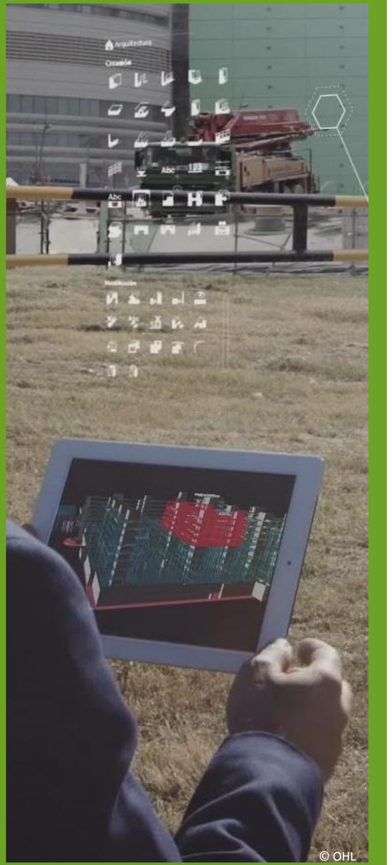

BUILT2SPEC
Tools for the 21st Century Construction Worksite

Thermal Imaging for Energy Efficiency Checks in Buildings

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www.built2spec-project.eu

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  - What is thermal imaging?
  - Need for thermal imaging
  - Thermal performance of buildings
- Section 2 Infrared Cameras, Thermography
- Section 3 Thermographic Surveys
- Section 4 Built2Spec Results

Section 1: What is Thermal Imaging?

- *Thermal Imaging is the use of special equipment that can detect the heat produced by people or things and use it to produce their images.*
- Thermal imaging produces a picture that maps the intensity of IR radiation across the field of view.
- The use of temperature-calibrated thermal images is generally referred to as ‘thermography’, a person who performs the task as a ‘thermographer’ and the images are often referred to as ‘thermograms’.

Section 1: What is Thermal Imaging?

- Thermal Imaging can be carried out on external or internal surfaces, and the meaning of hot and cold areas on the resulting thermal images demonstrate different things.

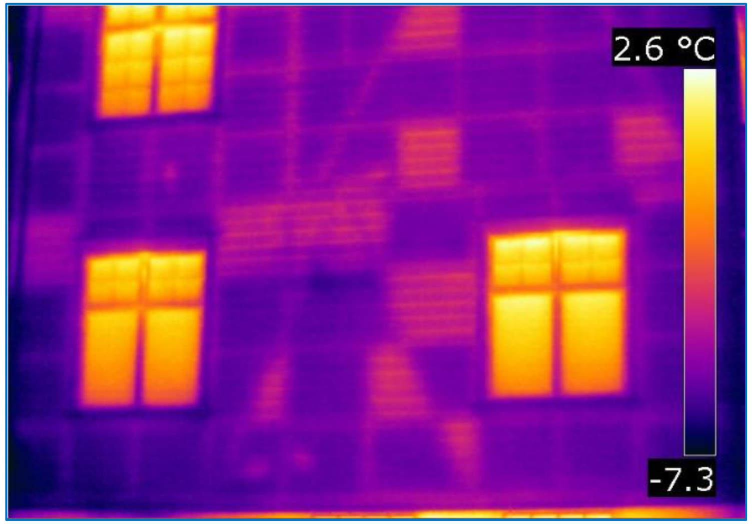
View	Cold areas	Warm areas
External images	• Normal well-insulated building fabric • Reflections of the sky • Damp	• Heat loss: - Poor insulation - Air leakage - Thermal bridging • Stored heat • Heat sources such as lights or air conditioning units • Damp
Internal images	• Heat loss: - Poor insulation - Air leakage - Thermal bridging • Air movement in cavity bypassing insulation • Damp	• Heat sources such as pipes or cables • Normal well-insulated building fabric

Section 1: Need for Thermal Imaging

There are three areas where thermal imaging can be used to help demonstrate compliance with the Building Regulations:

- Continuity of insulation (1)
- Identification of air leakage paths (2)
- Identification of thermal bridges (3)

1



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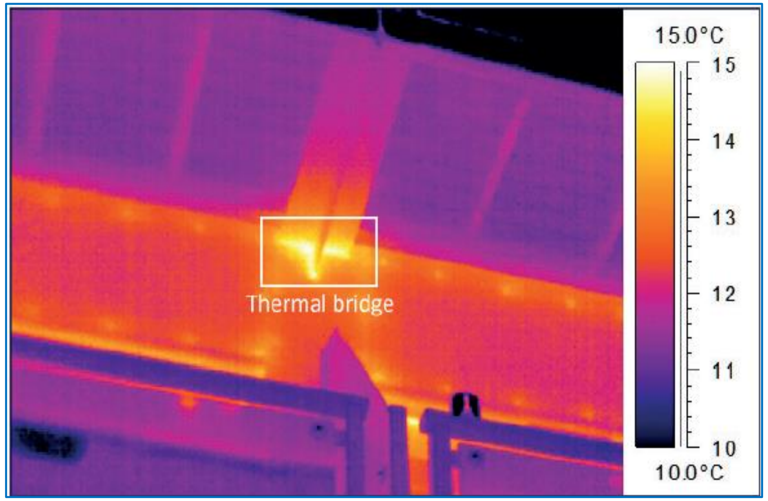

