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ENERGY PATHFINDER

Approaching Near Zero Energy in Historic Buildings

Deliverable No: T3.4.1

Deliverable Title: Embodied Carbon and Sustainable Retrofit Approaches: STBA Options Appraisal Tool Assessment in Orkney

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Introduction

This report sets out an in-depth carbon impact study carried out by the Sustainable Traditional Buildings Alliance (STBA) at two case study buildings (demonstrators) in Orkney. Historic Environment Scotland (HES) commissioned STBA to conduct a carbon impact analysis based on the embodied, sequestered and in-use carbon of two retrofit interventions at these Pathfinder project demonstrators.

STBA undertook the study by modelling two different retrofit interventions at the two sites. The interventions were based on the use of natural materials to achieve either existing Scottish Technical Standards or an alternative 'Conservation' standard based on a 0.7U value for walls. The modelling software is a pre-release version of the Green Building Calculator (GBC) used to calculate the operational and embodied carbon at each site.

The two demonstrators are located at the islands of Westray and North Ronaldsay. The Westray demonstrator is a former Harbour Master's house that had been split into four flats and recently retrofitted using conventional unnaturally-derived materials. The North Ronaldsay demonstrator is focussed on the two low buildings that sit next to the tower of North Ronaldsay Lighthouse. These are the former Lighthouse Keepers' cottages and a similar block that includes accommodation, a café, and a workshop that will all be retrofitted using naturally-derived materials.

Assessment strategies for the demonstrator buildings were originally devised in late 2019. However, these were subject to considerable disruption due to the coronavirus pandemic throughout 2020 and much of 2021. Scottish demonstrator sites were impacted especially severely by this due to their relative remoteness, making them inaccessible to HES staff for much of this period. Consequently, the strategies outlined in this report have been revised multiple times during the lifetime of the project in response to developing circumstances.

In addition, technical challenges arose from applying such a new methodology, primarily because of the nonstandard typology of the targeted buildings. The specificity of the two sites in terms of material, construction style, function, and form has challenged the calculator's embedded formulas, which required constant readjusting to its parameter, thus leading to some delay.

In consultation with project partners, significant redrafts took place in late 2021 and early 2022 to reflect those activities which had already been successfully completed and which partners considered could be undertaken during the remaining run of the project. This final version sets out the overall assessment strategy and specific activities which were ultimately implemented at each of the demonstrator sites.

The report explains that this approach to carbon analysis is sufficiently innovative that the project time available was largely dedicated to developing the methodology. Issues with this are summarised in Section 4.3 and in more detail in Appendix 6. This means that the final results of the exercise are not available prior to the Energy Pathfinder project's deadline although the STBA and GBC have committed to resolving the issues and completing the work for HES.

This report is the fourth in a series as follows:

T3.1.1 Demonstrator Buildings and Energy Assessment Strategies

T3.2.1 Initial Energy Performance Assessments

T3.3.1/T4.2.1 Energy Assessment Results and Retrofit Outcomes

T3.4.1 Embodied Carbon and Sustainable Retrofit Approaches: The STBA Options Appraisal Tool Assessment in Orkney

T3.4.1 Embodied Carbon and Sustainable Retrofit Approaches

The reports may be read together for a comprehensive overview of all energy and carbon assessment activities undertaken at Energy Pathfinder demonstrator buildings. HES has compiled this report as the work package coordinator for energy management and monitoring as part of the Energy Pathfinder project; however, HES does not necessarily endorse or recommend the assessment strategies outlined herein.

Yasser Battikha
Historic Environment Scotland 29 September 2022

Embodied Carbon and Sustainable Retrofit Approaches

The STBA Options Appraisal Tool Assessment in Orkney

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1. Introduction:

Historic Environment Scotland (HES) wished to test the newly developed Options Appraisal Tool (the Tool) from the Sustainable Traditional Buildings Alliance (STBA) and Green Building Calculator (GBC) to ascertain the carbon impacts on two retrofit projects in Orkney. The overall project has been funded by the European Union's Interreg Northern Periphery and Arctic Programme (2016-2020) through the Energy Pathfinder project.

The Tool offered the opportunity to compare the choices between using natural materials that might sequester carbon into the retrofit and more conventional materials that might provide better thermal performance. The Tool would calculate the carbon involved in both the choice of material and the in-use carbon reductions associated with it.

2. Retrofit Projects

The two projects chosen by HES to test the Tool were based on Westray and North Ronaldsay in the Orkney Islands.

Figure 1 Location map of Orkney Islands. From Google Maps

2.1 Westray

The Westray property was a detached house that had recently been split into four self-contained flats. The work undertaken was not to HES specification and the materials used were identified on site by HES whilst undertaking the survey designed by the GBC and STBA for the collection of appropriate data for using the Tool. An example of the GBC data collection form is shown in Appendix 1.

Figure 2 Three storey detached house on Westray. Photo: HES

2.2 North Ronaldsay

The North Ronaldsay project is likely to be subject to HES specification in terms of its retrofit. It was therefore important to ensure that the materials suggested were appropriate for its location and exposure. The suggested woodfibre insulation was therefore modelled and risk assessed in WUFI. The modelling was undertaken by Ecological Building Systems and the results are shown in Appendix 2.

The buildings selected were the Accommodation Block and a similar building containing the Café and Workshop at the category B listed North Ronaldsay Lighthouse. The site plan for these buildings is shown in Appendix 3

Figure 3 Accommodation block on North Ronaldsay. Photo HES.

3. The Options Appraisal Tool

The Tool has been developed by STBA and GBC to help organisations gauge both their immediate and long term carbon impact. The project was initially designed as a quick sense-checker for owners of buildings to assess this carbon balance. It has

pre-set dwellings within it to facilitate this (standardised areas for walls, windows etc for different property types: terrace, detached, cottage etc).
It did not have the capability for specialist buildings or individual flats. The HES project supplied a series of flats (one of which was on two floors) and a historic lighthouse complex partially made from poured concrete. The calculator therefore required extensive remodelling to be able to provide reliable results.

The Tool uses calculated areas and volumes of material for retrofit and draws on the ICE 3 database (see: https://circularecology.com/embodied-carbon-footprint-database.html) and a variety of manufacturers data via Environmental Product Declarations (EPD). This provides a figure both for embodied carbon and for any sequestered carbon. The Tool also calculates in-use energy consumption from rdSAP data to ascertain long term carbon savings associated with any thermal improvements. It has been taken that the savings would be calculated for 23 years in order to bring the figures up to 2045, the date for the zero carbon target in Scotland (see https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/pages/3/). The balance between the initial carbon intensity of the materials and the in-use savings then gives an overall balance of carbon associated with the material choices. Note: there are a range of common tasks that are not included in any results e.g. contractors fuel to and from site, materials that are used in all choices / applications in the retrofit works.

