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Research Question

Can BIM technologies calculate and visualise the global warming potential of building materials?

Research Purpose

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-To investigate if the application of BIM tools can be leveraged to automate Global Warming Potential (GWP) to support decision-making in meeting the RIAI 2030 Climate Challenge and contribute to the decarbonisation of the built environment

Research Objectives

Objective 1: To critically review the synergy of BIM and Life Cycle Analysis (LCA) in the construction sector

Objective 2: To hypothesise a solution with the capacity to incentivise stakeholders to decarbonise the built environment

Objective 3: To progress the hypothesis from theory to application using rigorous testing

Objective 4: -To analyse and present findings of the application for the potential implementation in the built environment

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BIM & LCA Literature Review Findings:

- **Support decision-making** in the early stages of design
- **Reduction of errors and inconsistencies** in LCA results
- **Improvement of GWP values** by combining LCA databases with the level of information need
- **Material libraries** for **quickly reviewing** and **visualising GWP impacts**
- **May facilitate environmentally friendly decisions to occur**. However, due to the task of **manually inputting LCA data** into BIM objects, real-time footprint analysis is not achievable without **an additional tool**
- **Reduction of effort** through **Revit and Dynamo to access GWP totals** and connect material databases
- **Reduction of human error** through automated **material mapping** for LCA using BIM software
- Introduction of ISO 22057 to standardise the **digitisation of EPDs providing data templates** for the use of Environmental Product Declarations (EPDs) for construction products in BIM

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Research Methodology – Hypothesis

-For this study, Design Science Research (DSR) was adopted as this is a problem-solving paradigm that seeks to enhance human knowledge via innovative solutions to real-world problems.

-Approaching this research to join existing processes (**BIM with building material databases**) to automate GWP values (**innovative solution**) to tackle the decarbonisation of the built environment (**real-world problem**) is the reason for choosing this methodology.

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H1 - The proposed tool/workflow will have the potential to deliver real-time lifecycle GWP calculation that will incentivise better decision-making in decarbonising the construction sector.

H2 – The model will be used as a verification tool to record and monitor the GWP totals of a building.

Research Testing

To investigate the proposed theories, the path for experimental research was organised into key stages:

-Preparation of **data sources** to be used in the study

-Creation of a **material library** and **shared parameters** based on GWP data

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-**Designing** and **modelling** an example to be utilised for research testing and experimentation for this study

-Creation of a **visual programming script** to **map EPD data** to building materials inside the model

-Creation of additional **visual programming scripts** used **to visualise the GWP data** of the model and **compare thresholds**

Stage 1 - Preparation

Before the research testing could commence, the following data sources were collated:

-Benchmark: The targets set out in the **RIAI 2030 Climate Challenge**

-Standards: Parameters based on **EN 15804** and **EN 15978**

- Material Database: **IGBC National Inventory of Generic Construction Materials Data** / The **Inventory of Carbon and Energy (ICE)**

-BIM Tools: **Revit**, **Dynamo**

RIAI-Embodied Carbon Threshold	Dwellings	Offices	Schools
2025 Target	800 $kgCO_2e/m^2$	970 $kgCO_2e/m^2$	675 $kgCO_2e/m^2$
2030 Target	625 $kgCO_2e/m^2$	750 $kgCO_2e/m^2$	540 $kgCO_2e/m^2$

IGBC — National Inventory of Generic Construction Materials Data (NIGCMD)

Date: 23-03-2022
Revision: 1
Author: Cambridge Architectural Research (CAR)/IGBC

	Product	GWP		
		number (n)	unit	$kgCO_2e$ (A1 - A3)
1	Average Cement for Ireland ≠	1	tonne	725
2	CEM I produced in Ireland *	1	tonne	763
3	CEM II/A-V (<20% PFA)	1	tonne	728
	CEM II/A-L (<20% Limestone) °	1	tonne	698
	CEM II/A-S (<20% GGBS)	1	tonne	724
	CEM II A-D (<10% silica fume)	1	tonne	896
	CEM II/B-S (<35% GGBS)	1	tonne	617
	Average CEM II	1	tonne	674
4	CEM III/A (35-60% GGBS)	1	tonne	512
	CEM III/B (66-80% GGBS)	1	tonne	371
5	Average Aggregate for Ireland	1	tonne	5
6	Average hot rolled steel coil used in Ireland	1	tonne	2140
	Average cold rolled coil used in Ireland	1	tonne	2630
	Average galvanised steel value used in Ireland	1	tonne	2800
	Average organic coated steel used in Ireland	1	tonne	2830
	Average steel section and steel rail value for Ireland	1	tonne	1490
	Average reinforcing steel used in Ireland	1	tonne	737
7	Average aluminium sheet used in Ireland	1	tonne	2751
	average aluminium foil used in Ireland	1	tonne	6780
	Average aluminium extrusion used in Ireland	1	tonne	4855
8	Average float or coated glass used in Ireland	1	tonne	1323
9	Average facing brick imported from the UK (excl transport)	1	tonne	213
10	Average Irish C16 timber			
	o Sequestration	1	m3	-736
	o Fossil fuel emissions (A1-A3)	1	m3	104
	o GWP A1-A3 incl sequestration	1	m3	-632
11	Irish produced OSB	See Smartply EPD in EPD Ireland		

