Climate Vulnerability Modelling

How resilient is Welsh housing stock to a changing climate?

Housing Information Group Seminar
19th January 2022

Professor Carolyn Hayles
Cardiff Metropolitan University

CARDIFF SCHOOL of ART & DESIGN

Cardiff Metropolitan University | Prifysgol Metropolitan Caerdydd

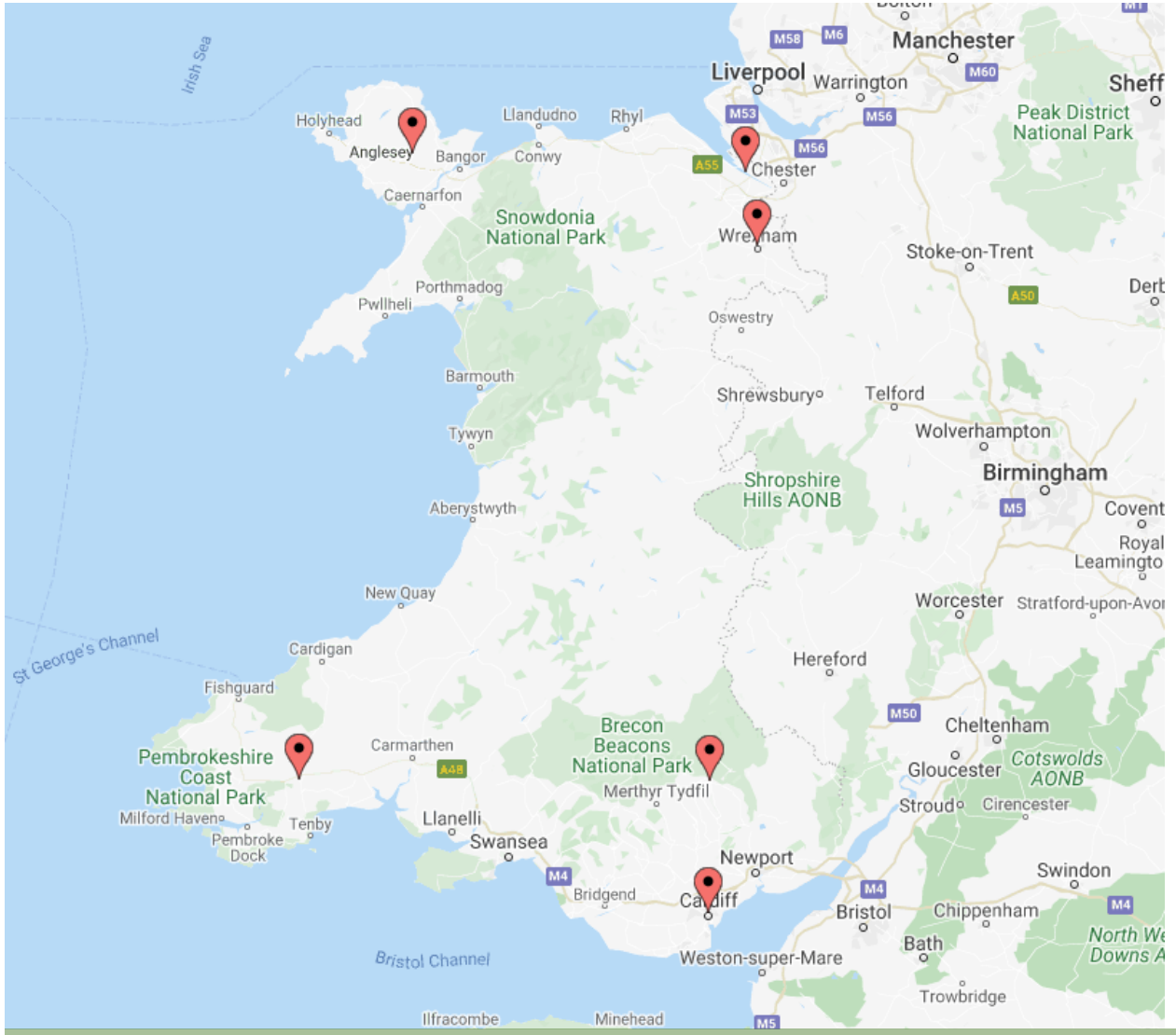
Climate Vulnerability Modelling
in collaboration with [Resilient Analytics](#).

Vulnerabilities:

- Indoor Environmental Quality
  - Thermal Comfort
  - Moisture
- Building Fabric

Datasets:

- UKCP18 Local (2.2km) projections
- Emissions Scenario: RCP8.5
- Time Periods:
  - 1981-2000 (Baseline)
  - 2021-2040 (2030)
  - 2061-2080 (2070)
- 12 HadGEM3-GC3.05 models
- 6 locations presented



Cardiff, Brynmawr, Narberth, Wrexham, Shotton, and Llangefni

IEQ - Thermal Comfort

General methodology

Input: Daily average outdoor temperature

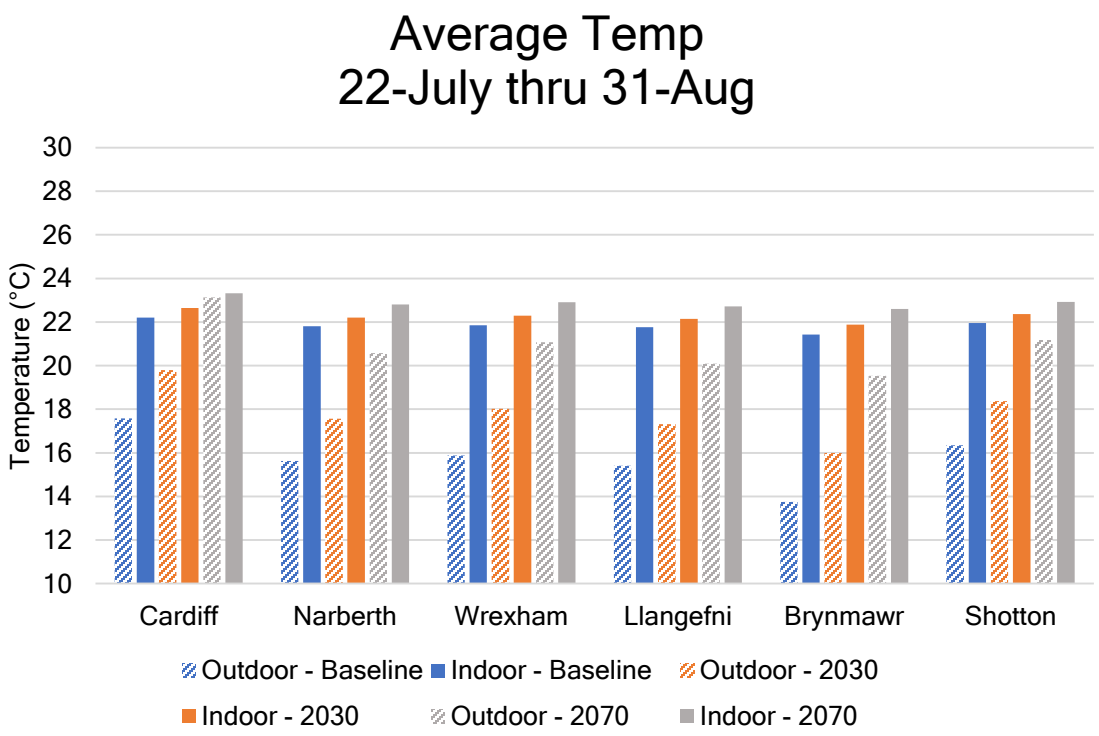
Output: Daily average indoor, daily maximum indoor, and hourly indoor temperatures

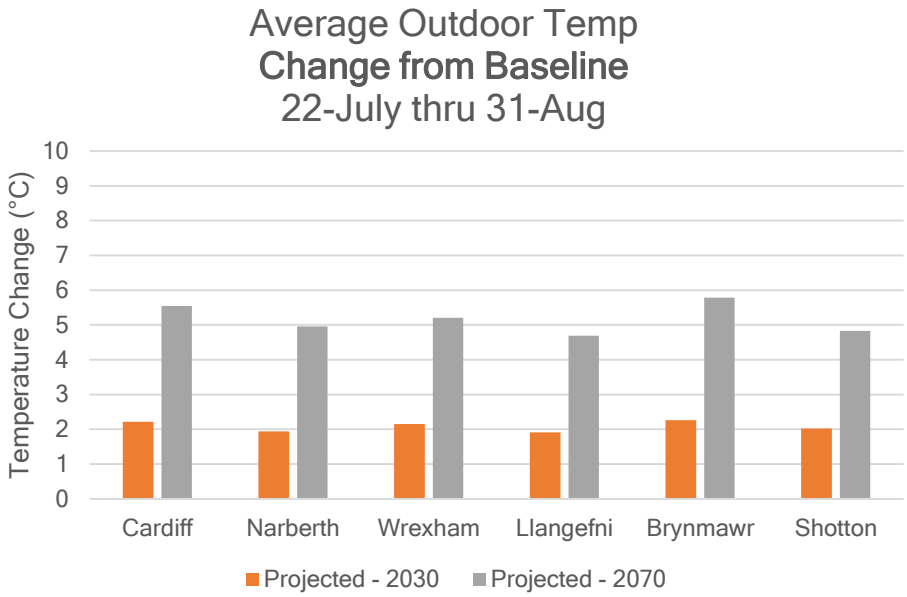
Relationship derived [°C adjustment] from a UK-based monitoring study of 193 dwellings [Beizaee et al. 2013]

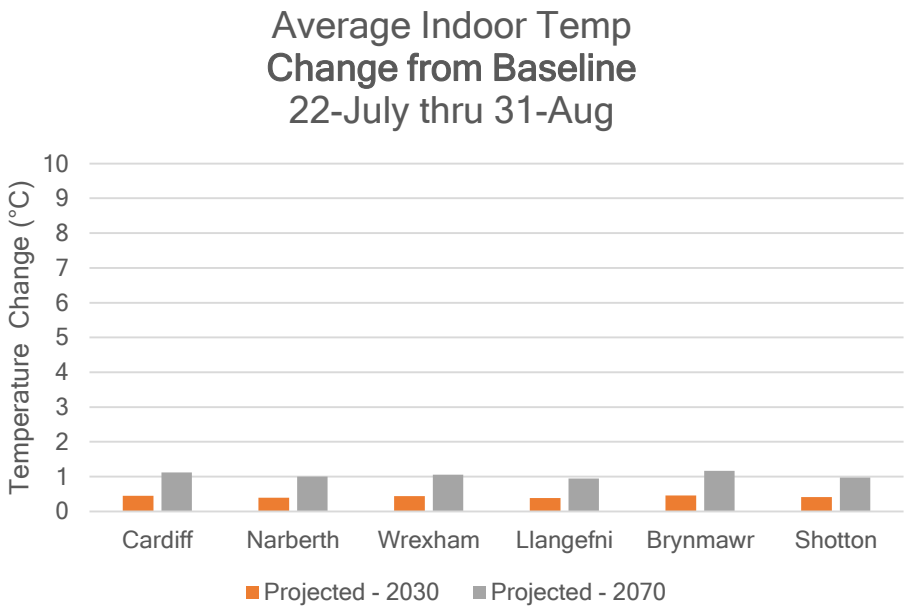
6-week period [22 July-31 August]

Welsh Housing Building Classifications			
Building Classes		Adjustment (°C) Add to calculated internal temp	
		Mean	Max
Age	Pre 1919	-1.0	-1.8
	1919-1990	0.1	0.2
	Post 1990	0.8	0.8
Wall Construction	Timber Frame	0.0	-0.3
	Solid - Stone	-1.6	-2.1
	Solid - Brick + Cavity - Brick	0.0	0.2
Dwelling Type	End Terrace + Mid Terrace + Semi Detached	0.1	0.2
	Detached	-0.4	-0.4
	Flat	0.7	0.8
Insulation	Internal Wall Insulation	0.4	0.6
Window	Double Glazing [pre-1919]	-0.4 (-1.4)	-0.6 (-2.4)

