USING WOOD WELL

WORKED EXAMPLE
LEVEL 2 FRAME

SUPERSTRUCTURE FRAME
WUI AND URR CALCULATION

Created by

changebuilding

University of Stuttgart
Institute for Computational Design and Construction

WAUGH THISTLETON ARCHITECTS

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FRAME - WUI AND URR WORKED EXAMPLE

Level 2 (Frame) Analysis

WorkStack, Charlton, dRMM

INTRODUCTION

This project has been focused on refining how to best calculate and use the metrics Wood Use Intensity (WUI: volume of timber / area) and Use to Renewal Ratio (URR: Expected use life of element / growth rate of material).

After trailing the different and evolving methodologies we decided on splitting the metrics into three different 'levels' of metrics not one single value which work with different levels of input data. This allows:

- the use of available data
- useful metric during the design phase that is easy and actionable
- different levels suited for different stakeholders or design stages to cover all three levels
- Links URR to the building scale in Level 2 and 3
- Allows for a full building study to align with an WLC assessment and floor areas in Level 3.

LEVEL 1 – MINIMUM

This uses General project data, total timber volumes and floor areas. Its primary use is for benchmarking and allows for the inclusion of the largest amount of available data.
Output: WUIgeneral

LEVEL 2 – FRAME

This metric can also be used to improve the material efficiency of the structure. It is quick to calculate during the design phases to optimise the amount of timber in the structure which is typically a large amount of the upfront carbon and more likely to be Bio based.
Input: Detailed Superstructure information
Output: WUIfloor/ WUIframe /URRframe/ Volume and Mass Bio/Non-bio

LEVEL 3 – BUILDING

This can be read and conducted alongside a WLC assessment to review all the timber used in the project. Gathering the additional data required will take time which will be best conducted when a WLC calculation process is already being undertaken.
Input: Detailed building information of all elements
Output: WUIbuilding/URRbuilding/ Volume and Mass Bio/Non-bio
Definition and data on all superstructure, façade, finishing elements

This document shows a worked example for calculating Level 2 – Frame.
This case study provides an example of how to calculate Level 2 – Frame WUI and URR by hand. An automated tool is being developed that does this calculation with data extracted from a BIM model.

Data may also be obtained from detailed LCA either of the structure (say using IStructE tool) or from a proprietary detailed tool.

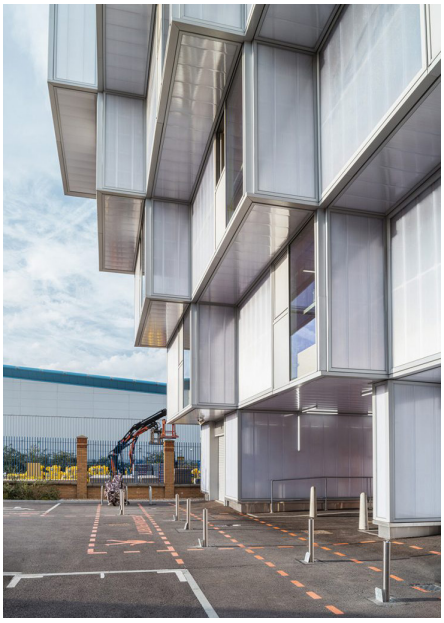
FRAME - WUI AND URR WORKED EXAMPLE

Stage 2 (Frame) Analysis

WorkStack, Charlton, dRMM

PROJECT EXAMPLE:

Charlton WorkStack, a 5 storey light industrial building in London built using CLT and lower braced steelwork podium.



Photograph of WorkStack

PROCESS SUMMARY:

1. Measure the Gross Superstructure Slab Area (GSSA) which is the area of the structural slab and structural superstructure at each level.
2. Classify the full primary structure by location and material,
3. Measure each structural elements by volume and mass.
4. Assign Use Renewal Rate to each Bio Based element.
5. Calculate Bio Mass and Volume
6. Calculate URR Range
7. Calculate Wood Use Intensity

1. AREA MEASURE

Using data from the BIM model, the Gross Superstructure Slab Area (GSSA) was calculated.

