ERDF Social Housing Energy Management Project

Final Project Report

October 2013

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Confidentiality

This report was prepared by Narec Distributed Energy Ltd, with support from the ERDF consortium, subcontractors, National Energy Action and Warm Zones on behalf of National Renewable Energy Centre Ltd.
For more information on Narec Distributed Energy please look to **www.narecde.co.uk**
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Contents

Tables

Figures

1 Executive Summary

This is the project report for the Social Housing Energy Management project. The project is a partnership project between the UK's National Renewable Energy Centre (Narec), South Tyneside Council and their managing agent South Tyneside Homes and Northumberland County Council and their managing agent Homes for Northumberland. The consortium has received £1.9m investment from the European Regional Development Fund (ERDF), the total project value is £3.84 million.

The project involved retrofitting low carbon and renewable technologies onto over 300 properties managed by South Tyneside Homes and Homes for Northumberland. The properties were selected as they were considered "hard to treat, hard to heat". A "hard to treat, hard to heat" property is one of non-traditional build or off the gas network, the properties selected for this project were all of non-traditional build. Under the original definition of fuel poverty, North East England had the highest levels of fuel poverty in England in 2010 [1], thus one of the major objectives of the project was to remediate fuel poverty in socially rented properties.

Throughout this project, Narec has worked with Narec Distributed Energy to monitor the homes. This has included resident surveys, thermal imaging and using data loggers to measure the internal and external temperatures of the homes. Air pressure tests were commissioned and carried out on a sample of five properties to understand the improvements in air infiltration rates.

In addition to the testing and monitoring aspect of the project, a unique SME capacity building programme was delivered. Through the project, regional SMEs were able to access tailored support and assistance to expand or diversify their business capabilities within the low carbon sector. By combining this with the retrofit programme, SMEs were able to visit the retrofit works as they were delivered allowing them a unique insight into the installation and use of these low carbon and renewable technologies.

This report uses the data collected, in addition to third party data, to understand the impacts of the improvements to the properties.

The building types and measures carried out are shown in ***Table 1***:

Table 1: *Summary of works*

Partner	Properties	Technologies
South Tyneside Homes	132 dwellings in total in 3 high-rise blocks of flats in Jarrow, Tyne & Wear	• Solid wall insulation • Replacement glazing • Lighting • Replacement of Elson Tanks with heat exchange units on district heating system • TRVs in flats
South Tyneside Homes	136 Tarran Newland Houses in Marsden, South Shields	• Photovoltaics • Replacement glazing • Solid wall insulation • Lighting • High efficiency boilers
Homes for Northumberland	53 houses in Blyth, Northumberland	• Solid wall insulation • Lighting • Secondary heat exchange • Voltage optimisers

The retrofit is now complete, and a detailed analysis of the available data from the project and third party sources carried out.

The most significant findings are;

- Tenant satisfaction with the comfort of their homes improved dramatically

  67% of residents in the Tarran Newlands properties are now very satisfied with the warmth of their homes, compared with 2% originally

  56% of residents in the Wimpey No Fines properties are now very satisfied with the warmth of their homes, compared with 22% originally

- Space heating /DHW energy bills decreased for all properties

  Tarran Newlands decreased by 57% - based on questionnaire data

  Wimpey No Fines decreased by 13% - based on questionnaire data

  High Rise flats bills decreased by 13.4% - based on over gas usage data from Corona Energy

- 78 % Residents in the Tarran Newland properties used to turn off the heating to save money, now only 63% do this
- The homes became far less draughty. Air pressure tests were carried out before and after the works, showing a 32% improvement for the sample Tarran Newland property, and 24% improvement for the sample High Rise properties.
- Data logging showed residents in the Tarran Newlands heat their homes to a higher temperature, whereas the Wimpey No Fines residents now actually heat their homes to a lower temperature. The High Rise flats show a mixture.
- Data logging showed that the Tarran Newlands and Wimpey No Fines properties to have more consistent internal temperatures after the works.
- Over a ten year period, this project is expected to have avoided 1,982,282 kgCO_{2eq} of greenhouse gas emissions

2 Introduction

This is the final report for the ERDF Social Housing Energy Management Project. This project is headed by the UK's National Renewable Energy Centre, collaborating with two local social housing providers; South Tyneside Homes and Homes for Northumberland.

The Social Housing Energy Management Project, part funded by the European Regional Development Agency (ERDF), is a collaborative project to improve and analyse over 300 post war prefabricated social housing through a range of measures. The properties included in the project are Tarran Newlands, High Rise blocks, and Wimpey No-Fines houses. Data monitoring was carried out by Narec Distributed Energy, which included outdoor and indoor temperature sensing, and collation and analysis of energy bill data.

This document provides the final review of the project. It gives a brief summary of the project and the homes, before looking at the quantitative and qualitative data gathered throughout the project, to understand the effectiveness of the measures on the different housing types.

In addition to the work included in this report, a unique SME capacity building programme was delivered. Through the project, over 95 regional SMEs were supported to access tailored support and assistance to expand or diversify their business capabilities within the low carbon sector. By combining this with the retrofit programme, SMEs were able to visit the retrofit works as they were delivered allowing them a unique insight into the installation and use of these low carbon and renewable technologies, over 200 individuals in north east SMEs were supported with skills development.

The European Regional Development Fund exists to reduce economic disparities within and between member states by supporting economic regeneration and safeguarding jobs. Since 2000, England alone has benefited from more than €5bn of funding, with a further €3.2 billion being invested between 2007 and 2013 in local projects around the country [2]. From 2014 to 2020 a further €6.2 billion will be invested in England, with €0.54 billion targeted at the North East of England [3].

3 Pre-Works Report

The Pre-Works report for this project was released in January 2013. It looked in detail at the project properties, and the improvements which were in the process of being carried out. The report detailed the levels of fuel poverty in the properties, and based on thermal modelling gave approximations of the possible improvements.

The highlights of the report were:

- Fuel poverty is a major problem amongst the residents of homes in South Tyneside Homes and Homes for Northumberland.
- The air change rates are up to 19.26 $m^3(h\ m^2)$ @50pa, which is twice that allowed under the 2010 Part L building regulations, and ~7 times that allowed for new build social housing in the UK under the Code for Sustainable Homes.
- Approximately half of residents were dissatisfied with the heating systems in their homes.
- In response to survey ~70% of residents indicated that they turned off their heating systems to save money.
- The worst case of fuel poverty in this project showed properties where residents (if they heated their home adequately) would spend 25% of their income on energy bills.
- One fifth of the Tarran Newlands residents, if they heated their homes adequately, would spend over one fifth of their income on energy bills.
- Some residents have heating bills per year of £2,500 – suggesting approximately 90MWh of heat, six times the amount that should be required for their property type.

This pre-works report is available from the Narec Distributed Energy website.

4 The Current State of Fuel Poverty

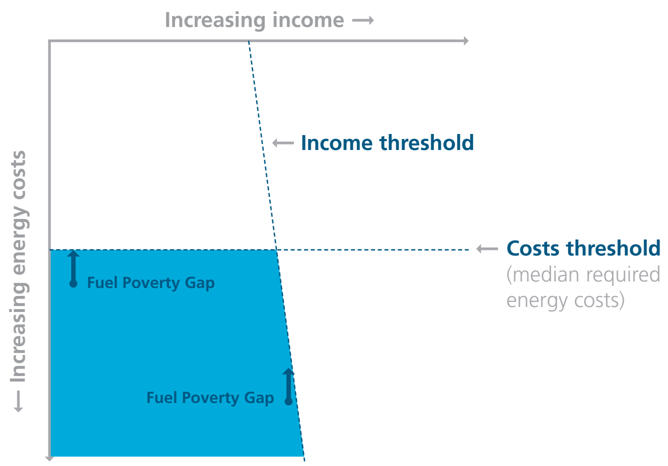
Since 1997, the UK government has targeted fuel poverty as a major policy issue [4]. In the year 2000 the Warm Homes and Energy Conservation Act was brought in, which had a legally binding target to eliminate fuel poverty in England by 2016 and in Wales by 2018 [5]. For various reasons, this target was removed in 2013 to be replaced by an as yet to be defined new framework [6]. Since 1997 numerous incentive and funding schemes have existed to increase the energy efficiency of homes (such as CERT, CESP, Warm Front and ECO) and to offer financial aid with fuel bills (Winter Fuel Payments).

However, in order to successfully tackle fuel poverty, first it must be defined exactly what fuel poverty actually is. The Warm Homes and Energy Conservation Act 2000 had the following definition of fuel poverty; "a person is to be regarded as living "in fuel poverty" if he is a member of a household living on a lower income in a home which cannot be kept warm at reasonable cost". However, in order to understand the levels of fuel poverty, and to aid identification of the most at risk groups, a statistical method was created. From 1997 until 2013, fuel poverty was defined as when 10% or more of a household's income would need to be spent to raise the temperature of a dwelling to a comfortable and safe level. This level was defined as 21°C in the living room, and 18°C elsewhere.

The logic for this was based on data from 1988, when the average spend on energy in the UK was 5% of a home's income, and the 30% of households with the lowest income spent over 10% of their income on energy [4].

In 2012 the Coalition Government sought to redefine fuel poverty. A review was carried out by Professor John Hills of the London School of Economics. This gave a new definition; fuel poverty is now defined as when a household's **required** fuel costs are above the median level; and if they were to spend what is required, then the household would be left with a residual income below the official poverty line. Additionally, a Fuel Poverty Indicator has been created, which shows how far into fuel poverty households are, not simply if they are in poverty or not. This is described below in ***Figure 1*** [7].

Figure 1: *Low Income High Cost (LIHC) methodology for defining fuel poverty*



This new definition of fuel poverty, known as the LIHC method, has been modified by the Department of Energy and Climate Change (DECC) and from now on the DECC version of the LIHC method will be used to define fuel poverty in all official government documentation. Some of the recommendations from the Hills report (such as looking at actual numbers of people in fuel poverty as opposed to numbers of dwellings) have not been included in the official version of the LIHC method. In addition to this, the 10% methodology results will still be reported.

The two definitions are shown together in ***Figure 2***. It does show a distinct difference between the two methods. Looking in addition to the Fuel Poverty Gap in ***Figure 3*** it can be seen that whilst the original definition shows that fuel poverty is increasing, the new definition shows that whilst the actual numbers of households in fuel poverty are remaining stable, those who are in fuel poverty are currently being pushed further into fuel poverty. Essentially, the poor are becoming poorer.

A key feature of the LIHC method is its impact on the distribution of fuel poverty in England. The changes can be seen when examining fuel poverty by region and by household type, with lone parent families now showing the highest levels whereas previously it was older single person households. Similarly, the definition has changed the regional distribution. Changes in the distribution can, at least in part, be attributed to the new definition using 'after housing costs' equivalised income. Regionally, the North East has moved from being that with the highest level of fuel poverty, to the fourth highest (out of the 9 English regions). It is very important to stress that some families who are living in poverty are not necessarily living in fuel poverty. This could be, for example, a situation where people are living in highly efficient social housing so have very low fuel bills. Therefore it is important to understand that although fuel poverty is related to poverty, it is not the same thing.

Figure 2: *Fuel poverty rates in the UK based on the 10% and Low Income High Cost methodologies – data from [8]*

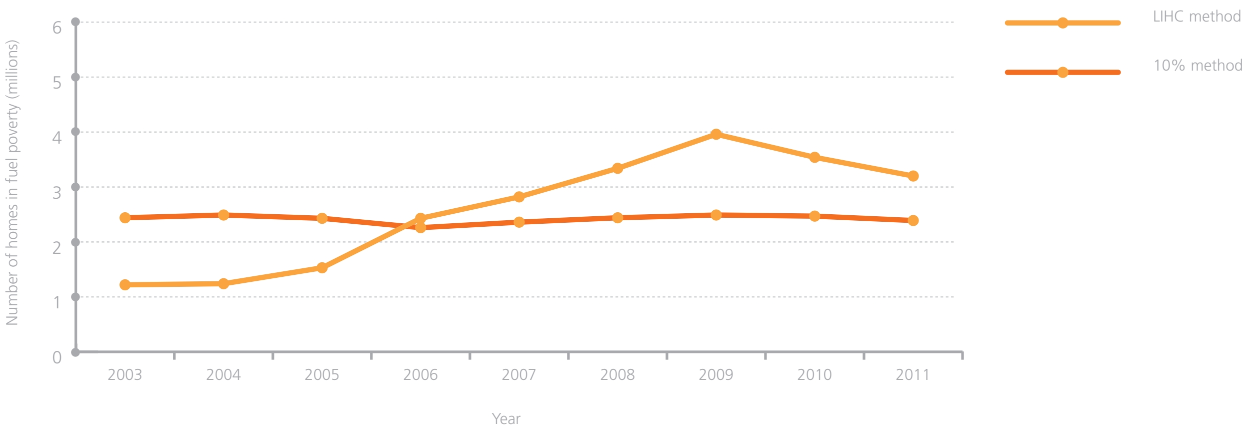
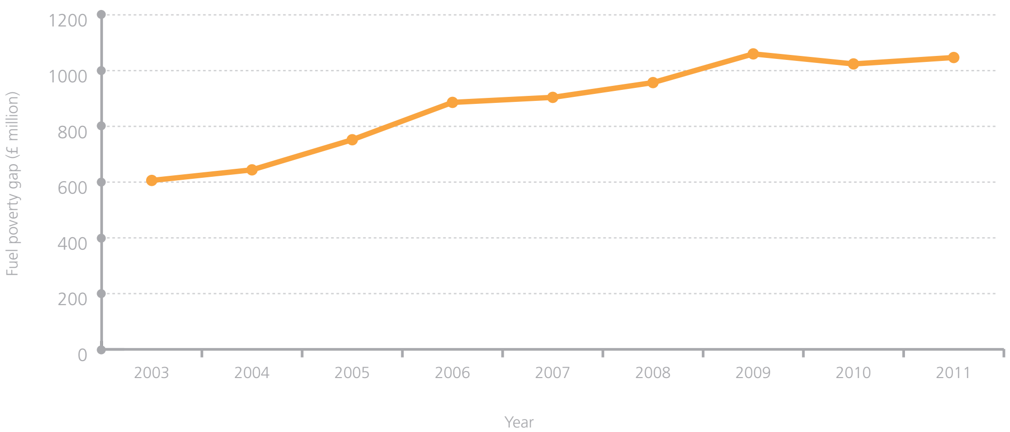


Figure 3: *Fuel poverty gap – data from [8]*



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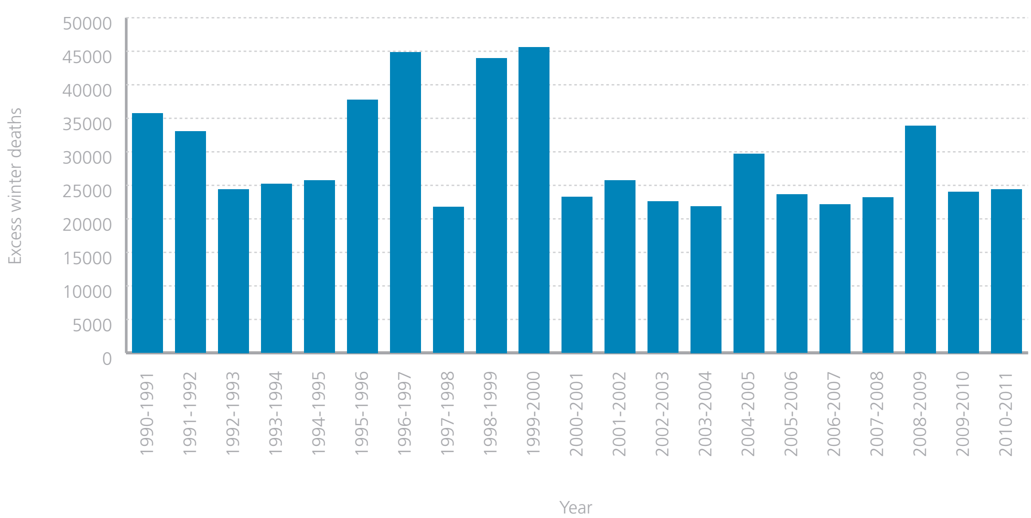
There are criticisms of the LIHC methodology for calculating levels of fuel poverty, partly due to the high levels of complexity. However, there were also criticisms of the original definition, partly for it's over simplicity. It is important to remember that whichever of these methods is used to define fuel poverty, they are merely statistical tools. The purpose of these tools is to understand the level of the problem, and where best to target fuel poverty alleviation measures. These are estimation tools, not absolute truth.

