REPORT FOR

Central Bedfordshire Council

Evidence base for requiring 10% of energy use from renewable or low carbon sources

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1. Introduction

In early 2013 Central Bedfordshire Council consulted on its new Development Strategy for adoption in 2014. The Development Strategy is the main planning document for Central Bedfordshire, and sets out several policies for development which will be used to determine planning applications.

The Council had originally hoped to set a policy target for all new residential development to achieve a minimum of 10% carbon dioxide emissions reduction as an improvement on the emissions standard set by the Building Regulations. Cutland Consulting Limited was appointed by the Council to explore alternative scenarios for achieving the 10% reduction in carbon dioxide emissions for a variety of on- and off-gas grid dwelling types. Report numbers C/128(rev1) and C/129 dated May 2013 present the outcomes of that work. The conclusions were broadly that the policy was viable both technically and financially using a variety of strategies.

At the start of that phase of the project there was insufficient clarity from Government to predict the energy standards which would be brought into force by the 2013 revisions to Approved Document L1A (ADL1A). We therefore agreed with the Council that it would be prudent to carry out the 10% 'beyond the Regulations' exercise against the then in-force ADL1A 2010 rather than trying to second-guess the 2013 revisions.

The details of the 2013 revisions were eventually published in November 2013, and the carbon dioxide emissions standard was tightened up somewhat less than anticipated (see section 2). Moreover, in March 2014 the Government announced, as an outcome of the Housing Standards Review, its intention to effectively repeal the Planning and Energy Act 2008. This Act gave local authorities the powers to set energy targets in advance of the Building Regulations, and was key to the energy performance aspects of Central Bedfordshire Council's Development Strategy (as well as the nationally significant 'Merton Rule'). In the event, two of the three clauses of the Act are likely to remain unchanged, but the critical energy efficiency clause will no longer apply to dwellings. This is discussed further in section 2.

The current phase of this project was carried out during May and June 2014 by Cutland Consulting's director Dr Neil Cutland and associate Energy Consultant/Architectural Designer Hetal Shah.

2. UK Policy Context

2.1 Approved Document L1A

The UK Government's legislative 'route to zero carbon' has changed more than once. As at 2006, the progressive tightening of the standards in ADL1A was expected to be as follows:

Proposed year	*Percentage reduction in regulated emissions w.r.t. 2006*	*Code level (ENE1)*
2006	-	*n/a*
2010	25%	level 3
2013	44%	level 4
2016	100%	level 5

Table 1

The carbon emissions covered by Building Regulations are known as 'regulated' emissions, and include those arising from heating, cooling, ventilation and lighting. The definition of zero carbon that was originally proposed for 2016 also included 'unregulated' emissions (ie. those arising from household appliances). This definition was subsequently diluted as per Table 1.

In January 2012 the Government undertook a Building Regulations consultation, in which its preferred option for 2013 was essentially a near-FEES[1] level amounting to an 8% emissions reduction with respect to 2010 (ie. 31% w.r.t. 2006):

Proposed year	*Percentage reduction in regulated emissions w.r.t. 2006*	*Code level (ENE1)*
2006	-	*n/a*
2010	25%	level 3
2013	31%	*n/a*
2016	100%	level 5

Table 2

The Government's 'one in, two out' policy for regulatory reform in fact refers to the *financial impact* of the regulations being introduced or cancelled. So for every £1 in costs incurred by an industry as the result of a regulatory change, there has to be a saving of £2 for that same industry. A side-effect of this rule means in the case of housebuilding that the calculation must not include the savings which accrue to the occupants of the homes. For example, the calculation is not permitted to reflect the fact that an additional £1,000 on the cost of building could result in a saving of, say, £25,000 in the occupants' heating bills over the lifetime of the home.

[1] See Appendix A of report number C/128 (rev1) for definition and discussion of FEES.

Hence, despite widespread lobbying for a greater emissions reduction than 8%, the impact assessment ultimately concluded that emissions resulting from ADL1A 2013 could in fact only be reduced by 6% with respect to 2010[2] (ie. 29% w.r.t. 2006):

Proposed year	*Percentage reduction in regulated emissions w.r.t. 2006*	*Code level (ENE1)*
2006	-	*n/a*
2010	25%	level 3
2013	29%	*n/a*
2016	100%	level 5

Table 3

The detailed requirements of ADL1A 2013 retain the concept of a Dwelling Emissions Rate (DER) which must not exceed a prescribed Target Emissions Rate (TER) - both expressed in $kgCO_2/m^2/yr$. It also includes, for the first time, a fabric performance measure known as the Dwelling Fabric Energy Efficiency rate (DFEE), expressed in kWh/m2/yr; this must not exceed a prescribed Target Fabric Energy Efficiency rate (TFEE). The DFEE/TFEE concept is intended to prevent the excessive trading-off of fabric performance where a dwelling's TER is met essentially through the use of low or zero carbon technologies.

2.2 The Planning and Energy Act 2008

The Planning and Energy Act 2008 states that:

> *(1) A local planning authority in England may in their development plan documents…include policies imposing reasonable requirements for—*
>
> *(a) a proportion of energy used in development in their area to be energy from renewable sources in the locality of the development;*
>
> *(b) a proportion of energy used in development in their area to be low carbon energy from sources in the locality of the development;*
>
> *(c) development in their area to comply with energy efficiency standards that exceed the energy requirements of building regulations.* [3]

The Government proposed in early 2014 to repeal all three clauses, but due to successful lobbying by the Renewable Energy Association the final outcome was to retain clauses (a) and (b) but to amend the Act as follows:

> *Subsection (1)(c) does not apply to…the construction or adaptation of buildings to provide dwellings.*[4]

[2] The 6% reduction is averaged across the typical mix of UK housetypes; individual reductions range from 12% to zero depending upon built form.
[3] http://www.legislation.gov.uk/ukpga/2008/21/contents
[4] http://www.publications.parliament.uk/pa/bills/cbill/2013-2014/0162/amend/pbc1622003m.pdf (page 7)

The amendment was accompanied with a Member's explanatory statement which read:

> *Section 1(1)(c) of the Planning and Energy Act 2008 allows local planning authorities to require that buildings meet higher energy performance standards than those set out in building regulations. The new clause inserted by this amendment disapplies this for dwellings in England, as Government policy is that all such requirements should be set out in building regulations.*

The intent was clarified by a supporting note to a Written Ministerial Statement on 13 March 2014:

> *We propose a 'Building Regulations only' approach, with no optional additional local standards in excess of the provisions set out in Part L of the Regulations.*[5]

It therefore seems clear that local authorities may continue to require a "reasonable" proportion of a dwelling's regulated energy (the energy usage corresponding to the carbon emissions that are regulated by ADL1A) to be provided from renewable or low carbon energy sources, but that local authorities may no longer impose performance standards (including for energy efficiency) that are any higher than those in ADL1A.

