Bioregional
Championing a better way to live

A2Dominion
Elmsbrook monitoring 2020-21:
Data on water, waste and energy use on site

Final report

November 2021

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Executive summary

This report forms the fourth in a series of monitoring reports to track the real-life performance of the UK's first ecotown. Known as Elmsbrook and part of the NW Bicester masterplan, the development was designed to the original Ecotown Planning Policy Statement – PPS. The development is to this day one of the most comprehensively monitored with data on travel, energy, water, waste and a range of other sustainability indicators collected as part of the planning requirements.

Some 241 homes are now occupied over phases 1-3, making for the largest dataset we have had since reporting started. As before there are some issues around data collection, with older monitoring equipment providing incomplete or patchy data sets. However, the data that is provided is becoming more robust, as 'bedding in' effects are reducing, and people are starting to embrace greener, more sustainable lifestyles.

The monitoring process has been benefiting immensely from improved reporting processes too. Future phases for example are now fitted with higher specification meters and more robust equipment. App development has allowed stakeholders to view their energy and water data more readily (in real time), assisting behaviour change and helping to highlight out of range readings. These systems are helping households and landlords to become 'smarter' over time, but do require engagement with the technology so other modes of feedback are important too.

Energy and carbon performance are highly dynamic processes. This year it looks like the overall performance of the development has not achieved its true zero carbon aspirations. Elmsbrook does however still provide large savings compared to other new build developments. This year's carbon balance has been impacted by a range of factors, some data related, others operational, none more so than the global pandemic, with more people staying at home (working or furloughed) having a significant effect on heat use for example.

Encouraging sustainability performance has been observed for electricity and water use. Annual average electricity use per household in 2020/21 stands at 2,964kWh, all but meeting the energy efficiency design target and saving 29% compared with the Bicester wide average. Water use on Elmsbrook is just a few % above the design target of 80 litres per person per day (compared to UK average of 150 litres per person per day). Total waste generated per household has remained largely the same, increasing marginally in 2020-21 by 2% compared to 2018-19 from 579kg to 591kg. The recycling rate stands at 62%, compared to 56% for the district, 58.8% for the county, and 45.5% for England (2019 national figure).

Heat and hot water demand at Elmsbrook was slightly higher than in previous years. On average Elmsbrook residents used around 24% more energy for heating and hot water than the design stage estimations, but they used around 55% less heat than their neighbours in Bicester, 64% less than the UK average, and some 40% less than the average post-2017 new build home. The effects of lockdowns and more time spent at home may have contributed to the heating energy performance gap relative to the design target, and the increase compared to previous years.

Feedback from the annual resident survey continues to be encouraging. People in Elmsbrook rate their health and happiness highly (83% rate their health good to very good; 71% felt happy), and many indicate a strong sense of community, as well as many reporting that they value the environmental friendliness of the development. Buying demand for these ground-breaking new homes is continuing to be very high, demonstrating that a more sustainable, healthy lifestyle within a fair share of the earth's resources is both viable and desirable.

Ongoing monitoring ensures that all of this learning (from design, construction to occupation) finds its way back to the decision makers and stakeholders at all levels. Feedback can influence lifestyle choices (i.e. residents), construction processes (i.e. the delivery team) and planning considerations. Effects can ripple out further to inform how other developments are designed and built, both nearby in the same local planning context and also more widely across the UK. In this decisive decade for climate action to stabilise global temperatures, Elmsbrook continues to show that net zero carbon developments are not only viable and important, but they are also popular too.

1 Introduction

This report has been prepared for A2Dominion by Bioregional and consists of the fourth set of monitoring results from Elmsbrook Ecotown development in Bicester. Monitoring is now bi-annual. This report covers a period of 12 months (April 2020 to March 2021) and includes data from 151 dwellings, 4 from the first phase of development, 68 from the second phase and 79 from the third. Information was collated from two main data sources, a survey questionnaire providing qualitative data, and from monitoring equipment (e.g. the shimmy) providing quantitative data. Other supplementary data sources complete the picture around waste and communal energy. While the number of full data sets (full year's worth of data) have been increasing and bedding in effects are diminishing, some monitoring equipment issues have resulted in data loss (mainly phase 1). While earlier phases generally include 365 days of data, some phase 3 dwellings were occupied for less due to recent move ins.

Technical issues around the meters and PV system on phase 1 have meant that some data was not collected correctly, even though a full year should have been available. The flat blocks share a communal roof space and their PV arrays are still not sub metered. As in the previous years, some PV inverters were tripped and others switched off at the isolator (unknown reason) resulting in generation failure. For this reason, the total electricity figure (as derived from a formula of generation, export and import) cannot be accurately reported for plots affected by these issues, reducing the available (and accurate) data set.

The COVID-19 pandemic has impacted residents' day-to-day lives, with a shift to more time spent at home reflected in the survey and wider studies. This is likely the reason for an increase in average household annual energy use and carbon emissions increased across Elmsbrook. Further, residents' consumption patterns have shifted, with increased use of home deliveries. Transport patterns are not covered in this report in detail, and are analysed in a report by Mode consultants, which should be published shortly. Data in this report is generally presented by theme, with a summary paragraph outlining headline figures in bullet point format, with further information on the data and analysis in the section below followed by results in graphical form. Conclusions and recommendations tie all chapters together, providing a summary of the headline findings and make recommendations for improvement.

2 Overview of the site

2.1 Environmental standards

Elmsbrook is the first phase of North West Bicester, the UK's first eco-town and will eventually include 393 homes, a primary school, community centre, an eco-business centre and local neighbourhood shops. The development included the following environmental features or standards:

- All homes built to Code for Sustainable Homes level 5, incorporating triple glazing, mechanical ventilation (MEV or MVHR) and rainwater harvesting
- PV solar panels on every home
- Energy centre featuring combined heat and power (CHP) plant providing space heating and hot water via district heating to all buildings on site
- Cycle and pedestrian routes, a bus stop within 400 metres of every home, live timetable updates in each home, charging point for electric vehicles and an electric car club
- 40% of the site is open space, with a net biodiversity gain targeted
- Water efficiency target of 80 litres/person/day
- One Planet Living framework & action plan

2.2 House types, tenure and phasing

Elmsbrook consists of a mix of 1-5 bed detached, terraced, semi-detached properties and flats. The development is made up of four phases, of which the first phase has been occupied for over five years, the second phase has been occupied for over 3 years and parts of the third phase for around 1-2 years (some part occupied) with phase four still currently being constructed (no data). Further detail of the housing type and tenure for phases 1 to 3 is outlined below in table 1.

Table 1- House types and tenures by phase.

Phase/ tenure	Detached units	Terraced units	Flats	Semi-detached units	Bungalow
Phase 1 – 87 dwellings occupied (Fully occupied, data for 4 dwellings due to monitoring equipment issues)					
Private	12	26	0	4	0
Affordable	0	9	18	4	3
Shared ownership	0	7	6	5	0
Phase 2 – 71 dwellings occupied (Fully occupied, full data)					
Private	12	47	0	4	0
Affordable	0	0	4	0	4
Shared ownership	0	0	0	0	0
Phase 3 – 90 dwellings occupied (Partially occupied, partial data)					
Private	36	30	0	0	0
Affordable	0	19	0	0	0
Shared ownership	0	5	0	0	0
Total dwellings - 255 [Of which occupied – 241]	60	143	28	17	7

3 Overview of the data

This report has been collated as part of a desk-based study with a small component of on-site data collection (e.g. meter readings taken on site) by Bioregional.

3.1 Sources of information

All data sources featured in this report were provided by A2Dominion and their partners for the purposes of monitoring agreed planning conditions. These include:

- In house residential monitoring – 'shimmy' data (Carnego)
- Waste data (Cherwell District Council)
- Resident survey (A2Dominion)
- Energy centre data from Scottish Southern Electric (SSE)
- Gagle Brook Primary School meter readings (White Horse Federation)
- Eco business centre (TownSq)

3.2 Data analysis

The shimmy dataset comprises the primary information source of this study. Prior to submission Carnego undertook an initial quality check of all readings to eliminate data issues. Bioregional then undertook some secondary analysis to detect further likely anomalies. This included a high-level sensitivity analysis using conditional formatting in excel, to highlight any anomalies significantly above or below the expected numerical averages. The data provider (Carnego) was then approached to comment on any detected, potential issues.

A very small number of unresolved issues remain, such as very high daily energy readings (less than 5 individual days' worth of data). Some issues remain unexplained even after querying them with Carnego e.g. current spikes in the monitoring equipment from nearby electrics, loose cable connections or server restart issue are hard to resolve remotely without accessing properties.

After this data screening and adjustment exercise, further detailed analysis was carried out in Microsoft Excel to produce a range of graphs using pivot functions.

3.3 Data quality and limitations

Several important points should be noted when reviewing the data.

1. Shimmy data (water, heat, PV, electric export, electric import) was submitted as daily figures, hourly or even minute-by-minute readings are available on request from Carnego.
2. The flats share a communal roof space and PV array which is not sub metered (landlord supply). Therefore, only data on water, electrical import and heat can currently be collected for these types remotely.
3. As with the flats, the school and Eco business centre are not sub metered via the shimmy system and so electricity and PV estimates are derived from manual meter readings. These manual readings are less accurate as they don't cover the exact monitoring period.
4. Suspected technical issues on PV inverters and some metering equipment have caused data loss and anomalies which have impacted the quality and cover of data. A large proportion of the older meter equipment in phase 1 seems to be affected in this year's reporting.
5. We have attempted to reconstruct missing data through extrapolation of averages in some cases (e.g. to answer the net zero carbon question), which affects the accuracy of results.
6. Problems with unplugged shimmy monitoring systems have impacted rented properties on site. A2Dominion head office arranged for a third-party provider to set up remote Feed In Tariff reporting which resulted in some meters being unplugged accidentally. Bioregional requested but did not get access to this third-party data for this year's reporting.
7. Phase 3 data nominally covers a full year, however only 62 properties (out of 90) provided 360 + days of data, due to late (or part) occupation with staggered move-in dates. Working out site wide averages is therefore further complicated.
8. Because of data protection issues (GDPR), no exact information was available on the number of persons per household, so an estimation was required to determine water consumption per person. Designed occupancy numbers were taken from the A2D schedule of housing and adjusted using statistical occupancy information by tenure.

4 Detailed results – 'shimmy' system

This section outlines the detailed results collected from the 'shimmy' system installed to households, the primary data source of this post occupancy study. For each reporting category, results have been set out in summary form (or the headline findings) followed by further information (containing specific details) and graphs. Results are expressed in both absolute terms and normalised by per square meter (or per person), to allow for easier comparison between house type etc.

4.1 Water

Buildings on Elmsbrook are designed to be water efficient through use of low flow taps, smaller baths, low flush toilets and rainwater harvesting.

Summary:

- The average daily household water consumption figure over the latest monitoring period was 246 litres per day (all phases).
- This compares to 227 litres in 2018-19, 375 litres in 2017/18 and 192 litres in 2016/17. (Period average: 2016-21 = 260 litres per household).
- The estimated average per person water consumption over the monitoring period was 83 litres per day. This is 4% above the design target of 80 litres . The average water use in the UK is currently 142 litres per person per day .
- This compares to the average daily water use per person of 84 litres in 2018-19, 151 litres in 2017-18 and 76 litres in 2016-17 (Period average: 2016-21 = 99 litres per person).
- On average 54% of households on Elmsbrook meet their water use targets of 80 litres per person per day.
- For an average household of 2.4 people, water savings equate to roughly 140 litres every day as a result of water efficient design measures and behaviour choices.

Table 2 – Elmsbrook water consumption, year-on-year comparison.

	Average daily per person (*litres/ day*)	**Average daily per household** *(litres/ day)*
2020 - 2021	83	246
2018 - 2019	84	227
2017 - 2018	151	375
2016 - 2017	76	192
Average 2016-21	**99**	**260**
Design target	80	Na
UK average	142[1]	Na

Further information:

[1] https://discoverwater.co.uk/amount-we-use

- From an estimated 241 occupied households on Elmsbrook (at time of writing), 151 households had their water use logged consistently through the shimmy system.
- Of these 151, four were located in phase 1, 68 in phase 2 and 79 in phase 3. 137 had good data of more than 360 days, the remaining were likely recent move ins with part occupation.
- 104 dwellings suffered other forms of monitoring issues, with 86 of those outages in phase 1 properties. Post analysis note: Carnego investigated the issue and informed Bioregional that a further ~30 data sets could likely be reconstructed which unfortunately didn't make the cut off date for incorporation into the report.
- Per person water usage has remained stable (~1%) compared to the previous period. This is despite (expected) effects from the pandemic, such as increased homeworking and hygiene requirements.
- As in previous years, no detailed information was available on the number of persons per household (required to calculate per person use), so designed occupancy numbers were taken from the A2D schedule of housing and statistical occupancy information was applied (e.g. average number of empty bedrooms by tenure) summarised in table 2.
- Household water use has increased slightly (~8%) from the last monitoring report. In part this is possibly explained by changes to housing mix, as more phase 3 dwellings have come online since the last reporting period (e.g. increased number of larger dwellings and no flats).
- The school's water data is unavailable because the BMS system is still not set up correctly. The school uses rainwater harvesting to flush its WC's, so water use is expected to be below average.
- The Eco business centre logged 132m^3 water use over 670 days. This works out as about 69m^3 over the monitoring period or 68,927 litres.
- The first four graphs below show the average daily household and per person water use (all phases), categorised by house type and number of bedrooms (Figure 1 and 2).
- Figure 3 shows the same results for per person water use collated and sorted, to capture the entire range of data.
- The last two graphs show the percentage of homes meeting the water target of 80 litres per person in two different categorised by number of bedrooms and house types (Figure 4 and 5).
- Table two provides a summary of water use over previous monitoring periods and compares that to the UK average.

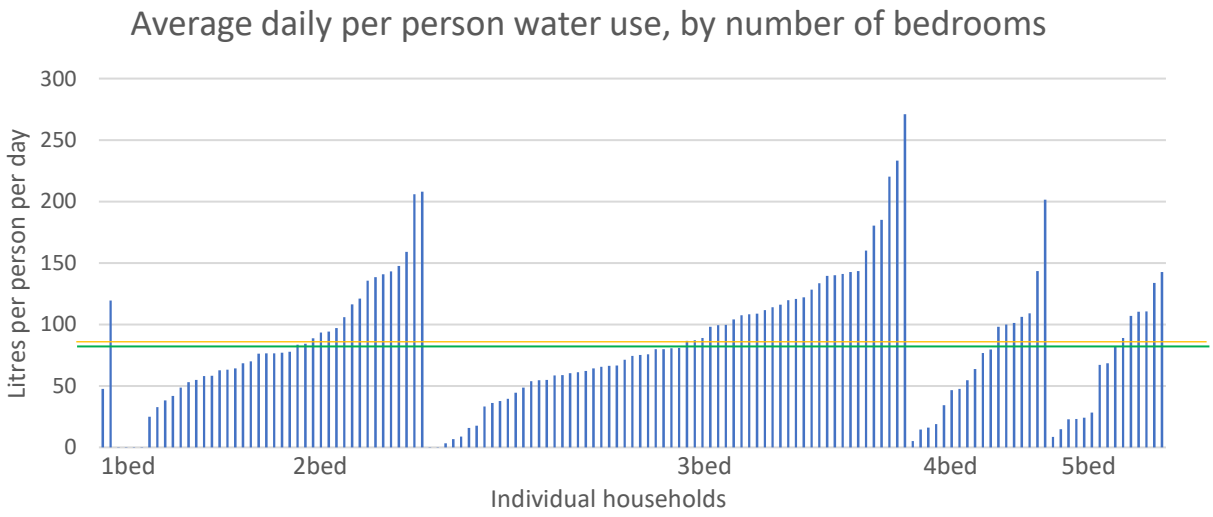

Figure 1- Average daily per person water use, by number bedrooms (all phases). Blue bars = actual per person water use in litres. Orange line = average all households (83 litres), Green line = target per person value of 80 litres.

