Sustainable Design with Respect to LCA Using Parametric Design and BIM Tools

Life Cycle Assessment Integration in BIM

Marios Tsikos, MSc Civil Engineer, BuroHappold Engineering
Kristoffer Negendahl, Postdoc Researcher, DTU
Jan Schipull Kauschen, PhD Architect, Vandkunsten Architects

DTU Civil Engineering
Department of Civil Engineering
Section for Building Design

Vandkunsten Architects

BUROHAPPOLD ENGINEERING

WORLD SBE HONG KONG 2017
WORLD Sustainable Built Environment Conference

Organisers:
CONSTRUCTION INDUSTRY COUNCIL 建造業議會
HKGBC 香港綠色建築議會

International Co-owners:
SBE SERIES
CIB
iiSBE
UNEP Sustainable Buildings and Climate Initiative
FIDIC
Global Alliance for Buildings and Construction

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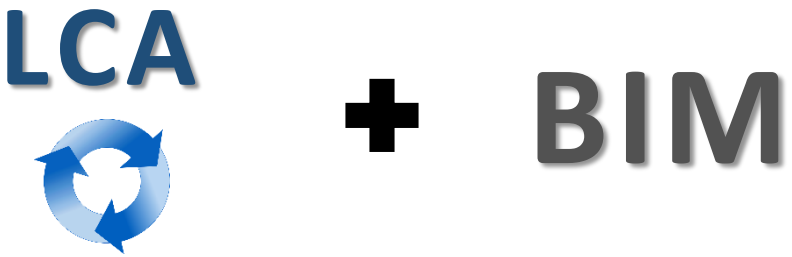
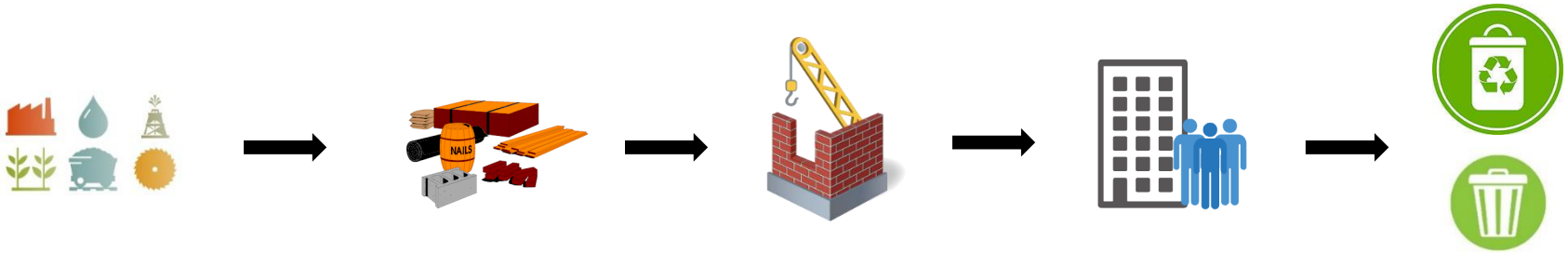


Life Cycle Assessment

- Method to quantify the environmental impacts of a process or product during its life cycle
- Used in AEC industry since 1990s

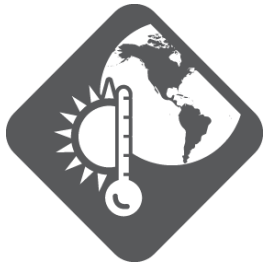


Why?

- To better integrate LCA in the design process from the early stages to the end of it.
- Render LCA a decision making tool.
- Reduce design cost
- Minimize environmental impacts

Buildings and the Environment

30-40% of energy consumption in Europe



40-50% of Greenhouse gas globally

LCA in Construction
Common Practice

- GaBi, SimaPro, etc.
  - Time consuming
  - Cost
  + Detailed & Accurate
- DGNB tool, custom excel sheets
  + Simplified
  + Easy to use
  - Time consuming (QTO)
- LCAbyg
  + Simple and easy to use
  - Time consuming (QTO)

LCA Integration in BIM

- Automatic QTO
- Instant preparation of results
- Instant update after changes are made
- Visual representation of impacts
- Time saving

LCA Integration in BIM

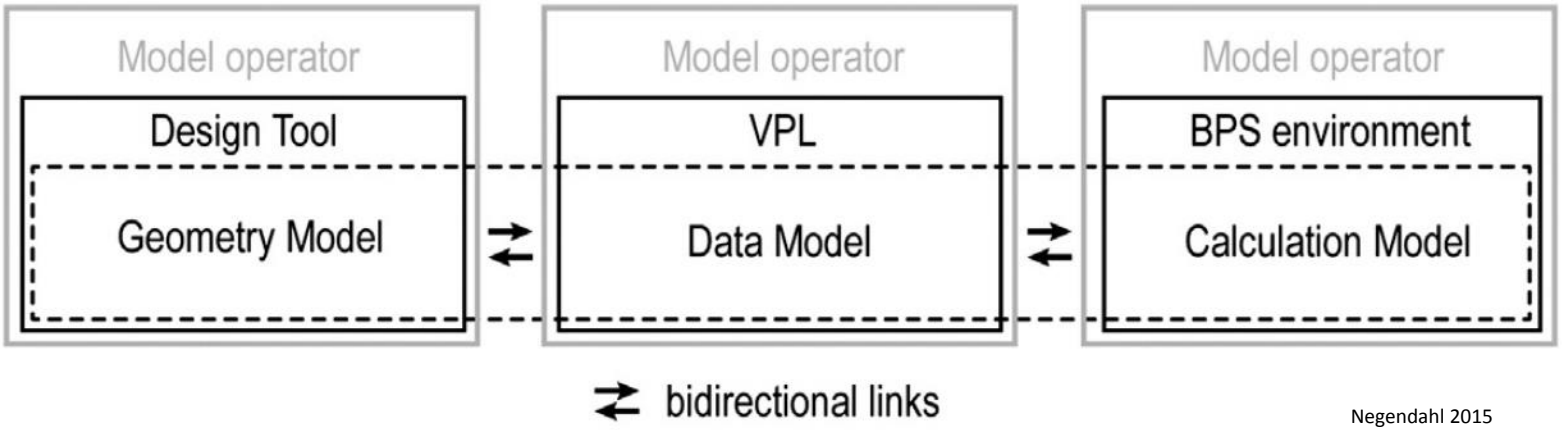
A joint development project from
KT Innovations, thinkstep, and Autodesk.

LCA Integration in BIM

- Cost
- American datasets
- Time
  - Manual material matching
- QTO issues?
  - Frames (length)
  - Door panels (thickness, area)
  - Studs, skeletons, non modelled elements
- New Datasets?
- Generic Models

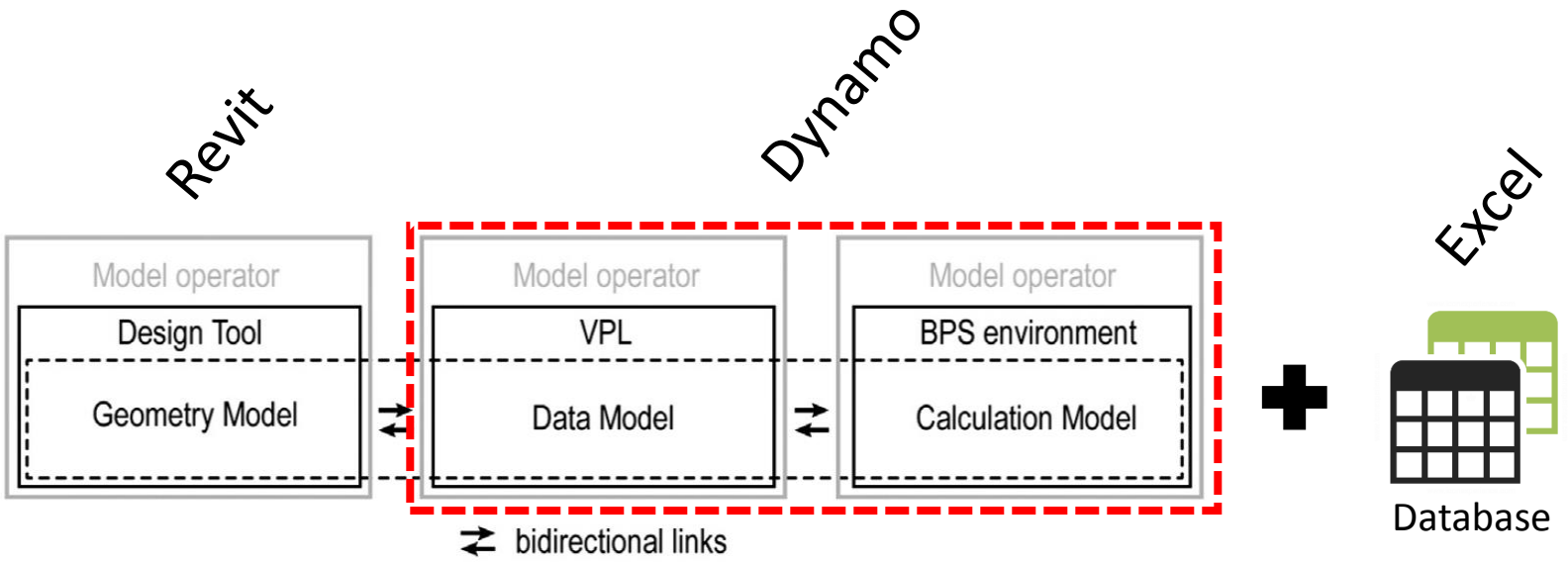
Why not tally?