[5] https://www.gov.uk/government/publications/building-regulations-housing-standards-review

3. Central Bedfordshire Council's Policy Targets

The Council recognises that the Earth's resources are limited and should be used in a sustainable manner. The resource efficiency policy seeks to reduce energy demand and carbon dioxide emissions in order to mitigate the effect of climate change and deliver sustainable and resource-efficient homes.

In light of the amendments to the Planning and Energy Act 2008, the Council no longer intends to set a policy target for new residential development to achieve emissions reductions in advance of the standards set by the Building Regulations. The Council is instead considering a policy which requires 10% of the regulated energy from new dwellings to be provided from renewable or low carbon sources in the locality of the development.

[Note: It might be argued that a local authority could require 10% of the total, as opposed to just the regulated, energy to be provided from renewable or low carbon sources. However, due to (a) the Government policy described in section 2.2, and (b) the fact that there is no recognised standard calculation method for unregulated energy (especially now that the Code for Sustainable Homes is no longer supported by Government) we believe that the Council must set its target as a percentage of regulated energy alone.]

The Council's original viability assessment allowed for a sum of £2,000 per dwelling to cover the increased cost of achieving a 10% 'beyond the Regulations' target, plus £795 per dwelling to achieve the anticipated uplift from ADL1A 2010 to ADL1A 2013. The Department for Communities and Local Government's impact assessment for the final version of ADL1A 2013 suggests that the cost of meeting the 2013 uplift is, averaged across a range of housetypes, £453.[6]

The fundamental aim of this project was to explore the capital cost implications of requiring that 10% of the regulated energy consumption of new dwellings be provided from a variety of renewable or low carbon sources in the locality of the development.

6 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226965/Part_L_2013_IA.pdf

4. The Base Cases

We modelled the same four dwelling configurations that were used in the 2013 study, which collectively represent the range of built forms and sizes which might typically be built by developers for private sale. The treated floor areas were as follows:

- 4-bed detached house: 125m^2
- 3-bed semi-detached house: 95m^2
- 2-bed mid-terraced house: 65m^2
- 1-bed top floor apartment with one external wall: 45m^2

For this study, however, we upgraded the fabric and services specification as per the "model designs" in section 5 of ADL1A 2013.[7] The specifications are based on a notional dwelling which will achieve a basic 'pass' by *just* meeting both the TER and the TFEE.

We modelled the base cases for both the mains gas-heated and off-gas grid (rural) situations, using the same dwelling configurations in both cases.

The basic philosophy of ADL1A is that the individual elements of a dwelling can be traded-off in order to achieve an overall Building Regulations pass. For this reason, and due to the specific dwelling-dependency of the calculated carbon dioxide emissions and fabric performance, in some cases the model design specifications did not quite achieve a pass when applied to our typical housetypes. In these cases we improved the roof U-value very slightly (on the basis that this is the cheapest improvement for a builder to make), and in some cases we also enhanced one or two of the non-repeating thermal bridge details. In all cases we 'tuned' the dwelling so that the DER was within a very small fraction of the TER.

Even for these tuned base cases, the DFEE generally turned out to be rather better than the TFEE. This is essentially because of a little-known relaxation in the TFEE which Government introduced at the AD publication stage, in order to "ease the burden" of ADL1A 2013 on housebuilders during an indeterminate interim period. The gap between the DFEE and the TFEE might be seen as the 'room for manoeuvre' which is available to a designer to relax the fabric specification, although in this case a larger amount of low/zero carbon technology would have to be installed in order to meet the TER. The DFEE will always limit the extent of potential 'gaming', and the current gap will disappear when/if the relaxation in TFEE is rescinded by Government.

Due to the carbon intensity of grid electricity in England, it is generally harder for electrically-heated homes to comply with the TER requirements of ADL1A than gas-heated homes (even though electrically-heated homes receive an additional concession in ADL1A 2013 via an 'easier' TER). In keeping with our objective of using a consistent model design specification across the dwelling types under study, if an electrically heated dwelling did not comply with ADL1A we achieved a pass by adding a suitable area of photovoltaic (PV) panels - again aiming to bring the dwelling's DER to within a very small fraction of the TER.

[7] http://www.planningportal.gov.uk/buildingregulations/approveddocuments/partl/approved#Download
Note that the "model designs" are described as "recipes" by SAP 2012.

As an aside, it should be noted that it is possible in principle for electric dwellings to comply with ADL1A 2013 without PVs - but only by adding mechanical ventilation with heat recovery (MVHR) as well as significantly tightening up the fabric specification. There is no cost benefit for electrically-heated dwellings to comply with ADL1A via fabric+MVHR rather than via PVs. Indeed, in all but the largest dwellings there would actually be a cost penalty.

The resulting detailed dwelling specifications are contained within Appendix A.

5. Methodology

The base case dwelling type data was transcribed into NHER Plan Assessor v. 6.0 software, which contains a Government-approved implementation of SAP v. 9.92 (aka. 'SAP 2012')[8]. Using this software we calculated the DER, TER, DFEE and TFEE for each dwelling type. We also recorded the SAP rating (which is not necessary for the analysis but which is of general interest to any carbon/energy strategy), and the total regulated energy (known in SAP terms as "delivered" energy) with its breakdown by space heating, water heating, etc.