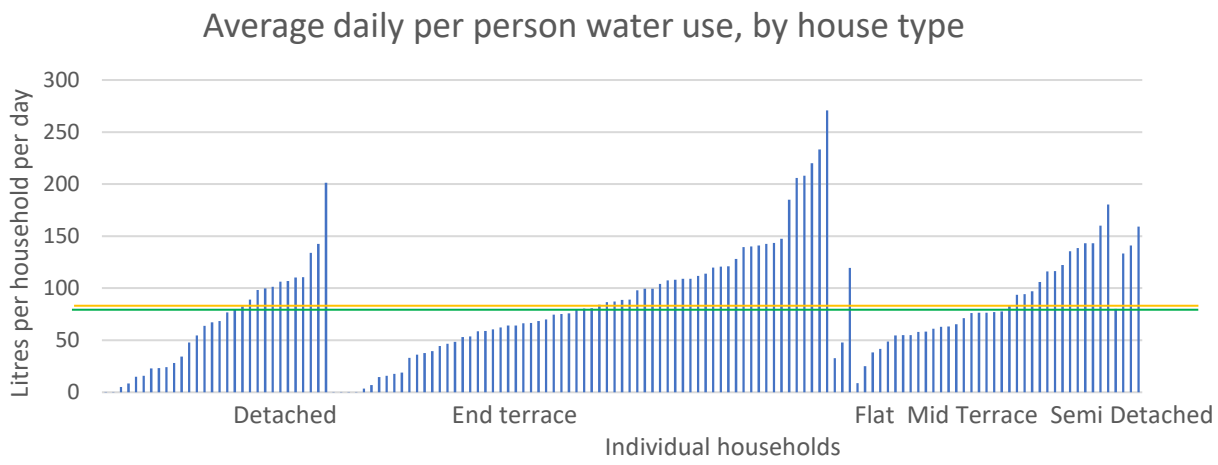

Figure 2 - Average daily per person water use, by house types (all phases). Blue bars = actual per person water use in litres. Orange line = average all households (83 litres), Green line = target per person value of 80 litres.

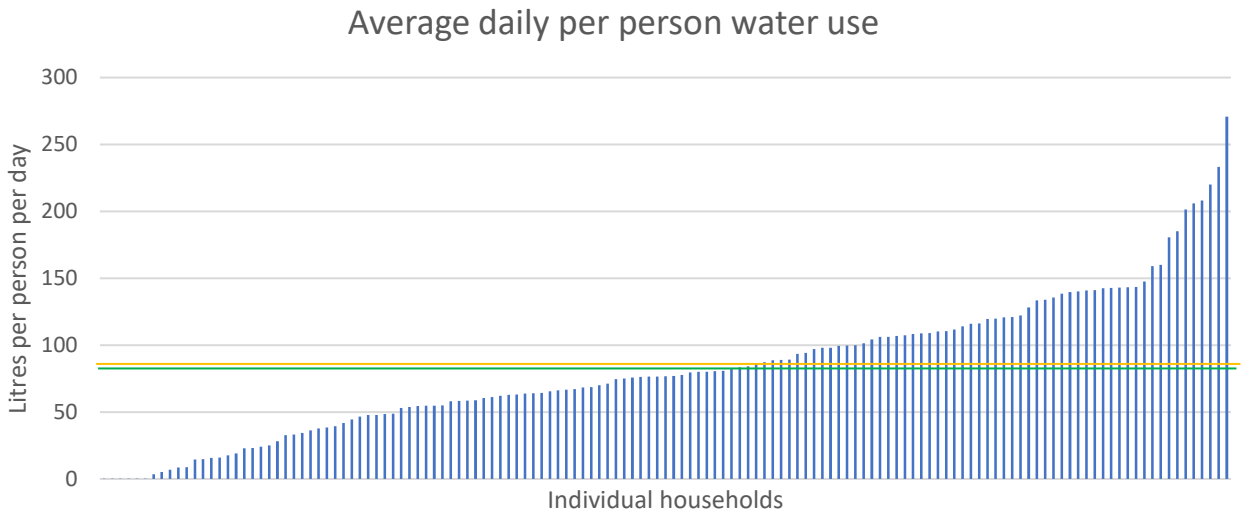

Figure 3 – Average per person water use (all phases). Blue bars = actual per person water use in litres. Orange line = average all households (83 litres), Green line = target per person value of 80 litres.

Table 2 – Assumed occupancy average for per person water usage.

	Flats	2B	3B	4B	5B	Bungalow
Designed occupancy	3	4	3	6	9	3
Assumed occupancy	1.7	2.4	3	3.8	3.8	3

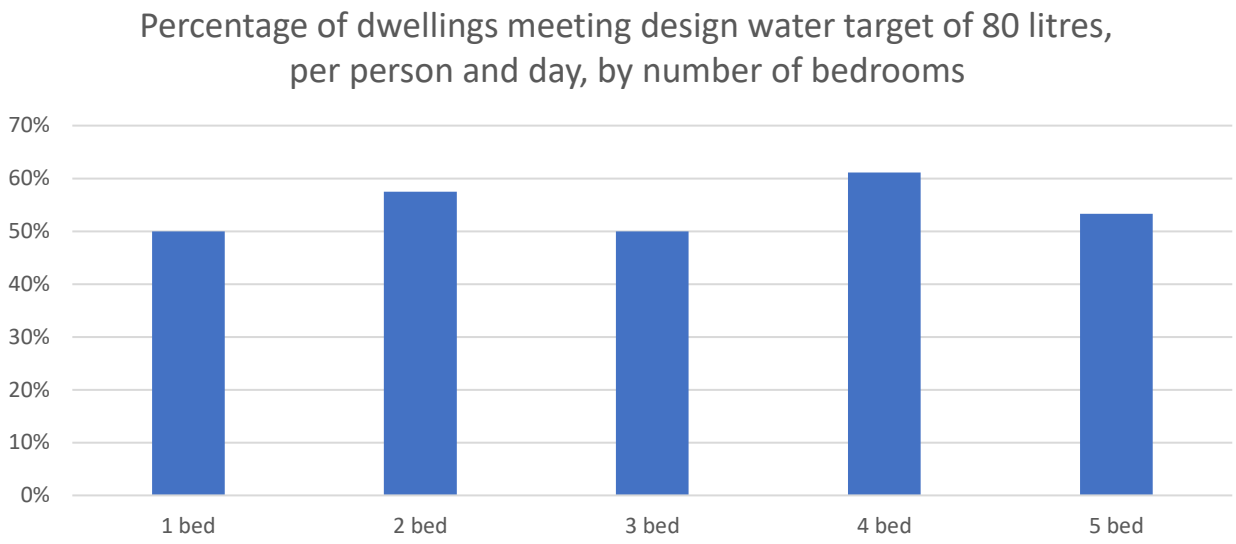

Figure 4 - Percentage of dwellings meeting their design water use target of 80 litres per person per day, by number of bedrooms. Site wide phases 1, 2 and 3.

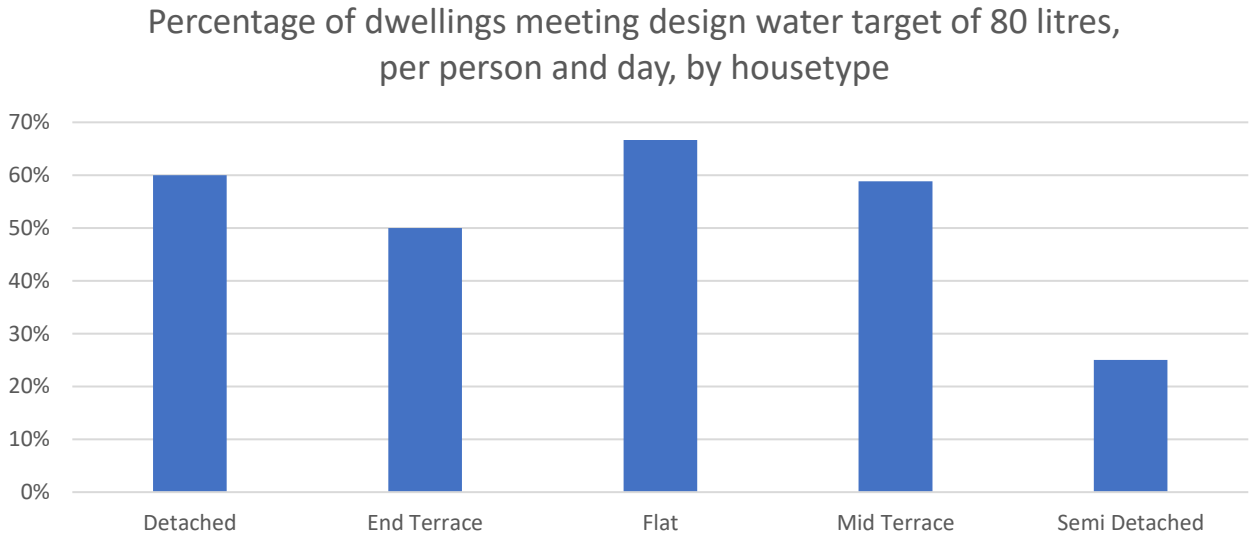

Figure 5 - Percentage of dwellings meeting design water target of 80 litres, per person, per day, by house types

4.2 Electricity

Buildings on Elmsbrook are designed to use less electricity, which is achieved by maximising natural light, energy efficient lighting and efficient electrical appliances. On top of that, each house utilises its roof space carefully to generate electricity from photovoltaics (PV). Sub metered energy data from PV generation, import and export can then be used to calculate the electricity consumption for each dwelling.

Summary:

- Over the latest monitoring period the average annual household electricity use at Elmsbrook was calculated as 2,964kWh.
- This compares to 2,631kWh in 2018-19, 2,550kWh in 2017-18 and 3,122kWh in 2016-17 in the previous monitoring periods (Period average: 2016-21 = 2,817 kWh/a).

- While electricity consumption rose 13% from the last report, the increase could relate to time spent at home during the pandemic. The BBC reported figures from Bulb energy firm showing an increase of 17%[2] in weekday domestic electricity use during the pandemic.
- The design stage benchmark figures for average electricity consumption were calculated as 2,932kWh annually (or 30.79kWh/m^2).
- On average Elmsbrook homes matched the design stage electricity targets very closely (~1% difference). 81% of households remained within this design target.
- Bicester's annual household electricity average as of 2019 is 3,835kWh[3] (4,311kWh in 2015), meaning that Elmsbrook residents used ~29% less electricity than their neighbours in Bicester. The UK average is 3,545KWh.
- In the same period Gagle Brook school used 35,167 kWh, which is 5% of the total electricity used on site.

Table 3 - Electricity use summarised by monitoring period

	Average annual electricity consumption per household *(KWh)*
2020 - 2021	2,964
2018 - 2019	2,631
2017 - 2018	2,550
2016 - 2017	3,122
Average 2016-21	**2,817**
Design target	2,932
Bicester average 2019	3,835
Bicester average 2015	4,311
UK average	3,545

Further information:

- Please note, electricity use has been calculated from sub metered shimmy data using the formula PV + import – export = total electricity used.
- When one of those sub metered data sets is missing, electricity use cannot be calculated accurately, and estimates incur a margin of error.
- PV on communal roofs (e.g. the flat blocks) usually only covers the landlords supply and requires meter readings which is less accurate than the shimmy. Flats electricity usage is therefore only generated from import readings.
- From an estimated 241 occupied households on Elmsbrook (at time of writing), 125 households had their electricity usage logged consistently through the shimmy system (more than 360 days data). Of these 125, four were located in phase 1, 60 in phase 2 and 61 in phase 3.

[2] https://www.bbc.co.uk/news/technology-52331534

[3] Calculation based on data from: 2021, (BEIS). Postcode level electricity statistics: 2019 (experimental). (Online). Available from: https://www.gov.uk/government/statistics/postcode-level-electricity-statistics-2019-experimental. Date accessed: 20/09/2021.

- 130 dwellings suffered other forms of monitoring issues, with 86 of those outages in phase 1 properties. Post analysis note: Carnego investigated the issue and informed Bioregional that a further ~30 data sets could likely be reconstructed which unfortunately didn't make the cut off point for incorporation into the report.
- The school used 35,167 kWh of electricity over the monitoring period, of that only 17,846 kWh was imported from the grid.
- The Eco business centre had its meter replaced just ahead of the scheduled meter readings, which resulted in zero usable data. An estimate based on the Passivhaus plus design targets suggests electricity usage of about 21,889 KWh per year.
- The first two graphs below show the average annual electricity usage for all phases, broken down by house type and number of bedrooms (Figure 6 and 7).
- The second pair of graphs show the same results collated and sorted for all house types together (Figure 8 and 9).
- The remaining graphs show the percentage of homes meeting the electricity target of 30.79Kwh/m^2 categorised by number of bedrooms and house types (Figure 10 and 11).
- Table three provides a summary of electricity consumption over previous monitoring periods and compares that to Bicester and UK averages.
- Note that as with previous years, electricity use for EV charger points at homes is included in household figures, which is being further analysed by Mode transport in a separate report (published soon). Therefore, actual average household electricity use is probably lower than reported.

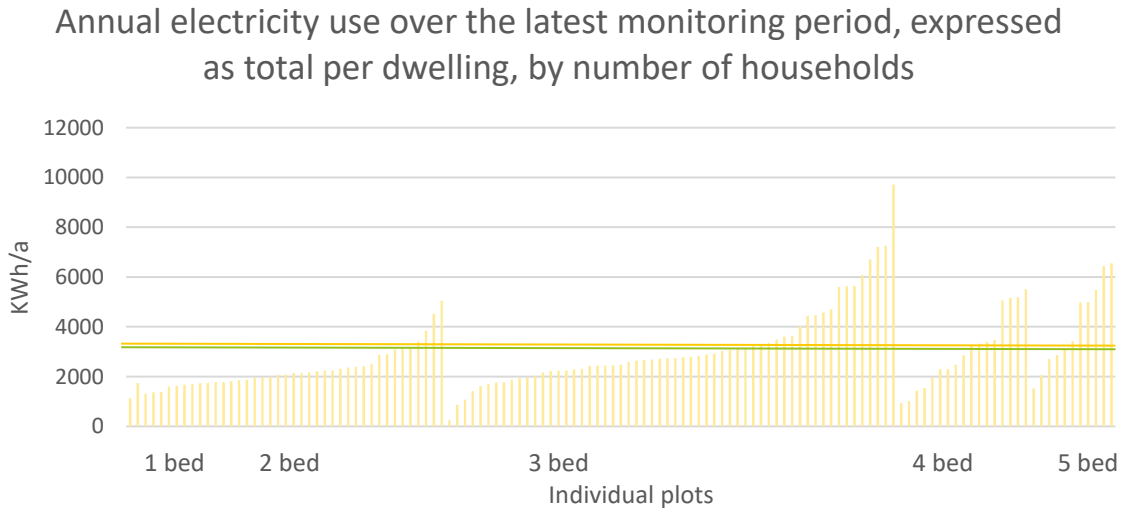

Figure 6 – Total electricity consumption per household, by number of bedrooms. Yellow bars = individual dwellings. Orange line = average all households (2,964 kWh/a), green line = target electricity use (2,932 kWh/a).

