WWF
WALES
2015

PROGRESS TOWARDS RESIDENTIAL ENERGY REDUCTION TARGETS IN WALES

Produced by Energy Saving Trust for WWF Cymru

July 2015

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Contents

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List of Acronyms

BAU	Business as usual
CERT	Carbon Emissions Reduction Target
CERO	Carbon Emissions Reduction Obligation (part of ECO)
CESP	Community Energy Saving Programme
CSCO	Carbon Saving Communities Obligation (part of ECO)
CWI	Cavity wall insulation
DECC	Department of Energy and Climate Change
DP	Draught proofing
ECO	Energy Company Obligation
EST	Energy Saving Trust
FiT	Feed-in Tariff
HEES	Home Energy Efficiency Scheme
HEM	Housing Energy Model
HHCRO	Home Heating Cost Reduction Obligation (part of ECO)
LI	Loft insulation
LiW	Living in Wales property survey
NAEI	National Atmospheric Emissions Inventory
RHI	Renewable Heat Incentive
SWI	Solid wall insulation

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Executive Summary

The project

In 2010, the Welsh Government committed to two greenhouse gas reduction targets:

- To reduce emissions within all areas of devolved competence by 3% each year from 2011 to 2020, against a baseline of average emissions over the period 2006-2010
- To reduce all Welsh emissions by 40% by 2020, against a baseline of emissions in 1990.

The residential sector is a significant contributor to greenhouse gas emissions in Wales, accounting for almost a quarter of the country's emissions. As such, reducing emissions in this sector is crucial if the above climate change targets are to be met. A number of policies and programmes have therefore been put into place, by both the Welsh and UK governments, aiming to improve the energy efficiency of the housing stock[1].

The purpose of this study is to evaluate the impact of these policies and programmes, and the ongoing activity required in order to achieve 2020 targets. This involves quantifying the total level of energy efficiency activity which has taken place in the Welsh housing stock since the last detailed property survey in 2008, and calculating the emissions reduction this has achieved. The study has then modelled a number of policy scenarios to 2020, showing the emissions reduction potential of each and therefore the activity required for 2020 target emission levels to be met.

Programme impact

Our modelling indicates that, between 2007 and 2014, energy efficiency programmes in Wales prevented the release of around 2.0 $MtCO_2e$. The programme responsible for both the greatest number of energy efficiency installations and the greatest carbon reduction was the Carbon Emissions Reduction Target (CERT), a UK government programme which ran from 2008-2012. However, whilst CERT accounted for over 70% of installations, our modelling suggests it was responsible for only 39% of the emissions reduction; other, smaller scale policies have had a much bigger impact on a per-measure basis. In particular, the Feed-in Tariff has contributed almost a third of the emissions reduction, despite accounting for only 5% of total installs.

The Welsh Government schemes Nest and Arbed, combined, accounted for 8% of the emissions reduction. Cumulatively, they have prevented the release of $0.17MtCO_2e$ between 2007-2015. The remaining 92% of policy-based emissions reduction, 1.85 $MtCO_2e$, is attributable to schemes led by the UK government.

[1] Details regarding the distinction between these two targets and how progress towards them is measured are available here: http://gov.wales/topics/environmentcountryside/climatechange/publications/measuring-greenhouse-gas-reduction/?lang=en

Meeting the 2020 targets

The 3% target

The 3% emissions reduction target requires a 3% year-on-year emissions reduction in all areas of devolved competence in Wales. To achieve the target, emissions must therefore be reduced by 27% (9 years at 3% annual reduction) compared to the baseline of average emissions between 2006 and 2010. This gives a target emissions level of 5.60 $MtCO_2e$ by 2020.

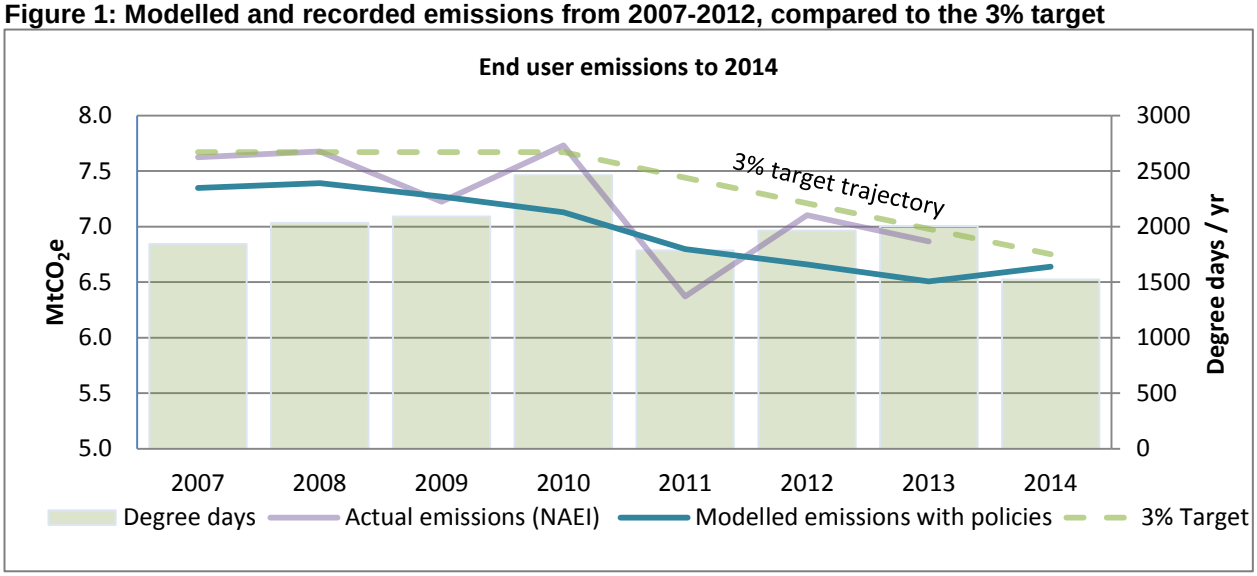
The target is based on 'non-traded' emissions (emissions which are not incorporated in the EU Emissions Trading Scheme), therefore does not include areas outside the devolved government's powers such as heavy industry and power generation. However, the target also includes 'end-user electricity' emissions – these are the 'traded' emissions produced due to electricity consumption. These are included because, whilst Welsh Government does not have control over electricity generation, their actions can have significant influence on electricity consumption by end-users. This inclusion of emissions related to electricity is of significant importance when evaluating progress towards the target. Electricity-related emissions make up a large proportion of emissions included within the 3% target, yet are strongly influenced by areas outside Welsh Government control, such as decarbonisation of the electricity supply.

In order to meet the 3% target, emissions from the residential sector need to be reduced to 5.60 $MtCO_2e$ by 2020. Looking at National Atmospheric Emissions Inventory (NAEI)[2] emissions up to 2013 (Figure 1), Wales is currently on-track to meet this target by 2020. However, as detailed below, this is heavily dependent upon decarbonisation of the electricity grid. Figure 1 plots the average degree days[3] per year in Wales to show the extent to which the yearly variation in emissions has been affected by external temperature.

[2] Based on source and end-user electricity emissions (those relevant to the government's 3% target) from the 2015 National Atmospheric Emissions Inventory (NAEI), available here: http://naei.defra.gov.uk/reports/reports?report_id=810 (Devolved administration tables)

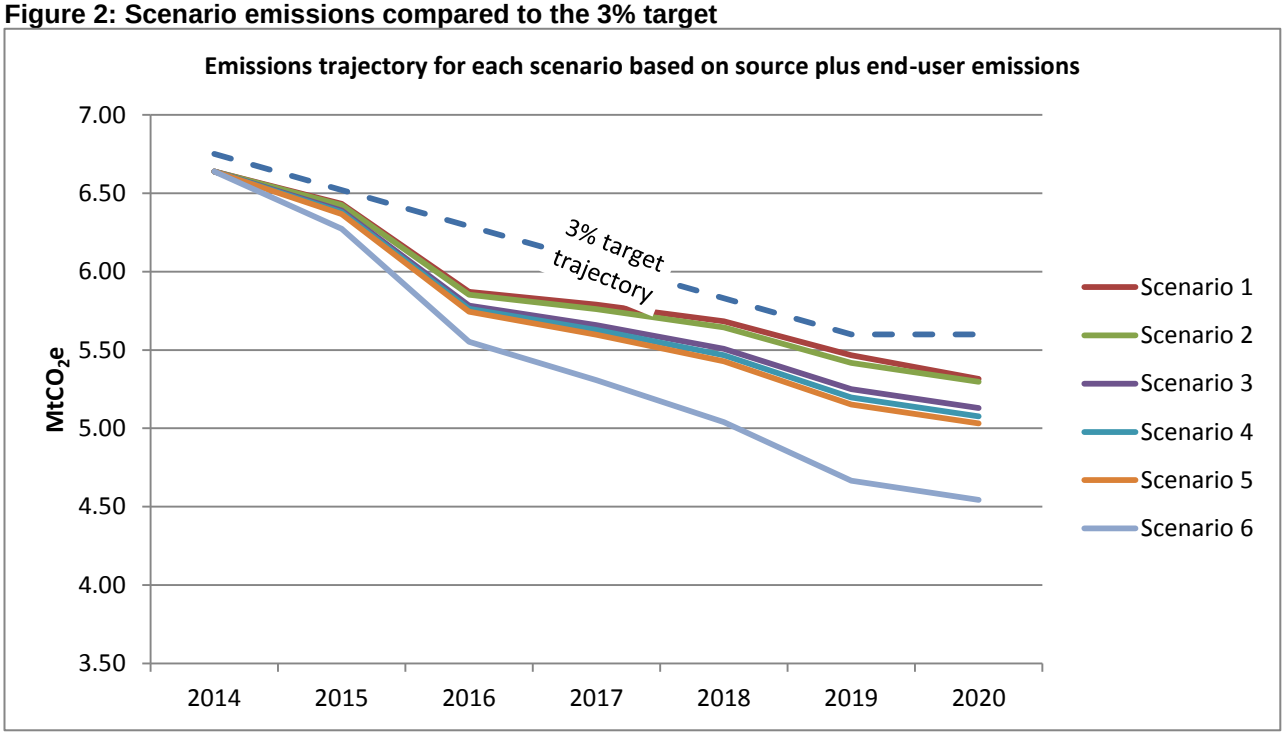
[3] Further information on heating degree days are given Section 4 of this report.

Figure 1: Modelled and recorded emissions from 2007-2012, compared to the 3% target



Our future modelling in Figure 2 indicates that even with no further action by energy efficiency programmes this 2020 target is likely to be met. Even under a scenario whereby there is no additional uptake of energy efficiency measures after 2014, emissions by 2020 drop to 5.31 $MtCO_2e$. Scenarios 1 to 6 in Figure 2 represent increasing degrees of uptake of energy efficiency measures. Details on each scenario can be found in the main body of the report in Table 3.1, Section 3.4. The data associated with this figure can also be found in Section 5.1, Table 5.1.

Figure 2: Scenario emissions compared to the 3% target



However, this ongoing drop in emissions from the residential sector is highly dependent upon the future decarbonisation of the electricity grid. The 'carbon-intensity' of the grid is a measure of how much carbon

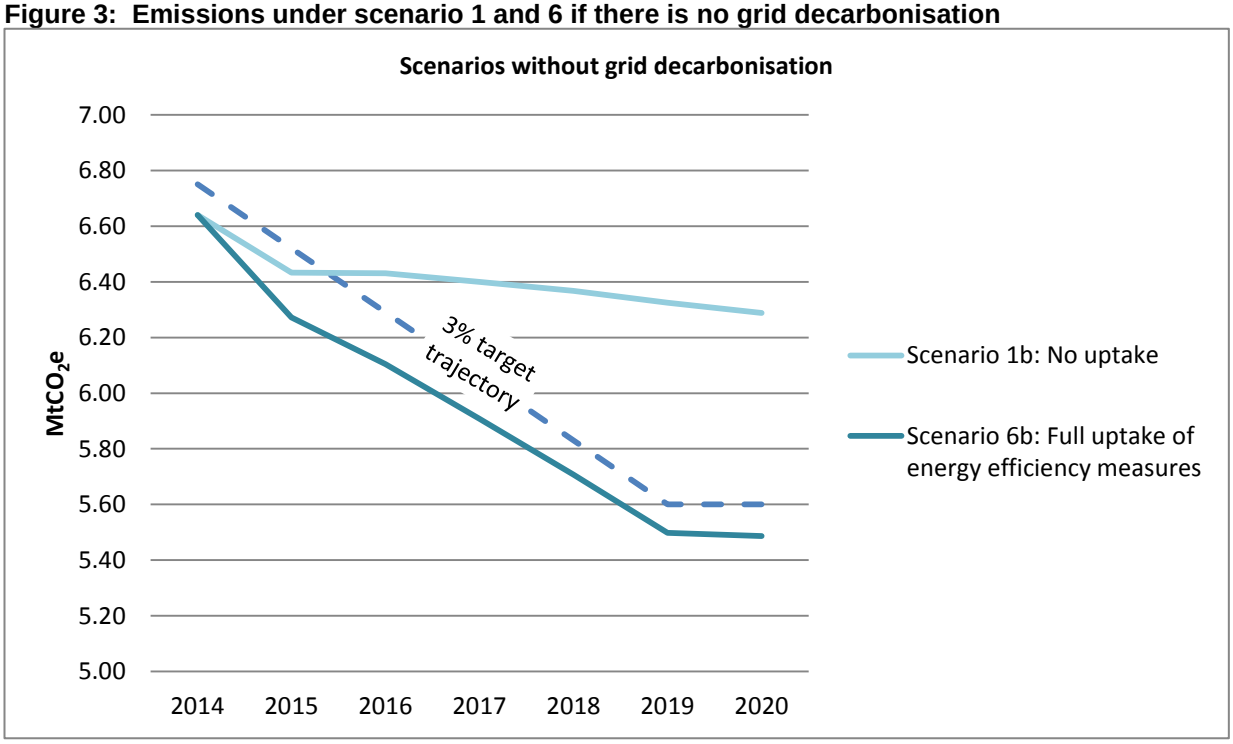
dioxide (and equivalent greenhouse gases) is released for electricity generation. As increasing amounts of electricity are generated by carbon-free renewable sources, the carbon-intensity of the grid will decline, meaning the environmental impact of electricity use decreases.

The Department of Energy and Climate Change (DECC) project that by 2020 the carbon-intensity of the grid will be 0.26 $kgCO_2$/kWh; this is 48% lower than the grid's carbon intensity in 2013 (the latest year of recorded data). Over the last 3 years of recorded data, carbon intensity has been relatively stable, and has not shown any significant decline; it is therefore questionable whether projections for such a significant and rapid decline in grid carbon-intensity will actually be achieved.

Figure 3 below projects emissions if grid decarbonisation does not progress at the projected pace. If, for example, grid carbon intensity remains at its present level[4], emissions in 2020 would be 6.29 $MtCO_2e$ under a 'no further uptake' scenario (scenario 1). This is considerably higher than the 5.60 $MtCO_2e$ target. This means significantly more effort will be required to meet the 2020 target.

Furthermore, Figure 3 shows that if grid carbon intensity remains at present levels, a large scale rollout of energy efficiency (Scenario 6) is required to meet the 3% target. Comparing scenario 1 in Figure 3 below to scenario 1 in Figure 2 above shows the importance of grid decarbonisation – 73% of the decrease in emissions seen in Figure 2 is due to decarbonisation rather than reduced energy consumption.

Figure 3: Emissions under scenario 1 and 6 if there is no grid decarbonisation



[4] Assumes a grid carbon intensity of 0.503 $kgCO_2$/kWh between 2015 and 2020; this is the average carbon intensity between 2010 and 2015.

The indication that Wales is on track to meet its 3% target with minimal effort should therefore be treated cautiously. A large proportion of the decrease in emissions seen is not due to Welsh Government action, but instead is due to grid decarbonisation. The emission reductions seen under these future scenarios are therefore vulnerable to activity outside Welsh Government's control. If decarbonisation projections are not met, which seems possible given the rapid decline predicted, the Welsh Government will not meet its 3% target at the housing stock's current level of energy efficiency. Significantly greater activity would be required to further reduce energy demand, through improving the energy efficiency of the housing stock, if the target is to be achieved without such heavy reliance upon grid decarbonisation.