With regard to the complexity of the new definition of fuel poverty, it is not possible for this project to measure the levels of fuel poverty using the LIHC methodology. The levels of data necessary on properties simply were not available. Neither were the complex algorithms used by the Department of Energy and Climate Change. Therefore throughout this project the original 10% definition of fuel poverty has been used.

4.1 Excess Winter Deaths

Figure 4: *Excess winter death rate data from the West Midlands Public Health Observatory [10]*



An important measure of the impact of fuel poverty is to consider excess winter deaths. In common with other countries, more people die in England and Wales in the winter than in the summer. These are referred to as Excess Winter Deaths (EWD). The standard method to calculate this is to compare the number of deaths in a winter period (defined as December to March) and compare this with the average number of deaths occurring in the preceding August to November and the following April to July [9].

There were 25,400 excess winter deaths in England and Wales in 2009/2010 and 2,760 excess winter deaths in Scotland in 2009/2010. It was estimated in the Hills report that of the excess winter deaths, 10% per year are due to fuel poverty. Other reports have estimated that this percentage is higher. As can be seen in ***Figure 4***, the levels of excess winter deaths currently stand at about 25,000 a year, which suggests fuel poverty related deaths are 2,500 a year.

According to the British Medical Association, the following observations can be applied to Excess Winter Deaths (EWD): [11]:

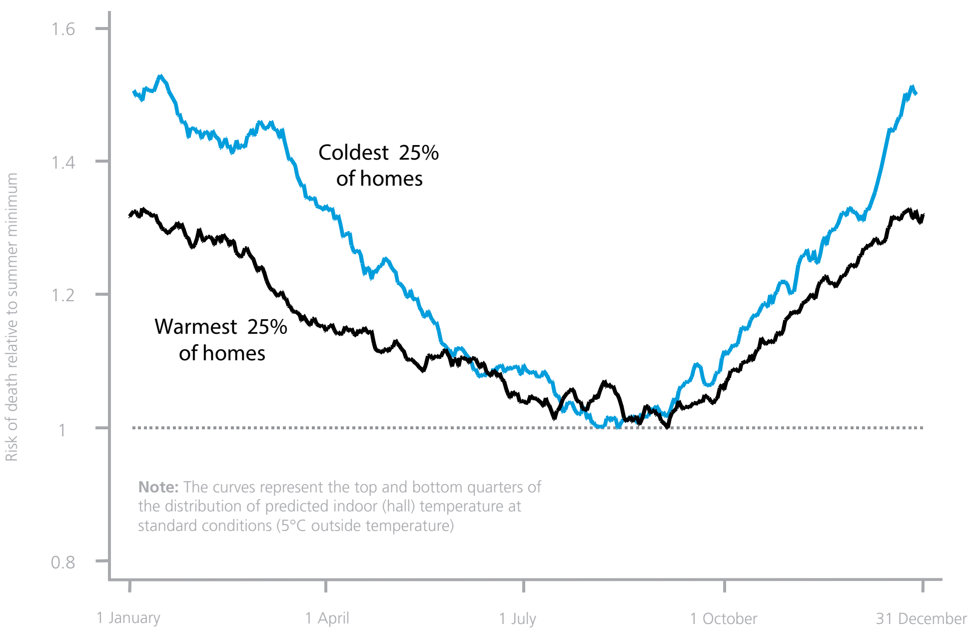
- Countries which have more energy efficient housing have lower EWDs.
- There is a relationship between EWDs and low SAP rating/low indoor temperature.
- EWDs are almost three times higher in the coldest quarter of housing than in the warmest.
- 21.5% of all EWDs are attributable to the coldest quarter of housing, because of it being colder than other housing.
- Around 40% of EWDs are attributable to cardio-vascular diseases.
- Around 33% of EWDs are attributable to respiratory diseases.

It is difficult to know what percent of EWD are due to fuel poverty, but work such as Wilkinson et al 2001 [12] shows that energy inefficient homes have a greater probability of excess winter deaths. The work of Wilkinson et al centred on the analysis of 80,331 deaths from cardiovascular disease in England between 1986 and 1996. Some of their results are shown in ***Figure 5*** and ***Table 2***.

Table 2: *Excess winter deaths per building type in England and Wales [12]*

Property age	Excess winter deaths compared with total annual deaths
Pre-1850	28.0%
1850–99	25.6%
1900–18	24.1%
1919–44	26.0%
1945–64	23.9%
1965–80	17.1%
Post1980	15.0%

Figure 5: *Excess winter deaths in the warmest 25% of homes and coldest 25% of homes from 1986 to 1996 [12]*
Additionally, there is evidence fuel poverty can negatively impact on residents physical and mental health, and clearly result in a poor quality of life [13]. This is detailed in the following sections.



4.2 Physical Health Issues

Of the medical issues that cold temperatures can either cause or exacerbate, the most serious conditions are cardiovascular and respiratory illnesses.

The temperature ranges for these issues are [14]:

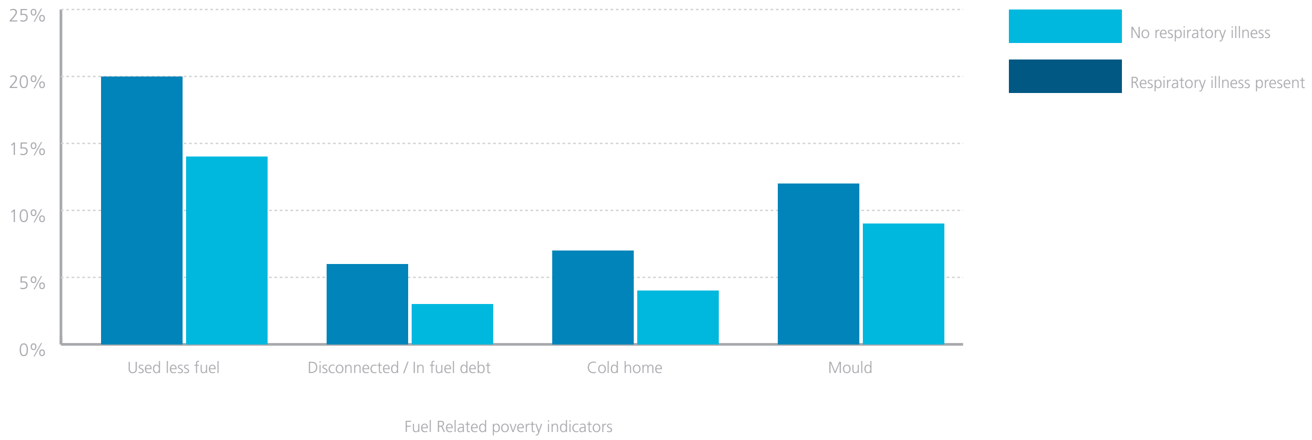
- 16°C – respiratory problems
- 12°C – circulatory problems
- 5-6°C – risk of hyperthermia

According to Macmillan Cancer support, 85% of health professionals who took part in a survey believe that feeling cold can affect a patient's recovery. The same survey showed that 77% of professionals have seen evidence of patients suffering from pain, for example neuropathic pain, triggered or worsened by feeling cold [15].

Additionally, lower temperatures will lead to a loss of dexterity from cold induced muscle seizures, leading to more accidents such as trips and falls. Cold indoor temperatures also increase pain for those suffering from arthritis [16].

The interaction of low temperatures and high humidity can lead to the growth of mould and dust mites, which can lead to or exacerbate respiratory illnesses such as asthma [17]. Mould growth, in poorly warmed homes, can be a major problem for children. ***Figure 6*** shows respiratory illness does have an increased prevalence amongst the fuel poor [18] [19].

Figure 6: *Aspects of fuel related poverty, by presence of a respiratory illness in the past year [18]*



4.3 Psychological Issues

In addition to the physical illnesses caused by fuel poverty there are also psychological effects.

Issues which have been shown to have a high prevalence amongst the fuel poor include:

- Depression
- Bipolar
- Anxiety

Various studies have been conducted which have found positive mental health impacts as the result of fuel poverty alleviation measures. A study using 12 Item General Health Questionnaire GHQ12 scores showed that those with anxiety or depression reduced from 300 per 1000 to 150 per 1000. This is a significant impact. [20] According to work by Macmillan Cancer Support, 92% of social care professionals believe there is a link between feeling cold and mental wellbeing [15].

4.4 Costs to the NHS

All of the above leads to a major cost on the National Health Service (NHS). Overall, according to the Chief Medical Officer, illnesses caused by cold homes cost the NHS more than £850 million a year [21].

4.5 Effects on Children

Fuel poverty can have major effects on children. A good introductory text on this is "The Impact of Fuel Poverty on Children" policy briefing written by Professor Christine Liddell [22]. This looked into peer reviewed research globally on the effects of fuel poverty on children.

For example, a study in the US compared two groups of low income children in five different cities. Group 1 lived in families which were receiving a winter fuel subsidy, and group 2 were not. It was found that infants in homes without subsidy were 40% more likely to be admitted to hospital or primary care clinics in their first three years. They were also more likely to be underweight. The reasons for this would be that as with any human being, infants stay warm by burning calories. Thus when they are cold they have fewer calories available for other bodily functions such as growing or building a healthy immune system. Additionally, the paediatricians involved in the US study speculated that there are risks to children's cognitive development from years of being underweight.

4.6 Disabled People

The increase in fuel poverty amongst disabled people has been somewhat dramatic as of late, in 2003, 2.7% of households containing a disabled person were in fuel poverty, by 2010 that had increased to 6% [23]. Additionally, living costs for disabled and ill people is higher than the UK average, according to the Joseph Rowntree Foundation report "Disabled people's costs of living: More than you would think" there are higher costs in food, clothing, household maintenance, fuel and power, household goods and services, transport, communications, recreation/culture, education, health, personal care, insurance and special occasions [24]. This puts disabled people at risk of fuel poverty.

As specified in section 4.2, low temperatures can have major health impacts, which disabled people are more vulnerable to due to reduced activity.

4.7 Older People

In 2010, according to Department of Energy and Climate Change figures, 38% of households where the youngest member was over 60 were in fuel poverty, looking at households where the youngest member is over 75, then in 2010, 53% of households were in fuel poverty [23]. Clearly this group are prone to various health complications, which fuel poverty can aggravate.

4.8 Single Parents

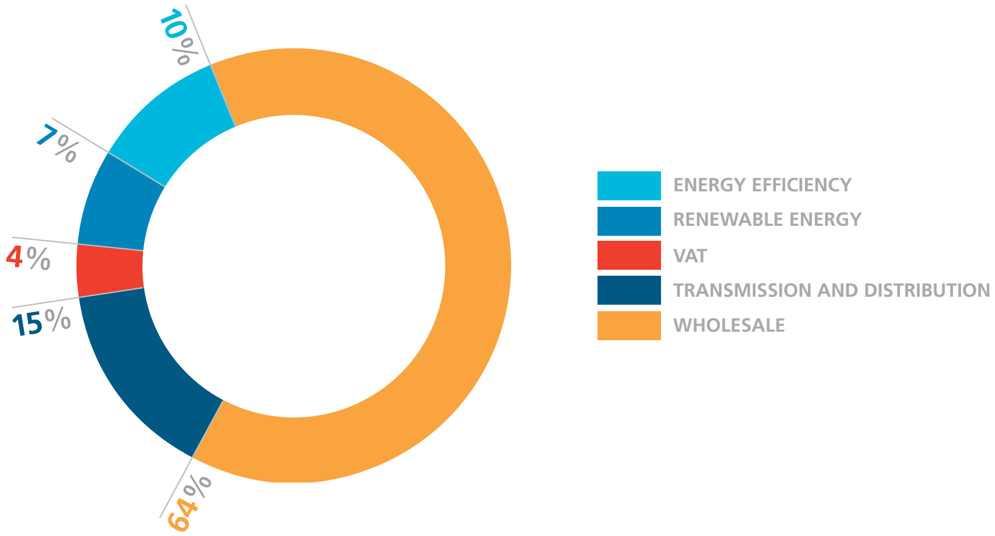
According to figures from the Department of Energy and Climate Change, in 2010 22% of single parents were in fuel poverty [23]. Research carried out by YouGov on behalf of the organisation uSwitch shows that in 2011 39% of single parents are in fuel poverty. This jump is blamed primarily on the increases in fuel prices [25].

These issues can be very detrimental for the development of children, and on the mental health of the parents as they struggle to deal with their financial situation.

4.9 Fuel Bills in the UK

One major factor in fuel poverty is clearly the size of fuel bills. These are currently increasing for several reasons, primarily due to the cost of wholesale gas. A detailed breakdown of cost increases is given in the report "Household energy bills – impacts of meeting carbon budgets" by the UK Government's Committee on Climate Change, the bill increases were split up as follows from 2004 to 2010 [26].

Figure 7: UK dual fuel price increases 2004-2010 [26]



Current bills are set out as follows:

Table 3: Fuel cost makeup in the UK [26]

	Electricity	Gas
Wholesale	59%	65%
Transmission, distribution and metering	22%	26%
Renewables/low carbon	14%	4%
VAT	5%	5%

It is important to stress that money funding low carbon measures, such as Carbon Emissions Reduction Target (CERT), was being used to insulate homes, and thus though the low carbon measures have slightly increased bills, this money is being used to lift the most vulnerable out of fuel poverty.

It seems likely that fuel bills will continue to increase with the wholesale price of fossil fuels, which are showing a general long term increasing trend. This is a major concern for fossil fuel users, and although greater dependence on renewable energy will protect the UK somewhat from these increases, the UK only expects to have 30% of electricity from renewables by 2020 [27].

There has been talk in the media that increased extraction of gas trapped within shale formations may reduce future energy bills. However, analysis by the oil and gas exploration company Cuadrilla Resources, who are involved in this type of extraction, suggests that the impact on UK bills will be insignificant. [28]. This conclusion is also in agreement with data from Bloomberg Energy Finance's response to the House of Lords Select Committee's Call for Evidence on "The Economic Impact on UK Energy Policy of Shale Gas and Oil" [29].

4.10 Building Quality

There are substantial issues with energy efficiency in buildings in the UK. This was one of the drivers which led to the creation of the UK Government's Green Deal and ECO policies, which will hopefully be successful. Within the private rental housing stock, half of the housing stock provided by private landlords doesn't meet official building regulation standards. Tenants often find it difficult to complain about their conditions due to the fear of eviction. [13]. Social housing from Housing Associations suffers a range of problems. One major issue is the level of housing stock with heating challenges inherited by housing associations from local authorities, such as the thousands of post war prefabs. Often, the higher quality housing has been bought up through the right-to-buy scheme and has not been replaced, leaving a smaller number of suitable housing properties for those most in need [30].

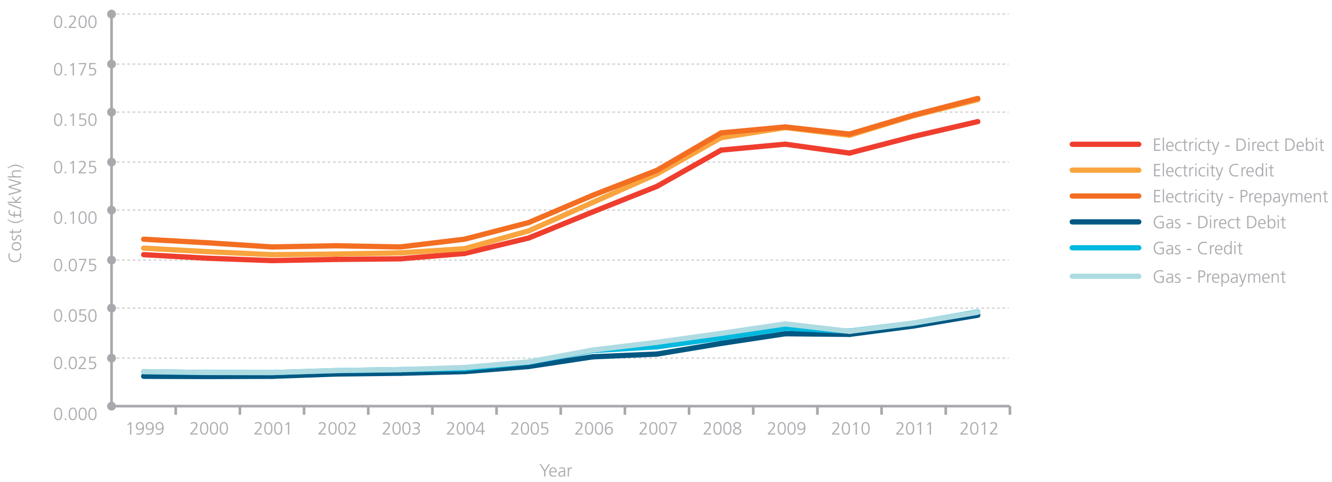
4.11 Tariff Problems

Those most at risk of fuel poverty tend to pay more for their electricity and gas due to the large amount of pre-payment meters. This is the most expensive way to buy electricity and gas in the UK compared to the option of using direct debit. For example, an annual dual fuel bill for a customer with average consumption would be £1,176 per year for electricity and gas via direct debit, compared against a customer with a pre-payment meter who would pay £1,255. This means an average customer with pre-payment meters pays around £80 extra for their electricity and gas every year [31].

