GM PLANNING AND HOUSING COMMISSION

Date: **30 NOVEMBER 2022**

Subject: **TANZ TASK FORCE- REVIEW OF EXISTING NET ZERO HOUSING DEVELOPMENT AND CHALLENGES OF DELIVERY AT SCALE**

Report of: **ANDREW MCINTOSH, DIRECTOR OF PLACE, GMCA**

PURPOSE OF REPORT

This paper gives an overview of the GM Truly Affordable Net Zero Homes (TANZ) Task Force, and presents the findings of the review of existing net zero housing development, presented to the first Task Force meeting on 18th November.

RECOMMENDATIONS

PHC Members are asked to:

1. Note the contents of the report

CONTACT OFFICERS

- Andrew McIntosh (Andrew.mcintosh@greatermanchester-ca.gov.uk)
- Mary Gogarty (mary.gogarty@greatermanchester-ca.gov.uk)
- Lucy Woodbine (lucy.woodbine@greatermanchester-ca.gov.uk)

1. INTRODUCTION

1.1 The GM Truly Affordable Net Zero Homes (TANZ) Task Force is a cross-sector group to steer the GMCA commitment to deliver 30,000 operational net zero carbon social rented homes in Greater Manchester by 2038; with a specific focus on housing's contribution to meeting the shared commitment that all new development will be net zero carbon by 2028. It provides strategic leadership to drive forward this collective commitment by delivering the whole system challenge required to support the delivery of net zero carbon homes.

1.2 A whole system challenge requires commitment from all parts of the system to co-produce an ambitious but achievable plan. The Truly Affordable Net Zero Homes (TANZ) Task Force will have a specific focus on housing's contribution to ensuring that all new development will be net zero carbon by 2028.

1.3 It's clear that to meet our ambitious net zero carbon targets we must tackle the residential component of carbon emissions. Every new home that is built that is not net zero carbon adds to the retrofit challenge that we face as we try to decarbonise our already poor carbon performing existing housing stock.

1.4 In Greater Manchester we've also pledged to increase affordable housing delivery. In the GM Housing Strategy and Places for Everyone Joint Development Plan for nine GM districts we've committed to delivering 30,000 social and affordable rent homes by 2037. We're further requiring that these 30,000 homes should be net zero carbon, as a step toward the existing 2028 target date for all new development in Greater Manchester to be net zero carbon.

1.5 In simple terms, this requires us to find ways to build more and higher quality homes, and to charge lower rents for them when they are complete, while also driving down the price of construction.

1.6 The first meeting of the Task Force will include a review of existing net zero housing development and challenges of delivery at scale. This literature review seeks to inform the GMCA's commitment to achieve delivery of net zero carbon housing in Greater Manchester.

1.7 It explores the term net zero housing, gives an overview of small-scale net zero building in Greater Manchester, England and beyond, and then looks at the barriers preventing this small-scale building from becoming larger scale. Finally, it looks at how net zero building can be monitored before detailing some potential gaps within the literature which might need further research.

2. KEY FINDINGS

2.1 There are various English examples of small-scale net zero or low carbon development, but there is so far little evidence of this being achieved at scale. Most examples tend to be Passivhaus homes which have taken fabric-first approaches to minimising energy demand.

2.2 Within Greater Manchester, there have been a few small-scale examples of net zero social homes:

- 96 affordable Passivhaus homes in Salford, operated by Salix Homes and part-funded by Homes England and GMCA grants, are set to be completed by 2024. Salford is also home to Barratt's Z house – an advanced case study home, lived in by an academic to monitor its performance.
- 22 Passivhaus social homes in Manchester completed in 2021, including two which claim the title of "the first true net zero carbon social homes in the UK" (because they are both operational net zero and embodied carbon net zero).

2.3 **Barriers** to the adoption of net zero building at scale identified in the review include:

- Meeting net zero standards requires a **higher initial capital cost**, particularly before widespread market adoption (though cheaper than retrofitting later).
- Both **skills shortages** and **limited supply chain capacity** make timely delivery difficult and expensive, and mean what is delivered may be of lower quality, and so less energy efficient.
- A **lack of regulatory clarity** results in uncertainty, with developers generally aiming for the bare minimum.
- The **absence of successful large-scale net zero precedents or benchmarks to follow** brings a higher level of risk to developer decisions.
- There is **little consumer awareness or demand** for net zero living.
- Increased electric demand from low carbon tech such as heat pumps, allied with renewables inputting surplus electricity to the grid, provides a short-term **challenge to grid capacity**.
- The **siting of net zero developments** can either be a barrier or an opportunity to developing net zero homes, with factors such as orientation, property type and shading being important.
- **Maintenance** of new technology such as heat pumps and mechanical ventilation require a different skillset to that required for the maintenance of existing heating systems.

