BUILDING SERVICES OPTIONS FOR 2016

A REVIEW OF ASSUMPTIONS & THINKING ON CARBON COMPLIANCE STANDARDS FOR DWELLINGS

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Prepared by:

The Chartered Institution of Building Services Engineering Energy Performance Group

(Chair – Phil Jones)

Prepared for:

The Zero Carbon Hub

Tessa Parnell

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Acknowledgements

We would like to thank all of the members of The CIBSE Energy Performance Group that volunteered contributions to this report. In particular, Mr Brian Spires who did much of the work involved.

1. Background

The government have a target for all new homes to be zero carbon by 2016. In support of this, the Zero Carbon Hub (ZCH) is tasked with providing a clear definition of what a national benchmark for carbon compliance should consist of. They have been asked to present appropriate options for setting a national benchmark for carbon compliance, to be set in addition to the minimum fabric energy efficiency standard. These options will be drawn from an evidence base, which considers the range of dwelling and development types and technologies, and a range of possible carbon compliance levels from 44% to 100% of regulated emissions (against a 2006 baseline).

The ZCH are developing a report outlining the options for meeting the objectives above, with links to the relevant evidence base. This will be followed by a presentation to the Housing Minister summarising the options and supporting evidence base.

The concept of a zero carbon home might appear simple at first sight however, when it is examined in terms of practicality and how zero carbon can be achieved in reality, then the concept becomes far less straightforward. The work of the ZCH is therefore crucial in defining what we mean by ‘zero carbon homes’ and how it might be achieved in practice. Carbon Compliance Standards must be evidence based and require industry input to ensure they are credible and most importantly, fit for purpose. The CIBSE Energy Performance Group (a voluntary Special Interest Group within CIBSE) has been asked to review some of the ZCH assumptions and thinking on carbon compliance standards for dwellings. This report presents this industry view.

2. Objectives

The main objectives were to:

- Review the Technical Working Group thinking on likely mainstream technology options and performance in 2016
- Input expertise, to aid Task Group thinking in the following areas (specifically related to homes built from 2016):
    - Hot water
    - Ventilation & cooling
    - Space heating
    - Lighting
    - Controls
    - Microgeneration
- Review the technology combinations and performance assumptions for modelling 2016 homes. To identify technology combinations that are realistic and likely for new homes in 2016 and to provide comments and practicalities that effect carbon performance

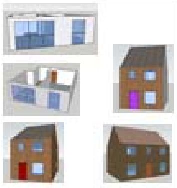
3. ZCH working assumptions

The ZCH modelling will be carried out using mSAP i.e. SAP 2009 with 2016 emissions factors and the ability to select the dwelling location. The main variables are:

- Dwelling type
- Fabric specification
- Core technology options
- Location
- Carbon target

The main dwelling assumptions are shown below:

Fabric specifications

		Apartments (small & large)	Mid terrace house	Semi detached house	Detached house	ALL
						
	Fabric Spec	Min. FEES	Min. FEES	Min. FEES	Min. FEES	Spec C
U-value (W/m^2K)	**External Walls**	0.18	0.18	0.18	0.15	0.15
U-value (W/m^2K)	**Party Walls**	0	0	0	0	0
U-value (W/m^2K)	**Floor**	0.15	0.17	0.18	0.15	0.15
U-value (W/m^2K)	**Roof**	0.13	0.13	0.13	0.13	0.11
U-value (W/m^2K)	**Windows / doors**	1.4 (double glazed) / 1.0	1.4 (double glazed) / 1.0	1.4 (double glazed) / 1.0	1.4 (double glazed) / 1.0	0.8 (triple glazed) / 1.0
	Airtightness ($m^3/hr/m^2$)	5	5	5	3.1	1
	Thermal bridging (W/m^2K)	0.04	0.04	0.04	0.04	0.04
	Ventilation strategy	Natural (extract fans)	Natural (extract fans)	Natural (extract fans)	Natural (extract fans)	MVHR (SFP=0.5; HR=90%)