The Integrated Dynamic Model Approach

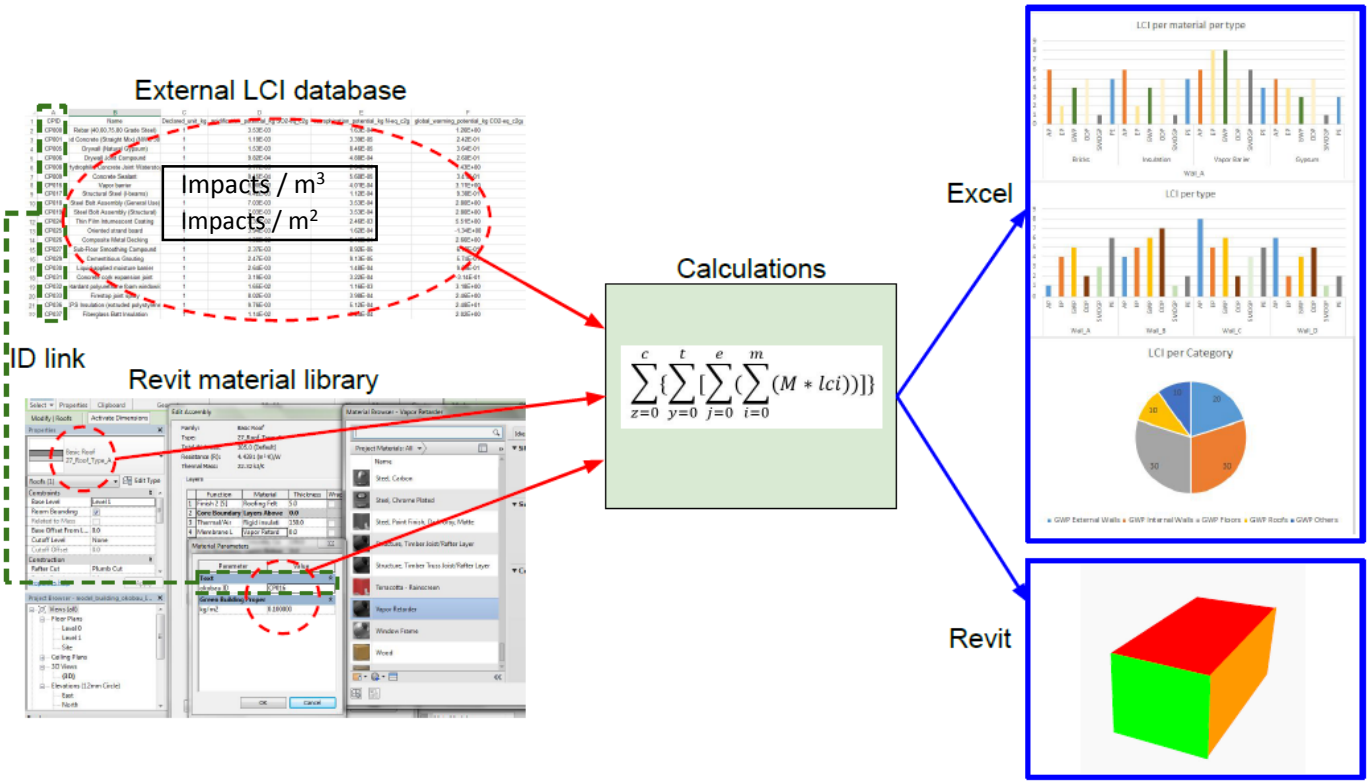


Negendahl 2015

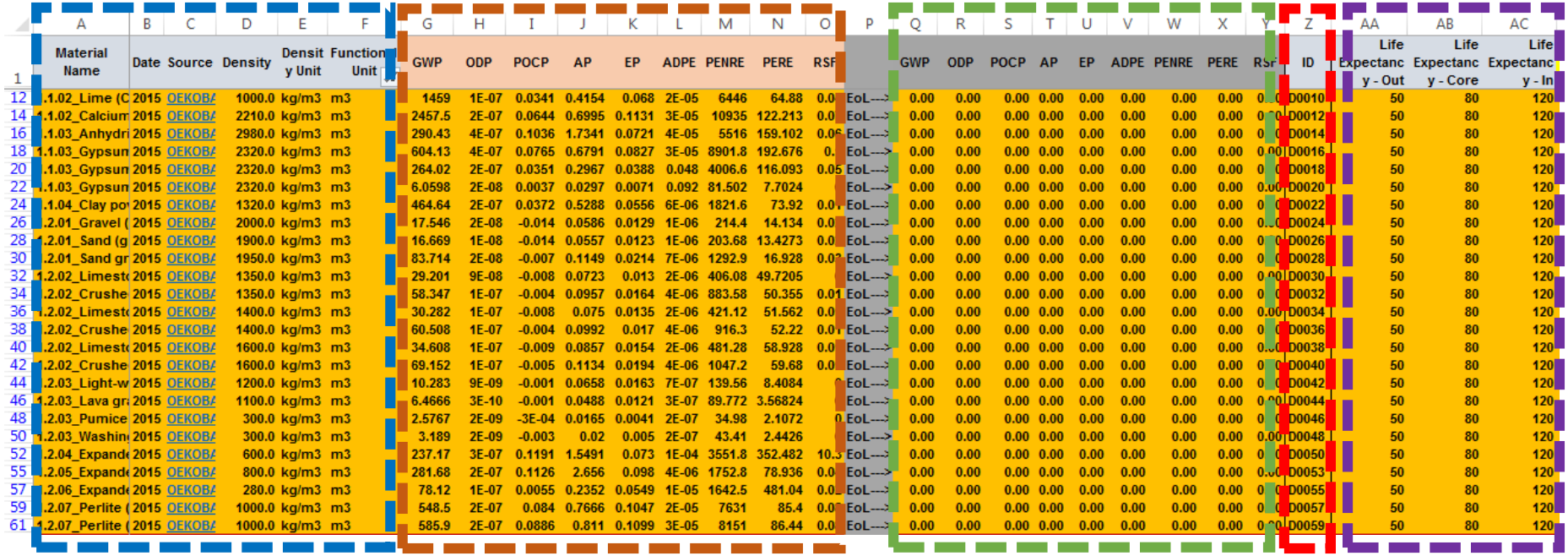
The Integrated Dynamic Model Approach



Excel + Dynamo + Revit

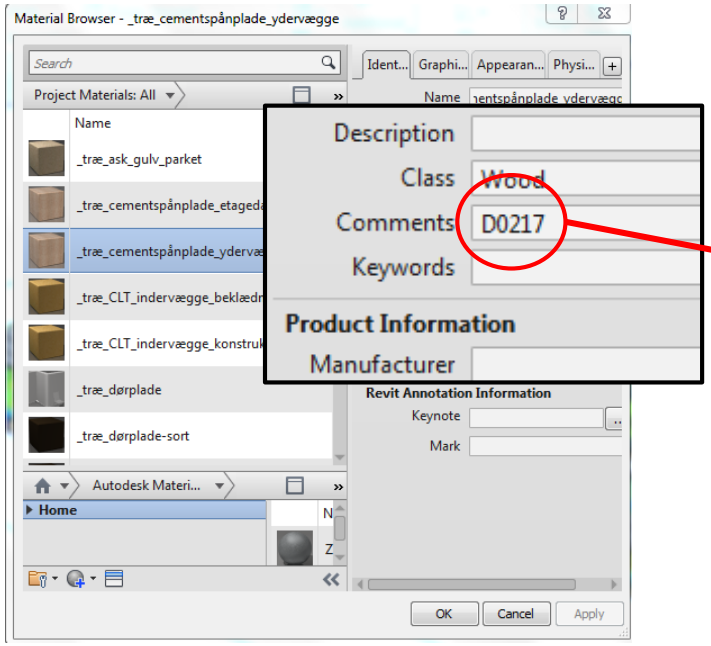


Life Cycle Impacts Database



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
1	Material Name	Date	Source	Density	Density Unit	Function Unit	GWP	ODP	POCP	AP	EP	ADPE	PENRE	PERE	RSF		GWP	ODP	POCP	AP	EP	ADPE	PENRE	PERE	RSF	ID	Life Expectancy - Out	Life Expectancy - Core	Life Expectancy - In
12	.1.02_Lime (C	2015	OEKOBA	1000.0	kg/m3	m3	1459	1E-07	0.0341	0.4154	0.068	2E-05	6446	64.88	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0010	50	80	120
14	.1.02_Calcium	2015	OEKOBA	2210.0	kg/m3	m3	2457.5	2E-07	0.0644	0.6995	0.1131	3E-05	10935	122.213	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0012	50	80	120
16	.1.03_Anhydri	2015	OEKOBA	2980.0	kg/m3	m3	290.43	4E-07	0.1036	1.7341	0.0721	4E-05	5516	159.102	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0014	50	80	120
18	.1.03_Gypsun	2015	OEKOBA	2320.0	kg/m3	m3	604.13	4E-07	0.0765	0.6791	0.0827	3E-05	8901.8	192.676	0.	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D0016	50	80	120
20	.1.03_Gypsun	2015	OEKOBA	2320.0	kg/m3	m3	264.02	2E-07	0.0351	0.2967	0.0388	0.048	4006.6	116.093	0.05	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0018	50	80	120
22	.1.03_Gypsun	2015	OEKOBA	2320.0	kg/m3	m3	6.0598	2E-08	0.0037	0.0297	0.0071	0.092	81.502	7.7024		EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D0020	50	80	120
24	.1.04_Clay po	2015	OEKOBA	1320.0	kg/m3	m3	464.64	2E-07	0.0372	0.5288	0.0556	6E-06	1821.6	73.92	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0022	50	80	120
26	.2.01_Gravel (	2015	OEKOBA	2000.0	kg/m3	m3	17.546	2E-08	-0.014	0.0586	0.0129	1E-06	214.4	14.134	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0024	50	80	120
28	.2.01_Sand (g	2015	OEKOBA	1900.0	kg/m3	m3	16.669	1E-08	-0.014	0.0557	0.0123	1E-06	203.68	13.4273	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0026	50	80	120
30	.2.01_Sand gr	2015	OEKOBA	1950.0	kg/m3	m3	83.714	2E-08	-0.007	0.1149	0.0214	7E-06	1292.9	16.928	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0028	50	80	120
32	.2.02_Limest	2015	OEKOBA	1350.0	kg/m3	m3	29.201	9E-08	-0.008	0.0723	0.013	2E-06	406.08	49.7205		EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D0030	50	80	120
34	.2.02_Crushe	2015	OEKOBA	1350.0	kg/m3	m3	58.347	1E-07	-0.004	0.0957	0.0164	4E-06	883.58	50.355	0.01	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0032	50	80	120
36	.2.02_Limest	2015	OEKOBA	1400.0	kg/m3	m3	30.282	1E-07	-0.008	0.075	0.0135	2E-06	421.12	51.562	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D0034	50	80	120
38	.2.02_Crushe	2015	OEKOBA	1400.0	kg/m3	m3	60.508	1E-07	-0.004	0.0992	0.017	4E-06	916.3	52.22	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0036	50	80	120
40	.2.02_Limest	2015	OEKOBA	1600.0	kg/m3	m3	34.608	1E-07	-0.009	0.0857	0.0154	2E-06	481.28	58.928	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0038	50	80	120
42	.2.02_Crushe	2015	OEKOBA	1600.0	kg/m3	m3	69.152	1E-07	-0.005	0.1134	0.0194	4E-06	1047.2	59.68	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0040	50	80	120