The calculation sequence was applied to the eight dwelling/fuel combinations in a systematic way which enabled us to explore a variety of scenarios for providing 10% of the regulated energy from renewable and low carbon energy.

The fundamental strategies were as follows:

- Photovoltaic panels (PVs)
- Solar hot water (SHW)
- Heat pumps - air source (ASHP) or ground source (GSHP) as appropriate
- Biomass heating - type appropriate to dwelling

The detailed results of the calculation runs are presented in Appendix B.

Note that there is no 'official' method for calculating the percentage of renewable or low carbon energy; it is not displayed by any compliance tool in the way that, say, the SAP rating is, and different methods have been used by different local authorities under the Merton rule. The method that is used in this study is both technically sound and politically defensible.

When studying the figures in Appendix B it is important to realise that there are several complex interactions at work. For example, when solar technology is added until 10% of the regulated (delivered) energy is from renewables, this *in itself* reduces the delivered energy and the DER of the dwelling. Hence the calculations can become recursive, endlessly 'chasing their own tail' without converging on an answer. In order to avoid this complication we added the technologies until the delivered energy was reduced by 10% with respect to the *baseline* (ADL1A-compliant) dwelling. Note that this does not mean that the Council is specifying a DER lower than the TER (which would be against Government policy), even though that may appear to be the case from some of the figures. The method is nothing more than a technique which enables us to evaluate the amount of a technology that is needed to meet the 10% target.

Further complexity lies in the fact that the DER and TER are expressed in terms of carbon dioxide, yet the DFEE, TFEE and the 10% target are all expressed in terms of energy. This can lead to results which may initially appear confusing, but which are in fact perfectly explainable when one focusses on the distinction.

[8] http://www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf

There is a specific complex case where biomass replaces electric heating. In this instance the delivered energy increases significantly due to the lower efficiency of the boiler. Nevertheless, nearly all of this delivered energy is now from low carbon (in fact near-zero carbon) sources, and as a result the percentage of low carbon energy *with respect to the baseline* is higher than 100%. This is clearly meaningless, so in this case it might be more helpful to express the low carbon energy as a percentage of the NEW dwelling's delivered energy – although even then it is still greater than 95%. To avoid the resulting confusion if we were to change the basis in this way, the percentage is annotated as "n/a" in the case of biomass.

As with the 2013 study, it was necessary to include PVs in the off-gas grid dwellings simply to achieve ADL1A compliance. This is, however, just one way of complying, and for an electrically-heated ADL1A-compliant dwelling the delivered energy would be the same regardless of the compliance strategy. For this reason we excluded the amount of renewable energy provided by the baseline PVs from the calculation of the 10% target; the *additional* amount of PV required to achieve 10% would be the same whatever the baseline specification. However, we did take the baseline PVs into account when evaluating the percentage of ground floor area constraint described below, and in the capital cost calculations wherever baseline PVs were removed.

The practical combinations of dwelling type, heating fuel and 10% strategy resulted in 38 calculation runs which form the basis of the cost analysis. In addition we carried out numerous calculation runs to explore the nuances of ADL1A compliance, as well as various issues which only became apparent as the analysis proceeded.

For each strategy under investigation, the dwelling specifications were changed until renewable or low carbon energy provided at least 10% of the total delivered energy. The size of the renewable / low carbon services was then noted, and the corresponding costs calculated as described in section 5.

Further notes:

- It was agreed with the Council that heat pumps and biomass heating are extremely unlikely to be installed by developers if mains gas is available. These technologies were therefore confined to the off-gas grid dwellings.

- In all cases we made assumptions typical of the Central Bedfordshire region, and erred on the conservative side (for example, by assuming average overshading and *not* assuming a strong southerly aspect).

- In considering heat pumps for the smaller dwellings, it was agreed with the Council that developer sale homes would be far more likely to use individual air-source heat pumps (ASHPs) than communal ground-source heat pumps (GSHPs), in part due to the potential need for Environment Agency permission where water extraction is involved. An individual GSHP with a closed loop 'slinky' collector was nevertheless considered as an alternative to an ASHP for the larger, detached dwelling.

- In considering communal biomass heating for the smaller dwellings, two different scheme sizes were analysed: (a) 5-10 dwellings, and (b) 30-40 dwellings. This has an impact on the cost per dwelling.

- Technology has advanced to the point where 1kWp of PV typically occupies an area of $7m^2$ (as opposed to the $10m^2$ that was assumed in the 2013 study). The Zero Carbon Hub considers that the appropriate reference point for feasibility of roof-mounted solar technologies is a maximum area equivalent to 40% of the ground floor area of the dwelling[9]. If the area required exceeds this amount, other measures may also be needed which are not necessarily feasible or desirable. Where PVs and SHW are used together the 40% criterion applies to the sum of their areas.

If the capital costs reported here are compared with those of the 2013 study, it is important to remember that the current study has been carried out on the basis of energy whereas the 2013 study was based on carbon dioxide emissions. Moreover, the baseline compliance standard has changed from ADL1A 2010 to ADL1A 2013, and the Council's policy target is also different. These three factors explain what might, at first sight, appear to be counter-intuitive results in certain cases if the 2013 and current studies are compared.

[9] 'Carbon Compliance: Setting an Appropriate Limit for Zero Carbon New Homes', Zero Carbon Hub, Feb 2011

6. The basis of the capital costs

The capital costs in this section should be regarded as indicative. It was agreed with the Council that since the study relates only to typical dwellings and covers a time period of several years, the analysis of capital costs should use generic cost data rather than employing a QS to carry out detailed cost calculations at this stage. Our philosophy was as far as possible to use technically robust and well-regarded sources that are in the public domain[10].

Where appropriate we have updated the sources that were used in the 2013 study, although in many cases the cost basis is unchanged. It is sometimes difficult to reconcile the different sources, due to the different methods that have been used over the years (eg. 'fixed cost plus cost per kWp' vs. 'cost per kWp only').

The work was undertaken on a simple 'first capital cost' basis (ie. ignoring net present value considerations, product lifetimes, maintenance costs, feed-in-tariff benefits, etc). The results are generally shown rounded up to the next £50 or £100 as appropriate.

The fundamental cost assumptions were as follows.