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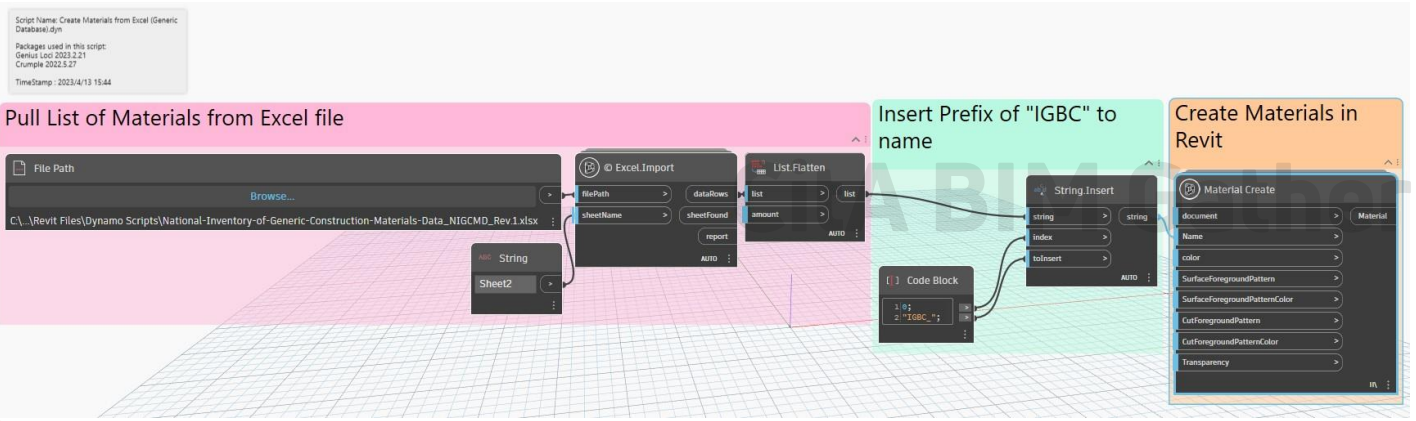
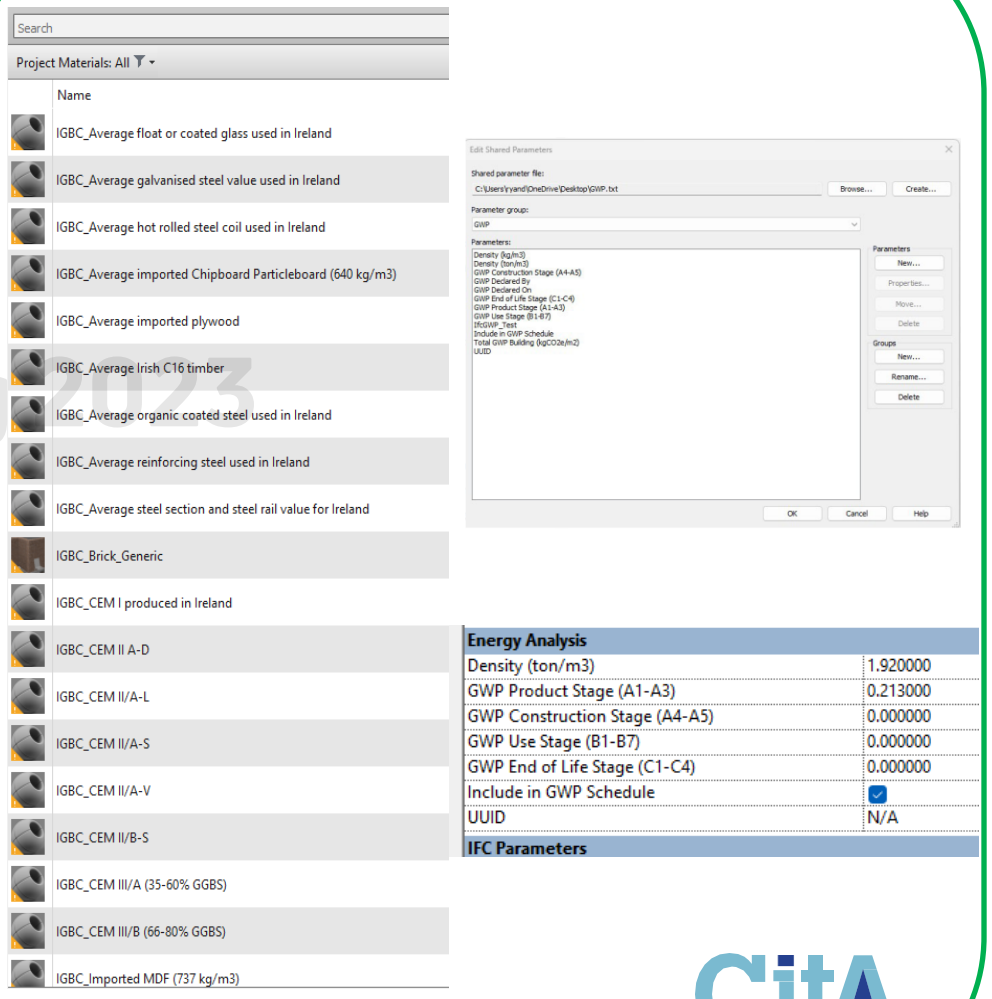
Stage 2 – Material Library and Shared Parameter Creation