GSSA is used as this relates more directly to what can be typically constructed in timber, the superstructure.

The GSSA (Used to define WUI-frame) was calculated as 1592m^2.

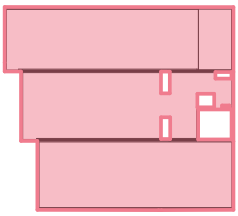
Meanwhile, the Typical Superstructure Slab Area (Used to define WUI-floor) was calculated as 291m^2.

It is important to note that all basement and roof levels are excluded.

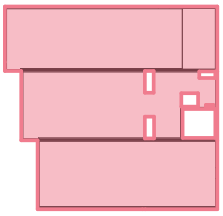
Level 2 areas are based on GSSA either for an individual floor or the sum of all superstructure floors In this example the floor area varies each floor.

The total GSSA includes:
- First floor (as CLT panels supported off a steelwork frame)
- Floors two to four and the roof slab

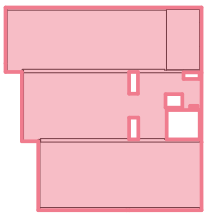
The Second floor is selected as the Typical Floor.



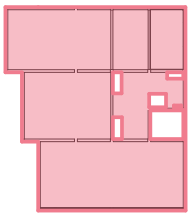
Fourth Floor



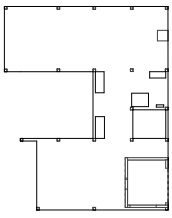
Third Floor



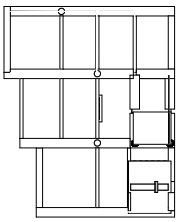
Second Floor



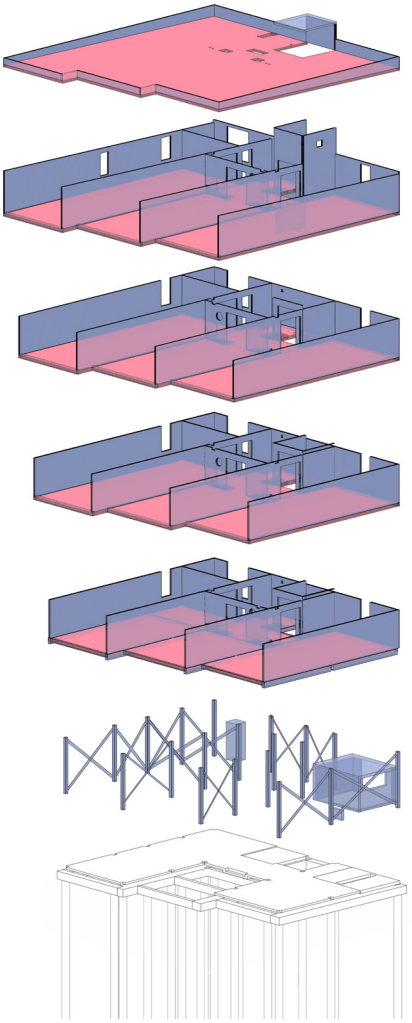
First Floor



Ground Floor



Foundation level

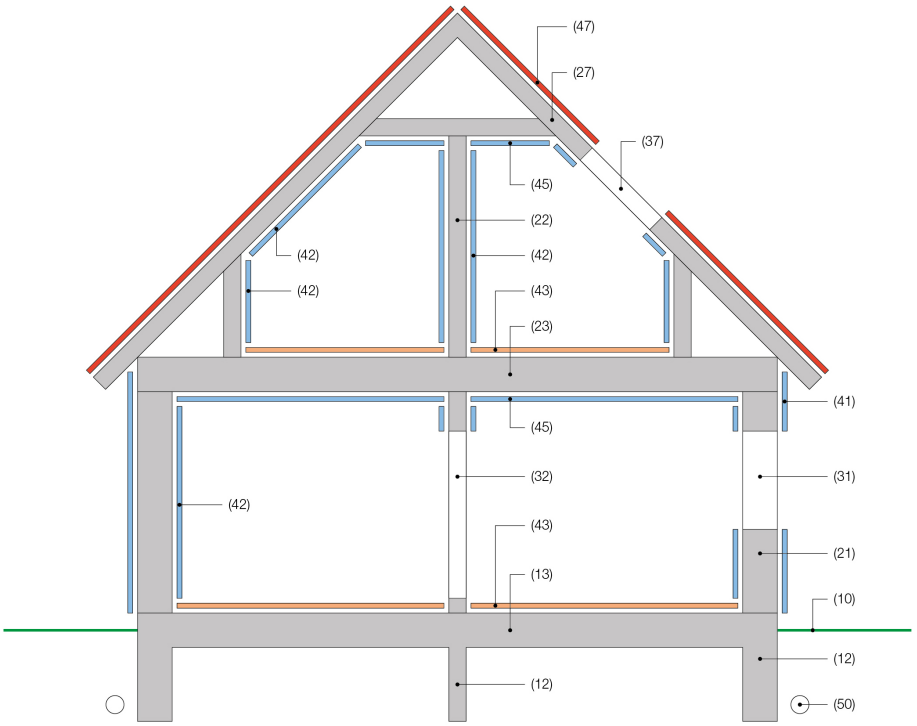


Exploded structural AXO of WorkStack

2. STRUCTURAL ELEMENT CLASSIFICATION

For each element of structure the following information was classified in the BIM model and then extracted.

- **Use**: i.e. lateral horizontal or vertical support system or fixings
- **Type**: Beam, Column Slab, Fixings
- SfB-Category: This allows for classification of elements which can relate to their exposure criteria and location within a structure which will later be used to select the potential use life.
- **Material-Category**: Steel, Timber, Concrete etc.
- **Material-Product**: Mild Steel, CLT, LVL, Plywood, Glulam etc.
- **Material Natural**: Bio or Non-Bio
- **Material-Circularity**: Primary / Secondary / Waste.
