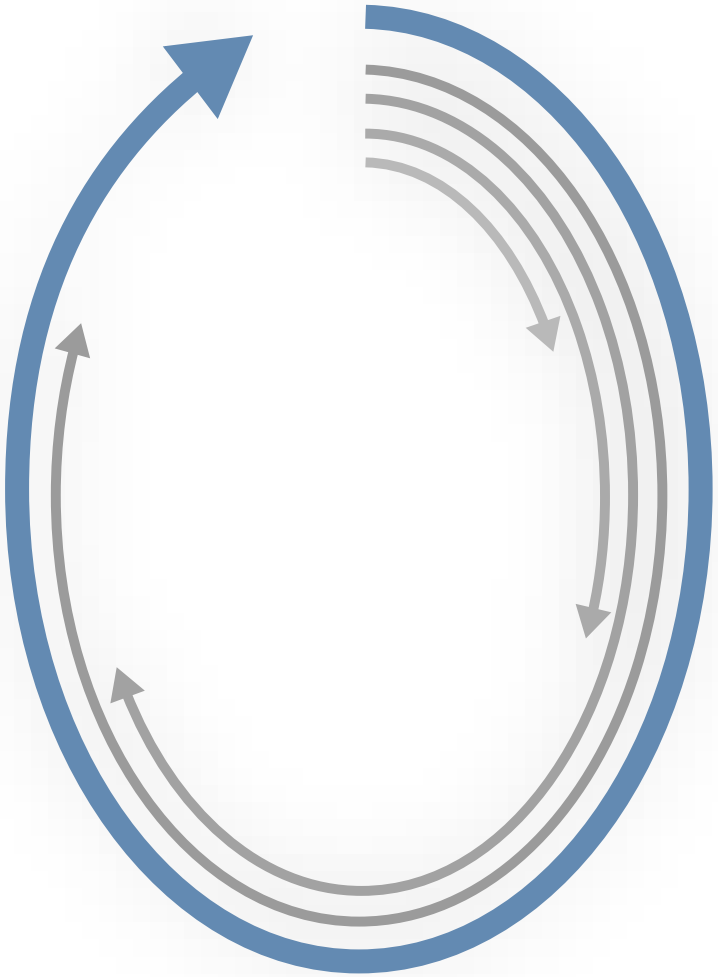
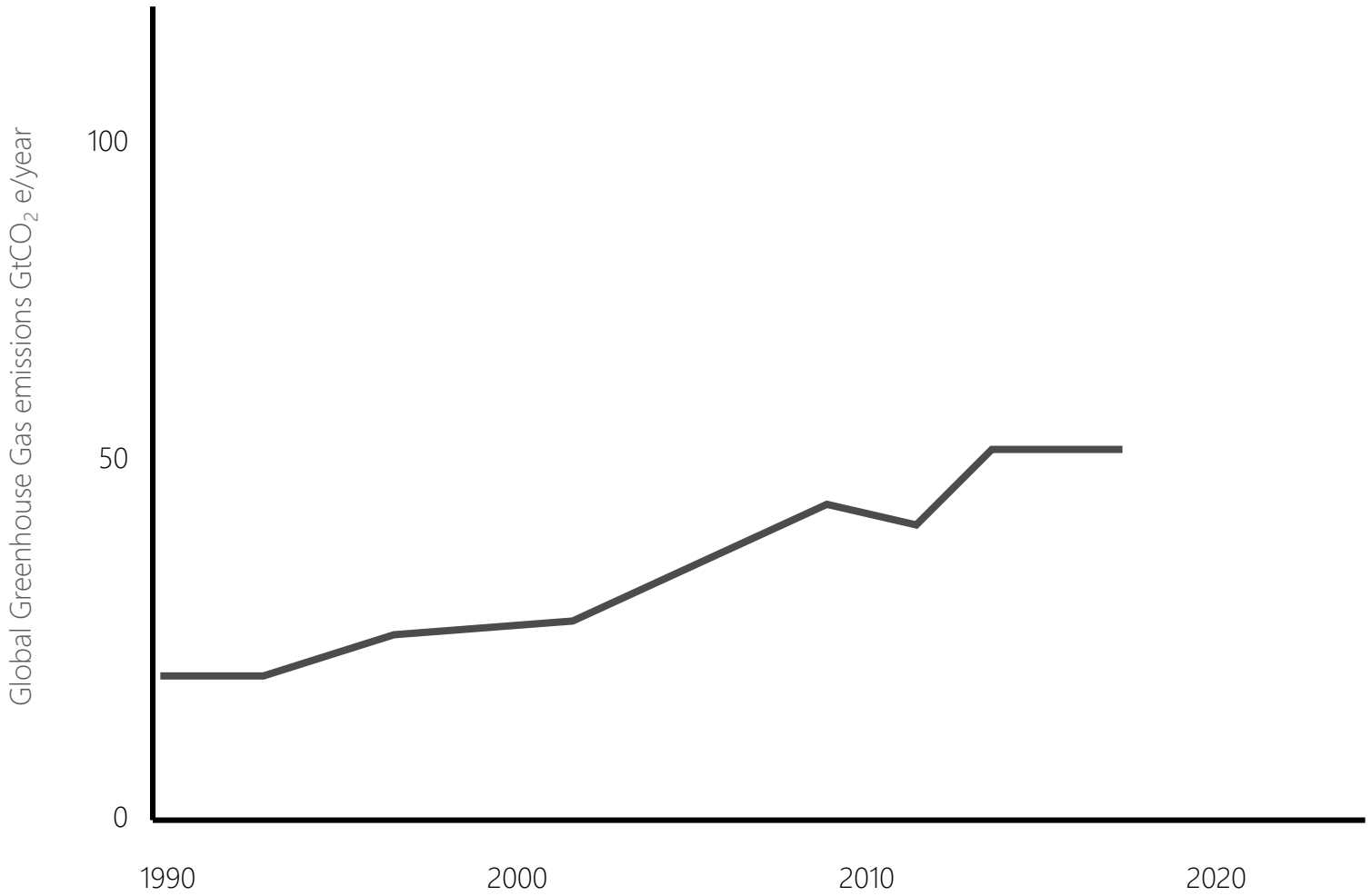


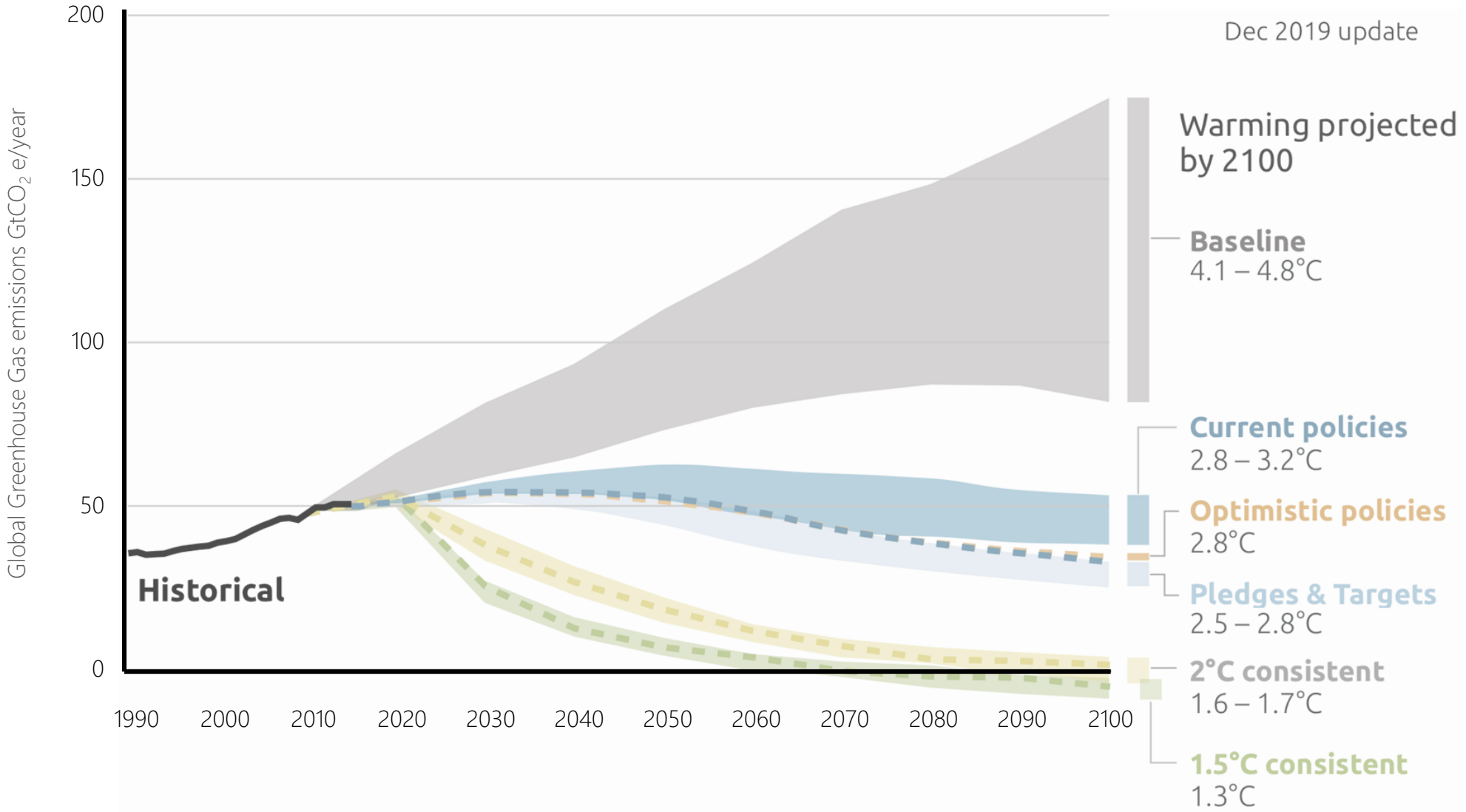
Towards **Zero Carbon** Buildings

Reducing the embodied carbon footprint of a construction

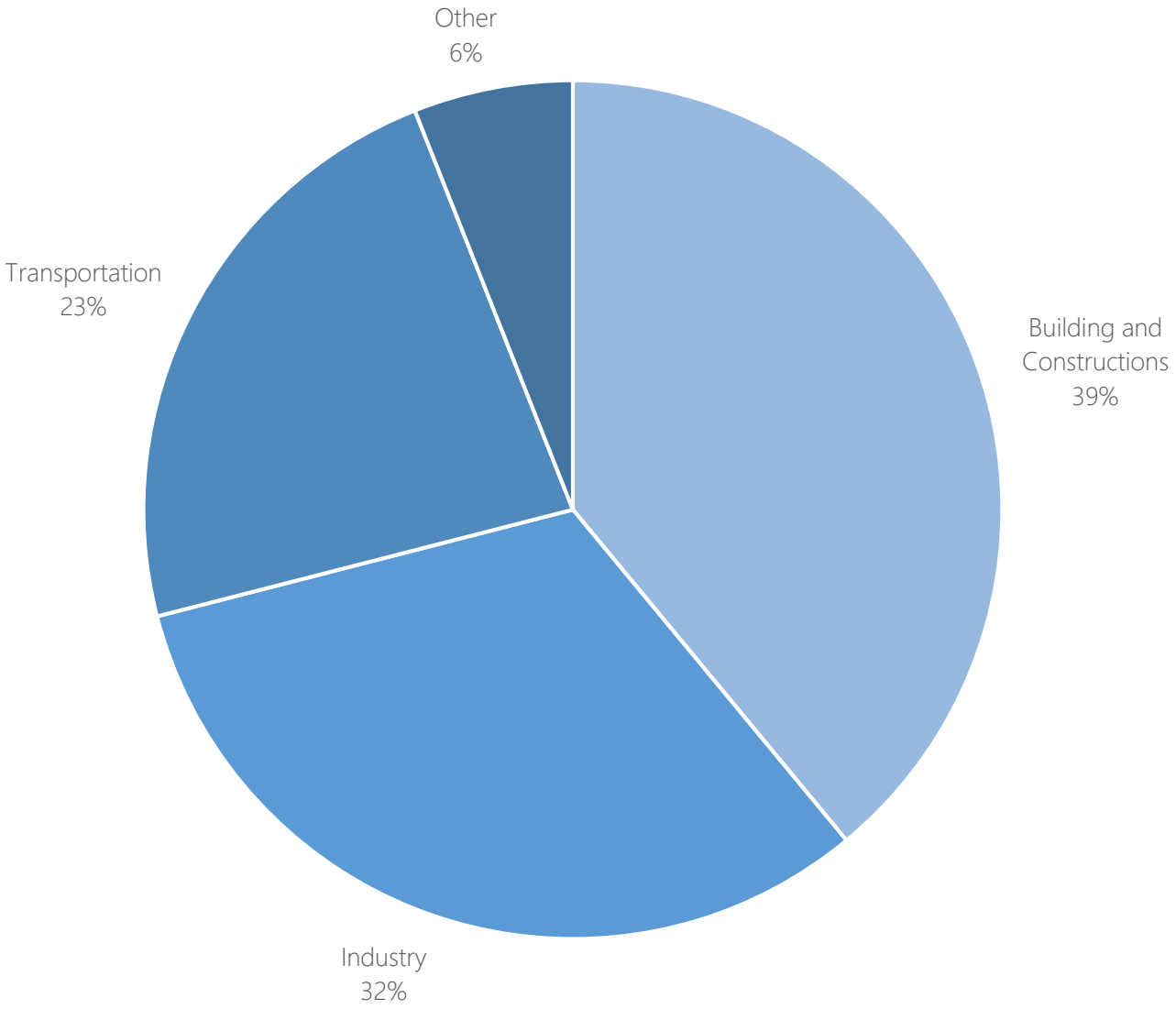
1st July 2020

Rahul Grover | 4771818


Global Greenhouse Gas emissions $GtCO_2$ e/year
100
50
0
1990
2000
2010
2020

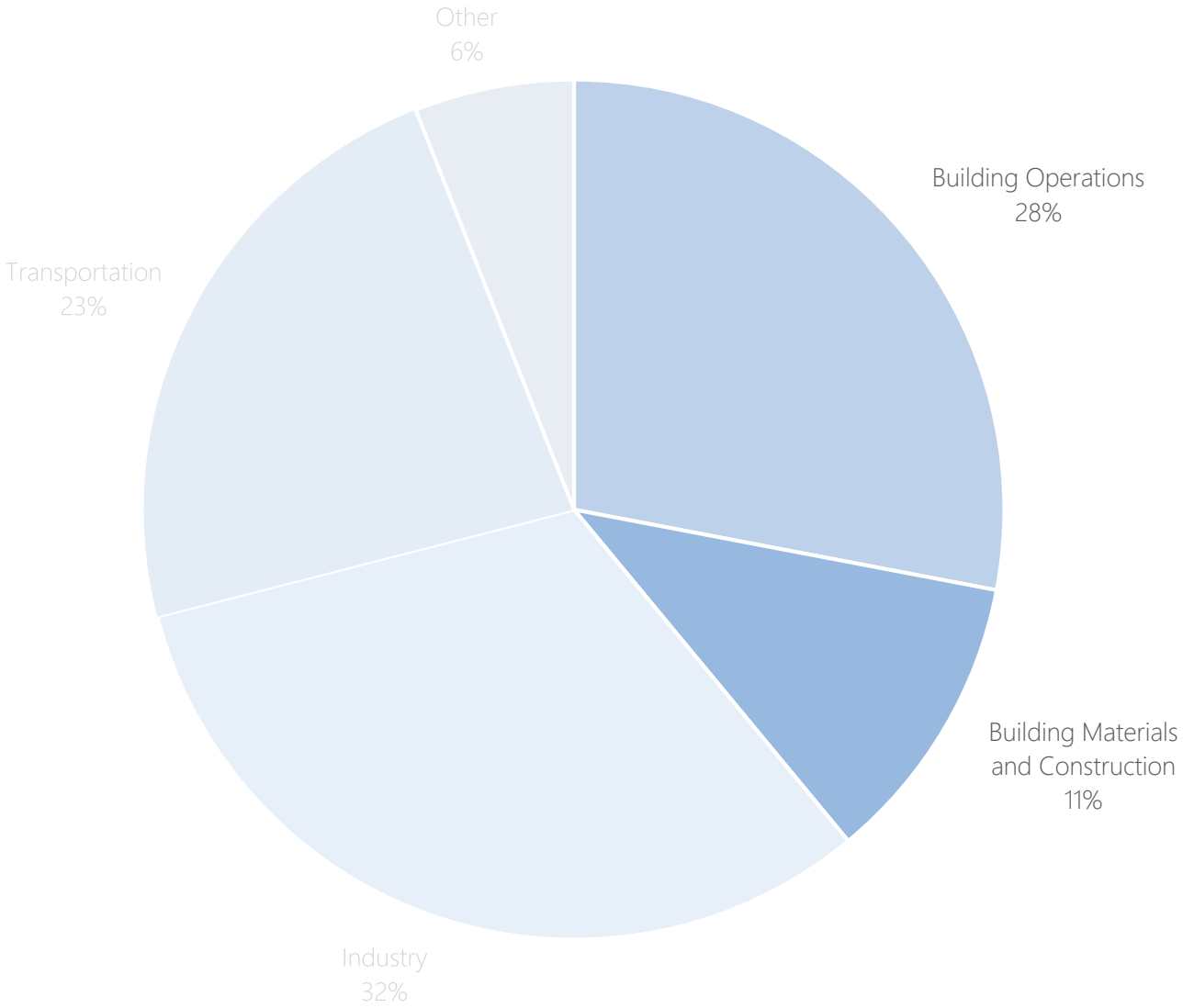


Source: https://climateactiontracker.org/global/temperatures/



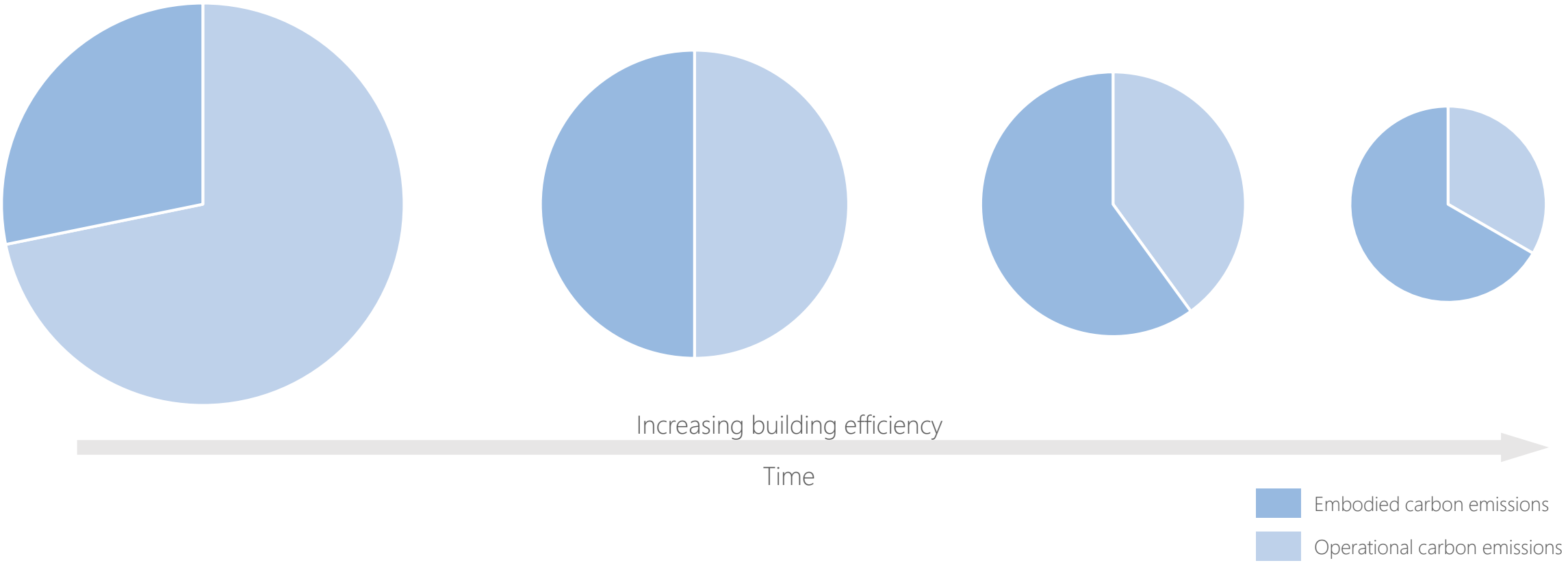
Global CO_2 emissions by sector

Source: Dean, B., Dulac, J., Petrichenko, K., and Graham, 2017



Global CO_2 emissions by sector

Source: Dean, B., Dulac, J., Petrichenko, K., and Graham, 2017

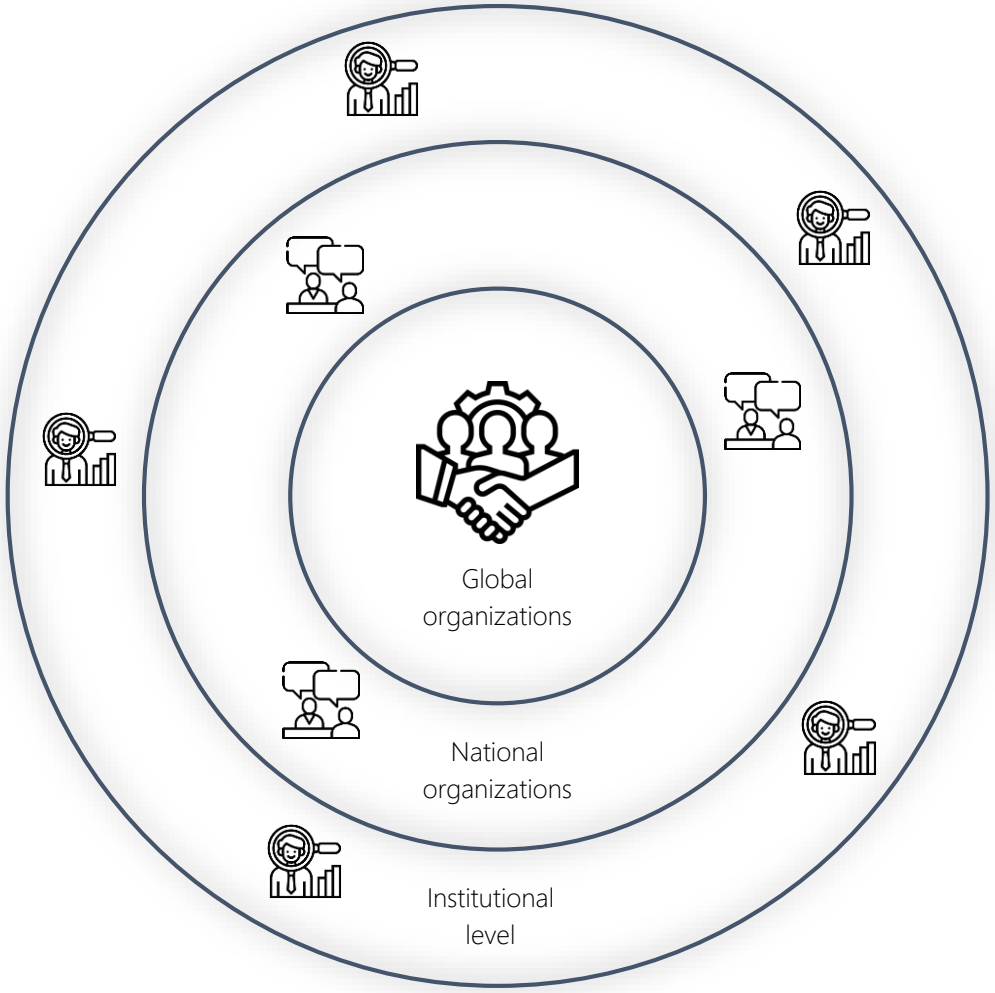


Operational vs Embodied carbon emissions

Source: Bionova Ltd/One Click LCA, 2018

Problem Statement

With advancements in the building industry towards achieving net-zero energy goals, the operational carbon emissions from the building have reduced remarkably. However, in this process of development, **the share of embodied carbon footprint has increased.**



WGBC

- By 2030, all new buildings must be net zero operational carbon and 40% reduction in embodied carbon of all construction.
- By 2050, all buildings, including existing buildings must be net zero operational carbon and all construction must be **zero embodied carbon.**

Klimaatakkoord by the Netherlands Government

- By 2030, reduce the carbon emissions by 49% as compared to 1990 in the Netherlands
- **By 2050, reduce carbon emissions by 95%** as compared to 1990 in the Netherlands

TU Delft

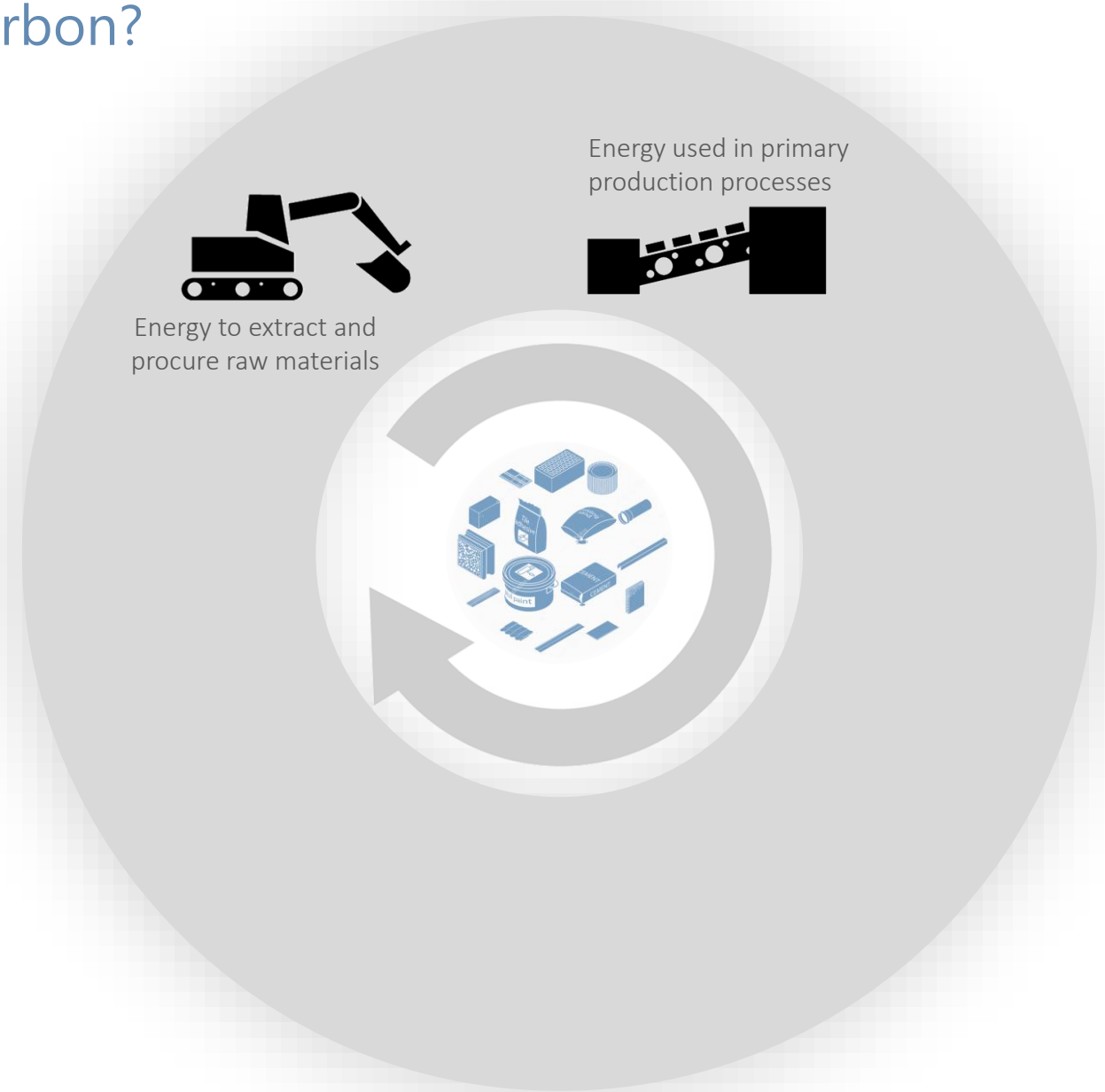
- **By 2030, carbon neutral campus** including scope 1 and scope 2 emissions.

Source: World Green Building Council, 2019

what is Embodied Carbon?

Energy to extract and procure raw materials

what is Embodied Carbon?



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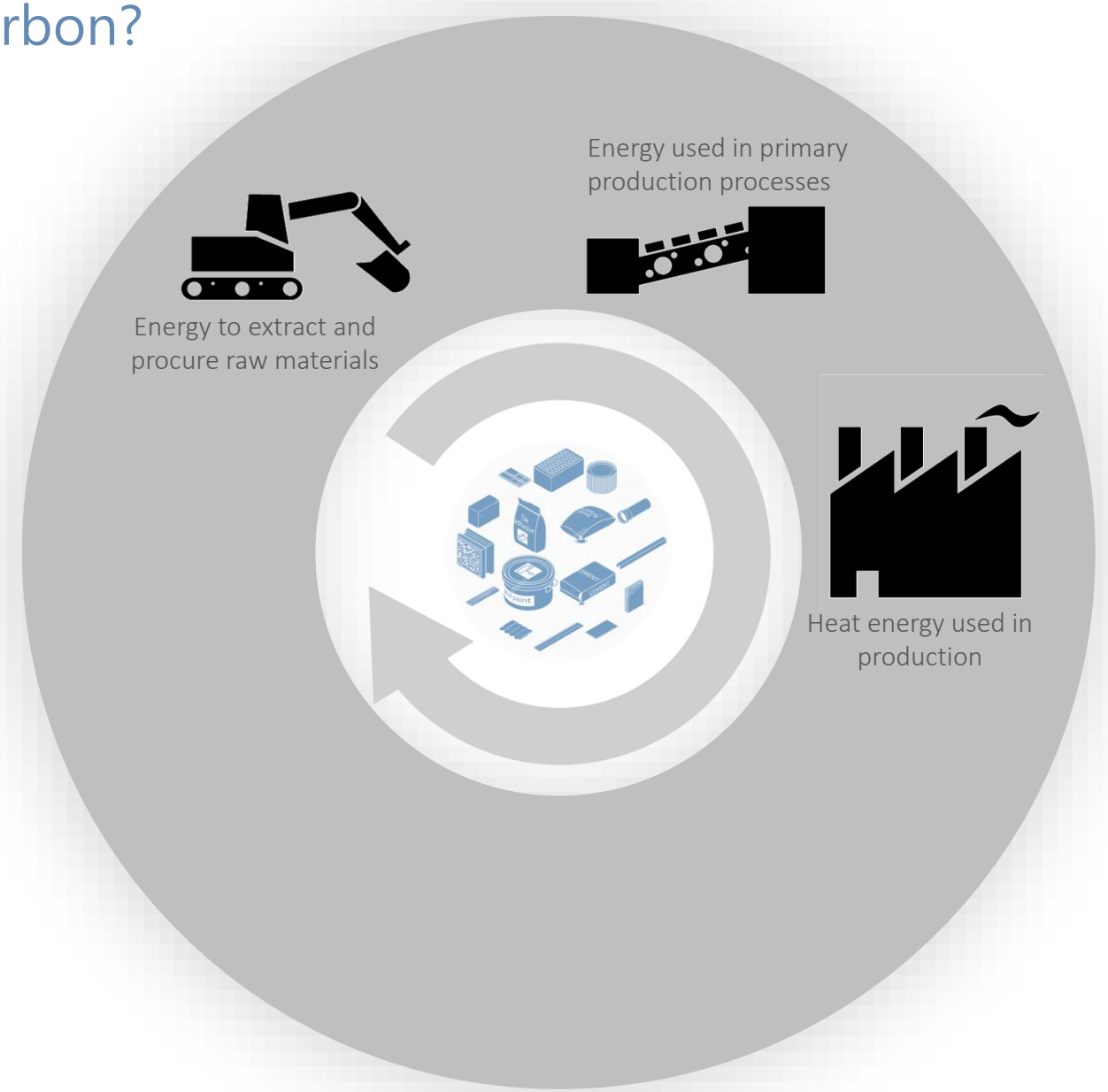