The Tool has different standards built into it. This exercise used the Scottish Technical Standards as its base, but one of the scenarios used was a STBA Conservation Standard. This standard has been used in the Tool primarily to allow for a lower U value for SWI based work on moisture open buildings. Research from UKCMB indicates that a U value of 0.4-0.7 rather than 0.3 is more appropriate and that any figures under 0.5 would require specialist calculations using Hygrothermal modelling (see https://ukcmb.org/wp-content/uploads/2017/10/Internal-Wall-Insulation-for-JBSAV.pdf).

The STBA's 2012 paper entitled '*A Short Paper on Internal Wall Insulation'* suggests that 0.6 is a maximum value due to thermal bridging and that risks will increase as depth of insulation increases. Given the NHBC wind driven rain (WDR) Index of Very Severe (similar to Swansea in the paper) a reasonable thickness for moisture open insulation was taken to be 60mm maximum. Thus this 'standard' uses 0.7 as per backstop in Part L of the Building Regulations in England or 60mm woodfibre insulation. Note however, for North Ronaldsay this was reduced to 40mm as the WUFI modelling suggested that 60mm was borderline in terms of moisture performance. See Appendix 4.

Where possible, the STBA standard will specify above minimum standards for certain building elements. To illustrate this, some of the specified U values were improved for low / non-risk elements like doors and windows.

4. Specifications for Westray and North Ronaldsay

4.1 Westray

The building has undergone a radical transformation using conventional materials. The creation of the four flats has gone hand-in-hand with the use of phenolic foam board based insulation, PVCu double glazed windows and the installation of a ASHP. This work has been modelled to assess its impact both in terms of its actual retrofit and a theoretical proposed one that utilises either the Scottish Technical Standards or the STBA Conservation Standard.

The Scottish Technical Standards used for identifying the U values are shown in Appendix 4. Note that the process of choosing proposed thicknesses for insulation was achieved by using indicative U values from an online U value calculator based on BS EN ISO 6946, 13370, 13789, BRE 443, 497.

Existing		
Element	**Material**	**Specification**
Door	Wood	1.6 U assumed
Window	PVCu	1.6 U assumed
External walls	Phenolic foam	120mm – 0.17 U assumed
Floor	Phenolic foam	100mm – 0.15 U assumed
Roof	Phenolic foam	120-200mm assumed with 0.13 U

Table 1 Westray Existing Specification

Proposed based on Scottish Technical Standards		
Element	**Material**	**Specification**
Door	Wood	1.6 U
Window	Wood	1.6 U
External walls	Wood fibre	110mm – 0.3 U
Floor	Recycled glass foam	200mm – 0.18 U
Roof	Wood fibre	200mm – 0.18 U

Table 2 Proposed improvements based on Scottish Technical Standards

Proposed based on STBA Conservation Standard		
Element	**Material**	**Specification**
Door	Wood	1.4 U*
Window	Wood	1.4 U*
External walls	Wood fibre	60mm – 0.45 U
Floor	Recycled glass foam	250mm – 0.15 U*
Roof	Wood fibre	280mm – 0.13 U*

Table 3 Proposed improvements based on STBA Conservation Standard

* These figures were improved in order to compensate for the higher U value stipulated for the 'STBA Conservation Standard'

4.2 North Ronaldsay

The buildings on North Ronaldsay have not been retrofitted recently, although there have been some changes made over time, notably the installation of mineral wool into the roof space. The doors, windows, walls and floors are unimproved.

Existing		
Element	**Material**	**Specification**
Door	Wood	3.0 U Assumed
Window	Wood	5.5 U Assumed
External walls	Solid Masonry	1.48 U Assumed
Floor	Solid	2.48 U Assumed
Roof	Flat w. Mineral wool	0.21 U Assumed

Table 8 North Ronaldsay Existing Specification

Proposed based on Scottish Technical Standards		
Element	**Material**	**Specification**
Door	Wood	1.6 U
Window	Wood	1.6 U
External walls	Wood fibre	130mm – 0.3 U
Floor	Recycled glass foam	200mm – 0.18 U
Roof	Wood fibre	200mm – 0.18 U

Table 9 Proposed improvements based on Scottish Technical Standards

Proposed based on STBA Conservation Standard		
Element	**Material**	**Specification**
Door	Wood	1.4 U*
Window	Wood	1.4 U*
External walls	Wood fibre	40mm – 0.78 U
Floor	Recycled glass foam	250mm – 0.15 U*
Roof	Wood fibre	280mm – 0.13 U*

Table 10 Proposed improvements based on STBA Conservation Standard

* These figures were improved in order to compensate for the higher U value stipulated for the 'STBA Conservation Standard'

4.3 Development Issues

The project outline was set out in the original proposal (dated 18th Jan 2022) and has largely been followed.

The project was originally conceived to work from standard archetypes or derivations thereof. As stated before, the buildings that HES required analysis of were far from standard and this only became really apparent when the data was returned from the on-site survey. GBC had to effectively re-write the calculator to take into account a number of different factors, notably: party walls and floors for Westray and also different materials for North Ronaldsay. A decision was also taken to change the spreadsheet so that it could compare different choices with the different standards in one spreadsheet rather than having to run the process through numerous times. This was originally felt to be a time saving process as it would help to automate any future comparison works.

Site information issues

Due to the remoteness of the sites it was decided to use paper-based surveying tools that GBC and STBA had developed for the purpose. The actual surveying was undertaken by HES staff and relayed back to GBC and STBA using online data sharing software. Photographic and rdSAP based data were also provided by the HES staff. STBA undertook some basic training with the staff prior to departure to ensure that they understood the process of data collection and the importance of photographic evidence.

Process issues

WUFI analysis and U value calculations were undertaken to assess the moisture risks and also the thicknesses of different insulations required to meet the Scottish Technical Standards and the STBA ‘Conservation Standard’. The spreadsheet was designed to take these measurements and translate them into both heat loss factors and carbon measurements.

Note: The spreadsheet developed by GBC is based on a much larger and more comprehensive one of theirs. This ‘mother’ spreadsheet has a number of additional functions that were deemed to be worth keeping as it would hasten any future developments. For example, there are multi-material layers in the various building elements, but the impact on materials like paint, boarding etc were ignored by the spreadsheet so that only the insulation layer factored into the calculations. This meant producing an automatic way of identifying which elements of a building structure were to be counted and those to be ignored. Whilst this sounds like an easy thing to do, the process behind it is quite complex. This is especially true when the calculations were part of a larger and more complicated spreadsheet spanning over 23 separate sheets and two external databases. Each sheet within the document has between 100 to 15,500 active cells, with an average of around 5,000 cells per sheet. The linkages between the cells is based on complex relationships and equations to draw down, combine, include and exclude, manipulate, conditionally choose, etc all of this data.

The additional functionality and choice to automate the production of certain options for the HES proved to be problematic as the core working function of the spreadsheet was lost in the additions.