The use of pre-payment meters is increasing. In 2004 a large proportion of pre-payment meter installations were on a voluntary basis but over time there has been a significant increase in the proportion installed to collect debts. This collection of debts on pre-payment meters poses another complication in the gathering of accurate bills data for this project. In the second quarter of 2011 around 53,000 electricity pre-payment meters and around 52,000 gas pre-payment meters were installed. Of these, around 90% of electricity and 87% of gas pre-payment meters were installed to collect debt. This contrasts with 2004 where only 44% of electricity and 50% of gas pre-payment meters were installed to collect debt [31].

5 Future Trends for Fuel Poverty in the UK

Figure 8: *Fuel costs in the UK for electricity and gas*

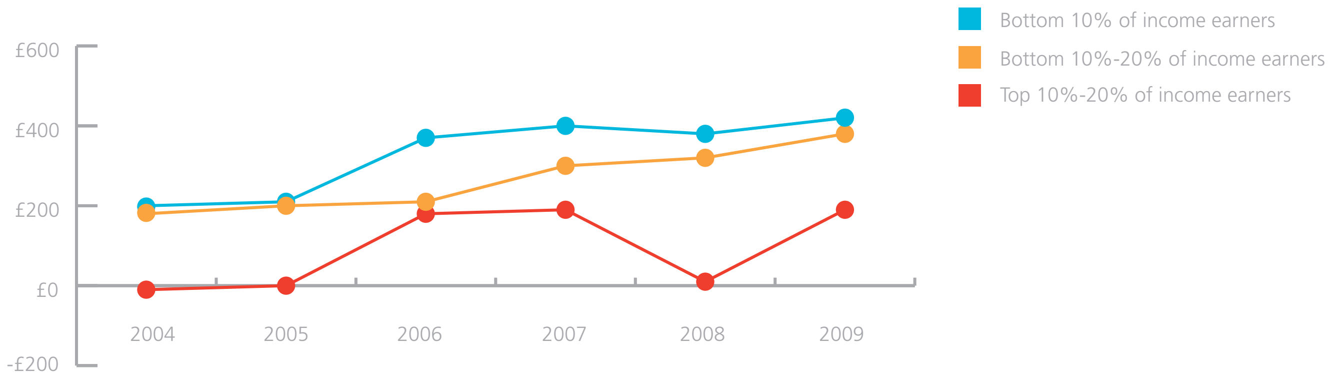


5.1 Costs of fuel

According to data from the Office of National Statistics (ONS), for those not using direct debit, from 1999 to 2012 actual fuel prices have increased by 94% (electricity) and 174% (gas). The historic costs are plotted in ***Figure 8*** using ONS data [32] [33]. Figure 7 shows fuel prices have dramatically risen since 2005 and that those on pre-payment meters consistently pay more.

Figure 8 shows the average extra annual spend to achieve an adequate level of warmth in relation to income banding. It is clear those of lowest income spend the greatest extra keeping adequate levels of warmth

Figure 9: *Cost of heating a home compared against poverty level [31]*



5.2 Economic Climate

The UK is undergoing tough times economically. In May – July 2013 unemployment in the UK was at 2.49 million 7.7% of the working population, and data shows that unemployment is levelling and even very slightly decreasing with 29.84 million people in employment [34]. This figure does not give the full picture, for example 8 million people are working only part time [35]. Additionally, many people are on zero hour contracts. This may be somewhere in the region of 250,000 [36] to 1 million workers [37], although higher estimates exist.

It is important to state that although employment has increased (partly due to part time and zero hour contracts) the average wages paid have decreased. From 2009-2010 to 2011-2012 earnings fell by 6.6% in real terms [38]. With regard to the living wage, currently 4.8 million (21%) workers earn below this level, a jump from 3.4 million in 2009 [39].

The lowering of wages leads to greater poverty, which in turn is linked to fuel poverty.

5.3 Welfare Reform

The UK welfare system is currently changing, which means the most vulnerable members of society are now having their budgets reduced. As shown in [40], many families are now having to choose between eating or using their heating systems. A major change has been the policy colloquially known as the "Bedroom Tax". This is intended to move residents from larger properties into smaller properties. Unfortunately, as these properties do not exist, or it would not be appropriate for these residents to move, the residents instead face a new financial burden they cannot afford. One of the impacts of the reforms is that use of food banks in the UK have increased by 170% from 2011-2012 to 2012-2013 [41]. In 2005 the number of people referred to the food banks of the Trussel Trust due to benefit issues was 20%, in 2013 that figure is now 57%. It is UK government policy to continue reducing the cost of the welfare system [42]. Logically, reducing the budgets of the poorest in society will increase the issues of fuel poverty.

In 2012 the UK Government Fuel Poverty Advisory Group recommended to The Secretary of State for the Department for Work and Pensions that the impacts of welfare reform on fuel poverty be investigated [43], however, at present no research has been completed.

5.4 Winter Fuel Payment

The winter fuel payment was introduced to help pensioners pay their winter fuel bills, and in winter 2010/2011 was worth £250 for the over 60s and £400 for the over 80s. However, in 2011 this was reduced by the government to £200 and £300 for the two age groups in the winter of 2011-12 on going forwards [44].

5.5 Climate and Extreme Weather Conditions

The Earth's climate is changing, and this will lead to major regional variations and an increased prevalence of extreme weather conditions, such as sudden cold snaps during winter [45]. These would presumably increase the levels of fuel poverty, and most probably the excess winter death rate. In a longer term, although not probable in the next hundred years, the Thermohaline current (known colloquially as the Gulf Stream) may slow or change direction, resulting in a change in the UK's climate to one resembling that of Canada. This is a strange but not impossible result of anthropogenically enhanced global warming [46].

6 Energy Hierarchy

When producing an energy strategy for any building, the energy hierarchy provides the most practical and cost effective methodology to achieve a low carbon development. The measures designed within the ERDF Social Housing Energy Management project have followed this hierarchy. This is a five stage process as detailed below:

ENERGY REDUCTION
Reduce the amount of energy used. In the simplest form this means turning off equipment which is not needed. Looking at intelligent lighting systems, timing the heating system for optimum operation, ensuring air conditioning does not turn on at the same time as heating.

ENERGY EFFICIENCY
Using energy efficient systems, such as A+++ rated electrical appliances and insulating the building as much as possible. Additionally, it means looking at passive design elements such as south facing windows and overhangs to capture solar energy efficiently.

RENEWABLE ENERGY
Having reduced the energy demand of a building as much as possible, the remainder of power must be generated. This phase involves generating heat and electricity from renewable generators. This includes photovoltaic panels and wind turbines for electricity, solar thermal for water heating.

LOW CARBON ENERGY
For the energy which cannot be generated through renewables, low carbon technologies can be used. These include ground/air/water source heat pumps.

CONVENTIONAL ENERGY
With no other options left, the final part of a building's energy demand will be generated through using conventional polluting options. In an optimum development this final phase will not be reached.

7 History of Buildings

The buildings selected to be improved through this project are all post war prefabricated buildings. These were built to replace the high levels of dwellings destroyed or damaged during the Second World War. The legal outline for the build of these was outlined in the Temporary Accommodation Act 1944. The plan from Winston Churchill was to build 500,000 prefabricated dwellings, with a planned life of up to 10 years. The buildings were to be all built within five years of the end of World War II. The final plan legally drawn up by the Labour government was reduced to 300,000 dwellings. The government set aside a budget of £150m for this construction. The idea was to use wartime production facilities and experience to roll out the construction of these homes quickly and effectively [47].

The prefabricated building project was coordinated by the Ministry of Works, who used the wartime manufacturing and organisation structure to roll out the building project in a military style. They opened a competition for designs of prefabricated buildings from commercial companies, and received 1,400 entries. After review of the proposals, and testing and construction of the most promising, the following designs were put into production by the post war government; Portal, Airey, Arcon, AIROH, BISF, Cornish Unit, Hawksley, Howard, Laing Easi-Form, Mowlem, Orlit, Phoenix, Reema, Swedish, Tarran, Uni-Seco, Unity structures, Wimpey No-Fines.

By the end of the program in 1951, a total of 156,623 prefabricated dwellings had been constructed. These were in addition to other social housing construction projects of non-prefabricated buildings which had led to over one million homes being built [48].

66 years on from the beginning of the project, there are many prefabricated buildings left over which are still surviving and still in use as social housing. With an original anticipated lifespan of 10 years, 56 years on these properties require dramatic improvements to ensure they are suitable housing for residents to have a good quality of life.

The types of prefabricated buildings in this project are Tarran Newlands, High Rise and Wimpey No-Fines houses.

7.1 Tarran Newlands

The Tarran Newlands in the ERDF Social Housing Energy Management project are owned by South Tyneside Council and managed on their behalf by South Tyneside Homes. The properties on Lincoln Road and Marsden Lane, have received various improvements throughout their lifetime.

7.2 Wimpey No-Fines

This design was created by the George Wimpey Company. “No-Fines” refers to the type of concrete used, which is concrete with no fine aggregates.

The buildings in Northumberland, specifically Blyth, are all Wimpey No-Fines. Unlike the Tarran Newlands there are multiple designs of the Wimpey No-Fines, although all following the same basic construction.

7.3 High Rise flats

There are three block of flats in Jarrow which are involved in this project. These are Monastery Court, Wilkinson Court and Ellen Court. All three are Wimpey No-Fines construction.

7.4 Summary

Of these buildings, the following numbers are being improved within the ERDF Social Housing Energy Management Project.

- **High Rise**
  Monastery Court - **44 dwellings**
  Wilkinson Court - **44 dwellings**
  Ellen Court - **44 dwellings**
- **Tarran Newlands**
  Lincoln Road - **89 dwellings**
  Marsden Lane - **47 dwellings**
- **Wimpey No-Fines**
  Brookside Avenue - **23 dwellings**
  Brierley Road - **9 dwellings**
  Hartleigh Place - **5 dwellings**
  Tynedale Drive - **12 dwellings**
  Malton Close - **6 dwellings**

Total properties: 322

Figure 10: *Tarran Newland - South Tyneside*

Figure 11: *Wimpey No-Fines - Blyth*

Figure 12: *High Rise Flats - Jarrow*

7.5 State of the Properties Prior to the Project

7.5.1 Tarran Newlands

The Tarran Newlands buildings on Lincoln Road and Marsden Lane were all built between 1935 and 1949. They are all two storey semi-detached properties. Prior to this project the properties had been retrofitted with double glazed uPVC, whilst walls had received no added insulation since construction. The walls were made up of 20mm of concrete panelling, with an air gap and then 25mm of fibre glass insulation, finished with a thin layer of fibreboard. This compares with a typical new build from this decade, which would have two layers of bricks 102.5mm thick surrounding a 75mm cavity which is relatively easy to fill using blown fibre, a common ECO/CERT measure. Almost all had a standard boiler (except for 2 with condensing boilers), these were fuelled by natural gas. The gas boilers supplied heat to the domestic hot water systems. The air change rates prior to the works were extremely high.

Two thirds of the properties already had 100mm insulation in the roofs, but one third only had 50mm. This was possibly due to the difficulty of placing insulation in the shallow roofs of the Tarran Newlands.

7.5.2 High Rise flats

Also built following the war, these are of Wimpey No-Fines concrete construction. Prior to this project all had double glazing with plastic frames, although site visits showed that these were poorly sealed with excessive draughts, as evidenced by the high air change rates in section 14. The properties are heated with a communal heating system. Each resident must purchase heating tickets, at a cost of £15.67, each of these supply 200kWh of heating. However, due to the high levels of energy required to heat the homes these do not last long. Additionally, due to the tickets only being purchased from the Town Hall, residents who do not plan ahead or are not able to buy sufficient tickets in advance can run out of tickets when the Town Hall is closed. The domestic hot water is served by individual Elson tanks in each property.

The properties are constructed on No-Fines concrete blocks, which are approximately 439mm thick (including finishing). The estimated U-values for the walls is 0.74W/m^{2}K, this is far higher than the individual houses in this project, but still could be improved. The roof includes 200mm of concrete slab and 25mm Cork/PUR insulation. The roofs have a U-value of approximately 0.34W/m^{2}K, but as a tower block this only affects the top floor flats; a small percentage of the total.

7.5.3 Wimpey No-Fines

There are three types of property in the Wimpey No-Fines, all of the same construction. The only differences are in the positions of doors and windows, and some internal walls.

Table 4: *Data on Wimpey No-Fines properties*

Type of house				
Semi	**Mid-terrace**	**End-terrace**		
67%	13%	20%		
Loft Insulation				
50mm	**75 mm**	**100mm**	**150mm**	**200mm**
4%	17%	56%	13%	11%
Heating system				
Standard boiler	**Condensing boiler**	**Condensing combi boiler**	**Room heaters (eg gas or coal fires)**	
6%	69%	24%	2%	

All the properties had double glazing with plastic frames. The solid walls had received no insulation added since their construction. The water systems are connected to the space heating, which are both fuelled by natural gas. Condensing boilers were most common heating systems.

The properties had concrete profiled tiling on treated timber battens which are in turn on a roofing membrane. The loft insulation, although present, was poor, with the majority only having 100mm of loft insulation, and none having 250mm.

The external wall construction was No-Fines concrete. This was finished internally with 12mm of plaster, and externally with 20mm of render with a thick pebbledash finish. Most of the properties (87%) were either semi-detached or end of terrace, so had a high surface to volume ratio, which meant there was a high area for energy loss through external walls.

The ground floor was thought to be 28mm of screed on 100mm of 1:3:6 concrete on a polythene sheet, which in turn was on 100mm of hardcore base.

7.6 Fuel Poverty Levels

Warm Zones, a national fuel poverty alleviation charity, provided the project with fuel poverty data they already had from previous work. This included 15 properties from Marsden Lane/Lincoln Road, 45 flats from the Jarrow High Rise flats, and 36 properties from the Blyth Wimpey No-Fines housing stock. Only properties involved in the project have been included in this analysis.

Table 5: *Summary of Warm Zones data*

Location	House Type	Homes in survey	% in fuel poverty	Maximum fuel poverty index
South Shields	Tarran Newlands	15	66%	25%
Jarrow	High Rise	45	9%	13%
Blyth	Wimpey No-Fines	36	19%	15%

The most concerning is the Tarran Newlands, where the level of fuel poverty is approximately 4 times that of the national average, with two thirds of dwellings suffering from fuel poverty. Additionally, the fuel poverty index goes up to 25%. This means families are spending a quarter of their income on their energy bills.

7.7 The Improvements

7.7.1 Tarran Newlands

The solid walls were extremely thin, so cladding was necessary to improve the insulation of the construction. Externally, 40mm of Kooltherm K5 EWB/K15 Rainscreen board was fitted, with 13mm of Wetherby system render on top. Internally the original 25mm glass fibre quilt (where still present) and vertical timber battens were removed and replaced with a 45mm Gyproc I stud with a minimum of 25mm Rockwool infill between studs. Finally, 12mm Gyproc foil backed plasterboard was installed, with tape and plaster skim, and painted with standard white emulsion. This in theory decreased the U-value of the walls from 2.35W/m^{2}K to 0.29W/m^{2}K. All of the above fits in with NBS specifications.

