Barking Riverside green roof experiment

Phase 1

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Barking Riverside Green Roof Research Project: Phase 1

1. Researchers, collaborators and Knowledge Exchange partners:

Project coordinator:

Name and title	Dr. Gyongyver Kadas,
Institution	University of East London
Address	Environmental Research Group, UEL, Water Ln., E15 4LZ
Telephone No	0208 223 4985
E-mail	gkadas@mac.com

Lead researchers:

Institution:	Researchers involved:
Living Roofs	Dusty Gedge
Environmental Research Group (ERG), University of East London	Dr Stuart Connop; Dr Gyongyver Kadas; Richard Lindsay; Melissa Marr
Sustainability Research Institute (SRI), University of East London	SRI Director: Darryl Newport
Institute for Sustainability	Jennifer Schooling

Collaborative partners:

Barking Riverside Ltd	Ian Millard/ Clive Wilding
ABG Ltd	Steve Humberstone
Consultant (Engineering)	Dr. Charles Fentiman (Expert in substrate composition and properties)
London Borough Barking and Dagenham (LBBD)	Jo Sinclair
London Thames Gateway Development Corporation (LTGDC)	Ian Short
Environment Agency	Marc Deeley
Bauder	Mike Jones
Eco-Green Roofing Ltd	Malcolm Bennett
Acclaim Contracts	Ian Duggan/Keith Gower

2. Project outline:

Our ever-increasing need for housing and associated infrastructure brings with it a growing expanse of impervious surfaces. This has several environmental consequences (White 2002). It results in rapid rainwater run-off and overloading of storm drains and increases the tendency of rivers to overtop their banks and flood surrounding land (Environment Agency 2002; Villareal *et al*. 2004; Mentens *et al*. 2006). It reduces the quantity of water held in the soil immediately beneath the hard surfaces. It reduces the possibilities for surface seepage to re-charge groundwater aquifers. It creates effective desert conditions for wildlife. These hard surfaces also significantly reduce the possibilities for contact with nature and thus they also result in a reduction in the health and well-being of our urban communities (English Nature 2003).

Extensive or intensive green roofs are a potential intervention for this problem. Establishing plant material on rooftops provides numerous ecological and economic benefits including water management (Mann 2000; Mentens *et al*. 2006), mitigation of the urban heat island effect (Ernst and Weigerding 1985; Von Stülpnagel *et al*. 1990; Bass *et al*. 2002), energy conservation (Takakura *et al*. 2000; Niachou *et al*. 2001) and it is also a positive step to promoting a sustainable community capable of supporting and enhancing biodiversity (Pickett *et al*. 2001; English Nature 2003; Schochat *et al*. 2006; Cadenasso *et al*. 2007; Hunter and Hunter 2008). To better understand the influence of roof type on each of these benefits, the University of East London's Sustainability Research Institute (SRI) and Environmental Research Group (ERG), Living Roofs, Barking Riverside, and the Institute for Sustainability are developing a research project to monitor the effects of varying substrate, substrate depth, drainage layer depth and vegetation cover of extensive green roofs on biodiversity, water attenuation and thermal dynamics.

3. Project's phase 1 goals and objectives:

The initial 12 months of the study will investigate ***the performance of a series of green roof test platforms in terms of their thermal dynamics, water attenuation, water quality of runoff, and flora and associated fauna when depth of aggregate, depth of drainage layer and initial vegetation cover are manipulated experimentally.***

4. Project work plan:

The initial phase of the research will be divided into four Work Packages, namely:

- WP 1 – Design and build: green roof structure.
- WP 2 – Experimental manipulation: drainage layer depth; substrate depth; vegetation cover.
- WP 3 – Environmental monitoring: thermal modelling; water attenuation; runoff water quality; biodiversity.
- WP 4 – Green roofing systems and policy implications.

WP 1 – Design and build – green roof structure

Under WP 1, 32 test platforms were designed in which green roof structural elements could be manipulated and their performance assessed (Figure 1). These platforms have since been constructed at Barking Riverside offices (51:31:12N, 0:07:09E). Each test platform measures approximately 2m x 1m and is a regular subset of the constructed test platform as a whole (Figure 2). All platforms are identical in terms of size and depth. The depth of each platform is approximately 200mm, focussing the investigation exclusively on extensive green roof systems.