- **Material-Source Location**: Local, National, Regional, International



SfB Classification System for Use Life Definitions

Layer	Use	Type	SfB	Material Category	Material Product	Material Natural	Material Species	Material Circ-Econ	Material Source Location
Superstructure	Horizontal	Wall	17	Concrete	-	Non-Bio	-	Primary	-
Superstructure	Horizontal	Wall	22	Concrete	-	Non-Bio	-	Primary	-
Superstructure	Horizontal	Slab	23	Concrete	-	Non-Bio	-	Primary	-
Superstructure	Horizontal	Beam	12	Concrete	-	Non-Bio	-	Primary	-
Superstructure	Vertical	Wall	22	Laminated Timber	CLT	Bio	Spruce	Primary	-
Superstructure	Vertical	Wall	21.1	Laminated Timber	CLT	Bio	Spruce	Primary	-
Superstructure	Horizontal	Slab	23	Laminated Timber	CLT	Bio	Spruce	Primary	-
Superstructure	Vertical	Wall	27	Laminated Timber	CLT	Bio	Spruce	Primary	-
Superstructure	Horizontal	Wall	27	Laminated Timber	CLT	Bio	Spruce	Primary	-
Superstructure	Horizontal	Slab	27	Laminated Timber	CLT	Bio	Spruce	Primary	-
Superstructure	Vertical	Wall	22	Laminated Timber	CLT	Bio	Spruce	Primary	-
Superstructure	Horizontal-Typical	Slab	23	Laminated Timber	CLT	Bio	Spruce	Primary	-
Superstructure	Horizontal	Beam	21	Laminated Timber	Glulam	Bio	Spruce	Primary	-
Superstructure	Horizontal-Typical	Beam	21	Laminated Timber	Glulam	Bio	Spruce	Primary	-
Superstructure	Vertical	Wall	21	Masonry	-	Non-Bio	-	Primary	-
Superstructure	Vertical	Beam	21	Masonry	-	Non-Bio	-	Primary	-
Superstructure	Vertical	Core	24	Steel	Galvanised Steel	Non-Bio	-	Primary	-
Superstructure	Vertical	Column	25	Steel	-	Non-Bio	-	Primary	-
Superstructure	Horizontal	Beam	21	Steel	-	Non-Bio	-	Primary	-
Superstructure	Horizontal	Beam	23	Steel	-	Non-Bio	-	Primary	-
Superstructure	Horizontal	Beam	22	Steel	-	Non-Bio	-	Primary	-
Superstructure	Horizontal	Braces	23	Steel	-	Non-Bio	-	Primary	-
Superstructure	Fixings	Fixings	23	Steel	-	Non-Bio	-	Primary	-