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Stage 3 – Schedule Design & Modelling

-Material: Name
-Material: UUID
-Material: Volume
-Material: Density (ton/m3)
-Weight of Material (ton)*
-Material: GWP Product Stage (A1-A3)
-Material: GWP Construction Stage (A4-A5)
-Material: GWP Use Stage (B1-B7)
-Material: GWP End of Life Stage (C1-C4)
-GWP All Stages (A1-C4)*
-Total Material GWP (tonC02e)*
-Total Material GWP (kgC02e)*
-Building Gross Area (m2)
-GWP Footprint (kgCO2e/m2)*

***Denotes where formulae were used**

<Global War

A	B	C	D	E	F	G
Material: Name	Material: UUID	Material: Volume	Material: Density (ton/m3)	Weight of Material (ton)	Material: GWP Product Stage (A1-A3)	Material: GWP Construction Stage (
ICE_Concrete - Cast In Situ 25/30	N/A	9.76 m³	2.2	21.464685	0.119	0
ICE_Concrete_Block_215mm	N/A	23.65 m³	2.3	54.39362	0.093	0
ICE_Insulation - Mineral Wool	N/A	23.65 m³	0.025	0.591235	1.28	0
ICE_Plaster (Gypsum)	N/A	1.48 m³	1.12	1.655458	0.13	0
IGBC_Brick_Generic	N/A	12.12 m³	1.92	23.27101	0.213	0
Grand total: 17		70.65 m³		101.376008		

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bal Warming Potential Schedule>

H	I	J	K	L	M	N
ion Stage (A4-A5)	Material: GWP Use Stage (B1-B7)	Material: GWP End of Life Stage (C1-C4)	GWP All Stages (A1-C4)	Total Material GWP (tonCO2e)	Total Material GWP (kgC02e)	Building Gross Area (m2)	Embodied Carbon F
	0	0	0.119	2.554298	2554.297515	73.73	34.643938
	0	0	0.093	5.058607	5058.60666	73.73	68.609883
	0	0	1.28	0.756781	756.7808	73.73	10.264218
	0	0	0.13	0.21521	215.20954	73.73	2.918887
	0	0	0.213	4.956725	4956.725045	73.73	67.228062
				13.54162	13541.61956		183.664988

