DESK-BASED REVIEW OF PERFORMANCE AND INSTALLATION PRACTICES OF BIOMASS BOILERS

For:

Department of Energy & Climate Change

Report by

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In partnership with

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Objectives and scope

This report presents an assessment of the performance standards and installation practices in the under 1MW biomass heating sector in the UK, and was undertaken in March and April 2014 using existing published data and via a desk based assessment of current industry practice both here and abroad. This means it examines the observed percentage efficiencies of systems from wood fuel input to useful heat output (i.e. measuring losses). In order to benchmark and understand observed efficiencies we have used our own professional judgment to develop 'expected' efficiencies. We have also provided recommendations for collecting better information (about efficiencies) and in terms of supporting the sector to improve in this area.

Literature review

Our review of the published literature and guidance shows there is no suitable and impartial information about performance standards and installation practices in the UK for schemes above 45kW. The Microgeneration Certification Scheme (MCS) is the UK's only recognised quality assurance scheme affecting biomass, but only covers heat generating technologies with a capacity of up to 45kW. In effect, this means there are no quality standards for almost 90% of all schemes accredited under the RHI.

In addition, we have not located any existing published audit data about the measured efficiency and performance in-situ of biomass schemes, other than the 2010 WEBS review, which found that only 27% of its sample (of 63 biomass schemes) was working as specified by the customers.

The only 2 published references to expected[1] performance standards we have located are mentioned by the Carbon Trust (at 75% to 90%), and in the RHI Impact Assessment (at 81%). As this assessment shows these figures are higher than either our own expected standards or our in-situ measured performance.

Anecdotally have also found that some installers appear to be overstating the likely performance standards of systems (at 85% and higher) by presenting boiler combustion efficiency as part of the sales process. In the confines of this study it hard to be precise about the significance of this, but it must raise customer expectations that cannot be met.

Overseas performance standards and installation practices

In the main developed biomass markets of northern mainland Europe (notably Austria, Denmark, Switzerland and Germany), many of the efficiency issues we are now facing in the UK were avoided or mitigated by following long-term clearly defined quality standards and training programmes. These were typically developed by government working in partnership with industry and academia, and often supported by EU-funding schemes. These standards

[1] That might be regarded as the performance standard to aim for by all installers and operators.

and programmes mostly emerged about 2 decades ago and have been developed and maintained since then. The UK biomass heat sector can learn from these.

The Countries that we reviewed are now at a stage where performance standards and installation practices are mainstreamed into general building and heating system standards. A large body of hard-won technical knowledge, transferred through training, information sharing and general cooperation is a feature of all developed biomass markets.

European quality standards schemes have emerged as a response to issues such as high heat losses, low plant utilisation rates and variations in investment costs per kW, largely as a result of poor design. The resulting quality standards are underpinned by continuous data collection, which is a key part of the quality process in many regions and countries.

In the UK, the absence of any quality standard above 45kW, and of data collection and sharing is remarkable, and differs from most other countries that have seen a biomass heat sector develop successfully.

Case studies

We made contact with 41 companies involved in the installation of biomass heating systems and with 27 of their customers, ranging from large public sector bodies and private sector companies, to small estates and not-for-profit enterprises. As a result, we obtained actual performance data on 106 schemes (fuel purchased and heat outputs).

The table below offers a summary of the system efficiency levels we observed from the schemes and shows that the efficiency of these schemes (excluding district heating networks) ranges from 55% to 90%. A 90% outlier figure relates to a single small pellet boiler, so the vast bulk of our data is in the range 55% to 85%.

Sites	Average	Median	Top Ten Avg	Best
63 x Large Retail Sector	55%	58%	71%	85%
1 x pellet fired residential scheme	90%			
5 x high rise (forecast not actual)	69%	72.3%		77%
Large Hospital	59%			
Village hall pellet boiler	74%			
8 x schools	72%			

Our central conclusion is that the typical levels of actual system efficiency (excluding district heating networks) from our case study samples **are in the range 58% to 75%, with an average figure of 66.5%.**

An important limitation about this data is that we cannot be certain of its accuracy and there are several reasons why such data could be incorrect or misleading in some circumstances:

1. Heat meters may be incorrectly calibrated;
2. The tonnes of delivered fuel were not correctly weighed;
3. The moisture content of fuel was not properly recorded;
4. Heat meters are likely to be located in different positions, thereby recording heat outputs in different ways (not always at the point of use);
5. Data is not entered at all for periods in question;
6. It contains a preponderance of pellet-fired schemes.

However, these figures are likely to be the most accurate available in the UK, and probably for the first time indicate a general order of actual performance from a large sample size.

How do our expected performance standards compare to case study performances?

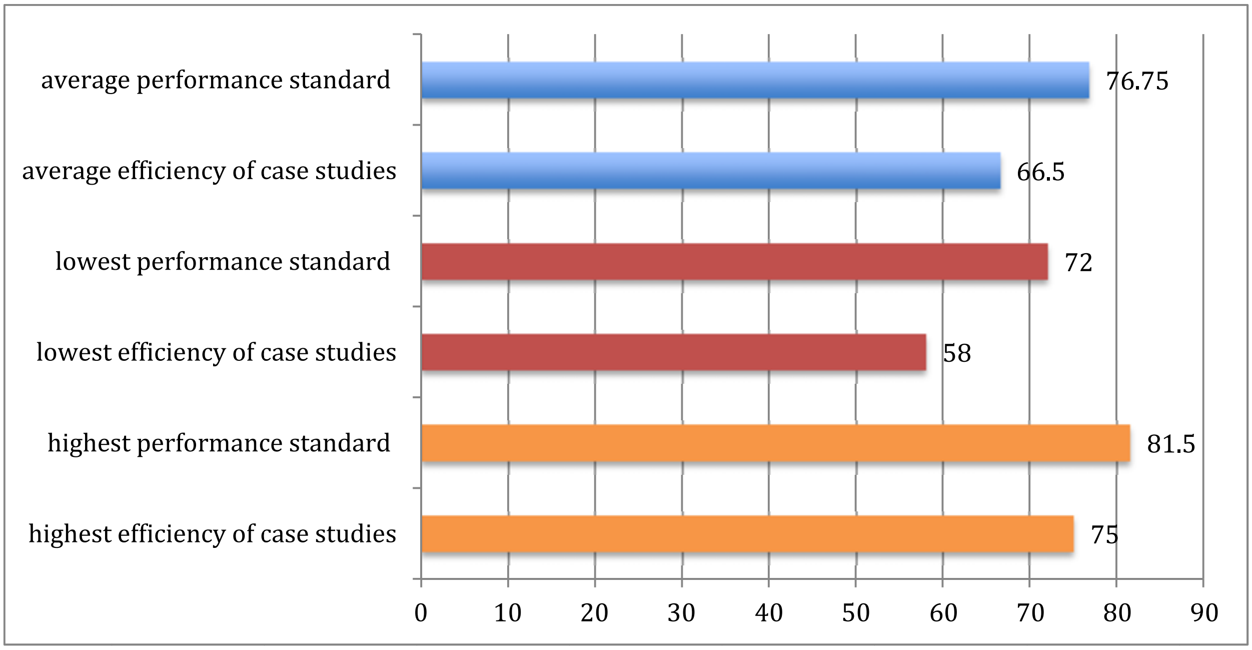
The performance of a biomass heating system can be measured by its efficiency in converting the energy stored in wood fuel into useful heat at the point of use.

Discounting district heating losses (that are highly site specific), our professional judgment is that the **expected** average (central) performance standard is 76.75% (equal to 23.25% overall losses) with a range from 72% at worst to 81.5% at best[2].

These figures assume that the systems are well designed, properly optimised and adequately maintained. These figures might therefore be regarded as the performance standard to aim for by all installers and operators.

We have compared our expected performance standards to the data we collected on the case study schemes (all figures are %). The chart below illustrates that in all cases (average, lowest and highest) the case study samples recorded performance standards that fall below our suggested performance standards.

[2] It is important to note that these estimates are not very different from how a gas, oil or coal fired heating system would perform in a similar situation. The only 2 inherent differences will be that fossil fuel boiler systems tend not to have buffer tanks (which will increase standing losses slightly) and don't have the problem of varying moisture content fuels to cope with. In other words, the estimated central performance standards would only be slightly exceeded if the boiler were gas, oil or coal fired.



In approximate terms, we show that there is 10% under-performance[3], however this will be even worse when recorded performance standards are compared to the statements made by many installers about performance levels, as these can be stated as 85% or more, and not the 66.5% average we have found in the case study sample.

RHI data analysis

We have attempted to reconcile our findings about relatively poor performance standards shown above with RHI statistical data. The RHI data suggests that the tariff bandings are encouraging schemes just under the 200kW break, and some at just under 1,000kW. There is a strong likelihood that a number of these schemes are not correctly sized for the heat loads. Where boilers are oversized in particular, the implications are that they will operate less efficiently and also give rise to higher emissions. They may also experience increased maintenance burdens and shortened life expectancy.

The data also suggests that (taking a 20% load factor as the expected benchmark), systems under 200kW are delivering around 20% less heat than the benchmark suggests they should. Schemes between about 300kW and 1,000kW appear to be performing to standards associated with 20% load factor, however, using the higher load factors that could be expected from larger boilers, these sizes of schemes may also be under-performing.

These findings are broadly consistent with the case study findings, and confirm that under-performance appears widespread in the UK biomass heat sector.

[3] Subject to the data limitations mentioned above

Boiler emissions

Emissions limits standards are set local authorities, but in 2013, the RHI regulations were amended to ensure the maximum permitted emissions are 30 grams per gigajoule (g/GJ) net heat input for PM, and 150 g/GJ for NOx, and this is likely to form a de-facto standard in the future.

Evidence from the boiler manufacturers shows that most modern biomass boilers will not exceed these levels when tested in laboratory conditions. However research in Europe shows that emissions rise with inefficient schemes.

We have sought to identify any study or survey of actual in-operation emissions from UK-based biomass schemes. However, to our knowledge, no such data has been published since a 2008 study for the Scottish Government by the AEA Group. Furthermore, we cannot find any data preceding this. The Scottish AEA study looked at 6 sites, and found that 3 exceeded the 30g/GJ limit. This raises the basic concern that whilst most optimally operated biomass boilers will probably meet the new RHI standards, in operational practice some boilers may exceed the limits.

If it is correct that biomass boilers in the UK are working between 10% and 20% less efficiently than they should, it also means emissions will be higher than laboratory test results suggest. The available data set is too small and of insufficiently consistent quality to draw statistically significant conclusions, and further UK based field trials will be required to establish the true levels of emissions in operation.

Gap analysis and specification of field trials

We are able to conclude with some confidence that biomass heating installations are not performing as efficiently as they should and our case study data and the RHI data indicate between a 10% and 20% under-performance, which affects the economics of the schemes and increases emissions. This appears to be compounded by a widespread perception that schemes should achieve efficiencies of above 85% when in fact they can only achieve levels around 76% (on average). However these conclusions are based upon limited and incomplete data.

The case studies we have collected for this study offer an excellent starting point that can be further understood and extended. Subject to the agreement of the parties who supplied the information, it would be necessary to:

- Understand exactly how the data was collected and expose any limitations;
- Carry out selected site visits to perhaps 20% of the installations;
- Set up a process that then collects and reviews that data over a 12 month period.

Our view is that there will be more data sets than the ones we have managed to obtain so far. We suggest that contacting 150 accredited installations might secure 20 new useful data sets. Following this, all these installations could be included in the follow-up process described above.

The outcome should be to have about 40 installations in a single data set. This would represent 1.4% of currently accredited RHI installations.

The process described above remains largely a desk based exercise, with the ongoing responsibility to actually collect and record useful data remaining with the parties who own the installations. DECC would then have no control over how and when this is done; and most significantly it only relates to fuel supply and meter readings.

We therefore propose that for a group of 10 selected reference installations, a year-long extensive field trial is planned and delivered, to sit alongside the 40 data sets mentioned above. This would cover:

- Data collection from the BMS data/electronic controls systems of the installations;
- A degree day analysis (to compare weather conditions with heat demand);
- Actual measurement of kWh standing losses in the plant rooms, associated with the boiler and in terms of any district heating;
- Collection of fuel supply data in a consistent manner;
- Measurement of flue emissions.

Development of performance standards

These field trials and desk based data sets can be used to empirically measure and then confirm the main causes of underperformance, and from this develop guidance that improves future installation practices develops national performance standards, so that the sector has a recognized standard to achieve and work within.

Since the UK has no quality standards for schemes above 45kW, our recommendation is to scope out how installation practices and quality standards could be developed in the UK for all schemes above 45kW.

This is a large and complex task that requires collaboration between the industry, government and academia. Our proposal is that DECC initially undertake a time-limited consultation exercise to determine who could be involved in the development and management of improved installation practices and new quality standards, how that might be delivered and what the costs and benefits would be. This should result in short report, ideally published as soon as autumn 2014. In this we would propose a focus on data collection and sharing to drive up standards.

1.0 Introduction, Scope and Purpose

1.1 Objectives

The objective of this research is to undertake a desk-based assessment of the performance standards and installation practices of biomass heating installations in the UK, in order to inform the development of guidance or standards that could improve efficiencies and minimize emissions of installations incentivised through the Renewable Heat Incentive (RHI). In particular the dramatic uptake of biomass boilers incentivised through the RHI means that there is considerable potential for DECC to work with industry to understand and improve best practice. As such, this study begins by analysing the current state of the industry in the UK and further afield.

This study brings together such information that does exist, and examines it critically to establish key trends and performance indicators. This is important for a number of reasons:

- Customers may be making investment decisions in the absence of accurate information about how their schemes are likely to perform;
- Suppliers and installers could be criticized for performance standards that are unlikely to be met;
- It appears that performance standards and installation practices could be inadequate in some instances, and this needs to be more accurately measured and then addressed;

In simple terms, customers must know what they are buying and to what standard it will perform, but this basic requirement does not appear to be part of standard practice in the market place at present.

1.2 Scope

This assessment was undertaken in March and April 2014 using existing published data and an assessment of current industry practice both here and abroad.

We have contacted 5 biomass sector trade associations across Europe, plus those in the USA and New Zealand. We also made contact with 39 companies involved in the installation of biomass systems and 24 of their customers (see appendix 1) and from this we obtained in-situ operational data on 106 installed schemes in the UK (case studies). We are grateful to all those that took the time to respond and provide us with this information, without whose help the report could not have been completed.

The scope of this research precludes a structured development of biomass performance standards, however, we have developed some suggestions that we have used to compare with our case study findings. We also have been provided with some generic data about all the schemes that have obtained RHI accreditation and we have compared this with the case studies and our suggested performance standards.

We have examined biomass boiler emissions and drawn some preliminary conclusions about concerns in this area. Finally we have reviewed the nature and availability of training in the sector and developed a gap analysis and proposed some field trials and other work to better evaluate biomass performance standards.

1.3 Definition of biomass performance standards

This report defines biomass performance standards as the overall annual efficiency of biomass schemes in converting the fuel delivered to the scheme into useful heat. In other words it measures the energy of the wood fuel in the store in terms of kWh per tonne and then measures the amount of heat delivered to the customer in kWh. The losses between the store and heat at the point of use can then be expressed as a percentage efficiency. We have excluded district heating losses, as these losses are site specific (and are not a biomass related issue per se), but we have commented on this in terms of the types of losses that could be expected (in section 4.4).

Unless otherwise stated, when this report refers to efficiency it means the definition described above.

2.0 Literature review of performance standards/installation practices

2.1 Introduction

We have reviewed all known sources of publically available information on performance standards and installation practices in the UK[4].

From this review we have sought to find either information on required performance standards and installation practices, and as well, in-situ measurements of actual performance. Below we present the findings of this review process.

2.2 Publications and websites

It is worth commenting first on the Biomass Energy Centre, as this was the UK government's main information centre (primarily a web-based resource) for promoting the use of biomass in the UK.

Funding for the Biomass Energy Centre Enquiry Service came to an end in 2013, and whilst the website was updated to reflect the changes in RHI rates that occurred on 1 April 2014, the site is increasingly out of date. That said, the site received 540,000 site visits and 420,00 unique visitors in 2013/14[5], so it clearly remains a well-used source of information.

[4] Including: Energy Savings Trust (http://www.energysavingtrust.org.uk/); Carbon Trust (http://www.carbontrust.com/); Community Energy Scotland (http://www.communityenergyscotland.org.uk/); Forestry Commission (http://www.forestry.gov.uk/); The Biomass Energy Centre Website (http://www.biomassenergycentre.org.uk/) and MCS.

[5] Forestry Commission, May 2014

Despite the need to update the site, it represents the single most comprehensive repository of biomass-related information in the UK, and about 60 direct links to technical reports about biomass energy remain available on the website. We have reviewed all these and established that there is only limited and patchy information on performance standards and installation practices or reported in-situ measurements of actual performance.
We have looked elsewhere for such information and the following describes what is available and merely confirms that such data is not generally available, and such data that does exist is patchy or out of date.

There are some publications on the subject of heating system design, some of which are relevant to biomass heating, although all are now out of date[6]. Some of the more recent documents include:

- Biomass Heating - CIBSE Knowledge Series: KS10 (for peak heating demand 50kw to 5000kW); Chartered Institution of Building Services Engineers London, 2007
- Domestic Heating Systems Ranked by Carbon Emissions; BRE; 2007
- Energy Efficiency Best Practice Guide in Housing - Domestic heating: solid fuel systems; Energy Saving Trust CE47 (EST; 2005)
- Heating CIBSE Guide B1, Chartered Institution of Building Services Engineers London, 2002
- The Whole House Boiler Sizing method; BRECSU Energy Efficiency Best Practice Programme; 2000
- Guide A: Environmental design; CIBSE; 2006

Again none of these provide clear and useful information on performance standards and installation practices.

For example in 2008, the Carbon Trust published one of the best, largest and widely used guides to biomass installations. This 94 page document called '*Biomass Heating: A Practical Guide for Potential Users'* (In-depth guide CTG012), does not directly refer to performance standards, other than one individual reference in the context of fuel supply, on page 78. Here the guide simply states the estimated efficiency of the plant is likely to be in the range '75% to 90%.'

Given the stage of market development in 2007/8, it is not particularly surprising that the Carbon Trust publication offered only a limited view on biomass performance standards. Clearly, however, the market has matured and such standards could now be refined and improved.

[6] The accumulated knowledge of sector has expanded and improved dramatically in the last decade, such advances are associated with applied skills such as the design and planning of schemes, rather than the technology, which is mostly imported and was highly developed even a decade ago.

2.3 RHI Impact Assessment

In March 2011, DECC published an Impact Assessment (IA) of the then proposed RHI (IA No: DECC 0057). This IA was intended to detail the costs, benefits and impacts of the RHI mechanism, and so proceed with the legislation required for the incentive. This IA does contain one of the very few references we can locate to performance standards, and an important technical assumption made by the IA was the efficiency of biomass boilers.

This was assumed to be 81%[7], as noted below, which informed the support levels.

