx) is an ongoing cost for running a product, business, or system |
| **Reflective roof** | Roofs that have a surface finish that reflects more (and absorbs less) solar radiation than a conventional roof |
| **Reflectivity or albedo** | A measure of the ability of a surface to reflect radiation, equal to the reflectance of a layer of material sufficiently think for the reflectance not to depend on the thickness |
| **Retrofit** | Adding a component or new technology to something that did not feature when the system/asset was first manufactured |
| **Thermal mass** | The ability of a material to store, absorb and release heat |
| **Urban Heat Island (UHI)** | An urban or metropolitan area that is significantly warmer than the surrounding rural areas due to human activities |
| **Green roof** | A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It |

| | |
|---|---|
| | may also include additional layers such as a root barrier and drainage and irrigation systems. |
| **Blue roof** | A blue roof is a roof of a building that is designed explicitly to provide initial temporary water storage and then gradual release of stored water, typically rainfall. |

# Data Sources

## Data Sources for Cool Roof Opportunity Maps

Data used to produce the reflective roof opportunity map is shown in Table 14.

**Table 14 – Data Sources for reflective roof opportunity map**

| Data | Format | Author | Date |
|---|---|---|---|
| Statistical GIS boundaries – London | Vector (ESRI shapefile) | Greater London Authority | 2015 |
| TFL 350m grid hexagons | Vector (ESRI shapefile) | Greater London Authority | 2018 |
| OS Terrain 50 DTM | Raster (ASCII) | Ordnance Survey | 2021 |
| Sentinel 2 Albedo | Raster (TIF) | Copernicus | 2020 |
| Urban Atlas 2018 Land Cover Classification | Raster (TIF) | Copernicus | 2018 |
| OS Open Map – Local – Buildings | Vector (ESRI shapefile) | Ordnance Survey | 2019 |

Other data was obtained from the GLA Climate Vulnerability Map data (Bloomberg Associates, 2021) and includes: areas of deficiency in access to public open space, canopy cover, income deprivation, land surface temperature, English non-proficiency, elderly people, social renters, and young people.

The maps were produced using QGIS (Desktop Version 3.1.8.1) and FME Workbench (Version 2021, Safe Software)

*Data Sources for "Study: 2 the impact of reflective roofs on UHI in London"*

Key variables for the site data were updated from the sample data using imported datasets for London (listed in Table 15).

**Table 15 – Data Sources for UHI Model**

| Data | Format | Author | Date |
|---|---|---|---|
| Statistical GIS boundaries – London | Vector (ESRI shapefile) | Greater London Authority | 2015 |
| TFL 350m grid hexagons | Vector (ESRI shapefile) | Greater London Authority | 2018 |
| OS Terrain 50 DTM | Raster (ASCII) | Ordnance Survey | 2021 |

| | | | |
|---|---|---|---|
| Sentinel 2 Albedo | Raster (TIF) | Copernicus | 2020 |
| Urban Atlas 2018 Land Cover Classification | Raster (TIF) | Copernicus | 2018 |
| OS Open Map – Local – Buildings | Vector (ESRI shapefile) | Ordnance Survey | 2019 |
| LANDSAT 8 Surface Temperature | Raster (TIF) | NASA | 2020 |
| Curio Canopy | Vector (Geopackage) | Greater London Authority | 2018 |

The following variables were updated in the model inputs for the initial site data:

- Surface cover fraction
    - Since there are several surface types and no dataset that includes information on all of them, surface cover fraction for different surface types were extracted from different datasets (Table 16)
- Location data (longitude and latitude and altitude)
    - The coordinates are taken from the centre of each hex
- Mean building albedo
- Building height
- Hex area
- Average land surface temperature

**Table 16 – Data sources and processing for land cover fraction for the model land surface types**

<table>
<tr><th>Surface type</th><th>Data source</th><th>Processing</th></tr>
<tr><td>Buildings</td><td>OS Open Map – Local – Buildings</td><td>None</td></tr>
<tr><td>Water</td><td>OS Terrain 50 DTM</td><td>None</td></tr>
<tr><td>Deciduous Trees</td><td>Curio Canopy</td><td>Assumed 95% of trees are deciduous</td></tr>
<tr><td>Evergreen Trees</td><td>Curio Canopy</td><td>Assumed 5% of trees are evergreen</td></tr>
<tr><td>Grass</td><td>Urban Atlas 2018 Land Cover Classification</td><td rowspan="3">The data contains multiple land cover types which are grouped into paving, grass, and bare soil. This is used to obtain the relative ratios of grass, bare soil and paving which are then multiplied with the remainder of the hex (subtracting the buildings, trees, and water) to get the surface cover fractions.</td></tr>
<tr><td>Bare soil</td><td>Urban Atlas 2018 Land Cover Classification</td></tr>
<tr><td>Paving</td><td>Urban Atlas 2018 Land Cover Classification</td></tr>
</table>

The hex cell analysed was selected based on highest land surface temperature. The urban parameters of the hex are listed in Table 17.

**Table 17 – Parameters used for UHI Model Calculation**

| Parameter | Value |
|---|---|
| Longitude | 0.1552 |
| Latitude | 51.5149 |
| Altitude | 28.352581 [m] |
| **Land cover fraction** | |
| Paved | 0.18 |
| Buildings | 0.76 |
| Evergreen Trees | 0.00 |
| Deciduous Trees | 0.05 |
| Grass | 0.0 |

| | |
|---|---|
| Bare Soil | 0.0 |
| Water | 0.0 |
| **Albedo** | |
| Paved | 0.10 |
| Buildings | 0.21 |
| Deciduous Trees | 0.18 |
| Population density | 57.1 [people/ ha] |
| Average building height | 14.0 [m] |

### Forcing data

Energy balance and general hydrological models (including SUEWS) require data for hydrologically important variables including evaporation, soil moisture, and runoff. This data is referred to as forcing data or meteorological forcing data. The meteorological data used in the modelling was downloaded from Copernicus ERA5 (https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5) via https://shinyweatherdata.com/ as a csv for London in 2021.

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