Department of Energy & Climate Change

# UK Literature Review for

*International Energy Agency (IEA) Annex 36 on investigating the effect of quality of installation and maintenance on heat pump performance.*

Report prepared by The National Energy Foundation (NEF)

On behalf of The Department of Energy and Climate Change (DECC)

May 2013


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Registered in England with liability limited by guarantee No 2218531

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# Acknowledgements

The authors would like to acknowledge the provision of information, support and other valuable contributions to this Literature Review from the following key individuals:

Robin Curtis at Mimer Energy

John Parker, Independent Consultant

Rosemary Rawlings

Tony Bowen at Heat Pump Association

Prof Peter Boait at De Montfort University

John Barnham and Johnathan Nea at Orbit Housing Group

William Routh and Vincent Wedlock-Ward at Southern Housing Group

Ciaran Burns and Sarah Rubinson at Renewable Energy Assurance Ltd

Prof Malcolm Bell and Dr Anne Stafford at Leeds Metropolitan University

Natalie Moore and Victoria Haines and Loughborough University

Rafał Kowalski and Laura Dugdale at Danfoss Heat Pumps Ltd

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Dr Dan Lash at Exeter University

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# 1. Executive summary

The aim of this work was to undertake wide-ranging literature review of the current standards, requirements, legislation and training within the UK heat pump industry compared to those found internationally, and a thorough review of key field trials and documented problems.

Each section of the literature review provides a critical discussion of the issue in question, delivering both insight and awareness of opposing cases, theories, approaches and experiences across government, businesses, industry and non-governmental organisations. The key findings and conclusions from each section of the review are summarised below.

## 1.1. MIS guidance prior to MIS 3005 Issue 3.1

In the heat pump sector, guidance and standards can be categorised into three key areas:

- **Technical standards** for efficiency, safety and longevity etc., and for geothermal systems standards for environmental protection (drilling, boreholes etc).
- **Certification** of competence and installation/drilling quality
- **Regulations and guidelines**, e.g. for licensing of geothermal systems

Prior to MIS 3005 Issue 3.1, the main guidance and advice for the design and installation of heat pumps in the UK consisted of MIS 3005 Issue 2.0 along with advice provided by the HVCA, Energy Saving Trust, CIBSE, heat pump manufacturers and the Environment Agency.

In the UK, the Microgeneration Installation Standard: MIS 3005 Requirements for Contractors Undertaking the Supply, Design, Installation, Set to Work Commissioning and Handover of Microgeneration Heat Pump Systems Issue 3.1 was first published by DECC on 1st February 2012 and subsequently updated in March 2012. MIS 3005 addresses six key areas: heat loss calculation (including power & energy), heat pump sizing, heat emitter selection, domestic hot water preparation, cost calculations and ground collector design and installation but also places additional emphasis on handover and documentation.

MIS 3005 has brought in many changes. In particular, by being prescriptive and requiring the use of British and CIBSE standards as well as developing guidance and clarification on MIS 3005 through MGD 002 and the supporting MCS 022 installer standards which include the Heat Emitter Guide and the Ground Loop Sizing Tables (and their associated use through Table 3 of MIS 3005 Issue 3), there was a fundamental change in both MCS as a scheme and Heat Pump design methods. MCS and DECC have also supported the changes to MIS 3005 through webinars, spreadsheets and software.

Since publication of MIS 3005 Issue 3.1, there have been rewrites to standards such as BS EN 12831 National Annex and CIBSE Domestic Heating Design Guides to meet the new requirements. VDI 4640 has been superseded by the Ground Loop Sizing Tables because the new standard includes allowance for ground temperature which varies by several degrees between southern England and northern Scotland. Also, many of the existing sources of advice such as TR30 are now being reviewed to bring them in line with the new standard.

International guidelines and standards for heat pumps exist relatively widely. There currently exists comprehensive, consistent set of technical standards for heat pump equipment across Europe, through EN standards for testing and safety etc, which Member states have adopted into national standardisation or are in the process of replacing pre-existing national standards with the EN standards. National standards for heat pumps existed in countries with a mature heat pump market e.g. Germany, Switzerland and Sweden, and in some cases these national standards still exist to cover areas not covered by EN standards. For Ground Source Heat Pumps, EN standards currently only exist for drilling safety, with national technical standards and certification/licensing requirements existing in countries where the heat pump market is already well developed including Germany, Sweden and Austria, and Switzerland.

## 1.2. Training programmes prior to MIS 3005 Issue 3.1

Prior to MIS 3005 v3.1, certification and accreditation was typically provided via training programmes for Heat Pump Installers and System Designers. Accreditation meant that an installer had demonstrated the necessary skills, knowledge and competencies required of a practitioner to competently design, install, maintain and troubleshoot a small-scale/domestic Heat Pump (HP) system or part thereof. Those training programmes in turn needed to be accredited and/or certified by a credible authority to ensure that they consistently applied sufficiently stringent and uniform training standards; and were suitably designed to reach their ultimate objectives.

Within the European member states, those countries where formal certification and accreditation scheme and design and installation training has been implemented are: Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Spain, Slovakia, Sweden and the United Kingdom; although in the latter the recognition by the industry that fundamental gaps in understanding and competency eventually led to MIS 3005 v3 being introduced.

European member countries where no specific certification or accreditation and/or training schemes had been implemented were: Cyprus, Hungary, Romania, Poland and Slovenia.

Training for heat pump installers was provided by several training providers depending on the specific country. Training providers including institutions, manufacturers, federations and guilds offered different levels of training dependent upon the level of knowledge and skill-set required and was typically categorised into five broad areas of competency:

- **System design & technology overview;**
- **Heat pump installation, commissioning and test;**
- **Fault finding and troubleshooting;**
- **Specific considerations** (e.g. Groundworks for GSHP and noise constraints for ASHP); and
- **Pump product types and operation.**

Training courses and course content were accredited by public authorities or by a certifying body with whom the course provider usually signed a partnership agreement. National certification and accreditation schemes did not necessarily contain an audit or assessment component for training courses; however installers needed to ensure that they employed suitably qualified and trained staff and this typically formed a key part of an accreditation assessment process.

However there was a general agreement within the sector about the crucial role of both training and continuous assessment in order to control the quality, safety and performance of the installations and this was primarily achieved through administrative audits based on documentation and/or site audits.

The key training providers and programmes are listed below and described in further detail in Section 3.1 of this report.

**Table 1 Key heat pump training prior to MIS 3005 Issue 3.1**

| Country | Training Courses / Schemes | Provider / Accreditation Body |
|---|---|---|
| Europe | ©Geotrainet; EU-Cert.HP; EUCERT | European Geothermal Energy Council (EGEC) |
| France | QualiPAC | Qualibat / COFRAC |
| France | Qualiforage | ADEME-BRGM-EDF / BRGM |
| Sweden | EUCERT | SWEEP and others |
| UK | Manufacturers' Installer Courses | HP Manufacturers including Viessmann and Dimplex; |
| UK | EUCERT | BSRIA |
| UK | Domestic Heat Pump Design and Installation | BPEC / Logic Certification |
| USA | Accredited training for drillers and installers; Certified GeoExchange Designer Course; Train the trainer; Building load analysis and pumping. | IGSHPA |

## 1.3. Domestic heat pump field trials in the UK

The most recent and first wide-ranging large-scale field trial of 83 heat pumps in the UK was undertaken by the Energy Saving Trust in response to the lack of data on heat pump performance in domestic properties. The trial monitored technical performance and customer behaviour at sites across the UK; the first phase of monitoring in this trial was undertaken during 2009 and 2010, and following several interventions a second phase of monitoring was commissioned to monitor the impact of these interventions. This data is currently being analysed and evaluated, with a report expected to be published in June 2013.

Field trials contain both positive and negative experiences. Nearly every installation has its good, poor and sometimes inadequate issues. There are benefits to be realised from collating and documenting the subjective and objective data available prior to the EST field trials, as well as trials and monitoring currently being undertaken, and comparing this data and findings to the subsequent information that these trials brought to light.

The first monitoring of a domestic heat pump in the UK is believed to be a study undertaken by BRE and BSRIA in 1995 and 1996. The study involved monitoring of a borehole based closed loop GSHP system and was led by Rosemary Rawlings initially at Southampton University and then at BSRIA. There is no published data on this study.

This report has reviewed the following published domestic field trials prior to the EST field trial:

- The York Energy Demonstration Project (1998); 1 x ASHP
- Energy Efficiency Best Practice Programme (Salisbury, 2000); 1 x GSHP
- Nottingham Eco House (2007 – 2008); 1 x GSHP
- Westfield Air Source Heat Pump Field Trial (Scotland, 2008 – 2009); 8 x ASHP
- Harrogate Heat Pump Trials (2008 – 2011); 10 x GSHP
- Elm Tree Mews (York, 2007 – 2009); 1 x communal GSHP

In addition, information on a number of unpublished trials and monitoring of heat pumps was reviewed including: Orbit Heart of England, Penwith Housing Association, Chale Community Project, and Nottingham new build social housing projects. It is also know than monitoring of groups and individual heat pumps has been or is currently being undertaken by Earth Energy Engineering, GeoScience and Mimer Energy.

The review of heat pump monitoring in the UK prior to the EST's field trial has highlighted some key information that can support future guidance for monitoring and reporting of heat pump performance, including:

a. **The performance of heat pumps** is good when they are appropriately designed, installed and commissioned; if not the performance can be significantly reduced.
b. **Reporting of Seasonal Performance Factor** of heat pumps is not always fully defined in reporting performance of heat pumps, such that it is not clear whether it is the performance of the heat pump unit or the overall system including pumps, ground collector loops etc. Monitoring of heat pumps should allow the performance of the heat pump unit and the total performance of the system to be evaluated, and reporting of performance should clearly state whether it is H1, H2, H3 or H4 as per the SEPEMO guidance.
c. **Side-by-side monitoring of heat pump systems** that allows comparison with similar buildings with conventional systems can provide valuable information. Information about occupancy patterns and control usage is essential to evaluation of differences in performance between similar systems.
d. **Monitoring of communal systems** is required to understand the performance of systems in practice and to evaluate their proper application.
e. **Controls and communication** issues require greater attention to ensure end users understand that heat pumps are more sensitive than conventional systems and require some change in heating patterns and behaviour to maximise performance.

## 1.4. Documented problems in domestic heat pumps

Using some information gathered from end users and from providers of end user advice / customer care, we have been able to provide a snapshot of the current types and level of problems with domestic heat pumps in the UK, and the consequences of these problems for the end user and the industry sector.

There are two main types of heat pumps, which due to their different designs and applications have different issues. Key problems and issues with heat pumps can be divided into six main categories, with regards to the source of the problem:

- Equipment and components
- Design and specification
- Application and site suitability
- Installation and commissioning
- End user control/use
- Maintenance/faults

There are limited reporting systems for heat pump failure within the UK. Gemserv, the MCS secretariat, only records data before passing it through to Certification Bodies to investigate the matter in question. There is no centralised analysis of the different failure modes.

The REAL Code, the only MCS consumer code, have a database of consumer complaints about installers (rather than manufacturers) and the nature of the most recent complaints are largely in relation to technical issues, poor performance and design problems.

This work highlights the diverse nature of the complaints process within MCS. Secretariat, the Consumer Code and the certification bodies all have overlapping responsibilities and no one organisation is holding the structure together or overseeing the complaints process.

There is only limited numerical information available in the UK on problems and failures. However, there is a lot of reported information from many sources on the many different types of problem, which are discussed in greater detail in Section 3.4 of this report.

## 1.5. SAP Appendix Q

The UK Government's Standard Assessment Procedure (SAP) for Energy Rating of Dwellings, including Reduced Data SAP (RdSAP), is the UK's National Calculation Methodology (NCM) for dwellings.

To assess a dwelling's energy performance, data is needed that describes the dwelling in terms of the energy performance of installed construction components and building services equipment. Such data is either generic (i.e. determined by the materials and type of product used) or specific (i.e. where validated individual product performance data has been made available). The SAP rating is used to measure the energy performance of dwellings using a scale from 1 to 100, where the higher the number, the lower the running costs.

Within the scope of this report there have been two significant editions of SAP:

- SAP2005 (Appendix G: Heat Pumps) and;
- SAP2009 (Appendix N: Microgeneration (or micro-CHP) and Heat Pumps).

***SAP Appendix Q***

SAP2005 Appendix G: Heat Pumps centred on ground and/or water source HPs, ASHP and heat emitter delivery temperatures, whereas SAP2009 Appendix N: Microgeneration and Heat Pumps centred on both the HP technology and set of optional other components including thermal stores and / or auxiliary heaters. Furthermore there are no longer fixed Coefficient of Performance (COP) values in SAP 2009; and performance data for HPs is obtained from:

- The Product Characteristics Database (Appendix Q); and
- Table 4a of the SAP2009 document

SAP Appendix Q is a route whereby manufacturers can demonstrate enhanced performance within SAP, the UK's Energy Rating of Dwellings calculation methodology. Competitor accreditation schemes such as the EHPA quality label will continue to press to be recognised as equivalent routes to accreditation.

## 1.6. Heat Pump Emitter Guide

The Heat Emitter Guide for Domestic Heat Pumps was developed by a series of Trade Associations with the support of the Department of Energy and Climate Change (DECC) and the Energy Saving Trust. The guide is intended to be used by heat pump designers when they are using either an existing radiator based heat emitter circuit or designing a new heat distribution emitter circuit. The Heat

Emitter Guide is an innovative document that associates heat pump flow temperature with ASHP & GSHP SPF and heat emitter oversize factors. It is useful for both the designer and also for providing the householder with a temperature star rating for their installation. The Heat Pump Emitter Guide would benefit from a dedicated committee for its future development.

## 1.7. MCS020 permitted development rights for air source heat pumps

Because ASHP units emit noise, planning permission restrictions are placed on these heating systems and these planning permission restrictions vary from country to country within the UK. In certain circumstances and locations, permitted development rights (PDRs) apply.

In some areas of the country, known generally as 'designated areas', there are more restrictions on permitted development rights. In particular, if a building or site is a Conservation Area, a National Park, an Area of Outstanding Natural Beauty or the Norfolk or Suffolk Broads, it will be necessary to apply for planning permission for certain types of work which do not need an application in other areas. There are also different requirements if the property is a listed building.

The full English requirements for PDR on ASHPs are set out on Communities and Local Government's Planning Portal where it says that *'Development is permitted only if the air source heat pump installation complies with the Microgeneration Certification Scheme Planning Standards or equivalent standards.'* The Microgeneration Certification Scheme (MCS) planning standards for ASHPs are provided in MCS 020 issue 1.

The MCS 020 standard sets out that as well as using an MCS (or equivalent) product and the installation being the latest version of MIS 3005 compliant, the ASHP installation shall be carried out in compliance with the calculation procedure contained in Table 2 of MCS 020. Installers must complete the 'results/notes' column in Table 2 for each step of the calculation procedure to show how it has been followed.

The MCS ASHP planning standard has three main criticisms levelled at it:

- Noise abatement notices can be raised to limit ASHP use at certain times
- MCS 020 calculation reliant on supply of accurate A-weighted sound power level
- Tonality and aural characteristics not adequately addressed

These issues are discussed in further detail in the section 3.7 of this report.

The noise issue related to ASHP is far from settled and it is noted that the Institute of Acoustics called for a 35 dB LAeq limit. Manufacturers need to implement further work to minimise sound power levels and also address tonality matters. There also needs to be a further robust discussion on noise issues.

## 1.8. Arrangements for insurance & consumer protection

If a customer has an issue or complaint about a heat pump, it is likely to fall within at least one of the following categories:

1. **Technical** relating to the performance of the installed system
2. **Non-technical** or contractual relating to the service and/or customer care

Protection is provided for customers of renewable energy in these two areas and covers the prevention of or limitation of risk of problems occurring and the procedures and customer support in the event of claims.

In the UK and across Europe, consumer rights are protected through statutory laws and directives covering the process of selling and sale of goods, guarantees and warranties and contractual agreements and through Codes of Conduct which businesses have to abide by to gain approval from trade organisations or schemes such as the Renewable Energy Association, Ground Source Heat Pump Association or the Buy with Confidence scheme. These laws and codes are enforced by Government supported organisations such as Trading Standards services as well as independent trade and consumer organisations and schemes.

In the UK, there are now schemes such as the Microgeneration Certification Scheme (MCS) and the Renewable Energy Consumer Code (RECC) in place to provide customer protection and insurance for the sale of domestic microgeneration products. These schemes are relatively new and the recent UK Government Microgeneration Strategy consultation revealed some key areas for improvement.

During the Government consultation on the Microgeneration Strategy, key organisations including Consumer Focus, REAL and Which? provided responses. Key topics in the area of insurance and consumer protection discussed by these organisations are listed below, with further details of recommendations in 3.8 Arrangements for insurance & consumer protection.

- Lifetime Repair and Maintenance Guarantees
- Enforcement of Installer Standards & Certification
- Clarity on/ Enforcement of Sub Contracting Responsibility
- Clarity on Commissioning of Installation
- Approval of Companies Generating Sales Leads
- Approval of Companies Signing Contracts
- Guarantee Wording
- Method/Approach to Dealing with Consumer Complaints
- Funding for Independent Expert Reports
- Information Provision
- Insurance under Different Business Models
- Insurance Backed Warranties Cost

## 1.9. Laboratory test requirements of MCS

There are two main accreditation and certification schemes in the UK: the Microgeneration Certification Scheme (MCS); and the Enhanced Capital Allowance (ECA) scheme, where successfully registered HP products are included on the Energy Technology Product List (ETPL). A third scheme in the UK is the Competent Persons Scheme (CPS) introduced by the Department of Communities and Local Government to enable companies to self-certify plumbing and heating works that fall under the scope of Building Regulations.

HPs are tested by a UKAS accredited or similar test laboratory. In EU member states, BS EN 14511 specifies standard rating conditions for tests (including collector [source] and heat emitter [sink] temperatures) depending upon the type of HP. Whereas HPs sold in the US have an EnergyGuide Label which allows side-by-side comparison of HPs, by standardising test conditions, parameters and test methodology within BS EN 14511, it is possible to similarly compare the Coefficient of Performance (COP) of different HP units.

Thermal performance and power consumption can be tested in heating and cooling mode for air-source, water-source and ground-source HPs. Results include testing COP and Energy Efficiency Ratio (EER) (at full load to EN14511) and part-load testing of Heating Seasonal Performance Factor (HSPF), Seasonal Energy Efficiency Ratio (SEER) and part-load COP (to prEN14825). Testing for part-load COP demonstrates the product's long-term efficiency and gives more realistic performance data for a heat pump in real use.

In addition to thermal performance tests, safety tests must be conducted in accordance with EN 14511 Part 4.

Sound characteristic tests are also a requirement of the MCS, and are carried out in accordance with *BS EN 12102: 2008 Air conditioners, liquid chilling packages, heat pumps and dehumidifiers with electrically driven compressors for space heating and cooling*. *Measurement of airborne noise, Determination of the sound power level.*

There are two main accreditation and certification schemes in the UK, MCS & ECA. A third scheme in the England and Wales is the Competent Persons Scheme (CPS) introduced by the CLG to enable companies to self-certify plumbing and heating works that fall under the scope of Building Regulations. Rationalisation of MCS and CPS schemes would be beneficial.

MCS is a BS EN 45011 scheme. For MCS product testing, MCS 007 uses BS EN 14511 to test heat pumps and a Factory Production Control. An equivalent scheme to MCS, Solar Keymark which certifies solar thermal collectors uses a European standard BS EN 12975/76 to test the product and also has a Factory Production Control. MCS for solar collectors also uses BS EN 12975/76 and has a Factory Production Control. Solar Keymark is a product certification scheme and does not certify installation companies.

## 1.10. Heat pump control requirements

With combustion technology such as a gas condensing boiler, the efficiency of the system can be increased by several percentage points as the flow temperature from the boiler decreases. However, as can be seen in the Heat Emitter Guide, a heat pump performance can be improved by a factor of over 1.7 by reducing the flow temperature from 60 to 35 °C and this is a far more significant change as compared to combustion technology. System design is a key factor in reducing the flow temperature of a heating system e.g. large heat emitters facilitate low flow temperatures. However, without an effective control circuit, it will be difficult to maintain the flow temperatures at or below the design condition.

A typical British heating control system features the following items:

- A programmer
- A room thermostat
- A cylinder thermostat
- Thermostatic Radiator Valves (TRVs)
- A 3-way or 2 off 2-way valves

This typical circuit offers time and temperature control of space and hot water heating and is typically hot water priority. The ergonomics of this typical heating control system are generally poor. Whilst the temperature scales on thermostats are believed to be easy-to-understand by the majority of occupants, the thermostats are often located in hallways with little relation to room temperature. Time programmers are often complex and in the authors experience, difficult-to-explain to the end user. Wider research in the UK has shown that a significant proportion of householders do not understand their heating controls, don't set them appropriately or even don't use them; revealing that usability of controls is a key factor in determining if they are used at all or as intended by the designer. Similarly, TRVs typically have numbers 1 to 6 on their dials and these numbers are not related to actual room temperature.

Innovation is happening in the heat pump controls market. Companies such as Eco-innovate build a range of specific heat pump control units such as return temp > 30 °C, monoenergetic boost circuits to minimise electrical top-up energy, start-up controls, information on HP parameters and integrated buffer & thermal stores. It will be interesting to see whether there is demand in the market for these features and if so, whether manufacturers adopt or build-in these features. Like many innovators, claims are made for the benefits of these products that are open to question. For example, with Eco-innovate's products the need for Legionella pasteurisation cycles is disputed when Legionella bacteria can develop in both small pipework volumes as well as larger cylinders. Therefore, whilst the risk would be lower in thermal store as compared to a vented cylinder, the risk is not eliminated.

***Conclusions***

Existing heat pumps are either typically controlled by return set-point sensors on fixed speed compressor heat pumps and flow set-point sensors on variable speed compressor heat pumps. Weather compensation is common and so are internal thermostats. Currently, designers, installers and commissioning engineers have to attempt to establish the right heat pumps run times, weather compensation curves and offsets to set up the system for optimum performance.

There appears to be huge opportunities, given the very significant benefits to heat pump efficiency of high collection and low distribution temperatures and optimum compressor run times, for much "intelligence" to be built into the heat pump to maximise the unit's efficiency and reliability for any given set of internal and external parameters.

There is also a need to simplify the human interface on the control units and also to provide the occupants that so desire with information on energy consumption, running cost and operational efficiency.

Therefore, it is anticipated that there will be many developments in heat pump controls and interfaces over the coming years.

## 1.11. MCS requirement on end user advice

MIS 3005 Issue 3.1 is the UK standard for the supply, design, installation, set to work commissioning and handover of heat pump systems, as detailed in 3.1 MIS Guidance section of this report. The end user advice requirement is for 'the installer [to] provide the customer with a comprehensive document pack'. This document pack is required to include details on at least the following:

- Sizing
- Domestic hot water services

- Emitter design
- Ground heat exchanger design
- System performance
- Maintenance requirements and services available
- A certificate signed by the Contractor

The Energy Saving Trust's field trial of domestic heat pumps in the UK found that many householders reported difficulties in understanding the instructions for operating and using their heat pump, and that control systems on heat pumps were generally too complicated for the end user to understand, with some householders experiencing difficulty controlling the ambient temperature of rooms.

The MCS requirement on end user advice provision for heat pumps is detailed in Chapter 6 *Handover Requirements* within MIS 3005 Issue 3.0. The requirements set do not currently stipulate that information is provided by the Contractor that will advise the client on using or controlling their new heat pump or that the Contractor explains to the user how to control and use the heat pump to ensure it operates at maximum efficiency.

Currently, advice on the efficient use and control of a heat pump provided to the end user is contained either:

a. Within the information provided by the Manufacturer or Supplier/Distributer of the heat pump i.e. design, installation and operational manuals.
b. Dedicated/separate user manuals or guides for both the Heat Pump and/or control packages.

The key findings from a review of the level of information and advice contained within documentation provided by manufacturers of MCS accredited heat pump systems revealed:

- **Lack of information** on efficient operation found in many manuals
- **Use of technical jargon** on end user advice
- **Varying complexity** and level of information on operation of controls
- **Lack of dedicated user guides** which contain all user advice for heat pump and controller
- **Too much detail** for the average non-technical end user; lack of summary information

The review highlighted that as a minimum, the end user should ideally be provided with:

- **An introduction** to heat pump technology
- **Explanation of the key differences** between a heat pump and a conventional system
- **Advice on adjusting to living with the heat pump** and how to fine tune the system
- **Information on programming** of heating and hot water schedules
- **Advice on making the most of the heat pump** system
- **A 'Quick-Start' guide** or summary user guide

Examples of end user advice which meet some or all of the recommended requirements listed above include: Kingspan's Aeromax Plus Homeowners Guide; Diakin Air Conditioning User Guides for ASHPs; Mitsubishi Electric Heating Systems Homeowner Information and Quick Start Guide for Ecodan® Air Source Heat Pump and Nu-Heat User Guide for Hitachi Yutaki Air Source Heat Pump.

# 2. Introduction

## 2.1. Aims & objectives

The aim of this work was to undertake a wide-ranging literature review of the current standards, requirements, legislation and training within the UK heat pump industry compared to those found internationally, and a thorough review of key field trials and documented problems.

The objective of the work was to primarily review the following:

a) MIS guidance prior to MIS 3005 Issue 3.1;
b) Training programmes prior to MIS 3005 Issue 3.1;
c) Domestic heat pump field trials in the UK;
d) Documented problems in domestic heat pumps;
e) Arrangements for insurance and customer protection;
f) The Heat Pump Emitter Guide;
g) SAP Q for Heat Pumps;
h) MCS020 Permitted Development Rights for Air Source Heat Pumps;
i) MCS laboratory test requirements for heat pumps;
j) Heat pump control requirements; and
k) MCS requirement on end user advice

The literature review excludes the Energy Saving Trust's heat pump trials as these are already described in detail in other strands of Annex 36.

Each section of the literature review provides a critical discussion of the issue in question, delivering both insight and awareness of opposing cases, theories, approaches and experiences across government, businesses, industry and non-governmental organisations.

## 2.2. Methodology

The aim, methodology and approach to delivery of the objectives are described below.

### a) MIS guidance

**Aim:** Review the MIS guidance prior to MIS 3005 Issue 3.1, and compare this to various standards found internationally

**Method:** Within the UK, the main advice prior to MIS 3005 Issue 3.1 consisted of MIS 3005 version 2, TR30 HVCA Heat Pump guide to good practice, CE82 Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems – A guide for specifiers, their advisors and potential users, manufacturer's advice and Environment Agency advice. This Guidance has been reviewed and compared to European advice from various trade bodies and manufacturers, including the most influential guidance: 'VDI 4640 – German Guidelines for Ground Coupled Heat Pumps, UTES and Direct Thermal Use of the Underground'.

## b) Training programmes

**Aim:** Review training programmes prior to MIS 3005 Issue 3.1, and compare these to training programmes internationally

**Method:** Prior to MIS 3005 v3.1, City & Guilds, BPEC, EAL, EU-Cert, Logic Certification and various manufacturers either had courses on the market or in development. City & Guilds and EAL were working together with the National Skills Academy. These training programmes have been compared to international training, including one of the greatest influences on the UK market: the Oklahoma University based IGSHPA training along with the EU-Cert HP training course developed by stakeholders at EHPA and the Geotrainet ground collector designer and driller training materials developed by stakeholders at EGEC. The need for MCS to implement competency criteria has also been reviewed, along with other developments that are in the pipeline.

## c) Field trials

**Aim:** Review field trials of domestic heat pumps in the UK (excluding the EST heat pump field trials), depending on the availability of data

**Method:** Information, data and learning from field trials of domestic heat pumps in the UK conducted outside the EST's large scale field trial has been gathered through existing connections in the industry and academia, including specific contacts who were known to be active early on in the heat pump industry and involved in early trials of the technology. The data reviewed includes those studies that have been published and publicly available as well as some unpublished studies and findings.

## d) Documented problems

**Aim:** Review documented problems in domestic heat pumps (excluding those in the EST trials)

**Method:** As with task c), the existing network of relevant contacts have been used to source both official documented literature as well as informal /un-attributable sources information on problems with domestic heat pumps. Information has been gathered from end users and from providers of end user / customer advice to provide a snapshot of the current types and level of problems with domestic heat pumps in the UK, and the consequences of these problems for the end user and the industry sector.

## e) Insurance & consumer protection

**Aim:** Review the arrangements for insurance, and consumer protection in the event of a complaint, in the UK, and in other EU countries

**Method:** Information from key sources and contacts on insurance and customer protection arrangements have been gathered and reviewed. This information has been sourced through the work of the MGICG (Microgeneration Government Industry Contact Group), MCS, the REAL Assurance Code and several other companies who are providing insurance such as Insurance Backed Guarantees to the UK microgeneration industry, and information on other EU countries has been obtained through the EHPA and European Centre for Services (Trading Standards Institute).

## f) Heat Pump Emitter Guide

**Aim:** Review the Heat Pump Emitter Guide, and compare to SPF calculation methodologies found internationally.

**Method:** The Heat Pump Emitter Guide was developed by the portfolio of organisations as listed on its front cover and the detail is set out in the fine print within the document. The ground source SPF's were based on European Heat Pump standards and the air source SPFs are the ground source figures with 0.7 subtracted.

The HE Guide is extensively used in MIS 3005 v3 design methods including Table 3 and this has been reviewed with recommendations for improving the accuracy of the guidance and the design methods associated with the guidance.

## g) SAP Q

**Aim:** Review SAP Q for Heat Pumps, and compare to SPF calculation methodologies found internationally, and with the Heat Pump Emitter Guide

**Method:** SAP Q is a proprietary calculation methodology owned and implemented by BRE, and has been compared with other similar methodologies to discuss its benefits and issues and propose routes to rationalise its delivery.

## h) MCS020 permitted development rights

**Aim:** Review MCS020 Permitted Development Rights for Air Source Heat Pumps, and compare with planning requirements found internationally

**Method:** Noise implications and information have be collated in association with EHPA and other stakeholders to provide an improved understanding of air source implications hopefully leading to improved guidance and more confidence that current requirements will ensure satisfied end users and their neighbours.

## i) Laboratory test requirements

**Aim:** Review the heat pump laboratory test requirements of MCS and compare to those of the Solar Keymark requirements, and recommendations, if appropriate.

**Method:** MCS and Solar Keymark are both EN 45011 schemes that require Factory Production Control. This section provides a discussion of the benefits of each scheme which could lead to scheme development such as improved factory production control or scheme structures.

## j) Heat pump controls

**Aim:** Review of UK and international heat pump control requirements and evaluate whether these currently provide adequate time and temperature control for the efficient control of heat pumps.

**Method:** The design specification of key heat pump controls currently in the market have been compared to requirements for efficient control of heat pumps to evaluate any gaps and the potential impact on performance of heat pumps. The outcome is an understanding of the required controller specification to ensure adequate time and temperature control of heat pumps, with recommendations for improvement to help close the performance gap.

## k) End user advice

**Aim:** Review of MCS requirement on level of advice provided to end users of heat pumps on efficient control and use of heat pumps, and compare internationally.

**Method:** MCS requirements on end user advice have been reviewed and an evaluation the quality of key examples of information / advice given to end-users undertaken to review whether these meet the regulatory standards. The outcome of this has been a review of areas requiring improvement and inclusion in future MCS standards to ensure end-users are able to understand and control heat pumps efficiently.

# 3. Literature review

## 3.1. MIS guidance prior to MIS 3005 Issue 3.1

### Introduction

In the heat pump sector, guidance and standards can be categorised into three key areas:

- **Technical standards** for efficiency, safety and longevity etc., and for geothermal systems standards for environmental protection (drilling, boreholes etc.).
- **Certification** of competence and installation/drilling quality
- **Regulations and guidelines**, e.g. for licensing of geothermal systems

In the UK, the Microgeneration Installation Standard: MIS 3005 *Requirements for Contractors Undertaking the Supply, Design, Installation, Set to Work Commissioning and Handover of Microgeneration Heat Pump Systems* Issue 3.1 was first published by DECC on 1st February 2012 and subsequently updated in March 2012. MIS 3005 was developed by the MCS Working Group 6 'Heat Pumps' and was approved by the Steering Group of MCS. The Working Group includes representatives from trade and industry; manufacturers, installers and trade bodies as well as Government.

DECC instigated a review of MIS 3005 to make design standards more prescriptive, ensure consistent satisfactory performance and provide a standard that is clearer for installers to follow and for auditors to survey.

The standard addresses six key areas:

1. heat loss calculation (including power & energy);
2. heat pump sizing;
3. heat emitter selection;
4. domestic hot water preparation;
5. cost calculations; and
6. ground collector design and installation.

MIS 3005 also places additional emphasis on handover and documentation.

The aim of this report section is to review the MIS guidance prior to MIS 3005 Issue 3.1, and compare this to various standards found internationally.

### Comparison of MIS 3005 Issue 2.0 and Issue 3.1

Prior to MIS 3005 Issue 3.1, the main guidance and advice for the design and installation of heat pumps in the UK consisted of *MIS 3005 Issue 2.0*. The key differences between Issue 3.1 and 2.0 of MIS 3005 are described below.

#### *MIS 3005 Issue 2.0, DECC (2010)*

MIS 3005 Issue 2.0 was first published in 2010 and provided general principles to be met when designing, specifying and installing Microgeneration Heat Pump systems. While Issue 2.0 provided overall general principles and recommendations for specific requirements it referred to *HVCA publication Guide to Good Practice – Heat Pumps [TR30]* for specific requirements relating to the installation, materials, system commissioning checks, customer document pack and handover procedure.

The key changes within Issue 3.1 of MIS 3005 compared to MIS 3005 Issue 2.0 are outlined in Table 2 below.

**Table 2 List of Key Changes within MIS 3005 Issue 3.1**

| Topic | Description | Reason for Change |
|---|---|---|
| *Heat Loss Calculation* | Room by room heat loss calculation to comply with BS EN 12831 | Bring repeatability and accuracy to space heating power calculation |
| *Internal & External Temperatures* | Heat loss calculation to be based on internal and external temperatures using CIBSE Guide A | Bring repeatability and accuracy to space heating power calculation |
| *Heat Pump Sizing & Selection* | Selection of heat pumps to provide at least 100% of calculated design space heating power requirement (or fossil-fuel bivalent system) | Correctly size HP to space heating loss |
| *Energy Calculation* | Use of degree day or temperature bin data in calculation of design space heating power requirement | For ASHP & GSHP, to introduce an accurate costing calculation erring on the side of caution. For GSHP only, to size the ground loop accurately |
| *Hot Water Calculation* | Use of BS 6700 or BS EN 806 in determining the total heating energy consumption | Bring repeatability and accuracy to hot water cylinder sizing and energy consumption |
| *Control System* | Integration of heat sources through a single "interlocked" control system | Make sure building regs are followed |
| *Disclosure of Costs to Customer* | Communicate and explain to customer the implications of the space heating and domestic hot water system design on the building heat and hot water running costs | Empower the customer |
| *Heat Emitter Selection* | Full explanation and use of the Heat Emitter Guide, to help system designers/installers to select an emitter type and operating temperature which will result in high efficiency and low running costs. | Empower the customer and assist the designer in understanding relationship between HP settings and heat emitter system |
| *Ground Source Heat Pumps* | Specific requirements for Ground Source Heat Pumps (ground collector loop design) including:<br>• Fluid entry temperature of 0°C for 20 years<br>• The Reynolds number of the thermal transfer fluid in the ground heat exchanger active elements to be ≥ 2500 at all times<br>• Collector pump power to be < 2.5% of total heat pump power[1]<br>• Recalculation of ground heat exchanger if variation from geological conditions used in design | Fluid entry temperature of 0°C for 20 years:<br>*Avoid undersizing ground collector*<br>Reynolds number ≥ 2500 at all times<br>*Establish good heat exchange in collector*<br>Collector pump power t< 2.5% of HP power<br>*Avoid oversized ground loop pumps*<br>Recalibrate ground HX if variation in geology<br>*Good practice*<br>Purging to robust guidelines |

[1] Note that this is power, not energy consumption. MCS HP WG and SMG have approved a change from 2.5% to 3% but this is not included here as it is not on the market yet. The authors recommend that if this level is not being achieved in field trials, this should be highlighted and discussed further by all stakeholders

| | | |
|---|---|---|
| | • Purging to robust guidelines<br>• Pressure testing to BS EN 805 section 11.3.3.4<br>• Antifreeze solution protection to -10ºC with suitable biocide and tested twice with a refractometer | *No air in ground collector*<br>Pressure testing to BS EN 805 section 11.3.3.4<br>*No leaks in ground collector*<br>Antifreeze solution protection to -10ºC with suitable biocide & tested 2 times refractometer<br>*Fluid life and avoidance of freezing* |
| *Handover & Documentation* | Installer to provide customers with a comprehensive document pack including information on sizing, domestic hot water services, emitter design, ground heat exchanger design (if applicable), and system performance. | Empower the customer |

While MIS 3005 Issue 3.1 provides much more detail and specific guidance than MIS 3005 Issue 2.0, it also refers to a number of other key publications, standards and references for further guidance including:

- **MCS 001 –** Installer certification scheme document
- **MCS 002 –** Guidance on regulations and directives for microgeneration installations
- **BS EN 12831**: Heating systems in buildings
- **Guide A: Environmental Design**. A CIBSE publication
- **CIBSE Domestic Heating Design Guide**. A CIBSE publication
- **BS 6700**: Specification for design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages
- **BS EN 806**: Specifications for installations inside buildings conveying water for human consumption
- **Closed-loop Vertical Borehole –** Design, Installation & Materials Standard Issue 1.0 2011
- **HSE Approved code of practice (ACOP) L8** - The control of legionella bacteria in water systems, approved code of practice and guidance
- **Environmental good practice guide for ground source heating and cooling**. GEHO0311BTPA-E-E. Published by Environment Agency 2011.
- **MCS 022 –** Ground heat exchanger look-up tables. Supplementary Material to MIS 3005.
- Heat Emitter Guide.
- **MCS 020 –** Planning Standards.
- **"Report for DECC: Measurement of domestic hot water consumption in dwellings",** Energy Monitoring Company, March 2008.
- **BS EN ISO 13790**: Energy performance of buildings- Calculation of energy use for space heating and cooling

## Guidance prior to MIS 3005 Issue 3.1

In addition to MIS 3005 Issue 2.0, the main guidance and advice for the design and installation of heat pumps in the UK prior to MIS 3005 Issue 3.1, included advice provided by the HVCA, Energy Saving Trust, CIBSE, heat pump manufacturers and the Environment Agency, as outlined in Table 3 below.

