# Wales Housing Climate Analysis: Additional Information

### Climate Data

The climate data used in this analysis are the UK Climate Projections 2018 (UKCP18) local (2.2 km) projections for 12 Met Office Hadley Centre models (HadGEM3-GC3.05) under Representative Concentration Pathway (RCP) 8.5 (Centre for Environmental Data Analysis, 2021).

### Time Periods

Baseline, 2030 and 2070 results represent the average year in the 20-year period centred around each time period. The years from 1981-2000 are used for the baseline while 2021-2040 and 2061-2080 are used to represent projected results for 2030 and 2070, respectively.

### Indoor Temperature Conditions

The relationship between outdoor temperature and indoor temperature is based on a monitoring study of 193 free-running dwellings (without heating or cooling) located throughout England (Beizaee, 2013; CIBSE, 2006). The study reports mean and maximum hourly indoor temperature consolidated across all monitored dwellings for the 41-day period from July 22nd to August 31st. Average hourly outdoor temperature was also reported across all dwellings and for two of England's Government Office Regions. Using the study data, a relationship was developed between daily outdoor temperature and daily indoor temperature for the 41-day monitoring period.

The indoor-outdoor temperature relationships could be enhanced by the expansion of the monitoring period as well as the inclusion of additional paired data points for average outdoor temperature and indoor temperatures. Additionally, information on indoor temperature fluctuations due to occupant behaviour, and due to building characteristics besides those included in the referenced studies (air tightness, insulation performance, etc.), was not included in the monitored data, and so is not included in the analysis. Hourly indoor temperature is assumed to fluctuate following a linear pattern between maximum, average and minimum daily temperatures.

### Dwelling Classes

Results for internal overheating risk and indoor air quality are reported for eleven dwelling classes common within the Welsh housing stock. Temperature adjustments are applied to the indoor temperature calculation discussed above, which is based on data from 193 free-running dwellings in an English monitoring study (Beizaee, 2013). The same monitoring study also reported separate dwelling temperature data for five different dwelling types, six different dwelling age bands, and four different external wall types. This data formed the basis for nine of the eleven Welsh dwelling categories used in our study.

Internal wall insulation (IWI) and double-glazing temperature adjustments are based on a study by Mavrogianni et al. (2012) that used Energy Plus thermal simulations to model temperature conditions within London dwellings. The Welsh housing survey (Welsh Government, 2018) found that all dwellings built after 1920 have already been retrofitted with double glazing. The same is assumed to hold true for the dwellings in the Beizaee et al. (2013) monitoring study, since glazing properties were not specified as part of the study. The result is that the double-glazing temperature adjustment and associated results are only applicable to pre-1919 dwellings in this study.

**Indoor Humidity Conditions**

A similar method was used to calculate indoor humidity from outdoor humidity. The relationship between indoor and outdoor humidity depends heavily on the type of humidity. Relative humidity, which is the amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the given temperature, shows a poor correlation between indoor and outdoor levels (Tamerius, 2013). Conversely, in the case of specific humidity, which is the mass of water per unit mass of air and does not depend on temperature, indoor measurements track well with outdoor measurements across seasons, diverse climates, and a wide range of outdoor temperatures (Nguyen, 2015). Specific humidity data is also available as part of the UKCP18 climate data. For these reasons, specific humidity was used as the meteorological metric for the relationship between indoor and outdoor conditions, with indoor relative humidity then calculated using psychrometric relationships.

Linear regression relationships as reported in three separate monitoring studies were used as the basis for the relationship between average daily indoor and average daily outdoor specific humidity (Nguyen, 2015; Nguyen et al., 2014; Tamerius, 2013). The three studies include monitored specific humidity data from six global locations.

Current data availability does not allow for differentiation of specific humidity values based on building characteristics. Additionally, information on humidity fluctuations due to occupant behaviour (cooking, exercise, etc.), and due to building characteristics besides those included in the referenced studies, was not included in the monitored data, and so is not included in this analysis. Rather, indoor specific humidity fluctuation was assumed to mimic the outdoor specific humidity fluctuation. Lastly, a more tailored result could be achieved if whole-year hourly monitoring data existed for a wide range of Welsh dwellings, with humidity differences tracked between numerous combinations of building and occupant characteristics.

**Building Fabric**

The analysis aims to quantify the impact that projected changes in solar exposure, precipitation and relative humidity may have on degradation rates of six building fabric components common in Welsh dwellings: roof tiles (clay/slate/concrete), walls (brick/stone), render and mortar (lime/cement), masonry paint, sealant, and window and door frames (Jardim, 2019; Serralheiro, 2016; Silva, 2011; Menzies, 2013; Silva, 2016; Galbusera, 2014; Berdahl, 2006). The studied building fabric components are affected by the climate variables as follows:

- Roof tiles are vulnerable to solar, relative humidity and precipitation.

- Walls are vulnerable to relative humidity and precipitation.

- Render and mortar are vulnerable to solar, relative humidity and precipitation.

- Masonry paint is vulnerable to solar, relative humidity and precipitation.

- Sealant is vulnerable to solar and precipitation.

- Window and door frames are vulnerable to solar and precipitation.

It is important to note that there is an absence of data on any definitive climatic thresholds associated with lifespan degradation factors for any of the fabric components. The published durability factors are defined for qualitative thresholds such as “moderate” or “severe” exposure or, in the case of solar exposure, by compass orientation. As such, an adjusted service life factor of 0.9 was assigned each day for a given climate variable if it was projected to increase from the baseline average and a 1.0 if it was projected to decrease from the baseline average.

**Further Information**

Multiple peer reviewed articles have been published on this work. *Quantifying the Effects of Projected Climate Change on the Durability and Service Life of Housing in Wales, UK* covers the building fabric analysis while *Summertime Impacts of Climate Change on Dwellings in Wales, UK* covers the indoor air quality and overheating analyses. Additional details can be found within the Welsh Government report *How resilient are buildings in the UK and Wales to the challenges associated with a changing climate? Practical recommendations for risk-based adaptation*.

**Application of Results**

Please note that the results of this study contain inherent uncertainty due to that which exists within the climate projections and also due to the modelling generalisations and limitations discussed on this page and in the peer reviewed articles associated with this study. The use of this data is intended to inform the broader climate resilience planning process and detailed analyses is necessary prior to action on a portfolio- or building-scale. Climate vulnerabilities, and therefore maintenance, repair, and adaptation priorities, will be contingent on a dwelling’s location, orientation, age, and construction typology, and influenced by previous interventions including energy efficiency measures, such as external, internal, and cavity wall insulation.

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