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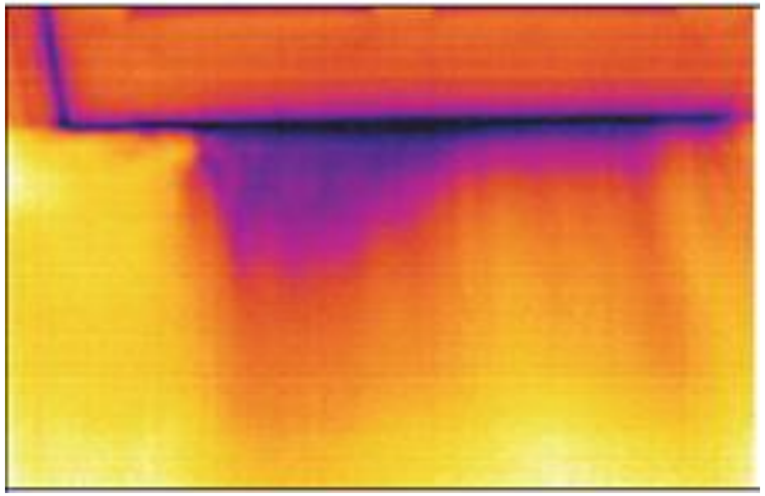


Section 1: Need for Thermal Imaging

Regulations

- Within the scope of Built2Spec, the research is on improving the energy performance of new builds, hence in UK the focus has been on Building Regulations 2010 for use in England - *Approved Document L1A Conservation of fuel and power in new dwellings*.
- The Building Regulations require that reasonable provision shall be made for the conservation of fuel and power in buildings by '…limiting heat gains and losses…' through thermal elements and other parts of the building fabric.

Section 1: Thermal Performance of Buildings

- The insulation effectiveness is measured by ‘U value’.
- A low U value shows good insulation effectiveness; for example, 0.18 W/m^2K is considered a good U value for walls.
- The Building Regulations require that new construction projects minimise the use of energy, and compliance with this requirement is demonstrated in the Approved Documents.

Table 2 Limiting fabric parameters

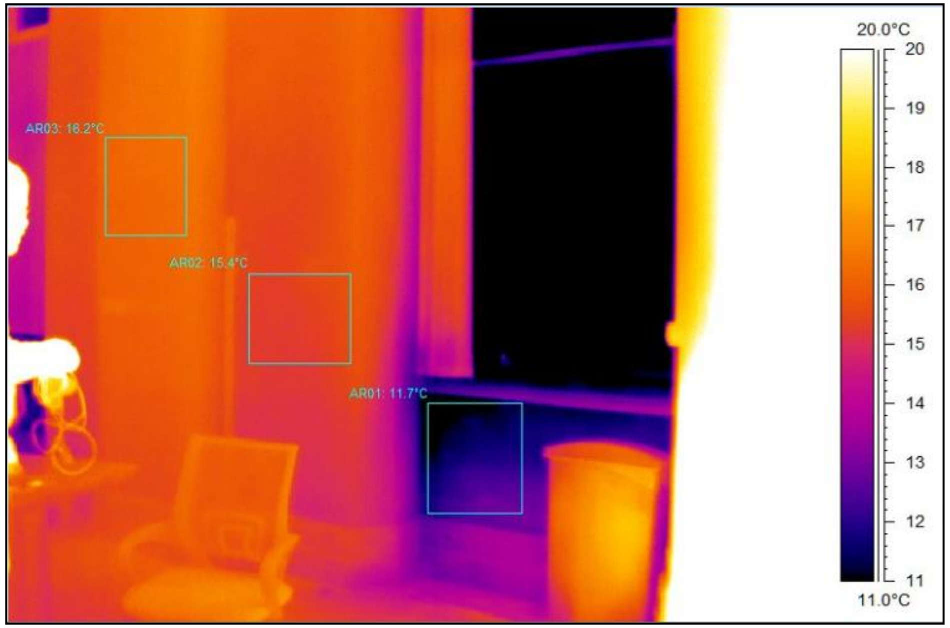
Roof	0.20 $W/(m^2 \cdot K)$
Wall	0.30 $W/(m^2 \cdot K)$
Floor	0.25 $W/(m^2 \cdot K)$
Party wall	0.20 $W/(m^2 \cdot K)$
Swimming pool basin[1]	0.25 $W/(m^2 \cdot K)$
Windows, roof windows, glazed roof-lights[2], curtain walling and pedestrian doors	2.00 $W/(m^2 \cdot K)$
Air permeability	10.0 $m^3/(h \cdot m^2)$ at 50 Pa