There is notably a greater level of guidance available for ground source heat pumps, which is both due to the relative maturity of the ground source heat pump market and the greater level of technical complexity inherent with ground source heat pump installations (ground works, ground collector loop etc.). Since 2008, the domestic ASHP sector in the UK has grown to be several times the size of the domestic GSHP sector and so it is anticipated that the quantity of advice for installing ASHPs should increase to match this market size. However, so far there has been a lag in this advice provision.

**Table 3 List of main UK heat pump guidance prior to MIS 3005 v 3.1**

| Author | Date | Document Title / Ref |
|---|---|---|
| MCS | 2010 | Microgeneration Installation Standard: MIS 3005 Requirements for Contractors Undertaking the Supply, Design, Installation, Set to Work Commissioning and Handover of Microgeneration Heat Pump Systems |
| HVCA | 2007 | Guide to Good Practice: Heat Pumps (TR30) |
| Energy Saving Trust | 2007 | Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems – A guide for specifiers, their advisors and potential users (CE82) |

| | | |
|---|---|---|
| CIBSE | 2004 | Domestic Heating Compliance Guide (now called the Domestic Building Services Compliance Guide) |
| Environment Agency | - | GEHO0311BTPA-E-E Environmental good practice guide for ground source heating and cooling |
| Manufacturers (various) | - | Key manufacturers providing guidance on design and installation include Dimplex, Kensa Engineering etc. |

The background, aims, objectives and content of these key guidance publications is described below.

***TR30 Guide to Good Practice Heat Pumps, HVCA (2007)***

The Guide to Good Practice Heat Pumps publication was first published in 2007 and written by BSRIA on behalf of HVCA and reviewed by the BRE, CIBSE, FETA, HPA and the HVCA Technical Committee.

The Guide covers the installation of air to air, air to water, ground to water heat pumps and open loop water to water heat pumps, surface water heat pumps and borehole heat pumps. It also includes guidance on heat distribution, domestic hot water provision and controls.

The aim of the Guide was to assist professional building services engineers to specify and design heat pump systems for heating and cooling in buildings. However, it does not cover matters relating to design or commissioning; and the document explicitly states that reference should be made to appropriate CIBSE or BSRIA documentation (commissioning codes and pre-commissioning cleaning of pipework systems) for these requirements and specifications.

MIS 3005 Issue 2.0 includes the requirement for heat pumps to be installed in accordance with HVCA TR30 Section 3. The specific requirements in TR30 include adherence/compliance with:

- Section 8 of Domestic Heating Compliance Guide (now Domestic Building Services Compliance Guide)
- BS7671 (electrical installations) and Part P of Building regulations
- Water fittings regulations and Part G of Building Regulations where applicable
- The Ozone Depleting Substances (Qualifications) Regulations 2006
- Manufacturer's recommendations for the electrical installation, ventilation (in accordance with BS EN 378), clearances for maintenance, refrigerant pipework (with reference to RAC/80 – Design Specification for DX Packaged Air-Conditioning Equipment in Buildings), and minimum air flow rates.
- HVCA Publications: DW/144 - Specification for Sheet Metal Ductwork - low, medium and high pressure/velocity air systems or DW/154 - Specification for Plastic Ductwork
- HVCA Publication: TR/6 - Guide to Good Practice - Site Pressure Testing of Pipework
- BSRIA AG1/2001.1 (flushing of steel or copper pipework)
- HVCA Publication: TR/20 - Installation and Testing of Pipework Systems Part 1 – Low temperature hot water heating
- HVCA Publication: DCHI/1 – Domestic Central Heating Installation Specification
- CIBSE Commissioning Codes

Prior to MIS 3005 v3, version 2 of the MIS standard was based on TR30. This document is not as prescriptive as the requirements in version 3 of MIS 3005 and TR30 for ground source technologies was based on VDI 4640 rather than MCS 022 (the look-up tables). TR30 still called for such features as a full heat loss calculation but did not specify how this was to be performed whereas version 3 of MIS

3005 looks to specify the design method throughout. For example, it requires a BS EN 12831 heat loss calculation rather than just a heat loss calculation.

***CE82 Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems, Energy Saving Trust (2007)***

The Energy Efficiency Best Practice in Housing guide on Domestic Ground Source Heat Pumps was first published in 2007, and was developed to provide guidance for specifiers and their advisors as well as potential users, on: types of systems; how to achieve an integrated design; how to maximise efficiency; capital and running costs; and do's and don'ts for the design and installation of ground source heat pumps.

This publication provides general guidance on aspects such as the depth of trenches for horizontal loop collectors, the length of collector loop taking into consideration the ground conditions, pipe diameters, operating temperatures and energy consumption of the circulating pumps, insulation of pipework, installation of ground loop collectors, heat pump sizing, electrical requirements, heat distribution for space and hot water, control strategies.

It also referred to a number of general information sources and British Standards for further guidance. In particular, CE82 referred to the IEA Heat Pump Centre for guidance on design tools and sizing and suppliers.

***Domestic Heating Compliance Guide, CIBSE (2004)***

The Domestic Heating Design Guide was first published in 2004 by CIBSE, and has since been updated to the Domestic Building Services Compliance Guide (DBSCG). It was developed to assist professional heating engineers to specify and design wet central heating systems, and provides a simple method for engineers to design and understand central heating systems including topics such as: energy efficiency; heat losses and u-values; heat loss calculations; radiators and other heat emitters; boilers; domestic hot water supply; system layouts; circulator selection; open vented systems; sealed heating systems; pipework insulation; system controls; combustion air, ventilation and flues; fuel storage; and handover and future service.

The heat pump section of the DBSCG initially covers definitions of GSHP, WSHP and ASHPs and then specifies minimum CoP/SPF (to be measured according to BS EN 14511-4:2000) as follows:

- Space heating CoP ≥ 2.2
- Hot water CoP ≥ 2.0
- SPF ≥ minimum required by BS EN 15450 table C1 for new build and table C2 for existing build

<u>For wet systems:</u>

- underfloor flow temp between 30 to 40˚ C new build and 30 to 55 ˚ C existing build
- radiators to be high volume and flow temp between 40 ˚ to 55 ˚ C
- fan coil units to be flow temp between 35 to 45 ˚ C
- layout to reverse return or a low loss header
- all pipework to Part L of the Building Regulations
- Ground loops to contain antifreeze and inhibitor and cleaned including a biocide
- an inhibitor should be used in the distribution circuit
- the HW system must be capable of heating between the secondary water to 60 and 65 ˚ C (with immersion heaters as required) and time & temperature controlled

- The controls must manage as appropriate all pumps, water temps, fans, defrost cycles etc. Controls must provide protection for water/air flow, high temp and high refrigerant pressure failure and allow for time and temperature control of space heating.

For air systems

- manufacturer's advice should be followed on airflows, pipe sizes and pipe insulation. With summer cooling, internal condensate drainage is required.
- For GSHP and WSHP, TIMSA guidance should be followed for insulating between the collector and building and constant water flow must be maintained in the HP unit.
- Control of as appropriate room air temperature, outdoor fans & pumps, defrost cycles, secondary heating and protection for high water temp, high refrigerant pressure and for air/water flow failure. Time and temperature control must be interlocked to the heat pump unit.

***Environment agency***

This environmental good practice guide (EGPG) has been developed for designers, developers, installers, drillers and owners of Ground Source Heating and Cooling (GSHC) schemes, providing advice and guidance on complying with environmental legislation and managing environmental risks. This is of particular relevance to Ground Source Heat Pumps, and covers general requirements for GSHC schemes and good practice guidance for closed loop and open loop schemes including:

- Environmental Impact Assessment;
- Good practice for excavations, drilling and borehole completion;
- Decommissioning;
- Pollution prevention; and
- Groundwater investigation consent.

***Manufacturer advice***

A number of key manufacturers have published guidance on planning, design and installation for their heat pump product range. For example Dimplex produced two key documents in 2008 and 2009:

- Project Planning and Installation Manual: Heat Pumps for Heating and Hot Water Preparation (Version 07/2009)
- Project Planning Manual: Heating and Cooling with Heat Pumps (Edition 11/2008)

This guidance is very detailed and specific to the manufacturers' products, providing a much greater level of advice on the design and installation of heat pumps compared to the guidance in MIS 3005 Issue 2.0, EST's CE82 and HVCA's TR30. However, while manufacturer's guidance does provide reference to the relevant EU and BS standards, it also includes the use of shortcuts such as for estimating the heat demands of a building using existing consumption data or 'rules of thumb'. In particular, many manufacturers used an average W/m$^2$ calculation for the whole property type to size the heat pump rather than a specific room-by-room fabric and ventilation heat loss calculation, as now required by MIS 3005 Issue 3.1.

## International heat pump guidance & standards

International guidelines and standards for heat pumps exist relatively widely. There currently exists comprehensive, consistent set of technical standards for heat pump equipment across Europe, through EN standards for testing and safety etc., which Member states have adopted into national standardisation or are in the process of replacing pre-existing national standards with the EN standards. National standards for heat pumps existed in countries with a mature heat pump market e.g. Germany, Switzerland and Sweden, and in some cases these national standards still exist to cover areas not covered by EN standards[2].

For Ground Source Heat Pumps, EN standards currently only exist for drilling safety, with national technical standards and certification/licensing requirements existing in countries where the heat pump market is already well developed including Germany, Sweden and Austria, and Switzerland[3].

The most influential advice and guidance on the design and installation of heat pumps both European and internationally are listed in Table 4.

**Table 4 List of key international heat pump guidance prior to MIS 3005 v 3.1**

| Author | Country | Date | Document Title / Ref |
|---|---|---|---|
| IGSHPA -International Ground Source Heat Pump Association | International | 1980 - 2009 | Residential and Light Commercial Design and Installation Manual (#21025) (2009), Slinky™ Installation Guide (#21050) (1994), Design and Installation Standards (#21035) (1980s), Soil and Rock Classification Field Manual (#21060) (1989), Grouting for Vertical GHP Systems (#21015), CLGS Installation Guide (#21020) |
| Ochsner, Karl | International | 2007 | Geothermal Heat Pumps: A Guide for Planning and Installing |
| CEN - European Committee for Standardisation | Europe | 2007 | Heating systems in buildings – Design of heat pump heating systems, EN15450 |
| ÖWAV - Austrian Water and Waste Management Association | Austria | 2009 | ÖWAV - Regelblatt 207 - Thermal use of the groundwater and the underground, heating and cooling |
| AWP Schweiz - Swiss Working Committee of Manufacturers and Distributors | Switzerland | 2007 | AWP T1 - Heating system with heat pumps |
| SIA - Swiss Society of Engineers and Architects | Switzerland | 2005 | SIA D 0190 - Use of earth heat through foundation piles etc. |
| SIA - Swiss Society of Engineers and Architects | Switzerland | 2009 | SIA 384/6 (SN 565) - Borehole heat exchangers for heating and cooling |
| DIN - German Institute for Standardization | Germany | 2002 | DIN 8901 - Refrigerating systems and heat pumps- Protection of soil, ground and surface water |
| VDI - Society Civil Engineering and Building Services | Germany | 2001 - 2010 | VDI 4640 German Guidelines for Ground Coupled Heat Pumps, UTES and Direct Thermal Use of the Underground |
| SE | Sweden | 2008 | Normbrunn-07 Drilling for water wells and energy |

The background, aims, objectives and content of three key publications; one International (US), one Europe-wide standard and one National standard (Germany) are described below.

[2] Sanner, B. (2008) Guidelines, Standards, Certification and Legal Permits for Ground Source Heat Pumps in the European Union. In: *Proceedings of the 9th International IEA Heat Pump Conference, Zürich, Switzerland, May 2008*. Brussels: European Geothermal Energy Council, pp. 1-9. Available at: http://www.sanner-geo.de/media/iea$20hpc$202008$20sanner$20standards.pdf

[3] Ibid

***IGSHPA Residential and Light Commercial Design and Installation Manual (#21025) (International)***

The IGSHPA's Residential and Light Commercial Design and Installation Manual (#21025) is a 560-page manual for the design and installation of residential and light commercial GSHP systems, covering heating and cooling design load calculations; piping materials, properties and flow characteristics; configuration and layout of closed-loop ground heat exchangers; flushing and purging the GSHP system, heat pump start-up and check-out; and troubleshooting.

Published by the Oklahoma State University which manages the IGSHPA, this publication was written for professionals or those who wish to become professionals in the Ground Source Heat Pump (GSHP) industry and provides a source of reference and guidance to geothermal system designers and installers with a range of illustrations, charts, diagrams, and tables to support and expand the guidance provided.

***EN15450 Heating systems in buildings – Design of heat pump heating systems (European)***

This Normative Standard covers the design of water, ground and air source heat pumps. It was the first general EN standard for heat pumps. Due to variations in climatic conditions, geological conditions and traditions in heating and cooling across Europe, EN15450 only provides a basic framework for design and installation of heat pumps, with the need for other requirements for the system, installation, commissioning and maintenance etc. to be covered locally or regionally.

The standard provides guidelines for determining design parameters, designing heat pumps systems and recommended minimum and target values for the Seasonal Performance Factor (SPF)[4].

***VDI 4640 German Guidelines for Ground Coupled Heat Pumps, UTES and Direct Thermal Use of the Underground (National)***

VDI 4640 is considered the most advanced and comprehensive national standard, and is available in both German and English. The standard covers the GSHP system as a whole and includes general information on GSHP design principles, heat pump safety, assessment of location and environmental aspects and specific design and installation requirements for a complete GSHP system covering open loop and closed-loop systems, incorporation of the system components, heat usage and decommissioning. It also provides information and guidance on thermal energy storage and thermal source systems.

## Conclusion

MIS 3005 has brought in many changes. In particular, by being prescriptive and requiring the use of British and CIBSE standards as well as developing guidance and clarification on MIS 3005 through MGD 002 and the supporting MCS 022 installer standards which include the Heat Emitter Guide and the Ground Loop Sizing Tables (and their associated use through Table 3 of MIS 3005 Issue 3), there was a fundamental change in both MCS as a scheme and Heat Pump design methods. MCS and DECC have also supported the changes to MIS 3005 through webinars, spreadsheets and software[5].

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[4] Sanner, B. (2008) Guidelines, Standards, Certification and Legal Permits for Ground Source Heat Pumps in the European Union. In: *Proceedings of the 9th International IEA Heat Pump Conference, Zürich, Switzerland, May 2008*. Brussels: European Geothermal Energy Council, pp. 1-9. Available at: http://www.sanner-geo.de/media/iea$20hpc$202008$20sanner$20standards.pdf

[5] See: http://www.microgenerationcertification.org/mcs-standards/webinars-and-calculators

Since publication of MIS 3005 Issue 3.1, there have been rewrites to standards such as BS EN 12831 National Annex and CIBSE Domestic Heating Design Guides to meet the new requirements.  VDI 4640 has been superseded by the Ground Loop Sizing Tables, because the new standard includes allowance for ground temperature, which varies by several degrees between southern England and northern Scotland.  Also, many of the existing sources of advice such as TR30 are now being reviewed to bring them in line with the new standard.

## 3.2. Training programmes prior to MIS 3005 Issue 3.1

### Introduction

Pre MIS 3005 v3.1 certification and accreditation was typically provided via training programmes for Heat Pump Installers and System Designers. Accreditation meant that an installer had demonstrated the necessary skills, knowledge and competencies required of a practitioner to competently design, install, maintain and troubleshoot a small-scale/domestic Heat Pump (HP) system or part thereof. Those training programmes in turn needed to be accredited and/or certified by a credible authority to ensure that they consistently applied sufficiently stringent uniform training standards and were suitably designed to reach their ultimate objectives.

Within the European member states, those countries where formal certification and accreditation scheme and design and installation training has been implemented are: Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Spain, Slovakia, Sweden and the United Kingdom; although in the latter the recognition by the industry that fundamental gaps in understanding and competency eventually led to MIS 3005 v3 being introduced.

European member countries where no specific certification or accreditation and/or training schemes had been implemented were: Cyprus, Hungary, Romania, Poland and Slovenia.

Training for heat pump installers was provided by several training providers depending on the specific country. Training providers including institutions, manufacturers, federations and guilds offered different levels of training dependent upon the level of knowledge and skill-set required and was typically categorised into five broad areas of competency:

- **System design –** encompassing basic to intermediate technology overview including (but not limited to)
    - Equipment components including; Compressor, Evaporator, Condenser, Expansion Device, collector, thermal transfer fluid (brine), hot water storage vessel / cylinder, heat emitter circuitry and safety components;
    - The Vapour Compression Cycle (VCC);
    - Geological / location and siting considerations, system sizing (including reference to but not necessarily practical use of load analysis and/or heat-load calculation) and pumping;
    - Correct use and handling of Refrigerants (Fluorinated Greenhouse Gases Regulations - referred to as 'F-Gas' Regulations);
    - National and/or International Best Practice guidelines and standards documentation appropriate at that time, examples of which are detailed earlier within this report;
    - Basic mode(s) of operation;
    - Central control; and
    - Determination of heat pump Coefficient of Performance (CoP) and Seasonal Performance Factor (SPF)
- **Heat pump installation**, commissioning and test;
- **Fault finding and troubleshooting;**
- **Groundworks** (for GSHP) and/or other specific considerations (such as noise constraints (for ASHP)) – encompassing specific instruction on 'how to' install; and
- **Heat Pump product types and operation** (predominantly led by manufacturers' courses)

Training courses and course content were accredited by public authorities or by a certifying body with whom the course provider usually signed a partnership agreement. National certification and accreditation schemes did not necessarily contain an audit or assessment component for training courses; however installers needed to ensure that they employed suitably qualified and trained staff and this typically formed a key part of an accreditation assessment process.

However there was a general agreement within the sector about the crucial role of both training and continuous assessment in order to control the quality, safety and performance of the installations and this was primarily achieved through administrative audits based on documentation and/or site audits.

The aim of this section of the work was to review training programmes prior to MIS 3005 Issue 3.1, and compare these to training programmes internationally. An observation about training programmes is that they tend to follow the skill levels and competencies of the country in question. Therefore, German training schemes are often focused on engineering issues whilst UK training courses use more rules of thumb and focus on practical issues. The EU-Cert programme has been run a few times in Britain. However, because it spends some time on refrigeration cycles and is about 5 days, UK based installers have favoured heat pump training from manufacturers and British training providers which have tended to focus on 2 and 3 day courses. Each day off-site is considered a day's income lost by most British installers.

The key training providers and programmes are described below.

## United Kingdom

Prior to MIS 3005 v3 the UK operated training that was predominantly centred on HP manufacturers training and accreditation programmes. Each HP manufacturer had its own training programme which was product specific.

Early in the UK domestic sector were Viessmann and Dimplex; although it was the accredited installation company that was required to design a system and the manufacturer that would install and commission a system.

***Competent Person Schemes*** (CPS) were introduced by the Government to allow individuals and businesses to self-certify that their work complied with the Building Regulations as an alternative to submitting a building notice or using an approved inspector: However membership of CPS was not compulsory. If a company or individual chose to join a competent person scheme, they were first vetted to ensure that they met the conditions of membership, including appropriate and relevant levels of competence. Installers meeting these conditions were classified as 'competent persons'.

The work of organisations or individuals accepted as members of a CPS was not subject to Building Control inspection. Instead, the competent person self-certified that the work was in compliance with the Building Regulations. The installer issued a certificate to the consumer to this effect.

A Competent Person had to be registered with a scheme that had been approved by The Department for Communities and Local Government (DCLG).

***Microgeneration Certification Scheme***

The Microgeneration Certification Scheme (MCS) was launched by the Department of Energy and Climate Change (DECC) in 2006. The MCS is a third-party certification covering all microgeneration technologies; and more specifically solar thermal, solar photovoltaic, biomass and heat pump installations.

The Scheme is led by a stakeholder panel, comprised of representatives from the industry; including certification bodies, government departments, trade associations and other interested parties. The role of Licensee is undertaken by Gemserv; an industry-independent organisation appointed by DECC to manage and coordinate the MCS. The certification is delivered by certification bodies which are private companies accredited by the United Kingdom Accreditation Scheme (UKAS).

- **Training and competence**: all staff employed in installation activities must have received adequate training (the company must have a training record for each employee); and
- **Audit testing**: the company provided details of recent or current installations and arranged access to installations selected by the assessor

***UK heat pump training courses***
UK heat pump training courses were and still are conducted by both heat pump manufacturers and approved National Providers e.g. BSRIA (in association with EHPA; and using HPCERT heat pump training material) and BPEC and Logic Certification (both utilising a customised Domestic Heat Pump Design and Installation Course that have been written in-line with standards and best practice methodology of the day).

Each course typically lasted between three to five days after which the candidate installer had to pass a final theoretical and practical examination. Course pre-requisites for a candidate were typically either City & Guilds 2399-31/32 – Heat Pumps – Level 3 Award in the installation, service and maintenance of Heat Pump Systems (Non-refrigerant circuits) or National Vocational Qualification (NVQ) level 2/3 or equivalent experience (i.e. three years direct experience in the heating sector). An additional pre-requisite was that a candidate installer should ideally hold a G3 certificate in domestic (unvented) hot water systems[6].

***Typical course content***
The typical course content of the above named UK heat pump training courses includes:

- Background, overview and considerations;
    - Environmental relevance of Heat Pump
- Costs associated with purchasing and running a Heat Pump;
    - Capital costs;
    - Operating costs;
    - End of Life costs
- Project Planning;
- Health and Safety;
- Regulations and Standards;
- Risk Assessments for Legionella Prevention – Bacterial Growth - (HSE ACoP Guide L8), Refrigerant Practical Limit (PL), Thermal Transfer Fluid ('Anti-freeze' Mono Ethylene / Mono Propylene Glycol
    - Consideration of limescale on system performance and degradation

[6] Numbers of attendees are not available.

- National and/or International Best Practice guidelines including;
    - Insulated energy efficient building
    - Carbon Dioxide ($CO_2$) emission savings
- Heat Pump types;
    - Air Source Heat Pump (ASHP) - Air to Water;
    - Ground Source Heat Pump (GSHP) - Water (Brine/Glycol) to Water;
    - Exhaust ASHP with Whole House Mechanical Extract Ventilation – Exhaust air only - Air to Water;
    - Exhaust ASHP with Whole House Mechanical Extract Ventilation – Exhaust air plus mixed ambient air - Air to Water;
    - Exhaust ASHP with Whole House Balanced Mechanical Ventilation with Heat Recovery – Air to Air;
    - Monovalent and Bivalent modes of operation;
    - Secondary heating requirement
    - Heating only, Cooling only, Heating and Cooling
- Equipment components including;
    - Compressor;
    - Evaporator;
    - Condenser;
    - Expansion Device;
    - Thermal (heat) Collector;
        - Closed Loop Collector;
        - Horizontal – straight, Slinky™;
        - Vertical Bore;
            - Use of thermal grout (e.g. Bentonite)
    - Thermal transfer fluid (usually referred to as 'brine');
    - Pump selection and sizing;
    - Heat water storage vessel / cylinder;
    - Heat distribution emitter circuitry including;
        - Radiators;
        - Underfloor Heating;
        - Forced Air distribution;
        - Heating water Flow Rate(s) and temperatures
    - Safety components;
        - Expansion vessels;
        - Valves;
        - Frost protection;
        - Bacterial growth;
    - Manufacturer specific equipment instruction;
- Material Phase Change i.e. the Vapour Compression Cycle (VCC);
- Fluid Mechanics and Hydraulic design;
- Geological / location and siting considerations
    - Feasibility and suitability of installing a heat pump
    - Reference to British Geological Survey (BGS) for geological conditions and Abstraction rate (i.e. expected heat generation);
        - BGS Water Well Prognosis;

        - Ground Probe Prognosis
    - ASHP Noise consideration
- System sizing (including reference to and use of SAP and Degree Day Data; practical use of load analysis; and/or heat-load /heat loss calculation)
    - Collector sizing
    - Emitter sizing
- Correct use and handling of Refrigerants (Fluorinated Greenhouse Gases Regulations - referred to as 'F-Gas' Regulations) – specifically R134a and R407C;
- Mode(s) of operation and Control Systems including:
    - Basic (user)
    - Advanced (commissioning)
    - Service mode (troubleshooting and fault finding)
- Determination of heat pump Coefficient of Performance (CoP) and Seasonal Performance Factor (SPF)
    - Identification and appreciation of factors affecting CoP
    - Energy Losses
        - Parasitic losses
        - Non-parasitic losses
    - Weather compensation
- Domestic Water Storage and appreciation of Bacterial Risk (Legionella)
    - Hot Water Cylinders
    - Thermal Stores
    - Buffer Tanks
- Heat Pump installation including;
    - Filling, Commissioning and Setting to work;
    - Pressure testing;
    - Test, Fault finding and troubleshooting; and
    - Groundworks and/or other specific considerations (such as noise constraints) – encompassing specific instruction on 'how to' install

## European Geothermal Energy Council - EGEC

The European Geothermal Energy Council (EGEC) was founded in 1998 as an international non-profit association in Brussels. It currently consists of over 120 members from 27 European countries including private companies, consultants, research centres, geological surveys and other public authorities. EGEC is a member of the European Renewable Energy Council (EREC) which groups together all main European renewable industry and research associations. EGEC is also a member of the International Geothermal Association (IGA).

The European Renewable Energy Sources (RES) Directive 2009 – Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009, on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC defines both 'geothermal' (GSHP) and 'aerothermal' (ASHP) HPs; Article 14 – Information and Training of RES2009 states that EU members:

- …"Shall ensure that certification schemes or equivalent qualification schemes become or are available by 31 December 2012 for installers of… shallow geothermal systems and heat pumps…"
- Annex IV – Certification of installer's states that the certification schemes or equivalent schemes referred to… shall be based on the following criteria:
    - Part 2 …"shallow geothermal… installers shall be certified by an accredited training programme or training provider"…
    - Part 6 a ii …"in the case of heat pump installers: training as a plumber or refrigeration engineer and have basic electrical and plumbing skills… as a prerequisite"…

In order to achieve these objectives two projects ©GEOTRAINET and EU-Cert.HP were implemented.

***©GEOTRAINET, Geo-Education for a sustainable geothermal heating and cooling market***
The objective of the ©GEOTRAINET project was to develop a pan-European Education programme as an important step towards the certification of geothermal installations. From the different groups of professionals involved in a GSHP, the ©GEOTRAINET project focused on two target groups: designers (i.e. those who carry out feasibility and design studies, including geology) and drillers (i.e. who make the boreholes and insert the tubes). The ©GEOTRAINET project (contract reference IEE/07/581/S12.499061) ran from 09/2008 to 02/2011. ©GEOTRAINET training courses included:

- Training for trainers (24hrs duration) – GSHP professionals: Effectively for designers, installers and drillers
- Training for drillers (12-24hrs duration)
- Training for designers (16-24hrs duration)

Geotrainet is still undergoing course development and so final course length and syllabus is yet to be finalised.[7]

***EU-Cert.HP***
EU-Cert.HP was a project to develop a common training framework and a certification scheme for heat pumps installers. The vision of the project was that the training and certification programme would be recognized all over Europe and presented a common standard for voluntary further education in the field of HP technology in all participating countries.

EU-Cert.HP was implemented by all the countries detailed below and finished in 2006. As most of the project participants were also members of the European Heat Pump Association (EHPA) they agreed to transfer the programme management to the EHPA and operate it as **"EUCERT training programme for heat pump installers"**.

The certification scheme was implemented in 2006 and has been active in 10 countries since January 2007: Austria, Czech Republic, France, Ireland, Italy, Slovenia, Sweden, UK, Germany and Slovakia. Since integration within the EHPA, Finland (2007) and Belgium (2010) joined the programme.

EHPA and members associations managed the EUCERT programme which followed the ISO/IEC 17024 standard for personnel certification. The national certification bodies in the different countries have been involved in the project.[8]

[7] Numbers of attendees are not available.

In order to become accredited an installer had to fulfil the following requirements to obtain the EUCERT certification standard:

- Proof of vocational (hands-on) training;
- Proof of participation certificate confirming completion of the EUCERT training OR of an equally valid training course;
- Certificate of successfully passed EUCERT final examination;
- The employer of the applicant must be operating as an electrician, installer or Heating Ventilation and Air Conditioning (HVAC) engineer and be providing HP system planning and/or installation services.
    - In addition there were additional national requirements including the correct handling and use of F-Gas Refrigerants;
- Alternatively the applicant must be the owner of his/her own business in one of these sectors providing HP system planning and/or installation services;
- Proof of relevant professional experience; and
- Completion of a certification contract between the installer and the national certification body.

**EUCERT training programme for heat pump installers**

EUCERT training programme for HP installers was provided by training institutes accredited by the national coordinators of the EUCERT programme and supported by legally binding agreements. To become accredited the training centres would have had as minimum adequate laboratory equipment that followed technical specifications and trainers would have had both sufficient experience in the related field and had attended a 'train-the-trainer' seminar.

In order to control the quality of training delivered, members of the EHPA education Committee visited the training centres albeit infrequently.

The installer had to attend the EUCERT training and pass a final examination. HP training consisted four days of theory and one day of practical training.

Once certified an installer was accredited for three years after which time it would need to be renewed. To maintain certification the accredited installer had to prove that he/she had been active in the field. Additionally, the installer had to undergo at least one further training of half a day within the three-year period.[9]

## France

Qualibat is an Association under private Law which issues qualifications and certifications in the construction sector. Its governing bodies, together with its decisions making bodies, are composed with equal shares of representatives of users, of general interested parties and of contractors. Qualibat is accredited for its activities by COFRAC, the French accreditation body.

In the fields of solar energy, of bio energy and of geothermal energy, Qualibat manages a certification scheme in order to assess the technical skills of installers. The company has to fulfil the following requirements:

[8] Numbers of attendees not available.
[9] Numbers of attendees not available.

- Provide legal and administrative documents about the company's existence, activities, fulfilment of tax obligations, staff and equipment;
- Provide evidence of insurance liability and decennial insurance;
- Proof of relevant education and appropriate training;
- List of all installations realised by the company (i.e. list as complete as possible);
- Documentation of approximately three installation references representative of the technical qualifications of the company; and
- Technical operating processes

A technical audit performed with the installer enabled testing of the knowledge of staff, the correct implementation of the operating process and an audit on site enabled to check the quality of an installation. Certification was valid for four years although it was a requirement to renew it every year. An annual supervision of the companies was performed through a follow-up questionnaire. In order to renew the certification, the company had to fulfil the same requirements as for obtaining the certification.

In France Qualifelec delivers qualifications to electrician companies, Qualit'EnR for installers of small-scale Renewable Energy Systems, Qualisol for solar thermal installations, QualiPV for photovoltaic installations; Qualibois for biomass systems and QualiPAC for HPs (from January 2010). Heat pump installation is a 5 day course.

The Quality Charter scheme was a voluntary certification process. The Quality label was delivered to the company which committed for a three year period and the label needed to be renewed annually. To maintain the quality standard the company had to fulfil the following requirements:

- Provide legal and administrative documents attesting the company's existence, activities, insurances;
- Technical skills of referents: provide proof of previous experience by providing installation references / or proof of relevant training;
- Provide at least one installation reference each year; and
- Signature of the Quality Charter.[10]

***AFPAC (from 2006 to 2009)***

The French Association for HPs (AFPAC) managed the QualiPAC label for HP installers. The quality scheme transferred from AFPAC to Qualit'EnR from 2010. The company had to fulfil the following requirements:

- Provide legal and administrative documents attesting the company's existence and activities;
- Proof of civil liability insurance;
- Technical skills of referents: including providing proof of EUCERT training or equivalent qualifications;
- Provide documentation about installation references; and
- Signature of a quality charter

AFPAC was a member of the EHPA and participated in the EU-CERT.HP project on HP installer training. It contributed in the development of the training material which was subsequently used for

[10] Numbers of attendees not available.

training throughout France. Training was provided by training institutions collaborating with AFPAC. The installer had to pass a final examination.

***BRGM/Qualiforage***

Qualiforage is a quality label for ground source installers established by ADEME-BRGM-EDF and managed by BRGM, a public institution (BRGM Geoscience for a sustainable Earth). It was a voluntary process and the accredited installer signed a Quality Charter and committed to comply with technical standards and good practices. The installer had to provide evidence of adequate equipment, appropriate training and administrative documents such as decennial insurance.

***Training***

The training centres providing training to installers had to prove prerequisites in the related area and evidence of specific training equipment. Additionally, the trainers had to attend a 'train-the-trainer' programme. Training standards were continually enhanced through a national initiative gathering experts. Training of installers lasted from two to five days and was composed of both theoretical and practical exercises. The installer had to pass a final examination.

## Sweden

Sweden also operated the EUCERT training programme developed by the EHPA. It was/is administered by the Swedish Heat Pump Association (SWEEP) (Svenska Värmepump Föreningen - SVEP) and conducted centrally at Mittuniversitetet Mid Sweden University, as well as by the major manufacturers; notably IVT, Danfoss and NIBE.

The heat pump course was and is also included as part of the candidate training course to Energy Engineer, also at Mid Sweden University. Each EUCERT accredited installer was registered on a reference list of certified installers and was expected to be able to demonstrate competency having satisfactorily passed the EHPA installer training programme EUCERT.

Training included:

- Calculating domestic building energy demand;
- Thermal stores and hot water cylinders;
- Potable Water System;
- Control and regulation of the HP;
- Liquid Air Cycle Engine (Lace) heating and additional heating;
- Solid and liquid condensation;
- Refrigerants;
- Selection of energy source;
- Design of collector; and
- Contracts and claims

In addition the training course included additional specific modules including [the] correct handling and use of F-Gas Refrigerants; which included both theoretical and practical tests. The installer had to pass a final examination.[11]

[11] Number of attendees not available.

## USA: International Ground Source Heat Pump Association (IGSHPA)

IGSHPA offered various training programmes, each of which were directed towards imparting a certain level of knowledge. IGSHPA provided training that covered system design and troubleshooting in detail as that was seen as a critical part for installation and maintenance. As in the other markets each Heat Pump manufacturer also had its own training programme which was product specific. A number of manufacturers also worked with IGSHPA and used its products for demonstration purposes.

**Training courses** included:

- Accredited drillers training (3 days duration) – Applications of Production Drilling and Borehole Construction for GeoExchange Systems;
- Accredited installers training (3 days duration);
- Certified GeoExchange Designer Course (3 days duration) – Utilising Ground-Loop Heat Exchanger Software GLHEPRO Design Software;
- Train the Trainer (5 days duration)– For IGSHPA accredited installers with a minimum of five installations; and
- Building load analysis and pumping Course (2 days duration)

For further information visit the IGSHPA website[12].

**Training documentation** material included:

Residential and Light Commercial Design and Installation Guide (#21025): A 560-page manual for the design and installation of residential and light commercial GSHP systems, chapter headings include:

- The case for ground source heat pumps;
- Heating and cooling design load calculations;
- Piping materials, properties and flow characteristics;
- Configuration and layout of closed-loop ground heat exchangers;
- Flushing and purging the GSHP system, HP start-up and check-out; and
- Troubleshooting

In addition IGSHPA provided a set of five training reference manuals including;

- Residential and Light Commercial Design and Installation Manual (#21025);
- Closed-Loop Geothermal Systems Slinky™ Installation Guide (#21050);
- Closed-Loop Geothermal HP Systems Design and Installation Standards (#21035);
- Soil and Rock Classification for the Design of Ground-Coupled HP Systems Field Manual (#21060);
- Grouting for Vertical Geothermal HP Systems Engineering Design and Field Procedures Manual (#21015); and
- Closed-Loop Ground Source HP Systems Installation Guide (#21020).[13]

[12] IGSHPA (2013) *Training* [WWW] Available from: http://www.igshpa.okstate.edu/training/ (Accessed 8th April 2013)
[13] Number of attendees not available.

## 3.3. Domestic heat pump field trials in the UK

### Introduction

The Energy Saving Trust undertook the first wide-ranging large-scale field trial of 83 heat pumps[14] in the UK in response to the lack of data on heat pump performance in domestic properties. The trial monitored technical performance and customer behaviour at sites across the UK.

The first phase of monitoring in this trial was undertaken during 2009 and 2010, and following several interventions, a second phase of monitoring was commissioned to monitor the impact of these interventions. This data is currently being analysed and evaluated, with a report expected to be published in June 2013.