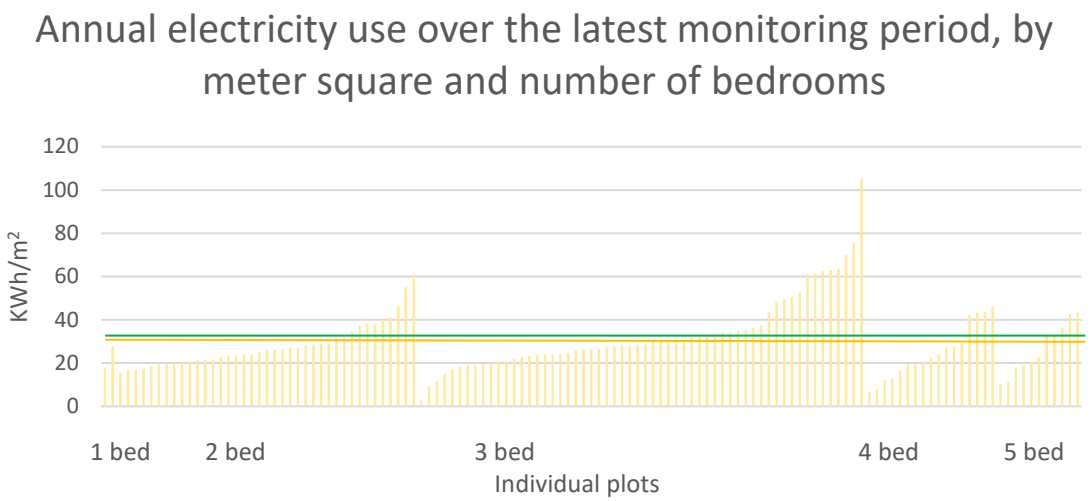

Figure 7 - Total annual electricity use over the latest monitoring period, by number of bedrooms, normalised by meter square. Yellow bars = individual dwellings. Orange line = average all households (29.29 kWh/m²a), green line = target electricity use (30.79 kWh/m²a).

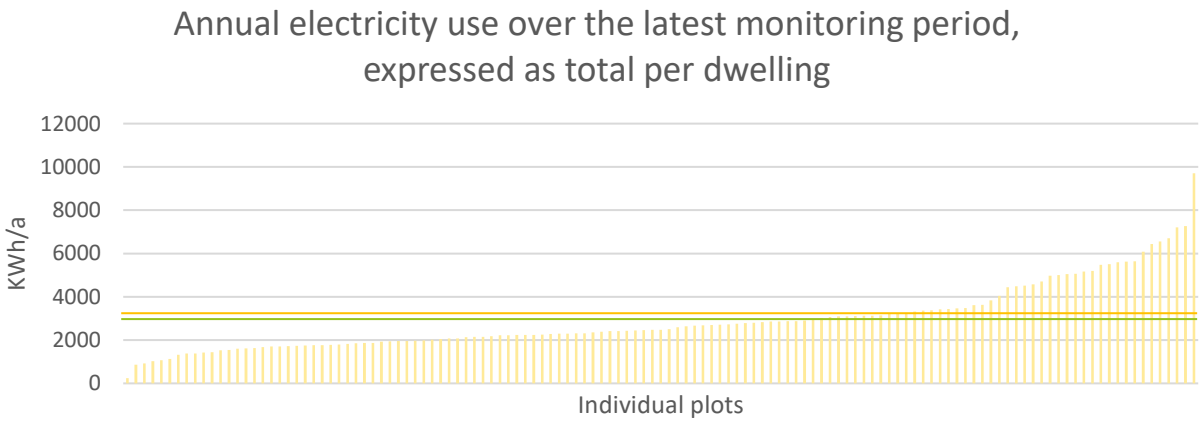

Figure 8 - Total annual electricity use over the latest monitoring period. Electricity use = Pv + Imp - Exp. Yellow bars = individual dwellings. Orange line = average all households (2,964 kWh/a), green line = target electricity use (2,932 kWh/a).

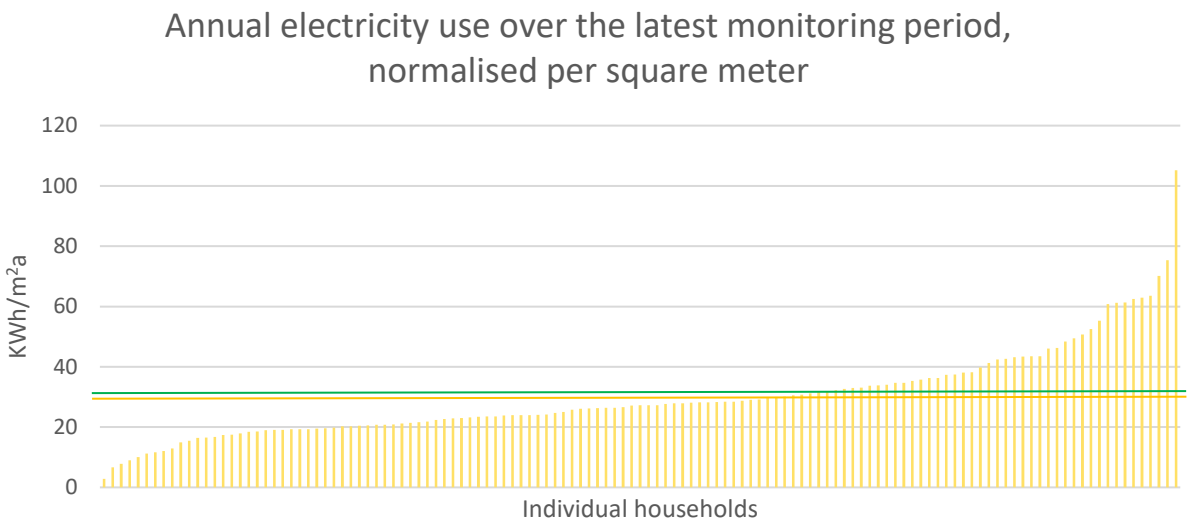

Figure 9 - Total annual electricity use over the latest monitoring period, normalised by meter square. Yellow bars = individual dwellings. Orange line = average all households (29.29 kWh/m²a), green line = target electricity use (30.79 kWh/m²a).

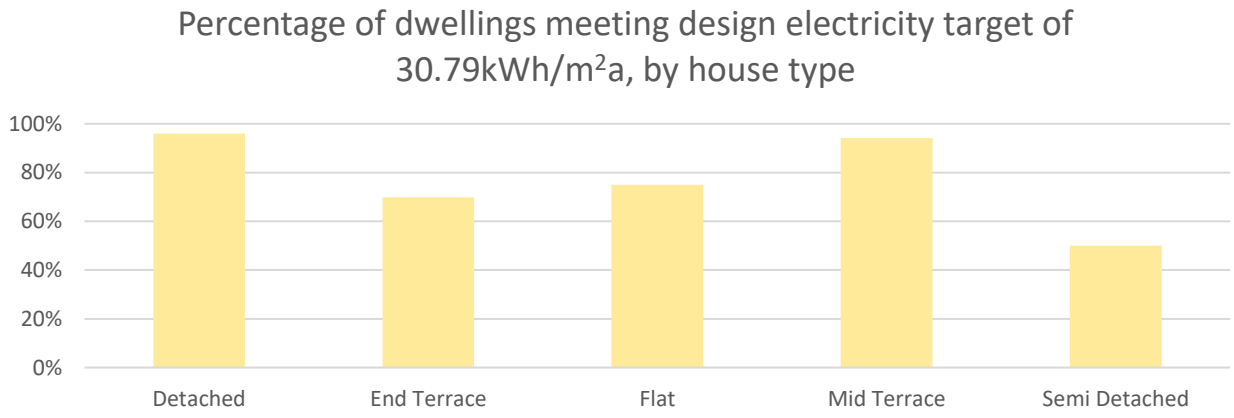

Figure 10 - Percentage of dwellings meeting design electricity target (30.79 kWh/m²), site wide by house type.

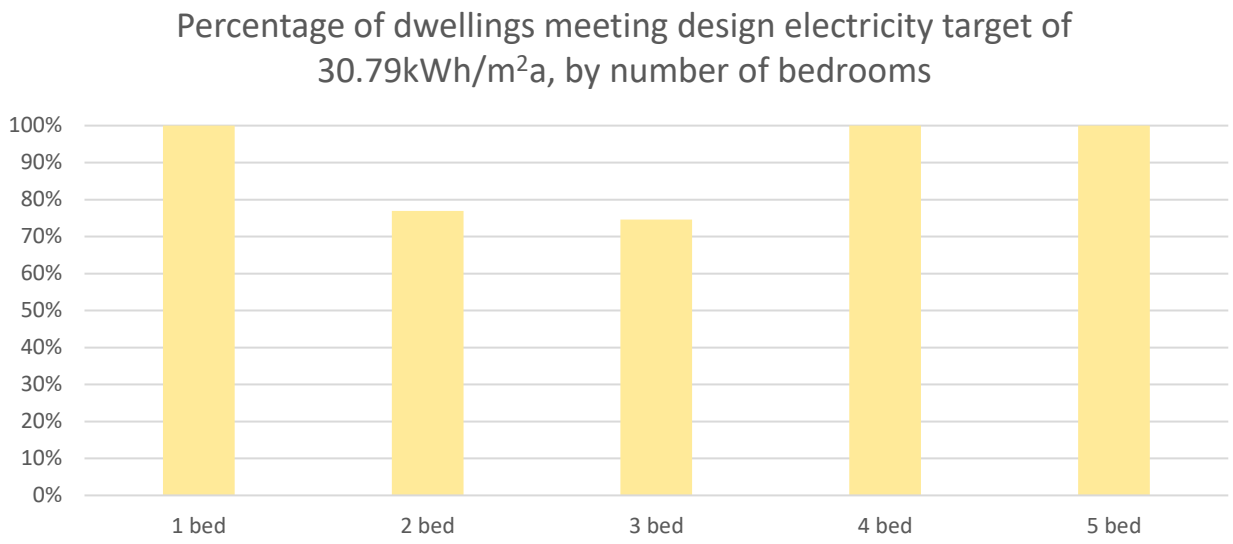

Figure 11 - Percentage of dwellings meeting design electricity target (30.79 kWh/m2), site wide by number of bedrooms. Note: flats have a very small sample size due to data issues (3x 1 bed and 1x 2 bed), based on import only.

4.3 Heat

Elmsbrook is served by an energy centre supplying heat to all buildings to cover space heating and hot water demand via a conventional district heating system. Data is collected at the point of use in the household for dwellings (via a heat meter at the heat interface unit reporting by the shimmy) and is centrally reported by SSE for Gagle Brook school and Eco Business Centre.

Summary:

- Over the latest monitoring period, the average household heat usage at Elmsbrook (all phases) was estimated at 5,580 kWh (hot water and space heating).
- This compares to 4,924 kWh in 2019-20, 5,473 kWh in 2018-19 and 4,023 kWh per household in 2017-18 in the previous monitoring periods (Period average: 2016-21 = 5,000 kWh/a).
- While heat usage rose by about 13% from the last reported usage, some of that will have been due to the average dwelling size increasing, seasonal affects and the pandemic (more time spent at home).
- A study[4] of changes in UK energy demand in 2020 during the pandemic found that domestic gas demand showed no change in the first lockdown but increased by 6.1% in the second lockdown which was likely a result of increased heat demand.
- Design stage annual heat use (all phases) was estimated at 4,269 kWh, for an average dwelling on site. This design figure converts to 44.83 kWh/m²a on an area basis and compares to 55.37 kWh/ m²a for the measured average. On average Elmsbrook residents used ~24% more energy for heating and hot water than the design stage estimations.
- KWh/m² is a more useful metric for comparison of heat usage, as the housing mix changes from phase to phase. Hot water usage is strongly correlated to occupation and space heating usage can be further influenced by tenure.

[4] https://iopscience.iop.org/article/10.1088/1748-9326/abf876

- The average annual Bicester household heat consumption based on 2018 data is 12,373 kWh, decreasing from 12,755kWh in 2015 (derived from gas use data only)[5]. This compares to the UK average of about 15,462 kWh (gas only data).
- Elmsbrook residents used around 55% less heat than their neighbours in Bicester, around 64% less than the UK average, and around 40% less than the average for new builds since 2017 in England and Wales (comparing all with gas use only).
- In the same period, the Eco Business Centre used 57,151 kWh and Gagle Brook school 161,644 kWh, which is 4% and 10% of the total heat used on site.

Table 4 - Heat usage summarised by monitoring period

	Average annual heat usage per household *(kWh)*
2020 - 2021	5,580
2018 - 2019	4,924
2017 - 2018	5,473
2016 - 2017	4,023
Average 2016-21	**5,000**
Design target	4,269
Bicester average 2018	12,373
Bicester average 2015	12,755
UK average (existing stock)	15,462
Average for 2017 new build England and Wales[6] (gas consumption)	9,300

Further information:

- This analysis was derived from a dataset of 130 plots of which 17 were removed for extremely low usage (dwelling likely unoccupied). This left us with 113 good quality heat use data points (or plots).
- The breakdown of heat use data by phase is as follows: 4 were from phase 1, 59 from phase 2 and 50 from phase 3.
- As before, data with less than 360 days' worth of readings was excluded in this analysis.
- Phase 1 data is using older less reliable data capture technology and is missing significant portions of data. Post analysis note: Carnego investigated the issue and informed Bioregional that a further ~30 data sets could likely be reconstructed which unfortunately didn't make the cut off point for incorporation into the report. Previous phase 1 monitoring sets were impacted by equipment failure and data transfer issues.

[5] "Postcode Level Gas Estimates: 2018 (Experimental) - GOV.UK". Gov.uk. N.p., 2020. Web. 7th October 2021. https://www.gov.uk/government/statistics/postcode-level-gas-statistics-2018-experimental

[6] BEIS, (2019). Energy consumption in new domestic buildings 2015 to 2017 (England and Wales), p.15. Web. 7th October 2021. https://www.gov.uk/government/statistics/energy-consumption-in-new-domestic-buildings-2015-to-2017-england-and-wales

- 44% of sampled homes are currently meeting the design heat target of 44.83 kWh/m² (space heating and hot water). The domestic hot water to space heating split was estimated at 42% to 58% respectively.
- The first two graphs overleaf show the average annual heat usage (all phases), absolute and normalised by area (Figure 12 and 13).
- Graph 14 shows the average heat use by ventilation type, normalised by floor area. Please note that all social rented dwellings properties are fitted with MVHR while private households are fitted with MEV and the Ventive system. This will impact heat usage.
- The remaining two graphs show the percentage of homes meeting the heat target of 44.83 kWh/m² in two different categories by number of bedrooms and house types (Figure 15 and 16).
- Table four provides a summary of heat usage over previous monitoring periods and compares that to Bicester and UK averages.

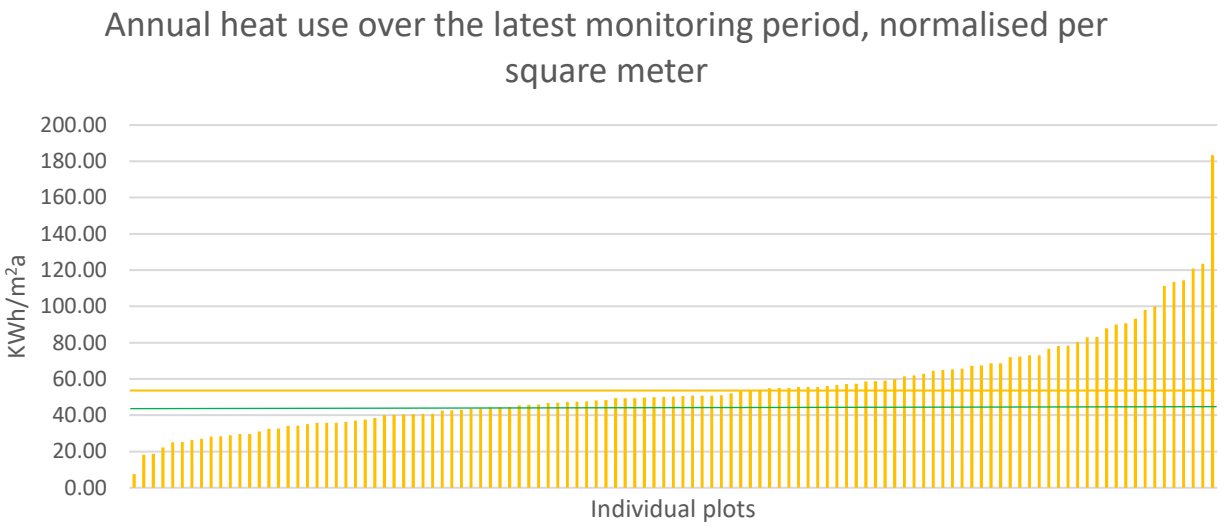

Figure 12 – Total annual heat use by metre square, over the latest monitoring period. Heat = space heating and hot water. Orange bars = individual dwellings. Orange line = average all households (55.37 kWh/m²a), green line = target heat use (44.83 kWh/m²a).