The test platforms are situated on the roof of transport containers to replicate the conditions of a standard green roof (Figure 3). A waterproofing layer has been added to each test platform, as standard for green roofs. Design of the platforms was based on German FLL green roof standards to enable compatibility of test criteria with other research elsewhere.

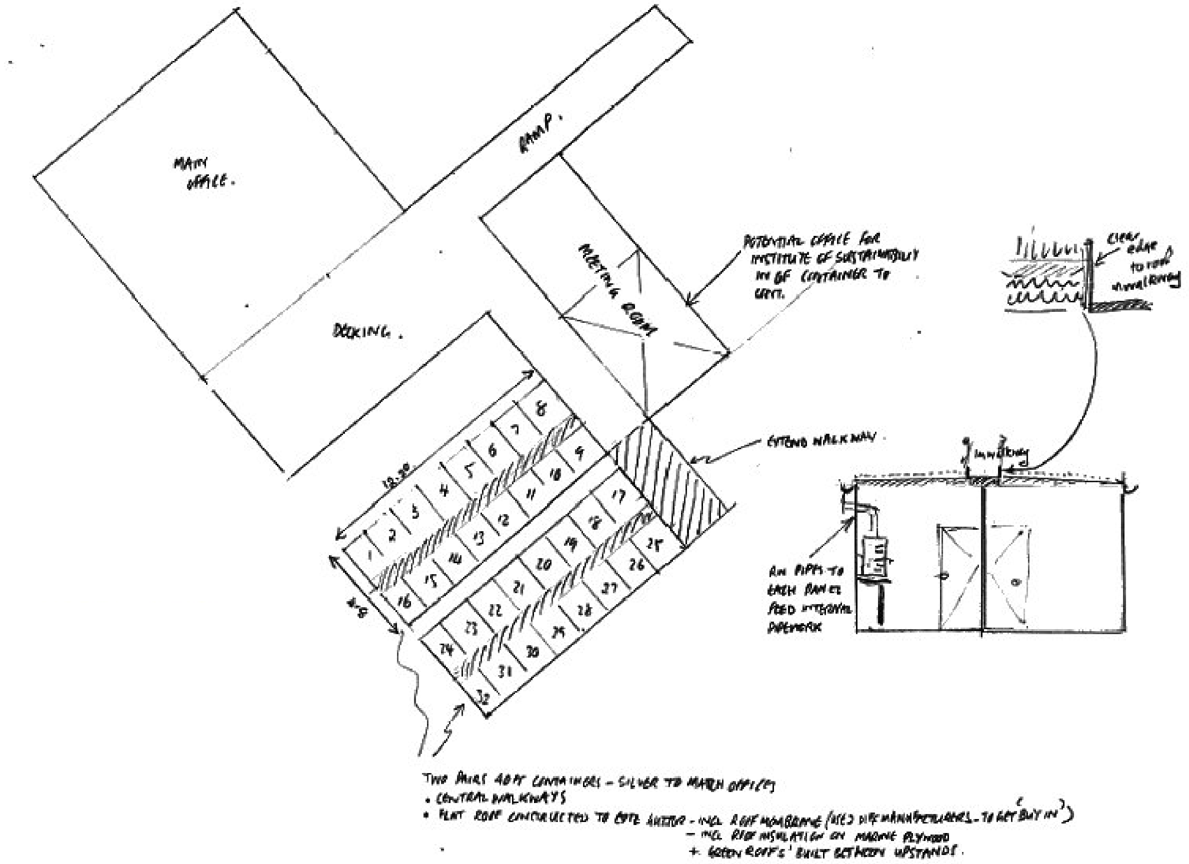

Figure1. Plan of test platform layout.

Figure 2. Green roof test platforms constructed at Barking Riverside offices.

Figure 3. Test platforms situated on metal cargo containers to replicate roof conditions.

WP 2 – Experimental manipulation: Drainage layer depth; substrate depth; vegetation cover

WP 2 involves the incorporation of experimental design into the installation of the green roofing structural elements (Figure 4) in order to enable assessment of best practice. For the purpose of research phase 1 the design elements being investigated are:

- Drainage layer depth;
- Substrate depth;
- Vegetation cover.