Reference installation characteristics:

The table below sets out in detail the technology assumptions used for the setting of the final proposed RHI support levels for biomass boilers and Ground Source Heat Pumps (details of the assumptions used for the biomethane tariff are provided in Annex 5)

Segment assumptions							Technical assumptions						Non-Financial Barrier assumption	
Technology	Size	Consumer segment	Fuel counterfactual	Sub-segment	Location	Building age	CAPEX costs	OPEX costs	Efficiency	Load factor	Size	Lifetime	Upfront	Ongoing
							£/KW	£/KW/year	%	%	KW	Years	£	£/year
Biomass boilers	Small	Commercial / Public	Gas	Small private	Urban	Post-1990	448	10	81%	20%	107	20	6,965	828
	Medium	Commercial / Public	Gas	Large private	Rural	Pre-1990	526	27	81%	20%	350	20	8,070	878
	Large	Commercial / Public	Gas	Large public	Urban	Post-1990	412	20	81%	45%	1602	20	8,070	878
GSHP	Medium	Commercial / Public	Gas	Small public	Suburban	Post-1990	1,312	7	400%	35%	30	20	6,333	16
	Large	Commercial / Public	Gas	Large private	Urban	Post-1990	962	0.7	400%	35%	300	20	6,469	66

All the costs and performance data are for 2011 in 2010 prices

Figure 1: RHI efficiency estimate

2.4 Wood Energy Business Scheme 1 (WEBS 1)

This section summarises the findings of the only published large-scale audit of schemes we have managed to find. Between 2004 and 2008, Forestry Commission Wales administered a grant scheme called the Wood Energy Business Scheme (WEBS). To learn the lessons from this £7m programme, FC Wales commissioned a review, which was undertaken between January and March 2010. The review comprised 58 structured telephone interviews with applicants who had installed schemes (75% of the schemes that obtained grants). The telephone interviews were augmented by site visits to 10 schemes. From the sample of 63 schemes, the review found that:

- 5 systems were non-operational;
- 41 systems reported some operational or other problem;
- 17 systems reported no problems.

[7] The source of this 81% figure is not explicitly determined in the IA, and it might not be an unreasonable assumption at the time and given the paucity of UK data on this.

The most concerning finding was that only 27% of the total sample was found to be working properly. It also found that almost all the serious problems were rooted in poor planning and design, and inadequate expert advice.

In general, the principal operational issue was oversized systems that then operate at low efficiencies or are unable to modulate down to low heat loads. A problem at all stages was the lack of expert impartial help and professional advice. The most common source of project planning advice was cited as the suppliers and installers. The study found that many customers were concerned that they had to rely upon suppliers and installers for advice, as they felt it was likely to be biased towards the commercial interest of that company, rather than being wholly impartial.

The design, tendering, procurement, implementation, commissioning and maintenance of projects without bespoke contracts were a direct cause of problems, and it was found that there were often no clear lines of communication or defined responsibilities for the parties involved in the planning, design and execution of the schemes.

Interestingly, wood chip boilers in large public buildings exhibited the greatest level of problems; it was thought that these schemes were relatively complex and that public sector procurement processes were not particularly suitable for such schemes.

The study made the following recommendations:

- DECC be made aware of the findings of this report so that they can consider how they respond in the light of the RHI proposals;
- To conduct a similar review of grant aided schemes in England and Scotland;
- Set up a technical advice support service;
- Issue up-to-date best practice guidance on system design and installation practices;
- Draft and publish a standard installation contract;
- Draft and publish standard fuel and maintenance contracts;
- Offer accredited training to building services professionals.

2.5 Wood Energy Business Programme 2 (WEBS 2)

WEBS 2 was the immediate successor scheme to WEBS 1, and operated across Wales, providing technical support, training and grant aid for those installing biomass boilers. Issues with scheme design, the arrival of the RHI, and EU audit requirement meant that the project did not support many boiler installations directly with grant-aid, but the evaluation highlighted issues affecting customers and installers. For potential customers, these were :

- their initial lack of knowledge of wood fuel boilers
- their inability to produce an appropriate tender specification
- over specification of the system e.g. installation of 100KW boilers when 50KWwould suffice
- fuel delivery and storage
- maintenance costs.

The WEBS 2 evaluation also found that :

> *"Those installing wood fuel boilers could not identify a single reliable or independent source of advice. Most of them relied upon their own ability to research the subject area or the advice of those companies who were providing a quote for the supply and installation of a wood fuel boiler."*[8]

2.6 Microgeneration Certification Scheme (MCS)

The Microgeneration Certification Scheme (MCS) is the UK's only quality assurance scheme affecting biomass, and is the mandated scheme which meets the UK's requirements under the EU RED. It is supported by the Department of Energy and Climate Change (DECC). MCS is a BS EN ISO/IEC 17065:2012 Scheme, and was launched in 2008.

In terms of biomass, MCS certifies products and also certifies installation companies to try and ensure the microgeneration products have been installed and commissioned to the highest standard for the consumer. The certification is based on a set of installer standards and product scheme requirements.

[8] An Evaluation of the Wood Energy Business Scheme 2, Natural Resources Wales (2013)

MCS only covers heat generating technologies with a capacity of up to 45kW. In addition MCS only addresses system performance in the context of ensuring that the boiler proposed matches the design heat loss of the building. It does not provide performance standards and installation practices that would be applicable above 45kW.

2.7 Applied performance standards in the UK biomass sector

If we take the BSI definition of a standard, which is "*put at its simplest, a standard is an agreed, repeatable way of doing something*", it is clear that in the UK biomass sector, there is considerable confusion on what constitutes performance standards and installation practices for biomass systems. In our view, this lack of clarity is impacting on the procurement and efficient operation of systems, and on the expectations that customers have about the performance standards that should be achieved.

At this stage we can only offer a limited, experience-based assessment of how performance standards are commonly understood and applied, but the review below does indicate some common themes.

The understanding and use/misuse of standards appears to be a two-way process (installers and customers both getting it wrong). For example in the absence of published standards for installations over 45kW, our experience is that some customers procure large boilers against the Microgeneration Certification Scheme, which does not apply to systems at this scale.

A further common confusion is the MCS stipulates that biomass boilers are CE marked and achieve a certain level of boiler combustion efficiency, and EN 303:5 2012 (the EU standard for testing solid fuel heating boilers up to 500kW) also makes reference to the boiler combustion efficiency of biomass boilers. These standards are often taken as the *system efficiency*, whereas of boiler combustion efficiency is only one part of the overall *system efficiency* of a biomass installation.

From the supplier-side, it appears that in an absence of applicable performance standards and installation practices, a proportion of installers are quoting the same information to customers - product CE marking, tested boiler combustion efficiency figures and the fact that they are MCS accredited. This appears to be occurring both in formal tender responses, and in proposals that are submitted to potential customers as part of a sales process.

Customers therefore expect that boiler combustion efficiency will be the overall efficiency of their installed systems, when this is of course impossible.

As an example, we have seen a detailed quotation for the supply and installation of a 150kW boiler provided to customer in March 2014. The quotation makes no reference to standards, and quotes modern biomass heating systems as being *"up to 96% efficient"*, before stating the efficiency of the product proposed to this client as 85%, a figure on which all the calculations about RHI income, fuel use and payback are based, resulting in a stated 3½ year pay back. Even accounting for this being an oil replacement scheme, our view is that the performance standards that will be seen in operation, and therefore the achievable paybacks, are grossly overstated.

Whilst a proposal of this nature will mislead a typical customer (either by accident or design), we acknowledge that many suppliers do offer a more informed assessment of the performance of their offerings, and we cannot offer empirically-evidenced comment on the overall scale of this issue at this stage, suffice to say that it is of significant concern to many in the industry at present.

In reality, MCS accreditation, CE marking and the quoted combustion efficiency of a boiler in a manufacturers' brochure is highly unlikely to be sufficient to guarantee either the quality of the equipment deployed in a particular application, or that the installation is carried out to an appropriate quality standard. Although we have not empirically established this, we can assert with a high degree of confidence that tender documents typically used (when they are used at all) to procure biomass systems typically quote either no standards, or require *"current standards"* to be complied with.

We could provide numerous examples, but to represent all these we highlight a tender for a commercial project in the north of England issued by a consulting engineer in November 2013 that listed the following as "*standards*" with which the *"installation"* must comply:

- *Energy Act 2008*
- *Ofgem Draft Renewable Heat Incentive Guidance Docs 1&2*
- *DECC Renewable Heat Incentive Policy Document*
- *Renewable Heat Incentive: Impact Assessment*
- *Renewable Heat Incentive Scheme Regulations 2011*
- *Renewable Heat Incentive Scheme (Amendment) Regulations 2012*
- *Renewable Heat Incentive Scheme (Amendment) Regulations 2013*
- *Renewable Heat Incentive Scheme (Amendment No.2) Regulations 2013*
- *Clean Air Act 1993*
- *CIBSE Knowledge Series KS10*
- *Approved Document J*
- *British Standards - Various*

In reality, none of the above listed requirements are actually applicable standards.

This anecdotal overview is to some extent justified by the 2013 Wood Heat Association Survey described below.

2.6 Wood Heat Association Establishment Survey

In Autumn 2013 the recently established Wood Heat Association conducted a survey and achieved 134 respondents from the breadth of the UK biomass heating industry.

That survey has shown that *"poor quality installations damaging the reputation of the industry"* is rated as the issue of fourth highest importance to the UK wood heat industry (out of 12 possible issues ranked).

To give this further context, the two highest rated issues related to uncertainty over the continuation of the RHI and the implementation of degression, while the third highest was the *"lack of expert and impartial advice available to customers".* This third-ranked point is very closely related to that of *"poor quality installations…"*, as many of these result from customers only having installers/salesmen to call on for advice and information.

In our view there must be a relationship between the absence of suitable performance standards and clear installation practices and widespread concerns over poor quality installations.

2.7 Summary

Our review of the published literature and guidance shows that there is no suitable and impartial published information about performance standards and installation practices in the UK for schemes above 45kW.

In addition, we have not located any detailed *published* audit data about the actual efficiency and performance in-situ (of biomass schemes), other than the WEBs review, which found that only 27% of its sample was working as the customers expected.

The only 2 published references to efficiency standards are mentioned by the Carbon Trust report (at 75% to 90%) and in the RHI IA (at 81%). As this report later shows these figures are not consistent with either possible standards or in-situ measured performance.

Arguably many of those installing biomass heating systems, and their advisors, are unaware of how to effectively procure the right system for their needs, and are reliant on installers for even the most basic information on performance and installation practices.

A number of suppliers appear to be overstating the likely performance standards of systems (at 85% and higher), and are using figures for boiler combustion efficiency as part of the sales process.

Therefore, our conclusion is that the main source of information about performance standards and installation practices in the UK are the suppliers and installers. It is clearly unsatisfactory that customers must reply upon suppliers for such information, and there is considerable incentive for the suppliers to overstate the performance standards, particularly given the RHI payments that motivate their customers.

3.0 Performance Standards and Installation Practices Overseas

3.1 Introduction

In order to understand and build a clear picture of installation practices and biomass boiler performance standards overseas, we contacted a range of bodies across Europe, predominantly sector trade associations. The most positive responses to our requests for information were from Denmark and Austria, and it is with these countries that we have concentrated our efforts. We contacted:

- State of Green, Denmark (http://www.stateofgreen.com/en/Bioenergy)
- Svebio, Sweden (http://www.svebio.se/english/heating)
- Bioenergia, Finland (http://www.bioenergia.fi/In%20English)
- Hozenergie, Switzerland (http://www.holzenergie.ch/home.html)
- Biomass Thermal Energy Council, USA (http://biomassthermal.org/)
- Biomasse-Verband, Austria (http://www.biomasseverband.at/home/)
- Bioenergy Association of New Zealand, (www.bioenergy.org.nz)

In addition we have examined the Quality Management System for Wood Heating Plants that applies pan nationally to Germany, Austria and Switzerland and is partially adopted in Slovenia, Belgium, the Netherlands and Japan.

3.2 Denmark

Denmark has one of the most advanced wood heating sectors in the world, and is also at the forefront of deploying district heating infrastructure, almost all of which is connected to centralised boilers burning wood or other forms of biomass, principally agricultural residues (95% in 2009). With over 450 district heating schemes supplying 62%[9] of all the households in Denmark, they are a major player in the European biomass sector and the only EU country which is wholly energy self-sufficient.

General standards and guidance governing boilers, heating and hot water production

As in the UK, there are standards covering the safe design and installation of heating and hot water systems, which in Denmark are primarily regulated by *Arbejdstilsynet* (Working Environment Authority - WEA hereafter), an organisation that has responsibilities which parallel those of the Health and Safety Executive in the UK.

The principal standards applicable to the sector are:

1. Decree No. 743 of 23 September 1999 : Interior of the Pressure Equipment Directive (PED)
2. Decree No. 99 of 31 January 2007 : Design, renovation and repair of pressure equipment

[9] Ecoheat4eu Project, Intelligent Energy Europe, 2011

3. Decree No. 100 of 31 January 2007 (100/07): The use of pressure equipment
4. Executive Order No. 1109 of 15 December 1992 : The use of technical aids

The industry-facing guide to these standards is *At-VEJLEDNING Tekniske Hjælpemidler - B.4.8* (included as Appendix 1), a text-heavy document published by WEA in 2007, and which sets out the requirements and minimum standards which must be observed when designing and installing boilers and heating systems with temperatures of not more than 110^{o}c. The guidance stipulates the minimum safety features that have to be included on heating and hot water systems, e.g. pressure sensors and gauges, alarms, expansion tanks and built-in safety heat exchangers to dissipate residual heat on boilers that can be manually fired.

Emphasis is placed on adherence to manufacturers' instructions, and on following a proper process when installing, filling, setting up and commissioning a boiler, as well as ensuring correct maintenance procedures are followed and that an inspection regime is put in place. The guidance also requires that customers are given appropriate instructions for the operation and care of the particular system.

Standards and guidance governing biomass boilers

As far as we have been able to determine, there are no specific mandatory standards in place governing the installation of biomass boilers in Denmark beyond those that apply to heating and hot water systems generally. This, we feel, is an indication of the level of maturity of biomass heating technology and the degree of its penetration in the Danish marketplace.

From the reference documents provided by contacts in Denmark, and from targeted internet searches based on this information, it appears that the Danish biomass heating sector went through a similar phase to that which we are now experiencing in the UK, in the period 1995-2000, which is when most guidance documents date from.

As an example, the principal guidance documentation available for installers that we have been able to identify is the manual *Installationsvejledning for biobrændselskedler* (Installation Instructions for Biofuel Boilers), which dates from October 2000. This document, which is included as Appendix 2, runs to 54 pages, around 30 of which can be regarded as meaningful guidance. The document is roughly equivalent to the 2009 Carbon Trust publication, *CTG012 Biomass Heating, A practical guide for potential users*, which has been discussed previously.

There is specific guidance regarding fire safety in relation to biomass boilers in the form of *Vejledning 32, Biobrændselsfyrede centralvarmekedler* (Fire Technology Guide 32, 4th Edition, Biomass Central Heating Boilers), which is published by the Danish Institute of Fire and Security Technology (DBI), an independent not-for-profit organisation which is approved by the Danish government.

The 4th edition of the Fire Technology Guide 32 was updated in 2011 to account for developments in biomass boiler technology, particularly protection against back-burn, and because of changes in Danish building regulations since the 3rd edition was published in 2002. The guide covers combustion plant up to 120KW in output, and addresses not only fire safety but also a section on protecting against dust explosions - an inclusion felt necessary because of the rising number of boilers receiving deliveries from pneumatic tankers in a maturing Danish market.

Quality standard or assurance schemes

There are two quality schemes in Denmark that have relevance to biomass boiler installations. The first is KSO Ordningen (www.kso-ordningen.dk), a quality assurance scheme for biomass boilers, solar thermal and solar photovoltaic technologies, which is aimed at installation companies. The scheme replaced a previous QA system - KSO/KSC - which ran until 2002. KSO Ordningen is a response to the requirements of EU RED Article 14, which holds that member states shall ensure certification or equivalent qualifications schemes are available to installers of a range of renewable energy technologies. This EU requirement is intended to assure customer protection in the deployment of new, government-subsidised, renewable energy equipment.

Figure 2: Danish QA scheme logo

The scheme aims to ensure that installed systems meet quality requirements, and that companies participating in the scheme can prove that they are able to deliver high quality projects which meet customer needs and expectations. Companies can become member of KSO Ordningen if they have one or more employees with an Installer Certificate, and then commit to meet the requirements of the scheme. The installer Certificate is issued by KSO Ordningen to individuals who hold a minimum set of qualifications, and then attend a QA course and who pass the end-of-course test. The scheme currently has 97 members registered as biomass installers.

The scheme is industry-led, with a broad range of organisations[10] forming the “coordination group” - seemingly the equivalent of a Board or Committee.

Whilst bearing some similarities to the UK’s MCS scheme, KSO Ordningen appears to be focused more on the quality of the installation and supporting installers than on consumer protection and maintaining audit trails. Specifically, the activities within the scheme are:

[10] These are: the Association of Manufacturers of Solid Fuel Systems, DS Trade and Industry, Tekniq (a trade association for technical companies in a range of industries, including IT, plumbing, energy, process engineering, etc), the Danish Solar Association, the Electricity and Heating Industry Education Board, the Technology Institute at the Centre for Installation and Calibration, with the two government bodies, the Energy Agency and the Working Environment Authority, present as observers. Secretariat is provided by one of the coordination group, the Centre for Installation and Calibration.

1. Updating the membership list and database;
2. Issue of certificates;
3. Review and ensure education;
4. Follow-up inspections of installed systems;
5. Preparation of newsletters;
6. Continuous contact with members and branches;
7. Participation in the selection of solar, boilers and solar cells for certification;
8. Answering questions from members;
9. Liaising with relevant authorities.

The second relevant quality scheme has been introduced more recently than KSO Ordningen, and relates specifically to district heating - a major part of the energy landscape in Denmark, and particularly when discussing biomass heat. The *Fjernsvarmens Serviceordning* (www.fjr-ordning.dk), which roughly translates as District Energy Service System, was established in 2005 to provide a national quality assured service system for district heating. We feel this is of particular interest to the UK wood heating sector, and this review, as district heating is being increasingly used in conjunction with biomass boilers.

The District Energy Service System scheme sets out the technical requirements and specifications for the work required to install and service district heating systems, which can only be carried out by service engineers with specific expertise in district heating. The scheme also includes provisions for the periodic overhaul of district heating schemes, particularly the heat interface units, and for biennial servicing.

The scheme is open to suitably qualified professionals who commit to complying with the provisions of the scheme statutes, and who pay the registration fee of 2,000DKK (about £220), and also the annual membership subscription of 1,800DKK (c. £200). As part of scheme membership, technicians must attend and pass a 7 day, formally examined training course on district heating schemes, and also participate in further training and education to maintain their professional skills. Accredited technicians are issued with ID cards that they must carry while working on district heating jobs.

The courses are subject to regular review to ensure that they remain state of the art, and are delivered at technical schools (akin to colleges in the UK) in 10 cities across Denmark. The course content covers all the necessary technical aspects of district heating, building interfaces and suchlike, as well as providing information on legislation and the rules and regulations of the quality scheme itself. Engineers are required to recertify every three years.

There are currently 250 companies registered under the Fjernsvarmens Serviceordning scheme.

The degree to which biomass heating systems are accepted as the norm in Denmark is reflected in the way training is delivered to the industry by a range of providers, including colleges, trade bodies and private sector companies. Underpinning the sector is the standard apprenticeship, which every heating engineer must complete before becoming qualified - biomass boiler systems are regarded as the norm, alongside other renewable technologies, and so their design and installation is covered as standard alongside oil and gas,solar thermal and heat pumps.