The results that were generated were sense-checked by the STBA and certain indicators were raised as problematic, but with the spreadsheet being created and subsequently re-shaped by GBC it was not possible for the STBA to point to where the problems might be, just that they existed. GBC would then have to investigate the data and resolve the root cause. Some of these were simple spelling errors that the calculator didn’t recognise, so this functionality was automated using drop-down lists.

Timings for the work were starting to get lost at the point in July / August as GBC and STBA had other commitments to fulfil. The original bid to HES had worked on around 5 days development time and 2 days analysing and writing up the findings. GBC by now have spent well over double this amount of time with the various developmental requirements.

The process of making changes, reviewing results and interrogating the spreadsheet to find errors was linear in nature. This stretched the timeline of the development side of the project as it took a review of every revision to sense-check the outputs and almost each time there was a full revision new issues came to light. In hindsight, there should have been more time spent just on the core spreadsheet with one worked example. This would have saved time in generating results to all the properties at each stage. This was done as it was believed that the problems were caused by a single issue at each stage. The reason for this was that the original spreadsheet that we had hoped to use for the project had been working correctly at the start of the project.

Outputs issues

The lack of reliable information coming from the calculator has meant that the data has yet to be analysed and reported back to HES. The relationships between the carbon ‘footprints’ of material choices has been illustrated by the calculator, but the actual calculations have been questionable. E.g. one material choice with a known high embodied carbon figure is indeed showing a higher footprint than a lower embodied carbon material, but the projected figure over a period of time has been too high / low. The calculations are therefore partially right in terms of relationships to each other, but the final figures have been wrong.

The information on risk factors has been extended from the original ‘archetype’ spreadsheet to include those associated with construction types from Orkney. It will therefore be possible to report back on the risk profiles associated with each material choice.

STBA and GBC have pledged to get the calculator working and the results of the Westray and North Ronaldsay buildings over to HES. The calculator will also be adapted into a SQL database and presented as an online tool. This will require a simple front-end User Interface (UI) to be developed. The outputs from the tool will also require a simple UI so that it can become a easy to use and intuitive tool for those wishing to compare the material choices presented to them in terms of embodied, sequestered and in-use carbon.

Cost issues

The costs incurred by GBC and STBA have been significant in terms of time, however this will not be passed onto HES.

5. Conclusion

The development of the carbon calculator has proven to be more complicated than originally expected. This was due to a number of factors including:

1. Unusual buildings to be analysed
2. Delays in data collection due to remoteness of the site
3. Adaptation requirements associated with the use of a pre-existing spreadsheet
4. Lack of Excel knowledge from STBA in being able to identify issues with functionality within the spreadsheet
5. Reliance on GBC to undertake all necessary revisions and corrections
6. Linear development / checking of spreadsheet
7. Assumption that issues within the spreadsheet were simple and isolated and hence time being used to recalculate the results for all buildings rather than taking one property and sense checking this before embarking on a full analysis of all properties

The calculator has shown itself to be valuable and adaptable, but in need of simplification so that it is easier for others to use. For it to be really useful to the market it needs to have a simplified UI that facilitates easy inputting of data and clear and reliable outputs.

Peter Draper

STBA Project Associate

September 2022

Glossary:

ASHP	Air Source Heat Pump
EDP	Environmental Product Declarations
EWI	External Wall Insulation
IWI	Internal Wall Insulation
GBC	Green Building Calculator
NHBC	National Housing Building Council
RH	Relative Humidity
STBA	Sustainable Traditional Buildings Alliance
STS	Scottish Technical Standards
SWI	Solid Wall Insulation
U Value	Measurement of thermal resistance of a building element
UKCMB	United Kingdom Centre for Moisture in Buildings
WDR	Wind Driven Rain
WUFI	Wärme Und Feuchte Instationär – A modelling tool for calculating hydrothermal performance in structures

Appendix 1: Example of the site survey notes

B2 Paper based site survey

Survey Plot, House or Flat No.	Cafe, North-West Block, Dennis Ness
Core Data Source	Site survey
Construction Era	Pre-1919 (late 19th to early 20th century)
Site Location Postcode	KW17 2BG
Site Location City	Orkney (North Ronaldsay)
Existing Wall Material	Poured concrete
Existing Wall Format	Solid Masonry
Existing Wall Thickness (mm)	600mm
Existing Internal finish	Dry-lined, most likely lath and plaster
Previous External Wall Insulation Position	NA
Previous External Wall Insulation Material	NA
Previous External Wall Insulation Thickness	NA
Habitable rooms	5
Bathrooms	2 WCs, one is of sufficient size to house a shower/bath
BuildingFormat	Semi-detached cottage
Total Floor Area	100.72m2
Number of Stories in house	1
Area of ground floor	100.72m2
Ground floor construction	Suspended timber
Ground floor insulation position	NA (assumed none)
Ground Floor Insulation material	NA
Ground Floor Insulation thickness	NA
Area of Roof	100.72m2
Existing Roof Pitch	Flat roof
Previous Roof Insulation Position	Unknown, could be deafening/insulation above false ceiling
Previous Roof Insulation material	Unknown, most likely none.
Previous Roof Insulation thickness	Unknown/NA
House width	13.7m
House Depth	8.16m
HLP Heat Loss Perimeter per floor	43.72m
Floor to ceiling height	2.74m (false ceiling likely, also suggested by IR imaging)
Storey (Floor to Floor) Height	3.56m (estimate)
Architypes	Semi-detached cottage
Area of external walls minus openings	105.63m2
Party wall thickness	200mm (estimate)
Party Wall Format	Solid Masonry
Party wall length	3.90m
Area of Party Walls	10.69m2
Previous Party Wall Insulation Position	NA
Previous Party Wall Insulation material	NA
Previous Party Wall Insulation thickness	NA
No. of existing doors	3
Average size of Existing Doors	2.25m2
Existing Door Insulated or uninsulated	Uninsulated timber (all have draught lobbies however)
Existing Door U value	Unknown
No. of existing windows	7
Average size of existing windows	1.06m2
Area of existing Windows & Doors	14.16m2
Existing Window Glazing	Single glazed sash-and-case (varying astragal pattern)
Existing Window U Value	Unknown (likely approx 5.5)
Roof Pitch above horizontal	0 (flat)
Volume of house interior	275.97m3
Existing Fuel	Electricity (via community heating, see notes)
Existing Heat Source Appliance	Immersion cylinder (in unheated store)
Existing Thermostat	Room thermostat
Exiting Radiators	Radiators, no TRVs
Exiting Controller	Programmer (in store)
Exiting Heating Efficiency	100% minus distribution losses
Water heating	Immersion cylinder (170 litre, 35mm foam, w/thermostat)
Lighting Luminaires	14

Appendix 2: WUFI Modelling summary:

40mm Gutex Thermoroom

Dewpoint: The temperature is always significantly above the dewpoint temperature and hence no interstitial condensation is occurring.

Moisture Content: The moisture content peaks at ~14% and averages ~12.5% - this is a safe value for Gutex Thermoroom (typically wood fibre should be less than 18% moisture content on a permanent all year around basis.