Field trials contain both positive and negative experiences. There are benefits to be realised from collating and documenting the subjective and objective data available prior to the EST field trials, as well as trials and monitoring currently being undertaken, and comparing this data and findings to the subsequent information that these trials brought to light.

As part of this UK literature review, information, data and learning from field trials of domestic heat pumps in the UK (outside the EST field trial) have been collected through key contacts in the industry and academia, and has provided an overview of the current published evidence on the operational performance of domestic heat pumps in the UK.

### Summary of UK field trials & monitoring (published)

The following section provides a summary of domestic field trials in the UK that have been reviewed, in order of the date they were undertaken.

The first monitoring of a domestic heat pump in the UK is believed to be a study undertaken by BRE and BSRIA in 1995 and 1996. The study involved monitoring of a borehole based closed loop GSHP system and was led by Rosemary Rawlings initially at Southampton University and then at BSRIA. There is no published data on this study.

***The York Energy Demonstration Project (1998), England***

The Department of Environment's Greenhouse Programme supported a number of energy efficiency projects in local authority housing, with the aim that these would serve as models for future housing modernisation and refurbishment schemes. As part of the York Energy Demonstration Project, York City Council, installed a Genvex GE 215 VP warm air heating system (air-to-air source heat pump) in one of four 2-storey brick and block 1940/50's properties to replace gas fire and electric immersion heater. Electric resistance heaters were provided to supply ducts if further heat was required to satisfy demand, along with a focal point electric fire. The heat pump system was chosen instead of direct electric heating, for efficiency reasons (Bell and Lowe, 1998)[15].

Long term monitoring of these properties was undertaken by York City Council's technical staff with supervision by Malcolm Bell and Robert Lowe of Leeds Metropolitan University. The study revealed

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[14] Energy Saving Trust (2010) *Getting warmer: A field trial of heat pumps,* The Energy Saving Trust. Available at: http://www.heatpumps.org.uk/PdfFiles/TheEnergySavingTrust-GettingWarmerAFieldTrialOfHeatPumps.pdf [Accessed 26/03/2013]

[15] Bell, M. and Lowe, R. (1998) The York Energy Demonstration Project: final report [pdf] UK: Leeds Metropolitan University. Available at: http://www.leedsmet.ac.uk/as/cebe/projects/york/york_final.pdf [Accessed 22/01/2012]

that the property fitted with the air-to-air heat pump did not perform as predicted. This was partly due to the heat pump not operating for long periods, leading to the anticipated efficiency gains not being realised. This was due to a) water heating in the house still being provided entirely by electric resistance heating, and b) a significant proportion of the space heating being supplied by the internal electric resistance heater of the heat pump. As a result, the findings of this study did not provide a reliable basis upon which to evaluate the performance of the Genvex system.

A key conclusion from the study was that the use of top-up resistance heating would need to be addressed if electric heat pumps were to out-perform gas fired domestic heating in the UK[16].

***Energy Efficiency Best Practice Programme (2000), Salisbury, England***

This project was undertaken by BRE on behalf of the Energy Saving Trust and the findings were published under the Government's Energy Efficiency Best Practice Programme. The project monitored the performance of water-to-water 3.96kW ground source heat pump during its first year of operation. The heat pump (IVT Greenline 4) was installed in a detached, four bedroomed, two-storey domestic property with a linked single-storey, two-room annex. The heat pump was sized to provide only 50% of the design heat load with an in-line direct electric heater to provide auxiliary heating through two 2 kW heaters[17].

The results of the monitoring showed the energy consumption for space and water heating to be lower than predicted; it was concluded that the difference in space heating energy required was likely to be due to differences in weather conditions. Domestic hot water consumption was found to be extremely variable. During the first year of operation, the GSHP was found to provide 91.7% of the total heating requirement and 55.3% of the domestic water heating requirement even though it was sized to meet only half of the design load. The overall performance factor ($SPF_{H4}$) of the heat pump system was calculated at 3.16, with an average over the heating season of 3.31 and average over the summer of 2.5 when predominantly providing water heating.

A key finding from the monitoring and evaluation of this system was the estimation that if the circulation pump was controlled to operate only when the heat pump was operating the overall annual performance factor of the heat pump could have been 3.43 with average system efficiencies in winter and summer being 3.42 and 3.44 respectively[18].

***Nottingham Eco House (2007 – 2008), England***

The Nottingham Eco-House is a four bedroom detached dwelling constructed of brick, block, glass and steel which has an 18kW gas boiler. A Ground Source Heat Pump and several other low energy systems have been installed and monitored in the Eco-House since construction.

During the heating season of 2007/2008, the heat load was controlled to simulate the heat demand of a modern detached four-bedroomed low-energy residential property. A software modelling programme was used (Earth Energy Designer) to model the ground temperature and compared with the measured results in the trial. The $SPF_{H4}$ of the heat pump was measured as 3.62, and ground temperature at distance of 5m from the plot was found to be undisturbed by the heat extraction, following the seasonal variation predicted.

[16] Bell, M. and Lowe, R. (1998) The York Energy Demonstration Project: final report [pdf] UK: Leeds Metropolitan University. Available at: http://www.leedsmet.ac.uk/as/cebe/projects/york/york_final.pdf [Accessed 22/01/2012]
[17] Energy Saving Trust (2000) *Heat pumps in the UK – a monitoring* report (GIR72). London: Energy Saving Trust.
[18] Ibid

The key finding from the study was the observation that the designed SPF of a heat pump can be achieved through proper installation and careful consideration of the operation of the whole system (Doherty et al, 2004)[19].

***Westfield air source heat pump field trial (2008 – 2009), West Lothian, Scotland***

Ten rented houses of similar size located in the village of Westfield in West Lothian were retrofitted with Heat King Air Source Heat Pump systems by West Lothian Council through funding provided by Scottish and Southern Energy. The heat pumps were manufactured by TEV[20].

Eight of these systems were monitored during the winter and spring of 2008 by the University of Strathclyde, and the results showed a consistent relationship between CoP and external temperature. Any additional variation in the results was found to be due to uncontrolled factors such as occupant behaviour in setting thermostatic controls, window opening, time switch settings, and internal gains. The $SPF_{H4}$ was calculated as 2.7, with running costs 54% less than direct electric heating and 8% more than mains gas heating. The trial found no significant nuisance due to noise or vibration and the reliability of the units was seen to be very good[21].

***Harrogate heat pump trials (2008 – 2011), England***

Ten one or two bedroom rural social housing bungalows built between 1976 and 1980 and let by Harrogate Borough Council as social housing for the elderly were upgraded with cavity wall insulation, double glazing and additional loft insulation, and fitted with ground source heat pumps during the winter of 2007 to 2008.

These ground source heat pumps (IVT Greenline HT Plus C6) extracted heat from bore hole collectors and provided space heating and domestic hot water. The radiators were conventional but oversized to allow low temperature heating and hot water heating was supplemented by a 3 or 6kW electric resistance heater, typically during the weekly pasteurisation cycle (Stafford and Bell, 2009)[22].

The heat pumps were monitored in detail over a period of more than one year by Leeds Metropolitan University. The intensive part of the study shows that there is a wide variation in the performance of the building fabric, even in broadly similar properties of a similar age, which may have a significant effect on heat pump SPF.

An outcome from the study was the conclusion that without monitoring the SPF of the heat pumps over a long time period, it was believed impossible to accurately estimate either the pump electricity usage or the effect of different occupant practices. SAP type calculations rely on a number of assumptions about heat pump operation which may or may not be valid in individual cases[23&24].

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[19] Doherty, P.S. et al (2004) Ground source heat pump––description and preliminary results of the Eco House system, Applied Thermal Engineering 24 (2004) 2627–2641

[20] Kelly, N.J. and Cockroft, J. (2010) Analysis of retrofit air source heat pump performance: Results from detailed simulations and comparison to field trial data. Energy and Buildings and Kelly, N.J. and Cockroft, J. (2009) Report for Scottish and Southern Energy: Monitoring the Performance of Air Source Heat Pumps at Westfield, West Lothian. Glasgow: University of Strathclyde

[21] Ibid

[22] Stafford, A., and Bell, M. (2009) Report to Harrogate Borough Council and Npower. Evaluation of Heat Pump Installations: Extracting Meaning from Existing Datasets: Final Report. Leeds: Leeds Metropolitan University.

[23] Ibid

[24] Stafford, A. (2011): Long-term monitoring and performance of ground source heat pumps, Building Research & Information, 39:6, 566-573

***Elm Tree Mews (2007 – 2009), York, England***
Elm Tree Mews is a housing development by Joseph Rowntree Housing Trust consisting of one four-bedroom house, three three-bedroomed houses, one two-bedroomed apartment and one one-bedroomed apartment, built on the site of a former garage, available for rent, shared-ownership and full sale.

The heating system is a 24 kW 3-phase communal ground source heat pump with 300l buffer tank and nominal SCOP 3.2. The heat pump located in a plant room and connected to a district heating system, and the ground source heat is supplied via three 115m deep bore holes.

In order to maximise the efficiency gains of the heat pump, the space heat distribution system was redesigned within each dwelling using an underfloor heating system in place of radiators. The hot water system was modified from one supplied by solar thermal panels and gas boiler to a system that involved heat inputs from the solar thermal panels, the heat pump and a back-up electrical immersion heater.

Leeds Metropolitan University ran a research programme from the spring of 2007 to the end of 2009 which included observations of the construction of the Elm Tree Mews development, post-construction measurement of fabric performance and air tightness, and monitoring of the dwellings for a year following occupation.

The monitoring results showed that the communal ground source heat pump did not achieve its expected performance, with the measured annual Coefficient of Performance (SCoP) of the pump of 2.7 being significantly lower than the nominal design SCoP of between 3.2 and 3.5. The annual CoP of the communal system as a whole was 2.15, after taking into account the performance of the heat pump unit, energy usage of the circulation pump, heat losses from the distribution system, and the control arrangements. A number of interventions were made during the monitoring period to improve the system efficiency, which included replacing one of the circulation pumps and altering the system controls.

The various problems identified with the heat pump and hot water systems were related to design philosophy, the integration of the various systems in the initial design, and the robustness of the installation and commissioning processes[25&26].

## Other domestic heat pump trials and monitoring (unpublished)

During the literature review, information was gathered about a number of other trials and monitoring of heat pumps currently being undertaken in the UK, although the majority of these do not currently have any published information or data. An outline of some key unpublished monitoring of heat pumps is provided below.

***Orbit Heart of England, West Midlands, England***
In an email on 25th January 2013, J. Nea stated that Orbit Heart of England began installing heat pump technology in their social housing properties in 2008 and to date has installed heat pumps in 176

[25] Bell et al (2010) *Low Carbon Housing: Lessons from Elm Tree Mews,* Joseph Rowntree Foundation. Available at: http://www.jrf.org.uk/publications/low-carbon-housing-elm-tree-mews [Accessed 27/03/2013].
[26] Wingfield et al (2011) *Elm Tree Mews Field Trial – Evaluation and Monitoring of Dwellings Performance Final Technical Report,* Leeds Metropolitan University. Available at: http://www.leedsmet.ac.uk/as/cebe/projects/elmtree/elmtree_finalreport.pdf [Accessed 27/03/2013]

properties (164 ground source heat pumps and 12 air source heat pumps), some in conjunction with solar thermal and solar PV technologies.

Orbit is satisfied with the performance of the heap pump systems which have been installed to date, and is continuing to install more heat pumps in homes off the mains gas grid. Currently a project is nearing completion to install 43 ASHP to a sheltered housing schemes and a GSHP project is due to commence which consists of 36 installations.

In the same email on the 25th January 2013, J. Nea, KTP Associate at Orbit Housing Association stated that Orbit has found the vast majority of customers to be happy with the installation and performance of their heat pump systems, although some issues have been found with intrusive noise and slow warm up periods. There has also been a variation in the level of savings seen through tenants' energy bills; some tenants' bills have reduced including one tenant who has seen a reduction of 50%, while other tenants have complained that bills have increased; this could be due to several reasons such as tenants being on the wrong tariff, increased usage, family moving back home or inefficient operation of the system.

In an email on the 3rd April 2013, J. Nea stated that the noise issue highlighted by tenants was in part fault with the anti-vibration pads in the heat pump; this only happened in a small number (3 or 4) of the heat pumps and was easily solved by replacing bearings. However, some tenants and neighbours still complained about noise but from what could ascertained the noise levels were in accordance with the manufacturers guidelines.

In an email on 19th February 2013, J. Nea confirmed that the first set of monitoring trials had involved monitoring the internal temperature and electricity consumption of 6 properties for four weeks; two weeks pre installation and two weeks post installation. However, this monitoring did not prove successful and due to problems with procurement, the monitoring deployment ended up running in conjunction with the installation process. This resulted in the before and after data collected not being typical for a dwelling due to contractors entering and exiting the property, external doors being left open and power tools being plugged in etc. Orbit is planning to undertake another monitoring trial this year.

***Penwith Housing Association, Cornwall***

A number of retrofit and new build properties built and/or managed by Penwith Housing Association have been fitted with heat pumps, and have been monitored to varying degrees as outlined below.

In an email on 13th December 2013, R. Curtis stated that four new build bungalows, built by Penwith Housing Association (PHA) around the late 1990s and early 2000's were fitted with IVT heat pumps and ground loop slinky collectors providing heating to radiators and a proportion of the hot water. These properties are understood to have been monitored by South Western Electricity Board, although some monitoring problems/issues were identified and the data is not in the public domain.

PHA retrofitted a number of their hard to treat properties with ground source heat pumps, to replace either storage heating or solid fuel heating systems, and some simple monitoring of these through meter readings and temperature logging was undertaken by Exeter University. The data revealed the energy consumption to be similar to that predicted at the design stage. The monitoring found the systems to have very slow response times, with maximum temperatures being recorded in properties at around midnight. This indicated that control schedules need to be checked to ensure they are used correctly by the occupants[27].

In an email on the 13th December 2012, R. Curtis also stated that six PHA properties fitted with heat pumps were monitored under Phase 1 of the EST field trial, and five of these were monitored under phase 2. It is understood that a seventh property was monitored by E.ON using similar equipment for years, but the results of this have not been published. The before and after performance of a PHA semi-detached property, which has been retrofitted with a novel ground source heat pump system, has been monitored in considerable detail under the Technology Strategy Board Retrofit for the Future project,. The pre-retrofit data was collected over the course of a year and post-retrofit data is currently being collected and analysed by Earth Energy Engineering, Mimer and Woodmead Energy Services.

***Chale community project (2011)[28], Isle of Wight***

Chale is an off-gas community to the South of the Isle of Wight, with 1970s houses and flats previously heated with storage heaters. The project was funded through a partnership of Ellen MacArthur Foundation, South Wight Housing Association, the Footprint Trust and Island 2000.

In a conversation on 22nd December 2011, K. Steiness stated that 67 properties were upgraded and fitted with renewable energy systems including ASHP systems and solar PV. During the project, it was discovered that all properties had cavities but thermal image checking revealed that some did not have insulation. The standard of the windows was also poor.

Prior to installation of the air-source heat pumps, the properties were fitted with triple glazed windows and adequate loft insulation and notable draughts were fixed.

As part of the pilot project, the project group have surveyed about ¾ of residents and found evidence of significant savings. Where householders were previously paying £40 a week, they are now paying £15/week on average. The residents feel warmer in their homes and are not so much in debt; there is evidence that people are happier as a result. It is believed that further monitoring of energy and water consumption was planned during 2012 but results have not yet been published.

***Nottingham new-build social housing projects***

A number of new build houses constructed between 2001 and 2004 by a Housing Association in Nottingham were fitted with closed loop borehole ground source heat pump systems to supply heating and hot water. Information on monitoring of these social housing properties in Nottingham was provided in emails from John Parker (of Earth Energy Engineering) on the 22nd, 25th and 26th February 2013 detailing key findings from three social housing sites, as outlined in Figure 1.

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[27] Coley, D. and Lash, D. (2007), Monitoring of energy consumption and internal temperatures in properties with ground source heat pumps in social housing in Penwith, Cornwall (Internal Document 546), University of Exeter.
[28] See Chale Community Project website at: http://www.chalecommunityproject.com/technology-pilot

Site A
This was a prototype site in a small town outside Nottingham that was designed in 1999/2000, built in 2001 and occupied in early 2002. This was developed as sheltered housing and comprised of 10 single storey terraced houses to high insulation standards (NHER10) with an all-electric heating system using a specially designed dual temperature ground source heat pump manufactured by Calorex Ltd to supply low temperature space heating into underfloor pipe coils. The heat pump also provided the hot water at 60oC using a gravity fed indirect cylinder of 150 litres capacity.
Following commissioning and occupation, electricity consumption was measured using a single 2 rate meter in each house for a total period of just over 5 years starting in May 2002 and finishing in July 2007. There was no sub-metering of the heat pump, so analysis was dependent on calculations based on seasonal differences, but the overall purpose of the site was to test the overall annual energy consumption against the measured consumptions from 3 separate gas heated sites of similar social housing buildings elsewhere in the Nottingham area. The trial showed the heat pump buildings to use less energy and result in lower carbon emissions with similar running costs against gas heating, with calculations showing that compared with oil, LPG or standard electrical heating systems the savings from GSHPs were substantial.

Site B
This site was similar in construction and insulation standards to Site A, but consisted of 8 pairs of identical semi-detached bungalows designed for elderly tenants. The properties were fitted with an Eon HeatPlant 35 GSHP (each with a single 60m vertical borehole ground loop) feeding into an under floor heating system. Domestic hot water provision was identical to Site A with the heat pump feeding an indirect gravity fed 150litre cylinder, with immersion for emergency purposes only. The site was occupied in May 2003.
The intention at this site was to measure the efficiency to a greater degree of accuracy using two dual rate electricity meters; one a sub meter of the main house meter measuring electricity feeding the heat pump (and association ground loop circulating pump). The meters in each of the 16 houses were read over a period of 4 years enabling both the GSHP and general electricity use to be analysed. While internal temperatures and hot water use were not specifically measured, tenants were allowed to set their thermostats to their own comfort levels and it was noted during site visits that internal temperatures were often found to be around 23oC which was 2K higher than the original design point. Tenants were free to adjust their hot water charging times until there was sufficient hot water for their daily needs.
The site average Seasonal Performance Factors for the heat pumps were calculated as 4.25 for the underfloor heating, and 2.13 for the domestic hot water. The overall annual SPFH4 of the heat pump for both these services combined was 3.27.

Site C
Site C in a suburb of Nottingham was a third new-build site monitored at the start of the Eon HeatPlant Project, and included some larger 2 storey houses as well as the single storey properties similar to Sites A and B. Neither type of property was as well insulated as the original design with specific heat losses of 43 and 40W/m2 compared to the original design of 35 W/m2.
The larger properties were fitted with E.ON HeatPlant 50 with a 75m vertical borehole ground loop and larger indirect hot water cylinder of 210 litres, with underfloor heating on the ground floor and radiator systems on the first floor. The one storey properties were fitted with the Eon HeatPlant 35 GSHP and 60m vertical borehole ground loop and 150 litre hot water cylinder.
Electricity was measured at these properties using the same method as Site B but with additional details to ascertain the system power factor. A full year of readings was taken on a monthly basis between 2004 and 2005. The average annual combined thermal efficiencies for heating and hot water were in the range 3.0 to 3.5 for correctly designed and sized systems.

**Figure 1 Key findings from monitoring heat pumps at three social housing sites in Nottingham**

## Other trials and monitoring of heat pumps

In an email on 13th December 2012, R. Curtis provided a list of other heat pump monitoring and trials he is aware of, which include the following:

### *Earth Energy Engineering*

Earth Energy Engineering in partnership with E.ON have undertaken simple electricity meter monitoring of a collection of around 10 to 15 new build bungalows with ground source heat pumps.

This data has been monitored for around 5 years. It is believed that this has been released into the public domain although data was not sourced during this literature review.

***GeoScience***

GeoScience have extensively monitored a domestic property with a 6kW closed loop GSHP system for over five years. There is no published data or results from this currently available.

***Mimer Energy***

Mimer has fitted a domestic heat pump retrofit property with metering equipment, which has now been collecting data for at least two years. There is no published data or results from this currently available.

## Conclusions

The review of heat pump monitoring in the UK prior to the EST's field trial has highlighted some key information that can support future guidance for monitoring and reporting of heat pump performance, including:

a. **Heat pumps perform well when** they are appropriately designed, installed and commissioned; if not the performance can be significantly reduced.
b. **Reporting of Seasonal Performance Factor** of heat pumps is not always fully defined in reporting performance of heat pumps, such that it is not clear whether it is the performance of the heat pump unit or the overall system including pumps, ground collector loops etc. Monitoring of heat pumps should allow the performance of the heat pump unit and the total performance of the system to be evaluated, and reporting of performance should clearly state whether it is H1, H2, H3 or H4 as per the SEPEMO guidance.
c. **Side-by-side monitoring of heat pump systems** that allows comparison with similar buildings with conventional systems can provide valuable information. Information about occupancy patterns and control usage is essential to evaluation of differences in performance between similar systems.
d. **Monitoring of communal systems** is required to understand the performance of systems in practice and to evaluate their proper application.
e. **Controls and communication** issues require greater attention to ensure end users understand that heat pumps are more sensitive than conventional systems and require some change in heating patterns and behaviour to maximise performance.

## 3.4. Documented problems in domestic heat pumps

### Introduction

The wide variety of documented problems and issues that have occurred with heat pumps are difficult to obtain due to their commercially sensitive nature and as such this review has attempted to provide an overview of the published or publicly available information on problems with domestic heat pumps. Using some information gathered from end users (including social housing providers Orbit Housing Group and Southern Housing Group), and from providers of end user advice / customer care (e.g. Renewable Energy Association), we have been able to provide a snapshot of the current types and level of problems with domestic heat pumps in the UK, and the consequences of these problems for the end user and the industry sector.

### Heat pump problems

There are two main types of heat pumps, which due to their different designs and applications have different issues. Key problems and issues with heat pumps can be divided into six main categories, with regards to the source of the problem:

1. **Equipment & components**
   - **a.** Poor materials (pipes, antifreeze, mechanical joints, grouts etc.)
   - **b.** Poor quality or unsuitable equipment (not designed for UK climatic conditions leading to problems such as excessive use of 'defrost cycle')
   - **c.** As air temperature drops too low (e.g. -10 or -15 °C), ASHP performance deteriorates
   - **d.** Refrigerant loss

2. **Design & specification**
   - **a.** Undersizing (leading to excess use of direct electricity or other back-up heating)
   - **b.** Oversizing of heat pump (leading to excess cycling)
   - **c.** Inaccurate/poor heat loss and energy calculations (leading to under or over-sizing)
   - **d.** Poor heat emitter design
   - **e.** Poor DHW system design
   - **f.** Inadequate control strategy (sometimes leading to excessive use of direct electric heating)
   - **g.** ASHP - Poor location
     - i. Poor air flow
     - ii. Noise
     - iii. Vibration
     - iv. Inadequate condensate drainage
   - **h.** GSHP - Inadequate collector design
     - i. Overlapping pipework
     - ii. Poor hydraulic layout (massive pumps)
     - iii. Under or over-sized collector
     - iv. Inadequate trench or borehole spacing and depth
     - v. Misunderstanding of climatic (especially ground temperature), geological and hydrogeological (especially water table depth)conditions
     - vi. Laminar rather than turbulent flow (of thermal transfer fluid)
     - vii. Poor computational analysis

i. Lack of design training and skills

3. **Application & site suitability**
    a. Insufficient surface area/depth or proximity (GSHP)
    b. Inadequate location (ASHP)
    c. Inadequate insulation (space heating & hot water heating) and draught proofing, or high heat loss
    d. Undersized heat emitters including HW heat exchanger
    e. Poor location/incorrect siting of temperature sensor for weather compensation control

4. **Installation & commissioning**
    a. Poor heat distribution installation
    b. Flow temperature set too high
    c. GSHP - Inadequate collector install:
        i. Poor drilling/trenching practice (too shallow or deep, aquifer contamination, artesian aquifers, etc.)
        ii. Inadequate joints (leaks)
        iii. No capping off (dirt in pipework)
        iv. Poor backfilling or grouting
        v. Poor filling and purging
        vi. Incorrect antifreeze concentration and/or wrong biocide
        vii. Inadequately fitted manifold and HP connection
    d. ASHP – inadequate installation
        i. Vibration mounts
        ii. Connections
        iii. Condensate drain
    e. Lack of experience of installers / insufficient training and standards

5. **End user control/use**
    a. Inadequate /unclear/complicated handover instructions/guidance and advice
    b. Lack of information or help in obtaining incentives, planning permission or other government support
    c. Human behaviour and attitudes
    d. Longer heat up times and background heating rather than intense heat
    e. Incorrect use/understanding of controls and/or complex/inadequate controls

6. **Maintenance / faults**
    a. Maintenance matters
        i. Obstructed airways
        ii. Blocked or frozen condensate drains
        iii. Degraded antifreeze (thermal transfer fluid)
    b. Heat Pump Faults
        i. Refrigerant leakage
        ii. Failed compressor
        iii. Broken PCB
        iv. Failed expansion/4-way valves

    v. Failed fan/ground collector pump
  c. Central Heating circuit faults
    i. Failed CH pumps, valves etc.

***Scenarios / failure modes***

The above list can create a number of different scenarios or failure modes:

- Instantaneous failure due to failed component or system
- Instantaneous failure due to environmental conditions e.g. frozen condensate
- Low efficiency and associated high running costs
- Under performance leading to lack of space heating or hot water
- Degradation in performance over time
- Damage to the environment e.g. refrigerant leakage or antifreeze in water course
- Damage to the property or garden
- Unsatisfied householders or neighbours due to noise or vibration issues
- Unsatisfied householders due to difficulty in accessing Government support

## Documented problems & consequences

There are limited reporting systems for heat pump failure within the UK. Gemserv, the MCS secretariat, only records data before passing it through to Certification Bodies to investigate the matter in question. There is no centralised analysis of the different failure modes. In an email on 12 February 2013, Sarah Rubinson of the REAL Code, the only MCS consumer code, provided from their database the following January 2010 to January 2013 data on heat pump complaints about installers (rather than heat pump manufacturers):

> We have received 56 complaints about ground source heat pumps and 80 about air source heat pumps. With regard to the nature of complaints, we are aware of the following issues (listed in order, most common first):
>
> - **Technical issues**
> - **Poor performance (e.g. system not producing as much heat as the consumer thought it would)**
> - **Design problems**
> - Misinformation about/difficulty registering for the RHPP/RHI
> - Poor workmanship
> - Undersizing
> - High running costs
> - Warranty/maintenance issues
> - Damage
> - Insulation problems
> - Excessive hot water consumption
> - Materials
> - Planning permission
> - Company not MCS certified
> - Handover pack
>
> The majority of complaints have been about the issues highlighted in bold. These type of complaints are normally forwarded to the installer's MCS certification body, so we are not in a position to comment in detail or advise on whether the complaints were justified.
>
> The answers may not be 100% accurate but I hope this is helpful. I would suggest that you also contact MCS as they can provide you with a better overview of the technical/performance complaints.

**Figure 2 Heat pump complaints received by the REAL Code from January 2010 to January 2013**

This work highlights the diverse nature of the complaints process within MCS. Secretariat, the Consumer Code and the Certification Bodies all have overlapping responsibilities and no one organisation is holding the structure together or overseeing the complaints process.

So whilst there is limited information on the categorisation of issues and the consequences of these "failures", it is known that all of the above "problems" under the six headings listed above have occurred in UK heat pumps situations. Before continuing, it is worth noting that heat pumps systems, if well-designed and installed with high quality components and systems will normally perform in a predictable and effective manner leading to satisfied building occupants. It is only when short cuts are taken that problems typically arise. Performance of heat pumps is discussed in the field trials section of this report. This section will now set out these documented problem issues:

***Equipment & components***

**a.** Poor materials. Andy Howley of Loopmaster, initially through his regular presentations related to this subject including his presentation at the GSHPA AGM Seminar in June 2010 and his subsequent championing of the Vertical Borehole Standard (VBS), has been the main promoter of the problems associated with poor materials. The GSHPA Vertical Borehole Standard (VBS)[29] sets out materials that are suitable for GSHP installation. Known issues are the incorrect use of PE 80 pipe or low quality PE100 pipe which have been replaced with PE 100+ and PE-RC (Resistance to Crack) so that the pipework in the ground has a long and effective life. The VBS also specifies polypropylene glycol antifreeze and yet many suppliers and manufacturers continue to only ship ethylene glycol against the Environment Agency's recommended advice[30]. **The authors would encourage a cross party discussion on this matter**.

**b.** Mechanical joints are a common source of failure as ground movement often creates leaks as mentioned in Stafford and Bell 2009[31]. The VBS specifies electrofusion only joints and it is preferable to avoid all subterranean joints. Grouts and backfilling materials are also a source of failure. Grouts need to be of the required thermal conductivity as specified in the design and backfilling materials need to be free of stones and other materials that can degrade the pipework.

**c.** Poor quality or unsuitable equipment. Concerns were expressed by manufacturing representatives at the January 2013 MCS HP WG meeting that some ASHPs were passing MCS 007 the heat pump standard at 7 air / 35 water test conditions, but did not maintain their performance at sub-zero test conditions. There is a need to improve the MCS heat pump test standards to ensure that they cover the full range of climatic and operational conditions likely to be encountered in the UK. As a result of this, MCS is now reviewing the heat pump product standard.

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[29] GROUND SOURCE HEAT PUMP ASSOCIATION (September 2010) Closed-loop Vertical Borehole Design, Installation & Materials Standards Issue 1 Milton Keynes, GSHPA retrieved from www.gshp.org.uk/pdf/GSHPA_Vertical_Borehole_Standard.pdf

[30] Environment Agency (n.d.) *Environmental good practice guide for ground source heating and cooling Version 3* Bristol, EA as retrieved from http://www.gshp.org.uk/pdf/ea_gshc_good_practice_guide.pdf

[31] Stafford and Bell (2009) *Evaluation of Heat Pump Installations: Extracting Meaning from Existing Datasets Final Report* Leeds Metropolitan University, Centre for the Built Environment

**d.** As air temperature drops to very low levels (e.g. -10°C or -15°C), ASHP performance deteriorates. In an email on 4th December 2012, Dr Jeremy Cockroft, researcher at the University of Strathclyde stated that the Westfield field trial which monitored eight air source heat pumps during the winter and spring of 2008 had concluded that the heat pumps could meet the heat demand down to around -2°C, however, the study had also found that the heat pumps proved to be totally unsatisfactory when temperatures dropped to -10°C or lower.

**e.** Refrigerant loss. This is a much debated topic. Sealed units which are carefully recycled at the end of their life should reduce the impact. However, refrigerant loss is a reality and HFCs have a global warming potential of 1300 to 2200 times greater than carbon dioxide. Petinot (2011)[32] states "Considering this extra environmental impact of 11% to 25%, heat pumps using HFCs have to be still more efficient to be equivalent to a gas boiler." Further information and studies on refrigerant loss and its effects are anticipated to be undertaken by DECC in the foreseeable future.

***Design & specification***

**a.** Undersizing. This has been widely discussed in many other papers and reports. It can be caused by a number of factors such as inaccurate heat loss calculations, design philosophies that rely on sizing to part load, lack of understanding etc.

**b.** Oversizing of heat pump. This tends to create cycling of the heat pump system. This is discussed in greater detail by Green (2012)[33].

**c.** Inaccurate/poor heat loss and energy calculations. These can result from errors in spreadsheets or software through to poor surveying or data entry. The CIBSE Domestic Heating Design Guide[34] does not specify an internal room or external room plus wall thickness measurement requirement. Evaluating whether cavity walls are filled requires expertise, insulation levels in solid floors are difficult to establish and glazing U-values are also estimates. Patchy cavity wall filling as reported in the Signpost Housing Association case study[35] and missing loft insulation in corners as reported in Stafford & Bell (2009) all create inaccuracies. Ventilation rates also vary depending on property age and type with suspended floors have significantly higher air change rates as compared to solid floor properties[36].

**d.** Poor heat emitter design. CIBSE through its domestic design guides and MCS through the heat emitter guide have both looked to improve heat emitter design standards. In the early days of heat pump installation, heat emitters might be oversized by 30% or some other arbitrary

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32 PETINOT (2011) Assessment of Seasonal Performances of Air Source CO2 Heat Pump by Dynamic Modelling Glasgow, University of Strathclyde

33 GREEN (November 2012) The Effects of Cycling on Heat Pump Performance Chester, EA Technology Limited retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65695/7389-effects-cycling-heat-pump-performance.pdf

34 CHARTERED INSTITUTE OF BUILDING SURVEYORS (2011) Domestic Heating Design Guide London, CIBSE

35 Signpost Housing Association (2006) *Completing the Loop, Case Study*, Signpost Housing Association Dorset, Spectrum Housing Group retrieved from http://www.completingtheloop.org.uk

36 Stafford and Bell (2009) *Evaluation of Heat Pump Installations: Extracting Meaning from Existing Datasets Final Report* Leeds Metropolitan University, Centre for the Built Environment

figure; Exercise 1, space heating and heat emitters on the Greenb website[37] sets out a good example of how different types of heat emitter are sized with their associated temperature star rating, flow temperature and SPF. The Heat Emitter Guide[38] also features several worked examples.

**e.** Poor hot water system design. Leading UK cylinder suppliers now offer heat pump specific cylinders as part of their product ranges. This leads to the question of whether suitable sized cylinders with much larger heat exchangers were regularly used before these cylinders were readily available.

**f.** Inadequate control strategy. Boait et al (2011) as cited by Baster (2011)[39] reported that "it was found that the high thermal mass and low distribution system efficiency of typical retrofit installations can compromise the controllability of heat pump systems. Analysis of simplified mathematical representations of a ground source heat pump installation with weather compensation suggested that, although set back periods can reduce energy use in some circumstances, they increase it in others". This is because the higher heating system flow temperature required to regain the set point reduces heat pump COP. It is not clear whether these results would be replicated for ASHPs and night-time set-back periods; unlike ground temperature, air temperature drops overnight. Stafford and Bell (2009)[40] explain how weather compensation curves and offset work in practice. If the curves or set points are inaccurately specified, then poor design could follow.

**g.** ASHP - Poor location. MCS 020 (DECC 2008a)[41] directly addresses noise requirements to obtain permitted development rights in England. These vary in other parts of the UK. Manufacturer's advice is required for air flow, anti-vibration mounting and condensate drainage. Issues that affect heat pumps often affect other types heating system. For example, the Hanlon (2010)[42] reported in the Daily Mail advice to its readers on frozen condensate drain pipes and this will affect both Condensing Boilers and ASHPs in equal measure if the same preventative measures are not taken.

**h.** GSHP - Inadequate collector design. Overlapping pipework tends to increase pumping losses for minimal heat gain from the ground. Howley (2010)[43] displayed significantly oversized pumps in his GSHPA 2010 AGM Conference presentation. Undersizing the collector can lead to frost heave where the ground freezes and so expands leading to disruption in the garden.

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[37] See: http://www.greenb.org.uk/heatpumps/

[38] DECC (n.d.) Supplementary Information 2 Heat Emitter Guide version 2.0, DECC. Available at: http://www.microgenerationcertification.org/mcs-standards/installer-standards [Accessed 26/03/2013].

[39] Baster (2011) *Modelling the performance of Air Source Heat Pump Systems* Glasgow, University of Strathclyde

[40] Stafford and Bell (2009) *Evaluation of Heat Pump Installations: Extracting Meaning from Existing Datasets Final Report* Leeds Metropolitan University, Centre for the Built Environment

[41] DECC (2008a) *MCS 020, MCS Planning Standards for permitted development installations of wind turbines and air source heat pumps on domestic premises* London, DECC retrieved from http://www.microgenerationcertification.org/mcs-standards/installer-standards

[42] Hanlon, M. (2010) *Did your central heating break down in the big freeze? Here's why...* , Daily Mail 29 December 2010, retrieved from http://www.dailymail.co.uk/sciencetech/article-1342357/Central-heating-break-big-freeze-Heres-.html

[43] Howley (2010) *Training and Standards; how the industry is responding to meets the demand generated by the RHI. Ongoing work of T&SC,* Presentation at the GSHPA Annual Conference and Exhibition 2010 on 28 June 2010. Available at: http://www.gshp.org.uk/documents/documents/AGM2010/2.Training&Standards-AH.pdf

Gupta and Irving (2008)[44] report that as a rule-of-thumb, a ground collector will be 1.5 to 2 times the area of the property and continues "Further, the collector must be 2m from trees, 1.5m from cables and 3m from septic tanks, water, waste and sewage pipes because of possible freezing." However, MCS 022: Ground Heat Exchanger Look Up Tables (DECC 2008b)[45] demonstrate that rules-of-thumb are exactly that, very approximate rules and only full design procedures suffice. Over-sized collectors lead to excessive cost and more pumping losses. Ground works contractors prefer to have a maximum trench depth of 1.2 m. This is because below 1.2 m, the trench walls require shuttering and this adds considerable work and cost to the job. Collectors too close to the surface are more prone to accidental damage and are also more susceptible to freezing in winter. Trenches more than 1.2 m deep require shuttering as trench collapse can have tragic consequences. Trenches and boreholes too close together will interfere on energy acquisition although in certain design scenarios, where the ground is used for both heating and cooling the building, this can be used by the designer as a benefit rather than a hindrance. Asking building services engineers to evaluate geological conditions and water tables levels is outside their normal core expertise. MCS offers some guidance and Geotrainet[46] is looking to provide information and training but it is still at the development phase so the only full training on ground collector design is available by correspondence through IGSHPA[47]. Reynolds number and its relationship to laminar and turbulent flow is beyond the level 2 to 3 competency of the typical British heating engineer and so needs to be evaluated at this design stage.