Photovoltaics
The installed cost of a PV system, at scale and in the newbuild context, is £1,500/kW_p[11]. The Zero Carbon Hub 2014 figures are somewhat higher than this for small-scale installations, but are generally in agreement across most of the size range. The 2013 DECC/Sweett figures are generally higher than this overall, although it is not stated whether they refer to newbuild or retrofit.

In one case (the 4-bed detached electric dwelling with PVs) it was necessary to enhance the window U-value from 1.4 to 1.2 W/m^2K in order to avoid the '40% of GFA' conflict. The extra cost is £30/m^2 of window area (ref. DCLG Impact Assessment 2013).

Solar hot water
The installed cost of a SHW system is £1,420 fixed cost plus £580/m^2 (ref. CE317). Informal research via manufacturer/installer websites tends to support this basis. The 2013 DECC/Sweett figures are hard to compare directly, being uniquely based on kW rather than m^2.

10 Our sources were:
'Domestic low and zero carbon technologies', Energy Saving Trust publication CE317, 2010;
'Cost of building to the Code for Sustainable Homes – updated cost review', DCLG, August 2011;
'Research on the costs and performance of heating and cooling technologies', DECC/Sweett, February 2013;
'Changes to Part L of the Building Regulations 2013: Impact Assessment', DCLG, August 2013;
'Cost analysis: meeting the zero carbon standard', Zero Carbon Hub, February 2014.

11 Private communication with a national housebuilder and Central Bedfordshire Council, 2013. Note that one-off installations in the retrofit context (eg. FIT-driven householder installations) can cost 2-3 times more than in volume newbuild.

Heat pumps

The installed cost of an ASHP is £4,000 fixed cost plus £280/kW (ref. CE317). The DECC/Sweett 2013 figures are variable across the size range but generally support this basis.

The installed cost of a trench (as opposed to borehole) GSHP is £3,170 fixed cost plus £560/kW (ref. CE317). The DECC/Sweett 2013 figures support this basis for smaller-scale installations, but rise to twice this cost at lager scales. We believe that this is due to the different costing method used, and since it does not seem likely that GSHP costs could have doubled between 2010 and 2013 we have used the CE317 figures for consistency with the 2013 Central Bedfordshire Council study.

Biomass heating

The installed cost of biomass heating (ref. CE317) is

a) for a 10kW individual biomass boiler: £10,000
b) for a communal system,
    - for a 50kW or smaller cluster: £10,000 fixed cost plus £250/kW
    - for a 200kW community scheme: £410/kW

The DECC/Sweett 2013 figures generally support this basis, except at the 200+kW scheme size where they show considerably lower costs. The difference is currently unexplained, but their accuracy is not critical to the conclusions of this study since community biomass schemes at that scale are unlikely to become common in the near future.

7. Results

The input data and the detailed results of each of the calculation runs are presented in Appendix B. The capital costs are presented here, with notes where appropriate.

7.1 Indicative costs for providing 10% of regulated energy from renewable or low-carbon sources: *mains gas-heated dwelling types*

Strategy: Photovoltaics (PV)				
Dwelling type	***Gas detached 4B, 125m²***	***Gas semi-det 3B, 95m²***	***Gas mid-terrace 2B, 65m²***	***Gas top-floor flat 1B, 45m²***
Cost to provide 10% of energy from RE or LCE	£1,500	£1,200	£750	£600

Strategy: Solar Hot Water (SHW)				
Dwelling type	***Gas detached 4B, 125m²***	***Gas semi-det 3B, 95m²***	***Gas mid-terrace 2B, 65m²***	***Gas top-floor flat 1B, 45m²***
Cost to provide 10% of energy from RE or LCE	£4,300	£3,200	£2,600	£2,300

- In terms of the 10% target strategy the SHW systems are strictly over-sized, insofar as they provide more than 10% of the regulated energy. However, the systems are sized correctly for each housetype; it would not be normal practice to install smaller systems due to the characteristics of the solar tank etc.
- Engineer to confirm domestic hot water usage calcs in each individual case.

7.2 Indicative costs for providing 10% of regulated energy from renewable or low-carbon sources: *off-gas grid (rural) dwelling types*

Strategy: Photovoltaics (PV)				
Dwelling type	***Electric detached 4B, 125m²***	***Electric semi-det 3B, 95m²***	***Electric mid-terrace 2B, 65m²***	***Electric top-floor flat 1B, 45m²***
Cost to provide 10% of energy from RE or LCE	£900	£950	£750	£700
With enhanced U_{win}	£1,300	-	-	-

- The costs correspond to the amount of PV which is required additionally to that needed for compliance with ADL1A (as shown in Appendices A and B).

- The top table entry for the detached dwelling type is shaded grey because the area of PV required is greater than the '40% of GFA' technical viability limit suggested by the Zero Carbon Hub.
- The area of PV required for this dwelling type can, however, be brought within the technical viability limit if the window U-values are enhanced from 1.4 to 1.2 W/m^{2}K. The corresponding total cost (for enhanced windows plus PVs) is shown below the shaded entry.

Strategy: Solar Hot Water (SHW) - without PV				
Dwelling type	***Electric detached 4B, 125m^2***	***Electric semi-det 3B, 95m^2***	***Electric mid-terrace 2B, 65m^2***	***Electric top-floor flat 1B, 45m^2***
Cost to provide 10% of energy from RE or LCE	Fails ADL1A	Fails ADL1A	Fails ADL1A	£2,500

- For the detached, semi-detached and mid-terrace dwelling types, replacing all of the PV required for ADL1A compliance with SHW causes the dwellings to fail the TER requirements of ADL1A. It is not possible to achieve compliance by increasing the area of SHW alone, because the DER calculation caps the benefit of SHW at 50% of the dwelling's hot water demand.
- For the top-floor flat, however, no PVs are required in order to achieve the 10% target via SHW – and the cost reflects this capital saving.
- Engineer to confirm domestic hot water usage calcs in each individual case.