Notes:

1. Where a swimming pool is constructed as part of a new building, reasonable provision should be made to limit heat loss from the pool basin by achieving a U-value no worse than 0.25 $W/(m^2 \cdot K)$ as calculated according to BS EN ISO 13370.
2. For the purposes of checking compliance with the limiting fabric values for roof-lights, the true U-value based on aperture area can be converted to the U-value based on the developed area of the roof-light. Further guidance on evaluating the U-value of out-of-plane roof-lights is given in *Assessment of thermal performance of out-of-plane rooflights*, NARM Technical Document NTD 2 (2010).

Section 1: Thermal Performance of Buildings

- Factors that affect the U value of building fabric elements include – position, thickness and condition of insulation, moisture content and component's material properties.
- Thermal imaging of the structure can detect these variations in conductivity by finding differences in the surface temperature, but skill is required to differentiate variations in emissivity, reflections, evaporation or air leakage that can look similar.



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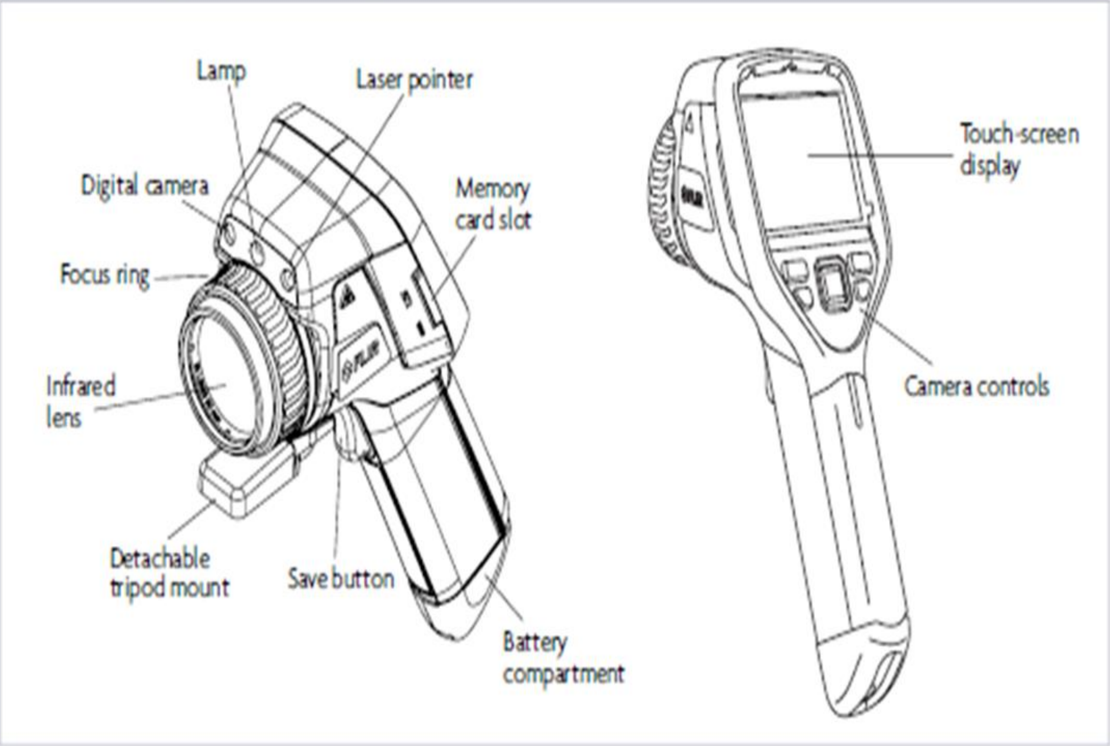
Section 2: Infrared Cameras



Conventional Infrared Camera

Temperature measurement range	-20°C to 600°C
Temperature measurement accuracy	±2°C
Thermal sensitivity (NETD)	≤0.05°C at 30°C target temperature
Infrared detector	320 x 240 pixel focal plane array uncooled microbolometer
Image capture frequency	60 Hz
Infrared spectral band	7.5 µm to 14 µm (long wave)
Lens angle	25° horizontal
On screen emissivity correction	Yes
On screen RAT correction	Yes
On screen transmission correction	Yes
File formats	.bmp or .jpg
Standard palettes	8
Visible light detector (conventional camera)	640 x 480 pixels

Specification for a Conventional Infrared Camera

Some advantages of the larger conventional infrared cameras are reliability, robustness, more adjustment, higher resolution and greater sensitivity.