Average Temperature



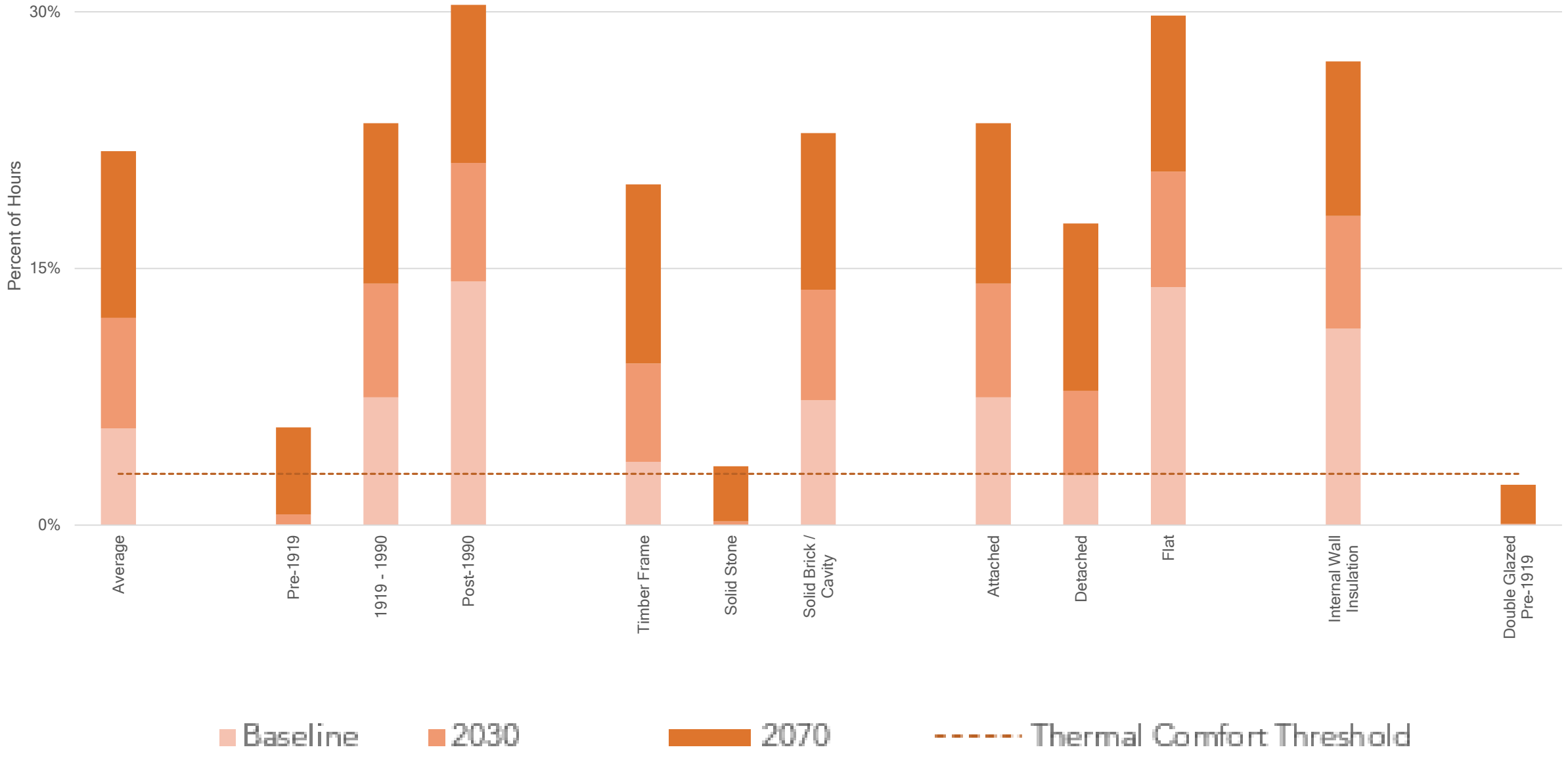




Percent of Hours over 26°C

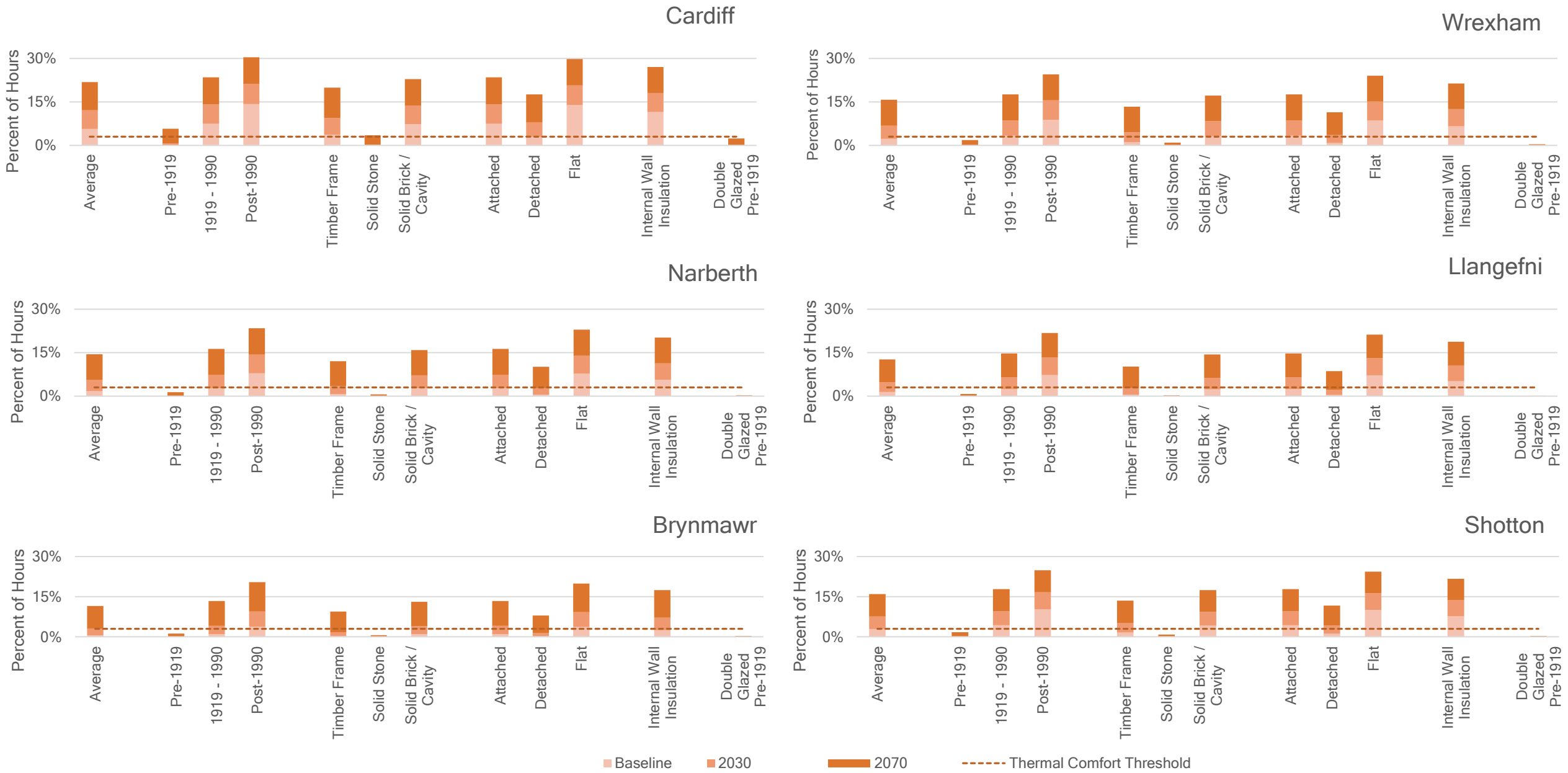
July 22nd - August 31st

Cardiff



Percent of Hours over 26°C

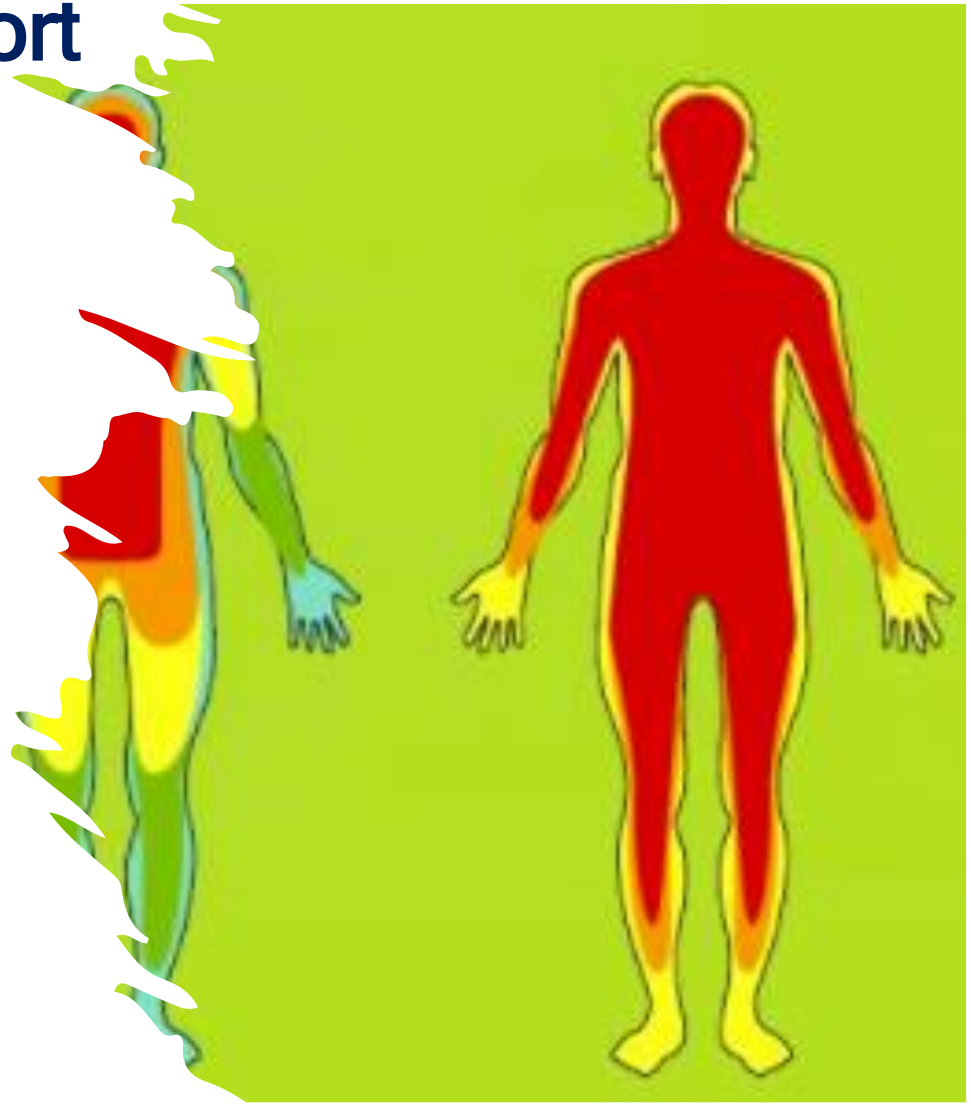
July 22nd - August 31st



Summary of results for Thermal Comfort

Increased incidences of summertime overheating in a majority of dwellings

- Best performing dwellings were pre 1919 dwellings and dwellings with solid stone walls.
- Poorest performing dwellings were post 1990 dwellings, flats and properties with internal wall insulation.
- Cooling strategies to reduce indoor air temperature will increasingly be required.



IEQ - Relative Humidity

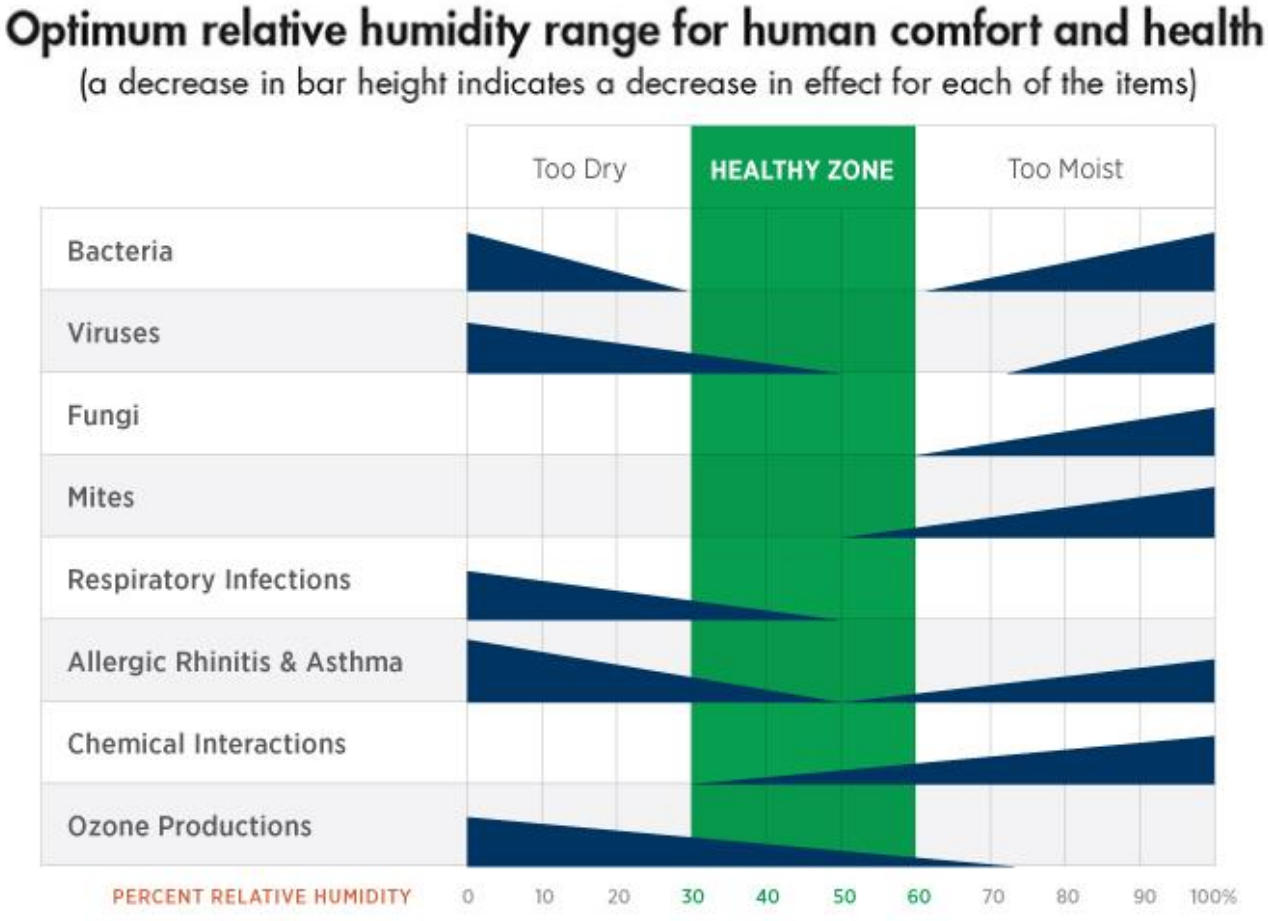
Vulnerability Calculations

Maximum and average relative humidity used as an indicator for multiple indoor air quality metrics

