Collaborative Approach to Design: Case-study of Future-Proofing A Paragraph 80 House

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Abstract
This paper demonstrates future-proofing preliminary design phase of a Paragraph 80 (DLUHC, 2021) housing case study by using Building Performance Simulation. Paragraph 80 is about the design of new isolated homes in the countryside defined as outstanding buildings of the highest quality in the UK. The objective of the simulations was to optimise the trade-off between the architect’s vision, the client’s requirements and the building physicist’s focus to achieve maximum energy efficiency, investigating the applicability of net-zero operational energy and providing thermal comfort in the current and future climate considering current low occupancy and higher design occupancy. The results show operational net-zero energy is achievable and no overheating is predicted in the current weather however local active cooling is necessary for 2050 despite passive cooling mitigations. A more definitive Paragraph 80 policy is needed which also requires whole lifecycle carbon analysis and achieving net-zero carbon.

Highlights
- Collaborative architectural design and Integrative approach
- Optimised operational energy for a Paragraph 80 house, UK
- Building design was future-proofed by using Building Performance Simulation (BPS)
- The use of BPS to mitigate overheating risk in over-exposed Building Design.
- Net-zero operational energy and providing thermal comfort

Introduction
There is no doubt that the construction industry with specific reference to the building sector accounts for an excessive portion of global energy consumption and carbon emissions (Berardi, 2017; Elnokaly et al., 2019). Therefore, it is vital to be considered a significant target for implementing energy-saving initiatives (Chafik et al, 2022).

To reach climate change neutrality designing net- or nearly-zero energy buildings is becoming a necessity. Hence, globally the construction of buildings accounts for 39% of process-related greenhouse gas emissions (Ürge-Vorsatz, 2020). Zero-energy buildings go some steps further than low-energy buildings that aim at constructing buildings with energy-saving measures and renewable energy generation in mind (Longo et al., 2019) or minimizing the building operating energy (Sartori and Hestnes, 2007; Ramesh et al., 2010). Zero-energy buildings aim to further decrease consumption for the operation of the building to become self-sufficient (Cabeza et al., 2014; Zimmermann et al., 2005), and generate enough energy to counterbalance their consumption (Liu et al., 2019; Crawley, 2009).

This paper presents a near-zero energy design of a Paragraph 80 building in Nottinghamshire in the UK. 'Paragraph 80' buildings refer to criterion (e) of Paragraph 80 of the UK National Planning Policy Framework (DLUHC, 2021), formerly Para 79 & Para 5' and prior to this ‘PPS 7. It is also known as the country house exemption clause that allows new isolated homes to be built in the countryside. General policies restrain new dwellings in the countryside, whereas the NPPF, allows new dwellings to be built in the countryside obligating two conditions; the building is truly outstanding, reflecting the highest standards in architecture, and would help to raise standards of design more generally in rural areas; and would significantly enhance its immediate setting, and be sensitive to the defining characteristics of the local area (DLUHC, 2021)

There are several examples of Paragraph 80 houses despite the slow uptake due to the difficulty of the design, and planning approval and also the lack of guidance. There are architectural practices which have specialised in Paragraph 80 house design. However, lack of guidance and benchmarks is a definite issue since the local authorities are responsible for assessing whether a design fulfils the Paragraph 80 requirements and there is no clear agreement between local authorities. A national database (Para80 2023) which collates information on Paragraph 80 houses (Para80 Map 2023), was conducted by an architectural practice in 2018 by recognising the lack of a central database and quantitative data. They reported that based on the data provided by local authorities which have responded to the query- 33% of planning permission submissions are refused (Para80 Map 2023). The wasted time and costs of unsuccessful submissions accelerate the need for clearer guidance.