2.4 **Monitoring** of net zero new build progress has been undertaken using Energy Performance Certificates (EPCs), which assess efficiency. However, there are significant flaws in using EPCs for this purpose, as primarily an EPC rating is a measure of how much a home's energy costs, rather than how low carbon it is. In recent years, electricity has increasingly come from low carbon sources rather than coal, while electricity prices have remained more expensive than gas. As a result, an EPC rating's focus on cost has meant a low carbon, electrified home may get a lower EPC rating that one which actually produces more carbon.

2.5 **Gaps identified in the literature** which could be the focus of further research include: in-depth evaluations of small/medium scale examples of net zero building, including how they came about (e.g. finance, what enabled them), the barriers they faced during the process, and how the homes performed from environmental, occupant and registered provider perspectives. Further analysis could include: how have environmental targets adopted by the GLA and others affected local development and offset funds, and what lessons might this hold for meeting GM's incoming targets; what lessons can be learned from international examples of building at scale, including learning from success in Scandinavia and how they incentivised the market; specific barriers faced within GM.

2.6 TANZ Task Force members were asked to:

1. Note the contents of the review
2. Consider the following discussion questions:
   a. Taking account of the issues identified in the literature review, how should we approach monitoring the delivery of net zero homes?
   b. Do the barriers outlined in the paper resonate with your experiences of net zero housing development? How can these barriers be overcome?

Review of net zero housing development and the challenges of delivering at scale

This literature review seeks to inform the GMCA's commitment to achieve delivery of net zero carbon housing in Greater Manchester. It explores the term net zero housing, gives an overview of small-scale net zero building in Greater Manchester, England and beyond, and then looks at the barriers preventing this small-scale building from becoming larger scale. Finally, it looks at how net zero building can be monitored before detailing some potential gaps within the literature which might need further research.

1 What do we mean by net zero housing?

1.1 This review follows GMCA's Places for Everyone (2021a) report in defining net zero homes with reference to the UK Green Building Council's (UKGBC, 2019) net zero framework. For development up to 2028, Places for Everyone expects new homes to seek to be operational net zero.[1] In UKGBC's words, this means:

> *"When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."*

1.2 Places for Everyone explains this can be achieved, in order of importance, by:

a) minimising energy demand,
b) maximising energy efficiency,
c) utilising renewable energy,
d) utilising low carbon energy and
e) utilising other energy sources.

[1] Places for Everyone (GMCA, 2021a, p.85) also specifies specific targets, for 2021-25 and 2025 onwards, relating to reducing energy demand for both space heat and hot water, and for minimum levels of renewable energy generation.

1.3 In addition, beyond 2028, Places for Everyone (GMCA, 2021a, p.87) expects emissions from construction to also be net zero (UKGBC, 2019: *"When the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy").*

1.4 In the wider literature, the primary focus tends to be on building homes which are operational net zero *ready*. These homes have very low energy demand, use solely electrical energy from a renewable source *wherever possible*, and will be 100% renewable *once the grid is decarbonised* (Karampour & Burgess, 2022).

1.5 Typically, this requires adopting a fabric first approach which means properties are highly airtight and therefore need minimal energy to operate (primarily heat), as well as adopting low carbon technology wherever possible. Technology options include heat pumps, heat districts, locally sourced biomass, solar panels, mechanical ventilation with heat recovery (MVHR) and smart controls which optimise energy use (Karampour & Burgess, 2022). For more in-depth specifications, see Karampour & Burgess (2022) and UKGBC (2019).

2 Are there examples of net zero new homes which we can follow?

2.1 There are various English examples of small-scale net zero or low carbon development, but there is so far little evidence of this being achieved at scale. Most examples tend to be Passivhaus homes which have taken fabric-first approaches to minimising energy demand. Examples include:

- Greenwich: In 2019, Greenwich Council's Greenwich Builds programme set out to build 750 affordable rent net zero homes. 730 of these are now either completed or under construction, while up to 1,000 more may also be built as a result of their early success (RB Greenwich, 2022a). The initial homes built on larger sites tended to be modular builds, which can take just 4 days to assemble in a factory, and only 8 hours to erect onsite (Inside Housing, 2020a), and come fitted with solar panels and air-source heat pumps (e.g. see EPCs at Kyle Mews). Similar modular approaches have been adopted by Orbit Homes (a social housing provider) in the West Midlands and Sussex

(Inside Housing, 2022a), and Bristol & Worthing councils (Inside Housing, 2020b). The newly-announced 1,000 extra Greenwich homes may be on smaller sites and so use more traditional building methods (853, 2022). The homes are funded by a combination of grant funding from the Mayor of London, Right to Buy receipts and loans (RB Greenwich, 2022b). Skills shortages are reported to have been a factor in increased initial cost estimates for delivery (853, 2021).