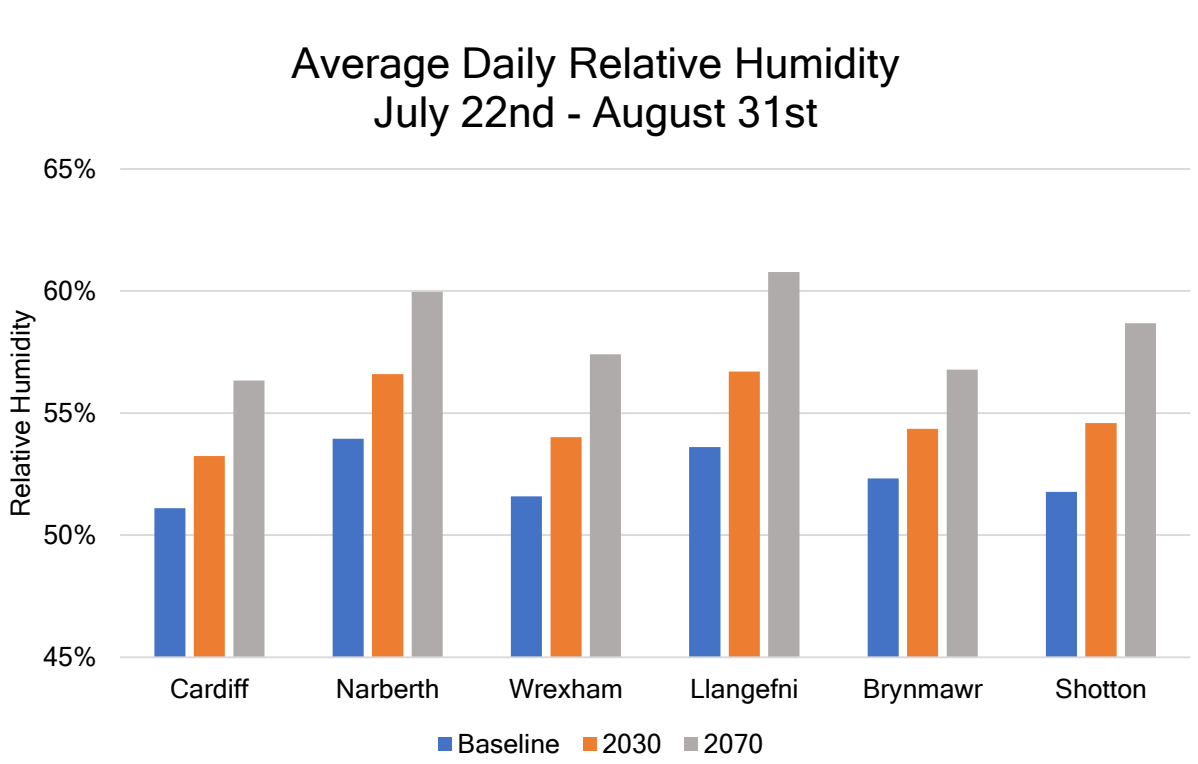
General methodology

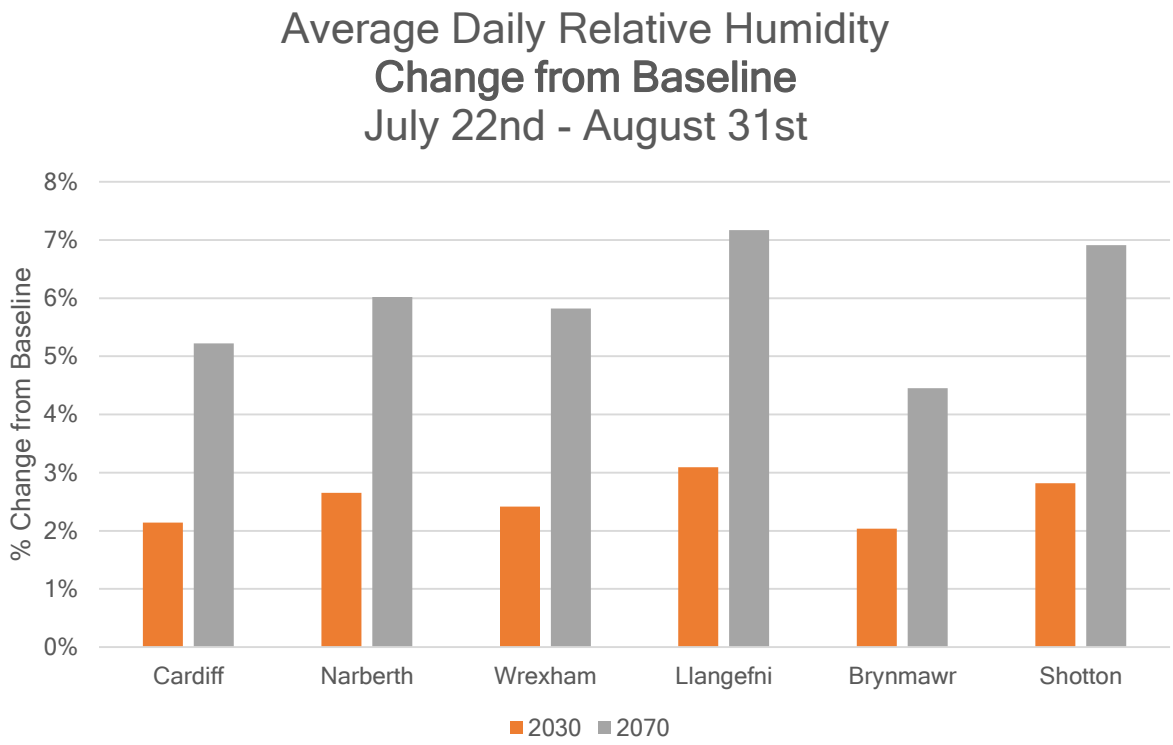
- Input: daily average outdoor specific humidity
- Output: daily maximum indoor relative humidity
- Relationship derived from a global monitoring study of 6 locations