Strategy: Solar Hot Water (SHW) - with reduced PV				
Dwelling type	***Electric detached 4B, 125m^2***	***Electric semi-det 3B, 95m^2***	***Electric mid-terrace 2B, 65m^2***	***Electric top-floor flat 1B, 45m^2***
Cost to provide 10% of energy from RE or LCE	£3,600	£2,300	£2,000	£2,500

- Practical amounts of SHW were added to the dwellings at the same time as retaining sufficient PV to ensure ADL1A compliance as well as achieving the 10% target.
- For the detached, semi-detached and mid-terrace dwelling types, the majority of the PVs required for ADL1A compliance remained in place. The reductions in PV area are reflected in the costs.
- For the top-floor flat, however, no PVs were required in order to achieve the 10% target via SHW – and the cost reflects this capital saving. The apparently anomalous size-dependency of this cost is due to the extremely small area of PV that was required for ADL1A compliance.
- Engineer to confirm domestic hot water usage calcs in each individual case.

Strategy: Air Source Heat Pumps (ASHP) – without PV				
Dwelling type	***Electric detached 4B, 125m²***	***Electric semi-det 3B, 95m²***	***Electric mid-terrace 2B, 65m²***	***Electric top-floor flat 1B, 45m²***
Cost to provide 10% of energy from RE or LCE	£600	£1,700	£3,400	£4,300

- It is not normal practice to heat only part of a dwelling using a heat pump; as a result, in all cases the heat pump provides more than 10% of the regulated energy. We investigated the effect of relaxing the fabric specification until the 10% target was only *just* achieved, but this has the undesirable side effect of increasing the overall capital cost, because (ironically) a larger heat pump becomes necessary.
- The PVs that were included for ADL1A compliance are no longer required in any of the cases. The costs reflect the capital saving.
- ASHPs have a relatively high fixed cost and a low cost per kW. Moreover the larger dwellings necessarily included significantly more PVs for ADL1A compliance than the smaller ones, so the capital savings are higher when they are removed. These two facts explain the apparently anomalous size-dependency of the costs.
- An ASHP may not be technically viable in the detached house due to the dwelling's relatively high heat load (engineer's calcs to confirm in each individual case). In this instance the indicative cost of an individual ground source heat pump (GSHP) with a closed loop trench-type collector would be £1,200 net of the PV capital savings. This, too, provides more than 10% of the regulated energy.

Strategy: Biomass Heating				
Dwelling type	***Electric detached 4B, 125m²***	***Electric semi-det 3B, 95m²***	***Electric mid-terrace 2B, 65m²***	***Electric top-floor flat 1B, 45m²***
Cost to provide 10% of energy from RE or LCE	£5,200	£6,600	(a) £450 or (b) £250	(a) £1,200 or (b) £1,100

- Where two costs are shown for a dwelling type, they represent the cost per dwelling for a communal heating scheme size of (a) 5-10 dwellings, or (b) 30-40 dwellings. Where a single cost is shown it is for an individual heating system.
- In all cases the percentage of regulated energy supplied by the biomass system is considerably higher than 10%. The actual percentage is arguably meaningless in this instance, as discussed in section 5.
- The PVs that were included for ADL1A compliance are no longer required in any of the cases. The costs reflect the capital saving, the apparently anomalous size-dependency reflecting the different areas of PV that are available to offset the capital cost.

8. Conclusions

This study considered the technical feasibility and financial viability of Central Bedfordshire Council's policy intent to impose reasonable requirements that a proportion of the energy consumption of new dwellings be provided from renewable or low carbon sources in the locality of the development. The Council has provisionally defined "reasonable requirements" to be 10% of the dwelling's energy, and this report argues that "energy consumption" means the energy corresponding to the carbon dioxide emissions that are regulated by Approved Document L1A 2013. A wide variety of strategies were modelled for a range of dwelling types and heating systems.

The Council must now consider the capital costs presented in this report, and satisfy itself that they allow a 10% requirement to be described as "reasonable". *Within the degree of accuracy afforded by the dwelling types that were studied and the generic nature of the cost data used,* there is no dwelling type where the target is unachievable in principle, or where the only options have an particularly high capital cost. This is the case in both mains gas and off-gas grid (rural) contexts in principle, although the number of strategies which can be used in practice depends on the context.

Appendix A

Base case full specifications

Part L 1A 2013 Compliance

note: "model design" except where shaded

Gas		Detached House 125m²		Semi-detached House 95m²	
Fabric Specification					
Ext Wall U-value	(W/m²K)	0.18		0.18	
Party Wall U-value	(W/m²K)	n/a		0	
Floor U-value	(W/m²K)	0.13		0.13	
Roof U-value	(W/m²K)	0.13		0.13	
Windows U-value (whole windov	(W/m²K)	1.4	double glazed	1.4	double glazed
Window g-value		0.63		0.63	
Opaque Door U-value	(W/m²K)	1		1	
Semi-glazed Door U-value		1		1	
Thermal mass parameter (TMP)		Medium		Medium	
Airtightness	(m³/m²/hr @ 50Pa)	**5**		**5**	
Linear thermal transmittance		All approved details except the following improved			
E2 - External wall to lintels (including other steel lintels)	(W/mK)	0.05		0.05	
E12- External wall to Gable (ceiling insulation)	(W/mK)	no		no	
P4 - Party wall to Roof (ceiling insulation)	(W/mK)	n/a		no	
Services Specification					
Ventilation Type		natural(with extract fans)		natural(with extract fans)	
Number of extract fans		4		3	
Air conditioning		none		none	
Low energy lighting		100%		100%	
Electric tariff		standard		standard	
125ltrs/person/day, Water used ?		yes		yes	
Space Heating System (Gas)		Condensing regular (89.5%efficiency) room sealed, fan flue, radiators		Condensing regular (89.5%efficiency) room sealed, fan flue, radiators	
Space heating controls(individual)		Time temp zone control		Time temp zone control	
FGHRS included ?		yes		yes	
DHW cylinder size	(Litres)	200ltrs		200ltrs	
Declared loss factor	(KWh/day)	1.44		1.44	