Allowing exceptional design to be built where otherwise their location is not permitted for any construction, Paragraph 80 aims for continual innovation and development within architecture. In particular, promoting
finding newer and better ways to make homes that are sustainable and environmentally sound is targeted. However, there is no robust guidance on how “truly outstanding, reflecting the highest standards in architecture” will be achieved. Therefore, there are many challenges surrounding the design and construction of Paragraph 80 houses. The current policy for a Paragraph 80 house makes it very difficult for these applications to go through and the title ‘Truly Outstanding’ is the benchmark. This means covering all bases such as design, landscape, ecology, and holistic sustainability. The policy is a response to the reality that, despite the drive to improve the design quality of new housing generally, new housing continues to be very ordinary, homogenous and with very poor environmental considerations which cannot be accepted in the design of such houses.

The aim of this paper is to present a case study for demonstrating the use of building performance simulations (BPS) to analyse and improve the thermal behaviour of the preliminary design using its climatic conditions and context. Key aspects such as the magnitude and type of building energy demand and the capacity of renewable energy generation with specific reference to solar energy depend on climate and location (Tsirigoti & Tsikaloudaki, 2018). Hence, it makes it imperative to design buildings according to their context and climatic conditions during the early stages of the design process (Rode et al, 2014). In addition, climatic variables must be known in advance to simulate the thermal behaviour of the building envelope (Oral, & Yilmaz, 2003). Due to the exceptional nature of the design, the objective of the simulations was not to determine the best possible option based on the building physics theory (e.g. window-wall ratio, e.g. shading type) but to optimise the trade-off between the architect’s vision of outstanding design, the client’s requirements and building physicist’s focus to achieve maximum energy efficiency, investigating of the applicability of net-zero operational energy and providing thermal comfort in the current and future climate. The optimisation was the outcome of the collaborative design process and demonstrating this process could provide guidance to future Paragraph 80 projects.

**Methods**

The study adopts an empirical investigation conducting building performance simulations based on the input data derived from client-user behaviours, architect-BIM 3D model, material specifications and the Standard Assessment Procedure (SAP 2023) inputs. The objectives of the BPS were to determine the net energy consumption of the design to assess whether achieving net-zero operational energy is possible by installing photovoltaics to generate enough energy to counterbalance the building consumption and to investigate overheating risk. CIBSE Environmental Design: Guide A (2015) suggested the term ‘future-proof building’ to indicate that designers must consider the impacts of climate change in their building designs. 2050 was chosen as a representative year to analyse the implications of future weather on overheating risk. To provide futureproofing, four alternative scenarios are determined based on occupancy density and weather data. The occupant density is significantly lower (2 people) than the design density (6 people). This has a considerable impact on energy consumption and comfort analysis, therefore, the scenario alternatives include:

- Current weather and current occupancy (2 people)
- Current weather and design occupancy (6 people)
- 2050 weather and current occupancy (2 people)
- 2050 weather and design occupancy (6 people)


**Building Model and Input**

The Paragraph 80 house is located in the East Midlands, Nottinghamshire, UK with relatively mild summers, cool winters and abundant rainfall throughout the year. It is a timber frame structure building with steel and timber roof cladding and bamboo and timber external-wall cladding. Figure 1 shows the 3D model of the house which comprises four bedrooms, five bathrooms, a living room, a kitchen, a gym and a garage; a total area of 320 m². Bedrooms, gym and study are located on the double-storey north block and the living room and kitchen are on the single-storey south block.

![Figure 1: Design Builder building model – rendered](https://doi.org/10.26868/25222708.2023.1217)
implemented on the model. For this, a questionnaire survey was filled out by the client which investigates daily, weekly and seasonal usage of appliances, lighting and domestic hot water (DHW). The survey conducted by the architect with the client asks what type of appliances were used, how often during the weekdays and weekends, and lighting and hot water use habits. A log sheet was also filled indicating in which room, which appliances were in operation and for how long. In addition, the questionnaire also investigated window-opening behaviour.