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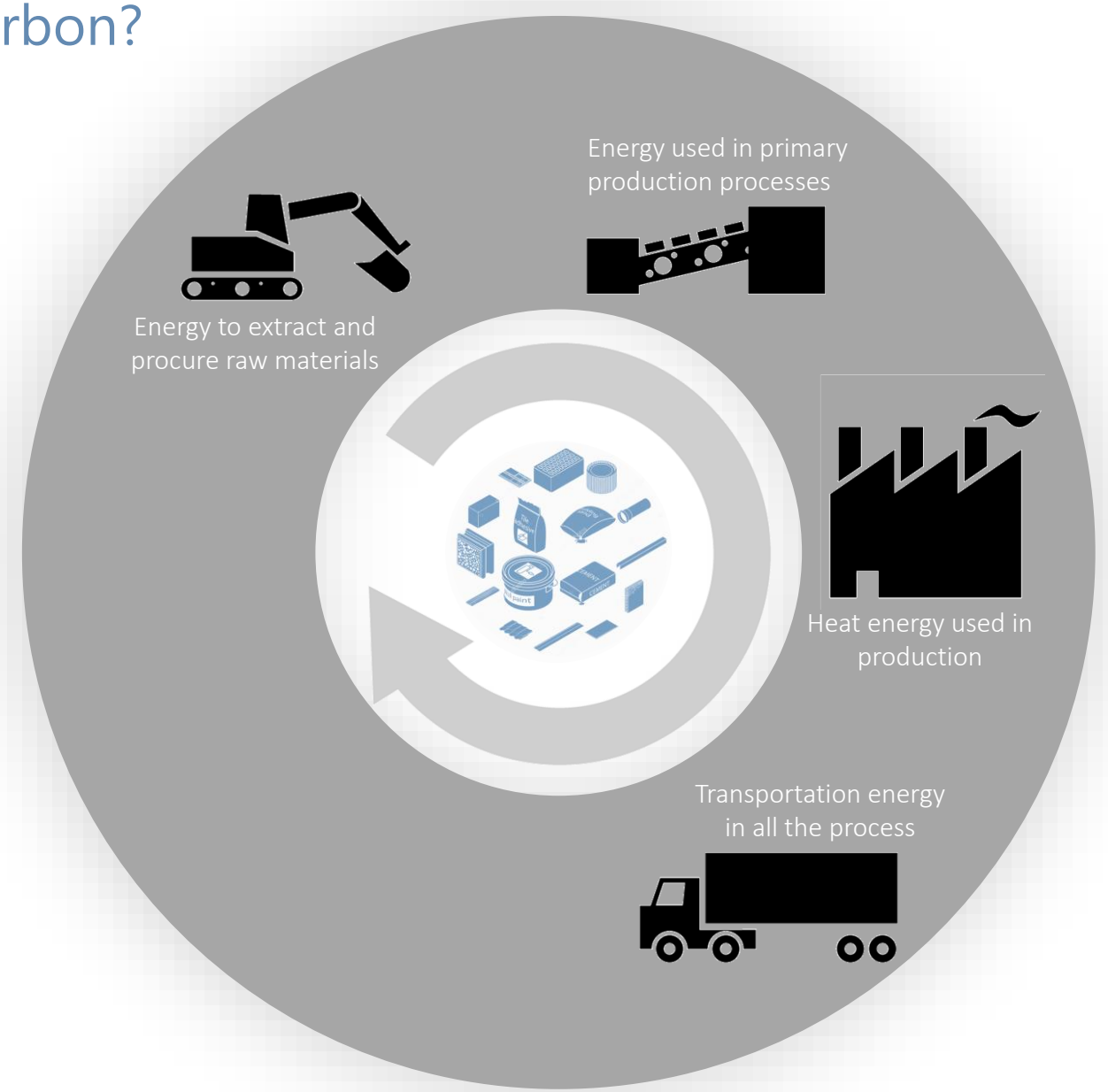
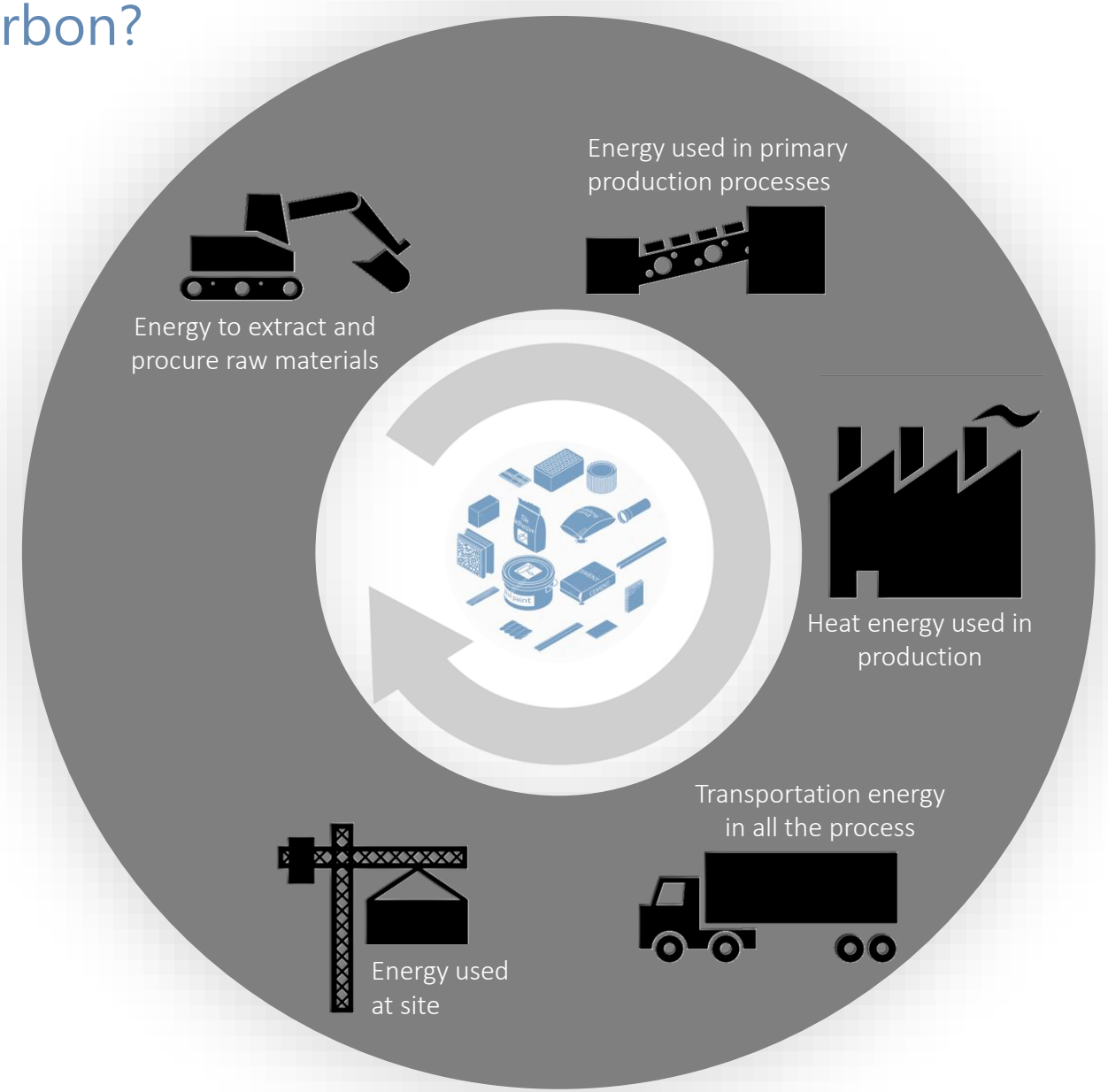
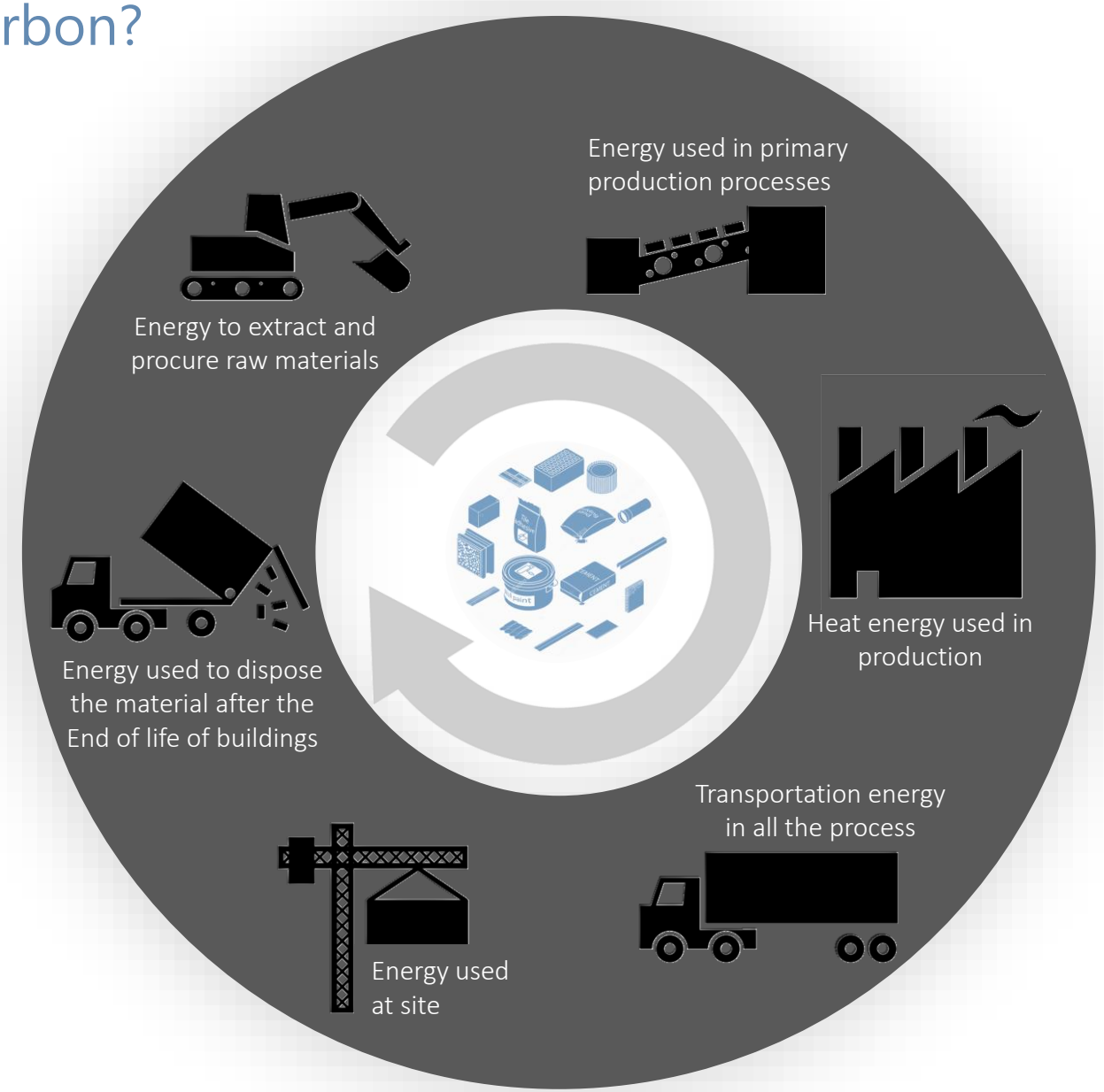


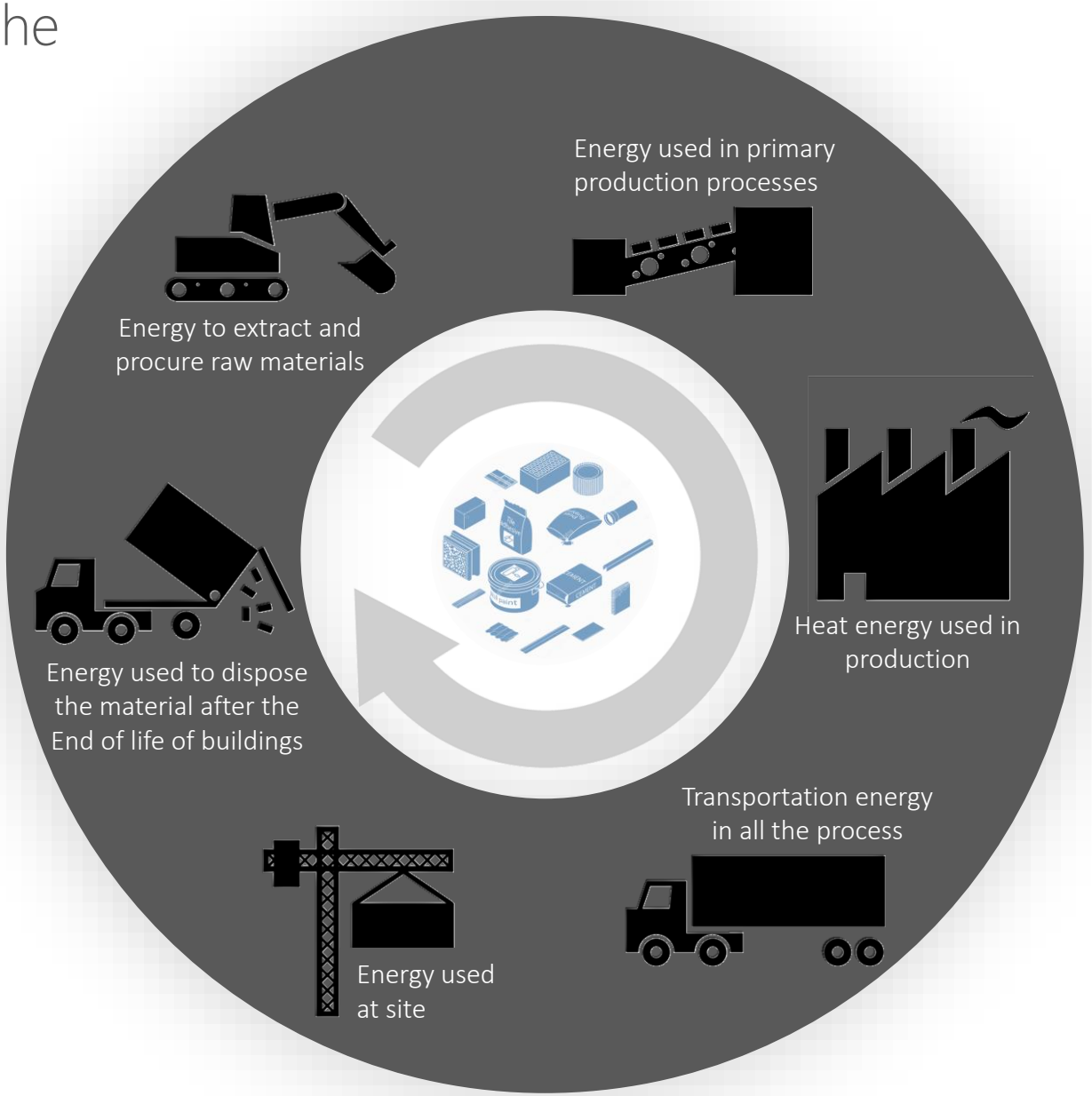
what is Embodied Carbon?



what is Embodied Carbon?

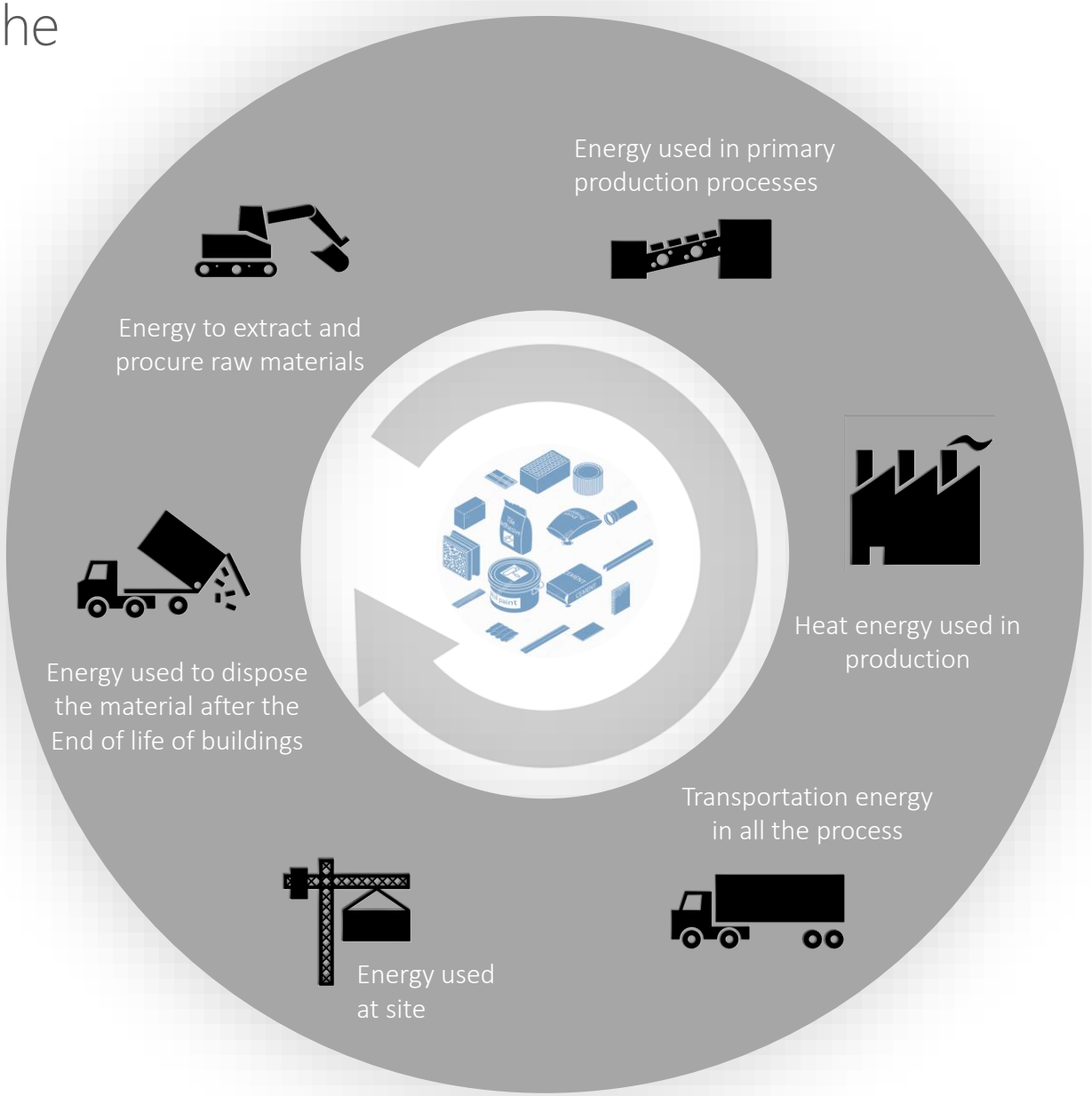


so how can we lower the Embodied Carbon?



so how can we lower the Embodied Carbon?

- Using less materials
- Buying local materials
- Using renewable energy



so how can we lower the Embodied Carbon?

- Using less materials
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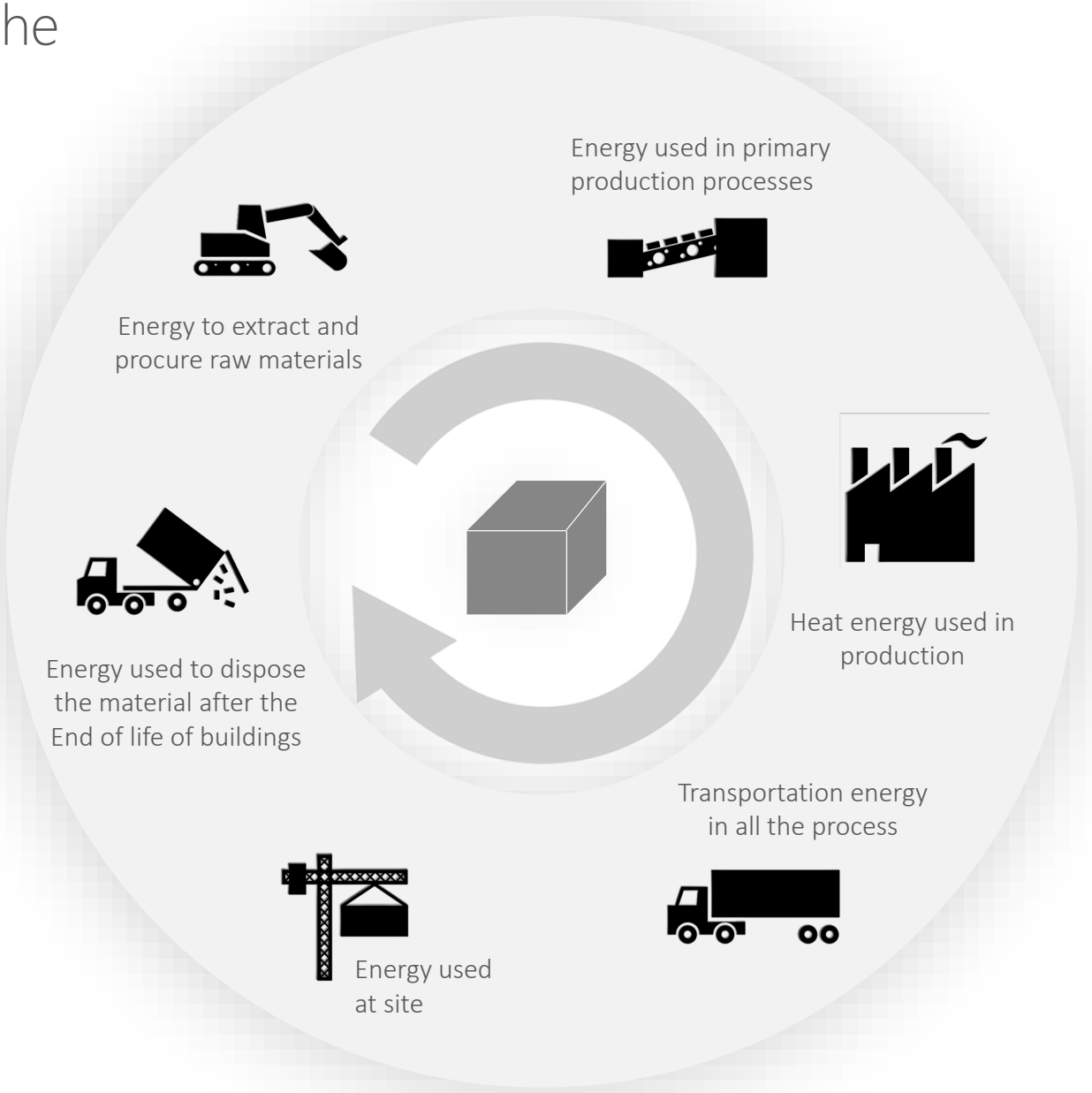
- Using renewable energy

Using carbon sequestering materials



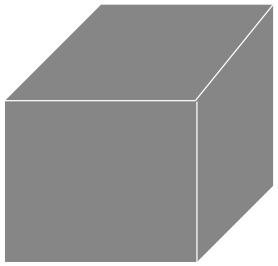
Carbon Sequestration

Bio-Based Materials

Wood

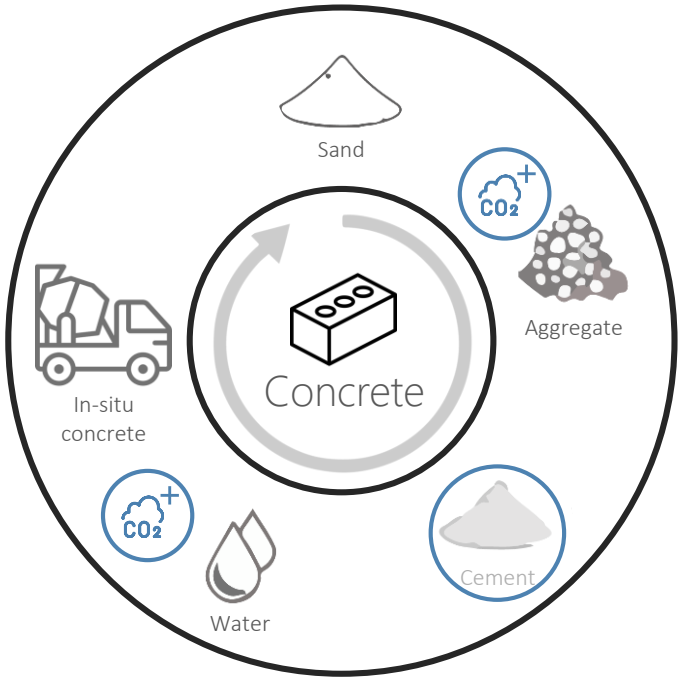
Bamboo

Hempcrete



Carbon Capture and Utilization

Artificial Sequestration



Carbon curing

Low cement concrete

Carbon storing aggregates

Concrete change: Making cement carbon-negative

By **Jeffrey Rissman** December 6, 2018

Cement is one of the world's most-used building materials, with production reaching 4.3 billion tons/year in 2014 and growing 5 percent to 6 percent annually. Today, it is responsible for 5.6 percent of global carbon dioxide (CO_2) emissions and a major contributor to climate change — if the cement industry were a country, it would be the world's third-largest emitter. To stay below 2 degrees Celsius of global warming, cement's carbon intensity must be reduced to near-zero as soon as technically feasible.

Fortunately, the right policies and technologies can make cement manufacturing a net climate benefit. During its lifetime and after demolition, cement naturally captures a significant fraction of the CO_2 emitted during its manufacture. When this effect is combined with carbon capture and storage (CCS), energy efficiency technologies and biofuels or

CarbiCrete

2020 GLOBAL CLEANTECH 100 COMPANY

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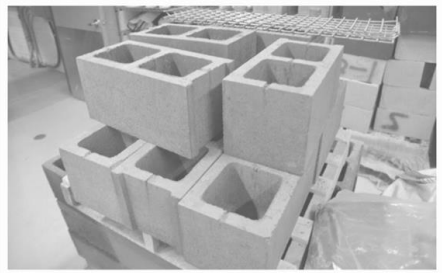


Game-changing technology

Carbicrete's technology enables the production of high-quality concrete using mineral waste and CO_2 as raw materials.

Using a process called carbonation activation, we eliminate the need for cement in concrete by replacing it in the mix with ground steel slag, a by-product of steel-making. The concrete mix is poured into molds just like conventional concrete and is then cured using CO_2.

During curing, the gas becomes a solid, binding together the slag granules, and giving the concrete its strength.

The process can be implemented in any precast concrete manufacturing plant.

Lower your carbon footprint through carbon-negative concrete

Carbicrete's process avoids the GHG emissions associated with cement production (about 2kg of CO_2 per standard-size concrete block) and then injects CO_2 (1kg per block) into its products. Because more CO_2 is consumed than emitted during the process, it is carbon-negative, allowing users of the technology to lower their carbon footprint.

Services Markets Innovation Sustainability News Careers

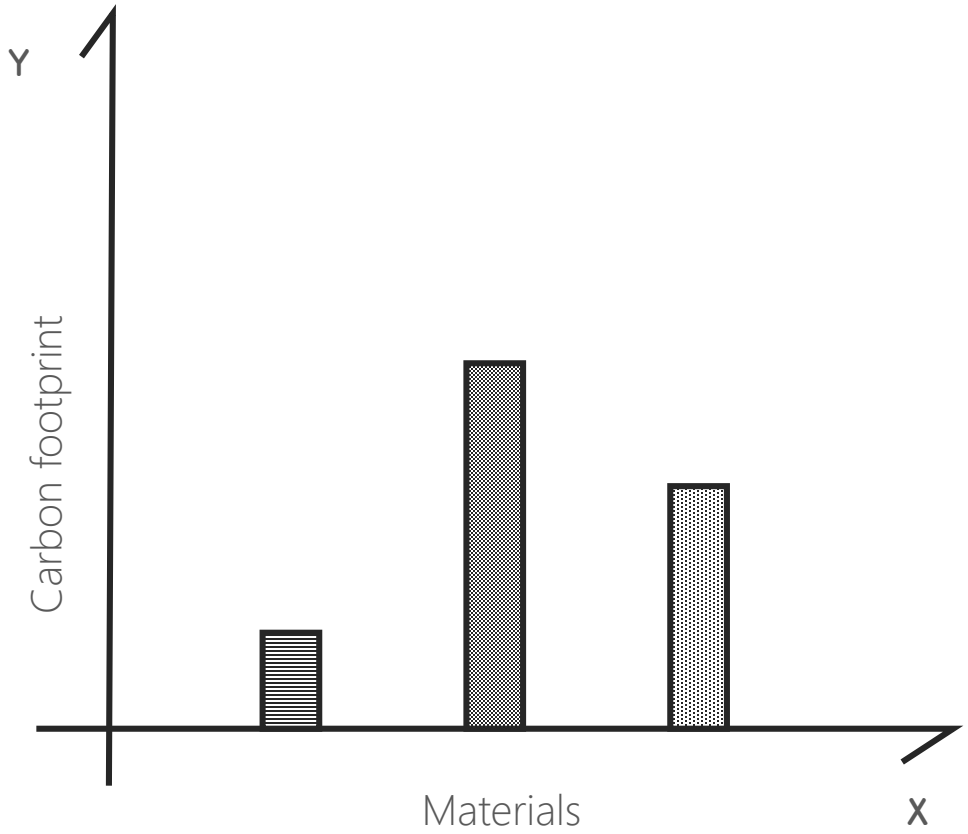
Steel for a sustainable future

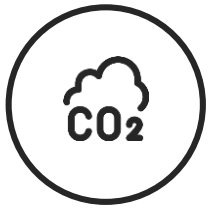
Steel is the most commonly used metal in the world. It is intrinsic to our way of life now, to the products society will demand in future, and to achieving a circular economy. Steel maximises the value of resources more than any other material, through its recovery and reuse, manufacturing and recycling.

Carbon-neutral steelmaking for a sustainable future

The steel industry today is responsible for a significant contribution to carbon dioxide emissions. As a primary steelmaker, we bring together iron ore and coal in blast furnaces to create iron, which is then refined to create thousands of different grades of steel. This process also produces carbon dioxide. There are limits to how much the blast furnace

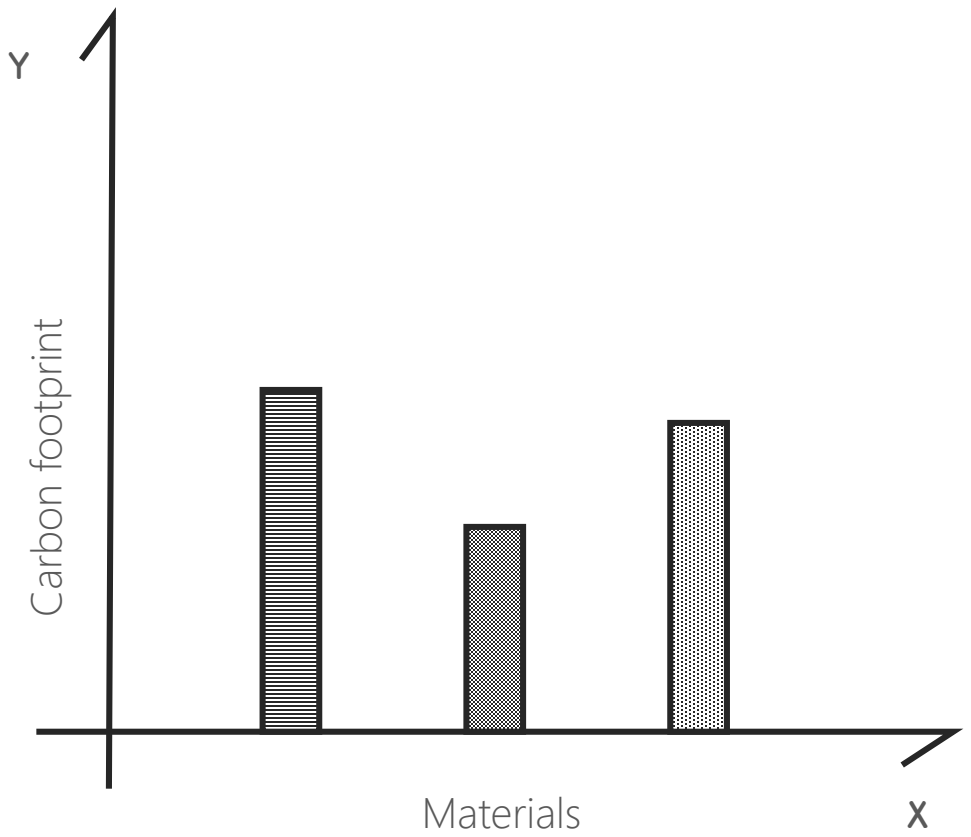
parameters effecting Embodied Carbon?





Primary production

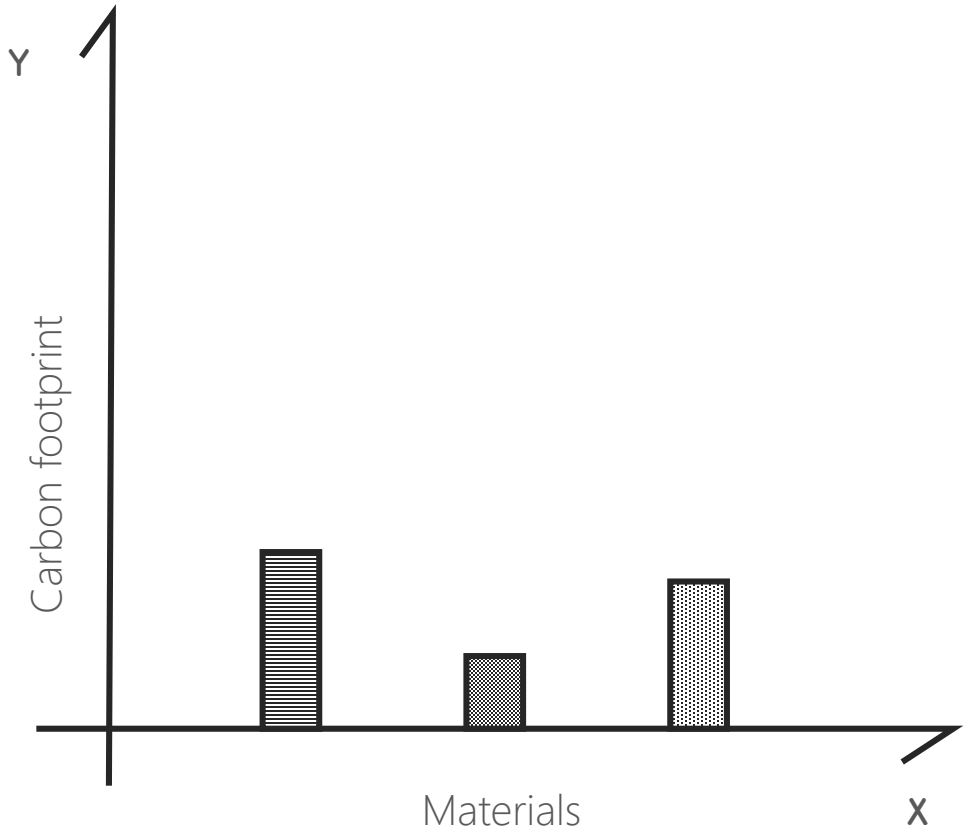
parameters effecting **Embodied Carbon?**



Primary production

Life span of material

parameters effecting Embodied Carbon?