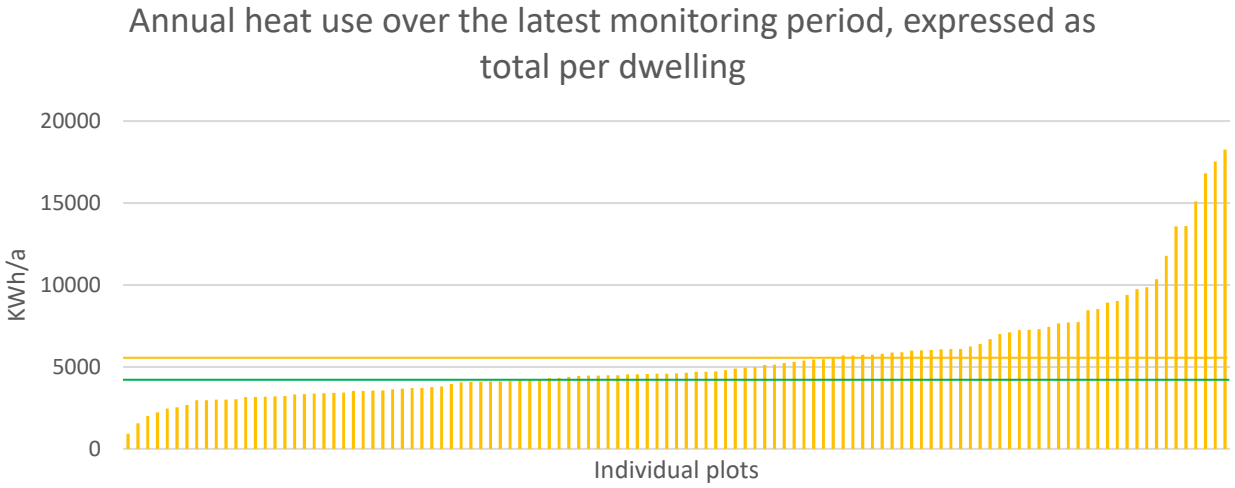

Figure 13 – Total annual heat use per dwelling, over the latest monitoring period. Heat = space heating and hot water. Orange bars = individual dwellings. Orange line = average all households (5,580 kWh/a), green line = target heat use (4,269 kWh/a).

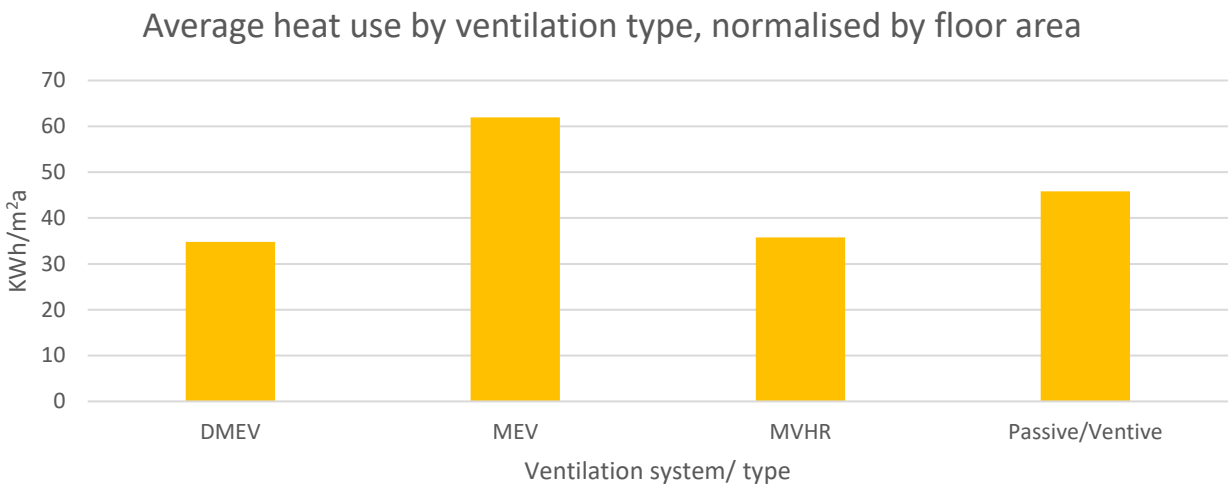

Figure 14 – Average annual heat use by metre square over the latest monitoring period, categorised by ventilation types/systems. Heat = space heating and hot water. Orange bars = average usage, normalised by floor area

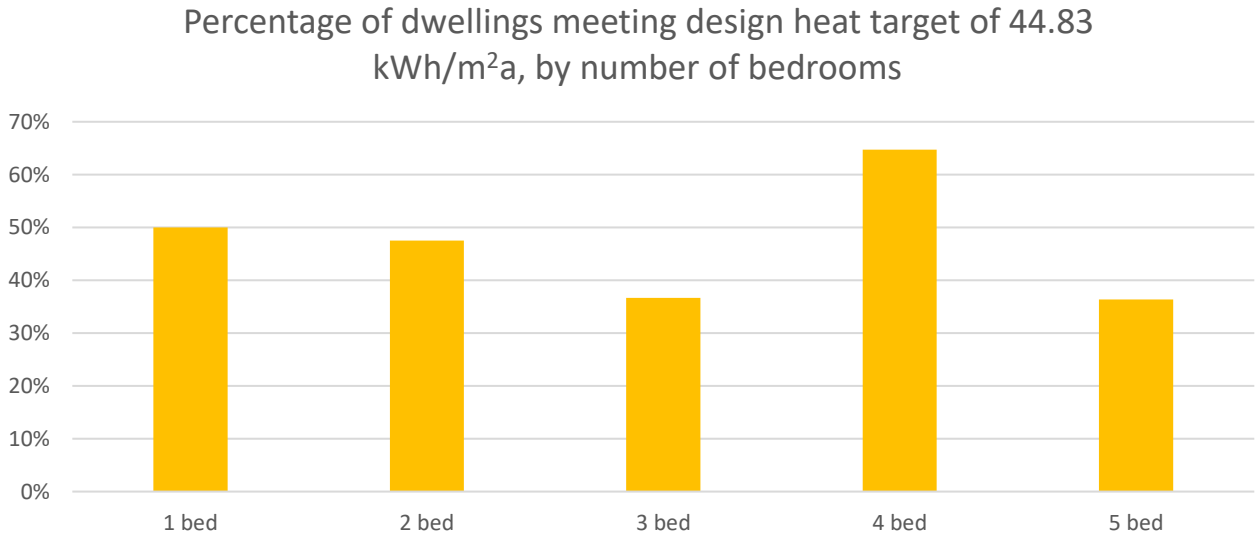

Figure 15 – Percentage of dwellings meeting design heat target (44.83 kWh/m²), by number of bedrooms

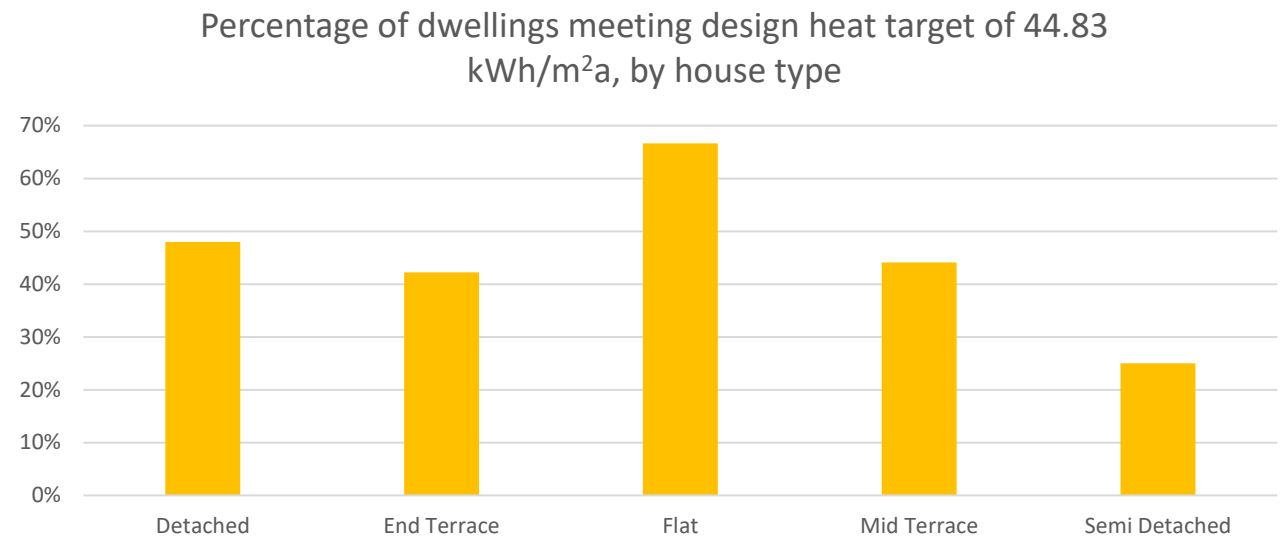

Figure 16 – Percentage of dwellings meeting design heat target (44.83 kWh/m²), by house type

4.4 PV

Buildings on Elmsbrook are fitted with roof mounted PV, an important sustainability feature that contributes renewable energy and offsets operational carbon emissions elsewhere. The combined generation of all systems on site makes it one of the largest residential PV arrays in the country. The data below summarises the electricity output from all buildings on site.

Summary:

- Over the latest monitoring period, the average PV generation (per household; all phases) was estimated at 3,113 kWh.
- This compares to 3,361 kWh in the previous period (2018-19), a slight decrease of 7% (Period average: 2017-21 = 2,993 kWh/a).
- PV yield is dynamic and affected by climatic and weather patterns as well as building design (orientation, shading, pitch and area). Since the last report further dwellings have been built and occupied affecting the average so comparison is less useful.
- A large proportion of dwellings in phase 1 were affected by monitoring issues or inverter (e.g. the flat blocks on phases 1 and 2).
- The Eco Business Centre had an estimated PV generation of 56,076 kWh over the latest monitoring period, reconstructed from meter readings.
- Gagle Brook school had an estimated PV generation of 94,079 kWh (based on meter readings).
- The PV array on the energy centre roof generated a further 23,506 kWh over the monitoring period (sub metered)
- The site wide total generation from PV was estimated as 923,924 kWh in the latest monitoring period, a majority of this (750,263 kWh) has been generated by dwellings on site.

Table 5 – PV generation summarised by monitoring period

	Average annual PV generation per household *(kWh)*
2020 - 2021	3,113
2018 - 2019	3,361
2017 - 2018	2,505
2016 - 2017	N/a
Average 2017-21	**2,993**
Design target	N/a

Further information:

- Of the 241 dwellings on site 123 had useable PV data of more than 360 days. 24 flats were not sub metered of which some had full or partial inverter failure.
- Missing PV data was affected by a range of factors this year, some a result of monitoring equipment failure (mainly phase 1), some inverter outages and others still result from connection loss through equipment being exchanged by other data providers without coordination with Carnego (e.g. for FIT's payment).
- Due to the large amount of missing data, a design vs measured comparison is not possible for phase 1 in this monitoring period.
- The design stage estimates for phase 2 were 200,135 kWh per year based on MCS calculations. The measured total for Phase 2 was calculated at 198,136 kWh for 66 dwellings (data for five dwellings is missing).
- The measured total for Phase 3 was calculated at 189,755 kWh for 79 dwellings (no design comparison data is available).
- The flat blocks are still not sub metered (i.e. monitored via the shimmy) so require manual meter readings. This affects 24 plots on Phase 1 and four on Phase 2.
- A manual reading of the export meters suggested part or full generation failure on a number of these blocks from tripped inverters and one DC isolator being found turned off. We therefore recommend for the maintenance teams to undertake status checks of all inverters in these locations.
- A manual meter reading for Gagle Brook school was taken and compared with the last available reading to calculate proportional usage withing the monitoring period. This doesn't allow for year to year fluctuations from weather effects, so could be under or overstating this year's PV generation.
- Figures 17 and 18 show the annual PV generation by house type and number of bedrooms (all phases).

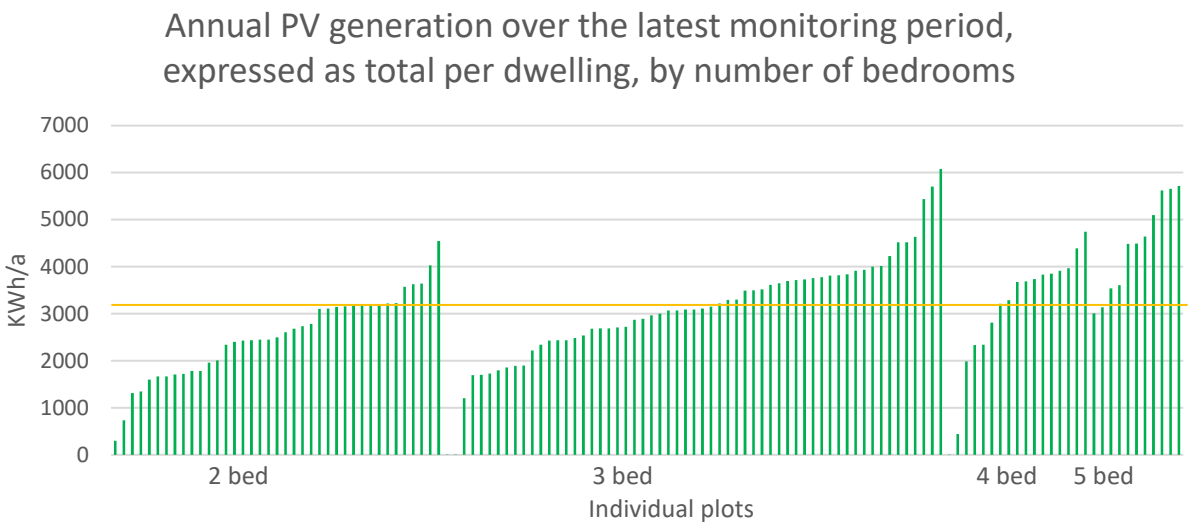

Figure 17 - Average PV generation per household by number of bedrooms. Orange line = site wide average (3,113 kWh).

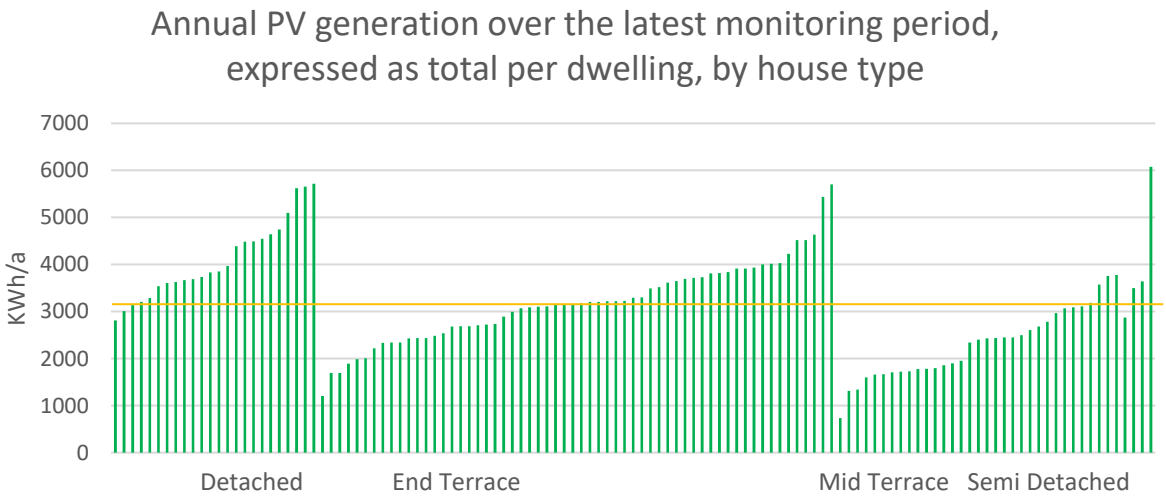

Figure 18 - Average PV generation per household by house type. Orange line = site wide average (3,113 kWh).