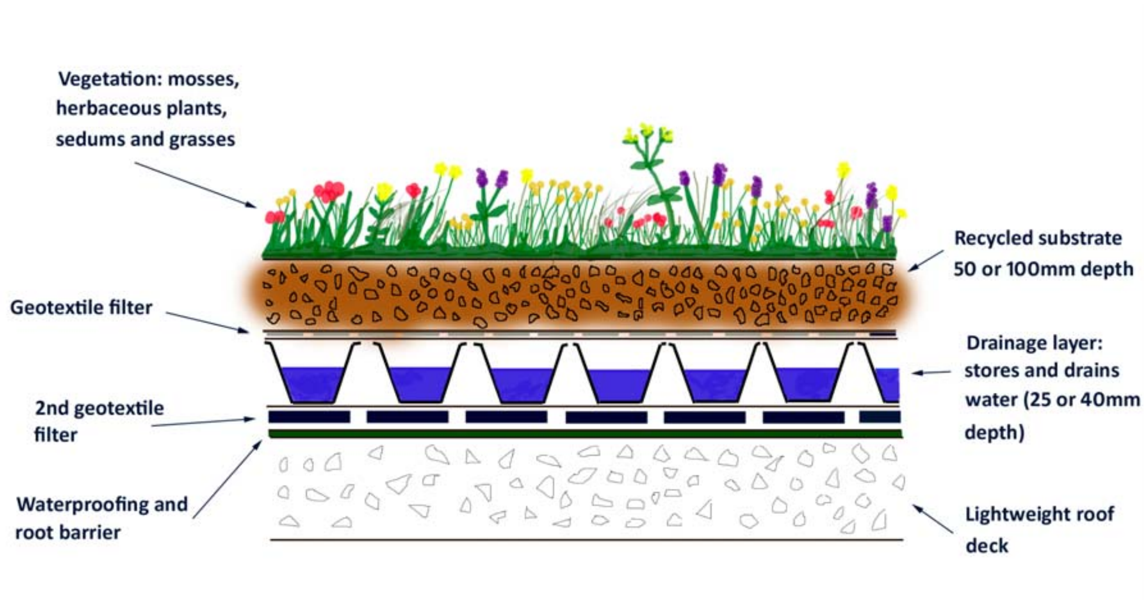

Figure 4. Typical design features of an extensive green roof (© Stuart Connop).

The aforementioned green roof elements will be manipulated to assess best practice as follows:

i) **Drainage layer depth** – two drainage later depths will be trialled: a 25mm drainage layer and a 40mm drainage layer. ABG Geosynthetic FINESSE ROOFDRAIN systems are being used throughout for the phase 1 study to ensure uniformity of experimental design. These drainage layers are made of ~90% recycled material. This includes a layer of polypropylene water reservoirs between two geotextile layers. Water reservoir volumes are 5.5 L/m^2 for the 25mm drainage layer and 12 L/m^2 for the 40 mm drainage layer.

ii) **Substrate depth** – two substrate depths will be trialled: a 50mm substrate depth and a 100mm substrate depth. An ABG Geosynthetic ‘meadow mix’ recycled aggregate blend is being used throughout for the phase 1 study to ensure uniformity of experimental design. The aggregate blend comprises 100% recycled material. This is based on a specially matured and graded green compost to provide optimal stability and minimal leaching of organic matter and nutrients, plus carefully selected and graded clay aggregate: recycled from clean brick and tile.

iii) **Vegetation cover** – two vegetation regimes will be trialled: sedums and wildflowers. The sedums will be plug-planted with five plugs of each of six sedum species distributed evenly across each test platform. The wildflower cover will comprise a mix of plug-planting, bulbs and seeding. Plug-planting will comprise five plugs of each of the following species: birdsfoot trefoil; small scabious; wild thyme; wild basil; common toadflax; autumn hawkbit; kidney vetch. Position of the plugs will be grouped by species but the position of each group will be randomised within the test platform. Position of each group of plugs will however be replicated between platforms. Bulb planting will comprise of two bulbs of each of: bluebell; wild daffodil; wild tulip; crocus. These will be grouped and randomised within the plug layout. Seeding will comprise of a standardised weight of the Livingroofs Meadow Mix: agrimony; kidney vetch; common knapweed; viper's-bugloss; lady's bedstraw; perforate St John's-wort; field scabious; rough hawkbit; oxeye daisy; common toadflax; bird's-foot-trefoil; musk-mallow; wild marjoram; hoary plantain; cowslip; selfheal; meadow buttercup; bulbous buttercup; wild mignonette; salad burnet; bladder campion. Seeds will be scattered evenly across each test platform.