Section 2: Infrared Cameras

Smartphone infrared cameras

Smartphone infrared cameras differ from conventional infrared cameras in that all the control is done from a smartphone app.

Advantages:

- The location is recorded with the image
- GPS and enhanced location features are available
- Communication using WiFi or the mobile phone network allows image sharing
- They are lightweight and fit in a pocket
- They are relatively low cost
- You can make phone calls on it!

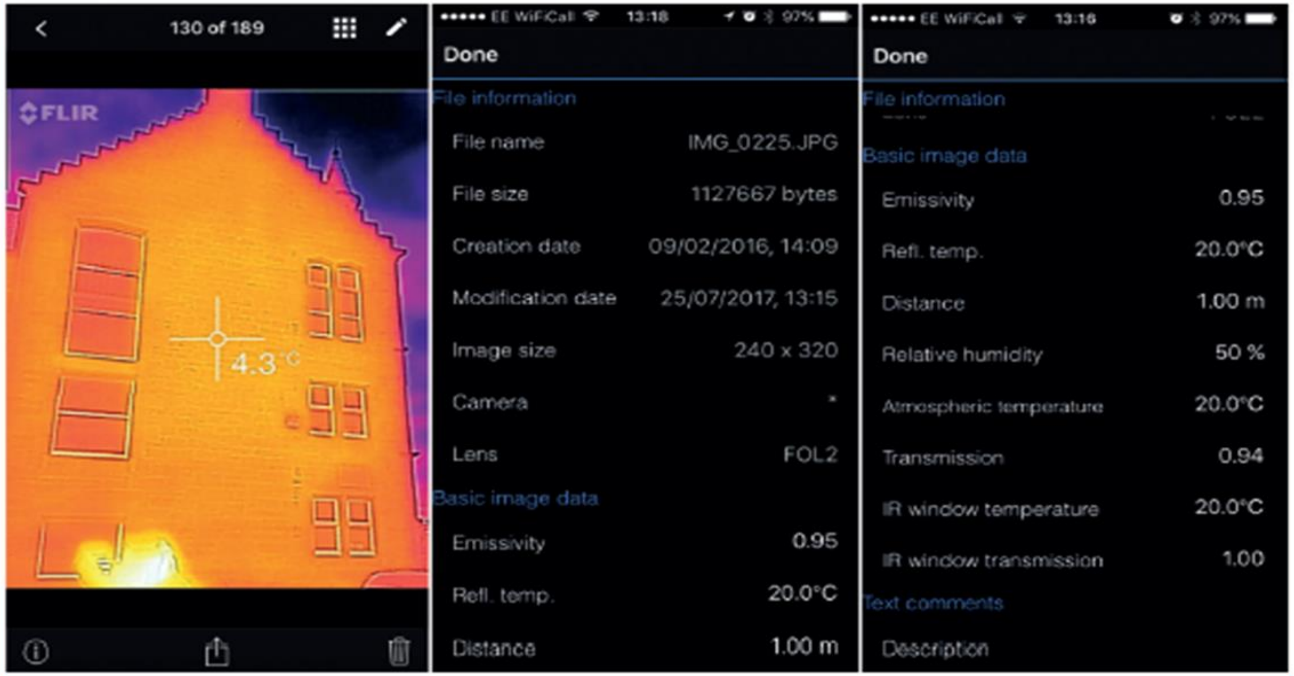
Drones are increasingly used for external thermographic surveys and they can be used inside large buildings too.

Section 2: Infrared Cameras

Calibration tests carried out at BSRIA have shown that :

- Sensitivity and accuracy of smartphone infrared cameras can be quite good.
- Few / no settings for reflected temperature, air temperature or humidity, but these settings can be corrected in software later.
- May lack the ability to focus.
- Not suitable for quantitative analysis.

Thermal image of a building wall from a smartphone camera and editable data to allow for correction to values set at time of image capture.



Section 2: Thermography

What is possible?

Thermography can detect high or low temperature surfaces, measure surface temperatures and show temperature differences. This means that in buildings you can find:

- Gaps in or missing insulation
- Thermal bridges
- Air leakage locations
- Damp areas
- Effectiveness of heating or cooling equipment
- Flue gases (if they contain water droplets or solid particles)
- And much more

But you can't

- See through concrete, brick, metal or glass
- Measure air or exhaust gas temperatures
- Detect anything without a temperature difference

Section 2: Thermography

Getting a good image

There are four things you must get right at the time of capturing a thermal image:

- Temperature Range
- Image Composition
- Focus
- Steady Hand

All other camera settings can be adjusted later in desktop software.

