Case Study

July 2012

9. Green and Brown Roofs

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9.1 Introduction to the technology

Green roof on Chicago City Hall, November 2008

A green roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. Green roofs are also referred to as eco-roofs, oikosteges, vegetated roofs or living roofs.

A brown roof is similar but the overall aim is to increase biodiversity, and often aim to provide a home for local plants that may have been displaced by the build.

Example of a brown roof from Norðragøta, Faroe Islands, from July 2006

A brown roof usually has a more complex structure than a green roof to provide a more diverse range of habitats. These may include:

- Specific plants local to the area,
- Water and wetland areas for mosses and lichens,
- Logs to provide a habitat for insects and other invertebrates,
- Boulders, sand and stones to increase the range of habitats, and
- Land forms created to provide different landscape levels.

A prime example of a brown roof being effective is that rare Northern Lapwings are breeding on a Swiss factory roof.

Because the prime difference between brown and green roofs is generally about plant diversity, both are referred to as green roofs in this study. Generally the issues and benefits are the same.

Green roofs benefit a property by:

- absorbing rainwater, so alleviating flood issues
- providing increased insulation
- protecting the underlying roof and waterproofing, possibly extending the lifetime of the roof
- creating a habitat for wildlife, frequently in an urban environment
- benefitting specific species, such as than may benefit from protection (brown roof)
- maximising biodiversity (brown roof)
- lowering urban air temperatures and mitigate the heat island effect
- being attractive
- improving local air quality.

Green roofs may be pitched or flat. Pitched green roofs have a lower risk of water penetration but an increased risk of landslides. The maximum angle is thought to be about 35^{O}.

The term green roof may also be used for roof gardens (i.e. a garden of pots or containers), roofs with some form of green technology (e.g. cool roof, solar thermal collectors or photovoltaic panels), or roofs with ponds to treat grey water. These are outside the scope of this study.

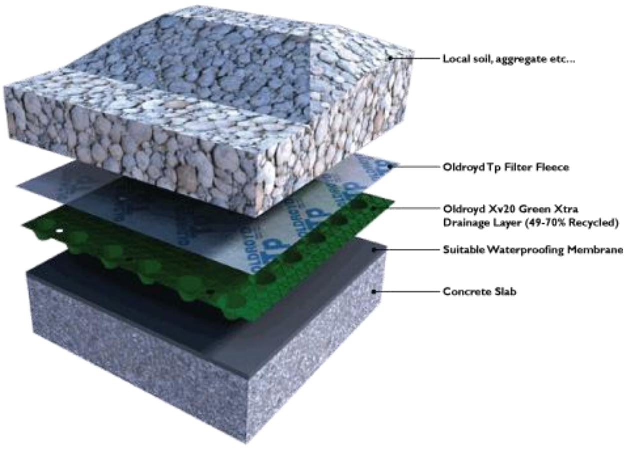
In Germany, about 10,000,000m^2 of new green roofs are being constructed each year. Germany is the leading EU nation to adopt this eco-technology.

9.2 Available types of this technology

Green/brown roofs are effectively a layer of soil populated by plants, for example grasses and sedums, over a water-proof membrane. There are two broad types:

- extensive roofs, which are covered in a light layer of vegetation, are lighter and are generally left alone, and
- intensive roofs, which are thicker to support a wider variety of plants so are heavier and require more maintenance. These are more normally brown roofs.

Construction



A green roof is typically built up of five layers. From the top:

Layer 1 - Substrate. The top layer is made up of plants and soil. Soil may be imported, but for a brown roof, soil is ideally taken from the local environment and there may also be a range of other features (e.g. ponds, logs, concrete or gravel to increase the range of habitats and thereby encourage more species and increased biodiversity.

The range of plants on a green roof is usually limited to one or two species and it is often seeded during construction. Typically, the plants are sedum, sempervivums or grasses. Dwarf grasses will require less maintenance and be less dominant allowing for other species to colonise. Brown roofs are usually planted with local plants by using local soil but can take up to three years to establish.

Layer 2 - Filter or separation layer. This layer prevents fine particles from the substrate collecting in the lower drainage layer. This layer must not clog as this reduces drainage and therefore the effectiveness of the roof.