The 40% target

The 40% emissions reduction target aims to reduce all emissions in Wales by 40% compared to 1990 levels. This target includes all emissions, not just those which fall within the Welsh Government's devolved powers. The target is measured based on 'source' emissions, meaning it only includes emissions which are directly released by each sector of the economy.

When looking at all sectors collectively (residential, industrial, agricultural etc.), source emissions will therefore include all emissions released in Wales. However, when looking only at the residential sector in isolation, emissions due to electricity consumption are not included within the target. Emissions from electricity are attributed to the power station generating the electricity, rather than the household using it. The 'source' emissions from the residential sector therefore does not include any emissions related to electricity use; any measures which impact emissions from electricity use (such as installation of low energy lighting or solar photovoltaics) therefore have no impact on progress towards the 40% target.

Although within the 40% target there is no sub-target set exclusively for the residential sector, if we were to assume an even 40% reduction across all sectors of the economy, progress towards the 40% reduction in the residential sector is currently not on-track[5]. Since progress towards the 40% target in the residential sector requires a reduction in all non-electricity based consumption, achieving the target cannot rely on decarbonisation of the grid. Figure 4 shows progress towards this target to 2014; modelled emissions in 2014 are 0.28 $MtCO_2e$ above the target level (recorded NAEI emissions show high levels of variability due to changes in weather between the years).

[5] It is likely that the 40% target will not be met by a proportionally equal reduction in emissions in all sectors, therefore the residential sector may not be required to reduce emissions by a full 40%. However, due to lack of information regarding a breakdown of emissions targets by sector, for this analysis we have compared progress against a direct 40% emissions reduction.

Figure 4: Source emissions, modelled and recorded, from 2007-2014[6]

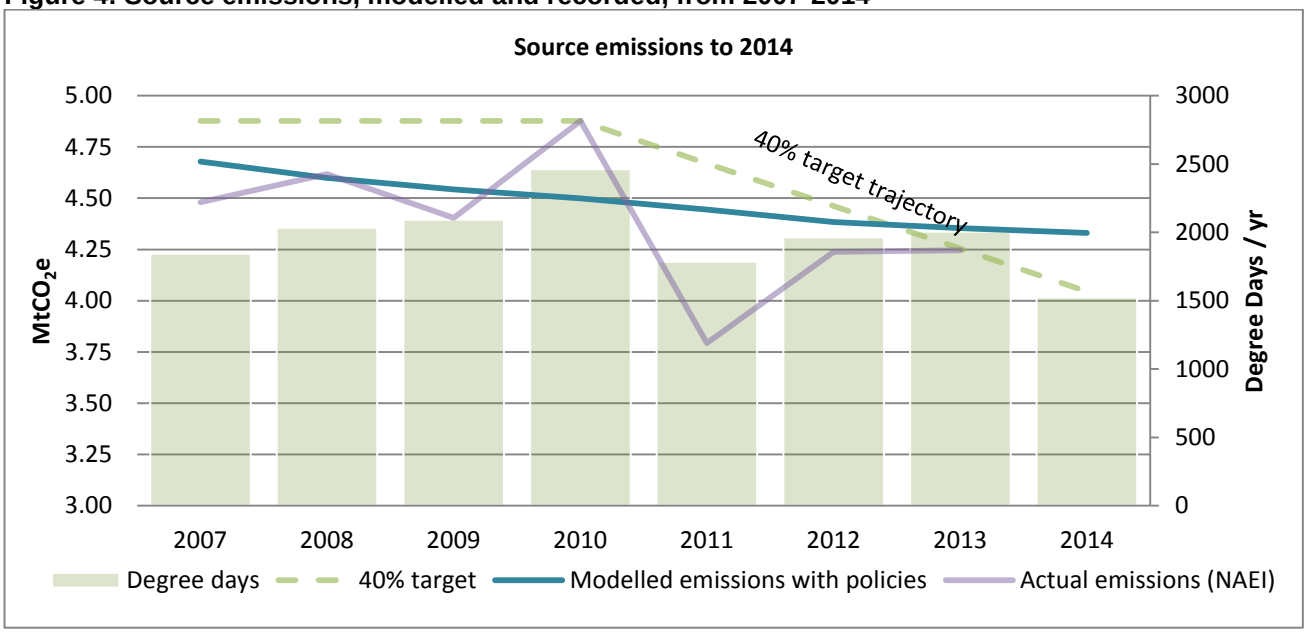
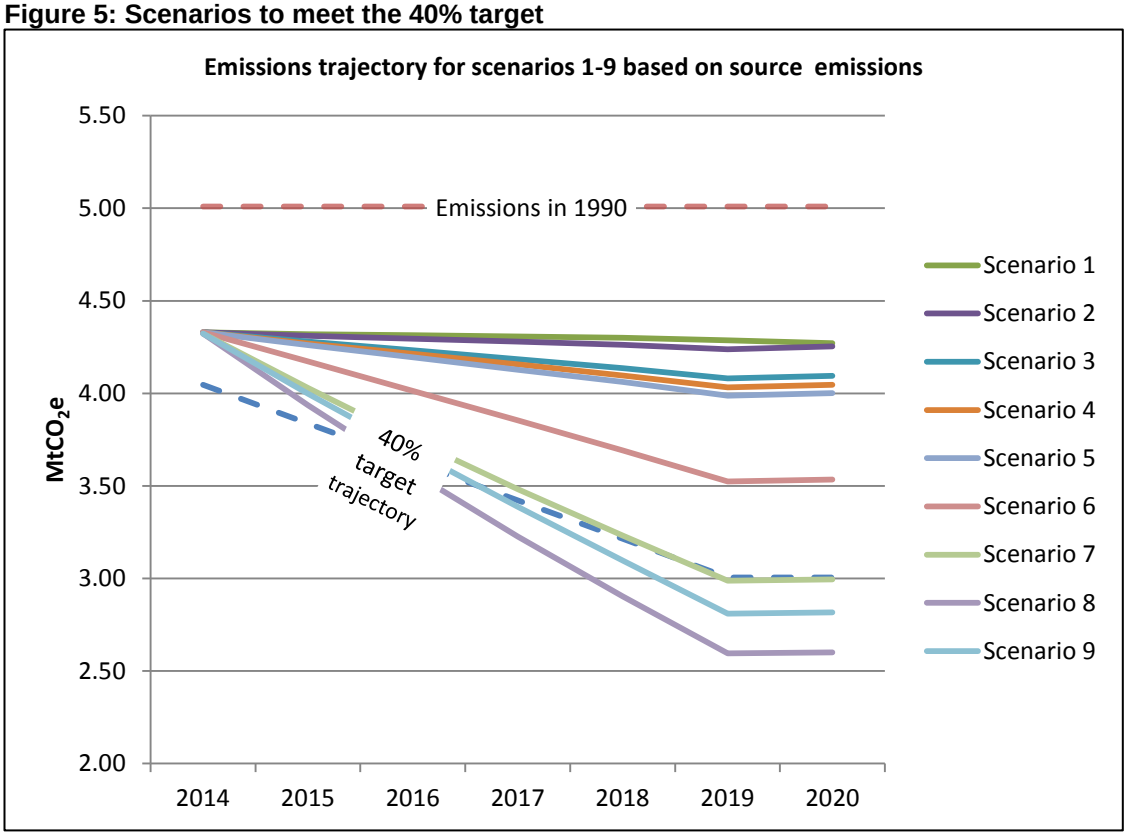


Figure 5 shows the results of our future scenarios modelling with regards to the 40% target, and what action is required to meet the 2020 target. Since 'source' emissions from the residential sector are predominantly due to heating, achieving the target will require investment both in methods to reduce heating demand (for example, through insulation) and to reduce the carbon intensity of heating fuels (for example, using renewable heating sources). Our scenarios indicate that significant action in these areas will be required between 2015 and 2020 if this target is to be met. Even under a scenario modelling 100% uptake of cavity wall insulation, loft insulation, draught proofing, condensing boilers and solid wall insulation source emissions are reduced only to 3.53 $MtCO_2e$; this is still 0.52 $MtCO_2e$ above the 40% target level.

Achieving the target will therefore also require uptake of renewable heating. We modelled three scenarios incorporating renewable heat (scenarios 7, 8 and 9)[7]. The most viable scenario which could achieve the target was scenario 9, which requires: 100% uptake of cavity wall insulation, loft insulation, draught proofing and condensing boilers; 25% uptake of solid wall insulation; and uptake of renewable heat into 25% of homes. In total, this would require installation of over 2.2 million energy efficiency measures, at a cost of around £5.2 to £9.3 billion.

[6] The target trajectory shown is based on emissions starting at the level recorded in the NAEI in 2010 (since this is the start year of the policy), and reducing evenly to the target level (40% below 1990 emissions) in 2020
[7] Full details on each of the scenarios can be found in Table 3.1, Section 3.4.

Figure 5: Scenarios to meet the 40% target



Since this analysis is based purely on source emissions, it does not account for the important role played by domestic renewable electricity generation in cutting Welsh carbon emissions. Whilst these systems are installed on residential properties, under residential energy efficiency schemes, their benefit is instead attributed to the power generation sector. These systems are therefore not incorporated when evaluating the residential sector's progress towards the 40% target. This shows how the 40% target, in its current form, poses challenges to valuing the impact of electricity demand reduction and micro-renewables in the residential sector. Since the actions required to achieve emission reduction targets will vary considerably between sectors, the inability to effectively monitor progress on a sector-by-sector level may limit the 40% target's utility in stimulating practical on-the-ground action.

Summary

Our modelling indicates that progress towards the Welsh Government's climate change targets is mixed. To date, the residential sector is on-target for its 3% year-on-year reduction commitment, leaving the sector well placed to achieve the 2020 target even with minimal ongoing action. However, future progress towards this 2020 goal is heavily dependent on grid decarbonisation. In our scenario 1 (no uptake of energy efficiency measures post-2014), 73% of the reduction in emissions seen between 2014 and 2020 is due to grid decarbonisation. Since electricity generation is outside of the Welsh Government's devolved powers, this high dependence on decarbonisation leaves progress towards the target vulnerable to processes outside Welsh Government's control. To reduce this vulnerability, Welsh Government must focus greater efforts on reducing energy consumption, rather than relying on reduced

carbon intensity of the energy itself. Reducing consumption will require ongoing action to continue improving the housing stock's energy efficiency.

Progress towards the 40% residential target has been much slower. This target requires a reduction in non-electricity based emissions from households. Achieving this target therefore requires further energy efficiency measures to reduce heating demand, plus significant uptake of renewable heating technologies to reduce the carbon-intensity of heating. Given what is required, achieving a 40% emission reduction in the residential sector by 2020 will be extremely challenging. Our analysis indicates that around 2.2 million additional energy efficiency measure installations will be required between now and 2020 for the target to be met; this is almost 3 times the number of installations made from 2007 to 2014. Significantly greater investment will therefore be required for a 40% reduction in source emissions to be achieved.

1. Introduction

The residential sector is responsible for almost a quarter (24%) of carbon dioxide emissions in Wales[8]. As such a significant contributor to the country's emissions, improving the efficiency of energy use in this sector must be a central component in strategies to reduce Welsh greenhouse gas emissions.

The Welsh Government has committed to two greenhouse gas reduction targets: an annual 3% reduction in emissions year-on-year to 2020 against a 2006-2010 baseline; and a 40% reduction in all emissions in Wales by 2020 against a 1990 baseline. In order to meet these targets in the residential sector, a number of energy efficiency programmes have been put into place, by both the Welsh and UK governments. The purpose of this study is to investigate the impacts of these programmes on Welsh CO_2 emissions, in order to establish whether annual CO_2 reduction targets are being met and what level of ongoing activity is required to meet the 2020 targets.

This will be achieved using Energy Saving Trust's (EST) Welsh Housing Energy Model (HEM). The most recent assessment of the Welsh housing stock's energy efficiency is from the 2008 Living in Wales property survey; the HEM has therefore been used to model how improvements in the housing stock since 2008, and subsequently how emissions from the sector have changed.

1.1 Project aims

The project has four main aims:

1. To quantify the total level of energy efficiency activity in the Welsh Housing stock from 2008 (when the last Living in Wales survey was conducted) to 2015;
2. To calculate the emissions reduction this activity has achieved;
3. To compare this reduction in emissions to the requirements set by the Welsh Governments targets;
4. To evaluate the scale of energy efficiency activity needed between now and 2020 in order for these targets to be met.

1.2 Previous work

The study builds upon a previous piece of research conducted by EST for WWF Cymru in 2011. In this previous study, the potential costs, benefits and carbon impacts of several residential energy efficiency policy scenarios were explored. Two different approaches to improving energy efficiency were explored: the first looked at improving the worst performing homes in the private rented sector and in the whole

[8] Based on source and end-user electricity emissions (those relevant to the government's 3% target) from the 2015 National Atmospheric Emissions Inventory (NAEI), available here: http://naei.defra.gov.uk/reports/reports?report_id=810 (Devolved administration tables)
Also quoted in the 'Climate Change Annual Report' (2014) (which is based on the 2014 NAEI – the percentage has not changed between the two years) available here: http://gov.wales/docs/desh/publications/150616-climate-change-annual-report-2014-en.pdf

Welsh housing stock, the second looked at achieving a 60% CO_2 reduction in around a third of Welsh homes by 2020. The impact of these scenarios was tested using the Welsh HEM.

In this study, we again use the Welsh HEM in order to evaluate progress made to date on greenhouse gas emissions reduction targets, and then evaluate the scale of activity required between 2015 and 2020 for the targets to be met.

2. Context

2.1 The targets

In the 2010 Climate Change Strategy, the Welsh Government committed to two emissions reduction targets:

1. To reduce emissions within all areas of devolved competence by 3% each year from 2011 to 2020, against a baseline of average emissions over the period 2006-2010
2. To reduce all Welsh emissions by 40%, against a baseline of 1990, by 2020

The 3% target

The 3% target covers the 6 main greenhouse gases[9] (each reported as CO_2 equivalent) and covers all areas of devolved competence in Wales. This means that the target is based on 'non-traded' emissions (emissions which are not incorporated in the EU Emissions Trading Scheme), therefore does not include areas such as power generation and heavy industry which are outside of the Welsh Government's devolved powers.

However, the target does involve the end-user 'traded' emissions relating to electricity consumption. This is because whilst electricity generation is outside Welsh Government control, they are able to influence electricity consumption. Reducing electricity consumption will be of significant importance in mitigating climate change, therefore it was deemed necessary to incorporate this within the national target. The relevant emissions from the National Atmospheric Emissions Inventory (NAEI) for the 3% target are therefore the 'source' emissions (those emitted directly at the site) plus the 'end-user electricity' emissions for the residential sector.

The 3% target was agreed in 2010, and requires an annual emissions reduction of 3% compared to a baseline of average emissions between 2006 and 2010. Since the baseline is based on 2006-2010 emissions rather than previous year emissions, it provides a fixed reference point for emissions reductions. However, slight alterations may occur in the baseline each year with the update of the NAEI. Any alterations to the methodology used to compile the NAEI are back-cast across the entire time series of emissions, meaning small changes in historic emissions do occur.

In the residential sector, the baseline is 7.67 $MtCO_2e$ (based on the most recent NAEI, published June 2015). This figure is slightly lower than that stated in the 2014 Climate Change Annual Report (7.69 $MtCO_2e$), but higher than the original baseline stated in the 2010 report (7.48 $MtCO_2e$) due to changes in the NAEI methodology explained above.

The 3% overall target does not need to be met evenly across all sectors. In the original 2010 Climate Change Strategy for Wales Delivery Plan for Emission Reduction it was anticipated that around 19% of

[9] This is the 6 direct greenhouse gases under the Kyoto Protocol, all of which contribute directly to climate change due to their positive radiative forcing effect: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)

the overall emissions reduction would be met by the residential sector[10]. However, in the more recent 2014 Annual Report, the target emissions in the residential sector have been defined "assuming a 3% per annum reduction" (Climate Change Annual Report 2014, p29). In this study therefore, we have assumed the residential sector target to be a 3% annual emissions reduction, meaning an annual reduction of 0.23MtCO_2e must be achieved each year until 2020.