### Table 1 Building model input data

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-value wall</td>
<td>0.15</td>
<td>W/m²K</td>
</tr>
<tr>
<td>U-value roof</td>
<td>0.11</td>
<td>W/m²K</td>
</tr>
<tr>
<td>U-value windows</td>
<td>1.2</td>
<td>W/m²K</td>
</tr>
<tr>
<td>G-value south-facing window</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>G-value window others</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Airtightness</td>
<td>4</td>
<td>m³/h-m² @50Pa</td>
</tr>
<tr>
<td>Ventilation Minimum fresh air</td>
<td>10</td>
<td>l/s/person</td>
</tr>
<tr>
<td>Heating setpoint Living room</td>
<td>21</td>
<td>°C</td>
</tr>
<tr>
<td>Heating setpoint other rooms</td>
<td>18</td>
<td>°C</td>
</tr>
<tr>
<td>Ventilation for cooling</td>
<td>22</td>
<td>°C</td>
</tr>
<tr>
<td>MVHR setpoint</td>
<td>25</td>
<td>°C</td>
</tr>
</tbody>
</table>

### Environmental Strategies

The heating system is designed to include a ground source heat pump and underfloor heating. Heating is triggered by temperature settings, but manual overwriting is also possible. The heating source is solely electricity from the grid and photovoltaic panels (PV). PVs occupied 50m² of roof space which is on the double storey bedroom block. A hybrid ventilation strategy is adopted; natural cross ventilation through operable windows and sliding doors and stack ventilation using temperature-triggered skylights. This was modelled by “calculated ventilation” function in DB which takes wind, bouncy-driven pressure, opening and crack sizes and operations settings and schedules into account. Window openings are set to be 30% of the window area and operated by occupants using electronic controllers. Mechanical ventilation with heat recovery (MVHR) unit was installed which operates when natural ventilation is not adequate for ventilation and cooling. Heating and ventilation for cooling setpoints are based on CIBSE TM59 templates (CIBSE TM59, 2017).

### Weather Data

For current climate conditions, Test Reference Year (TRY) weather data were available at the Climate One Building Org (2023) Repository of free climate data for building performance simulation. Design Summer Year (DSY) weather files for future predictions were derived from the Prometheus web portal (2017) of Exeter University (Eames et al., 2011) which are based on the UKCP09 weather generator (UKCP09, 2009). They were derived from the regional climate model downscaling using the weather generator model. The method (described by Eames et al., 2010) produces 50th-percentile weather data under a medium emissions scenario which, overall, might be the most likely weather condition. A higher percentile, such as the 90th percentile, indicates the conditions during a particularly warm year and likewise, the 10th percentile gives an idea of the likely conditions in a cooler future year. For future weather cases, the 50th percentile weather data was chosen in order to represent the average conditions rather than the extreme conditions.

### Overheating Analysis

CIBSE TM59 (2017) is a standardised approach to predicting overheating risk for residential building designs (new-build or major refurbishment) using dynamic thermal analysis. CIBSE TM59 sets two criteria based on the ventilation strategy.

Criteria for homes predominantly naturally ventilated: Compliance is based on passing both of the following two criteria: (a) For living rooms, kitchens and bedrooms: the number of hours during which temperature is greater than or equal to one degree (K) during the period of May to September inclusive shall not be more than 3 per cent of occupied hours. (CIBSE TM52 Criterion 1: Hours of exceedance).

(b) For bedrooms only: to guarantee comfort during the sleeping hours the operative temperature in the bedroom from 10 pm to 7 am shall not exceed 26 °C for more than 1% of annual hours (Note: 1% of the annual hours from 10 pm to 7 am shall not exceed 26 °C for more than 3 per cent of occupied hours (CIBSE Guide A, 2015), i.e. all occupied rooms should not exceed an operative temperature of 26 °C for more than 3% of the annual occupied annual hours (CIBSE Guide A, 2015).