- Exeter: Exeter began their first Passivhaus development in 2008 due to concerns about fuel poverty, and have since built more than 200 Passivhaus Standard council homes, with 1,000 more homes (half affordable) in the pipeline to be delivered between 2021 and 2026 (The Guardian, 2021; also see some examples here). Exeter's housing development team are now Passivhaus Certified (UK100, 2021). They are currently on their seventh generation of design (now "idiot-proof"; The Guardian, 2021). In 2018 analysis suggested there was an 8% cost premium associated with their preference for Passivhaus (Passivhaus Trust, 2019a), but this was forecast to drop and by 2021 the council said they can deliver Passivhaus homes "on sites of 100+ units at no additional cost". Homes are said to be low or net zero carbon (Exeter City Living, 2021), albeit this is not always reflected in EPC ratings, which tend to be B (possibly indicative of the EPC measuring system rather than an issue with the homes – see section 4 of this review for more details).
- Norwich: a development of 93 Passivhaus social homes in Norwich won the 2019 Stirling Prize (Passivhaus Trust, 2019b)), while another 112 were under development elsewhere in the city (Passivhaus Trust, 2019c).
- York: York have committed to building 600 Passivhaus homes by 2030, with development already underway on 220 homes (mixture of market sale, social rent, and low cost-ownership options) (Passivhaus Trust, 2021a). The project seeks to learn from Norwich's Stirling Prize winning new social development. Joseph Rowntree Housing Trust have also pioneered their mixed-tenure model village of 481 low carbon, biomass & gas district-heated homes in York

(JRHT, 2022), with the first homes completed in 2012 and found to have high resident satisfaction over a 6 year evaluation period (Quilgars et al., 2018).

- Leeds: 60 low-energy homes were built as part of Solar Avenue within Leeds' 1,000 home Climate Innovation District (Karampour & Burgess, 2022). The 60 homes are so well-insulated renewable energy can be used to charge shared electric cars via their community grid.
- Cambridge: The success of 18 Passivhaus social homes completed in 2022 has supported Cambridge's commitment to deliver all new council houses to Passivhaus standard (Karampour & Burgess, 2022). Several other projects across Cambridge should deliver almost 300 net zero homes in the near future.
- Other notable projects include:
    - 507 new Passivhaus homes being developed in Camden, around half of which are affordable (Camden CIP, 2021)
    - 226 new net zero homes in Barking & Dagenham, 55% of which will be affordable (Karampour & Burgess, 2022)
    - 81 Passivhaus homes being built in Newham (Passivhaus Trust, 2022a)
    - Milton Keynes Council's plan to deliver 115 net zero homes by 2024 (Karampour & Burgess, 2022)
    - A 187 mixed tenure home development in Bristol which was the first to reach the 2016 net zero standard when completed in 2014 (UKGBC, 2022a)
    - A pilot of 8 zero carbon (regulated emissions only – i.e. not appliances etc, which aren't impacted by building fabric) homes led to Oxford Council looking to build 2,500 in the next ten years (UK100, 2021)
    - Reading Borough Council introduced a policy which states "All major new-build residential development should be designed to achieve zero carbon homes", albeit this was amended after inspection to clarify the clause is "subject to viability" (UK100, 2021)

- More examples can be found here

2.2 Karampour & Burgess (2022) note several of these small-scale developments, but point out more in-depth evaluation of them is needed to understand how suitable they would be for scaling up.

2.3 Within Greater Manchester, there have been a few small-scale examples:

- 96 affordable Passivhaus homes in Salford, operated by Salix Homes and part-funded by Homes England and GMCA grants, are set to be completed by 2024 (Place North West, 2022). Salford is also home to Barratt's Z house – an advanced case study home, lived in by an academic to monitor its performance (Building Back Britain, 2022).
- 22 Passivhaus social homes in Manchester completed in 2021, including 2 which claim the title of "the first true net zero carbon social homes in the UK" (because they are both operational net zero and embodied carbon net zero) (One Manchester, 2021; UKGBC, 2021a).

2.4 Beyond England:

- Edinburgh Council has begun work on a 444 home development (44% social rent), which will eventually form part of a 3,500 home development by 2032 (Edinburgh Council, 2022). The project is in partnership with construction and manufacturing business CCG, who have developed an optimised range of house and flat types to achieve operational net zero (CCG, 2022).
- Glasgow's Newfield Square includes ten homes trialling different net zero methods such as Passivhaus to see which work best (Passivhaus Trust, 2021b).
- Welsh social housing must now meet an efficiency equivalent (such as Passivhaus certification or SAP) to an energy performance certificate (EPC) of A, using a fabric first approach (Passivhaus Trust, 2022b). 7 social homes were built to Passivhaus Standard in Powys in 2021 (County Times, 2021). Welsh RP Tai Tarian completed 61 homes in 2021-22, and all 61 were rated A (only one other RP in the UK built more A rated homes than this). They say

the cost compared with standard builds is less than £10,000 upfront per property (Inside Housing, 2022b).