Although not funded by ERDF, 2.3kWp photovoltaic systems were installed on all south facing roofs possible in the Lincoln Road/ Marsden Lane area. A basic guidance sheet was drawn up to educate residents on how to change their energy usage habits to maximise the help the photovoltaic systems can give, for example running laundry equipment at mid-day This guidance sheet is to be sent out in October 2013.

7.7.2 Wimpey No-Fines

The roofs were improved with top up insulation to bring all properties up to 270mm insulation. Additionally insulation was installed in the box eaves. The wall constructions were improved with external insulation. This was made up of Wetherby Building Systems (WBS) 70mm phenolic insulation board, WBS scrim adhesive coat (4-6mm) reinforced with alkali resistant glass fibre reinforcing mesh, WBS scrim adhesive levelling coating (2-3mm) finished smoothly, with a final layer of WBS silicone finish coat (1.5mm).

Voltage Optimisers were installed in properties as part of this project. As part of a separate project funded by Homes for Northumberland, some properties have also had photovoltaic systems installed. Other improvements included the installation of a secondary heat exchanger (gas saver unit) to recycle wasted heat from the central heating boiler flue and low energy light bulbs.

7.7.3 High Rise flats

As with the other properties, the High Rise flats were improved with external cladding, which theoretically decreased the U-value to 0.22 W/m²K. The roofs were fitted with a decotherm system of insulation, which will theoretically brought the roof U-value down to 0.18 W/m²K. The windows were replaced with new double glazing with a lower air leakage rate than the pre-project windows.

The Elson Tanks used for domestic hot water were replaced with a heat exchanger design working directly from the communal heating system.

In order to give residents a greater control of heating throughout the flats, thermostatic radiator valves were installed on all the radiators.

Finally, the large open ventilation grills on the landings were closed to stop excessive energy loss.

***Figure 13:** Tarran Newlands pre works*

Typical existing wall construction - U value 2.35W/m²K

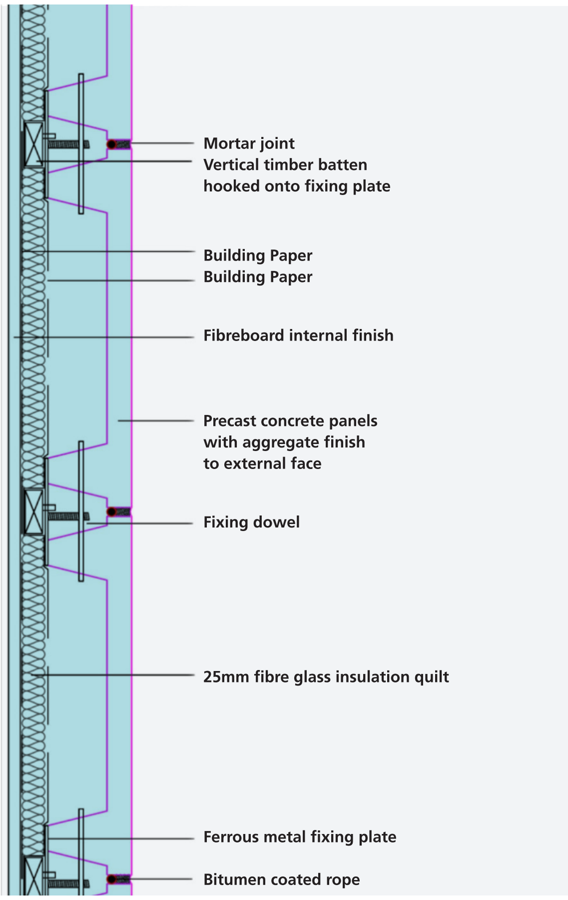


***Figure 14:** Tarran Newlands post works*

Typical existing wall construction - U value 0.29W/m²K

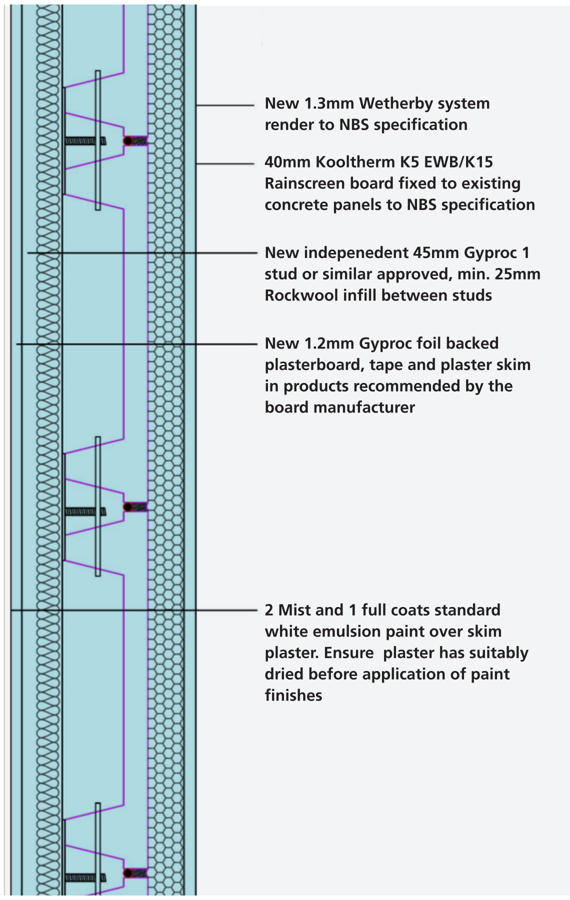


Figure 15: *Wimpey No-Fines construction Pre-Works*

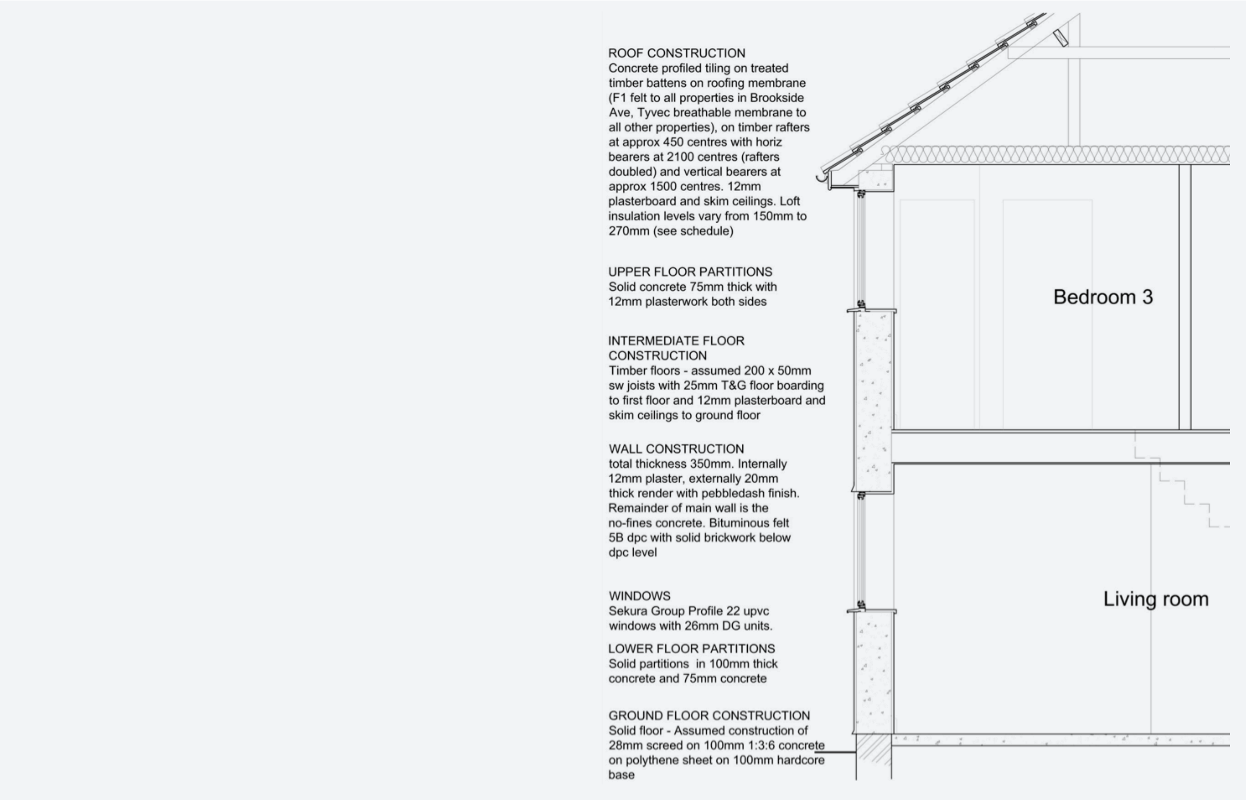
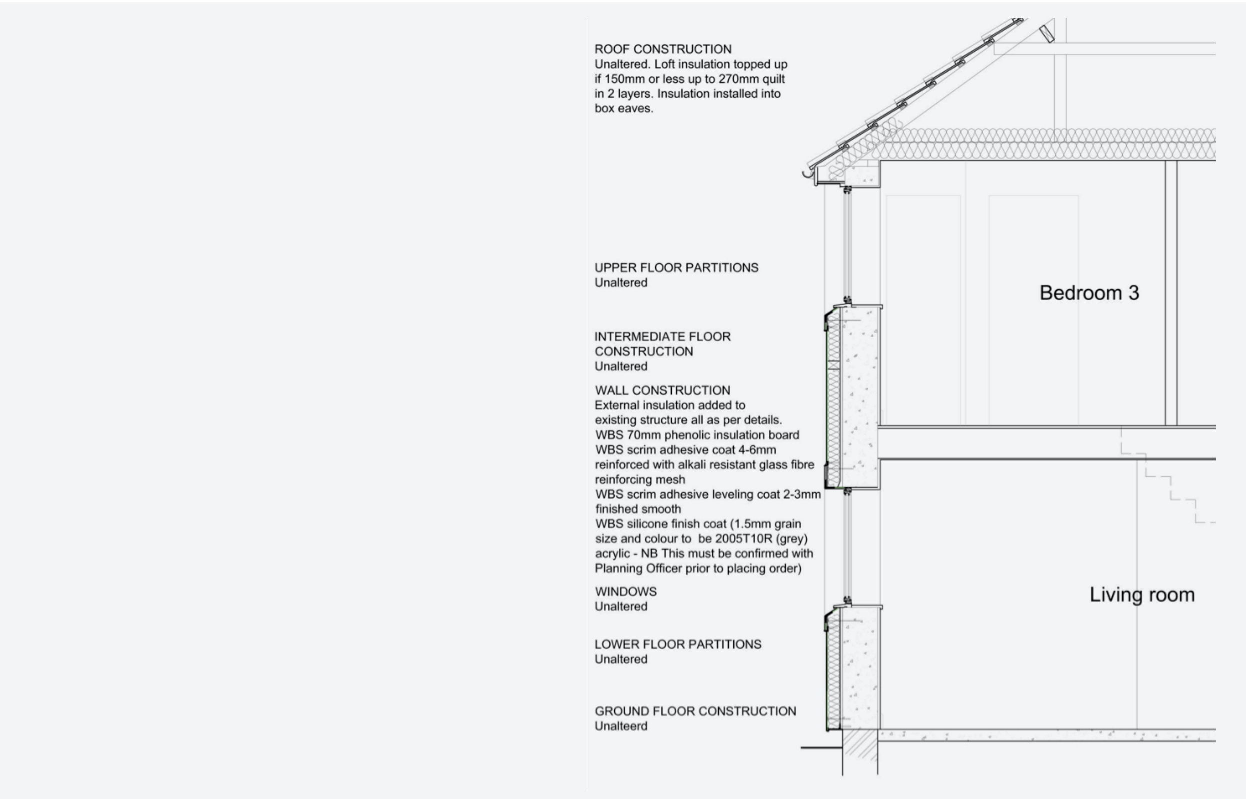


Figure 16: *Wimpey No-Fines construction Post-Works*



8 Photovoltaic Systems

Photovoltaic (PV) systems were installed on the roofs of the south facing roofs on the Wimpey No-Fines and Tarran Newlands. These are 2.3kW peak systems. It is important to stress that the ERDF project funded the enabling work for these systems, whilst the actual systems themselves were purchased by the housing providers using their own funds.

Calculations of the energy output of the systems were carried out using the Photovoltaic Geographical Information System, which is a European funded system which is part of the SOLAREC action at the JRC Renewable Energies Unit. Calculations were carried out using the PVGIS-CMSAF database, which is based on ground solar data from 1998 to 2006.

This showed for a roof pointing 0 degrees off South, with a pitch of 15 degrees, a 2.3kWp system would have a total yearly output of 2.040MWh.

The monthly outputs are shown in the below table:

Table 6: *PVGIS calculations for Tarran Newlands PV systems*

Month	Daily Average [kWh]	Monthly total energy [kWh]
Jan	1.79	55.6
Feb	3.33	93.2
Mar	5.65	175
Apr	7.94	238
May	9.76	303
Jun	9.13	274
Jul	8.91	276
Aug	7.54	234
Sep	5.98	179
Oct	3.8	118
Nov	2.16	64.9
Dec	1.44	44.5
Yearly average	**5.63**	**171**
Total for year	**2,060kWh**	

To put these figures in perspective, a typical average household in South Tyneside uses 3.262 MWh of electricity a year. Therefore the photovoltaic system such as this could produce 63% of the electricity needs of the property. However, it is important to remember power will be exported in times of excess production, so this will not lower the bills by the full 63%.

With regard to the Blyth homes, these have roofs at a range of angles off from South, but it can be approximated from PVGIS that the average home will have an annual energy input from the 2.3kWp system of 2,090 kWh/year.

9 Data Monitoring

A major part of the ERDF project was to understand the effectiveness of the improvements. This understanding was to be based on both quantitative and qualitative sources. Some of this data was gathered directly by the consortium, and other data from third party sources.

The data monitoring strategy included the following sources:

- Internal temperature loggers fitted to a 10% sample of the properties
- An external temperature datalogger for each geographical area
- Detailed questionnaires given to 10% of residents, which asked questions on bills, contentment and behaviour to assist with thermal modelling
- Questionnaires given to 90% of residents, which asked questions on bills, contentment and behaviour
- Air Pressure tests carried out on five properties
- Thermal imaging of properties in December 2011 and December 2012
- Gas use data from the plant room in Monastery Court

The following sections discuss the data collection, issues encountered, and analyse the results.

10 External Temperatures

External weather loggers were installed in South Shields, Jarrow and Blyth to understand the relationship between energy use and the outside temperatures before and after the works. The loggers installed were Gemini Tinytag TGP-4017 loggers. They were set to measure the ambient temperature every 30 minutes.

These were placed in the following locations:

- Roof of Ellen Court on the east side of the plant room
- A fence at the back of a property on Marsden Lane
- The fence of a property on Malton Close in Blyth

Unfortunately, two of these loggers were lost during the works. This left only one logger remaining, which was based in Malton Close in Blyth.

Fortunately, external weather data has been acquired from a third party source. The website “Weather Underground” (www.wunderground.com) collates data from Personal Weather Stations (PWS) around the globe. Included on this site is a weather station in Marsden (ITYNE) and one in Jarrow (ITYNEAND7). The technical details of the Jarrow system are unknown whilst the Marsden system is a Davis Vantage Pro2 Plus Electronic Weather Station.

Data from TYNEAND7 and ITYNE was not recorded in a constant fashion, with gaps between recordings varying from five minutes to half an hour. Therefore, a linear map was applied to the data using DIADEM 10.2. This left the data in the same form as the internal data loggers with half hourly reads at on the hour and at half past the hour.

There are calibration concerns with using the Weather Underground data as opposed to the Gemini Tinytag systems, as Narec has no control over third party data sources. In order to give some confidence on the data, the weather data from Jarrow and Marsden was compared. The two weather stations are within approximately five miles of each other, with one on the coast and one inland. This comparison showed very similar results, which suggested that the data is reliable, although the ITYNE weather station occasionally went offline and would record -17.80 C.