4.5 Waste

Waste data is provided by Cherwell District Council (CDC) and is collected by weighing the waste collection trucks leaving Elmsbrook. The data includes recycling, refuse and garden & food (compost), between 4 April 2017 to 20 March 2021. Note that CDC data was not provided on glass collected from bottle banks for recycling, and therefore is not included in the figures.

The headline figures:

- Total waste generated per household during 2020-21 increased marginally by 2% compared to 2018-19 from 579kg to 591kg.

- Refuse (general waste) per household in 2020-21 was 210kg per household (based on 241 occupied households). This is a decrease from the 2018-2019 average of 318kg per household (based on 158 households). The CDC average for 2020/21 was 433kg (106% higher)
- Recycling totals at Elmsbrook were logged at 213kg per household over the monitoring period. The CDC average recycled waste for 2020/21 was fractionally more than Elmsbrook at 215kg.
- Compost waste was 168kg per Elmsbrook household on average in 2020/21, up from 122kg in 2018/19. The CDC 2020/21 average was 332kg, that's 98% more compost produced outside the development.
- Elmsbrook has an average recycling rate between April 2019 – March 2021 of 62% compared to 56% for the district, 58.8% for the county, and 45.5% for England (2019 national figure).

Further information:

- County wide comparison figures were given by Cherwell District Council for each year. Figures provided were total tonnes of waste for each waste stream per average household, without information on the number of households.
- The waste stream patterns over the course of the monitoring period are outlined in the graphs below (Figures 19 and 20).
- Recycling is the largest waste stream in 2020/21, followed closely by refuse and then finally garden and food waste.
- Residual waste decreased from 55% to 36% of total waste produced at Elmsbrook in 2018/19 and 2020/21 respectively, dropping below the CDC average which has stayed relatively stable, increasing slightly from 40% to 44%. Total recycling rate (including dry recycling and organic waste compost) increasing from 45% to 62% this period, which is 6% higher than the Cherwell District average rate. Within these Elmsbrook recycling figures, the proportion of dry recycling has increased from 24% in 2018/19 to 36% in 2020/21 whilst the proportion of organic waste increased from 21% to 28% (table 6).

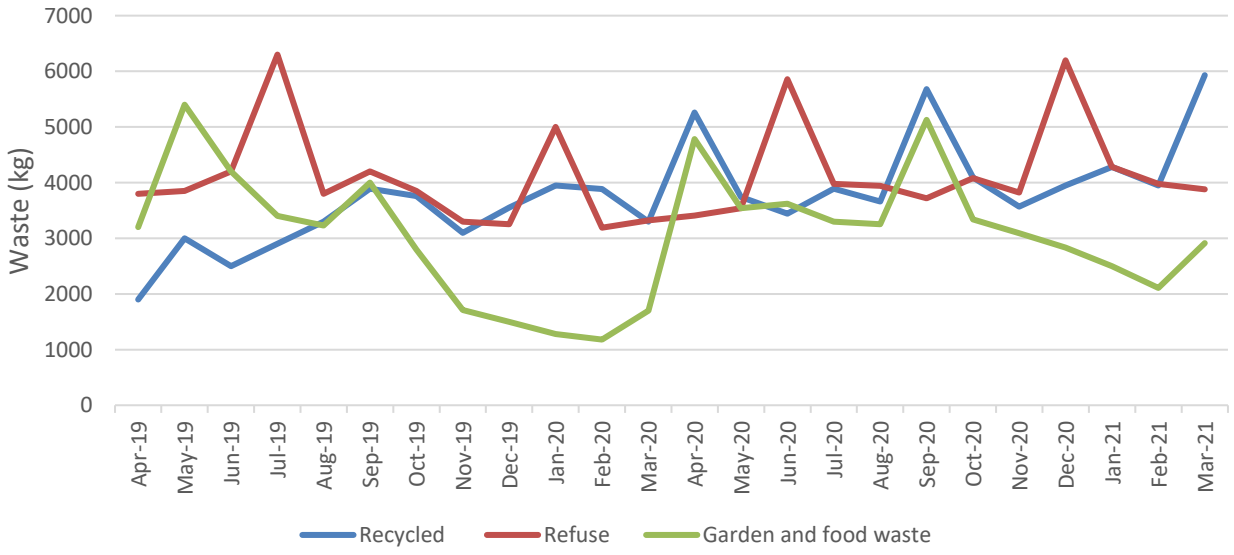

Figure 19 - Weight of monthly waste (kg) by stream over the last two years (April 2019 - March 2021)

Table 6 - Average annual household waste treatment - Elmsbrook and CDC total (%)

	2017/18		2018/19		2019/20		2020/21	
	Elmsbrook	CDC	Elmsbrook	CDC	Elmsbrook	CDC	Elmsbrook	CDC
Dry Recycling	20%	20%	24%	19%	32%	22%	36%	22%
Organics	25%	34%	21%	40%	28%	34%	28%	34%
Residual Bins	55%	45%	55%	40%	40%	45%	36%	44%

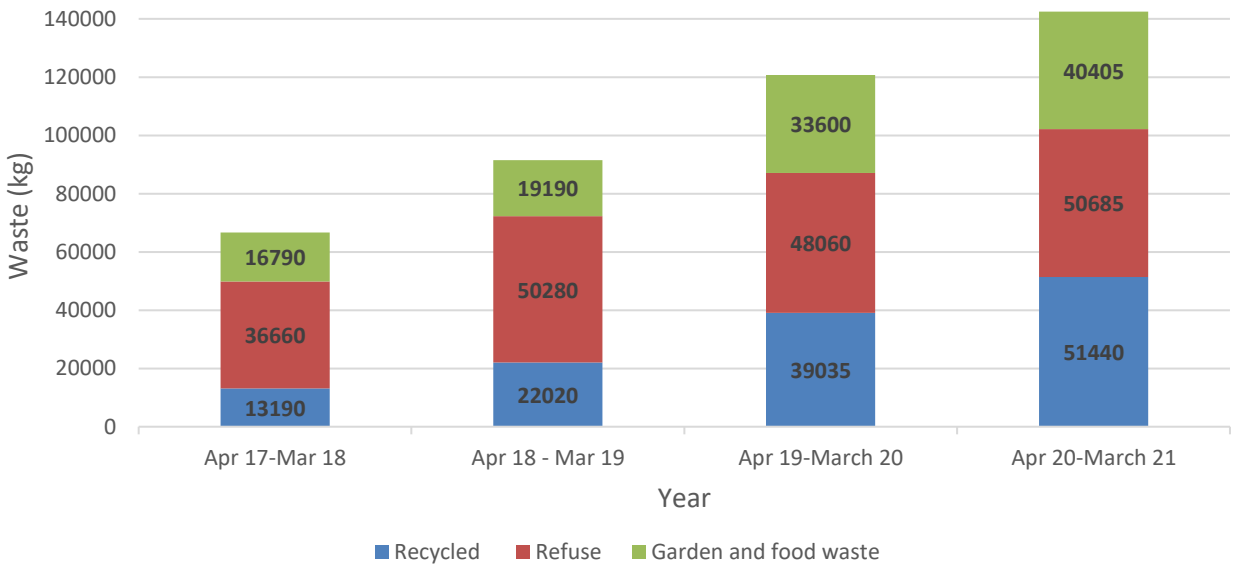

Figure 20 - Weight of annual waste (kg) by stream between April 2017 - March 2021, covering four monitoring periods.

- Figure 21 shows the average household percentage breakdown of waste, and figures 22 and 23 show the average weight of each waste stream per household in 18-19 compared to 20-21.
- We can see that dry recycling waste has increased from 24% to 36% of total household average waste, and green waste decreased slightly from 21% to 28%, while refuse has reduced from 55% to 36%.
- Average household annual waste has increased year-on-year for dry recycling and compost waste streams. Dry recycling increased from 83.5kg in 2017/18 to 213kg in 2020/21, and compost rose from 106 kg in 2017/18 to 168kg in 2020/21. In contract, refuse peaked at 318 kg per household in 2018/19, before a 2019/20 decrease to 199kg and subsequent rise to 210 kg in 2020/21.

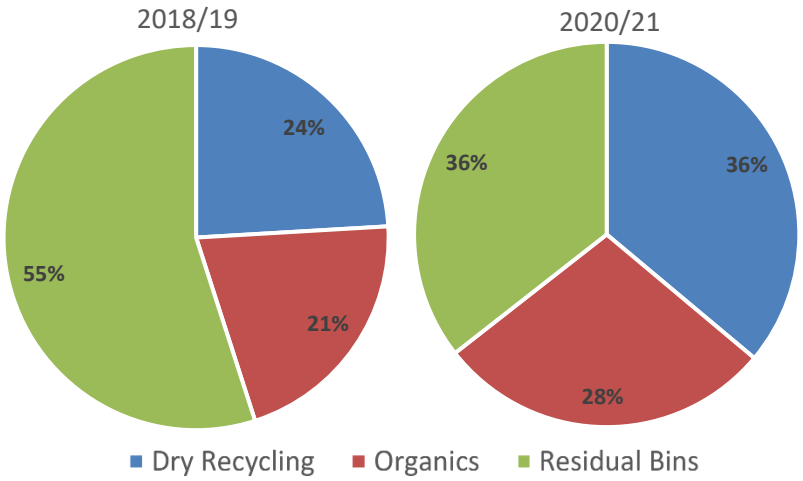

Figure 21 - dry recycling, organic waste (compost) and residual waste as proportions of total waste produced, 2018-19 and 2020-2021

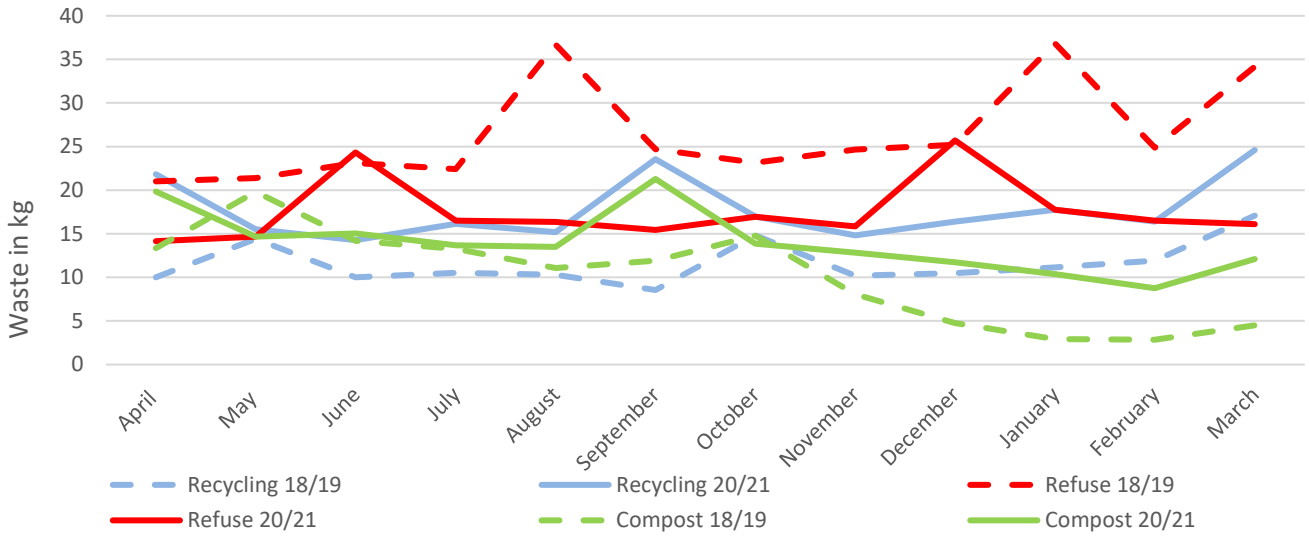

Figure 22. Average monthly waste per household over 2018/19 and 2020/21, site wide

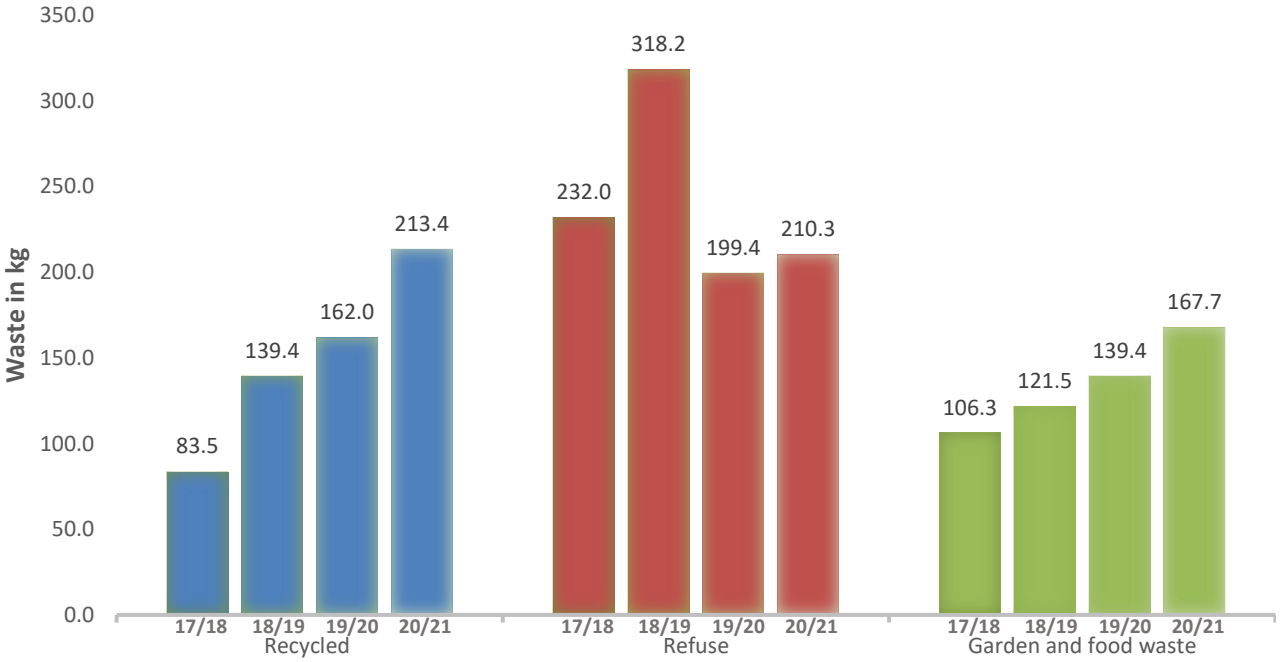

Figure 23 - Average annual waste per household by type, year-on-year comparison from 2017/18 to 2020/21.

4.6 Energy centre

The Elmsbrook energy centre provides the development with heat via a district heating network. Heat is generated from a gas-powered combined heat and power (CHP) unit with backup gas boilers. A roof mounted PV array provides further renewable energy to offset equipment loads. Energy data was provided by the energy centre provider Scottish Southern Electric (SSE) from automated meter readings (AMR) and some manual meter readings.

Summary:

- The majority of heat generated in the energy centre, over the latest monitoring period, was supplied by CHP (58%) a reduction from the previous monitoring period where 62% of heat was supplied by CHP.
- The remaining 42% was generated by gas boilers, well short of the design split of 90:10 (CHP:Boiler) and increasing the carbon intensity of the operation. The CHP is supposed to meet most of the heat demand by the end of phase 2 but continues to be significantly off the expected trajectory.
- Total heat generated was 2,617,400 kWh, up by ~17% from the last monitoring period.
- Approximately 40% of heat energy generated is currently being lost through either storage, distribution or commissioning loads. The designed distribution loss was 28%.
- The CHP delivered a monitored efficiency of 76% during 2020-21, as compared with a design stage assumption of 78% and a monitored efficiency of 73% in 2017-18, 62% in 2018-19.
- The boilers delivered a monitored efficiency of 75% in 2020-21, below the design stage assumption of 87%.
- Solar PV electricity generated on the energy centre rooftop over the latest monitoring period was 23,506 kWh. Figures are dependant on climate and weather conditions and have fluctuated between a low of 13,295 kWh in 2017-18 to a high of 26,182 kWh in 2019-20.