Example Structural Element Classification

3. CALCULATE MASS & VOLUME OF EACH ELEMENT

Volume information of each structural element is taken from the BIM model. This value is then multiplied by the density to calculate the mass of each element.

For material densities we have used those provided in the IstructE carbon tool

Mass (kg) = Material Density (kg/m^3) X Volume (m^3)

E.g. 500 kg =2500 kg/m^3 X 0.2 m^3

If the amount of fixings are not available then this can be estimated. For this project we used 9kg of Steel / m^3 of timber as the fixing quanity was higher than typical. As a default we suggest a value of 7.5 kg / m^3

4. CALCULATE USE RENEWAL RATE OF EACH ELEMENT

A Use Renewal Rate of 0 is applied to all non-bio elements.

For bio elements, the BUILD 2021 table is used to look up the element's lower and higher potential use life. The appropriate renewal rate for each material is also found from the 'Renewal_lookup' tab in the build 2021 table.

The Lower and Upper URR for each element was calculated by dividing the Lower or Upper Use Time by the Renewal Rate.

Lower Use Renewal Rate = Lower Use Time / Renewal Rate

E.g. 1.20 = 60/50

Lower Use Renewal Rate = Lower Use Time / Renewal Rate

E.g. 1.20 = 60/50

SfB	Material Category	Material Natural	Material Species	Volume	Material Density	Mass	Volume%	Mass%	Lower USE TIME	Upper USE TIME	RR	Lower URR	Upper URR
17	Concrete	Non-Bio	-	0.2	2500	500.0	0%	0%	60	120	0	0	0
22	Concrete	Non-Bio	-	0.06	2500	150.0	0%	0%	60	120	0	0	0
23	Concrete	Non-Bio	-	4.29	2500	10725.0	1%	3%	60	120	0	0	0
12	Concrete	Non-Bio	-	0.35	2500	875.0	0%	0%	60	120	0	0	0
22	Laminated Timber	Bio	Spruce	75.85	500	37925.0	12%	10%	60	100	50	1.20	2.00
21.1	Laminated Timber	Bio	Spruce	96.98	500	48490.0	15%	13%	60	100	50	1.20	2.00
23	Laminated Timber	Bio	Spruce	259.43	500	129715.0	41%	35%	60	100	50	1.20	2.00
27	Laminated Timber	Bio	Spruce	8.41	500	4205.0	1%	1%	60	120	50	1.20	2.40
27	Laminated Timber	Bio	Spruce	7.17	500	3585.0	1%	1%	60	120	50	1.20	2.40
27	Laminated Timber	Bio	Spruce	76.1	500	38050.0	12%	10%	60	120	50	1.20	2.40
22	Laminated Timber	Bio	Spruce	12.68	500	6340.0	2%	2%	60	100	50	1.20	2.00
23	Laminated Timber	Bio	Spruce	81.17	500	40585.0	13%	11%	60	100	50	1.20	2.00
21	Laminated Timber	Bio	Spruce	2.25	450	1012.5	0%	0%	60	100	50	1.20	2.00
21	Laminated Timber	Bio	Spruce	1.13	450	508.5	0%	0%	60	100	50	1.20	2.00
21	Masonry	Non-Bio	-	1.95	1500	2925.0	0%	1%	60	80	0	0	0
21	Masonry	Non-Bio	-	4.4	1500	6600.0	1%	2%	60	80	0	0	0
24	Steel	Non-Bio	-	2.9	7850	22765.0	0%	6%	60	60	0	0	0
25	Steel	Non-Bio	-	0.8	7850	6280.0	0%	2%	60	120	0	0	0
21	Steel	Non-Bio	-	0.21	7850	1648.5	0%	0%	60	120	0	0	0
23	Steel	Non-Bio	-	1.15	7850	9027.5	0%	2%	60	100	0	0	0
22	Steel	Non-Bio	-	0.08	7850	628.0	0%	0%	60	100	0	0	0
23	Steel	Non-Bio	-	0.01	7850	78.5	0%	0%	60	100	0	0	0
23	Steel	Non-Bio	-	0.60	7850	4716	0%	0%	60	100	0	0	0