%RH: This averages below 80%, which is a safe value

In conclusion the use of a 20mm Diathonite Level coat with 40mm Gutex Thermoroom internally has a very high degree of security against moisture and interstitial condensation.

60mm Gutex Thermoroom 20mm Diathonite Level Coat

Dewpoint: The temperature at this interface is always higher than the dewpoint temperature and hence no interstitial condensation is occurring.

Moisture Content: The moisture content averages ~15% and peaks in the winter below 18%. This is acceptable for Gutex Thermoroom, although is higher than in the case with the 40mm Gutex Thermoroom

%RH: The %RH is peaking in the winter at just under 90% and is averaging ~80%. This is acceptable, but again is higher than is the case with the 40mm Gutex Thermoroom.

Overall, the 60mm Gutex Thermoroom gives an acceptable degree of security against interstitial condensation and moisture. On the basis of the data, I would say that if a 20mm Diathonite level coat is used then 60mm Gutex Thermoroom would be a maximum thickness.

Note:
WUFI Calculation in accordance with EN15026 over a 15 year period.

Modelled build up (done before site visit)

External render
Existing Stone wall (assumed 500mm thickness average)
20mm Insulated Lime render (Diathonite Thermactive) levelling coat
Gutex Thermoroom Adhesive (~8mm)
40mm or 60mm Gutex Thermooroom
10mm Lime Green Solo Finish

From: Neil Turner, UK Technical Sales Manager
Ecological Building Systems UK Ltd

Appendix 3: Site plan of North Ronaldsay

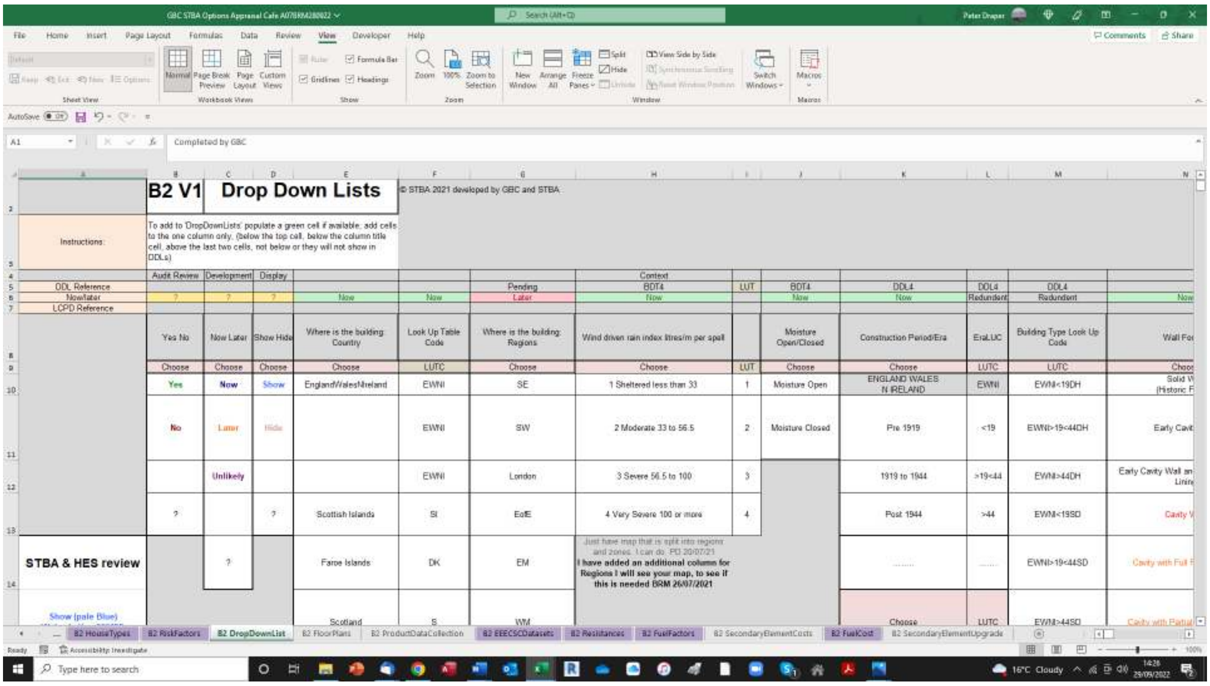
Appendix 4: U values from Scottish Technical Standards

Table 6.5. Maximum U-values for building elements of the insulation envelope

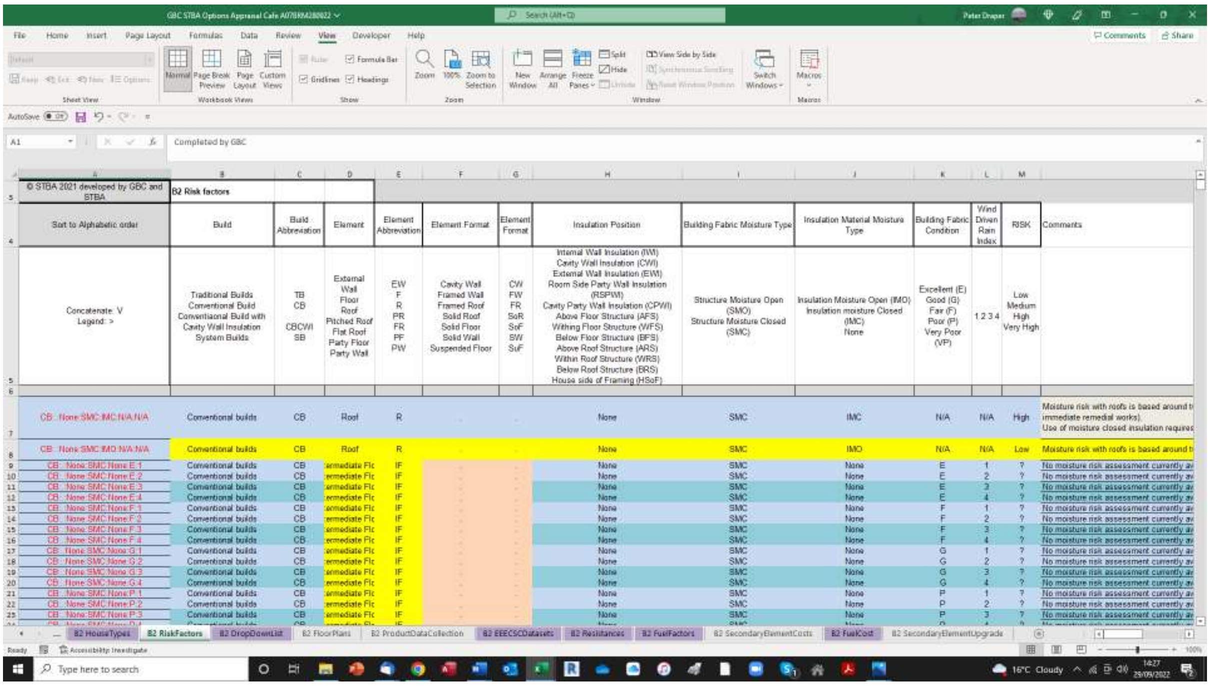
Type of element	Area-weighted average U-Value (W/m²K) for all elements of the same type		(c) Individual element U-Value (W/m²K)
	(a) Where U-Values for wall and roof of the existing dwelling are poorer than 0.7 [1] and 0.25 respectively	(b) where parameters for column (a) do not apply	
Wall [2]	0.17	0.22	0.70
Floor [2]	0.15	0.18	0.70
Pitched roof (insulation between ceiling ties or collars)	0.11	0.15	0.35
Flat or pitched roof (insulation between rafters or roof with integral insulation)	0.13	0.18	0.35
Windows, doors, rooflights	1.4 [3]	1.6 [4]	3.3

