Case Study

July 2012

1. Photovoltaic Panels (PVs)

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1.1 Introduction to the technology

Photovoltaics (PVs) are a renewable energy technology which generate electricity when exposed to direct or diffuse sunlight. They can be integrated into buildings in various ways – on sloping or flat roofs, in atria, in facades or as part of a shading device. They differ from other renewable generation technologies in that they have no moving parts and have corresponding noise and maintenance benefits.

Individually manufactured PV cells are mounted in frames (panels) and connected together to provide a direct current (DC) output. In order to convert this DC into an alternating current (AC) supply suitable for export to the electricity grid, an electronic inverter and other switchgear is needed. Inverter equipment can represent up to 50% of the cost of the whole system.

When a PV panel is partially overshaded (for example by a tree or adjacent building), its output can be significantly reduced. Moreover, if that panel is connected in series with other panels, as is often the case, the output of the entire string of panels will be similarly affected even if only the one panel is shaded. This effect can be mitigated by using a number of micro- (or 'unitary-') inverters, essentially one per panel, but capital costs will increase as a result.

The capital and installation cost of a PV system can often be offset by savings made in the building cladding material which they replace. At the time of writing, capital costs are falling rapidly, mainly as a result of state subsidies/grants for the exported electricity ('feed-in tariffs'). Caution is urged when making investment decisions, however, as such subsidies can be reduced or removed at very short notice.

As a rule of thumb, 1m^2 of PV panels has a peak output of 0.1–0.15 kW, which will generate 80-120 kWh per annum (typical UK figures). The size of a PV installation is only constrained by the area of roof (or other building elements) available for installation, and the capital budget.

Depending on type, PV panels have an expected lifetime of 25-40 years, although inverters have a typical lifetime of 15 years.

1.2 Available types of this technology

Photovoltaic panels are currently based on one of the following types of semiconductor technology:

- **Monocrystalline**. Individual cells consist of a slice of a single crystal, most commonly silicon. Relatively expensive and energy-intensive to manufacture, but have the highest conversion efficiency (14-19%).
- **Polycrystalline**. Cells are produced from slices of an ingot formed by carefully cooling molten silicon, and consist of many crystals. Slightly cheaper to manufacture but less efficient (10-16%) than monocrystalline cells. More potential for cost reduction in the future.
- **Amorphous/thin film.** Semiconductor material is deposited onto a glass or plastic substrate. Thin film cells contain less silicon so are cheaper, although their efficency is around 4-5% (which can be boosted to 8-10% by multiple-layer deposition).
- **Second generation thin film** (eg. dye-sensitised polymers). Currently only 1-2% efficient, but potentially extremely cheap to manufacure. Large areas can be mass-produced and handled easily, because there is no need to wire up smaller cell units.
- **Hybrid silicion.** Emerging technology – a mixture of crystalline and amorphous silicon.

Panels can be installed either:

- **integated** (as weatherproof panels, roof tiles, facades, shading devices, etc), or
- **free-standing** (mounted using frames at an angle on the ground, on flat roofs, etc)

Monocrystalline

Polycrystalline

Amorphous (tiles)

1.3 Strengths, weaknesses, opportunities and threats

This section outlines a discussion of the key drivers affecting PV panels.

Strengths

- Simple, low-maintenance system.
- Rapidly evolving technology, with efficiencies increasing and costs decreasing.
- Relatively long life.
- Displaces, at the point of use, the need for central generation.
- Increases security of supply.

Weaknesses

- Even partial overshading can significantly reduce performance.
- 'Islanded'[1] generation is rare, due to intermittent nature of PV generation.
- Requires a grid connection in order to provide energy storage viably.
- Complex regulatory and compliance requirements.
- Installation issues:
  - requires special training
  - system is potentially 'live' during installation
  - normally requires scaffolding
  - apartment blocks have a small roof area per apartment
- Widespread adoption of PVs may require grid reinforcement.

Opportunities

- Cost/benefit equation will continue to improve for some time.
- Straightforward on a mass scale (eg. developer sale housing)
- Highly scalable (from a small home to major solar farms)
- Easy to incentivise householders to retrofit PVs, via subsidies/grants/feed-in-tariffs.