Example Calculations of Bio Mass, Volume and Use Renewal Rate

5. CALCULATE BIO MASS AND VOLUME

To provide context to the WUI value and to weight the URR the volume and mass of each material is calculated to understand how much % the structure is bio based.

The following figures are calculated as follows:

Total Bio Volume = ∑ Volume of all bio based elements
Total Non-Bio Volume = ∑ Volume of all non-bio based elements
Total Volume = Bio Volume + Non-Bio Volume

Total Bio Mass = ∑ Mass of all bio based elements
Total Non-Bio Mass = ∑ Mass of all non-bio based elements
Total Mass = Bio Mass + Non-Bio Volume

Percentage of Bio based = (Total Bio Volume / Total Volume) * 100

6. CALCULATE URR FRAME RANGE

The Lower Use Renewal Rate was found by calculating the sum of the % mass and lower use renewal rate of all elements.

∑ (Mass % × Lower Use Renewal Rate)

Lower URR = $(Mass\%_1 \times URR_1) + (Mass\%_2 \times URR_2) + (Mass\%_3 \times URR_3)$ ....

Similarly, the Upper Use Renewal Rate was found by calculating the sum of the % mass and upper use renewal rate of each element.

∑ (Mass % × Upper Use Renewal Rate)

Upper URR = $(Mass\%_1 \times URR_1) + (Mass\%_2 \times URR_2) + (Mass\%_3 \times URR_3)$ ....

7. CALCULATE WOOD USE INTENSITY (WUI)

The Frame WUI and Typical Floor WUI is calculated as follows:

WUI-Frame = Total Bio Volume of Structural Elements / GCFA Frame (m^2)

WUI-Frame = 621.2 m^3/ 1592 m^2

The Floor WUI is calculated as follows:

WUI-Floor = Total Bio Volume of Structural Elements / CFA Floor (m^2)

WUI-Floor = 82.3 m^3/ 291 m^2

WUI-Frame (m^3/m^2)	0.39	
Total Bio Volume (m^3)	621.2	
Total Bio Mass (kg)	310416.0	
Total Bio Volume (%)	97.4	
Total Bio Mass (%)	83.3	
URR Frame Range	1.00	1.72
	Lower URR	**Upper URR**
WUI-Floor (m^3/m^2)	0.28	
Floor Bio Volume (m^3)	82.3	
Floor Bio Mass (kg)	41093.5	
Floor Bio Volume (%)	100.0	
Floor Bio Mass (%)	100.0	