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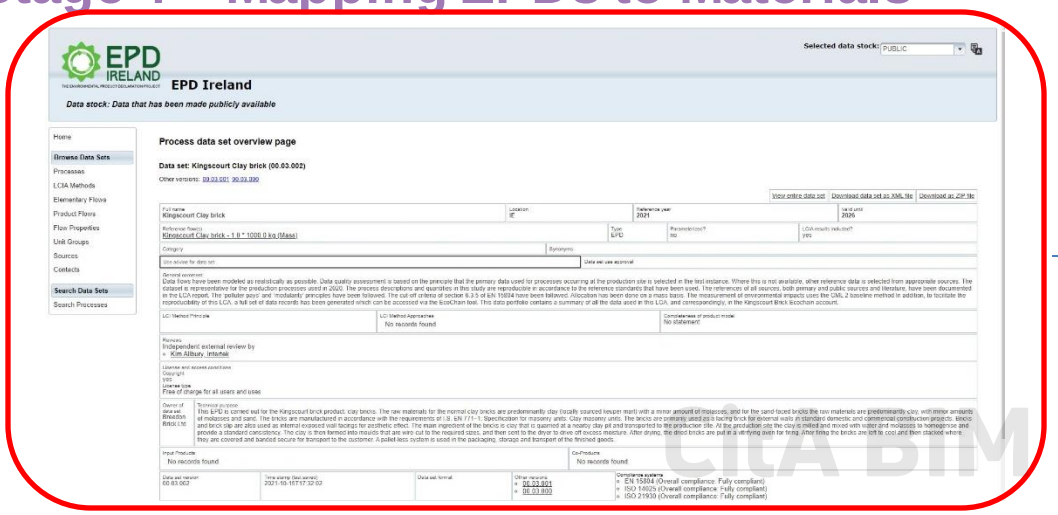
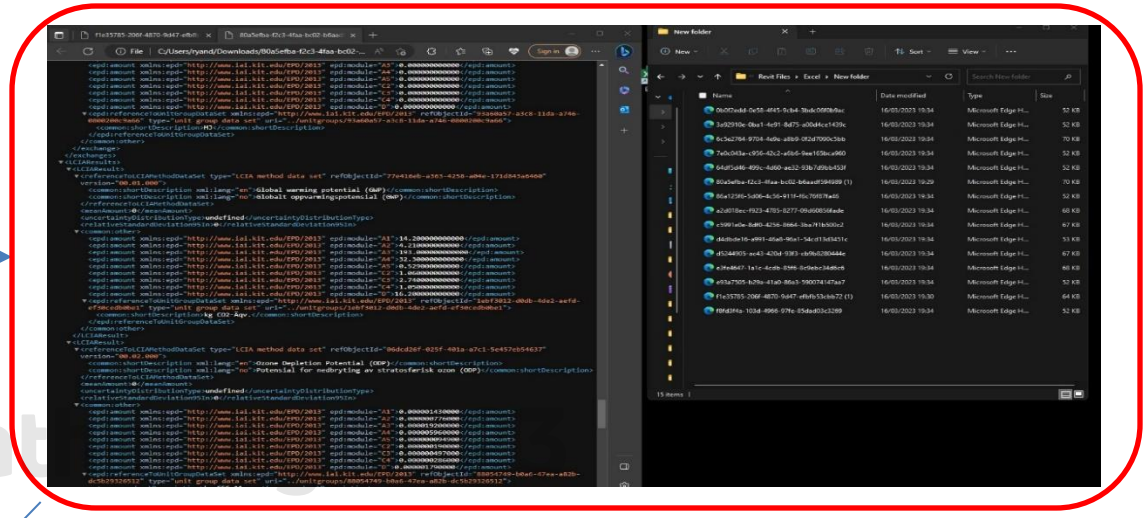