The alternative scenarios are tested against both predominantly naturally ventilated and predominantly mechanically ventilated criteria considering a hybrid ventilation strategy in place.

### Results

Table 2 shows the net energy consumption of scenario alternatives in the subdivision of heating, domestic hot water (DHW), lighting, and equipment energy. The electricity generation from photovoltaic panels, which are located on the double-storey bedroom block, was estimated by the provider as 39.6 kWh/m², taking account of the geographical location, orientation and inclination of the array. The area of PV (50 m²) was optimised considering costs, embodied carbon emissions of PV production and energy demand. If it is needed in the future, in the case of an increased occupant number, additional PV installation could be considered on the roof of the common areas block. The roof area can take over the double the amount of PV cells that are currently proposed. This indicates net-zero operational energy could be achieved.
The impact of design occupancy is clearly seen in DHW, lighting, and equipment energy by 103%, 63%, and 72% increase respectively. Heating energy decreases in design occupancy scenarios because of additional internal gain from people, DHW, lighting and equipment. Warmer 2050 weather also decreases heating demand by 12%.

Table 2 Energy consumption of scenario alternatives kWh/m²

<table>
<thead>
<tr>
<th></th>
<th>Net energy</th>
<th>Heating</th>
<th>DHW</th>
<th>Lighting</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current occupancy</td>
<td>43.0</td>
<td>21.0</td>
<td>12.5</td>
<td>3.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Design occupancy</td>
<td>60.6</td>
<td>19.3</td>
<td>25.2</td>
<td>6.2</td>
<td>9.9</td>
</tr>
<tr>
<td>Current occupancy</td>
<td>40.3</td>
<td>18.2</td>
<td>12.5</td>
<td>3.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Design occupancy</td>
<td>57.6</td>
<td>16.3</td>
<td>25.2</td>
<td>6.2</td>
<td>9.9</td>
</tr>
</tbody>
</table>

Initial results – Interventions

Considering the dominantly south-facing high window-wall ratio, of 48%, the initial concern was overheating risk. In the basecase scenario, ventilation was provided by MVHR. No shading or night ventilation was set. The initial results showed that overheating has occurred in all cases except current occupancy in current weather scenario main bedroom. The most effective mitigation was external shading either in the form of overhangs, louvres or blinds. External shading eliminated overheating even in the worst case scenario – design occupancy in 2050 weather – including in kitchen and living room. However, the architect rejected this option due to aesthetical and visual considerations.

The recomendation then was reducing the g-value of south and southeast windows (from 0.8 to 0.5) and installing internal shading/blinds which otherwise was not considered. Internal blinds with high reflectivity slats are defined for all rooms which operate from May to October when the internal temperature is above 22°C and are operated by the occupants.

As ventilation strategy, nighttime ventilation was proposed to run in conjunction with MVHR. It is assumed to be achieved through open windows and operating MVHR. Window operation was not set on the ground floor during the night because of security considerations. MVHR operated on both floors when the temperature was 22°C and above. Window operation on the first floor is dependent on occupants’ behaviour since they would not operate windows while they are asleep. The ventilation is assumed to be achieved either by open windows during the night or MVHR starts to operate.

For both window opening and internal blind operation, the assumption was that occupants will operate these components using remote controllers. Therefore, natural ventilation and shading are dependent on the occupancy schedule. This significantly limits the capacity of ventilation and shading. Therefore, when occupants are not present to operate windows and internal temperatures are above the threshold, MVHR operates to achieve ventilation for cooling purposes. However, the full capacity of shading to mitigate overheating is not achieved since an automation system is not installed.

Overheating Tests

Based on CIBSE TM59 naturally ventilated homes overheating test and mechanical ventilation test results, for current and design occupancy scenarios overheating was not predicted in current weather. In the current occupancy scenario, only the main bedroom is assumed to be in use whereas three bedrooms are occupied in the design scenario. In 2050 scenarios, living rooms and kitchens failed the tests despite MVHR being activated for longer periods. This is because of warmer external temperatures. Table 3 and Table 4 summarise the overheating tests. Other functions: gym, study, and bathrooms which are not in the scope of CIBSE TM59, are individually investigated against CIBSE TM52 and the gym also repeatedly failed the overheating test.