**i.** Lack of design training and skills. This point was addressed in the last numbered point.

### *Application & site suitability*

The main problems in relation to application and site suitability of heat pumps are:

- **a.** Insufficient surface area/depth or proximity (GSHP)
- **b.** Inadequate location (ASHP)
- **c.** Inadequate insulation (space heating & hot water heating), draught proofing or high heat loss
- **d.** Undersized heat emitters including HW heat exchanger
- **e.** Poor location/Incorrect siting of temperature sensor for weather compensation control

There is a significant desire in the UK Government to convert Britain away from gas based heating systems to low carbon heating systems, and David MacKay, DECC's chief scientific adviser is a leading advocate for this process. However, as highlighted in the Signpost Housing Association case study[48], finding suitable properties for heat pump conversion is not easy. If the necessary due diligence is not followed before sites are selected for either ASHP or GSHP conversion, many of the documented design problems highlighted above might ensue.

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[44] GUPTA, R. and IRVING, R. (2008) Assessing the potential of ground source heat pumps to provide low-carbon heating and cooling in UK dwellings in a changing climate Proceedings of Conference: Air Conditioning and the Low Carbon Cooling Challenge, Cumberland Lodge, Windsor, UK, Retrieved from http://nceub.org.uk

[45] DECC (2008b) MCS 022: *Ground Heat Exchanger Look-up Tables Supplementary Material to MIS 3005 Issue 1.0* London, DECC retrieved from http://www.microgenerationcertification.org/mcs-standards/installer-standards

[46] Geotrainet website, see: http://www.geotrainet.eu/moodle/

[47] IGSHPA website, see: http://www.igshpa.okstate.edu/

[48] Signpost Housing Association (2006) *Completing the Loop, Case Study*, Signpost Housing Association Dorset, Spectrum Housing Group retrieved from http://www.completingtheloop.org.uk

***Installation & commissioning***

**a.** Poor heat distribution installation. Modern British Heating Engineers are normally Gas Safe competent which means they are required to hold gas safety certificates and to be registered with Gas Safe[49]. Gas safety reassessment has to be completed every 5 years and this typically takes 3 days whilst initial assessment usually takes about 4 days. The initial training time varies between long term apprentice to experienced workers who will normally cover 5 days of gas safety training. The introduction of gas safety drove a significantly improved understanding in combustion, fluing and carbon monoxide across the sector. However, the introduction of TRVs and sealed rather than open vented heating circuits means that a lower level of heating knowledge is required to implement the whole system than was previously the case. Heat pumps, by their intrinsic nature, require high levels of heating competency but no combustion, fluing or carbon monoxide knowledge. Therefore, the switch to new technologies is associated with a switch to new competencies.

**b.** Flow temperature set too high. Weather compensation makes very significant performance benefits to a heat pump installation. Stafford and Bell (2009)[50] discuss setting up weather compensation systems. These require some time, care and consideration and this extra work needs to be built into the quote. Existing British heating engineers rarely set up weather compensation systems and so new competencies and quotation practices will need to be implemented.

**c.** GSHP - Inadequate collector installation. Howley in his GSHPA 2010 AGM Seminar presentation[51] set out many examples of bad and poor installation practice. Examples of aquifer contamination, bad joints, no capping off leading to dirt & rodent ingress and poor grouting practice leading to lost boreholes were all set out. Short cuts taken at this stage on antifreeze mixing, purging, pressure testing, biocide inclusion or antifreeze variety will lead either to early failure of the collector or short thermal transfer fluid life leading to expensive refills.

**d.** ASHP – inadequate installation. Poor practice can lead to a series of specific air source related issues such as excessive vibration or frozen condensate drains due to uninsulated pipework.

**e.** Lack of experience of installers / insufficient training and standards. Whilst MIS 3005 Issue 3 (DECC 2008c)[52] was implemented in April 2012, to the author's current knowledge only some of the 4 current awarding bodies have updated their training courses and assessments to reflect these changes in heat pump installation methods. Certainly, a rigorous training updates feedback loop should be established between the MCS scheme and the awarding bodies.

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[49] Gas Safe Register website, see: http://www.gassaferegister.co.uk/

[50] Stafford and Bell (May 2009) *Evaluation of Heat Pump Installations: Extracting Meaning from Existing Datasets Final Report* Leeds Metropolitan University, Centre for the Built Environment

[51] Howley (2010) *Training and Standards; how the industry is responding to meets the demand generated by the RHI. Ongoing work of T&SC,* Presentation at the GSHPA Annual Conference and Exhibition 2010 on 28 June 2010. Available at: http://www.gshp.org.uk/documents/documents/AGM2010/2.Training&Standards-AH.pdf

[52] DECC (2008c) *Microgeneration Installation Standard: MIS 3005 Issue 3.1a* London, DECC retrieved from http://www.microgenerationcertification.org/mcs-standards/installer-standards

***End user control/use***

**a.** Inadequate /unclear/complicated handover instructions/guidance and advice. Stafford and Bell (2009)[53] set out a common user interface in their paper with this interface being fairly complex. A Scottish Consumer Focus (2012)[54] report highlights this complexity issue further by saying *'Heat pumps clearly presented more issues in relation to daily use and controllability. Perceptions of user-friendliness varied, but the control panel itself seems to be very important in making it easy for tenants to use. One housing association now specifies the use of a very simple thermostatic controller in all their ASHP installations, and this seems to have addressed earlier problems.'*

**b.** Lack of information or help in obtaining incentives, planning permission or other government support. This is not made any easier by the complex and frequently varied nature of Government. It is hoped that once Domestic RHI is implemented, a full suite of long term Government support including permitted development, financial incentives and zero carbon homes policies will stabilise this sector and assist in strengthening this element.

**c.** Human behaviour and attitudes. Behaviour change is a key element in promoting climate change and system performance improvements and new initiatives such as the Groundwork initiative[55] hope to address these attitudes.

**d.** Longer heat up times and background heating rather than intense heat. Point of use heating such as fires, electric fires or even radiators with a flow temperature of around 80 °C can all create hot spots in a room and so a feeling of warmth. Low flow temperatures associated with heat pump systems tend to provide background heat and so the end user can have a different perception of the heat. In the Signpost Housing Association case study[56], a flat occupier was not informed of the slower heat up times with the GSHP system and so was dissatisfied with the end result. In a conversation on 22nd December 2011, Katie Steiness, Project Manager at the Ellen MacArthur Foundation stated that some tenants of the South Wight Housing Association properties retrofitted with ASHP systems were complaining that their new heating system was not providing adequate heat and an advisor had to be sent out to these properties to measure the ambient temperature and show tenants that the temperature of their homes was in fact the same as it had been previously, even though they could not feel the same level of heat coming off the radiators.

**e.** Incorrect use/understanding of controls/complex/inadequate controls. See point (a) in this section above which sets out the consequences of complex documentation and complex controls.

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[53] Stafford and Bell (May 2009) *Evaluation of Heat Pump Installations: Extracting Meaning from Existing Datasets Final Report* Leeds Metropolitan University, Centre for the Built Environment
[54] Consumer Focus Scotland (2012) *21st century heating in rural homes; Social landlords and tenants' experience of renewable heat* Glasgow, Consumer Focus Scotland
[55] For further information see: http://www.groundwork.org.uk/news--events/news/2011/groundwork-initiative-features.aspx
[56] Signpost Housing Association (2006) Completing the Loop, Case Study, Signpost Housing Association Dorset, Spectrum Housing Group retrieved from http://www.completingtheloop.org.uk

### *Maintenance/faults*

**a.** Maintenance matters. These issues were discussed as part of the DECC sponsored Heat Pump training for Housing Associations[57]. In difference to gas boilers, there is no annual legal requirement to service a heat pump. However, this does not mean they are maintenance free and as a minimum ASHPs should have the airways cleared and condensate drains checked on a regular basis. GSHPs need to have regular checks of the antifreeze concentration & pH level. All heating systems should be inspected to ensure on-going efficient and effective performance.

**b.** Heat pump faults. Well manufactured heat pumps should have a long and reliable life. However, like all mechanical engineering devices, they will suffer component failure especially in rotary or reciprocating components. As documented in the design section, some refrigerant leakage will occur and the compressor will often be replaced at some point during the life of the heat pump. SP from Sweden (2012)[58] reported during the Oct 2012 IEA Annex 36 Conference that compressors, ASHP evaporators and PCBs were in order the 3 most common causes of heat pump failure. ACR News (2010)[59] reported that in 2010, Mitsubishi undertook a national product safety recall of one model of ASHP (Ecodan), following one system affected by a faulty pressure pump which led to an explosion

**c.** Central heating circuit faults. As well as heat pump faults, faults will develop in the central heating system and like all new or significant technologies, the main heat source will often be blamed rather than the components within the heating system. Valves, pumps and other moving parts are the most common failure points and the heating system and controls also requires regular maintenance to make sure all susceptible components are functioning correctly.

### *Exhaust air heat pumps*

Exhaust Air Heat Pumps (EAHP) have received some poor national media coverage in the past year. The BBC's Rip Off Britain[60] reported that families living in new government-funded affordable housing have reported that the heating system used in their homes is costing up to four times more to run than expected. The programme reported that they had heard about 13 estates with the same issue. Inside Housing[61] has also reported that in Castefields, the Housing Association Runcorn is removing 200 of these units (costing £5k each) and replacing them with gas boilers.

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[57] See: www.greenb.org.uk/heatpumps

[58] SP (2012) Residential Heat Pump Failures Analysis Sweden, SP retrieved from http://www.heatpumpcentre.org/en/hppactivities/hppworkshops/Nuremberg2012/Documents/S3%20P11%20ORNL%20Baxter_A%2036%20-%205.10.pdf

[59] ACR NEWS (2010) Mitsubishi issues Ecodan recall after "explosion" ACR News 2010 27 July 2010 retrieved from http://www.acr-news.com/news/news.asp?id=2180&title=Mitsubishi+issues+Ecodan+recall+after+%22explosion%22

[60] BBC (2012) *'Efficient' heating system left families with big bills* [WWW] Available from: http://www.bbc.co.uk/news/business-19511637 (Accessed 8th April 2013)

[61] INSIDE HOUSING (2012) *Have Housing Associations have made an foolish error installing exhaust air heat pumps* [WWW] Available from: http://www.insidehousing.co.uk/have-housing-associations-have-made-an-foolish-error-installing-exhaust-air-heat-pumps/1042.thread (Accessed 8th April 2013)

Good technical reports on what has actually happened in these cases are not available and the manufacturer's website[62] only provides limited design information on sizing these units saying quoting heat loss must be below 50 $W/m^2$ and air extraction rates in litres/s.

## Conclusions and recommendations

There is only limited numerical information available in the UK on problems and failures. However, there is a lot of reported information from many sources on the many different types of problem and so this paper has set out a comprehensive list of where failures can occur and what the consequences are for the property owner, installation company, manufacturer, Government and other stakeholders. In doing this, the authors' hope that the information contained within assists the sector in raising standards in the future uptake of this technology. Further technical guidance on sizing EAHPs would also be beneficial so that these units are installed in suitable properties.

In particular, this review of documented problems with heat pumps found the following key areas for improvement:

- There are limited reporting systems for heat pump failure within the UK, and a need for a centralised analysis of the different failure modes. A funding stream is required for this work.
- These failure reporting systems should document all types of failure including such items as noise issues as well as callouts to repair ineffective heating systems. There are many forms of inadequate heating systems and reliability is just one of these. It is not easy to capture end user reactions although householder surveys often shed light on the issues under review.
- Relevant industry trade bodies and professional institutes need to develop UK relevant design, installation and commissioning protocols for all types of heat pump. The exhaust air heat pump performance issue is an example of where there has been a design failure and expectation gap.
- Training and assessment needs further work. Heat pump design, installation and commissioning all need to be taught to relevant stakeholders. Courses also need to keep abreast of latest developments such as currently cycling and buffer sizing advice as well as new technologies such as gas absorption heat pumps.
- MIS 3005 needs further work to make its systems yet more prescriptive. For example, energy calculations in this standard are either degree day or binned data based. This level of latitude opens up the standard to multiple interpretations.
- Further domestic heating design advice needs to be developed, especially for new build properties where accurate modelling would include:
    - inclusion of MVHR and accurately modelling of air change rates related to draught proofing, location and wind speed regime.
    - inclusion of thermal bridging into the fabric heat loss
    - solar gains and house location
    - thermal mass and especially thermal mass in heat emitters (screed underfloor systems)
    - clear advice on where to take measurements (currently there is no clear guidance on internal or external measurement protocols)
    - reviewing latest field trials and advice on "as designed" and "as built" differences in performance

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[62] NIBE (2013) *NIBE Exhaust Air Heat Pump Installation Notes* [WWW] Available from: http://www.nibe.co.uk/Listor-pa-startsidan1/Literature/NIBE-Exhaust-Air-Heat-Pump-Installation-Notes/ (Accessed 8th April 2013)

    - inclusion of internal heat gains onto degree day data calculations so that accurate energy consumption data can be obtained
    - inclusion of advice on maximum and minimum energy consumption for different occupancy rates and lifestyles
    - advice on specific requirements for HW systems and HPs including heat exchanger sizes, cylinder volumes and bacteria pasteurisation cycles
    - designing weather compensation and advanced controls and modelling ideal settings for the commissioning engineer.
- End users need high quality information on how to optimise the performance of the heat pump system for low running cost and warm, draught free comfortable homes. The control interface needs considerable improvement and the customer needs to be capable of controlling individual zones and the hot water provision.

## 3.5. SAP Appendix Q

### Introduction to SAP

The UK Government's Standard Assessment Procedure (SAP) for Energy Rating of Dwellings, including Reduced Data SAP (RdSAP), is the UK's National Calculation Methodology (NCM) for dwellings.

To assess a dwelling's energy performance, data is needed that describes the dwelling in terms of the energy performance of installed construction components and building services equipment. Such data is either generic (i.e. determined by the materials and type of product used) or specific (i.e. where validated individual product performance data has been made available). The SAP rating is used to measure the energy performance of dwellings using a scale from 1 to 100 where the higher the number the lower the running costs.

Within the scope of this report there have been two significant editions of SAP:

- SAP2005 (Appendix G: Heat Pumps) and;
- SAP2009 (Appendix N: Microgeneration (or micro-CHP) and Heat Pumps).

***SAP Appendix Q***

SAP2005 Appendix G: Heat Pumps centred on ground and/or water source HPs, ASHP and heat emitter delivery temperatures, whereas SAP2009 Appendix N: Microgeneration and Heat Pumps centred on both the HP technology and set of optional other components including thermal stores and / or auxiliary heaters. Furthermore there are no longer fixed Coefficient of Performance (COP) values in SAP 2009; and performance data for HPs is obtained from:

- The Product Characteristics Database (Appendix Q); and
- Table 4a of the SAP2009 document

The Product Characteristics Database (Appendix Q) is a procedure where technologies can be recognised in SAP between revisions (these occur every three years). In SAP 2009 they were adopted and included in the newly expanded Appendix N which also includes micro-CHP. It is a process through which information including product performance data is made available to energy performance assessors that was not available when SAP was published. The process also derives test and calculation methodologies that can be used to measure product performance and integrate within the applicable SAP calculation version[63].

A product's performance data is determined by testing against a specification that has been agreed by DECC's National Calculation Methodology contractor, the relevant manufacturer(s) and industry sector representatives. This process also derives test and calculation methodologies that can be used to measure product performance and integrate within the applicable SAP calculation version.

Technologies assessed via Appendix Q include:

- Mechanical ventilation systems;
    - Mechanical extract ventilation (MEV)
    - Balanced whole house mechanical ventilation

[63] BRE (2013) SAP Appendix Q Website. Available at: http://www.sap-appendixq.org.uk/ [Accessed 27/03/2013].

- Solar Air Preheat Positive Input Ventilation (SAPPIV)
  - Semi-Rigid duct systems
- Dynamic Insulation;
- Flue Gas Heat Recovery Systems (FGHRS);
- Waste Water Heat Recovery Systems (WWHRS);
- Hot Water Only Boilers; and
- Heat Pumps
  - HP models assessed by SAP Appendix Q methodology are grouped into five sub-categories which have been determined according to 'heat source'. They are:
    - Air Source HP (air to water)
    - Ground (Brine) Source HP (water to water)
    - Exhaust Air Source HP with Whole House Mechanical Extract Ventilation – Exhaust air only (air to water)
    - Exhaust Air Source HP with Whole House Mechanical Extract Ventilation – Exhaust air plus mixed ambient air (air to water)
    - Exhaust Air-Source HP with Whole House Balanced Mechanical Ventilation with Heat Recovery (air to air)

There are four heat emitter types used within SAP:

- Radiators;
- Radiators with fans;
- Under-floor heating; and
- Warm Air

### SAP calculation methodology

The SAP method of calculating the energy performance and the ratings is set out in the form of a worksheet, which is accompanied by a series of tables and the calculation should be carried out using a computer program that implements the worksheet and is approved for SAP calculations[64].

SAP Appendix Q calculation methodology includes both carbon dioxide calculations and energy saved (or consumed) compared to a default HP specified in the SAP calculator; used to calculate HP sizing.

If the HP provides domestic hot water heating by an electric immersion heater, it is assumed that the immersion will operate in conjunction with the HP – unless it is known that the HP can provide 100% of the water heating requirement. Any space heating requirement not met by the HP is by definition provided by secondary heating; which if un-specified is assumed to be met by electric heaters.

Test and calculation methodologies of HPs are defined in *BS EN 14511: Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling.* SAP2009 states that the characteristics of HP packages depends on temperature conditions and running hours; which are affected by the HP output rating and the design heat loss of the dwelling.

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[64] BRE approves SAP software on behalf of the Department for Energy and Climate Change; the Department for Communities and Local Government; the Scottish Government; the National Assembly for Wales; and the Department of Finance and Personnel, Northern Ireland

Note: In the Approved Document (AD) Part 1A 2006 it was assumed by default that within the SAP calculation, some form of secondary heating was provided in order to meet the space heating requirement. In AD Part L1A 2010 the default secondary heating assumption was removed and the actual secondary heating technology must be entered where present.

### Test conditions

In EU member states BS EN 14511 specifies standard rating conditions for tests (including source and sink temperatures, etc.) depending upon the type of HP and the intended application. If a HP is specified with a sink temperature of 55°C, test data must also be entered at 55°C. By standardising test conditions, parameters and test methodology it is possible to compare the Coefficient of Performance (COP) of different HP units.

### Coefficient of Performance (COP) and Seasonal Performance Factor (SPF)

The efficiency of a HP is defined by BS EN 14511 as the ratio of heat capacity (Pc) to the effective electrical power input of the heat pump unit (P).

$$COP = \frac{heat\ capacity}{electrical\ power} = \frac{Pc}{P}$$

Where:

The effective power input to the HP unit could be obtained from the rated power input for the operation of the compressor together with any power input that used to defrost the vaporiser; the power input for all control and safety devices; and the electrical power that is used within the HP to move thermal transfer fluid around the unit itself. However COP does not consider the power input for any external components such as circulation pump used within the heat collector and/or emitter circuit.

For the purposes of comparison the current MCS COP values are defined within *MCS 007: 2011: Product Certification Scheme Requirements: HPs Issue 2.1* and are as follows:

| HP type | Collector temperature °C | Emitter temperature °C | COP |
|---|---|---|---|
| Ground to Water | 0 | 35 | ≥3.5 |
| Ground to Air | 0 | 35 | ≥3.2 |
| Water to Water | 10 | 35 | ≥3.8 |
| Water to Air | 10 | 35 | ≥3.5 |
| Air to Water | 2 | 35 | ≥3.2 |
| Air to Air | 2 | 35 | ≥3.0 |
| Exhaust Air | 2 | 35 | ≥2.5 |

By comparison with COP, a heat pump Seasonal Performance Factor (SPF) provided a clearer indication of the HP systems operating efficiency over a given period (typically one year); as it compares the actual thermal heat energy produced by the heat pump against the electrical energy used to generate it. However the calculation of the Seasonal Performance Factor (SPF) was not defined in BS EN 14511 and it was therefore essential to identify, and where possible measure, the energy consumed by all appropriate auxiliary equipment and make an assessment of all system losses.

The SPF of a HP was therefore defined as the ratio of the Sum of the heat delivered by the HP (∑Qc) to the total electrical energy consumption (∑W) over a given period.

$$SPF = \frac{Sum\ of\ delivered\ heat}{Sum\ of\ the\ electrical\ energy\ consumption} = \frac{\sum Qc}{\sum W}$$

Whereas the COP of a HP is theoretically calculated, the SPF of a HP is a measure of a larger number of variable factors that affect the HPs performance. These include:

- Climate: specifically with regard to degree day data, used to calculate:
  - Annual heating and cooling demand
  - Maximum peak loads
- Temperature(s) of the heat source
- Temperature(s) of the heat distribution system (and hence demand by the consumer)
- Auxiliary energy consumption (pumps, fans, control etc.)
- Quality of the HP design and manufacture
- Sizing of the HP in relation to the heat demand and the operating characteristics of the HP
- HP and building control systems

## European Heat Pump Association (EHPA) Quality Label for heat pumps

The EHPA Quality Label for HPs originated in the activities of various heat pump associations of Austria, Germany and Switzerland which created a common set of requirements to ensure product and service quality. In addition to the founding countries, the EHPA quality label was introduced in Sweden (2007), Finland (2008), Belgium and France (2010).

The label can be granted to standardised space heating electrically driven HPs, with or without domestic hot water heating capability, with a capacity up to 100 kW from air, geothermal or water heat sources.

In order to qualify for the EHPA quality label, the HP in question must comply with EHPA HP test criteria and the distributor must provide a defined level of service. The key requirements are (list not exhaustive):

- Minimum COP efficiency values defined as follows and tested in laboratories accredited to *ISO/IEC 17025:2005 - General requirements for the competence of testing and calibration laboratories to perform HP test according to BS EN 14511*:

| HP type | Collector temperature °C | Emitter temperature °C | COP |
|---|---|---|---|
| Brine to Water | 0 | 35 | ≥4.30 |
| Water to Water | 10 | 35 | ≥5.10 |
| Air to Water | 2 | 35 | ≥3.10 |
| Direct exchange ground coupled to water | 4 | 35 | ≥4.30 |

- Declaration of sound power level

## USA – EnergyGuide label

Domestic HPs sold in the US have an **EnergyGuide label** which displays the HPs heating and cooling efficiency performance rating; thus allowing direct comparisons between alternative makes and models.

Cooling efficiency is indicated by the Seasonal Energy Efficiency Ratio (SEER) which is the total heat removed from the 'conditioned' space during the annual cooling season (expressed in British thermal units (Btu)), divided by the total electrical energy consumed by the HP during the same time period (expressed in Watt-hours).

$$SEER = \frac{heat\ extracted}{electrical\ power\ consumed}$$

The term SEER is used to define the average annual cooling efficiency of an air-conditioning or HP system. The term SEER is similar to the term Energy Efficiency Ratio (EER) but is related to a typical (hypothetical) season rather than for a single rated condition. The SEER is a weighted average of EERs over a range of rated outside air conditions following a specific standard test method. For purposes of comparison, the higher the SEER the more efficient the system.

Although SEERs and EERs cannot be directly compared, SEERs typically range from 0.5 to 1.0 higher than equivalent EERs.

Heating efficiency for air-source electric HPs is indicated by the Heating Season Performance Factor (HSPF) which is the total space heating required during the heating season (expressed in Btu), divided by the total electrical energy consumed by the HP system during the same season, (expressed in Watt-hours).

$$HSPF = \frac{total\ space\ thermal\ energy}{electrical\ power\ consumed}$$

The term HSPF is similar to the term SEER, except it is used to signify the seasonal heating efficiency of HPs. The HSPF is a weighted average efficiency over a range of outside air conditions following a specific standard test. The term is generally applied to HP systems with a capacity less than 60,000 Btu/h (rated cooling capacity.)

For purposes of comparison, the higher the HSPF the more efficient the system with the most efficient HPs having an HSPF of between 8 and 10.

## Conclusion

SAP Appendix Q is a route whereby manufacturers can demonstrate enhanced performance within SAP, the UK's Energy Rating of Dwellings calculation methodology. Competitor accreditation schemes such as the EHPA quality label will continue to press to be recognised as equivalent routes to accreditation.

## 3.6. Heat Pump Emitter Guide

## Introduction

The Heat Emitter Guide ('the guide') for Domestic Heat Pumps was developed by the following Trade Associations with the support of the Department of Energy and Climate Change (DECC) and the Energy Saving Trust:

- British Electrotechnical and Allied Manufacturers Association (BEAMA);
- Ground Source Heat Pump Association (GSHPA);
- Heat Pump Association (HPA);
- Heating and Hot Water Industry Council (HHIC);
- Institute of Domestic Heating and Environmental Engineers (IDHEE); and
- Underfloor Heating Manufacturers' Association (UHMA)

The guide is intended to be used by Heat Pump (HP) designers when designing HP based heating systems using either an existing radiator based heat emitter circuit or when designing a new heat distribution emitter circuit.

Although the guide was not a detailed design tool, it prompts the HP designer to consider and use appropriate standards (specifically BS EN ISO 7730, PR EN14825, BS EN 1264 and BS EN 442) and is written in a manner to enable installers to demonstrate in an easily understood format that HP performance could be optimised by a correctly specified low-flow / low-temperature heat emitter circuit.

Additional, albeit not specified, heat load and heat emitter design tools are recommended within the guide in order to ensure that the HPs operational performance is optimised. Reference is also made within the guide to use the knowledge of competent heat system designers who would be able to provide site-specific solutions to *'...meet your exact requirements...'*

***Design process flow chart***

The guide does include a simplified design process flow chart and associated colour coded guidance table as generic aids to ensure that all salient design parameters are included within the initial design stage specification (Appendix 4.1, A Heat Emitter Guide for Domestic Heat Pumps, figures 10 and 11). It is intended that the flow chart process would be repeated for all of the heating rooms in the dwelling. The guidance table is annotated to assist the HP designer achieve the most suitable design for the room/dwelling and illustrates that the HP performance may be improved significantly by initially reducing fabric and ventilation losses and/or achieving lower heat emitter circuitry flow rates and temperatures.

***Building regulations***

Although not referenced or stated within the guide, Building Regulations Approved Document ADL2 sets out the requirements for existing buildings.

The regulations do not oblige the system designer to perform Dwelling Emissions Rate / Target Emissions Rate (DER/TER) calculations, but where a new system is installed or an existing system replaced the installation must follow the requirements of the Domestic Building Services Compliance Guide (DCLG, 2010).

## Documents referenced within the Guide

***BS EN ISO 7730:2005 Ergonomics of the thermal environment***

With reference to the guide, BS EN ISO 7730:2005 describes the methodology for predicting the general thermal sensation and degree of discomfort (i.e. thermal dissatisfaction) of people exposed to moderate thermal environments.

It enables the analytical determination and interpretation of thermal comfort using Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) and local thermal comfort criteria; giving those environmental conditions considered acceptable for general thermal comfort as well as those representing local discomfort.

***PR EN 14825:2008 Conditioners, Liquid Chilling Packages And Heat Pumps, With Electrically Driven Compressors, For Space Heating And Cooling - Testing And Rating At Part Load Conditions.***

The PR EN 14825 standard defines a reference Seasonal Coefficient of Performance (SCOP) to be used in energy labelling and legislation in which the number of operational hours can be determined and in which the heating demand curve can be identified on the basis of a single input parameter.

SCOP describes the heat pumps average annual efficiency performance, and is therefore an expression for how efficient a specific HP would be for a given heating demand profile.

In essence the SCOP calculation method consists dividing the heating season into a number of hours with different temperatures (called bins) and which together are to reflect the variations in temperature over a given heating season.

Furthermore, a heating demand curve is determined for the temperatures providing the heating demand that the HP is met for each set of temperatures. A Coefficient of Performance (COP) value for each of the bins is found and together they formed the basis for calculating the average (or seasonal) COP, i.e. the SCOP.

***BS EN 1264:2008 Water based surface embedded heating and cooling systems.***

BS EN 1264 specifies boundary conditions and test methodology required to determine thermal output of hot water floor heating systems. The standard is applicable to heating and cooling systems embedded into the enclosure surfaces of the room to be heated or cooled.

With intermediate floors there is no requirement under building regulations to have thermal insulation. However, BS EN 1264 requires that intermediate floors that had a heated area below are to be insulated, and the insulation is to have a thermal resistance (R value)[65] of $\geq 0.75 m^2 K/W$.

***BS EN 442:1996 Specification for radiators and convectors***

BS EN 442 defines the technical specification and requirements of radiators and convectors to be installed in central heating systems in residential buildings. It covers radiators and convectors fed with water or steam at temperatures below 120°C and supplied by a remote heat source. The standard also defines additional common data that a manufacturer needs to provide to the trade in order to ensure the correct application of the product.

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[65] Where the thermal resistance (R Value) is the ability of a material to resist heat flow: the greater the R value the more effective the insulation material

## Heat Emitter Guide assumptions

The guide uses the following assumptions (bullet points are commentary):

1. Leeds is used for weather data
    - Weather data changed between SAP 2005 (average 1960-1979) and SAP 2009 (average 1987-2006)
    - Regional weather data was adopted within SAP 2009 to allow for a more accurate calculation of solar gain
    - SAP 2009 uses monthly calculations which separates summer and winter efficiencies and allows for an increased assessment of the performance of those very low energy dwellings which have a shorter heating season
    - SAP 2009 also includes a more accurate representation of summer energy demand and overheating potential.

2. Provision of domestic hot water is not included
    - This has been carried through to MIS 3005 v3.1.
        - It is likely that any revision of the guide will maintain the distinction between space heating and hot water production due to the need to minimise the risk of bacterial growth (Legionella) with the use of a secondary heating system (typically via an immersion heater).

3. Room temperature is based on European Winter standard 21°C operative temperature per BS EN ISO 7730
    - This has been carried through to MIS 3005 v3.1

4. The HP is sized to meet 100% of the space heating load and is the only heat source in the dwelling
    - This has been carried through to MIS 3005 v3.1

5. GSHP SPF is the SCOP calculated in accordance with PR EN14825
    - This has been carried through to MIS 3005 v3.1, where:
        - The SPF of a heat pump is defined as the ratio of the Sum of the heat delivered by the HP (∑Qc) to the total electrical energy consumption (∑W) over a given period.

$$SPF = \frac{Sum\ of\ delivered\ heat}{Sum\ of\ the\ electrical\ energy\ consumption} = \frac{\sum Qc}{\sum W}$$

- Whereas the COP of a HP is theoretically calculated, the SPF of a HP is a measure of a larger number of variable factors that affect the HPs performance. These include:
    - Climate, specifically with regard to degree day data, used to calculate:
        - Annual heating and cooling demand; and
        - Maximum peak load
    - Temperature(s) of the heat source
    - Temperature(s) of the heat distribution system (and hence demand by the consumer)
    - Auxiliary and parasitic energy consumption (e.g. pumps, fans, control etc.)
    - Quality of the HP design and manufacture

- Sizing of the HP in relation to the heat demand and HP operating characteristics
- HP and building control systems

6. GSHP B0/W35 COP = 3.5 (MCS minimum thresholds)
   - This figure is based on an expected Ground to Water GSHP system with no reference to other HP types. The figures shown are collector [brine] 0°C and emitter [water] 35°C.

7. Heating flow temperature in heat emitter guide is peak design conditions (i.e. at the lowest external design temperature)
   - This has been carried through to MIS 3005 v3.1
     - However, to ensure that the optimum heating flow temperature is maintained, reference must be made to both the HP manufacturers' product specifications together with hydraulic pump flow rates.

8. The temperature difference across the heat emitters is fixed at 1/7th of the emitter circuit flow temperature. For example if the emitter circuit flow temperature was 40°, then the return temperature would need to be 35.3°C (i.e. ΔT = 5.7K or flow temperature /7).
   - Although the guide includes information on emitter circuit temperature there is no distinction between emitter types (i.e. between radiators or underfloor heating (UFH) )- where flow temperatures are typically between 35° and 45° or where the emitted temperature is dependent upon additional factors to those included; specifically including hydraulic flow rate(s)).

9. Weather compensation is used
   - This has been carried through to MIS 3005 v3.1

10. 100W has been added for the electrical consumption of heating circulation pumps
    - The Energy using Products (EuP) Directive, passed on July 6th 2005, established a framework of rules and criteria for setting requirements on a number of products including HP circulator pumps.
      - By 2015, all circulators sold in the EU will have to meet or exceed stringent energy-efficiency requirements.
      - Typically, existing circulation pumps were D-labelled (whereas A-labelled HP circulator pumps use up to 80% less energy than D-labelled pumps).
      - The energy rating system for glandless stand-alone circulators will form part of the Declaration of Conformity (CE) marking and without a CE mark products may not be sold in the EU.

11. The heat emitter control system meets current building regulation requirements
    - This has been carried through to MIS 3005 v3.1

12. No allowance has been made for losses from: cycling, buffer vessels, or associated water pumps
    - This has been carried through to MIS 3005 v3.1 and is in-line with SPF calculation methodology.

13. The GSHP ground array is designed with a minimum heat pump entry water temperature of 0°C
    - This has been carried through to MIS 3005 v3.1 and is based on data received from several HP manufacturers that contributed to understanding the methodology required for the optimal design of horizontal collectors.
        - However there is no variation [to this figure] to distinguish between horizontal and vertical collectors.

14. A ground circulation pump is included
    - This has been carried through to MIS 3005 v3.1 and is line with SPF calculation methodology.

15. The SPF values for ASHP are 0.7 less than for GSHP, which is consistent with SAP
    - At the time that the guide was written ASHP SPFs were typically 0.7 lower than that of equivalently sized GSHPs; however latterly the SPF of both ASHPs and GSHPs has improved and this improvement should be factored in to any update of the guide.

16. Installation of screed UFH has floor insulation to BS EN 1264 or building regulations, - whichever is greater – with UFH and finishing floor laid over
    - This has been carried through to MIS 3005 v3.1. However, the onus passed from the HP system designer to the [independent] UHF heating company to ensure that the screed is laid in such a way as not to reduce the thermal performance of the HP emitter circuit.

17. Installation of Al-plated UFH to BS EN 1264 or building regulations (whichever is greater), with UFH pipework laid on top of a proprietary aluminium plate system with no air gaps between the aluminium plates, chipboard flooring and finishing floor
    - This has been carried through to MIS 3005 v3.1 however again the onus is arbitrarily transferred from the HP system designer to that of the UHF heating company.

18. Performance of UFH is calculated to BS EN 1264 and is shown using differing floor coverings with resistance values of: Carpet = 0.15m²K/W (or 1.5 TOG), Wood = 0.10m²K/W, Tile = 0.00m²K/W
    - The basic unit of insulation coefficient is $R_{SI}$ (1m²K/W) and 1 TOG = 0.1 $R_{SI}$ (BS EN 4745: 2005 Determination of thermal resistances of textiles. Two-plate method: fixed pressure procedure, two-plate method fixed opening procedure and single plate method).

    Thermal resistances ($R_{SI}$) for typical floor finishes adhering to BS EN 1264 are as follows:

| Thermal Resistance | TOG | Floor Finish |
|---|---|---|
| 0.00m²K/W | 0.0 | 2mm Vinyl tile<br>5mm Ceramic tile<br>3mm Epoxy Coating |
| 0.05m²K/W | 0.5 | 25mm Marble<br>Cushion Linoleum |
| 0.1m²K/W | 1.0 | 9mm Carpet Floor tile<br>13mm Hardwood |
| 0.15m²K/W | 1.5 | Deep pile Carpet<br>Wood Blocks<br>22mm Laminates |

- However the thermal resistance of carpet is reported by the Carpet Institute of Australia as being in the region of $0.18m^2K/W$ (i.e. 1.8 TOG) and the thicker the carpet the greater the thermal insulation provided.

19. Required performance of Fan Coils, Fan Convectors and Radiators is expressed as an Oversize Factor or Heat Transfer Multiplier to determine the required manufacturers' catalogued output per BS EN 442 at mean water to air temperature difference of 50°C. The exponents used in the heat transfer equation to calculate the Heat Transfer Multipliers are 1.3 for Standard Radiators, 1.1 for Fan Coils and 1.0 for Fan Convectors. The room temperature used to calculate the Heat Transfer Multipliers is fixed at 21°C
    - For existing heating systems the Oversize Factor or Heat Transfer Multiplier is based on the actual heat emitter size and type and the heat output potential compared with the calculated space heating load.
        - The oversize factor could then be used to provide an indication of how successful it would be to use lower temperature heating water supplied by a heat pump. In essence the greater the heat emitter oversize, the greater the opportunity to increase the operating performance of the heat pump; since the larger the heat emitter areas allowed the use of lower water flow temperatures.
    - It should be noted that actual SPF would be directly influenced by the heating load calculation and an accurate assessment of the existing heating system.
    - For new buildings the guide enables the selection of heating systems that are likely to operate at a SPF that would in effect reduce carbon dioxide ($CO_2$) emissions as it uses a combination of room heat loss, heat emitter types and heating flow temperatures.

## Conclusion

The Heat Emitter Guide is an innovative document that associates heat pump flow temperature with ASHP & GSHP SPF and heat emitter oversize factors. It is useful for both the designer and also for providing the householder with a temperature star rating for their installation. However, the guide currently has no issue date or structure for updating and so the industry needs to form a structure for maintaining the guide as further information becomes available or relevant. The Heat Pump Emitter Guide would benefit from a dedicated committee to work on its future development.