Other than that which is associated with the KSO Ordningen scheme, there appears to be no specific training programme for biomass heating available in Denmark. However, there are some stand-alone courses that are specific to biomass boilers and the heating systems to which they are connected, although they are few and far between. Where they are available, provision ranges from manufacturer-specific short courses, through to Summer Schools and in-depth technical training on specific aspects of biomass heating and district heating.

3.3 Austria

Austria is widely considered to have the most advanced wood heating sector anywhere in the world, and Upper Austria in particular is seen as the powerhouse of modern biomass heating, with an estimated 25%[11] of all modern biomass boilers installed in the EU manufactured in this small region. In Upper Austria, wood makes up 15% of the total primary energy demand, and renewable heating accounts for around 50% of the total heating demand via 40,000+ automatic wood-fired boilers.

As with Denmark, district heating is a key component of the heat infrastructure in Austria, and large biomass-fired district heating schemes are a common feature, with 20% of the population connected to district heating systems[12]. These are variously owned by farmer cooperatives, private companies (usually SME's, although there are a few large players) and local communities. District heating has benefited from a support regime, which dates back to the 1980's.

These large schemes differ considerably from the types of district heating scheme which are proliferating in the UK under the RHI mechanism, and have an average size of around 900KW. Schemes in the UK are typically much smaller, with many coming about on rural estates as a means of accessing the commercial RHI (connecting a large manor house/hall to a cottage or other building), and as a means of maximising the use of the boiler as an asset.

Not including schemes below 100kW in size, figures from the Styrian Chamber of Agriculture and Forestry indicate that there were at least 1,500 biomass-fired district heating schemes in operation in 2008. The scale of the market, and the long-term involvement of government in supporting the development of district heating schemes in Austria is of particular relevance to this study, given efforts made to address similar issues to those revealed in the course of the research.

[11] Biomass Heating in Upper Austria, O.O. Energiesparverband, 2011
[12] Ecoheat4eu Project, Intelligent Energy Europe, 2011

General standards and guidance governing boilers, heating and hot water production

In Austria, there are standards in place to ensure that biomass installations are undertaken in line with best practice, and are safe and efficient in operation, although as with Denmark, these standards are applicable across all forms of heating systems. They are a mixture of EN, German DIN and Austrian Önorm standards, the most relevant of which are listed below:

- EN 12828: Heating systems in buildings - planning for hot-water heating systems
- ÖNORM H 5170: Heating systems - construction and fire safety requirements
- EN 12831: Heating systems in buildings - method for calculating standard heating load
- EN 13384: Flue systems - thermal and fluid-dynamic calculation methods
- EN 15287-1: Flue systems for heating appliances dependent on ambient air - planning, installation and commissioning
- EN 15287-2: Flue systems for heating appliances with external air supply - planning, installation and commissioning
- DIN 18160: Flue systems - planning and design.

In practice, it is regulations which relate to the competence of individuals to practice as heating engineers which ensures standards are adhered to and maintained, and specifically the pathway of training and education taken by heating engineers. Although similar to the UK - in both countries an apprenticeship is the starting point - it takes approximately 4 years in Austria, compared to 2-4 years in the UK, with apprentices starting at the age of 15 or 16 working alongside a trained and qualified tradesman.

After the 4 years of training in Austria, apprentices are then classed as trained installers, but are only permitted to work for a company and not to start their own business. In order to do this, they need to attend further training and prove that they have enough practical and theoretical knowledge of the heating industry. At all stages, knowledge and competence are assessed, and crucially, biomass heating systems are part of the mainstream education of heating engineers.

Quality standard or assurance schemes

Austria has a quality management scheme for its biomass heat sector that is an Austria-specific version of the Swiss-originated *QM Heizholzwerke* quality management programme. In Austria, QM Heizwerke (heating plants) is a quality assurance scheme specifically for district heating plants with a primary output in excess of 400kW and/or where the length of heat mains exceed 1,000 metres. QM Heizwerke is run as part of the Klima:aktiv (www.klimaaktiv.at) programme, funded by Federal Ministry of Agriculture, Forestry, Environment and Water Management.

The scheme is now mandatory, and originally came about from a desire on the part of the many small district heating system operators to improve the efficiency of their networks and reduce losses from the system, and (interestingly) observations by government of the poor performance of many publicly-funded district heating projects. The programme also aims to improve scheme reliability in operation, lower emissions and increase long-term profitability.

Launched in 2005, the scheme was a response to issues such as high heat losses, low plant utilisation rates, high electricity consumption and huge variations in investment costs per kW, largely as a result of poor design.

klima:aktiv
qm heizwerke

Figure 3: QM Heizwerke (Austrian Quality Management Scheme) logo

Baseline data from QM Heizwerke showed that at the start of the programme, the mean heat loss from surveyed district heating schemes was 20%, with the worst performing schemes showing heat losses of 48.5%. Since the introduction of QM Heizwerke, this mean value has now dropped to around 10%, and the worst performing scheme to around 28%. With over 1,100 schemes registered in the programme, this is a significant result for the industry.

Central to QM Heizwerke is the appointment of a QM Project Manager to each district heating project which falls within the schemes' remit. The QM Project Manager is selected/appointed at the start of the planning process from a regional pool of suitably trained and qualified experts in district heating systems. In a mature market like Austria, it is perhaps not surprising that this pool runs to well over 100 individuals - such a list in the UK would perhaps include two dozen. The cost of the QM Project Manager is paid for by the client, and the argument that they will ensure that a plant is optimised, high quality and efficient appears accepted without question.

The QM scheme relies on good data from heat networks, and continuous and automated data collection is a key part of the QM process. In contrast, it can be suggested that the removal of the requirement under RHI regulations to meter at the point of production and point of use, in an effort to simplify the scheme, actually deprives the industry, government and the operator of the network of this vital information. In the UK, a district heating system is typically a single entity (e.g. a traditional rural estate) heating a collection of buildings in their ownership, and efforts to cut costs by the customer and installer typically now result in the plant room heat meter being omitted from district heating schemes, other than where best-practice is argued for (either by the customer, their advisor or their installer) and is then subsequently applied.

A second leg of the QM Heizwerke scheme involves a service to optimise existing heating plants and heat distribution networks. The application of many decades of accrued and nationally collated expertise and information, underpinned by large quantities of operational data, allows QM Heizwerke to work with customers to correct and improve underperforming installations.

The QM Heizwerke programme also includes an active programme of training and events. As an example, these include:

- 2 day courses on “Lessons Learned”
- 2 day symposiums on district heating practice
- 4 day courses on training as a biomass district heating plant quality manager
- 1 day specialist seminars on topics such as “heat plant tuning”, “damage and failure analysis of biomass heating plants”, “optimisation of district heating plants” and “cutting edge control technology training”.
- Regular “feedback” days for QM Project Mangers to encourage information exchange.

Clearly, in a mature market with many hundreds of district heating systems and tens of thousands of automated biomass boilers installed, the body of hard-won technical knowledge in the Austrian biomass heating sector is huge, and they appear to be particularly successful at transferring this through training, information sharing and general cooperation. In our experience this differs from the UK, where technical knowledge gained in the field generally becomes closely-guarded intellectual property, used to provide a competitive advantage.

3.4 QM Holzheizwerke in Switzerland, Germany and Austria

QM Holzheizwerke (trans. Quality Management for Wood Heating Plants) was developed in Switzerland with the support of the Federal Office of Energy, and is a quality management system for the design and installation of biomass heating systems. The programme began in 1998, largely as a response to the same issues as those currently experienced with biomass heating systems in the UK, and with systems elsewhere in Europe over the past 30 years. QM Holzheizwerke covers all uses of biomass heat, and has three tiers: *QM Standard* is the standard method for all systems over 500kW and any biomass-fired district heating system over 200kW; *QM Holzheizwerke Vereinfacht* (trans. “simplified”) is for smaller bivalent installations in the 70-500kW range, including district heating, while for equivalently-sized monovalent systems, the *QMMini* scheme is used.

QM Holzheizwerke now operates as a partnership between Swiss, Austrian and German organisations, and is a requirement of state funding support for many biomass projects in these countries - all Swiss cantons recommend the QM approach, and its application is mandatory for subsidy support in several of them. In Germany, three regions have adopted *QM Heizholzwerke :* Baden-Württemberg, Bavaria and Rhineland.

The objectives of *QM Holzheizwerke* are to ensure reliable and low maintenance operation, high efficiency, low distribution losses, low emissions in all operating conditions, precise control and sustainable economic benefits - all of which appear to be regularly missed in many UK biomass heating projects. A key difference between the UK and the *QM* countries is likely to be the maturity of the market and of the businesses active within it, as well as the nature of the subsidy regimes, which in the UK (until the RHI) have been characterised by boom-and-bust, in contrast to the slow-and-steady approach of the German-speaking nations.

QM

Holzheizwerke

Figure 4: QM Holzhezwerke logo

In Austria, Switzerland and Germany, wood heating systems, particularly those with district heating networks, are recognised as long-term projects with high investment requirements and long payback periods. Equally high are the technical requirements for projects, meaning that even in highly developed biomass markets, professional project management is essential for realising a successful scheme.

Integral elements of project management are quality management, in the form of a quality plan, and the production of a detailed business plan. These documents and their accompanying processes provide assurance to clients that schemes will achieve high utilisation rates, require lower overall investment costs and can be operated successfully with low emissions.

Central to *QM Heizholzwerke* are detailed technical publications, which currently run to 6 volumes:

Volume 1 : Q-Guide - QMstandard
Volume 2 : Standard Circuits - Part I
Volume 3 : Pattern tender wood-fired boiler (Switzerland)
Volume 4 : Planungshandbuch
Volume 5 : Standard Circuits – Part II
Volume 6 : Guide for biomass boiler tender (Austria)

We have reviewed a German language copy of the Planungshandbuch (Planning Handbook), in order to give an indication of the level of development that the biomass heat sector has reached in Switzerland, Germany and Austria. At 248 pages, the *QM Heizholzwerke* Planning Handbook represents a huge resource of collective and collected knowledge and experience, gained over 16 years in three of the most developed biomass markets in the world.

Elements of *QM Heizholzwerke* have now been adopted in Slovenia, Belgium, the Netherlands and Japan.

3.5 Ireland

In June 2011, an in-situ study was published that looked at the performance of 39 schemes in the 7 western counties of Ireland from Donegal in the north to Clare in the south. This study was commissioned by the Western Development Commission (a regional economic development agency), that secured funding from the EU INTERREG IIIB Northern Periphery Programme for a project called: Regional Approach to Stimulating Local Renewable Energy Solutions (RASLRES).

The study is relevant to the UK because the western region of Ireland has a wood energy sector at a similar early stage of market development, so it can be assumed it faces similar issues to the UK market, unlike the continental European examples described above.

The study determined that there were 39 biomass boilers from 60 kW to 1 MW in the 7 western counties, 25 of these were visited and a number of trends were observed:

- Many of the schemes had a number of relatively minor issues that together had the cumulative result that the owner was not satisfied with the installation;
- The majority of boiler owners were unaware of other systems in their vicinity and operated in isolation, although many of the problems faced are the same.
- There were very few issues with the actual boilers.
- Problems tended to arise with the ancillary equipment; connecting to the heating system, loading fuel store, flues, unloading ash, etc.
- Of the 39 boilers installed, 15 different manufacturers were used. With such a range of boilers it is difficult for any one individual to understand them all thoroughly. Maintenance is a problem.
- The most common complaint was to do with the expense and difficulty in organising quality maintenance.
- A training programme to encourage local technicians to maintain a number of makes of boiler could go towards reducing this problem.

The following 2 quotes from the report are informative :

'*Our clear conclusion is that the sites that have had the fewest problems were those that invested the most in the design, installation and continued maintenance of the boilers. This was achieved by higher levels of client participation in the process and the use of well drafted contracts for the services being purchased'.*

'It was observed that private sector buildings tended to have more success with biomass systems than the public sector'.

3.6 Summary

One of the key findings has been that in the highly developed biomass markets of northern Europe (Sweden, Denmark, Germany, Austria, etc), many of the issues we are now experiencing in the UK biomass heat sector were eventually avoided and reduced by following long term clearly defined quality standards and training pathways to deploying biomass energy.

These pathways were typically developed by government working in partnership with industry and academia, and often supported by EU-funded projects such as Intelligent Energy Europe and Framework Programme 7.

These developed markets now appear to be at a stage of development where performance standards and installation practices for biomass systems are fully mainstreamed into general building and heating system standards, and as a consequence, the education required to ensure awareness and conformity with these standards is also mainstream. Finland, Sweden, Denmark and Austria lead in this regard.

This situation differs from the UK, which by comparison is still at a very early stage in the deployment of biomass heating technology, and also in the provision of standards and training to support its effective uptake. That said the absence of any quality standard above 45kW is remarkable, and contrasts markedly with most other countries that have seen a developing biomass heat sector.

EU standards have been developed through collaboration and knowledge sharing amongst the industry and with stable on-going public sector support over several decades. The body of hard-won technical knowledge, transferred through training, information sharing and general cooperation is a feature of all developed biomass markets. In our experience this differs from the UK, where what technical knowledge that is gained in the field often becomes closely-guarded intellectual property, used only to provide a competitive advantage.

European quality standard schemes were generally a response to issues such as high heat losses, low plant utilisation rates and variations in investment costs per kW, largely as a result of poor design. The quality standards rely on good data, and continuous and automated data collection is a key part of the process in many regions and countries. The application of many decades of accrued and nationally collated expertise and information, underpinned by large quantities of operational data, allows these schemes to work with customers to correct and improve underperforming installations.

For example, baseline data from QM Heizwerke showed that at the start of the programme, the mean heat loss from surveyed district heating schemes was 20%, and that this value has now dropped to around 10%.

A further factor has been the focus on standards that require that installers are well trained and are certified under detailed quality assurance and management schemes run in each country, and sometimes across borders. For example, a QM Project Manager is selected/appointed at the start of the planning process from a regional pool of suitably trained and qualified experts in district heating systems. In Austria, this pool runs to well over 100 individuals - such a list in the UK would perhaps include two dozen (for a country with an 8 times greater population).

In the one comparable overseas example (Ireland), the performance standards and installation practices for biomass systems appear similar to the UK, and of course they also lack the shared, developed and long term standards developed in the developed biomass markets.

4.0 Case Studies

4.1 Methodology

We made contact with 39 companies involved in the design, supply and installation of biomass heating systems. We believe this represents a good proportion of the UK market, although there is no way of exactly determining the actual number of companies currently active as installers.

We also made contact with 24 customers, ranging from large public sector bodies and private sector companies, to small estates and not-for-profit enterprises. We believe this is also a good sample of the current biomass heat customer base, and appropriate given the project budget for this study.

Appendix 1 contains a full list of all the suppliers and customers we contacted.

Our intention in making contacting with these suppliers and customers was to identify and secure case study data that illustrated the performance standards of biomass schemes. We focused on suppliers and customers we had prior knowledge of, or knew were likely to have suitable data. The data we were interested in securing was that which showed how much fuel (energy) was purchased and the amount of useful heat that was provided (metered heat at the point of use) by each scheme. Inevitably our data sample is not statistically representative of the sector, but we do believe it is the best and largest sample that has been gathered together in the UK.

We are grateful to all those that took the time to respond and provide us with information, without whose help the report could not have been completed. As a result we obtained performance data on 106 schemes. In order to keep the data anonymous we have removed references to individual sites and suppliers. Below, we have provided a description of these schemes, our understanding of how they are performing and what the data implies.

An important limitation about this data is that we cannot be certain of its accuracy, and there are several reasons why such data could be incorrect or misleading in some circumstances:

7. Heat meters may be incorrectly calibrated;
8. The tonnes of delivered fuel were not correctly weighed;
9. The moisture content of fuel was not properly recorded;
10. Heat meters are likely to be located in different positions, thereby recording heat outputs in different ways (not always at the point of use);
11. Data is not entered at all for periods in question;
12. It contains a preponderance of pellet-fired schemes.

In our experience, many of these possible problems will exist with the data, and this is exposed (but not fully explained) only when the efficiency of the system is subject to analysis. We have attempted to correct for these problems in examining the data we have obtained. Any corrections that have been made are explained for each case study below. In virtually all cases the data was a 'data set', showing in an excel spreadsheet the fuel purchased and the heat generated.

A further statistical point is that our sample, while relatively large, was self-selecting, and we could only include schemes for which we obtained suitable data. This means it is unlikely to be genuinely representative of the whole market. For example, we have no examples of process heat users, hotels, care homes, chicken farms or swimming pools; any of which could exhibit different performance standards. Furthermore, it is possible that data sets are most often collected where schemes are not performing as hoped, thus we may have used data that is worse than could normally be expected from the market as a whole.