44	.2.03_Light-w	2015	OEKOBA	1200.0	kg/m3	m3	10.283	9E-09	-0.001	0.0658	0.0163	7E-07	139.56	8.4084		EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0042	50	80	120
46	.2.03_Lava gr	2015	OEKOBA	1100.0	kg/m3	m3	6.4666	3E-10	-0.001	0.0488	0.0121	3E-07	89.772	3.56824		EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D0044	50	80	120
48	.2.03_Pumice	2015	OEKOBA	300.0	kg/m3	m3	2.5767	2E-09	-3E-04	0.0165	0.0041	2E-07	34.98	2.1072	0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0046	50	80	120
50	.2.03_Washin	2015	OEKOBA	300.0	kg/m3	m3	3.189	2E-09	-0.003	0.02	0.005	2E-07	43.41	2.4426		EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D0048	50	80	120
52	.2.04_Expand	2015	OEKOBA	600.0	kg/m3	m3	237.17	3E-07	0.1191	1.5491	0.073	1E-04	3551.8	352.482	10.3	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0050	50	80	120
55	.2.05_Expand	2015	OEKOBA	800.0	kg/m3	m3	281.68	2E-07	0.1126	2.656	0.098	4E-06	1752.8	78.936	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D0053	50	80	120
57	.2.06_Expand	2015	OEKOBA	280.0	kg/m3	m3	78.12	1E-07	0.0055	0.2352	0.0549	1E-05	1642.5	481.04	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0055	50	80	120
59	.2.07_Perlite (	2015	OEKOBA	1000.0	kg/m3	m3	548.5	2E-07	0.084	0.7666	0.1047	2E-05	7631	85.4	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0057	50	80	120
61	.2.07_Perlite (	2015	OEKOBA	1000.0	kg/m3	m3	585.9	2E-07	0.0886	0.811	0.1099	3E-05	8151	86.44	0.0	EoL--->	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	D0059	50	80	120

Life Cycle Impacts Database



Material Name	ID	Functional Unit	GWP	ODP	POCP	AP	EP
1.2.03_Light-weight sand pumice (grai	D0042	m3	1.03E+01	8.52E-09	-1.29E-03	6.58E-02	1.63E-02
1.3.02_Facing brick [m3]	D0069	m3	4.19E+02	3.06E-07	1.47E-01	8.91E-01	1.04E-01
1.3.04_Lightweight concrete block (exp	D0075	m3	3.94E+02	2.19E-07	9.35E-02	2.58E+00	1.53E-01
1.3.13_Gypsum fibre board [m3]	D0119	m3	2.84E+02	2.90E-07	3.57E-02	3.30E-01	6.08E-02
1.4.01_Ready-mix concrete C20/25 [m	D0147	m3	2.34E+02	1.31E-07	1.16E-02	3.69E-01	6.69E-02
Default [m3]	M0913	m3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.5.04_Asphalt supporting layer [m3]	D0171	m3	1.62E+02	1.32E-07	3.77E-01	4.34E-01	4.97E-02
2.1.01_Mineral wool (Facades) [m3]	D0177	m3	7.20E+01	9.40E-08	2.55E-02	3.35E-01	4.53E-02
3.1.01_Timber pine (12% moisture [m	D0217	m3	-8.77E+02	2.93E-07	2.28E-02	3.42E-01	5.71E-02
4.1.05_Cast iron component [m3]	D0251	m3	2.03E+04	7.27E-05	2.22E+00	2.94E+01	3.18E+00
4.1.05_Steel forged component [m3]	D0255	m3	2.21E+04	2.77E-05	9.84E+00	7.18E+01	5.82E+00
4.3.01_Aluminium sheet [m3]	D0261	m3	3.04E+04	7.99E-04	9.39E+00	1.59E+02	7.44E+00
6.5.01_High pressure laminate HPL bo	D0356	m3	-1.83E+04	2.28E-05	1.75E+00	2.78E+01	5.16E+00
1.4.04_Stuckgips [m3]	D0836	m3	1.10E+02	1.13E-08	1.56E-02	1.51E-01	2.01E-02
7.2.01_Double glazing unit [m2] (tykke	G0453	m2	7.64E+02	5.29E-07	2.04E-01	3.20E+00	5.98E-01
vapor barrier [m2]	M0912	m2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cement FibreBoards [m3]	M0915	m3	2.84E+02	2.90E-07	3.57E-02	3.30E-01	6.08E-02

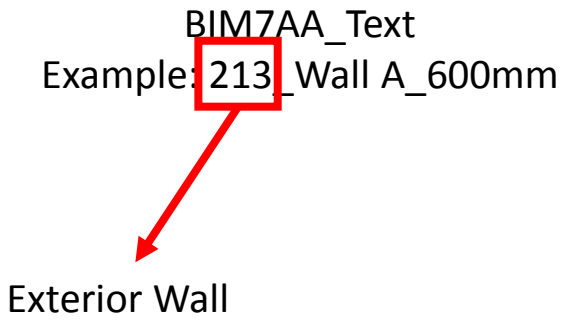
Revit Material Library

Excel LCI Database

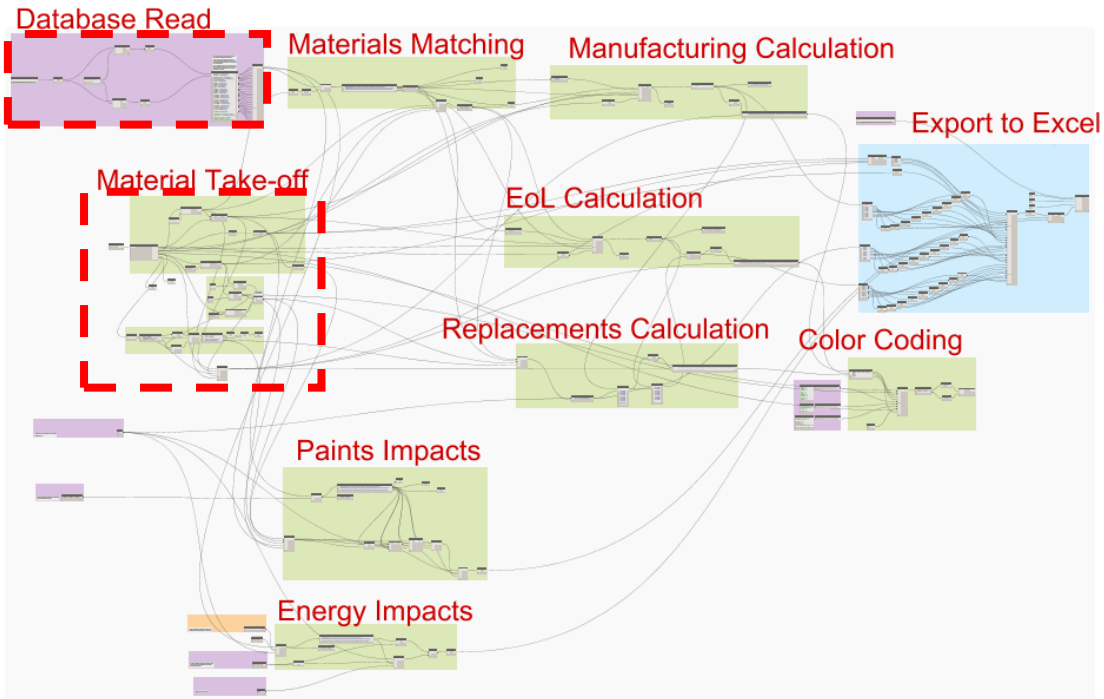
Classification System

BIM7AA encoding system

- Results grouping
- Location reading (exterior, interior)