## 3.7. MCS020 Permitted Development Rights for Air Source Heat Pumps

### Introduction: Understanding Permitted Development Rights (PDRs)

Because ASHP units emit noise, planning permission restrictions are placed on these heating systems and these planning permission restrictions vary from country to country and within the UK. In certain circumstances and locations, permitted development rights (PDRs) apply and these PDRs are defined in the Communities and Local Government (2013) Planning Portal as:

*'You can make certain types of minor changes to your house without needing to apply for planning permission. These are called "permitted development rights" ...They derive from a general planning permission granted not by the local authority but by Parliament....the permitted development rights which apply to many common projects for houses do not apply to flats, maisonettes or other buildings.'*

In some areas of the country, known generally as 'designated areas', there are more restrictions on permitted development rights. In particular, if a building or site is a Conservation Area, a National Park, an Area of Outstanding Natural Beauty or the Norfolk or Suffolk Broads, it will be necessary to apply for planning permission for certain types of work which do not need an application in other areas. There are also different requirements if the property is a listed building (CLG, 2013)[66].

The Planning Portal's general advice to building owners is that they should contact their local planning authority and discuss a proposal before any work begins, and that they will be able to provide information on any reason why the development may not be permitted and if it is necessary to apply for planning permission for all or part of the work (CLG, 2013) [67].

***Permitted Development Rights withdrawn***

CLG (2013)[68] advise that local planning authorities have the power to issue an Article 4 direction, the consequence of which is that planning application will have to be submitted for work which does not usually require one.

Article 4 directions are made when the character of an area of acknowledged importance would be threatened by a development and are most common in conservation areas.

***Legislation: The Town and Country Planning (General Permitted Development) Order 1995***

The above Order clearly indicates that whilst permitted development rights can be a useful way of assessing whether planning permission is required or not, they are often difficult to interpret as there are many examples such as listed buildings, conservation areas and where permitted development rights are withdrawn that permitted development does not apply.

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[66] Communities and Local Government (2013) *Permitted Development Rights* (WWW) Available from: http://www.planningportal.gov.uk/permission/responsibilities/planningpermission/permitted (accessed 19/03/13)

[67] Ibid

[68] Ibid

***Energy Saving Trust (2013) information on planning permission in the countries of the UK***
The Energy Saving Trust's website provides useful information on how the planning permission requirements for ASHPs are applied across the different nations of the UK, in particular:

*'Air source heat pump installations In Wales and Northern Ireland require planning permission. In England and Scotland they may be considered Permitted Development, in which case you will not need planning permission, but the criteria are complex so it is always a good idea to check with your local planning office.'*

## Permitted development criteria

The Permitted Development criteria for England and Scotland as outlined on the Energy Saving Trust's website are listed in Table 5 below.

**Table 5 Permitted Development Criteria in England and Scotland**

***England***
From 1st December 2011, domestic air source heat pump systems will be classed as Permitted Development provided that they comply with certain criteria, including:

- there is no wind turbine at the property
- the external unit is less than 0.6 $m^3$ in size
- the unit is more than one metre from the edge of the householder's property
- it is not on a pitched roof, or near the edge of a flat roof
- it meets additional criteria if in a conservation area, World Heritage Site or similar.

Note: This list is not comprehensive and customers are advised to read the full legislation at the government's legislation website or contact their local planning office for full details.

***Scotland***
A domestic installation of an air source heat pump in Scotland is currently permitted unless:

- it would result in the presence within the curtilage of a dwelling of more than one air source heat pump
- the air source heat pump would be situated less than 100 metres from the curtilage of another dwelling
- the air source heat pump is visible from the road in a conservation area
- the air source heat pump would be within a World Heritage Site or the curtilage of a listed building

In addition, before beginning the development the developer must apply to the planning authority for:

- a determination as to whether the prior approval of the authority will be required for the siting and external appearance of the air source heat pump
- the application also needs to be accompanied by a range of other information and a number of other conditions apply.

## Further information on PDR in England

The full English requirements for PDR on ASHPs are set out on Communities and Local Government's Planning Portal (CLG, 2013)[69] where it says that *'Development is permitted only if the air source heat*

[69] Communities and Local Government (2013) Heat Pumps, Planning Permission (WWW) Available from: http://www.planningportal.gov.uk/permission/commonprojects/heatpumps (accessed 19/03/13)

*pump installation complies with the Microgeneration Certification Scheme Planning Standards or equivalent standards.'* The Microgeneration Certification Scheme (MCS) planning standards for ASHPs are provided in MCS 020 issue 1 (DECC, 2011)[70].

The Planning Portal then goes on to discuss MCS and says:

*'The Microgeneration Certification Scheme includes clear standards to support the installation of wind turbines and air source heat pumps. The main purpose of the scheme is to build consumer confidence in microgeneration technologies.*

*The scheme includes certification for products and installer companies. One of the limits of permitted development rights for wind turbines and air source heat pumps is that equipment must be installed by an installer who has been certificated through the scheme using a certificated product.*

*While it is ultimately the landowners responsibility to ensure that all of the conditions and limits to be permitted development will be met, the installer of the equipment should check to ensure that the installation complies with the Microgeneration Certification Scheme planning standards, including requirements on noise.' (CLG, 2013)*[71]

### Further information on PDR in Scotland

The full Scottish regulations are contained within Scottish Statutory Instruments (2010)[72].

The Scottish Government Social Research (2009)[73] commissioned a report 'Permitted Development Rights: Domestic Wind Turbines and Air Source Heat Pumps' by SQW Energy. This report sets out the full consultation and development process for ASHP PDR in Scotland. The report was written before MIS 3005 v3 was implemented.

### Air source heat pump requirements as set out in MCS 020

The MCS 020 standard sets out that as well as using an MCS (or equivalent) product and the installation being the latest version of MIS 3005 compliant, the ASHP installation shall be carried out in compliance with the calculation procedure contained in Table 2 of MCS 020. Installers must complete the 'results/notes' column in Table 2 for each step of the calculation procedure to show how it has been followed.

Table 2 sets out a calculation method whereby:

**Step 1:** insert the A-weighted sound power level of the heat pump.

**Step 2:** establish the directivity "Q" of the heat pump noise.

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[70] DECC (2011) MCS 020, MCS Planning Standards for permitted development installations of wind turbines and air source heat pumps on domestic premises Available from: http://www.microgenerationcertification.org/mcs-standards/installer-standards (accessed 19/03/2013)
[71] Ibid
[72] Scottish Statutory Instruments (2010) No. 27 The Town and Country Planning (General Permitted Development) (Domestic Microgeneration) (Scotland) Amendment Order 2010 Available from: http://www.legislation.gov.uk/ssi/2010/27/pdfs/ssi_20100027_en.pdf (accessed 19/03/13)
[73] Scottish Government Social Research (2009) Permitted Development Rights: Domestic Wind Turbines and Air Source Heat Pumps by SQW Energy, Available from: http://www.scotland.gov.uk/Resource/Doc/296738/0092262.pdf (accessed 19/03/13)

**Step 3:** measure the distance from the heat pump to the assessment position in metres.

**Step 4:** use Note 4 table to obtain a dB reduction.

**Step 5:** establish whether there is a solid barrier between the heat pump and the assessment position (see note 5)

**Step 6:** calculate the sound pressure level from the heat pump at the assessment position using the following calculation: (STEP 1) + (STEP 4) + (STEP 5)

**Step 7:** Background noise level. For the purposes of the MCS Planning Standard for air source heat pumps the background noise level is assumed to be 40 dB(A) Lp.

**Step 8:** Determine the difference between STEP 7 background noise level and the heat pump noise level using the following calculation: (STEP 7) – (STEP 6)

**Step 9:** Using the table in Note 7: Decibel correction‟ obtain an adjustment figure and then add this to whichever is the higher dB figure from STEP 6 and STEP 7. Round this number up to the nearest whole number.

**Step 10:** Is the FINAL RESULT in STEP 9 lower than the permitted development noise limit of 42 dB(A)?

- If YES - the air source heat pump will comply with the permitted development noise limit for this assessment position and may be permitted development (subject to compliance with other permitted development limitations/conditions and parts of this standard). NOTE - Other assessment positions may also need to be tested.
- If NO – the air source heat pump will not be permitted development. This installation may still go ahead if planning permission is granted by the local planning authority.

**Note 7: Decibel correction (STEP 9)**

Please note that the left hand column should be used for both positive and negative differences (e.g. a difference of +3 and -3 both attract a correction of 1.8 dB).

**Table 6 Decibel Correction for Note 7 (MCS 020)**

| Difference between the two noise levels (dB) (+/-) | Add this correction to the higher noise level (dB) |
|---|---|
| 0 | 3.0 |
| 1 | 2.5 |
| 2 | 2.1 |
| 3 | 1.8 |
| 4 | 1.5 |
| 5 | 1.2 |
| 6 | 1.0 |
| 7 | 0.8 |
| 8 | 0.6 |
| 9 | 0.5 |
| 10 | 0.4 |
| 11 | 0.3 |
| 12 | 0.3 |
| 13 | 0.2 |
| 14 | 0.2 |
| 15 | 0.1 |

## Critical assessment of MCS 020 ASHP planning standards

The MCS ASHP planning standard has three main criticisms levelled at it:

***Noise abatement notices can be raised to limit ASHP use at certain times***

The procedure can be carefully followed, the ASHP installed and the neighbours raise a noise abatement notice that in theory could lead to the ASHP unit being shut down or being limited in its times of operation.

An abatement notice can be served by the local authority if they are satisfied that a noise problem amounts to a statutory nuisance. The notice may require that the noise be stopped altogether or limited to certain times of day. The notice can be served on the person responsible for the noise, who then has 21 days to appeal (UK Environmental Law Association, 2008 – 2011)[74].

***MCS 020 calculation reliant on supply of accurate A-weighted sound power level***

The MCS 020 calculation is reliant on the manufacturer supplying an accurate A-weighted sound power level for the heat pump.

The Building Performance Centre (2011)[75] published a report which documented 10 sites where 4 sites matched the manufacturer's figure, with 1 site -4 dB below the manufacturer's figure and 5 sites +2 to +5 dB greater than the manufacturer's figure.

***Tonality and aural characteristics not adequately addressed***

The issue of tonality and other aural characteristics has not been adequately addressed, even though these can result in a higher level of disturbance than would be implied by the overall A-weighted sound level alone (Institute of Acoustics, 2009)[76].

The Building Performance Centre (2011)[77] report also discussed tonality and the Joint Nordic Method, cited by the paper, demonstrates that tonal noise is more disturbing than "white noise" and applies a penalty, depending on the audibility of the tone. The penalty was found to be 0-6 dB for the sites examined in the Building Performance Centre Study. The report then documented that the actual distance including tonality from unit at which noise level would be LAeq 42 dB (m) (free field) would be between 8, 9, 11, 11, 14, 16, 18, 20, 25 & 45 metres respectively for the 10 different ASHP units. Tonality was affected by both the compressor and fan within the ASHP units as well as the design of the unit. A number of the ASHPs surveyed were identified as having significant acoustic tones, particularly during the defrost cycle. The tonal content was found to be typically in the low frequency region. This tonal content can adversely affect the subjective acceptability of the ASHP noise signature. Manufacturers should be encouraged to present a uniformed set of noise data for their

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[74] UK Environmental Law Association (2008 – 2011) Frequently Asked Questions (WWW) Available from: http://www.environmentlaw.org.uk/rte.asp?id=76

[75] Building Performance Centre (2011) Acoustic Noise Measurements of Air Source Heat Pumps (EE0214) (WWW) Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48204/3307-acoustic-noise-air-source-heat-pumps-1.pdf (accessed 26/03/2013)

[76] Institute of Acoustics (2009) Permitted Development Rights for Small Scale Renewable and Low Carbon Energy Technologies, and Electric Vehicle Charging Infrastructure, DCLG Consultation Document Available from: http://www.ioa.org.uk/uploads/publication-documents/IOA%20Response%20to%20PDR%20Consultation%208%20February%202010.pdf (accessed 19/03/13)

[77] Building Performance Centre (2011) Acoustic Noise Measurements of Air Source Heat Pumps (EE0214) (WWW) Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48204/3307-acoustic-noise-air-source-heat-pumps-1.pdf (accessed 26/03/2013)

ASHPs in a similar manner to the Micro Wind Turbine Noise Labels. This should ideally include sound power levels, sound pressure levels at a range of distances in addition to a tonal penalty figure calculated in accordance with JMN2 or ISO 1996-2. The designers of ASHPs should be encouraged to compartmentalise the compressor and internal workings of the system as much as possible such that an acoustic box is formed which prevents the compressor noise radiating out of the open fan enclosure. A well designed acoustic enclosure would typically have a casing mass of at least 10 kg/m2. All pipe and electrical penetrations should be well sealed with rubber glands and incorporate flexible joints where possible. The enclosure design should include acoustic absorption material. The ASHP which used a centrifugal fan type appeared to be a noisier arrangement than the ASHPs with axial fan types. Further advice was provided on avoiding amplitude modulation effects.

### Comparison of MCS 020 with international planning requirements

Our understanding of noise requirements in Germany are, as published by BWP[78]:
Emission values for emission outside buildings:

a) **In developed areas:** Full-time 70 dB (A)
b) **In commercial areas:** Daytime 65 dB (A); At night, 50 dB (A)
c) **In core areas, village areas and mixed:** Daytime 60 dB (A); At night 45 dB (A)
d) **In general residential and small settlements:** Daytime 55 dB (A); At night, 40 dB (A)
e) **In purely residential areas:** Daytime 50 dB (A); At night 35 dB (A)
f) **In the spa areas, for hospitals and nursing homes:** Daytime 45 dB (A); At night 35 dB (A)

Individual, short-term noise peaks which may occur in the day (06.00 - 22.00) up to 30 dB (A) and in the night (22.00 - 06.00) up to 20 dB (A).

To identify the relevant noise pollution, measurements should be made 0.5m from the centre of the open window (outside the building) of the most affected space. Rooms that re in need of protection (DIN 4109) include:

- Living rooms and bedrooms
- Nursery
- Workrooms / offices
- Classrooms / seminar rooms

### Conclusion

The above would seem to indicate that the noise issue related to ASHP is far from settled and it is noted that the Institute of Acoustics (2009)[79] called for a 35 dB LAeq limit. Manufacturers need to implement further work to minimise sound power levels and also address tonality matters. There also needs to be a further robust discussion on noise issues. Current EU member states seem to follow different policies on this noise issue.

[78] BWP (n.d.) *Leitfaden Schall* Available from: http://www.waermepumpe.de/uploads/tx_bwppublication/2012-08-23_MK_Leitfaden_Schall.pdf (accessed 08/04/2013)
[79] Ibid

## 3.8. Arrangements for insurance & consumer protection

### Introduction

The aim of this section of the report is to review the current provisions for insurance, and consumer protection in the event of a complaint and their sufficiency, including whether they protect the consumer in cases where there are problems if related to manufacture, installation or maintenance along with recommendations for closing any existing loopholes.

If a customer has an issue or complaint about a heat pump, it is likely to fall within at least one of the following categories[80]:

1. **Technical** relating to the performance of the installed system, including:
   - Technical issues
   - Poor performance (e.g. system not producing as much heat as the consumer thought it would)
   - Design problems
   - High running costs
   - Excessive hot water consumption
   - Undersizing

2. **Non-technical** or contractual relating to the service and/or customer care, including:
   - Misinformation about/difficulty registering for the RHPP/RHI
   - Poor workmanship
   - Warranty/maintenance issues
   - Damage
   - Insulation problems
   - Materials
   - Planning permission
   - Company not MCS certified
   - Handover pack

Protection is provided for customers in these two areas, and this section of the report reviews the degree of protection provided by key schemes in the UK in comparison to provisions across Europe.

***Consumer protection for renewable energy systems***

Consumer protection for renewable energy systems covers prevention of (or limitation of) the risk of problems occurring and the procedures and customer support in the event of claims, including:

- Statutory Protection
- Payment Security (pre-handover)
- Product Warranty
- Insurance-backed Guarantees

There are a number of insurance schemes that cover and protect aspects such as:

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[80] Energy Saving Trust (2013), *Making a Complaint,* Energy Saving Trust. Available at: http://www.energysavingtrust.org.uk/Generating-energy/Finding-an-installer/Making-a-complaint [Accessed 25/03/2013]

- possible third-party damage, which may be caused by any of the installer activities in supplying energy generators to consumers;
- any liabilities which might reasonably be expected to arise from installer activities;
- deposits and advance payments by the customer;
- goods paid for by consumers in advance and delivered to the installer prior to installation; and
- installer guarantees.

Provision of consumer protection and insurance in the UK and Europe is achieved through a number of organisations and schemes set up for this purpose including:

- product and installer certification schemes;
- trade bodies and approved consumer codes of conduct;
- consumer advice and support organisations;
- private insurance providers; as well as
- statutory consumer law.

The key organisations and schemes within these categories are outlined below.

## Product & installer certification schemes

***The Microgeneration Certification Scheme (MCS)***

The Microgeneration Certification Scheme (MCS) is a quality assurance mechanism administered by the licensee, Gemserv, on behalf of Government. MCS sets out standards for small-scale heat and power generation systems including technical and process standards for:

- installers of small-scale heat and power generators; and
- small-scale heat and power generating products.

The Certification Mark for Onsite Sustainable Energy Technologies

Installers wishing to become MCS certified have to demonstrate that they have signed up to a Code of Practice that meets the guidelines set by the UK's Consumer Codes Approval Scheme (CCAS). The aim of this requirement is to ensure that contractors offer consumers protection, including complaints handling and a comprehensive performance prediction for products to avoid mis-selling. In order to become MCS certificated, installation companies must be members of REAL (or an equivalent scheme).

***European Heat Pump Association (EHPA) Quality Label***

The EHPA quality label for heat pumps was originally set up by heat pump associations in Austria, Germany and Switzerland through the need to create a common set of product and service quality standards for heat pumps. This was developed further in the European Heat Pump Association and the scope of countries taking part is currently extending with a total of 10 participating countries: Austria; Belgium; Czech Republic; Finland; France; Germany; The Netherlands; Slovakia; Sweden; Switzerland; and the United Kingdom.

The EHPA quality label can be granted to standardised space heating electrically driven heat pumps, with or without domestic hot water heating capability, with a capacity up to 100 kW from air, geothermal or water heat sources. In order to qualify for the EHPA quality label, a heat pump must comply with EHPA heat pump test criteria and the distributor must provide a defined level of service. The key requirements are outlined in Figure 3.

a) Conformity of all main components and compliance with the national rules and regulation (CE marking)
b) Minimum efficiency values defined as follows (operating points - required COP), tested in labs accredited to ISO 17025 to perform heat pump test according to EN 14511:
    - Brine to water B0/W35 - 4.30
    - Water to water W10/W35 - 5.10
    - Air to water A2/W35 - 3.10
    - Direct exchange ground coupled to water E4/W35 - 4.30
    - hot water heat pump (currently under revision)
c) Declaration of sound power level.
d) Existence of sales & distribution, planning, service and operating documents in the local language of the country where the heat pump is distributed.
e) Existence of a functioning customer service network in the sales area that allows for a 24h reaction time to consumer complaints.
f) A two year full warranty which shall include a declaration stating that the heat pump spare parts inventory will be available for at least ten years.
g) The full set of requirements and/or further information can be obtained from EHPA's quality label committee or the associations websites:

**Figure 3 Key requirements of EHPA quality label (list not exhaustive)**[81]

Further information on quality standards and test requirements can be found in the Laboratory Test Requirements section of this report.

## Trade bodies & approved codes of practice

### *UK Consumer Codes Approval Scheme (CCAS)*

The OFT is a non-ministerial government department that was established by statute in 1973, and is the UK's authority on consumer and competition, and plays a leading role in promoting and protecting consumer interests while enduring that business are both fair and competitive.[82]

Until April 2013, the OFT approved codes of practice for trade bodies in the UK, and a business with an OFT approved code are operating under a trade body with an approved code of practice – the aim of which was to provide customers with high standards of customer service and ensure customer rights were better protected. Businesses operating under an OFT approved code are committed to:

- provide customers with good standards of customer service
- give customers clear information about the goods or services they're selling
- use clear and fair contracts
- have user-friendly, and prompt procedures for dealing with customer complaints and provide access to low cost, independent advice to resolve disputes.[83]

[81] EHPA (2013) *European Heat Pump Association (EHPA) Quality Label* [WWW] Available at: http://www.ehpa.org/ehpa-quality-label/
[82] Office of Fair Trading (2013) *What we do* [WWW] Available at: http://www.oft.gov.uk/about-the-oft/what/ [Accessed 03/04/2013]
[83] Office of Fair Trading (2013) *Why look out for the approved logo?* [WWW] Available at: http://www.oft.gov.uk/consumer-advice/approved-codes-explained/about-codes/ [Accessed 03/04/2013]

From April 2013, under changes to the consumer landscape protection regime which was introduced by UK Government, the OFT is no longer responsible for approving consumer facing codes of practice. In April 2012, the Government invited the Trading Standards Institute (TSI) to operate a successor scheme to the Consumer Codes Approval Scheme on a self-funding basis.

The TSI has now announced details of the new code approval criteria for its Consumer Codes Approval Scheme[84], and is inviting existing code sponsors to transfer to the new scheme and has made the scheme open to potential new sponsors. The TSI consulted on proposed changes to the core criteria within the CCAS, and the key changes include:

- Respect of established 'no cold-calling zones' when dealing with customers in their home
- Strengthening of some codes approval criteria to reduce customer detriment.
- Update of criteria to be consistent with the Consumer Protection from Unfair Trading Regulations 2008 and a new European directive on alternative dispute resolution.
- Broadened range of acceptable criteria from members on their deposit and pre-payment protection.
- Retention of monitoring of codes requirement and in future code sponsors will be invited to identify the key performance indicators relevant to their market.
- No longer a need for code sponsors to provide a pre-alternative dispute resolution but inclusion of an eight weeks time-limit for informal resolution; thereafter customers can insist upon independent dispute resolution conciliation service.
- Strengthened requirements for ADR in line with European law.
- Plan to pre-approve at least two ADR providers for code sponsors to use if don't have their own.
- Code sponsors required to establish an independent disciplinary and sanctions panel to ensure a breach of a code of practice is dealt with quickly and impartially.
- The scheme will be open to any eligible code of practice.

***Renewable Energy Consumer Code (RECC)***

The Renewable Energy Association (REA) is a leading trade association in the UK which represent renewable energy producers and suppliers of electric and heating energy technologies. The Renewable Energy Consumer Code (RECC)[85] was set up by Renewable Energy Assurance Ltd (REAL) and provides standards relevant to the selling or leasing of small-scale renewable or low carbon heat and power generators to domestic customers. It is governed by specific bye-laws by which members of the Code must abide. The standards relate to the various contacts that companies have with consumers, including:

- Marketing
- Pre-contractual information
- Quotations
- Deposits
- Contracts
- Guarantees
- After-sales service

The Code was designed to help its members achieve high consumer protection standards, and to provide consumers with confidence to generate their own heat or power.

[84] Trading Standards Institute (2013)
[85] Further details can be found at: http://www.recc.org.uk

The RECC is currently the sole Consumer Code in the microgeneration market that has been approved under the Consumer Codes Approval Scheme (CCAS). The content of and changes to the Code are monitored by a panel made up of members, consumer representatives and others interested in these issues.

In the response to DECC on its Microgeneration Strategy Consultation , REAL stated that they currently had 25 active complaints concerning heat pumps, which were primarily ground source. At the time this represented around one third of the complaints they were working on and typically involved systems that cost between £10 and £20k up front. The majority of complaints were regarding undersized systems relying on auxiliary energy source which is usually electricity resulting in very high electricity bills; between £5k and £9k per year. REAL were concerned that heat pumps were being marketed to unsuitable households resulting in a 'high degree of consumer detriment'.

**Figure 4 Office of Fair Trading Consumer Codes Approval Scheme (CCAS)**

The RECC scheme is the code that the Department of Energy & Climate Change (DECC) has accepted for the Microgeneration Certification Scheme (MCS). [86] The MCS works in partnership with the RECC to ensure that MCS installation companies are working to a CCAS approved Code of Practice and to make sure that they sell their products and services to consumers appropriately, without mis-selling or misleading consumers.[87]

To check compliance of its members with the Code, REAL audit a sample of members through mystery shopping, compliance checks and pro-actively challenging members on consumer service provided before, during and after contracts are agreed, and this includes:

- advice provided
- information on systems and their performance
- sales and marketing techniques
- arrangements for installation and connection of the system
- selection and quality of goods supplied
- conditions of business
- standard of installation and on-site work
- guarantees, maintenance and after-sales services
- action taken to deal with any problems

REAL also analyse complaints received and provide a free conciliation service; 250 serious complaints have been handled between 2007 and 2011[88]; 100 serious complaints were resolved in the year 2010/2011. The Code is continuously being improved to address issues arising such as tightening the application processes and providing training on consumer protection legislation.

The RECC has also recently introduced a Deposit and Advance Payment Insurance Scheme for the insurance of all consumer funds paid in advance, which was set up in response to risks facing small businesses (i.e. in the event the company goes into receivership before the installation has taken

[86] HETAS Ltd (2013), *Microgeneration Certification* [WWW] Available at: http://www.hetas.co.uk/professionals/installers/mcs-installer/ [Accessed 03/04/2013]

[87] The Microgeneration Certification Scheme (2013) *Why MCS?,* [WWW] Available at: http://www.microgenerationcertification.org/about-us/why-mcs [Accessed 03/04/2013]

[88] REA Ltd (2011) *Response to Consultation on the Microgeneration Strategy,* REA Ltd [WWW] Available at: http://www.realassurance.org.uk/images/upload/news_13_REAL-Assurance-Scheme-response-to-Microgeneration-Strategy-consultation.pdf [Accessed 03/04/2013]

place) and therefore their customers. [89] This also includes insurance of workmanship warranties to cover consumers if the company goes out of business before the end of the insurance period.

Deposit and Workmanship Warranty Insurance (DAWWI) Scheme

Under the REAL Assurance Scheme, members are required to protect any funds paid in advance and protect any installer guarantee should the business cease to trade while it is still valid. One way that members are able to do this is directly through an insurance scheme set up by Renewable Energy Assurance Ltd who worked with an insurance provider, QANW, to set up a scheme in 2010 which in 2012 became part of the Deposit and Workmanship Warranty Insurance (DAWWI) Scheme.

The DAWWI Scheme covers:

- **deposit and advance payment policy:** valid from the date the deposit is paid until the date agreed in the contract for the goods to be delivered for installation (as long as the process is 120 days or less)
- **workmanship warranty policy:** valid from the date the installation was completed, for the same length of time as the written workmanship guarantee is valid for (usually 2, 5 or 10 years).

Where a customer makes a claim, the insurer (Guarantee Protection Insurance Ltd (GPI Ltd)) can either provide a refund (i.e. for deposits) or arrange for another member of REAL to provide/undertake the business.[90]

Complaints Process

The way REA handle consumer complaints depends on the nature of the complaint and when it is received. Figure 5 illustrates how REA decide on the process, and how they work jointly with MCS and the certification bodies to resolve complaints.

[89] Consumer Focus (2013) *Consumer Focus response to consultation on microgeneration strategy* [WWW] Available at: http://www.consumerfocus.org.uk/files/2009/06/Consumer-Focus-response-to-consultation-on-a-microgeneration-strategy1.pdf [Accessed 03/04/2013]

[90] REA Ltd (2013), *The Deposit and Workmanship Warranty Insurance (DAWWI) Scheme*, [WWW] Available at: http://www.realassurance.org.uk/consumers/insurance [Accessed 03/04/2013]

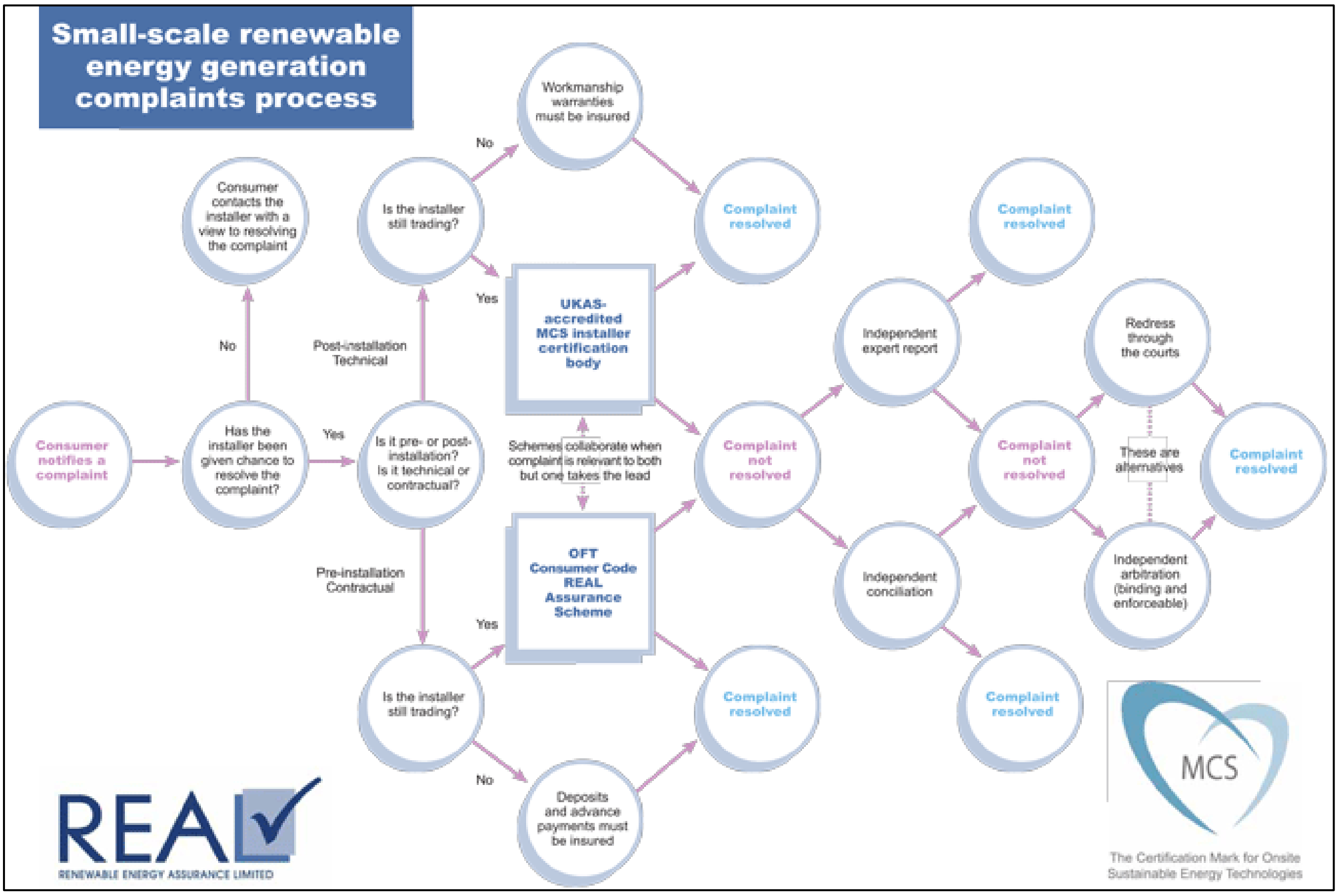


**Figure 5 REA & MCS Complaints Process Diagram**[91]

## Ground Source Heat Pump Association (GSHPA)

### *Code of Ethical Practice*

Members of the Ground Source Heat Pump Association (GSHPA) include installers, designers, consultants, borehole drilling specialists and suppliers to the ground source industry, and are bound by the GSHPA's Code of Ethical Practice, which regulates the conduct of members in:

- Advertising
- Sales
- Insurance
- Installation
- Servicing
- Legal obligations
- Complaints and
- Conciliation

The Code requires members to have sufficient insurance cover applicable to their business activity.

[91] REA (2013) *Small-scale renewable energy generation complaints process* [WWW] Available at: http://www.recc.org.uk/pdf/complaints-diagram.pdf [Accessed 16/04/2013].

***Association of Plumbing and Heating Contractors (APHC) Customer Charter***[92]
The APHC is the leading trade association for the plumbing and heating industry in England and Wales. APHC members have committed to provide high levels of customer service and undertaken an annual assessment to ensure they are meeting the strict Business Performance Standards set by the association which covers: level of competency, insurance, complaints handling, financial probity.

As part of these standards, is the requirement for members to hold and operate an approved Customer Complaints system and members must adhere to the minimum terms set out in the APHC's Customer Charter which covers:

- Provision of written estimates/quotes
- Specification of work
- Any exclusions
- Terms of payment

***Renewable Energy Installation Guarantee Agency (REIGA)***
REIGA is a non-profit organisation which has been set up by the renewable energy market to monitor and maintain high standards among installers and suppliers who are members. REIGA provides an independent 10 year guarantee for the installation of renewable energy devices, such that customers with these devices will not be reliant on the installers to guarantee their installations.

If a customer has a problem with an installer who is a member of RIEGA, they will approach the installer on behalf of the customer to establish the details and appoint a surveyor to report on the issues. REIGA will then take the necessary action to ensure the issue is resolved, which may involve appointing another installer to remedy any problem.[93]

***Local Authority Assured Trader Scheme Network (LAATSN)***
These Local Authority Assured Trader Schemes[94] are run by individual local authorities to provide a way for consumers to find trustworthy local businesses. Any business signed up to such a scheme must promise to meet their legal obligations and treat consumers fairly in return for support and promotion from the local authority Trading Standards Services.

The LAATSN member schemes have a common aim to:

- give consumers a reliable way of finding businesses they can trust
- offer source of help and advice if things go wrong
- enable local businesses to demonstrate they have signed up to national standards

While not all Network schemes offer enhanced protection, such as pre-payment protection and independent redress, consumers can be assured that the members are subject to an independent and impartial application and monitoring process; the LAATSN currently has 22 members and is monitored by the National Standards and Support Committee (NSSC) made up from representatives of the Office of Fair Trading (OFT), Local Authorities Coordinators of Regulatory Services (LACORS), Trading Standards Institute (TSI), Trading Standards Services and CCAS Advisor Group.

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[92] Association of Plumbing and Heating Contractors website: http://www.aphc.co.uk/
[93] REIGA (2013) *REIGA Consumer Information* [WWW] Available at: http://www.reiga.org.uk/#!consumers/c21iz
[94] OFT (2013) *Local authority assured trader schemes* [WWW] Available at: http://www.oft.gov.uk/OFTwork/consumer-protection/consumer_initiatives/trader/#.UXEpKspvC8B [Accessed 19/04/2013]

***Buy with Confidence***
One of the members of the LAATSN is Buy with Confidence[95]; a scheme set up by a partnership of Local Authority Trading Standards Services to provide consumers with a list of approved local businesses who have committed to trading fairly and who have undergone a series of detailed checks. Originally set up by Hampshire Trading Standards in 1999, there are now over 50 local authority partners in this Scheme, which is run through the cooperation of a number of Trading Standards Services and is administered by local authority Trading Standards Services directly.

***Trustmark***
TrustMark[96] is a not for profit organisation supported by the UK Government Department for Business, Innovation and Skills, the building industry, retailers and local trading standards and consumer groups.

The aim is to help consumers find reliable and reputable tradespeople to carry out repair, maintenance and improvement work inside and outside their homes. A business can be awarded the logo by a TrustMark Approved Scheme Operator (these include trade associations, local authorities / Trading Standards, certification inspection schemes and commercial organisations) but they must comply with Government-endorsed standards covering technical competence and good customer service.

Many of the TrustMark approved scheme operators insist their tradesmen meet higher standards due to the requirements of the particular specialist trade and consumers are advised to find out what the Scheme Operator requires of their members to ensure it is clear what the consumer is entitled to expect. The TrustMark team monitors approved Scheme Operators on behalf of the TrustMark Board; the Board reviews each approved scheme operator's performance, including an independent assessment of the quality of their work and how they handle complaints etc.[97]

## Customer support organisations

***Citizens Advice***
The Citizens Advice consumer service is responsible for providing free consumer advice and information on consumer issues and operate a telephone helpline and online help services.

***Trading Standards Institute***
The Trading Standards Institute is a membership and training organisation, and in cases of reported criminal behaviour e.g. scams, unsafe goods and rogue traders, the Citizens Advice consumer service refer details to the relevant local authority Trading Standards service who will take the issue forward.[98]

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[95] Hampshire Trading Standards (2011) *Buy with Confidence* [WWW] Available at: http://www.buywithconfidence.gov.uk/sitepages/bwchome.aspx [Accessed 19/04/2013].
[96] UK ECC (2013) *Trustmark* [WWW] Available at: http://www.ukecc-services.net/TM.cfm [Accessed 19/04/2013]
[97] Trust Mark (2013) *Government Endorsed Standards for Tradesmen* [WWW] Available at: http://www.trustmark.org.uk/government-standards/government-standards/ [Accessed 19/04/2013].
[98] Trading Standards Institute (2013) *Help and Advice* [WWW] Available at: http://www.tradingstandards.gov.uk/advice/index.cfm [Accessed 16/04/2013]

Under the customer protection regime introduced by Government, there will be an increasing role for the local authority Trading Standards Services in the enforcement of consumer protection law at a national level from April 2013.