Table 7 - Energy centre data summarised from 2017-21

	2017-18	2018-19	2019-20	2020-21
CHP				
Electricity generated (kWh/year)	304,600	661,900	1,249,800	1,400,000
Heat output (kWh/year)	317,200	741,200	1,387,300	1,522,300
Gas consumption (kWh/year)	944,206	1,866,069	3,562,459	3,903,626
Boiler				
Heat output (kWh/year)	904,100	866,400	843,800	1,095,100
Gas consumption (kWh/year)	1,029,940	995,997	866,996	1,215,852
PV				
Electricity generated	13,295	22,952	26,182	23,506

Further information:

- The energy centre generated 2,617,400 kWh of heat (CHP and boiler) in 2020-21 to meet the space heating and hot water demand on site. The breakdown is as follows: Residential (estimated from shimmy and extrapolation of missing data) = 1,344,733 kWh, Gagle Brook school = 161,644 kWh (billed data), Eco Business Centre = 57,151 kWh (billed data).
- The CHP ran 1,610 hrs over the monitoring period, gas boiler 2,065 hrs.
- Operationally, the CHP ran 96% (CHP not operational for 12 days – likely maintenance) of days throughout the monitoring period with an average of ~7 hrs per day. Longer running hours for the CHP would improve the carbon balance.
- Figure 24 shows the electricity generated against heat output over the monitoring period by generation mode. CHP electricity generated, and heat output are aligned for most of the year, with the boiler providing additional assistance during the colder months and remaining mostly off during the summer.
- Figure 25a and 25b shows gas consumption over the current and previous monitoring periods.
- There is a sharp decrease in consumption over the summer months across the years, for example in 2020 falling sharply from 540,506 kWh in March to 346,211 kWh in April, and steadily declining to 246,474 kWh in August.
- During Autumn and Winter, the consumption gradually increases from September through until a peak usually in January (2019, 2020, and 2021), reaching a peak across the years of 700,672 kWh in January 2021. Consumption then gradually decrease as months get warmer.
- CHP gas consumption is greater than boiler consumption across the years except from July and August 2017 and 2018 when the CHP did not run, or at minimal level.

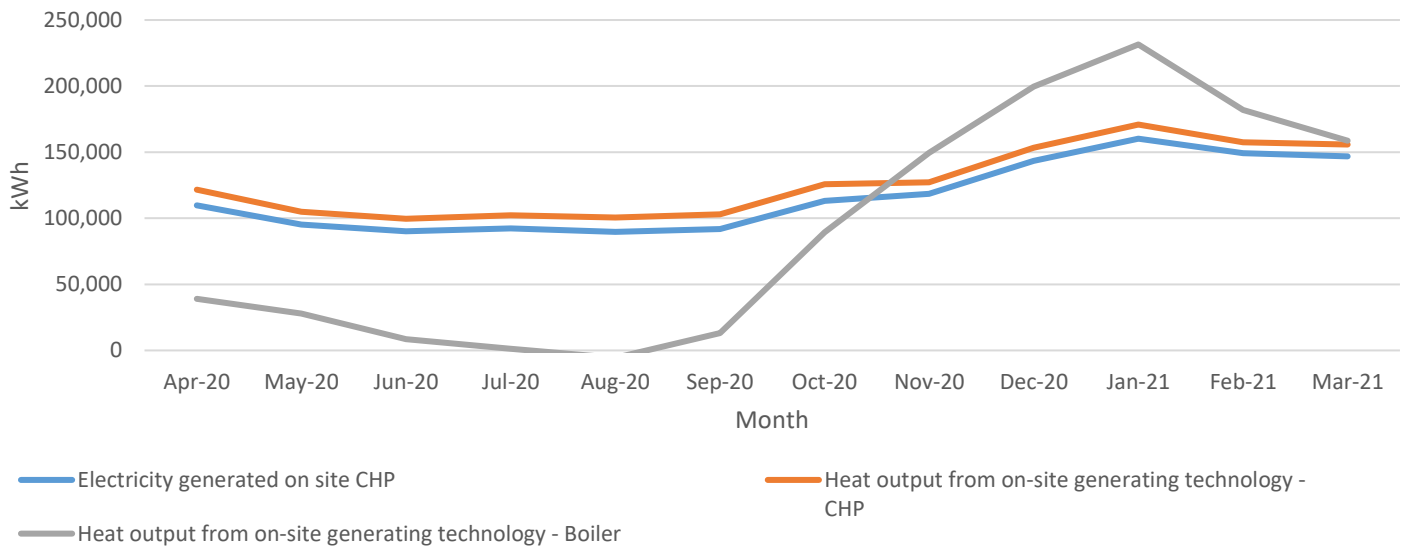

Figure 24 - Electricity generated vs. heat output from CHP and boiler.

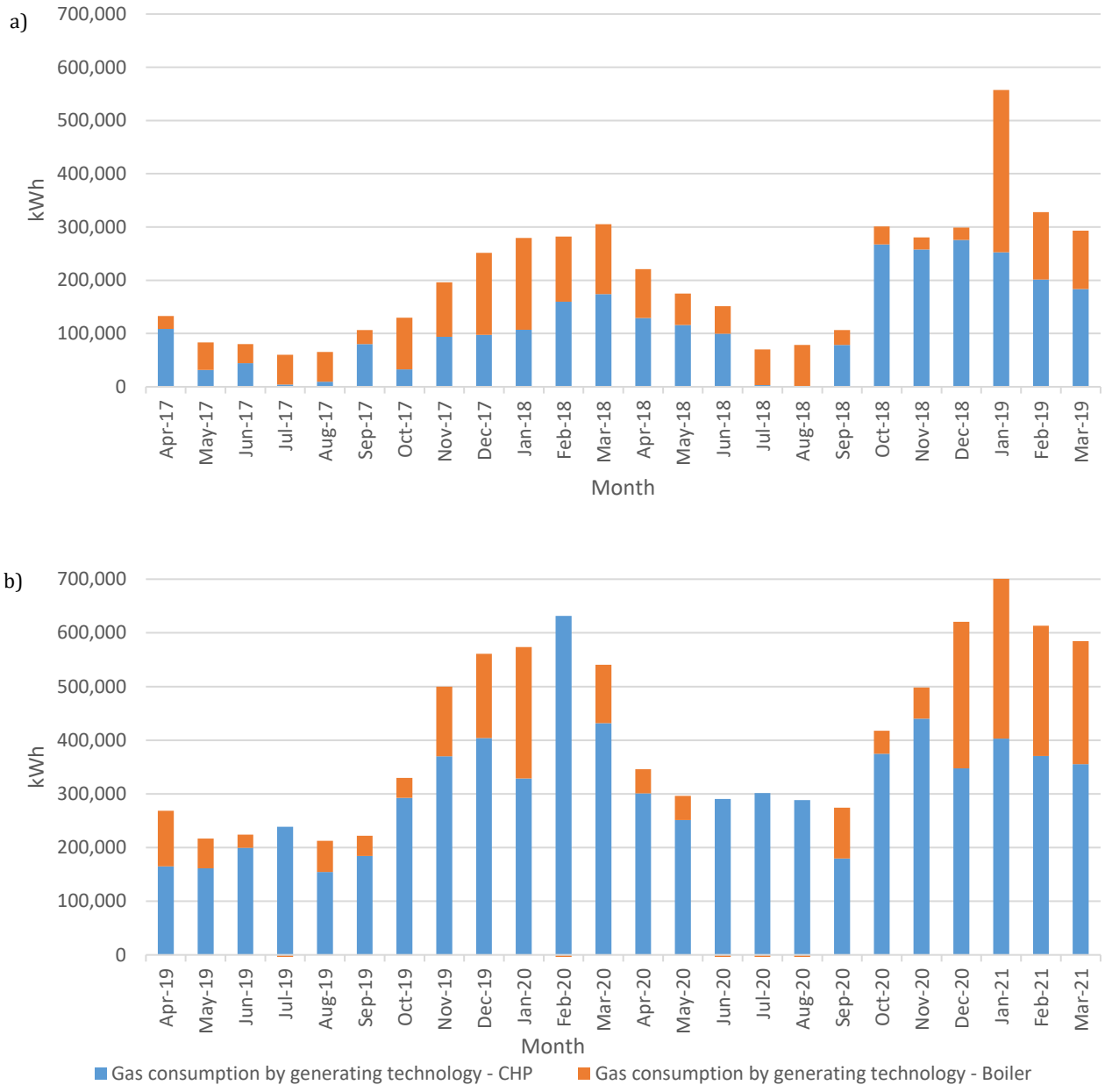

Figure 25a and 25b - Gas consumption by CHP and boilers, 2017/18 –2018/19 (a), and 2019/20 – 2020/21 (b)

4.7 True zero carbon

Elmsbrook was designed to be a 'true' zero carbon development, meaning both regulated energy (lights, pumps & fans) and unregulated energy (appliances & cooking) are accounted for and offset in the carbon balance. The development was designed to be net zero carbon, over the course of a year. As noted here previously, reporting against this target ahead of final completion and occupation of all buildings on site is difficult, as the energy strategy relies on a certain demand utilisation for the energy centre to run efficiently and economically (e.g. CHP to boiler contribution and split). The exact carbon balance is also highly dynamic. External temperatures, sun hours, user behaviour and electrical grid carbon intensity all impact the final result. Ahead of completion of the development, results are only intended to provide an update and snapshot of the performance during the monitoring period.

Summary :

- We estimate that in 2020-21 the average home at Elmsbrook emitted 894 $kgCO_2$, a rise of 21% from 741 $kgCO_2$ in the previous reporting period. This is based on SAP 2012 carbon factors (currently used in UK Building Regulations Part L).
- Our figure compares to 5,424 $kgCO_2$ (or 5.42 tonnes CO_{2e}) for an average UK household (all stock). That's around 16% of the UK average footprint for existing homes. It compares against an estimated new build footprint of 3,500 $kgCO_2$[7] (Elmsbrook is 74% lower).
- The development as a whole (energy centre, business centre, school and residential) did not manage to achieve zero carbon over this reporting period with 383 tonnes CO_2 net emissions (Previous years: 115 tonnes CO_2 net emissions, -25 tonnes net emissions CO_2 (site wide).
- Data problems and operational issues this year mean that the level of confidence in the carbon balance is low and is likely understating real performance. We also envisage the pandemic having had an effect on the energy consumption, e,g, with homeworking increasing. Other influencing factors include district heating commissioning heat load for Phase 3 and 4. Elmsbrook as a whole is still emitting significantly less carbon emissions than an equivalent new build development – around 628 tonnes of CO_2 less during this year alone (comparing our per dwelling footprint of 894 $kgCO_2$ with the estimated UK new build footprint of 3,500 $kgCO_2$ for 241 dwellings on site.

Further information:

- We estimate that in 2020-21 the average home on Elmsbrook emitted 894 $kgCO_2$ per year. This figure is likely an overstatement (i.e. less favourable) than actual performance.
- The reason for that is commissioning heat load for the phases still under construction which can account for as much as 10-30% of total heat use. Commissioning heat loads are basically hot water being circulated in the mains ring and sub rings to prevent the pipes clogging up.
- Commissioning heat use and network distribution losses are hard to segregate and remove from the dataset so are currently featured in the result.
- Other sources of error arise from missing data (data logging issues), which resulted in extrapolation of ~100 data sets (mainly on phase 1).
- Four flat blocks on Phase 1 (24 flats) have experienced some level of inverter outages. The resultant generation loss is hard to estimate as the data is collected through manual meter readings on site. A good proportion of that data will be missing and will have adversely affected the site wide carbon balance.

[7] http://transitionbath.org/impact-housing-standards-energy-costs-co2-emissions/

- The single flat block on Phase 2 did not generate any PV over the duration of the year due to inverter outage that wasn't corrected.
- By the end of phase two, the proportion of heat supplied by CHP as compared with gas boiler split was intended to be 90:10 but this is currently not the case. In reality, the ratio is 58:42 a slight decrease from 65:35 in the last monitoring period.
- Re-running the site wide carbon emissions calculations, with the intended 90% CHP utilisation the development would likely achieve its true zero carbon status.
- The average household footprint figure (used as UK carbon emission comparison) was taken from two data sources. One is using a UK government figure[8] of 147 Mt CO_2 for all emissions generated directly by households in 2016. The office for national statistics (ONS)[9] provides a figure of 27.1 million households for that same time period. This results in an average footprint of 5.42 tonnes $CO_{2e.}$
- The site-wide carbon balance has again been calculated using the current SAP 2012 carbon factors of 0.216 and 0.519 kgCO2/ kWh for gas and electricity respectively. The UK electricity grid has decarbonised further since the energy strategy was written so although the old (SAP 2009) carbon factors would give a more favourable carbon balance, they are outdated and would potentially expose the development to criticism.
- Changing the factors to the proposed new carbon factors (SAP 10.1), which the next set of Building Regulations will likely adopt, would increase the reported footprint to 886 tonnes CO_2 net emissions (site wide). The per dwelling carbon footprint using SAP 10.1 has been estimated as 1,908 $kgCO_{2.}$
- Again changing the factors to the original carbon factors which are now outdated (SAP 2009), would decrease the reported footprint to 294 tonnes CO2 net emissions (site wide). The per dwelling carbon footprint using SAP 2009 was estimated as 703 kgCO2.
- The energy and carbon balance remain highly dynamic and will change from year to year. Switching new parts of the development online alters the energy balance and the utilisation of the energy centre. Ongoing construction results in commissioning heat loads. As dwellings come online, the energy centre adjusts to the new heat demand. Weather and sunlight hours also impact on heat demand and PV generation.
- It is possible that commercial considerations (by the energy centre operator) are driving the boiler to CHP split. Running the CHP outside peak time export tariffs might incur higher operational costs than using the boiler (better thermal efficiency) for the same gas consumption.

8

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794557/Consumption_emissions_April19.pdf

9

https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/bulletins/familiesandhouseholds/2016

Table 8 – Energy balance over the monitoring period 2020/21.

Element	Exported Electricity (KWh)	Imported Electricity (KWh)	Gas imported (KWh)	Comments
Dwellings (all phases) - submetered data, 360+ days data	290,567	279,982	Na	128 properties or data sets
Dwellings (all phases) - data reconstructed	274,164	247,171	Na	Meter issues resulted in extrapolation of 113 properties
Eco Business Centre - manual meter readings	34,187	21,889		Meter replacement resulted in data loss, reconstructed from design target
Gaglebrook school - manual meter reading	76,758	17,846	Na	Part occupied, part empty due to pandemic
Energy centre - submetered	1,352,045	68,279	5,119,478	Includes distribution and commissioning heat loss
Total	**2,027,722**	**635,167**	**5,119,478**	**kWh**

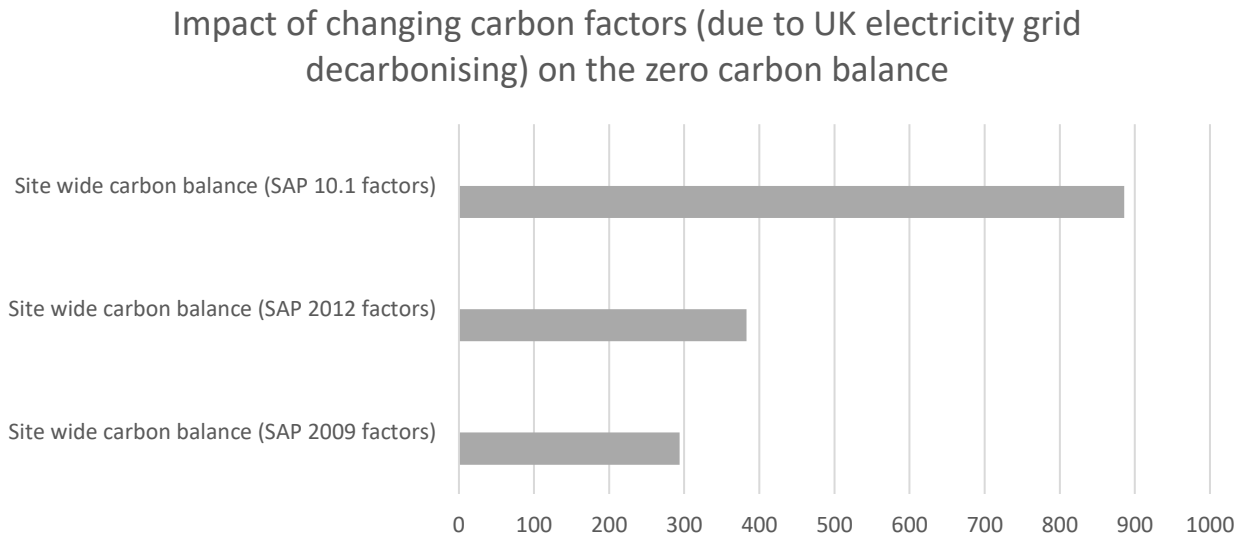

Figure 26 – Impact of changing carbon factors: SAP 2009 factors at time of application, SAP 2012 current factors, SAP10.1 proposed future carbon factors.