Part L 1A 2013 Compliance

note: "model design" except where shaded

Gas		Mid Terrace House 65m²	Top Floor Flat 45m²
Fabric Specification			
Ext Wall U-value	(W/m²K)	0.18	0.18
Party Wall U-value	(W/m²K)	0	0
Floor U-value	(W/m²K)	0.13	n/a
Roof U-value	(W/m²K)	0.11	0.11
Windows U-value (whole windov	(W/m²K)	1.4 double glazed	1.4 double glazed
Window g-value		0.63	0.63
Opaque Door U-value	(W/m²K)	1	1
Semi-glazed Door U-value		1	1
Thermal mass parameter (TMP)		Medium	Medium
Airtightness	(m³/m²/hr @ 50Pa)	**5**	**5**
Linear thermal transmittance		All approved details except the following improved	
E2 - External wall to lintels (including other steel lintels)	(W/mK)	0.05	0.05
E12- External wall to Gable (ceiling insulation)	(W/mK)	no	no
P4 - Party wall to Roof (ceiling insulation)	(W/mK)	0.06	no

Services Specification

Ventilation Type	natural(with extract fans)	natural(with extract fans)
Number of extract fans	3	2
Air conditioning	none	none
Low energy lighting	100%	100%
Electric tariff	standard	standard
125ltrs/person/day, Water used ?	yes	yes
Space Heating System (Gas)	Condensing combi (89.5%efficiency) room sealed, fan flue, radiators	Condensing combi (89.5%efficiency) room sealed, fan flue, radiators
Space heating controls(individual)	Time temp zone control	programmer, room thermostat & TRVs
FGHRS included ?	yes	yes
DHW cylinder size (Litres)	n/a	n/a
Declared loss factor (KWh/day)	n/a	n/a

Part L 1A 2013 Compliance	note: "model design" except where shaded			
ELECTRIC	**Detached House** 125m²		**Semi-detached House** 95m²	
Fabric Specification				
Ext Wall U-value (W/m²K)	0.18		0.18	
Party Wall U-value (W/m²K)	n/a		n/a	
Floor U-value (W/m²K)	0.13		0.13	
Roof U-value (W/m²K)	0.11		0.11	
Windows U-value (whole window) (W/m²K)	1.4	double glazed	1.4	double glazed
Window g-value	0.63		0.63	
Opaque Door U-value (W/m²K)	1		1	
Semi-glazed Door U-value	1		1	
Thermal mass parameter (TMP)	Medium		Medium	
Airtightness (m³/m²/hr @ 50Pa)	**5**		**5**	
Linear thermal transmittance	All approved details except the following improved			
E2 - External wall to lintels (including other steel lintels) (W/mK)	0.05	High perfor-mance lintels	0.05	High perfor-mance lintels
E12- External wall to Gable (ceiling insulation) (W/mK)	0.06		0.06	
P4 - Party wall to Roof (ceiling insulation) (W/mK)	n/a		0.06	
Services Specification				
Ventilation Type	natural(with extract fans)		natural(with extract fans)	
Number of extract fans	4		3	
Air conditioning	none		none	
Low energy lighting	100%		100%	
Electric tariff	off peak 7hrs		off peak 7hrs	
125ltrs/person/day, Water used ?	yes		yes	
Space Heating System (Electric)	Integrated storage & direct acting Storage heaters			
Space heating controls(individual)	Automatic charge control		Automatic charge control	
Emitters type (& pump in hetaed space?)	Radiators	(yes)	Radiators	(yes)
Water Heating System (Electric)	Dual Immersion		Dual Immersion	
DHW cylinder size (Litres)	200ltrs		200ltrs	
Declared loss factor (KWh/day)	1.44		1.44	
Photovoltaic panels (kWp)	3.2 kWp		2.3 kWp	

Part L 1A 2013 Compliance **ELECTRIC**		note: "model design" except where shaded **Mid Terrace House** 65m²		**Top Floor Flat** 45m²	
Fabric Specification					
Ext Wall U-value	(W/m²K)	0.18		0.18	
Party Wall U-value	(W/m²K)	0		0	
Floor U-value	(W/m²K)	0.13		n/a	
Roof U-value	(W/m²K)	0.11		0.11	
Windows U-value (whole window)	(W/m²K)	1.4	double glazed	1.4	double glazed
Window g-value		0.63		0.63	
Opaque Door U-value	(W/m²K)	1		1	
Semi-glazed Door U-value		1		1	
Thermal mass parameter (TMP)		Medium		Medium	
Airtightness	(m³/m²/hr @ 50Pa)	**5**		**5**	
Linear thermal transmittance		All approved details except the following improved			
E2 - External wall to lintels (including other steel lintels)	(W/mK)	0.05	High perfor-mance lintels	0.05	High perfor-mance lintels
E12- External wall to Gable (ceiling insulation)	(W/mK)	no		no	
P4 - Party wall to Roof (ceiling insulation)	(W/mK)	0.06		no	
Services Specification					
Ventilation Type		natural(with extract fans)		natural(with extract fans)	
Number of extract fans		3		2	
Air conditioning		none		none	
Low energy lighting		100%		100%	
Electric tariff		off peak 7hrs		off peak 7hrs	
125ltrs/person/day, Water used ?		yes		yes	
Space Heating System (Electric)		Integrated storage & direct acting Storage heaters			
Space heating controls(individual)		Automatic charge control		Automatic charge control	
Emitters type (& pump in hetaed space?)		Radiators (yes)		Radiators (yes)	
Water Heating System (Electric)		Electric Instantaneous		Electric Instantaneous	
DHW cylinder size	(Litres)	n/a		n/a	
Declared loss factor	(KWh/day)	n/a		n/a	
Photovoltaic panels (kWp)		1.2 kWp		0.4 kWp	