The 40% target

The second commitment made by Welsh Government is to reduce greenhouse gas emissions by 40% by 2020, against a baseline of 1990. This target encompasses all emissions, both traded and non-traded, therefore incorporates emissions outside the Welsh Government's devolved competence. The baseline for 1990 emissions is 57.6MtCO_2e, giving a 2020 target for total emissions of 34.6MtCO_2e. Within the residential sector, the baseline is 5.01MtCO_2e.

This target is based on 'source' emissions, whereby emissions are attributed to the sector that emits them directly. This means that all emissions from electricity use are attributed to the power station generating the electricity, rather than the end-user. This is an important feature to note when evaluating progress towards the 40% target: any emissions relating to electricity use are not included when looking only at the residential sector, since electricity-related emissions are released by a power station rather than the households directly. At a national scale, looking at all sectors, emissions from electricity use will form an important part of the 40% target, but at the scale of the residential sector they are not included, as residences are not the direct 'source' of emissions. This also means that actions which reduce emissions from household electricity use, such as domestic renewable technologies, will be accounted for as reduced power station emissions rather than reduced residential emissions. Domestic micro-generation will therefore not contribute to the residential sector's progress towards the 40% target, but will contribute to the overarching, non-sector specific target.

It is not specified how this 40% emissions reduction is to be met at a sectoral scale, therefore it is not known what the specific target for the residential sector is. If we assume the 40% target is reached through a proportionally equal reduction across all sectors, the target for residential emissions would be 3.01MtCO_2e by 2020. In reality, it is likely that proportionally higher emissions reductions are anticipated in the power generation sector, allowing lower emission reductions in the residential sector.

Clarity of targets

Effective monitoring of progress towards these targets is complicated due to the lack of clarity on sectoral level targets. For the 3% target, there are slight discrepancies between the targets given within the 2010 Climate Change Strategy and 2014 Climate Change Report. In the 2010 Strategy, the target specified for the residential sector is stated as: "Residential emissions reduced to between 5.46 and 6.04

[10] 'Climate Change Strategy for Wales: Delivery plan for emissions reduction' (2010), p3. Available here: http://gov.wales/docs/desh/publications/101006ccstratdeliveryemissionsen.pdf
Pie chart in Figure 3 shows 0.57% of emissions reduction will be in residential sector, equivalent to 19% of the target.

$MtCO_2e$ against a baseline of 7.48$MtCO_2e$"[11]. This is equivalent to a 19%-27% reduction against the stated baseline by 2020, or a 2.1%-3.0% reduction per year. In the 2014 Report, this range is lost; instead, a simple 3% per annum reduction is applied as the target, giving a 2020 target of 5.61 $MtCO_2e$ (based on the 2014 baseline figure of 7.69 $MtCO_2e$)[12].

For the 40% target, no measurable target is set at all for the residential sector. Since the target is based on 'source' emissions, monitoring progress in the residential sector alone may appear to give misleading results, since the recorded carbon reduction will not incorporate any emissions reduction related to electricity consumption. Since action to achieve the target must occur at a secrotal level, measureable, achievable targets are required for each sector to allow for effective monitoring and to motivate ongoing action.

The lack of clarity around both targets is likely to limit their effectiveness in spurring action within the residential sector. It also limits the ability of stakeholders to easily evaluate the effectiveness of schemes in relation to these targets.

2.2 Energy efficiency programmes

In order to achieve these targets, a number of energy efficiency programmes have been put into place by both the Welsh and UK governments. These schemes have been designed to improve the energy efficiency of the Welsh housing stock, thereby reducing emissions from the sector and reducing the number of people suffering from fuel poverty.

Welsh Government schemes

Nest

Nest is the Welsh Government's fuel poverty scheme. It is an ongoing scheme which was launched in 2011, to replace the Home Energy Efficiency Scheme (HEES). It provides energy improvement measures such as insulation and new boilers to households which receive particular means tested benefits and are living in low efficiency F and G rated homes. This was very recently extended to also cover E rated homes. In addition, the Nest scheme encompasses an advice and support service, which helps to refer people onto other energy efficiency schemes such those provided under supplier obligations, alongside referrals to other services such as energy tariff switching services and debt advice.

In this analysis, we are only attributing carbon reduction to measures installed with Nest funding. Measures installed under other energy efficiency schemes due to a referral from Nest (for example, an

[11] 'Climate Change Strategy for Wales' (2010), p38. Available here: http://gov.wales/docs/desh/publications/101006ccstratfinalen.pdf
Note, this target is based on a baseline of 7.48 $MtCO_2e$, which has since changed due to updates to the NAEI methodology.

[12] 'Climate Change Annual Report' (2014), p 29 (graph). Available here: http://gov.wales/docs/desh/publications/150616-climate-change-annual-report-2014-en.pdf

install CERT funding but installed under the Nest scheme) have not been included to avoid double counting with other schemes.

Arbed

Arbed is another energy efficiency programme run by the Welsh Government. It is an area based scheme which targets deprived areas. The first phase ran from 2009-2011, and installed energy saving measures in over 6,000 homes. The second phase began in 2012 and will finish later in 2015; this phase aims to provide measures to around 4,800 homes.

UK government schemes

Energy Company Obligation (ECO)

The Energy Company Obligation (ECO) was launched in 2013, with the first phase running until 2015. The second obligation period was launched in April 2015, extending the programme to 2017. ECO is an obligation upon energy suppliers to provide energy efficiency measures to households in the UK. This includes insulation measures such as wall and loft insulation as well as heating measures such as district heating connections and boiler upgrades. There are three main parts to ECO:

- Carbon Saving Communities Obligation (CSCO) – this specifically targets low income households, with at least 15% of installs required to be in rural areas
- Carbon Emissions Reduction Obligation (CERO) – this targets hard to treat properties, which could not be cost-effectively financed under other schemes such as the Green Deal
- Home Heating Cost Reduction Obligation (HHCRO) – this targets low income and vulnerable households and aims to achieve heating savings

Carbon Emissions Reduction Target (CERT)

CERT ran from April 2008 to December 2012, and was the predecessor to ECO. Energy companies were required to achieve 293 million tonnes of CO_2 reduction in the UK, with over 40% of those savings in a 'priority group' of people over 70 years of age or in receipt of certain benefits.

Community Energy Saving Programme (CESP)

CESP ran from 2009 to 2012. It was an area based scheme targeting those living in the most deprived 15% of areas, as defined under the Indices of Multiple Deprivation. It was designed as a 'whole house' approach, to maximise fuel savings for vulnerable households.

Green Deal Finance and Green Deal Home Improvement Fund

The Green Deal is an ongoing programme launched in 2012, which targets 'able-to-pay' households to encourage them to install energy efficiency measures. Loans are provided for the purchase and installation of energy efficiency products, with loan repayments made through savings on energy bills. The Green Deal is complemented by the Home Improvement Fund, which allows money to be claimed back on certain measures.

Feed-in-Tariff (FiT)

Feed-in Tariffs for domestic renewable energy generation have been available since 2010. They provide guaranteed income over 20 years for those purchasing and installing an eligible renewable technology. Payments are based upon the amount of energy the system produces, with additional income for any

energy they export to the grid. It has proven most popular in the domestic sector for incentivising solar photovoltaic installations. FiT payments are made from FiT licensees (energy suppliers) to installation owners.

Domestic Renewable Heat Incentive (RHI)

The domestic Renewable Heat Incentive (RHI) is a similar scheme to the Feed-in-Tariff, designed to incentivise renewable heating technology uptake in single properties (rather than on district heating or a system that shares heat between two or more domestic dwellings). It covers technologies such as heat pumps, solar thermal water heating and biomass boilers. The RHI was launched in April 2014 and provides users with a payment tariff for 7 years from accreditation Payments are made from the Department of Energy and Climate Change (DECC) directly to the owner of the renewable heat systems. This is different to the non-domestic RHI which is aimed at commercial or district heating schemes, where the payments are made over 20 years.

3. Methodology

3.1 Overview

The most comprehensive assessment of the Welsh housing stock is the Living in Wales (LiW) property survey. This survey is made up of a representative sample of homes in Wales, recording the characteristics such as building size, heating system, level of insulation and building type. Based on this information, it is possible to evaluate the energy efficiency of the Welsh housing stock, and subsequently model the carbon emissions it generates.

However, the most recent LiW property survey was undertaken in 2008. Since this time, the energy efficiency of the Welsh housing stock has evolved considerably, as a result of energy efficiency programmes, construction of new homes, and improvements made outside of government programmes (such as the spread of low energy lighting). As no publicly available central record exists of the energy performance of the Welsh housing stock in 2014, we have collected data about the number of measures installed through each of these mechanisms to develop a picture of the present state of the Welsh housing stock's energy performance.

This data has then been input into EST's Welsh Housing Energy Model (HEM), which distributes the measures across appropriate property archetypes within the housing stock. From this, the HEM models annual CO_2 equivalent (CO_2e) emissions from the housing stock, up to 2014.

In this way, a detailed picture of the changing energy efficiency of the Welsh housing stock from 2008 to 2014 was built up, and carbon emissions over the period modelled. Building on this, a series of future scenarios were modelled up to 2020. These scenarios were constructed to represent increasingly ambitious policy scenarios for the next five years. The scenarios were modelled using the HEM, allowing carbon emissions under each scenario to be projected. These could then be compared to Welsh Government targets in order to evaluate what further action will be required to achieve 2020 targets.

A more detailed examination of each methodological step is provided in the following sections.

3.2 Data collection

In order to create an accurate picture of the current Welsh housing stock, it was necessary to collect data regarding the number of energy efficiency installations made to properties since the 2008 LiW survey. Data on each of the programmes outlined in Section 2.2, plus any additional relevant schemes identified, was therefore collected.

For a number of these programmes, detailed installation data was available from EST's Home Energy Efficiency Database (HEED). HEED contains records of all domestic energy efficiency and renewable measures installed in the UK under the supplier obligations EEC, CERT and CESP as well as installations that took place under HEES and the Low Carbon Buildings Programme. It therefore gives at a complete picture of all government and supplier funded installations to have taken place up until 2012 in Wales.

For the more recent schemes, including Nest and Arbed, data was not available from HEED and was therefore compiled from other sources. In these cases, data available was often less detailed, therefore certain assumptions had to be made to create a full dataset. Detail on the data sources and any assumptions made regarding the data for each scheme can be seen in Appendix A, Table A.1.

Alongside the total number of measures installed, it was also important to understand the number of households into which more than one measure was installed, since this has an impact on the carbon saving attributable to each measure. For each possible combination of the three main energy efficiency measures (wall insulation (solid/cavity), boiler installation and loft insulation) a figure for households receiving that combination was therefore calculated, using probabilistic calculations.

Data was also collected on natural, 'business as usual' uptake of measures which occurs unrelated to any government schemes. Figures for non-programme related uptake of new condensing boilers, low energy lighting and energy efficient appliances were collected, since these are all measures which have been installed in large numbers by individual householders. Details on the sources for this data are also in Appendix A, Table A.1.

3.3 Modelling to 2014

The data collected above was used to model the changing energy efficiency of the Welsh housing stock, and subsequently the change in annual CO_2 emissions. This modelling was undertaken using the Welsh HEM. The HEM is a Standard Assessment Procedure (SAP)[13] based model which, using a detailed picture of the Welsh housing stock, can assess changes in energy consumption of the residential sector based on the application of different combinations of measures. Being SAP-based, the HEM takes account of interactions between measures, for example the savings from a new boiler if loft insulation is already installed will be different to savings from installing a new boiler and loft insulation at the same time. The HEM is able to model a wide range of different measures, applied to different house types, with varying annual uptake rates.

In the 2011 analysis undertaken by EST for WWF, the HEM was based upon SAP 2005, the most recent version of SAP available at the time. For this project, we have updated the assumptions within the HEM to those given in SAP 2012, to give a more accurate reflection of building parameters. In addition, a number of other factors have been updated to incorporate the most up to date input data. Full details of changes made to the HEM can be seen in Appendix B.

We used 2008 as the base year of the model, since the latest assessment of the Welsh housing stock was made in 2008. From this, two scenarios were modelled up to 2014, a 'business as usual' (BAU) scenario and a policy scenario.

[13] For more information on SAP, see https://www.gov.uk/standard-assessment-procedure

Business as usual (BAU) scenario

This scenario provides a 'business as usual' assessment of Welsh residential emissions. The difference between the BAU and policy scenarios is therefore the additional CO_2 saving achieved by the energy efficiency programmes.

The BAU scenario includes the uptake of all energy efficiency improvements that have taken place, and are likely to take place, without direct intervention from an energy efficiency schemes such as NEST, CERT or FIT.

However, the BAU scenario does include policies that have led to the installation of efficient heating systems, low energy lighting and energy efficient appliances indirectly, for example through regulations that phase-out or prohibit the sale or installation of less efficient products. This includes policies such as:

- Changes to the 2005 building regulations that prohibit replacing Gas, Oil and LPG boilers with non-condensing boilers
- EU Ecodesign directive leading to the phase out of incandescent light bulbs
- EU Energy Labelling and Ecodesign directives leading to general reduction in appliance consumption.

Business as usual replacement of boilers between 2008 and 2015 has been estimated using data from DECC's UK Housing Energy Factfile[14] about boiler replacement and scaled to match data from the Living in Wales 2008 survey regarding the number boilers suitable for replacement in Wales.

The uptake rate of low energy lighting in Wales (energy saving lightbulbs and LEDs) between 2008 and 2014 has been derived from DECC's Energy Consumption in the UK[15] (ECUK) and scaled to match numbers of households in Wales. The number of households with at least 80% low energy lighting was calculated, and the ongoing uptake rate calculated as a percentage of remaining potential. This rate was then applied to the Welsh housing stock.

The HEM model only allows for percentage reduction in electricity consumption from electrical appliances as an input. Therefore policies affecting individual electrical appliances cannot be modelled. We have used trend data from ECUK, which shows an average 1.53% per year reduction in electricity consumption from appliances. This has been projected for future years to 2020.

Policy scenario

The policy scenario is the net impact of all energy efficiency programmes implemented in Wales since 2008. The data on annual installation of each measure (see Section 3.2) was distributed across appropriate property archetypes within the HEM. A range of characteristics determined whether a

[14] DECC (2014) United Kingdom Housing Energy Fact File: 2013 https://www.gov.uk/government/statistics/united-kingdom-housing-energy-fact-file-2013
[15] DECC (September 2014) Energy Consumption in the UK https://www.gov.uk/government/statistics/energy-consumption-in-the-uk

property archetype was deemed appropriate for each measure. For example, cavity wall insulation is only appropriate in uninsulated cavity walled homes. This appropriateness also varies amongst the policies; for all installations made under Nest, for example, measures were restricted to only F and G rated properties. Any overlap in properties into which measures were installed was restricted to the limited number of households which received multiple measures, as calculated in Section 3.2. Installing multiple measures in the same property has dynamic effects which influence the carbon saving potential of each measure, therefore avoiding overlap is important to ensure an accurate emissions estimate is produced.

3.4 Modelling to 2020

In order to evaluate future progress required to achieve 2020 targets, a series of different scenarios were constructed and modelled in the HEM. These scenarios ranged from 'no uptake of measures after 2014', to provide a baseline for what would happen if no new policies are implemented, to full uptake of a range of different measures.

Nine scenarios were modelled. The first 6 scenarios model the savings for the consecutive complete uptake of condensing boilers, cavity wall insulation, loft insulation, draught proofing and solid wall insulation. The measures have been applied in order of cost effectiveness based on the Committee on Climate Change's marginal abatement cost curve provided in the 4th carbon budget review[16]. The remaining 3 scenarios combine measures required in order for Wales to meet the 40% reduction target. These scenarios: 7, 8 and 9 include a varying combination of renewable heat technologies and solid wall insulation to find a cost optimal means of reaching the 40% target.

The scenarios are detailed in Table 3.1 below. Scenarios 1-9 were created using DECC's projected grid carbon factors for electricity; scenarios 1b and 6b were created assuming carbon intensity remains at its present level (see Section 5.1, 'Grid decarbonisation' for more detail). In all cases, unless otherwise stated, business as usual uptake of low energy lighting, double glazing, insulated hot water cylinders, insulated doors, and condensing boilers is included in the scenario. This BAU uptake represents the number of measures which we could expect would be installed naturally by householders regardless of future policies.