4.2 Large Retail Sector

We have obtained data about 63 pellet-fired schemes in the range 350kW to 930kW, with a total installed capacity of 35,839kW. The data set relates to the period 2012/13 and 2013/14. The schemes are all heating large retail stores. The full data set analysis is shown in Appendix 2, This provides a very useful and large data set about how efficient the schemes are. The data set clearly contains errors so we have refined it and used only the 2013/14 data set (that contains 56 data sets), and we believe it offers a better view of the actual efficiency levels. Details of the error corrections which were applied are in appendix 4. This is shown in the table below:

Installation Capacity kWth	Fuel purchased KWh (13/14)	RHI kWh claimed (13/14)	Efficiency % (13/14)
520	1,488,960	1,277,819	85.8
697	2,179,200	1,803,575	82.8
696	2,456,400	1,775,235	72.3
755	1,424,000	1,000,210	70.2
520	1,372,800	941,898	68.6
520	1,862,851	1,271,776	68.3
520	1,693,128	1,148,371	67.8
520	1,887,663	1,266,267	67.1
465	1,840,533	1,220,175	66.3
755	1,330,285	879,088	66.1
520	1,700,945	1,113,196	65.4
520	1,957,028	1,271,822	65
520	1,780,114	1,151,863	64.7
520	1,688,746	1,092,522	64.7
464	1,645,714	1,040,763	63.2
520	2368000	1,496,782	63.2

755	2,117,866	1,328,546	62.7
465	1,245,818	780,273	62.6
465	1,116,266	694,163	62.2
755	1,999,542	1,233,290	61.7
520	2,123,586	1,303,303	61.4
464	952,246	581,555	61.1
520	1,632,000	988,671	60.6
696	1,939,200	1,171,398	60.4
630	2,317,776	1,359,347	58.6
696	2,142,857	1,250,709	58.4
520	1,591,200	925,008	58.1
630	1,333,527	771,831	57.9
755	1,116,872	645,784	57.8
464	1,654,400	953,372	57.6
465	1,680,000	962,577	57.3
348	1,570,863	887,950	56.5
520	1,644,218	926,526	56.4
465	1,378,400	743,559	53.9
464	1,381,800	743,746	53.8
697	1,723,733	896,990	52
520	1,098,830	561,271	51.1
465	1,566,424	799,663	51.1
406	1,596,800	807,473	50.6
750	1,974,400	993,629	50.3
465	1,200,685	588,464	49
930	2,007,360	982,978	49
520	1,547,657	751,327	48.5
580	1,902,670	918,028	48.2
348	1,254,400	559,650	44.6
520	2,188,114	928,079	42.4
520	1,540,800	641,556	41.6
465	1,200,000	498,637	41.6
520	1,508,400	598,555	39.7
520	1,606,400	592,680	36.9
464	1,913,066	694,875	36.3
520	1,950,933	698,497	35.8
465	1,364,135	372,529	27.3
465	1,374,600	356,875	26

630	1,291,200	302,807	23.5
930	2,759,712	569,390	20.6
			55.12%/Avg

Figure 5: Retail sites efficiency outcomes 2013/14

The graph below shows the distribution of the efficiency outcomes:

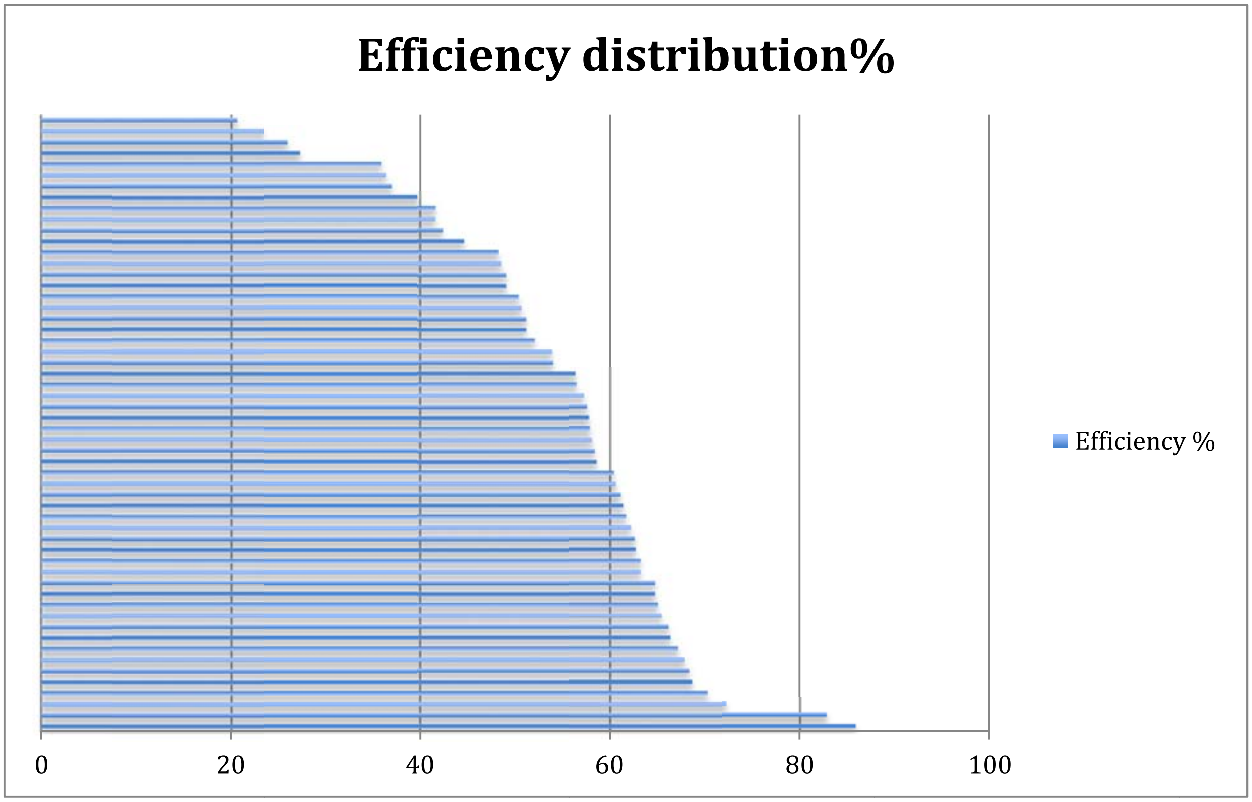


Figure 6: Large retail distribution of efficiency outcomes

The table and graph show the overall average efficiency of the schemes as 55%. The median efficiency is 58% and the highest efficiency is 85%. The average efficiency of the top ten performing schemes is 71%, however, a large group of schemes were operating at below 50% efficiency. Whilst limitations in the data mean we cannot categorically state that these are actual system efficiencies, the sample is sufficiently large that the observed performances are a cause for concern.

We cannot comment confidently on the validity of these figures until we have visited a sample of the sites to establish how the data is collected and what it is recording. However, we know all these sites are pellet fired schemes, and that removes a significant concern about variability in the energy content of fuel (as would be the case with chip fired schemes). We also understand that district heating pipes between the biomass scheme and the point of heat use (that would distort the data) are not likely as these are in a retail setting and so will have service yards with easy enough access to the existing heating plant. These factors suggest we may have reliable data, and the average efficiency of the top ten performing schemes (at 71%) would indicate expected outcomes. However, the large number working below 50% might equally indicate data problems as this is much lower than we would expect. It is hard to reach any other conclusion than the data indicates cause for concern.

4.3 Small Scale Residential District Heating

The second customer has a wood pellet boiler that serves three residential properties. The system also has a backup LPG boiler, although this has not yet been used. The scheme has heat meters on the outputs from the pellet boiler and the LPG boiler, and on the inputs to the heating systems in each property, as per the original requirements for schemes classified as “complex” for the RHI.

The pellet silo has a level-sensor to monitor fuel levels, so we are able to make reasonably accurate comparisons between pellet usage and the output from the boiler.

The system was installed in October 2011 and was approved for the RHI in April 2012. The table below shows recorded efficiency over time.

	Meter readings (cumul. MWh)						Wood pellets	Boiler	Network
	Pellet boiler	LPG boiler	House 1	House 2	House 3	All houses	(cumul. tonnes)	efficiency	efficiency
18-Dec-11	6.25	0	7.16	3.82	3.39	14.37	5.12		
14-Feb-12	34.91	0	18.21	9.37	8.69	36.27	11.71	90.6%	76.4%
01-Apr-12	53.36	0	24.99	12.44	11.78	49.21	15.95	90.6%	70.1%
16-Aug-12	82.95	0	33.30	15.67	14.53	63.50	23.18	85.3%	48.3%
19-Nov-12	111.10	0	42.83	19.50	16.55	78.88	29.31	95.6%	54.6%
16-Feb-13	158.74	0	60.59	28.55	23.24	112.38	40.12	91.8%	70.3%
31-May-13	206.71	0	76.69	38.69	28.79	144.17	51.50	87.8%	66.3%
13-Aug-13	220.99	0	79.48	40.11	29.23	148.82	55.00	85.0%	32.6%

Figure 7: Small scale residential district heating efficiency

The pellet boiler appears to be roughly as efficient as expected when the scheme was first planned (90% as stated by the boiler manufacturer). It is impossible to be absolutely precise about the quantity of fuel used, but the fuel supplier is confident that the error in estimation of this figure would not account for a discrepancy of more than around one or two percentage points.

This leaves the boiler still at around 90% efficient and the average efficiency of the network since the first meter reading at around 64%, giving a combined efficiency of 58%.

The network efficiency is higher in winter than in summer because the losses are primarily a result of constant heat circulation rather than badly-insulated pipes. When circulation happens in summer when there is little or no load in the property, then heat losses are proportionally far higher than in winter. The boiler is probably also experiencing a small lower efficiency impact as it works less well as the load reduces (and cannot work at all below about 30% of its full load).

4.4 District heating x 25

We have been provided with data on the operational performance of 25 district heating schemes (see Appendix 3 for the full data set). The data set does not include performance information about boiler combustion losses, it only measures standing losses inside the plant room (after the boiler) until the point of use at the end of the heating networks. The graph below shows the main findings:

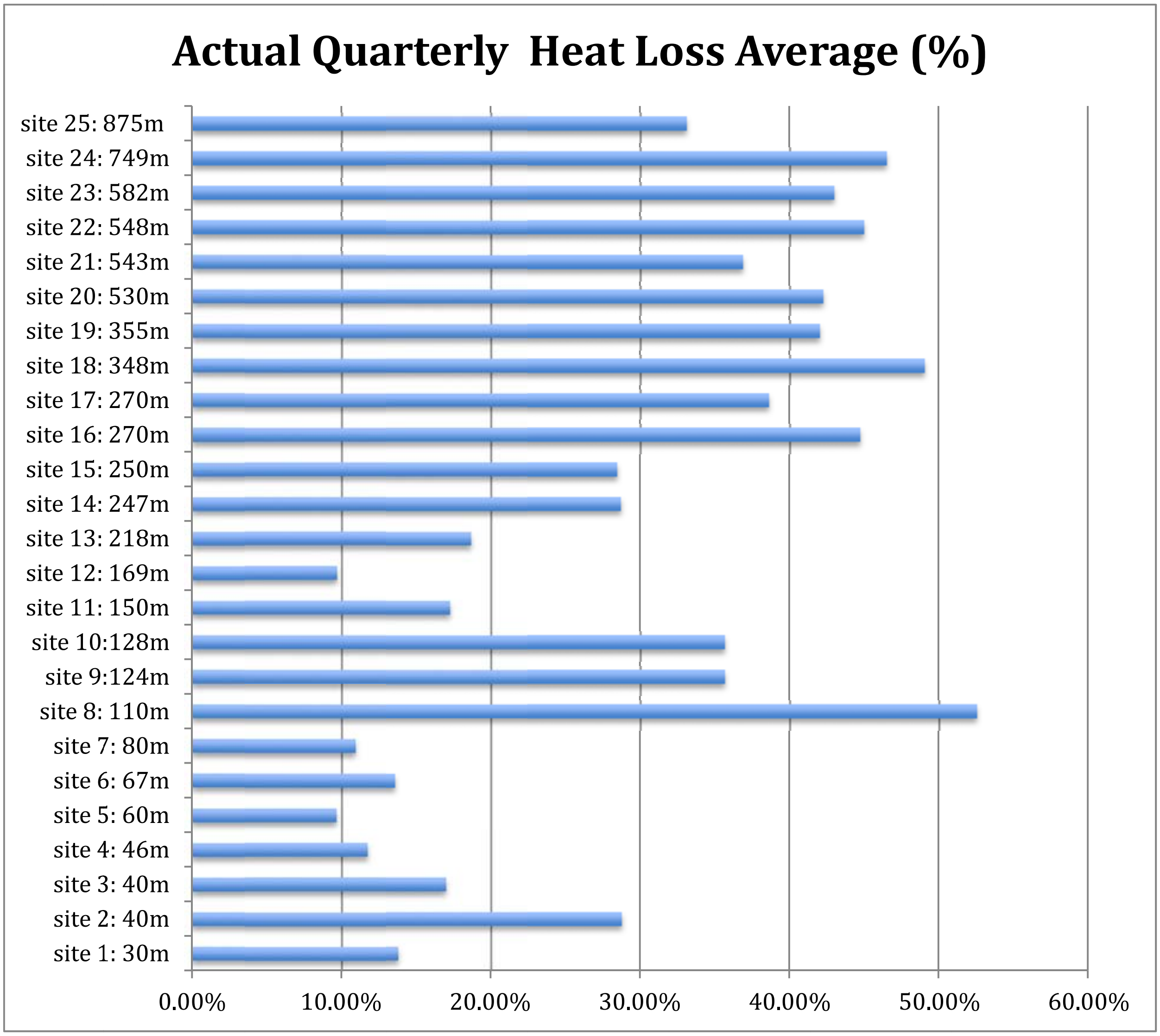


Figure 8: District Heating Losses

The chart shows the length of district heating pipe and the losses recorded in that pipe from the boiler to the point of use. These figures are a little distorted by the fact they also measure plant room losses, that we would expect will typically amount to between 5% and 10%.

Because the data set is relatively large, it provides very good average performance information on small-scale biomass fired district heating schemes *heat networks* (i.e. in this case not overall system efficiency). In general, it covers boilers under 300kW with district heating mains varying from 30m to 875m, with an average across all schemes of 258 metres.

The principle finding is that actual heat loss is running at about 32% for this group of sites. The data also shows that this is higher than would be expected if the pipe manufacturers' data on heat loss had been relied upon. It is important to note that this 32% loss is measured **after** boiler combustion, and therefore excludes the combustion efficiency losses experienced in the boiler. Taking into account the plant room losses this suggests a range of 22% to 27% losses on average. However the data is highly variable and site visits are required to fully understand the findings and better explain some unexpected outcomes (such site 2, site 8 site 12 and site 25).

4.5 Residential High Rise Heating

In 2011/12, a registered social landlord (RSL) commissioned biomass heating into 5 large existing high rise blocks. Since then, they have been working on a programme of optimisation to ensure the biomass schemes are working effectively. As part of this, a model of how they are intended to perform has been developed, and is shown in the table below:

Site	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Average**
Run hours	4122	4354	4354	1194	3877	3580 hrs
Input energy/fuel - MWh	8066	6815	3089	834	2534	4268
Gas/biomass split	40/60	25/75	25/75	10\90	10\90	NA
Boiler combustion losses	15%	15%	15%	15%	15%	15%
Inside plantroom losses - MWh	400	263	175	113	131	216
Outside plantroom losses - MWh	555	745	105	17	53	295
Inside plantroom losses - %	5.9%	7%	7%	15%	6%	8.18%
Outside plantroom losses - %	8.5%	21.5%	4%	3%	2%	7.8%
Total heat delivered - MWh	5,901	4,784	2,345	572	1,970	3,114
Overall efficiency	**70.6%**	**56.5%**	**74%**	**67%**	**77%**	**69.02%**

Figure 9: High rise - design standards

This data is useful in that it provides an indication of how the schemes were designed to perform. So the calculated average efficiency losses come to 31% for these sites, meaning the designed level of efficiency can be stated as 69%, assuming the all the schemes were operating as intended and fully optimised. The best modeled efficiency is 77% and the median is 72.3%. It should also be noted that early data on actual performance (with not yet a full year's worth) is showing that these schemes are not achieving these standards as yet, but progress is being made.[13]

4.6 Large Hospital

This boiler scheme is a 500kW step-grate boiler fed from a bank of hook bins. The boiler provides heat to a large public sector hospital in Scotland. We have been provided with fuel supply and heat meter data for this scheme. The data covers 2 periods:

[13] However we have included these figures in our review as if they are achieved

Period 1

From April 2012 to September 2013 (17 months), the scheme took delivery of 2,540 tonnes of wood chips with an average moisture content of 31%. As each tonne of wood chip at 31% moisture content contains 3,431 kWhs of energy, the total amount of energy delivered over the 17 months was 8,714,740 kWhs. A heat meter on the output side of the boiler records that 4,708,940kWhs of useful heat was supplied by that fuel.

Period 2

From September 2013 to March 2014 (7 months), the scheme took delivery of 1,016 tonnes of wood chips with an average moisture content of 38%. As each tonne of wood chip at 38% moisture content contains 3,014kWhs of energy, the total amount of energy delivered over the 7 months was 3,062,224kWh. The heat meter records that 2,382,580kWh of heat was supplied by that fuel.

Total Period

From April 2012 to March 2014 (2 years), the fuel as purchased was 11,776,964kWh. In the same period, recorded heat output was 7,091,520kWh.

We can therefore conclude that this scheme was operating at an efficiency of 60% in this period.

4.7 Wood Chip District Heating

In 2010, a rural estate and charity installed a biomass boiler to supply heat to 13 of its community facilities: a performing arts centre, a community centre, an office and educational building, several guest bungalows and a hot tub.

The boiler, boiler-house, district heating pipework and requisite plumbing within each of the facilities cost approximately £350,000. The boiler is rated at 250kW, factory fitted within a purpose designed boiler house that also contains a fuel store. The system was commissioned in September and was fully operational by October 2010.

A feasibility study commissioned before the project went ahead (and upon which that decision was based) predicted that the scheme would save between £10,000 and £12,000 per year in fuel costs. The first year actual savings were £11,358.55, so this figure is exactly as the feasibility study predicted (i.e. between £10,000 and £12,000).

In the first year of operation they took 47 deliveries, a total of 565.25 m^3 of fuel costing £9,326.76 + VAT. That works out at 217 tonnes of wood fuel, which was about 30% moisture content. This means they purchased about 766,000kWhs of energy.

The scheme was recording as producing about 422,190kWhs of heat (at the points of use in each connected building). Therefore, it lost 343,810KWhs of energy in the biomass system and district heating network.

This means this system was working at an overall efficiency rate of 55%. In this case, the customer was fully aware of the system efficiencies, and was highly satisfied with a 55% efficiency - as they knew this was the likely outcome. In this case the efficiency includes a district heating network and so it far higher than simple schemes without heating networks.

4.8 Pellet Boiler Heating a Village Hall

We have obtained data on the supply of pellets for a small boiler over the period February 2012 to March 2014, where 19.15 tonnes were supplied in total. At 4,800kWh per tonne, gross, the energy delivered in that period was 91,920kWh.

In the same period the heat meter recorded 66,000kWhs.

This indicates that the scheme was operating at 74% efficiency. We have no details on the measurement points, but since this is small scheme run on pellets we expect this data to be a reliable indication of biomass efficiency in this case.

4.9 Schools x 8

We have obtained data on 8 Primary and Secondary schools[14] for the full year of 2012, showing the amount of fuel purchased in kWh and the meter readings at the point of use (therefore the losses are associated with the boiler and plant room until heat is supplied into the schools). This data is summarised in the table below for the 7 schools that we have reasonably reliable data for.

This data suggests the average efficiency of these 7 schools is 79%. However this includes one scheme which shows an efficiency of 92%, which is not possible, as it suggests no standing losses in or outside the plantroom, and a boiler combustion performance that probably exceeds manufacturers' tested figures. If we exclude this scheme, the average efficiency of the remaining 6 schools is 72%. The worst performing site is down at 47% efficiency.

School Site	kW (boiler size)	Meter readings in 2012	Fuel purchased in 2012	Efficiency
Secondary School	900	552,418	601,138	92%

[14] The data one school shows more energy supplied by the meter than purchased as fuel and so we have rejected this data.

Secondary School	600	970,346	1,066,098	90%
Primary School	300	78,393	119,040	65%
Secondary School	300	155,596	329,865	47%
Secondary School	300	180,870	271,826	66%
Primary School	250	146,206	212,432	69%
Primary School	300	231,752	345,915	67%
Totals	2,950	2,315,581	2,946,314	79%

Figure 10: Schools x 7

4.10 Biomass-Fuelled Stoves with Back Boilers

The scope of this study includes examining the efficiencies of biomass fuelled stoves with back boilers. A stove with a back boiler can be used to supplement domestic existing heating systems or to entirely run domestic heating and hot water.

Stoves Online (http://www.stovesonline.co.uk) publishes data on the efficiencies of a large number of companies that supply wood boiler stoves. Below we have listed the reported efficiencies and the calculated the overall average, best and worst efficiency.

Manufacturer	Average	Best	Worst
Woodfire	79.85%	84%	74%
Stratford	69.51%	72.8%	60.8%
Broseley	77.6%	82%	75%
Aquatherm	77.81%	78.4%	75.1%
Esse	74.5%	78.5%	70.5%
Klover	90.93%	92%	89.4%
Herald	76.1%	78.9%	71%
Stockton	75.66%	81%	65%
Franco Belge	72.87%	74.3%	71.9%
Morso	75.25%	80%	71%
Aarrow	77.33%	86.3%	72%
Charnwood	77.24%	80.5%	74.1%
Villager	75.16%	78.4%	71.5%
Averages	**76.91%**	**80.62%**	**72.31%**

Figure 11: Stove combustion efficiencies

This shows that the suppliers of wood boiler stoves expect that the typical (average) combustion efficiency of their products will be 76.91%.

We have no reason to suppose this figure is not a reasonable estimate of the direct combustion efficiency of a typical wood boiler stove.

However this figure is not a measure of how efficient the whole system is in providing central heating or domestic hot water, or both. Ranges of factors are likely to affect the overall efficiency of a system.