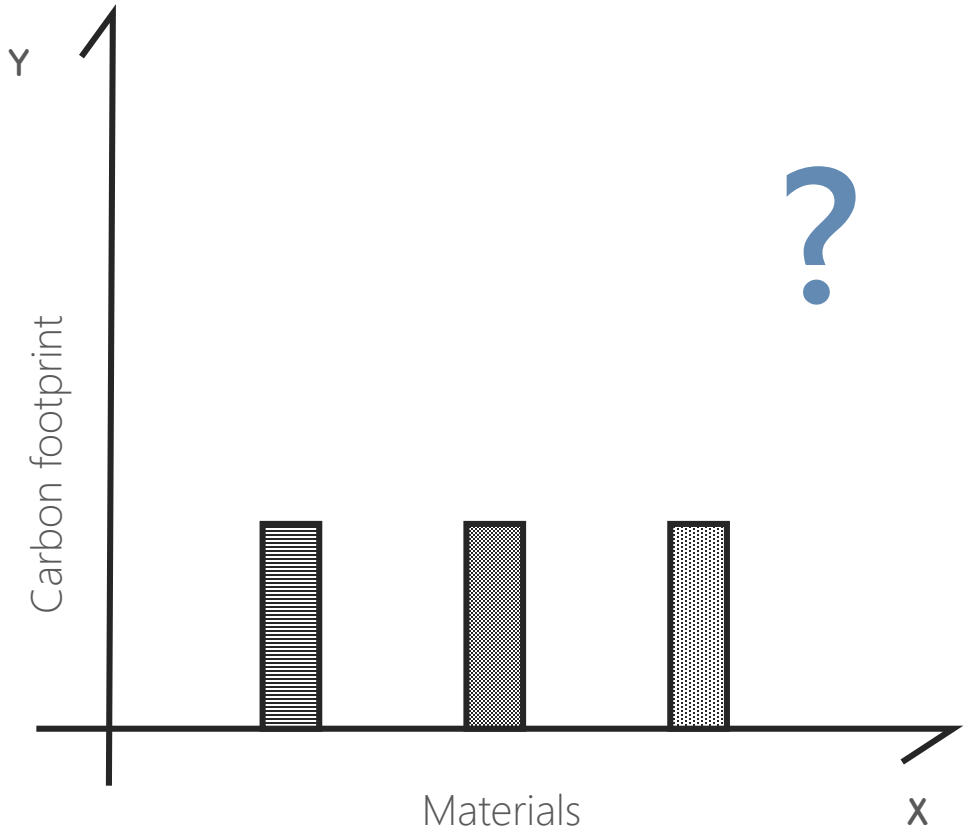


Primary production

Life span of material

Circular use of material

parameters effecting Embodied Carbon?



- Primary production
- Life span of material
- Circular use of material

Net impact?

Research Question

What **alternate materials** and strategies can be used in building design to reduce its **embodied carbon** footprint and meet **zero-carbon goals?**

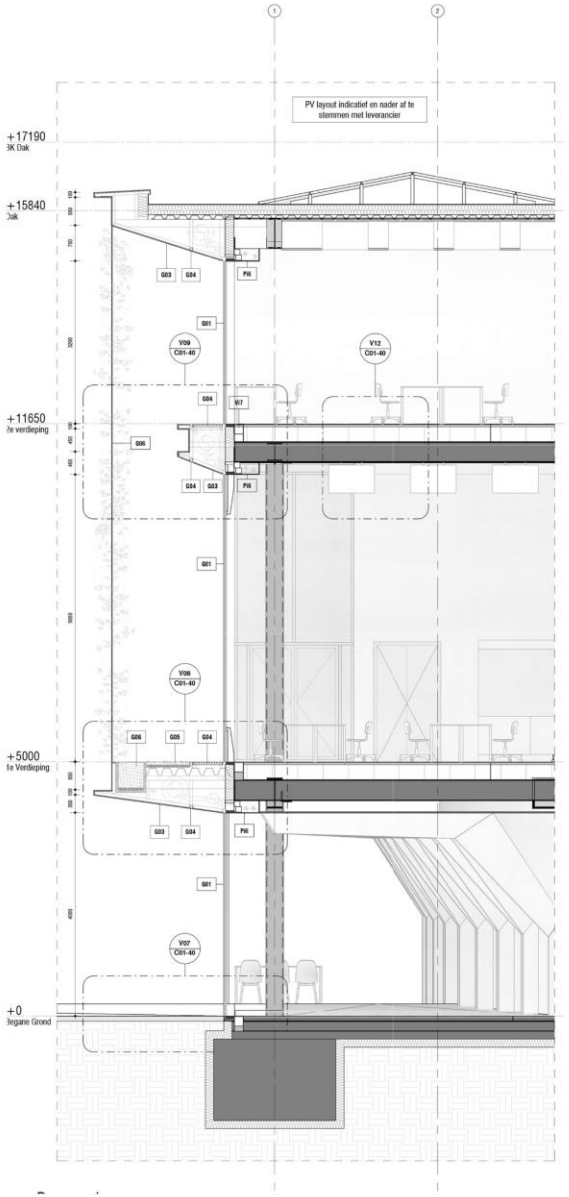
Methodology

what Materials?

What **alternate materials** and strategies can be used in building design to reduce its **embodied carbon** footprint and meet **zero-carbon goals?**

Assessment method?

Analysis Results?


PV layout indicatief en nader af te stemmen met leverancier
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BK Dak
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Dak
+11650
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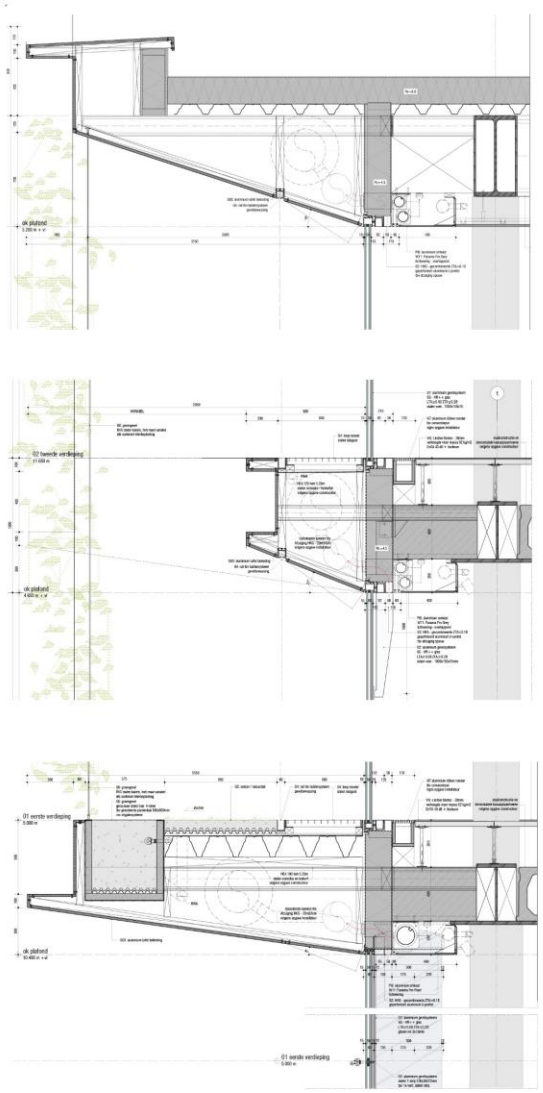
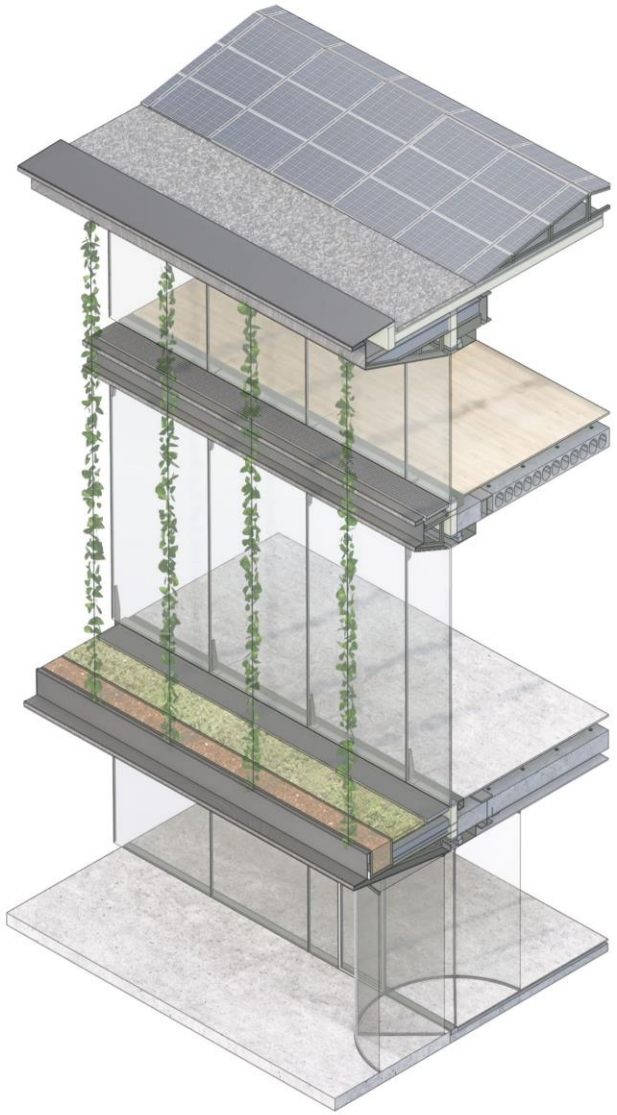
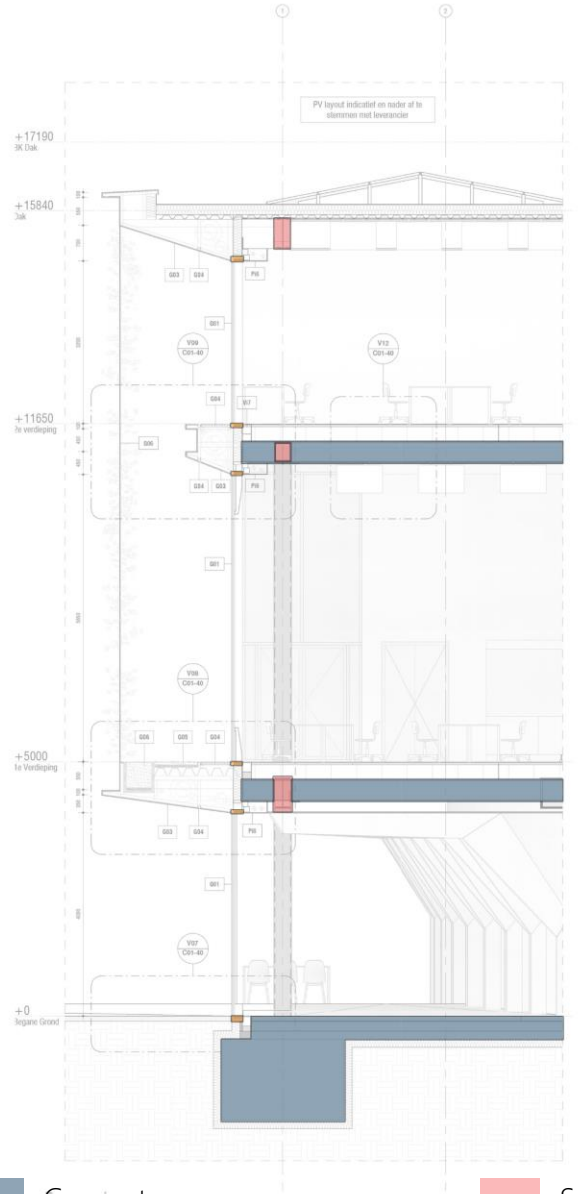
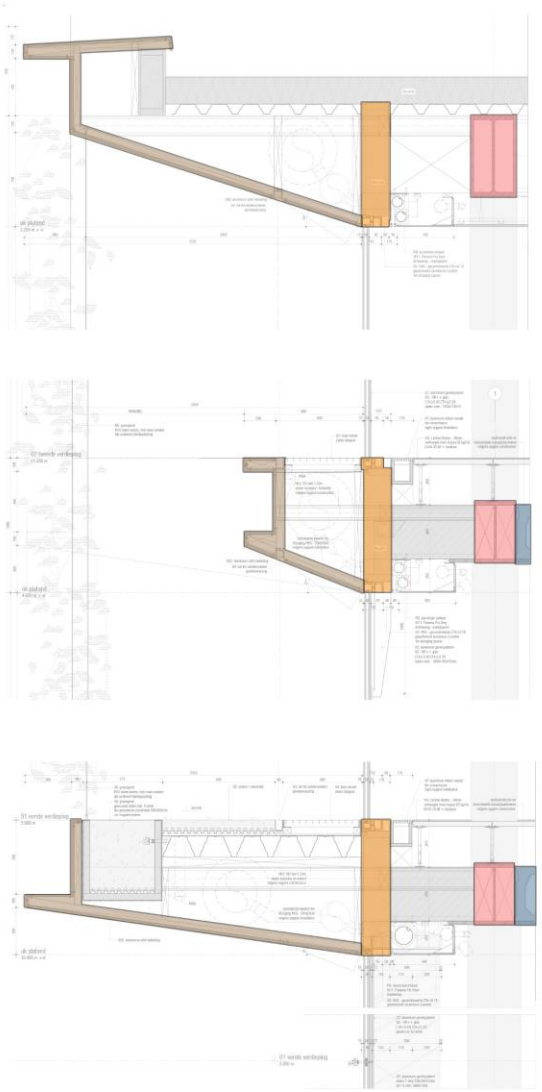
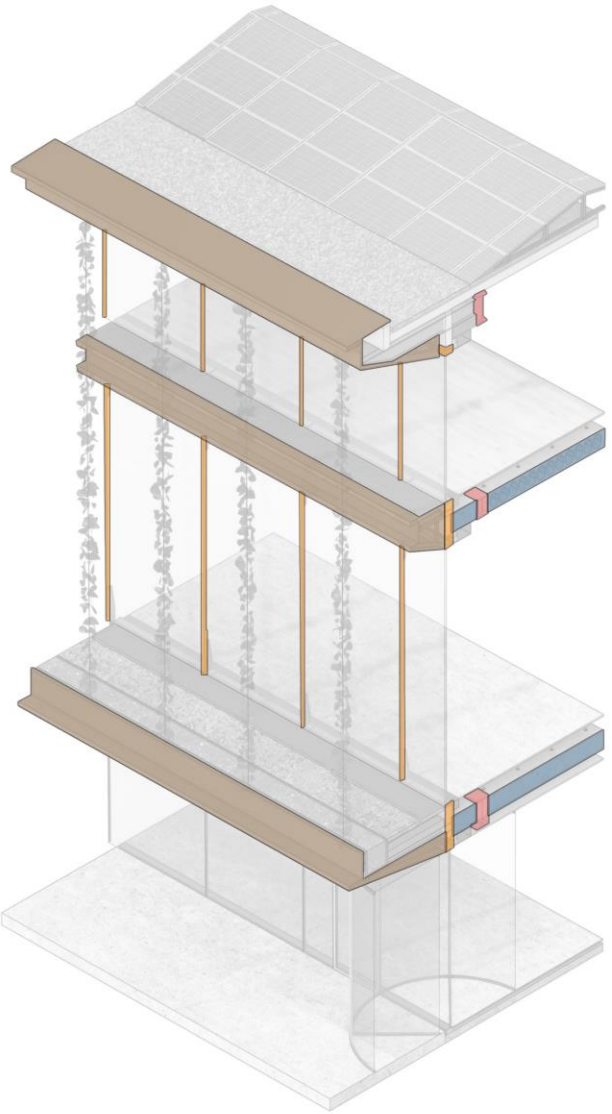
+5000
1e Verdieping
+0
Begane Grond











Concrete

Structural steel

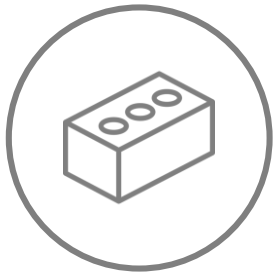
Aluminium in window frames

Aluminium awnings

Life cycle assessment method

Life Cycle Assessment (LCA) is a method to assess the environmental impact of a product or a service. It uses the Life Cycle Inventories (LCI) of smaller units to calculate the impact on a specific indicator.

Conduct a Whole building life cycle assessment



Assess a product or a process

Compare two or more products or processes

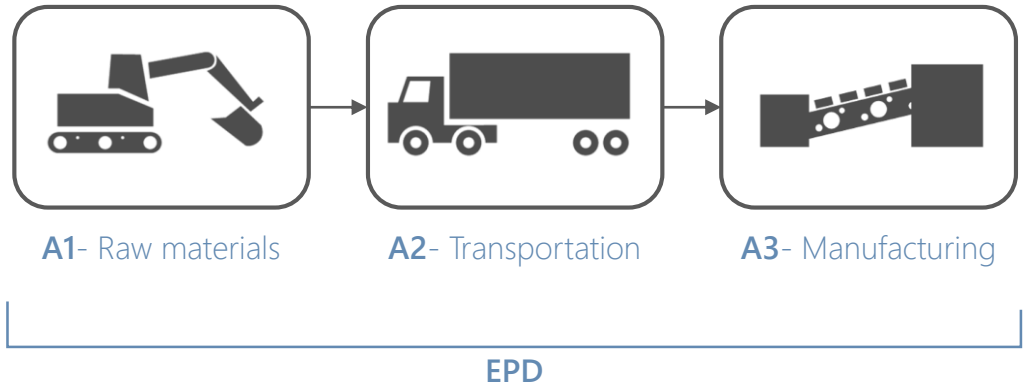
Achieve green labels such as EPD (Environmental Product Declaration)

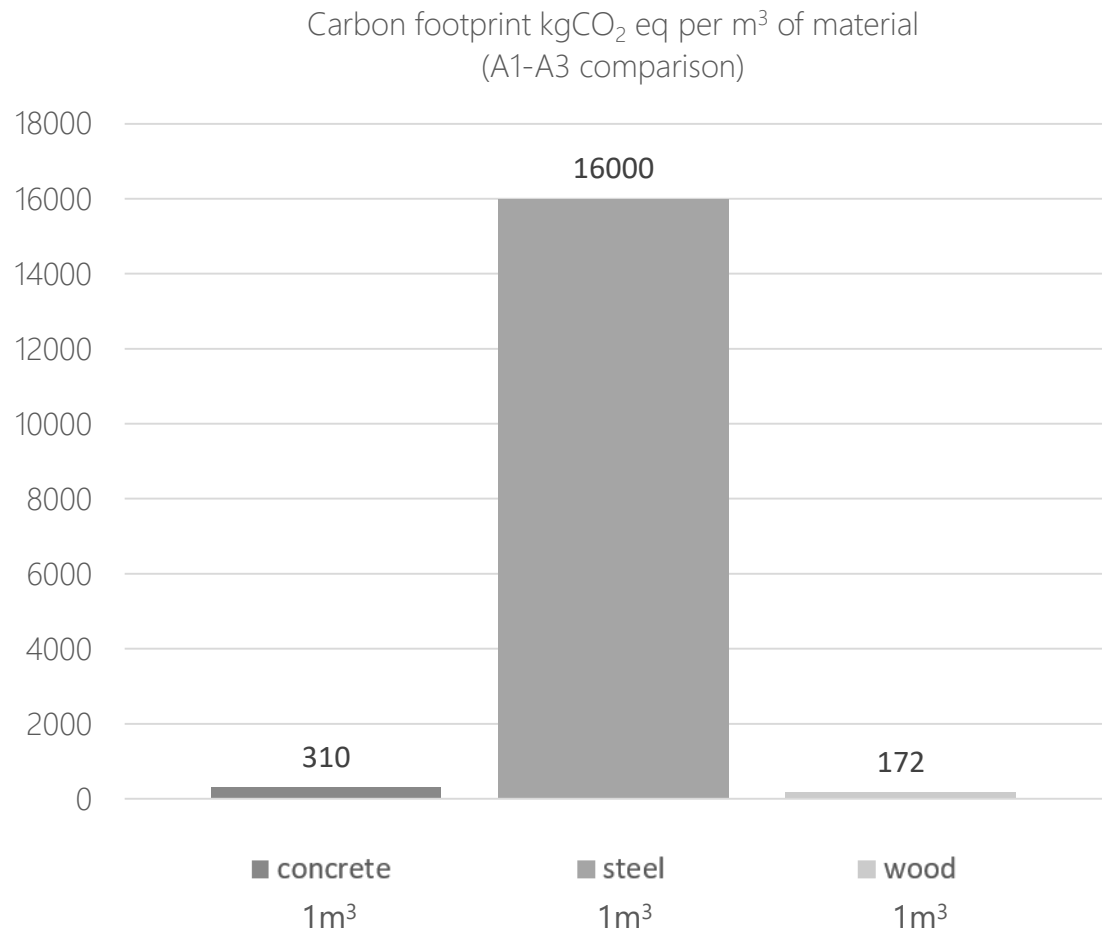
Life cycle assessment method

Production Stage (A)					Use Stage (B)							End-of-Life Stage (C)				Benefits and loads beyond the system boundary (D)		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D
X			x	x	x					Module not relevant		x				x		

Shortcomings of existing assessment method

- Material quantities are often not considered





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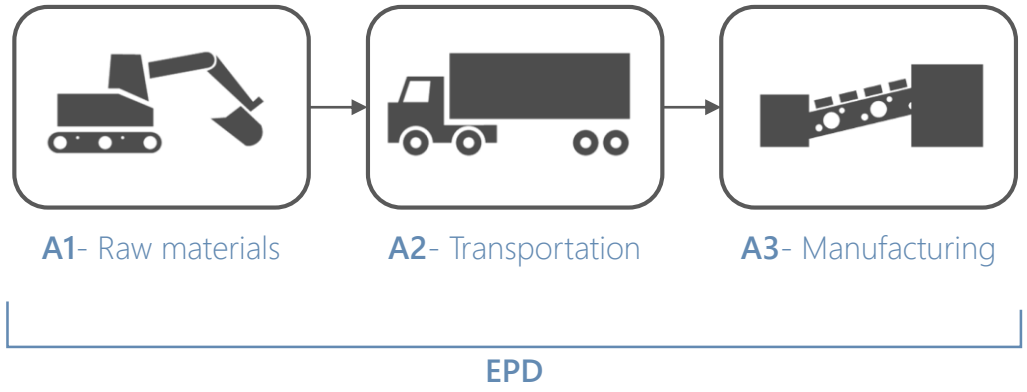
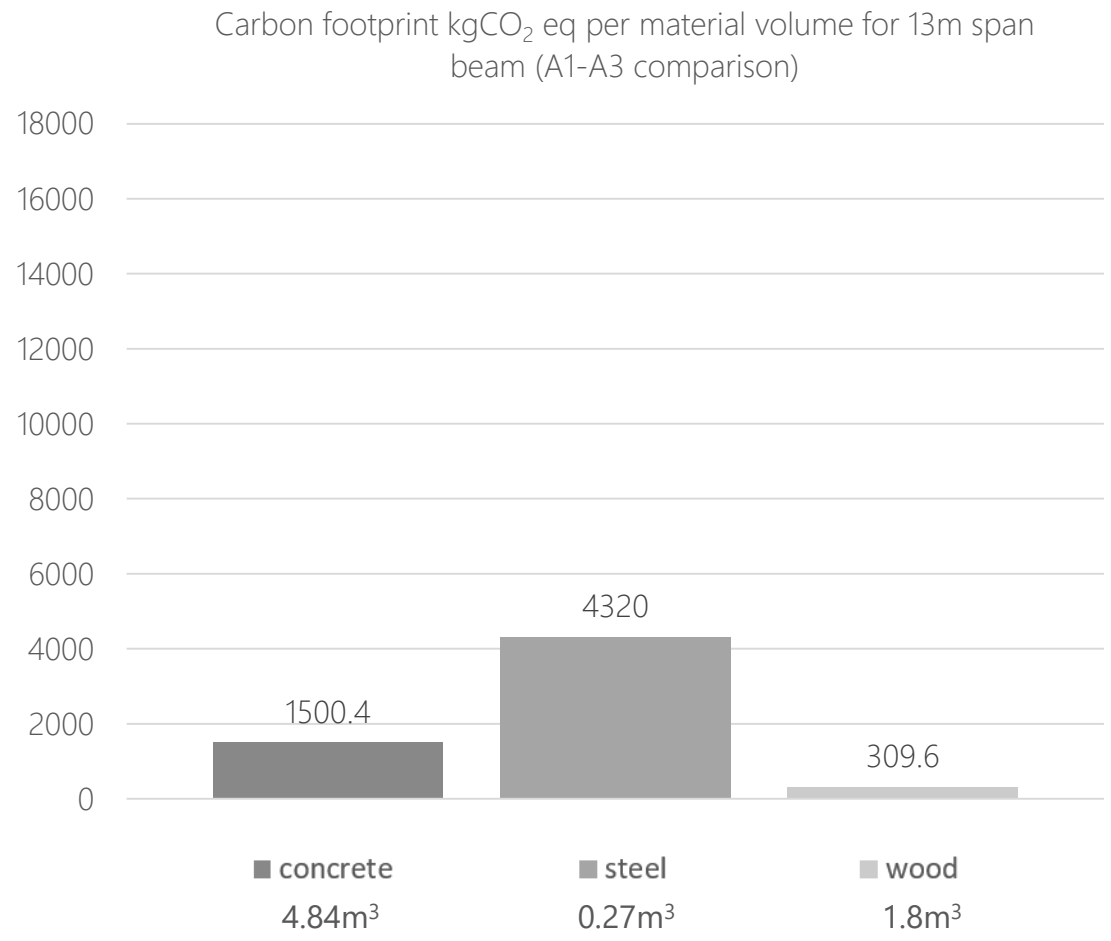
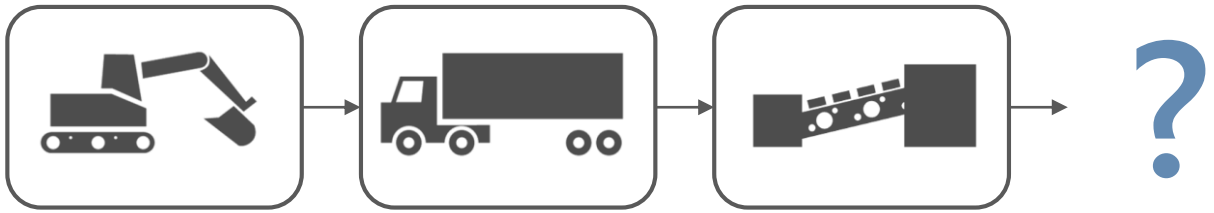




Shortcomings of existing assessment method

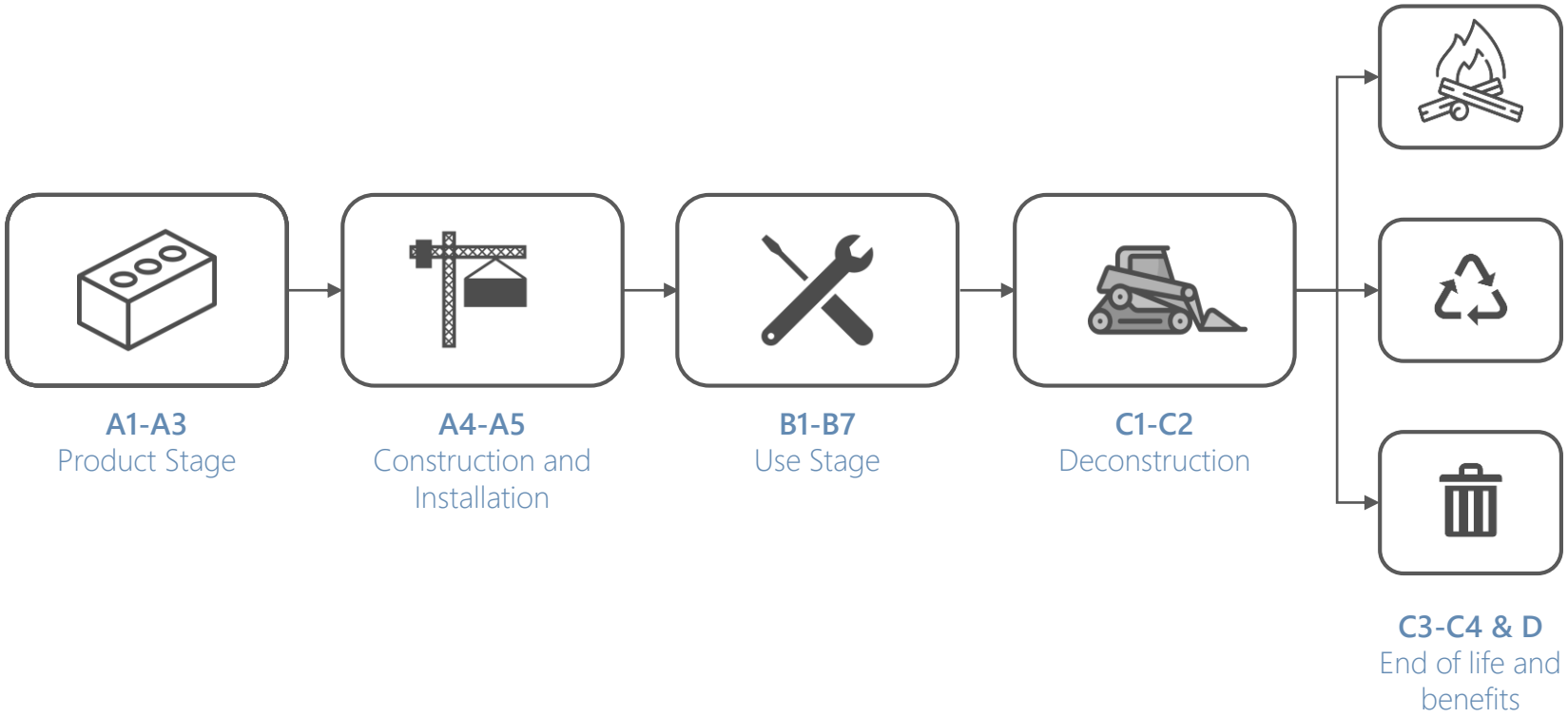
- Material quantities are often not considered
- Module B (repair/replacement) and C-D (end-of-life) not accounted



A1- Raw materials **A2**- Transportation **A3**- Manufacturing

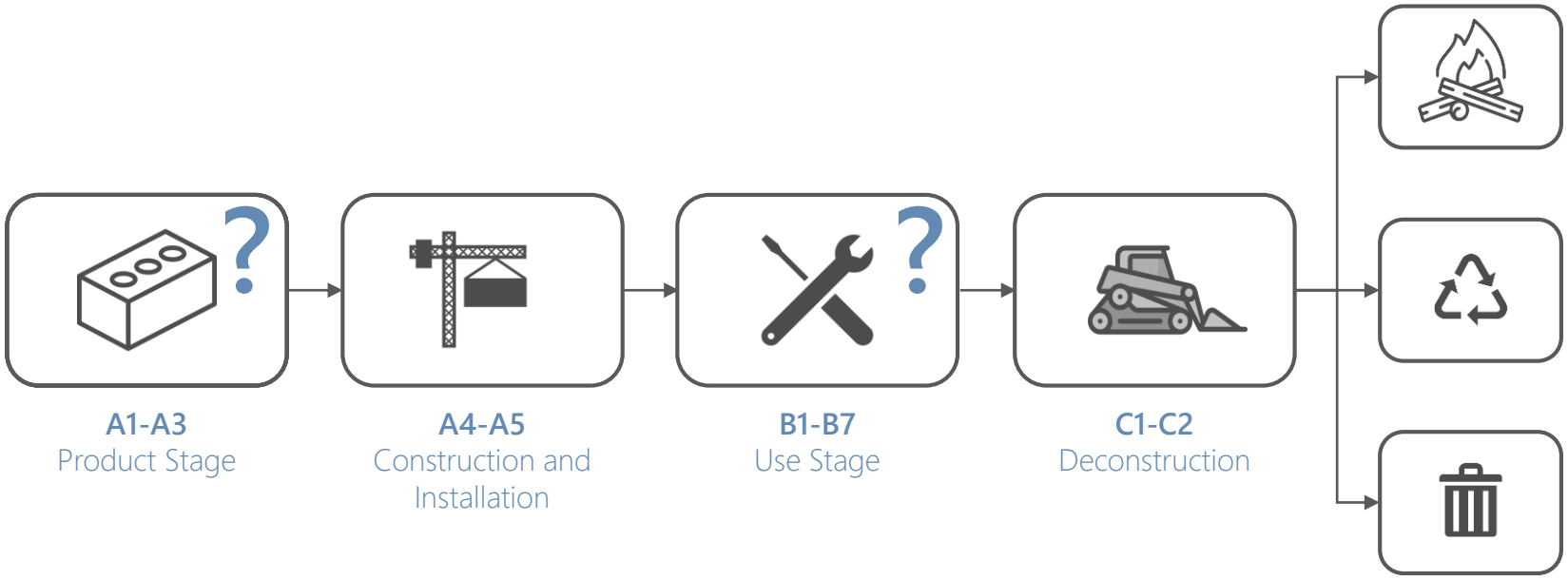
Shortcomings of existing assessment method

- Material quantities are often not considered
- Module B (repair/replacement) and C-D (end-of-life) not accounted



Shortcomings of existing assessment method

- Material quantities are often not considered
- Module B (repair/replacement) and C-D (end-of-life) not accounted
- Carbon sequestration not accounted (e.g. concrete carbonation)