Appendix B

Detailed results for the 10% strategies

Dwelling type	SAP	DER	TER	DER / TER variance (for information)	DFEE	TFEE	DFEE / TFEE variance (for information)
		kg CO_2/m2/year		%	kWh/m2/year		%
GAS - PART L							
(Gas) 4Bed Detached House	85	16.52	16.54	0.1%	51.2	56.8	10%
(Gas) 3Bed Semi Detached House	84	17.3	17.36	0.3%	46.5	51.2	9%
(Gas) 2Bed Mid Terrace House	84	18.23	18.37	0.8%	40.3	46.5	13%
(Gas) 1Bed Top Floor Flat	83	19.16	19.18	0.1%	34.5	41.1	16%
GAS - 10% by PV							
(Gas) 4Bed Detached House	88	13.22	16.54	20.1%	51.2	56.8	10%
(Gas) 3Bed Semi Detached House	87	14	17.36	19.4%	46.5	51.2	9%
(Gas) 2Bed Mid Terrace House	87	14.75	18.37	19.7%	40.3	46.5	13%
(Gas) 1Bed Top Floor Flat	86	15.53	19.18	19.0%	34.5	41.1	16%
GAS - 10% by SHW							
(Gas) 4Bed Detached House	86	14.65	16.66	12.1%	51.2	56.8	10%
(Gas) 3Bed Semi Detached House	85	15.21	17.5	13.1%	46.5	51.2	9%
(Gas) 2Bed Mid Terrace House	84	16.36	18.37	10.9%	40.3	46.5	13%
(Gas) 1Bed Top Floor Flat	84	17.66	19.18	7.9%	34.5	41.1	16%
ELECTRIC- PART L							
(Electric) 4Bed Detached House	90	24.41	24.41	0.0%	49.5	56.8	13%
(Electric) 3Bed Semi Detached House	91	25.3	25.35	0.2%	44.6	51.2	13%
(Electric) 2Bed Mid Terrace House	85	26.07	26.3	0.9%	40.3	46.5	13%
(Electric) 1Bed Top Floor Flat	84	27.81	27.87	0.2%	34.5	41.1	16%
ELECTRIC- 10% by PV							
(Electric) 4Bed Detached House	93	22.35	24.41	8.4%	49.5	56.8	13%
(Electric) 4Bed Detached -enhanced fabric	93	22.13	24.41	9.3%	47.4	56.8	17%
(Electric) 3Bed Semi Detached House	93	23.24	25.35	8.3%	44.6	51.2	13%
(Electric) 2Bed Mid Terrace House	87	23.83	26.3	9.4%	40.3	46.5	13%
(Electric) 1Bed Top Floor Flat	86	25.49	27.87	8.5%	34.5	41.1	16%
ELECTRIC- 10% by SHW (without PV)							
(Electric) 4Bed Detached House	80	31.23	24.61	-26.9%	49.5	56.8	13%
(Electric) 3Bed Semi Detached House	82	30.79	25.58	-20.4%	44.6	51.2	13%
(Electric) 2Bed Mid Terrace House	83	29.05	26.3	-10.5%	40.3	46.5	13%
(Electric) 1Bed Top Floor Flat	86	25.56	27.87	8.3%	34.5	41.1	16%
ELECTRIC- 10% by SHW (with reduced PV)							
(Electric) 4Bed Detached House	90	22.35	24.61	9.2%	49.5	56.8	13%
(Electric) 3Bed Semi Detached House	90	23.28	25.58	9.0%	44.6	51.2	13%
(Electric) 2Bed Mid Terrace House	87	23.92	26.3	9.0%	40.3	46.5	13%
(Electric) 1Bed Top Floor Flat	86	25.56	27.87	8.3%	34.5	41.1	16%
ELECTRIC- 10% by ASHP (without PV)							
(Electric) 4Bed Detached House	83	18.37	24.41	24.7%	49.5	56.8	13%
(Electric) 3Bed Semi Detached House	84	19.86	25.35	21.7%	44.6	51.2	13%
(Electric) 2Bed Mid Terrace House	82	19.87	26.3	24.4%	40.3	46.5	13%
(Electric) 1Bed Top Floor Flat	83	20.52	27.87	26.4%	34.5	41.1	16%
ELECTRIC- 10% by GSHP (without PV)							
(Electric) 4Bed Detached House	86	16.37	24.41	32.9%	49.5	56.8	13%
ELECTRIC- 10% by BIOMASS (without PV)							
(Electric) 4Bed Detached House	80	7.3	16.54	55.9%	49.6	56.8	13%
(Electric) 3Bed Semi Detached House	81	7.61	17.36	56.2%	44.6	51.2	13%
(Electric) 2Bed Mid Terrace House	83	7.63	18.2	58.1%	40.3	46.5	13%
(Electric) 1Bed Top Floor Flat	86	7.43	19.43	61.8%	34.5	41.1	16%