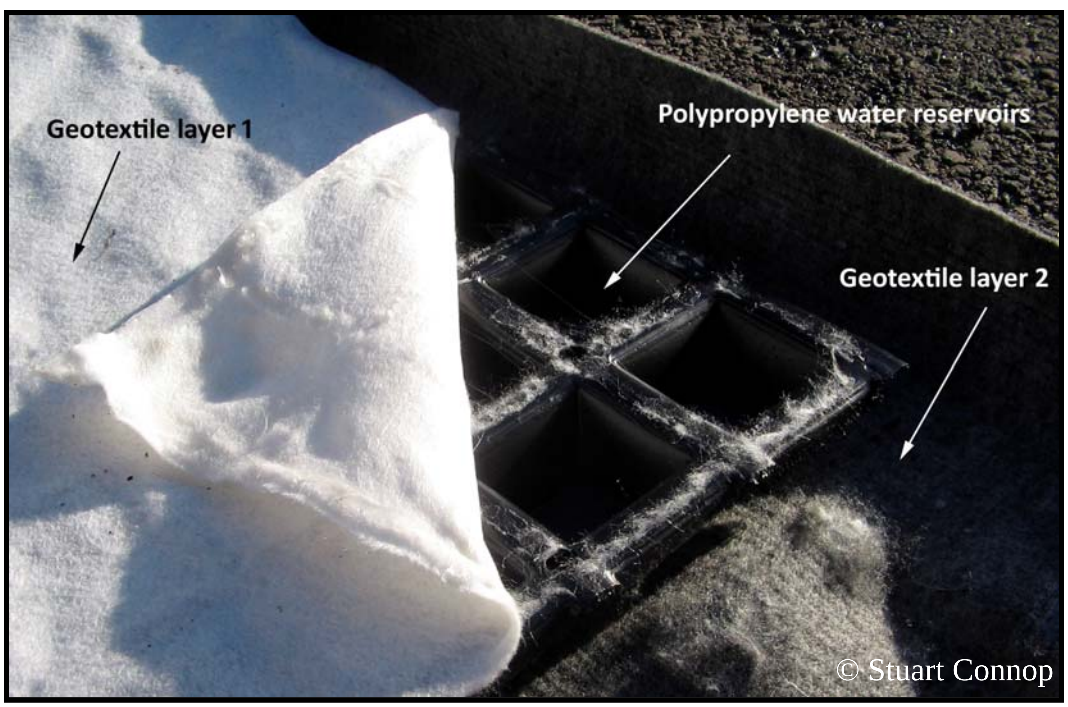

Figure 5. ABG Geosynthetic FINESSE ROOFDRAIN green roof drainage layer.

Each combination of design elements (e.g. 25mm drainage layer with a 50mm substrate layer and sedum cover) will be replicated three times within the test platform layout to ensure that scientifically robust data is generated by the study. Three test platforms will also remain empty to act as a control in the absence of green roofing features. The layout of each green roof treatment and the controls will be randomised across all of the test platforms to remove any effect of position within the test set-up on green roof performance.

WP 3 – Environmental monitoring: thermal modelling; water attenuation; runoff water quality; biodiversity

Green roof test platforms will be monitored to assess the effects of manipulating these design elements on roof performance in terms of:

- Thermal dynamics of the roofing system (insulating and cooling properties);
- Water attenuation (water retention and run off rates);
- Water quality of runoff (with a specific focus on grey-water recycling);
- Value for biodiversity (floral cover and colonisation by bees, spiders and beetles).

The aforementioned environmental parameters will be monitored to assess best practice as follows:

i) **Thermal dynamics** - thermocouples will be used to measure heat flow through the roof envelope (Figure 6):

  - above the roof;
  - at various depths in the growing substrate;
  - inside the structure.

  This will enable an evaluation to be made of the influence of roof vegetation, substrate depth and drainage layer depth on roof temperatures and heat movement into and out of the structure. This will provide information on the best results for energy saving.