***Office of Fair Trading***

The role of the OFT will tend to use its powers where breaches of consumer protection law are related to systematic market failures or where cases are likely to be against a number of business rather than individual firms.

***UK European Consumer Centre (UK ECC)***

The UK ECC is a service delivered by the TSI to provide consumers with advice and information when shopping within the Internal Market of Europe. It is part of the European Consumer Centre Network, made up of 29 centres throughout Europe (one in each EU country plus Iceland and Norway).

The European Consumer Centre for Services has been set up to assist consumers to make informed choices when looking to buy services across Europe. It provides general information on consumer laws and rights when buying a service in another EU member state, as well as contact details for organisations that could provide practical assistance in the case of a dispute.[99]

## Other Insurance and Consumer Protection Schemes

***Insurance backed guarantees***

These types of schemes can operate for the product or system lifetime, and provide protection to consumers in the event that the installation company goes out of business while any guarantees (e.g. for repair/maintenance) are still valid, and they are often combined with a servicing/maintenance contract. These largely cover any latent faults or breakdowns but their primary protection is to ensure that faults are rectified even if the original installer/contractor is no longer trading. MCS are currently working on a requirement for installers to offer Insurance Backed Guarantees (IBGs) in order to provide the best protection and on-going peace-of-mind to their customers.

## Private insurance providers

There are a small number of insurance providers now in the UK market who specialise in renewable energy insurance, both for business and for homeowners. The type of insurance policies available to are outlined in the examples shown in Figure 6 and Figure 7.

[99] Trading Standards Institute (2013) *Help and Advice* [WWW] Available at: http://www.tradingstandards.gov.uk/advice/index.cfm [Accessed 16/04/2013]

***Business Insurance Example: Northern Counties Insurance (NCi)*** [100]
NCi Energy provide insurance for UK companies specifically for renewable energy products, including: solar panels, wind turbine, biomass, hydro, erection/risks including testing and commissioning.
The cover available under NCi's Renewable Energy Insurance policies for businesses includes:

- Third Party Liabilities including public and products liability with employers liability, engineering and breakdown risks, property and business interruption risks
- Premises Pollution Liability e.g. sudden/accidental and gradual pollution, damage to third party property, third party claims for nuisance, trespass and obstruction etc.
- Construction: single project basis and can include subcontractors, manufacturers and suppliers, consultants, delays in start-up, testing and commissioning etc.
- Transportation Risks including loss or damage while in transit, loss of profit etc.
- Additional Policies including personal accident, business travel, professional indemnity, data protection etc.

**Figure 6 Example of installer/contractor insurance policies for renewable energy**

***Household Insurance Example: Naturesave Insurance*** [101]
Naturesave is one of the UK's leading providers of insurance policies for the renewable energy sector, from large to small scale projects. They offer insurance cover for renewable energy contractors and installers covering: construction risks; transit risks; engineering risks; material damage; loss of revenue and business interruption; employers, public and products liability; professional indemnity, directors and officers and trustees liability.
They also offer a 'Domestic Renewable Energy Systems Insurance' for homeowners within their Home and Annual Travel insurance policy which includes renewable energy systems up to 50kW.
Cover available for homeowners includes:

- Materials damage for wind turbines, solar PV, hydro, micro CHP and anaerobic digestion as part of contents insurance with additional premium applied (if eligible for FiT and installed under MCS)
- Public Liability: third party property damage and bodily injury emanating from the customers renewable energy system
- Mechanical Breakdown: Over and beyond any warranty cover in place
- Loss of Revenue: Remuneration for loss of revenue (i.e. from export/feed in tariffs) following physical loss or damage to renewable energy systems

**Figure 7 Example of homeowner/domestic customer insurance policies for renewable energy**

## Statutory consumer law

The laws, guidance and codes that apply to the legal rights of customers of microgeneration technologies are listed in Table 1 below.

**Table 7 UK Laws, guidance and codes**[102]

| |
|---|
| Arbitration Act 1996 |
| British Code of Advertising and Sales Promotion |
| Business Names Act 1980 |
| Cancellation of Contracts made in a Consumer's Home or Place of Work Regulations 2008 |
| Companies Act 1980 |
| Consumer Protection Act 1987 |
| Consumer Protection (Distance Selling) Regulations 2000 |

[100] Northern Counties Insurance (2013), *Renewable Energy Insurance* [WWW] Available at: https://www.ncinsurance.co.uk/renewableenergyinsurance.html [Accessed 03/04/2013]
[101] Naturesave Insurance (2013), *Personal Insurance,* [WWW] Available at: http://www.naturesave.co.uk/personal_insurance.html [Accessed 03/04/2013]
[102] REA (2013), *Renewable Energy Consumer Code* [WWW] Available at: http://www.recc.org.uk/scheme/consumer-code#tagC

| |
|---|
| Consumer Protection from Unfair Trading Regulations 2008 ('CPRs'). |
| Data Protection Act 1998 |
| Direct Selling Association Consumer Code |
| Enterprise Act 2000 (and all the legislation covered by it) |
| Misrepresentation Act 1967 |
| Ofcom Consumer Code |
| PhonePayPlus Consumer Code |
| Provision of Services Regulations 2009 ("the Regulations") |
| Sale and Supply of Goods to Consumers Regulations 2002 |
| Sale of Goods Act 1979 |
| Supply of Goods and Services Act 1982 |
| Trade Descriptions Act 1968 |
| Unfair Terms in Consumer Contracts Regulations 1999 |

There are laws in place that cover the whole of the EU and give you protection to consumers goods and services and traded across the EU. The relevant Directives listed in Table 8 are applicable to all EU states.

**Table 8 EU Directives and Laws**[103]

| |
|---|
| Doorstep selling 85/577/EEC |
| Unfair Contract Terms 93/13/EEC |
| Distance Selling 97/7/EC |
| Unit Prices 98/6/EC |
| Injunctions 98/27/EC |
| Sale of Goods and Associated Guarantees 99/44/EC |
| EU Services Directive 2006/123/EC |

Some of the key relevant consumer statutory rights listed above are described below.

***Sale of goods***

When a consumer buys goods from a trader they enter into a contract which is controlled by a number of laws including the Sale of Goods Act 1979 which states that goods should be:

- **Of satisfactory quality** taking account of the products description, price and other circumstances as well the state and condition of the goods, their fitness for purpose, appearance, safety, durability and whether there are any minor defects.
- **Fit for the purpose made known to the trader –** fit for general purpose and any particular purpose made know to the trader by the consumer at time of purchase.
- **As described –** goods correspond with any description applied to them.

In the case that goods to not conform to the contract (not of satisfactory quality, fit for purpose or as described) the consumer is legally entitled to one of the following: a full refund; repair or replacement; rescission or reduction in price; damages.[104]

[103] UK ECC (2013) *Rights when buying in the EU* [WWW] Available at: http://www.ukecc-services.net/RightswhenbuyingEU.cfm [Accessed 19/04/2013]
[104] Trading Standards (2013) *Consumer Safety and Training* [WWW] Available at: http://www.warwickshire.gov.uk/consumersafety [Accessed 17/04/2013]

***Guarantees and warranties***

Under the Sale and Supply of Goods to Consumer Regulations 2002, a provider is contractually responsible for honouring conditions set out in any guarantee that has been offered on the goods sold or supplied to the consumer. If the provider refuses to provide repair of goods as set out in the terms of the guarantee, the consumer has a right to take legal action against the guarantee provider for breach of contract which could involve claiming back any cost of repairs if carried out by another provider. [105]

In the EU, the Sale of Goods and Associated Guarantees Directive (99/44/EC) is concerned with the legal guarantee and commercial guarantees. Sellers of consumer goods within the EU are obliged to guarantee the conformity of the goods with the contract for a period of two years after the delivery of the goods.[106]

***Incorrect pricing, misleading or aggressive sales***

The Consumer Protection from Unfair Trading Regulations 2008 act outlaws the practice of misleading actions, omissions and aggressive sales. [107]

***Cooling off periods***

The key legislation relating to cooling off periods are described below[108]:

Consumer Protection (Distance Selling) 2000 Regulations (as amended) and E-Commerce Regulations 2002: For goods purchased by telephone, mail order, fax, digital TV, the Internet, consumers have the unconditional right to cancel an order seven working days after receipt of the goods.

Consumer Protection (Cancellation of Contracts made in a Consumer's Home or Place of Work) Regulations 2008: Consumers who enter into a contract away from business premises have a right to cancel the contract within seven days. In the case of doorstep selling, members who fail to give the consumer written notice that they can cancel the contract may be committing a criminal offence.

## Conclusion & recommendations

In the UK and across Europe, consumer rights are protected through statutory laws and directives covering the process of selling and sale of goods, guarantees and warranties and contractual agreements and through Codes of Conduct which businesses have to abide by to gain approval from trade organisations or schemes such as the Renewable Energy Association, Ground Source Heat Pump Association or the Buy with Confidence scheme. These laws and codes are enforced by Government supported organisations such as Trading Standards services as well as independent trade and consumer organisations and schemes.

In the UK, there are now schemes such as the Microgeneration Certification Scheme (MCS) and REAL Code in place to provide customer protection and insurance for the sale of domestic microgeneration

[105] Trading Standards (2013) *Consumer Safety and Training* [WWW] Available at: http://www.warwickshire.gov.uk/consumersafety [Accessed 17/04/2013]

[106] UK ECC (2013) *Rights when buying in the EU* [WWW] Available at: http://www.ukecc-services.net/RightswhenbuyingEU.cfm [Accessed 19/04/2013]

[107] UK ECC (2013) *United Kingdom Your Consumer Rights* [WWW] Available at: http://www.ukecc-services.net/ukycr.cfm

[108] REA (2013), *Renewable Energy Consumer Code* [WWW] Available at: http://www.recc.org.uk/scheme/consumer-code#tagC

products. These schemes are relatively new and the recent UK Government Microgeneration Strategy consultation revealed some key areas for improvement.

The Government announced a consultation on its Microgeneration Strategy on 12th July 2010 and the Government's Microgeneration Strategy document was published on 22nd December 2010. This welcomed the proposed establishment of a Microgeneration Government-Industry Contact Group (GICG) facilitated by the Energy Efficiency Partnership for Homes (EEPH); set up to coordinate industry actions with Government to enable the successful implementation of the Microgeneration Strategy and build the necessary capabilities and capacity of the industry to deliver the Strategy.

During the Government consultation on the Microgeneration Strategy, key consumer support organisations including Consumer Focus[109], REAL Assurance[110] and Which?[111] provided responses. Key topics in the area of insurance and consumer protection discussed by these organisations are listed below, with further details of recommendations in Appendix B: Microgeneration Strategy Consultation: key recommendations*.*

- Lifetime Repair and Maintenance Guarantees: linking insurance schemes and the provision of repair and maintenance
- Enforcement of Installer Standards & Certification: strengthening of certification processes to make them more rigorous and consistent
- Clarity on/ Enforcement of Sub Contracting Responsibility: enforcement of sub-contracted work to ensure full responsibility of MCS-certified companies
- Clarity on Commissioning of Installation: who can sign off and commission installations and circumstances around this
- Approval of Companies Generating Sales Leads: require companies generating sales leads to be approved under a Consumer Codes scheme
- Approval of Companies Signing Contracts: require company signing contracts and taking payments to be MCS-certified and member of an approved Consumer Code
- Guarantee Wording: altered wording in REAL Code guarantee to differentiate statutory rights from additional rights within the REAL scheme.
- Method/Approach to Dealing with Consumer Complaints: set up of a one-stop shop to deal with all microgeneration complaints (both technical and contractual)
- Funding for Independent Expert Reports: reinstatement of funded expert reports for situations where negotiations between consumer and company have dissolved
- Information Provision: greater required level of information to consumers on microgeneration and its suitability prior to signing contracts or installation
- Insurance under Different Business Models: ensure consumers are aware of contractual issues under long-term contracts e.g. 'rent-a-roof' schemes and have adequate insurance and protection

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109 Consumer Focus (2011) *Consumer Focus response to consultation on a Microgeneration Strategy.* Available at: http://www.consumerfocus.org.uk/policy-research/energy/green-deal/consultation-responses-and-discussion-documents [Accessed 11/04/2013]

110 Renewable Energy Assurance Ltd (2011) *Response to Consultation on the Microgeneration Straetgy.* Available at: http://www.realassurance.org.uk/images/upload/news_13_REAL-Assurance-Scheme-response-to-Microgeneration-Strategy-consultation.pdf [Accessed 11/04/2013]

111 Which (2011) *Which? response to DECC Consultation on a Microgeneration Strategy.* Available at: http://www.which.co.uk/documents/pdf/microgeneration-strategy-which-response-247729.pdf [Accessed 11/04/2011]

- Insurance Backed Warranties Cost: provision of an automatic insurance-backed warranty for consumers.

## 3.9. Laboratory test requirements of MCS

### Introduction

The European Renewable Energy Sources (RES) Directive 2009 – Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009, on the promotion of the use of energy from renewable sources, and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC defines both 'geothermal' (GSHP) and 'aerothermal' (ASHP) HPs; Article 14 – Information and Training of RES2009[112] states that EU members:

- …'Shall ensure that certification schemes or equivalent qualification schemes become or are available by 31 December 2012 for installers of… shallow geothermal systems and heat pumps…'
- Annex IV – Certification of installers states that the certification schemes or equivalent schemes referred to shall be based on the following criteria:
    - Part 2 … 'shallow geothermal… installers shall be certified by an accredited training programme or training provider…'
    - Part 6 a ii … 'in the case of heat pump installers: training as a plumber or refrigeration engineer and have basic electrical and plumbing skills… as a prerequisite….'

There are two main accreditation and certification schemes in the UK: the Microgeneration Certification Scheme (MCS); and the Enhanced Capital Allowance (ECA) scheme, where successfully registered HP products are included on the Energy Technology Product List (ETPL). A third scheme in the UK is the Competent Persons Scheme (CPS) introduced by the Department of Communities and Local Government to enable companies to self-certify plumbing and heating works that fall under the scope of Building Regulations.

### Microgeneration Certification Scheme (MCS)

The Microgeneration Certification Scheme (MCS) was launched by the Department of Energy and Climate Change (DECC) in 2006. The MCS is a third-party certification scheme covering all microgeneration technologies including HP installations. The scheme is led by a stakeholder panel, comprised of representatives from the industry; including certification bodies, government departments, trade associations and other interested parties. The role of Licensee is currently undertaken by Gemserv Limited; an industry-independent organisation appointed by DECC to manage and coordinate the MCS.

The scheme is designed to provide reassurance to consumers through the assessment of both approved microgeneration products and installation companies against quality, performance and reliability and safety criteria.

Certification is delivered by third party certification bodies which are private companies accredited by the United Kingdom Accreditation Scheme (UKAS). Those certification bodies that are based in the UK

[112] RES Directive (2009) *Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009, on the promotion of the use of energy from renewable sources, and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC defines both 'geothermal' (GSHP) and 'aerothermal' (ASHP) HPs; Article 14 – Information and Training of.* Available at: http://www. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0028:en:NOT [Accessed 03/05/2013]

and that have been accredited by UKAS to assess HP products and installers to the appropriate MCS Standards are:

- Ascertiva Group, trading as NICEIC
- Ascertiva Group, trading as NQA
- Benchmark Certification
- BRE Global Ltd
- British Board of Agrèment
- BSI
- ECA Certification Ltd, incorporating ELECSA
- Intertek
- NAPIT Certification Ltd
- Stroma Certification Limited

For certified and MCS registered products, conformity to specification is ensured through satisfying European and International standards; specifically BS EN 14511. In addition, MCS accreditation requires: a factory production control visit in accordance with BS EN ISO/IEC 17065:2012; Conformity assessment; Requirements for bodies certifying products, processes and services, which replaced BS EN 45011:1998; and General requirements for bodies operating product certification systems, which was withdrawn 31st October 2012.

Furthermore, MCS certified companies are required to comply with annual surveillance audits to ensure an on-going compliance to both standards and scheme requirements. Should any requirement not be met, the certification body may issue a notice of non-conformity and call upon the company to rectify the issue. MCS accredited products and installers enable subsidiary eligibility (in particular under the [UK] Feed-In-Tariff (FIT) and Renewable Heat Incentive (RHI) schemes).

Technologies covered within the MCS include:

- Air Source HP
- Ground Source HP
- Biomass
- Hydro
- Wind Turbine
- Micro Combined Heat and Power (CHP)
- Solar Photovoltaic
- Solar Thermal

Installer certification includes assessment of the following:

- Supply;
- Design;
- Installation; and
- Set-to-work and commissioning

### Competent Persons' Scheme (CPS) self-certification

The Competent Persons' Scheme (CPS) was introduced by the Department of Communities and Local Government (DCLG) to enable companies to self-certify plumbing and heating works that fall under the scope of Building Regulations,, where self-certification provided a potentially lower cost route when compared with the alternative of notifying work through local building control bodies.

Installation of microgeneration systems, particularly solar thermal and solar photovoltaic, is classed as building work for the purposes of Building Regulations.  There are many companies that can self-certify the whole installation as well as many that can only certify, for example, the electrical work. However, the difficulty for members of the public is identifying who can certify what.

If a company has been assessed as competent to self-certify certain works, the method of assessment and measurement of competency is outside the remit of Building Control.  Although MCS is not a requirement for Building Regulation purposes, it is the installer entries that are relevant; significantly where MCS accreditation is a pre-requisite for Government funding through the Feed in Tariff (FIT), Renewable Heat Incentive (RHI), and will be linked to the Green Deal.

***Applicable work areas (not exhaustive list):***

- Installation of Oil Fired Appliances covering;
  - Oil Fired, Pressure Jet Appliances
  - Oil Fired, Vapourising Appliances
  - Oil Storage Tanks & Supply Pipelines
- Solid Fuel Appliances;
- Woody Biomass Boilers;
- Ground Source and Air Source HPs;
- Solar Thermal Hot Water Systems;
- Electrical Installations, Defined Competence Schemes; and
- Installation of Heating & Hot Water Supply Systems

To self-certify plumbing and heating works that fall under the scope of Building Regulations, companies must become certified CPS installers through a CPS Certification Body.

## Energy Technology Product List (ETPL)

Companies buying Energy Technology Product List (ETPL) products are entitled to claim an enhanced capital allowance; which is a tax benefit against the purchase cost of the HP and other direct costs (including delivery, installation and professional fees).

The ETPL is audited annually and a selection of products from each accredited technology and multiple manufacturers can be chosen to be tested by an independent test laboratory with UKAS accreditation (or similar).

When products are tested independently the manufacturer declared performance values must be at least 95 per cent of the independent test results in order to remain on the ETPL.

HP products eligible under the ECA scheme include:

- Air source
  - Split and multi-split including variable refrigerant flow (VRF);
  - Gas-engine-driven split and multi-split including VRF;
  - Packaged; and
  - Air to water

- Water source (internal water loop only)
    - Split and multi-split including VRF
- Ground source
    - Brine to water (indirect closed-loop heat exchanger) buried in the ground
- Heat pump dehumidifiers
- Heat pump driven air curtains

## Test conditions

HPs are tested by a UKAS accredited or similar test laboratory. In EU member states, BS EN 14511 specifies standard rating conditions for tests (including collector [source] and heat emitter [sink] temperatures) depending upon the type of HP. Whereas HPs sold in the US have an EnergyGuide Label which allows side-by-side comparison of HPs, by standardising test conditions, parameters and test methodology within BS EN 14511, it is possible to similarly compare the Coefficient of Performance (COP) of different HP units.

Thermal performance and power consumption can be tested in heating and cooling mode for air-source, water-source and ground-source HPs. Results include testing COP and Energy Efficiency Ratio (EER) (at full load to EN14511) and part-load testing of Heating Seasonal Performance Factor (HSPF), Seasonal Energy Efficiency Ratio (SEER) and part-load COP (to prEN14825). Testing for part-load COP demonstrates the product's long-term efficiency and gives more realistic performance data for a heat pump in real use.

In addition to thermal performance tests, safety tests must be conducted in accordance with EN 14511 Part 4.

Sound characteristic tests are also a requirement of the MCS, and are carried out in accordance with *BS EN 12102: 2008 Air conditioners, liquid chilling packages, heat pumps and dehumidifiers with electrically driven compressors for space heating and cooling*. *Measurement of airborne noise. Determination of the sound power level.*

## CEN Solar Keymark Scheme

Currently the only other scheme that is comparable to MCS is the CEN Solar Keymark Scheme. However, whereas MCS includes both products and installation companies, the CEN Solar Keymark covers the certification of Solar Thermal products only.

The CEN Solar Keymark was developed between 2001/2007 [Solar Keymark I 2001/2003, Solar Keymark II 2006/2007] by the European Solar Thermal Industry Federation (ESTIF); CEN [the European Committee for Standardisation], and European Test Laboratories together with the support of the European Commission. CEN Solar Keymark was designed to ensure certification of solar thermal collectors and systems throughout Europe.

The CEN Solar Keymark uses the following standards [Note: EN12975 is under review at the date of this report]:

| | |
|---|---|
| EN 12975-1:2006. Thermal solar systems and components - Solar collectors | • Part 1: General Requirements. Amendment EN12975-1+A1:2010<br>• Part 2: Test methods |

| | |
|---|---|
| EN 12976-1:2006. Thermal solar systems and components - Factory made | • Part 1: General requirements<br>• Part 2: Test methods |
| ENV 12977-1:2001. Thermal solar systems and components - Custom built systems | • Part 1: General requirements<br>• Part 2: Test methods<br>• Part 3: Performance characterisation of stores for solar heating systems |
| EN ISO 9488:1999. Solar energy -Vocabulary (ISO 9488:1999) | |

In addition there are a number of applicable standards that are under development:

| | |
|---|---|
| prCEN/TS 12977-1 Thermal solar systems and components - Custom built systems | • Part 1: General requirements for solar water heaters and combi-systems |
| prCEN/TS 12977-2 Thermal solar systems and components - Custom built systems | • Test methods for solar water heaters and combi-systems |
| prCEN 12977-3 Thermal solar systems and components - Custom built systems | • Part 3: Performance test methods for solar water heater stores |
| prCEN/TS 12977-4 Thermal solar systems and components - Custom built systems | • Part 4: Performance test methods for solar combi-stores |
| prCEN/TS 12977-5 Thermal solar systems and components - Custom built systems | • Part 5: Performance test methods for control equipment |

The CEN Solar Keymark is marketed as delivering benefits to both manufacturers' [of Solar Thermal products] and consumers.

***Manufacturers benefit by experiencing:***

- A simpler testing procedure;
    - One test valid for all European countries;
- Freedom of choice amongst a number of accredited test labs;
- An easier introduction of new products in different European countries; and
- Simplified procedures for replacing components in certified products

***Consumers benefit by:***

- Access to products of known quality and performance;
    - Confirmation that products are fully tested according to the relevant standards; and
- Being assured that the product sold is identical to the tested product;
- Being eligible to receive subsidies

## Comparison of MCS [Solar Thermal] and CEN Solar Keymark

The MCS [Solar Thermal] accreditation scheme audits manufacturing, installation and certification process of solar thermal hot water systems with additional consumer protection. The CEN Solar Keymark accreditation scheme audits manufacturing [factory made systems] and certification process of solar thermal collectors and hot water storage systems.

| Criteria | Microgeneration Certification Scheme | CEN Solar Keymark |
|---|---|---|
| EU Scheme created under BS EN 45011, General requirements for bodies operating product certification systems<br>ISO/IEC 17065:2012 Conformity assessment – Requirements for bodies certifying products, processes and services | ✓ | ✓ |
| Factory production control | ✓ | ✓ |
| Audit of all materials used, specifications and manuals | ✓ | ✓ |
| Verification of Solar collector standards BS EN 12975 or BS EN 12976 as appropriate. | ✓ | ✓ |
| Manufacturer audit | **Annually** | **5 years** |
| On-going audit of installer competence | ✓ | ✗ |
| Installer Quality system | ✓ | ✗ |
| Installer Insurance scheme | ✓ | ✗ |
| Registration of installations | ✓ | ✗ |

## Conclusion

There are two main accreditation and certification schemes in the UK, MCS & ECA. A third scheme in the England and Wales is the Competent Persons Scheme (CPS) introduced by the CLG to enable companies to self-certify plumbing and heating works that fall under the scope of Building Regulations. Rationalisation of MCS and CPS schemes would be beneficial.

MCS is a BS EN 45011 scheme. For MCS product testing, MCS 007 uses BS EN 14511 to test heat pumps and a Factory Production Control. An equivalent scheme to MCS, Solar Keymark which certifies solar thermal collectors uses a European standard BS EN 12975/76 to test the product and also has a Factory Production Control. MCS for solar collectors also uses BS EN 12975/76 and has a Factory Production Control. Solar Keymark is a product certification scheme and does not certify installation companies.

## 3.10. Heat pump control requirements

### Introduction

With combustion technology such as a gas condensing boiler, the efficiency of the system can be increased by several percentage points as the flow temperature from the boiler decreases. However, as can be seen in the Heat Emitter Guide[113], a heat pump performance can be improved by a factor of over 1.7 by reducing the flow temperature from 60 to 35 °C and this is a far more significant change as compared to combustion technology. System design is a key factor in reducing the flow temperature of a heating system e.g. large heat emitters facilitate low flow temperatures. However, without an effective control circuit, it will be difficult to maintain the flow temperatures at or below the design condition.

This chapter provides a basic overview of the features of typical heat pump controls at this time and a review of heat pump control requirements to evaluate whether these currently provide adequate time and temperature control for the efficient control of heat pumps. It concludes with a set of recommendations for improvement in the specification of heat pump controls to help close the performance gap.

### Aims of an effective heat pump control circuit

Occupants and installers have requirements and expectations of their heat pump and control system, which includes:

- Provision of adequate space heating and hot water available
- Good ergonomics e.g. easy to understand and operate (for both installer and occupant)
- Control of both time and temperature
- Optimisation of HP efficiency in both space heating and hot water mode (good weather compensation) thereby minimising running cost
- Makes use of any reduced cost electricity tariffs (as appropriate)
- Minimises the use of auxiliary direct electric heat or other back-up heat sources
- Minimises HP cycling
- Ability to adjust for different system layouts such as buffer stores, radiators and underfloor heating (both aluminium and screed)
- Ensure occupants health and safety e.g. bacteria and scalding protection

A typical British heating control system features the following items:

- A programmer
- A room thermostat
- A cylinder thermostat
- Thermostatic Radiator Valves (TRVs)
- A 3-way or 2 off 2-way valves

This typical circuit offers time and temperature control of space and hot water heating and is typically hot water priority. The ergonomics of this typical heating control system are generally poor. Whilst

[113] EST et al (n.d.) Supplementary Information 2 Heat Emitter Guide Available from: http://www.microgenerationcertification.org/mcs-standards/installer-standards

the temperature scales on thermostats are believed to be easy-to-understand by the majority of occupants, the thermostats are often located in hallways with little relation to room temperature. Time programmers are often complex and in the authors experience, difficult-to-explain to the end user.  Wider research in the UK has shown that a significant proportion of householders do not understand their heating controls, do not set them appropriately or do not even use them; revealing that usability of controls is a key factor in determining if they are used at all or as intended by the designer[114]. Similarly, TRVs typically have numbers 1 to 6 on their dials and these numbers are not related to actual room temperature.

Weather Compensation

Reducing heat pump flow temperature can have a significant impact on both system efficiency and running cost, and therefore weather compensation can make a very significant difference to heat pump operation.  Stafford and Bell (2009)[115] include the following diagram in Figure 8 which shows a series of return set-point weather compensation curves:

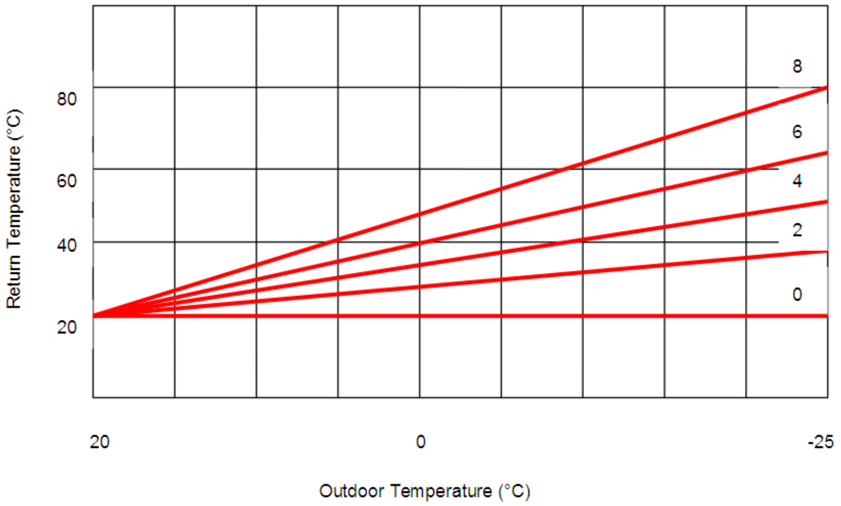


**Figure 8 Series of return set-point weather compensation curves (Stafford and Bell, 2009)**

The default on the heat pumps in question was curve 4, and these units also had an interior temperature sensor and the above curves could be fine-tuned by adjusting the offset of the curve as demonstrated in Figure 9.

[114] Consumer Focus (2012) *Consumers and Domestic Heating Controls: A Literature Review* [WWW] Available at: http://www.consumerfocus.org.uk/files/2012/01/Consumers-and-domestic-heating-controls-a-literature-review.pdf [Accessed 11/04/2013]
[115] Stafford, A., and Bell, M. (2009) *Report to Harrogate Borough Council and Npower. Evaluation of Heat Pump Installations: Extracting Meaning from Existing Datasets: Final Report.* Leeds: Leeds Metropolitan University.

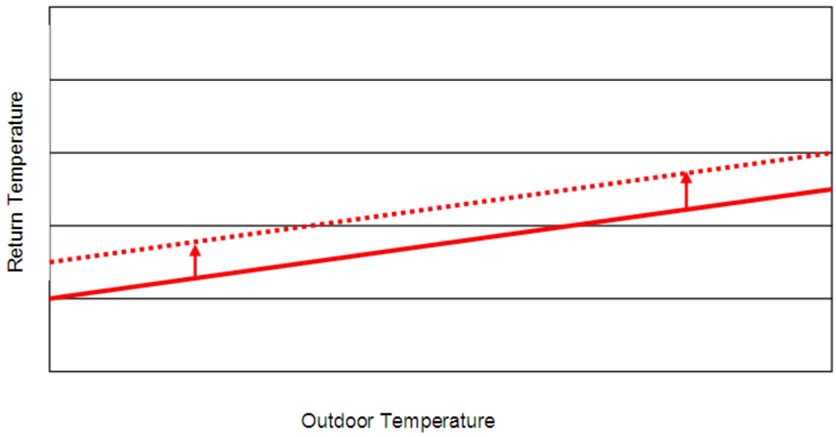


**Figure 9 Fine tuning of weather compensation curve for interior temperature**

Weather compensation temperature sensors should ideally be located on north facing walls and protected from wind and solar gain.

## Underfloor heating controls and heat pump cycling

There is some information on heat pump cycling produced by the heating sector that has a reasonable degree of accuracy and yet is not fully referenced or explained and so the advice is based on what is considered to be best practice rather than rigorous engineering knowledge. Without the laboratory reports and field trials, the engineers promoting this knowledge are using their experience base to recommend industry procedures.

An example of this is on the Continental Underfloor (2013) website[116] where Bill McConnel, Operations Director delves into some of the issues surrounding heat pump controls. He recommends against cycling the heat pump because:

- it can produce power spikes on the grid;
- it can reduce heat pump life expectancy due to compressor start-ups; and
- it reduces system efficiency.

However, the website does not inform us of the maximum recommended frequency of cycling. Buffer vessels to minimise cycling are discussed, so that full thermostatic control can be used for every heating zone but it is also noted that some manufacturers do not advocate buffer vessels as they make the system marginally less efficient. However, we have no indication on buffer sizes or associated loss of efficiency. The article concludes by discussing inverter-driven heat pumps which allow the heat pump to match the demand of the heating system meaning full control can be used. It is up to the wider industry to support heating industry design leaders such as Bill McConnel by engaging in further research and dissemination so that he and others in similar positions can further improve their advice.

<u>Effects of Cycling on Heat Pump Performance</u>
EA Technology (2012)[117] have produced a stimulating report on heat pump cycling which goes a way to addressing some of the information missing on the Continental Underfloor website. The report

[116] CONTINENTAL UNDERFLOOR (2013) *Heat Pumps and Controls with Underfloor Heating* [WWW] Available from: http://www.ufh.co.uk/news-heat-pumps-and-controls-with-underfloor-heating.asp [Accessed 31/03/2013]

looks at a fixed speed compressor ASHP system and a fixed speed compressor GSHP system both in open and 4-pipe 50 litre buffer store distribution system layouts. All systems had weather compensation and an internal room thermostat which was sometimes in the hall and sometimes in the living room. The report emphasises again that the highest collection temperatures and lowest distribution temperatures make significant differences in HP performance and also that short cycling reduces the CoP of both ASHPs and GSHPs with a much larger effect on ASHPs. Run time on ASHPs increases as the ambient temperature drops and the heated area increases. When TRVs were closed, a 2 radiator circuit (lounge and dining room) was considerably better for minimising short cycling as compared to a 1 radiator circuit. Similarly, for GSHP, the run times increase with the number of open radiators. Ground loop recovery mitigates the effects of short cycling for GSHPs which is why ASHPs show a greater deterioration on short cycling with COP reduction measured in the GSHP tests was around 16% in the worst case of the single radiator circuit.

For both the ASHP and the GSHP, short cycling induced by the room thermostat (rather than the return temperature at the heat pump) can give benefits due to lower flow temperatures. This is particularly the case with the GSHP where such room thermostat induced short cycling gave the best performance of all the GSHP results. Concerns with the effects of short cycling on compressor reliability and specifically a need for a minimum run time to ensure the establishment of good oil circulation (in oil lubricated compressor) would seem to rule out this approach in favour of achieving good COP by ensuring that longer run-times are achieved.

The 4-pipe buffer tank arrangement worked well. This produced a separation of the CH from the operation of the heat pump, and allowed a much lower flow rate through the CH circuit as compared to the flow rate through the heat pump. It was difficult to compare the buffer tank results precisely with the non-buffer tank results because of the slight changes in flow temperatures between the systems. However, it is clear that run times are increased through the use of the optimum setting of system volume (via careful heat emitter and buffer tank sizing) resulting in improved COPs. It should be noted that a buffer tank is not always necessary; if the system volume is large enough, cycling can be avoided.

Short cycling conditions are more likely to occur in households which aim to minimise energy use by closing down TRVs in rooms that are not occupied.

The recommendations that came out from the report were that:

- Both ASHPs and GSHPs should be designed for a minimum run time of circa six minutes, which will avoid the detrimental performance caused by short cycling;
- Ideally, systems should be designed for slightly higher run times than this – for the particular GSHP system used here there appears to be an optimum performance at around 10 to 15 minutes, whilst run times of ~ 8 minutes for the ASHP gave COP values close to catalogue steady state values;
- Explore all options to achieve these minimum run times including:
    - Zoning to ensure sufficient radiator surface is available at all times

[117] EA TECHNOLOGY (2012) *The Effects of Cycling on Heat Pump Performance* Prepared for: Department of Energy and Climate Change (DECC) Available from: https://www.gov.uk/government/publications/heat-pump-performance-effects-of-cycling

- Buffer tanks; the 4-pipe buffer tanks arrangement tested here shows a promising method of achieving the required minimum run times without the need for excessive volumes
- Ideally the 4-pipe buffer tank would be designed to achieved a high degree of stratification so as to maintain flow temperatures to the CH system throughout the heat pump off periods
- Taking care in setting-up a 4-pipe buffer tank system to ensure that the flows through the heat pump and through the fully open CH system are well matched.

## Innovations in heating controls

It is worth noting that Nest [118] have noticed this gap in the market and so have looked to develop niche products that end users both like and understand and the product also has in-built intelligence to hopefully improve the householders comfort and minimise their running costs. Similarly, CubeSensors[119] are bringing to market a product that offers the end user far more information on the indoor air quality and this includes information such as humidity so by aiming to offer the householder better control of their environment and health.

### *Heat pump controls*

Innovation is also happening in the heat pump controls market. Companies such as Eco-innovate[120] build a range of specific heat pump control units such as return temp > 30 °C, monoenergetic boost circuits to minimise electrical top-up energy, start-up controls, information on HP parameters and integrated buffer & thermal stores. It will be interesting to see whether there is demand in the market for these features and if so, whether manufacturers adopt or build-in these features. Like many innovators, claims are made for the benefits of these products that are open to question. For example, with Eco-innovate's products the need for Legionella pasteurisation cycles is disputed when Legionella bacteria can develop in both small pipework volumes as well as larger cylinders. Therefore, whilst the risk would be lower in thermal stores as compared to a vented cylinder, the risk is not eliminated.

Soflex[121] also state that the Samsung controller they supply can control back-up immersion heating, Legionella pasteurisation cycles, solar thermal integration and the series hybrid integration of a back-up boiler. None of these features in themselves are new to market but as in integrated package of features in a single control unit, they demonstrate a trend in controller development.