In a traditional wood boiler stove the boiler is usually a simple metal box filled with water. Generally then a boiler stove installation is coupled with a thermal store that then connects to the radiators and hot water pipes in the property. Finally the output of the stove will vary according to the heat load.

This process means there will be standing losses between the stove and the point of use, which will vary according to design, output, heat load and operation. Self evidently the typical combustion efficiency of 76.91% will not be actual efficiency in converting the fuel (generally logs or pellets) into useful heat at the point of use. For example a system with low loads charging a large thermal store may well have very high standing losses and system efficiency could be well below 60%.

We have therefore searched for independent tests or research on the efficiency of these domestic scale installations and cannot find any published data. We can say that typical system efficiency will be below 76.91%, but how far below that figure we do not know.

Furthermore, unlike for the larger biomass heating systems reviewed in this report, we also cannot source any case study information about specific installations. It is perhaps not surprising given that these are domestic applications.

Finally we also do not know what would be a benchmark figure for system efficiency as this is not provided by the suppliers or suggested by others involved. To that extent boiler stove installations have the same absence of performance standards as larger biomass boilers.

4.11 Conclusions from Case Studies

The table below offers a summary of the system efficiency levels we observed from the 106 schemes on which we obtained data. We have removed data we believe to be incorrect or distorted. This means we have removed losses associated with heat networks and any efficiency above 91% (as we believe that would be impossible). Our confidence in this data is somewhat limited as we have not site verified how it was collected and of course we did not collect the data personally. However, we are confident that the data offers a reasonable guide to how schemes are performing given its wide range and scope, and is better than any other information so far collected in the UK.

This shows that the reported efficiency of schemes (excluding district heating networks) ranges from 55% to 90%. A 90% outlier figure relates to a single small pellet boiler, so the vast bulk of our data is in the range 55% to 85%.

The data can be analysed in a number of different ways, so for example the average reported efficiency is 69.8%. However the largest data set shows median efficiency at 58%. All efficiencies reported relate to schemes excluding district heating and refer to the overall efficiency of the system in delivering heat as defined at the start of this report.

Sites	Average	Median	Top Ten Avg	Best
63 x Large Retail Sector (pellets)	55%	58%	71%	85%
1 x pellet fired residential scheme	90%			
5 x high rise (forecast not actual) (Chips)	69%	72.3%		77%
Large Hospital (chips)	59%			
Village hall pellet boiler	74%			
8 x schools (chips	72%			

Figure 12: Summary Findings

Our central conclusion is that the typical levels of actual system efficiency (excluding district heating networks) from our case study samples are in the range 58% to 75% with an average figure of 66.5%. These figures must be treated with a degree of caution given the case study samples available to us, and the limitations of that data. However these figures are likely to be the most accurate available to date in the UK, and certainly indicate a general order of performance from large sample size.

5.0 Performance and Efficiencies of Biomass Heating Systems

5.1 Introduction

In order to determine if biomass heating systems are performing efficiently, it is necessary to establish and understand the appropriate performance standards they should be achieving. As noted previously, the UK sector has not yet developed any standards in this area (and has no long term data to draw upon unlike some EU nations).

The scope of this research precludes a structured and complete development of such standards, however, we have developed some suggestions (using only our professional judgments) that we have used to compare with our findings on what is actually happening in practice. It is important to note these are lower than the references that have been used by DECC and the Carbon Trust, and certainly lower than the many suppliers who quote appliance combustion efficiencies as a matter of routine in promotional and sales literature, and in proposals to customers. This is not necessarily a deliberate attempt to mislead, as these figures can be used by customers to compare different appliances, albeit with no further clarification of where other losses can occur in a system.

5.2 System Losses

The performance of a biomass heating system can be measured by its efficiency in converting the energy stored in wood fuel into useful heat at the point of use[15]. The three main measurable factors that determine the efficiency of biomass fired systems are:

- Boiler-related losses
- Plant room losses
- Outside the plant room losses (including district heating networks)

It is worth defining each of these and exploring the issues that affect efficiency outcomes in operation, and we have attempted to offer a preliminary view on the actual levels of performance that can be expected.

5.3 Boiler Related Losses

The energy stored in the delivered fuel is converted into useful energy by transferring heat from combustion to hot water in the heat exchanger of a boiler. This process results in some loss of heat energy, primarily to flue gases, and most biomass boilers manufacturers will measure performance against the EN 303-5:2012 standard for "heating boilers, manually and automatically stoked, nominal heat output of up to 500kW", with the losses and reported efficiency levels typically in the range of 88% to 94% cited in promotional and technical literature.

[15] The point of use is defined as the place where the heat enters the customers heating system - generally in an existing plant room

Overall boiler efficiency is somewhat different, and can be defined as useful heat output per hour divided by energy input (in the form of fuel) per hour, and is of particular interest to boiler owners and operators, as it also considers radiation losses from the boiler to the plant room and from unburnt fuel in the ash. Boiler efficiency is determined and expressed as an instantaneous value, but the nature of construction of most biomass boilers means they have considerable heat storage capacity in water jackets, heavy steel construction and in refractory linings. Therefore, a reliable value for boiler efficiency can only be determined over a period of operation.

Furthermore, other factors may also impact on boiler efficiency, such as whether the boiler is designed and set up for base load operation, or is intended to meet peak loads, which will affect boiler efficiency. For example a typical base load situation would be heating a swimming pool, where the load is high and constant and so makes it easier for the boiler to operate at higher efficiency levels. Conversely a peak load situation such as a school with high morning peaks as the school is heated when staff and students arrive, reduces performance somewhat (due to constant cycling up and down in output). In addition, the settings and control optimisation of the boiler will impact upon achieved efficiency, by promoting effective combustion and reducing issues like cycling (the boiler constantly ramping up and down or on and off).

Biomass boilers are also manufactured to use a specific range of fuels. For example, small boilers using dry pellets (10% moisture content) and large moving grate boilers that can use wood chips (45% to 50% moisture content). Manufacturers often state the combustion efficiency of their boilers for these different fuels, and our experience is that this can range from c. 94% (for pellets), down to c. 80% (for wet chips). Ash content can also impact on combustion efficiency, and fuel quality can influence boiler efficiency to some extent.

Overall, our professional judgment is that boiler related losses could be as high as 20% and as low as 6% measured over a whole year.

5.4 Plant Room Losses

All plant rooms contain pipework that move hot water from the point of production (by the boiler) to the point of use. Plant rooms will also typically contain various interfaces and other pieces of fixed equipment, such as plate heat exchangers, pumps, valves and so on. With biomass boilers, almost all installations should also contain buffer tanks (also referred to as accumulator tanks) that store water heated by the boiler. All of these system components hold, move or exchange hot water, with the result that energy is lost from the system.

All things being equal, a high stable heat load reduces standing losses compared to situations where the heat load varies significantly over the day or over the year (such as small school or in residential district heating). Generally systems are designed to either be base load (stable) or peak load (variable), although a combination of the 2 approaches is also possible.

Clearly, good practice design that minimises unnecessary components and has a control strategy to reduce unnecessary operation, as well as properly-insulated pipes and equipment, will reduce standing losses. The measurement of these standing losses is expressed in kWh of loss over time, but is often (more crudely) expressed as a percentage of fuel input. We expect that such losses are typically between 5% and 10% in most situations.

5.5 Outside the Plant Room Losses (District Heating Networks)

Once heat has been created in a plant room, it must be delivered to the point of use. Where that point of use is next to the plant room, there will be some minor losses in transmitting the heat from the plant room to the heat demand. However, where long distances of district-heating pipes are required to deliver the heat, and depending upon the type of pipe, the quality of installation and the distances involved, there are likely to be significant losses associated with this heat transfer.

The measurement of these standing losses is expressed in kWh of loss, and expressed as a percentage of fuel input, we expect such losses will be low, at around 3% where there is no district heating element. With district heating however, evidence in this report suggests that the losses will vary greatly - from 15% to over 30%.

5.6 Estimated Losses

Using this analysis we have developed 4 general scenarios that illustrate expected typical losses across a range of system types over a 12 month period.

Situation	**Boiler-related losses**	**Plant room losses**	**Outside plant room losses**	**Range of total expected annual losses**
Base load boilers without district heating	6% to 15%	5%	3%	**14% to 23%**
Peak load boilers with district Heating	10% to 20%	10%	15% to 40%	**35% to 70%**
Peak load boilers without district Heating	10% to 20%	10%	3%	**23% to 33%**
Base load boilers with district heating	6% to 15%	5%	15% to 40%	**26% to 60%**

Figure 13: Likely Whole-System Losses (% of energy in input fuel)

This simple analysis offers a view on the possible range of system losses from the most extreme situations of smaller peak load boilers using wet fuel connected to large district heating networks to base load boilers using dry fuels. Of course, the inversion of these figures can express overall performance standards.

5.7 Possible Performance Standards

The table below shows this range and a central measure for schemes without district heating. These figures assume that the systems are well designed, accurately sized, correctly installed, properly optimised and adequately maintained. They show the overall system efficiency from fuel input to heat output at the point of use. In practice, these ideal conditions may not always be achieved. To reiterate these are figures we have developed using our professional judgment for the purposes of comparing actual performance levels.

Situation	Max efficiency (annual)	Worst efficiency (annual)	Central efficiency (annual)
Base load boilers (without district heating)	86%	77%	81.5%
Peak load boilers (without district heating)	77%	67%	72%

Figure 14: Possible Performance Standards (% of energy in input fuel)

The average (central) performance standard is therefore 76.75% (equal to 23.25% overall losses).

For those schemes that include district heating, the performance standard range could well be in the range 65% at best to 30% at worst. However, reporting likely figures for those schemes that include district heating is less useful, as the losses are highly affected by the size of the heat network and so are always site specific.

It is important to note that these estimates are not very different from how a gas, oil or coal fired heating system would perform in a similar situation. The only 2 inherent differences will be that fossil fuel boiler systems tend not to have buffer tanks (which will increase standing losses slightly) and don't have the problem of varying moisture content fuels to cope with. In other words, the estimated central performance standards of 81.5% to 72% (and 76.75% on average) would only be slightly exceeded if the boiler were gas, oil or coal fired.

Of course, district heating losses will be exactly the same regardless of the heat source, but very few district heating systems (other than those in major cities) are coupled with fossil fuel boilers. The desire to maximise the use of an expensive biomass boiler by linking additional loads through district heating networks is one reason why district heating networks are often a feature of biomass installations. Similarly, the ease of external packaged plant rooms means they are proliferating under the RHI and require connections to the building(s) they are heating. Finally, district heating is, in many cases, being used as an 'enabler' for the commercial RHI - providing eligibility for the scheme, regardless of whether district heating is an appropriate design choice for a particular group of properties or not.

5.8 How do possible performance standards compare to case study performance?

Below, we have compared our suggested performance estimates to the data we collected on the case study schemes.

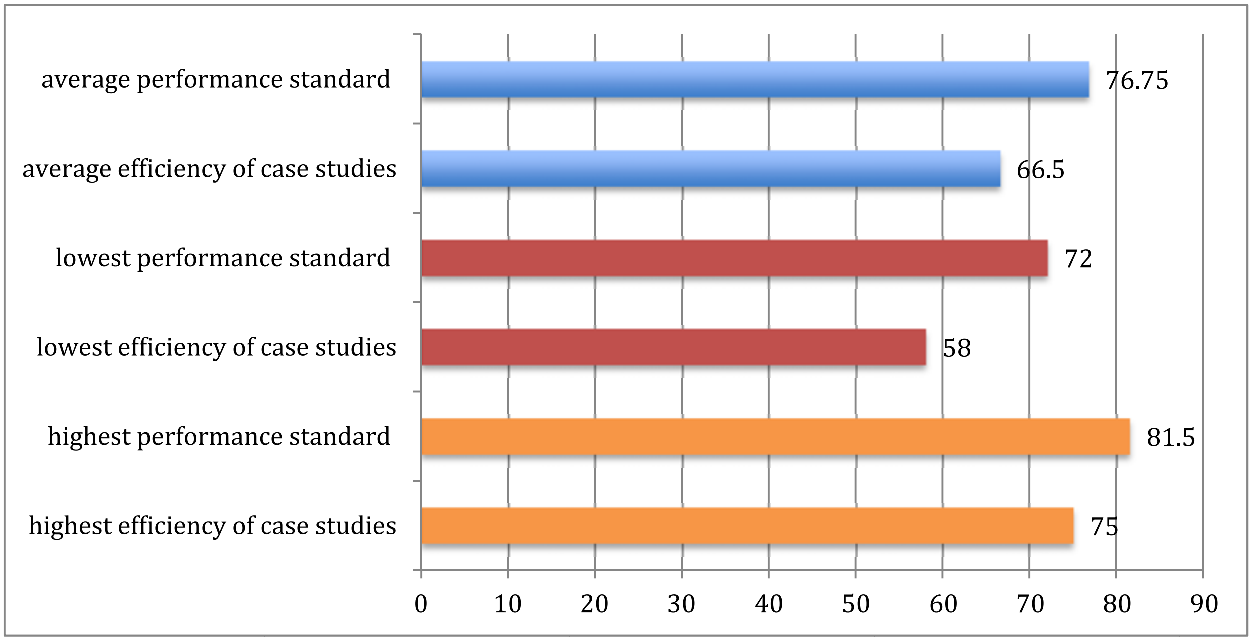


Figure 15: Case study sample compared to suggested performance standard (% efficiency levels)

The chart illustrates that in all cases (average, lowest and highest), the case study observed performance standards fall below our suggested standards.

In approximate terms, we show that there is 10% under performance, however this may be worse when recorded performance standards are compared to the statements made by many installers about performance standards: which, as we have already noted, can be 90% or more, and not the 66.5% average we have found in the case study sample.

It appears highly likely that suppliers, installers and advisors involved in the biomass heat sector have not fully recognised or adequately acknowledged overall system performance standards, tending to simply focus on the boiler combustion figures stated on test reports when asked about performance standards. Of course, we have acknowledged that some individuals and companies have appreciated the importance of this issue, nevertheless, it is disappointing if not surprising, that most customers are not afforded the correct information when they are deciding to invest often considerable sums of money.

In our view the consequences are that this lack of clarity has created expectations amongst customers that cannot be fulfilled, leading to the perception that biomass heating systems are inefficient and don't compare well to fossil fuel systems. From anecdotal evidence, this would appear to be a growing reputational issue for the sector.

6.0 RHI Data Analysis

6.1 Introduction

The RHI data offers a good source of information that can demonstrate trends and provide an indication of whether performance standards are a cause for concern. In this section, we have attempted to reconcile our main findings about poor measured performance standards in Section 5 with RHI data.

The RHI scheme opened in November 2011, at which point Ofgem started accrediting biomass installations (and other forms of renewable heating technology). We have been provided with some aggregated data about all the biomass schemes to date that have obtained RHI accreditation[16]. The following provides an analysis and commentary on this data, which covers the period from the beginning of July 2009 to the end of January 2014; some 4½ years.

6.2 Number and Size of Installed Schemes

Over the 4½ years since systems were counted as eligible for the RHI, 3,143 installations have been accredited under the scheme to date. The rated outputs of these (in kW) is shown below, grouped into 8 bands :

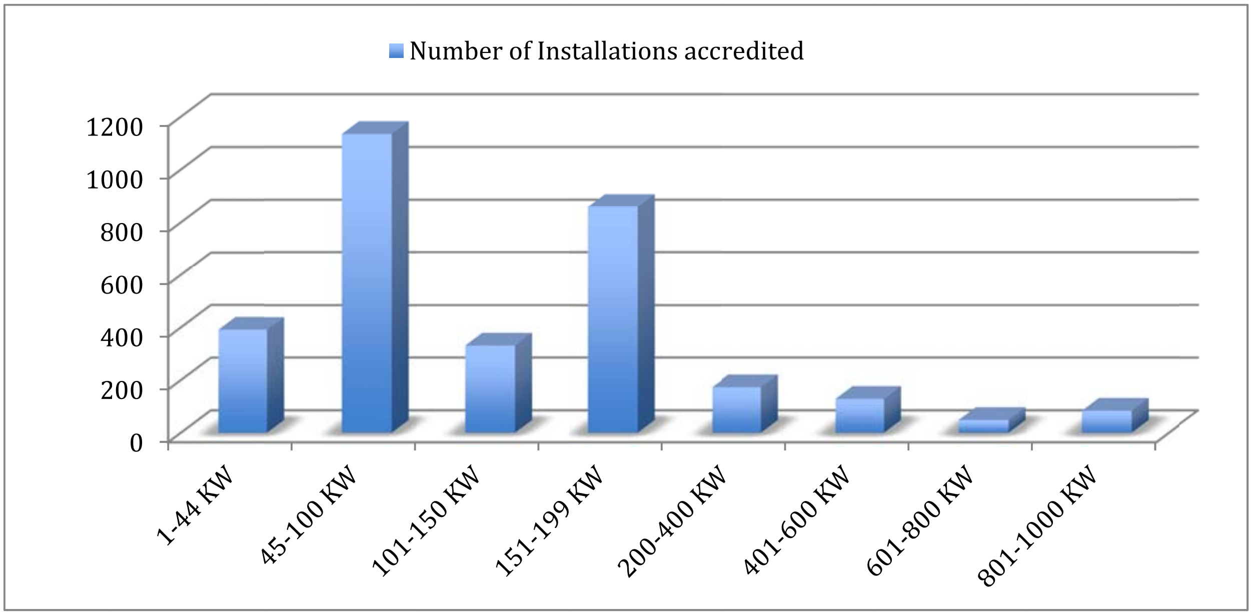


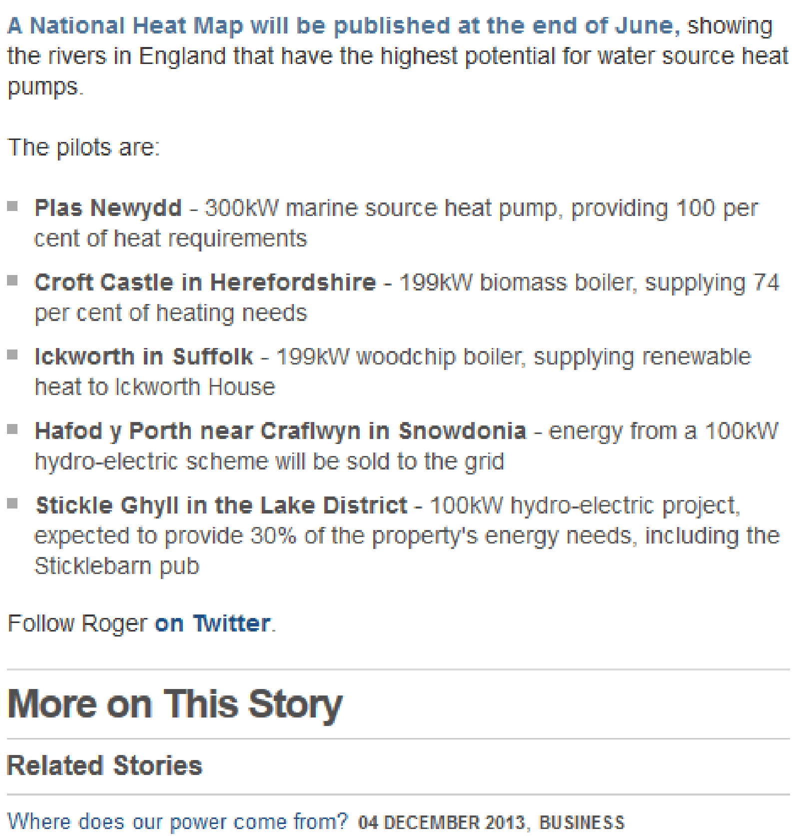
Figure 16: Number of RHI Biomass Schemes by Boiler Size (as at April 2014)

Due to the nature of the tariff bands, we would have expected a preponderance of schemes just below 1,000kW and just below 200kW. The data does suggest this is happening to a certain extent, and, for example, of the 857 schemes in the range 151kW to 199kW, 795 (67%) are above 189kW. Similarly, of the 83 schemes in the range 801kW to 1,000kW, 72 (87%) are above 899kW.