Temperature range:
Some infrared cameras have two temperature ranges such as -20°C to 120°C and 0°C to 1000°C. An object at 500°C can't be analysed if captured with a camera that has a -20°C to 120°C temperature range, and an object at 20°C would not be shown accurately in the 0 to 1000°C range.

Composition:
Ensure that what you want is clearly shown in the image; not too far away or obscured by other objects. Most infrared cameras produce simultaneous digital photos but these may cover a wider angle than the thermal image. Make sure the image shown on the camera screen includes what you want to show and is not confused by other items in the picture.

Focus:
This is probably the most important setting. Getting focus wrong makes the image unclear and the temperature measurement less accurate. Some infrared cameras have automatic focus, a few even use a laser to find the distance to the object of interest and set the focus to that distance. Simple cameras, such as some smartphone cameras, have a fixed focus so there is no adjustment of focus.

A steady hand:
Some infrared cameras are slow to capture thermal images, taking as much as a tenth of a second, so it is important to keep the camera steady. You can use a tripod or monopod to help with this.

Section 3: Thermographic Surveys

- Thermographers work to European or International standards such as BS EN 13187 to interpret thermal images. This makes recommendations on suitable conditions for a thermographic survey and what to expect in a survey report.

- A well conducted thermographic survey should show if there are any variations in the thermal performance of similar parts of a building. It should show with images and any necessary text:

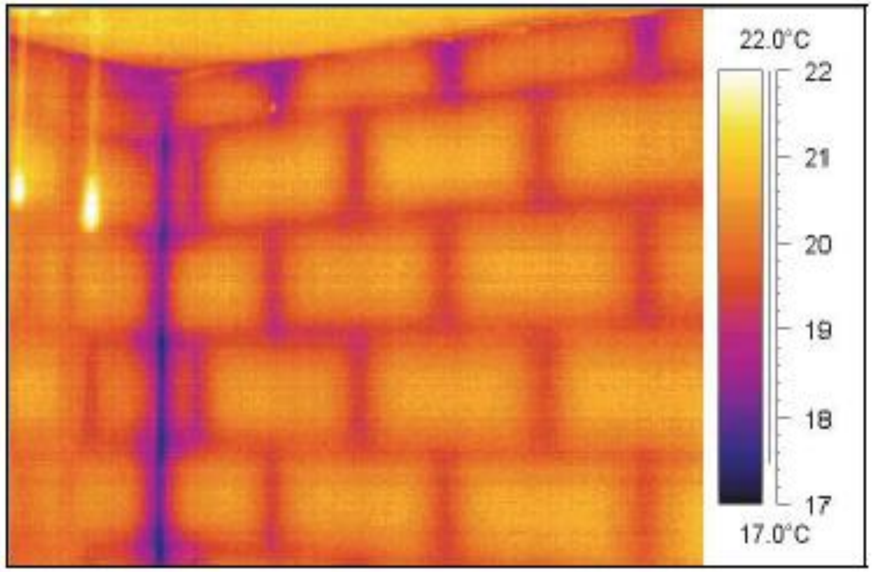
- Summary of conditions at the time of the survey
- Method used to analyse and draw conclusions from the images
- Any conditions that might compromise the results
- Differences between superficially similar parts of the fabric
- Variations in emissivity across the image
- Location of air leakage – dependent on wind speed, direction or artificial pressurisation

Section 3: Thermographic Surveys

- Qualitative surveys
- Show locations of anomalies that are abnormal thermal features.
- **External surveys** give overview of a building, comparing one part of a building with another. Best results are obtained on cold (temperature difference of atleast 10 °C), cloudy, dry, still winter nights (wind speed for external imaging no more than 5m/s).
- Internal surveys are more effective as wind speeds over 5m/s, rain or mist occur for much of the winter.
- The air speed of 0.13 m/s corresponds to the almost still air that is found inside buildings.