The timespan recorded by the two stations was January 2011 – present (ITYNE) and December 2011 – present. A monthly mean comparison of the three weather stations for the period December 2011 to July 2013 (when they were all operating) is shown in ***Table 7*** below:

Table 7: *Monthly average outdoor temperatures for three outdoor weather stations used in this project*

		Mean Temperature		
Year	Month	ITYNE	ITYNEAND7	Blyth
2011	December	5.172 °C	3.452 °C	3.188 °C
2012	January	4.733 °C	4.936 °C	4.372 °C
2012	February	5.074 °C	5.624 °C	5.111 °C
2012	March	8.561 °C	9.320 °C	8.527 °C
2012	April	5.962 °C	7.185 °C	7.182 °C
2012	May	9.094 °C	10.681 °C	10.325 °C
2012	June	12.074 °C	13.330 °C	12.899 °C
2012	July	14.349 °C	15.422 °C	14.589 °C
2012	August	15.453 °C	16.684 °C	16.094 °C
2012	September	12.839 °C	13.894 °C	12.936 °C
2012	October	8.602 °C	9.291 °C	8.379 °C
2012	November	6.755 °C	7.724 °C	6.307 °C
2012	December	5.044 °C	4.326 °C	3.939 °C
2013	January	4.623 °C	4.394 °C	3.873 °C
2013	February	3.398 °C	3.644 °C	3.313 °C
2013	March	2.798 °C	3.189 °C	3.183 °C
2013	April	7.088 °C	8.096 °C	7.630 °C
2013	May	9.536 °C	11.382 °C	10.510 °C
2013	June	12.837 °C	15.578 °C	14.029 °C

All three weather loggers showed that the winter of 2012/2013 was colder than that of 2011/2012. The difference between 2011/2012 temperatures and 2012/2013 temperatures are shown in Table 8. As winter 2012/2013 was colder than winter 2011/2012 any savings in bills, or increases in internal temperatures of the properties can be considered real, and not merely due to warmer weather conditions. All data loggers showed March 2013 to be a particularly cold month.

Table 8: *Differences between December 2011 to June 2012 and December 2012 to June 2013*

Month	ITYNE	ITYNEAND7	Blyth
December	0.128 °C	-0.874 °C	-0.751 °C
January	0.110 °C	0.542 °C	0.499 °C
February	1.675 °C	1.979 °C	1.798 °C
March	5.764 °C	6.132 °C	5.344 °C
April	-1.126 °C	-0.912 °C	-0.448 °C
May	-0.442 °C	-0.701 °C	-0.184 °C
June	-0.763 °C	-2.247 °C	-1.130 °C

The comparisons between data loggers give confidence in using their results. These temperatures are used when looking at the bills and internal temperatures of the homes in this project.

11 Questionnaires

Questionnaires were given out to all residents before and after the works were carried out. The pre-works questionnaires given to the residents in the 10% data logger sample were more detailed, to enhance the accuracy of the thermal models. The return rate of the questionnaires prior to the works was higher than that after. The return rates of the Tarran Newlands was best, and also enough questionnaires from the Wimpey No Fines to allow for a reasonable analysis. The return rates of the questionnaires from the High Rise flats were not sufficient for a reasonable data analysis to be carried out.

11.1 Tarran Newlands

Of the original questionnaires, 83 were returned, for the second questionnaires, there was a lower return rate of 59. This represented a sample of 43% of the homes. Of these, 46 surveys were from residents who had filled in the original survey. For the following analysis, the 46 respondents who filled in both surveys have been used, this represents 34% of the sample of Tarran Newlands. However, it is worth pointing out that the full 59 surveys when compared with the initial 83 surveys give very similar results.

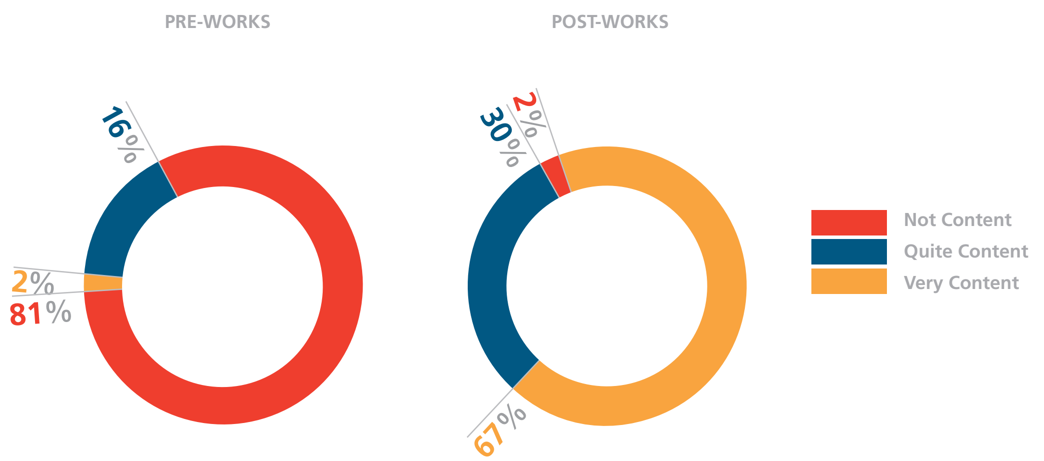
11.1.1 Satisfaction with warmth of homes

The major change in the surveys was the satisfaction with the heating of the homes. Of the 46 cross-over surveys analysed, 43 answered this question. Residents were given the options of "very content", "quite content", or "not content". 81% of residents before the works selected "not content". However, after the works only one resident selected "not content". The significant change in resident satisfaction is shown in ***Table 9*** and ***Figure 17.***

Table 9: *"How satisfied are you with the warmth of your home?" answers for Tarran Newlands*

	Very Content	Quite Content	Not Content
Pre-works	2%	16%	81%
Post-works	67%	30%	2%

Figure 17: *"How satisfied are you with the warmth of your home?" answers for Tarran Newlands*



11.1.2 Bills

A significant saving was made on the energy bills. These represented a saving of 57% on gas and 43% on electricity. The space heating requirement saving according to the thermal models in the pre-works report was estimated at 75%, so far higher than that which was observed. However, there has still been an impressive improvement.

The electricity saving will be in part from the installation of the photovoltaics, but other factors will have also contributed. These include the lowering of use of electric backup heating, and the new boilers using less energy in the fans and pumps.

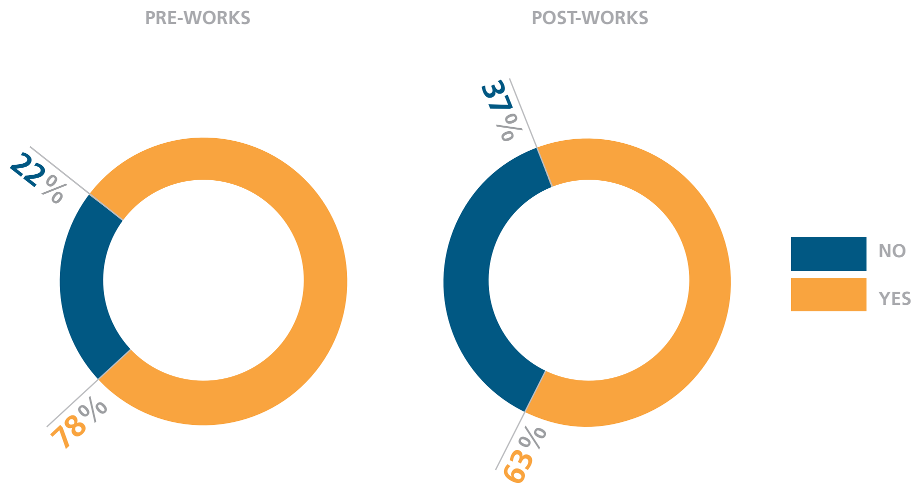
11.1.3 Turning off heating to save money

In answer to the question "Do you turn off the heating to save money?" the numbers changed from 83% saying yes to 57% after the works. This is a significant improvement. During the site visits in the pre-works stage, many of the homes were too cold, as residents could not afford to keep the heating on for long enough to make their homes warm.

Table 10: *"Do you turn off the heating to save money?" answers for Tarran Newlands*

	Yes	No
Pre-works	78%	22%
Post-works	63%	37%

Figure 18: *"Do you turn off the heating to save money?" answers for Tarran Newlands worksTyneside 2010 [26]*



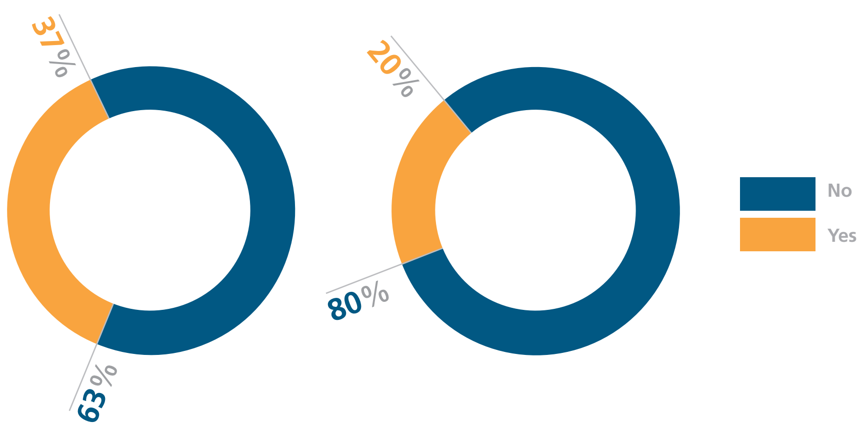
11.1.4 Additional heating requirements

When asked prior to the works if the residents needed additional heating systems, extra to the main central heating system, 37% replied yes. Invariably the backup heating system used was an electric fire, which is very expensive to run. After the works, this was reduced to only 13%.

Table 11: *"Do you use an additional heating system?" answers for Tarran Newlands*

	Yes	No
Pre-works	37%	63%
Post-works	20%	80%

Figure 19: *"Do you use an additional heating system?" answers for Tarran Newlands*



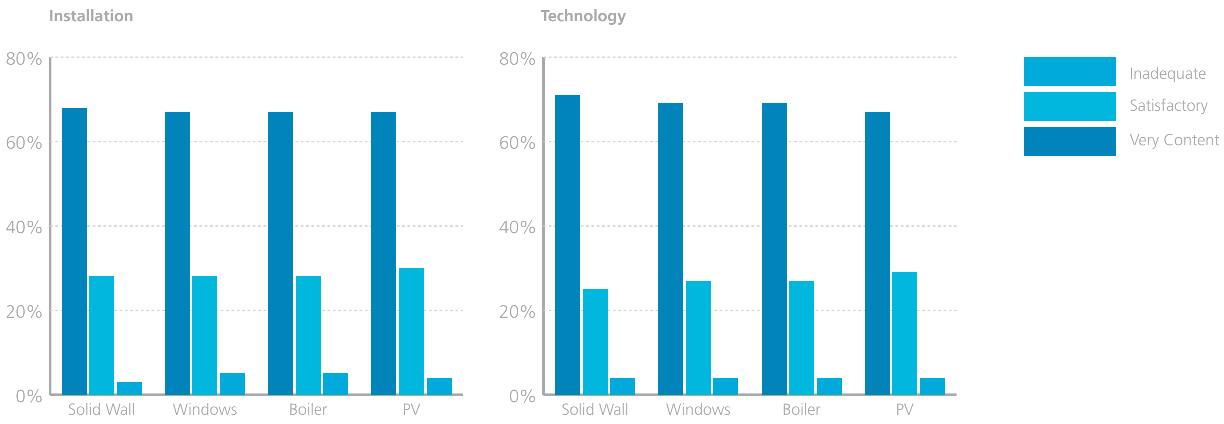
11.1.5 Technologies

After the works, the tenant satisfaction with both the installation and performance of the technologies was surveyed. With regard to the technologies, there was broad satisfaction with the technologies, although some residents did have issues. The majority of complaints centred on the windows not fitting correctly.

Table 12: *Satisfaction with installation and operation of the technologies - Tarran Newlands*

	Installation				Technology			
	Solid Wall	Windows	Boiler	PV	Solid Wall	Windows	Boiler	PV
Very Content	68%	67%	67%	67%	71%	69%	69%	67%
Satisfactory	28%	28%	28%	30%	25%	27%	27%	29%
Inadequate	3%	5%	5%	4%	4%	4%	4%	4%

Figure 20: *Satisfaction with technologies - Tarran Newlands*



11.2 Wimpey No Fines

The low numbers of surveys from the Wimpey No Fines did cause issues with the analysis. There were 28 questionnaires initially filled in (52% of the Blyth homes in this project). However, the after surveys were only completed by 41%. More problematic was the lack of overlap between the original residents who filled in the first and second questionnaires, which was only 9 households.

Because of this, it is felt that the data from Blyth is less reliable than the Tarran data.

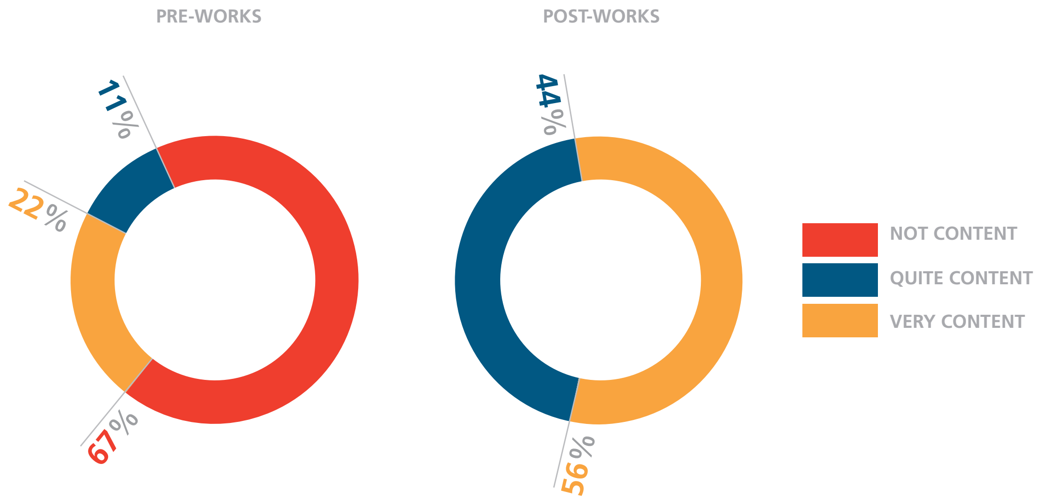
11.2.1 Satisfaction with warmth of homes

As with the Tarrans; the satisfaction in the homes has improved. As detailed in the pre-works report, the Wimpey No Fines properties were in far better condition than the Tarran Newlands. The sample of 9 properties who filled in both initial and post survey showed a dramatic improvement in contentment. The full sample showed less of an improvement.

Table 13: *"How satisfied are you with the warmth of your home?" answers for Wimpey No-Fines*

	Very Content	Quite Content	Not Content
Pre-works	22%	11%	67%
Post-works	56%	44%	0%

Figure 21: *"How satisfied are you with the warmth of your home?" answers for Wimpey No-Fines*



11.2.2 Bills

The Wimpey No Fines showed a 13% decrease in the gas usage, and a 19% reduction in electricity bills. With regard to the electricity usage decrease, it can be assumed that this is mostly due to the photovoltaic systems. The gas usage will be mostly due to the space heating requirement lowering.

11.2.3 Turning off heating to save money and additional heating requirements

When asked if residents turn off their heating systems to save money, the results were the same for before and after the works. This is interesting as they are now all either "quite content" or "very content" with the warmth of their homes. Also, it was found that the same numbers of residents still use additional heating.