[16] The data has been anonymised to ensure no individual schemes are commented upon. RHI data does not include information on the amount of fuel purchased to produce eligible heat. It was supplied the RHI statistician at DECC.

However, the large number of schemes between 45kW and 100kW does not follow that trend, but could be accounted for by an unseen tariff 'band' at 45kW, namely the requirement to be MCS registered and accredited for installations at 45kW and below. Anecdotally, we are aware of installers oversizing boilers to ensure the installation falls outside the MCS requirement, and it is also the case that many manufacturers have no boilers models in the 41-45kW range.

Overall, our view is that the data indicates that the tariff bands are encouraging schemes just under 200kW and just under 1,000kW. We highlight this trend as there is no reason to suppose such schemes are responding to heat loads and market trends, they are in fact probably mostly driven by maximizing the returns achievable from the incentive. This is illustrated by the article below from the BBC website on 22 May 2014, which shows 5 pilot renewable energy schemes being undertaken by a large conservation charity - both biomass boiler projects are sized at 199kW, one of which is stated as supplying "74% of heating needs".



A National Heat Map will be published at the end of June, showing the rivers in England that have the highest potential for water source heat pumps.

The pilots are:

- **Plas Newydd** - 300kW marine source heat pump, providing 100 per cent of heat requirements
- **Croft Castle in Herefordshire** - 199kW biomass boiler, supplying 74 per cent of heating needs
- **Ickworth in Suffolk** - 199kW woodchip boiler, supplying renewable heat to Ickworth House
- **Hafod y Porth near Craflwyn in Snowdonia** - energy from a 100kW hydro-electric scheme will be sold to the grid
- **Stickle Ghyll in the Lake District** - 100kW hydro-electric project, expected to provide 30% of the property's energy needs, including the Sticklebarn pub

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Figure 17: 5: News Article, www.bbc.co.uk/news/science-environment-27505207

Therefore, in every likelihood, a number of these are not correctly sized for the heat loads - they are either too large or too small, with consequences either way[17].

[17] A third consequence is that rather than design an installation around a single large boiler at, say 800kW, projects are being 'broken down' into multiples of 199kW systems in order to maximise RHI returns. There is clear evidence for this 'breaking

Where boilers are oversized, the implications are generally that it will operate less efficiently and also give rise to higher visible emissions (particulates). The installation may also experience issues with condensation forming in the flue and boiler tubes, and with tarring in the same, both of which increase the maintenance burden and shorten the life expectancy of the equipment. The frequency and reasons for oversizing are not easily quantifiable without more field research, but reasons may include:

- Lack of knowledge on part of designers and installers;
- Routine oversizing, as with oil and gas boilers, to avoid customers 'being cold';
- Oversizing to meet planned future need (particularly with district heating schemes);
- Large gaps or steps in manufacturer size ranges;
- Use of the returns possible at 199kW as a sales tool, i.e. making the investment case as attractive as possible to customers;
- Sales staff incentivised with bonuses based on % of equipment or final sale value.
- Other legitimate and illegitimate reasons are undoubtedly possible.

Undersizing of biomass boilers appears to be less common, although a proportion of the 857 schemes that fall into the 151-199kW range in the data will undoubtedly have been sized at 200kW or above were it not for the 199kW tariff break point. Undersizing is, generally speaking, less serious for boiler equipment than oversizing. Unless the boiler is significantly undersized for the load it is tasked with meeting and there is no backup boiler, the client will only be able to tell by the higher than anticipated consumption of fossil fuel by the backup boiler.

Whilst this is less than desirable, it's only if the biomass system is set to act as a baseload boiler, but is not of a sufficiently robust build quality to operate in this duty, that a problem will arise. Throughout the course of this research, several schemes with undersized boilers which are too lightweight have been brought to our attention by installers and clients with whom we have had contact. These have generally been highlighted because they have encountered problems in operation. [18]

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down'. (see appendix 7 for a 2013 tender that is a common example of customers seeking this arrangement). This is not necessarily a cause for concern in terms of performance standards however.

[18] We have been made aware of one example where a 90kW woodchip boiler, installed in 2010, has been tasked with operating as the baseload boiler in a municipal swimming pool. The consequences for this system, which is a good quality marque, are predominantly related to accelerated wear, and the boiler was out of its manufacturer warranty (2,500 hours per year for 5 years) within two years. After 3 years, including significant periods where the boiler was not available because maintenance was required, the counter on the boiler indicated that around 19,800 full load hours had been recorded. The boiler is clearly undersized and of the wrong build-weight to perform in this duty effectively for long.

6.3 Heating Applications

The table below shows the different heating applications to which RHI-registered systems have been tasked:

Boiler size Band	Space Heating	Water Heating	Process Heating	Space & Water Heating	Space & Process Heating	Space, Water, Process Heating
1-44 kW	51	13	5	322	#	#
45-100 kW	87	13	#	999	#	28
101-150 kW	38	#[19]	0	274		9
151-199 kW	335	9	31	457	6	19
200-400 kW	41	#	5	112	#	9
401-600 kW	23	0	12	86	#	6
601-800 kW	10	0	7	27	#	#
801-1000 kW	39	#	9	20	7	6
Totals	**624**	**35**	**69**	**2,297**	**13**	**77**

Figure 16: RHI Schemes - Nature of Heat Demand

A large majority of the schemes are designed to provide space and water heating, with only a tiny minority designed for process heating. This is useful to know, as process heating situations are likely to have higher load factors and higher efficiencies, but the very small number means the impact will be statistically insignificant when examining efficiency of the sample overall.

6.4 Utilisation Issues

The concerns over misleading performance standards are of course being compounded by 'utilisation issues'. In other words, irrespective of the theoretical achievable performance standard of a system, it is not running properly or has broken down for periods. This is, in simple terms, one explanation for the difference observed between our suggested performance standards and the case study sample outcomes.

The standard means of measuring utilisation is via the 'load factor', also known as 'run hours' or 'capacity factor'. This measures heat output over a set time, usually a 12 month period.

There are 8,760 hours in a year. So for example, a 300kW boiler running all year at full output could produce 2,628,000kWh (300kW x 8,760 hours) of heat. In practice, boilers typically run for much lower hours, and exactly how many will depend upon the heat load. Designers, suppliers and installers are therefore required to forecast the load factor to assist with sizing the boiler correctly, selecting the appropriate build-weight of boiler, and working out how much heat will be generated.

[19] # = A value between 1 to 5

The DECC RHI impact Assessment (Mar 2011) based its calculations on medium boilers (200kW to 1,000kW) having a 20% load factor. So a 300kW boiler would run at 20% of 8,760 hours (1,752 hours) x 300kW, so delivering an annual heat output of 525,600kWh. Large boilers (above 1,000kW) are reported as having a 40% load factor (3,504 hours), while The Carbon Trust publication, Biomass Heating: A Practical Guide for Potential Users, presents the following capacity factors :

***Table 15** Typical biomass capacity factors for different applications*

Category	Typical capacity factor
General occupancy building	0.2 (20%)
Service applications	0.45 (45%)
Process applications	0.6 (60%)

Figure 18: Carbon Trust Suggested Capacity Factors

The Carbon Trust guide makes an assumption that 20% load factors should be the benchmark for boilers under 1,000kW, although we would acknowledge that there should really be a distinction between peak and base load boilers when determining capacity factors. A finer-grained approach to this is clearly required, perhaps relating load factors to heat load types. However, for the purposes of this report, we use 20% (1,752 hours) and assume that schemes falling below that level are likely to be experiencing performance problems.

The load factor should also be an important tool in selecting the right type of boiler, as the build quality and features of biomass boilers differs considerably from one manufacturer to the next, and not all boilers are suited to all duties. The warranty hours are usually the best indicator of a boilers' suitability to a particular application, but this information is not always made available to customers or even to installers. We are aware of boilers which are not designed or manufactured to operate in high duties which are being tasked with just that, largely on grounds of cost saving or a lack of knowledge on the part of the client, their advisors or the installer. This has significant implications for boiler maintenance and reliability/availability, and over time, it is inevitable that issues with accelerated wear will manifest themselves in these situations.

The table below shows the mean average size of boiler (in bands), and the mean average amount of heat produced measured by the meters over 12 months for that band of boiler.

Boiler size Band	Mean Size of Boiler	Mean Annual Heat Produced[20] (kWh)
1-44 kW	30kW	34,136
45-100 kW	73kW	81,160
101-150 kW	132kW	157,248
151-199 kW	191kW	313,848
200-400 kW	326kW	349,724
401-600 kW	510kW	945,816
601-800 kW	746kW	1,120,844
801-1000 kW	942kW	2,171,380

Figure 18: Heat Outputs

The table below compares the achieved run hours against the suggested benchmark of a 20% load factor. To make the data easier to understand, we have reported this against a single boiler size (mean).

Boiler Size Band	Mean Size of Boiler	Number of Installations accredited	Actual Mean Annual Heat Produced (kWh)	Heat Output at 20% Load Factor
1-44 kW	30kW	391	34,136	52,560
45-100 kW	73kW	1134	81,160	127,896
101-150 kW	132kW	330	157,248	231,264
151-199 kW	191kW	857	313,848	334,632
200-400 kW	326kW	172	349,724	571,152
401-600 kW	510kW	128	945,816	893,520
601-800 kW	746kW	48	1,120,844	1,306,992
801-1000 kW	942kW	83	2,171,380	1,650,384

Figure 19: Heat Output Compared to Run Hours

The data shows that for all boilers up to 326kW the amount of heat produced by RHI accredited boilers is less than would be expected if a 20% load factor was being achieved. Boilers above 510kW fare better are close to or exceed the heat outputs that arise with a 20% load factor.

6.5 Conclusions

The data suggests that the tariff bandings are encouraging schemes just under the 200kW break, and some at just under 1,000kW, and there is a strong likelihood that a number of these schemes are not correctly sized for the heat loads.

[20] Data is supplied by quarters and we have converted this an annual figure assuming each mean quarter is the same over 4 quarters.

Where boilers are oversized in particular, the implications are that they will operate less efficiently and also give rise to higher visible emissions (particulates). They may also experience increased the maintenance burdens and shortened the life expectancy.

The data also suggest that taking a 20% load factor as the expected norm, systems under 200kW are delivering around 20% less heat than the benchmark suggests they should. Schemes between about 300kW and 1,000kW appear to be performing as could be expected, but using higher load factors as the benchmark would show that these sizes of schemes are also under-performing against what might be realistically expected.

7.0 Boiler Emissions Issues

7.1 Background

Biomass boiler emissions are often a cause for concern, either in terms of planning authorities who must determine if proposed biomass schemes are likely to breach air quality standards (individually or cumulatively), or for nearby residents and communities who feel they might be adversely affected by emissions. Our own experience is that this is often the main factor affecting the consenting of schemes, especially in schools, educational campuses and residential district heating.

We have sought to identify any study, survey or analysis of actual in-operation emissions from UK-based biomass schemes. We hoped that we could find a range of recent data that recorded actual emissions. However, to our knowledge, no such data has been published since a small sample 2008 study[21] for the Scottish Government by the AEA Group. Furthermore, we cannot find any data preceding this.

This is clearly an important gap in knowledge, and a later section of this report suggests how this might be addressed.

At this stage, it also means we can make only some preliminary comments on emissions, and these are inferred from emissions standards, equipment standards, and our views on system performances and efficiencies; and also we must solely rely upon the very small sample in the AEA Group study for actual in-operation emissions levels.

7.2 The Policy and Legislative Context

The main biomass boiler emissions are fine dust known as Particulate Matter (PM) and Nitrous Oxides (NOx). Local Authorities have powers under the Clean Air Act to request the measurement of dust emissions from a biomass boiler exhaust stack, and also require emissions clean-up equipment to be installed to control emissions. This might include bag filters, cyclones, electrostatic precipitators or hot gas ceramic filters.

However, the Clean Air Act originally dates from 1956, and is primarily aimed at controlling visible smoke and grit, so this legislation does not serve to mitigate fine particulate matter emissions (although it is currently under review). Partly for this reason, in February 2013, DECC published an Impact Assessment (ref DECC0092) called 'Introduction of air quality requirements into the Renewable Heat Incentive'. That Impact Assessment noted :

[21] Measurement and Modeling of Fine Particulate Emissions (PM10 & PM2.5) from Wood-Burning Biomass Boilers Report to The Scottish Government 26 September 2008. This measured emissions from 6 sites.

"There are, however, no emission limits consistently applying to all biomass boilers under 20MWth capacity in the UK beyond the Clean Air Act 1993 which limits the emission of dark smoke. Installations of this size are currently considered to be inadequately covered by legislation."

Accordingly, the RHI regulations were amended to reduce the permissible levels of particulates, and from September 2013 biomass boilers had to have either an RHI emission certificate or an environmental permit. The purpose of this requirement is to ensure that emissions from biomass boilers do not exceed a set level of particulate matter (PM) or oxides of nitrogen (NOx). For RHI emission certificates, the maximum permitted emissions are 30 grams per gigajoule (g/GJ) net heat input for PM, and 150 g/GJ for NOx. Environmental permits also normally include emissions limits, however these vary depending on the boiler in question. Biomass boilers that do not have an RHI emission certificate or an environmental permit are ineligible for RHI payments.

Beyond the new RHI emission certificate requirement, Local Authorities have a duty to review and assess air quality following a 3-year cycle mandated by the Environment Act 1995. Biomass sources are considered during this process, both as single installations and as cumulative sources.

The attitude that each Local Authority takes to this varies according the levels of concern about local air quality. Typically, urban areas with poorer air quality will require detailed emissions modeling for any proposed biomass scheme, whereas in rural areas, only standard manufacturers data is usually required to enable schemes to be consented.

It seems likely that the RHI emissions certificate will become the de-facto national standard for the sector in regard to emissions from biomass boilers (other than in specific urban areas with air quality concerns).

7.3 The Performance of Biomass Boilers

The table below is extracted from a 2010 Study for Forestry Commission Scotland by AEA[22], and shows *test data* for a range of biomass boilers. The information is from selected test reports published either by the manufacturer, or by Austrian or Danish testing bodies, based on the EN303-5 tests. As such, this data merely illustrates the levels of emissions that could be achieved in ideal (laboratory) operating conditions, rather than in the field.

[22] The assessment of flue gas particulate abatement in wood burning boilers, AEA 2010

Boiler make/type	Year of test	Boiler size kW	Fuel type	PM emissions g/GJ	NOx emissions g/GJ
Set 1 (boilers meeting RHI consultation emission criteria)[13]- 30g/GJ PM and 150g/GJ for NOx					
Buderus Logano SH 50	2007	50	Pellet	12	68
BIOTECH HZ 50	2007	50	Chip	14	69
Ecotherm HS 50	2006	50	Chip	14	69
HMS HP 50	2003	50	Pellet	17	63
HEIZOMAT RHK-AK 50	2005	50	Chip	8	88
Rennergy HSV 50	2001	55	Chip	20	113
Pyrogrande PMT 55	2004	55	Pellet	13	82
Classic 60 Lambda	2007	58	Pellet	25	107
Turbomatic 55	2000	55	Chip	29	111
Turbomatic 55	2000	55	Pellet	13	82
UTSS 60.30	2000	60	Chip	12	74
Pelletstar biocontrol 60	2006	60	Pellet	24	83
SOLARFOCUS therminator 60 kW	2006	60	Pellet	19	106
PELLEMATIC PE64	2007	64	Pellet	9	97
Type PV 80	2002	80	Pellet	21	127
SL 80T	1999	80	Chip	15	95
RennergyHSV 80S	2001	80	Chip	13	79

Figure 20 : Reported Laboratory-Measured Emissions from Boilers 50-200kW

It is interesting to note that the 30g/GJ PM and NOx 150g/GL limits set by the 2013 RHI amendment are not exceeded by any of these boilers. There is similar test data for boilers between 200kW and 1000kW that shows the same outcome - that the RHI limits are not exceeded by the laboratory test results.

7.4 Operational Emission Levels

In-operation levels of emissions in the flue gases depend on the biomass boiler design, the fuel characteristics and how the boiler is operated.

Furthermore, the impact of emissions on the environment, in particular local receptors, is related to the dispersion of emissions, which is influenced by the height of the boiler exhaust stack. As noted above, we have only identified one UK study[23] undertaken in 2008 for the Scottish Government by the AEA Group, which measures actual in-situ emissions. The study looked at 6 sites and found the following for particulate emissions :

[23] Measurement and Modeling of Fine Particulate Emissions (PM10 & PM2.5) from Wood-Burning Biomass Boilers Report to The Scottish Government 26 September 2008

Site	Test No.							Mean	Median
	1	2	3	4	5	6	7		
					PM_{10}				
A	26.6	30.9	27.9	-	-	-	-	**28.5**	**27.9**
B	55.8	54.3	-	-	-	-	-	**55.1**	**55.1**
C	19.3	10.9	14.6	-	-	-	-	**14.9**	**14.6**
D	45.2	50.3	92.8	59.8	66.7	45.2	62.3	**60.3**	**59.8**
E	3.1	25.2	28.3	32.5	18.6	18.0	355.1	**68.7**	**25.2**
F	22.1	34.4	16.1	23.4	20.9	30.5	31.2	**25.5**	**23.4**
					$PM_{2.5}$				
A	22.5	5.6	19.9	-	-	-	-	**16.0**	**19.9**
B	47.1	39.1	40.5	-	-	-	-	**42.2**	**40.5**
C	22.0	14.4	11.7	-	-	-	-	**16.0**	**14.4**
D	28.2	34.1	46.0	69.6	87.2	47.9	37.1	**50.0**	**46.0**
E	2.4	17.2	24.1	32.4	19.2	18.8	15.3	**18.5**	**18.8**
F	19.2	18.5	20.0	20.1	17.5	15.7	19.9	**18.7**	**19.2**

Figure 21 : Particulate Emissions by Test and Averaged Over All Tests (g/GJ)

It can be seen that 3 of the 6 sites examined exceeded the 30g/GJ limit for PM10, and 2 of the 6 sites for PM2.5. This raises the basic concern that, whilst most optimally operated biomass boilers will probably meet the new RHI standards, in operation, some boilers will exceed the limits. This data set is too small from which to draw meaningful conclusions however, and further field trials will be required to establish the true levels of emissions in operation.

7.5 Performance Standards and Emissions

Poorly performing schemes are likely to have higher emissions; this section reviews the issues that underpin this.

The characteristics of the fuel used in biomass boilers has an important influence on emissions. The most important characteristics are moisture content and the chemical and physical properties. Generally, wood with a consistent moisture content, size and density gives better combustion performance and lower emissions, but as the market grows, second grade and agricultural pellets, waste wood chip and the use of agricultural residues and grain may lead to higher emissions levels.[24]

Elsewhere in Europe, detailed work under IEA Bioenergy Task 32, which looked in depth at emissions from biomass systems, noted that:

[24] We have been provided with an example of a biomass installer using recent price rises seen in the pellet market (which has been under-pricing for a number of year) as a sales tool for their boilers, which can also fire with grain.