Threats

- Viability and rate of take-up is vulnerable to political decisions regarding subsidies/grants/feed-in-tariffs.
- Less attractive as a carbon abatement measure as the grid is progressively decarbonised.
- Sensitive to world availability of semiconductor materials.

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[1] **Islanding** refers to the condition in which a distributed (DG) generator continues to power a location even though electrical grid power from the electric utility is no longer present.

1.4 Building pathology, defects, and what can go wrong

1.4.1 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 1.1 – 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.

1.4.2 Responses received

At the closing date of 1st October 2012, 23 responses had been received which related specifically to Photovoltaic panels (PVs). This is 34% of the received questionnaires. The industry sectors of the respondents were as follows:

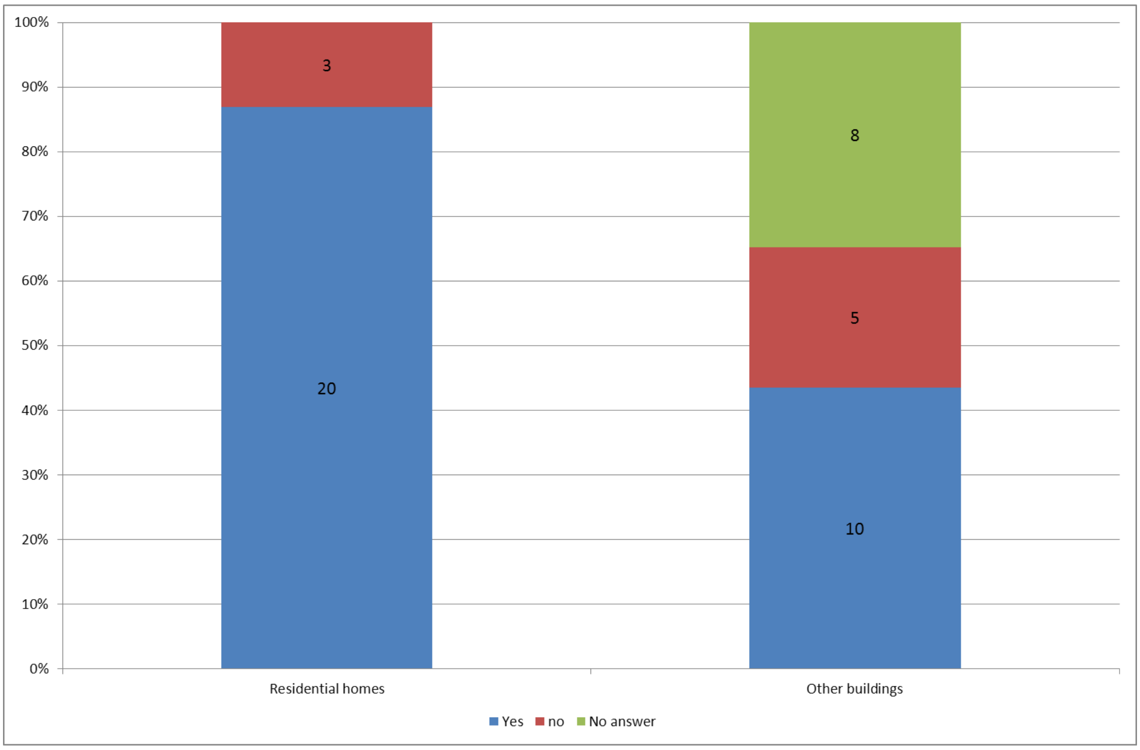
TABLE 1.2 – Responses

Sector	***Responses received***
Government organisation	1
Architectural practice	1
Housing organisation	7
Manufacturer	2
Retailer/merchant	0
Construction company	2
Installer	2
Building inspection service	4
Certification organisation	3
Insurance company	4
Trade association	2
Professional institution	1
Other (please specify)	4
Business in more than one sector	7
Total	***23***

The respondents collectively claimed to have data relating to 22,558 installations of the technology, of which 502 (2.3%) were said to have experienced failures or defects.