Shortcomings of existing assessment method

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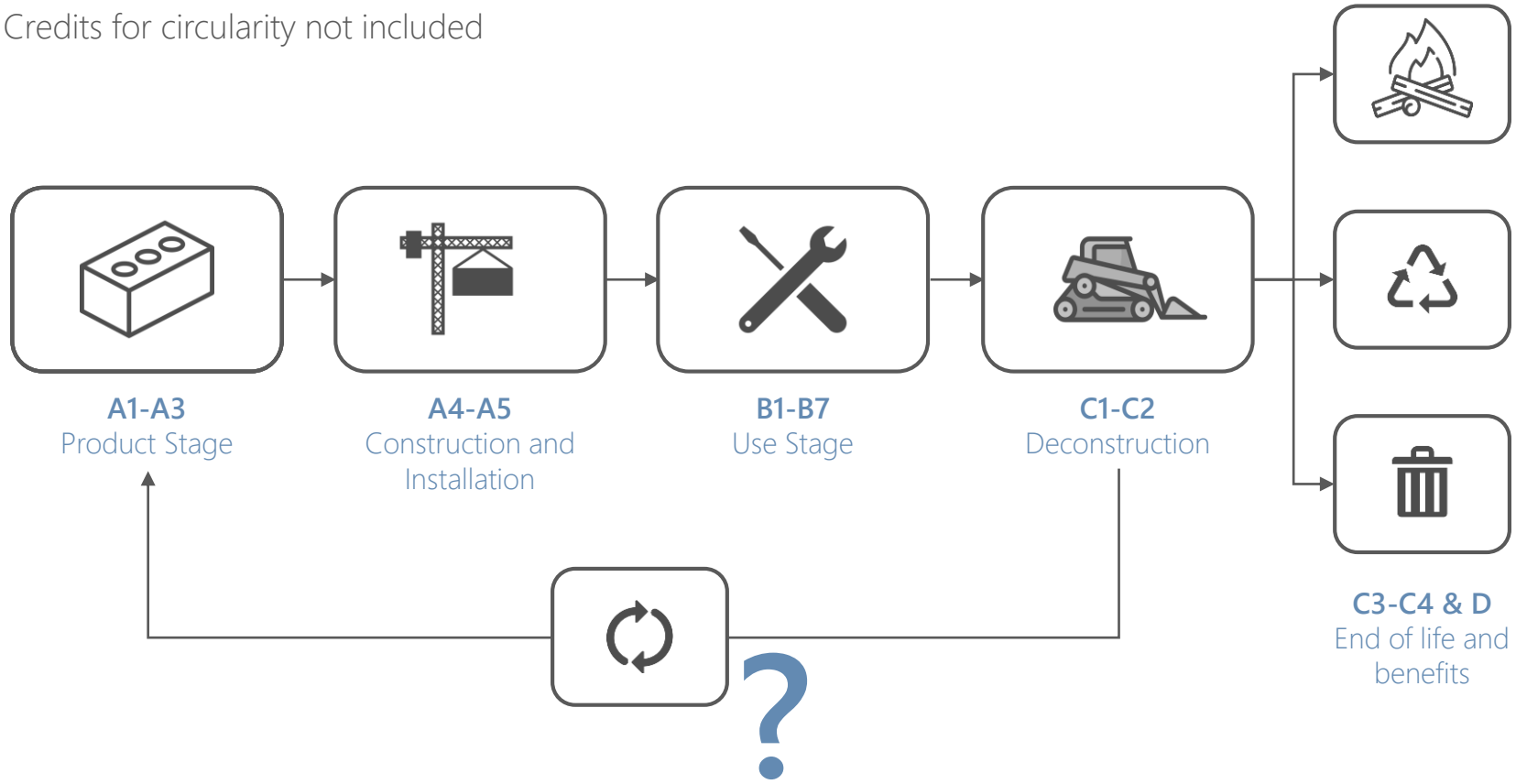
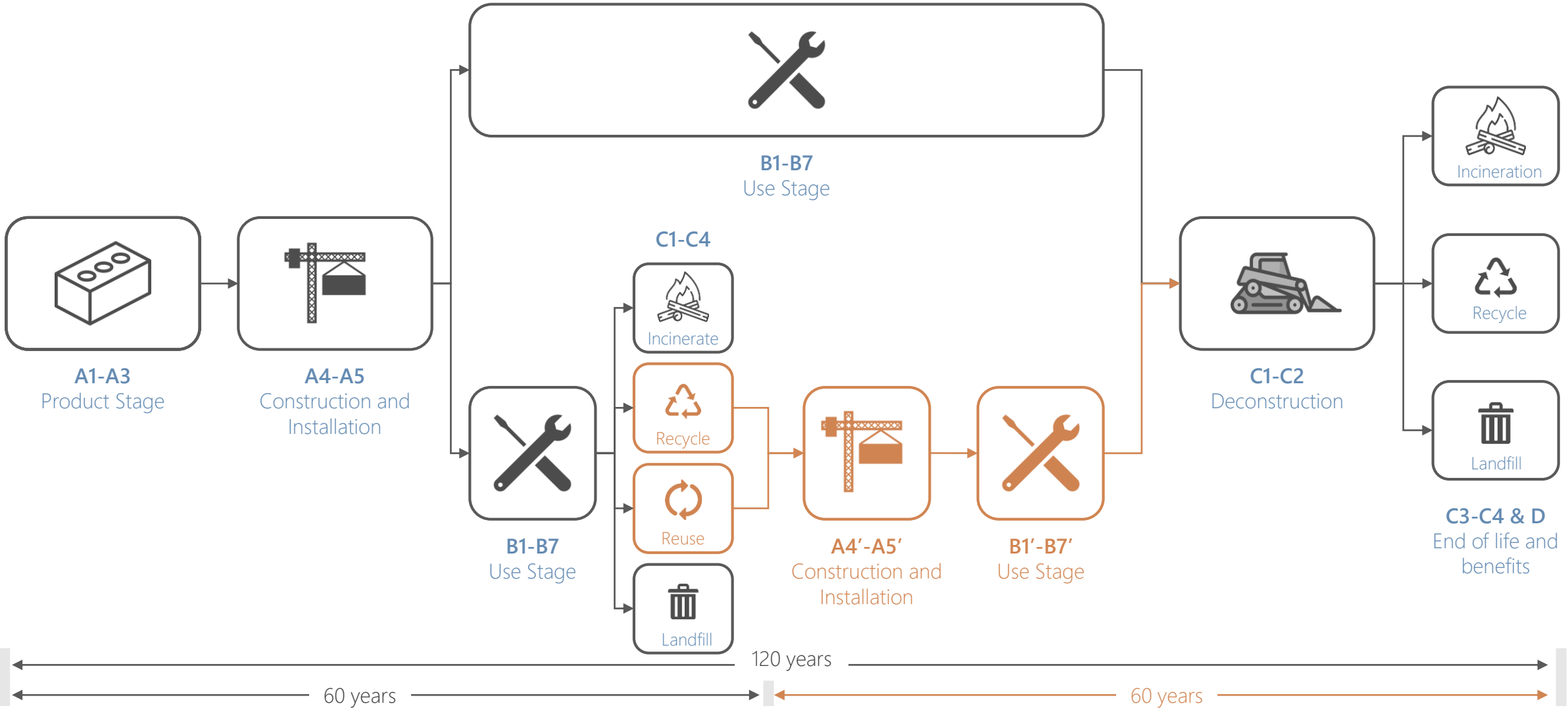
- Carbon sequestration not accounted (e.g. concrete carbonation)
- Credits for circularity not included

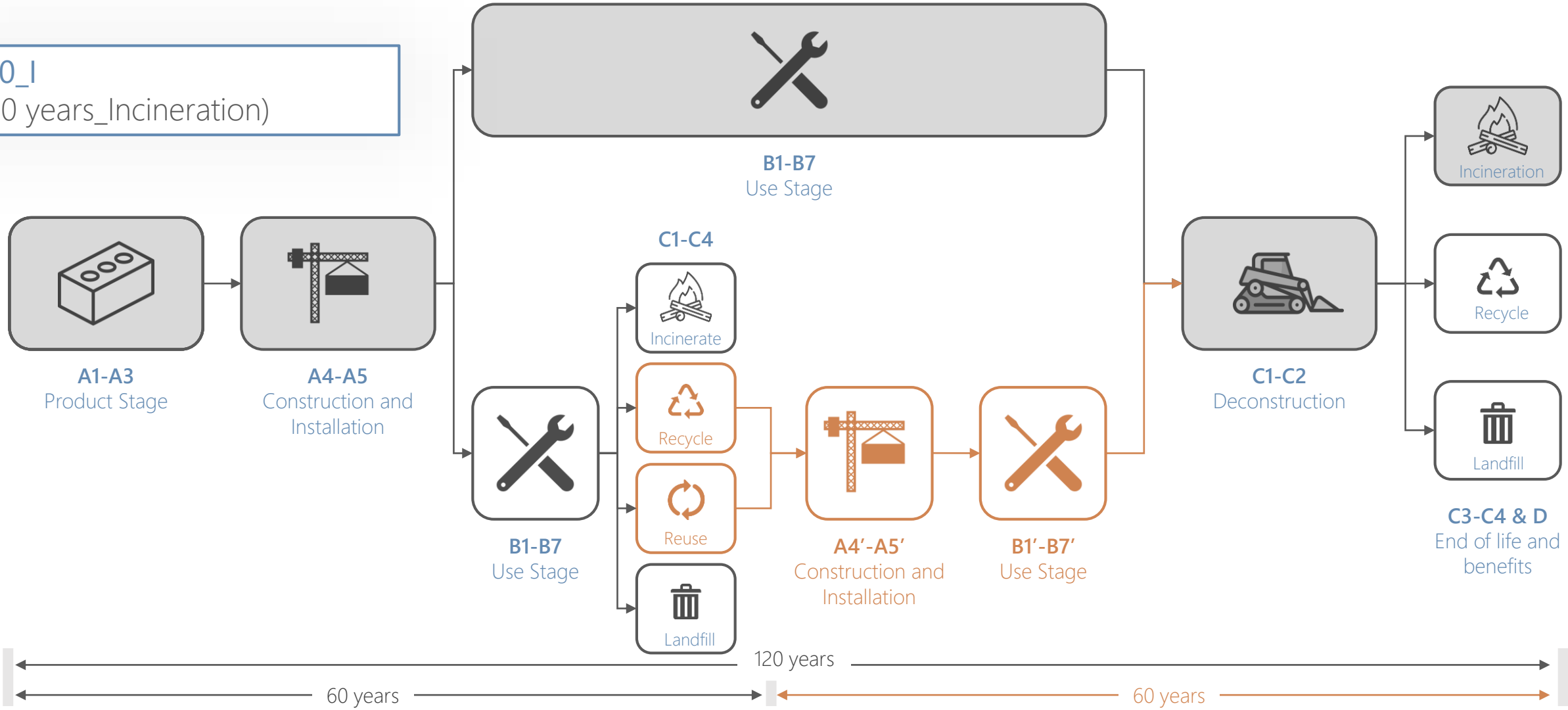


Proposed assessment method



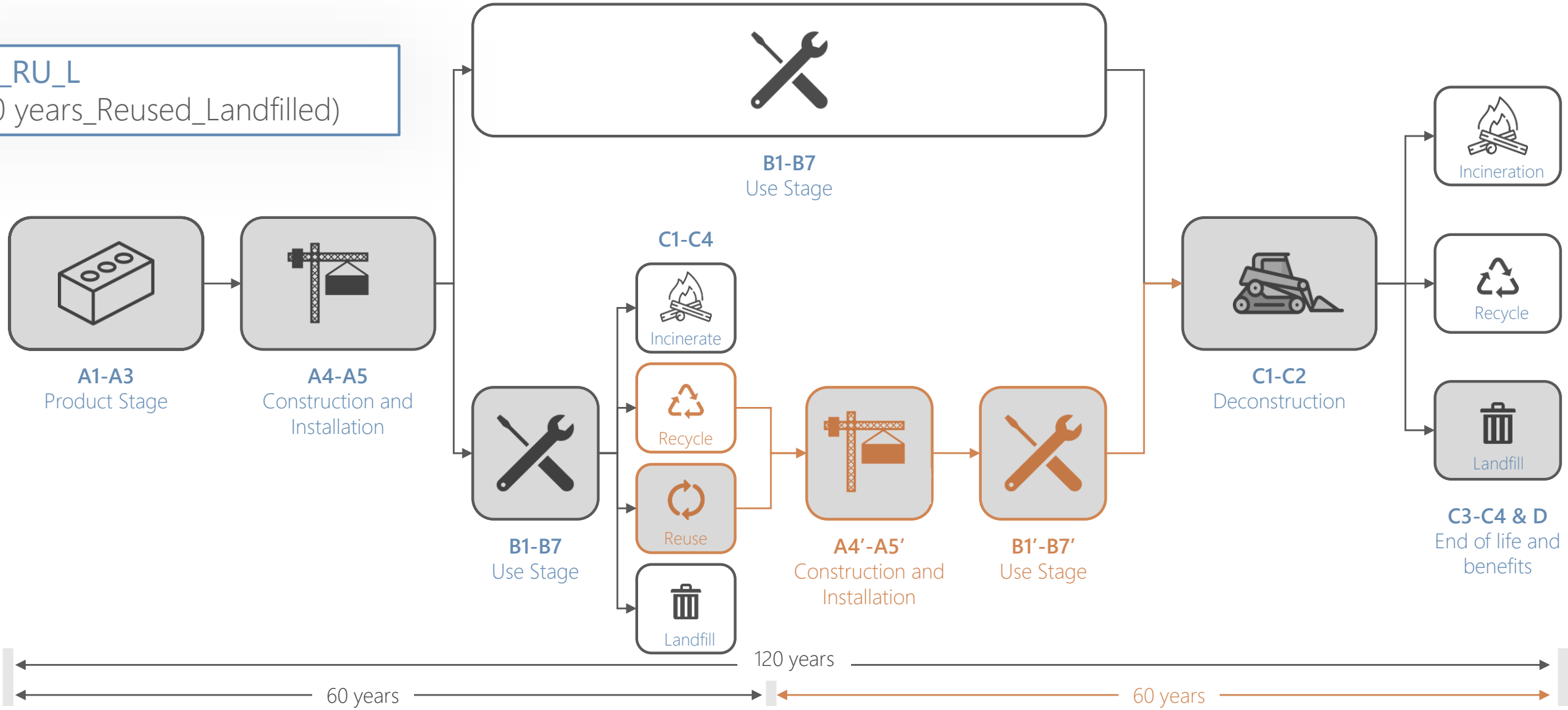
Proposed assessment method- scenario names

120_I
(120 years_Incineration)



Proposed assessment method- scenario names

60_RU_L
(60 years_Reused_Landfilled)



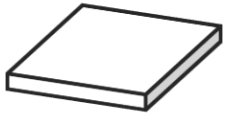
Echo building

Columns

- Concrete: 120_L, 120_RC, 60_RU_L, 60_RU_RC, 60_RC_L, 60_RC_RC
- Wood: 120_I, 120_L, 120_RC, 60_RU_I, 60_RU_L, 60_RU_RC, 60_RC_I, 60_RC_L, 60_RC_RC
- Steel: 120_RC, 60_RU_RC, 60_RC_RC

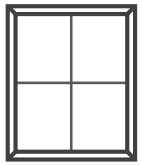
Beams

- Concrete: 120_L, 120_RC, 60_RU_L, 60_RU_RC, 60_RC_L, 60_RC_RC
- Wood: 120_I, 120_L, 120_RC, 60_RU_I, 60_RU_L, 60_RU_RC, 60_RC_I, 60_RC_L, 60_RC_RC
- Steel: 120_RC, 60_RU_RC, 60_RC_RC



Slabs

- Concrete: 120_L, 120_RC, 60_RU_L, 60_RU_RC, 60_RC_L, 60_RC_RC
- Wood: 120_I, 120_L, 120_RC, 60_RU_I, 60_RU_L, 60_RU_RC, 60_RC_I, 60_RC_L, 60_RC_RC



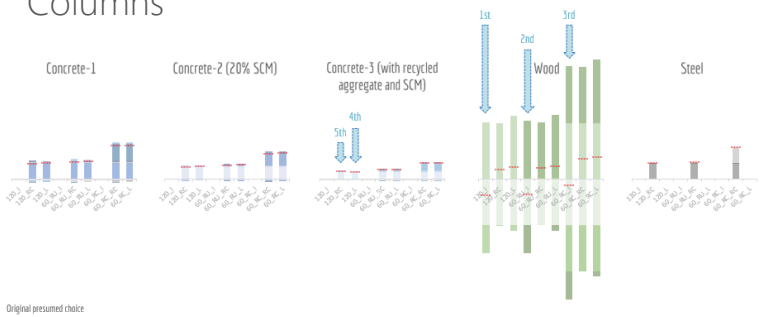
Facade

- Aluminium: 120_RC
- Wood-Alu: 120_I, 120_L, 120_RC
- PVC-U: 120_I, 120_L, 120_RC

Analysis

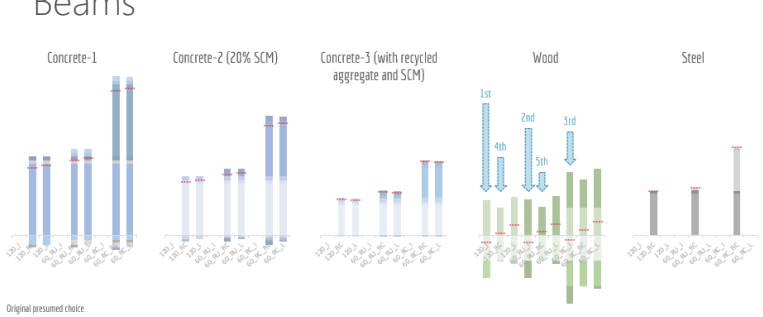
Building components

Columns



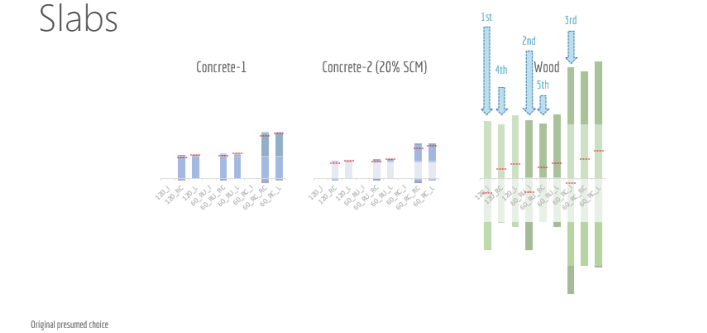
Original presumed choice						
Steel 60_RC_RC	Wood 120_I	Wood 60_RU_I	Wood 60_RC_I	Concrete-3 120_L	Concrete-3 120_L	
125,331	-61,774	-57,857	-22,522	30,142	30,704	Kg CO_2

Beams



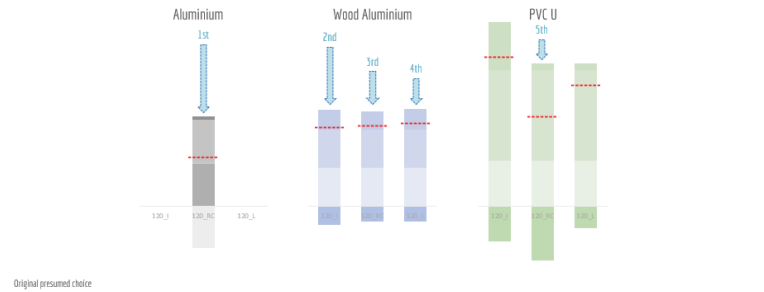
Original presumed choice						
Steel 60_RC_RC	Wood 120_I	Wood 60_RU_I	Wood 60_RC_I	Wood 120_RC	Wood 60_RU_RC	
708,370	-56,762	-52,556	-36,166	20,596	27,603	Kg CO_2

Slabs



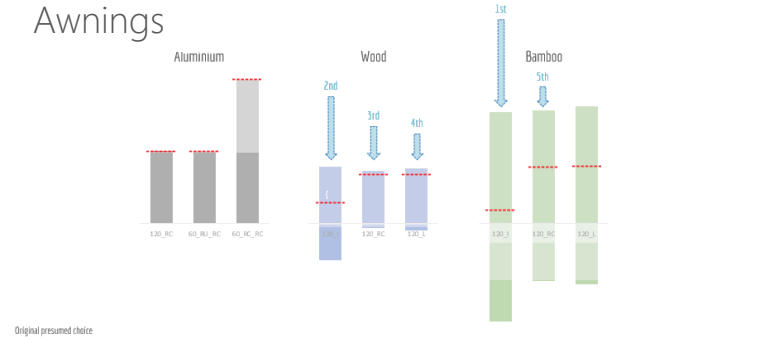
Original presumed choice						
Hollow core concrete 60_RC_RC	Wood 120_I	Wood 60_RU_I	Wood 60_RC_I	Wood 120_RC	Wood 60_RU_RC	
609,584	-208,555	-197,097	-74,971	133,584	153,226	Kg CO_2

Façade



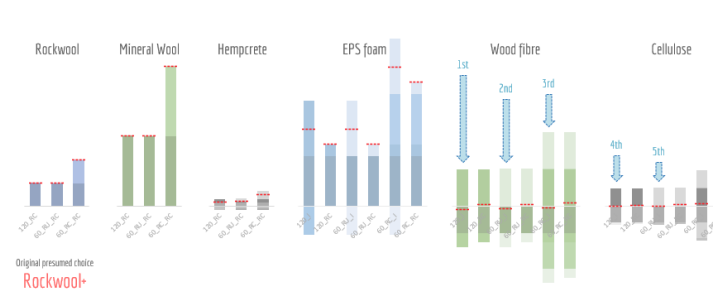
Original presumed choice						
Aluminium 120_RC	Aluminium 120_RC	Wood-Alu 120_I	Wood-Alu 120_RC	Wood-Alu 120_L	PVC U 120_RC	
186,436	186,436	301,709	309,511	316,929	342,318	Kg CO_2

Awnings



Original presumed choice						
Aluminium 60_RC_RC	Bamboo 120_I	Wood 120_I	Wood 120_RC	Wood 120_L	Bamboo 120_RC	
161,492	14,906	23,419	55,042	55,206	63,186	Kg CO_2

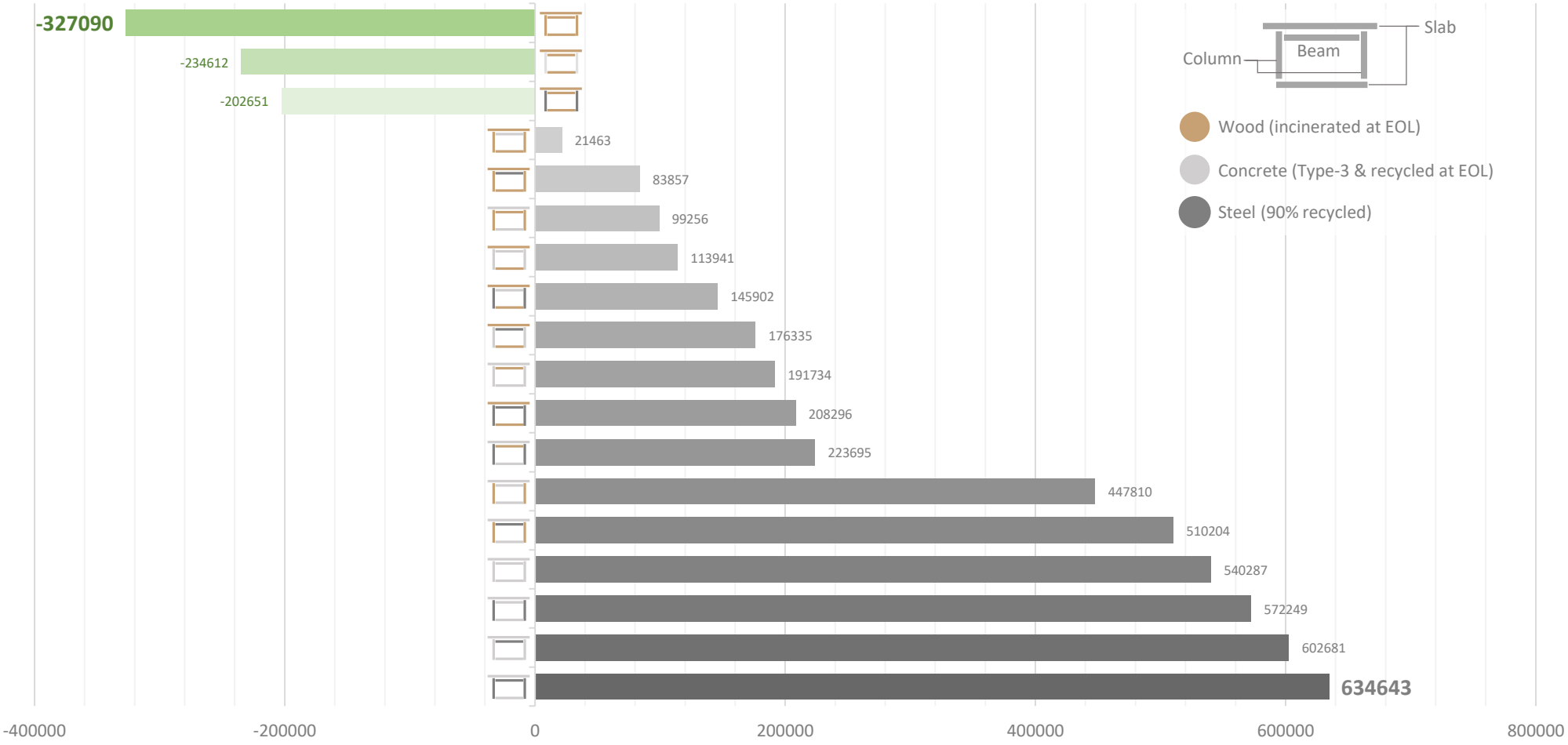
Insulation



Original presumed choice						
Rockwool+ Mineral wool 60_RC_RC	Wood fibre 120_I	Wood fibre 60_RU_I	Wood fibre 60_RC_I	Cellulose 120_I	Cellulose 60_RU_I	
13,500	-492	-448	-301	-87	-44	Kg CO_2