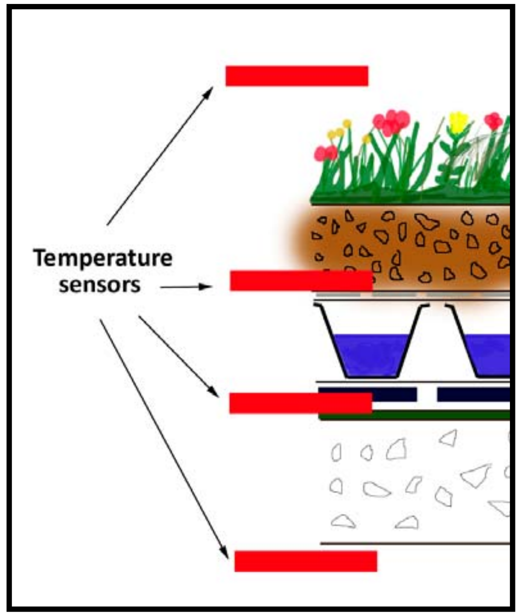

Figure 6. Position of thermocouples throughout the green roof test platform layers (© Stuart Connop).

ii) **Water attenuation** - water meters beneath each test platform (Figure 7) will measure the water retention values and run off rates to evaluate the influence of roof vegetation, substrate depth and drainage layer depth on water attenuation. Results will be compared to the control platforms (those with no green roof features) to assess water attenuation in comparison to total rain falling on the platforms.

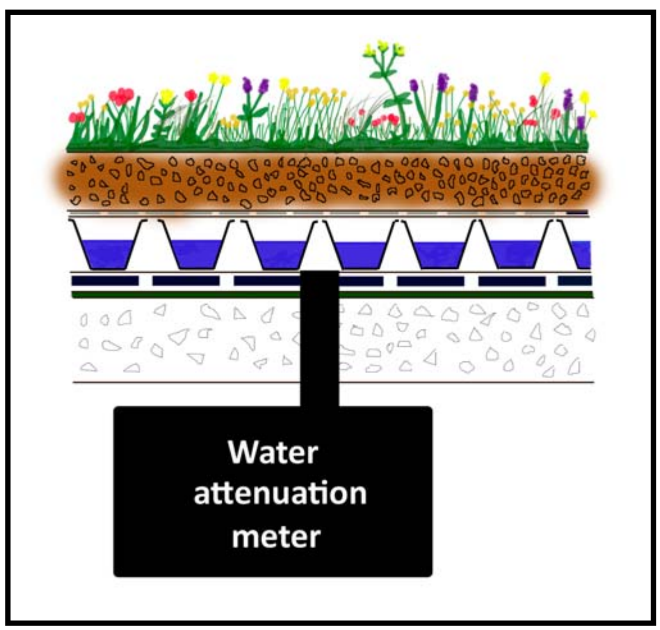

Figure 7. Position of water attenuation meter beneath each green roof test platform (© Stuart Connop).

iii) **Water quality** - water samples will be collected from the water attenuation meters and water chemistry analysis will be carried out to assess the effects of roof design elements on water quality. Initial water quality criteria will include:

- pH;
- conductivity;
- nitrates;
- phosphates;
- ammonia.

iv) **Biodiversity** - test platforms will be surveyed to assess the effects of substrate depth and drainage layer depth on the development of sedum and wildflower roof vegetation. Assessment of each roof's value in terms of supporting regional biodiversity will also be carried out through a series of invertebrate surveys. Surveys will record and quantify all invertebrates present, targeting certain important groups noted in the UK Biodiversity Action Plan and Natural England's Species Recovery Programme, including Aculeate Hymenoptera (bees), Coleoptera (beetles) and Arachnida (spiders). By quantifying invertebrates it will be possible to derive fundamental principles regarding the design of green roofs to maximise biodiversity value, in particular those associated with brownfield sites. Barking Riverside is situated in the heart of the Thames Gateway, a region of national importance for many rare and declining UK invertebrates such as the brown-banded carder bee (Figure 8). It is thus an ideal location for such investigation.

Figure 8. Brown-banded carder bee. A UK Biodiversity Action Plan species local to Barking that could benefit from green roof development.

WP4 – Green Roofing Systems and Policy Implications

This work package will investigate the various social, economic, environmental and cost implications associated with green roofing systems. It is well known that green roofing systems imply energy cost savings (both, heating and cooling costs) and consequently trigger a reduction in carbon dioxide production through the provision of a thermal insulation. Benefits within a social and ecological perspective further include the provision of a valuable wildlife habitat assisting in meeting local, regional and national biodiversity targets, as well as beautifying the city environment for its citizens through the creation of additional green spaces. WP 4 will also examine the various cost implications associated with the installation of green roofing systems, in particular with regards to additional engineering requirements and development.