Layer 3 – Drainage layer. This manages the water in the roof. For a brown roof, it may be a plastic sheet, embossed with water retaining cups. Once the cups fill, the excess water drains through and away on the next layer beneath. An alternative may be an aggregate, but this can add considerably to the weight of a roof.

Layer 4 – Water proof layer. This may also be a root proof layer. Clearly this layer must be effective and have a life expectancy that matches the roof. It is vital it is flood tested and known to be secure and water proof.

Layer 5 - Base layer. This is a supporting layer which must be sufficient to take the weight of the roof.

Cost-dependency

Pricing varies by roof size, with the business case for small roofs, especially a retro-fit, being poor at present. Typical costs (in the UK, 2012) range from £185/m^2 for a small roof to £55/m^2 for a larger (commercial) build. Self-build is also possible.

Costs are dependent on:

- the height of the roof (cranes may be needed to lift to the roof)
- green vs. brown
- roof features (e.g. roof lights, etc.)
- waterproofing needed
- the choice of plants
- colonisation
- annual inspections and maintenance.

There may also be cost benefits or savings:

- By extending roof lifespan
- By fuel saving – due to increased insulation
- By avoiding the need for alternative equipment during construction,
- By reducing drainage requirement as floods may be avoided
- By allowing the use of local aggregates

Brown roofs can be £10 - £12 per square meter more expensive than green roofs. This is because they tend to be more substantial and require more maintenance while the local species are establishing.

Maintenance

Green roofs require inspection or maintenance for 2 reasons:

- To detect compromise of the water proof layers
- To prevent monocultures being established, and maintain biodiversity.

The growth of invasive plant species, which can form monocultures and reduce the plant and animal diversity, is a common problem. Invasive species include rhododendron (which can poison the soil so other plants cannot grow), buddleia, Japanese knotweed, giant hogweed, Himalayan balsam, cotoneaster and many more. The solution is to carry out regular visits, usually twice a year.

9.3 Strengths, weaknesses, opportunities and threats

This section outlines a discussion of the key drivers effecting green and brown roofs.

Strengths

- Providing green spaces in urban areas.
- Encouragement of biodiversity.
- Attractive visual appearance.
- Filtering of water to remove pollution.
- Reduction of rainwater run-off.
- Reduced 'urban heat island' effect.
- Increased roof insulation.
- Enhanced roof lifespan by protecting underlying waterproofing system and by reducing stress (temperature changes, etc.,) on the roof.
- Increased sound insulation (eg. if under a flight path).
- No planning permission is needed (UK).

Weaknesses

- Risk of damage due to increased dampness, ponding, acidy, plant roots, etc.
- Maintenance of water integrity is vital. Weaknesses include abutting walls and perimeters, as well as the drainage and water proof layers.
- Chemical run-off from a green roof may include pesticides or other waste from the construction.
- Irrigation may be needed in some environments, depending on the choice of plant and local climate. This may be countered by selecting local plants that can survive extended dry periods.
- Susceptibility to high winds that can damage the plants by uprooting and by increasing de-hydration and frost.
- Only a small financial benefit to households, such as reduced energy costs. Unlikely to pay back extra build costs.
-

Opportunities

- Increasing legislation to encourage green roofs as part of flood management and sustainability. For example, in the UK, *"Living Roofs and Walls: Technical Report to Support the London Plan"*, has led to a policy to encourage green roofs.
- Changing patterns of rainfall leading to a need to change and adapt flood prevention systems. It is estimated that living roofs absorb a third of rainwater, as well as attenuating the rate of run-off.
- Cooling effect of green roofs can cause photovoltaic panels installed on green roofs to operate slightly more efficiently.

Threats

- Climate change may affect the dryness and effectiveness of green roofs, in particular in southern EU countries.
- Climate change may affect wind patterns and damage roofs.

9.4 Building pathology, defects, and what can go wrong

9.4.1 Invitations to complete questionnaire

An invitation to complete the online version of the Elios II questionnaire was sent to 374 individuals in the following industry sectors:

TABLE 9.1 – Invitations to complete questionnaire

Sector	***Number sent***
Insurance	64
Certification Bodies	10
Accreditation Organisations	4
Builders/Installers	55
Manufacturers	74
Trade Associations	27
Professional Institutes	19
Architects	14
Quantity Surveyors	2
Other	4
Building Inspection Services	13
Government Organisation	22
Housing Associations/Commissioner	16
Consultancies	15
Merchant/retailer	5
Unknown	30
Total	374

In total 70 respondents completed some or all of the questionnaire. This is an 18% response rate.