$$SH_i = SH_o * 0.752 + 2.186$$



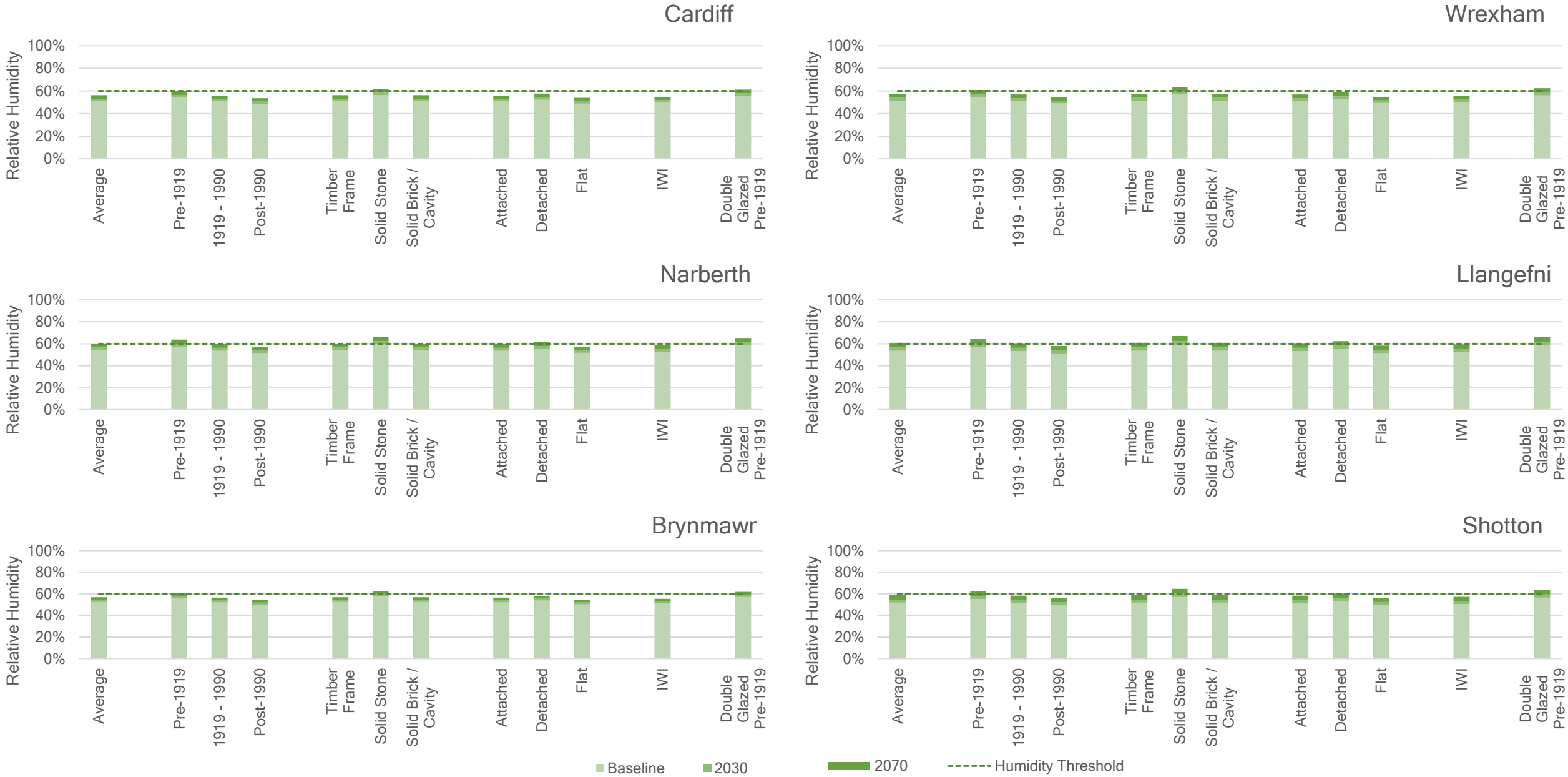
Average Indoor Relative Humidity



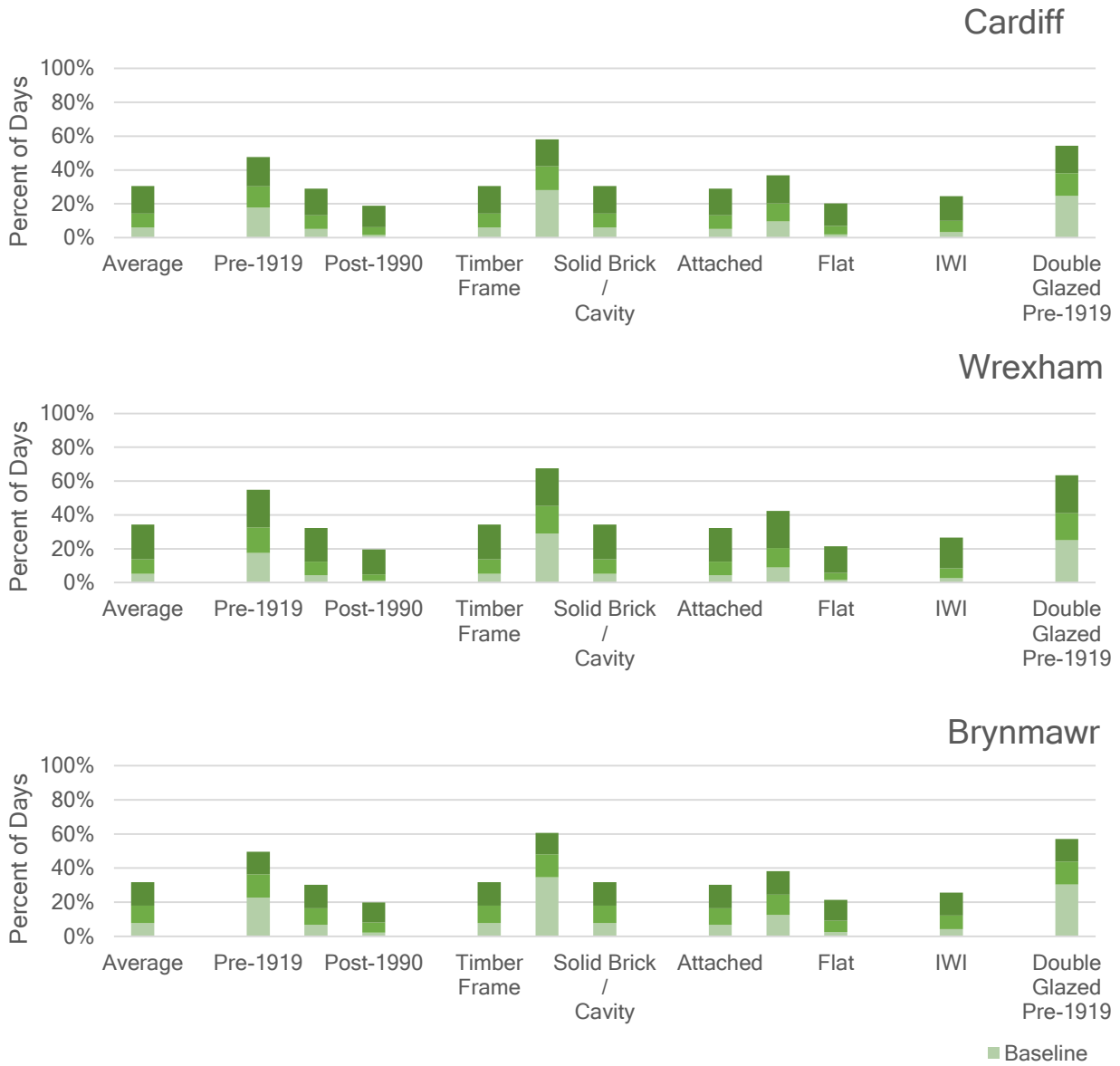


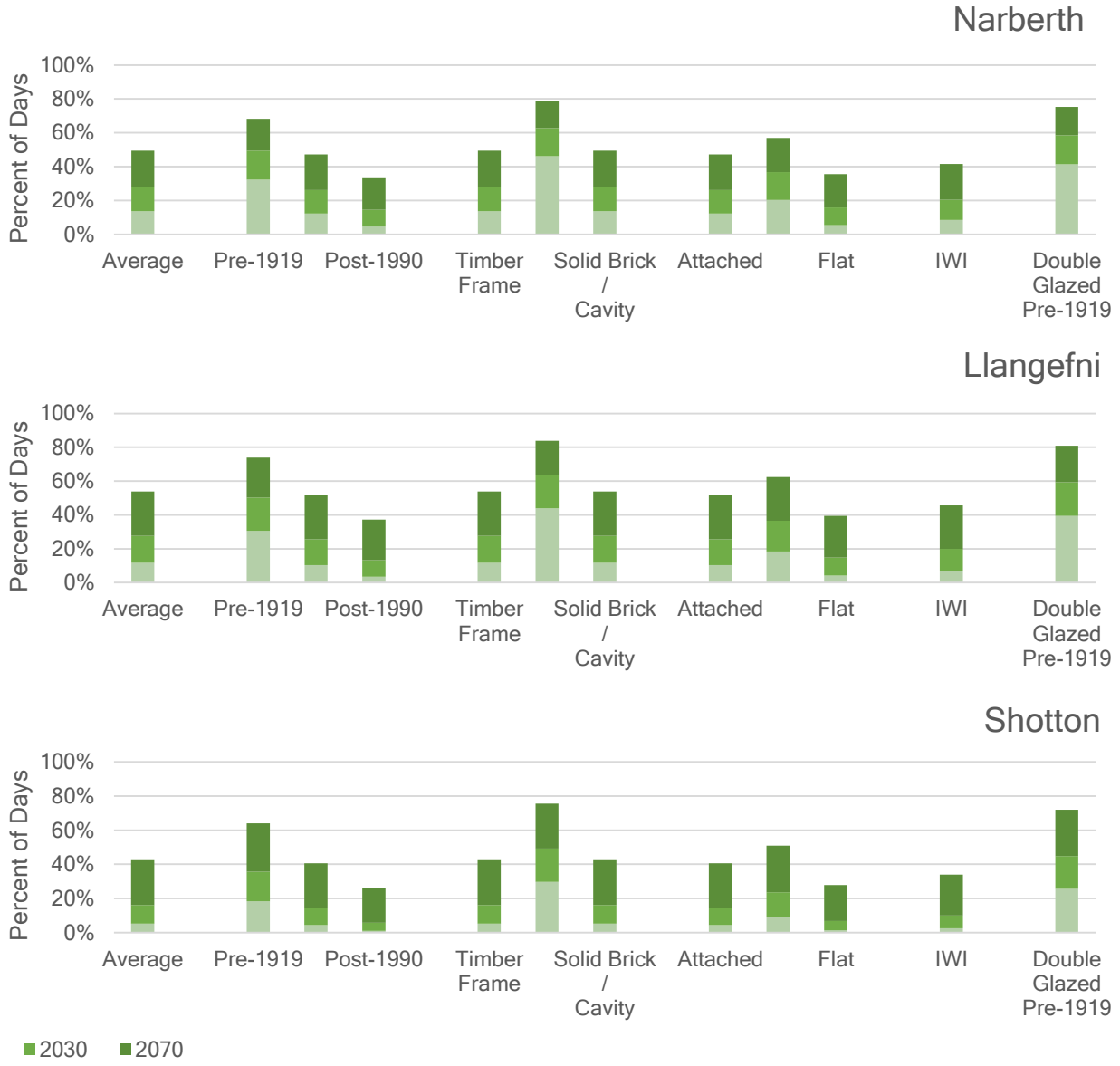
Daily Average Relative Humidity

Average for July 22nd - August 31st



% of Days with **Average** Relative Humidity Greater than 60%
Average for July 22nd – August 31st





% of Days with Average Relative Humidity Greater than 60%
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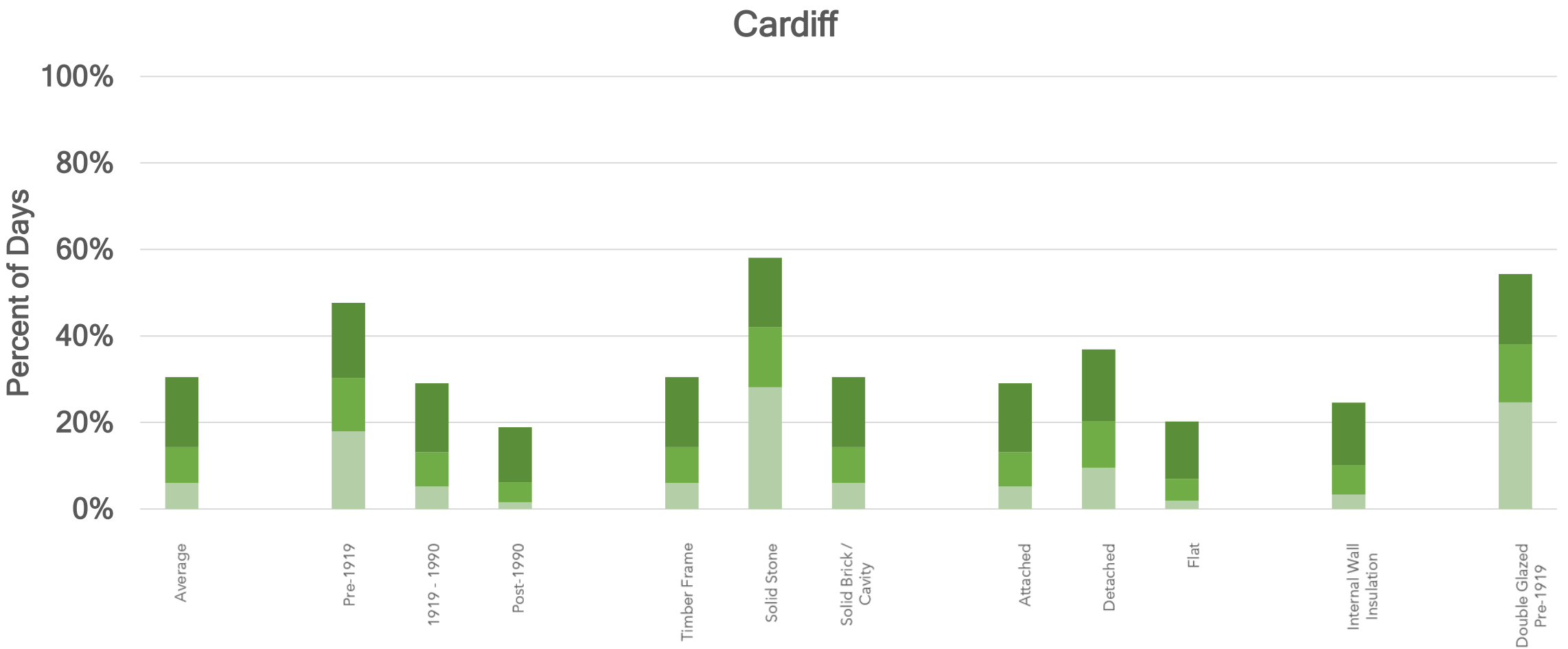
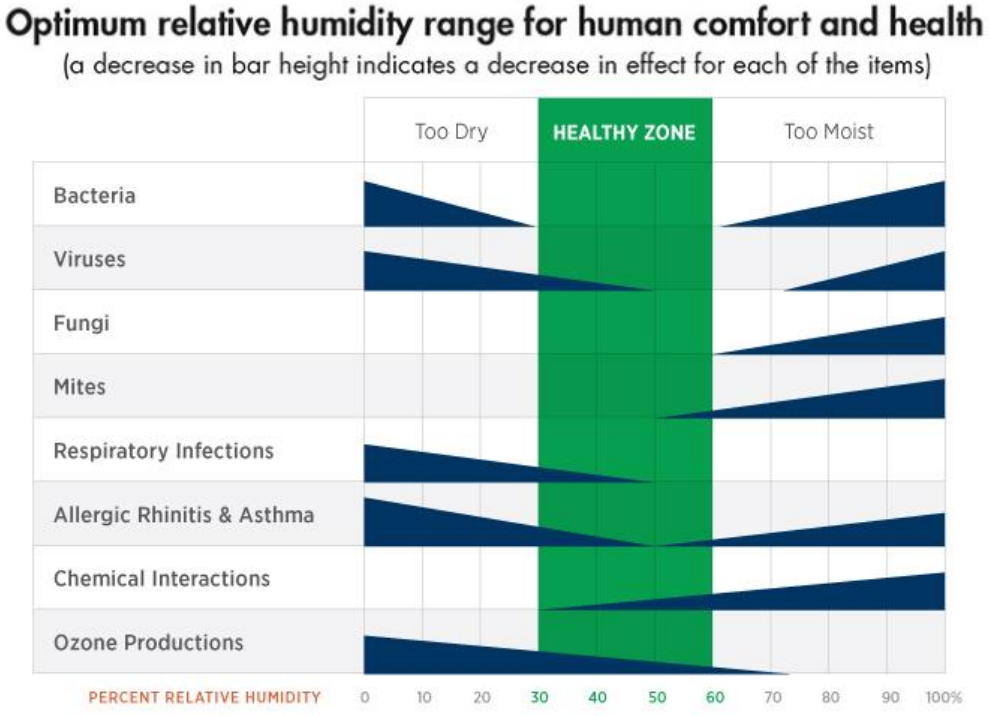


Summary of results for Indoor environmental quality

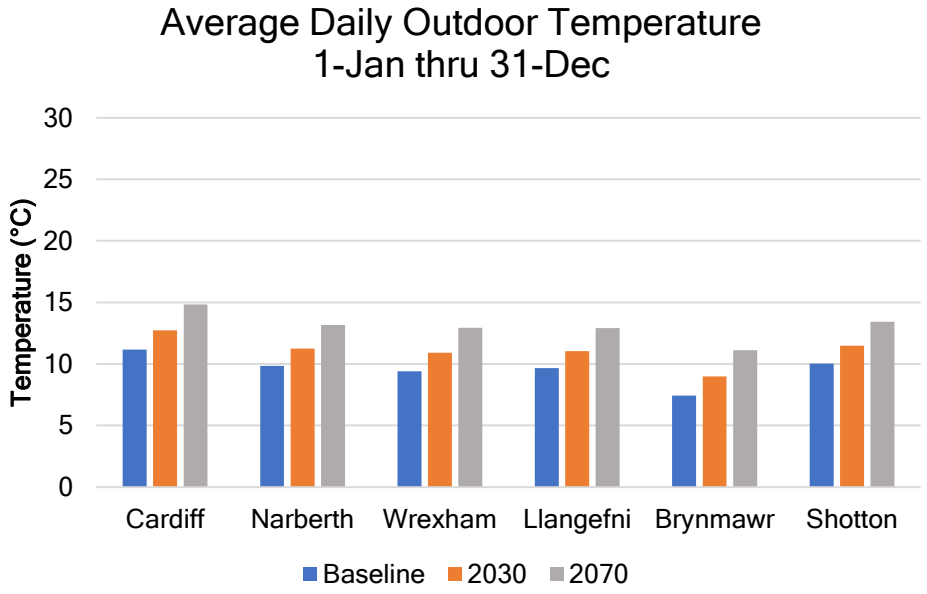
Potential for poorer indoor environmental quality [in the summer] due to an increase relative humidity.

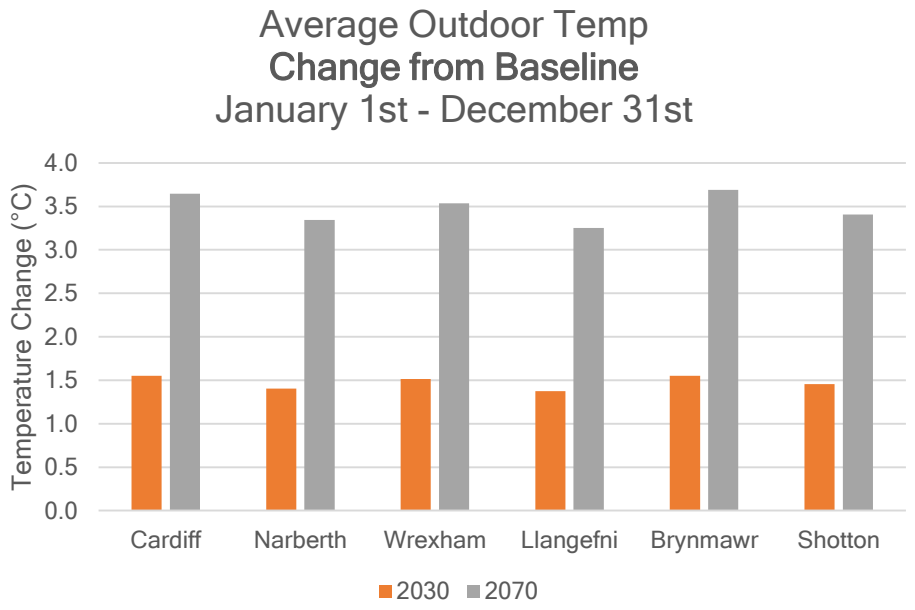
- All dwellings will experience increases in relative humidity regardless of dwelling typology.
- Relative humidity will be highest in pre 1919 dwellings and dwellings with solid stone walls regardless of location.
- Ventilation strategies to improve the extraction of moisture-laden air [and indoor-generated pollutants] are required if these dwellings are to avoid increased incidences of condensation, damp, and mould growth, and adverse impacts from other allergens, particles and pollutants.