Table 14: *"Do you turn off your heating to save money?" answers for Wimpey No Fines*

	Yes	No
Pre-works	78%	22%
Post-works	78%	22%

Table 15: *"Do you use additional sources of heating?" answers for Wimpey No Fines*

	Yes	No
Pre-works	33%	67%
Post-works	33%	67%

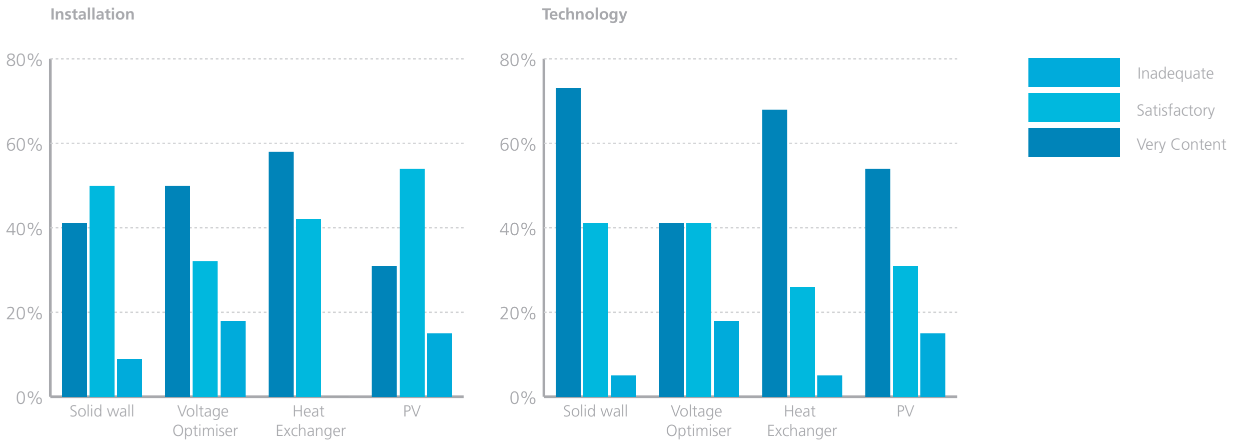
11.2.4 Technologies

The satisfaction with the technologies was lower for the Wimpey No Fines than the Tarran Newlands. The main issue that the tenants had were with the Voltage Optimisers. These caused the lights to flicker and dim. Additionally they caused a repeated buzzing noise in the houses which residents found distracting and annoying.

Table 16: *Satisfaction with installation and operation of the technologies – Wimpey No Fines*

	Installation				Technology			
	Solid wall	Voltage optimiser	Heat exchanger	PV	Solid wall	Voltage optimiser	Heat exchanger	PV
Very Content	41%	50%	58%	31%	73%	41%	68%	54%
Satisfactory	50%	32%	42%	54%	23%	41%	26%	31%
Inadequate	9%	18%	0%	15%	5%	18%	5%	15%

Figure 22: *Satisfaction with the installation and the performance of the different technologies worksTyneside 2010 [26]*



11.3 Jarrow High Rise

The return rate for the questionnaires in the High Rise flats was particularly poor. However, due to the information from Corona Energy, this is still the set of properties with the greatest level of information.

12 Energy Use Based on Bills

12.1 Tarran Newlands

The bills from the questionnaires for the Tarran Newlands and Wimpey No fines can be approximated into energy use levels. These values can be converted into approximate energy usage by assuming standard npower 2012 tariffs (for electricity this was £0.1376 /kWh for the first 728kWh units and £0.1323/kWh for the rest, whereas for gas this was £0.07308/kWh for the first 4572kWh and £0.02388/kWh for the rest).

This gives the following average energy levels for the property types before and after the works, based on the properties who had completed questionnaires for the pre and post works periods.

Table 17: *Changes in annual bills as reported by questionnaires - Tarran Newlands*

Pre-Works [kWh]		Post Works [kWh]		Reduction [kWh]		Reduction (%)	
Electricity	Gas	Electricity	Gas	Electricity	Gas	Electricity	Gas
5,212	30,992	2,945	8,056	2,268	22,936	44%	74%

According to the Digest of United Kingdom Energy Statistics (DUKES) [49] [50]the mean electricity usage for 2011 in South Tyneside is 3,280kWh, and the average gas usage 13,549kWh. The questionnaires show that the Tarran Newlands are now using less than the regional average. Comparing this with the EPCs in Section 16, it can be seen that the new energy use of the Tarran Newlands corresponds closely with the EPCs (8,673 +/- 614 kWh/year).

12.2 Wimpey No Fines

The same analysis as above was carried out on the Wimpey No Fines questionnaire answers. The results are given in ***Table 18***.

Table 18: *Changes in annual bills as reported by questionnaires - Wimpey No Fines*

Pre-Works [kWh]		Post Works [kWh]		Reduction [kWh]		Reduction (%)	
Electricity	Gas	Electricity	Gas	Electricity	Gas	Electricity	Gas
5,946	26,693	4,802	22,053	1,144	4,641	19%	17%

The pre-works Wimpey No Fines were in far better condition thermally that the Tarran Newlands. So logically the improvements experienced by the Wimpey No Fines were far less. Still there were substantial improvements. Comparing these with the regional average energy use, the gas use is still higher than the 14,915 kWh/year average, whilst the electricity usage is above the Northumberland average of 4,251 kWh/year.

12.3 High Rise flats

Accurate aggregated gas usage information was available for Monastery Court, one of the three blocks of flats improved within this project. It is important to state that all three blocks of flats are identical, and sited close to each other, so it can be assumed the results for Monastery will be the same as Wilkinson and Ellen Courts.

The gas for Monastery Court is supplied by Corona Energy, who with South Tyneside Homes' permission kindly supplied the meter readings from 2011 to 2013 to Narec. A complete 12 month period has not yet been completed since the works on Monastery Court were finished, however, there is enough data to make an initial impact assessment. Unfortunately there is no useable data for Wilkinson Court and Ellen Court, which are both served by the same gas system, as the majority of readings were estimates. Monastery Court on the other hand has predominantly actual readings.

The total gas use (which covers space heating and DHW) for the flats for April 2011 to April 2012 was 417432 kWh. Per flat this equals 9487kWh. As the heating tickets are worth 200kWh each, this equates to 47.43 heating tickets a year per flat. This correlates with the results given by residents during interviews.

The financial cost for residents in 2011 for a full year of heating was:
47.43 heating tickets × £15.67 = £743.31

The gas use for the period February 2012 to April 2012 (before the works) was 133662kWh. Whilst the gas use for the period February 2013 to April 2013 (after the works) was 115738kWh. This was a drop of 17924kWh, a reduction of 13.41%. Assuming the reduction from Feb/April is replicated across the year, then a 13.41% reduction in fuel costs can be assumed. This would equate to a saving of £99.67 per year per flat/year. Over the whole 44 flats this is a resident saving of £4,386 per year per block.

There are three major sources of savings. These are the Elson Tank replacements, the cladding on the outside of the building, and the replacement of windows.

It is important to state that the weather data shows the February to April 2012 was 6.8°C, compared with 4.83°C in 2013. This reduction in temperature may be masking a greater energy saving than the bills alone suggest.

An addendum to this report will be published in January 2014 with the full year data, to confirm the real savings for residents.

13 Thermal imaging

Thermal images were taken of a selection of Tarran Newlands homes on Marsden Lane and Lincoln Road, Monastery Court Jarrow and a number of Wimpey No-Fines building in Blyth. This was carried out in December 2011. This was in order to show the areas where there is the most heat loss. This was to be compared with the thermal imaging at a later date of the same properties to see how the improvements to the building have improved fabric heat loss and air leakage. Further imaging was carried out in December 2012. The thermal imaging was carried out using a FLIR Systems i5 and a Fluke TiRx.

Images were corrected for the external temperatures based on the external weather loggers, and set with the same scales to allow for a comparison with the before and after images.

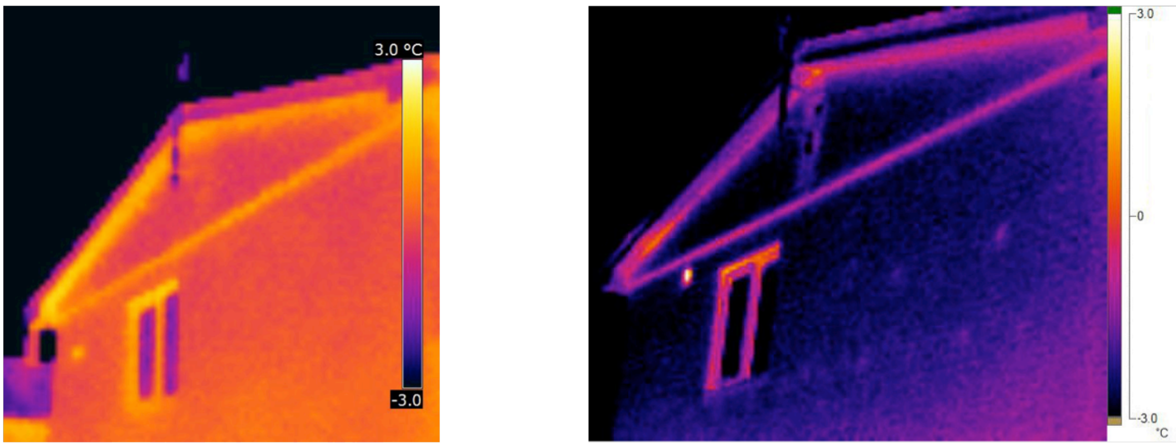
13.1 Tarran Newlands

The Tarran Newlands were the most thermally inefficient buildings at the start of this project. The images showed there was still thermal bridging between the loft and building, but this was now reduced. The major impacts were with the temperature of the walls, which were shown to be far cooler. It is important to note that the outdoor temperatures the first time data was collected were 1°C, whereas the second time temperatures were 6°C. Therefore the thermal improvements impact in the walls is slightly obscured.

The walls are significantly cooler. The two images in ***Figure 23*** show the side of a property before and after the works. As can be seen, there was a significant improvement in the building energy leakage. There are minor details, such as the connection between the side of the wall and the roof itself does show thermal loss.

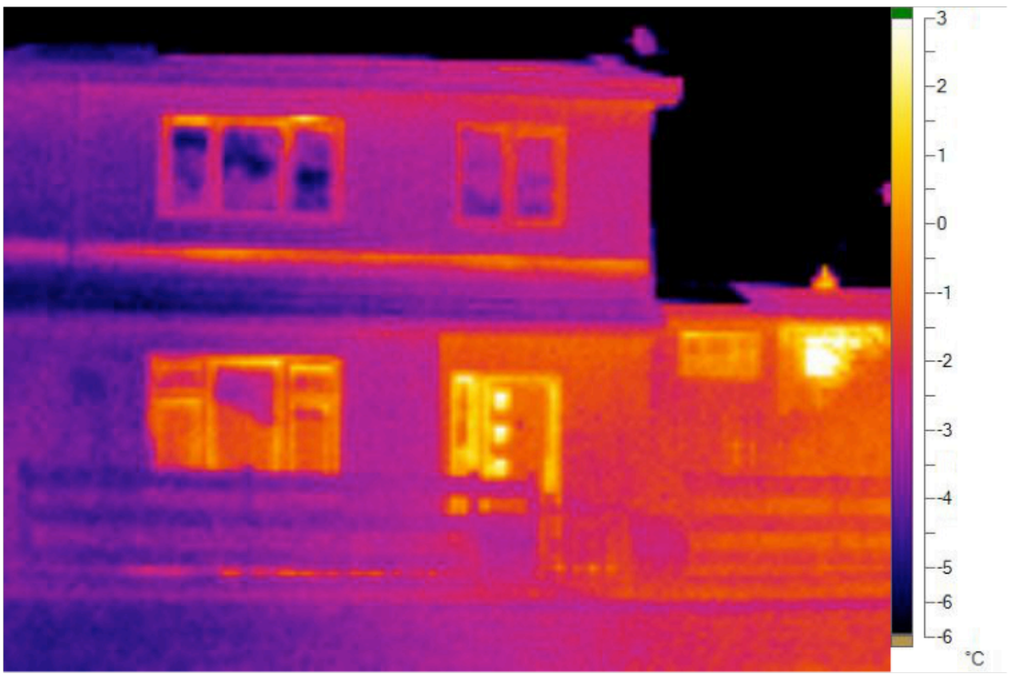
Figure 23: *Side wall and roof of example Tarran Newland constructed houses on Lincoln Road. Image (A) shows before the works, and image (B) shows after the works.*

A **B**



With regard to further improvements, ***Figure 24*** shows minor leackage of heat around the roof areas. Additionally, the glazing for the door shows some heat loss. However, overall, the thermal imaging shows a huge improvement to the Tarran Newlands. These details should be remembered for future works.

Figure 24: *Post works thermal image of a Tarran Newland property*



13.2 High Rise flats

Prior to the works the High Rise flats showed a number of issues. The windows suffered from significant thermal bridging, and minor thermal bridging was observed on the walls. However, the main thermal issue noticeable was the open ventilation slats on each landing.

The walls of the High Rise flats have been improved, however the improvement is far less than with the Tarran Newlands and Wimpey No Fines, as these external walls began in a far better state. The faint thermal bridging between flats is also no longer visible. The windows still show thermal bridging issues.

13.3 Wimpey No Fines

Prior to the works, the Wimpey No Fines buildings showed their greatest energy loss to be through the walls. This was not surprising as the roofs had been insulated prior to this project (although the insulation was topped up further on all properties for this project as well). The windows and doors had also been improved, therefore the walls were known to be the major issue.

Figure 25: *Wimpey No Fines building in pre-works state. Note the levels of energy loss from the un-insulated walls*

compared with the partially insulated loft

Figure 26: *Two Wimpey No Fines properties, (A) has had no insulation works, (B) has had external cladding*

The most significant example of the improvements was demonstrated with the Wimpey No Fines buildings when imaged in December 2012. In ***Figure 26*** there are two properties. The one on the left has had no improvements, whereas the one on the right has had the improvements completed. It can be seen that there is a difference of 2 degrees on the walls. The glow of the radiators below the windows in house A are visible, whereas house B shows no signs of the radiators. It can be seen that the topping up of loft insulation has made a minor improvement for house B (both houses already had some level of loft insulation prior to the works). It is noticeable that house B, although significantly improved, could benefit from an improvement to the front door. This could be due to an ill-fitting door, so draught excluders could make an impact.

To summarise, the thermal imaging showed the levels of thermal loss through the walls to have significantly decreased, and the only major element for improvement is now the front doors.

14 Air Pressure Test

Before and after the works air pressure tests were carried out on a sample of five of the properties. These were chosen to be representative of the full sample.

These were in the following locations:

- Lincoln Road, South Shields – Tarran Newland
- Monastery Court, Jarrow – Tower Block
- Ellen Court, Jarrow – Tower Block
- Harleigh Place, Blyth – Wimpey No-Fines
- Brookside Avenue, Blyth – Wimpey No-Fines

These were tested using a de-pressurisation method conducted in accordance with BS EN 13829:2001 Method B – Test of the Building Envelope and the ATTMA Technical Standard Issue 2. This work used a single fan automatic procedure utilising computer control of fan operation and measurement recording. The equipment used in this test was a model 3 Minneapolis Blow Door S/N APNT-06. The results are summarised in ***Table 19***.

Table 19: *Air change rate results*

Address	Building Type	Air permeability				Improvement
		Pre-Works		Post-Works		
		$m^3(h^{-1}\ m^2)$ @ 50Pa	Ach @ 50Pa	$m^3(h^{-1}\ m^2)$ @ 50Pa	Ach @ 50Pa	
Lincoln Road, South Shields	Tarran Newlands	19.26	19.33	13.03	13.8	32.3%
Monastery Court, Jarrow	Tower Block	3.56	4.72	2.78	3.69	21.9%
Ellen Court, Jarrow	Tower Block	5.08	7.22	3.72	5.29	26.8%
Hartleigh Place, Blyth	Wimpey No-Fines	7.4	8	7.56	8.18	-2.2%
Brookside Avenue, Blyth	Wimpey No-Fines	11.09	11.67	10.41	10.99	6.1%

The Tarran Newlands showed the greatest improvements of any properties. This ties in well with the results of the questionnaires, which showed a 56% reduction in the fuel bills. The High Rise flats, although not having a strong air penetration through the walls, did show a large improvement, most probably due to the replacement windows.

There were no improvements seen in the Blyth properties. This was to be expected, as the works on these properties did not include replacement doors or windows, so there was no way that the improvements could have improved the air penetration levels.

Essentially, this shows that with work the air leakage rates in Tarran Newlands can be reduced to a far more acceptable level. To put this in context, legally under the Code for Sustainable Homes social housing built from 2010 onwards must be built to Code Level 3. This means a maximum air permeability of 3 $m^3(h^{-1}\ m^2)$. Prior to this the maximum air permeability was 10 $m^3(h^{-1}\ m^2)$. Whereas Passivhaus buildings, the incredibly energy efficient domestic house standard used primarily in Germany and Austria require a level of air tightness of 0.6ach @50Pa. The works on the Tarran Newlands therefore almost brought the air permeability down to that of the level of Part L 2010, whilst the tower block air penetration is now almost at a level expected in a Code for Sustainable Homes property.