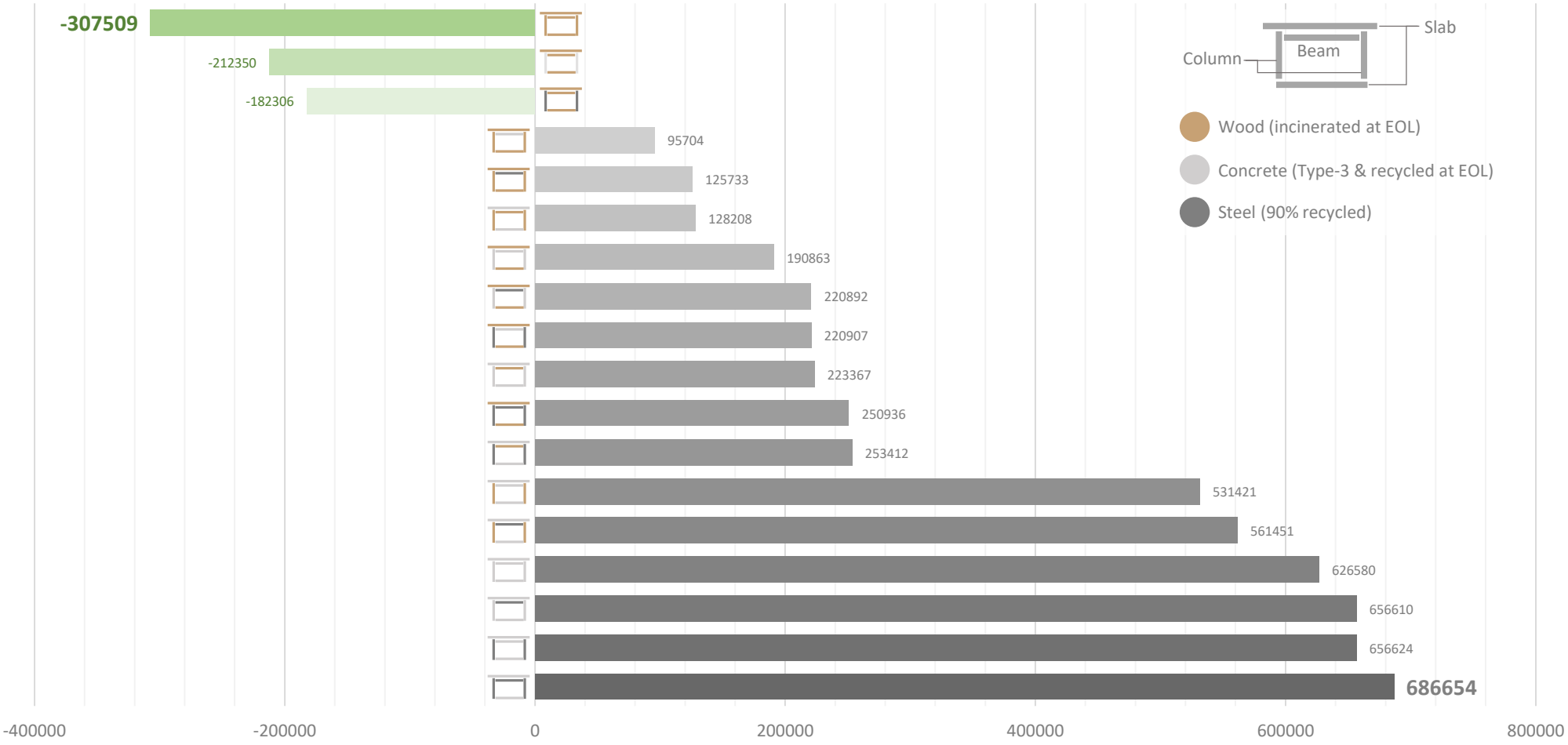
Carbon footprint of structure

All possible combinations for 120 years building



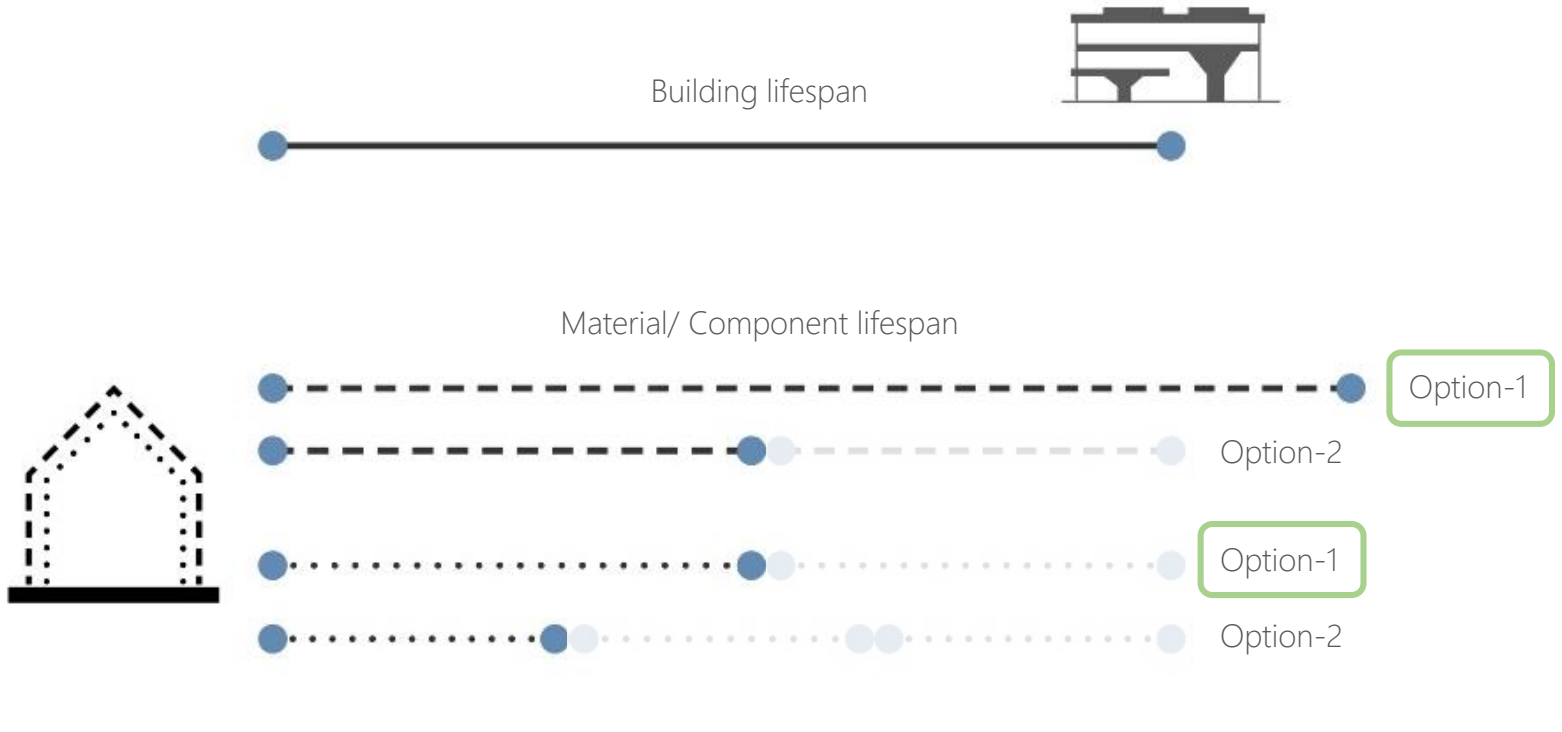
Carbon footprint of structure

All possible combinations for 60 years building



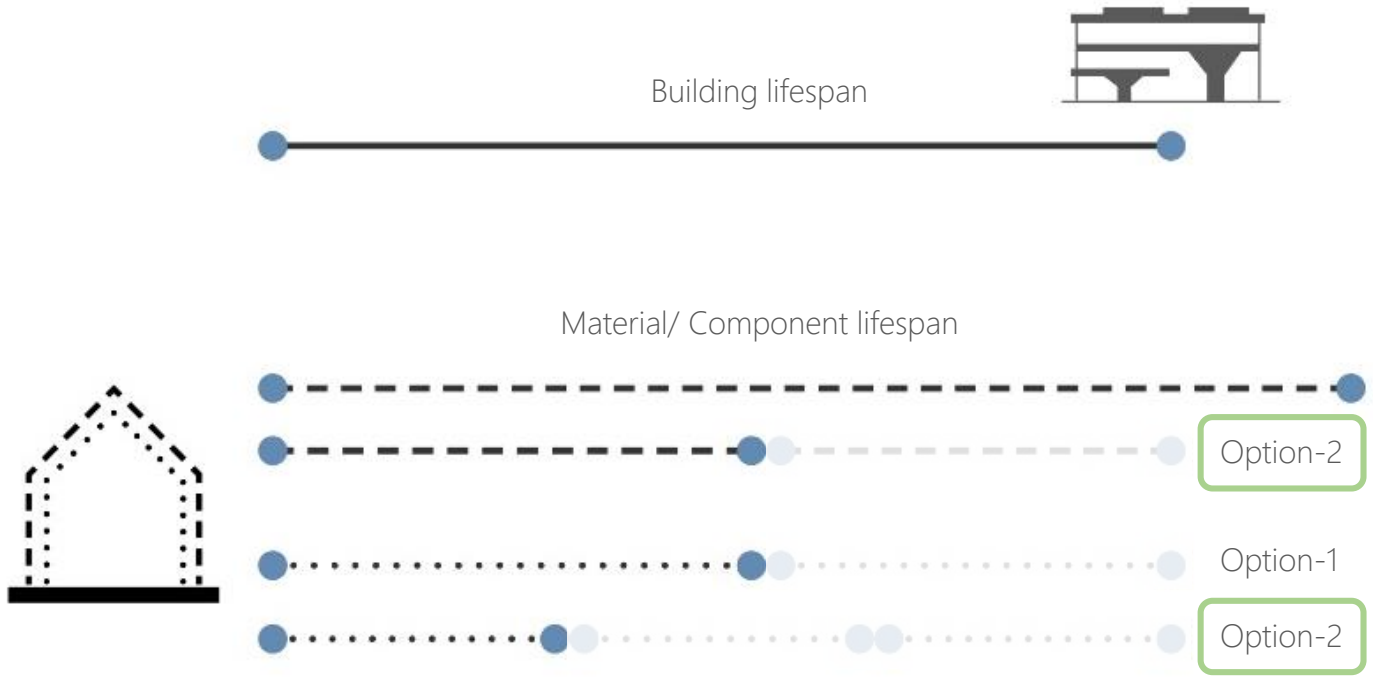
Interpretations

- Impact of life span of buildings and materials on embodied carbon

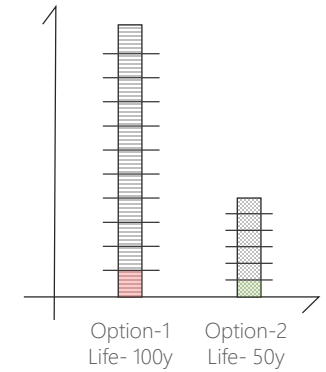


Interpretations

- Impact of life span of buildings and materials on embodied carbon

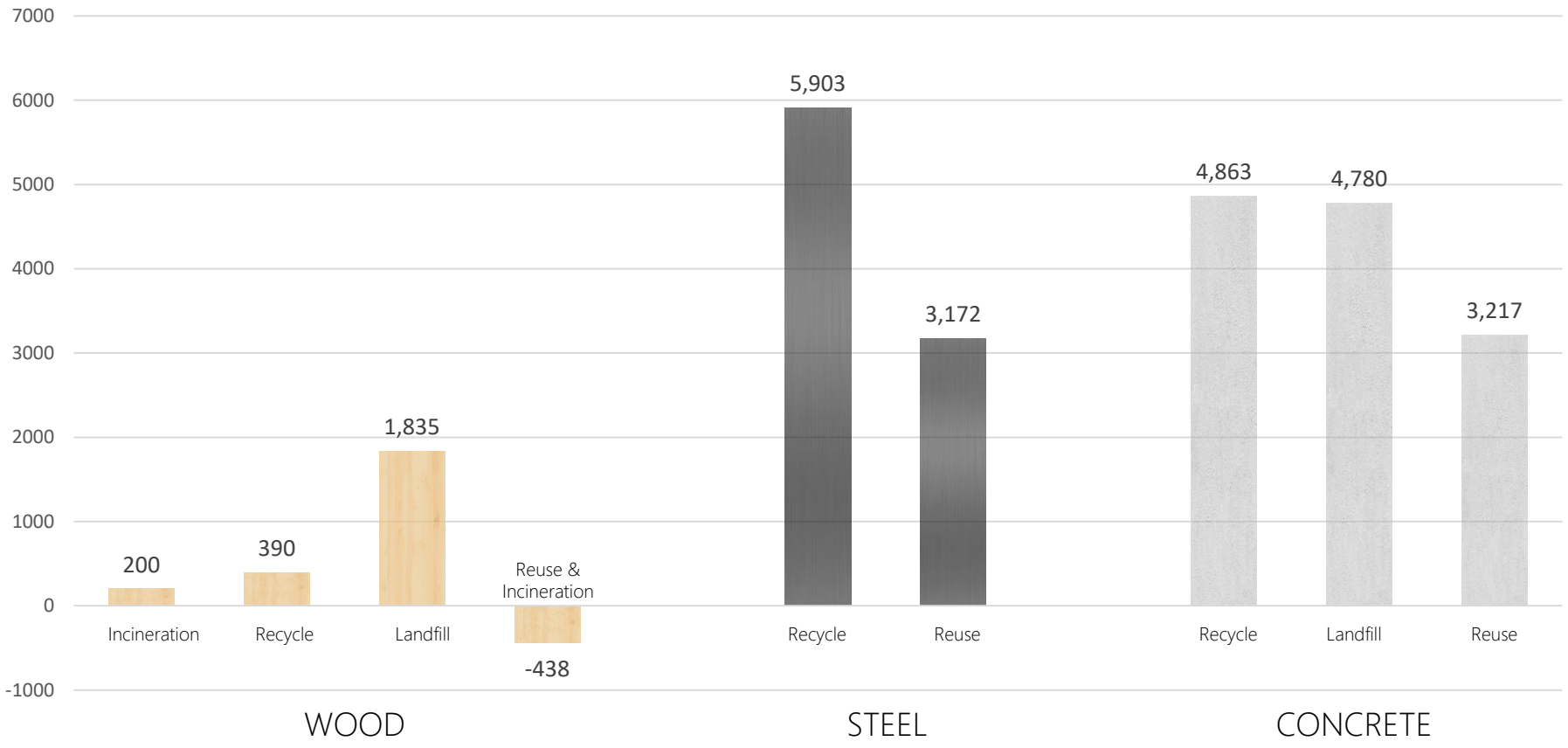


$$GWP_{1\ year} = \frac{GWP_{A1-A3} - ERP}{Service\ life}$$



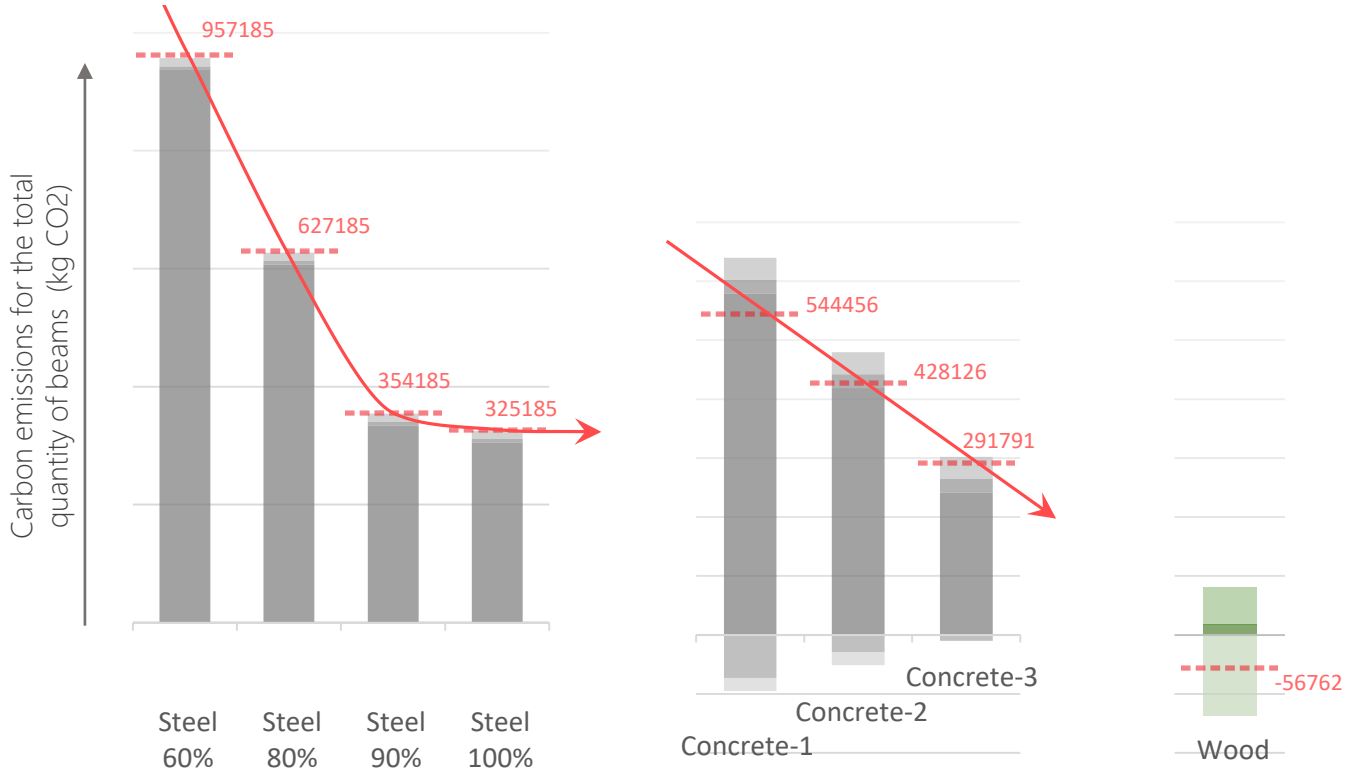
Interpretations

- Impact of **life span** of buildings and materials on embodied carbon
- Impact of **end of life** on embodied carbon



Interpretation

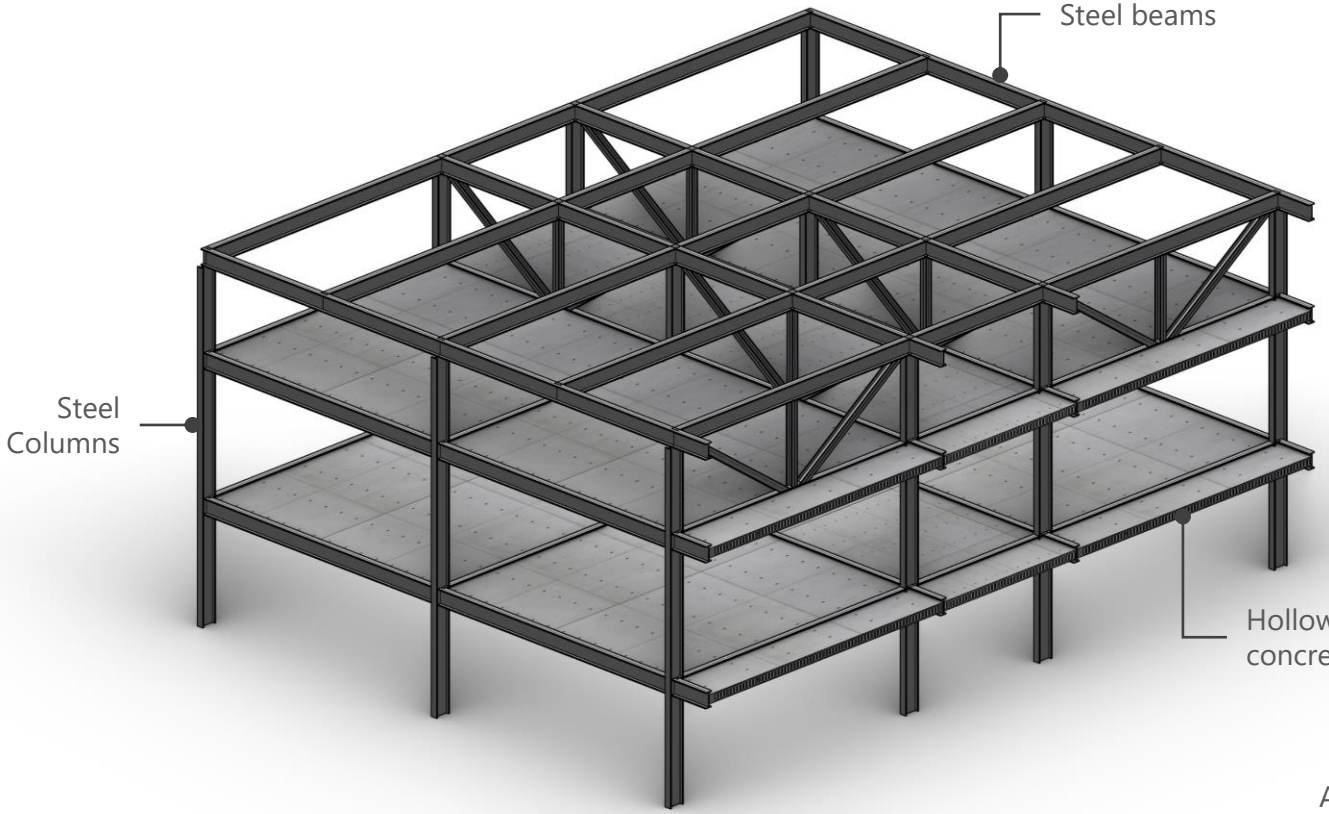
- Impact of **life span** of buildings and materials on embodied carbon
- Impact of **end of life** on embodied carbon
- Hypothesis check for artificial carbon sequestering materials

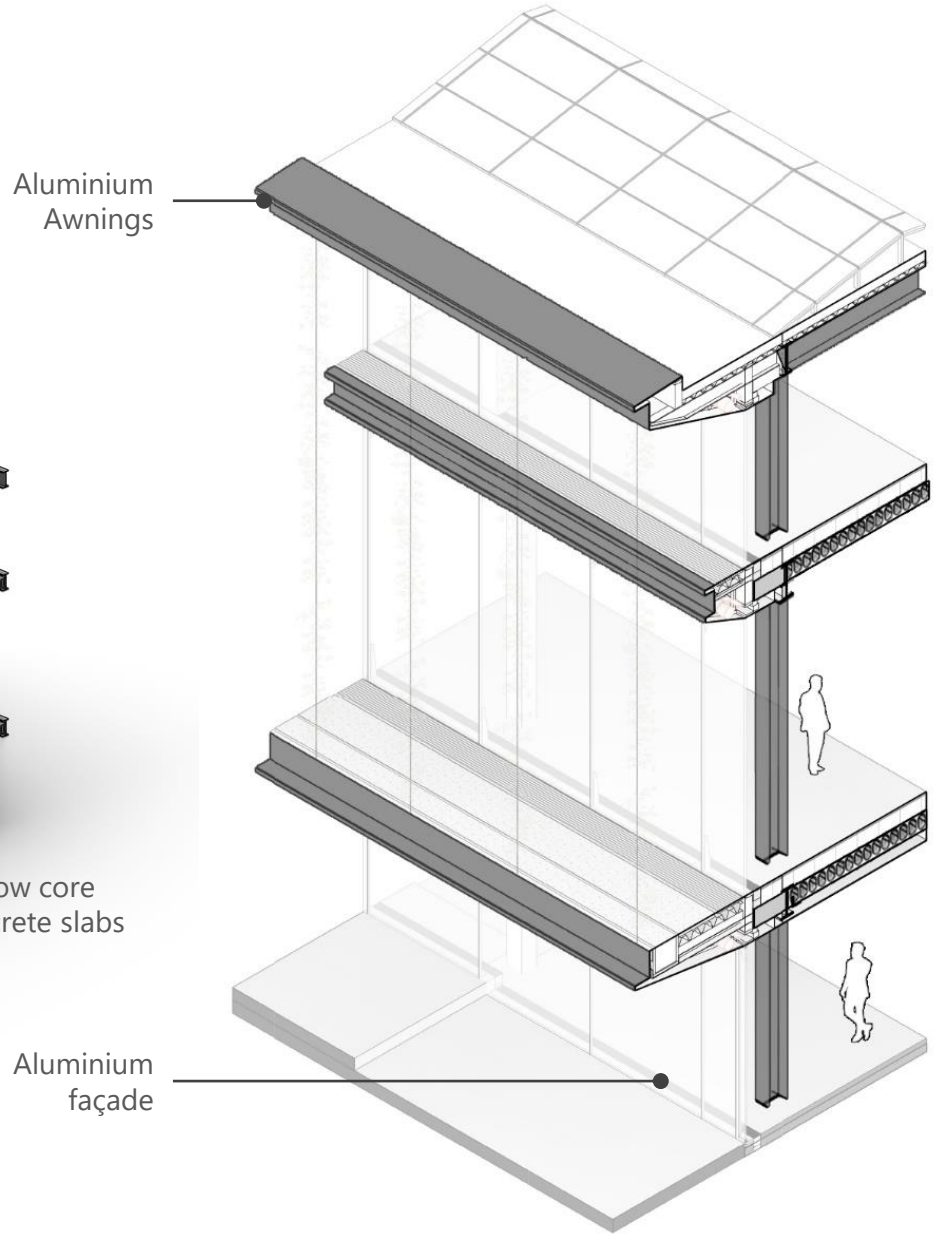


What does that mean for Echo building?