Wind speed m/s	R_s m^2K/W	Wind condition
0.13	0.13	**Calm:** the assumed indoor condition in calculation of U values
1	0.08	**Light air**
2	0.06	**Light breeze:** assumed sheltered outdoor condition in U values
5	0.04	**Gentle breeze:** assumed normal outdoor condition in U values
7	0.03	**Moderate breeze**
10	0.02	**Fresh breeze:** assumed exposed outdoor condition in U values

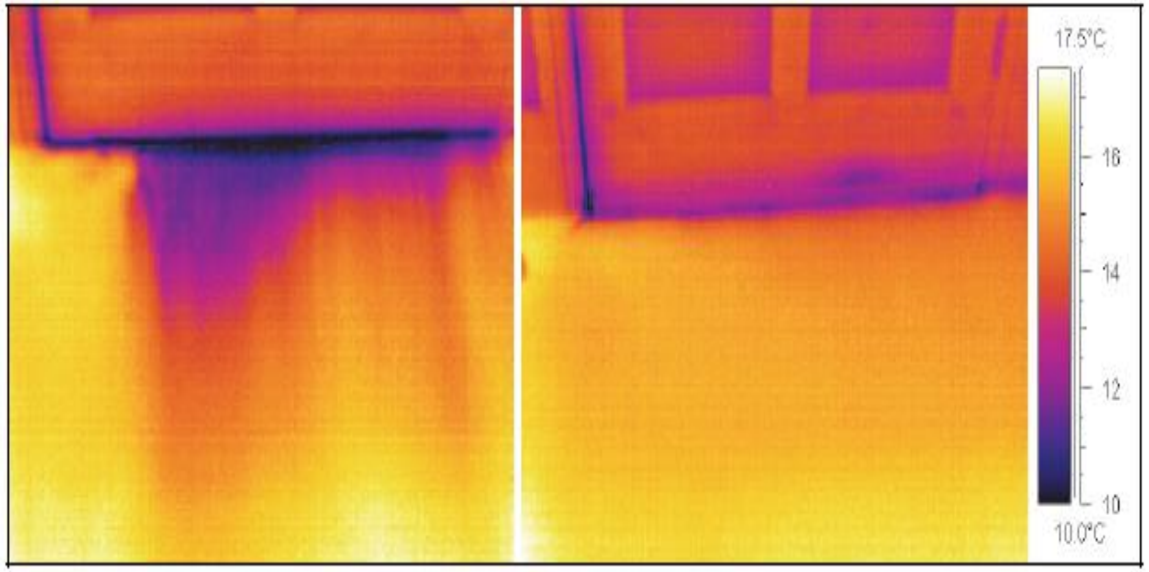
Section 3: Thermographic Surveys

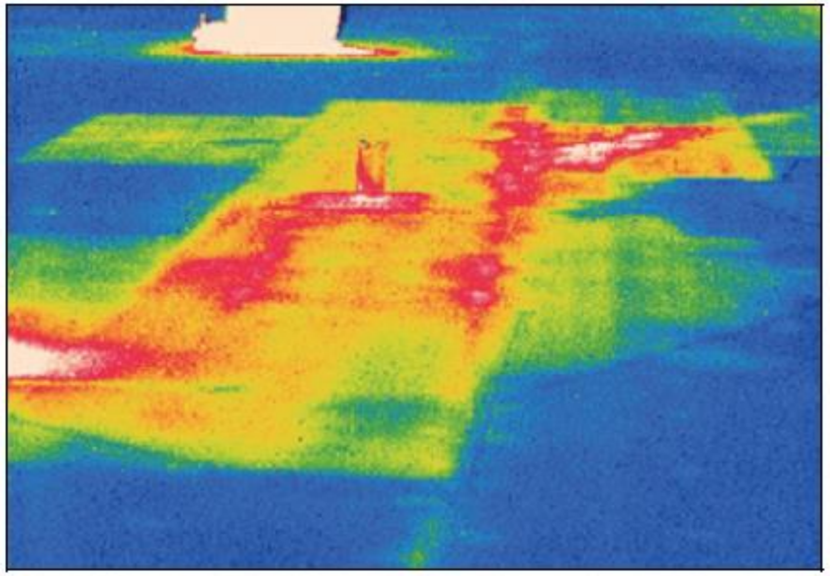


- This image shows differences between two semi-detached houses, but it is difficult to tell whether the differences are caused by different internal temperatures, loft conversions, air leakage, double glazing or reflections

- The short dark vertical lines at the top of the wall are indicative of air leakage where joints have not been fully filled with mortar.