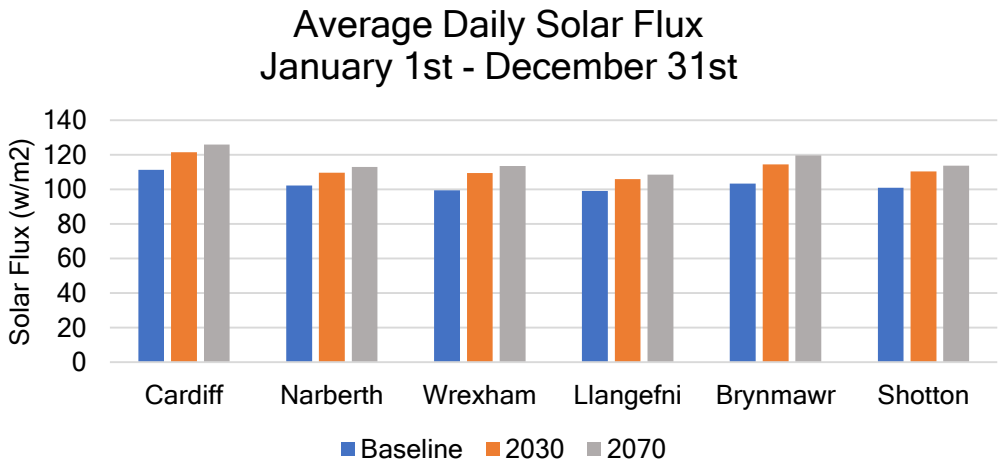


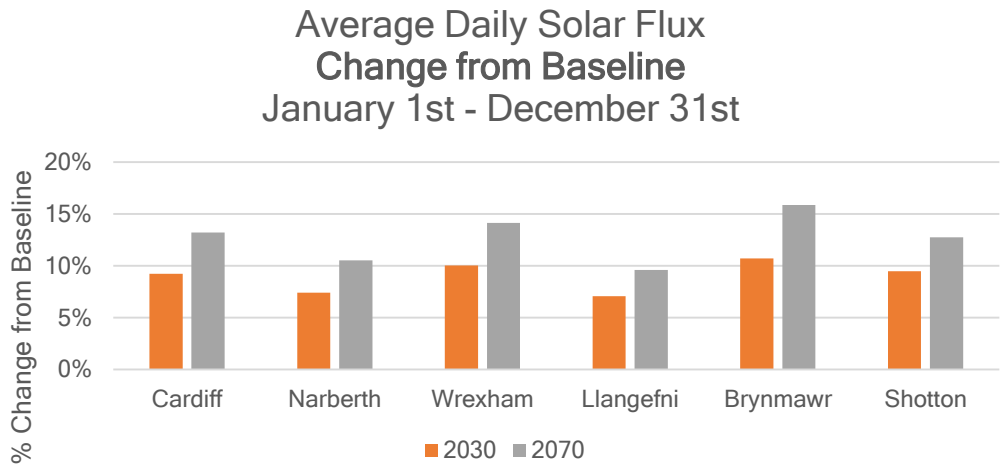
Building Fabric

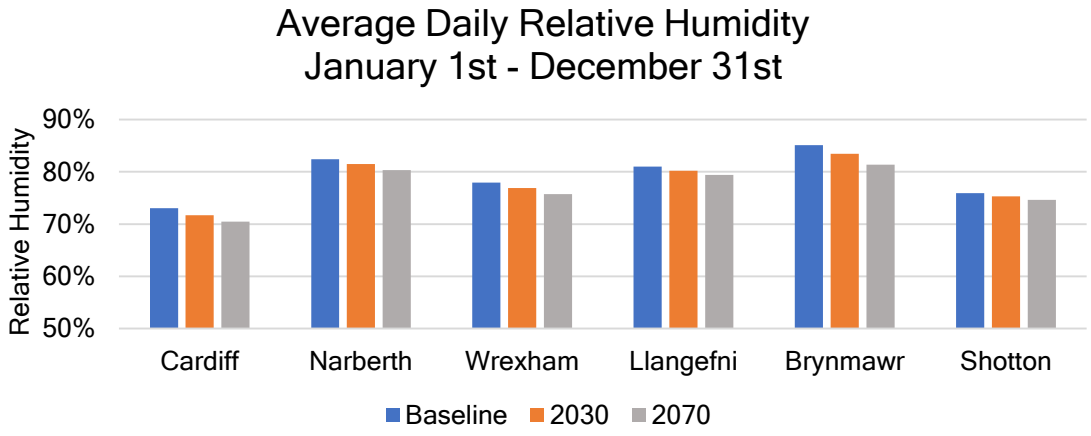
Building fabric vulnerabilities were calculated using **service life data** adjusted service lives [and associated costs] are presented for individual climate variables as a measurable and quantifiable output.

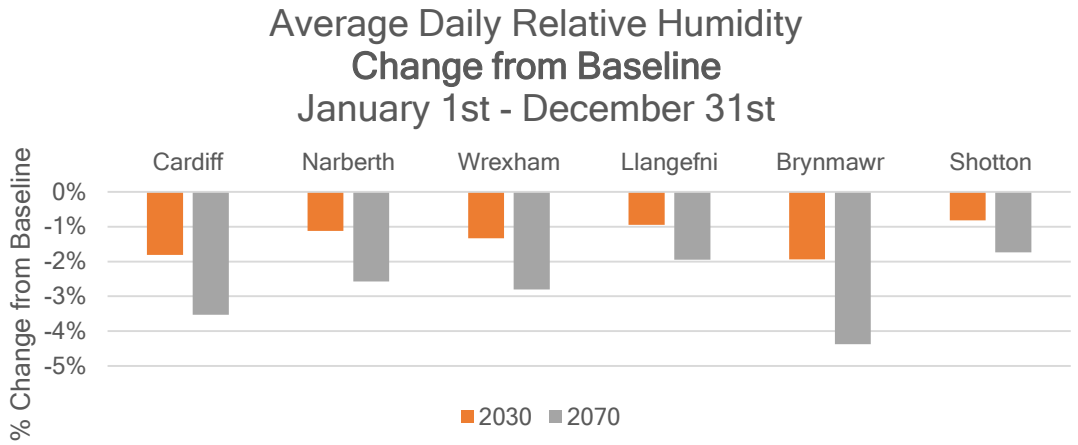

Average Daily Outdoor Temperature
1-Jan thru 31-Dec
Temperature (°C)
30
25
20
15
10
5
0
Cardiff
Narberth
Wrexham
Llangefni
Brynmawr
Shotton
Baseline
2030
2070


Average Outdoor Temp
Change from Baseline
January 1st - December 31st
Temperature Change (°C)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Cardiff
Narberth
Wrexham
Llangefni
Brynmawr
Shotton
2030
2070

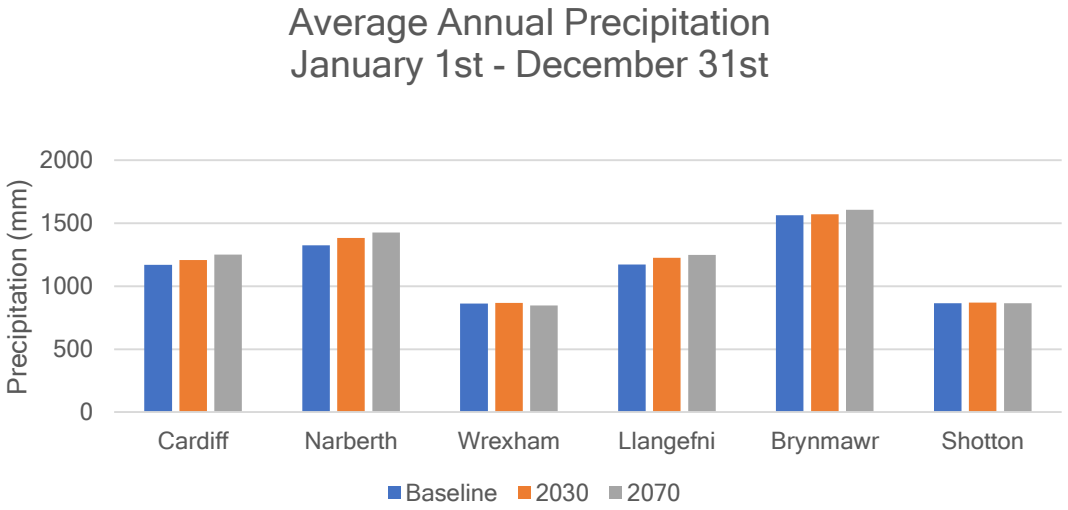

Average Daily Solar Flux
January 1st - December 31st
Solar Flux (w/m2)
140
120
100
80
60
40
20
0
Cardiff
Narberth
Wrexham
Llangefni
Brynmawr
Shotton
Baseline
2030
2070

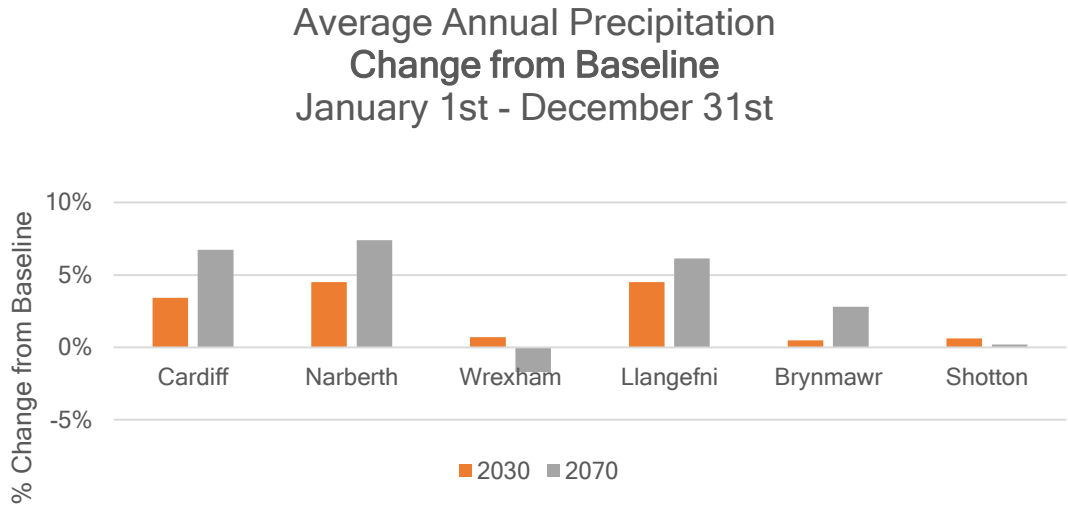

Average Daily Solar Flux
Change from Baseline
January 1st - December 31st
% Change from Baseline
20%
15%
10%
5%
0%
Cardiff
Narberth
Wrexham
Llangefni
Brynmawr
Shotton
2030
2070





Because warm air can carry more moisture than cold air, the **relative humidity** level will be higher in cold air and **lower** in **warm** air at the same absolute **humidity** level.





Methodology

- **Adjusted service life factors** were calculated based on exposure to each climate variable, quantified as the change from baseline, for each building fabric component [As outlined in the ISO 15686 Factor Method procedure].
- Factors were applied to baseline service life values to find the adjusted service life under projected climate conditions [as published in the British Standard 7543].
- Three separate adjusted service lives were calculated, one for each climate variable, which were then used to calculate the **percent change in maintenance and/or replacement costs** for each building component.
- The building fabric analysis is broken into **three separate evaluations of vulnerability** from solar exposure, from relative humidity and from precipitation.
- Climate factors could not be combined since degradation data was only available for each climate variable acting independently.