Existing design

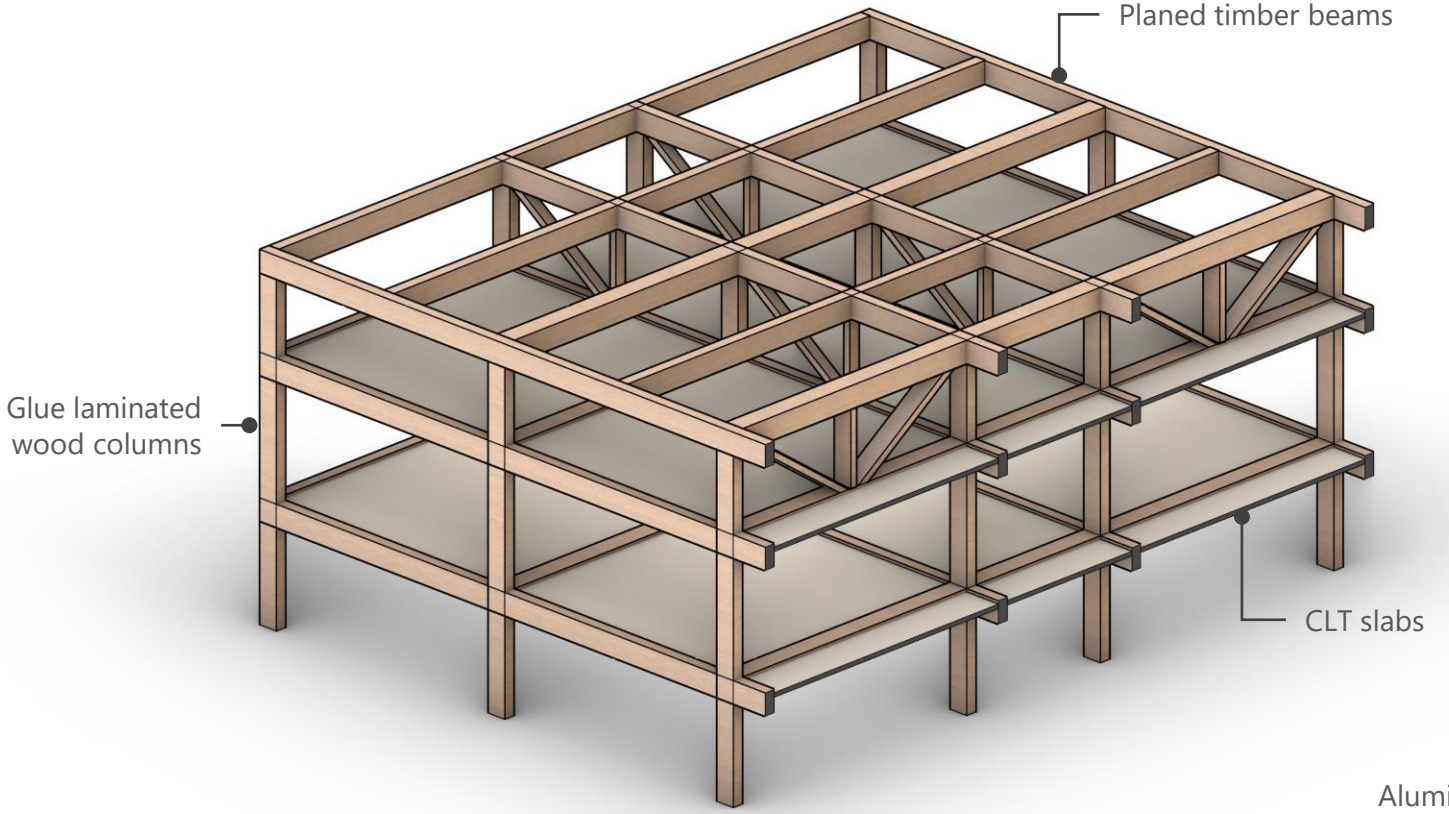
Materials used and construction detail

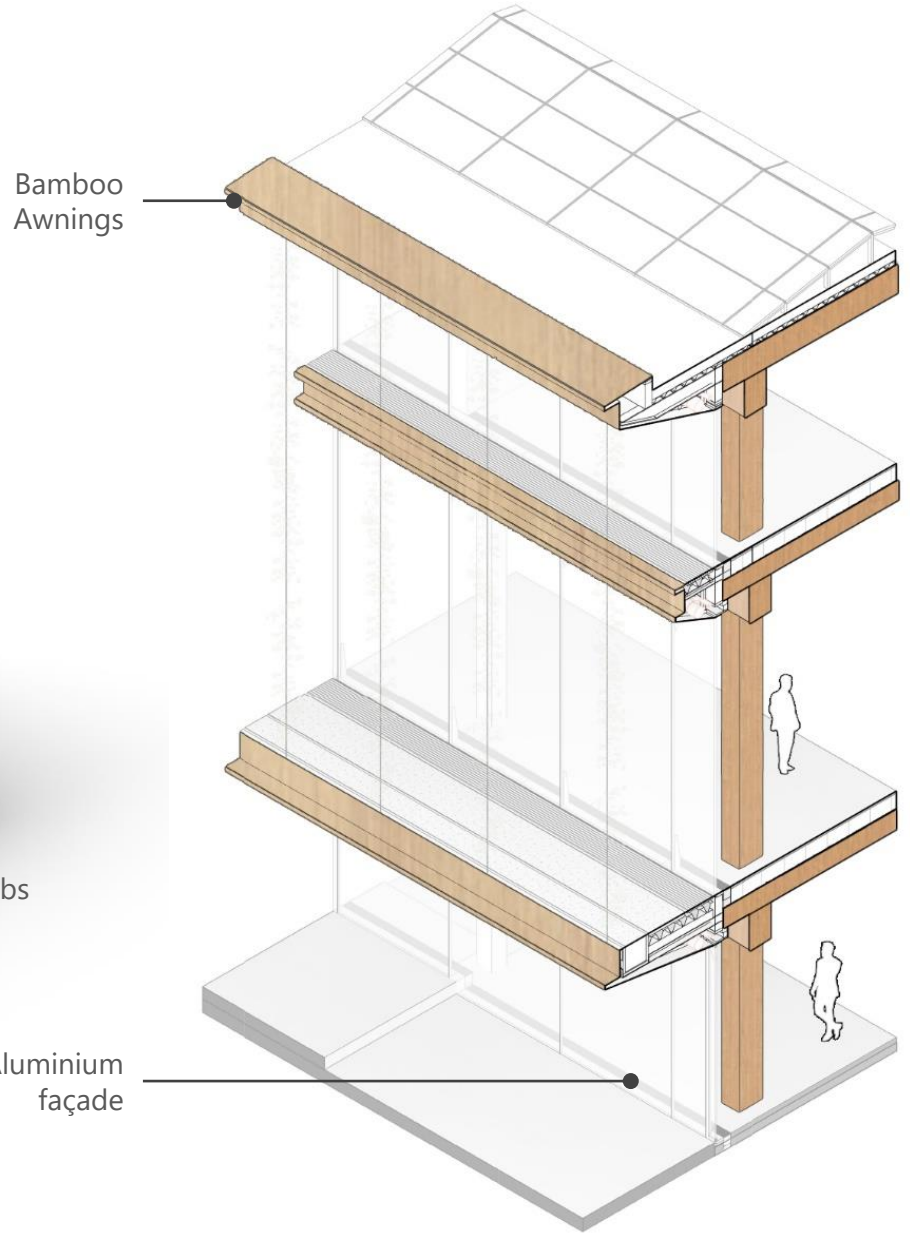




Proposed design

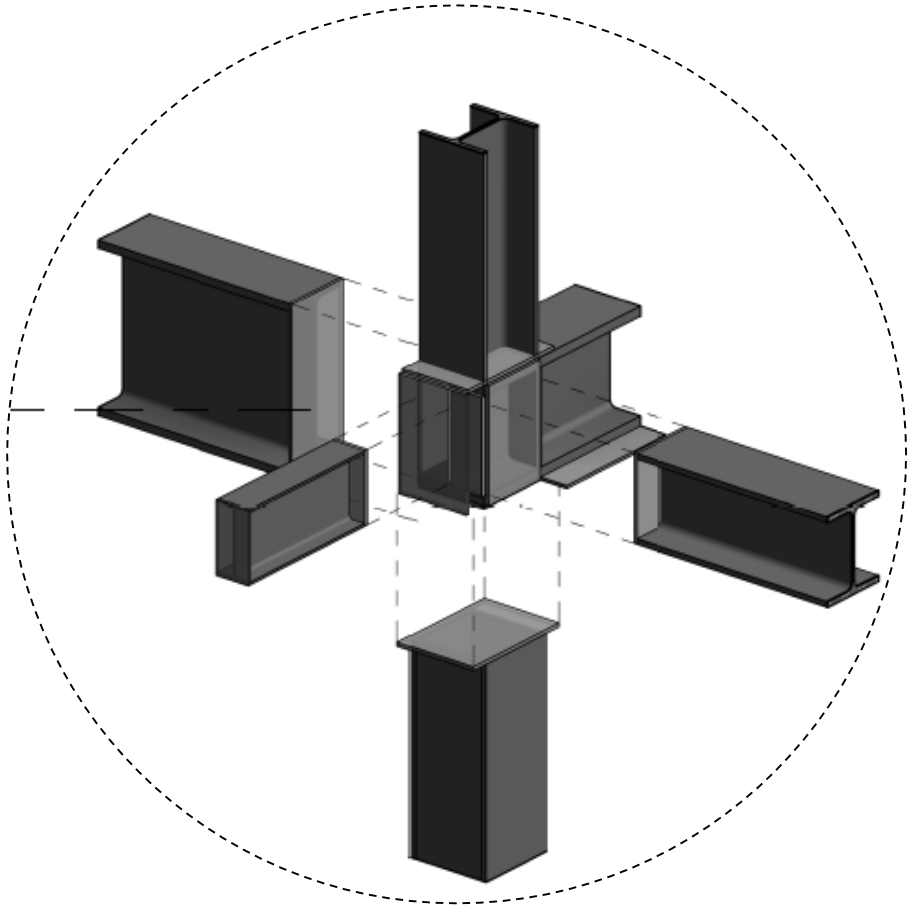
Materials used and construction detail



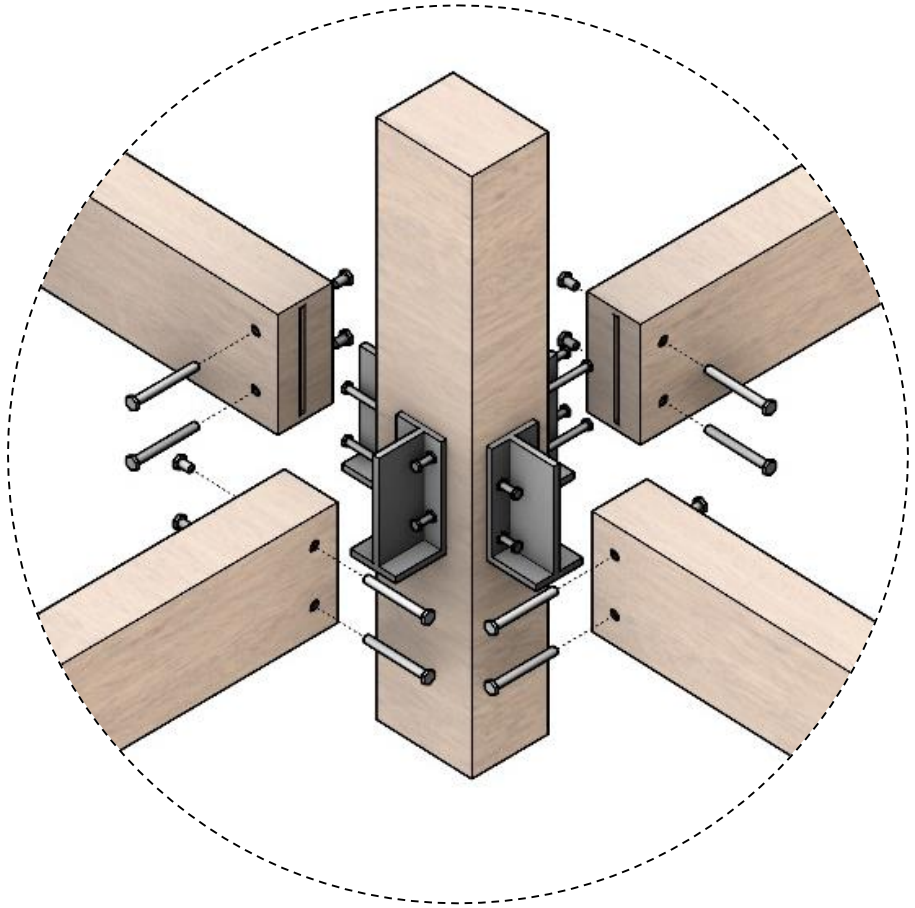


Details

Materials used and construction detail



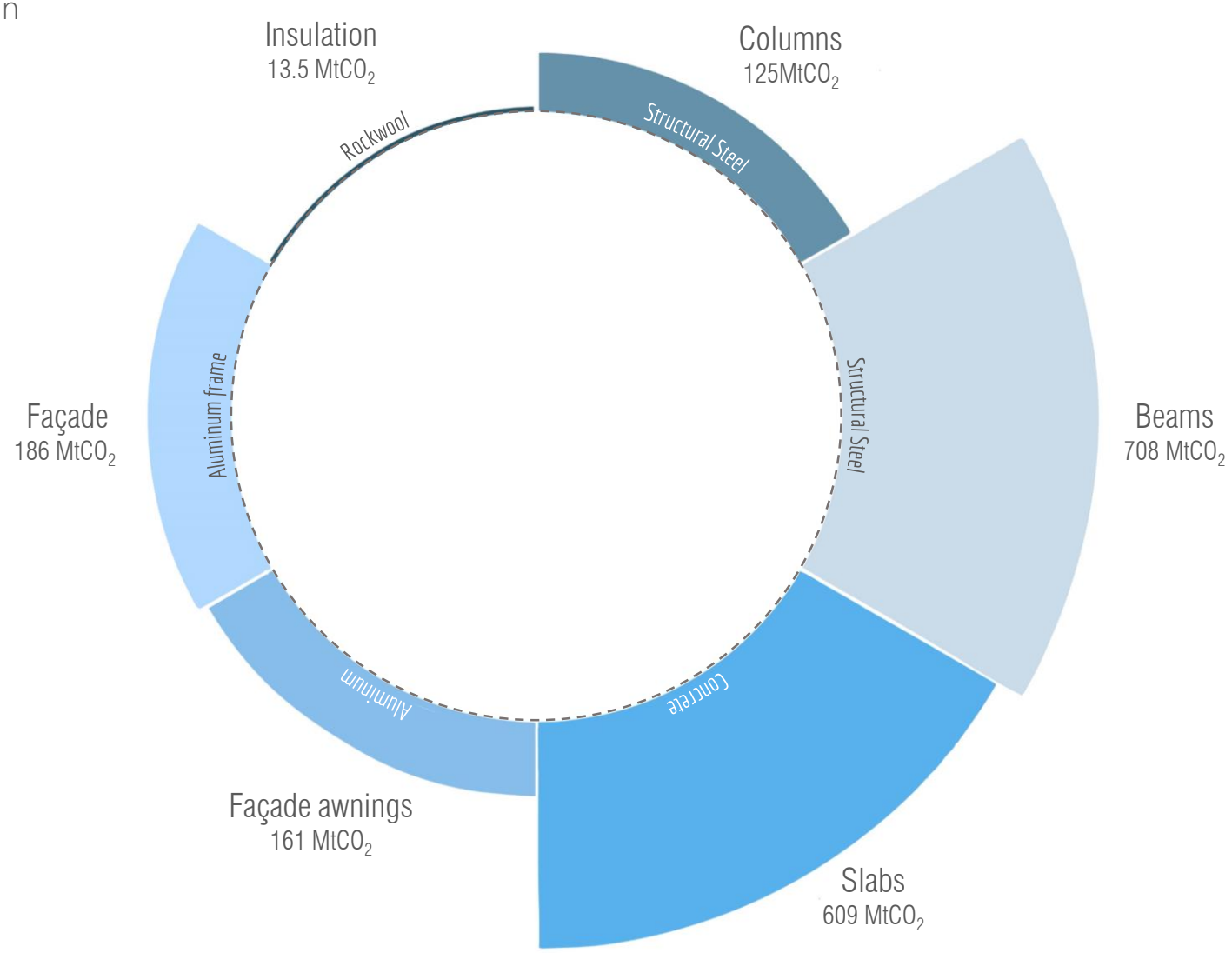
Existing Design



Proposed Design

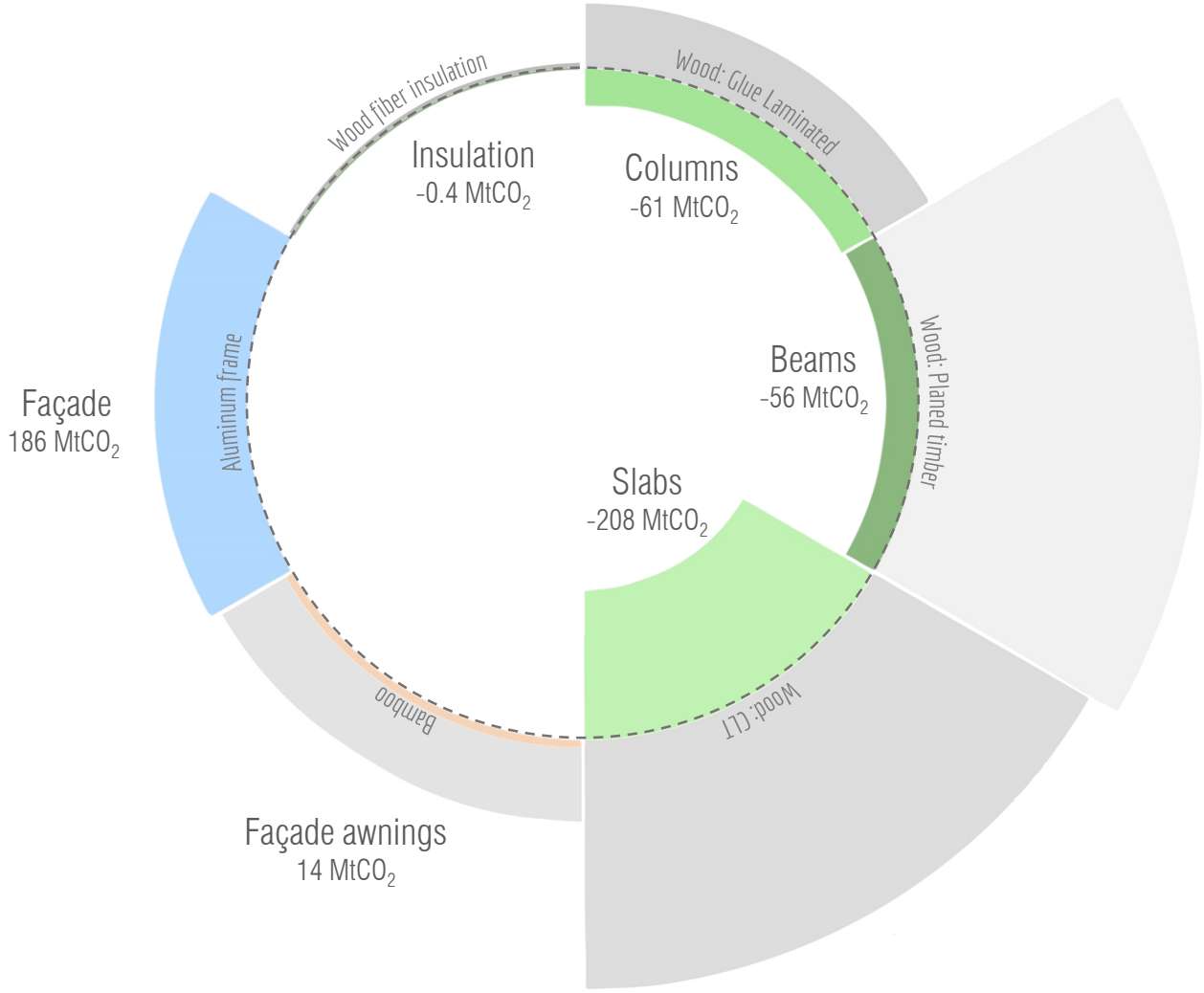
Results

Carbon emissions from existing design



Results

Carbon emissions from proposed design

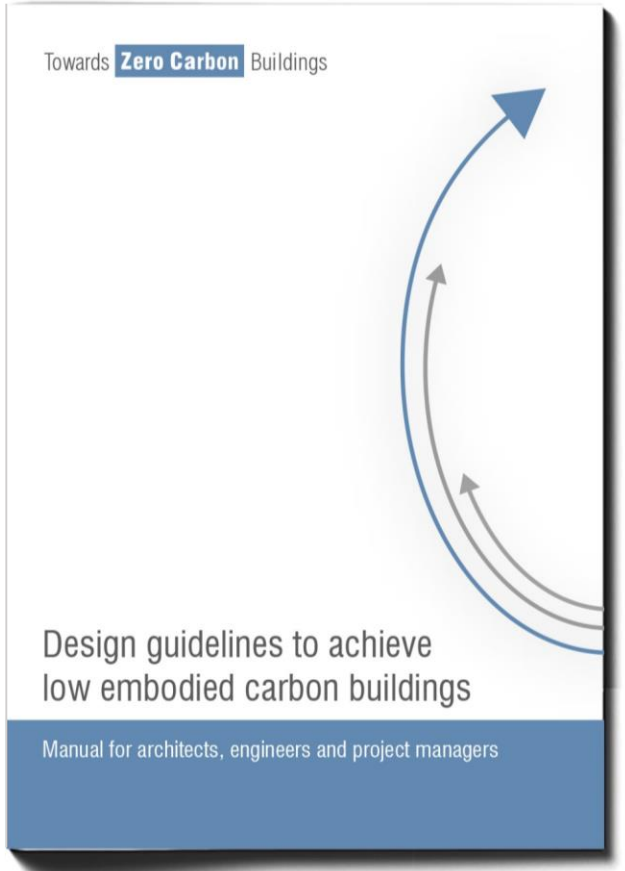


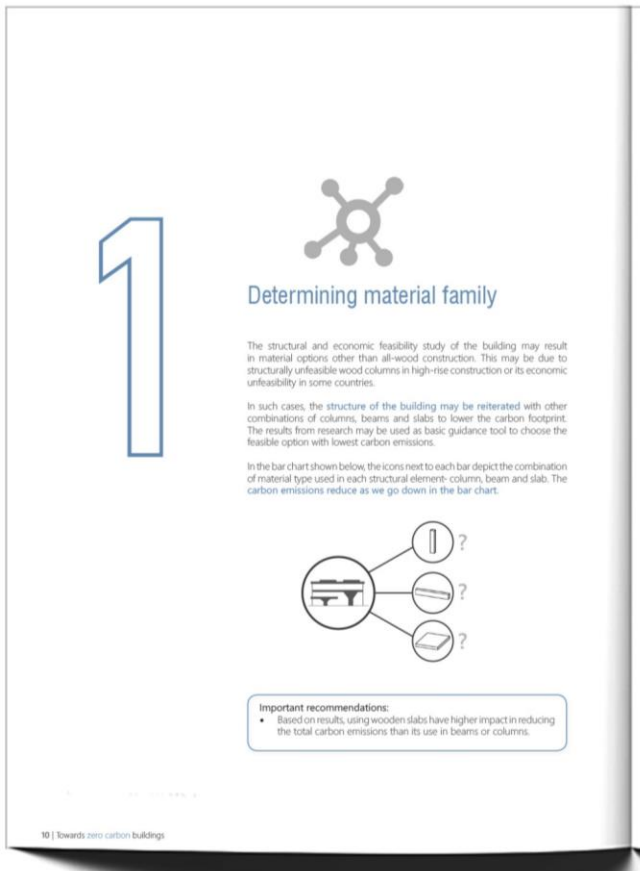
Results: summary for Echo Building

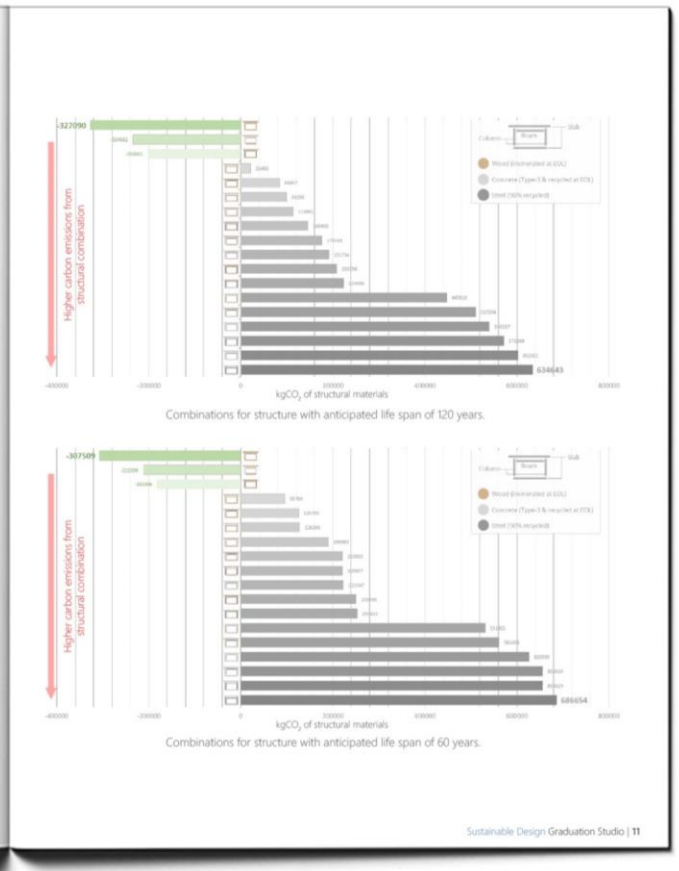
- **What?** **Bio-based materials** can serve as suitable alternatives
- **How much?** Almost **1900MtCO_2eq.** or **120% reduction** in carbon emissions
- **Offset period?** Carbon offset time reduces by **almost 30 years.**
- **120 years/ 60 years?** 120 years scenario has lower carbon footprint than 60 years (circular building)

Design Guidelines

For architects, engineers and project managers







Design Guidelines

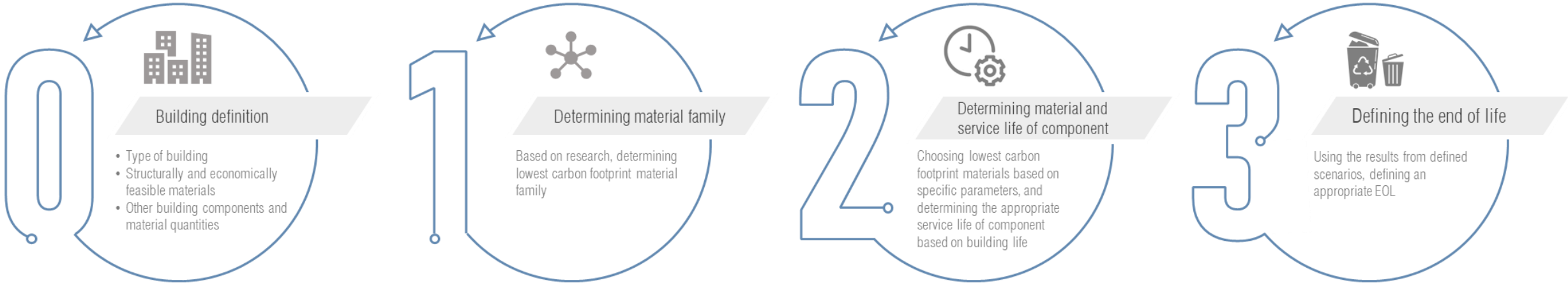
For architects, engineers and project managers

Aid **early design stage** to achieve feasible and low carbon building

Provides **estimation** to compare with benchmarks and green labels

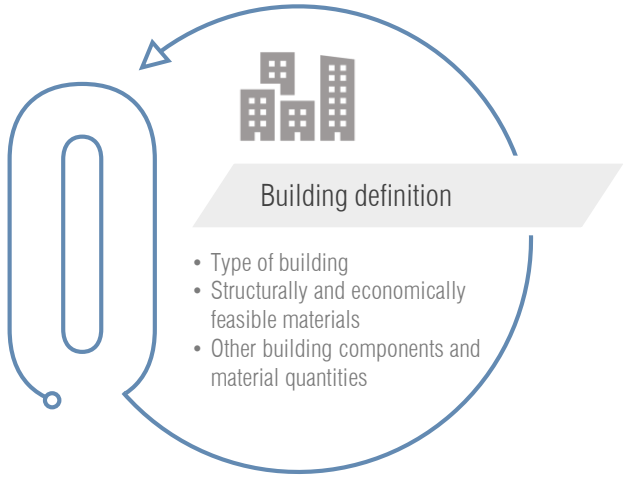
Design Guidelines

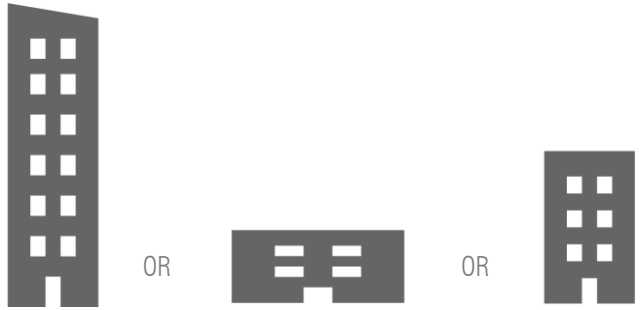
For architects, engineers and project managers



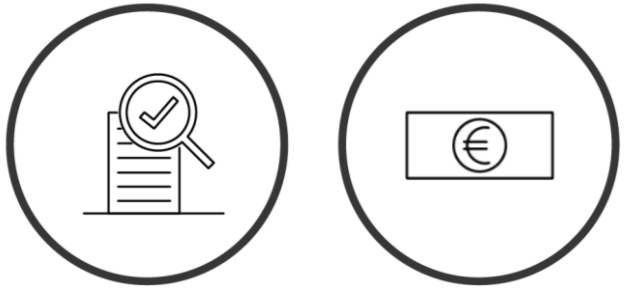
Design Guidelines

For architects, engineers and project managers





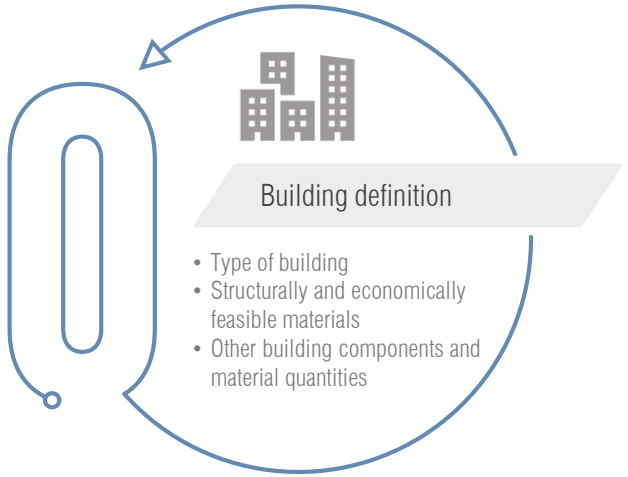
Defining the **type of construction**



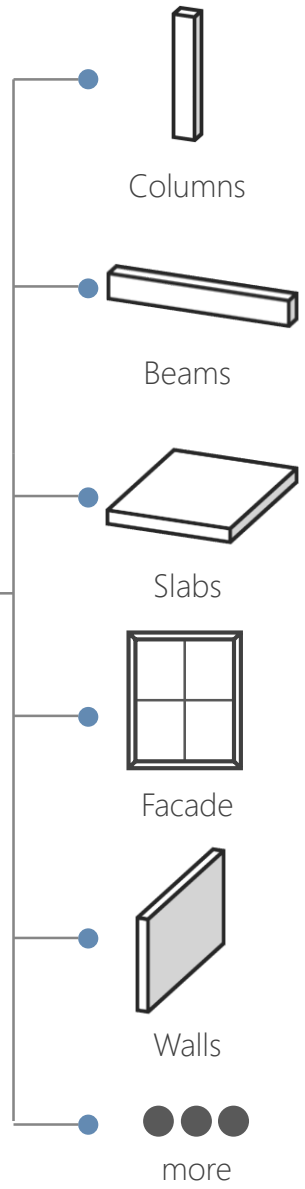
Checking **structural and economic** feasibility of material solutions

Design Guidelines

For architects, engineers and project managers

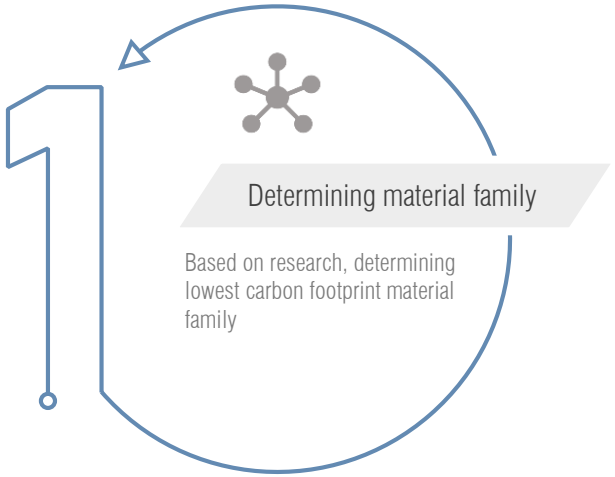


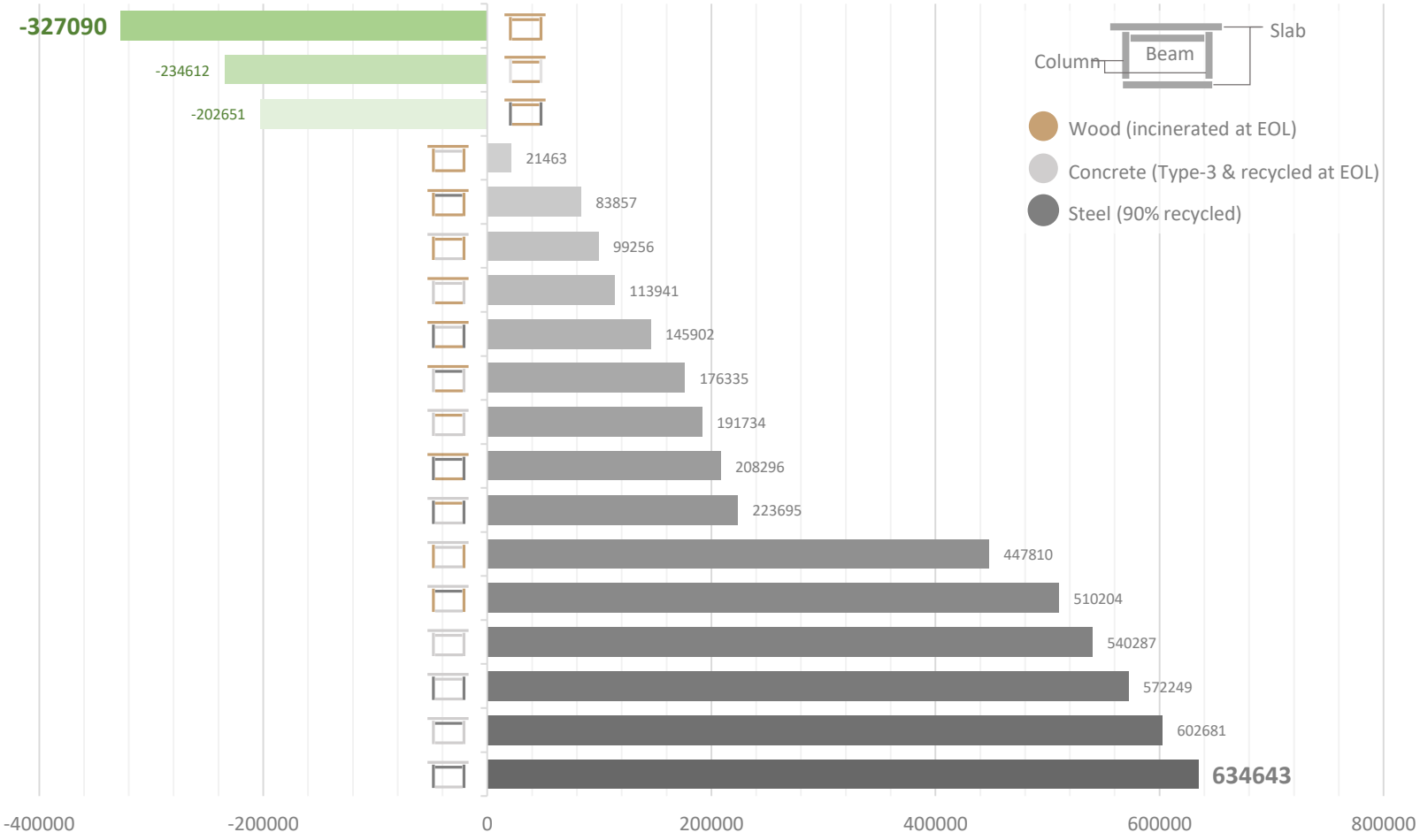
Determining the material **quantities** of each component



Design Guidelines

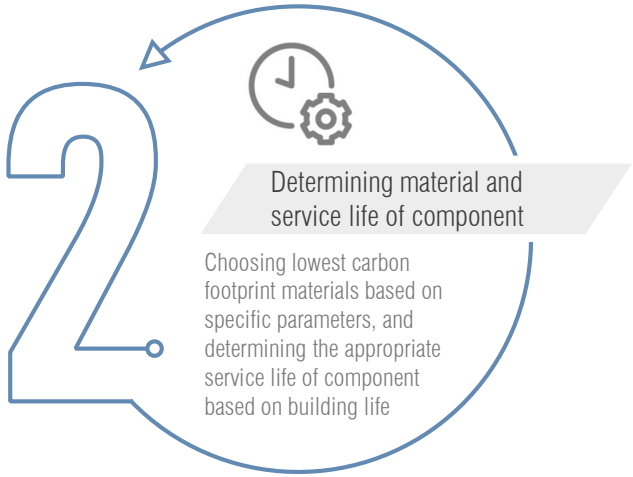
For architects, engineers and project managers

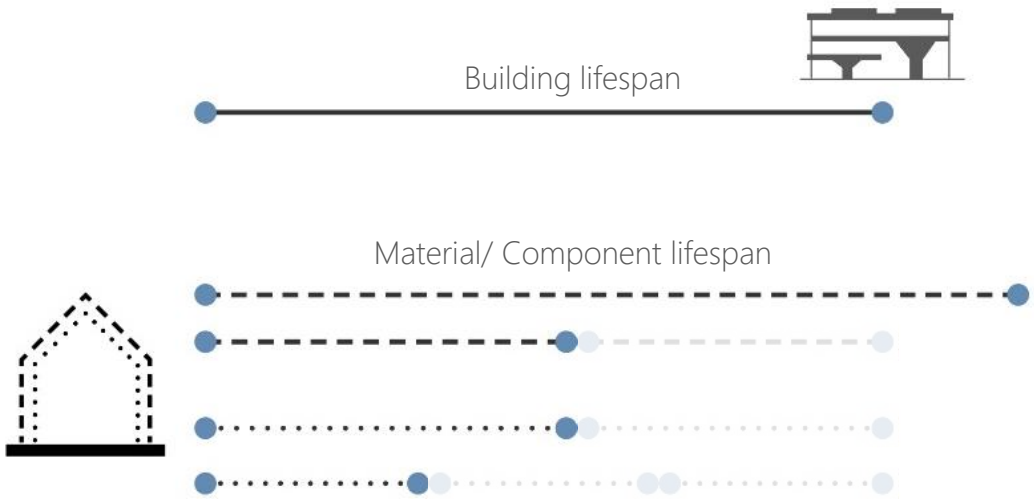




Design Guidelines

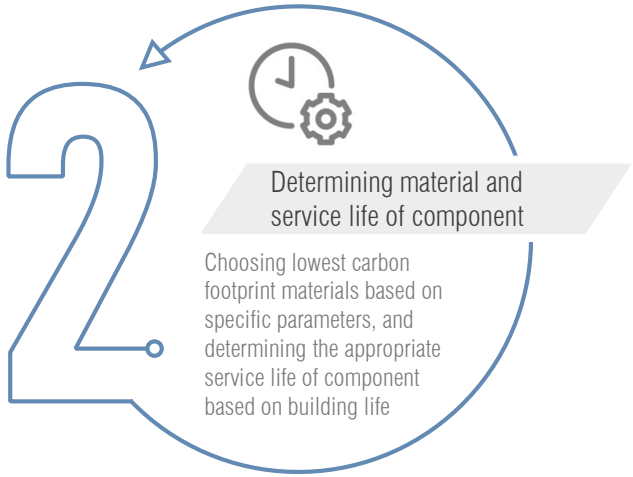
For architects, engineers and project managers





Design Guidelines

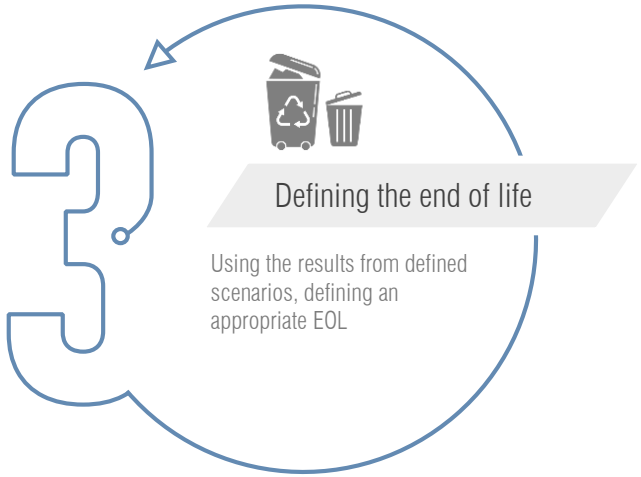
For architects, engineers and project managers



$$GWP_{1\,year} = \frac{GWP_{A1\text{-}A3} - E.R.P.}{S.L.}$$

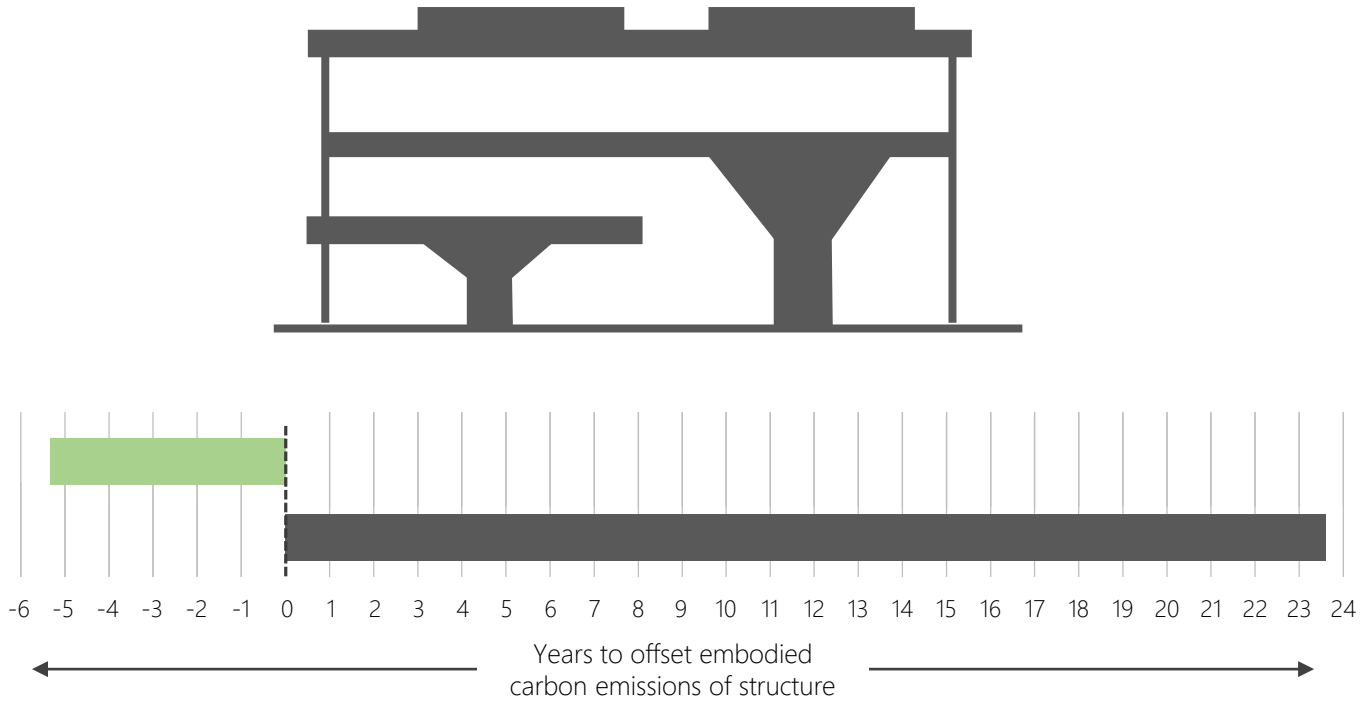
Design Guidelines

For architects, engineers and project managers



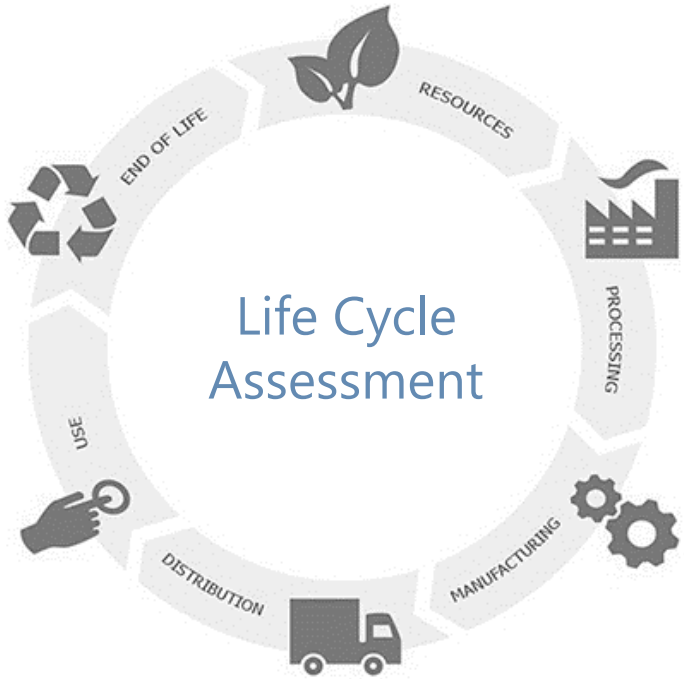
Relevance and Application

- Echo building and future projects- TU Delft Carbon Roadmap and CRE (Campus and Real Estate) department



Relevance and Application

- Echo building and future projects- TU Delft Carbon Roadmap and CRE (Campus and Real Estate) department
- Stepping stone in advancement of LCA- Integration of circularity in LCA



Relevance and Application

- Echo building and future projects- **TU Delft Carbon Roadmap** and **CRE (Campus and Real Estate) department**
- Stepping stone in advancement of LCA- **Integration of circularity in LCA**
- Highlighting the importance of **bio-based materials in mitigating climate change**

Relevance and Application

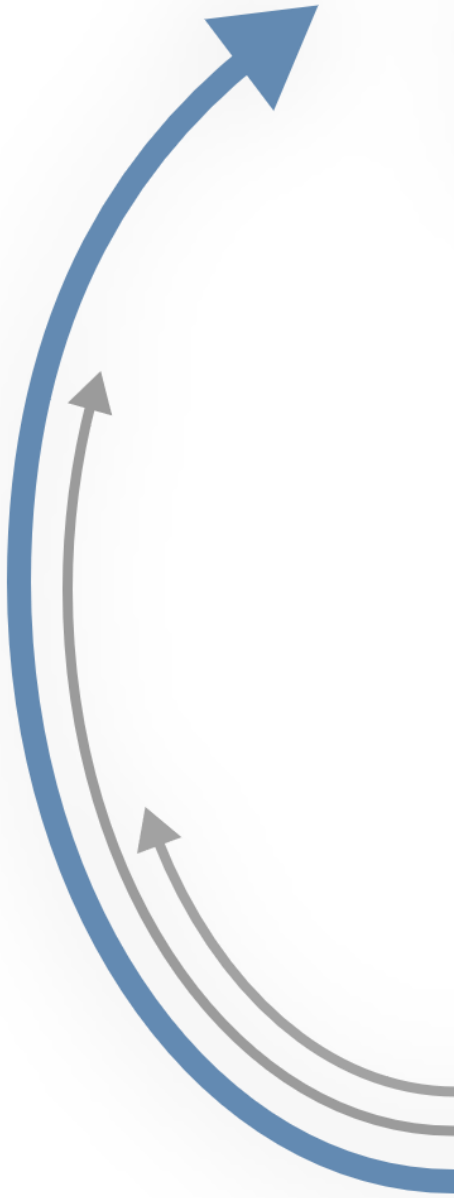
- Echo building and future projects- **TU Delft Carbon Roadmap** and **CRE (Campus and Real Estate) department**
- Stepping stone in advancement of LCA- **Integration of circularity in LCA**
- Highlighting the importance of **bio-based materials in mitigating climate change**
- **Highlighting the role** of policymakers, stakeholders and academia

> Using carbon might (must) soon become equivalent to using money and we'll have start making critical choices while spending it

Let's start acting on it!

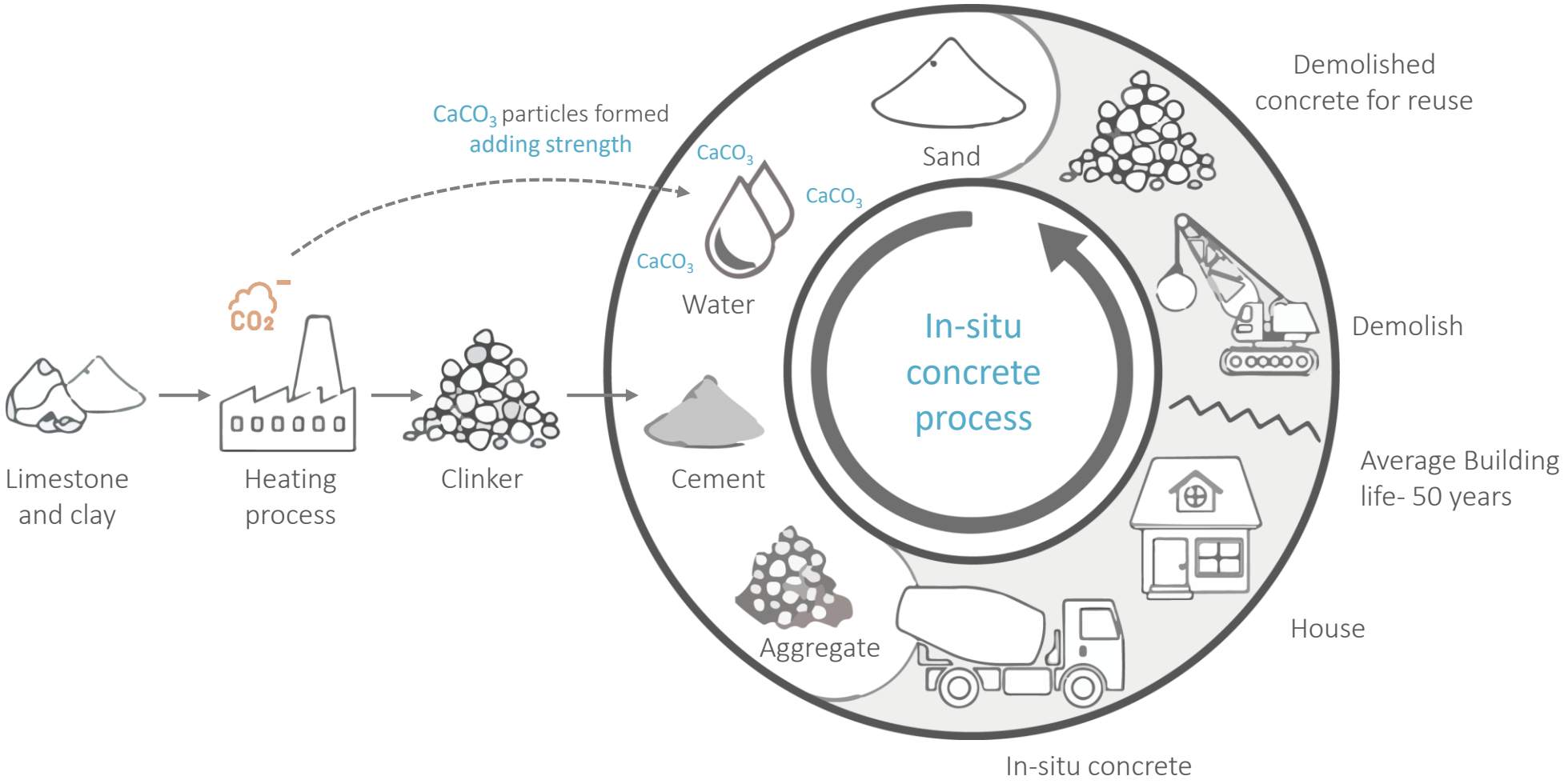
Thank you!

Questions?