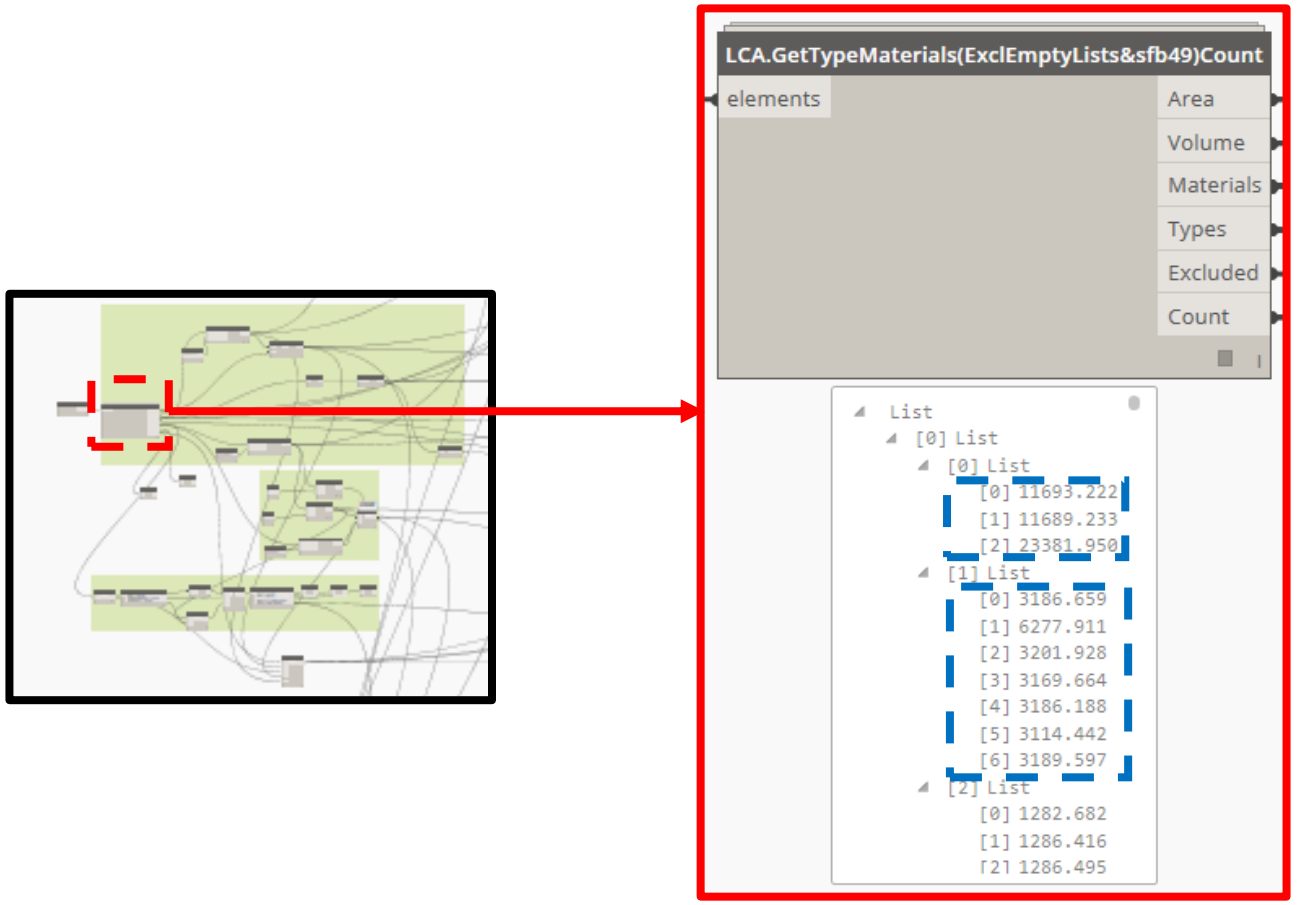
Dynamo Script



Information Take-Off

- Types' materials
- Types' BIM7AA code
- Types' function (exterior, interior)
- Materials' area
- Materials' volume
- Materials' name
- Materials' location (core, in, out)
- Excl. BIM7AA > 50

Information Take-Off



Impacts calculation

```
for imp_cat in range(len(lci)) : # The various impact categories.
    cat = []
    for el in range(len(keys)) : # The various types in revit.
        cat.append([])
        for mat in range(len(keys[el])) : # The materials of each Typ
            temp = 0
            key = keys[el][mat]
            if key != "not linked" :
                if d_unit[key] == "m3" :
                    temp = vol[el][mat]*lci[imp_cat][key]
                    cat[el].append(temp)
                elif d_unit[key] == "m2" :
                    temp = area[el][mat]*lci[imp_cat][key]
                    cat[el].append(temp)
                else :
                    cat[el].append(temp) # If the DB material is not in m3 or
                    in m2, then it is not included to the calculation.
                    errors.append("Material <"+ rvt_names[el][mat] + "> was
                    not considered in the calculation because it is linked
                    with a database material whose functional unit is neither
                    m3 nor m2. Please link with another database material and
                    re-run.")
            else :
                cat[el].append(0)
    outlist.append(cat)
```

for every family type:

for every material of this family type:

if functional unit = m^2, then:

impacts = area * database impacts per m^2

else:

impacts = volume * database impacts per m^3

Materials' Life Time Estimation and Maintenance LCI

Revit Family Layers

Layers

EXTERIOR SIDE

	Function	Material	Thickness	Wraps	Structural Material
1	Finish 1 [4]	_tegl_murværk	110.0	☐	☐
2	Core Boundary	Layers Above Wrap	0.0		
3	Thermal/Air	_isolering_mineraluld	225.0	☐	☐
4	Core Boundary	Layers Below Wrap	0.0		
5	Structure [1]	_beton_letbeton	120.0	☑	☐

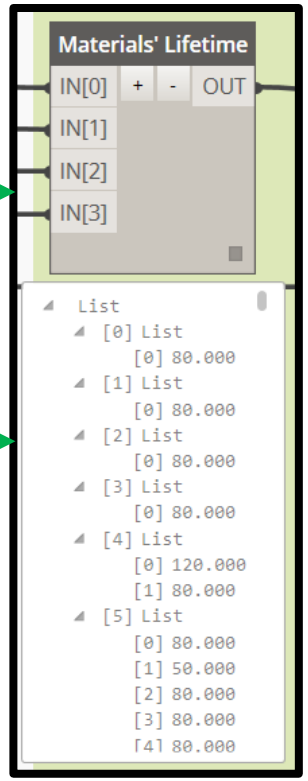
	A	AA	AB	AC
1	Material Name	LifeExpectancy_Out	LifeExpectancy_Core	LifeExpectancy_In
8	1.5.04_Asphalt supporting layer [m3]	20	60	60
9	2.1.01_Mineral wool (Facades) [m3]	20	40	40
10	3.1.01_Timber pine (12% moisture [m3]	30	50	40
11	4.1.05_Cast iron component [m3]	100	150	150
12	4.1.05_Steel forged component [m3]	100	150	150
13	4.3.01_Aluminium sheet [m3]	60	150	150
14	6.5.01_High pressure laminate HPL board	20	50	40
15	1.4.04_Stuckgips [m3]	20	50	40

Datasets' Life Expectancy

Materials' Life Time Estimation and Maintenance LCI

Type's function (exterior, interior)

Material's location (core, in, out)



Paints' LCI

- Element property
  - Time consuming
- Visually integrated in materials
  - Painted or not?
- Name Convention?

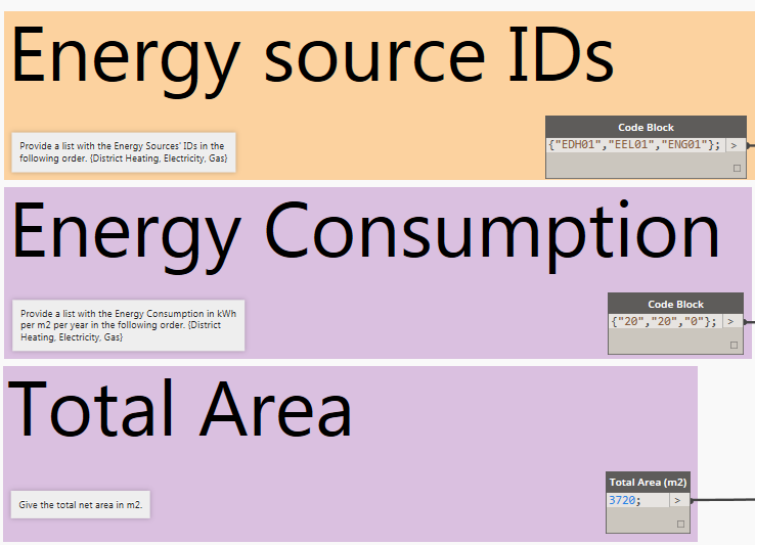
Paints' LCI

- Element property
  - Time consuming
- Visually integrated in materials
  - Painted or not?
- Name Convention?

if material's name contains "Paint", then:
paint's area = material's area
if material is placed exterior, then
paint type = generic exterior
else, if material is placed interior, then
paint type = generic interior
if material = wooden material
paint type = generic lacquer