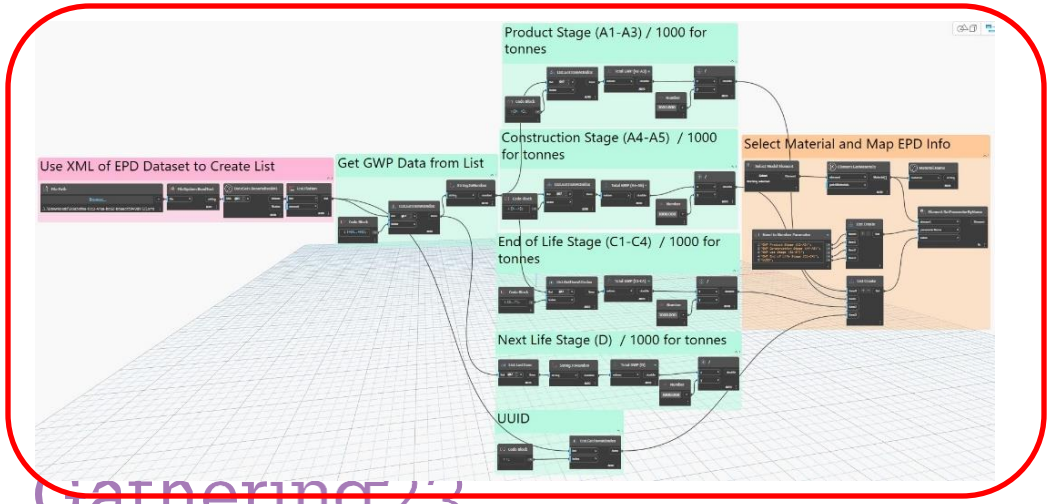
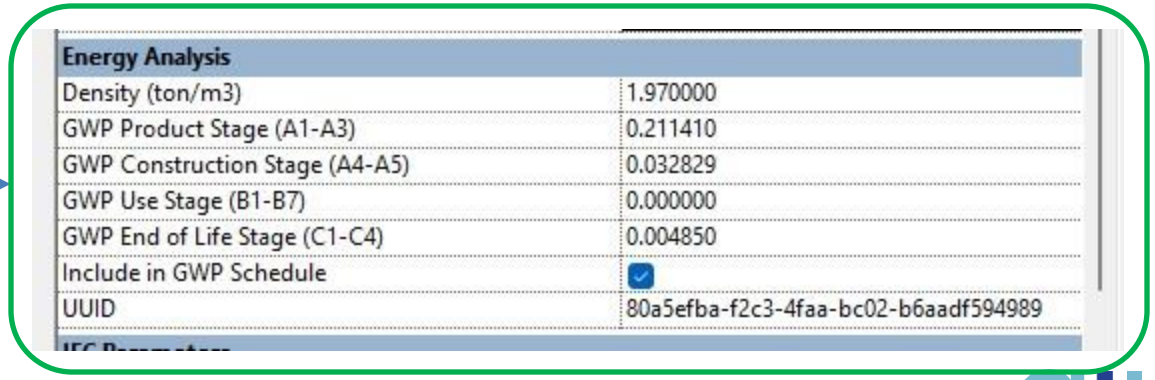
Stage 4 – Mapping EPDs to Materials