The Core technology options chosen by the ZCH are:

- Individual systems
    - Instantaneous electric (+ PV)
    - Gas condensing combi boiler (+ PV)
    - Gas condensing boiler (+ PV)
    - Gas condensing boiler + SHW (+ PV)
    - ASHP (+ PV)
- Communal systems
    - GSHP (+ PV)
    - Biomass boiler (+ PV)
    - Gas CHP + Gas boiler (+ PV)

The technology sensitivities chosen by the ZCH are:

- Individual systems
    - Biomass boiler (+ PV)
    - ASHP + SHW (+ PV)
    - GSHP + SHW (+ PV)
    - GSHP + biomass back boiler (+ PV)
    - Etc…
- Communal systems
    - Gas CHP + biomass boiler (+ PV)
    - Biomass CHP + gas boiler (+ PV)
    - Etc…

More detailed modelling assumptions are shown below:

Hot Water					
TFA	43	67	76	76	118
Dwelling type	Small Flat	Large Flat	Mid Terrace House	Semi-detached / End Terrace House	Detached House
Bedrooms	1	2	3	3	4
DHW cylinder					
Volume (litres)	120	120	150	150	200
Declared loss factor	0.96	0.96	1.14	1.14	1.44
Water use					
? 125l/p/day total	yes	yes	yes	yes	yes

Detailed technology assumptions, as discussed in Technical WG meeting, 9/9/10

	Specification	Notes
Gas condensing boiler (individual)		
Controls	Time & temp zone control	As proxy for well controlled heating system. To be used in all dwelling types
Emitter	Radiators	Standard solution
Compensator	Weather compensator	Weather and Enhanced Load compensators give same performance boost in SAP.
Efficiency	95%	Assuming an integrated flue gas heat recovery system - i.e. 91% for condensing boiler + 4% for FGHR. Note that SAP already has an in-use factor for boilers contained in it.
Cylinder in dwelling	Yes	
Gas combi condensing boiler (individual)		
Controls	Time & temp zone control	As proxy for well controlled heating system. To be used in all dwelling types
Emitter	Radiators	Standard solution
Compensator	Weather compensator	Weather and Enhanced Load compensators give same performance boost in SAP.
Efficiency	95%	Assuming an integrated flue gas heat recovery system - i.e. 91% for condensing boiler + 4% for FGHR. Note that SAP already has an in-use factor for boilers contained in it.
Cylinder in dwelling	no - combi boiler	
ASHP (individual)		
Type	HP - wet system (air-to-water)	
Controls	Time & temp zone control	As proxy for well controlled heating system. To be used in all dwelling types
Emitter	Underfloor	Cost for oversized radiators. But for proxy of performance, use underfloor in SAP (SAP can't model oversized radiators, low temp)
Compensator	Weather compensator	Weather and Enhanced Load compensators give same performance boost in SAP.
Efficiency	250%	Use current SAP default. HP trials said 80% performed worse than expected, however much of this was put down to poor installation. Assumption that by 2016 improvements in installation will bring performance up. So considered reasonable to assume current SAP default - no justification to assume anything different.
Cylinder in dwelling	Yes	
HP uses immersion for DHW	Yes	
GSHP (communal)		
Type	HP - wet system (ground-to-water)	
Controls	Programmer + TRV, charging linked to use	Gives best performance in SAP
Emitter	Underfloor	Cost for oversized radiators. But for proxy of performance, use underfloor in SAP
Efficiency	320%	Use current SAP default. HP trials said 80% performed worse than expected, however much of this was put down to poor installation. Assumption that by 2016 improvements in installation will bring performance up. So considered reasonable to assume current SAP default - no justification to assume anything different.
Cylinder in dwelling	yes	Considered more likely that developers will want to include cylinder in dwelling to give comfort to occupant regarding connection to communal system (e.g. ability to ameliorate concerns over connection to a communal system which is not under their direct control).
HP uses immersion for DHW	would like to say yes but ->	Can't enter this in SAP for communal HP system
Gas boiler (communal)		
System	100degC or below full control variable flow system	
Controls	Programmer + TRV, charging linked to use	Gives best performance in SAP
Emitter	Radiators	Standard solution
Efficiency	86%	Limit on non-condensing boilers. Note that check being done to see if likely that FGHR might be available on large communal size boilers. If so, then increase efficiency to 95% as for individual (small) gas boiler.