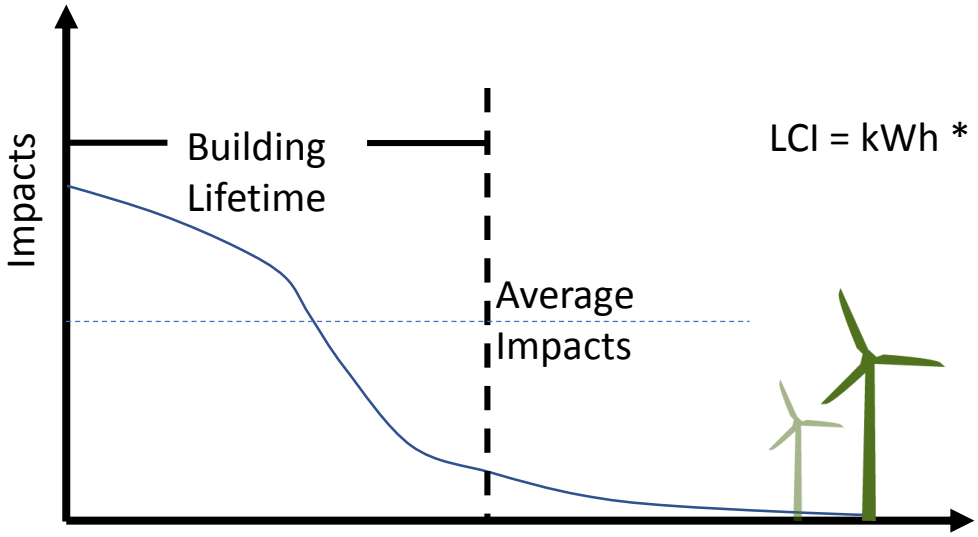
Prefix	Material Class	Material Type	Material Functio	Structure/Surface/Other	Colored/ Painte	Colo	Glossiness	New VK Name
VK_	Wood_		Frame_		Painted_	Black_	Mat	VK_Wood_Frame_Painted_Black_Mat

Energy Use Impacts



LCI = kWh * impacts per kWh

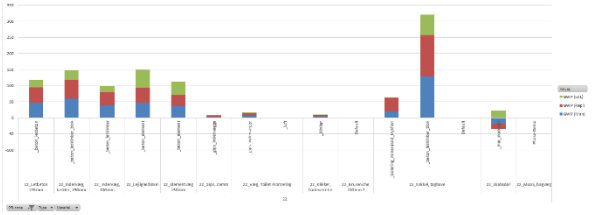
Energy Use Impacts



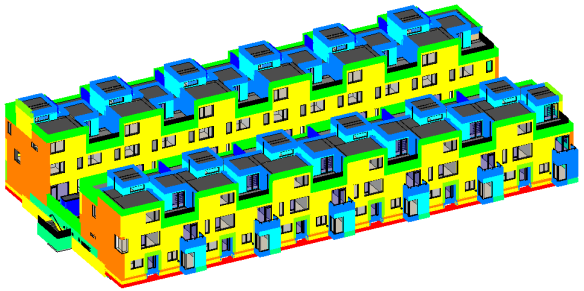
LCI = kWh * impacts per kWh*reducing factor

Results

- Analytical



- Visual



Analytical Results

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1						Manufacturing									Replacements									EoL		
2	SfB co	Type	Material	Type Quanti	Un	GWI	ODI	POCI	A		AD	PEN	PEI	R	GW	ODI	POCI	AI	EI	ADP	PENR	PEI	RSI	GWP	ODI	POCP
3	22	22_Indervægge 133mm	_kombi_konstruktionstr	11689.2	m2	0	0.00E+00	0	0	0	0	0	0	0	0	######	0	0	0	0	0	0	0	0	#####	0
4	22	22_Indervægge 133mm	_træ_krydsfiner_indervæ	11689.2	m2	-117714	8.35E-06	1.71E+01	198	##	####	431571	807829	17.8	0	######	######	0	0	######	0	0	0	87879	#####	#######
5	22	22_Indervægge 133mm	VK_Stone_GypsumBoarc	11689.2	m2	176572	1.15E-04	2.24E+01	198	##	####	3E+06	56315	29	0	######	######	0	#####	######	0	0	0	0	#####	#######
6	21	21_Ydervægge 415mm 2	_gips_indervægge	3114.4	m2	29531.61	1.92E-05	3.739082	33.2	4	0	435149	9418.6	4.86	0	######	0	0	0	0	0	0	0	0	#####	0
7	21	21_Ydervægge 415mm 2	_træ_ydervæg_konstrukt	3114.4	m2	-96779.8	3.23E-05	2.52E+00	37.7	##	####	343056	1E+06	3.4	0	######	######	0	#####	######	0	0	0	61605	#####	#######
8	21	21_Ydervægge 415mm 2	_dampspærre_PE-folie_	3114.4	m2	0	0.00E+00	0.00E+00	0	0	####	0	0	0	0	######	######	0	0	######	0	0	0	0	#####	#######
9	21	21_Ydervægge 415mm 2	_kombi_konstruktionstr	3114.4	m2	0	0.00E+00	0	0	0	0	0	0	0	0	######	0	0	0	0	0	0	0	0	#####	0
10	21	21_Ydervægge 415mm 2	_kombi_forskalling + is	3114.4	m2	0	0.00E+00	0.00E+00	0	##	####	0	0	0	0	######	0	0	0	0	0	0	0	0	#####	#######
11	21	21_Ydervægge 415mm 2	_træ_cementspånplade_	3114.4	m2	-27367.8	9.14E-06	0.712286	10.7	2	####	97011	321691	0.96	0	0	0	0	0	######	0	0	0	17421	#####	-1.4261
12	21	21_Ydervægge 415mm 2	VK_Stone_GypsumBoarc	3114.4	m2	29583.18	1.92E-05	3.75E+00	33.3	##	####	435909	9435	4.86	0	######	######	0	#####	######	0	0	0	0	#####	#######
13	22	22_Indervægge 120mm	_gips_indervægge	1282.7	m2	10063.19	6.53E-06	1.27E+00	11.3	##	####	148281	3209.5	1.65	0	######	######	0	#####	######	0	0	0	0	#####	#######
14	22	22_Indervægge 120mm	_kombi_konstruktionstr	1282.7	m2	0	0.00E+00	0.00E+00	0	##	####	0	0	0	0	######	######	0	#####	######	0	0	0	0	#####	#######
15	22	22_Indervægge 120mm	VK_Stone_GypsumBoarc	1282.7	m2	10092.9	6.55E-06	1.277891	11.3	1	0	148719	3219	1.66	0	######	0	0	0	0	0	0	0	0	#####	0
16	22	22_Indervægge 95mm	_gips_indervægge	3676.2	m2	57732.15	3.75E-05	7.309635	64.9	8	0	850685	18413	9.49	0	######	0	0	0	0	0	0	0	0	#####	0
17	22	22_Indervægge 95mm	_kombi_konstruktionstr	3676.2	m2	0	0.00E+00	0.00E+00	####	##	####	######	######	####	0	######	######	#####	#####	######	0	#####	######	######	#####	#######
18	21	21_Facadebeklædning - 6	_træ_ydervæg_beklædni	788.0	m2	-46307.4	1.55E-05	1.205217	18.1	3	####	164146	544315	1.63	0	######	0	0	0	######	0	0	0	29477	#####	-2.4129
19	22	22_Glasvæg 6mm	_glas_indervæg	92.1	m2	888.1108	6.09E-06	4.43E-01	7.78	##	####	13488	316.63	0.14	0	######	######	0	0	######	0	0	0	41.805	#####	1.53E-02
20	0	00_Generic - 140mm	_gips_indervægge	328.8	m2	10330.11	6.71E-06	1.31E+00	11.6	##	####	152214	3294.6	1.7	0	######	######	0	#####	######	0	0	0	0	#####	#######
21	0	00_Generic - 140mm	_kombi_konstruktionstr	328.8	m2	0	0.00E+00	0	0	0	0	0	0	0	0	######	0	0	0	0	0	0	0	0	#####	0
22	21	21_Endevæg skiffer - 262r	_skifer_ydervæg_claddir	985.2081529	m2	28674.86	1.63E-04	1.96E+01	169	##	####	350673	726456	0	0	######	######	0	#####	######	0	0	0	10989	#####	#######
23	21	21_Endevæg skiffer - 262r	_kombi_konstruktionstr	985.2081529	m2	0	0.00E+00	0.00E+00	0	0	####	0	0	0	0	######	######	0	0	######	0	0	0	0	#####	#######
24	21	21_Facadebeklædning - 6	_skifer_ydervæg_claddir	2849.471504	m2	82364.99	0.000469	56.31081	485	81	0	1E+06	2E+06	0	0	0	0	0	0	0	0	0	0	31565	#####	11.5385
25	21	21_Endevæg lister - 262mr	_træ_ydervæg_beklædni	393.75709	m2	-23140.6	7.73E-06	6.02E-01	9.02	##	####	82027	272003	0.81	0	0	0	0	0	######	0	0	0	14730	#####	#######
26	21	21_Endevæg lister - 262mr	_kombi_konstruktionstr	393.75709	m2	0	0.00E+00	0	0	0	0	0	0	0	0	######	0	0	0	0	0	0	0	0	#####	0
27	26	26_Skillevæg terrasse list	træ terasse beklædnii	257.4950855	m2	-30286.1	1.01E-05	7.88E-01	11.8	##	####	107355	355994	1.06	0	######	######	0	#####	######	0	0	0	19279	#####	#######