15 Data Loggers

Internal data loggers were placed in a sample of the properties. Unfortunately, during the works on the buildings a substantial number of the dataloggers were lost from the Tarran Newlands and High Rise flats. Only five data loggers were placed in properties in Blyth, and these were all recovered successfully.

15.1 Wimpey No Fines

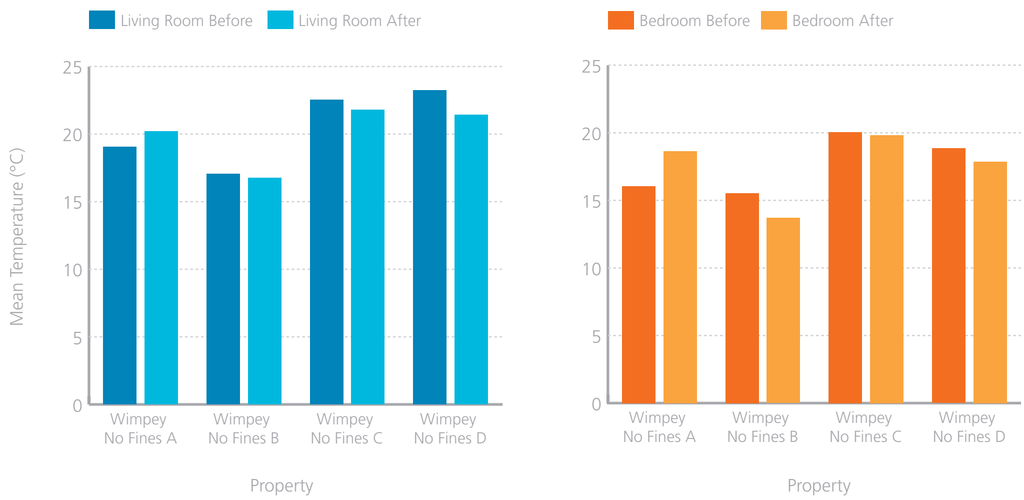
The Data loggers for the Wimpey No Fines were compared with the external weather logger data. Both the pre-works and post-works were compared. There were five properties which had data loggers inside. Three of them had significant data from the pre period, whereas two were only logged for two months before the works began.

The data for the Blyth homes was reduced down to only the points where external temperatures were in the range -1 to +1 °C. In these times, the average temperature of the homes in three out of the four monitored homes was in fact less than the temperatures of the homes prior to the works.

Table 20: *Mean of internal temperatures before and after the works when external temperatures are between -1 and 1°C - Wimpey No-Fines*

	Before			After			Difference		
	External	Living Room	Bedroom	External	Living Room	Bedroom	External	Living Room	Bedroom
Wimpey A	0.17	19.06	16.05	0.21	20.20	18.64	-0.04	-1.14	-2.59
Wimpey B	0.16	17.06	15.52	0.22	16.76	13.70	-0.06	0.30	1.82
Wimpey C	0.16	22.54	20.04	0.21	21.79	19.82	-0.05	0.74	0.22
Wimpey D	0.14	23.24	18.84	0.22	21.44	17.87	-0.08	1.80	0.97

Figure 27: *Mean of internal temperatures before and after the works when external temperatures are between -1 and 1°C - Wimpey No Fines*



Both the questionnaire data and thermal imaging show no suggestion that the houses are less efficient, quite the opposite. There is the possibility that the energy efficiency works have left the residents more aware of the cost of energy, and the impacts of energy efficiency.

This is shown well with the Wimpey No Fines data. This shows that when properties were in the range of temperatures -1 to 1°C, they were warmer than prior to the works.

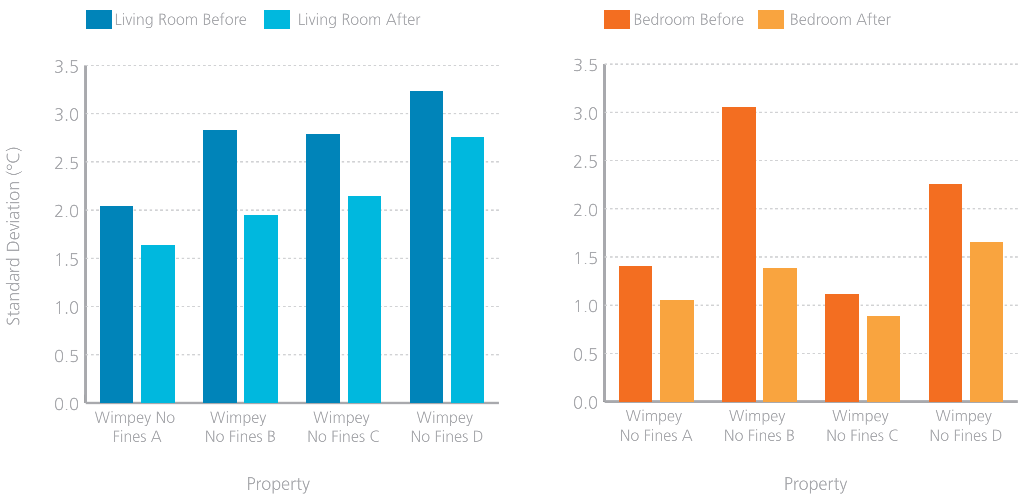
The reason for the lower temperatures may be because there was greater control of the heating system. This greater control in turn would lead to fuel bill savings. Partly because the average temperature could be kept down so the gas boiler is not running as often, and partly because this suggests the heating system would not be operating on "boost".

The standard deviation of internal temperature for the range of external temperatures -1 to 1 degree was calculated. This showed a consistent lower standard deviation. The standard deviation shows the spread of internal temperatures, so a lower standard deviation, a more consistent internal temperature. To ensure this was not simply due to more varied outdoor temperatures, the standard deviation of the external data was also calculated, and shown to be similar before and after the works.

Table 21: *Standard deviation of internal temperatures before and after the works when external temperatures are between -1 and 1°C - Wimpey No Fines*

	Before			After			Difference		
	External	Living Room	Bedroom	External	Living Room	Bedroom	External	Living Room	Bedroom
Wimpey A	0.54	2.04	1.40	0.51	1.64	1.05	0.03	0.40	0.35
Wimpey B	0.53	2.83	3.05	0.51	1.95	1.38	0.02	0.87	1.67
Wimpey C	0.54	2.79	1.11	0.51	2.15	0.89	0.03	0.64	0.23
Wimpey D	0.54	3.23	2.26	0.51	2.76	1.65	0.03	0.47	0.60

Figure 28: *Standard deviation of internal temperatures before and after the works when external temperatures are between -1 and 1°C - Wimpey No Fines*



15.2 Tarran Newlands

A similar analysis was carried out with the data from the Tarran Newlands. The Tarran Newland data had a major issue with losses of loggers during the works on the properties. However, four properties do have enough data to draw meaningful conclusions.

Table 22: *Mean of internal temperatures before and after the works when external temperatures are between -1 and 1°C – Tarran Newlands*

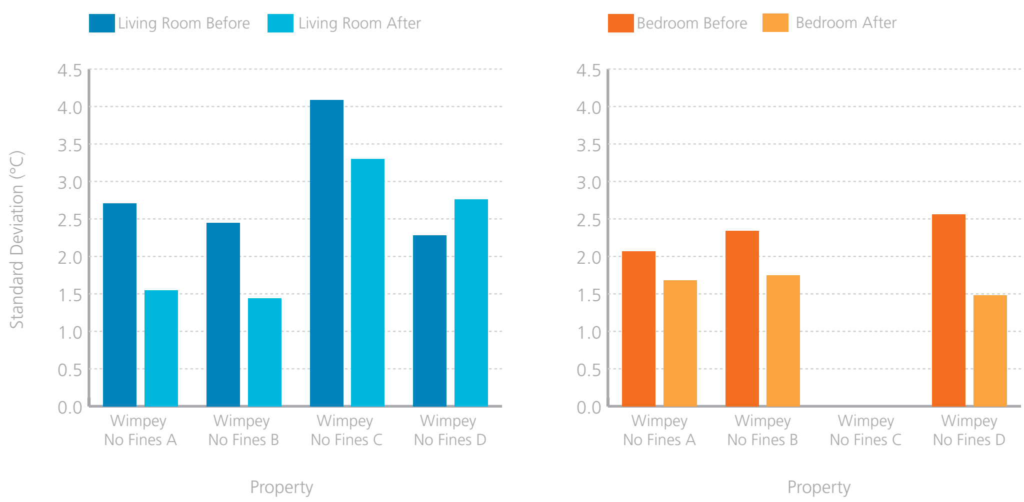
	Before			After			Difference		
	External	Living Room	Bedroom	External	Living Room	Bedroom	External	Living Room	Bedroom
Tarran A	0.18	16.10	17.82	0.19	19.26	20.72	0.00	3.16	2.90
Tarran B	0.18	19.09	19.50	0.20	21.64	22.24	0.01	2.55	2.74
Tarran C	0.18	19.44		0.22	19.46		0.03	0.02	
Tarran D	0.18	18.71	19.01	0.18		19.98	0.00		0.97

***Figure 29:** Mean of internal temperatures before and after the works when external temperatures are between -1 and 1°C – Tarran Newlands*

***Table 23:** Standard deviation of internal temperatures before and after the works when external temperatures are between -1 and 1°C – Tarran Newlands*

	Before			After			Difference		
	External	Living Room	Bedroom	External	Living Room	Bedroom	External	Living Room	Bedroom
Tarran A	0.55	2.71	2.07	0.55	1.55	1.68	0.00	1.16	0.39
Tarran B	0.55	2.45	2.34	0.55	1.44	1.75	0.00	1.01	0.59
Tarran C	0.55	4.09		0.54	3.30		0.01	0.79	
Tarran D	0.55	2.28	2.56	0.55		1.48	0.00		1.08

***Figure 30:** Standard deviation of internal temperatures before and after the works when external temperatures are between -1 and 1°C – Tarran Newlands*



The Tarran Newlands have increased in temperature, although, as the data shows, they initially were colder properties. During the site visits before the works, the properties were noticeably cold and draughty. Therefore, not all the efficiency savings have gone into reducing bills, some of them have gone into allowing the residents to keep the properties at a comfortable temperature.
The standard deviations once more showed that the properties now have a more stable internal temperature.

15.3 Jarrow High Rise

The five data loggers from the High Rise flats with the greatest level of data recorded when the external temperatures were low were analysed using the same methodology as the Wimpey No Fines and the Tarran Newlands.

Table 24: *Mean of internal temperatures before and after the works when external temperatures are between -1 and 1°C – High Rise Flats*

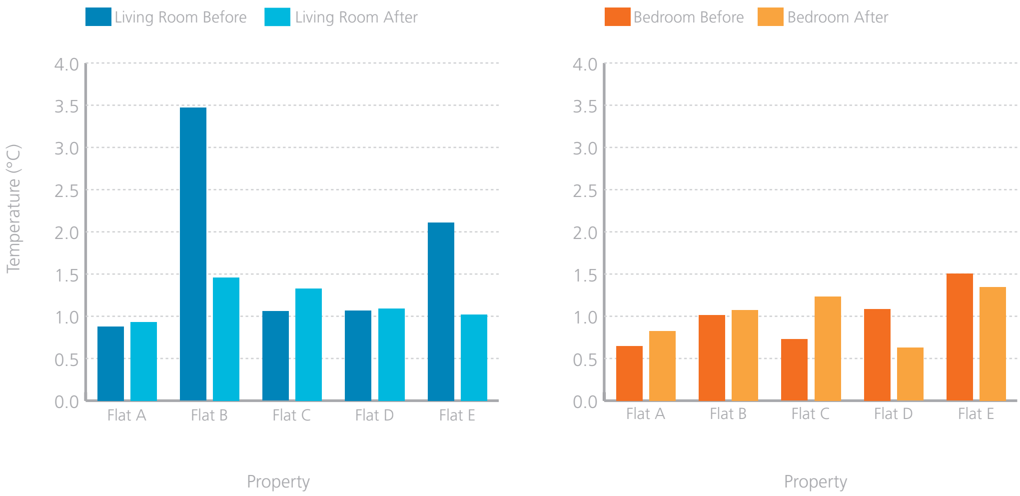
	Before			After			Difference		
	External	Living Room	Bedroom	External	Living Room	Bedroom	External	Living Room	Bedroom
Flat A	0.17	19.27	17.73	0.22	19.42	18.42	-0.05	0.17	19.27
Flat B	0.16	18.91	17.74	0.25	18.10	18.20	-0.09	0.16	18.91
Flat C	0.15	18.13	17.53	0.27	18.30	18.36	-0.12	0.15	18.13
Flat D	0.16	20.08	18.85	0.24	19.50	18.55	-0.08	0.16	20.08
Flat E	0.15	18.24	16.68	0.24	17.61	19.12	-0.09	0.15	18.24

Figure 31: *Mean of internal temperatures before and after the works when external temperatures are between -1 and 1°C – High Rise flats*

Table 25: *Standard deviation of internal temperatures before and after the works when external temperatures are between -1 and 1°C – Tarran Newlands*

	Before			After			Difference		
	External	Living Room	Bedroom	External	Living Room	Bedroom	External	Living Room	Bedroom
Flat A	0.56	0.88	0.65	0.56	0.93	0.83	0.56	0.88	0.65
Flat B	0.56	3.47	1.02	0.56	1.46	1.08	0.56	3.47	1.02
Flat C	0.57	1.06	0.73	0.56	1.33	1.24	0.57	1.06	0.73
Flat D	0.56	1.07	1.09	0.51	1.09	0.63	0.56	1.07	1.09
Flat E	0.57	2.11	1.51	0.51	1.02	1.35	0.57	2.11	1.51

Figure 32: *Standard deviation of internal temperatures before and after the works when external temperatures are between -1 and 1°C – High Rise flats*



It can be seen in ***Figure 32*** that the mean temperatures increased in some flats and decreased in others. The flats were the most energy efficient buildings prior to the works. The standard deviations of internal temperatures, unlike the houses, do not all show a greater level of control with the heating, instead there is a mixture of increases and decreases. One possible reason for these strange results could be that the external temperatures used in this analysis were not representative of those felt in the flats, due to the height of the high rise blocks and the wind chill effect. Additionally, it is important to state the high rise were the most efficient buildings with the lowest levels of fuel poverty prior to the works, which could impact how residents change behaviour.

16 Energy Performance Certificates

Prior to the works and after the works Energy Performance Certificates were carried out on behalf of South Tyneside Homes and Homes for Northumberland.

An EPC is a certificate based on the results of an RdSAP calculation of the energy requirements of a home. RdSAP itself is a simplified version of The Government's Standard Assessment Procedure for Energy Rating of Dwellings. EPCs have a rating of 1 to 100, where 100 represents the most energy efficient. This rating is graded with the letters A (most efficient) to G (least efficient. Most properties in the UK are in band D, which is the range 55-68.

These certificates were provided to Narec Distributed Energy. The majority of the certificates were for after the works. It is important to state that these do not reflect how much energy the residents are using, rather they show how it is estimated they would use to keep their property at a comfortable and safe temperature, in addition to lighting and domestic hot water.

16.1 Tarran Newlands

There were 36 EPCs available for properties on Lincoln Road and Marsden Lane which were involved in this project. Two of the EPCs were rejected due to concerns over accuracy. Of the remaining 34, EPCs existed for two of the properties on Lincoln Road prior to the works, these had scores of 49 and 64, with energy requirements of 393 and 273kWh/m^2/year.

All but one of the post works EPCs for the Tarran Newlands was provided by one contractor. Those from Contractor "A" all gave an EPC rating of 86. The energy demands had a mean value of 94.09kWh/m^2/year with a standard deviation of 1.1. Contractor "B" supplied an EPC for a property which had a rating of 80, with the energy demand as 129kWh/m^2/year. The heating demand differences appear minimal, lighting is the issue which has lowered the EPC. The serves as a good example how EPCs for identical properties can be different due to different contractors.