Example Output Calculations

New Build Commercial

WORKSTACK

dRMM Architects

London, UK

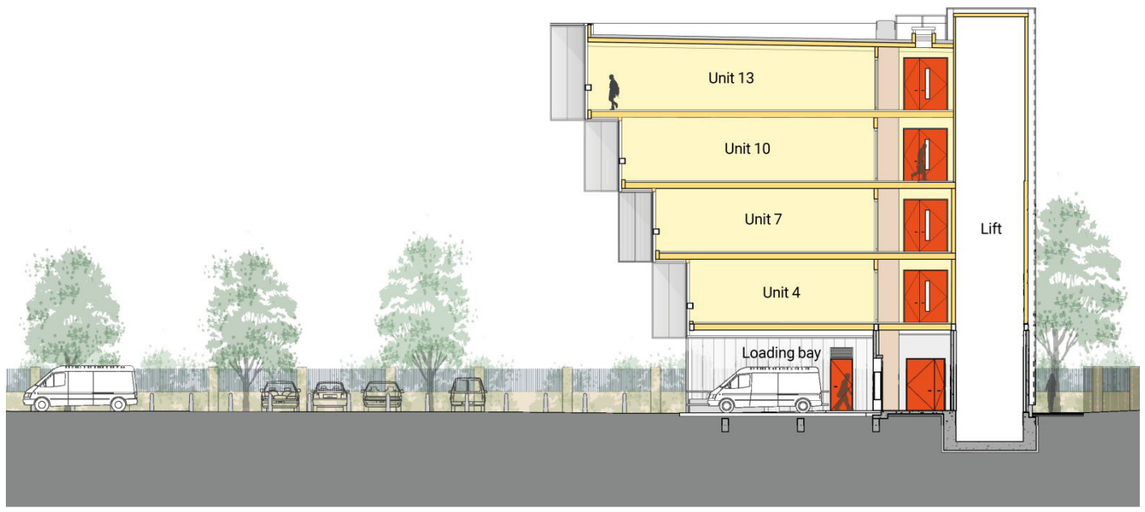
2023

FRAME

WUIfloor / WUIframe / URR

Exterior © dRMM Architects

Interior © dRMM Architects



Section A-A © dRMM Architects

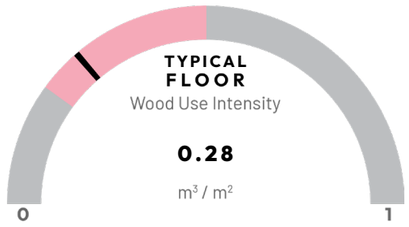
PROJECT DESCRIPTION

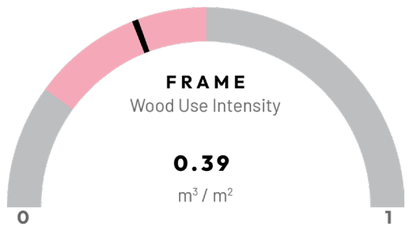
WorkStack was designed as a new model for high density industrial space on compact sites. Located in Charlton and developed for the Greenwich Enterprise Board (GEB), it addresses the twin pressures of rising land values and a growing need for high-quality industrial space within cities. Designed to be affordable to rent, operate and maintain, these workshops encourage manufacturing in central London.

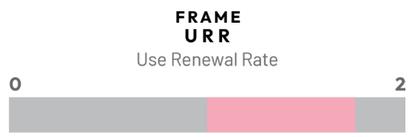
The building is a five-storey stacked structure on a compact 1,426 m^2 site, enabling 14 units (each between 55–110 m^2) and workspace for about 60 people. This delivers an employee density of 428 per hectare — far above London's industrial average of 69. Occupiers include furniture makers, knitwear producers, workwear manufacturers and a bicycle/ motorcycle workshop.

WorkStack uses engineered mass timber (CLT) for load bearing walls and slabs. The structure, with its stacked-bay organisation and cantilevered floorplates, gives the building a strong presence on the main road, while also providing solar shading and creating a covered delivery space. Organised in a simple and functional manner there are three units per floor, forming three structural bays stacked over five floors. Two lifts provide the primary access to the upper floors for goods and tenants whilst a staircase is located to the inside of the eastern façade.