9.4.2 Responses received

At the closing date of 1st October 2012, 11 responses had been received which related specifically to green roofs. This is approx. 16% of the received questionnaires. The industry sectors of the respondents were as follows:

TABLE 9.2 – Responses

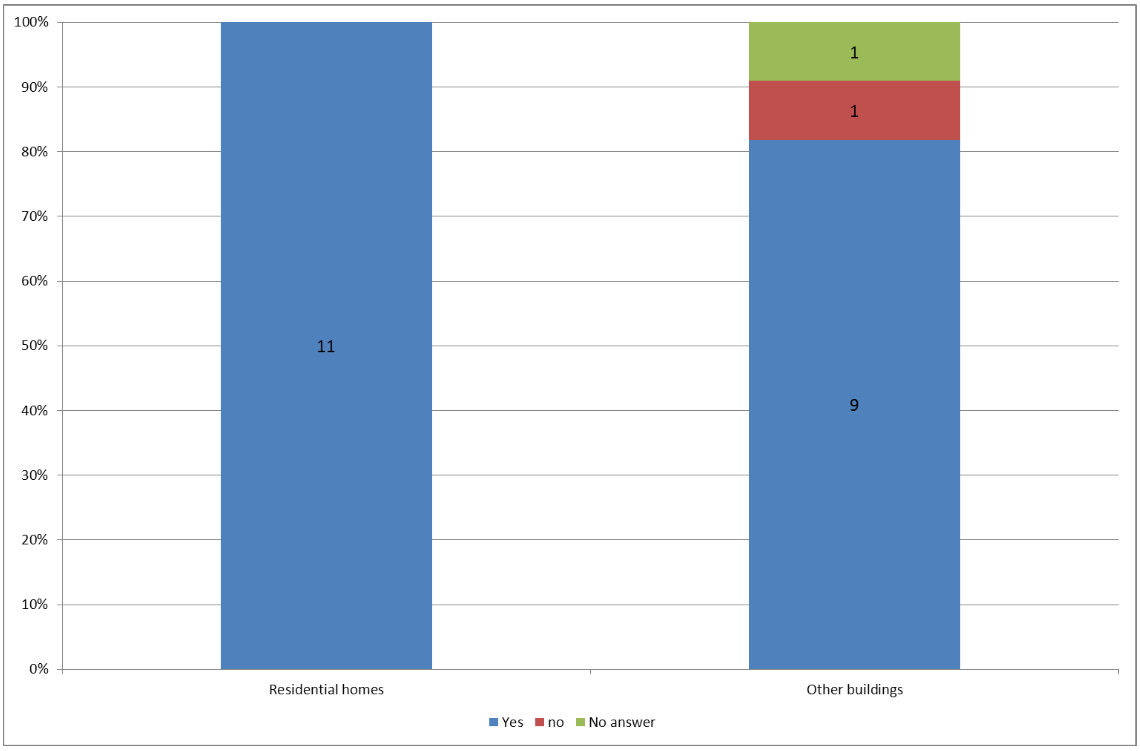
Sector	***Responses received***
Government organisation	2
Architectural practice	0
Housing organisation	0
Manufacturer	1
Retailer/merchant	0
Construction company	1
Installer	1
Building inspection service	3
Certification organisation	4
Insurance company	4
Trade association	0
Professional institution	0
Other (please specify)	3
Business in more than one	5
Total	***24***

Note that some businesses are in more than one sector. Five respondents gave specific detail and counts of installation, claiming to have data relating to 206 installations of the technology, of which 30 (15%) were said to have experienced failures or defects.

The following graphs and charts only relate to the people who responded about this technology.