- 597 Passivhaus social homes are being built on one site in County Dublin, Ireland, with work starting in 2022. It "will be the largest scheme in the world certified to achieve the 'passive house' low energy use standard" (DLRCC, 2022).
- Heidelberg's Bahnstadt district is one of the world's largest Passivhaus developments. Started in 2008 and due to complete in 2022, it will eventually have 3,700 homes (Heidelberg, 2022).
- Vauban in Freiburg has been described as "Europe's greenest district", with several clusters of around 50 homes built in the early 2000s all producing more energy from solar than they use (DBDH, 2019).
- Similarly, Vaxjo in Sweden has been christened "the Greenest City in Europe" (UBM, 2022), with a significant portion of the small city's homes built using Passivhaus techniques and low carbon heating (Green City Times, 2022).

3 Barriers to the adoption of net zero building at scale

A recent review by Cambridge Centre for Housing & Planning Research (Karampour & Burgess, 2022) highlighted a range of main barriers to the building of net zero homes at scale. The following section draws on their review, as well as additional sources, to detail the barriers which are likely to be faced within Greater Manchester. In short, likely barriers are:

- Meeting net zero standards requires a **higher initial capital cost**, particularly before widespread market adoption (though likely not as expensive as retrofitting later).
- Both **skills shortages** and **limited supply chain capacity** make timely delivery difficult and expensive, and mean what is delivered may be of lower quality, and so less energy efficient.

- A **lack of regulatory clarity** results in uncertainty, with developers generally aiming for the bare minimum.
- The **absence of successful large-scale net zero precedents or benchmarks to follow** brings a higher level of risk to developer decisions.
- There is **little consumer awareness or demand** for net zero living. When tenants move in, they may not like adapting to new technology and can struggle to run net zero homes efficiently.
- Increased electric demand from low carbon tech such as heat pumps, allied with renewables inputting surplus electricity to the grid, provides a short-term **challenge to grid capacity**.
- The **siting of net zero developments** can either be a barrier or an opportunity. By optimising the orientation, property type, shading, grey infrastructure and transport links of the new homes, the ideal siting can ensure new homes reach their maximum potential.
- New technology such as heat pumps and mechanical ventilation require a different skillset from those with responsibility for **maintaining new homes**, so without adequate training and preparation, this can be a barrier.

3.1 Costs of net zero building

3.1.1 Currently, building a home to net zero standards tends to cost more. The CCC (2019) have argued that the increase in costs is small enough that it should not be prohibitive to building, but Karampour & Burgess (2022) could find no conclusive study of net zero's impact on cost or affordability, while international literature reflects similar uncertainty over whether additional build costs can be made up for by increased sales prices (Souaid et al., 2020).

3.1.2 There are though several UK case studies which may give an indication of possible cost uplifts:

- UKGBC (2022b) looked at a 750-home low-rise development near Cambridge and estimated:

- meeting a 75-80% reduction in CO_2 emissions target would increase capital costs by 8%.
- meeting a 100% carbon reduction target would increase costs by 19%.

Significant upgrades to building fabric and additional building services (e.g. heat pumps, ventilation and solar) were the main cause of the cost increases.

- Looking at an 18-storey high-rise urban residential building, UKGBC (2020) estimated the capital costs of:
  - meeting LETI and RIBA's short-term net zero targets would cost 3.5% more than using business as usual methods.
  - meeting the more stringent 2030 LETI & RIBA targets would cost 5.3% more (and would also reduce the number of units possible).

  These extra costs primarily come from the frame (non-traditional concrete or timber), the air-source heat pump, and preliminaries/overheads/risk.

- Exeter Council estimated an 8% cost premium associated with their preference for Passivhaus (Passivhaus Trust, 2019a), but this was forecast to drop. By 2021, the council said they can deliver Passivhaus homes on sites of 100+ units at no additional cost.
- Welsh Housing Association Tai Tarian say building homes to EPC A standard cost less than £10,000 more upfront per property, when compared to a standard build (Inside Housing, 2022b).
- Vivid are among several registered providers currently exploring how much extra it costs them to build energy efficient homes, in comparison to potential retrofit costs (Inside Housing, 2022b), while Stockport Council have commissioned work exploring the potential bill savings of Passivhaus homes for different building types (UK100, 2021).
- Several guides aimed at reducing the cost of Passivhaus building are also available (Passivhaus Trust, 2019a; Passivhaus Trust, 2019d).

All of the above examples refer to costs in 2021 or earlier, and so are likely to have been impacted by recent inflation.