"many investigations have shown that the utilization of other biomass than wood with low amounts of bark for pellet combustion in residential heating appliances results in significantly increased emissions of particulate matter (i.e. typically by a more than a factor of 3) as well as in emission of NOx."[25]

Similarly large increases were seen in field trials that examined the use of woody and non-woody fuels on emissions levels from biomass boilers in Austria, and presented under IEA Bioenergy Task 32 by Prof. Ingwald Oberberger[26]. As an example, the impact of feedstock selection on the production of aerosol forming elements in biomass boilers can be clearly seen in the graph below.

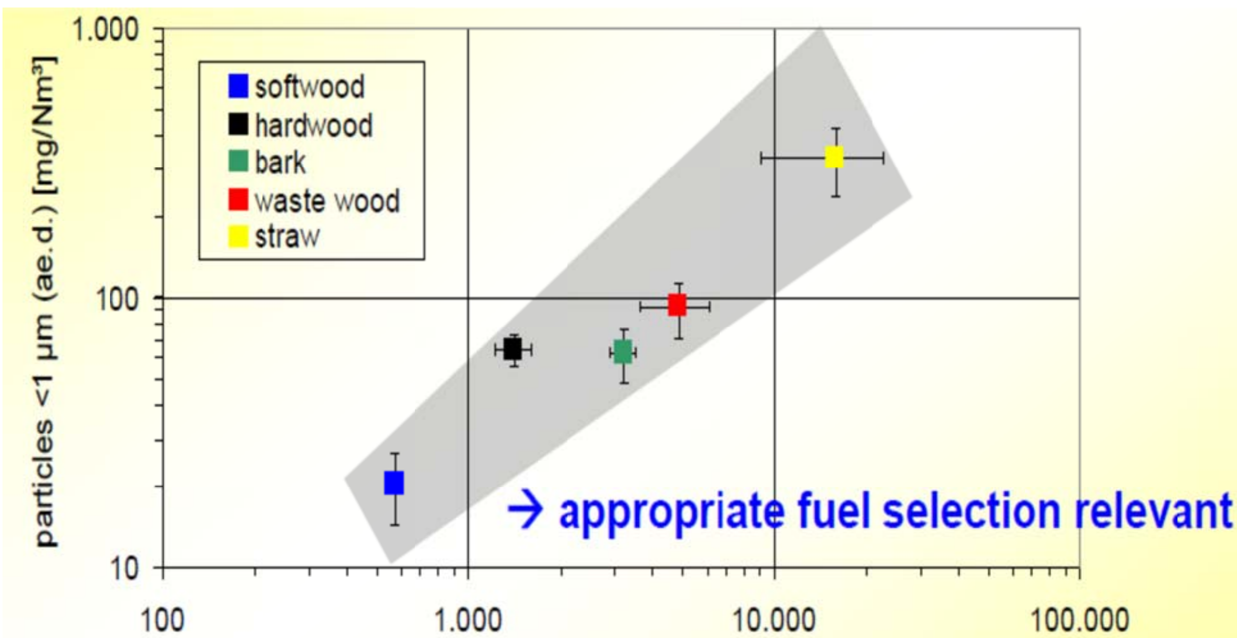

Figure 22 : Concentration of Aerosol Forming Elements in Fuel (K+Na+Zn+Pb) mg/kg (d.b.)

There are various biomass boiler design features that optimise combustion and ensure higher efficiency and lower emissions, and over time, refinement of combustion technology and the overall design of boilers has driven improvements in both efficiency and emissions levels.

This can be seen in the emissions data presented by Oberberger in the graph below, again part of the work under IEA Bioenergy Task 32.

[25] **Combustion in IEA Countries,** Survey on Measurements and Emission Factors, 2008, Thomas Nussbaumer, Claudia Czasch, Norbert Klippel, Linda Johansson & Claes Tullin

[26] **State of the Art Small Scale Biomass Combustion in Boilers**, 2011, Ingwald Obernberger

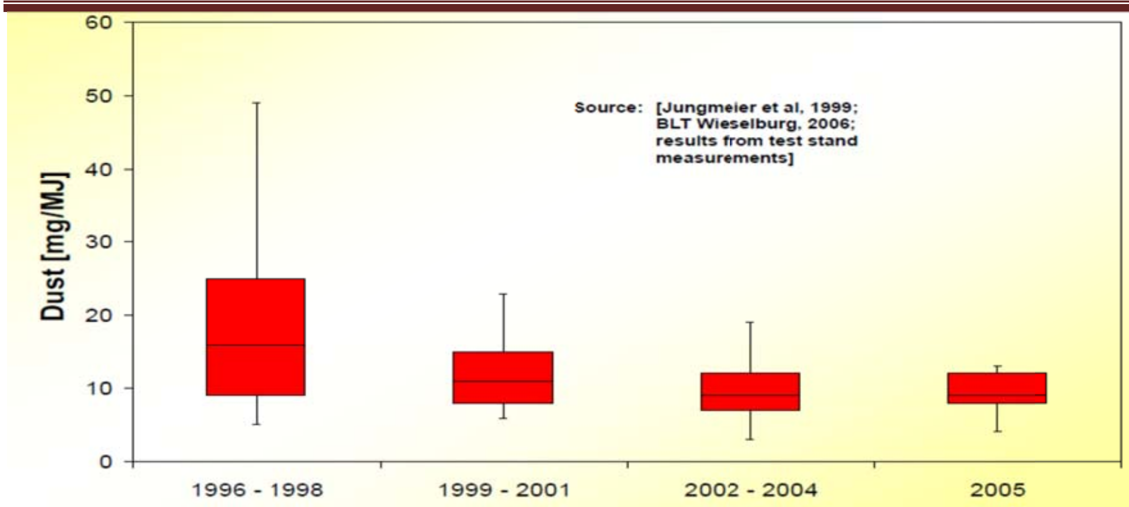

Figure 23 : Particulate Emission Levels in Pellet Boilers, 1996-2005, Oberberger, 2011

The design features listed below are all relevant to some degree for controlling emissions:

- Combustion chamber design and provision of secondary air supply;
- Combustion air control technology - lambda sensor;
- Flue gas recirculation;
- Automatic de-ashing;
- Heat-exchanger cleaning;
- Automatic fuel feed system;
- Automatic ignition;
- Variable load management and modulating ability, including the use of an accumulator tank;
- Particulate matter arrestment plant, such as a multi-cyclones or ceramic filter.

German research[27] found in 2009 that emissions and annual efficiencies of biomass boilers, when measured in the field, could differ significantly from laboratory-derived data. These findings were made when studying a sample of installed applicances which meet the "Excellent" standard for the Blue Angel environmental quality/performance scheme - i.e. have achieved the highest possible levels of performance. The main cause of these issues were found to be over-dimensioning and poor hydraulic integration, leading to insufficient modulation and short cycling. Another negative observation was that these installations also saw a disproportionately high electrical consumption, thanks to repeated ignition cycles using electronic igniters. In operation, this will lead to accelerated failure of these components, and a higher maintenance burden as a consequence.

[27]. Field Investigations of wood pellet central heating boilers - Evaluation of Real Emissions and Annual Utilization Rates, 2009, Kunde, R., Volz, F., Gaderer M., Spliethoff, H BWK 61 (1/2): 58-66.

Government-commissioned research in Austria[28] which developed a laboratory methodology for determining annual efficiency levels and emissions factors for biomass systems, found that lower **system** efficiencies does not necessarily mean elevated emissions, but only when buffer/accumulator tanks are responsible for the lower overall system efficiencies. While buffer/accumulator tanks saw a 3% reduction in overall measured **system** efficiency on the operation of a pellet boiler, (from standing losses in the tank), a dramatic reduction in carbon monoxide emissions (c. 80% lower) and organic carbon compounds (c. 90% lower) was also observed, thanks to the improved load profile and therefore combustion efficiency. NOx emissions also dropped by c. 40%, but particulate emissions remained roughly the same as systems operated without an accumulator. The research summary also states that chip and log boilers saw “distinct advantages” from the use of accumulators in relation to particulate emissions.

Data from IEA Bioenergy Task 32 research[29] found that boiler type also had an impact on emissions, particularly that the more efficient batch-fed systems (forced-air downdraft) showed dramatically better emissions results than the alternative (updraft, naturally aspirated), and greater improvements still when accumulator tanks were used. Data from a range of countries (Switzerland, Denmark, Finland, Germany, Austria and Sweden) was presented as part of this research.

7.6 Conclusions

Research in Europe, and elsewhere, highlights that there is direct link between the design and operation of a biomass scheme and its efficiency, and therefore its emissions. In other words, schemes that are badly sized and/or poorly integrated with heating systems are less efficient and will tend to have higher emissions. Earlier sections of this report have indicated that :

1. Through case studies we believe actual performance of biomass boilers appear to be around 10% below our suggested standards;
2. The RHI data suggests that all systems under 200kW are performing 20% worse than they could if the load factor was at 20%.

If it is correct that biomass boilers in the UK are working at between 10% and 20% less efficiently than they should, it also means emissions will be higher than those observed in laboratory testing as reported by manufacturers.

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[28] Determination of annual efficiency and emission factors of biomass for small burners on the test bench. Project final report, Heckmann, M., Friedl, G., Schwarz, M., Rossmann, P., Hartmann, H., Baumgartner, H., Lasselsberger, L., Themeßl, A. FFG Project Number : 815650

[29] Particulate Emissions from Biomass Combustion in IEA Countries - Survey on Measurements and Emission Factors, 2008 Nussbaumer, T., Czasch, C. , Klippel, N., Johansson, L., Tullin, C. , International Energy Agency (IEA) Bioenergy Task 32 & Swiss Federal Office of Energy (SFOE), ISBN 3-908705-18-5

8.0 Training issues

8.1 Background

As with quality standards, training availability for biomass installations over 45kW is currently limited in the UK, and with formal accredited training courses such as HETAS and BPEC limited to systems <100kW. Overall the installer base must rely on product training from importers and distributors to increase their knowledge and competence. The <100kW formal courses provided by training centres, colleges and other organisations to either the HETAS or BPEC course curriculum, are available to 'all comers', but only those who meet prerequisites in terms of qualifications and experience are eligible to claim the resulting qualification.

Distributor courses are typically of 1 to 3 days in duration, and for the most part are focused on imparting specific product knowledge to attendees who will go on to sell and install their equipment. More in-depth technical training is not available from either formal training centres or importers/distributors of biomass equipment.

8.2 Typical Distributors' Training Course Structure in the UK

As an example, a typical 1 day course structure from an established UK equipment distributor covers:

- Product range introduction
- Wood as a fuel, logs, chip or pellets
- Wood gasification and its importance
- Wood log boilers, range, size, output and sizing
- Log boiler combustion systems and controls
- Log boiler hydraulic boiler room design and system side connection
- Log boiler integration of fossil fuel backup
- Log boiler flue and chimney requirements
- Pellet boiler, range, size, output and sizing
- Pellet fuel delivery systems bulk
- Pellet store equipment, vacuum and auger
- Pellet store sizing and design
- Pellet boiler hydraulic boiler room design and system side connection
- Pellet boiler flue and chimney requirements
- Pellet boiler servicing requirements
- Wood chip boiler, range, size, output and sizing
- Wood chip fuel delivery systems
- Wood chip store equipment auger transfer and store filling
- Wood chip store sizing and design
- Wood chip hydraulic boiler room design and system side connection
- Wood chip flue and chimney requirements
- Wood chip servicing requirements
- Energy cabins, installation and application
- Financial returns (RHI and fuel savings)

The three day course covers the same subjects, but in more depth and usually with site visits.

8.3 Other Training Available

Manufacturers and importers of larger equipment have the ability to provide training at the point of production, as they often have technical staff and training resources in their factories, which typically serve many markets. However, once again, the vast majority of this training is product-specific. It is known that many UK based installers will get their staff to attend these factory based sessions in mainland Europe.

Other professionals who could find themselves involved in the sector, such as surveyors, specifiers, consulting engineers and architects, have little or no opportunity to gain in-depth technical knowledge of the design, specification and project management of biomass heating installations. We have only identified 2 courses available for this group:

- The Chartered Institute of Building Services Engineers does run a one-day training course entitled "Introduction to Biomass Heating Systems".

- CIBSE also run a practical course for system operators and maintenance staff: *"Biomass Systems Operation and Maintenance".*

Our view is that, generally speaking, there is a paucity of relevant, quality training in the biomass heat sector. This is an issue which has been raised many times over the last decade, including by CIBSE, who in their December 2012 Journal noted :

> *"Training will be needed for architects, civil engineers, cost consultants, town planners, project managers, construction managers, commissioning engineers and technicians, facilities managers, maintenance fitters and site staff. All of this will need to be built up from a very small initial skills base of people with knowledge of the biomass procurement process from start to finish."*

We believe that this lack of training availability, particularly for those working on larger systems (>45kW), is likely to be one of the principle reasons for the sub-optimal performance observed during this research.

Combined with the lack of quality standards and guidance for installations at this scale, the lack of in-depth or mandatory training effectively means there are no barriers to entry into the sector for those wishing to become commercial biomass installers. This is in marked contrast to the observed situation in the other EU countries examined as part of this research, where training is embedded throughout the careers of heating engineers and others in the sector, from apprenticeship level through to ongoing technical updates and CPD sessions.

However, the training needs in the UK are different from Europe given the introduction of the RHI, which has created the need to rapidly upskill the workforce in order to deliver large numbers of installations to a reasonable standard. It is clear that in the UK, we lack the training infrastructure and also the pool of individuals who are both sufficiently technically knowledgeable, and able to deliver good quality training to the industry.

9.0 Gap Analysis and Specification of Field Trials

9.1 Structured Programme of Field Trails

We are able to conclude with some confidence that biomass heating installations are not performing as efficiently as they should in many cases. However we are not certain as to the scale and reasons for this problem, but our case study data and the RHI data suggest a general 10-20% under-performance.

It is worth understanding the financial impact of a scheme that performs at 60% efficiency compared to one at 80% efficiency. In such a theoretical example we have assumed a 350kW scheme costing £250,000 to install. The 80% efficient scheme is able to claim £29,752 a year of RHI income, but the 60% efficient scheme only secures £25,715 a year of RHI income, and will consume more fuel in operation. The outcome is that the simple payback of the less efficient scheme extends by more than one year compared to the most efficient scheme. These differences will be important for individual installations and of course cumulatively for the sector. They are also almost always unexpected, and potentiallyfar worse than this example.

Given the concern over possible underperformance and its likely impact on the economics of schemes, we recommend that a structured evaluation programme be undertaken to assess the actual performance of a sample of biomass installations. Below we have specified the possible scope and nature of that proposed programme.

In order to get a better sense of the required scale of such a programme, it is necessary to consider the range of situations and applications that should considered. A preliminary attempt to structure and list these is made below. This structure assumes the likely inherent efficiency as the starting point.

- Peak load dry wood boilers under 200kW. These examples will tend to be heating small schools, care homes, etc, and often use pellets.
- Peak load dry wood boilers over 200kW. These examples will tend to be heating large schools, hospitals etc, and often use pellets and dry wood chips (i.e. <35%MC on a wet basis).
- Peak load wet wood boilers over 200kW. These examples will tend to be heating large schools, hospitals, volume housing, high rise flats etc, and use wet wood chips (i.e. >35%MC on a wet basis).
- Base load dry wood boilers under 200kW. These examples may be working with fossil fuel back up and meeting part loads in a wide variety of applications using pellets and dry wood chips.
- Base load dry wood boilers over 200kW. These examples will heat industrial applications, leisure centres, educational campuses, hospitals, care homes, residential high rise etc, with pellets or dry wood chips.
- Base load wet wood boilers over 200kW. These examples will heat industrial applications, leisure centres, educational campuses, hospitals, care homes, residential high rise etc, with wet wood chips.

This list creates six generic situations that broadly refer to likely efficiency groupings. It would be sensible to obtain 7 or 8 examples in each category, so performance and efficiency could be compared between schemes[30] in similar categories, and then between the categories in order to build a clear picture of performance. This would result in a dataset on about 46 schemes in total. The means by which this could be collected is discussed below.

9.2 Refining the Existing Data Sets

The data sets we have accumulated for this study provides a strong starting point that can be further understood and extended. The data was collected rapidly in March and April, and did not involve site visits or face-to-face meetings with the parties who provided it. Subject to the agreement of the parties[31] who supplied the information, it would be necessary to then :

- Liaise closely with the parties (face to face meetings) to understand exactly how the data was collected and expose any limitations (for example how moisture content and weight has been measured and what form of metering is being used);
- Liaise closely with the parties (face to face meetings) to fully understand the ongoing fuel, operation and maintenance standards being applied at each installation;
- Liaise closely with the parties (face to face meetings) to fully understand the profile of the heat load and how that is impacting upon performance;
- To carry out selected site visits to some of the 106 installations (perhaps 20% of the installations) to determine the design configuration of the installation (silo, boiler model, pipework design, buffer tanks etc), and confirm the exact location of metering points. This should also collect and summerise any available data on how the scheme was planned, procured and installed;
- To seek agreement with the parties that the data sets can continue to be collected and under what terms DECC could use the information this provides and for how long;
- To set up a process that then collects and reviews that data over say 12 months;
- To understand the load profile over a 12 month period.

These actions will enable the broad efficiency and performance findings (made so far) to be verified and substantially improved and refined. It will also allow that data to be collected for another 12 months (or more), in order to establish a longer term data set, showing trends over several years.

[30] Hopefully capturing 'good' and 'bad' schemes
[31] There are 8 parties that would need to offer their agreement

9.3 Extending the Existing Data Sets

Our view is that there will be considerably more data sets than those we have to obtained in the course of this rapid desk study. We suggest that a formal request is issued by DECC to secure long run data about the performance of installations. This could be issued to a selected group of accredited RHI installations. This should elicit additional existing data sets that should extend the range and quality of information we already have.

It is hard to forecast the outcome of this approach, but our judgment is that contacting say, 150 selected accredited installations, might secure 20 new useful data sets. This process requires active management and then data interrogation to establish if the responses and data will be useful, and whether or not it fills gaps in the data sets we already have.

Following this, all these installations could be included in the follow-up process described under refining the existing data set out above.

The outcome of refining and extending the data sets should be to have about 40 installations that have been visited and their owners interviewed, with a 12 month agreement to obtain and review data that they are willing to provide (about fuel supply and heat metering). This should offer a reasonable sample to evaluate biomass performance across the whole sector and match the six broad categories mentioned above. It represents 1.4% of the 3,143 currently accredited RHI installations, but if carefully selected as described it should offer a sufficiently large sample to be regarded as representative.

9.4 Field Testing and Trials

The process described above remains largely a (highly cost effective) desk based and data collection exercise along with simple inspection site visits to verify assumptions and confirm design and layout. Furthermore, the ongoing responsibility to actually collect and record useful data remains with the parties who own the installations and DECC would have no control over how it is done, if it continues to be done, and most significantly, it only relates to fuel supply and meter readings.

In particular, we do not expect that independent moisture content testing will be carried out at all the installations, and there will be different methodologies for such data collection (some may rely solely on suppliers invoices, others may take probe readings, others do oven tests, etc). Similarly, records of weight (of fuel) might be via suppliers invoices, or some sites may have weight sensors built into silos or use weighbridges. The collection of metering records will also vary depending upon the situation. Given that such data is being provided to DECC at no cost, and will be useful and informative if its limitations are clear, then this isn't a major concern.