Appendix 5: Images from various sheets of the GBC / STBA spreadsheet

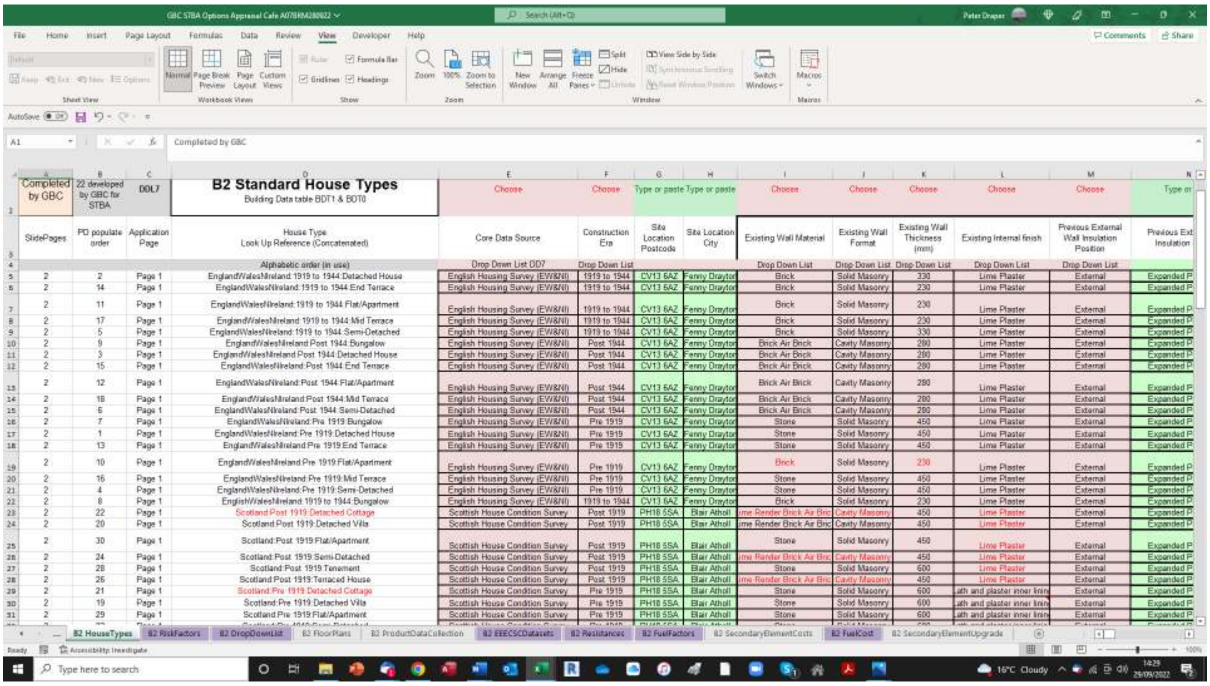
a. Options for dedicated choices in drop-down lists