3.1.3 As the UKGBC 2030 LETI & RIBA compliant example above alludes to, building to net zero standards may also take up more space. For instance, ventilation, heat pumps and thicker insulation all require extra room and therefore leave less internal space (Baily Garner, 2021, as cited in Karampour & Burgess, 2022). The result is fewer units can be delivered per site.

3.1.4 The combination of these two aspects – higher build costs and fewer units delivered – will have an impact on both the viability of projects and their affordability once built.

3.1.5 The CCC (2019) have argued any increase in cost remains less than the future retrofit costs a business-as-usual build might later incur. Similarly, UKGBC (2022b) point out any developers retaining the freehold would incur retrofit costs which would be much higher than the short-term cost increase in initially building to net zero standards. Pick Everard (2020) suggest the average costs for a registered provider retrofitting to net zero standards is over £20,000 per unit. These costs might be lower for a new build, but it illustrates that in the long-term, factoring a net zero standard into initial plans is likely to be cheaper than retrofitting the same property later on.

3.1.6 As well as reduced retrofit costs, significantly reduced bills may also help to offset the initial increased capital cost (Karampour & Burgess, 2022). If energy bills remain very high for several years, this could represent a large incentive for both developers and potential occupants alike. UKGBC (2022b) suggest lower running costs mean higher initial capital costs “may be recoverable through either an improved yield or market rent and/or improved eligibility for green financial products such as home improvement loans or mortgages”.

3.1.7 Currently, DLUHC’s Affordable Homes Programme provides grants to support building of affordable homes, but since 2015 it has not included any consideration of net zero standards, nor likely future retrofit costs, within the programme. The National Audit Office (NAO) review of the programme has recommended the programme's next iteration should be clear how it contributes to wider government objectives such as net zero (NAO, 2022).

3.1.8 In the medium to long-term, it is expected costs associated with net zero building will reduce. Karampour & Burgess (2022) note early adoption of low carbon tech brings with it a cost premium, while UKGBC (2020, 2022c & 2022d) suggest build costs may be reduced a) as the market gears up to deliver more net zero homes, b) if hypothetical future government interventions provide greater financial incentives to use net zero methods and c) if circular economy principles are adopted.

3.1.9 UKGBC's most recent assessment (2022b) even goes as far as to say "any aspiration to deliver credible net zero carbon new-build homes at scale is reliant upon specific and targeted policy interventions to help stimulate the market for low carbon technologies, products, materials and construction practices", and that history suggests "a clear and consistent medium and long-term policy direction would give sufficient confidence to the market for the supply chain to invest in necessary solutions and the costs to drop substantially over the course of the decade ahead."

3.2 Skills shortages

3.2.1 As discussed, building net zero homes is reliant on achieving very high levels of airtightness and installing low carbon technology wherever possible. To do both to the required standards requires specific skills among project managers, engineers, technicians and builders.

3.2.2 As seen in the Greenwich and Orbit examples above (see section 2.1), using modern methods of construction (MMC) such as airtight prefabricated panels can often be a good option for low carbon homes. Research from CITB (2019) shows enabling MMC across England requires a different skillset from traditional methods, as well as a shift to more offsite workers. However, MMC do not require as many skilled workers in total (i.e. across onsite and offsite) as traditional methods would (CITB, 2019).

3.2.3 While MMC may reduce the number of skilled workers required overall, the skills needed for either MMC or traditional low carbon methods are still currently in short supply. Finding experienced, skilled staff is therefore difficult and will make delivering net zero builds harder (Karampour & Burgess, 2022). Limited availability of skilled staff may increase the time it takes to build (e.g. see the Greenwich example detailed above), and therefore risk the viability of a development.

3.2.4 Furthermore, inexperienced staff who are unfamiliar with the techniques and technologies needed may result in installations being lower quality, and therefore the homes less efficient (Karampour & Burgess, 2022).

3.2.5 A survey of the construction industry suggested "a lack of training, a lack of funding for training, regulation changes and a lack of standards" are responsible for the skills shortage (Eunomia & CITB, 2021, cited in Karampour & Burgess, 2022).

3.2.6 The same skills shortages also impact large-scale attempts at retrofitting buildings, as well as the (not necessarily low carbon) construction industry more widely. This means the skilled workers who are available are highly sought after, and may even mean in some cases housing providers could be competing with themselves for the same skilled staff. For instance, if a registered provider is both building new net zero homes and retrofitting its existing stock, both may involve the installation of heat pumps which only certain skilled workers can perform.

3.2.7 Based on current trends, the GM Retrofit Action Plan (GMCA, 2022a) estimates achieving our environment goals will be hindered by a 7,000 – 8,000 shortfall of construction workers over the next five years. There are various challenges to overcoming this shortfall, including appropriate qualifications not yet being set up in some specialities, specialist training equipment being very expensive (GMCA, 2022b), and the stop-start nature of government subsidies and initiatives, which has diminished trust in the pipeline of green opportunities (GMCA, 2022c).