However, the data does not represent all the relevant data that could be collected at an installation, and it would be useful to carefully test the data we can obtain for 'free' against totally verifiable data that DECC has defined and collected in consistent ways. For these reasons, it is proposed that for about 10 installations, a year-long field trial is planned and undertaken, to sit alongside the 40 data sets mentioned above.

The first area of additional data collection would be to access the BMS data/electronic controls systems of the installations where available. It should be possible to download this data on a regular basis over a 12 month period (and going back in time). 12 months is required to cover a full range of heat load situations. These data sets will show exactly how the boiler is performing, recording a range of parameters. It should also record observed heat demand. As part of this programme, a degree day analysis can be included (to compare weather conditions with heat demand).

The second area is to measure is kWh standing losses in the plant rooms, associated with the boiler and in terms of any district heating. This requires the installation of heat meters at a number of points in each scheme. The main issue will be to determine the places on the system where meter readings should be taken, so that energy flows through the system can be measured. Depending upon the complexity of the system, we expect between 2 and 5 additional meters may be needed. Supposing that on average, 2.5 meters are needed and 10 sites are metered this way, this will mean 25 meters are needed. This will involve expenditure on heat meters, however it is thought that it might be possible to negotiate an arrangement with a company that sells heat meters to reduce these costs, perhaps via a rental agreement for a 12 month period.

The third area to collect data in a consistent way is in terms of the fuel supply. This requires a detailed method for accounting for the energy content of the fuel that is delivered to the store via its weight and moisture content. This will require a programme of fuel sample collection and regular testing at a laboratory. We expect this will lead to costs of £2,000 to £3,000 per site, per year, in lab testing.

The final area that DECC may wish to consider collecting data on flue emissions. Here it will be necessary to devise a specification that complies with CEN and ISO Standards for undertaking PM emission measurements. It is worth noting that the AEA report (in 2010) subcontracted testing to TUV NEL who provided ISO9901 and UKAS accredited emissions monitoring. The results for 1 of the 6 sites is shown below. 6 tests per site were undertaken.

Test	O_2 %, dry	H_2O %	Flow m3s-1	PM_{10} mgm-3	$PM_{2.5}$ mgm-3	Cutpoint µm	Velocity m/s	Gas Temp oC	Moisture %	Oxygen %	Emission factor g/GJ
1	16.0	3.8	0.3	96.1	-	9.8	12.0	164	3.8	16.0	55.8
2	16.3	3.7	0.3	93.5	-	9.7	12.0	162	3.7	16.3	54.3
3	20.3	2.2	0.1	-	-	9.5	12.0	135	2.2	20.3	
4	16.7	4.5	0.3	-	80.9	2.7	12.0	170	4.5	16.7	47.1
5	16.6	4.2	0.3	-	67.2	2.6	12.0	162	4.2	16.6	39.1
6	16.4	4.2	0.3	-	69.6	2.6	12.0	164	4.2	16.4	40.5

Figure 24: Emissions Test Results Example

Our view is that such testing should cover a full 12 months to account for differing load profiles and the ups and downs of operating efficiencies over time.

9.5 Development of Performance Standards

An important outcome of the biomass field trails (both in terms of the group of 40 and the 10) is to secure reliable long term data about the actual performance of biomass schemes in-situ. There are 2 important possible uses of this data:

- To highlight the main causes of underperformance and develop guidance that improves future design, installation and operational practices;
- To develop national performance standards, so that the sector has a recognized standard to achieve and work within.

It is proposed that during the 12 month field trails both these issues are examined and progressed. In terms of reporting on the causes of underperformance it will be important to clearly articulate common problems and ways to reduce and avoid them. In particular the better understanding of load factors is required, as will be the wider dissemination of achievable levels of performance.

In terms of performance standards, this report has already offered some very preliminary thoughts and of course these can be verified and refined and eventually published for suppliers and customers to use.

A final suggestion is that since field trails must take 12 months, but start with some evidence base, which will gradually develop and improve it would make sense to allow quarterly published updates as the knowledge base improves, so as to disseminate useful data as rapidly as possible.

9.6 Installation Practices and Quality Standards

The UK has no quality standards for schemes above 45kW, which in effect means there are no quality standards for nearly 90% of all the schemes accredited under the RHI.

In light of the evidence presented in this report about poor standards and quality, it makes sense to scope out if and how installation practices and quality standards could be developed in the UK for biomass schemes above 45kW.

In our view, the key mechanism for improving installation practices and quality standards is to create a body of high quality technical knowledge, transferred through training, information sharing and general cooperation, to the installers and suppliers.

We believe that a good start point for this would be to start to collect far more in-situ operational information about schemes and ensure that is shared through a purpose designed quality management and assurance system.

A well designed quality system will need to be supported and endorsed by Government, but will work most effectively if it is created by the industry, which has a vested interest and the technical skills required to make it useful and workable.

This is a large and complex task that requires collaboration between industry, government and academia – a path followed previously in many European countries. Our proposal is that DECC undertake a time-limited consultation exercise to determine who could be involved in the development and management of improved installation practices and new quality standards, how these might be delivered and what its costs and benefits would be. This should result in short report, ideally published in autumn 2014, that provides a route plan for action. This should be parallel with data collection (via field trails) and its effective dissemination.

Appendix 1: Supplier and customers contacted

List of suppliers we contacted:

Angus Biofuels
Imperative Energy
Wood Energy
Mawera (UK) Ltd
Mercia Energy Ltd
Innasol
Trianco
HW Energy
Highland Heat & Power
AFS Biomass
Rural Energy
Oakes Energy
Eco Fuels
EBTech
Treco
Dunster
Buccleuch Bioenergy
Cotswold Green Energy
Bio-Nordic Ltd
Asgard Biomass
Duncan Renewables
Oliver Carter Plumbing and Heating
Kilmac Renewables
LC Energy
Cheviot Heat and Power
AD Heating
Robinsons M&E Ltd
Grant UK
Novalux Energy Solutions
GF Consulting
Centre for Green Energy
Thermatech
Mindenwood
Euroheat
Econergy
Alternative Heat
Vital Energi
Pentland Biomass
Scot Heating

Customers we contacted:
Stockport Homes
North Lanarkshire Council

NHS Scotland
Highland Council
South Lanarkshire Council
Carstairs State Hospital
Barony College
Findhorn Foundation
Penicuik Estate -
NHS Highland
NHS Wales
Robertsons FM
Minsteracres Abbey
Penmorfa Council
Swansea Leisure Centre
Jedburgh Pool
Wentworth Leisure Centre
Field Studies Council
Watermillock Village Hall
Cultybraggan District Heating Scheme
Trigonos
Merthyr Mawr
Staffordshire County Council
Powys County Council

Appendix 2: Large retail sector performance data

The full data set below shows some sites with over 100% efficiency and these are omitted from our analysis in the body of the report.

Installation Capacity kWth	Fuel purchased kWh (12/13)	RHI claimed (12/13)	Efficiency % (12/13)	Fuel purchased kWh (13/14)	RHI claimed (13/14)	Efficiency % (13/14)
520	657,600	260,910	39.7	1,512,000	1,701,410	112.5
750	2,390,088	667,106	27.9	2,196,654	2,130,215	97
520	877,440	230,225	26.2	1,488,960	1,277,819	85.8
697	1,257,600	454,793	36.2	2,179,200	1,803,575	82.8
696	1,786,800	0	0	2,456,400	1,775,235	72.3
755	1,518,836	109,172	7.2	1,424,000	1,000,210	70.2
520	1,302,545	804,022	61.7	1,372,800	941,898	68.6
520	1,242,748	327,474	26.4	1,862,851	1,271,776	68.3

520	1,335,671	839,847	62.9	1,693,128	1,148,371	67.8
520	1,702,736	891,685	52.4	1,887,663	1,266,267	67.1
465	1,399,466	789,576	56.4	1,840,533	1,220,175	66.3
755	1,262,314	76,430	6.1	1,330,285	879,088	66.1
520	627,054	0	0	1,700,945	1,113,196	65.4
520	1,474,971	469,148	31.8	1,957,028	1,271,822	65
520	1,627,885	739,716	45.4	1,780,114	1,151,863	64.7
520	1,463,544	846,054	57.8	1,688,746	1,092,522	64.7
464	557,485	156,323	28	1,645,714	1,040,763	63.2
520	977,600	0	0	2368000	1,496,782	63.2
755	1,770,133	1,002,674	56.6	2,117,866	1,328,546	62.7
465	808,581	0	0	1,245,818	780,273	62.6
465	630,933	0	0	1,116,266	694,163	62.2
755	654,857	196,040	29.9	1,999,542	1,233,290	61.7
520	1,303,613	332,529	25.5	2,123,586	1,303,303	61.4
464	951,138	194	0	952,246	581,555	61.1
520	772,800	105,416	13.6	1,632,000	988,671	60.6
696	1,772,676	209,791	11.8	1,939,200	1,171,398	60.4
630	2,155,823	1,110,684	51.5	2,317,776	1,359,347	58.6
696	1,812,342	901,980	49.8	2,142,857	1,250,709	58.4
520	1,545,978	829,197	53.6	1,591,200	925,008	58.1
630	903,272	0	0	1,333,527	771,831	57.9
755	905,927	82,776	9.1	1,116,872	645,784	57.8
464	1,454,400	392,409	27	1,654,400	953,372	57.6
465	1,300,800	743,035	57.1	1,680,000	962,577	57.3
348	1,317,473	152,048	11.5	1,570,863	887,950	56.5
520	1,355,781	595,591	43.9	1,644,218	926,526	56.4
465	1,423,490	45,981	3.2	1,378,400	743,559	53.9
464	447,000	11,182	2.5	1,381,800	743,746	53.8
697	1,333,866	761,763	57.1	1,723,733	896,990	52
520	1,282,654	0	0	1,098,830	561,271	51.1
465	627,175	145,598	23.2	1,566,424	799,663	51.1
406	913,600	0	0	1,596,800	807,473	50.6
750	185,600	0	0	1,974,400	993,629	50.3
465	599,314	150,371	25.1	1,200,685	588,464	49
930	1,734,840	16,216	0.9	2,007,360	982,978	49
520	842,742	191,969	22.8	1,547,657	751,327	48.5
580	146,929	0	0	1,902,670	918,028	48.2

348	1,014,628	275,093	27.1	1,254,400	559,650	44.6
520	120,685	0	0	2,188,114	928,079	42.4
520	0	0	0	1,540,800	641,556	41.6
465	0	0	0	1,200,000	498,637	41.6
520	118,800	0	0	1,508,400	598,555	39.7
520	160,000	0	0	1,606,400	592,680	36.9
464	1,766,476	584,638	33.1	1,913,066	694,875	36.3
520	1,690,438	0	0	1,950,933	698,497	35.8
465	162,264	0	0	1,364,135	372,529	27.3
465	127,800	0	0	1,374,600	356,875	26
630	1,250,181	0	0	1,291,200	302,807	23.5
930	2,596,401	32,889	1.3	2,759,712	569,390	20.6
580	562,666	0	0	1,314,133	209,210	15.9
870	1,288,400	973,492	75.6	612,400	1,120,401	183
520	1,033,920	940,732	91	1,010,880	1,378,886	136.4
520	999,360	838,781	83.9	887,040	1,184,786	133.6
750	1,071,600	313,784	29.3	1,213,200	1,461,594	120.5
35,839						

Figure 2520: Retail sites efficiency outcomes

As can be seen, the data set clearly contains errors (over 100% efficiency), which might be associated with a reliance on fuel supply invoices (rather than measurements of energy content delivered). To try and account for these issues, we have removed 33 schemes from the 2012/13 data set, and the 9 schemes from the 2013/14 cohort that we believe provide the most misleading data. The cleaner data set is shown in the tables below for 2012/13 and 2013/14. One correction we were not able to make was an allowance for fuel remaining in the store from one measurement period to the next, and this will clearly impact upon the overall reported efficiency, particularly as the stores are not run to empty to coincide with RHI meter measurements at the end of calendar years.

Installation Capacity kWth	Fuel purchased kWh (12/13)	RHI claimed (12/13)	Efficiency % (12/13)
520	657,600	260,910	39.7
750	2,390,088	667,106	27.9
520	877,440	230,225	26.2
697	1,257,600	454,793	36.2
520	1,302,545	804,022	61.7
520	1,242,748	327,474	26.4
520	1,335,671	839,847	62.9

520	1,702,736	891,685	52.4
465	1,399,466	789,576	56.4
520	1,474,971	469,148	31.8
520	1,627,885	739,716	45.4
520	1,463,544	846,054	57.8
464	557,485	156,323	28
755	1,770,133	1,002,674	56.6
755	654,857	196,040	29.9
520	1,303,613	332,529	25.5
630	2,155,823	1,110,684	51.5
696	1,812,342	901,980	49.8
520	1,545,978	829,197	53.6
464	1,454,400	392,409	27
465	1,300,800	743,035	57.1
520	1,355,781	595,591	43.9
697	1,333,866	761,763	57.1
465	627,175	145,598	23.2
465	599,314	150,371	25.1
520	842,742	191,969	22.8
348	1,014,628	275,093	27.1
464	1,766,476	584,638	33.1
870	1,288,400	973,492	75.6
520	1,033,920	940,732	91
520	999,360	838,781	83.9
750	1,071,600	313,784	29.3
			44.25%/Avg

Figure 21: Retail sites efficiency outcomes 2012/13

The 2012/13 table seems likely to have more inherent problems, as it is the first year of most of the schemes and contains 'only' 32 apparently valid data sets. However, the 2013/14 data set contains 56 data sets, and we believe it offers a better view of the actual efficiency levels. This is shown in the table below:

Installation Capacity kWth	Fuel purchased KWhs (13/14)	RHI claimed (13/14)	Efficiency % (13/14)
520	1,488,960	1,277,819	85.8
697	2,179,200	1,803,575	82.8
696	2,456,400	1,775,235	72.3
755	1,424,000	1,000,210	70.2

520	1,372,800	941,898	68.6
520	1,862,851	1,271,776	68.3
520	1,693,128	1,148,371	67.8
520	1,887,663	1,266,267	67.1
465	1,840,533	1,220,175	66.3
755	1,330,285	879,088	66.1
520	1,700,945	1,113,196	65.4
520	1,957,028	1,271,822	65
520	1,780,114	1,151,863	64.7
520	1,688,746	1,092,522	64.7
464	1,645,714	1,040,763	63.2
520	2368000	1,496,782	63.2
755	2,117,866	1,328,546	62.7
465	1,245,818	780,273	62.6
465	1,116,266	694,163	62.2
755	1,999,542	1,233,290	61.7
520	2,123,586	1,303,303	61.4
464	952,246	581,555	61.1
520	1,632,000	988,671	60.6
696	1,939,200	1,171,398	60.4
630	2,317,776	1,359,347	58.6
696	2,142,857	1,250,709	58.4
520	1,591,200	925,008	58.1
630	1,333,527	771,831	57.9
755	1,116,872	645,784	57.8
464	1,654,400	953,372	57.6
465	1,680,000	962,577	57.3
348	1,570,863	887,950	56.5
520	1,644,218	926,526	56.4
465	1,378,400	743,559	53.9
464	1,381,800	743,746	53.8
697	1,723,733	896,990	52
520	1,098,830	561,271	51.1
465	1,566,424	799,663	51.1
406	1,596,800	807,473	50.6
750	1,974,400	993,629	50.3
465	1,200,685	588,464	49
930	2,007,360	982,978	49

520	1,547,657	751,327	48.5
580	1,902,670	918,028	48.2
348	1,254,400	559,650	44.6
520	2,188,114	928,079	42.4
520	1,540,800	641,556	41.6
465	1,200,000	498,637	41.6
520	1,508,400	598,555	39.7
520	1,606,400	592,680	36.9
464	1,913,066	694,875	36.3
520	1,950,933	698,497	35.8
465	1,364,135	372,529	27.3
465	1,374,600	356,875	26
630	1,291,200	302,807	23.5
930	2,759,712	569,390	20.6
			55.12%/Avg

Figure 22: Retail sites efficiency outcomes 2013/14

The table shows the overall average efficiency of the schemes as 55%. The median efficiency is 58% and the highest efficiency is 85%. The average efficiency of the top ten performing schemes is 71%, however, a large group of schemes were operating at below 50% efficiency. Whilst limitations in the data mean we cannot categorically state that these are actual system efficiencies, the sample is sufficiently large that the observed performances is a cause for concern.

Appendix 3: Data on 25 district heating sites

	Length of Pipe (m)	Buffer Tanks Size (l)	Predicted Annual Usage (kWh)	Actual Annual Heat Generated (kWh)	Predicted Annual Heat Loss (kWh)	Actual Annual Heat Loss (kWh)	Actual Quarterly Heat Loss Average (%)
Site 2	30	2 x 2200	450000	279276	7165	21778	13.82%
Site 3	40	2 x 2200	363590	389416	10249	107114	28.73%
Site 4	40	2 x 2200	200000	243225	7592	36553	17.00%
Site 5	46	2 x 4000	807354	862930	13096	99033	11.70%
Site 6	60	0	260000	271801	11388	26214	9.64%
Site 7	67	2 x 3000	444000	589302	17167	68025	13.61%
Site 8	80	2 x 3000	500000	377497	20498	41182	10.91%
Site 9	110	1800	131400	143416	22491	69403	52.55%

Site 11	124	2 x 1650	197514	165535	22140	54138	35.69%
Site 12	128	3000	222110	325134	21447	115924	35.65%
Site 13	150	1500	750000	759654	27996	119257	17.27%
Site 14	247	4400	275080	363700	45514	89817	28.65%
Site 15	250	2 x 2200	520000	329058	47450	72182	28.44%
Site 16	270	0	170000	153664	41566	66490	44.74%
Site 17	270	5000	257680	372581	55896	132005	38.63%
Site 18	348	0	225000	222460	63915	109539	49.06%
Site 19	355	3000	218507	223050	62681	76631	42.05%
Site 20	543	0	655000	633557	108717	197995	36.87%
Site 21	548	2 x 2200	300000	407640	100803	177456	45.01%
Site 22	169	0	570000	759120	33840	73150	9.68%
Site 23	218	3000	305144	396855	44267	68527	18.66%
Site 24	530	4000	172183	288756	64749	112959	42.24%
Site 25	582	4000	264307	354768	95987	137662	43.02%
Site 26	749	2 x 2200	258272	468271	150007	217719	46.49%
Site 27	875.1	0	657000	1383482	338387	442177	33.09%
Averages	**258**	**1856**	**357089**	**408554**	**54189**	**103754**	**32%**

Appendix 4: Tender Example

"Generally the building is split into separate areas serving the following activities :

- ***DELETED** - ACTIVITY A*
- ***DELETED** - ACTIVITY B*
- ***DELETED** - ACTIVITY C*
- ***DELETED** - ACTIVITY D*

The tender[er] is to detail three options. The options are related to the operation of the plant and the expected returns from the Renewable Heat Incentive.

- *Option 1 - 4 separate boilers to cover the heating loads as described in Systems 1 to 4*
- *Option 2 - 4 separate boilers to cover the heating loads as per option 1 but with gas boilers as back up*
- *Option 3 - 1 system to cover the whole of the building load, but designed with two or more biomass boilers to provide the system resilience when one system is down for maintenance."*