4. EPG Response

The CIBSE Energy Performance group have developed some responses to the technology mixes and assumptions and these are shown below in the form of comments and a matrix, issues and questions that raise issues the ZCH may wish to consider. Some of the comments are conflicting as the issues are controversial and it is currently difficult to reach a consensus. The following comments are in no particular order but should help in thinking through some of the issues:

1. The primary heating supply temperature of ASHP and GSHP will vary with the month or season in relation to the Coefficient of Performance, and this needs to be taken into account in the modelling, particularly in respect to heating energy for the DHW. ASHP COP will vary significantly more than GSHP as a result of seasonal air temperature changes.
2. Many of the 2016 heating options like GSHP and ASHP will require the use of supplementary electric hot water which would have previously been gas – this fuel switch on DHW needs to be accounted for.
3. But there are gas fired absorption heat pumps (e.g. Baxi) that will provide the supplementary heat from gas.
4. We are not aware of any small instantaneous gas water hot water heaters on the market – are there? These used to be commonplace as unflued devices but in limited supply now as a flue would be needed. But this may be a market the large gas boiler manufacturers go for when their larger Heating/DHW boilers start to disappear – this should be in the model.
5. A water consumption of 125l/person has been accounted for in the assumptions. Will any analysis be carried out on reduced water consumption volumes and the energy impacts of heating the water.
6. If using GSHP for heating ONLY then the ground may well gradually cool and freeze and this reduces long term COP significantly. This may be less of a problem with very shallow coils but is still a long term degradation in COP. The objective is to make sure that annual heat flow from - ultimately - the surface is sufficient to recharge the ground and it may be possible to size and locate the coil so that this occurs.
7. Will the modelling tool differentiate between vertical & horizontal GSHPs? With seasonal swing the expected COP from a vertical loop would be greater than the horizontal 'slinky.'
8. Heat pump Heating mode COP is generally one (1) better than cooling mode as the compressor energy goes into the heating system e.g. 4 for heating so 3 for cooling
9. Air Conditioning is currently being installed in greater numbers, particularly in high specification and high rise new build. Modelling might need to consider a high rise flat scenario.
10. Biomass (solids) CHP is not a well developed technology and is currently not working anywhere less than 5MWe and it is unlikely that in the next 6 years we will solve the problems experienced at a small > 1MWe level (tar in the gas) so this is unlikely to be a lead technology in the scenarios
11. Bio-oils and anaerobic digestion are much nearer market and well developed so are MORE likely scenarios
12. Heat to power ratios for CHP are 1:1 above about 1MWe communal

13. Will a gas condensing boiler really be part of a zero carbon home? It is a strong part of the technology scenarios but will that get anywhere near zero carbon?

14. What about larger Solar Hot Water (SHW) feeding into a district heating system being topped up by boilers?

15. The gas boiler market does seem to be going towards COMBI due to space saving i.e. this is a more likely scenario than boiler plus storage

16. If you are going to consider ASHP on underfloor then you should consider condensing boilers on underfloor – with seasonal efficiency 92%

17. Underfloor thermal lag needs to be accounted for somehow – these systems generally run 24/7 in the heating season but sometimes with a night setback so may lead to longer running but at lower temperatures. SAP has a "responsiveness" parameter that reflects (more or less) this.

18. Communal heating systems are generally installing virtually instantaneous plate heat exchangers i.e. not hot water storage – LESS likely to include storage in this scenario, not more.

19. Individual dwelling CHP is not even worth modelling – CT CHP field trail – the heat demand is not there, particularly in 2016 zero carbon home

20. Individual fuel cell might be worth modelling as this has Heat to Power of 1 to 1, and therefore more suited to domestic loads and could easily be made at small output. However, capital cost is still high and fuel cell stack life is limited. This will need to be heat-led with surplus electricity exported as domestic electric loads are very spiky.