Analytical Results

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1						Manufacturing									Replacements									EoL		
2	SfB co	Type				GWI	ODP	POCI	A		AD	PEN	PEI	R								PEI	RSI	GWP	ODI	POCP
3	22	22_Indervægge 133mm	_kom			0	0.00E+00	0	0	0	0	0	0	0								0	0	0	#####	0
4	22	22_Indervægge 133mm	_træ_			-117714	8.35E-06	1.71E+01	198	##	####	431571	807829	17.8								0	0	87879	#####	#######
5	22	22_Indervægge 133mm	VK_St			176572	1.15E-04	2.24E+01	198	##	####	3E+06	56315	29								0	0	0	#####	#######
6	21	21_Ydervægge 415mm 2	_gips			20531.61	1.92E-05	3.739082	33.2	4	0	435149	9418.6	4.86								0	0	0	#####	0
7	21	21_Ydervægge 415mm 2	_træ_																			0	0	61605	#####	#######
8	21	21_Ydervægge 415mm 2	_dam																			0	0	0	#####	#######
9	21	21_Ydervægge 415mm 2	_kom																			0	0	0	#####	0
10	21	21_Ydervægge 415mm 2	_kom																			0	0	0	#####	#######
11	21	21_Ydervægge 415mm 2	_træ_																			0	0	17421	#####	-1.4261
12	21	21_Ydervægge 415mm 2	VK_St																			0	0	0	#####	#######
13	22	22_Indervægge 120mm	_gips																			0	0	0	#####	#######
14	22	22_Indervægge 120mm	_kom																			0	0	0	#####	#######
15	22	22_Indervægge 120mm	VK_St																			0	0	0	#####	0
16	22	22_Indervægge 95mm	_gips																			0	0	0	#####	0
17	22	22_Indervægge 95mm	_kom																			#####	######	######	#####	#######
18	21	21_Facadebeklædning - 6	_træ_																			0	0	29477	#####	-2.4129
19	22	22_Glasvæg 6mm	_glas																			0	0	41.805	#####	1.53E-02
20	0	00_Generic - 140mm	_gips_Indervægge	328.8	m2	10330.11	6.71E-06	1.31E+00	11.6	##	####	152214	3294.6	1.7	0	######	######	0	#####	######	0	0	0	0	#####	#######
21	0	00_Generic - 140mm	_kombi_konstruktionstr	328.8	m2	0	0.00E+00	0	0	0	0	0	0	0	0	######	0	0	0	0	0	0	0	0	#####	0
22	21	21_Endevæg skiffer - 262r	_skifer_ydervæg_claddir	985.2081529	m2	28674.86	1.63E-04	1.96E+01	169	##	####	350673	726456	0	0	######	######	0	#####	######	0	0	0	10989	#####	#######
23	21	21_Endevæg skiffer - 262r	_kombi_konstruktionstr	985.2081529	m2	0	0.00E+00	0.00E+00	0	0	####	0	0	0	0	######	######	0	0	######	0	0	0	0	#####	#######
24	21	21_Facadebeklædning - 6	_skifer_ydervæg_claddir	2849.471504	m2	82364.99	0.000469	56.31081	485	81	0	1E+06	2E+06	0	0	0	0	0	0	0	0	0	0	31565	#####	11.5385
25	21	21_Endevæg lister - 262mr	_træ_ydervæg_beklædni	393.75709	m2	-23140.6	7.73E-06	6.02E-01	9.02	##	####	82027	272003	0.81	0	0	0	0	0	######	0	0	0	14730	#####	#######
26	21	21_Endevæg lister - 262mr	_kombi_konstruktionstr	393.75709	m2	0	0.00E+00	0	0	0	0	0	0	0	0	######	0	0	0	0	0	0	0	0	#####	0
27	26	26_Skillevæg terrasse list	træ terasse beklædni	257.4950855	m2	-30286.1	1.01E-05	7.88E-01	11.8	##	####	107355	355994	1.06	0	######	######	0	#####	######	0	0	0	19279	#####	#######

Analytical Results

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1						Manufacturing									Replacements									EoL		
2	SfB co(	Type																					RSF	GWP	ODF	POCP
3	22	22_Indervægge 133mm	_kombi_																				0	0	#####	0
4	22	22_Indervægge 133mm	_træ_kry																				0	87879	#####	#######
5	22	22_Indervægge 133mm	VK_Ston																				0	0	#####	#######
6	21	21_Ydervægge 415mm 2	_gips																				0	0	#####	0
7	21	21_Ydervægge 415mm 2	_træ																				0	61605	#####	#######
8	21	21_Ydervægge 415mm 2	_da																				0	0	#####	#######
9	21	21_Ydervægge 415mm 2	_kor																				0	0	#####	0
10	21	21_Ydervægge 415mm 2	_kor																				0	0	#####	#######
11	21	21_Ydervægge 415mm 2	_træ																				0	17421	#####	-1.4261
12	21	21_Ydervægge 415mm 2	VK_S																				0	0	#####	#######
13	22	22_Indervægge 120mm	_gip																				0	0	#####	#######
14	22	22_Indervægge 120mm	_kor																				0	0	#####	#######
15	22	22_Indervægge 120mm	VK_S																				0	0	#####	0
16	22	22_Indervægge 95mm	_gip																				0	0	#####	0
17	22	22_Indervægge 95mm	_kor																				######	######	#####	#######
18	21	21_Facadebeklædning - 6	_træ																				0	29477	#####	-2.4129
19	22	22_Glasvæg 6mm	_gla																				0	41.805	#####	1.53E-02
20	0	00_Generic - 140mm	_gip																				0	0	#####	#######
21	0	00_Generic - 140mm	_kor																				0	0	#####	0
22	21	21_Endevæg skiffer - 262m	_ski																				0	10989	#####	#######
23	21	21_Endevæg skiffer - 262m	_kor																				0	0	#####	#######
24	21	21_Facadebeklædning - 6	_ski																				0	31565	#####	11.5385
25	21	21_Endevæg lister - 262m	_træ																				0	14730	#####	#######
26	21	21_Endevæg lister - 262m	_kombi_konstruktionstr	393.75709	m2	0	0.00E+00	0	0	0	0	0	0	0	0	######	0	0	0	0	0	0	0	0	#####	0
27	26	26_Skillevæg terrasse list	træ_terasse_beklædnii	257.4950855	m2	-30286.1	1.01E-05	7.88E-01	11.8	##	####	107355	355994	1.06	0	######	######	0	#####	######	0	0	0	19279	#####	#######

F	G	H	I	J	K	L	M	N
Manufacturing								

O	P	Q	R	S	T	U	V	W
Replacements								
GW	ODF	POCI	AF	EF	ADP	PENR	PEF	RSF
0	#######	0	0	0	0	0	0	0
0	#######	#######	0	0	#######	0	0	0
0	#######	#######	0	#####	#######	0	0	0
0	#######	0	0	0	0	0	0	0

Analytical Results

	A	B	C	…	W	X	Y	Z
1				Manufacturing / Replacements		EoL		
2	SfB cod	Type			RSF	GWP	ODP	POCP
3	22	22_Indervægge 133mm	_kombi		0	0	#####	0
4	22	22_Indervægge 133mm	_træ_kr		0	87879	#####	#######
5	22	22_Indervægge 133mm	VK_Stor		0	0	#####	#######
6	21	21_Ydervægge 415mm 2	_gi		0	0	#####	0
7	21	21_Ydervægge 415mm 2	_tr		0	61605	#####	#######
8	21	21_Ydervægge 415mm 2	_da		0	0	#####	#######
9	21	21_Ydervægge 415mm 2	_kc		0	0	#####	0
10	21	21_Ydervægge 415mm 2	_kc		0	0	#####	#######
11	21	21_Ydervægge 415m				17421	#####	-1.4261
12	21	21_Ydervægge 415r				0	#####	#######
13	22	22_Indervægge 120				0	#####	#######
14	22	22_Indervægge 120				0	#####	#######
15	22	22_Indervægge 120				0	#####	0
16	22	22_Indervægge 95n				0	#####	0
17	22	22_Indervægge 95n				####	#####	#######
18	21	21_Facadebeklædn				477	#####	-2.4129
19	22	22_Glasvæg 6mm				.805	#####	1.53E-02
20	0	00_Generic - 140mn				0	#####	#######
21	0	00_Generic - 140mn				0	#####	0
22	21	21_Endevæg skiffe				989	#####	#######
23	21	21_Endevæg skiffe				0	#####	#######
24	21	21_Facadebeklædn				565	#####	11.5385
25	21	21_Endevæg lister				730	#####	#######
26	21	21_Endevæg lister				0	#####	0
27	26	26_Skillevæg terras				279	#####	#######

F	G	H	I	J	K	L	M	N
Manufacturing								

O	P	Q	R	S	T	U	V	W
Replacements								

X	Y	Z	AA	AB	AC	AD	AE	AF
EoL								
GWP1	ODP1	POCP1	AP14	EP15	ADPE1	PENRE1	PERE1	RSF1
126500.4	-2.28E-04	-9.248045	-94.3957	-8.41509	-0.004108	-1439401.4	-110379.9	-3.6270
87879.18	-1.06E-04	-2.73E+00	-12.435	4.58E+00	-1.71E-03	-664946.51	-51579.32	-8.1013
0	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0	0	
0	0.00E+00	0	0	0	0.00E+00	0	0	
61605.435	-1.13E-04	-5.04E+00	-48.618	-4.45E+00	-2.14E-03	-718936.03	-55121.42	-8.74