[16] Committee on Climate Change (2013) 'Fourth Carbon Budget Review – technical report – sectoral analysis of the cost-effective path to the 2050 target'. Available here: https://www.theccc.org.uk/wp-content/uploads/2013/12/1785b-CCC_TechRep_Singles_Chap3_1.pdf

Table 3.1: Scenarios

Scenario	Description
Scenario 1: No uptake	No uptake after 2014 of cavity wall insulation (CWI), solid wall insulation (SWI), loft insulation (LI), or draught proofing (DP); only BAU uptake of condensing boilers (i.e. natural replacement when boilers break down).
Scenario 2:	100% uptake by 2020 of condensing boilers; no uptake after 2014 of CWI, SWI, LI, or DP
Scenario 3:	100% uptake by 2020 of both condensing boilers and CWI; no uptake after 2014 of SWI, LI, or DP
Scenario 4:	100% uptake by 2020 of condensing boilers, CWI and LI; no uptake after 2014 of SWI or DP
Scenario 5:	100% uptake by 2020 of condensing boilers, CWI, LI and DP; no uptake after 2014 of SWI
Scenario 6:	100% uptake by 2020 of condensing boilers, CWI, LI, DP and SWI
Scenario 7:	100% uptake by 2020 of condensing boilers, CWI, LI, DP and SWI plus uptake of renewable heat in 75% of off-gas homes
Scenario 8:	100% uptake by 2020 of condensing boilers, CWI, LI, DP and SWI plus uptake of renewable heat in 25% of Welsh homes (including the 75% of off-gas properties)
Scenario 9:	100% uptake by 2020 of condensing boilers, CWI, LI, and DP; 25% uptake of SWI; uptake of renewable heat in 25% of homes (including the 75% of off-gas properties)
Scenario 1b:	Identical to scenario 1, but assuming grid carbon factor remains at 0.502 $kgCO_2/kWh$ (average of 2010-2015)
Scenario 6b:	Identical to scenario 6, but assuming grid carbon factor remains at 0.502 $kgCO_2/kWh$ (average of 2010-2015)

In order to allocate appropriate renewable heating technologies to homes, the following principles were used in scenario 7:

- Ground Source Heat Pumps (GSHPs): applied to all large (detached or semi-detached), off-gas homes deemed to have good thermal performance (archetypes more likely to have good insulation levels and double glazing than average)
- Air Source Heat Pumps (ASHPs): applied to all small, off-gas homes

- Biomass boilers: applied to all medium off-gas homes and all large off-gas homes deemed in poor condition (archetypes less likely to have good insulation levels and double glazing than average)

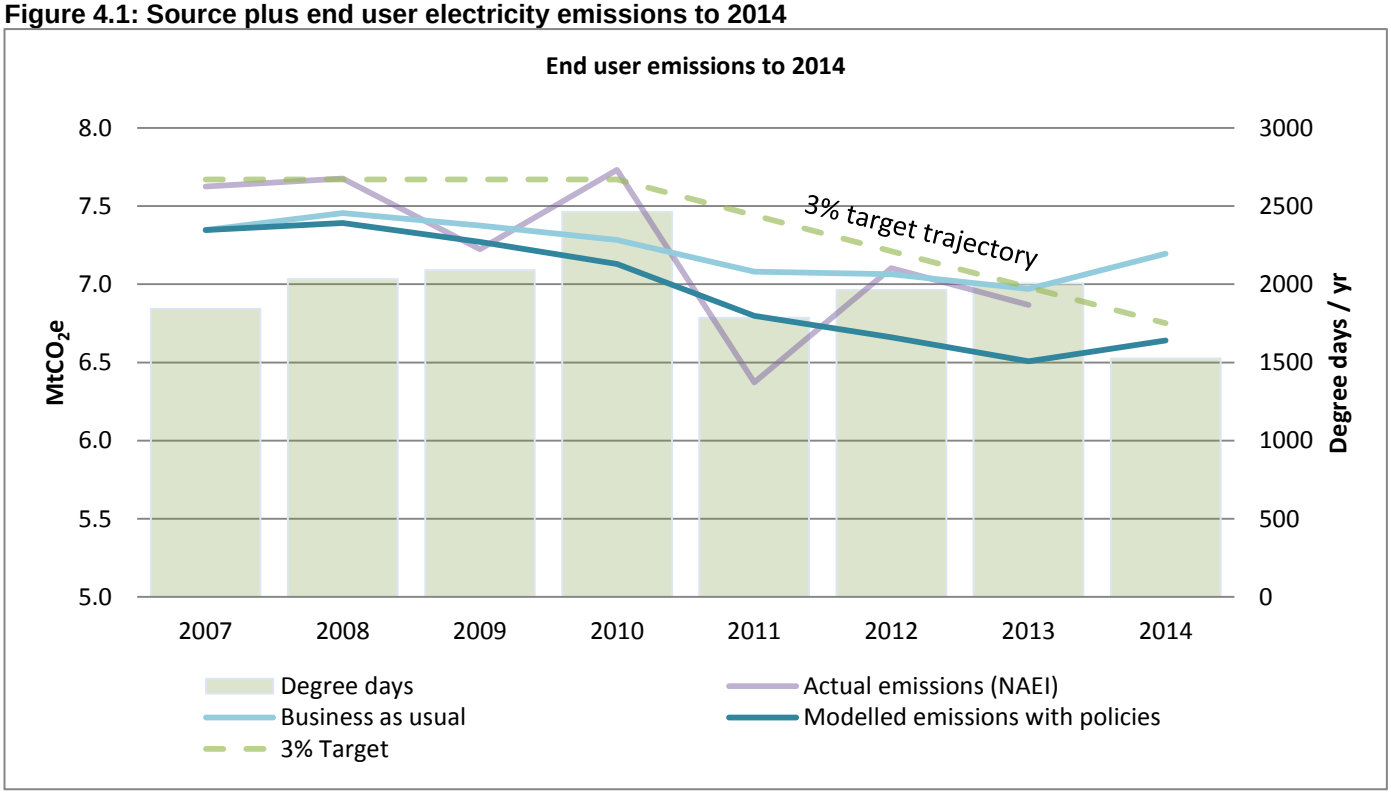
This ensured no overlap between households, so no household was allocated two different renewable heating technologies. In scenarios 9 and 10, the same principles were used to allocate technologies, except they could each also be installed in on-gas homes. In scenarios 8, 9 and 10, renewable heat systems were installed in 75% off-gas homes, representing 14% of the total housing stock. In scenarios 9 and 10, they were also installed in an additional 11% of the housing stock, to cover 25% of the housing stock in total.

4. Results: Modelling to 2014

4.1 Overall programme impact

Figure 4.1 shows the overall impact of energy efficiency programmes implemented between 2007 and 2014 (data in Table 4.1). From this, it can be seen that total residential emissions ('source' plus 'end-user') in 2014 were 6.64 $MtCO_2e$. This is compared to 'business as usual' (BAU) emissions for 2014 of 7.19 $MtCO_2e$, meaning the programmes have reduced annual CO_2 emissions by around 0.55 $MtCO_2e$. Cumulatively, since 2007, our modelling shows that the programmes have prevented the emission of 2.0 $MtCO_2e$. The slight increase in emissions in 2014 shown in Figure 4.1 is due to a change in carbon-intensity of the electricity grid. These results indicate that, in 2014, carbon emissions were on track to meet the 3% target.

Figure 4.1: Source plus end user electricity emissions to 2014



Heating degree days

Heating degree days per year is a measure which indicates the amount of heating required in a year, varying according to outside temperature. It is the number of degrees by which a day's average temperature is below 15.5 degrees Celsius, summed for each day over the year. This means that in colder years, when more heating is required, the number of degree days will be higher than for warmer years.

The 20 year average up to August 2015 for Wales is 1983 degree days per year. Between 2007 and 2013, 2010 was the coldest year with 2463 degree days/yr. This corresponded with a peak in end user and source emissions. Similarly 2011 was the warmest year with only 1786 degree days/yr when emissions fell to their lowest. These trends show the extent to which household emissions are dependent on external temperatures.

Table 4.1: Annual modelled and recorded emissions

Year	Required emissions to be on trajectory for the 3% target ($MtCO_2e$)	BAU modelled emissions (no policies post-2007) ($MtCO_2e$)	Modelled emissions with the policies ($MtCO_2e$)	NAEI recorded emissions[17] ($MtCO_2e$)
2007	-	7.35	7.35	7.63
2008	-	7.46	7.39	7.68
2009	-	7.38	7.27	7.22
2010	7.67	7.28	7.13	7.73
2011	7.44	7.08	6.80	6.37
2012	7.21	7.06	6.66	7.10
2013	6.98	6.97	6.51	6.87
2014	6.75	7.19	6.64	-

Figure 4.1 and Table 4.1 also show how these modelled results compare to the emissions recorded by the National Atmospheric Emissions Inventory (NAEI). Overall, our modelled results show slightly lower levels of emissions than those recorded. In part, this is due to comfort-taking, which is not included in the HEM model. Comfort taking would act to increase emissions, since the benefits of energy efficiency improvements are taken as additional warmth rather than reduced energy use. To some extent, it may also be because the NAEI data is not adjusted to account for annual variations in temperature, therefore peaks in emissions represent cold winters rather than a change in housing efficiency.

The change in 'source' carbon emissions since 2007 is shown in Figure 4.2 and Table 4.2; this shows emissions released directly from households, and therefore does not include those from electricity consumption. These are the emissions relevant to the 40% target. This shows that the programmes have reduced non-electricity-based emissions by 0.27 $MtCO_2e$ compared to what would have occurred under a BAU scenario.

Assuming the residential sector is required to reduce source emissions by 40%, this figure shows that Wales is currently not achieving its target in this sector. However, as noted in Section 2.1, it is likely that the emissions reduction required in the residential sector will be lower than 40%, therefore the overshoot seen in Figure 4.2 is speculative.

[17] Source plus end user electricity emissions from the NAEI (2015) dataset, 'Devolved Administration Tables', available here: http://naei.defra.gov.uk/reports/reports?report_id=810

Figure 4.2: Source emissions to 2014[18]

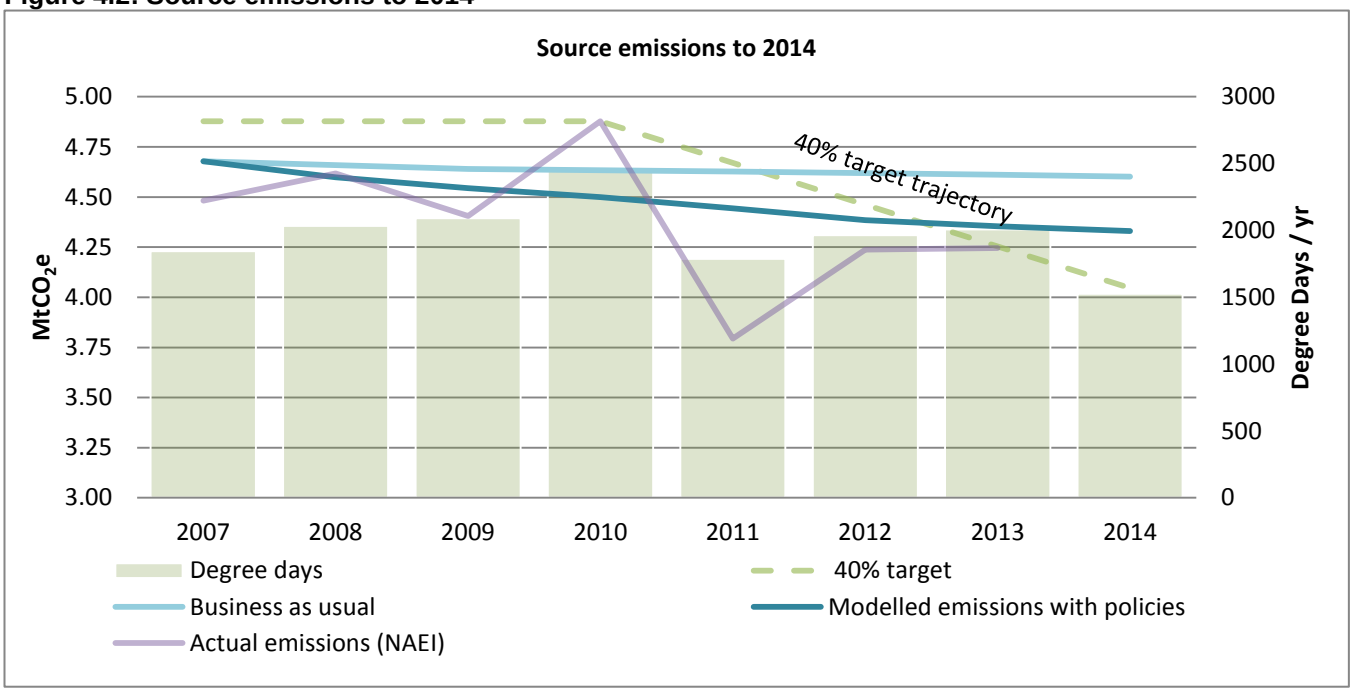


Table 4.2: Annual modelled and recorded source emissions

Year	Required emissions to be on trajectory for the 40% target ($MtCO_2e$)	Business as usual modelled emissions (no policies post-2007) ($MtCO_2e$)	Modelled emissions with the policies ($MtCO_2e$)	NAEI recorded emissions
2007	-	4.68	4.68	4.48
2008	-	4.66	4.60	4.62
2009	-	4.64	4.54	4.40
2010	4.88	4.63	4.50	4.88
2011	4.67	4.63	4.44	3.79
2012	4.46	4.62	4.38	4.24
2013	4.25	4.61	4.35	4.25
2014	4.05	4.60	4.33	-

4.2 Model uncertainty – differences between modelled and actual emissions

Models will only account for a certain number of factors affecting energy consumption. This means that there will always be a difference between modelled emissions and actual emissions.

[18] The target trajectory shown is based on emissions starting at the level recorded in the NAEI in 2010 (since this is the start year of the policy), and reducing evenly to the target level (40% below 1990 emissions) in 2020

Factors that the Housing Energy Model does not directly account for directly include comfort taking (see section 5.3 for further details) and year on year variation in weather. The HEM does assume an increase of around 1.5°C in global temperatures from 2008 to 2050, or 6% reduction in heating degree days by 2020, however it is not possible to input actual weather data for years passed. This is one of the reasons why modelled emissions between 2007 and 2014 decrease steadily compared with NAEI reported actual emissions which are more susceptible to changes in weather year on year.

Another limiting factor of this modelling work is that no detailed survey data profiling the current state of the housing stock in Wales has been carried out since the 2008 Living in Wales survey. As detailed in the section below the model incorporates data about improvements made to the housing stock since 2008. However, this modelling will not capture details as accurately as a survey. For example, details about the types of homes where improvements have taken place and details of the improvements made outside government and supplier-led schemes would be more accurately captured through a survey.

The average difference between modelled and actual end use emissions was -0.21 Mt CO_2 per year. This means on average the modelled emissions were 0.21 Mt CO_2e lower each year than the actual emissions. For source emissions the average difference was +0.12 MtCO_2e. These differences are margins of error worth taking into account when examining the modelled projections in section 5 of this report.

4.3 Attribution of impact

Measures installed by programme

The total number of measures installed under each programme can be seen in Table 4.3 below. A full breakdown of measures installed under each programme can be seen in Appendix C, Table C.1.