Energy Analysis	
Density (ton/m3)	1.970000
GWP Product Stage (A1-A3)	0.211410
GWP Construction Stage (A4-A5)	0.032829
GWP Use Stage (B1-B7)	0.000000
GWP End of Life Stage (C1-C4)	0.004850
Include in GWP Schedule	☑
UUID	80a5efba-f2c3-4faa-bc02-b6aadf594989

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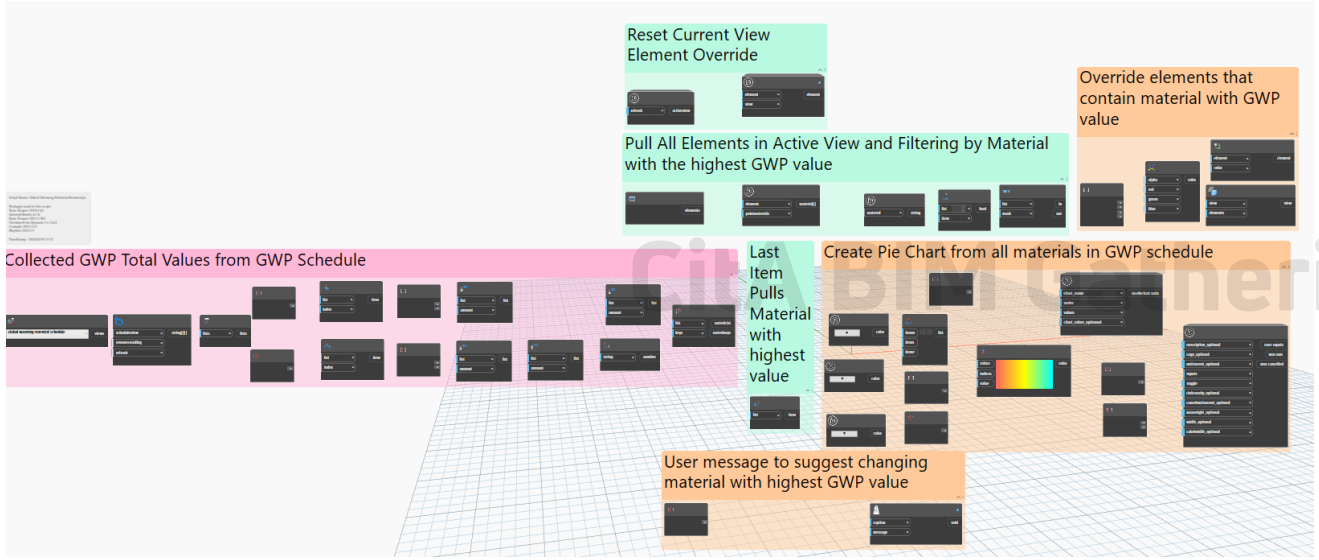
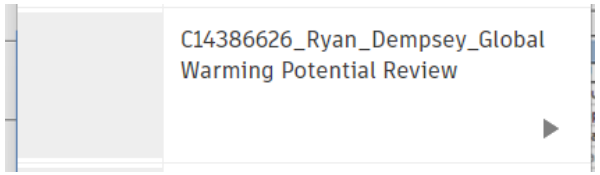
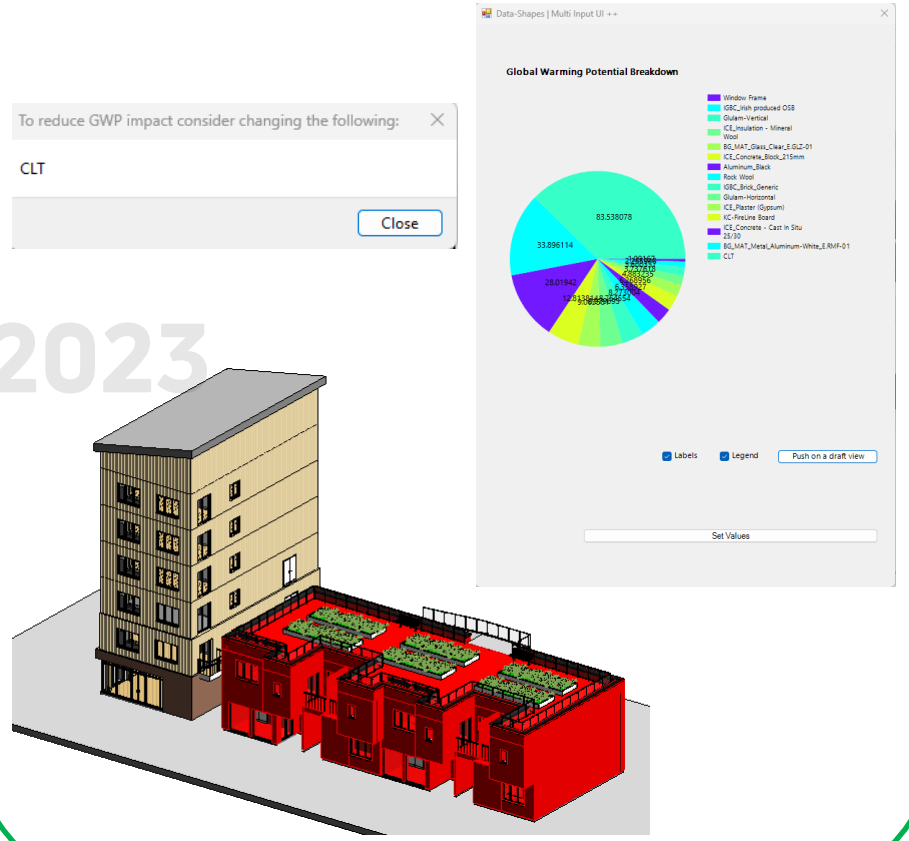
Stage 5a – GWP Visualization