21. One thing missing from the modelling is SIZE of the technologies. Space heating loads in 2016 will be small and the current technologies like boilers are not available in these very small size ranges. Secondly, DHW loads will remain about the same and require quite a high burner output to instantaneously produce DHW (COMBI) – this needs thinking about in the modelling as it could have an impact on the likelihood of the scenarios and even the technology efficiency relative to the loads. Integrated Thermal Storage Units within combi boilers may provide a solution for this and could integrate with SHW.

22. 2016 is only 6 years away and these homes will be designed by 2015, so the technologies are less than 5 years away and so are unlikely to be things we don’t know about already. Most of these analyses assume that the market will buy what it's told is good for it which is unlikely to be true. It is likely that for some time, potential purchasers will still ask "where are the radiators?" or "the radiators don't look big enough to me".

23. The UK is a maritime climate, therefore as soon as ASHP coils fall below zero Celsius (usually when air temperature falls below 7 Celsius) you have the problem of ice forming which reduces efficiency. This is often overlooked when comparing these systems elsewhere in the world. As insulation improves the temperature at which an ASHP will be required to start will fall, and the proportion of DHW in heating demand rises. The heat pump then gets hit on the efficiency front twice – as demand for high temperatures goes up in the coldest season, just as the potential for ice formation increases.

24. To counter ground freezing and low COPs for hot water generation, HPs should only be installed in dwellings with appropriately sized hot water systems and a solar thermal system to reduce reliance on the HP for this demand type.

25. EST study shows existing real world COPs of 2.2 – not even up to the SAP assumption of 2.5 – perhaps these should be aligned in the next version of Building Regulations – especially as the study has been extended.

26. In dwellings especially, it should be (really) simple to get heating loads minimal, so would question the need for a piece of equipment that might have a far larger output than required.

27. Don't see them as being much use for hot water heating, unless there's no scope for solar thermal and they can be arranged to preheat with say point of use top up?

28. As we focus on insulating and making dwellings air tight, what will happen to these technology scenarios if the space heating loads were less than say 1 kW? Oversized equipment operating at very low loads, probably at very poor efficiencies.

29. We have most of the technologies available now, what we invariably are unable to do is apply them well, install them well, operate them well and maintain them well. We are struggling to integrate new heating options with existing heating services. There are very significant concerns that the market lacks the skills to install commission and maintain and this will have an impact on uptake – consumers will be wary of technologies that can't be maintained or where maintenance costs are high.

30. There are concerns about how long some of these technologies will last, 5-10 years? The projected life will also have an impact on uptake and on whole life cost.

31. For ground Source heat Pumps it may only be 10-15 years before major costs are incurred to keep them in service, Biomass pellet boilers may operate for 5-15 years if well maintained: we do not have the experience. ASHP and DCHP in domestic dwellings, we simply do not know how long they will last or what the maintenance costs might be.

32. The better packaged ASHPs provide both space and water heating services with integrated controls (and integrated storage) of the direct heater (if provided). Some ASHPs use desuperheating to top up the water temperature rather than an immersion heater. Even a poor heat pump should provide more heat output than energy input. With separate systems it's difficult to have an integrated control strategy - and puts rather a lot at the mercy of the installer. Water heating CoPs of around 2 including top-up seem to be achievable in the laboratory by the better products.

33. For a decent hot water service an instantaneous heater needs a power of 25 to 35 kW - but today's combi boilers manage to provide this while also being able to deliver much lower heating outputs at decent efficiencies.

34. Do the carbon emissions from Grid electricity account for the proposed reduction/de-carbonising as detailed in the DECC statistics? Although proposed to remain steady until 2015, they do begin to reduce – see http://www.decc.gov.uk/en/content/cms/statistics/analysts_group/analysts_group.aspx

35. There is no mention of micro wind anywhere. Although a very marginal solution, it may have its place in the sensitivity section.