Table 4.3: Number of installs by programme

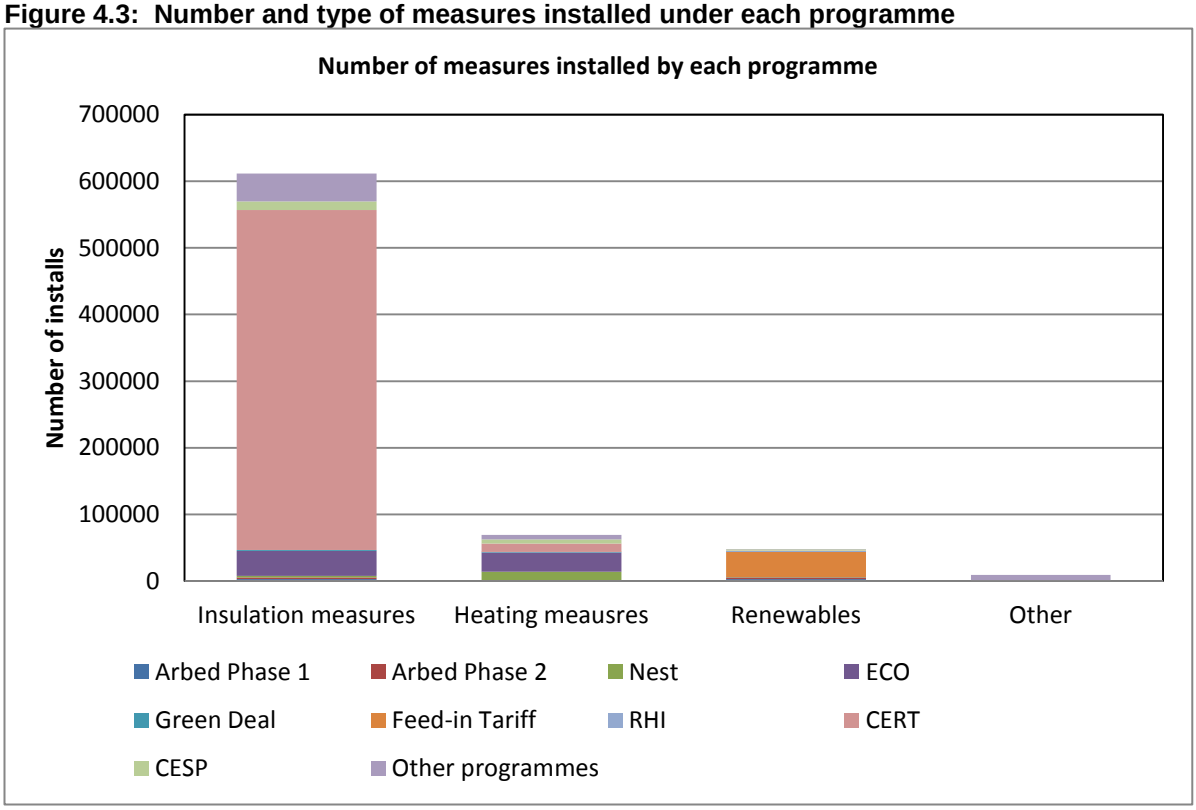
	Arbed	Nest	ECO	Green Deal	Feed-in Tariff	RHI	CERT	CEST	Other
Number of installs	11,980	15,150	66,180	2,520	38,340	1,330	522,780	21,120	58,020
Proportion of installs	1.6%	2.1%	9.0%	0.3%	5.2%	0.2%	70.9%	2.9%	7.9%

The vast majority of installs have been made under CERT. Of these, almost all (98% of CERT installs) were insulation measures, the majority either cavity wall or loft insulation. These are ‘easy win’ measures for policies targeting mass roll-out, giving relatively high energy savings for low cost.

By contrast, ECO and the Green Deal, schemes intended to replace CERT, have provided relatively low installation figures thus far. However, a larger number of the more costly measures have been

undertaken under these policies, with 43% of ECO installs being heating measures, and the majority of these condensing boiler installations[19].

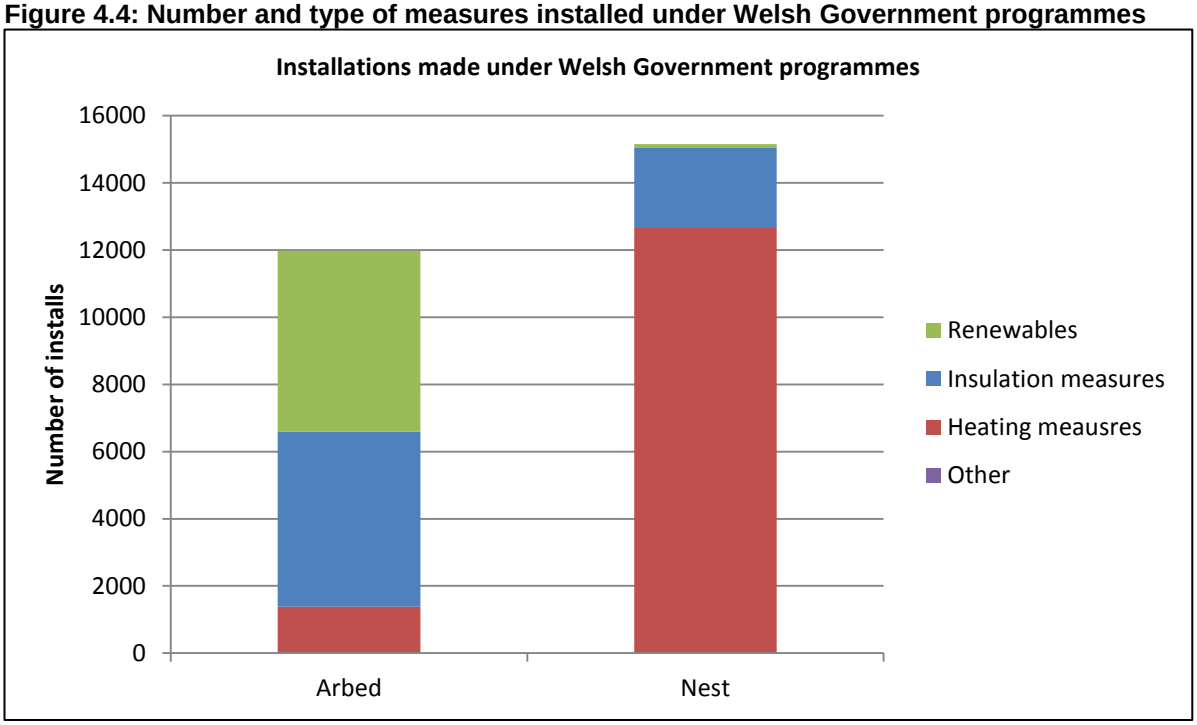
Figure 4.3: Number and type of measures installed under each programme



Looking only at the two Welsh Government schemes (Figure 4.4), a slightly larger number of installs have been made under the Nest scheme compared to Arbed. However, the spread of measures has been greater under Arbed, with a larger number of renewable installations.

[19] For detail on what measures fall under each category ('heating measures', 'insulation', 'renewables', 'other') see the breakdown in Appendix C Table C.1

Figure 4.4: Number and type of measures installed under Welsh Government programmes



Emissions reduction by programme

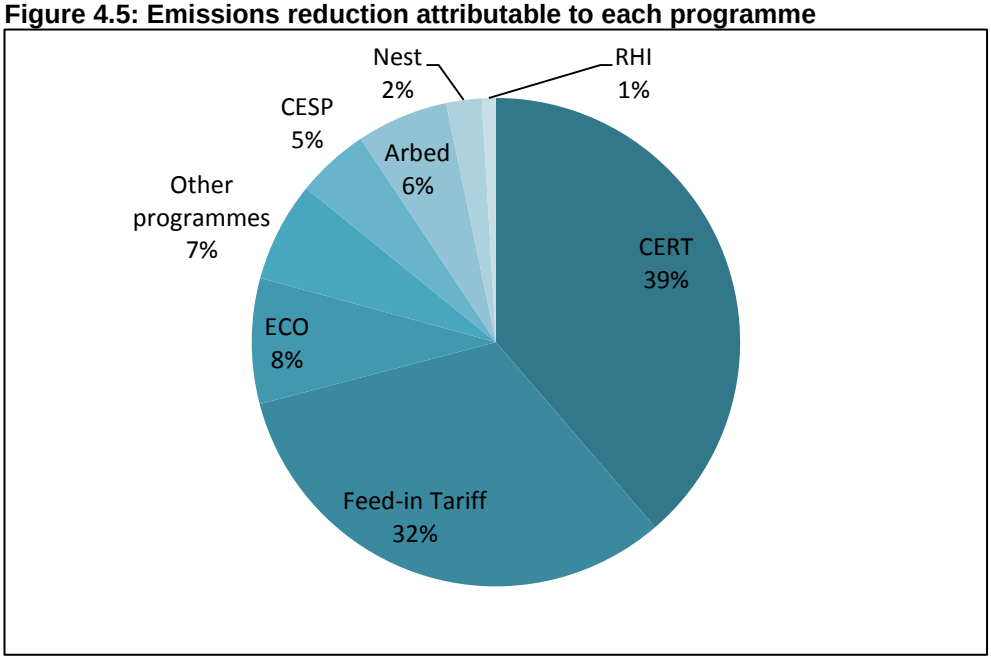
The reduction in emissions associated with each programme is not directly related to the number of measures installed. Rather, emissions savings will also depend on both the type of measure installed, and the type of home it is installed in. The impact of each programme on emissions can be seen in Table 4.4 and Figure 4.5.

Table 4.4: Emissions reduction attributable to each programme

	Arbed	Nest	ECO	Green Deal	Feed-in Tariff	RHI	CERT	CESP	Other
$MtCO_2e$	0.122	0.047	0.167	0.010	0.649	0.019	0.779	0.097	0.133
Proportion of total reduction	6%	2%	8%	0.5%	32%	1%	39%	5%	7%

Arbed Phase 1 contributed 0.068 $MtCO_2e$ (3% of total) whilst Arbed Phase 2 contributed 0.054 $MtCO_2e$ (3% of total)

Figure 4.5: Emissions reduction attributable to each programme



The most impactful programme has been CERT, accounting for 39% of emissions reductions. This is due to the large scale of the programme, which covered over 70% of total energy efficiency installations since 2007. This disparity between proportion of installs and proportion of carbon savings however implies that whilst CERT brought about a large number of installations, the carbon saving associated with each was relatively low in comparison to other programmes.

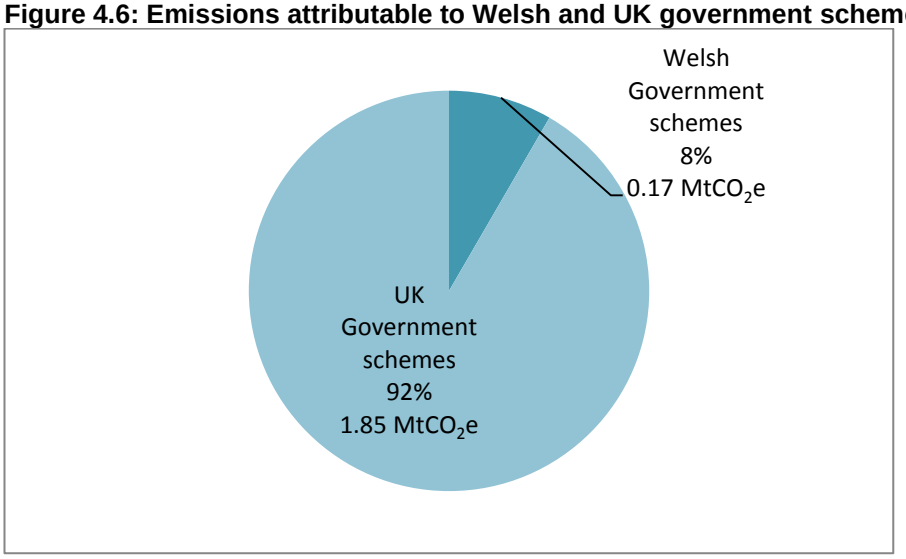
Despite accounting for only 5% of the total number of installs, 32% of CO_2 reduction is attributable to the Feed-in Tariff. This is because renewable installations have a disproportionately large impact on CO_2 emissions in comparison to other measures. For example, the annual CO_2 saving from installation of a 4kW solar photovoltaics (PV) system in Wales is around 1,750 kgCO_2, whereas the saving for cavity wall insulation in a typical 3-bed gas heated semi-detached home is only 650 kgCO_2 per year[20]. Despite the relatively low number of installations therefore, Feed-in Tariff installs have had the second largest impact on carbon emissions.

Combined, the schemes administered by Welsh Government account for 8% of the overall emissions reduction. The majority of this (6%) is due to Arbed; this is despite Arbed accounting for fewer installs than Nest. Whilst schemes such as CERT have impact through their mass scale, smaller schemes such as Nest and Arbed must target their measures effectively to ensure maximum impact. Arbed was more successful due to its effective focusing on high impact measures such as solid wall insulation, fuel switching and renewables installations. However, it should be noted that due to the lack of publically available detailed data on the Nest scheme, it was assumed in our modelling that the 'heating measures'

[20] Based on EST 2014 saving figures (not based on HEM modelling). Welsh solar PV saving is based on a 4kW system installed in Aberystwyth

figures given in annual reports were boiler replacements. If a large proportion were in fact fuel switching, it is possible that Nest carbon impact is underreported.

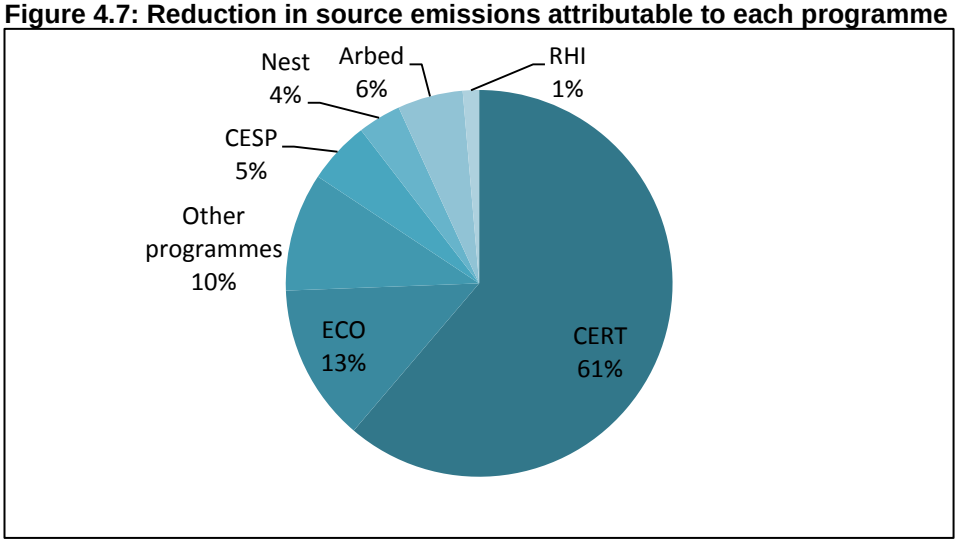
Figure 4.6: Emissions attributable to Welsh and UK government schemes



Looking only at source emissions (Figure 4.7), thereby excluding emissions from electricity, CERT has a much more dominant impact. The impact of the Feed-in Tariff here is lost since FiT installs are based around electricity rather than heating. The dominance of CERT over other ongoing schemes such as ECO is somewhat concerning when considering future emissions reductions, since CERT is no longer running and therefore will not contribute to any future increases in household efficiency. Although it's replacement, ECO, has only been in operation for around half as long as CERT, it has had considerably less than half as much impact on carbon emissions.

Whilst the domestic RHI has so far contributed only a small proportion of emissions reduction, its emission saving per install is very high. Since the domestic RHI was only launched in April 2014, this analysis only incorporates 9 months of respective installs. It is likely that the programme's impact will become more significant in later years once more renewable heating technologies have been installed.

Figure 4.7: Reduction in source emissions attributable to each programme



5. Results: Modelling to 2020

A series of scenarios have been modelled using the HEM to investigate how increasingly ambitious energy efficiency policies might influence Welsh carbon emissions up to 2020. The scenarios are detailed in Table 3.1, Section 3.4.

5.1 Achieving the 3% target

Modelling up to 2014 indicated that the Welsh residential sector is currently on track to achieve its 3% year-on-year emission reduction target by 2020. Our scenario modelling indicates that very little ongoing action is required to meet this target (Figure 5.1, Table 5.1); even under the 'No additional uptake' scenario 2020 emissions drop to 5.31 $MtCO_2e$, 0.29 $MtCO_2e$ below the target. In this scenario, there is no additional uptake of cavity or solid wall insulation, draught proofing, or loft insulation post-2014. However, the scenario does include an ongoing baseline uptake of other measures such as new condensing boilers, which will continue to be taken up at a low level regardless of energy efficiency policies (or lack of).

Each additional policy scenario modelled brings the residential sector increasingly below its target for maximum emissions. Applying such measures would therefore offset the need for action in other, non-residential sectors whilst allowing the overall 3% target to still be achieved. Figure 5.1 also highlights the relative importance of different measures. For example, ensuring there is 100% uptake of condensing boilers by 2020 has minimal impact compared to the no additional uptake scenario, due to the anticipated ongoing natural replacement of boilers. By contrast, the jumps in emission reduction between scenarios 2 and 3, and between 5 and 6, show the importance of cavity wall insulation and solid wall insulation respectively.