Cardiff

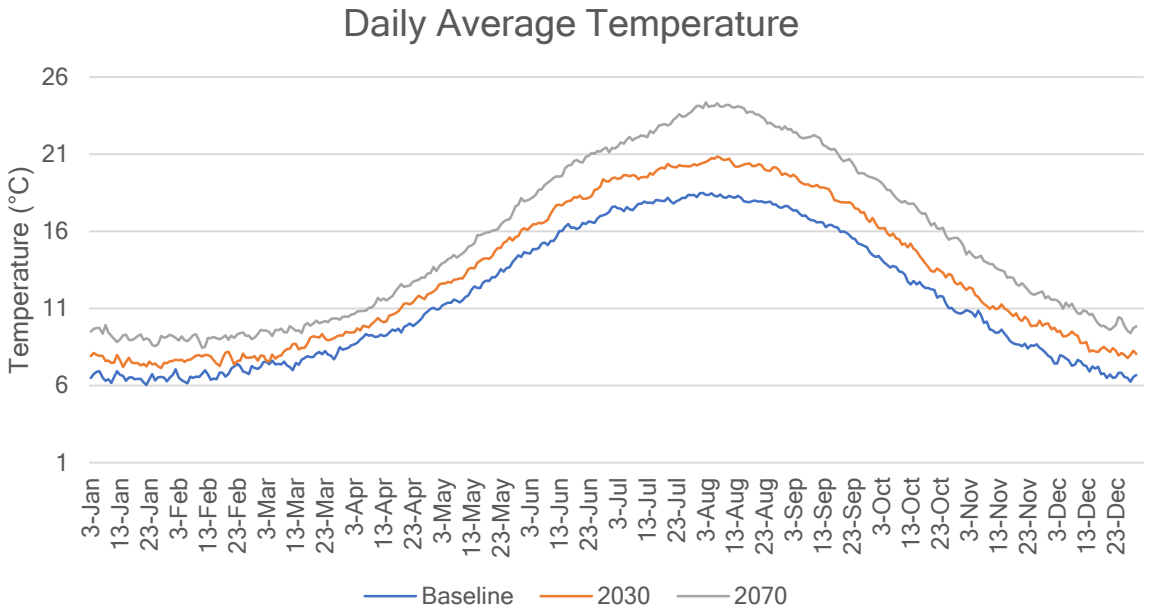
Building Fabric Degradation Results for: Cardiff													
Material / Component	Solar Flux	Relative Humidity	Precipitation	Forecast Level of Deterioration	Baseline Service Life	Adjusted Service Life				Change from Baseline Cost			
						Solar Flux	Relative Humidity	Precipitation	Average	Solar Flux	Relative Humidity	Precipitation	Average
2030													
Roof Tiles (clay/slate/concrete)	High	Low	High	Moderate	30	28.1	31.1	29.7	29.6	6.7%	-3.6%	1.1%	1.4%
Walls (brick/stone)		Low	High	Moderate	70		72.6	69.3	70.9		-3.6%	1.1%	-1.2%
Render & Mortar (lime/cement)	High	Low	High	Moderate	50	46.9	51.8	49.5	49.4	6.7%	-3.6%	1.1%	1.4%
Masonry Paint	High	Low	High	Moderate	20	18.8	20.7	19.8	19.8	6.7%	-3.6%	1.1%	1.4%
Window & Door Frames	High		High	Severe	20	18.8		19.8	19.3	6.7%		1.1%	3.9%
2070													
Roof Tiles (clay/slate/concrete)	High	Low	High	Moderate	30	28.1	31.3	29.4	29.6	6.7%	-4.3%	2.1%	1.5%
Walls (brick/stone)		Low	High	Moderate	70		73.1	68.5	70.8		-4.3%	2.1%	-1.1%
Render & Mortar (lime/cement)	High	Low	High	Moderate	50	46.9	52.2	49.0	49.4	6.7%	-4.3%	2.1%	1.5%
Masonry Paint	High	Low	High	Moderate	20	18.8	20.9	19.6	19.7	6.7%	-4.3%	2.1%	1.5%
Window & Door Frames	High		High	Severe	20	18.8		19.6	19.2	6.7%		2.1%	4.4%

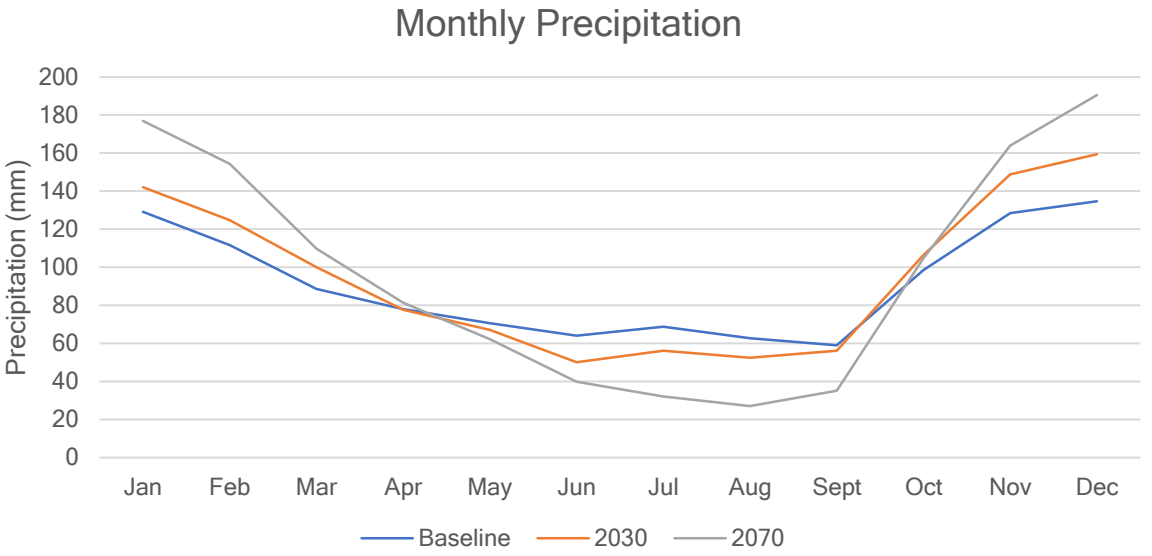
Summary of results for building fabric

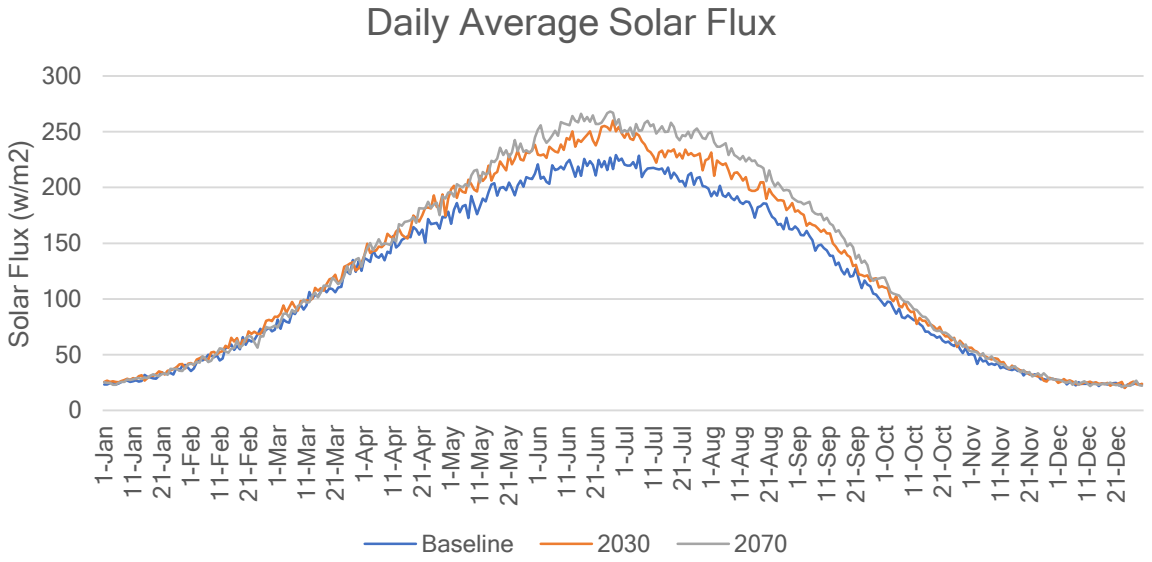
- Not every building material/component is impacted by every climate variable.
- Other climate variables may have detrimental affects, including extreme winds, concentrated downpours and associated events such as flooding.
- Building orientation will impact on adjusted service life, frequency of repair and maintenance, and thus change from baseline cost.
- These results can be used in combination with our knowledge and understanding of building fabric performance [and deterioration mechanisms] to better inform frequency of repair and maintenance to mitigate further damage.

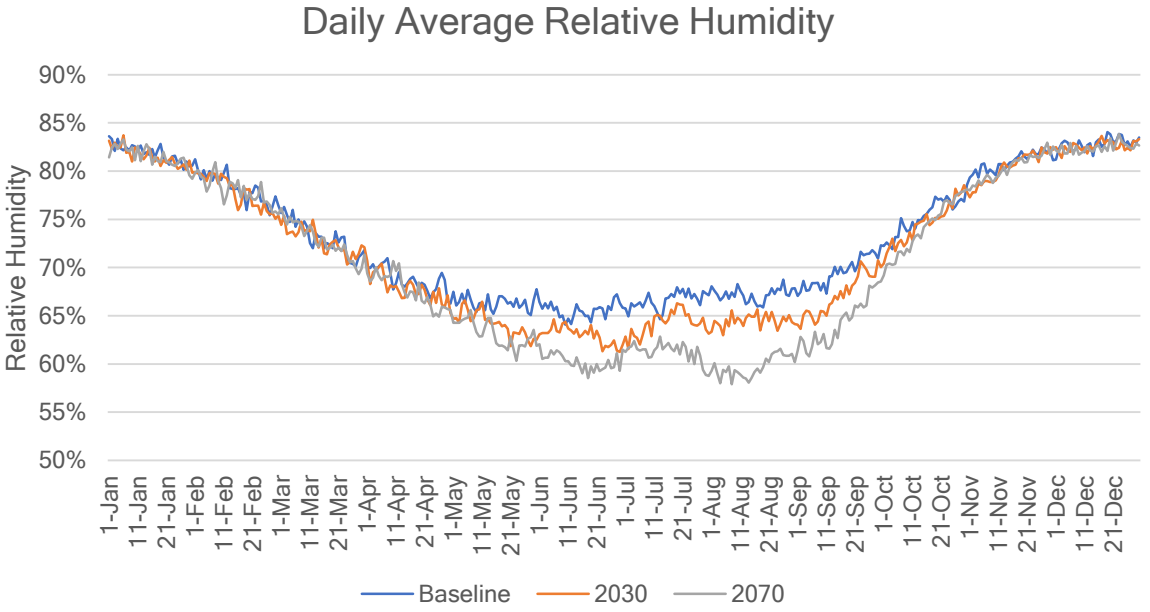
Application- how we apply this information to what we already know?

Cardiff Climate trends, predicted vulnerabilities and known deterioration mechanisms









Applying the building fabric vulnerabilities results

Combining known deterioration mechanisms with predicted climate stressors / vulnerabilities to drive adaptation priorities

Material/component	Deterioration mechanisms	Severe event safety measures
Solid stone or brick	❖ Masonry deterioration is associated with excessive moisture content. ❖ Water ingress, wet-dry cycles, freeze-thaw cycles, rain splatter at base of walls. ❖ Discoloration (staining) micro-cracking, biological/organic growth. ❖ Relative humidity < 75% can escalate crystallisation–hydration cycles, so drier, hotter summers could be a potential threat, especially for carbonate and sandstone but no estimate is yet available related to their correlation .	❖ WDR and heavier downpours will require more regular maintenance of stone/brickwork ❖ Address micro-cracking to reduce moisture ingress ❖ Increased impact likely on northerly elevations.
Painted render	❖ Water ingress, wet-dry cycles, freeze-thaw cycles, rain splatter at base of walls. ❖ Discoloration (staining), cracking, biological/organic growth. Loss of strength may also occur. ❖ A reflective/pale coating can prevent walls exposed to sunlight reaching a critically high temperature.	❖ Address cracking to reduce moisture ingress. ❖ Increased impact likely on northerly elevations.
Painted/treated timber (window frames and doors)	❖ Solar radiation and moisture lead to erosion or stains and blistering of varnish/paint, that allow timber saturation ❖ With high Solar flux, increased blistering will occur on painted timber on south facing elevations increased frequency of repair. ❖ If level of moisture is raised >20%, rot can damage frames.	❖ Frequency of repaint/retreating will increase on southern elevations.
uPVC replacement window frames and doors	❖ Moisture, atmospheric gases, and solar radiation acts on edge seal.	❖ Frequency of brittle failure of uPVC may increase on southern elevations.
Lime/cement mortar repointing	❖ Mortar should be sacrificial; a level of deterioration is expected	❖ Repointing the mortar more regularly will