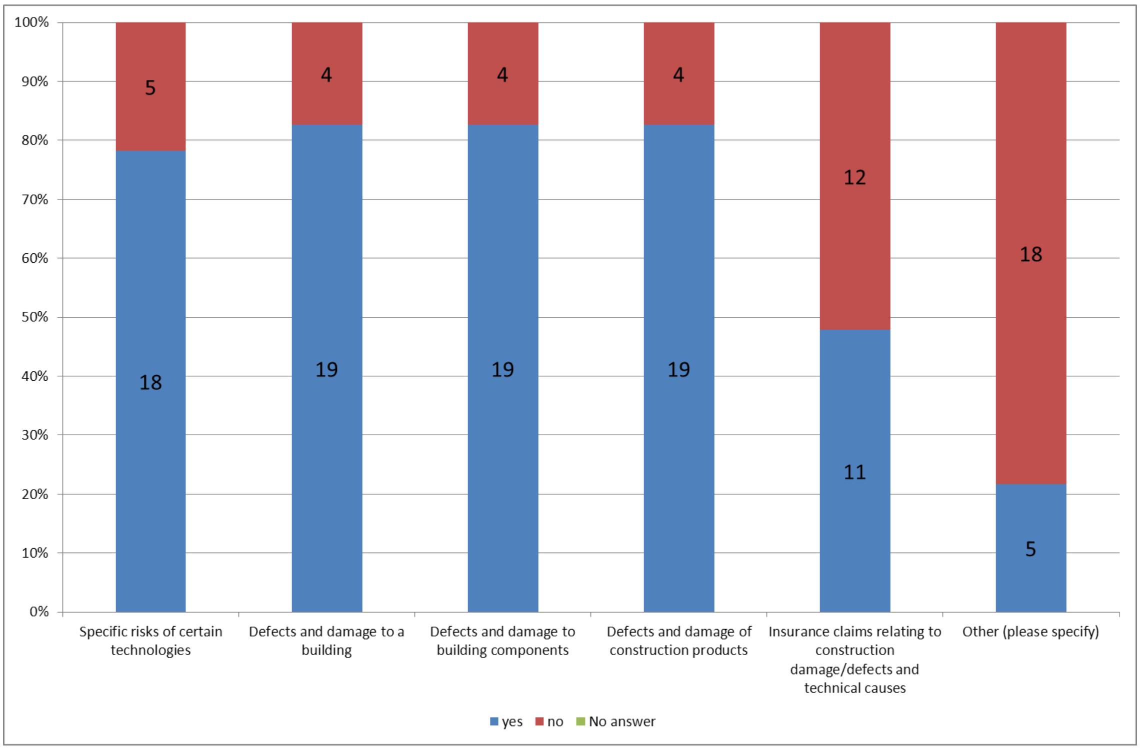
The following graphs and charts only relate to the people who responded about this technology.

CHART 1.3
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.

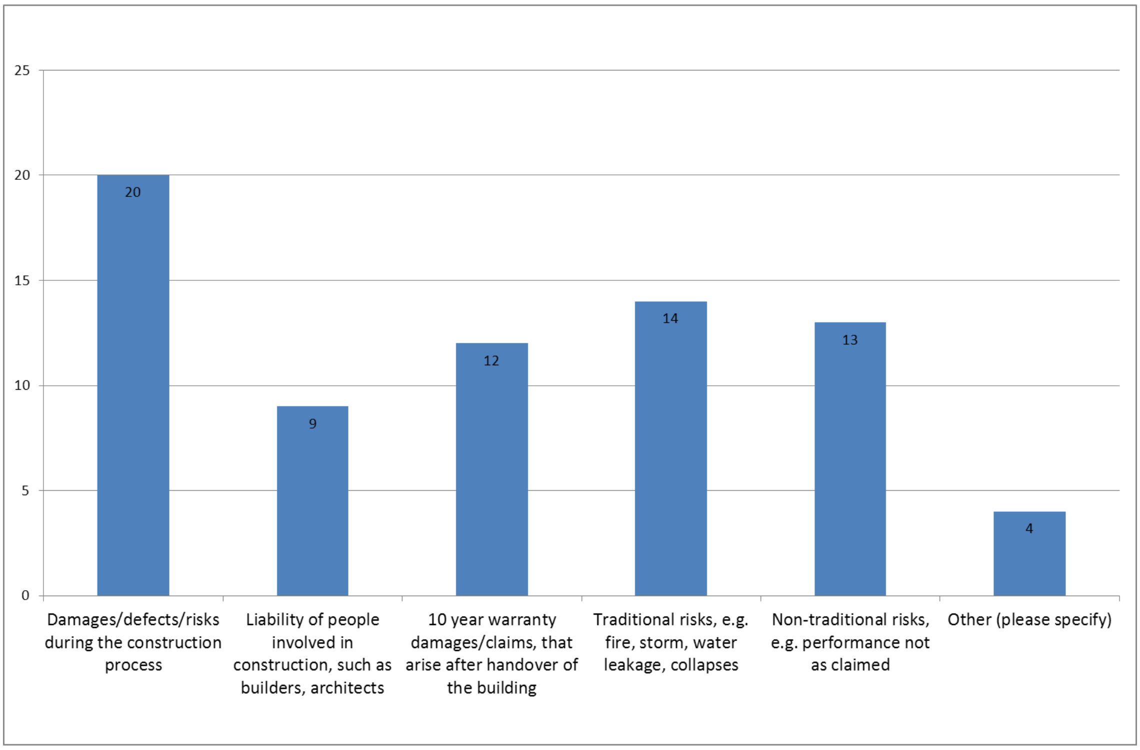
CHART 1.4
Question asked –*"Does your organisation collect its own data on these issues (please tick all that apply)?"*