3.2.8 Recent GMCA Industry Labour Market and Skills Intelligence Reports (2021b, 2022c) include a range of recommendations for beginning to respond to the skills shortages described here, while in 2023 new Local Skills Improvement Plans will set out employers' key priorities and changes needed in an area to improve post-16 technical education and training (GMCA, 2022b).

3.3 The supply chain has limited capacity

3.3.1 Much like with skills shortages, both high airtightness and low carbon technology often require specialist products which are not yet widely produced. Low carbon developers may therefore struggle to procure products such as heat pumps, mechanical ventilation with heat recovery or prefabricated panels.

3.3.2 The result of this can be delays in supply, which then cause delays on site and further increase building costs, again risking viability (Karampour & Burgess, 2022).

3.3.3 Until net zero housing is built at scale, the demand for these products is likely to remain relatively low, and so the supply chain may not have the capacity to cope with larger orders. As detailed in the costs section above, "a clear and consistent medium and long-term policy direction" would help to develop supply chain capacity (UKGBC, 2022b).

3.4 Lack of regulatory clarity leads to uncertainty, with bare minimum often aimed for

3.4.1 The government's Zero Carbon Homes Standard and Code for Sustainable Homes used to set standards for new builds efficiency. The Zero Carbon Homes Standard, first announced in 2006, would have committed new builds to being net zero, but was cancelled in 2015, the year before it was due to come into force (The Guardian, 2015) (note Hanham Hall in Bristol, detailed in section 2.1, met this standard in 2014, prior to its cancellation). At the same time, the complementary Code for Sustainable Homes was made just voluntary (MHCLG, 2015).

3.4.2 The CCC (2019) suggests this has led to only the bare minimum standards being implemented. SAP 10.2's improved, but still relatively minimal, efficiency standards came into force in June 2022, while the Future Homes Standard is expected to be more stringent, but will not be implemented until 2025. In the absence of clear targets or agreement on what successful net zero homes would look like, it is difficult for developers to know what to strive for (Karampour & Burgess, 2022).

3.4.3 The UKGBC has recommended a set of requirements (including minimum and stretch versions) which local authorities should adopt (UKGBC, 2021b). Places for Everyone's targets do not yet match these requirements, but some areas have already set stricter targets for development. For instance, the GLA has stipulated all large residential development should be net zero since 2016, though one option was to pay into a carbon offsetting fund (GLA, 2021a).

3.4.4 However, a lack of clarity on what requirements councils can make has made this more challenging for other areas (UKGBC, 2021b; CPCA, 2021). Further research would also be needed to determine the results of the stricter targets adopted by the GLA, to understand whether developments have typically complied with the regulations, or whether they have opted to pay into the offset fund.

3.4.5 UK100 (2021) argue the option of offset funds "allows buildings to be constructed to lower energy standards creating future problems of inefficiency, and moves the issue away from good design onto finding suitable other sites for emissions reduction, which will at some point run out." International literature acknowledges similar difficulties have been faced across Europe, but also notes the reverse – overregulation – can become a barrier to innovative methods (Souaid et al., 2020).

3.5 A lack of precedents or benchmarks to follow

3.5.1 The lack of regulation, small supply chain and lack of experienced workers all contribute to the lack of precedents for designing and implementing a net zero new build. It is not well known what approaches work best, and which examples should be followed.

3.5.2 Without clear guidelines, obviously leading suppliers or experienced workers, developers are having to make bold decisions without sufficient evidence to guide them. They cannot be sure which low carbon technology is likely to work best within the specifics of their project, nor be confident that they will not run into unforeseen problems.

3.5.3 The result is that each of the choices they make about their designs come with a higher level of risk than they otherwise might (Karampour & Burgess, 2022).

3.6 Consumer behaviour and satisfaction

3.6.1 There are two related factors concerning consumers which act as barriers to building net zero homes at scale.

3.6.2 First, there is low awareness of the potential for net zero housing, which means there is limited consumer demand for it to be built (LETI, 2021, cited in Karampour & Burgess, 2022). This means that although there may be many benefits to living in a net zero home (for example lower bills), this may not translate as easily into consumer preference to choose these homes over similar (perhaps slightly cheaper or more familiar feeling) homes. Research from Ireland even suggests low carbon building methods such as timber frames and prefabricated panels may sometimes be stigmatised as low-quality as a result of low quality building in the past (Souaid et al., 2020).