36. Has domestic scale voltage optimisation equipment been considered?

37. Has any analysis of the differing light source types been addressed?

38. The potential impact of the FIT and RHI should be factored in to the modelling of technology combinations? Specifically, the effect of the tariff on technology uptake and cost (and the indirect impact this might have on improvements to technology performance/ efficiency).

39. Modelling should consider whether the housing developer will factor the income generating potential of technologies into their decision on which technology to use (in addition to compliance, space, complexity, etc). This will depend on the type of procurement contract and whether there is a long term management company in place to take advantage of the FIT/RHI.

40. The complexity of occupier-technology interface is another important issue – the preference being towards those that are simple to operate and maintain and least likely for component degradation.

41. Whilst there are concerns regarding long term COP of GSHP systems employed for heating only, experience (at least anecdotal) appears to be indicating that maintaining ground temperatures and COPs for ‘balanced’ systems is also a significant challenge. Though this may be a design rather than technical issue it might be appropriate to highlight that such systems are limited in applicability if annual heating and cooling demand is to be balanced, or will require any imbalance to be mitigated by direct electric heating/cooling.

42. SHW feeding into district heating systems – we understand that SAP2005 is incapable/inadequate in evaluating such a system and this needs to be identified in modelling. Has SAP 2009 been upgraded in this respect? There are opportunities to connect to return pipes without need for storage, also the possibility of using diurnal/seasonal thermal storage. Seasonal thermal storage in particular could be exploited to increase the percentage of total heating requirements supplied by SHW.

43. In modelling DH systems will the impact of lower standard design temperatures for expected 2016 heating systems be taken into account, i.e. opportunities to improve plant efficiency and reduce losses by adopting $70^{o}C/40^{o}C$ or perhaps down to $60^{o}C/40^{o}C$. This may increase pumping requirements but does have significant implications for district heating systems. The evaluation of DH systems in SAP 2009 still appears to be very simplistic so is unlikely to accurately reflect the true advantages and disadvantages offered by such systems. Will measures be taken in the ZCH assessment variations in distribution losses and heat density depending on system size and house type/mix supplied?

Design considerations	Technology Scenario - CORE							
	Instantaneous electric (individual) + PV	Gas combi condensing boiler (individual) + PV	Gas condensing boiler (individual) + PV	Gas condensing boiler (individual) + SHW + PV	ASHP (individual) + PV	GSHP (communal) + PV	Biomass boiler (communal) + PV	Gas CHP (communal) + Gas boiler (communal) + PV
Energy and carbon emissions								
Does the hot water require supplementary* electric heating	No	No	No	No	Yes	Yes	No	No
Does SAP 2009 adequately calculate the hot water energy / carbon emissions for bespoke arrangements of this technology scenario?	Yes	Yes	Yes	Yes	No	No	Yes	Yes
If the answer to 1.2 is No, for what bespoke arrangements does SAP 2009 not provide adequate calculations and what are the current limitations / shortfalls of the calculation?					When the ASHP provides primaryl heating only which serves to preheat the hot water needs (i.e. not as a tested "Package" unit)	When the GSHP provides communal heating only which serves to preheat the hot water needs (i.e. not as a tested "Package" unit)		
					hot water demand is derived for the TFA of the dwelling, the energy requirement for which is calculated for a single heat source only, taking account of losses in heating and storage.	hot water demand is derived for the TFA of the dwelling, the energy requirement for which is calculated for a single heat source only, taking account of losses in heating and storage.		
					In the absence of manufacturer's data, the storage heat losses are derived from the stored volume (litres) x the appropriate factors for loss (table 2), volume (Table 2a) and temperature (Table 2b), the latter not being covered for supplimentry heated systems	In the absence of manufacturer's data, the storage heat losses are derived from the stored volume (litres) x the appropriate factors for loss (table 2), volume (Table 2a) and temperature (Table 2b), the latter not being covered for supplimentry heated systems		
What modifications are required for SAP 2009 to satisfy issue 1.2?					The capacity to calculate the monthly heating energy reqirements for both primary and supplimentary systems .	The capacity to calculate the monthly heating energy reqirements for both primary and supplimentary systems .		
					The addition of a temperature factor (table 2b) for supplimentary / dual heated sytems	The addition of a temperature factor (table 2b) for supplimentary / dual heated sytems		
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					Modification to Table 1d: 'Temperature rise of hot water drawn off (DTm, in K)' to take account of the temperature rise provided by both the primary and supplimentary heating sytems**.	Modification to Table 1d: 'Temperature rise of hot water drawn off (DTm, in K)' to take account of the temperature rise provided by both the primary and supplimentary heating sytems**.		
Plant space and builderswork reqirements								
Does the Technology Scenario require plant space within the TFA of the dwelling?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
If the answer to 2.1 is Yes, What is the total plant space requirement (m^2) and what fraction of the TFA does it represent.								
Does the Technology Scenario require plant space separate and additional to the TFA of the dwelling***	No	No	No	No	Yes	Yes		
If the answer to 2.3 is Yes, What is the total plant space requirement (m^2) and where is it located in relation to the dwelling?								
If the answer to 2.3 is Yes, What are the builders work requirements in respect to the plant space and connections to the dwelling systems?								
Maintenance requirements								
What is the recommended maintenance regime for this Technology Scenario?								
Is the recommended maintenance regime a requirement under the 2010 Building Regulations in part or whole?								
How can the recommended maintenance regime best be enforced								
Capital and whole life Costs								
What are the capital and whole life costs of 2,2, 2.4 and 2.5								
What are the operational costs of 3.1								