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.

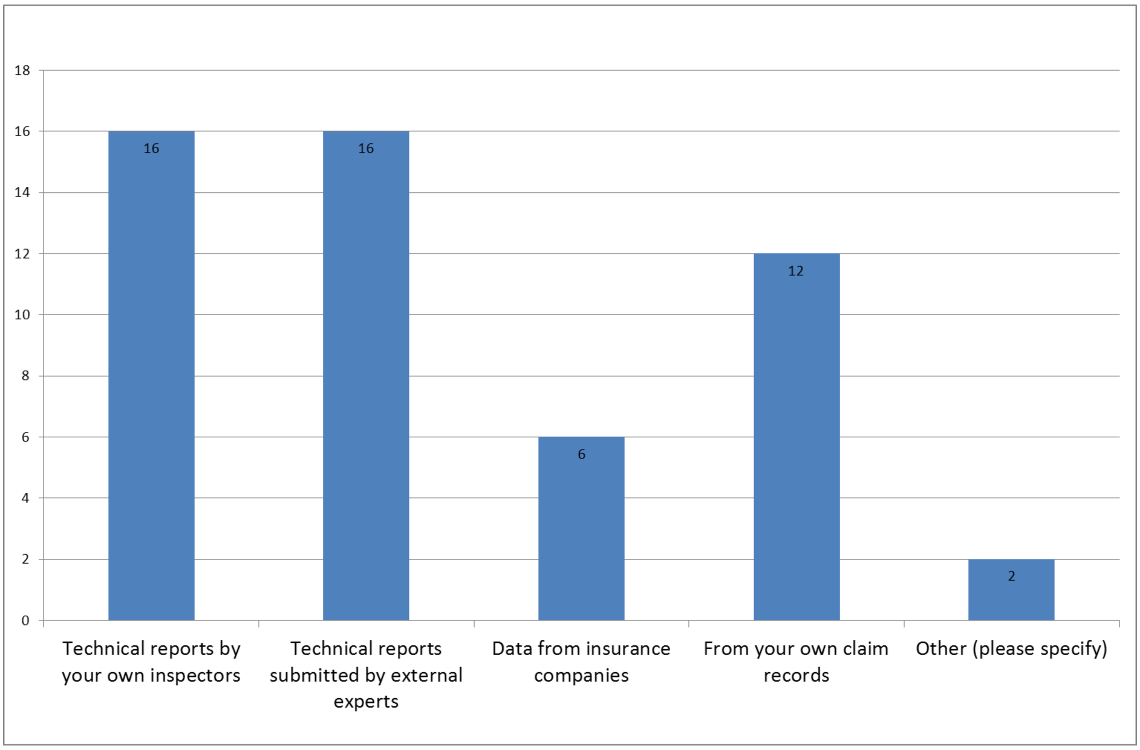
CHART 1.5

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



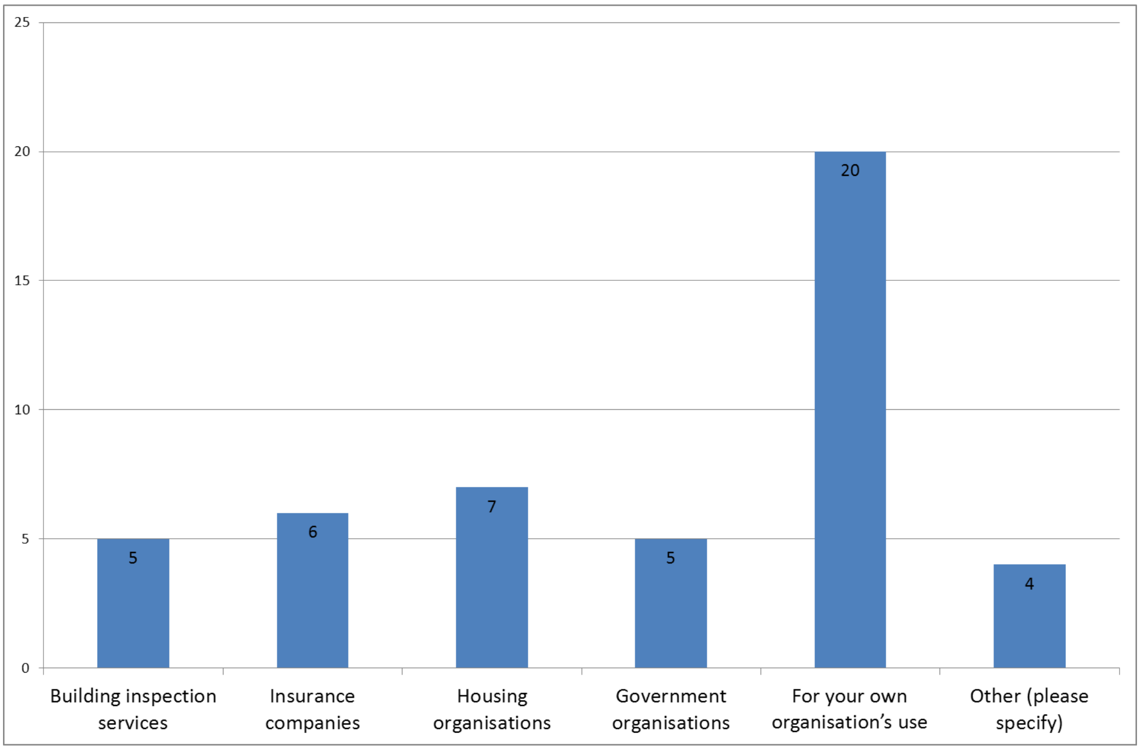
This chart shows the number of organisations that reported each kind of damage on which they collect data. Each column represents a different type of damage. This is only for this specific eco-technology, not overall. Organisations may collect data for more than one reason.

CHART 1.6
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 1.7
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.

1.4.3 Summary of responses about databases

About their database:

- 22 have a database, 1 did not respond;
- 10 provided a date when data collection started
  - 2 in 1990
  - 1 in 1998
  - 1 in 2000
  - 1 in 2002
  - 1 in 2005
  - 1 in 2007
  - 1 in 2008
  - 1 in 2009
  - 1 in 2011
- 11 carry out statistical analysis of the data;

About data publication:

- 14 make data available on the web;
- 11 in newsletters;
- 13 in other publications;

Names provided include

- Good Homes Alliance monitoring report
- www.structural-safety.org
- CROSS Newsletters

About the availability of data, of these 22 respondents:

- 14 publish summary data only;
- 6 publish raw data in any form;
- 7 publish raw data, even anonymously;

Comments were passed, as follows:

- *"Published results include expert comments on reports"*
- *"Sometimes during a conference presentation"*