3.6.3 Secondly, low awareness of net zero carbon homes leads to a risk that new occupants do not understand how best to run their home efficiently (Karampour & Burgess, 2022). Inefficient operation of the home may lead to higher bills for occupants, higher net emissions from the home and potentially dangerous hazards in the home such as lack of warmth, overheating or mould. Not only may these hazards impact consumer satisfaction with the property, but this dissatisfaction may also spread by word of mouth and damage the viability of similar homes within the development or elsewhere.

3.6.4 This factor can be limited if occupants are made aware of the importance of correct operation of the various factors within the home (e.g. see lessons learned for heat pumps in Scotland here and here), but more research about how to successfully teach this and change long-formed habits may be needed (Karampour & Burgess, 2022).

3.6.5 The aforementioned potential for cheaper energy bills could also positively impact consumer satisfaction. One aspect which would increase the potential cost saving for residents is if green levies were shifted away from electricity bills and more onto gas bills. As net zero ready homes seek to use only electricity rather than gas for energy, the disproportionate focus of green levies on electricity bills penalises this choice, and has resulted in calls from various sources for the burden to be placed solely on gas prices (e.g. NHF/LGA/Parity, 2022; Nesta, 2022; CCC, 2022). By obscuring the potential cost savings from a net zero property, the current price distortion acts as a barrier to net zero demand.

3.7 Grid capacity

3.7.1 Net zero's focus on using solely electrical energy presents a challenge to grid capacity, which may also be a barrier to building such homes at scale in the short-term (Karampour & Burgess, 2022). Using electricity for heating (as well as potentially travel) may mean higher electricity demand than a typical gas-heated house, while renewables supplying excess energy back to the grid can also present a challenge to the existing grid.

3.7.2 Resolving this will require upgrades to the grid and collaboration with various stakeholders when sites for large-scale net zero homes are identified.

3.7.3 If local, micro generation from sources such as solar or wind are embedded across a whole development, it may also be that local grid networks can provide a solution to this problem. GM's Local Energy Market and ten Local Area Energy Plans should inform and support GM's ability to respond to this challenge (see GM Green City, 2022 for further details).

3.8 Siting

3.8.1 Design at masterplan level is crucial to responding to this electricity demand and minimising emissions in each home. The siting and orientation of each home can often be neglected, but has a significant impact (Karampour & Burgess, 2022). Important factors include:

- Home and access orientation: ideally access to homes should run east/west, so that homes can have south facing rooves, ideal for maximising energy from solar power. Main windows should not point west to minimise unwanted solar gains on summer evenings which might cause overheating.
- Property type: terraced housing and apartment blocks are typically more efficient envelopes than detached or semi-detached homes. See UKGBC's recent report (2022b) for an in-depth comparison of different property types.
- Shading from trees: in winter, well-placed trees can protect from cold winter winds and ensure solar gain through south-facing windows, while in summer, the shading they provide can prevent overheating.
- Minimising grey infrastructure: minimising roads and hard surfaces can have a big impact on emissions.
- The aforementioned reduced space per site (due to thicker insulation, heat pumps etc – see 3.1.3) can be counteracted by reducing car parking spaces (with strong public transport links to support this).
- Well-connected areas: as with any new development, large-scale net zero developments must be both attractive to residents and promote sustainable lifestyles. This means excellent active and public transport links, local amenities and green space are all important.

3.8.2 Considering these factors when planning sites may help to maximise the low carbon potential of new developments.

3.9 Maintenance

3.9.1 Maintenance of net zero homes will require a different approach to ensure the proper working of these homes (Karampour & Burgess, 2022).

3.9.2 Registered Providers in particular may need to retrain staff to maintain heat pumps rather than boilers, for instance. While much of the low carbon technology should generally function without too much attention, mechanical ventilation with heat recovery may need more regular attention and cleaning than current maintenance schedules provide (e.g. filters changing every 6 months).

3.9.3 While this challenge may not appear until building at scale has been achieved, the aforementioned skills shortage means that providers will need to plan for the challenge in the near future.

4 How can we monitor new net zero homes progress?

4.1 All new build homes must receive an Energy Performance Certificate (EPC) which assesses energy efficiency. As a result, EPCs are often used to measure progress towards building more net zero homes (e.g. see this recent Inside Housing article). EPC ratings range from A (best performing) to G (worst performing).

4.2 However, there are risks to using EPCs for this purpose. Primarily, an EPC rating is a measure of how much a home's energy costs, rather than how low carbon it is. In recent years, electricity has increasingly come from low carbon sources rather than coal, while electricity prices have remained more expensive than gas. As a result, an EPC rating's focus on cost has meant a low carbon, electrified home may get a worse EPC rating than one which actually produces more carbon (Etude, 2021). EPC ratings also don't take into account unregulated energy use such as kitchen appliances or IT equipment (Etude, 2021), while anecdotal evidence suggests the EPC rating for low carbon homes can depend on the assessor's interpretation, and that ensuring factors such as the correct model of heat pump are inputted may make a significant difference. See FCE (2019) for more on EPC ratings bias against heat pumps in particular.