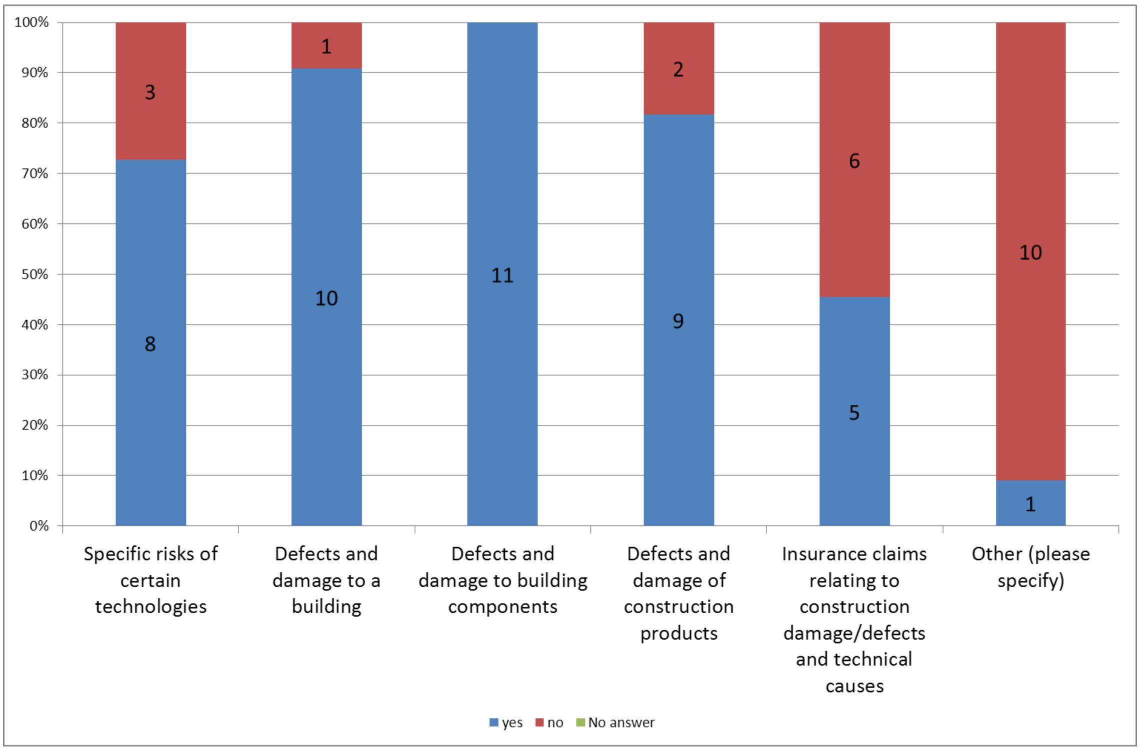
CHART 9.3

Question asked – *"Does your organisation collect or collate its own data on these types of buildings?"*



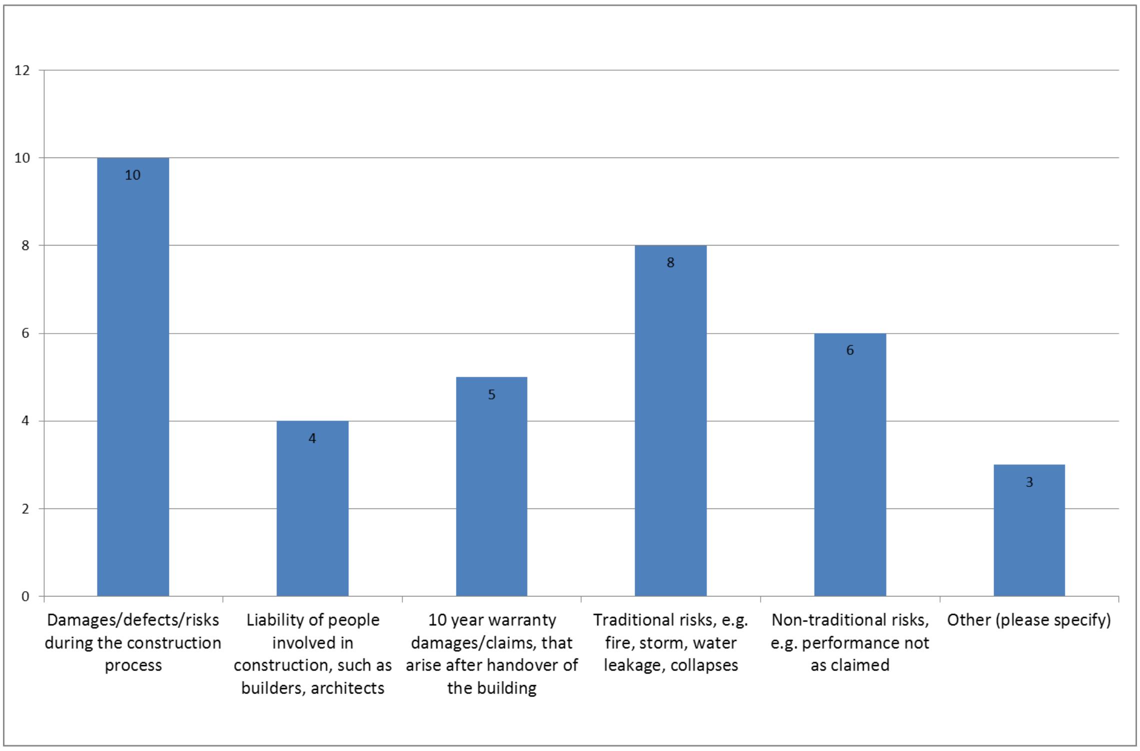
This chart shows the number of reporting organisations that collect data on each type of property. This is only for this eco-technology. Organisations may collect data on more than one type of property.