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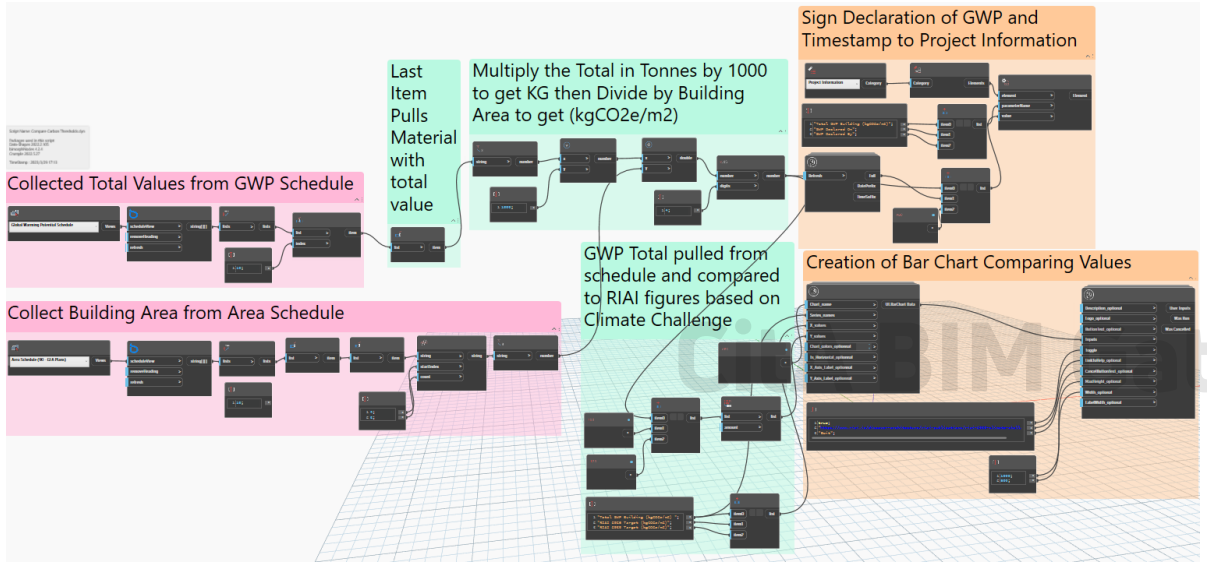
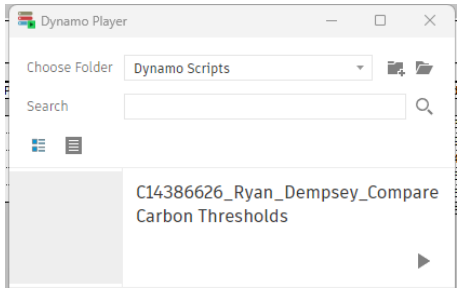
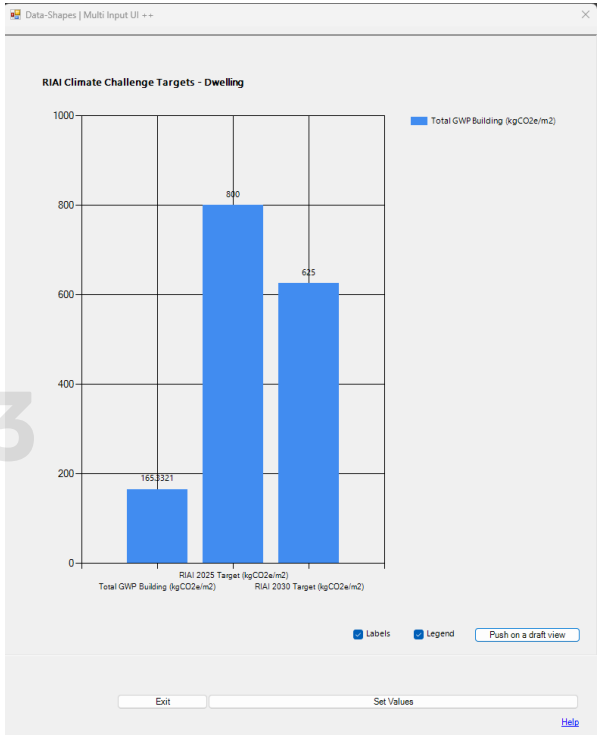
Stage 5b – GWP Targets Comparison & Declaration