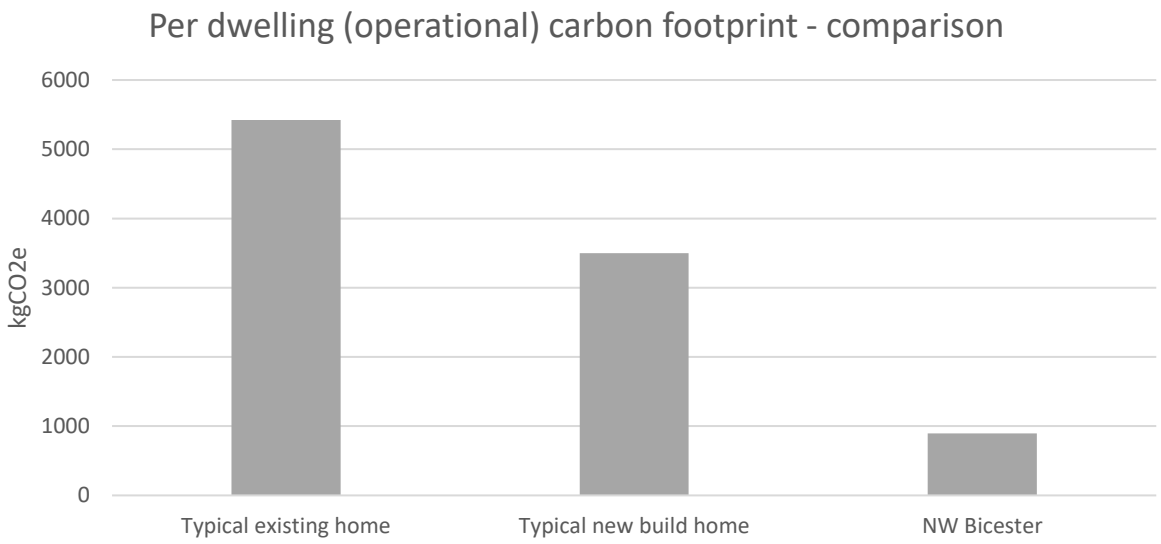

Figure 27 - Comparison of NW Bicester/ Elmsbrook per dwelling carbon footprint.

Table 9 – 2020/21 carbon balance (Energy use in kWh x SAP 2012 Carbon factor = Resultant carbon emissions).

Item		Carbon factor	Resultant carbon emission	Notes:
Electricity exported	-2,027,722 kWh	0.519 $kgCO_2$/kWh	-1,052,388 $kgCO_2$	Favourable to balance
Electricity imported	+635,167 kWh	0.519 kgCO2/kWh	+329,652 $kgCO_2$	Unfavourable to balance
Gas imported	+5,119,478 kWh	0.216 kgCO2/kWh	+1,105,808 $kgCO_2$	Unfavourable to balance
Resultant site wide carbon balance			**+ 383,071 $kgCO_2$**	Net emissions

4.8 Resident survey

The Elmsbrook survey was advertised through email, a letter to residents, on the shimmy device and with help of the Elmsbrook Community Organisation (ECO). The survey was hosted electronically on the Survey Monkey site over a period of 6 weeks. A total of 73 responses were received at the time of submission of this report.

Summary:

- 30% of households responded to the survey and provided data. Most responses were received in the first week of the survey going live.
- 83% of respondents indicated their health is good to very good (41 'good', 20 'very good'). 9 of the remainder answered "fair" and 2 "bad", with none stating "very bad" (73 responses total).
- Considering respondents' happiness the day before taking the survey, (on a scale of 1-10, where 0 is "not at all" and 10 is "completely" happy) 71% indicated they felt happy (above neutral, 6 or above).
- Surveying the sense of community belonging, 62% felt that they strongly belong in their immediate neighbourhood (27% very strongly, 34% fairly strongly). 11% did not feel a very strong sense of belonging (5% not strongly at all).

- Household use of greenspace by type (multiple choice question) (figure 28, question 5) is predominantly open countryside and nature reserves, comprising 48 and 37 households respectively. Country parks and play parks are the next most used types of greenspace, used by 22 and 20 households respectively. This is followed by sports greens, grow beds and allotments (elsewhere in Bicester) with 7,6 and 4 households respectively using these greenspaces. 11 respondents indicated their households do not use any of these green spaces. The frequency to which households use green spaces varies, with the majority indicating 17 daily, 31 weekly, and 15 ad hoc. 4 households used these spaces fortnightly, and 3 monthly.

- Due to the COVID-19 pandemic and lockdowns, 69% of respondents shifted to working from home more. National and regional statistics from the Labour Market Survey by ONS found that 46.6% of respondents worked from home (any at all during week of survey) (49.4% in South East), with 86% (84.2% in South East) of those homeworking answering that this was due to COVID-19[10]. Considering the number of people on furlough by local authority, there has cumulatively been 125,000 people in all of Oxfordshire and 33,500 in Cherwell District supporting by the furlough scheme at some point since March 2020. That is 29% of Oxfordshire's working age population, and 36%[11] of Cherwell's, based on latest (2019) figures.
- Considering the support that can be provided to help people with more home-based working, 13% felt that co-working space would be beneficial, with 37% feeling occasional use of such space would be beneficial, and 50% feeling they would not benefit.

Further information:

- 54% of respondents answered that they are using delivery companies for their shopping more due to the pandemic. This reflects national statistics that online retail sales reached a record high of 33.9% of all retail spending, and have remained above 27.8% (based on 2020 data), and Amazon's UK sales increased by 51% in 2020. In terms of food deliveries, the pandemic has also seen an 11.1% increase in volume sales of groceries (up to 21st June 2020 compared to equivalent period in 2019), 43% sales increase for Just Eat deliveries (in the third quarter of 2020 compared to same period in 2019), and a doubling of Deliveroo orders.

- Considering sustainable household waste management behaviours and practices, 60% answered that their household composts their green and/or food waste, while 4% only do sometimes, and 36% do not at all. This is a significant area to improve in terms of sustainable living of residents across the eco-development, and public engagement may help to improve the rate of green and food waste composting.

- While 78% of respondents answered that they understand how to operate the heating system effectively in their homes, there is scope for improvement through additional support to the 22% (16 respondents) that answered "no".

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[10] Office for National Statistics, (2020). Coronavirus and homeworking in the UK: April 2020. (Online). Available from: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/bulletins/coronavirusandhomeworkingintheuk/april2020

[11] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland

- Thematic analysis of responses around what residents value the most about living at Elmsbrook (question 17) found 52% answered that they value the sense of community and the people the most. 27% answered the environmental / eco-friendliness of the development, with 16% explicitly referring to features and technologies installed in their eco-house contributing to climate change mitigation. Being close to nature, having access to countryside, and green space in and around the development, were aspects valued the most by 23% of respondents. A further 11% most valued the quiet, calm, and peacefulness of the development, and 9% answered it is the space they value the most, and the airy and open feeling of the development. 8% most valued the location.

- Questions seeking feedback about Shimmy (questions 18 and 19) received a range of responses from 67 people. Numerous respondents found that the system is not user friendly, suggesting improvements to this, and several stated that the system does not work correctly. Some answered that they do not use the system at all, with a number stating they require technical support. Several users felt the system could have a better dashboard system, showing for instance daily view of energy usage/solar panel generation that people can navigate through, instead of the reportedly limiting options of viewing data for "Today, Yesterday, This Week, This Month". Other users feedback that other information could be integrated, such as water monitoring, bus times, information about roadworks, as well as community events, needs, news and forums. One aspect of integration was with EV charging, and being able to control these better such as being able to connect EV charging points to the house solar panels and charge only when they are generating electricity.

- The full table of answers can be found in the appendix.

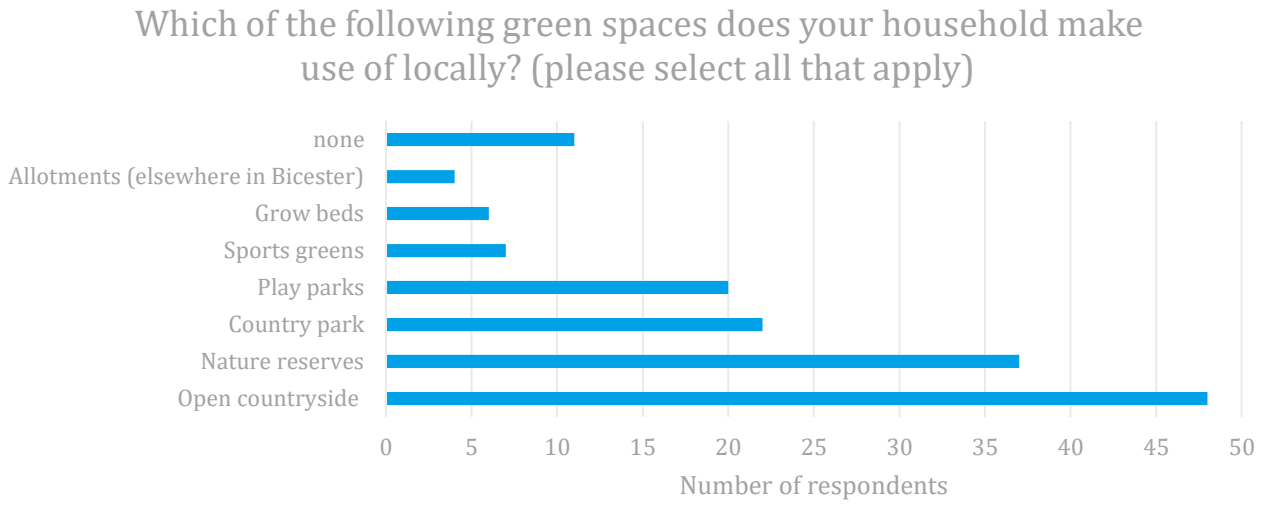

Figure 28 - Answers to question 5: 'Which of the following green spaces does your household make use of locally? (please select all that apply)'

5 Conclusions and recommendations

5.1 Overview

This post occupancy report forms the fourth in a series undertaken at the ground-breaking Elmsbrook development – the UK's first Ecotown.

Whilst the development (school, residential phases and energy centre) does not appear to achieve true zero carbon performance, Elmsbrook is still considerably more environmentally friendly than an equivalent new built settlement. The exact carbon balance year on year is dynamic and this year has been heavily influenced by the global pandemic, with more people staying at home (working or furloughed). Gas use (at the energy centre) was still elevated due to larger distribution losses and increased commissioning heat demand (Phase 4 construction). Because the energy centre is not yet running at the planned capacity, the CHP engine efficiency and CHP to boiler split, is likely to improve further as more homes are built, reducing the carbon intensity.

Considering other sustainability indicators, household daily water use has increased slightly from 227 to 246 litres, while water use per person has reduced incrementally from 84 to 83 litres a day. 54% of households are on average meeting their water use targets off 80 litres per person per day (compared to UK average of 150 litres per person per day). Annual electricity use increased by 12.6% compared to 2019/20, but decreased by ~5% compared to 2017/18, and is currently performing 10% better than the design target, and ~15% better than the average for Bicester. Waste practices are currently at a good standard in terms of the recycling rate which have improved from 45% in 2018-2019 to 62% in 2020-2021 (higher than the district, county and national levels), while total waste generated has remained largely the same (2% increase). This slight increase could relate to more time spent at home during the COVID-19 pandemic, but future analyses should monitor whether this rise continues, and if so take action to help residents reduce their waste.

In this year's household survey, 62% felt that they strongly belong in their immediate neighbourhood (with 27% indicating very strongly, and 34% fairly strongly), increasing slightly from 55% of survey respondents indicating they feel part of a community in the last reporting period. 71% of respondents indicated they feel happy, and 83% indicate their health is good to very good. The COVID-19 pandemic and lockdowns led 69% of respondents surveyed to move to home working. Considering whether residents could be supported in home based working by having co-working space, 13% felt this would be beneficial, 37% felt occasional use of such spaces would be valuable, and 50% felt they would not benefit. Given that 50% of respondents might benefit from co-working space, A2D could work with stakeholders to offer flexible workspaces to support them in the pandemic and new ways of working.

Despite technical elements of the development requiring improvement, Elmsbrook seems to be continuing to grow into a positive and happy community where residents generally consider themselves to have high levels of wellbeing and feel as though they belong to a community.

5.2 Key findings

- We estimate that in 2020/21 the average home at Elmsbrook emitted 894 kgCO_2 (or 0.89 tonnes CO_2) per year.
- That's 84% percent lower than the average UK household (5,424kgCO_2) and 74% lower than the average new build (3,500kgCO_2[12])
- The development as a whole (energy centre, school and residential) does not appear to achieve zero carbon over this reporting period with a balance of 383 tonnes CO_2 (i.e. carbon emitting). This figure was 115 tonnes CO2 net emissions in the previous reporting period.
- We estimate the carbon savings between Elmsbrook and a new built development of equivalent size at 628 tonnes CO_2 for this year of reporting (438[13] tonnes of CO_2 in the previous year). The development has considerably increased in size since then.
- Some of the reasons why 'true zero carbon' was not achieved this year include the high boiler usage in the energy centre compared to CHP (42:58 split), (the boilers are more carbon intensive), high system losses (distribution + commissioning heat use are ~40% of total), some metering problems (leading to data loss) and inverter failures leading to lost PV output.
- Assuming a better CHP (~90%) to gas boiler split in the energy centre and using SAP 2012 carbon factors, indicate that the development could have potentially achieved its true zero carbon status under these parameters. It is possible that commercial considerations are driving when and for how long the CHP comes on and are resulting in higher gas boiler usage.
- Dwellings are using 10% less electricity than anticipated at design stage, ~15% less than an average Bicester household.
- 24% more heat (hot water and space heating) than design estimate but 55% less than Bicester average, 64% less than UK average, and 40% less than average for new builds since 2017 in England and Wales.
- Unlike the findings in the last reporting year, Elmsbrook residents currently produce less residual waste than the county average. The average recycling rate for Elmsbrook has improved from 45% in the previous period to 62%, compared to 58.8% for the county, and 45.5% for England.
- Elmsbrook residents used 83 litres of water per person per day. That's ~4% above the design target of 80 litres per person per day. On average 54% of households on Elmsbrook meet their water use targets off 80 litres per person per day, saving around 140 litres saved every day through water efficient design measures.

[12] http://transitionbath.org/impact-housing-standards-energy-costs-co2-emissions/

[13] Based on dwelling average carbon footprint at Elmsbrook of 728kgCO2 (when school and energy centre are included) and 3,500kgCO2 for an average UK new build. 158 homes.

5.3 Recommendations

Bioregional recommend the following actions to improve the efficiency of the monitoring process and quality of data:

- Household occupancy numbers are still only estimations and will affect the accuracy of water use data. We therefore again recommend that the next resident survey probes for a single question that checks both the number of adults and children and links that to the house type and or number of bedrooms.
- The flats remain unmetered requiring on site manual meter readings. This affects the accuracy of electricity and PV calculations. Further equipment problems can run undetected if not hooked up to an automatic system. We recommend the installation of a PV sub metering system, similar to the other households on site.