<u>Hybrid controls</u>

MIS 3005 states that "For installations where other heat sources are available to the same building, the heat sources shall be fully and correctly integrated into a single control system." Both series and parallel control systems are being brought to market to cover this MCS requirement. For a series example, Glow-worm's Clearly Hybrid System[122] offers series control of a heat pump and boiler

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[118] See: http://www.nest.com [Accessed 31/03/2013]
[119] See: http://cubesensors.com [Accessed 02/04/2013]
[120] See: http://www.eco-innovate.co.uk [Accessed 8th April 2013]
[121] SOLFLEX (2013) *Samsung EHS Mono* [WWW] Available from http://www.solfex.co.uk/Product/135-samsung-ehs-mono/ [Accessed 08/04/2013]
[122] GLOW-WORM (2013) *Clearly Hybrid* [WWW] Available from http://www.glow-worm.co.uk/clearly-hybrid/ [Accessed 08/04/2013]

whereby below a programmed external temperature, the heat pump switches to a boiler. And for a parallel example, Kanmor's multistaging 264e can including weather compensation integrate up to a total of 4 boilers or heat pumps on a single heat distribution circuit.

Smartphone and PC based controls

Several HP suppliers are now integrating smartphone and PC based internet linked controls into their HP systems so that the heating system can be remotely controlled. Two examples of this are Ochsner[123] with their OTE2 Interior Climate Manager and Neura[124] with their webdialog systems.

## End User Information & Advice on Heat Pump Controls

### *Energy Saving Trust advice*

The Energy Saving Trust (EST)[125] advise on their website that the standard controls for heat pumps consist of an adjustable controller and room thermostat. EST also advise households with a heat pump to cover a number of tasks when purchasing a heat pump system, which includes:

- Check document pack from installer includes a user manual;
- Ask installer to explain how heat pump system works and how to use controls;
- Check if installer would prefer to make any adjustments to program settings.

On the last point, the Energy Saving Trust advise householders that their heat pump installer should set up the heat pump controller as part of the commissioning process, which should be done in line with the installer calculation of the home's heating requirements and to take into account of factors such as the times of day heating and how water is required. EST also advise that if an installer has programmed the heat pump controls correctly the householders should not need to make any adjustments, especially if the controller design includes automatic adjustment to external changes in temperature (i.e. weather compensation) [126].

The EST advice on heat pump heating controls (see C: Energy Saving Trust advice on heat pump heating controls) addresses most of the important points that a control system should provide, including:

- **Provides adequate space heating and hot water available.** This runs throughout the advice with several sections making sure the occupant has sufficient heat including that installers should use calculation of heating requirements and the times required for heating and hot water in the setup of the programmer.
- **Good ergonomics e.g. easy to understand and operate (for both installer and occupant).** Whilst not directly addressing the ergonomics issue, it encourages the end user to make sure that the heating controls are fully explained both verbally and in written form by the installer.
- **Control of both time and temperature**. The advice clearly explains time and temperature issues for both space and hot water heating.

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[123] OCHSNER (2013) *OTE2 Interior Climate Manager* [WWW] Available from http://www.ochsnerireland.com/admin/uploaddoc/39-34ote%20controls.pdf [Accessed 08/04/2013]

[124] NEURA (2013) *webdialog* [WWW] Available from http://webdialog.eu/ [Accessed 08/04/2013]

[125] Energy Saving Trust (2013) *Before you start, Understanding the system and Your energy consumption* [WWW] Available from http://www.energysavingtrust.org.uk/Generating-energy/Choosing-a-renewable-technology/Ground-source-heat-pumps/Getting-the-most-out-of-your-heat-pump [Accessed 31/03/2013]

[126] Ibid

- **Optimisation of HP efficiency in both space heating and hot water mode (good weather compensation) thereby minimising running cost.** By encouraging end user understanding, it facilitates the minimal running cost of the as built system.
- **Making use of any reduced cost electricity tariffs (as appropriate)**. The advice clearly explains when and how Economy 10 tariffs can be used with heat pump systems.
- **Minimising the use of auxiliary direct electric heat or other back-up heat sources**. This is a design and installation issue so would not be typically covered by this advice. However, elsewhere, EST advice does encourage the end user to obtain an MCS installation, all of which are designed to avoid the use of back up heating above the external design temperature.
- **Minimising HP cycling.** This is a design issue and outside EST's direct advice.
- **Ability to adjust for different system layouts such as buffer stores, radiators and underfloor heating (both aluminium and screed).** This is a design issue and outside EST's direct advice.
- **Ensure the occupants' health and safety e.g. bacteria and scalding protection.** The EST advice clearly addresses the Legionella bacteria issue explaining that the installer will have set the system up with a pasteurisation cycle. However, it does not explain the scalding procedures in use across different nations of the UK with Thermostatic Mixing Valves on certain points of use a building regulations/standards requirement.

***Kensa Control System user manual***

Kensa is a leading British GSHP manufacturer so here follows a brief review of their heat pump control system user manual[127]. They initially recommend that the client should, to maximise the efficiency of the heat pump, insulate the building, use the lowest possible flow temperature via large heat emitters, if well-insulated and underfloor screed, use an Economy 10 tariff (i.e. a low cost tariff when electricity is at low demand), if underfloor heating do not use a high tog value floor coverings and consider solar hot water heating to maximise SPF.

The Kensa heat pump is controlled on the return temperature and this is what is displayed in the heat pump control LCD panel. The controller will turn the heat pump off once a pre-set temperature of water returning from the heating system has been achieved. This setting is normally 30°C for underfloor applications, which is a typical return temperature for an underfloor application. The software is pre-configured for underfloor screed and so needs to be reset for other heat emitters.

There are alarms for low water pressure (both heating and ground loop circuits), high and low gas pressure and anti-freeze alarm and the display can be interrogated to show various temperatures and pressures. The manual states that the outflow temperature is set during commissioning, is password protected and a number is provided if it needs to be changed.

In DHW mode, the control system is designed to operate at the optimum temperature that provides DHW, at the maximum efficiency, without using any inbuilt direct electric heaters. The system does not need a tank thermostat or a software temperature set point. The user guide then includes the advice detailed in Table 9 below:

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[127] KENSA (2013) *Compact Heat Pump User Manual* [WWW] Available from http://www.kensaheatpumps.com/Library/Manuals/New%20Manuals/single%20and%20twin%20compressor%20user%20manual.pdf [Accessed 08/04/2013]

**Table 9 Kensa Heating Control User Manual Advice**[128]

| |
|---|
| *Using the in-built controls the heat pump will continue to produce DHW until the timeclock ceases to call for DHW or the controls automatically stop the heat pump. If the controls stop the production of DHW the heat pump will not restart for a period of approximately two hours as the number of compressor starts are limited in DHW mode for a given period of time.*<br>*The maximum temperature that the heat pump can produce depends on the ground temperature and hence the time of year. The heat pump will achieve a DHW temperature of approximately 50-55 °C. In summer, it could be higher, due to the warmer ground conditions. If 65 °C is required all year round it is recommended that an immersion heater is linked to a second channel on the DHW timeclock and this is programmed to operate for a period immediately following the DHW production. This means that the majority of the heating load for the DHW is produced at a lower cost using the heat pump, as opposed to using only the direct immersion heater.*<br>*If 50 °C water is acceptable, then it is recommended that the immersion heater is programmed to raise the temperature to above 60 °C once a week.* |

This manufacturer has chosen to implement DHW control without the use of a cylinder stat. The HP aims to produce HW to the maximum temperature available from the HP system and then, if the customer desires yet warmer water, to use an immersion heater for the last few degrees of temperature rise. To minimise cycling in HW mode, there is a 2 hour interlock on the system which some customers who want a HW boost feature might find restrictive. HW is produced either to the end of the time clock period or to when the controller reaches the maximum return water temperature in HW mode. Legionella pasteurisation is recommended on a weekly basis but there is no extra advice on a covering a HW risk assessment to review whether the property in question is a high or low bacteria risk building.

A fault finding checklist is also provided that relates to the LCD display.

Looking at the Kensa Control System in light of the parameters set out at the beginning of this chapter, it is noted that:

- **Provides adequate space heating and hot water available.** If the HP heating system is correctly sized, this point is fully covered.
- **Good ergonomics e.g. easy to understand and operate (for both installer and occupant).** The user manual is relatively easy to read and the display is accurate. However, the end user is interested in room and HW temperature rather than return water temperature and so there is room for further developments.
- **Control of both time and temperature***.* This is available on both space and HW heating although boost button features are limited.
- **Optimisation of HP efficiency in both space heating and hot water mode (good weather compensation) thereby minimising running cost.** These features are all available.
- **Making use of any reduced cost electricity tariffs (as appropriate).** Advice is provided on this issue.
- **Minimising the use of auxiliary direct electric heat or other back-up heat sources.** There are no space heating immersion heaters and HW water immersion heaters are only used after the HP has finished its work.
- **Minimising HP cycling.** This is minimised in HW mode. The HP when used on screed underfloor heating will also minimise cycling but this HP system will probably cycle frequently

[128] Ibid

on radiators during spring and summer heating seasons. More information on heat pump cycling is due to be published by DECC soon after this report is completed.

- **Ability to adjust for different system layouts such as buffer stores, radiators and underfloor heating (both aluminium and screed).** The system comes pre-configured for underfloor screed but can be reset to multiple system layouts.
- **Ensure the occupants health and safety e.g. bacteria and scalding protection.** Supplementary HW immersion heater control is available and bacteria issues are set out although there should be more discussion on risk assessments for Legionella bacteria.

Whilst there are some areas for improvement, the Kensa Control system covers most of the points as set out in the section of this report entitled Aims of an effective Heat Pump Control Circuit.

***Advice on controlling heat pumps in the book 'Heat Pumps for the Home'***

John Cantor (2011, chapter 9)[129] in his book points out a number of important issues about controlling heat pumps including:

- If flow temperature is reduced by 2 °C, likely savings on running costs are around 5%.
- The user should periodically reduce the weather compensation heating curve and see if the property is still warm enough.
- Fixed speed compressor heat pumps typically have the set-point sensor on the return pipe. All ground source and some air source heat pumps are fixed speed.
- Variable speed inverter drive heat pumps have the set-point sensor on the flow pipe.
- Weather compensation is particularly suited to ground and water based heat pump systems in insulated lightweight houses.
- The pros of weather compensation include the ability to increase CoP by reducing flow temperature.
- The cons of weather compensation are that:
  - in solid walled and exceptionally well insulated buildings, outside temperature is not always the best indicator of heat requirements.
  - it does not account for solar gains.
  - for air-source, it can switch the system on in the middle of the night when the ambient temperature is at its lowest point.
- An alternative weather compensation system whereby the maximum and minimum flow temperature can be set for high thermal mass buildings or for limiting the maximum CoP.
- All controllers have system information which should include total run hours of compressor and any included back-up heaters

The paper also points at the potential future of the electrical grid utilities having smart control of heat pumps for supply and demand management and also the importance of soft-starts for minimising grid impact and light diming on compressor start up.

## User behaviour, satisfaction and performance

In the Caird et al (2012)[130] report about users' feedback on their heat pump systems, the authors document that whilst overall most users are very satisfied with their ground and air source heat pump

[129] CANTOR J (2011) *Heat Pumps for the Home* Marlborough; Crowood

systems, the lowest satisfaction scores occurred with the question about the controls and displays are easy to understand and use which only gained a 54% positive response and a 27% negative response.

Nearly half (44%) of users were uncertain how to operate the system and its controls for optimum efficiency. Nearly a third (30%) of all users also claimed that they had 'difficulties understanding instructions on operating and using the system'. Further analysis showed that two-thirds (65%) of users had tried to adjust the system's controls. However, most of the adjustments were simply altering the temperature on thermostat(s) and only a few users attempted the more complex task of reprogramming controls on the heat pump unit. When users were questioned about which improvements to heat pump design and/or technology they would like to be developed, the main improvements desired were controls that provide the user with feedback on fuel and cost savings (68%) and system efficiency (58%) to help them operate their heat pump more efficiently. A problem identified by about a quarter (23%) of heat pump users was that they were sometimes unable to heat rooms to the required temperatures. There was also a complaint about the slow warm up of the heating by over a fifth (21%) of users. This report clearly indicates that the heat pump industry still has much to do on heat pump control system design (both product and as-built system) and end user communication to address these human interface and control issues.

Design simplicity and usability

Greenb[131] on the heat pump training section of their website document that during feedback from British housing associations, the following advice was provided for good control strategies:

- Supply an On/off switch and a thermostat i.e. keep it very simple (HW needs to have a boost button)
- Use diagrammatic only info close to heating controls
- Have trained call centre support

In other words, housing associations prefer to assist their clients by either avoiding central heating programmers or by providing diagrammatic advice on how to use the heating controls and often back-up any advice with telephone support.

## Importance of commissioning to optimise control systems

The YouGen website[132] contains practical advice on energy including heat pumps. It points out the importance of the careful commissioning of heat pumps systems in a blog entry titled 'Manufacturers can play a key role in preventing problems with heat pumps':

> *'Heat pumps can be a great way of heating a building if (and it's a big if) they are designed, specified, installed and commissioned right, and the building owner is given good, clear instructions about how to use the system and what the different controls do.*
> *The reason I say it's a big if, is because this is still a relatively new technology in the UK, the settings are complex, and installers aren't necessarily putting them in every day, so there isn't the same expertise as there is for installing gas boilers for example.'*

[130] CAIRD, S. et al (2012). *Domestic heat pumps in the UK: user behaviour, satisfaction and performance.* Energy Efficiency, 5(3), pp. 283–301.
[131] DECC (2013) *Greenb: Heat Pumps* [WWW] Available at: www.greenb.org.uk/heatpumps/ [Accessed 17/04/2013]
[132] YOUGEN (2013) *Manufacturers can play a key role in preventing problems with heat pumps* [WWW] Available from http://www.yougen.co.uk/blog-entry/2136/Manufacturers+can+play+a+key+role+in+preventing+problems+with+heat+pumps/ [Accessed 31/03/2013]

The blog entry gives an example from one YouGen reader who contacted YouGen about his air source heat pump which wasn't working as expected, who had to arrange for an engineer to sort out the problem which found:

'*the system hadn't been commissioned correctly - some of the settings were wrong. The system had also been over specified - it was bigger than he needed. Since the engineer changed the settings the water is heating to 48 degrees without backup heating, rather than the 35 degrees he was getting before.'*

The advice given by YouGen to readers is:

*"Get the manufacturer to commission the system, even if it costs an extra £300. Installers often won't pay for it, but it's money well spent. The engineer told me that they often have to phone the office for a setting. It's complex, and installers do a 2 day course, then they may not install any for a while."*

This is a very important point as the best heat pump available will still work poorly if it is incorrectly commissioned and because heat pump performance drops off so rapidly as the flow temperature increases, they are very susceptible to inadequate controls or commissioning.

### Control strategy conclusions

Existing heat pumps are either typically controlled by return set-point sensors on fixed speed compressor heat pumps and flow set-point sensors on variable speed compressor heat pumps. Weather compensation is common and so are internal thermostats. Currently, designers, installers and commissioning engineers have to attempt to establish the right heat pump run times, weather compensation curves and offsets to set up the system for optimum performance.

There appears to be huge opportunities, given the very significant benefits to heat pump efficiency of high collection and low distribution temperatures and optimum compressor run times, for much "intelligence" to be built into the heat pump to maximise the unit's efficiency and reliability for any given set of internal and external parameters.

There is also a need to simplify the human interface on the control units and also to provide the occupants, that so desire, with information on energy consumption, running cost and operational efficiency.

Therefore, it is anticipated that there will be many developments in heat pump controls and interfaces over the coming years.

## 3.11. MCS requirement on end user advice

### Introduction

This section of the report provides a review of the UK Microgeneration Certification Scheme (MCS) requirement on level of advice provided to end users of heat pumps on efficient control and use of heat pumps, and compares this to requirements on advice prior to MCS and internationally, and evaluates the quality key examples of information and advice given to end-users.

MIS 3005 Issue 3.1[133] is the UK standard for the supply, design, installation, set to work commissioning and handover of heat pump systems, as detailed in *3.1 MIS 3005 Guidance* section of this report. The end user advice requirement is for 'the installer [to] provide the customer with a comprehensive document pack'. This document pack is required to include details on at least the following:

1. **Sizing**
   - Details of heat loss calculations
   - HP power output at design ambient and emitter temperatures
   - Evidence that energy requirements of ASHP defrost cycles can be met within design temperature range
   - Designed proportion of building's space heating and domestic HW to be provided by the HP

2. **Domestic hot water services**
   - Evidence for choice of domestic hot water cylinder

3. **Emitter design**
   - HP power output at design ambient and emitter temperatures
   - Specific room heat losses (W/m$^2$)
   - Type of emitters to be used
   - Design emitter temperature (based on worst performing room)
   - The "Temperature Star Rating"[134]
   - The maximum "Temperature Star Rating"; an explanation why the maximum is not being achieved if it is not the maximum rating.

4. **Ground heat exchanger design**
   - Completed ground heat exchanger design table

5. **System performance**
   - Estimate of annual energy use; system SPF[135] and operating costs as per requirements of Section 4.3 of MIS 3005 issue 3.1 on the calculation of system performance.

[133] DECC (2008) Microgeneration Installation Standard: MIS 3005 Issue 3.1a London, DECC. Available at: http://www.microgenerationcertification.org/mcs-standards/installer-standards [Accessed 11/03/2013]
[134] The Temperature Star Rating can be determined using the Heat Pump Emitter Guide (see Section 3.6 of this report), and is used to indicate how efficient the proposed system is likely to be; the greater the number of starts the more efficient the system is likely to be e.g. due to lower heat emitter temperatures.

In addition to this, MIS 3005 issue 3.1 requires the documentation to be provided by the Contractor and explained to the client along with:

6. **Maintenance requirements and services available**

7. **A certificate signed by the Contractor containing at least:**
   - A statement confirming that the Microgeneration Heat Pump systems meets the requirements of MIS 3005 issue 3.1
   - Client name and address
   - Site address (if different)
   - Contractors name, address etc.
   - List of key components installed
   - Estimation of system performance calculated (according to section 4.3 of MIS 3005 Issue 3.1)

## End user advice review

The UK's widest ranging field trial of domestic heat pumps in the UK was carried out by the Energy Saving Trust between 2008 and 2011. The trial found that many householders reported difficulties in understanding the instructions for operating and using their heat pump, and that control systems on heat pumps were generally too complicated for the end user to understand, with some householders experiencing difficulty controlling the ambient temperature of rooms. These findings highlighted a need for *'clearer and simpler customer advice*'; both on the proper use of controls and in the choice of suitable electricity tariff (Energy Saving Trust, 2010)[136].

The MCS requirement on end user advice provision for heat pumps is detailed in Chapter *6 Handover Requirements* within MIS 3005 Issue 3.0. The requirements set do not currently stipulate that information is provided by the Contractor that will advise the client on using or controlling their new heat pump or that the Contractor explains to the user how to control and use the heat pump to ensure it operates at maximum efficiency.

Prior to MIS 3005 Issue 3.1, The HVCA's TR30 Guide to Good Practice Heat Pumps[137] was one of the main comprehensive sources of advice on the installation of heat pumps in the UK. TR30 stipulates that the *'control settings and operating programmes shall be set to achieve design conditions'* and that the *'operation of the system and its control shall be demonstrated and explained to the client or their representative'*. This includes handing over documentation, which should include basic operating guidance for users and operation and maintenance manuals.

### *Current level of advice*

Currently, advice on the efficient use and control of a heat pump provided to the end user is contained either:

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135 Note: MIS 3005 Issue 3.1 does not define which SPF should be included in the end user document pack and refers to the Heat Emitter Guide which states that 'SPF shall be calculated for space heating only' and that 'GSHP SPF is the SCOP calculated in accordance with prEN 14825'. See: http://www.microgenerationcertification.org

136 Energy Saving Trust (2010) *Getting warmer: A field trial of heat pumps,* The Energy Saving Trust. Available at: http://www.heatpumps.org.uk/PdfFiles/TheEnergySavingTrust-GettingWarmerAFieldTrialOfHeatPumps.pdf [Accessed 26/03/2013]

137 HVCA (2007) *TR30 Guide to Good Practice Heat Pumps*, HVCA

a. Within the information provided by the Manufacturer or Supplier/Distributer of the heat pump i.e. design, installation and operational manuals.
b. Dedicated/separate user manuals or guides for both the Heat Pump and/or control packages.

The level of information and advice contained within documentation provided by Heat Pump manufacturers varies considerably, demonstrated by a review undertaken as part of this work of key MCS accredited heat pump systems (see Appendix D: Review of end user advice).

The key findings from the review of end user advice are summarised below.

- **Lack of information** on efficient operation found in many manuals;

- **Use of technical jargon** on end user advice, particularly when contained with installation/operational manual i.e. not dedicated guide for end user;

- **Varying complexity and level of information** on operation of controls; some guides provided step by step guides and others providing just an overview of the display information referring the user to a separate document for guidance on how to use the controller; and

- **Lack of dedicated user guides** which contain all user advice for both the heat pump and heat pump controller in one place.

- **Too much detail** for the average non-technical end user, with a general lack of summary information such as a 'quick start guide' or 'top tips' on the operation and control of a heat pump.

***Recommended minimum end user advice and information***

The review has highlighted that as a minimum, the end user should be provided with the following key information and advice. It is recommended that this should be specified as a requirement of MCS accredited heat pump systems:

1. **An introduction to heat pump technology** explaining in simple terms how a heat pump works;

2. **Explanation of the key differences** between a heat pump and a conventional system, and what this means to the end user;

3. **Advice on adjusting to living with the heat pump**, and information on how to fine tune the heat pump to reach a comfortable indoor temperature;

4. **Information on programming of heating and hot water** schedules including how to use the control to do this (if heat pump is supplied with a separate controller) and when is best to set heating and hot water to run depending on occupancy patterns, user needs and electricity tariff; and

5. **Advice on making the most of the heat pump system**; keeping it running efficiently through correct use, maintenance, how to use with backup systems (e.g. electric immersion) etc.

6. **A 'quick-start' or Summary user guide** containing clear information on no more than 1 page of A4 specifically for the reference of the end user, containing the important information and essential advice about using and controlling the heat pump. For the actively engaged user, a detailed User Guide should also be provided alongside this.

***Good practice examples of end user advice***

Examples of end user advice which meet some or all of the recommended requirements listed above are included in Table 10 below.

Some particularly good examples found of this level of advice to owners of domestic heat pumps are listed in the Table below.

**Table 10 Key examples of good end user advice for domestic heat pumps**

| Manufacturer | User Guide/Manual(s) | Key Features / Comments |
|---|---|---|
| Kingspan | Homeowners Guide Kingspan Aeromax Plus | Advice on length of time the user should set their hot water before it is required in the morning or evening and setting the home heating to come on after hot water, including a typical winter programme schedule for heating and hot water time and temperature. Clearly presented guide with good level of detail although there is some technical jargon |
| Daikin Air Conditioning UK | User Guides for: Altherma high temperature (HT) ASHP, Large Monobloc ASHP, Small Monobloc ASHP, Alphaterm low temperature (LT) split heat pump. | Guidance on maximising energy savings by ensuring use of the weather compensation mode, and clearly presented instructions on how to use the remote controller (setting the clock and changing hot water settings/temperature). Clearly presented with minimal technical jargon although instructions for controller do not appear straightforward which is likely to be due to complex control design. |
| Mitsubishi Electric Heating Systems | Homeowner Information for Ecodan® Air Source Heat Pump and Flow Temperature Controller 2, Homeowner Quick Start Guide for Ecodan® Air Source Heat Pump | Good level of information although does include some technical jargon. The guidance on use of the controller seems particularly clear, perhaps an indication that the controller is more user-friendly than others. |
| Nu-Heat (UK Hitachi Distributor) | Nu-Heat User Guide for Hitachi Yutaki Air Source Heat Pump | Comprehensive advice on how to operate the heat pump system, and the guidance on how to maximise the efficiency and lower the running cost of the system is particularly clear. Well-presented guide with good use of photos and diagrams to help the user follow the advice. |

## Conclusion

This review has revealed a high level of variability in the level of advice offered to end users of heat pumps through manufacturer information, and the advice that is provided within dedicated 'User Manuals' is largely written using technical jargon and terms which the majority of end users are unlikely to understand.

There is considerable room for improvement in the provision of end user advice, and it is recommended that this be considered within future developments of the MIS 3005 standard to ensure a minimum standard advice is provided to all future end users of heat pumps and that this is communicated effectively.

# 4. Appendices

## 4.1. A: Heat Emitter Guide for domestic heat pumps[138]

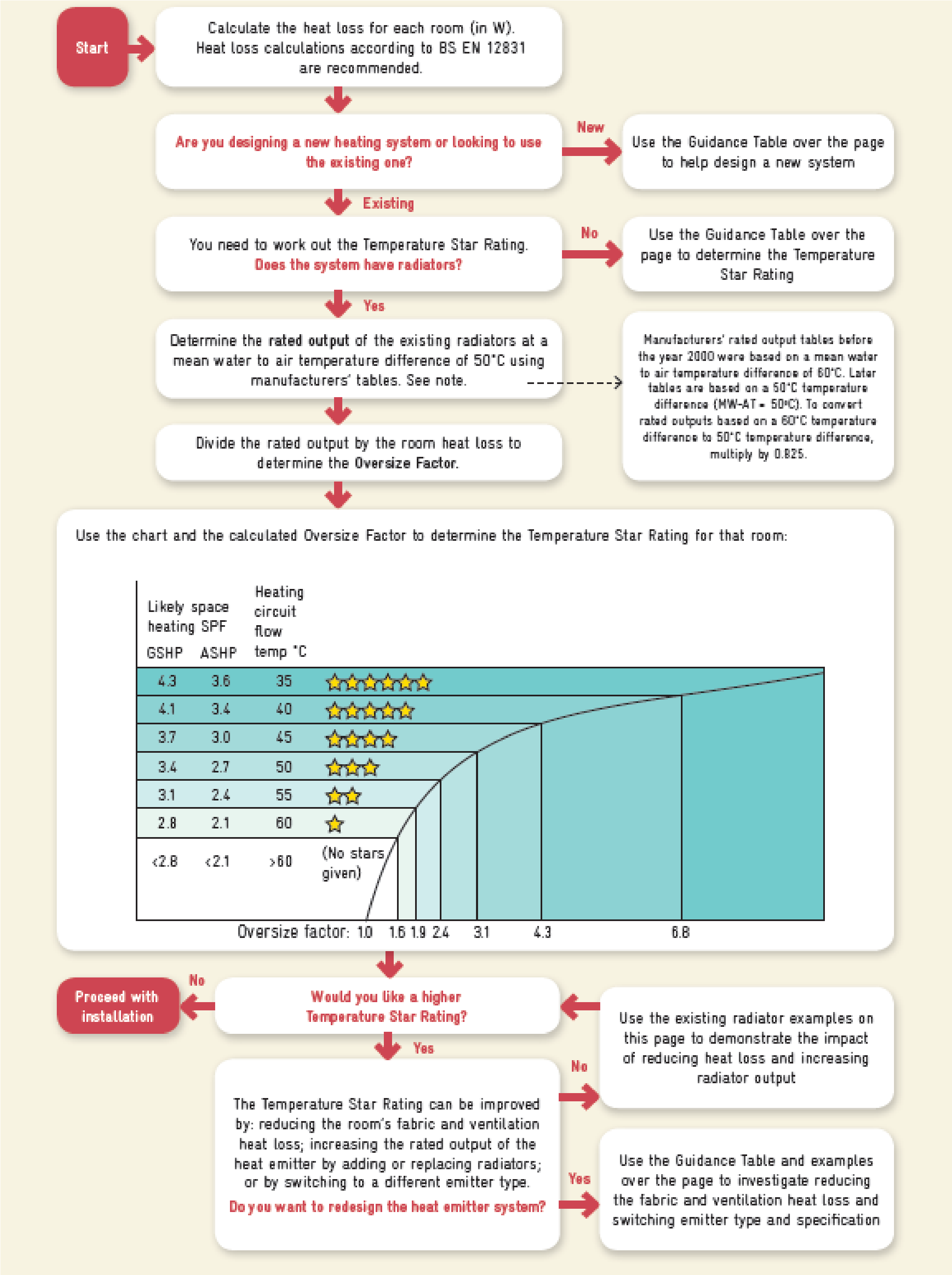


**Figure 10 Flow Chart A Heat Emitter Guide for domestic heat pumps**

[138] Source: http://www.microgenerationcertification.org

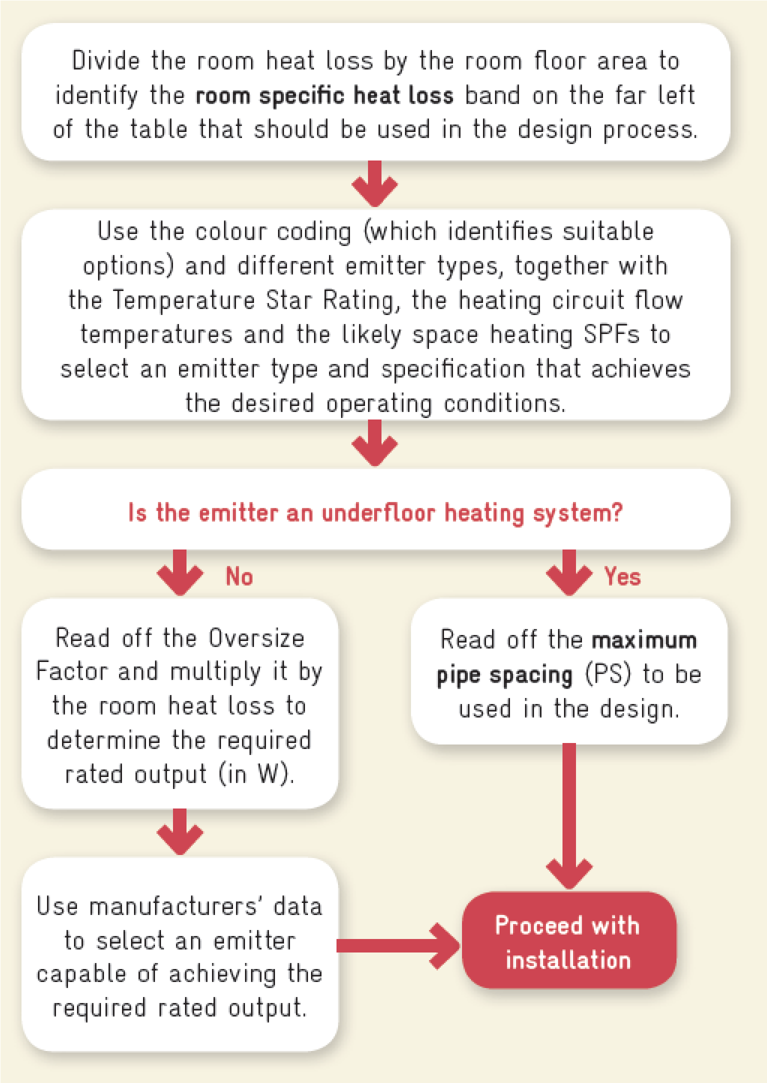


**Figure 11 Flow Chart B Heat Emitter Guide for domestic heat pumps**

**Note that some re-wording is proposed; the box marked "Read off the over-size factor and multiply it by the room heat loss to determine the required rated output in W" should be replaced by ""Read off the over-size factor and multiply it by the room heat loss to determine the required rated output <u>of the radiators</u> in W"**

## Key for GUIDANCE TABLE

- (Red) **REDUCE FABRIC AND VENTILATION HEAT LOSS -** System cannot perform at the design parameters stated; consider reducing heat loss and/or load-sharing design with other emitter types.
- (Dark orange) **CONSIDER MEASURES TO REDUCE FABRIC AND VENTILATION HEAT LOSS -** System can perform at these design conditions but emitter sizes are likely to be excessive
- (Light orange) **CAUTION -** System can perform at these design conditions with extra consideration on the emitter and heat pump design
- (Green) **GO AHEAD -** System can perform at the stated efficiencies with the selected emitter design.
- PS **Underfloor Pipe Spacing -** PS≤150 means UFH pipes should be spaced at 150mm or less to achieve the design condition.
- 2.4 **Oversize Factor –** multiply the room heat loss (in W) by the Oversize Factor to determine the required emitter output with a mean water to air temperature difference of 50°C. Oversize Factor is the same as a Heat Transfer Multiplier

Reducing fabric and/or ventilation heat losses can move a room up to the next specific heat loss band, making it easier to achieve a good SPF.

| | Temperature Star Rating | Heating circuit flow temperature °C | Likely space heating SPF: GSHP | Likely space heating SPF: ASHP | Oversize Factors for other emitters: Domestic Fan Convector/Fan-assisted Radiator | Oversize Factors for other emitters: Standard Radiator | Oversize Factors for other emitters: Fan Coil Unit | Underfloor heating: screed: with TILE | Underfloor heating: screed: with WOOD | Underfloor heating: screed: with CARPET | Underfloor heating: Aluminium panel: with TILE | Underfloor heating: Aluminium panel: with WOOD | Underfloor heating: Aluminium panel: with CARPET |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Room specific heat loss less than 30 W/m² | ★★★★★★ | 35 | 4.3 | 3.6 | 4.3 | 6.8 | 5.0 | PS≤300 | PS≤300 | PS≤200 | PS≤200 | PS≤200 | PS≤150 |
| | ★★★★★☆ | 40 | 4.1 | 3.4 | 3.1 | 4.3 | 3.5 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤200 |
| | ★★★★☆☆ | 45 | 3.7 | 3 | 2.4 | 3.1 | 2.6 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 |
| | ★★★☆☆☆ | 50 | 3.4 | 2.7 | 2.0 | 2.4 | 2.1 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 |
| | ★★☆☆☆☆ | 55 | 3.1 | 2.4 | 1.7 | 1.9 | 1.7 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 |
| | ★☆☆☆☆☆ | 60 | 2.8 | 2.1 | 1.4 | 1.6 | 1.5 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 |
| Room specific heat loss 30 to 50 W/m² | ★★★★★★ | 35 | 4.3 | 3.6 | 4.3 | 6.8 | 5.0 | PS≤300 | PS≤100 | | PS≤100 | Reduce heat loss | |
| | ★★★★★☆ | 40 | 4.1 | 3.4 | 3.1 | 4.3 | 3.5 | PS≤300 | PS≤200 | PS≤150 | PS≤200 | | |
| | ★★★★☆☆ | 45 | 3.7 | 3 | 2.4 | 3.1 | 2.6 | PS≤300 | PS≤300 | PS≤300 | PS≤200 | PS≤200 | PS≤150 |
| | ★★★☆☆☆ | 50 | 3.4 | 2.7 | 2.0 | 2.4 | 2.1 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤200 | PS≤200 |
| | ★★☆☆☆☆ | 55 | 3.1 | 2.4 | 1.7 | 1.9 | 1.7 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 |
| | ★☆☆☆☆☆ | 60 | 2.8 | 2.1 | 1.4 | 1.6 | 1.5 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤300 |
| Room specific heat loss 50 to 80 W/m² | ★★★★★★ | 35 | 4.3 | 3.6 | 4.3 | 6.8 | 5.0 | PS≤100 | Reduce heat loss | | Reduce heat loss | | |
| | ★★★★★☆ | 40 | 4.1 | 3.4 | 3.1 | 4.3 | 3.5 | PS≤200 | | | | | |
| | ★★★★☆☆ | 45 | 3.7 | 3 | 2.4 | 3.1 | 2.6 | PS≤300 | PS≤100 | PS≤100 | PS≤150 | | |
| | ★★★☆☆☆ | 50 | 3.4 | 2.7 | 2.0 | 2.4 | 2.1 | PS≤300 | PS≤200 | PS≤150 | PS≤200 | PS≤100 | |
| | ★★☆☆☆☆ | 55 | 3.1 | 2.4 | 1.7 | 1.9 | 1.7 | PS≤300 | PS≤300 | PS≤200 | PS≤200 | PS≤150 | PS≤100 |
| | ★☆☆☆☆☆ | 60 | 2.8 | 2.1 | 1.4 | 1.6 | 1.5 | PS≤300 | PS≤300 | PS≤300 | PS≤300 | PS≤200 | PS≤150 |
| Room specific heat loss 80 to 100 W/m² | ★★★★★★ | 35 | 4.3 | 3.6 | 4.3 | 6.8 | 5.0 | | | | | | |
| | ★★★★★☆ | 40 | 4.1 | 3.4 | 3.1 | 4.3 | 3.5 | PS≤150 | | | | | |
| | ★★★★☆☆ | 45 | 3.7 | 3 | 2.4 | 3.1 | 2.6 | PS≤200 | | | PS≤100 | | |
| | ★★★☆☆☆ | 50 | 3.4 | 2.7 | 2.0 | 2.4 | 2.1 | PS≤250 | PS≤100 | PS≤100 | PS≤150 | | |
| | ★★☆☆☆☆ | 55 | 3.1 | 2.4 | 1.7 | 1.9 | 1.7 | PS≤300 | PS≤200 | PS≤150 | PS≤200 | PS≤100 | |
| | ★☆☆☆☆☆ | 60 | 2.8 | 2.1 | 2.1 | 1.6 | 1.5 | PS≤300 | PS≤250 | PS≤250 | PS≤200 | PS≤150 | PS≤100 |
| Room specific heat loss 100 to 120 W/m² | ★★★★★★ | 35 | 4.3 | 3.6 | 4.3 | 6.8 | 5.0 | | | | | | |
| | ★★★★★☆ | 40 | 4.1 | 3.4 | 3.1 | 4.3 | 3.5 | | | | | | |
| | ★★★★☆☆ | 45 | 3.7 | 3 | 2.4 | 3.1 | 2.6 | | Reduce heat loss | | | Reduce heat loss | |
| | ★★★☆☆☆ | 50 | 3.4 | 2.7 | 2.0 | 2.4 | 2.1 | | | | | | |
| | ★★☆☆☆☆ | 55 | 3.1 | 2.4 | 1.7 | 1.9 | 1.7 | | | | | | |
| | ★☆☆☆☆☆ | 60 | 2.8 | 2.1 | 1.4 | 1.6 | 1.5 | | | | | | |
| Room specific heat loss 120 to 150 W/m² | ★★★★★★ | 35 | 4.3 | 3.6 | 4.3 | 6.8 | 5.0 | | | | | | |
| | ★★★★★☆ | 40 | 4.1 | 3.4 | 3.1 | 4.3 | 3.5 | | | | | | |
| | ★★★★☆☆ | 45 | 3.7 | 3 | 2.4 | 3.1 | 2.6 | | Reduce heat loss | | | Reduce heat loss | |
| | ★★★☆☆☆ | 50 | 3.4 | 2.7 | 2.0 | 2.4 | 2.1 | | | | | | |
| | ★★☆☆☆☆ | 55 | 3.1 | 2.4 | 1.7 | 1.9 | 1.7 | | | | | | |
| | ★☆☆☆☆☆ | 60 | 2.8 | 2.1 | 1.4 | 1.6 | 1.5 | | | | | | |

Changing the emitter specification can reduce the flow temperature and therefore increase SPF.