CHART 9.4
Question asked –*"Does your organisation collect its own data on these issues (please tick all that apply)?"*



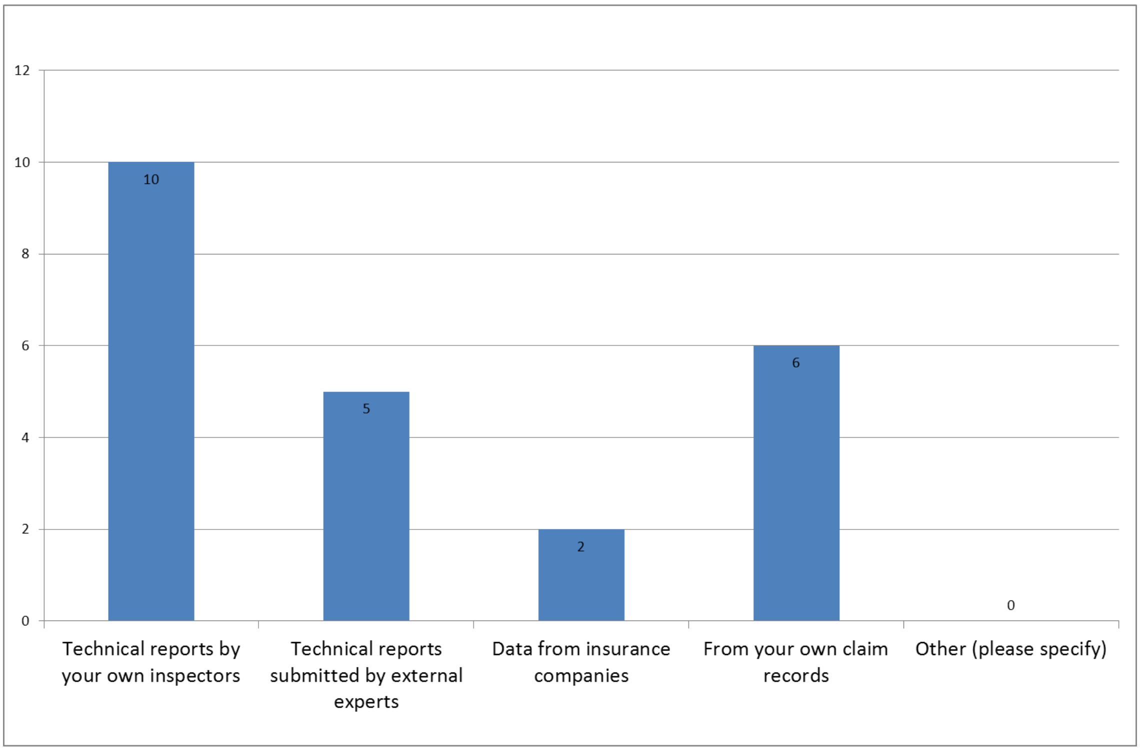
This chart shows the various reasons that the reporting organisations collect data, and the number of organisations that gave each reason. This is only for this eco-technology, and not for all 10 technologies. Organisations may collect data for more than one reason.