Figure 5.1: Scenario emissions compared to the 3% target

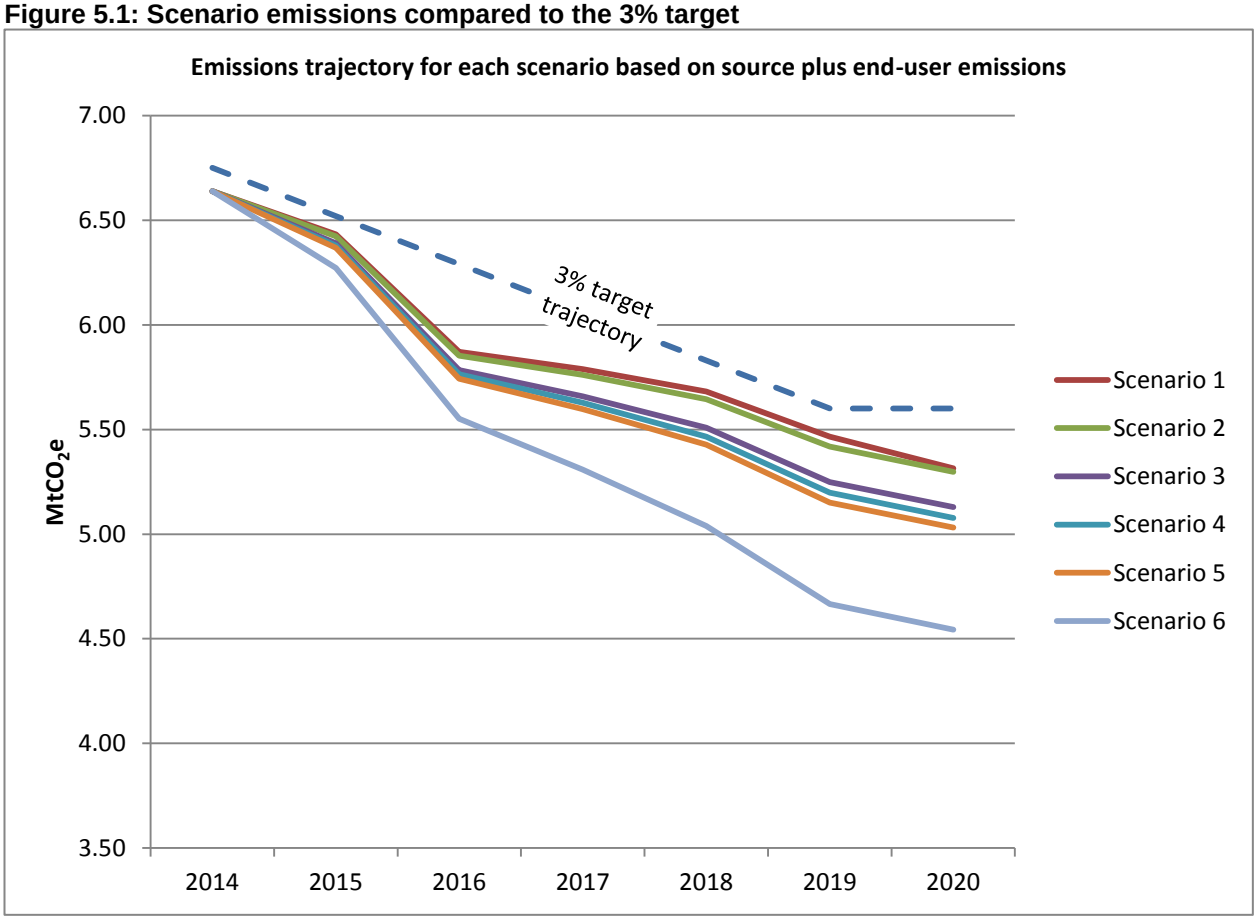


Table 5.1: Emissions under each scenario compared to 3% target emissions

2006-2010 baseline:	**7.67 $MtCO_{2e}$**
2020 target emissions:	**5.60 $MtCO_2e$**

Scenario	Emissions in 2020, under the scenario ($MtCO_2e$)	Emissions reduction compared to 'no action' ($MtCO_2e$)	Additional emissions reduction compared to target ($MtCO_2e$)
Scenario 1	5.31	0.00	0.29
Scenario 2	5.30	0.02	0.30
Scenario 3	5.13	0.19	0.47
Scenario 4	5.08	0.24	0.52
Scenario 5	5.03	0.28	0.57
Scenario 6	4.54	0.77	1.06
Scenario 7	4.07	1.24	1.53
Scenario 8	3.74	1.57	1.86
Scenario 9	3.99	1.32	1.61

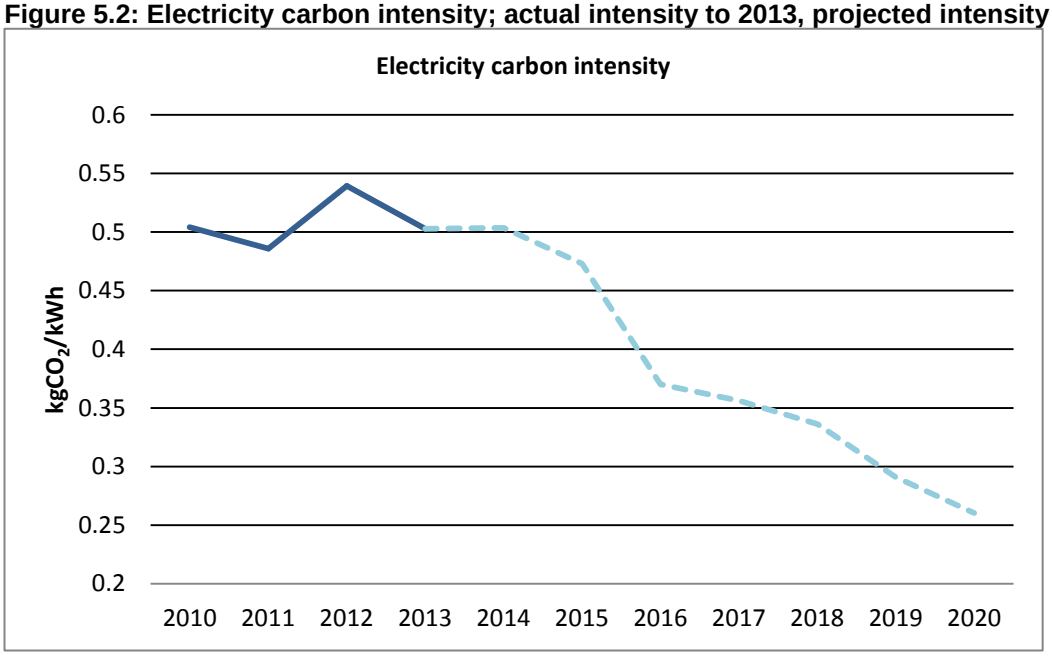
When evaluating these results however, it is important to take into consideration two key uncertainties of the model: grid decarbonisation estimates and comfort-taking. The exclusion of these factors may act to artificially lower the modelled emission projections.

Grid decarbonisation

With the continuing growth of renewable power generation in the UK, the carbon-intensity of the electricity grid is gradually declining. In order to estimate emissions relating to household electricity use into the future, this decarbonisation must be taken into account. The HEM therefore incorporates projected electricity carbon factors for future years into its emissions calculations. These carbon factors are taken from DECC's 'Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal' (2014). Since in Scenario 1 there is no additional uptake of the main energy efficiency measures, the rapid decline in emissions seen in Figure 5.1 must be a result of grid decarbonisation. This highlights the sensitivity of our modelled scenarios to projected values for future grid carbon-intensity.

Figure 5.2 shows DECC's projected electricity carbon factors from 2013, and the carbon intensity actually recorded (up to 2013) by Defra. From this, it can be seen that DECC projects a dramatic decline in carbon-intensity to 0.26 $kgCO_2/kWh$ by 2020. This is despite recorded electricity carbon intensity remaining relatively stable at around 0.5 $kgCO_2/kWh$ over the latest 3 years of data. Compared to 2013 recorded figures, DECC projects a 48% decline in grid intensity by 2020.

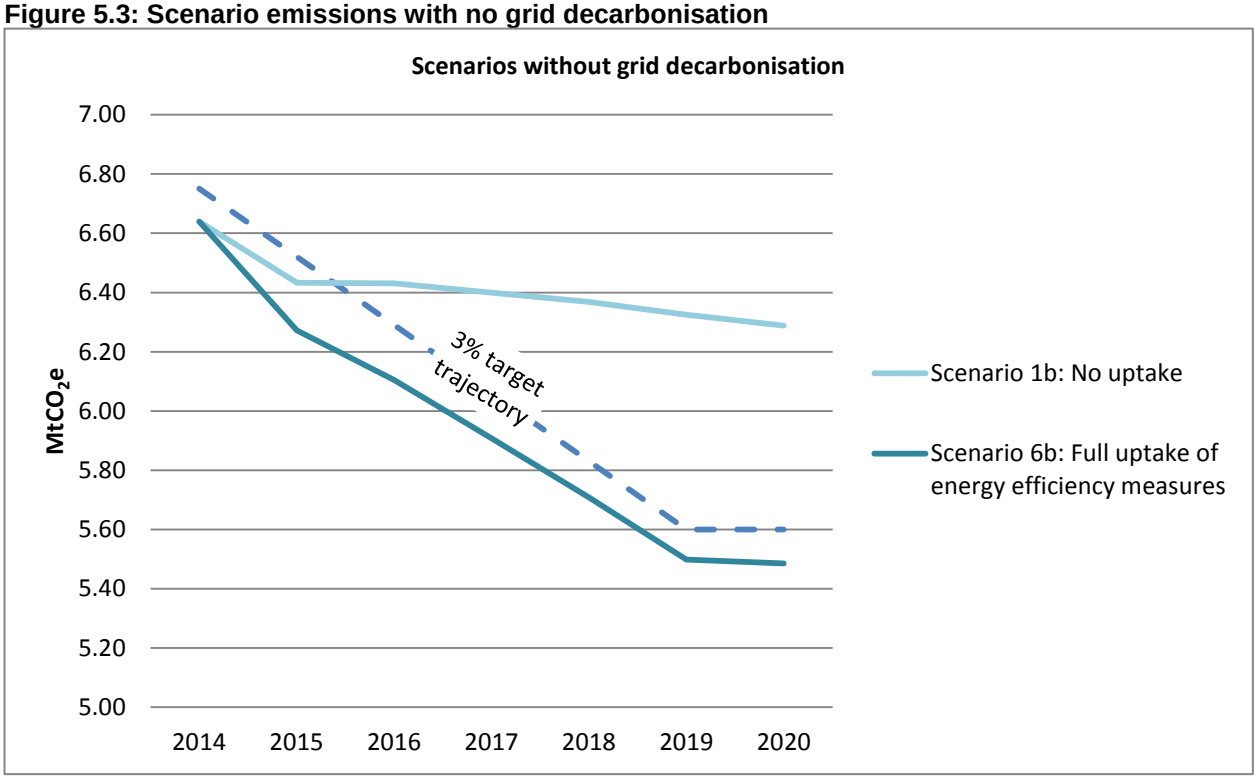
Figure 5.2: Electricity carbon intensity; actual intensity to 2013, projected intensity from 2013[21]



[21] Actual emissions taken from Defra's Greenhouse Gas Conversion Factor Repository, available here: http://www.ukconversionfactorscarbonsmart.co.uk/
Projected emissions from DECC's 'Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal' (2014), available here: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

If this decline is not realised, considerably more effort will be required to achieve the 2020 emissions reduction required by the 3% target. To test this sensitivity, two additional scenarios have been modelled assuming no decrease in grid carbon-intensity by 2020 (Figure 5.3). These scenarios are identical to Scenarios 1 and 6 above (no uptake of any measures, and 100% uptake of boilers, cavity wall insulation, loft insulation, draught proofing and solid wall insulation), but use a grid factor of 0.503 $kgCO_2/kWh$ (the years 2016-2020[22].

Figure 5.3: Scenario emissions with no grid decarbonisation



In these scenarios, taking no additional action (1b) leads to CO_2e emissions in 2020 of 6.29 Mt CO_2e, considerably higher than the target level of 5.60 $MtCO_2e$. The full uptake scenario (6b) (without renewable heat) leads to CO_2e emissions of 5.49 $MtCO_2e$, only slightly below the target. This highlights that if DECC's decarbonisation projections are not achieved, considerably more activity will be required in the residential sector to reach 2020 targets. A comparison of scenario 1 with DECC's grid decarbonisation to scenario 1 with no decarbonisation shows that 73% of the projected emissions decrease under scenario 1 in Figure 5.1 is due to decarbonisation rather than a reduction in energy consumption. This shows how heavily reliant progress towards the 3% target currently is on processes outside Welsh Government control.

Comfort-taking

The modelled emissions for 2020 do not account for comfort taking, which would likely increase the emissions under every scenario. The HEM uses the SAP assumption that homes are heated to 21°C in

[22] 0.503 $kgCO_2/kWh$ is the average carbon-intensity of the grid between 2010 and 2015.

the main living area and 18°C in other areas of the home, and that heating patterns remain the same before and after an energy efficiency installation. In reality, many homes are not heated to this temperature. In particular, many homes with very low energy efficiencies are currently under-heated, in order to maintain manageable heating bills. Once energy-saving measures are installed in these homes, householders are likely to increase the mean internal temperature of their home to a more comfortable level. The benefits of the efficiency improvement are therefore taken as an increase in warmth rather than a decrease in energy use, meaning the potential carbon savings are not realised. Since a number of programmes specifically target households in fuel poverty, the potential for comfort-taking is high. Fuel poor households are more likely to be under-heating their homes, and therefore more likely to take the benefits of energy efficiency improvements as increased warmth.

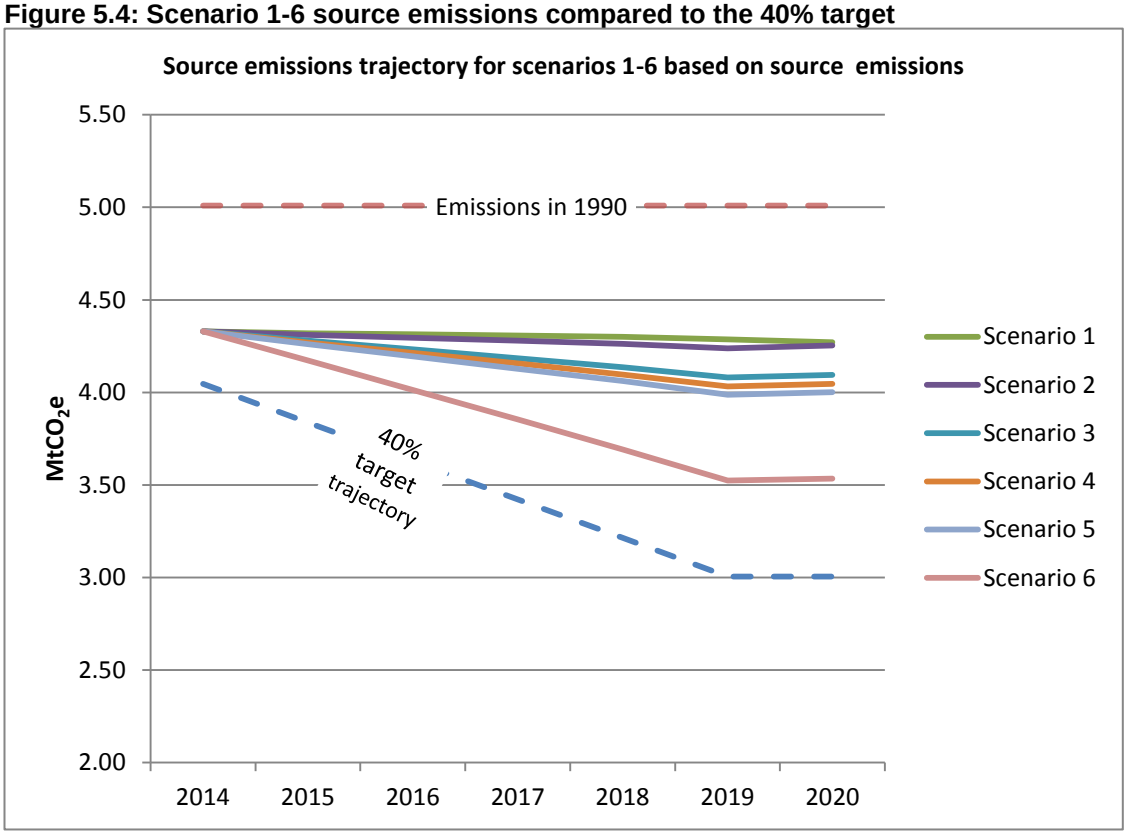
The significance of comfort taking varies by measure and by household. However, DECC estimates that for insulation, around 15% of the potential savings are lost due to comfort taking. If this were accounted for therefore, it is likely that the 'no uptake' scenario would not allow the 3% target to be reached.