Section 3: Thermographic Surveys



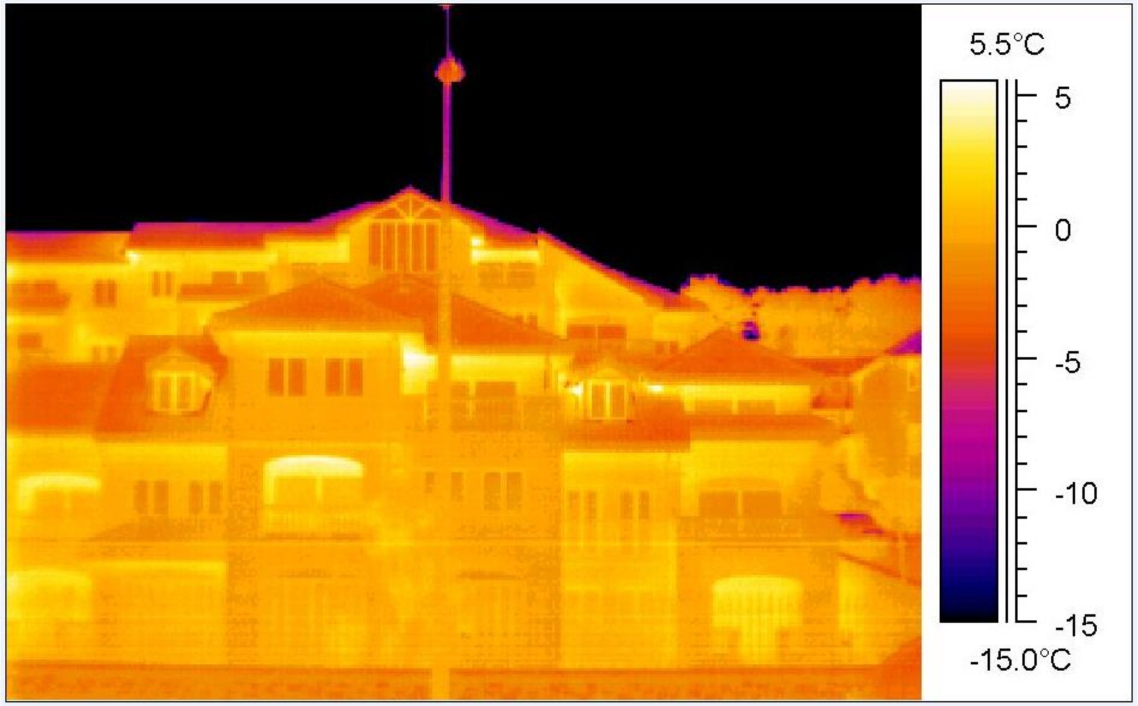


- Air leakage surveys showing the zones of air leakage during a depressurisation air tightness test.
- Roof surveys

Section 3: Thermographic Surveys

Interpreting Results

- Most thermal imaging cameras also produce a digital photograph in addition to the thermal image. The purpose of the photograph is to aid the location of the image in relation to the building.
- Thermal images are usually reproduced with a colour scale beside the image itself.



Survey Reports

- Following the survey a full written report should be submitted in accordance with BS EN 13187 presenting the survey data and the interpretation made.
- Where remedial work is recommended, it is important to conduct a repeat survey of that part of the building.

Section 4: Built2Spec Results

- Comparing the conventional camera with smart phone camera

Section 4: Built2Spec Results

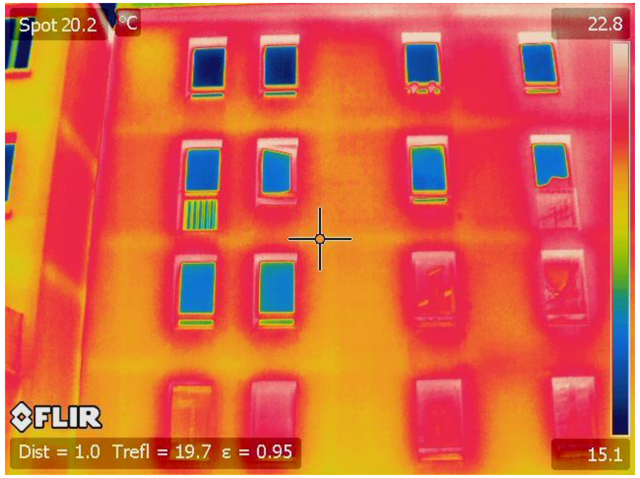
- Comparison of Conventional Infrared Camera with Smart phone camera checked in BSRIA calibration laboratory