* supplementary in this instance means a second level of heating, which is necessary to raise the hot water draw-off temperature to a minimum of 60oC, for 2 minutes, from the temperature achieved by the primary heating system on a month by month basis.

** The heating supply temperature of the ASHP and GSHP will vary monthly / seasonally in relation to its COP, as will the cold feed temperature, thus requiring a lesser or greater contribution from the direct electric heating.

Design considerations	Technology scenario - SENSITIVITY					
	ASHP (individual) + SHW + PV	**GSHP (individual) + SHW + PV**	**GSHP (individual) + Biomass back boiler + PV**	**Biomass boiler (individual) + PV**	**Gas CHP (communal) + biomass boiler (communal) + PV**	**Biomass CHP (communal) + Gas boiler (communal) + PV**
Energy and carbon emissions						
Does the hot water require supplementary* electric heating	Yes	Yes	Yes	No	No	No
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Capital and whole life Costs						
What are the capital and whole life costs of 2,2, 2.4 and 2.5						
What are the operational costs of 3.1						

One member of the EPG asked a PV manufacturer to comment on the PV assumptions and their results are shown below.

Estimated energy yield for PV Systems		pvsystems	
Location	**Met data**	**Estimated annual kWh/kWp**	**Tilt angle**
East Pennines	Leeds	851	35
THAMES	London	877	30
SOUTH WEST	Plymouth	968	35
BORDERS	Edinburgh	855	35

Assumptions: Solar arrays facing south

Note: The energy yield is estimated figure. There could be losses due to irradiance levels, temperature, quality, module mismatch, Ohmic wiring of up to 12%

5. Conclusions & Recommendations

We fully support the need for modelling to try and determine carbon compliance standards for zero carbon homes. However, we believe that the technology mixes and assumptions do need a more thorough review than the (voluntary) CIBSE Energy Performance Group can provide. We have tried to provide some practical issues that may guide the modelling.

We would like to see more account taken of likely market uptake and this will be driven by a wide range of complex issues. Not least of these are:

- Consumer response to new technologies and ways of operating them
- Actual installed in-use energy performance of these technologies
- Commissioning – will it actually happen in practice?
- Maintenance – will it happen , how often, at what cost and with what impact on performance

We strongly recommend that the ZCH consult some of the heating and heat pump manufacturers like Baxi and Worcester Bosch as they will be trying to model similar scenarios and trying to understand/predict the same market.