The indication from Figure 5.1 that Wales is on track to meet its 3% target with minimal effort should therefore be treated cautiously. A large proportion of the decrease in emissions seen is not due to Welsh Government action, but instead is due to grid decarbonisation. The emission reductions seen under these future scenarios are therefore vulnerable to activity outside Welsh Government's control. In addition, actual emissions reductions obtained are likely to be lower than those modelled due to the effects of comfort-taking. If decarbonisation projections are not met, Welsh Government will not meet its 3% target at the housing stock's current level of energy efficiency. Significantly greater activity will therefore be required to further reduce energy demand, through improving the energy efficiency of the housing stock, if the target is to be achieved without such heavy reliance upon grid decarbonisation and allowing for the effects of comfort-taking.

5.2 Achieving the 40% target

Figure 5.4 shows the impact of scenarios 1-6 on progress towards the 40% target, based only on direct emissions from the housing stock therefore not including electricity consumption. As seen in Section 4.1, by 2014 the residential sector was considerably behind on progress towards this target. As such, significant action will be required over the next 5 years if the target is to be met.

Figure 5.4: Scenario 1-6 source emissions compared to the 40% target



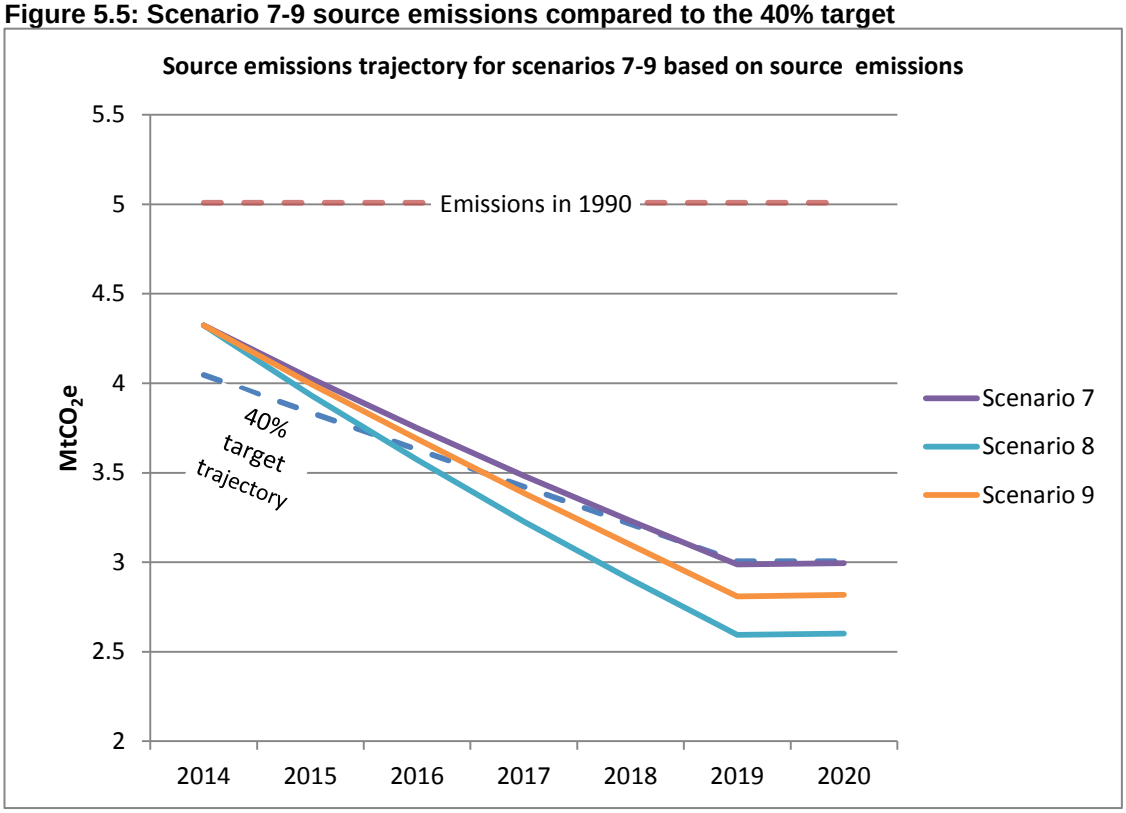
Achieving a reduction in source emissions in the residential sector is much more difficult than achieving a reduction in total emissions (source and end-user electricity). The 'big win' measures noted previously such as solar PV and other renewable electricity generators do not contribute to this target at residential scale, and the sector cannot simply rely on grid decarbonisation to reduce its source emissions (see 'Electricity and the 40% target' section below for discussion of this). Looking at Figure 5.4, even an extreme policy scenario which involves 100% uptake of solid wall insulation, cavity wall insulation, loft insulation, draught proofing and condensing boilers (scenario 6) would only bring emissions down to 3.53 $MtCO_2e$ by 2020, 0.53 $MtCO_2e$ above the target level.

The only way to achieve this target is therefore to incorporate renewable heat into policies. Scenario 7, shown in Figure 5.5, does allow the target to be met by 2020. In this scenario, in addition to the uptake in scenario 6, a renewable heating technology is installed in 75% of off-gas homes[23] (equivalent to around

[23] Due to data limitations of the HEM, it was not possible to model uptake in 100% of off-gas homes.

14% of the total Welsh housing stock). However, with the addition of comfort-taking, it is likely that even under this scenario the target would not be met. Scenario 8, therefore, shows full uptake of all measures (as in scenario 6 and 7) plus uptake of renewable heat in 25% of all Welsh homes. This includes the 14% comprised of off-gas homes modelled in scenario 7, plus an additional 11% comprised of on-gas homes. This expansion of renewable heat technologies does allow the target to be more comfortably met; however, it is an unrealistic scenario to be achieved by 2020. Solid wall insulation is currently installed in only a very small proportion of Welsh homes; expanding this to 100% within 5 years is not a viable option. In scenario 9, therefore, solid wall insulation uptake was reduced to uptake in 25% of suitable homes (renewable heat left at 25% of all homes, and all other measures remain at 100%). This also allows the target to be met, and provides a more achievable, if still very challenging, policy scenario.

Figure 5.5: Scenario 7-9 source emissions compared to the 40% target



As previously noted (Section 2.1), it is unlikely that a 40% decrease in source emissions in the residential sector will be required to meet the overall target, since it may be easier to make greater emission savings in other areas (such as the power generation sector). As such, our comparisons of scenarios to a 40% reduction of source emissions in the residential sector may exaggerate the ongoing action required in this sector. Table 5.2 shows the carbon saving under each scenario in comparison to a 'no uptake' business as usual scenario and compared to the 1990 baseline. If a different, lower target is specified for the residential sector, this table can be used to see which scenarios would meet the lower target. Without additional information on how the 40% target is to be achieved however, we have at this stage simply assumed a proportionately equal reduction across all sectors.

Table 5.2: Emissions under each scenario compared to 40% target emissions

1990 baseline:	**5.01 $MtCO_2e$**			
2020 target emissions:	**3.01 $MtCO_2e$**			
Scenario	Emissions in 2020, under the scenario ($MtCO_2e$)	Emissions reduction compared to 'no action' ($MtCO_2e$)	Additional emissions reduction compared to target ($MtCO_2e$)	% reduction on baseline
Scenario 1	4.27	0	-1.27	15%
Scenario 2	4.25	0.02	-1.25	15%
Scenario 3	4.09	0.18	-1.09	18%
Scenario 4	4.05	0.23	-1.04	19%
Scenario 5	4.00	0.27	-1.00	20%
Scenario 6	3.53	0.74	-0.53	29%
Scenario 7	2.99	1.28	0.01	40%
Scenario 8	2.60	1.67	0.41	48%
Scenario 9	2.82	1.45	0.19	44%

Electricity and the 40% target

The above analysis of progress towards the 40% target does not incorporate any carbon emissions reduced as a result of changes in electricity consumption. This is due to the definition of the 40% target as only relating to 'source' emissions; those directly emitted at the site. Since all emissions relating to electricity are produced at power stations, reducing electricity consumption or generating renewable energy through domestic micro-renewables does not impact the 'source' emissions generated directly by households.

However, excluding electricity from this analysis does not provide a fair representation of CO_2 reduction efforts in the residential sector. It masks the significant contribution played by domestic renewables in reducing national emissions. It is not possible however to incorporate electricity within analysis of the 40% target, as this would lead to a double counting of the impact an all-sector scale; impact of domestic renewables would be counted both as a household emissions reduction and again through reduced electricity generation in the power station sector.

Despite the complexities of analysing domestic electricity consumption and generation within the boundaries of the 40% target at residential scale, it is nonetheless important to recognise the contribution this makes to the overall all-sector target. In 2013, domestic renewable technologies were responsible for an emission saving of 0.19 $MtCO_2e$. This is equivalent to 1% of the total emissions from electricity generation in Wales in 2013. However, since the residential sector was only responsible for 28% of electricity end-use emissions in 2013, in relation to the sectors electricity use this generation is

more significant. The emissions reduction attributable to domestic renewable technologies is equivalent to around 7% of the total emissions due to electricity use in the domestic sector in 2013[24].

It should also be noted however that this target also masks any increases in electricity consumption at the residential scale. For example, installation of a heat pump will be accompanied by an increase in electricity use, since heat pumps use a small amount of electricity to run. Theoretically, if the entirety of Wales switched to electric heating, the source emissions recorded for the residential sector would decrease to close to zero; reducing source emissions in one sector can therefore be achieved simply by displacing them to another.

This highlights that the singular 40% target based on source emissions is not appropriate for analysis at a sectoral scale. Understanding emissions and targets at a sector-by-sector level will however be important to achieve the practical implementation of policies required to meet the targets. Future target setting should therefore create appropriate sector-specific targets. This will allow policies applicable to certain sectors to be designed and monitored effectively, and their contribution to larger, overarching targets fairly quantified.

5.3 Scenario costs

The above analysis indicates that an ambitious installation programme will be required to meet a 40% emissions reduction in the residential sector. The number of measures to be installed under each scenario, and estimated measure installation costs, are shown in Table 5.3. This shows that implementation of scenario 9, the most feasible option which meets the 40% target, would cost around £5.2 to £9.3 billion, and would require installation of over 2.2 million energy-saving measures (not including boilers installed through natural replacement). This is almost 3 times the number of installations made under programmes from 2007-2014.

These costs should be treated only as rough estimates. Costs will vary depending on a range of factors, such as the proportion of hard-to-treat cavity walls compared to easy-to-treat; the proportion of internal solid wall insulation as opposed to external; the size and ease of installation of each renewable technology; amongst other things. The costs also do not account for any economies of scale, which would likely lower costs significantly in a mass-rollout programme.

[24] Figure for emissions saving due to domestic renewables taken from our modelling. Figures for the total emissions from electricity generation, total end-use electricity emissions, and residential end use electricity emissions (all used to calculate the percentages in the text) taken from the NAEI (2015) datasets 'Devolved Administration Tables', available here: http://naei.defra.gov.uk/reports/reports?report_id=810

DECC's latest assessment of the remaining potential for home insulation levels in Great Britain identifies that of the remaining homes without cavity wall insulation 91% are non-standard cavity walls[25]. These walls are generally much more expensive to treat than standard cavity walls. In these cost estimates we have assumed that the average cost to insulate a standard cavity is £550 and that the cost of treating a non-standard cavity is on average between £1,600 and £3,300.

Table 5.3: Installation numbers required under each scenario and estimated costs

Scenario	Number of installs of each measure								Total Cost[26]
	Condensing boiler	Cavity wall insulation	Loft insulation	Draught proofing	Solid wall insulation	ASHP	GSHP	Biomass boiler	
Cost range per measure	£2,000 - £2,800	£550 - £3,300	£250 - £330	£190	£8,800 - £15,600	£7,000 - £11,000	£13,000 - £20,000	£9,000 - £21,000	
Scenario 1	251,600[27]	0	0	0	0	0	0	0	**£0**
Scenario 2	361,400	0	0	0	0	0	0	0	**£220 million to £300 million**
Scenario 3	361,400	233,200	0	0	0	0	0	0	**£580 million to £1020 million**
Scenario 4	361,400	233,200	150,400	0	0	0	0	0	**£620 million to £1.1 billion**
Scenario 5	361,400	233,200	150,400	1,266,400	0	0	0	0	**£860 million to £1.3 billion**
Scenario 6	361,400	233,200	150,400	1,266,400	432,600	0	0	0	**£4.7 billion to £8 billion**
Scenario 7	361,400	233,200	150,400	1,266,400	432,600	4,400	103,900	53,000	**£6.6 billion to £11.3 billion**
Scenario 8	361,400	233,200	150,400	1,266,400	432,600	4,400	156,300	148,900	**£8.1 billion to £14.3 billion**
Scenario 9	361,400	233,200	150,400	1,266,400	108,100	4,400	156,300	148,900	**£5.2 billion to £9.3 billion**

[25] DECC (June 2015) Domestic Green Deal, Energy Company Obligation and Insulation Levels in Great Britain, Quarterly report

[26] These costs are based on the current VAT rate for energy-saving products of 5% (excluding boilers, which are not eligible for this reduced-rate VAT). The European Court of Justice recently ruled (June 2015) that this reduced VAT rate should not be applied, and VAT on energy-saving products must be increased to 20%, in line with standard taxation. If this is enforced, cost of these measures will rise.

[27] This is the number of assumed condensing boilers which will be installed regardless of energy efficiency programmes as a result of natural replacement when old boilers break. The cost of these boilers is not included in any of the cost estimates, since these costs would not be borne by householders rather than a programme.

6. Conclusion

Progress to date

Between 2007 and 2014, energy efficiency programmes in Wales have, cumulatively, prevented the emission of around 2.0 $MtCO_2e$. The residential sector is currently on track to meet the Welsh Government's 3% year-on-year emission reduction target by 2020. However, looking only at those emissions produced directly by the housing stock, thereby not including electricity use, the reduction in emissions has been less significant. As such, the housing stock is currently overshooting its target for a 40% 'source' emissions reduction by 2020.

The vast majority of installations and the highest proportion of emission (CO_2e) savings made to date are attributable to CERT. The successor schemes to CERT – ECO and the Green Deal – have so far had considerably less impact on carbon emissions. It must be recognised that these schemes have so far been in operation for around half the lifespan of CERT, and that CERT installs continue to reduce emissions even after the end of the scheme. Nonetheless, ECO and the Green Deal have had relatively little impact on carbon emissions to date, reducing emissions by only around 0.18 $MtCO_2e$, compared to a 0.78 $MtCO_2e$ reduction due to CERT (based on 'source' plus 'end-user electricity' emissions).

The Feed-in Tariff has also had a significant impact on residential emissions in Wales, accounting for almost a third of the total emissions reduction despite being only 5% of installs. However, since these technologies reduce emissions from electricity, they do not contribute towards the 40% target.

For other programmes, the most successful at reducing emissions have been those which focus on high impact measures such as solid wall insulation and renewable heat. As such, the Welsh Government's Arbed scheme has had greater impact on CO_2e emissions than the Nest scheme, despite a greater number of installs made under Nest. As noted in Section 4.2 however, this may, in part, be due to our data input into the HEM which assumed all 'heating measure' installs were condensing boilers.

Tracking improvements to the building stock in Wales

Each nation within the UK undertakes surveys to understand the quality of housing and its impacts on the households inhabiting these. These surveys help to give an in-depth profile of energy requirements in homes, help to estimate emissions from the domestic stock as well as estimate incidents of fuel poverty. The English Housing Survey and Scottish House Condition Survey are carried out annually, whereas the Living in Wales property survey has not been undertaken since 2008.