Dwelling type	% Actual Energy Reduction for 10% target	Total Delivered Energy SAP worksheet (238)	Space heating fuel - main system 1	Space heating fuel - secondary	Water heating fuel	Electricity for pump, fans etc (231)	Electricity for lighting (232)	PV Energy Produced (233)
		kWh/year	kWh/year					
GAS - PART L								
(Gas) 4Bed Detached House		**7926**	**5081**	0	2311	75	459	**0**
(Gas) 3Bed Semi Detached House		**6042**	**3240**	0	2286	75	441	**0**
(Gas) 2Bed Mid Terrace House		**4355**	**1884**	0	2084	75	311	**0**
(Gas) 1Bed Top Floor Flat		**3155**	**957**	0	1897	75	226	**0**
GAS - 10% by PV								
(Gas) 4Bed Detached House	10%	7131	**5081**	0	2311	75	459	**-795**
(Gas) 3Bed Semi Detached House	10%	5437	**3240**	0	2286	75	441	**-605**
(Gas) 2Bed Mid Terrace House	10%	3920	**1884**	0	2084	75	311	**-435**
(Gas) 1Bed Top Floor Flat	10%	2840	**957**	0	1897	75	226	**-315**
GAS - 10% by SHW								
(Gas) 4Bed Detached House	15%	6757	**5123**	0	1049	125	459	**0**
(Gas) 3Bed Semi Detached House	17%	5037	**3286**	0	1184	125	441	**0**
(Gas) 2Bed Mid Terrace House	15%	3715	**1884**	0	1394	125	311	**0**
(Gas) 1Bed Top Floor Flat	12%	2768	**957**	0	1459	125	226	**0**
ELECTRIC- PART L								
(Electric) 4Bed Detached House		**4952**	**4619**	513	1930	0	459	**-2570**
(Electric) 3Bed Semi Detached House		**3751**	**2934**	326	1858	0	441	**-1807**
(Electric) 2Bed Mid Terrace House		**2624**	**1896**	211	1130	0	311	**-924**
(Electric) 1Bed Top Floor Flat		**1954**	**991**	110	948	0	226	**-321**
ELECTRIC- 10% by PV								
(Electric) 4Bed Detached House	10%	4457	**4619**	513	1930	0	459	**-3065**
(Electric) 4Bed Detached -enhanced fabric	11%	4414	**4359**	491	1930	0	459	**-2825**
(Electric) 3Bed Semi Detached House	10%	3374	**2934**	326	1858	0	441	**-2184**
(Electric) 2Bed Mid Terrace House	11%	2343	**1896**	211	1130	0	311	**-1205**
(Electric) 1Bed Top Floor Flat	10%	1753	**991**	110	948	0	226	**-522**
ELECTRIC- 10% by SHW (without PV)								
(Electric) 4Bed Detached House	-33%	6590	**4655**	517	908	50	459	**0**
(Electric) 3Bed Semi Detached House	-26%	4712	**2934**	326	961	50	441	**0**
(Electric) 2Bed Mid Terrace House	-14%	2998	**1896**	211	530	50	311	**0**
(Electric) 1Bed Top Floor Flat	10%	1757	**991**	110	380	50	226	**0**
ELECTRIC- 10% by SHW (with reduced PV)								
(Electric) 4Bed Detached House	10%	4453	**4655**	517	908	50	459	**-2137**
(Electric) 3Bed Semi Detached House	10%	3374	**2968**	329	961	50	441	**-1375**
(Electric) 2Bed Mid Terrace House	10%	2356	**1896**	211	530	50	311	**-642**
(Electric) 1Bed Top Floor Flat	10%	1757	**991**	110	380	50	226	**0**
ELECTRIC- 10% by ASHP (without PV)								
(Electric) 4Bed Detached House	18%	4074	**1860**	0	1725	30	459	**0**
(Electric) 3Bed Semi Detached House	12%	3302	**1163**	0	1668	30	441	**0**
(Electric) 2Bed Mid Terrace House	14%	2245	**773**	0	1130	30	311	**0**
(Electric) 1Bed Top Floor Flat	18%	1605	**401**	0	948	30	226	**0**
ELECTRIC- 10% by GSHP (without PV)								
(Electric) 4Bed Detached House	26%	3668	**1454**	0	1725	30	459	**0**
ELECTRIC- 10% by BIOMASS (without PV)								
(Electric) 4Bed Detached House	n/a	9442	**5591**	466	2896	30	459	**0**
(Electric) 3Bed Semi Detached House	n/a	7050	**3488**	291	2800	30	441	**0**
(Electric) 2Bed Mid Terrace House	n/a	5026	**2001**	167	2517	30	311	**0**
(Electric) 1Bed Top Floor Flat	n/a	3500	**936**	78	2230	30	226	**0**

Dwelling type	PV required	PV area	Solar Thermal panel area	(% of Ground floor Area for solar tech)	Boiler Size	Additional variations to Part L 2013 compliance baseline specs
	kWp	sq.m	sq.m	%	(kW)	
GAS - PART L						
4Bed Detached				0%	9	
3Bed SemiDetached				0%	7	
2Bed Mid Terrace				0%	5	
1Bed Top Floor Flat				0%	4	
GAS - 10% by PV						
4Bed Detached	1.0 kWp	6.9 m2		11%	9	
3Bed SemiDetached	0.8 kWp	5.3 m2		11%	7	
2Bed Mid Terrace	0.5 kWp	3.8 m2		12%	5	
1Bed Top Floor Flat	0.4 kWp	2.7 m2		12%	4	
GAS - 10% by SHW						
4Bed Detached			5.0 m2	8%	9	
3Bed SemiDetached			3.0 m2	6%	7	
2Bed Mid Terrace			2.0 m2	6%	5	
1Bed Top Floor Flat			1.5 m2	7%	4	
ELECTRIC- PART L						
4Bed Detached	3.2 kWp	22.4 m2		36%		
3Bed SemiDetached	2.3 kWp	15.8 m2		33%		
2Bed Mid Terrace	1.2 kWp	8.1 m2		25%		
1Bed Top Floor Flat	0.4 kWp	2.8 m2		12%		
ELECTRIC- 10% by PV						
4Bed Detached	3.8 kWp	26.7 m2		43%		
4Bed Detached-enhanced fabric	3.5 kWp	24.6 m2		39%		Better window U-value of 1.2 W/m2K
3Bed SemiDetached	2.7 kWp	19.0 m2		40%		
2Bed Mid Terrace	1.5 kWp	10.5 m2		32%		
1Bed Top Floor Flat	0.7 kWp	4.6 m2		20%		
ELECTRIC- 10% by SHW (without PV)						
4Bed Detached	Not passing with increased size of ST panels		5.0 m2	8%		
3Bed SemiDetached			3.0 m2	6%		
2Bed Mid Terrace			2.0 m2	6%		
1Bed Top Floor Flat			2.8 m2	12%		
ELECTRIC- 10% by SHW (with reduced PV)						
4Bed Detached	2.7 kWp	18.6 m2	5.0 m2	38%		
3Bed SemiDetached	1.7 kWp	12.0 m2	3.0 m2	32%		
2Bed Mid Terrace	0.8 kWp	5.6 m2	2.0 m2	23%		
1Bed Top Floor Flat			2.8 m2	12%		
ELECTRIC- 10% by ASHP (without PV)						
4Bed Detached				0%	5	
3Bed SemiDetached				0%	4	
2Bed Mid Terrace				0%	4	
1Bed Top Floor Flat				0%	3	
ELECTRIC- 10% by GSHP (without PV)						
4Bed Detached				0%	5	
ELECTRIC- 10% by BIOMASS (without PV)						
4Bed Detached				0%	10	
3Bed SemiDetached				0%	7	
2Bed Mid Terrace				0%	5	
1Bed Top Floor Flat				0%	4	

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