Table 3 Current and 2050 weather design occupancy (6 people) TM59 overheating test results

<table>
<thead>
<tr>
<th>Zone</th>
<th>Current weather design occupancy</th>
<th>2050 weather design occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Criterion</td>
<td>Criterion</td>
</tr>
<tr>
<td></td>
<td>A (%)</td>
<td>B (hr)</td>
</tr>
<tr>
<td>Bedroom1</td>
<td>0.24</td>
<td>6.5</td>
</tr>
<tr>
<td>Bedroom2</td>
<td>0.07</td>
<td>6.5</td>
</tr>
<tr>
<td>Main Bedroom</td>
<td>0.17</td>
<td>6</td>
</tr>
<tr>
<td>Bedroom</td>
<td>0.17</td>
<td>3</td>
</tr>
<tr>
<td>Kitchen</td>
<td>1.26</td>
<td>N/A</td>
</tr>
<tr>
<td>LivingRoom1</td>
<td>1.13</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 4 Current and 2050 weather current occupancy (2 people) TM59 overheating test results

<table>
<thead>
<tr>
<th>Zone</th>
<th>Current weather Current occupancy</th>
<th>2050 weather Current occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Criterion</td>
<td>Criterion</td>
</tr>
<tr>
<td></td>
<td>A (%)</td>
<td>B (hr)</td>
</tr>
<tr>
<td>Main Bedroom</td>
<td>0.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Kitchen</td>
<td>1.26</td>
<td>N/A</td>
</tr>
<tr>
<td>LivingRoom1</td>
<td>1.1</td>
<td>N/A</td>
</tr>
</tbody>
</table>

In all scenarios bedrooms benefited from night-time ventilation; especially in 2050 warmer weather. Night-time ventilation through windows is not set in the living room and kitchen because of security considerations. Figure 2 and Figure 3 show the living room and main bedroom conditions in summer design week (15 July-22 July) presenting the outdoor temperature and indoor operative temperature in comparison with air change rate and air intake factor. Since occupants cannot operate windows during the night when they are asleep, MVHR is assumed to be providing external air intake when the temperature is above the cooling setpoint. Although MVHR was available during the night, the impact of the cooler night-time air change was not adequate to
To overcome 2050 overheating, in the living room, kitchen and gym installing local active cooling is recommended in the future. This could be during a potential MVHR retrofit considering the 15-20 lifespan of the device.

![Figure 2 Main bedroom conditions in summer design week (15 July-22 July)](image1)

![Figure 3 Living room conditions in summer design week (15 July-22 July)](image2)
Discussion
The case study demonstrates a collaborative design process to optimise the performance, aesthetics and value of the design. The collaboration was possible based on the fact that the architect and the client were climate crisis conscious, aware of the importance of analysing the performance of the building, and are keen to monitor their use of heating and cooling energy and their own occupant behaviour and also flexible to reconsider their decisions. They prioritised the input of a building physicist despite there being no regulation which requires such analysis. Though, it is worth highlighting the participation of building physicists in the early design stages - instead of providing mitigations after the preliminary design is finalised - could overcome the requirement of adapting active cooling in the future. Collaborative design process and early design performance analysis are crucial to optimise the building design.