4.3 There are numerous examples of homes that are purported to be net zero which do not receive an A rated EPC. For instance, homes in Solar Avenue in Leeds' Climate Innovation District claim to be so heat efficient that small electric radiators are sufficient for heating individual rooms (Citu, 2022), but they tend to receive a B EPC rating, with their heating described as "very poor" (see this EPC, for example). Likewise, Manchester's Blackrock Street development aims to meet Passivhaus fabric performance standards (UKGBC, 2021a), but these homes also received a B EPC rating (see the EPCs here which expire in 2031, for example).

4.4 Given the above, if GM uses A rated EPC certificates to track delivery of new net zero homes, there is no guarantee that homes built to ambitious net zero standards will be included within this measure.

4.5 Another option might be using the environmental impact (EI) rating, which is also included within an EPC certificate and focuses not on cost but on emissions. Until recently, outdated carbon factors meant electrified heating received a much worse EI rating than gas heating (FCE, 2019), so EI has not been widely used. The introduction of SAP 10.2 (a new version of the Standard Assessment Procedure used to calculate EPCs) should mean some improvement, because carbon factors used to reach the rating now better reflect the increasingly renewable energy which produces electricity. However, as these carbon factors are static, there is no guarantee they will not become outdated again as the grid is further decarbonised (Etude, 2021). Several of the other issues outlined in section 4.2 also still apply. SAP 11, set to be introduced in 2025, may resolve these issues when it arrives, with a recent BEIS-commissioned report recommending measuring net zero ready new homes becomes "SAP 11's primary function" (Etude, 2021).

4.6 While EPC rating in its current format may not be ideal, some of the supporting data contained within the EPC assessment might still give a useful indication. Monitoring the main heating method and/or fuel of new builds (via data collected as part of the EPC), could be an alternative which would indicate whether new builds are increasingly low carbon (e.g. see this news report, based on ONS data originally sourced from EPCs). Tenure data is not usually available for new builds within the EPC, so focusing on social housing alone may require an additional complementary data source.

4.7 The Standard Assessment Procedure (SAP) which produces an EPC rating once a home is built is also required during the planning stage to meet Part L Building Regulations. SAP includes a Dwelling Emission Rate measure which is not influenced by energy costs (much like the EI rating above), and which should now use representative carbon factors (though they may become outdated). It may therefore be used to assess emissions reductions at the planning stage. For example, the GLA has reported London's progress using information from the energy assessment they require as part of all major planning applications (GLA, 2022a). As this was prior to the introduction of SAP 10.2, they also instructed assessors to use more up to date carbon factors in some cases, rather than the outdated SAP 2012 factors which could have encouraged installation of high-carbon systems (GLA, 2021b).

4.8 The GLA has also recently decided to monitor actual ongoing emissions for a home's first 5 years, rather than theoretical emissions at the planning stage or at build completion, as part of the "Be Seen" element of the 2021 London Plan (GLA, 2022b). Public reporting on this data does not yet seem to be available, but this could be an alternative to explore further. Similarly, in Wales, the increasing prevalence of smart meters within social housing recently led to calls for their use in determining actual rather than theoretical net zero performance (LABM, 2022).

4.9 If a commitment were made to make all new homes achieve Passivhaus certification, another alternative may be to monitor these certificates. Some data on this is available publicly (e.g. see here) and shows clear clusters in places such as Exeter where councils have committed to Passivhaus building. However, some potentially compliant developments (e.g. Blackrock Street) may be put off applying for accreditation by the cost, even if they might meet the necessary standards.

4.10 There remains general consensus across the literature and local authorities that, whilst EPCs are not without fault, they provide the most accessible and timely dataset through which to monitor energy performance of housing stocks. Nonetheless, given some of the issues, future developments and alternatives suggested above, and the limited information this review was able to find on the subject, further research and discussions on how net zero developments are being tracked elsewhere may be beneficial.

5 Gaps in the literature

5.1 Potential gaps in the literature where more research could help include:

- In-depth evaluations of small/medium scale examples of net zero building, including how they came about (e.g. finance, what enabled them), the barriers they faced during the process, and how the homes performed from environmental, occupant and registered provider perspectives
- How to move from small scale net zero building to large scale
- How have environmental targets adopted by the GLA and others affected local development and offset funds, and what lessons might this hold for meeting GM's incoming targets
- What lessons can be learned from international examples of building at scale, (including learning from success in Scandinavia and how they incentivised the market) and how might they translate to GM's context
- Specific barriers faced within GM
- How many net zero homes there are in England, and how they may be reliably measured in future
- How much overlap is there between skills shortages in retrofit, new build and general construction