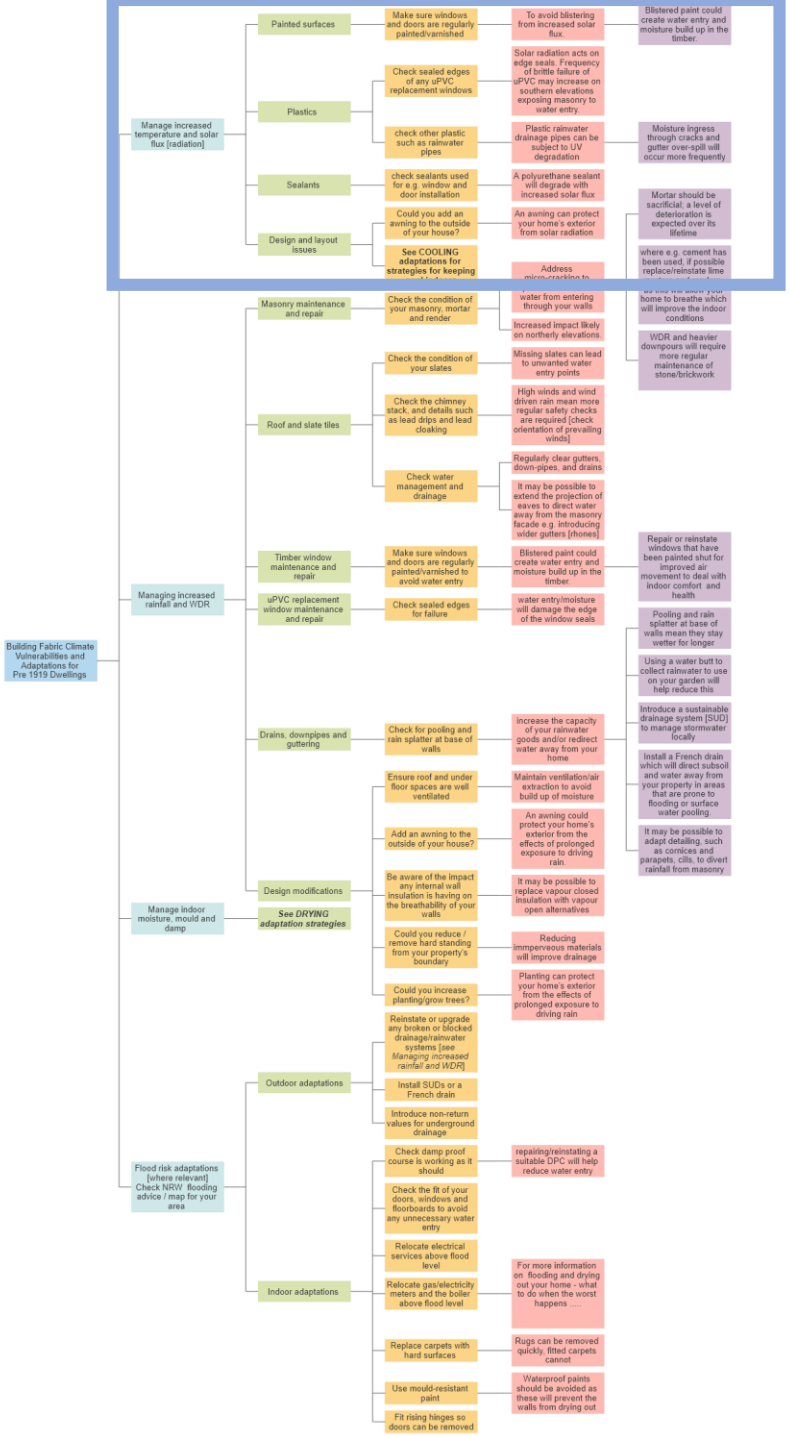
Adaptation requirements

Adaptation

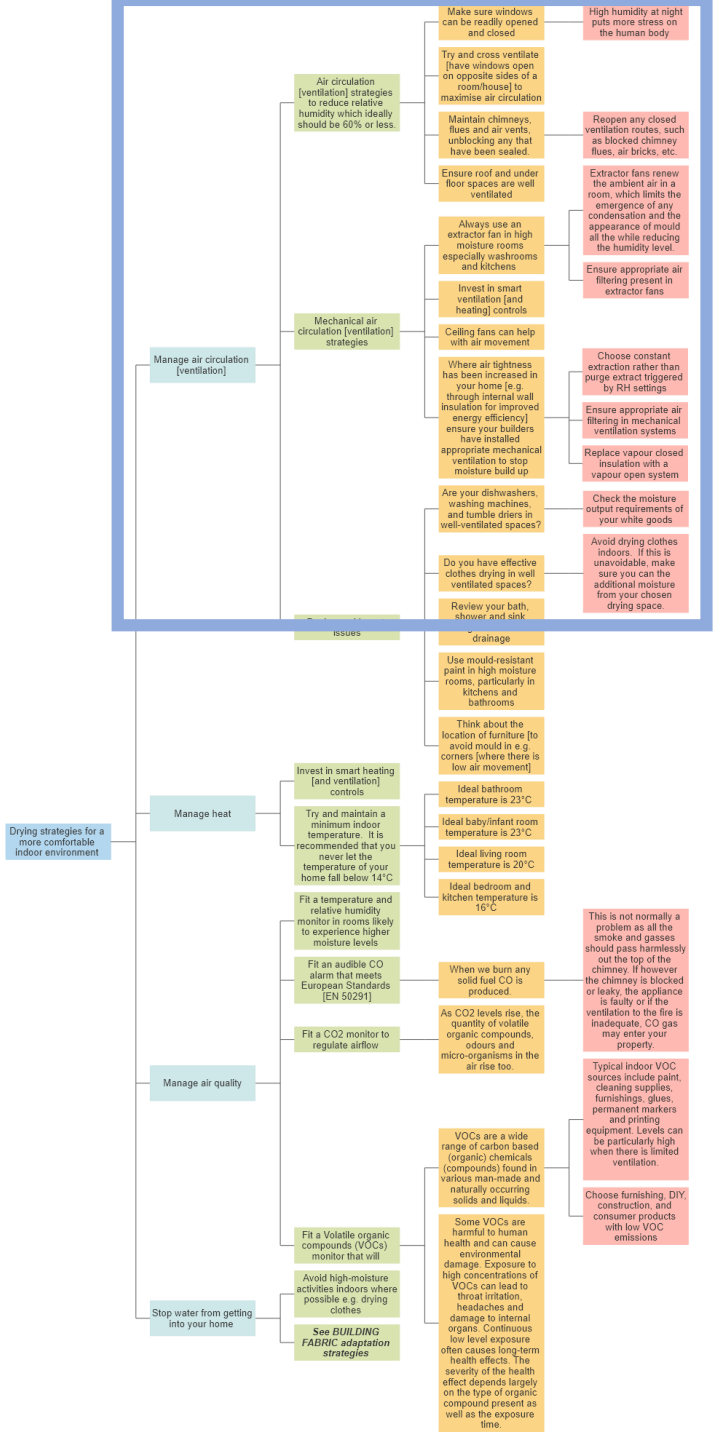
Co-creating prioritisation indices for **Indoor Environmental Quality** and **Building Fabric** including consideration of **overheating**, indoor air quality, mould, damp, rain, flooding and solar flux.

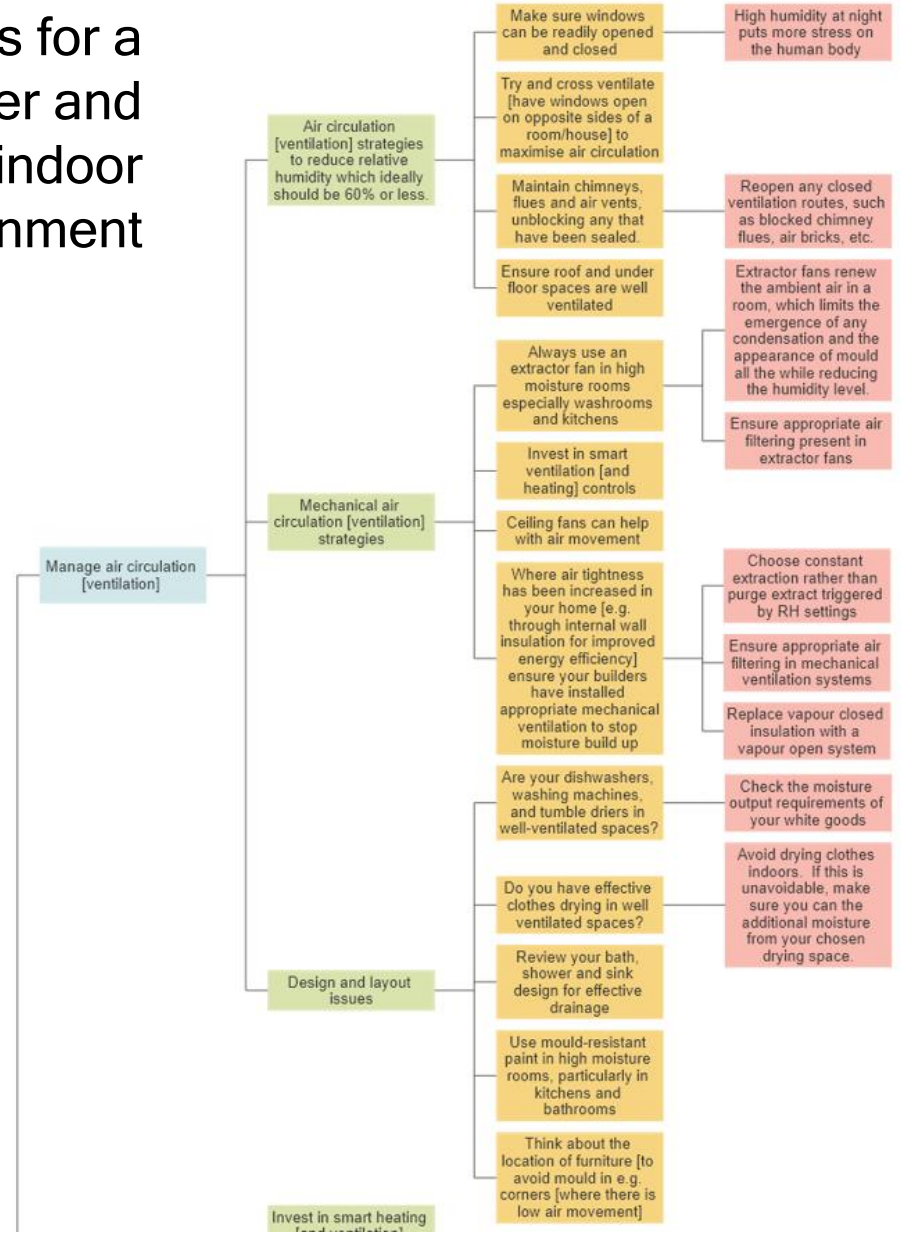
- **Behavioural adjustments** [making small changes to the way we live in the home]
- **Internal fit-out alterations** [owner/occupier focused]
- **Building fabric modifications** [owner/occupier as well as where contractor/trades required]