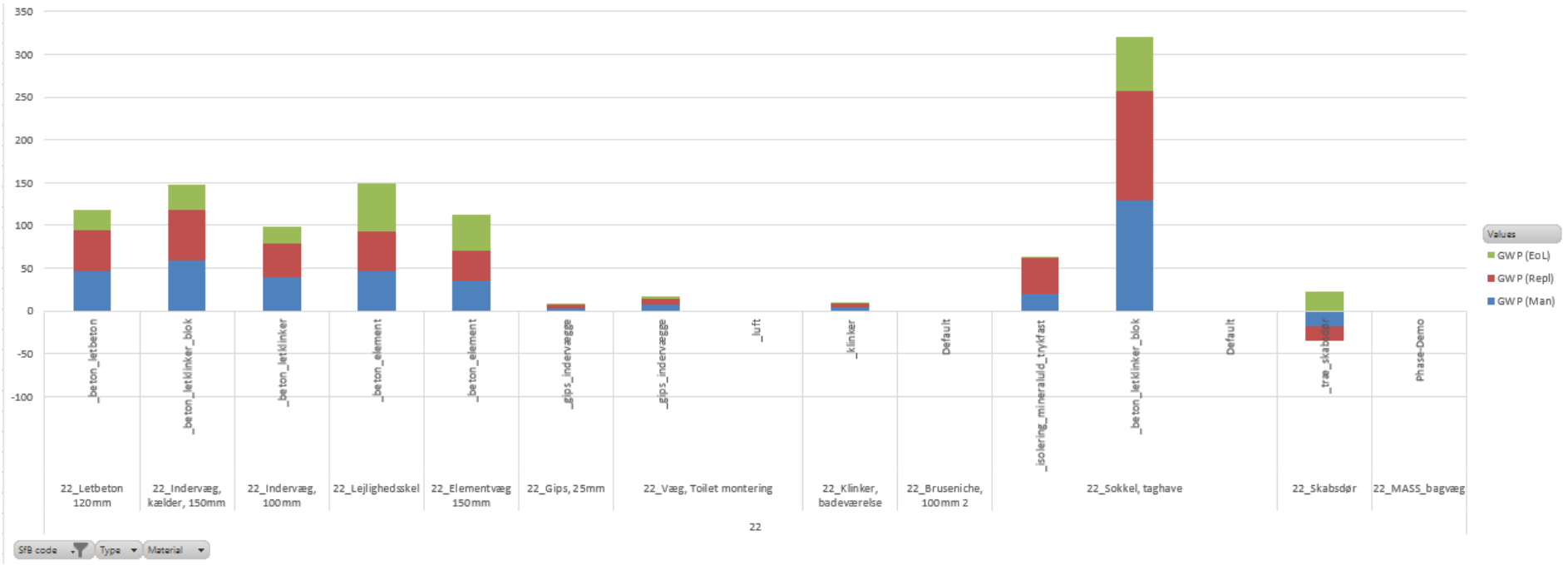
Analytical Results

Row Labels	GWP(Man)	GWP(Repl)	GWP(EoL)
21	**-23440.79031**	**0**	**165788.3544**
21_Endevæg lister - 262mm	**-23140.55582**	**0**	**14730.18837**
_kombi_konstruktionstræ + isolering	0	0	0
_træ_ydervæg_beklædning	-23140.55582	0	14730.18837
21_Endevæg skiffer - 262mm	**28674.86302**	**0**	**10989.27776**
_kombi_konstruktionstræ + isolering	0	0	0
_skifer_ydervæg_cladding	28674.86302	0	10989.27776
21_Facadebeklædning - 67mm skiffer	**82364.99245**	**0**	**31565.33926**
_skifer_ydervæg_cladding	82364.99245	0	31565.33926
21_Facadebeklædning - 67mm vandret lister	**-46307.36377**	**0**	**29477.08761**
_træ_ydervæg_beklædning	-46307.36377	0	29477.08761
21_Ydervægge 415mm 2	**-65032.7262**	**0**	**79026.46138**
_dampspærre_PE-folie_ydervægge	0	0	0
_gips_indervægge	29531.60508	0	0
_kombi_forskalling + isolering	0	0	0
_kombi_konstruktionstræ + isolering	0	0	0
_træ_cementspånplade_ydervægge	-27367.75828	0	17421.02644
_træ_ydervæg_konstruktionstræ	-96779.75395	0	61605.43494
VK_Stone_GypsumBoard_Painted_White_Mat	29583.18094	0	0
22	**137634.6624**	**0**	**87920.98467**
22_Glasvæg 6mm	**888.1108325**	**0**	**41.80455355**
_glas_indervæg	888.1108325	0	41.80455355
22_Indervægge 120mm	**20156.09079**	**0**	**0**
_gips_indervægge	10063.19451	0	0
_kombi_konstruktionstræ + isolering	0	0	0
VK_Stone_GypsumBoard_Painted_White_Mat	10092.89628	0	0
22_Indervægge 133mm	**58858.30803**	**0**	**87879.18012**

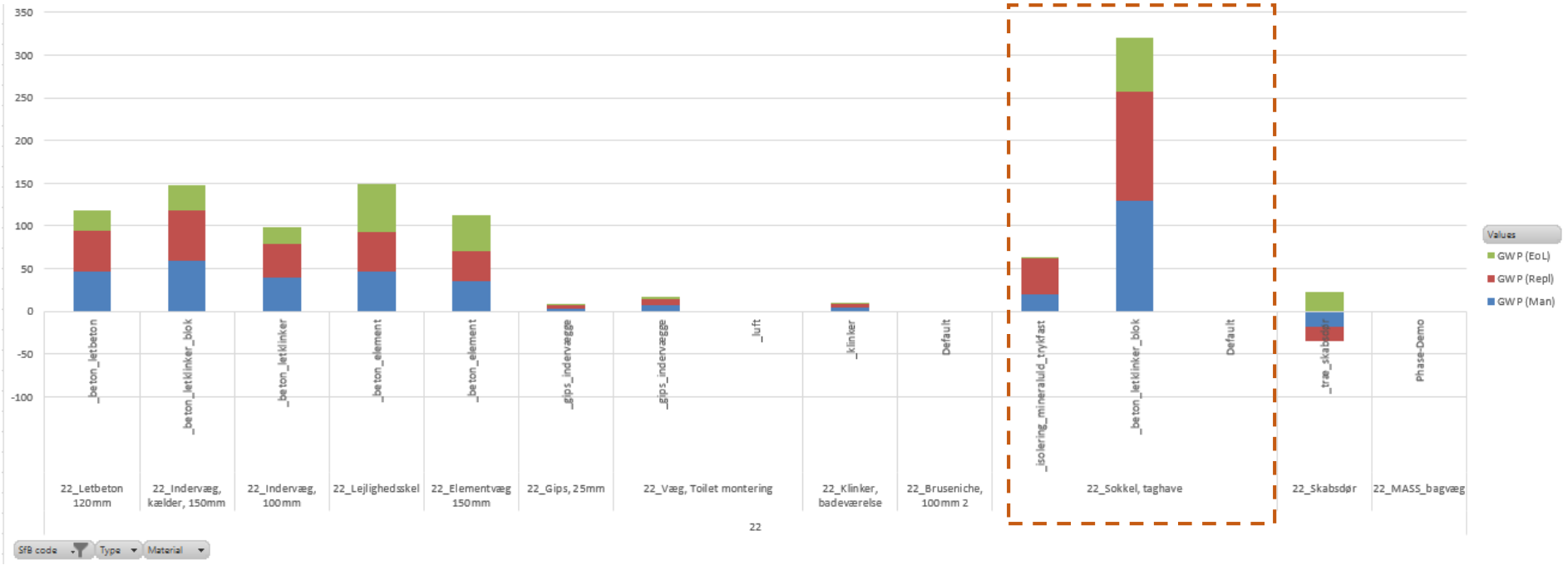
Filters

SfB code	Type	Material
0	21_Endevæg lister - 2...	Metal
21	21_Endevæg skiffer - ...	Naturgas, EU
22	21_Facadebeklædnin...	Paint - withe
23	21_Facadebeklædnin...	VK_Stone_GypsumB...
24	21_Ydervægge 415m...	Wood - Flooring
26	22_Glasvæg 6mm	Wood - vandret bekl...
27	22_Indervægge 120mm	(blank)
30	22_Indervægge 133mm	