The TM59 tests predicted that the living room, kitchen and gym will suffer from overheating in 2050 weather, despite the availability of night-time ventilation using MVHR and internal blinds. Higher external temperatures are expected in the future; therefore, the overheating risk is expectedly to increase. In this case, however, the design choice of high solar gain due to the dominantly south-facing high window-to-wall ratio (48%) and preference for internal blinds (in oppose to external shading) are not providing the required overheating mitigation capability. This is a good example of the conflict between building physics theory and architectural practice. The aesthetic consideration of the architect and client’s desire to access a wider view (hence the high window-to-wall ratio) has led the design to consider active cooling in the future whereas overheating may have been mitigated by applying passive design strategies. A compromise was achieved based on the assumption that in the future the grid will be majorly powered by renewable energy hence carbon footprint of active cooling is minimised.

Another aspect is that until an unforeseen future, the house will be occupied by fewer occupants (2) than it is designed for (6). This results in additional heating energy due to the space heating of unused spaces to the setback temperature, heat flow from heated spaces and also not benefitting from the internal gain of the occupants. This could cause a performance gap. Additionally, services must be sized for the design occupancy to consider future occupancy scenarios. The client’s perspective could be to achieve higher asset value considering not many people have multiple opportunities to build a house within their lifetime.

This case study demonstrates that a building design is an outcome of the trade-off between client’s, architect’s and building physicist’s (if involved) perspectives and optimisation of compromises. A more definitive policy could provide a more robust design strategy for Paragraph 80 buildings to be categorised as “outstanding design”. Whole lifecycle carbon analysis (LCA) and achieving net zero carbon could be a norm and required by the policy. This could assure maximising energy efficiency and minimising carbon emissions while providing thermal comfort in accordance with building regulation Part O (DCLG 2022). Also, standardising the strategy to design Paragraph 80 houses could help designers to achieve planning permissions considering that currently, for these specific housing, a third of the applications are likely to fail.

Conclusion
Paragraph 80 buildings of the UK National Planning Policy Framework (DLUHC, 2021), allow new isolated homes to be built in the countryside which promotes finding newer and better ways to make homes that are sustainable and environmentally sound. However, there is no robust guidance on how “truly outstanding, reflecting the highest standards in architecture” will be achieved as stated by the policy or how this can be quantified and proven by the architects of such buildings.

The aim of this paper is to present a case study for demonstrating the use of building performance simulations (BPS) to analyse and improve the preliminary design of a Paragraph 80 building. Due to the exceptional nature of the case study design, the objective of the simulations was not to determine the best possible option based on the building physics theory but to optimise the trade-off between the architect’s vision of outstanding design, the client’s requirements and the building physicist’s aspect. The focus was to achieve maximum energy efficiency, investigating the applicability of net-zero operational energy and providing thermal comfort in the current and future climate. The optimisation was the outcome of the collaborative design process and demonstrating this process could provide guidance to future Paragraph 80 projects.

The initial simulations detected overheating risk in all scenarios due to the high window-wall ratio. The most effective mitigation was external shading which could have resolved the overheating issue. However, this option was discarded by the architect based on the aesthetical and visual considerations. The consensus was applying internal shading with night ventilation. The results showed that although no overheating is predicted in the current weather, the living room, kitchen and gym will suffer from overheating in 2050 weather despite the availability of night-time ventilation using MVHR and internal blinds. Therefore, local active cooling is recommended in the future during a potential MVHR retrofit considering the 15-20 lifespan of the device.

The architectural design is an optimisation of compromises between the architect, the client and in an ideal world, the building physicist. Therefore, the involvement of building physicists in the early design stage is crucial to achieving optimised building performance and providing data-driven architecture which can then be “truly outstanding, reflecting the highest standards in architecture” (DLUHC, 2021).

Paragraph 80 houses require a clear and robust design strategy to avoid planning permission failures. For developing guidance, (LCA) and achieving net zero carbon could be a norm and required by the policy to
maximise energy efficiency and minimise carbon emissions and provide thermal comfort. A future publication will focus on how LCA transforms the preliminary design while optimising costs versus carbon emissions.

**Acknowledgement**

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Para80 Map (2023) Website https://studiobark.co.uk/paragraph-80-map/ (accessed on March 2023)