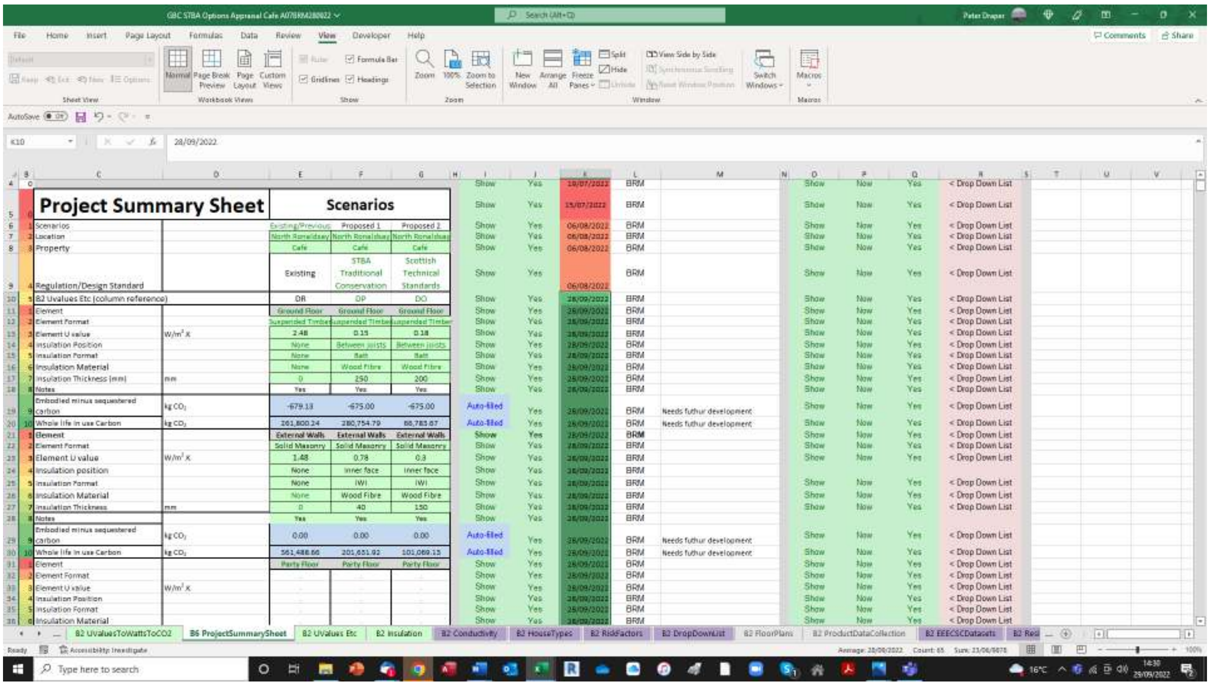
b. Risk factor analysis



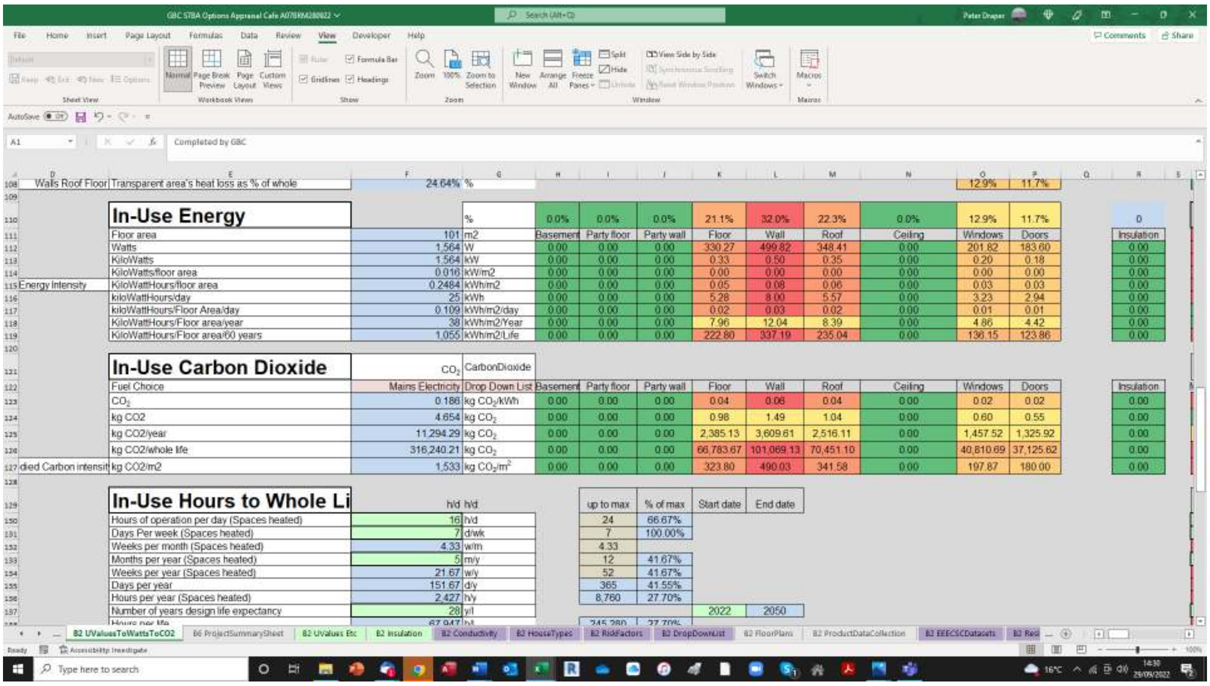
c. Standard House types built in



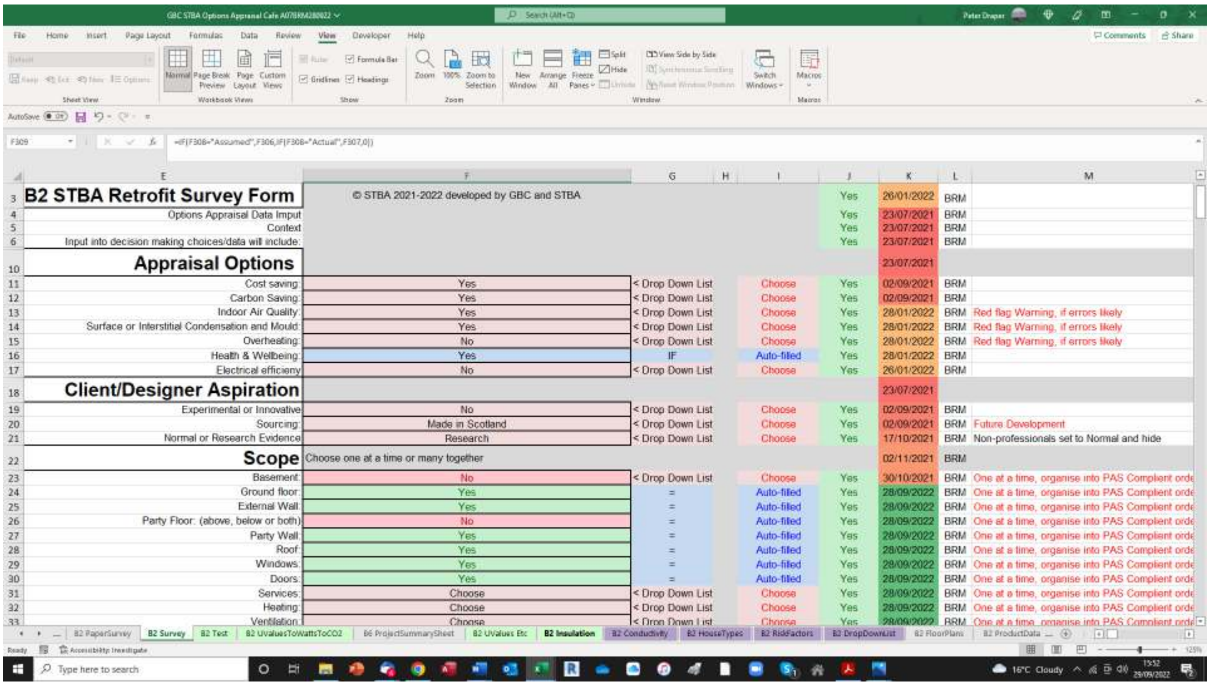
d. Project summary sheet



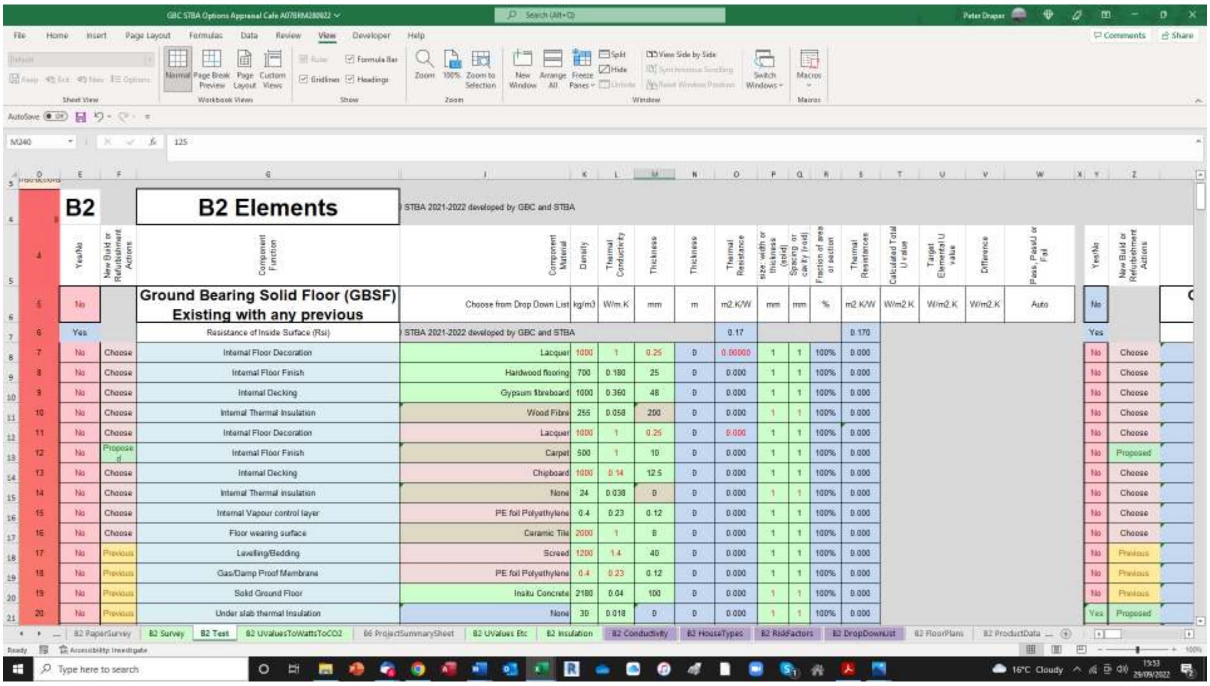
e. CO2 calculations



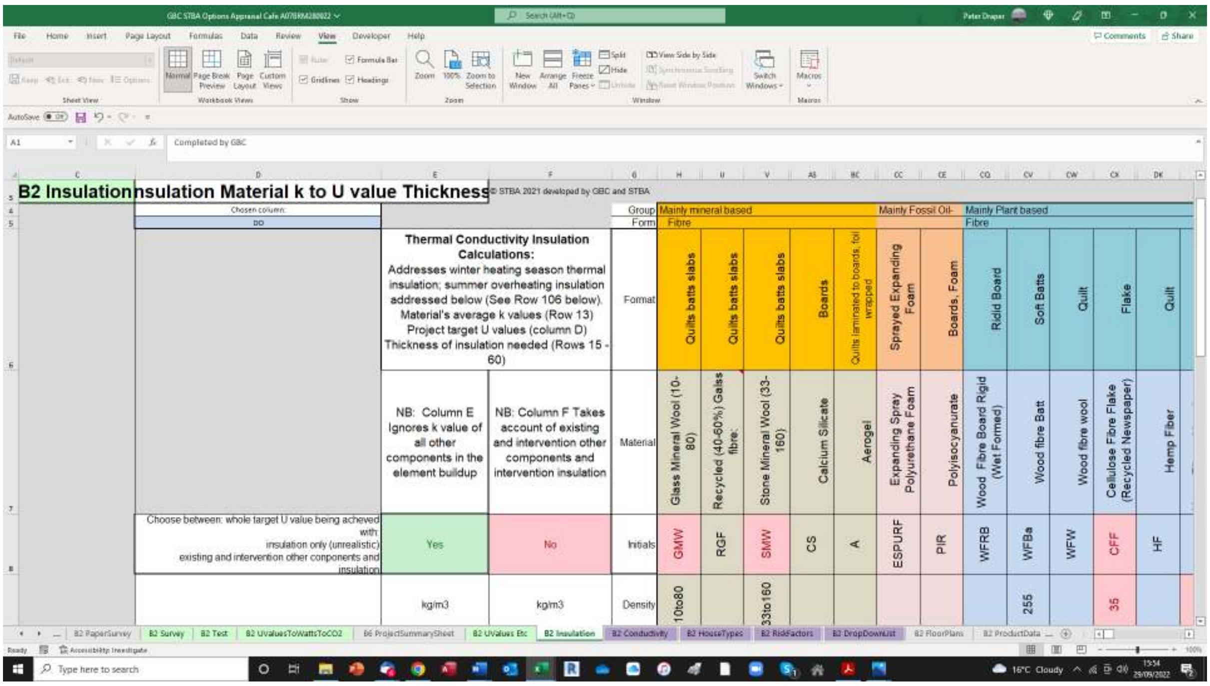
f. Survey input form



g. U value and heat loss calculations



h. K values for insulations



Appendix 6: Review of Green Building Calculator

Interreg Energy Pathfinder Carbon Calculation Review

GBC

Green Building Calculator

Challenges with assessing the Energy Pathfinder project's Scottish Island properties using the STBA Sustainable Traditional Building Alliance's Retrofit Options Evaluation tool, based on MS Excel.

Reviews by Brian Murphy (BRM) of GBE (Author of the Calculator)

- followed by the review by Peter Draper of STBA (Reviewer of results and author of report)

Paper Survey

- STBA's calculator is designed as desk-top analysis, however Energy Pathfinder survey required a 5 day round trip to remote islands and physical surveys carried out on sites with additional recorded notes.
- A worksheet was developed transposing wide tables to vertical tables for simple printing to A4 portrait.
- The survey needs to capture as many as possible of the items in the 'House Type' worksheet of the STBA calculator and others from the 'Survey' worksheet.
- This information is then used as a 'look up table' in the calculator, which automatically populates many cells once the house type had been chosen;
- The 'House type' is chosen by selecting options from three 'drop down lists' in three cells.

- The three cell contents are ‘concatenated’ to make a bespoke combination to interrogate specific lines of the ‘look up table’.
- STBA developed a paper-based survey form (printed from within the Excel file) to be completed on site, then transferred into the calculator when back at base