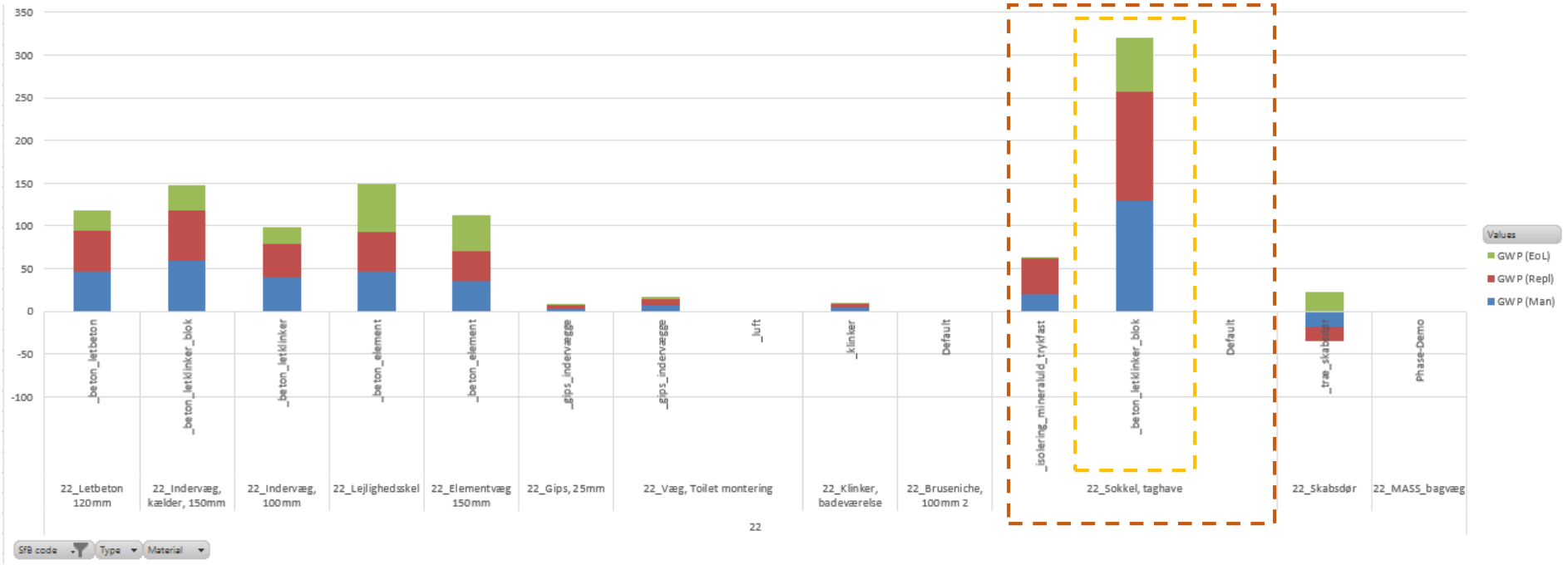
Analytical Results



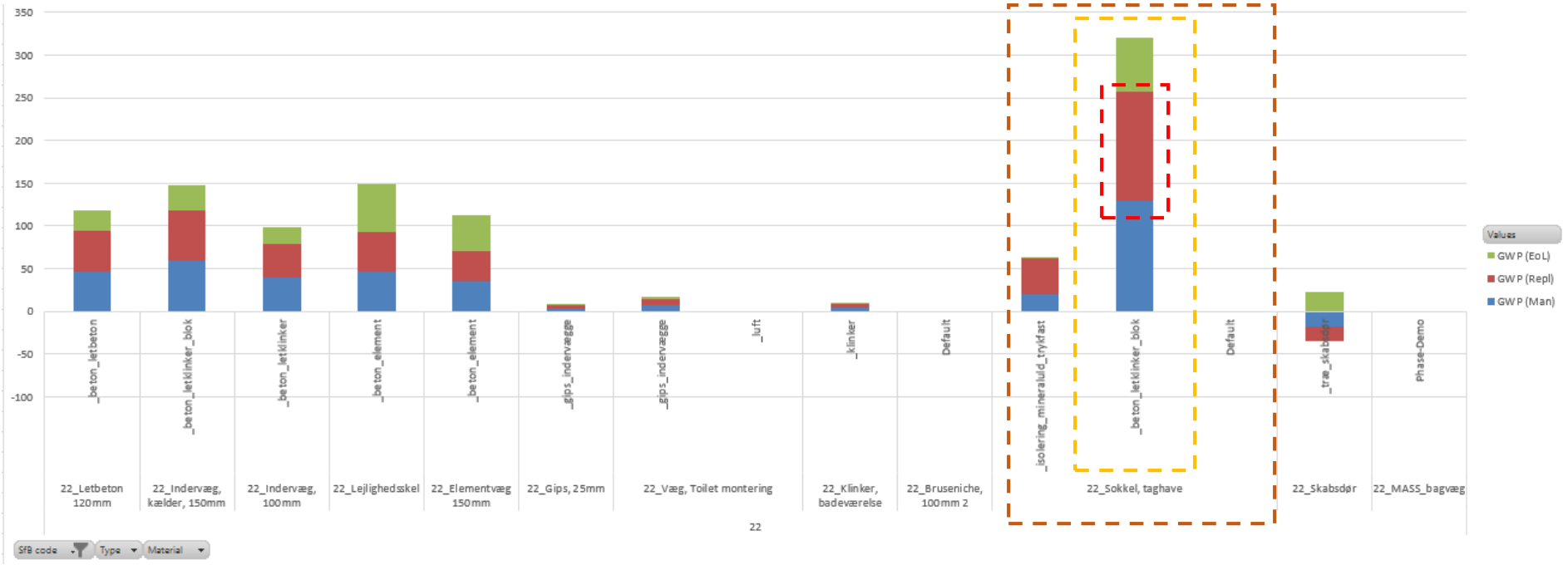
Analytical Results



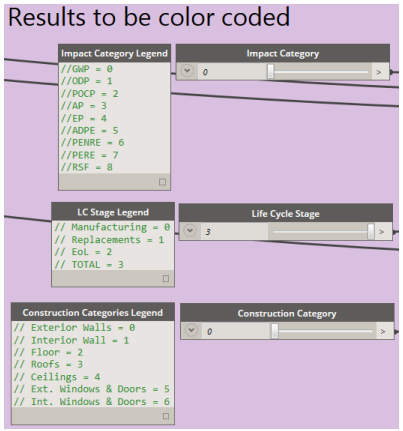
Analytical Results

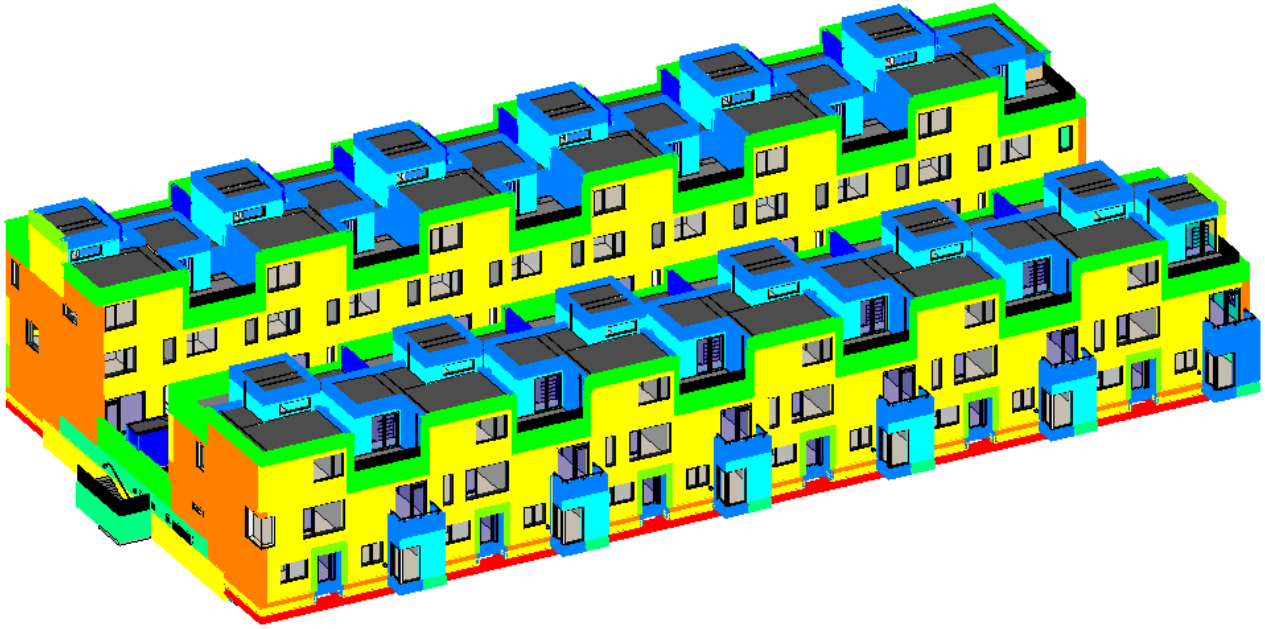


Analytical Results



Visual Representation of Results





Evaluation

- Intgrated Dynamic model
- LCAbyg
- Tally

Evaluation

- Integrated Dynamic model
- LCAbyg
- Tally

- Accuracy
- Time

Evaluation

	GWP (kg CO_2 Eq.)	Deviation
Dynamic model	1,38E+06	-
LCAbyg	1,44E+06	+4%
Tally	2,84E+06	+51%

Evaluation

	Time Scale
Dynamic model	Seconds
LCAbyg	Hours-Days
Tally	Hours

Conclusion

- LCA integration in BIM, achieved
- Dynamic model – Decision making tool
  - Fast assessments
  - Detailed results(LC stage, category, type, material)
  - Hotspot analysis
  - Visual representation of the impacts

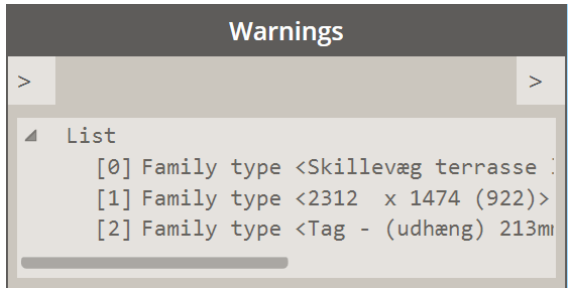
Conclusion

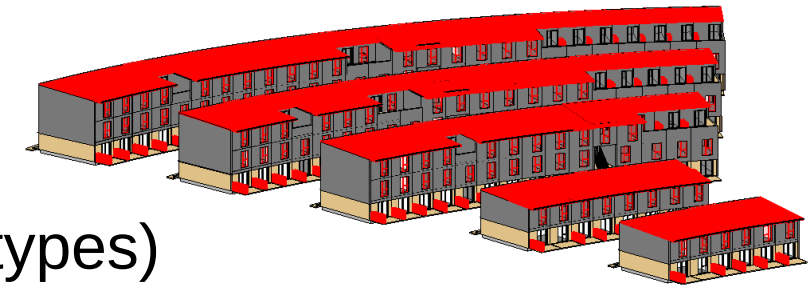
UNCERTAINTIES

- Database
- Revit QTO
- Revit model accuracy
- Very specific framework (BIM7AA, IDs, Glazing, Frames, Insulation studs)

Pre-Check Tool

- BIM7AA code missing
- Revit materials without IDs
- Invalid IDs
- Datasets with impacts per m2
- Wrong dataset unit
- Columns' and Beams' function
- Missing materials (compound types)
- Empty types (no materials assigned)





Future Development

- Link of Environmental Product Declarations with BIM objects
- LCC Dynamic Model
- Integration of LCA software in the Integrated Dynamic Model

Thank you