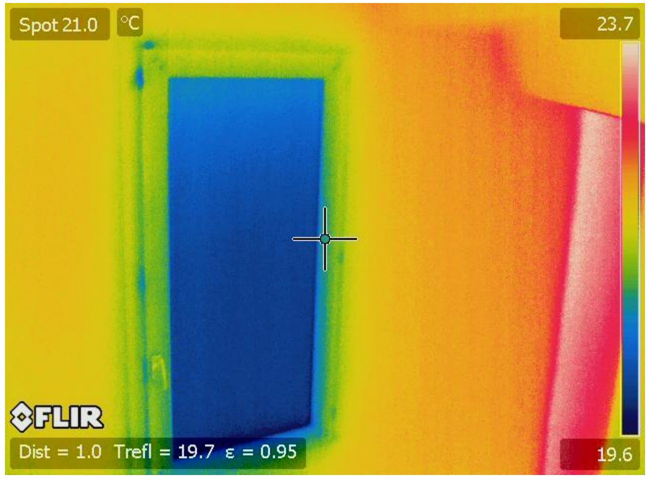
	Units	Typical IR Camera	Smartphone Camera 1	Smartphone Camera 2	Smartphone Camera 3
Purchase Date	year	2007	2015	2016	2017
Price	UK Pounds	~10,000	135	165	200
Weight	g	880	220	144	140
Pixels	No.	320 x 240	80 x 60	160 x 120	160 x 120
Sensitivity	K	0.05	0.1	0.1	0.1
Field of View	Angular degrees	25 x 19	50 x 39	46 x 35	55 x 43
Temperature Range	°C	-20 to 650	-10 - 120	-20 - 120	-20 - 400
Wavelength	µm	8 to 14	8 to 14	8 to 14	8 - 14
Minimum Focus	mm	400	150	150	150
Specified Accuracy	K	± 2	± 2	± 2	± 2
Measured Accuracy	K	± 0.83	± 1.25	± 0.98	NA

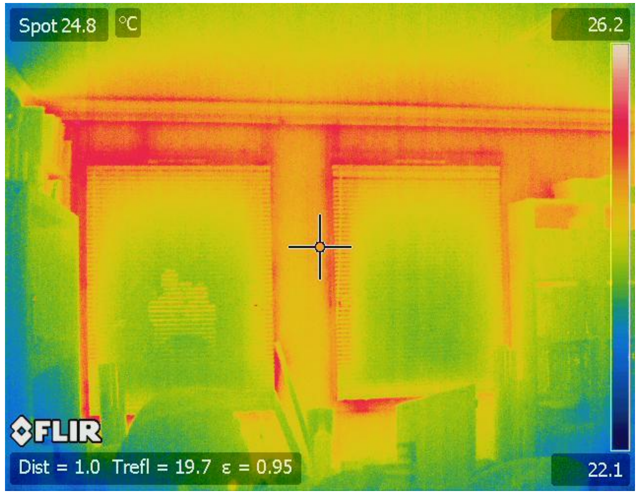
Section 4: Built2Spec Results

BSRIA pilot tested the camera at 14 sites. Pilot tests results of the smart phone thermal imaging camera state it:

- Can’t be used for external building thermography as thermographer needs to be very close to the surface measured.
- Not suited for quantitative analysis, quality assurance, thermographic surveys and certification
- Good qualitative indicator to identify errors
- Handy, lightweight, relatively low cost

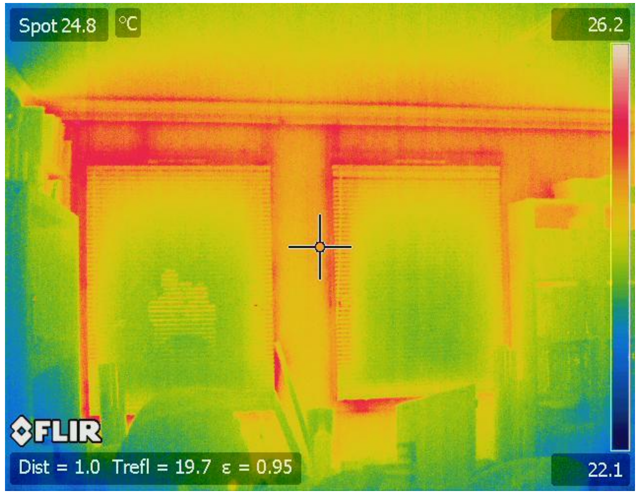


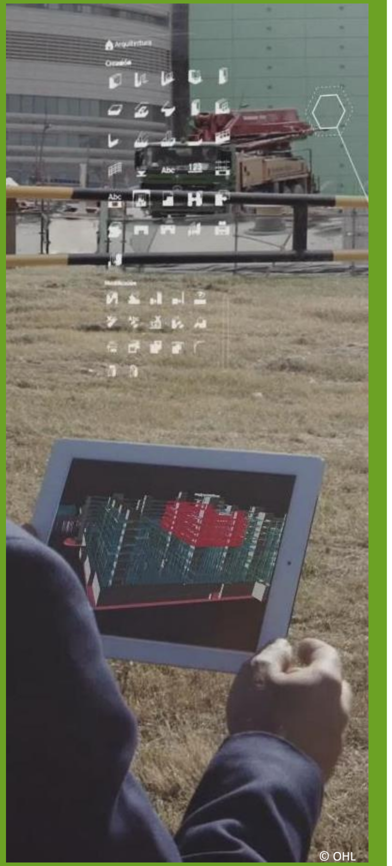




Section 4: Built2Spec Going Forward

More pilot tests in the next few months comparing results of the conventional thermal imaging camera with the smart phone camera.





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