Whilst it is possible to track changes in emissions from the domestic sector in Wales, the lack of up to date housing stock data means that it is difficult to attribute the extent to which emissions reductions are due to energy improvements made to the housing stock. EST would urge Welsh government to consider undertaking another housing survey in Wales to give a more authoritative picture of progress to date on improving the state of Welsh housing.

Meeting the 2020 targets

Looking forward to 2020, our modelling indicates that the residential sector could meet its 3% target with very little ongoing energy efficiency activity. However, this ongoing emissions reduction is heavily dependent on ambitious projections of grid decarbonisation, which is outside Welsh Government control. In fact, 73% of the emissions reduction projected under our scenario 1 (no uptake of energy efficiency measures post-2014) are due to grid decarbonisation; with no decarbonisation this 'no uptake' scenario would leave emissions 0.69 $MtCO_2e$ above the target by 2020. If grid decarbonisation stays at its current level, our modelling predicts a large scale rollout of energy efficiency (Scenario 6) is required to meet the 3% target.

To ensure the target is met therefore, Welsh Government needs to further reduce energy *consumption*, rather than simply relying on reductions in the energy's carbon-intensity. Whilst the 3% target is based on areas of 'devolved competence', at present it is only likely to be met due to changes in electricity generation, which are outside the Welsh Government's devolved powers.

Looking at the 40% target, the story is very different. In this area, ongoing decarbonisation of the grid will not contribute to emissions reductions relevant to the target. As such, considerable activity is required to lower the source emissions produced directly by the housing stock. The most effective scenario modelled to reach this target requires: installation of cavity wall insulation, draught proofing, condensing boilers and loft insulation in 100% of appropriate homes; installation of solid wall insulation in 25% of appropriate homes; and installation of a renewable heat technology in 25% of all Welsh homes. The total cost of this scenario is likely to be in the range of £5.2 to £9.3 billion; considerably higher than total investment in Wales to date.

Reducing 'source' emissions in the residential sector to a large extent will be based around reducing energy used for heating. Our modelling has shown that reducing demand for heat alone is insufficient; even with full insulation of all homes it is not possible to both heat homes to an adequate, healthy temperature and meet the 40% target. Alongside reducing demand therefore, it is also important to reduce the energy-intensity of heating fuels (as is occurring with decarbonisation in the electricity sector). The expansion of renewable heating technologies will therefore be crucial to meeting this target.

Summary

Overall, our analysis indicates that the Welsh residential sector is currently on-track to meet its 3% target, but that ongoing progress towards the target up to 2020 will be highly sensitive to a rapid decarbonisation of the electricity grid. If this decarbonisation does not progress as rapidly as projected by DECC, considerable ongoing action will be required to improve the energy efficiency of Welsh homes, and thereby reduce household energy demand.

With regards to the 40% target, programmes to date have not proved sufficient to reduce source emissions to target levels. Considerable ongoing activity and investment is therefore required in reducing non-electricity-based consumption if the 2020 target is to be met; both in generating cleaner energy for heating, and reducing overall heating demand.

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Appendix A – Data sources and assumptions

Table A.1: Data sources

Programme	Source	Data manipulation and assumptions
Nest	Nest Annual Report 2011-2012, Nest Annual Report 2012-2013, Nest Annual Report 2013-2014	No detailed datasets for Nest installs have yet been made available, therefore only headline figures could be used from the annual reports. Annual reports give figures for 'standard insulation' and 'enhanced insulation'. Enhanced insulation is assumed to be entirely solid wall insulation, as indicated in the reports. Standard insulation has been assumed to be 50% loft insulation and 50% cavity wall insulation; an even split was assumed due to lack of information regarding cavity wall to loft insulation ratios.
Arbed	Welsh Government (2011), 'Arbed phase 1: post-installation review', Welsh Government website (2013), Arbed - Strategic energy performance investment programme	Arbed phase 1 data was available from the post-installation review. No Arbed phase 2 data has yet been made publicly available. The target for number of homes in which measures are installed for phase 2 is 4,800. In Arbed phase 1, 11% of homes received multiple measures. It was therefore assumed that a similar proportion of homes would receive multiple measures in phase 2, giving 5,316 measures installed in total. To determine the number of each individual measure installed, it was assumed that the same proportions of each measure type are installed under phase 2 as under phase 1. For example, 44% of installs in phase 1 were solid wall insulation, therefore it was assumed that 44% of the installs in phase 2 would be solid wall insulation. Due to lack of alternative data regarding the split of measures, this was deemed the most appropriate way to allocate measure installs.
ECO	DECC (2015), 'Green Deal and ECO Statistics'	DECC publishes data on the monthly number of installs made under each of CERO, CSCO and HHCRO. It also publishes data on the total number of installs of each energy efficiency measure made to date, and the total number of installs made in Wales to date. It does not however provide combined data for the annual number of installs made in Wales of each measure type. As such, we have used the published data to produce annual and regional weightings, which can be applied to each energy efficiency measure. This therefore assumes

		that, for example, if 30% of all installs were made in 2012, we assume 30% of the installs for each individual measure were made in 2012. It also assumes that since 5% of total installs were made in Wales, 5% of installs of each measure have been made in Wales.
CERT	HEED	HEED data available for all years of programme, no data manipulation required
CESP	HEED	HEED data available for all years of programme, no data manipulation required
Green Deal	DECC (2015), 'Green Deal and ECO Statistics'	As with ECO (above), DECC provides data on the total number of Green Deal measures installed per month, the total number of each measure installed to date, and the total number of all measures installed in Wales to date, but does not provide the combined data for the annual number of installs made in Wales of each measure type. Again therefore, annual and regional weightings were applied to the total install figures
Feed-in-Tariff	DECC (2015) 'Feed-in Tariff statistics'	Similarly to ECO and the Green Deal, DECC provides data on annual FiT installs, split by technology type, and total installs of each technology type in Wales. To produce annual install figures for Wales, an annual weighting was applied to the Welsh figures. In addition, it was assumed that any installation of a FiT-eligible technology made since 2008 would have been FiT registered. This means that renewable installs under other schemes such as Nest would be recorded in both the FiT and Nest data. To avoid double counting, we therefore removed the total number of renewable installs made under all other programmes each year from the annual FiT figures.
RHI	DECC (2015) 'Renewable Heat Incentive statistics'	As with FiT installs, DECC provides data on annual RHI installs, split by technology type, and total installs of each technology type in Wales. To produce annual install figures for Wales, an annual weighting was applied to the Welsh figures. As with FiT, it was assumed that any installation of an RHI eligible technology made under other programmes would also be RHI registered. Whilst the RHI was only introduced in 2014, all installs since 2008 are eligible for legacy applications. To avoid double counting, we therefore removed the total number of renewable heat

		installs made under all other programmes since 2008 from the annual RHI figures.
Other programmes	HEED	Other schemes included were: - Energy Efficiency Commitment phase 1 and Energy Efficiency Commitment phase 2 (EEC1 & EEC2) - Low Carbon Buildings Programme - FENSA - HEES HEED data available for all years of these programmes, no data manipulation required
Non-programme led installations		
Boiler replacement	UK Energy Factfile and Living in Wales (2008) survey	Data from the UK Energy Factfile was used to plot the increase in number of condensing boilers in the UK each year. It was assumed that the rate of boiler uptake in Wales was the same as the rate of uptake in the wider UK. This rate was then applied to the number of boilers in the 2008 Living in Wales survey, in order to project, from this, the number of boilers installed in each subsequent year.
Low energy lighting	Energy Consumption in the UK (ECUK) 2014	The uptake rate of low energy lighting (energy saving lightbulbs and LEDs) was calculated from ECUK data. The number of households with at least 80% low energy lighting was calculated, and the ongoing uptake rate calculated as a percentage of remaining potential. This rate was then applied to the Welsh housing stock
Energy efficient appliances	Energy Consumption in the UK (ECUK) 2014	The uptake rate of both refrigerators/fridge-freezers and wet appliances were calculated from ECUK data. A weighted average of these two rates was then applied to the Welsh housing stock. This is therefore based on the assumption that all households have a fridge or fridge-freezer and at least on wet appliance.

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Appendix B – Updates to the HEM

This appendix provides details on the changes made to the Welsh HEM inputs in order to update it to the most recent version of SAP and most recent estimates of housing stock growth and fuel factors.

Housing stock

The housing stock projections were updated using data from the 'Live tables on household projections', produced by the Department for Communities and Local Government (DCLG) (Table 401 – Household projections, United Kingdom, 1961-203728). This data is used by the model to calculate the number of new build properties in future years, allowing the emissions of new properties in the future to be accounted for.

Demolition levels are negligible in Wales, therefore the demolition rate was left at 0.

House inputs

The original HEM used in the previous EST report was based upon SAP 2005 inputs. For this work, the model was updated to SAP 2012 inputs. SAP 2012 contains revised U-values for a number of measures. Values for post-2007 properties were also altered to reflect new 2010 (and 2013 amendments) building regulations. The following inputs were therefore altered:

Table B.1: Changes to house inputs

Measure	Change	Source
Glazing	U-value for a 'good' window altered from 2.3 to 2.2	SAP 2012 – value for a double glazed, air filled, low-E, εn=0.2, hard coat window with wooden frame and 12mm gap
	U-Value for 2007-2011 altered from 1.8 to 2	SAP 2012 – value for a double glazed window, 2002 or later
	U-value for 2012-2019 and for post-2019 altered from 0.8 to 1.4	2010 Building Regulations – minimum value for a 'notional dwelling'
	U-values for 2007-2011 doors altered from 1.8 to 2	SAP 2012
	U-values for 2012-2019 and post-2019 doors altered from 1.5 to 1.8	SAP 2012
Walls	Uninsulated pre-1919 cavity walls altered from an average of 1.85 to 1.93	SAP 2012 – average of applicable age bands

[28] https://www.gov.uk/government/statistical-data-sets/live-tables-on-household-projections

	Insulated 1919-1980 cavity walls altered from an average of 1.82 to 1.77	SAP 2012 – average of applicable age bands
	2007-2011 walls altered from 0.28 to 0.3	SAP 2012 and 2010 Building Regulations
	2012-2019 and post 2019 walls altered from 0.15 to 0.18	2010 Building Regulations – 'notional dwelling'
Roof	2012-2019 and post 2019 values altered from 0.11 to 0.13	2010 Building Regulations – 'notional dwelling'
Floor	2012-2019 and post 2019 values altered from 0.15 to 0.13	2010 Building Regulations – 'notional dwelling'
Primary circuit losses	Values for all 'Poor' pre-2007 properties were changed from 610kWh to 677kWh	SAP 2012 equation – assumes uninsulated primary pipework and a cylinder thermostat with water heating not separately timed
	Values for all 'Good' pre-2007 properties were changed from 610kWh to 574kWh	SAP 2012 equation – assumes all accessible pipework insulated and a cylinder thermostat with water heating not separately timed
	Values for all post-2007 properties were changed from 610kWh to 274kWh	SAP 2012 equation – assumes fully insulated primary pipework and a cylinder thermostat with separately timed water heating
Additional gains	Altered from 10W to 3W in all post-2007 properties	SAP 2012 – value given for post-2013 properties, is assumed to be applicable for all post-2007 properties

Improvement measures

Various inputs relating to Measures were also updated. Typical lifetimes for each measure were updated in line with the estimates provided by Ofgem for the Energy Company Obligation (ECO). U-values were updated in line with the latest building regulations, and new boiler efficiencies were updated (from 86% to 88% for a new gas boiler) to reflect technological improvements since the HEM was created, using typical new boiler efficiencies from EST research.

In particular, several inputs for renewable micro-generation technologies have been updated to reflect improvements in the technology and changes in the market:

Table B.2: Changes to renewables inputs

Technology	Change	Source
Solar PV	Typical install altered from a 2.5kWp system generating 864kW annually to a 4kWp system generating 3570kW annually	EST analysis – using most common install size in the UK and solar insolation data for Aberystwyth
Biomass	Biomass boiler efficiency revised down from 86% to 80%	EST analysis
GSHP	Space heating efficiency altered from 272% to 363% and water heating efficiency altered from 224% to 266%	RHI (March 2015) data on average efficiency of installed systems. Space to water efficiency ratio calculated using EST field trial results and applied to the more up to date RHI data
ASHP	Space heating efficiency altered from 213% to 298% and water heating efficiency altered from 175% to 255%	RHI (March 2015) data on average efficiency of installed systems. Space to water efficiency ratio calculated using EST field trial results and applied to the more up to date RHI data
Mini Wind	Typical capacity altered from 5kWp to 6kWp, and load factor altered to 19%	EST field trials

Fuel factors

Fuel factors have been updated in line with SAP 2012 emission factors. These emission factors are measured in CO_2 equivalent, therefore incorporate the impact of other greenhouse gases alongside CO_2. Since the Welsh Government targets are also measured in CO_2 equivalent (CO_2e), the results using these factors will be directly comparable to the target emission figures.

The fuel factors for electricity have also been changed. For 2007-2013, electricity factors were taken from Defra's Greenhouse Gas Conversion Factors[29] for UK electricity (including transmission and distribution losses). For 2014 onwards, updated values were taken from DECC's 'Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal' (2014)[30].

[29] Available here: http://www.ukconversionfactorscarbonsmart.co.uk/
[30] Available here: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Appendix C – Number of measures installed by energy efficiency programme

Table C.1: Number of measures installed under each programme

	Arbed		Nest	ECO	Green Deal	Feed-in Tariff[31]	RHI	CERT	CESP	Other	Non-programme installs	Total
	Phase 1	Phase 2										
Insulation measures												
Cavity wall insulation	-	-	1060	19740	40	-	-	129810	90	6070	-	**156,810**
Solid wall insulation	2900	2320	260	3010	990	-	-	4860	9100	-	-	**23,440**
Loft insulation	-	-	1060	14400	100	-	-	375530	1940	8840	-	**401,870**
Floor insulation	-	-	-	260	20	-	-	-	-	-	-	**280**
Double glazing	-	-	-	90	10	-	-	-	1250	26060	-	**27,410**
Insulated doors	-	-	-	-	10	-	-	-	-	-	-	**10**
Draught proofing	-	-	-	50	10	-	-	140	700	1100	-	**2,000**

[31] It was assumed that all FiT-eligible technologies installed since 2010 under any programme will have been registered for the FiT. To avoid double counting of renewable technologies therefore, the total number of FiT-eligible installs installed since 2010 under any other programme was subtracted from the recorded number of FiT installs in DECC's data.

	Arbed		Nest	ECO	Green Deal	Feed-in Tariff[31]	RHI	CERT	CESP	Other	Non-programme installs	Total
	Phase 1	Phase 2										
Heating System measures												
Condensing boiler replacement	-	-	12660	22380	970	-	-	5230	5520	3820	488590	**539,170**
Fuel switch	770	610	-	-	-	-	-	3740	580	2770	-	**8,470**
Heat recovery	-	-	-	-	130	-	-	-	-	-	-	**130**
Heating controls	-	-	-	6210	50	-	-	-	-	-	-	**6,260**
High performance hot water tank	-	-	-	40	10	-	-	3380	-	250	-	**3,680**
Micro-CHP	-	-	-	-	-	20	-	-	-	-	-	**20**
Renewables measures												
GSHP	-	-	-	-	-	-	340	50	-	10	-	**400**
ASHP	120	100	-	-	-	-	340	-	-	-	-	**560**
Biomass boiler	-	-	40	-	-	-	650	-	-	10	-	**700**
Solar hot hater	1070	850	-	-	-	-	-	10	240	30	-	**2,200**

	Arbed		Nest	ECO	Green Deal	Feed-in Tariff[31]	RHI	CERT	CESP	Other	Non-programme installs	Total
	Phase 1	Phase 2										
Solar PV	1800	1440	70	-	180	38040	-	30	1700	10	-	**43,270**
Micro-wind	-	-	-	-	-	280	-	-	-	-	-	**280**
Other measures												
Low energy light bulbs	-	-	-	-	-	-	-	-	-	9050	13675000	**13,684,050**
Energy efficient appliances	-	-	-	-	-	-	-	-	-	-	2238800	**2,238,800**
Total	**6660**	**5320**	**15150**	**66180**	**2520**	**38340**	**1330**	**522780**	**21120**	**58020**	**16402390**	**17,139,810**