Artificial carbon sequestration

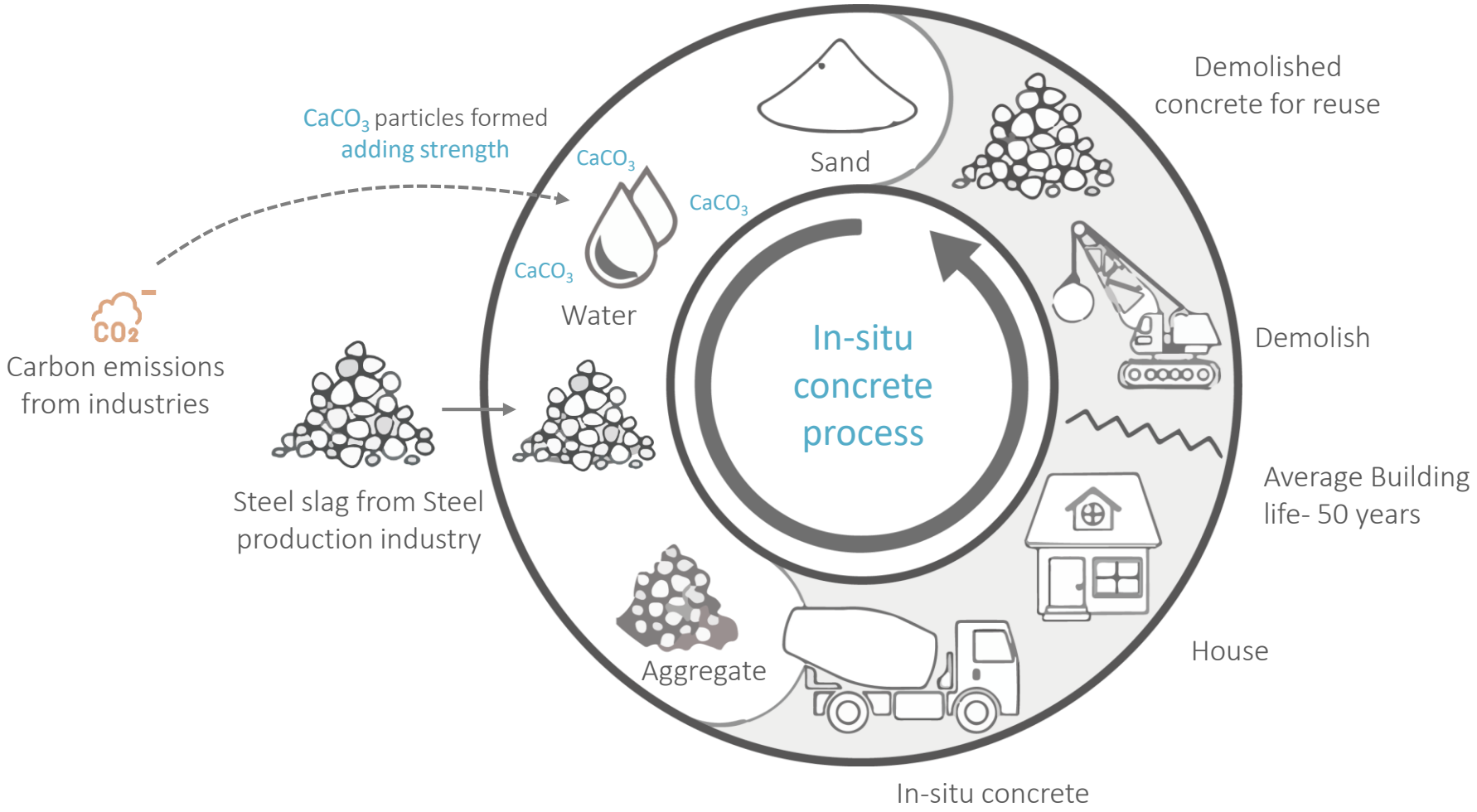
Method 1: Capturing CO2 from industries and curing concrete with it



Artificial carbon sequestration

Method 1: Capturing CO2 from industries and curing concrete with it

Method 2: Using steel slag in place of cement

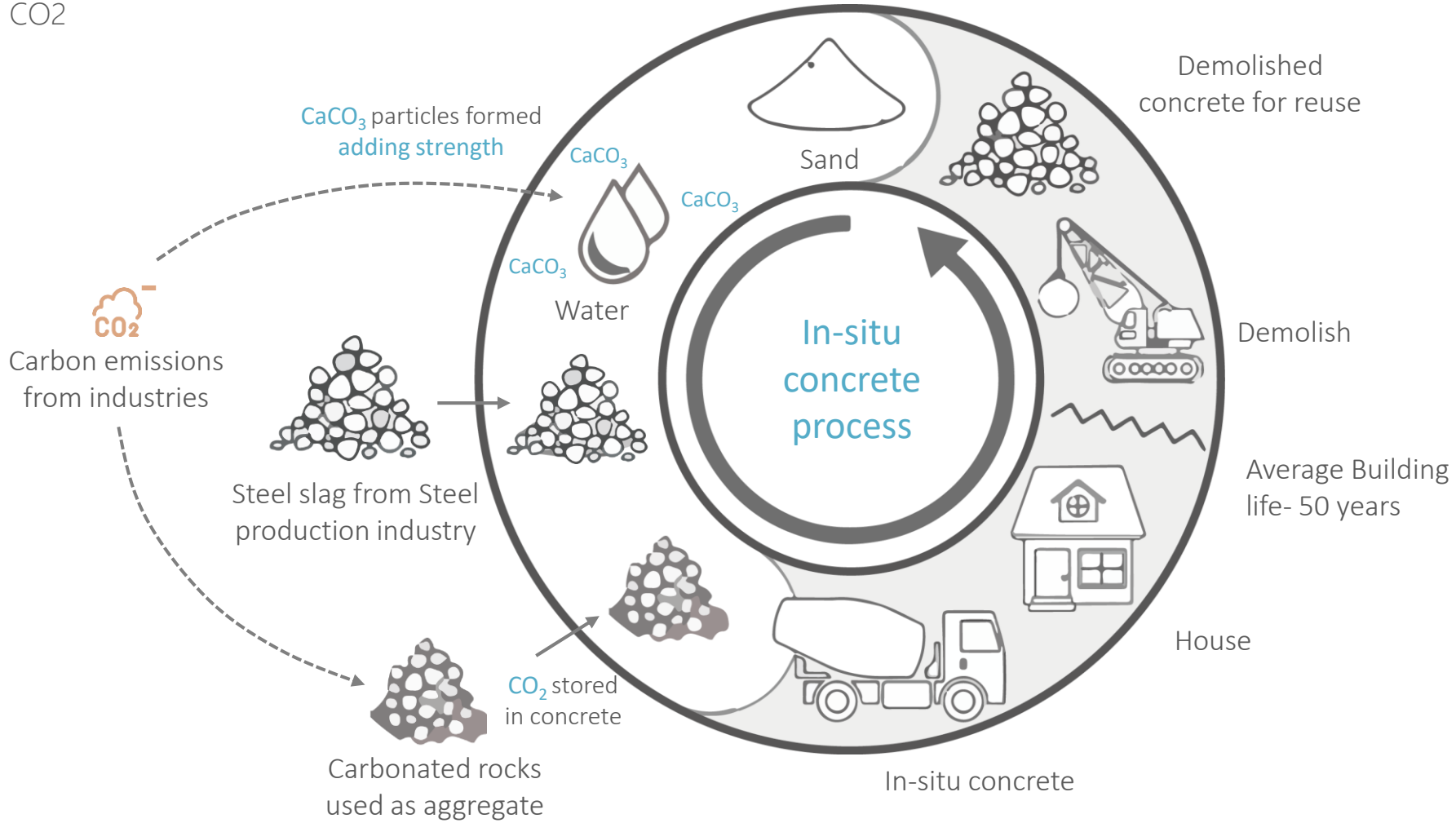


Artificial carbon sequestration

Method 1: Capturing CO2 from industries and curing concrete with it

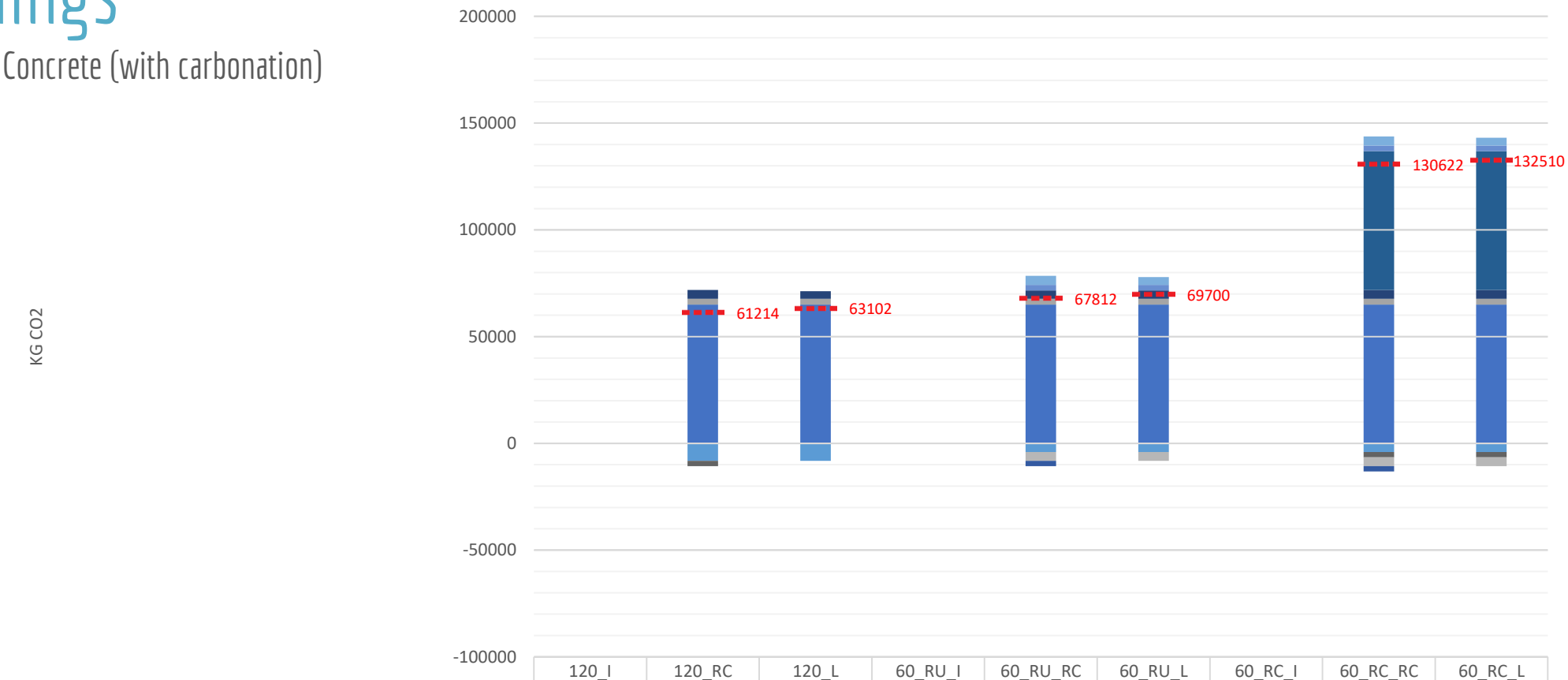
Method 2: Using steel slag in place of cement

Method 3: Forming aggregates using CO2



Findings

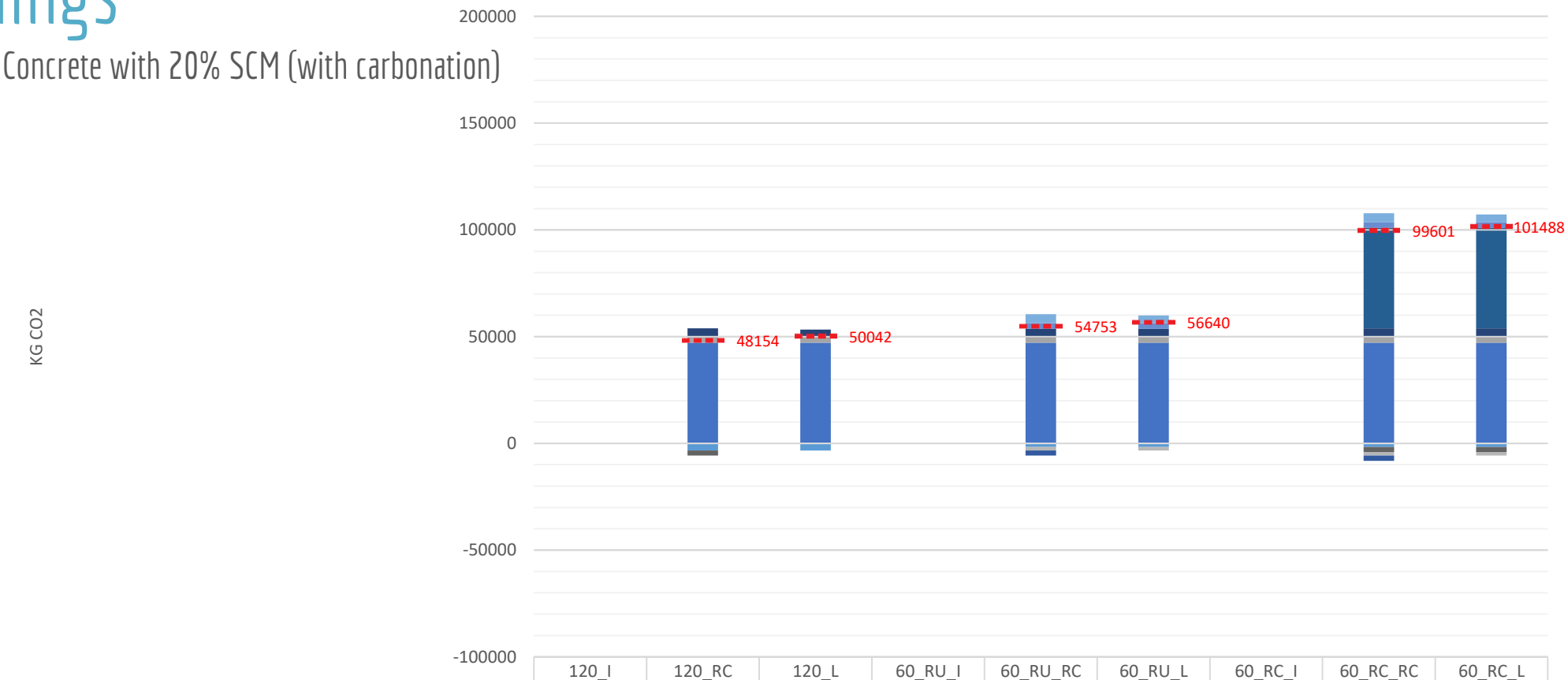
Column- Concrete (with carbonation)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account					-2450			-2450	
Second Life End of Life (C1'-C4')					4167	3605		4167	3605
Second Life Maintenance and replacement (B1'-B5')					-4097	-4097		-4097	-4097
Second Life Transportation (A4')					2629	2629		2629	2629
Second Life Primary Production (A1'-A3')								65062	65062
First Life External Impacts (D) *A5 not included		-2450						-2450	-2450
First Life End of Life (C1-C4) *A5 not included		4167	3605		3969	3969		4167	4167
First Life Maintenance and replacement (B1-B5) *A5 not included		-8194	-8194		-4097	-4097		-4097	-4097
First Life Transportation (A4) *A5 not included		2629	2629		2629	2629		2629	2629
First Life Primary Production (A1-A3)		65062	65062		65062	65062		65062	65062

Findings

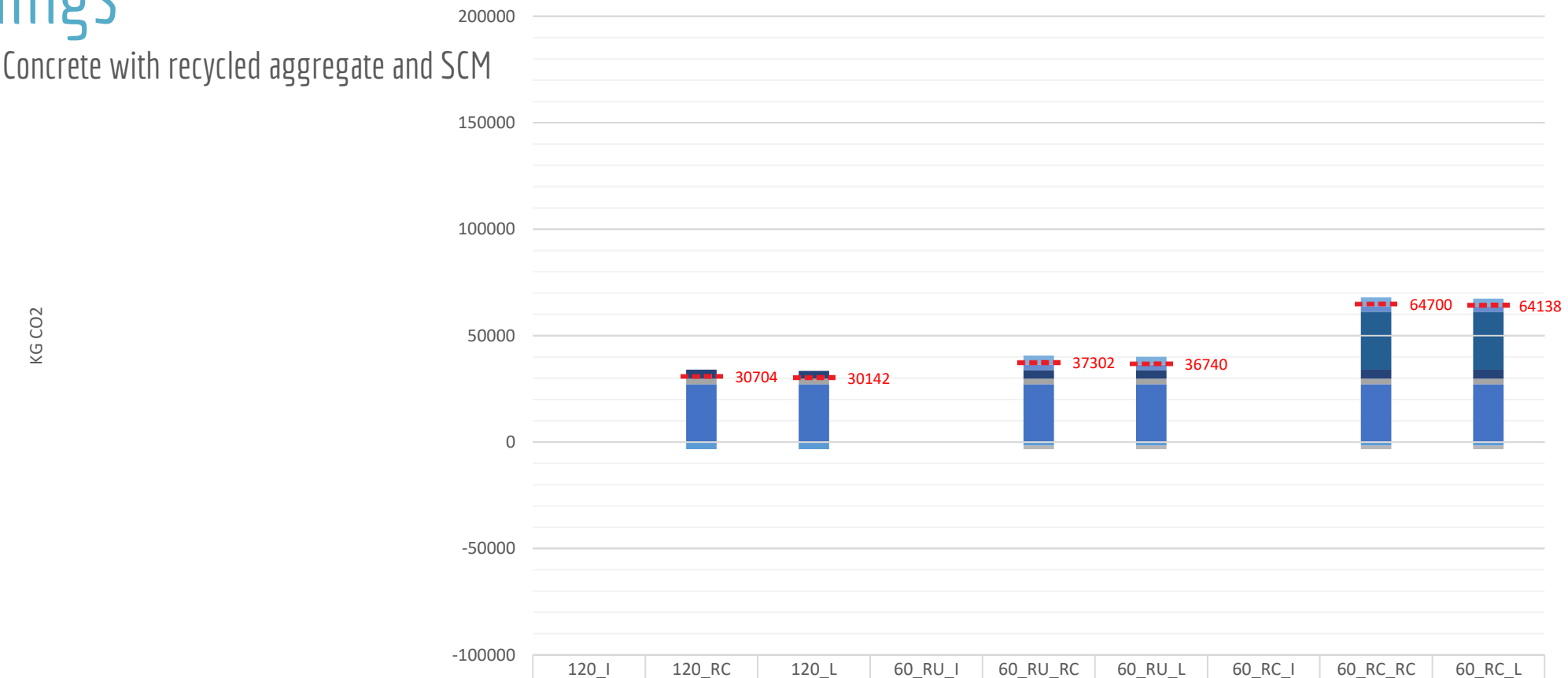
Column- Concrete with 20% SCM (with carbonation)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account					-2450			-2450	
Second Life End of Life (C1'-C4')					4167	3605		4167	3605
Second Life Maintenance and replacement (B1'-B5')					-1646	-1646		-1646	-1646
Second Life Transportation (A4')					2629	2629		2629	2629
Second Life Primary Production (A1'-A3')								47100	47100
First Life External Impacts (D) *A5 not included		-2450						-2450	-2450
First Life End of Life (C1-C4) *A5 not included		4167	3605		3969	3969		4167	4167
First Life Maintenance and replacement (B1-B5) *A5 not included		-3292	-3292		-1646	-1646		-1646	-1646
First Life Transportation (A4) *A5 not included		2629	2629		2629	2629		2629	2629
First Life Primary Production (A1-A3)		47100	47100		47100	47100		47100	47100

Findings

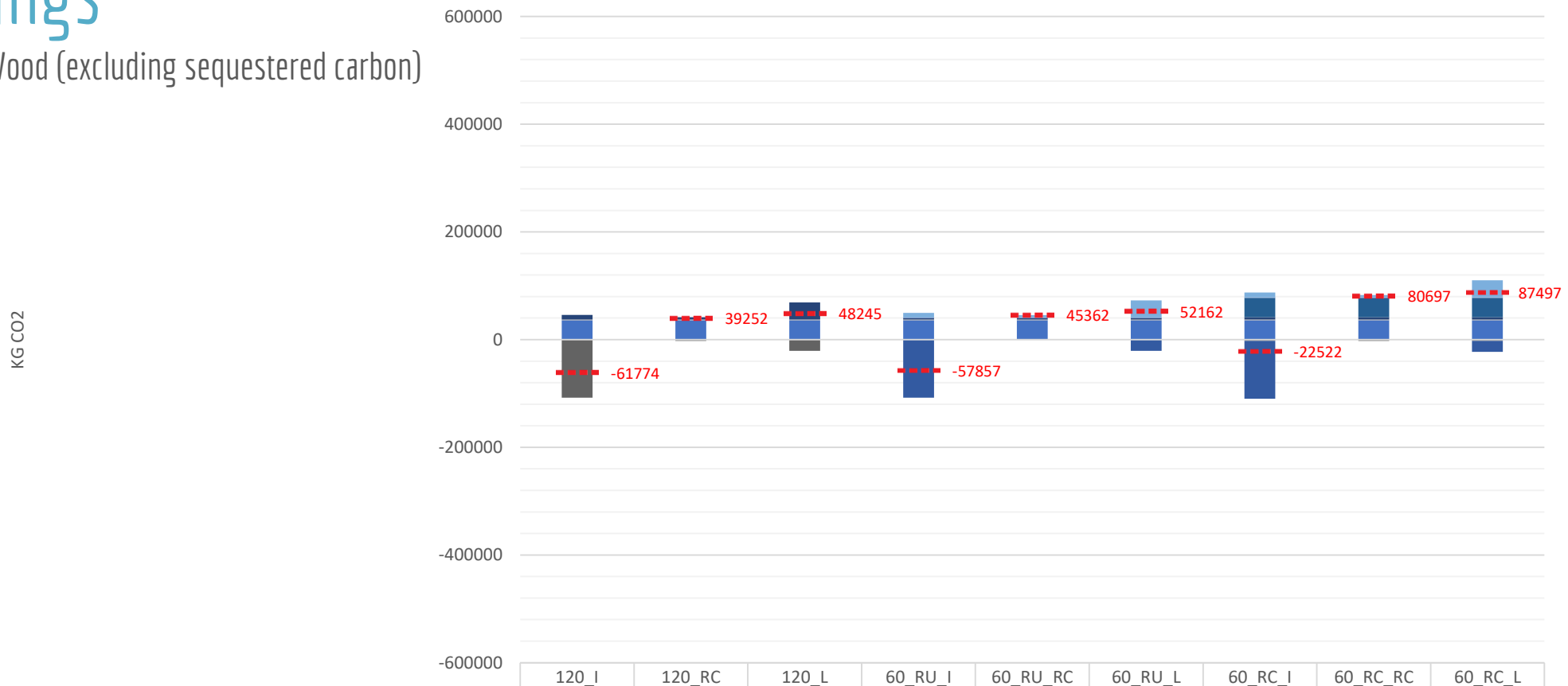
Column- Concrete with recycled aggregate and SCM



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account									
Second Life End of Life (C1'-C4')					4167	3605		4167	3605
Second Life Maintenance and replacement (B1'-B5')					-1646	-1646		-1646	-1646
Second Life Transportation (A4')					2629	2629		2629	2629
Second Life Primary Production (A1'-A3')								27200	27200
First Life External Impacts (D) *A5 not included									
First Life End of Life (C1-C4) *A5 not included		4167	3605		3969	3969		4167	4167
First Life Maintenance and replacement (B1-B5) *A5 not included		-3292	-3292		-1646	-1646		-1646	-1646
First Life Transportation (A4) *A5 not included		2629	2629		2629	2629		2629	2629
First Life Primary Production (A1-A3)		27200	27200		27200	27200		27200	27200

Findings

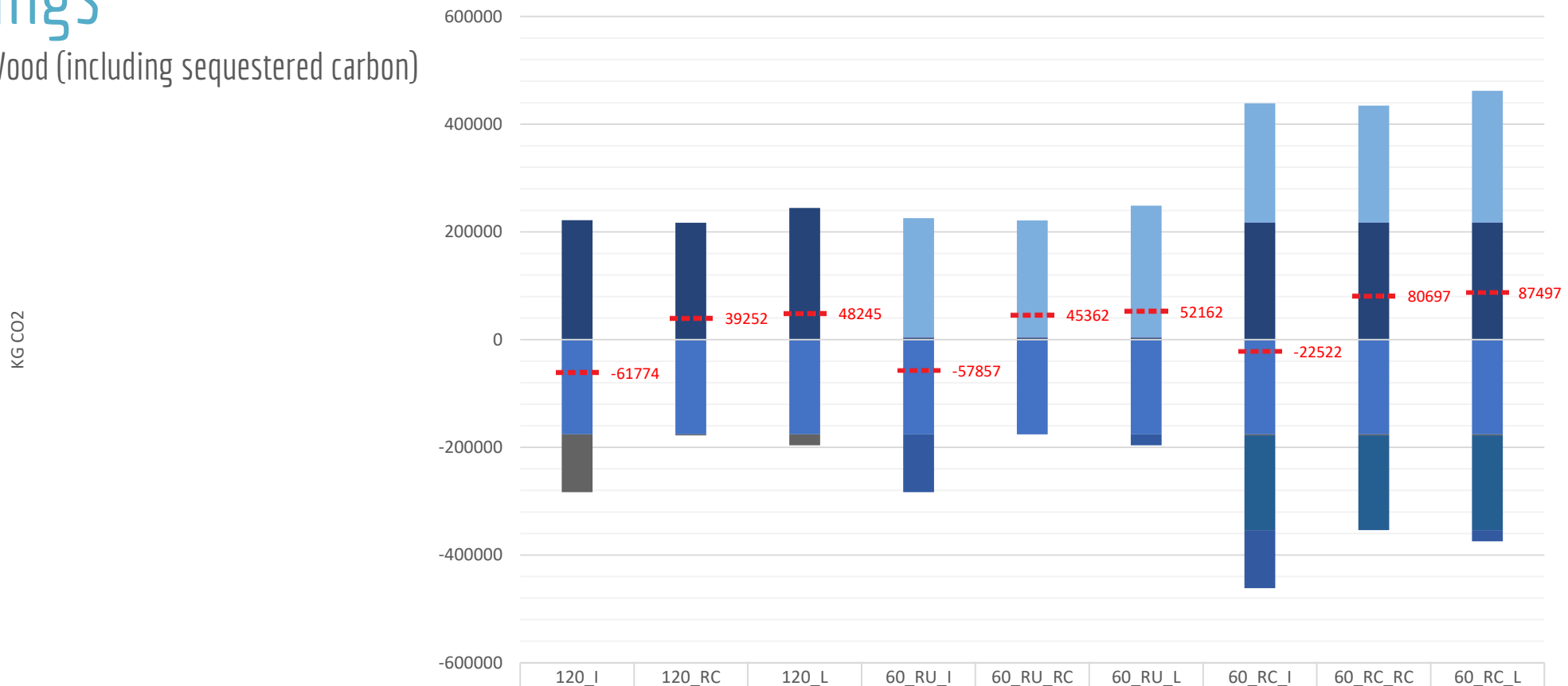
Column- Wood (excluding sequestered carbon)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account				-107698	0	-20627	-107698	0	-20627
Second Life End of Life (C1'-C4')				8736	4257	31684	8736	4257	31684
Second Life Maintenance and replacement (B1'-B5')				0	0	0	0	0	0
Second Life Transportation (A4')				1098	1098	1098	1098	1098	1098
Second Life Primary Production (A1'-A3')							36091	36091	36091
First Life External Impacts (D) *A5 not included	-107698	-2193	-20627				-2193	-2193	-2193
First Life End of Life (C1-C4) *A5 not included	8736	4257	31684	2819	2819	2819	4257	4257	4257
First Life Maintenance and replacement (B1-B5) *A5 not included	0	0	0	0	0	0	0	0	0
First Life Transportation (A4) *A5 not included	1098	1098	1098	1098	1098	1098	1098	1098	1098
First Life Primary Production (A1-A3)	36091	36091	36091	36091	36091	36091	36091	36091	36091

Findings

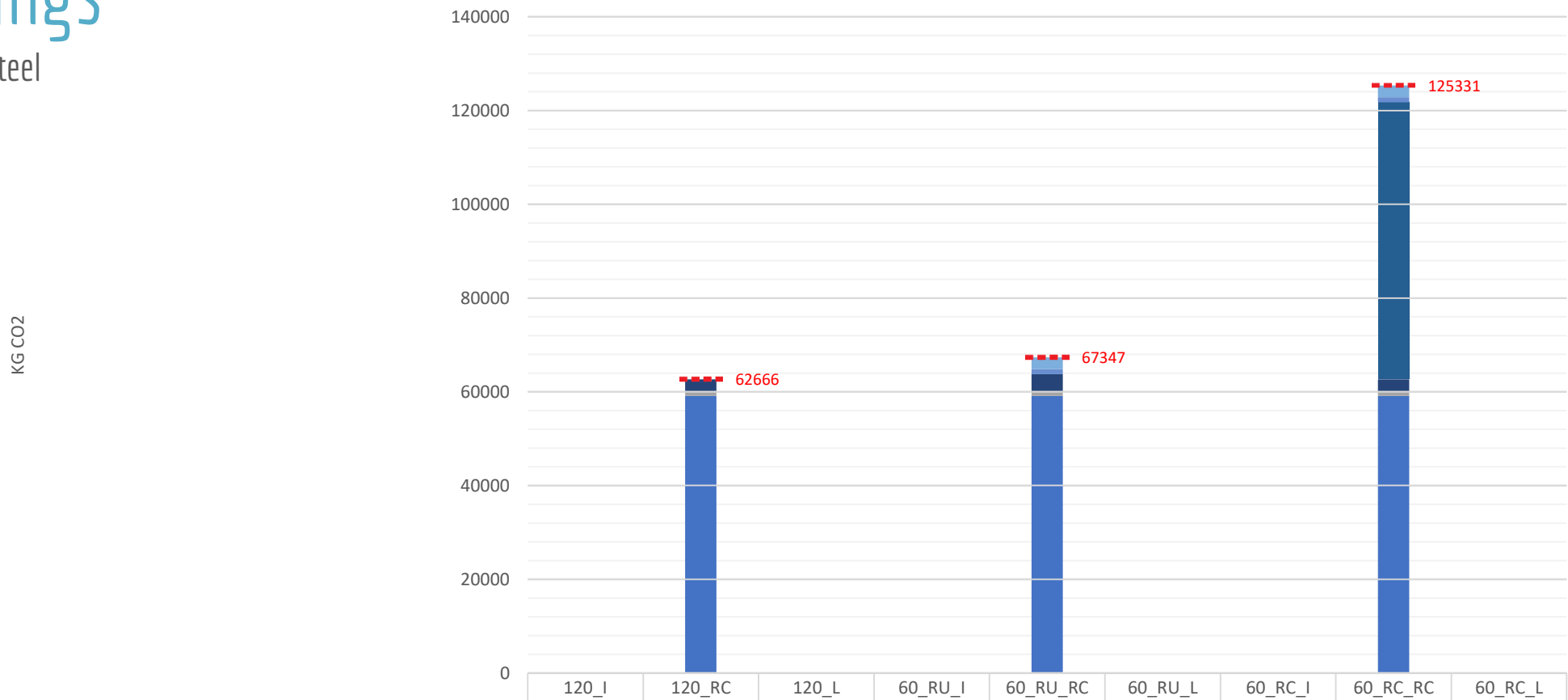
Column- Wood (including sequestered carbon)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account				-107698	0	-20627	-107698	0	-20627
Second Life End of Life (C1'-C4')				220611	216132	243559	220611	216132	243559
Second Life Maintenance and replacement (B1'-B5')				0	0	0	0	0	0
Second Life Transportation (A4')				1098	1098	1098	1098	1098	1098
Second Life Primary Production (A1'-A3')							-175785	-175785	-175785
First Life External Impacts (D) *A5 not included	-107698	-2193	-20627				-2193	-2193	-2193
First Life End of Life (C1-C4) *A5 not included	220611	216132	243559	2819	2819	2819	216132	216132	216132
First Life Maintenance and replacement (B1-B5) *A5 not included	0	0	0	0	0	0	0	0	0
First Life Transportation (A4) *A5 not included	1098	1098	1098	1098	1098	1098	1098	1098	1098
First Life Primary Production (A1-A3)	-175785	-175785	-175785	-175785	-175785	-175785	-175785	-175785	-175785

Findings

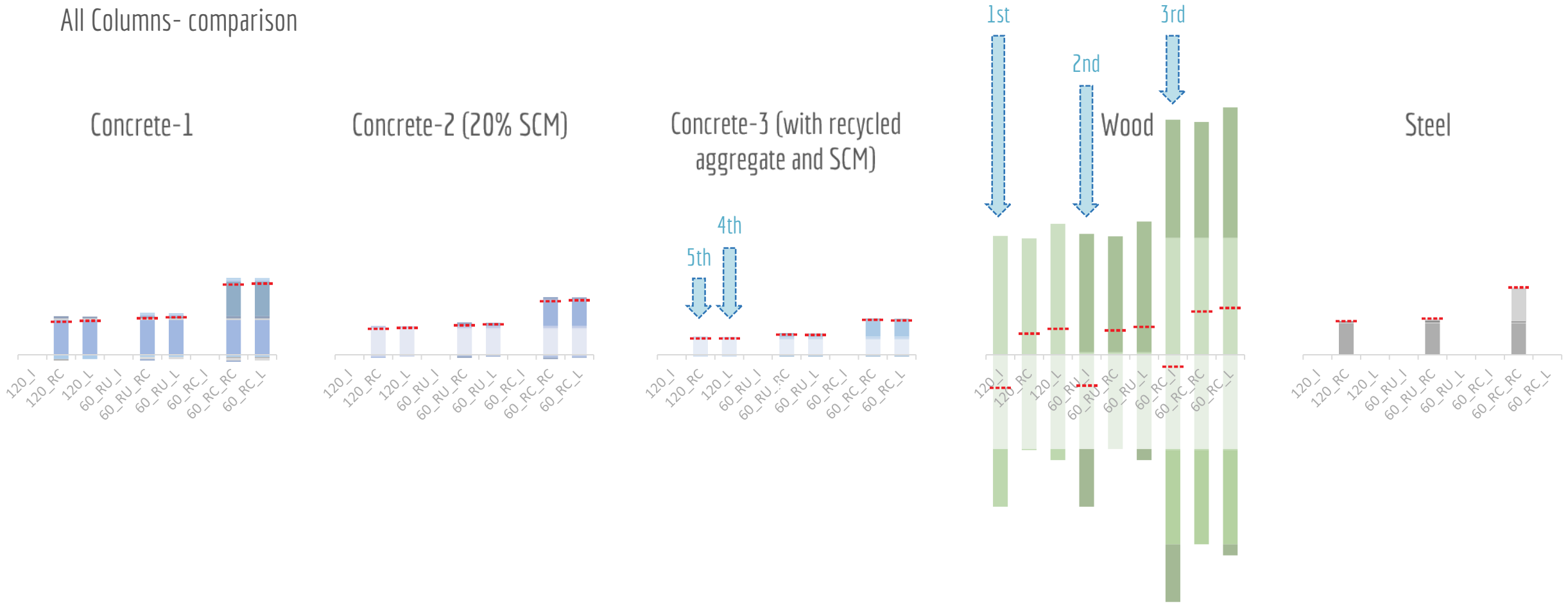
Column- Steel



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account									
Second Life End of Life (C1'-C4')					2474			2474	
Second Life Maintenance and replacement (B1'-B5')									
Second Life Transportation (A4')					1092			1092	
Second Life Primary Production (A1'-A3')								59100	
First Life External Impacts (D) *A5 not included									
First Life End of Life (C1-C4) *A5 not included		2474			3589			2474	
First Life Maintenance and replacement (B1-B5) *A5 not included									
First Life Transportation (A4) *A5 not included		1092			1092			1092	
First Life Primary Production (A1-A3)		59100			59100			59100	