CHART 9.5
Question asked – *"What kind of damages/defects do the data refer to (please tick all that apply)?"*



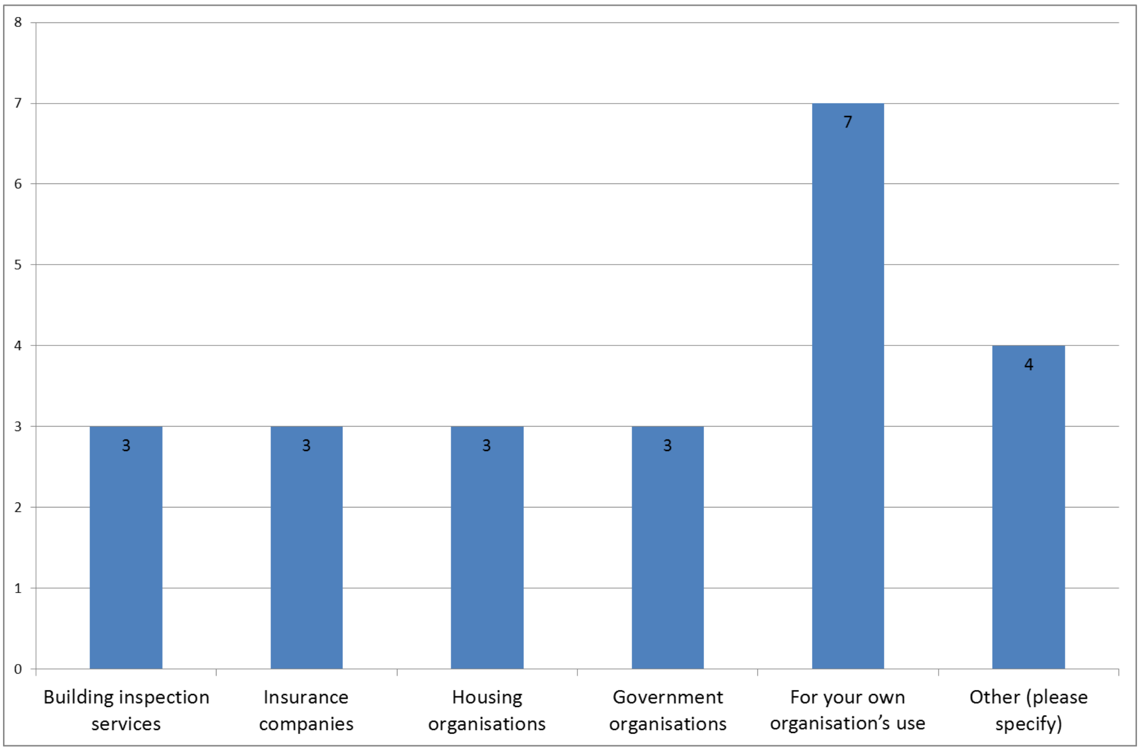
This chart shows the number of organisations that reported each kind of damage on which they collect data. Each column represents a different type of damage. This is only for this specific eco-technology, not overall. Organisations may collect data for more than one reason.

CHART 9.6
Question asked – *"How do you collect the data (please tick all that apply) ?"*



This chart shows the method by which each organisation collects data; each column represents a different method of data collection. This is only for this eco-technology, not overall. Organisations may collect data for more than one reason.

CHART 9.7
Question asked "*For whom do you collect the data (please tick all that apply)?*"



This chart shows the number and type of organisations that reported that they collect data about this eco-technology. Organisations may collect data for more than one type of organisation.

9.4.3 Summary of responses about databases

About their database:

- Of the 10, 7 have a database; 3 do not;
- 4 provided a date from when data collection started:
  - 1967, 1970 and 2 in 1990;
- 5 carry out statistical analysis of the data;

About data publication:

- 4 make data available on the web;
- 2 in newsletters;
- 3 in other publications;

About the availability of data, of these 10 respondents:

- 9 publish summary data only;
- 3 publish raw data in any form;
- 4 publish raw data, but made anonymously;

4 comments were passed, about data as follows:

- *"Confidential to ourselves and the providers - used to inform various services and policy."*
- *"It is usually only seen by the client."*
- *"Publically to house builders not general public on defects"*
- "Only the results of research work."