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

1.4.4 Reasons for failures and defects

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

TABLE 1.8

Reason for failure/defect	Number	% of total
Requirement management		
Change in client's requirements	0	0.0%
Misunderstanding of the effectiveness of the technology	1	0.0%
Poor project management	0	0.0%
Inaccurate engineering or architectural data	3	0.0%
Delivery		
Late delivery	0	0.0%
Storage issues	0	0.0%
Awkward packaging	1	0.0%
Poor transport of product	11	0.0%
Installation		
Incorrect design for installation	1	0.0%
Incorrect installation documentation	401	1.8%
Failure in installation	141	0.6%
Commissioning failure	137	0.6%
Operational failure		
Product failure once installed	31	0.1%
Incorrect user documentation	256	1.1%
Misuse of product by end-user	0	0.0%
Performance not as claimed	142	0.6%
Other		
No other reasons were given for failure		
Total		

Note that an installation may have had more than one reason to fail. This is measured against the total number of sites reported by all correspondents.

1.4.5 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 1.9

Reason for failure/defect	Commentary
Requirement management	
Change in client's requirements	For example: a change in the orientation of the building because of zoning requirements from the municipality. In general: better standardized training is extrem*[ly]* important to improve the quality of the installations.
Misunderstanding of the effectiveness of the technology	The theoretical yield in the sales brochure is often different from the yield in practice. In the Netherlands there is much change in the converter due to clouds. Thereby the converter Is subject to wear and tear. In the southern European countries there is more constant sunshine, so less change in the converter.
Poor project management	For new dwellings, PVs are put into the design for reaching the Dutch building requirements on energy performance of the building. They are not put in as an eco-technology (with the purpose to save environment).
Inaccurate engineering or architectural data	Design drawings and wiring layouts very complex and difficult to ascertain relations between trades. Further detail collected at survey stage. With new housing projects, PVs are included during the design phase to contribute to energy performance of the building (in order to reach the Dutch building regulations on energy performance). The PVs are not used from an 'eco' point of view. Then, during the tender phase and construction phase, the contractor and installer are not very much interested to install the PVs in a correct way on the building (for example a wrong gradient, or place in the cast shadow of a skylight).
Delivery	
Late delivery	
Storage issues	
Awkward packaging	Panels on big pallets.
Poor transport of product	No fork lift truck to get them off the lorry.

Installation	
Incorrect design for installation	The design of the PV installation is key, ensuring sufficient access to direct and diffuse solar irradiation. The sizing of the inverter in order to maximise efficiency is then key.
Incorrect installation documentation	Complexities around inverter set up, isolator switches and commissioning & future maintenance/ DIY issues. Nearly all installations do not have the right documentation.
Failure in installation	Simple switching not activated. Wrong connection on roof, leading to leakages. Breakage.
Commissioning failure	Weathertightness of roof sarking felt compromised.
Operational failure	
Product failure once installed	Damage by vandals. Energy display units not working or providing inaccurate information to householders. Remote metering equipment not sending regular performance updates to the centrally held performance database
Incorrect user documentation	Need simplified maintenance and quick start guide. User manual in German.
Misuse of product by end-user	Tenants running out of credit on their pre-payment meters causing systems to shut down.
Performance not as claimed	Disappointing yield. Usually because of deficient installation work. The performance/yield is not as was promised in the sales brochure, because of for example bad fine tuning after installation.
Other (specified)	

Other comments included:

- Have seen evidence on all of the above but don't know the numeric incidence. Also safety issues associated with inappropriate use
- The technology is quite well understood now, with installation rarely causing any issue from a defects perspective.
- From the customers perspective there is very little they have to do to adapt to the technology.
- performance actually exceeding predictions
- We do not have the detailed information that you request but simply a few reported concerns about structural aspects of these installations.
- In general there is a huge difference between residential and large scale projects. In general the smaller the installation the more poor the quality.
- The numbers mentioned above are NOT the numbers but the % of our claims!!
- Therefore the % is more than 100%.(**Editor's note – this has been allowed for in these figures and %s above)**

1.4.6 Key findings

In summary:

- Significant amounts of data exist for this technology.
- High degree of satisfaction in all areas, although performance sometimes not as expected.
- The failures (albeit a small percentage) are generally associated with installation/commissioning (notably inadequate documentation), user documentation and breakages from both transportation and vandalism.

Lessons:

- Improve documentation in general
- More training for installers