- The rules for completing a cell in Excel e.g. numbers only or choose from a drop down list are not present in the paper-based survey form, so it is easy to collect information in a format that the calculator cannot process.
- When the data is transferred back into the Excel template some interpretation is required to enable the calculator to work, e.g. N/A (text) converted to 0 (number).
- Excel cells can have restrictions added to ensure the data is provided in the right format or a warning message appears.
- Any missing or incompatible format information needed to be reinterpreted for calculator integrity.
- Once numerous cells are populated from the ‘look up table’ then additional calculations can occur.
- The Paper Survey worksheet could become an intelligent form within a ‘Smart tablet’ loaded with ‘Google Sheets’ or MS Excel with ‘drop down lists’ and ‘format restricted cells’ that automatically feed into the calculations. (Something for November launch?)

Adding additional data cells out of sequence

- Additional answers to questions were needed for the Energy Pathfinder that were not present in the STBA calculator.
- In order to maintain the integrity of the existing STBA calculations, additional data collection points were added for the project, on to the right hand end of the existing lists; so they are not in convenient topical clusters.
- It was realized that the calculator’s ‘Survey’, ‘House type’ worksheets and the ‘paper-based survey’ could be better organized in clusters, rationalized and improved to ensure the on-site survey is more intuitive and consequently more precise.
- This would require the calculator to be rebuilt and all the calculations disconnected and reconnected; this is a time heavy task, that was not available; but will happen in the immediate future, in time to launch Version 1 at Regen ’22 in Liverpool.