- Commissioning heat loads potentially make up a large proportion of the unaccounted system losses. These need to be factored into the zero-carbon equation for accuracy. We recommend that these commissioning heat loads are therefore reported on by the energy centre provider in next data submission.

- Active monitoring of data is immensely useful to spot out-of-range values and address potential equipment failures ahead of large-scale data loss. With work by Carnego already underway, Bioregional recommend that this process is tested ASAP, in order to put in place a protocol that is practical. A2Dominion need to ensure that the relevant maintenance people have access to this data and resources to respond.

- Similar to above, Bioregional recommend that the shimmy App link out of range warnings to private households with message to inform them of potential equipment failure or malfunction.

6 Appendix

Table 5 - Elmsbrook residents survey 2021, summary of survey results

Ref.	Question	Responses	Results
Health and wellbeing			
1	In general, would you say that your health is: Very good, good, fair, bad, very bad	72	The majority of answers were "very good" or "good", comprising 20 and 41 responses. Of the remainder, 9 answered "fair" and 2 "bad", with nobody answering "very bad".
2	Happiness overall: How happy did you feel yesterday? Please give an answer on a scale of 0 to 10, where 0 is "not at all" and 10 is "completely".	70	0 to 1: 2 1 to 2: 1 2 to 3: 0 3 to 4: 0 4 to 5: 4 5 to 6: 13 6 to 7: 6 7 to 8: 22 8 to 9: 13 9 to 10: 9
3	During the last 7 days, how many days have you taken part in exercise over a period of 10 minutes or longer? For example: Lifting, digging, cycling, running, walking, yoga?	72	0 days: 8 1-2 days: 15 3-4 days: 24 5-6 days: 13 7 days: 12
4	In terms of physical activity, comparing time during lockdown to before lockdown, have you: Been more active, been less active, about the same	72	Been more active: 15 Been less active: 18 About the same : 39
5	Which of the following green spaces does your household make use of locally? (please select all that apply) Options: Open countryside, nature reserves, country park, play parks, sports greens, grow beds, allotments (elsewhere in Bicester), none	73	Open countryside: 48 Nature reserves: 37 Country park: 22 Play parks: 20 Sports greens: 7 Grow beds: 6 Allotments (elsewhere in Bicester): 4 None: 11
6	If you selected any of the green spaces above, how often does your household use these? Options: Daily, weekly, fortnightly, monthly, ad hoc	70	Daily: 17 Weekly: 31 Fortnightly: 4 Monthly : 3 Ad hoc: 15
7	Did you shift to working more form home during lockdown? Options: Yes, no, occasionally	72	Yes: 50 No: 18 Occasionally: 4
8	Do you feel that the use of a co-working space could help you with more home-based working? Options: Yes, no, occasionally	70	Yes: 9 No: 35 Occasionally: 26
9	As result of the COVID-19 Pandemic are you using delivery companies more for your shopping and good? E.g. Amazon Options: Yes, no, about the same	72	Yes: 39 No: 12 About the same: 21

10	How strongly do you feel you belong in your immediate neighbourhood? Options: Very strongly, fairly strongly, neither strongly or not strongly, not very strongly, not strongly at all	73	Very strongly: 20 Fairly strongly: 25 Neither strongly or not strongly: 20 Not strongly: 0 Not very strongly: 4 Not strongly at all: 4
11	To what extent do you agree or disagree with the following statement? "If I needed help, other local community members would support me during the Covid 19 outbreak" Options: Strongly agree, agree, neither agree or disagree, disagree, strongly disagree. Comments optional	73	Strongly agree: 24 Agree: 35 Neither agree or disagree: 13 Disagree: 0 Strongly disagree: 1
12	How much do you agree or disagree with the following statement: "I regularly talk with people in the neighbourhood?" Options: Strongly agree, agree, neither agree or disagree, disagree, strongly disagree	73	Strongly agree: 18 Agree: 33 Neither agree or disagree: 0 Disagree: 6 Strongly disagree: 3
13	During lockdown, my contact with neighbours has: Increased, decreased, stayed the same	72	Increased: 26 Decreased: 13 Stayed the same: 33
14	Does your household compost your green and/or food waste? Options: Yes, no, sometimes	72	Yes: 43 No: 26 Sometimes: 3
15	Please indicate any activities any members of your household may like to attend/get involved with (please select all that apply) Options: Walking, healthy cooking and eating, cycling, gardening/grow your own, nature trails, reducing energy, forest school working party, up-cycling and reusing, none of the above Are there any activities not listed above that you would like to see at Elmsbrook?	72	Open countryside: 42 Healthy cooking and eating: 36 Cycling: 29 Gardening/grow your own: 35 Nature trails: 37 Reducing energy: 35 Forest school working party: 11 Up-cycling and reusing: 26 None of the above: 10 Are there any activities not listed that you would like to see at Elmsbrook?: - Children's activities - Pub, shops - Protest against new non-Eco housing development(not the A2D Eco-development) - Wildlife preservation - Book club, movies club - Table tennis - Too many to list!!! Hoping the Hub will provide seeding location and growth for these. (Note, two responses like this) - More activities for teenagers like skate park etc - community protesting against the estate and heating charges - Dog walking - Sports - Basketball on the new court in phase 3.
16	Are you involved in any type of community governance activities? For example, do you volunteer locally, organise any events, participate in any clubs or groups?	72	Yes: 18 No: 54

	Options: Yes, no If you answered yes, please state the nature of these activities		
17	What do you value most about living at Elmsbrook?	64	- The community feel and the eco-friendliness - Close to nature - Environment - Discovering - People - Not much as it has turned out to be a disappointment with every aspect of arrival and living through the pandemic to the terrible experience with Crest Nicholson with 18 months of wait for a snag list - Green fields around (which apparently will be built up by new houses very soon - what a waste!) - Eco friendly living - The community and our neighbours - The people - Community and people we have got to know through living here - Relationship with neighbours and the sense of community - It's a peaceful place, where even if it's a busy day you feel relaxed from the surrounding area - Neighbours - The friendly and helpful members of the community. - The community - The quiet - The space between the houses and the green - The community - The other residents - People and district heating - The green spaces - The green spaces surrounding us and the airy and open feeling of the development. I also value the bus service which I use every day. It makes my commute easier and the drivers are fantastic and friendly. my eco house - the community - the free charging point - all the green spaces - my garden - Location - The green fields to the front and rear of my house - My values do not involve Elmsbrook. A2 and it's approach to its residents has been distructive and we need a mechanism To bring community values together - The community - no dog bins, i value dog shit literally everywhere, it really gives the eco vibe walking around dodging shit everywhere - Regenerative energy in the houses, running club, access to countryside - School - Sense of community with eco flavour peace and quiet. Green spaces - Friendly and safe community - Nothing. The development deserves to be exposed to the media but that would devalue homes that already struggle to sell or change tenancy - Eco-friendly idea - the location of the site - the space per household - the density of this development is perfect, i.e. not squashed the whole site - community group - Eco environment - The eco objectives so it is disappointing that the house's eco management system has not been working since we moved in. - Energy efficient housing. Quiet pleasant location - Contributing to a low-carbon future; Green spaces; - Tranquility - The people, and eco aspirations - and making these happen, as best we can! - The people, and eco aspirations - and making these happen, as best we can!

			- Community and open space - The Community - community and passive houses - Well kept neighbourhood - The open spaces for walking the dog and community - The community and green space - I'm new to the area but am a fan of most things about it - Good community feel. Lots of play parks - Neighbors - Lower electric bills - The community/quiet/village feel - The community and quietness. - The community, my neighbours, the eco-friendliness. - the community - Being in a small village style community outside of the main town of Bicester - the green space - carbon zero development and eco side of things; sense of community; free charging point for EV; proximity to open countryside; proximity to Bicester - Nice house close to the countryside. - Community and open space - The amount of space, and lack of traffic (the latter unfortunately likely to be significantly affected by the proposed new development) - Good community - The calm
18	What do you think Shimmy could be better at?	67	- Discussion Group/board to raise urgent issues, sharing news, contacts details update, neighbourhoods needs, service standard on gererel area, bus ticket for residents, rights & procedures to modify house & garage, Q&A, resources sharing, bus route to nearby schools, etc - I still don't know how to use - Monitor the energy consumption - Usability - Everything. It needs a lot of work to be useful - Don't use it very often - More up to dates news and notices - Their app is slow and clunky. Not user friendly. Always sends notifications then there is nothing on the app. - Functioning correctly - Working on older phone operating systems. More accurate data on energy usage today - I'm happy with shimmy as it is - Show the nearest amenities - Our it's not working .It only did in the first year - It should work - notifications and more user friendly. Also not clear on the energy reporting - N/A - Never used it - Na - Alerting us to problems. - Showing utilities usage - Nothing comes to mind - Notifications often appear at the last moment (e.g. road closures). - being consistent - Dynamic. It feels like a filing system - Everything. The software doesn't inspire confidence especially the meter readings - Accuracy. It is not reflective of any usage - Items on it need updating. - could put some dog bins around the place.

			- I have not used it much so not sure. - Correct information - Don't use it - I hardly use it any more. It should be used for booking the Bromptons and sharing parking spaces/EV chargers etc. - i have requested Shimmy login since I moved here in March but have not received it - so I don't know!!!! - I don't use it so can't comment - The Shimmy is a pointless use of technology. Perhaps is it were kept up to date it might be useful, but it would need to be available on my desktop. That's where I look for information. - There was nothing wrong with Shimmy it's lack of education and guidance that's the problem. Not the App - I don't have one - What's a Shimmy? - Only just moved it so not sure - Not sure about solar generation/usage as our solar panels have never worked. Shimmy is useful in confirming that the panels do not work. It could perhaps provide basic information such as how to pay for the buses (not contactless) and assume that when people move in, there is plenty of information that is not readily available online. - Accuracy of readings. Heat readings are approx 10-15 kWh out from daily meter observation - I haven't even used it yet! - Ours is missing a connection for the Water monitoring - which we STILL need A2 to put in!!! - outstanding for several years now! I think the whole system could also really make use of Real Time Monitoring Analytics - run at Carnego's end, but able to spot faults quickly and spot trends. I have a background in algorithm design, and could help with this!!! - Ours is missing a connection for the Water monitoring - which we STILL need A2 to put in!!! - outstanding for several years now! I think the whole system could also really make use of Real Time Monitoring Analytics - run at Carnego's end, but able to spot faults quickly and spot trends. I have a background in algorithm design, and could help with this!!! - Unsure - Giving proper readings. Better communication on roadworks etc - more accurate costings including the standing charges and estate charges ... integration to other apps... - Unable to get shimmy - Giving better access to the information. e.g. energy usage doesn't seem right and no comparison with other people on the app. It's there but does not work. - It could be better at most things. Regularly glitches and gives false information so much that I don't bother with it anymore. It's useless. - Accurate data - I haven't used it yet - It's a lot better than before - More accurate comparisons and monthly summary's you can look back on - Actually give accurate meter readings - Regular updates - Able to see more data over longer time frame. Dashboard view. Able to view data even without internet connection. - I do not use it - N/a - Meter readings have been completely inaccurate for the most part. - should be more accurate - offering averages; being more accurate - Being connected to my EV charging point so that it only charges when the solar panels are generating energy. - Third-party integration / API & reliability - N/A

			- Accurate energy displays - Giving my actual readings
19	What do you think that Shimmy could be used for that it is not doing today?	54	- Report problems or concerns - No idea - Order food for the new coming cafe in Elmsbrook - Not sure - NA - Not sure - Sharing local events -? - Don't know - Any activity in the estate - N/A - It would be good if it would work as intended. - Unfortunately I find it quite useless as it does not work properly - Na - I find it quite limiting that the only options are "Today, Yesterday, This Week, This Month". I wish I could see a daily view of energy usage/solar panel generation that I can click through to compare each days' readings. - Raising alerts/ service issues by neighbours - Nothing comes to mind - n/a - not sure - Bus times, live information - Add bus times More community information - Accuracy - I don't look at it very often! It's just another tech gadget in the home - reporting when bins are full and the bloke getting paid our extortionate amount from our service charge can come and actually do something like clean them. - I would like it to show more detail information about solve usage. I would also like to be able to book the folding bikes. - Don't know - see above - don't know - N/A - Nothing - It was doing fine for me but user manuals for appliances and rainwater/PV panels should be updated and made available - N/A - Don't know - It could help coordinate some repairs on site by offering some time slots. It seems that waiting for repairs (with no or little response/update) has been a most time-consuming and frustrating experience for quite a few. - n/a - See previous answer - See my answer to 18 - (1) all be working! (2) analytics to find faults very fast, and spot trends that could help re usage issues for greener living. - See my answer to 18 - (1) all be working! (2) analytics to find faults very fast, and spot trends that could help re usage issues for greener living. - Forums - stated above - More accurate usage measurements and logging - …giving accurate readings… and notifying when is best to put on dishwasher and washing machine based of solar input - Data accuracy - I haven't used it yet - No additional ideas at the moment

			- More accurate billing by maybe putting actual readings in it - Na - Home automation integration. - Not sure - have daily notifications about environment - not sure - Controlling EV charging points. Reporting how much rain water is in the rainwater harvesting tank. - Third party integration & API - The app user experience is not great, seems to just be a load of links to PDFs. Could be better structured, more engaging, more useful energy graphs. Could have better energy cost predictions if we put it in our energy rates. - Community forum or some kind
20	Do you understand how to operate the heating system effectively in your home? Options: Yes, no Comments optional	72	Yes: 56 No: 16
Travel and transport			
21	On average over the past year, please indicate the household's main mode (longest distance/travel time) of travel for the most frequent journey undertaken in a typical week.	72	Car - sole occupant: 51 Car as a passenger: 16 Train: 11 Cycling: 13 Walking: 29 Motorbike/Scooter: 0 Community Transport: 8 Taxi: 3
22	Please indicate the distance travelled for the most frequent journey undertaken in a typical week	70	0-15 miles: 38 15-20 miles: 14 20-30 miles: 7 30 – 40 miles: 3 50+miles: 8
23	Do you utilise any other travel modes as part of the most frequent journey travelled in a typical week?	59	Bus: 13 Cycle: 5 Train: 9 Walking: 17 Car share/passenger: 12 Motorbike/Scooter: 0 Community Transport: 0 Taxi: 3
24	Why do you choose this way of travelling?	70	Cheapest: 12 Environmental reasons: 10 Healthiest option: 12 Lack of infrastructure: 13 Most convenient: 37 Quickest: 28 Safety concerns: 3 Travel with others: 2 Work requirements: 18 No other travel option: 6 Other (please explain): 9
25	Please confirm how many of each type of vehicle are kept at the residence	73	Bicycle: 37 Petrol car: 38 Diesel car: 26 Hybrid car: 5 Full electric car: 9 Motorcycle: 1 Bicycle: 47

			Electric bicycle: 5 Cargo bike: 1 Fold-up bicycle: 5 eScooter: 1
26	Do you own or have access to the following (please select all that apply)?	56	Bicycle: 47 Electric bicycle: 5 Cargo bike: 1 Fold-up bicycle: 5 eScooter: 1
27	What stops you from considering to travel by bus? (Please select all that apply)	71	None of the above: 14 N/A already use E1 bus: 9 N/A already use 505 bus: 1 Cost: 11 Bus only accepts cash and I do not carry cash: 18 Distance from nearest bus stop (at home or destination): 4 Journey times: 17 Lack of service information: 6 No service available when required: 12 Poor waiting facilities (e.g. shelter, seating, lighting): 5 Covid-19 considerations: 15 Other (see explanations): 26
28	What stops you from considering travelling by cycle? (Please select all that apply)	68	N/A already travel by bike: 10 I do not have a bike: 14 Cost of purchasing a bike: 3 Distance I have to travel: 20 I haven't explored using the Elmsbrook free Brompton bike hire: 6 Time: 9 Work requirements: 12 Lack of bike storage at my home: 4 Lack of experience or confidence cycling: 11 Lack of dedicated cycle infrastructure on route e.g. cycle lanes: 16 Weather conditions: 14 Bike security away from home: 14 Others (see explanations): 13