Energy Analysis	
Total GWP Building (kgCO2e/m2)	165.332100
GWP Declared On	14/09/23 22:19:38
GWP Declared By	RD
IFC Parameters	

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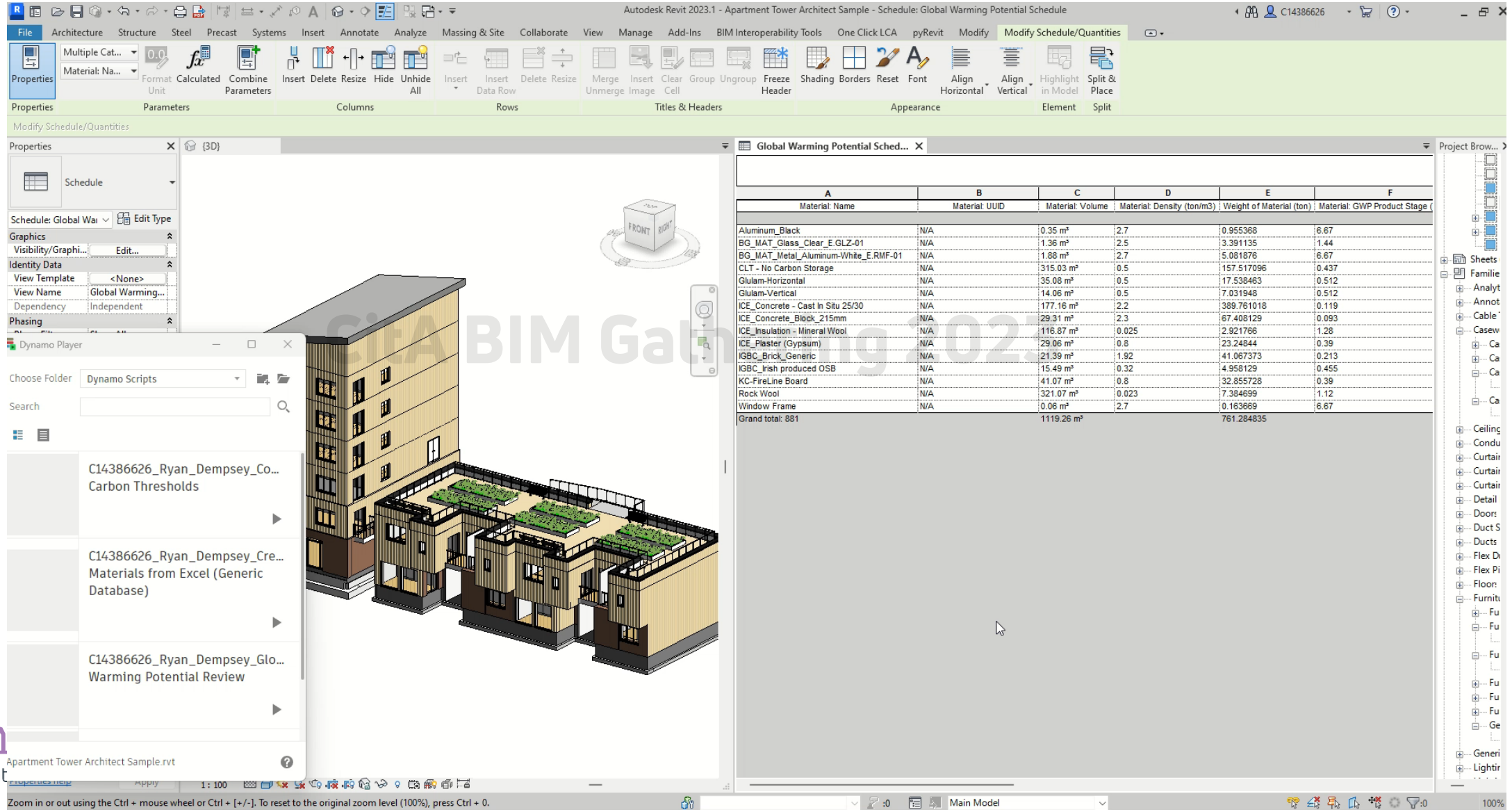
Design Options



Material: Name	Material: UUID	Material: Volume	Material: Density (ton/m3)	Weight of Material (ton)	Material: GWP Product Stage (
Aluminum_Black	N/A	0.35 m³	2.7	0.955368	6.67
BG_MAT_Glass_Clear_E.GLZ-01	N/A	1.36 m³	2.5	3.391135	1.44
BG_MAT_Metal_Aluminum-White_E.RMF-01	N/A	1.88 m³	2.7	5.081876	6.67
CLT - No Carbon Storage	N/A	315.03 m³	0.5	157.517096	0.437
Glulam-Horizontal	N/A	35.08 m³	0.5	17.538463	0.512
Glulam-Vertical	N/A	14.06 m³	0.5	7.031948	0.512
ICE_Concrete - Cast In Situ 25/30	N/A	177.16 m³	2.2	389.761018	0.119
ICE_Concrete_Block_215mm	N/A	29.31 m³	2.3	67.408129	0.093
ICE_Insulation - Mineral Wool	N/A	116.87 m³	0.025	2.921766	1.28
ICE_Plaster (Gypsum)	N/A	29.06 m³	0.8	23.24844	0.39
IGBC_Brick_Generic	N/A	21.39 m³	1.92	41.067373	0.213
IGBC_Irish produced OSB	N/A	15.49 m³	0.32	4.958129	0.455
KC-FireLine Board	N/A	41.07 m³	0.8	32.855728	0.39
Rock Wool	N/A	321.07 m³	0.023	7.384699	1.12
Window Frame	N/A	0.06 m³	2.7	0.163669	6.67
Grand total: 881		1119.26 m³		761.284835	

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Findings

- Template and material library provides a **starting point** for **early-stage GWP assessment**
- A proof-of-concept workflow with **schedules and visual aids** offering real-time lifecycle GWP calculation that may **influence decision-making**
- **Design Options** can be used to compare different materials and their environmental impacts
- By declaring GWP totals, the model **may be used as a verification tool** to record and track targets at project stages
- **Potential for automated material mapping** through **EPD datasets** and **XML files** through Revit and Dynamo. However, the density of materials used for testing **was not included in the dataset** and was found in the technical specification of the manufacturer. This proved one element of the **automated mapping process required manual input**
- Future work to investigate the impact of **ISO 22057** using **structured EPD data templates** for construction products in BIM to improve the process of automating material mapping for GWP calculation

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-On a final note, this workflow was introduced to provide a **free alternative solution** for calculating and visualising GWP totals for users without experience in LCA and EPD terminology. It was never envisioned that this **could replace industry tools** for LCA calculations.


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THANK YOU