Expanding scope of calculator

- Energy Pathfinder project includes method of construction and materials not included in the limited set of materials in STBA so far.
- These included: concrete walls and concrete roofs, flat roofs; these had to be developed
- Some materials were not present so additional data sets were found, included and listed
- STBA’s calculator did not include Compartment Walls and Floors: These needed to be added
- Energy Pathfinder project includes solid, cavity and framed walls and floors between the 8 buildings

- STBA needed more than one version of walls and floors and roof to accommodate different methods of construction between 6 surveys to be able to bring them together in one summary sheet.

Adding and evaluating option scenarios

- STBA's calculator did not accommodate analyzing different scenarios yet
- Additional columns were developed to calculate, record and preserve 3 sets of calculations:
    - Existing building and two improvement scenarios
- This was developed as a part manual and part automatic function, which takes time to process
- Eventually more 'IF' functions were introduced to replace as many manual processes as possible
- The calculator contained one set of elemental U value for all existing elements.
- In order to interrogate different scenarios a second set of elemental U values were created for the proposed changes in insulation materials and thicknesses.
- This process effectively meant the whole calculator was being rebuilt in the process.
- Preserving the results of calculation whilst carrying out 3 scenarios is the challenge we have not yet mastered.
- MS Excel may be able to record and preserve results in Scenarios, but we were not yet familiar with these methods, we will investigate to try to make this as automatic as possible.
- We have found how to get results for one scenario at a time in the same place using 'IF' function.
- We may have found a way to show 3 at a time side by side and retain the unique results in each.
- It is now anticipated that Scenarios could be developed within one elemental assembly spreadsheet using many 'IF' or more efficiently 'What If' functions, etc.; possibly for the November launch.

Fault finding and correcting

- Currently if a fault is discovered in any part of the calculator, it can be corrected and then the 3 scenarios need to be reworked from scratch to get correct results in all 3 scenarios.
- A process of repasting calculations into cells with results is necessary to get back to a fresh starting point, the three scenarios can be run; the results are copied and values pasted back in their place to preserve the results of each scenario.
- If a recalculation is found necessary the repasting of the calculations cells to replace the result values is necessary.
- These complexities mean the calculator is not and cannot become standalone and work independently of the calculator author.
- More work is needed.
- We have introduced more drop down lists in cells to choose readymade options with correct spellings, these have been proved necessary in more

locations where a typed in and incorrectly spelt word can generate no or wrong results.
- See PD's review below.

Big Open Access Data: we still need lots more

- So far datasets of material and products are proving challenging, the calculator needs data for both:
    - U value calculations
    - Embodied energy and carbon calculations
    - GBE bigger ambitions calculator has many more datapoints all needing data
- Many data source have one set of data but not offer both.
- Merging of datasets is not entirely satisfactory, however merging of datasets within the calculator is essential to get results in all parts
- Numerous sources are being merged together to provide more comprehensive collections to choose from.
- In some cases where data is only available in the U values a different material of similar but not necessarily the same characteristics has to be chosen for the embodied energy and carbon to get results in both locations.

Bringing results together for comparison

- Having 8 buildings and 6 surveys needed 6 files to calculate and preserve the results
- To bring the results together we created a summary file.
- The summary file is currently populated by copying values for three scenarios from the 6 source files and paste > values only into the readymade summary file matrix.
- Automatic populating of the cells should be possible by linking the files using = function.

Risk Analysis

- Different moisture permeability of insulation, materials and exiting construction give different risk factors
- With years/decades of experience PD was able to develop a very simple yet very clever set of risk scenarios for adding insulation to construction
- This table was expanded into a multitude of rows of permutations of results
- Using different results in numerous cells and 'Concatenation' the correct risk row was selected and the results presented in the 'Survey' form.
- The calculator engaged well with these, but was challenged if the insulation choice was set to 'none'; this is likely to result in less risk, other than costly to occupy
- It displays "No risk assessment available at moment"
- More risk scenarios could be developed.

State of the Art or not?

- The calculator is made using MS Excel not an App so it could be argued this is not 'state of the art'

- There are many carbon-only calculators being developed and launched almost monthly.
- But GBE and STBE have brought together so many interconnected calculation functions and datasets into one place that is can act as a broader design and decision tool.
- Any change will recalculate throughout many worksheets
  - o giving a multitude of instantaneous results
  - o allowing scenario or option evaluation
  - o allowing value engineering
  - o these are its claim to being 'state of the art'

Review of Calculator by Peter Draper (PD) of STBA also the reviewer of the analysis and Energy Pathfinder report writer

Reducing a big calculator to a more restricted set of functions:

- The Energy Pathfinder calculator spreadsheet was originally based on a much more comprehensive GBC design & decision tool that includes: pricing, quantity surveying, etc. etc. It was reduced and expanded for STBA Options Appraisal and further reduced and expanded for Energy pathfinder
- Paring them back has been an issue within itself:
  - o There is a tendency to want to hang on to the detail - and hence more accuracy in the data, as this is inherent within the existing GBE D&DT; however it was not really needed for the indicative version required by STBA nor for Energy Pathfinder
  - o Omitting existing worksheets, adding new ones, stripping back data and associated disconnections and reconnections has implications for the integrity of calculations that may go un-noticed due to high complexity and interconnectivity

Reviewing the results

- The inner workings of the calculator were visible to BRM, but due to the method developed to interrogate scenarios, no longer visible to PD in the review process
- The equations in cells to carryout the evaluations, would reset the results with each scenario; the solution adopted was to copy the equations and paste only the result values back into the same cell to preserve them.
- Process: Run each scenario followed by 'copy and past values' then the next scenario…
- This way 3 scenarios could be displayed side by site to compare and evaluate
- PD could only see the result values and not the equations that generated them, this meant the equations could not be interrogated by PD
- Complex equations and inter-relationships between cells and worksheets require an in-depth knowledge of Excel and or an intimate knowledge of their creation (BRM); PD a non-expert reviewer doesn't have these - thus certain functions in cells (if visible) were not meaningful nor could be checked.
- Excel function shorthand
  - o is pretty well meaningless to a non-expert reviewer

  - can take time to remember what was being done and why even by their author
- Review process was based on intuition and knowledge of 'expected' results based on years of experience as a surveyor using available tools or long hand calculations, rather than forensic knowledge of MS Excel,
  - Thus certain issues only came to light in 'series'.
  - Once one issue was identified and corrected another issue came to light.
  - So solving problems was linear rather than concurrent.
  - This extended timescales

Conclusions

- Building and Rebuilding multi-functional calculators can be tricky, challenging and time consuming
  - but now this one is now working fine
- Reviews by a fresh pair of eyes is essential, visibility of equations is essential for reviewers
- Experience of expected results is essential to check the results
- We have learned a few more MS Excel tricks in the process
- Wherever possible ALL scenarios dataset needed to be replaced automatically
- More work is needed to make this calculator stand-alone
- We have seen how other improvements can be implemented when time is available
- More rationalizing of datasets into topical issue groups
- There is much more scope to improve the tool and expand its scope
- More big open data is essential to progress low carbon building

2nd September 2022 – 20th September 2022