5. Project phase 2 and beyond

With the roof test platform facility constructed during WP1 at Barking Riverside, it is intended that further research into best practice for green roof design will be carried out at this research facility beyond the first phase of the research plan. It is hoped that this will include research into:

i) Recycled aggregates

Green roofs provide an ideal opportunity for the widespread use of recycled aggregates. During the second phase of the Barking Riverside green roof experiments it is anticipated that aggregates formed through a mix of recycled material of both porous and non-porous aggregates will be tested to assess their suitability as growing medium. The aim will be to deliver commercially acceptable recycled green roofing substrates able to support and enhance sustainability and biodiversity**.**

In order to deliver intensive, commercially acceptable green roofing systems, growing substrates must be lightweight, permanent, able to sustain plant health without leaching nutrients which may harm the environment, and capable of supporting and enhancing the natural development of biodiversity. The research will endeavour to create green roof substrates which meet the German standards in terms of water retention and technical specification, but which also eliminate the need to use artificial fertilizers in the substrate.

Initial testing will determine optimum material blending for the use of recycled material as a substrate. A range of different substrates/aggregates will be installed on the green roof test platforms. They will be tested in terms of their water retention values, thermal dynamics, runoff water quality and ability to support biodiversity, in particular vegetation cover. Blends of local provenance, devised from secondary aggregates from within London/Barking Riverside will be prioritised for testing to reduce the environmental impacts of transporting associated with local green roof development.

ii) Enhancement for biodiversity

Once best practice for green roof design has been established in terms of structural design elements and recycled aggregates, further research into best practice for the enhancement of the roofs value in terms of supporting biodiversity will be investigated. This will include investigation of:

- the benefits of creating small-scale structure (micro-relief and micro-habitats) across substrate surfaces to generate increased niche development and consequent enhancement of biodiversity. This could include varied substrate size, depth and type. A further aim will be to monitor the small-scale variation in surface topography in terms of microclimate conditions to establish the function of such microtopography in relation to the creation of niche diversity, thereby enhancing biodiversity.

- the creation of ‘clonal’ varieties of recommended herbs/wildflowers for green roofs/biodiversity specifically developed for use on green roofs. A focus will be put on the relationship between known ecological behaviour and establishment success across a range of appropriate green-roof species.

6. Overall project outputs:

It is intended that the three main outputs of the research project as a whole will be:

1. Develop Local Business Opportunities for London Based SMEs

Enabling product development for London-based SMEs engaged in green roof process and production. We are working with both Living Roofs and Eco-Green Roofing Ltd to enhance their product offer.

2. Promoting Knowledge Transfer

The most important output from of the research will be a range of information, which can underpin and inform policy-making and the development of a set of standards for UK-wide green roofing systems. In association with Barking Riverside we will provide a high-profile research facility supplying clear and practical guidance for green roof development through knowledge transfer.

This will be achieved through delivery of our findings in scientific journals and conference papers. In addition, local knowledge exchange events will be provided for local planners, developers, recycled aggregate producers and green roof companies in the form of workshops on-site, in collaboration with Barking Riverside.

3. Integration with, and enhancement of, green space

The Thames Gateway London Partnership (TGLP) has a vision for the East London Green Grid defined by five key objectives designed to establish sustainable living and enhanced quality of life through the extensive use of green infrastructure. Development and adoption of green roof design principles supports and significantly enhances all five of these key objectives. In particular it offers the potential to add significant green-space within the built environment. This directly enhances quality of life associated with such built environments, and also offers substantial benefits in terms of enhancing the established green-space and parkland.

Green roofs and associated structures not only add to the total area of green-space and parkland, but also provide important biodiversity-friendly corridors and stepping stones, thus enabling wildlife connections to be established and maintained between areas of parkland. In addition, a network of green roofs reduces the total area of hard surfaces within the built environment. As such, it not only reduces flood risk, but also acts as a resource for water management and cleansing.

7. Our aim

It is intended that the research facility will also act as a visual statement of the commitment being made by Barking Riverside Development to green-roof research, technology and adoption. The facility will form an important and much-needed source of information and guidance for design teams, developers and public bodies.

Besides supplying policy makers, engineers and designers with new insights into best practice guidance and management of green roofing systems, the specific research outcomes will further serve to inform the wider public about the various social, ecological and economic benefits represented by green roofs in the development of a sustainable environment, particularly within the space of the city.

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Project partners