Building fabric Climate Vulnerabilities
e.g. Pre-1919 Dwellings

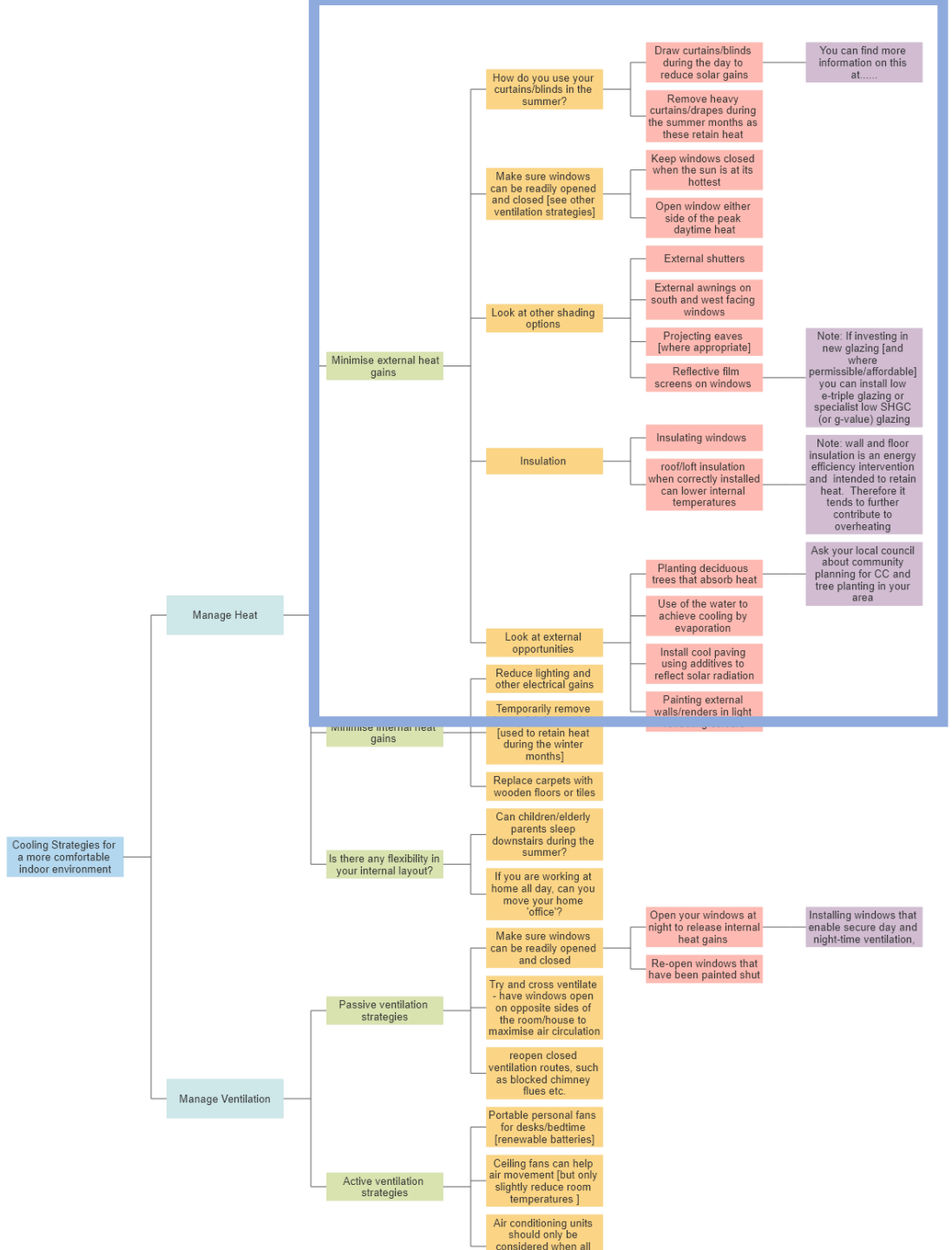


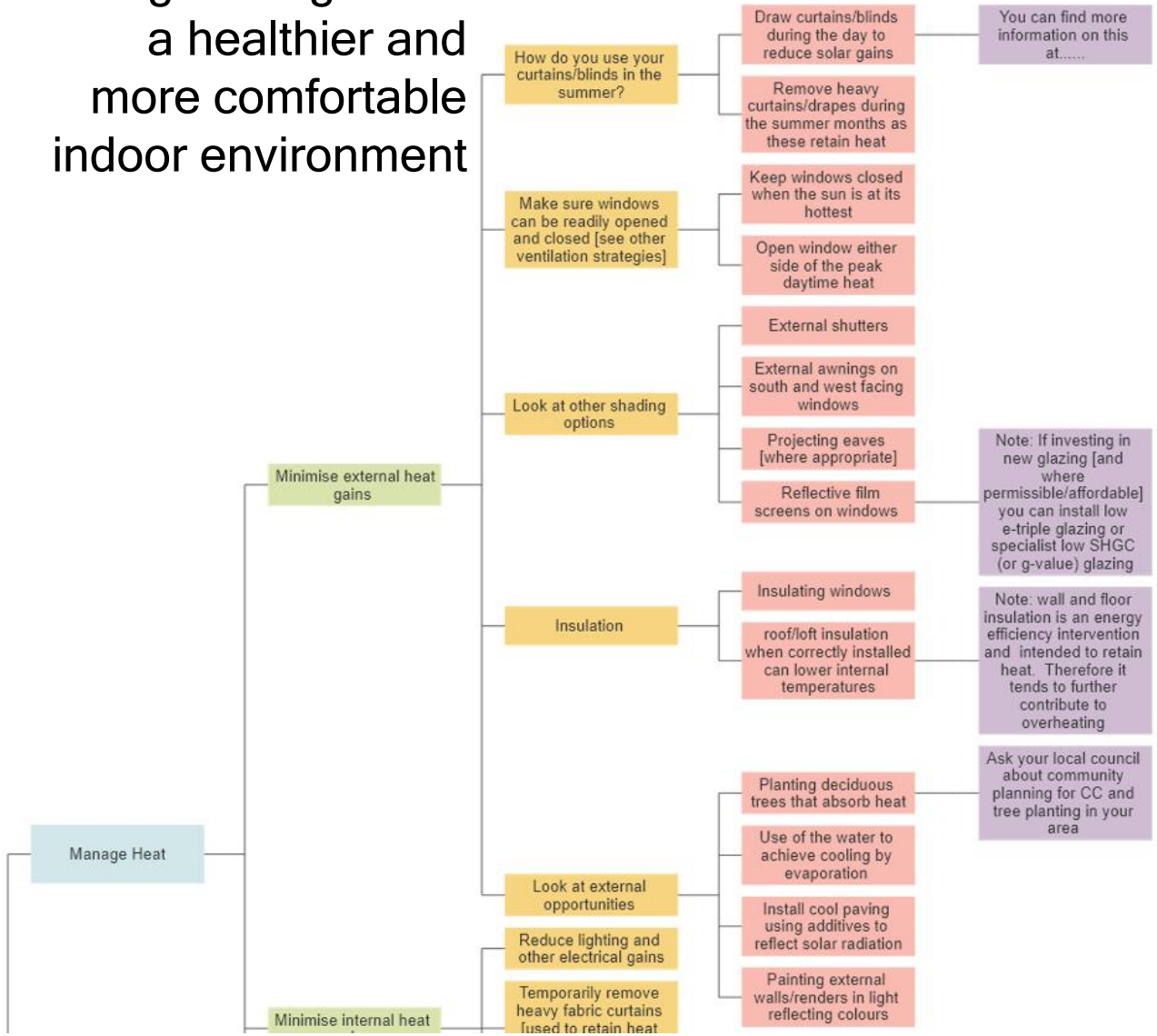
Drying strategies for a healthier and more comfortable indoor environment





Cooling strategies for a healthier and more comfortable indoor environment





Dissemination

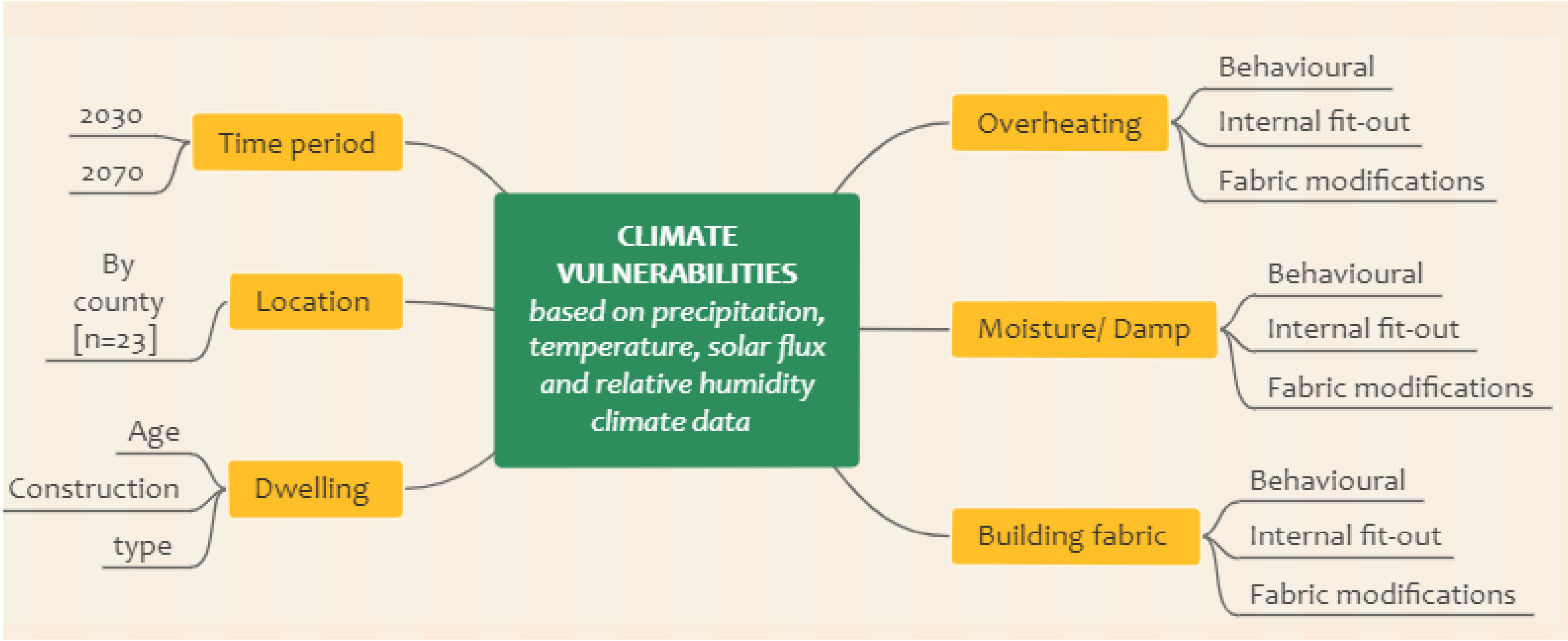
Proposed public facing dissemination

- Interactive climate vulnerability map using *Tableau*
- Climate adaptation factsheets
- *What else would be useful?*

Input

Vulnerability

Adaptation

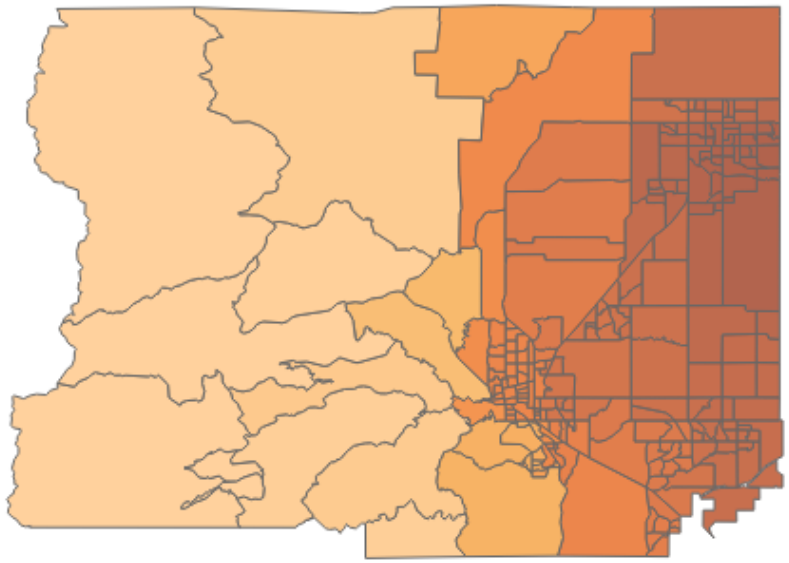


* May need to add in a forth dwelling category to direct dwelling owners/managers to a set of adaptations where IWI, EWI CWI has been retrofitted.

Boulder County Localized Climate Mapping & Equity Initiative

Change in Days Over 90 Graphic View

Map View Satellite View



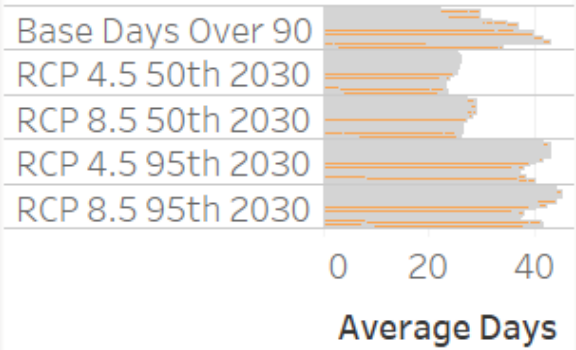
Back Home

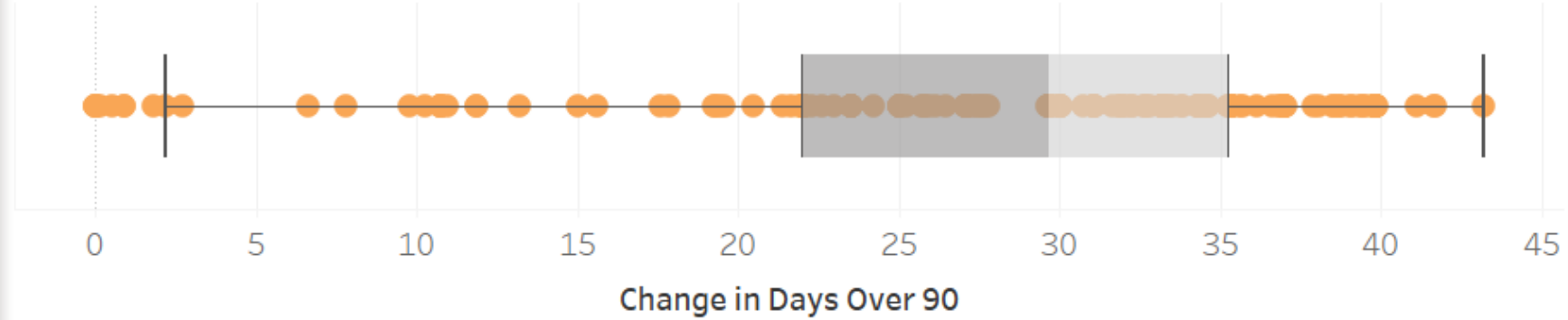
Select RCP

- ○ RCP 4.5 50th 2030
- ○ RCP 8.5 50th 2030
- ○ RCP 4.5 95th 2030
- ○ RCP 8.5 95th 2030
- ◉ Base Days Over 90

Change in Days Over 90

0 — 40





Boulder County Localized Climate Mapping & Equity Initiative

Cooling Degree Days Satellite View

Map View | Graphic View

Back | Home

Select RCP

Baseline

Select Percentile

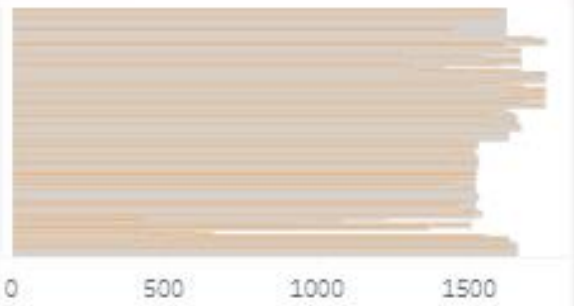
Null

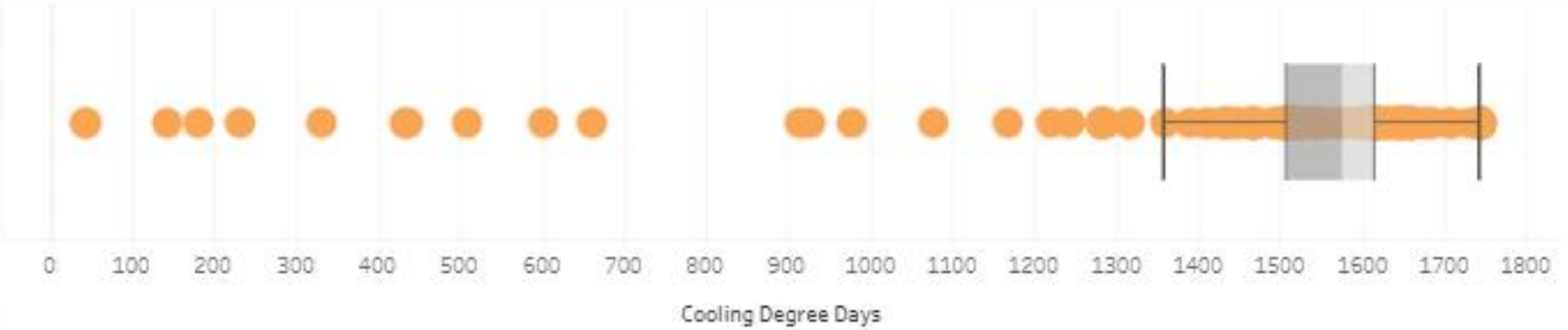
Select Year

Null

Cooling Degree Days

0 1,800





Diolch yn fawr iawn

cshayles@cardiffmet.ac.uk

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