The panelised CLT structure sequesters approximately 343 tonnes of carbon, achieving about 21% less upfront embodied carbon than the London Energy Transformation Initiative (LETI) 2030 embodied carbon target of 350 kg CO_2/m^2 and 44% less than RIBA's 2030 Built Target for whole life carbon (of 750 $kgCO_2/m^2$).

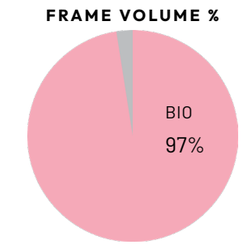


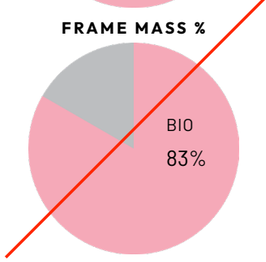




1 - 1.72

Use / Growth





HEIGHT | STOREY
20 m | 5 Storey

STOREYS IN WOOD
4 Storey

STRUCTURE TYPE
Panel

TYPICAL SPAN
6.5 m

FLOOR TYPE
Panel

MATERIAL
Timber - CLT
Steel podium

SOURCING
-

GCFA
1,569 m^2

TIMBER VOLUME
621.2 m^3

3. CALCULATE MASS & VOLUME OF EACH ELEMENT

Volume information of each structural element is taken from the BIM model. This value is then multiplied by the density to calculate the mass of each element.

For material densities we have used those provided in the IstructE carbon tool

Mass (kg) = Material Density (kg/m^3) X Volume (m^3)

E.g. 500 kg =2500 kg/m^3 X 0.2 m^3

4. CALCULATE USE RENEWAL RATE OF EACH ELEMENT

A Use Renewal Rate of 0 is applied to all non-bio elements.

For bio elements, the BUILD 2021 table is used to look up the element's lower and higher potential use life. The appropriate renewal rate for each material is also found from the 'Renewal_lookup' tab in the build 2021 table.

The Lower and Upper URR for each element was calculated by dividing the Lower or Upper Use Time by the Renewal Rate.

Lower Use Renewal Rate = Lower Use Time / Renewal Rate

E.g. 1.20 = 60 years / 50 years

Lower Use Renewal Rate = Lower Use Time / Renewal Rate

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23	Non-Bio	4.29	2500	10725.0	1%	3%	60	120	0		
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23	Non-Bio	0.01	7850	78.5	0%	0%	60	100	0		

Example Calculations of Bio Mass, Volume and Use Renewal Rate

5. CALCULATE BIO MASS AND VOLUME

To provide context to the WUI value and to weight the URR the volume and mass of each material is calculated to understand how much % the structure is bio based.

The following figures are calculated as follows:

Total Bio Volume = ∑ Volume of all bio based elements
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Total Volume = Bio Volume + Non-Bio Volume

Total Bio Mass = ∑ Mass of all bio based elements
Total Non-Bio Mass = ∑ Mass of all non-bio based elements
Total Mass = Bio Mass + Non-Bio Volume

∑ (Mass % × Lower Use Renewal Rate)
Percentage of Bio based = (Total Bio Volume / Total Volume) * 100

6. CALCULATE URR FRAME RANGE

The Lower Use Renewal Rate was found by calculating the sum of the % mass and lower use renewal rate of each element.

Similarly, the Upper Use Renewal Rate was found by calculating the sum of the % mass and upper use renewal rate of each element.

∑ (Mass % × Upper Use Renewal Rate)
Lower URR = $(Mass\%_1 \times URR_1) + (Mass\%_2 \times URR_2) + (Mass\%_3 \times URR_3)$ ....

7. CALCULATE WOOD USE INTENSITY (WUI)

The Frame WUI and Typical Floor WUI is calculated as follows:

WUI-Frame = Total Bio Volume of Structural Elements / GCFA Frame (m^2)

WUI-Frame = 621.2 m^3/ 1592 m^2

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