Overall, this shows that the energy use estimated for these properties has gone from in the range of 273 to 393kWh/m^2/year pre-works to the range of 93 to 129kWh/m^2/year post works. There are not enough pre-works figures to feel confident with this result, but it represents and improvement of about 71%. Interestingly, the actual energy demand for heating and lighting from the EPCs was 8,673 =/-614 kWh/year. The actual heating demand for the Tarran Newlands from bills was found to be 8,056kWh/year.

16.2 Wimpey No Fines

There were 13 available EPCs from Wimpey No Fines properties Of these, 7 were pre-works, four were post works, and two were carried out half way through the works so were disregarded. These EPCs showed a clear improvement between the pre-works and post-work states of properties. Table 26 shows the rating and energy demands of each property. The Total Floor Area (TFA) is also given to show that the samples of buildings were similar.

Table 26: *Comparison of EPCs for Wimpey No Fines before and after the works*

		TFA [m^2]	Rating	Energy [kWh/m^2/year]
Pre-Works	Mean	78.4	64.6	263.9
	Standard Deviation	5.9	6.4	49.0
Post Works	Mean	78.8	81.8	114.3
	Standard Deviation	4.5	4.7	26.4

The above represents an improvement on the mean energy/m^2/year of 57%

In summary, the EPCs show that the actual energy needed for the properties has in theory significantly dropped due to the improvement works.

16.3 Comparison with thermal models

Detailed thermal models were constructed of the properties prior to the works using the software IES<VE>. These models were built to give an idea of the energy reductions which the works may give, using detailed information on the building construction and data from questionnaires.

Table 27: *Comparison of Dynamic Thermal Models, bill information, and EPCs*

Properties	Theoretical Improvement	Real Improvement	EPC Improvement
Tarran Newlands	75%	56%	71%
Wimpey No Fines	62%	13%	57%
High Rise	51% (small flat)	13% (average)	Insufficient data
	36% (large flat)		Insufficient data

The above shows that thermal modelling and EPCs gave similar results. However, the real energy use was quite different to that given by the models.

This shows two interesting points:

1. Dynamic thermal modelling fits well with EPCs
2. The dynamic thermal modelling and EPCs did not give accurate results for the percentage reduction in energy demand.

There are numerous reasons why thermal modelling did not fit with reality. Some options are:

- External weather loggers have shown that winter 2012/2013 (the post works period) was two degrees colder than winter 2011/2012. This result was collaborated by all the external data loggers
- The thermal models did not take account of imperfections in the pre and post works building
- Thermal models assume that residents will turn on their heating when it is cold, and off when it is warm. As shown in the questionnaires, more residents in the Tarran Newlands turned off the heating to save money before the works than after the works.
- Residents in the Tarran Newlands reported using additional (mainly electric) heating less. So therefore heating requirements which were hidden in the electricity bills were now visible in the gas bills after the works.

17 Fuel Poverty

The fuel poverty rates for the properties were initially measured by Warm Zones. They discovered the following results for the rates of fuel poverty, detailed in Table 28.

It is important to state that this is using the initial 10% definition of fuel poverty. This is mainly due to the limitations of data, and to allow for comparisons with other recent work. As described earlier in this document, the LIHC methodology for fuel poverty has not been used in this report due to complexity issues.

Table 28: *Fuel poverty rates before the works*

Location	House Type	Homes in survey	% in fuel poverty	Maximum fuel poverty index
South Shields	Tarran Newlands	15	66%	25%
Jarrow	High Rise	45	9%	13%
Blyth	Wimpey No-Fines	36	19%	15%

Because of the particularly high level of fuel poverty in the Tarran Newlands, a more detailed analysis was carried out by Warm Zones to understand the impacts of the works. For this analysis, three of the properties were taken, and had their EPCs worked backwards to give a before and after picture of the energy demands. Each property had the fuel poverty index (the percentage of income spent that would be spent on energy for a comfortable home) calculated for the minimum, maximum and mean income levels on Lincoln Road/Marsden Lane. The results are shown in Table 29. The differences between the maximum fuel poverty index in Table 29 and Table 28 are due to differences in the software, methodology and input data.

There are a number of important points to state. The maximum income in this area is still exceptionally low, those who are not in fuel poverty may still be defined as being in poverty. It is important to state that the same income levels were used for the before and after fuel poverty levels. It is appreciated that incomes are decreasing due to welfare reform, but that this is a separate driver on fuel poverty. The purpose of this chapter is to understand simply how the measures applied have reduced fuel poverty.

Table 29: *Fuel poverty rates in the Tarran Newlands after the works based on three properties in the Lincoln Road/ Marsden Lane area*

Property	SAP	Fuel Poverty Index		
		Min Income	Mean Income	Max Income
Pre-works				
Property A	65	19.4%	7.3%	3.7%
Property B	66	19.4%	7.3%	3.7%
Property C	66	19.6%	7.3%	3.8%
Post-works				
Property A	85	14.4%	5.4%	2.8%
Property B	85	14.3%	5.3%	2.7%
Property C	85	14.5%	5.4%	2.8%

The incomes of residents vary significantly, although even the maximum incomes are by regional standards very low. The analysis shows that the fuel poverty indexes have decreased due to the measures in this project.

18 Greenhouse Gas Emissions

It is now established that increases in carbon dioxide (and other greenhouse gases) from human activities are leading to increased global warming, which is causing climate change. A recent review of 4,014 peer reviewed scientific papers by 10,336 authors showed 97.1% agreed recent climate change is due to human activities [51]. The increases in temperature caused by climate change may well lead to the initiation of climatic feedback cycles, which could dramatically change the Earth's climate [52] [53] [54] [55] [56] [57] [58] [59]. A demonstration of this speed of change was given at the end of the last glacial period when average global temperatures increased by 5°C in less than 10 years [60]. The results of this type of change could include temperature and precipitation pattern changes, which could result in scarcity of food and fresh water, extreme weather conditions, flooding, sea level change and expansion of tropical disease [60]. In turn, these could result in major refugee issues and could stimulate significant global conflict over resources [61].

The scientific consensus is that emissions of greenhouse gases must be curtailed to lower the risks from climate change [62]. Therefore, one of the measures of the success of this project is the reduction in greenhouse gas emissions.

For this work, the emissions are based on CO_2 equivalent over 100 years (CO_{2eq}). This is where all emissions of greenhouse gases (such as methane and nitrous oxide) are normalised based on their radiative forcing impact in comparison with CO_{2eq}. This is the general approach used by most greenhouse gas calculations. There are arguments that 20 year period should be used, but these are more relevant to biofuels, which have higher methane and nitrous oxide emissions.

18.1 Year 1 Greenhouse Gas Savings

First, the savings in the first year post works will be calculated. The energy savings of the measures are based on the data from questionnaires and Corona Energy. It have been shown within this project that the energy demands predicted by thermal modelling (both dynamic thermal modelling and EPCs) is wildly inaccurate for residents on low incomes such as these. Therefore real data must be used.

To convert these into CO_{2eq} savings, figures from "2013 Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors" and data from the Department for Environment, Food and Rural Affairs (DEFRA) Greenhouse Gas Conversion Factor Repository [63] have been used. These are split into Scopes 1, 2 and 3. For this work all scopes are used, which means all emissions are included. This means that in addition to direct emissions, non-direct emissions are also factored in such as the initial mining of fuel (be it coal, oil, gas, uranium or other), transport of fuel and other related activities. Losses in transportation are also included. There are issues with the figures, as the CO_{2eq} for methane and nitrous oxide are based on the IPCC Second Assessment Report to stay in line with the Kyoto agreement [64]. The latest report from the IPCC (the fourth assessment report) [65] shows these figures to be too low for methane and too high for nitrous oxide. The overall impact is that the CO_{2eq}/kWh figures used by the UK government are slightly lower than reality.

The CO_{2eq}/kWh emissions for consumed natural gas and electricity in the UK, based on 2011 figures using all scopes are:

Electricity: 0.5539 $kgCO_{2eq}$/kWh
Natural Gas: 0.21214 $kgCO_{2eq}$/kWh

Therefore, based on this, the year one savings for gas are as follows:

Table 30: *Savings from decrease in gas use in year 1*

		kWh/year	$kgCO_{2eq}$/year
Jarrow High Rise	Original gas usage per block of flats	417,431	88,554
	New gas usage (estimated from Jan-April result)	361,495	76,688
	Saving per year	55,936	11,866
	Saving per year in all three blocks	167,807	35,599
Tarran Newlands	Original average gas usage per house	30,992	6,575
	New average gas usage per house	8,056	1,709
	Saving per year	22,936	4,866
	Saving across all homes	3,256,912	690,921
Wimpey No Fines	Original average gas usage per house	26,693	5,663
	New average gas usage per house	22,053	4,678
	Saving per year	4,640	984
	Saving across all homes	204,160	43,311
	Total saving	**3,628,879**	**769,830**

With regard to the electricity savings, there will be savings from the use of photovoltaics and from the lower usage of electric fires.

The photovoltaics will dominate the savings, hence the figures for photovoltaics calculated earlier in Section 8 will be used. These give a total electricity saving over year 1 of 212,501 $kgCO_{2eq}$
This makes the total greenhouse gas saving in year 1: 982,331 $kgCO_{2eq}$

18.2 Predicting 10 Year Savings

In order to predict the amount of energy saved over the long term, there are a number of major uncertainties. The first is the CO_{2eq}/kWh level of electricity and gas in the UK. The second is that, as has been shown in this project, behaviour has a very large impact on the energy used. As currently in real terms incomes for the employed and unemployed are falling in the UK (see section 5.2), it can be expected that energy usage in homes will decrease.

It is hard to predict the future CO_{2eq} intensity of the electricity grid in the UK. The UK is signed up to the European 2020 target for 20% of all energy to come from renewables. The UK has a lower target than the majority of Europe, with only 15% of energy to come from renewables. This is distributed through three types of energy, heat, electricity and transport [66]. Electricity is the major target for the UK, with 30% of all electricity to come from renewable sources by 2020 [67]. Additionally, the UK has a legally binding target of an 80% in CO_{2eq} emissions by 2050 based on a 1990 baseline [68].

Additionally, with gas there are uncertainties. If biogas for example becomes a major player in gas production in the UK, then the CO_{2eq} of mains gas will decrease. However, currently the shale gas industry in the UK is growing. There is currently debate over if this method of extracting gas due to methane leaks could have a high global warming impact. Studies by different researchers have found quite different results to this question [69] [70] [71].

In order to predict the ten year savings of the measures, the following assumptions have been made

- No major climatic shifts will occur in the next ten years
- The UK electricity grid will be 35% renewable by 2020, and continue increasing
- The natural gas CO_{2eq}/kWh level will remain stable
- There will be a linear progression to 2020 of the % of electricity which comes from renewable sources

Using the above, then the 10 year gas saving will be 7,698,304 $kgCO_{2eq}$. The electricity saving as detailed in Table 31 will be 1,982,282 $kgCO_{2eq}$.

***Table 31:** Offset greenhouse gas emissions from photovoltaic systems*

Year	% renewable electricity	Grid CO_{2eq} intensity $kgCO_{2eq}$/kWh	Emissions avoided [$kgCO_{2eq}$]
2013	11.3%	0.553	212,155
2014	14.0%	0.536	205,766
2015	16.6%	0.520	199,376
2016	19.3%	0.503	192,987
2017	22.0%	0.486	186,597
2018	24.7%	0.470	180,207
2019	27.3%	0.453	173,818
2020	30.0%	0.436	167,428
2021	32.7%	0.420	161,039
2022	35.3%	0.403	154,649
2023	38.0%	0.386	148,259
		Total	

The total CO_{2eq} saving from the measures over a ten year period are predicted to be 9,680,586 $kgCO_{2eq}$

18.3 Emissions from the measures

The production and installation of the measures will lead to some emissions of CO_{2eq}. There are several pieces of software which can be used to calculate these emissions, the preference of Narec is to use GaBi by PE International, which is one of the major industry standards in this field. This uses two main databases, the EcoInvent database and the PE International Professional Database, although further addons are available.

It is already known that, for example, an optimally angled full PV system in England will take about 18 months of operation to pay back the CO_{2eq} emissions of manufacture and transport. This is similar to that of an offshore wind turbine.

A very basic GaBi model was run, with the following assumptions:

- PV modules and infrastructure manufactured in China
- System transported 2000 km by container ship running on heavy fuel oil
- System transported 100 km in the UK by van running off diesel

This gave an output of 1,630kg CO_{2eq} for each 1kWp of PV installed. Looking at the energy produced per year by this system, as detailed in section 8, this would be 893kWh/year for the Tarran Newlands of electricity (with a range of slightly higher values for the Wimpey No Fines). Using the present day CO_{2eq} intensity discussed above the CO_{2eq} avoided per year per kWp installed is 494 kgCO_{2eq}.

If it is assumed that the electricity CO_{2eq}/kWh reduces by 1.99% per year, as it did from 2009 to 2011, then it would take the photovoltaic systems approximately just over 3 years to pay back the CO_{2eq} produced through manufacture and transport. Detailed information was not gathered on the types of materials used to generate Life Cycle Analysis models of the other measures. A large number of traditional insulation measures are available with CO_{2eq} impacts on the Building Research Establishment (BRE) Green Guide 2008 [72]. However, measures such as the cladding used in this project is not available.

It would be interesting to understand the impacts of producing energy efficiency measures. However, it is expected the major impact from this project would be from the photovoltaic systems. The total impact of this over all the properties would be, based on the above, approximately 140,180 kgCO_{2eq}. This value is very small compared to the ten year savings of the project.

19 Summary

Within this project over 300 hard to treat homes were improved. The data monitoring, questionnaires and third party data recorded in this project has given the following information about the works:

SATISFACTION

The satisfaction of residents with the warmth of their homes has improved significantly, as detailed in Table 32

Table 32: *Satisfaction with warmth of homes before and after the works - Tarran Newlands and Wimpey No Fines*

Tarran Newlands	Very Content	Quite Content	Not Content
Pre-works	3%	17%	80%
Post-works	53%	33%	3%
Wimpey No Fines	**Very Content**	**Quite Content**	**Not Content**
Pre-works	22%	11%	67%
Post-works	56%	44%	0%

BEHAVIOUR

Before the works, 83% of residents in the Tarran Newlands would turn off the heating to save money, and 37% used additional heating. After the works this was cut to 57% and 13% respectively. However, the Wimpey No Fines, which were in better condition, partly due to previous improvements, did not change their behaviour at all on these two metrics.

ENERGY SAVINGS

The energy bills for residents were decreased through this project. The reductions for space heating and domestic hot water were:

Table 33: *Reduction in energy demand of gas (houses) or district heating (flats)*

Properties	Gas/District Heating reduction
Tarran Newlands	56%
Wimpey No Fines	13%
High Rise	13% (average)

Electricity usage savings were also observed, due to the installation of photovoltaic modules, and the lowering in use of electric fires.

THERMAL MODELS

The thermal models which were built did not accurately predict the levels of energy use after the works. One of the reasons for this will have been that models do not take into account the behaviour of residents. Specifically, the issue that those in fuel poverty will clearly turn off their heating before their home is comfortable in order to save money, and how much they may do this after improvements. It also does not take into account how residents may become more aware of energy efficiency through such projects on their home, which may also lead to behavioural changes.

AIR PRESSURE TESTS

The air pressure tests showed that initially the Tarran Newland buildings were particularly leaky, and therefore very hard to heat. The High Rise Flats were the best buildings with regard to air pressure tests.

After the works, the sample Tarran Newland tested was shown to have an air infiltration rate in line with Part L for new domestic buildings. Whilst the High Rise flats were almost at the level necessary for the Code for Sustainable Homes for new build. The Wimpey No Fines did not receive any improvements which could alter the air infiltration rate, as they had already done so prior to the project.

THERMAL IMAGING

A clear improvement was observed in the fabric of the properties. The clearest visualisation of this was when comparing two Wimpey No Fines properties next to each other in December 2012. There are still improvements which can be made, specifically with the doors of the properties. However, clear reductions in energy loss can be seen.

DATA LOGGING

The data logging showed that in all but the High Rise flats, the control residents had over their heating systems had improved. The Tarran Newland properties, which were particularly cold, were heated to a higher level after the works, whilst the Wimpey No Fines were in fact heated less.

CONCLUSION

Overall, this project has led to significant improvements, which has demonstrated that Hard to Treat buildings can be significantly improved, and thus improve the quality of life for residents.

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