Finally, note that this question was answered in general about all 10 eco-technologies and may not apply to the specific technology.

9.4.4 Reasons for failures and defects

The reported reasons for the failures and defects were as follows:

TABLE 9.8

Reason for failure/defect	Number	% of total
Requirement management		
Change in client's requirements	0	0.0%
Misunderstanding of the effectiveness of the technology	0	0.0%
Poor project management	3	1.5%
Inaccurate engineering or architectural data	0	0.0%
Delivery		
Late delivery	0	0.0%
Storage issues	0	0.0%
Awkward packaging	0	0.0%
Poor transport of product	0	0.0%
Installation		
Incorrect design for installation	6	2.9%
Incorrect installation documentation	0	0.0%
Failure in installation	13	6.6%
Commissioning failure	0	0.0%
Operational failure		
Product failure once installed	9	4.6%
Incorrect user documentation	0	0.0%
Misuse of product by end-user	1	0.5%
Performance not as claimed	6	3.0%
Other		
No other reasons were given for failure		
Total		

Note that an installation may have had more than one reason to fail.

9.4.5 Failures/defects commentary

The respondents offered the following general comments and suggestions on the ways in which the failures and defects might be avoided in future:

TABLE 9.9

Reason for failure/defect	Commentary
Requirement management	
Change in client's requirements (a)	
Misunderstanding of the effectiveness of the technology (b)	
Poor project management (c)	Compliance with the GRO[1] Code and understanding that a green roof is a living thing that can not be abused. A green roof requires a[n] integral design for the build up of the roof. Also ~~here~~ the air tightness of the roof box is very important to avoid internal condensation problems.
Inaccurate engineering or architectural data (d)	
Delivery	
Late delivery	
Storage issues	
Awkward packaging	
Poor transport of product (h)	

[1] GRO – Green Roof Organisation

Installation	
Incorrect design for installation (i)	Improved training of specifiers specific to green roofs, use of the GRO Code. Design better detailed specially for singular points of the roof
Incorrect installation documentation (j)	
Failure in installation (k)	Improved training of installers specific to green roofs, not roofers 'having a go'. Find contractor who really knows about them Careless build up of the roof box.
Commissioning failure	
Operational failure	
Product failure once installed (m)	Improved understanding that green roof materials are engineered solutions, not 'cheap' waste. Damage due to not following specific application requirements.
Incorrect user documentation	
Misuse of product by end-user	Incidentally, for example: installing roof windows, additional penetrations, etc.
Performance not as claimed	Compliance with GRO Code recommendations.
Other (specified)	

There were three general comments:

- Difficult to put actual numbers against the above questions without going through all our files as there is no database of information in existence. Problems are generally caused due to items a, b, c, d, h, i, j, k and m especially i & j due to many roofing contractors installing green roofs without any horticultural knowledge. Happy to discuss specifics with a member of the survey team.

- General anecdotal information about costs of maintenance and attack by vermin

- Most green roofs don't 'fail' if they have been wrongly installed or specified, they just don't perform to their full potential OR they do not fore fill the clients expectations. A badly installed green/brown roof will still deliver some benefits. However super shallow (less than 80mm depth - GRO Code 2011) light weight vegetated roofs are prone to fail, dry up and die - resulting in no benefits. This can be overcome by longterm irrigation, but irrigation is neither sustainable or particularly reliable. Most green/brown roof 'failure' or lack of performance, is due to poor water management. Either the roof drains too fast or not fast enough.

9.4.6 Key findings

In summary:

- The most significant failures (6%) would appear about installation issues. They imply that the design and construction is inappropriate to get the best from this technology. These may be about the lack of knowledge of making the “roof box” i.e. layer 5, watertight.

Lessons:

- Improve training for builders and installer.
- Raise awareness of the 2011 GRO (Green Roof Code).
- Perhaps consider creating an accreditation scheme for builders/roofers based on the GRO.