Changing the emitter type can enable the emitter to operate at a lower temperature.

Changing the floor covering on UFH can reduce the required emitter temperature.

**Figure 12 Guidance Table Heat Emitter Guide for domestic heat pumps**

## 4.2. B: Microgeneration Strategy Consultation: key recommendations

During the Government consultation on the Microgeneration Strategy, key organisations including Consumer Focus[139], REAL Assurance[140] and Which?[141] provided responses. Key issues discussed in the consultation include insurance and consumer protection, and some of the issues raised and recommendations made are outlined below:

Lifetime repair and maintenance guarantees

- Repair and maintenance for consumers of firms who are no longer in business.
- Link between insurance schemes and the provision of repair and maintenance recommended, which could encourage suppliers to invest in related skills and processes.

Enforcement of installer standards & certification

- Rigorous, effective and consistent enforcement of certification needed; some certification bodies more rigorous than others.
- Annual inspection an area of weakness in the installer certification process; currently installer selects the installation to be inspected.

Clarity on / enforcement of sub-contracting responsibility

- Sub-contracted work should be full responsibility of MCS-certified company; checking/enforcement of this in practice.

Clarity on commissioning of installation

- Clarity needed on who can sign off and commission an installation and under what circumstances.

Approval of companies generating sales leads

- While the company that installs and commissions a system must be MCS-certified, it may be the case that the installer takes sales leads from a company that is not MCS-certified.
- Companies generating sales leads could also be part of an OFT approved Consumer Code, even if this company doesn't sign a contract with consumers. This would reduce the risk that consumers may be given false or misleading information about the benefits of the system they are purchasing.

Approval of companies signing contracts

- The company that signs the contract with the consumer as well as take payment from and provide performance information to the end user should be MCS-certified and therefore a member of an OFT approved Consumer Code.

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[139] Consumer Focus (2011) *Consumer Focus response to consultation on a Microgeneration Strategy.* Available at: http://www.consumerfocus.org.uk/policy-research/energy/green-deal/consultation-responses-and-discussion-documents [Accessed 11/04/2013]

[140] Renewable Energy Assurance Ltd (2011) *Response to Consultation on the Microgeneration Straetgy.* Available at: http://www.realassurance.org.uk/images/upload/news_13_REAL-Assurance-Scheme-response-to-Microgeneration-Strategy-consultation.pdf [Accessed 11/04/2013]

[141] Which (2011) *Which? response to DECC Consultation on a Microgeneration Strategy.* Available at: http://www.which.co.uk/documents/pdf/microgeneration-strategy-which-response-247729.pdf [Accessed 11/04/2011]

- REAL have evidence that, due to the ambiguity on this point, some MCS-certified installers have set up subsidiary companies which enables them to sell to and contract with consumers outside the MCS/REAL standards which is leading to agreement of unsatisfactory contracts and prices being agreed and unsuitable systems being installed.

Guarantee wording

- Which? believe that the REAL Code's guarantee wording should be altered as this does not currently differentiate statutory rights (Sale of Goods Act) from the additional rights provided by the scheme.

Method/approach to dealing with consumer complaints

- Complaints from Consumers often initially come through EST, Consumer Direct (now Citizens Advice), Trading Standards and Consumer focus. Currently MCS installer certification bodies are required to deal with any complaints with regard to technical aspects of the installation whereas the REAL Assurance scheme resolves any pre-contractual or contractual complains. REAL and Which? recommend that a one-stop shop be set up for microgeneration complaints.
- Which? believe that complaints procedures are often not as speedy as they should be.
- Which also recommend that MCS should require installer certification bodies to publicise their complaints procedures in an accessible way.

Funding for independent expert reports

- There is no longer a fund for the provision of independent expert reports, which is essential in cases where negotiations between a consumer and a company have dissolved.

Information provision

- Information provision to consumers prior to installation and signing contracts: many households are not aware of full information about microgeneration, its suitability for them and or the support and advice they can receive.
- One key target group for installers is retired or recently retired: these groups are less likely to have access to this information via the internet, for example.

Insurance under different business models

- A recommendation from Consumer Focus in its response to the consultation on the Microgeneration Strategy was that the industry should consider how insurance applies to consumers under different business models such as 'free solar energy' schemes.
- The long-term contracts through 'free solar' or 'rent a roof' schemes raise issues of consumer protection: Which? Believe there is a need to ensure consumers are aware of and safeguarded in relation to contractual issues such as liability for maintenance costs and insurance.

Insurance backed warranties cost

- Which? Believe there should be an automatic insurance-backed warranty for consumers, with consumers not having to pay money for the guarantee of workmanship to be worth the paper it is written on if the installer/contractor ceases to trade. The REAL Code Guarantee provisions state that a workmanship guarantee must be provided at no extra cost but currently consumers have to pay £35 to insure this warranty.

## 4.3. C: Energy Saving Trust advice on heat pump heating controls[142]

### Understanding the system

The standard system controls for a heat pump are an adjustable controller and a room thermostat. They may be separate units or they can be combined.

***Controller***

The controller may either be an integral part of the heat pump (common in the case of ground source heat pumps) or a separate unit (common in the case of air source heat pumps) fixed to the wall within a few metres of the heat pump. If your heat pump provides hot water as well as space heating it is likely to have a two-channel controller for which will allow different temperatures and times to be programmed for each.

The controller is used to:

- set the appropriate flow and return temperatures of the fluid passing through the heat pump to provide space heating
- set the temperature of hot water in a system that provides hot water as well a space heating; in a system where the hot water is usually runs at less than 60°C it will be programmed to raise the temperature of the water to 60°C or more at periodic intervals to avoid problems with legionella bacteria
- set when the heat pump comes off and on
- display error signals which will assist repair in the event of a fault arising.

Your installer should programme your heat pump using the controller as part of the commissioning process. They will do this in accordance with their calculation of the heating requirements of your home taking into account a number of factors including the times of the day you require heat and hot water. If they do this correctly you are unlikely to need to touch the controller, particularly if it has been designed to automatically adjust to outside temperature changes. Because heat pumps usually work at lower temperatures than other types of heating system it is normal for certain makes of heat pump to be set so that they are on continually or for longer periods than you might otherwise expect (to allow for a slower warm-up time).

***Thermostat***

The room thermostat is used to:

- monitor temperatures to ensure that they do not go too low
- communicate with the heat pump to come on if the temperature in the room is below the desired level.

***TRVs***

In order to get the most from your heat pump you can also look at installing and making use of additional heating controls such as thermostatic radiator valves (TRVs) if you have radiators installed as part of your heat pump system. However, seek advice from your installer on this.

### Your energy consumption

Monitoring your energy consumption will enable you to calculate whether your heat pump is achieving the SPF estimated by your installer and if it is not, whether any adjustments to your system are required. In order to obtain a complete picture you should monitor both your electricity bills and any other fuel still used for heating and hot water such as gas or oil.

[142] Energy Saving Trust (2013) *Before you start, Understanding the system and Your energy consumption* [WWW] Available from http://www.energysavingtrust.org.uk/Generating-energy/Choosing-a-renewable-technology/Ground-source-heat-pumps/Getting-the-most-out-of-your-heat-pump [Accessed 31/03/2013]

There are a number of online tools that will help you keep a record of your energy consumption. Most require that you input meter readings on a monthly basis. They include:

- the online calculator at the Direct Gov website
- Home Energy and Carbon Monitoring Calculator at imeasure - this automatically incorporates weekly heating degree-days to help your household accurately monitor energy use seasonally
- the Carbon Account - which lets you share data with friends and colleagues if you wish.

### Your electricity tariff

Unless you previously used electricity to provide your space heating, your electricity bills will increase once you have a heat pump installed, because the heat pump uses electricity to run the pump and compressor. Your reduced bills for heating should make up for this, but it's still worth ensuring you are getting the right tariff at a competitive rate.

If you were previously using night storage heaters and were on an Economy 7 or 10, this may no longer be appropriate. Economy 10 could be ideal if you have a well-insulated home with underfloor heating (not radiators) mounted on a screed that can act as a thermal store. We recommend you discuss with your installer or site manager the most appropriate tariff to use with your heat pump and how to set your controls to make the most of it.

Cost comparison websites let you shop around for the cheapest electricity tariff in your area: these include

- u-switch
- cheapest gas and electricity
- money facts
- confused.com
- Money Saving Expert.

## 4.4. D: Review of end user advice

### Contents: List of manufacturers/suppliers reviewed

1. Baxi Heating UK
2. Carrier Corp
3. CTC
4. Daikin Air Conditioning UK
5. Danfoss Heat Pumps UK
6. Eko Warrior
7. Glen Dimplex Deutschland GmbH (Dimplex)
8. Grant UK
9. HeatKing
10. Ideal Heating
11. IDM Energie Systeme
12. Kensa Engineering
13. Kingspan
14. Lämpöässä
15. Mitsubishi Electric Heating Systems
16. NIBE
17. Nu-Heat (Hitachi)
18. Samsung
19. Stiebel Eltron
20. Vaillant
21. Viessmann
22. Worcester Bosch

***Baxi Heating UK***

*Baxi Geoflo Single Compressor Compact Heat Pump Operation Installation & Maintenance Instructions*[143]

Information for the end user / occupier is contained within this 24-page instruction booklet on the operation, installation and maintenance of the heat pump. The advice contained within this document includes:

- Safety information
- Basic instructions on the Microprocessor Controllor and Alarms including:
- Typical temperatures for underfloor and radiator heat emitters
- How to read the parameters on the display
- How to interpret and remedy alarms on the controller

This instruction document contains minimal advice for the end-user, and no guidance on how to operate the system to maximise efficiency.

[143] Source: http://www.baxi.co.uk/docs/Baxi_Geoflo_Single_Compressor_Heat_Pump_Installation_Guide.pdf

***Carrier Corp***

*Infinity™ Variable Speed Heat Pump with Greenspeed™ Intelligence Owner's Manual (OM25VNA-01) (ASHP system)*[144]

The 2 to 4 page Owner's Information Manuals provided by Carrier contain information on:

- Brief description of system
- System operation with Infinity Control.
- Basic information on heating and cooling the home
- Additional info on deluxe thermostats available
- Operation of the heat pump under extreme conditions (e.g. very hot or cold days, higher occupancy, hot showers, opening doors frequently etc)
- Important facts about heat pump systems (low temperature operation, defrost cycle)
- Advice on how to get the most from the heat pump system (listening to the system, keeping filter clean, not blocking air flow, checking condensate drain, operational temperatures, increasing heating temperature no more than 2 degrees at a time)
- Sound (variable speed heat pump)
- Routine maintenance (indoor unit, outdoor unit etc)
- Troubleshooting

This guide contains some very basic generic guidance for the user although the wording includes some technical jargon which the majority of end users are unlikely to understand. The layout of this information is much like an instruction manual, with no pictures or diagrams to illustrate any information and is therefore unlikely to be read by the end user.

There is a notable lack of information about how to control the time of the heating provided (there is a separate 30-page user guide for the Infinity Control) or any guidance for the user on how to ensure efficient operation.

***CTC***

*EcoHeat 300 complete heat pump system (ground/water Heat Pump)*[145]

Advice for the end user of the CTC EcoHeat heat pump is contained within the installation and maintenance manual. Within the 63-page manual, the following advice and information is provided:

- Introduction/overview to the heat pump.
- Detailed description of the Home Heating Curve and adjustment if too cold or too warm indoors (for GSHP)
- Description of the control system and factory values:
- Detailed description of menus in the control system
- Operation and maintenance:
- Boiler and radiator system safety valve
- Mixing vale
- Draining the tank
- Operation stop

[144] Source: http://www.residential.carrier.com/products/acheatpumps/heatpumps/index.shtml
[145] Source: http://www.ctc-uk.com/

- Description of general Heat Pump functions
- Fault measures/troubleshooting including a fault tracing procedure

Of particular note in the CTC guidance is the level of detail provided on the House Heating Curve, and how this can effectively be adjusted by trial and error by the end user following installation. This has been written in a highly technical language and the level of information will be too detailed for the majority of end users.

This particular system is installed with an intuitive looking touch display control panel and comprehensive guidance provided on how to use and understand this system, although the instructions are very detailed and have not been written with a non-technical end user in mind.

***Daikin Air Conditioning UK***
*User Guides for: Altherma high temperature (HT) ASHP[146], Large Monobloc ASHP, Small Monobloc ASHP, Alphaterm low temperature (LT) split heat pump.*

Daikin have produced a set of comprehensive and well-presented user manuals for each type of heat pump, which aim to provide information and guidelines to allow the end user to run their heat pump system in the 'most energy efficient and cost efficient way'. The 8-page guides include:

1. Description of the system and its key components including the heat pump units, hot water cylinder, controls, heat emitters.
2. Detailed explanation of the operation and functions of the remote controller, including:
   - Central heating operation
   - Reheat function
   - Setting the clock
   - Changing the hot water timer settings
3. Advice on maximising energy savings through:
   - Use of weather compensation mode
   - Adjusting water supply temperature (in the above mode)
4. Checklist for diagnosing possible faults

The guide provides advice on maximising energy savings by ensuring use of the weather compensation mode, and clearly presented instructions on how to use the remote controller (setting the clock and changing hot water settings/temperature) with minimal technical jargon in the text. However, the instructions for adjusting any of the control settings do not appear to be straightforward for the end user; this is most likely due to the complexity of the control design and complexity of the menu processes which Daikin have tried to communicate as clearly as possible (see Figure 13).

[146] Source: http://www.daikin.co.uk/binaries/AlthermaHT_UserGuide_UKEPCEN12-927_LR_tcm511-237647.pdf

**Setting the clock**

If for any reason you require to re-set the clock,

1. Press ⌂ to go to any home page
2. Press ☰ to enter the menu function and press (OK) when 'set time / date' is highlighted
3. Press ▼ until you reach the 'time' setting. Press (OK)
4. Press to adjust the hour ▲ or ▼ and then ◀ or ▶ to move across to adjust the minutes. Now Press ▲ or ▼ to adjust the minutes
5. Press (OK) to confirm and save the new time and press ⌂ to return to the home page

**Changing the central heating timer settings**

If you wish to set the central heating to heat at times other than those already set, you need to adjust the settings on the controller:

1. Press ⌂ to go to the home page
2. Press ☰ to enter the menu function
3. Press ▼ until 'user settings' is highlighted, press (OK)
4. Press ▼ until 'set schedules' is highlighted, press (OK)
5. When 'room temp.' is highlighted, press (OK)
6. When 'set heating schedule' is highlighted, press (OK)
7. If you wish to change an existing schedule choose the name of the schedule you wish to change and press (OK), OR if you want to start a new schedule, choose 'empty' and press (OK)
8. 'Mon' will be highlighted, this is the schedule for Monday. Press ▶ to enter the schedule for the selected day, or ▲ or ▼ to select another day

*Continued overleaf...*

**Changing the central heating timer settings**

*Continued...*

9. Press ▲ or ▼ to change the hour time of the schedule and press ▶ to change minutes. Press ▶ to set type of schedule. You can either set a room temperature or choose 'eco' (18°C) or 'comfort' (20°C) modes. Press ▲ or ▼ to switch between modes or to adjust temperatures
10. Press ▶ to move to the next schedule for the day. Repeat step 9 for the next timer schedule
11. When you have set all schedules for the day, press (OK)
12. You are able to copy the schedule set for Monday, to other days in the week. Press ▼ until 'copy day' is highlighted. Press (OK)
13. 'No' will be highlighted under 'Tue'. If the same schedule is required for Tuesday, press ▲ until 'yes' appears. Press ▶ to move to Wednesday. Repeat this step until you have copied the schedule for the days you require. Press (OK) to confirm and return to the schedule timer screen
14. If you would like a different schedule, for example on the weekend, press ◀ until the days on the left-hand side are highlighted
15. Press ▲ or ▼ until the day you wish to adjust is highlighted. Press ▲ to enter schedule timer adjustment screen and adjust timer schedules as described in step 9
16. When all schedules are set, press (OK) and press ▼ until 'same schedule' is reached, press (OK)
17. Save the schedule timer under either 'user defined 1, 2 or 3'. Press ▲ or ▼ to move between the user schedules 1, 2 or 3. Press (OK) to confirm
18. You can edit the name of the schedule. Press ▲ or ▼ to adjust the first letter and ▶ to adjust the next letters. Press (OK) to confirm
19. Press ⌂ to return to the home screen

**Figure 13 Daikin Heat Pump User Guide - Instructions on using remote controller**

### *Danfoss Heat Pumps UK*

*User manual for domestic heat pumps (A, A Opti, AL, AL Opti, C, H, H Opti Pro, L and L Opti)*[147]

One dedicated user manual is provided for 9 variations of domestic heat pump.

1. Information about the heat pump and its functions (principles of function, components, the units, outdoor and defroster function, passive cooling, speed (rpm) control, HGW technology, auxiliary heat, water heater,
2. Control system overview, display description including operating modes and symbols
3. Advice on 'Trimming the heating system' to obtain an even and comfortable indoor temperature
4. Instructions on the heating settings including setting/adjusting/changing:
    - Operating mode, room values, curve values, specific part of the heat curve, minimum and maximum values, heat stop and reading temperatures
5. Instructions for carrying out a manual defrost
6. Regular checks
    - Operation, brine level, heating system water level, safety valve, leakages, cleaning
7. Troubleshooting (alarms)

This 49 page user manual provides a considerable level of detailed information to the end user, both with regards to understanding the principles of heat pumps, the features and functions of the system, and operating modes. Although this information is of value to the technical end users who are willing and able to engage with their heat pump systems, it is likely to be too detailed for the majority of users. For example, this guide provides detailed instructions on 'Trimming the heating

[147] Source: http://heating.danfoss.com/PCMPDF/Danfoss_Total_User_VUGFE202_en.pdf

system'; how to obtain a heating system balance and obtain an even and comfortable temperature, which is unlikely to be understood by most end users as it uses a considerable level of technical jargon.

***Eko Warrior***

*The Eko Warrior Split System Air Source Heat Pump Manual (Models: KS50-DC / KS70-DC / KS90-DC / KS120-DC / KS150-DC)*[148]

This 56-page operating and instruction manual include the following areas of guidance for the end user:

1. Brief overview of how the heat pump works
2. Description of the order and display panel including overview of functions, symbols etc and brief operating instructions, description of the modes of operation.
3. Error codes and alarm messages

While this guide offers detailed instruction, it does not appear to have been written with the end user in mind. The contents offer potentially too much information and it has not been written in an easy to understand language; tending to use technical jargon which the average end user is unlikely to understand or follow even if the terms have been defined.

***Grant UK***

*Grant Aerona Air Source Heat Pump Installation & User Instructions*[149]

The user advice and information is provided within the installation manual for this heat pump, and includes:

1. General information about the product
2. Servicing and Maintenance
3. Fault finding

Within the installation guide, there is limited information of use to the end-user and the information on controls and temperature settings is hidden within sections intended for the installer only (e.g. the temperature that the hot water cylinder should be set at).

***Glen Dimplex Deutschland GmbH (Dimplex)***

*Installation and Operating Instructions for Air-to-Water Heat Pump for Outdoor Installation and Brine-to-Water Heat Pump for Indoor Installation*[150]

This 12 page installation and operating guide includes the following information and advice to the end user:

1. Purpose of the heat pump
    - Application, operating principles etc
2. Cleaning and maintenance
3. Faults and troubleshooting

[148] Source: http://www.ekowarrior.co.uk/CMS/cms-files/Eko%20Warrior%20Manual%20%28small%29.pdf
[149] Source: http://www.grantuk.com/downloads/Grant-ASHP-manual-DOC87-Rev05-January-2011.pdf
[150] Source: http://www.dimplex.de/nc/en/downloads/installation-instructions/heat-pumps-for-heating-purposes.html

This guide does not include any information on the efficient control and use of the heat pump system and for information on this, reference is made to the operating instructions of the heat pump manager (WPN Econ Plus controller), although it was not possible to source this.

***HeatKing***

*HeatKing User Guide (BWarm heat pumps)*[151]

The HeatKing user guide is a 2-page information leaflet that provides general guidance on:

1. Heat pumps
2. Setting of time clocks and controls (allowing extra time)
3. Temperature of radiators
4. Noise
5. Frosting
6. Safety
7. Servicing
8. Disposal

The information contained within this guide, while written relatively clearly with minimal technical jargon, is fairly limited and does not give any specific guidance such how much extra time to allow for the heat pump to raise water temperature compared to a conventional boiler.

***Ideal Heating***

*Users Guide Airtherm Air Source Heat Pump 4.5, 9, 12*[152] *& Users Guide Groundtherm Ground Source Heat Pump 3.5 & 5*[153]

These are 3 to 4 page guides written specifically with the end user in mind; separate to the installation guides, and include:

1. Very brief description of the system and how it works
2. Heat pump system controls; advice on when to set programmer to heat hot water with a typical winter heating programme i.e. on/off periods for heating and hot water (see Figure 14).
3. Advice on setting the programmer to allow for extra time to raise the temperature, and for users to be aware of lower temperature of radiators compared to conventional boiler
4. Advice on procedures relating to:
    - Shutdown / Preparing for winter / Start up
    - Loss of system water pressure
    - Automatic defrost (ASHP)
    - Condensate drain (ASHP)

IDEAL recommend users to set their programmer to heat hot water 1 ½ to 2 hours before it is required first thing in the morning or later in the day. The typical winter heating programme provided in the ASHP User Guide is as illustrated.

| On/Off | Heating | Hot water |
|---|---|---|
| On | | 5.00 am |
| Off | | 6.30 am |
| On | 6.30 am | |
| Off | 9.00 am | |
| On | | 2.00 pm |
| Off | | 4.00 pm |
| On | 4.00 pm | |
| Off | 10.30 pm | |

**Figure 14 IDEAL Advice on Heating Control Programming**

[151] Source: http://www.heatking.co.uk/pdfs/70408018-03_ASHP_user_guide.pdf
[152] Source: http://www.idealheating.com/downloads/manuals/204855_users.pdf
[153] Source: http://idealheating.com/downloads/manuals/206312_users.pdf

- Safety precautions
- Cleaning & Servicing
- Troubleshooting

The main notable aspect of this guide is the inclusion on advice regarding the time settings of the programmer in the winter to take consideration of the lower temperature system and time to reach set temperature; although technical jargon is used which may make the valuable information difficult to understand and follow for the majority of end-users. In addition, there are no instructions included on how to use the programmer as the heat pumps are designed to operate with a standard heating controller.

***IDM Energie Systeme***

*Technical documentation Operating Manual (TERRA HGL/BA with Navigator®1.0)*[154]

This comprehensive 28-page user operating manual provides:

1. General information (sound emission, construction drying, servicing and maintenance, cleaning etc.)
2. Operation: using the control unit, interpreting the display and symbols.
3. Operating modes: visual explanation of various operating modes and features
4. Faults

This guide provides detailed information to the end user on operating and controlling the heat pump, although much of this unlikely to be understood or of value to users as with other guides there is considerable use of technical jargon and it would seem the control product in use is not very intuitive or straightforward.

***Kensa Engineering***

*Kensa Heat Pumps Compact Heat Pump User Manual*[155]

This comprehensive 18 page user and operational guide for Kensa's domestic heat pumps includes:

1. A general introduction to heat pumps (explanation of how a GSHP works) and overview of the different components
2. Safety information
3. Technical details
4. Operational instructions including advice on maximising the efficiency of the heat pump including:
    - Running heat pump off-peak using Economy 10 if the building is well insulated with underfloor heating
    - Avoiding the use of insulative coverings with underfloor systems
    - Using the heat pump in conjunction with solar thermal for hot water
    - Timing of the hot water in conjunction with heating

[154] Source: http://www.idm-energie.at/asp_service/upload/content/ba_en_812202_Navigator%2816%29.pdf
[155] Source: http://www.kensaengineering.com/Library/Manuals/New%20Manuals/single%20and%20twin%20compressor%20Operational%20Instructions%20v2.4.pdf

5. Overview of the information display and the typical settings for temperature for different heat emitters.
6. Maintenance

The guide by Kensa contains a high level of information, some of which is of considerable value to the end user although it is not written with a non-technical user in mind. There does not appear to be any advice in this guide on suitable programming times, apart from the recommended use of Economy 10 for systems with underfloor heating and/or for the domestic hot water and allowing sufficient time to the space heating (since DHW takes priority over the space heating).

***Kingspan***

*Homeowners Guide Kingspan Aeromax Plus*[156]

This 8-page guide has been designed for the homeowner, and the content includes:

1. An introduction to the air source heat pump including a visual diagram of key elements
2. An explanation of how a heat pump works using visual diagrams to explain the heat pump cycle
3. Advice on operational temperatures and use of economy electricity tariffs
4. Information on the use of the heat pump with a programmable room thermostats, and advice on temperature settings.
5. Advice on the setting of heating, including typical winter settings for heating and hot water (see Figure 15 and Figure 16), TRVs.

| Weekdays (Mon-Fri) | | |
|---|---|---|
| Event | Time | Temp. °C |
| 1 | 06.00 | 20 |
| 2 | 09.00 | 15 |
| 3 | 11:30 | 20 |
| 4 | 13:30 | 15 |
| 5 | 16:30 | 21 |
| 6 | 22:30 | 18 |

| Weekend (Sat-Sun) | | |
|---|---|---|
| Event | Time | Temp. °C |
| 1 | 07:00 | 20 |
| 2 | 10.00 | 20 |
| 3 | 11:30 | 20 |
| 4 | 13:30 | 20 |
| 5 | 16:30 | 21 |
| 6 | 22:30 | 18 |

**Figure 15 Kingspan - Typical winter settings for the programmable room thermostat**

| Event No | Hot water | Mon - Fri | Sat - Sun |
|---|---|---|---|
| 1 | 1st ON | 03:00 | 05:00 |
| 2 | 1st OFF | 05.00 | 06:30* |
| 3 | 2nd ON | 15:00 | 15:00 |
| 4 | 2nd OFF | 16:30 | 16:30 |

**Figure 16 Kingspan - Typical winter settings for the hot water time switch**

6. Safety, Servicing and Troubleshooting

This guide is clearly presented and the level of detail is good although there is still some use of technical jargon, which a non-technical user may find easy to follow.

The notable feature of this guide is the level of advice on programming the heating and hot water. Kingspan give advice regarding the length of time the user should set their hot water before it is required in the morning or evening and setting the home heating to come on after hot water. As

[156] Source: http://www.kingspansolar.co.uk/DatabaseDocs/doc_4284233_aeromax_plus_homeowners_guide_issue_2_aug_11.pdf

illustrated in the figures above, the guide also provides a typical winter programme schedule for heating and hot water time and temperature.

***Lämpöässä***

*User Manual Lämpöässä v 7.0 – 30.0 Ground Source Heat Pump*[157]

The user manual includes both installation guidance and end user information. The section on 'User Information' within the 32-page manual covers:

1. Settings and a diagram of the key features of the User manual (with reference to the 203/GT Controller/regulator manual).
2. Settings for the heating curve and how to adjust output water temperature
3. Information on common temperature settings (room temperature, min and max limits, autumn drying, summer period, water etc)
4. Display readings/measurements
5. Care and maintenance
6. Troubleshooting

The information in this guide for the end user is contained within information aimed at the installer. While the information is presented clearly, there is a lack of explanation of some of the technical jargon used and the menu system on the control does not appear to be very user-friendly. This guide doesn't advice on the timing of heating or hot water.

***Mitsubishi Electric Heating Systems***

*Homeowner Information for Ecodan® Air Source Heat Pump and Flow Temperature Controller 2*[158], *Homeowner Quick Start Guide for Ecodan® Air Source Heat Pump*[159]

The guides produced by Mitsubishi for the Ecodan® Air Source Heat Pump system are separate from the Design, Installation and Maintenance manual. There are two main parts to the homeowner information:

1. The Homeowner Information (Standalone Manual) with 5-pages of information which provides an introduction to heat pump technology, the difference between heat pumps and conventional systems, and advice on the timing of heating and hot water depending on lifestyle and user needs, and some advice on running costs and FAQs.
2. The 4-page Homeowner Quick Start Guide (booklet) which aims to enable the end user to personalise the heating system controls to provide optimal operation conditions. This is presented very clearly, and in particular it includes:
    - A table showing the difference of the heat pump to conventional systems, the implication of this and action needed for the end user.
    - Clear guide to the heat pump controller functions and icons

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[157] Source: http://www.lampoassa.com/cgi-bin/webio-f?id=222&saitti=lampoassa&hash=84855F5CFBDAA68D4748156859A02188

[158] Source: http://domesticheating.mitsubishielectric.co.uk/files/library/files/ecodan/Brochure%20downloads/Homeowner%20Standalone%20Manual%20%28SAP%20No_%20233838%29.pdf

[159] Source http://domesticheating.mitsubishielectric.co.uk/files/library/files/ecodan/Brochure%20downloads/Ecodan%20Quick%20Start%20manual.pdf

- Information on how to interpret the information on controller display and how to view and adjust the settings and heating schedule, with reference to detailed setting instructions provided with the cylinder unit.
- Troubleshooting information

This guide provides the user with a good level of information although it does include some technical jargon which may make it difficult for the non-technical user to understand and follow; the guidance on use of the controller seems particularly clear, which is perhaps an indication that the control product used is more user-friendly than others.

***NIBE***

*User manual NIBE™ F2300 Air/water heat pump*

This 32-page user manual contains information on:

1. Safety precautions and care
2. A description of a heat pump and its different features (in a diagram)
3. Information on power consumption (a graph showing how the energy distribution will be spread over the year in terms of annual consumption)
4. Advice on use of the radiator thermostat valves to reduce electricity consumption of the heat pump
5. Troubleshooting

This user manual provides some valuable information to the end user, but is somewhat lacking information on programming and operating the heat pump in practice to ensure it runs at optimal efficiency. This guide is also rather lengthy, and it would require some effort for the end-user to sift through the pages to find the information they need.

***Nu-Heat (Hitachi)***

*Nu-Heat User Guide for Hitachi Yutaki Air Source Heat Pump*

Nu-Heat is the sole UK distributor for Hitachi air source heat pumps, and has produced this user guide. This  guide is explicitly separate from the MCS Handover Pack which includes information on the installation. Reference is made in their guide to a user's guide for the Hitachi wireless room unit and Nu-Heat underfloor heating user guide.

This guide covers:

1. An overview of the air source heat pump, how it works and the various components, explanation of the difference to conventional boiler systems, typical house temperatures and the definition/explanation of weather compensation, COP etc.
2. Information on the controls (room thermostat and wireless room unit), with reference to the Underfloor Heating User Guide for further information on how to use the room thermostat. Information on the controls include:
    - Operating modes
    - Increasing / decreasing room temperatures: in a particular room; and gradually
    - Hot water programmers (DHW, legionella purge etc)
3. Running the system economically, including advice on:
    - Heat pump set up
    - First year of use

- Choosing the heating mode
- Hot water temperature
- Hot water reheat
- Electricity tariff
- Extreme weather

4. Maintenance

This guide is well presented and provides comprehensive advice on how to operate the heat pump system, and the advice on how to maximise the efficiency and lower the running cost of the system is communicated relatively clearly with good use of photos and diagrams.

***Samsung***

*Air to Water Heat Pump – Hydro Unit user manual*[160]

1. Safety precautions/information
2. Overview of the control panel and the function of buttons and indicators for:
    a. Space operation mode
    b. DHW operation mode
    c. Temperature adjustment
    d. Hot key
    e. Schedule
    f. Status indicator
3. Step by step instructions on:
    a. Space heating and cooling operation
    b. Water law (operation according to parameters for weather dependent)
    c. DHW operation & Urgent DHW Mode
    d. Outing mode
    e. Setting the time
    f. Setting the 7 day weekly schedule and daily schedule
    g. Advanced functions

The level of instructions provided with this manual are lengthy and the processes required to adjust settings appear to be quite complex and beyond the capability of non-technical users. There is no advice on the most appropriate settings or how to ensure the system is operating efficiently.

***Stiebel Eltron***

*Operation and Installation Air/Water Heat Pump, WPMW II, WPMS II Heat pump manager for heating system heat pumps Operation and installation instructions*

The heat pump operation and installation guide provides some advice to the end user including:

1. An overview of the heat pump technology, its characteristics and function
2. Safety information
3. Operation (just a reference to the heat pump manager instructions)
4. Maintenance and care
5. Troubleshooting

[160] Source: http://www.samsung-heatpumps.co.uk/pdfs/User%20Manuals/EHS%20User%20Manual%20v2.pdf

The operating instructions for the heat pump manager have been written for both the user and the contractor, and provide information on:

1. Operating modes
2. Making adjustments
3. Heating curves
4. Heating programs
5. DHW programmes
6. Remote control

The level of diagrams explaining the steps for setting up and using the controller are detailed and complex and a non-technical end user may find this difficult to follow. In addition, there is no advice in the heating control manual or the heat pump manual on the most suitable heating and hot water schedules; the information given on timing are just as examples.

***Vaillant***
*Operating manual geoTHERM Heat pump*[161]

The operating manual for the geoTHERM heat pump includes:

1. Notes on the installation and operation, including:
    - Cleaning and care
    - Energy saving tips: both general and economising by the correct use of the control sytem
    - Description of the equipment and its function and features
2. Operation (control/programmer)
    - Description of the programmer and features
    - Flow diagram showing the menu levels
    - Description of displays/symbols on the operator level.
    - Advice on aspects such as the room temperature, and modes with indications of potential energy savings or costs (e.g. by increasing the room temperature by 1°C), using off-peak tariffs
    - Examples of heating and hot water schedules for particular occupancy patterns with information on factory settings (see Figure 17).

[161] Source: http://www.vaillant.co.uk/homeowners/products/heat-pumps/

| Display shown | Description | Factory setting |
|---|---|---|
| WW loading 5<br>Time programme<br>>Mon<br>1 06:00 22:00<br>2 : :<br>3 : :<br>>Select weekday/block | You can set the times at which the domestic hot water cylinder is heated in the **"WW Timer Programme"** menu.<br>Up to three times can be programmed per day or block.<br><br>The hot water generation should only be active at times when really hot water is to be run. Please set this timer programme to your minimum requirements.<br>As an example, for working people a window from 6.00 - 8.00 hrs. and a second window from 17.00 - 23.00 hrs.can minimise the energy consumption due to hot water generation. | Mo. - Fr.<br>6:00 - 22:00 hrs.<br>Sat<br>7:30 - 23:30<br>Su.<br>7:30 - 22:00 |

**Figure 17 Vaillant - Example of Instructions given on setting hot water schedule**

The information within the Vaillant guide is comprehensive and provides the user with instructions on how to operate their system to reduce unnecessary running costs. However, the majority of this information is likely to be beyond the understanding or interest of users and there is no clear division between essential advice and information for interest.

***Viessmann***

*Operating instructions for the system user – Compact heat pump with electric drive VITOCAL 300-G*

These dedicated end user instructions provide advice on:

1. Factory settings
2. Control functions and indicators, including:
    - Menu tree diagram
    - Switching on central heating/cooling and DHW heating
    - Modes of operation
    - Setting/selecting room temperatures
    - Modifying heat pump characteristics
3. Energy saving tips

The advice in this guide on how to control the heat pump is highly detailed and technical and is not presented in a way which is easy to follow for the end user. The controller itself appears to be relatively user friendly. However, there is no specific advice on what to expect from the heat pump or what the most appropriate schedule for heating and hot water might be.

***Worcester Bosch***

*User Manual Air to Water Heat Pump with Domestic Hot Water Distribution Unit GREENSOURCE (6kW, 7kW and 9.5kW)*

1. Safety information
2. General information on the Heat Pump and its function
3. Control unit
    a. Advice, including: additional electric heater boost function, automatic defrosting, and domestic hot water priority over heating water
    b. Control description and function
    c. Control panel overview description, settings and menu

    d. Instructions on how to set up the heating and hot water temperature and time, and modes of operation
    e. Setting/adjusting the Heat Curve
4. Maintenance, Errors and Alarm Management

This guide provides a good level of advice on the key information necessary for set up and operation of the heat pump system; although as with many of the other guides it is written in a technical language. It doesn't provide any advice on suitable time and temperatures as time control of heating and hot water is not recommended as it 'can negatively affect energy consumption' of heating or 'impair the DHW availability'.