Findings

All Columns- comparison

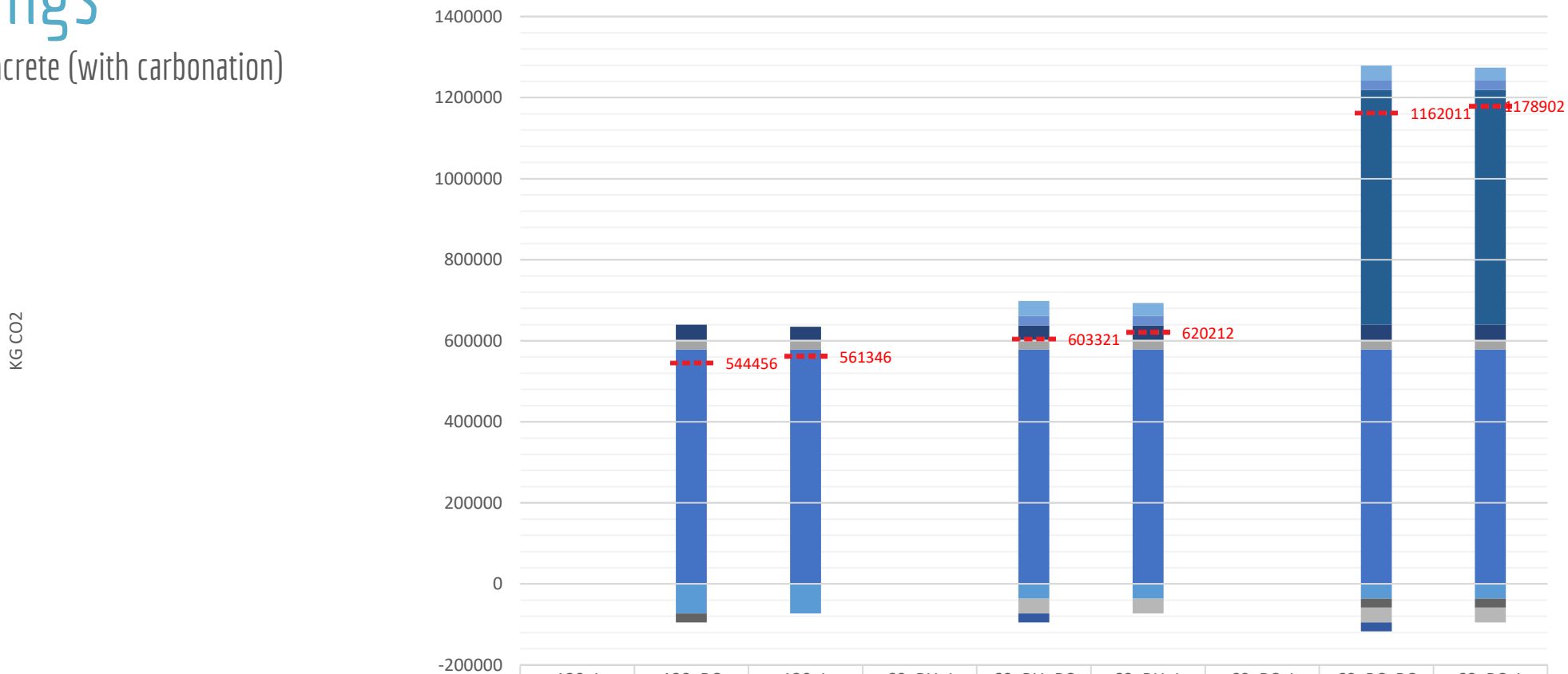


Original presumed choice

Steel	Wood	Wood	Wood	Concrete-3	Concrete-3	
60_RC_RC	120_I	60_RU_I	60_RC_I	120_L	120_L	
125,331	-61,774	-57,857	-22,522	30,142	30,704	Kg CO_2

Findings

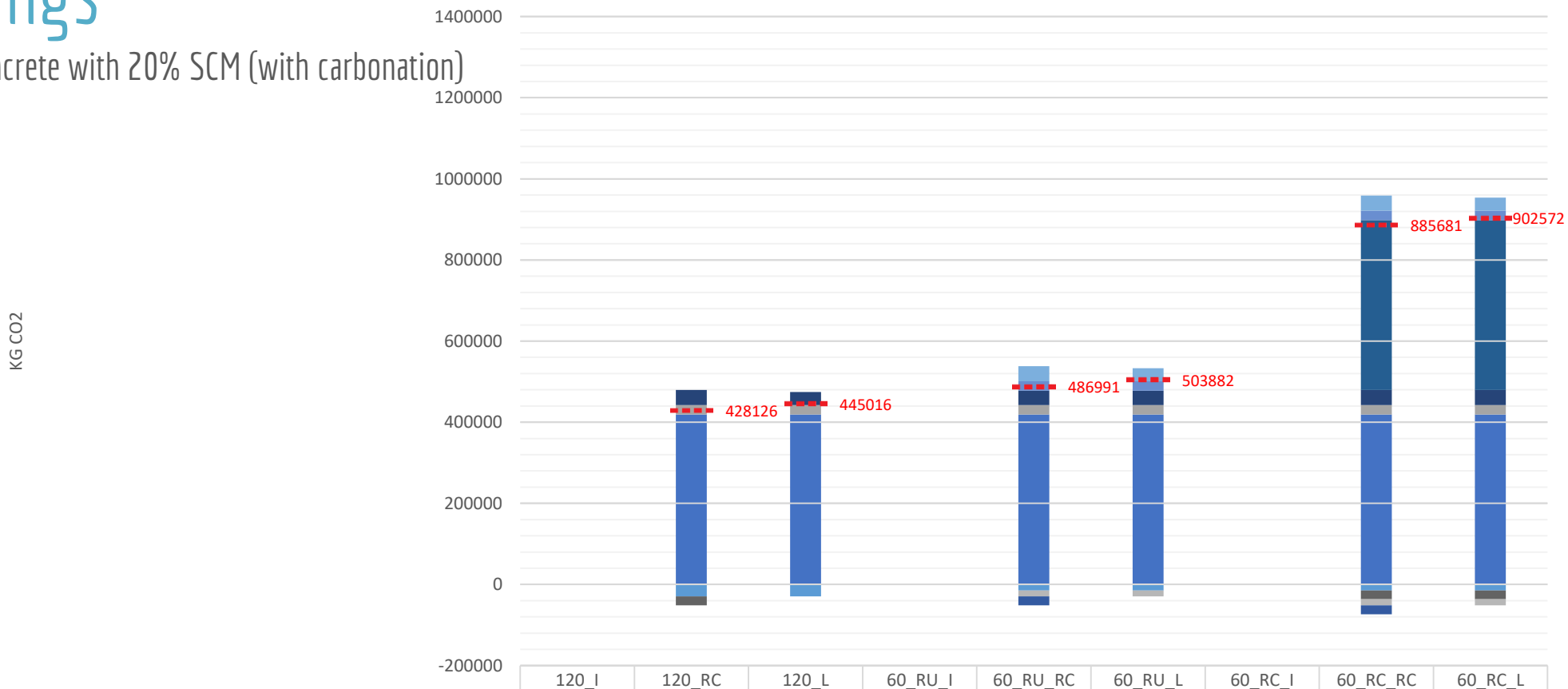
Beam- Concrete (with carbonation)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account					-21907			-21907	
Second Life End of Life (C1'-C4')					37189	32172		37189	32172
Second Life Maintenance and replacement (B1'-B5')					-36550	-36550		-36550	-36550
Second Life Transportation (A4')					23444	23444		23444	23444
Second Life Primary Production (A1'-A3')								578830	578830
First Life External Impacts (D) *A5 not included		-21907						-21907	-21907
First Life End of Life (C1-C4) *A5 not included		37189	32172		35422	35422		37189	37189
First Life Maintenance and replacement (B1-B5) *A5 not included		-73100	-73100		-36550	-36550		-36550	-36550
First Life Transportation (A4) *A5 not included		23444	23444		23444	23444		23444	23444
First Life Primary Production (A1-A3)		578830	578830		578830	578830		578830	578830

Findings

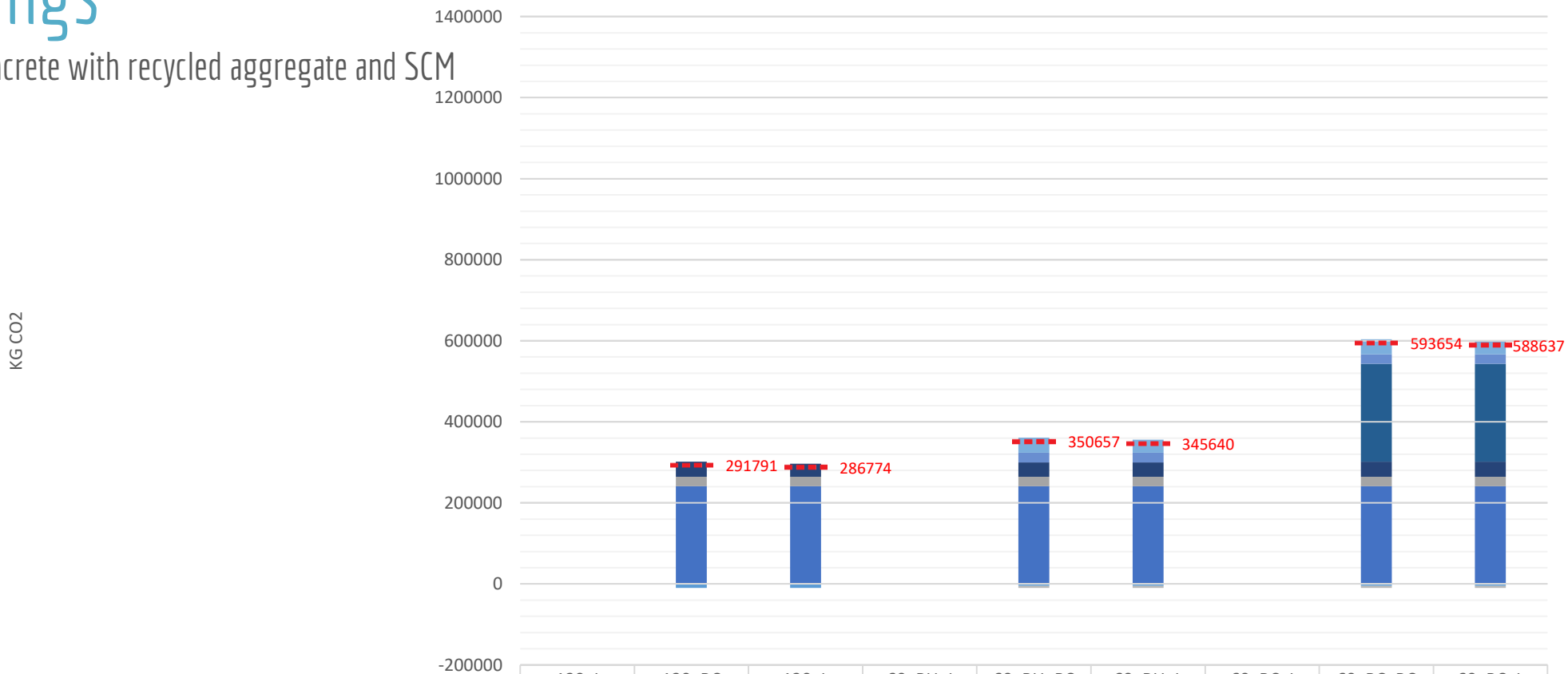
Beam- Concrete with 20% SCM (with carbonation)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account					-21907			-21907	
Second Life End of Life (C1'-C4')					37189	32172		37189	32172
Second Life Maintenance and replacement (B1'-B5')					-14715	-14715		-14715	-14715
Second Life Transportation (A4')					23444	23444		23444	23444
Second Life Primary Production (A1'-A3')								418830	418830
First Life External Impacts (D) *A5 not included		-21907						-21907	-21907
First Life End of Life (C1-C4) *A5 not included		37189	32172		35422	35422		37189	37189
First Life Maintenance and replacement (B1-B5) *A5 not included		-29430	-29430		-14715	-14715		-14715	-14715
First Life Transportation (A4) *A5 not included		23444	23444		23444	23444		23444	23444
First Life Primary Production (A1-A3)		418830	418830		418830	418830		418830	418830

Findings

Beam- Concrete with recycled aggregate and SCM



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account									
Second Life End of Life (C1'-C4')					37189	32172		37189	32172
Second Life Maintenance and replacement (B1'-B5')					-5036	-5036		-5036	-5036
Second Life Transportation (A4')					23444	23444		23444	23444
Second Life Primary Production (A1'-A3')								241230	241230
First Life External Impacts (D) *A5 not included									
First Life End of Life (C1-C4) *A5 not included		37189	32172		35422	35422		37189	37189
First Life Maintenance and replacement (B1-B5) *A5 not included		-10072	-10072		-5036	-5036		-5036	-5036
First Life Transportation (A4) *A5 not included		23444	23444		23444	23444		23444	23444
First Life Primary Production (A1-A3)		241230	241230		241230	241230		241230	241230

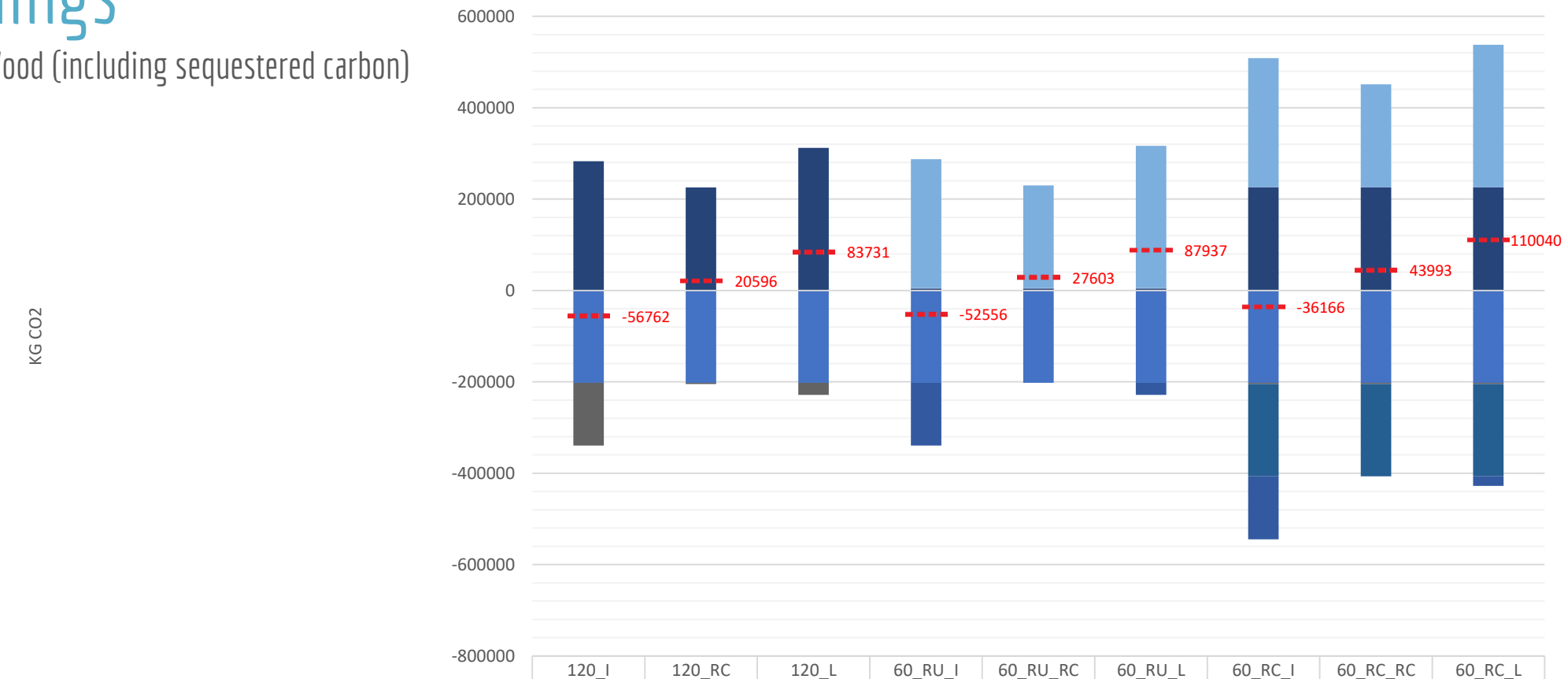
Findings

Beam- Wood (excluding sequestered carbon)

	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account				-137529	0	-26340	-137529	0	-20627
Second Life End of Life (C1'-C4')				61938	4568	91242	61938	4568	91242
Second Life Maintenance and replacement (B1'-B5')				0	0	0	0	0	0
Second Life Transportation (A4')				1180	1180	1180	1180	1180	1180
Second Life Primary Production (A1'-A3')							17649	17649	17649
First Life External Impacts (D) *A5 not included	-137529	-2801	-26340				-2801	-2801	-2801
First Life End of Life (C1-C4) *A5 not included	61938	4568	91242	3026	3026	3026	4568	4568	4568
First Life Maintenance and replacement (B1-B5) *A5 not included	0	0	0	0	0	0	0	0	0
First Life Transportation (A4) *A5 not included	1180	1180	1180	1180	1180	1180	1180	1180	1180
First Life Primary Production (A1-A3)	17649	17649	17649	17649	17649	17649	17649	17649	17649

Findings

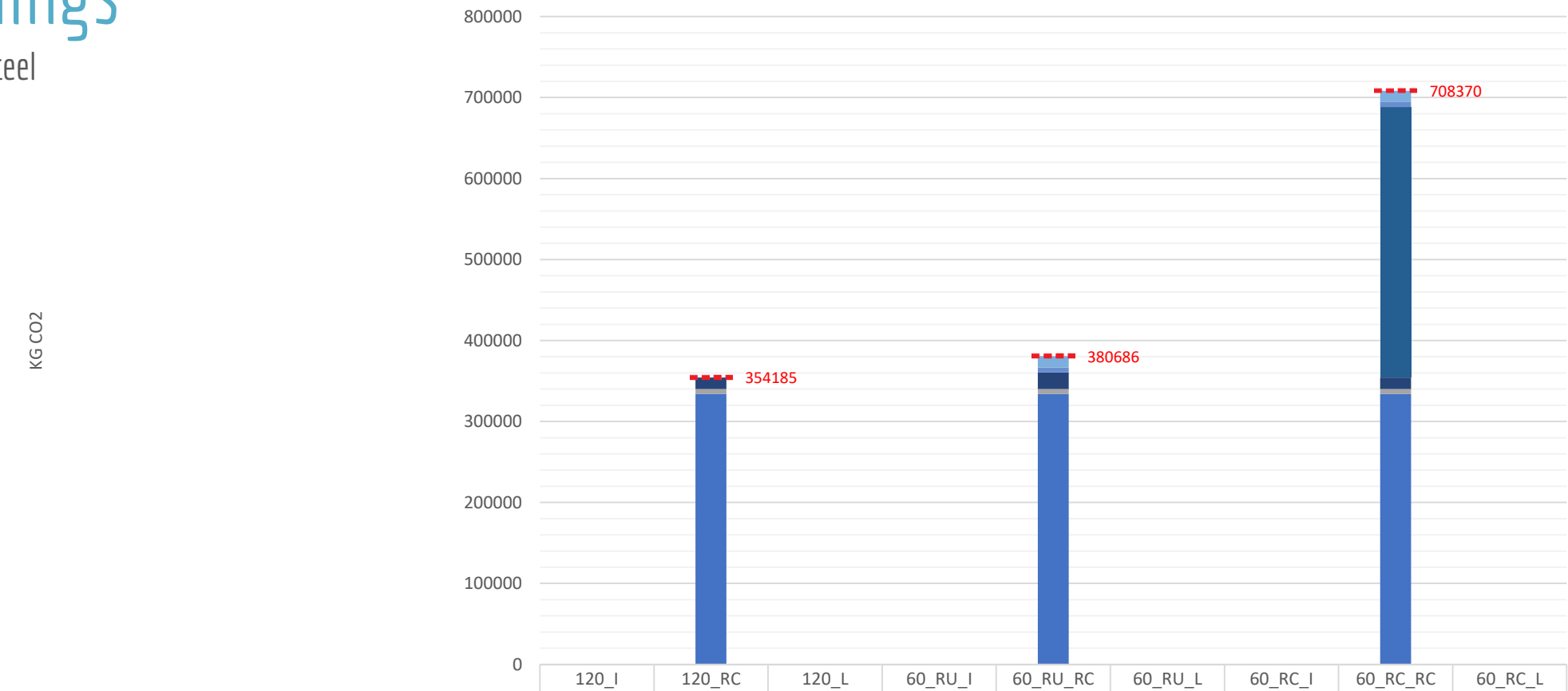
Beam- Wood (including sequestered carbon)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account				-137529	0	-26340	-137529	0	-20627
Second Life End of Life (C1'-C4')				281718	224348	311022	281718	224348	311022
Second Life Maintenance and replacement (B1'-B5')				0	0	0	0	0	0
Second Life Transportation (A4')				1180	1180	1180	1180	1180	1180
Second Life Primary Production (A1'-A3')							-202131	-202131	-202131
First Life External Impacts (D) *A5 not included	-137529	-2801	-26340				-2801	-2801	-2801
First Life End of Life (C1-C4) *A5 not included	281718	224348	311022	3026	3026	3026	224348	224348	224348
First Life Maintenance and replacement (B1-B5) *A5 not included	0	0	0	0	0	0	0	0	0
First Life Transportation (A4) *A5 not included	1180	1180	1180	1180	1180	1180	1180	1180	1180
First Life Primary Production (A1-A3)	-202131	-202131	-202131	-202131	-202131	-202131	-202131	-202131	-202131

Findings

Beam- Steel

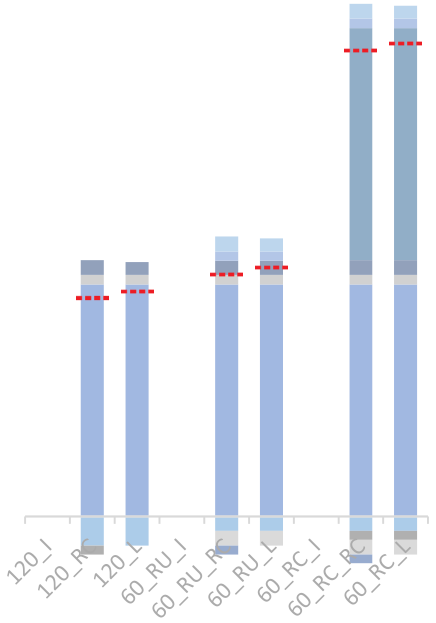


	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account									
Second Life End of Life (C1'-C4')					14003			14003	
Second Life Maintenance and replacement (B1'-B5')									
Second Life Transportation (A4')					6182			6182	
Second Life Primary Production (A1'-A3')								334000	
First Life External Impacts (D) *A5 not included									
First Life End of Life (C1-C4) *A5 not included		14003			20319			14003	
First Life Maintenance and replacement (B1-B5) *A5 not included									
First Life Transportation (A4) *A5 not included		6182			6182			6182	
First Life Primary Production (A1-A3)		334000			334000			334000	

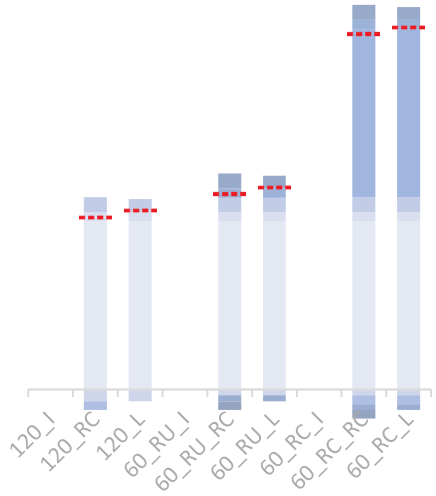
Findings

All Beams- comparison

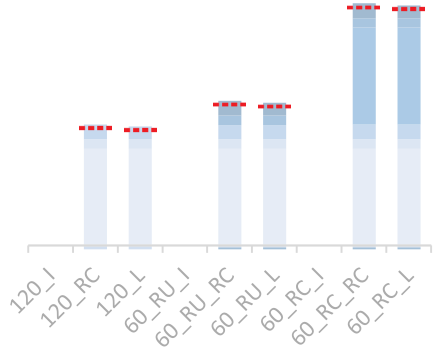
Concrete-1



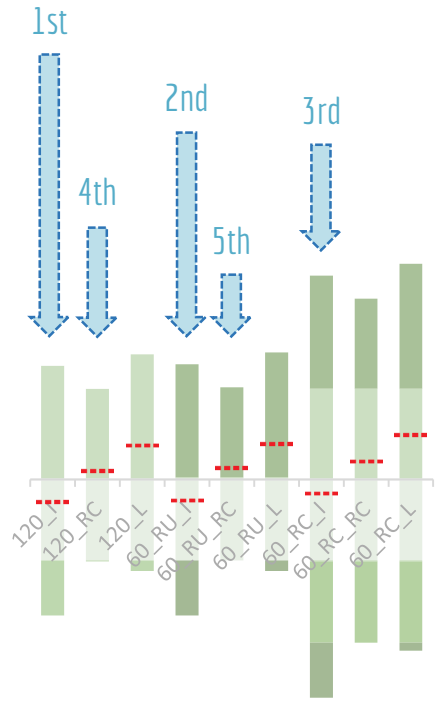
Concrete-2 (20% SCM)



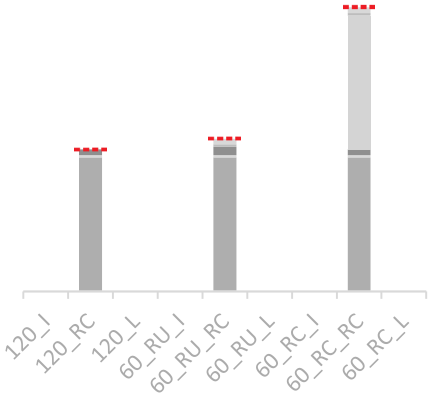
Concrete-3 (with recycled aggregate and SCM)



Wood



Steel



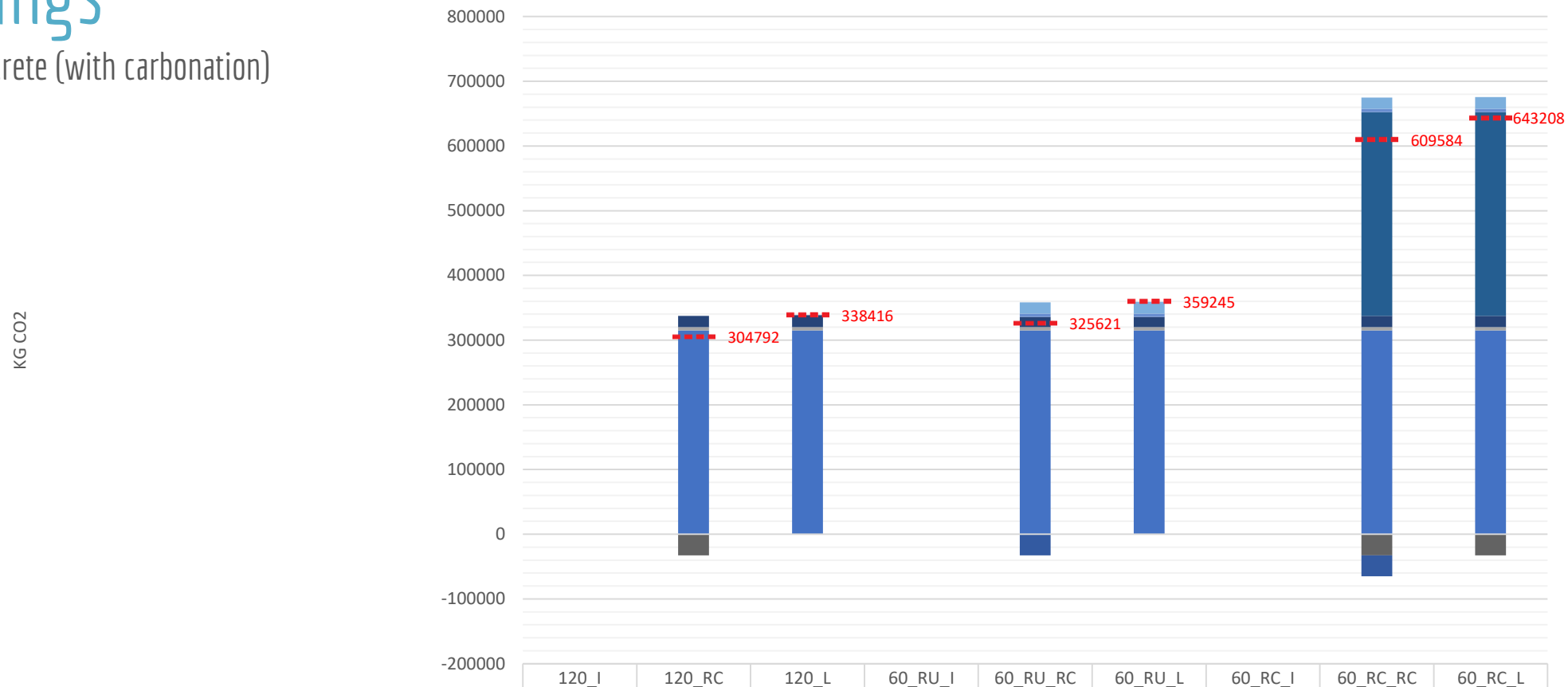
Original presumed choice

Steel	Wood	Wood	Wood	Wood	Wood
60_RC_RC	120_I	60_RU_I	60_RC_I	120_RC	60_RU_RC
708,370	-56,762	-52,556	-36,166	20,596	27,603

Kg CO_2

Findings

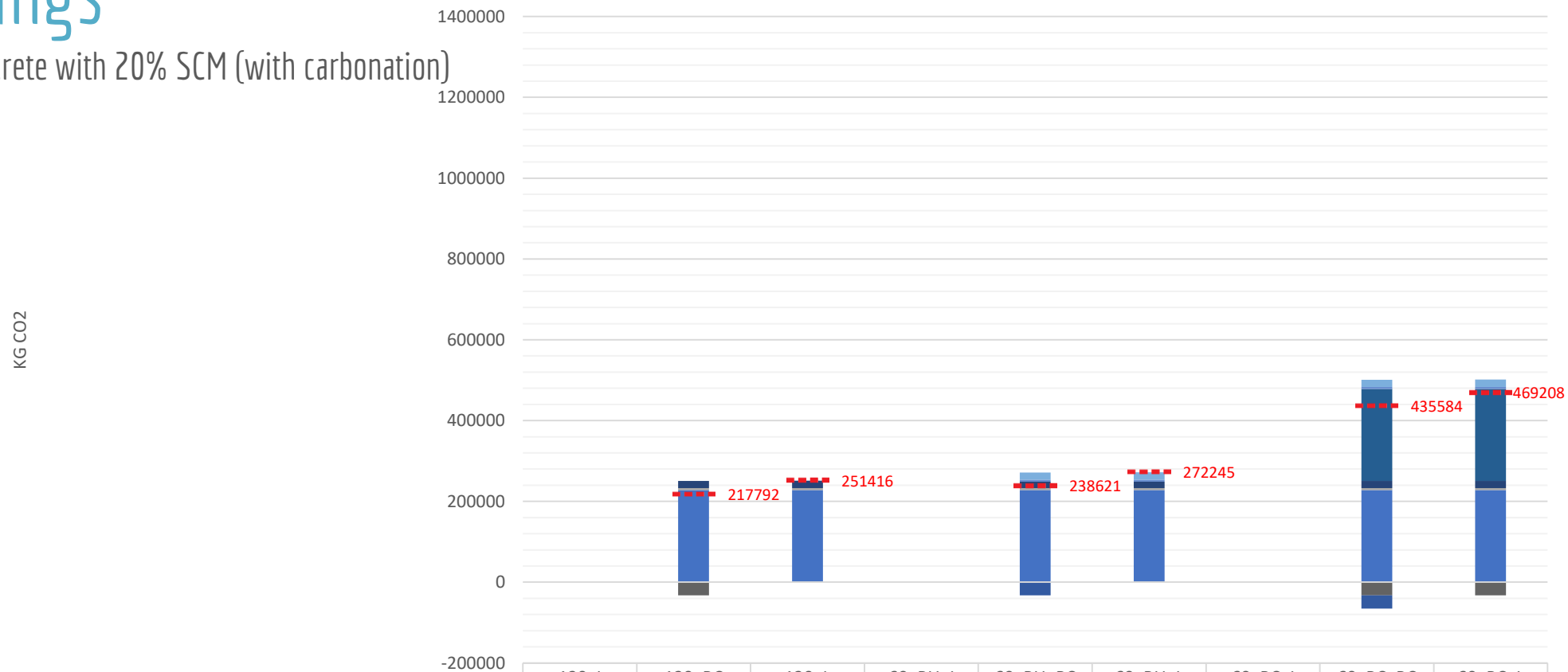
Slab- Concrete (with carbonation)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account					-32570			-32570	
Second Life End of Life (C1'-C4')					17142	18196		17142	18196
Second Life Maintenance and replacement (B1'-B5')					0	0		0	0
Second Life Transportation (A4')					5220	5220		5220	5220
Second Life Primary Production (A1'-A3')								315000	315000
First Life External Impacts (D) *A5 not included		-32570						-32570	-32570
First Life End of Life (C1-C4) *A5 not included		17142	18196		15609	15609		17142	17142
First Life Maintenance and replacement (B1-B5) *A5 not included									
First Life Transportation (A4) *A5 not included		5220	5220		5220	5220		5220	5220
First Life Primary Production (A1-A3)		315000	315000		315000	315000		315000	315000

Findings

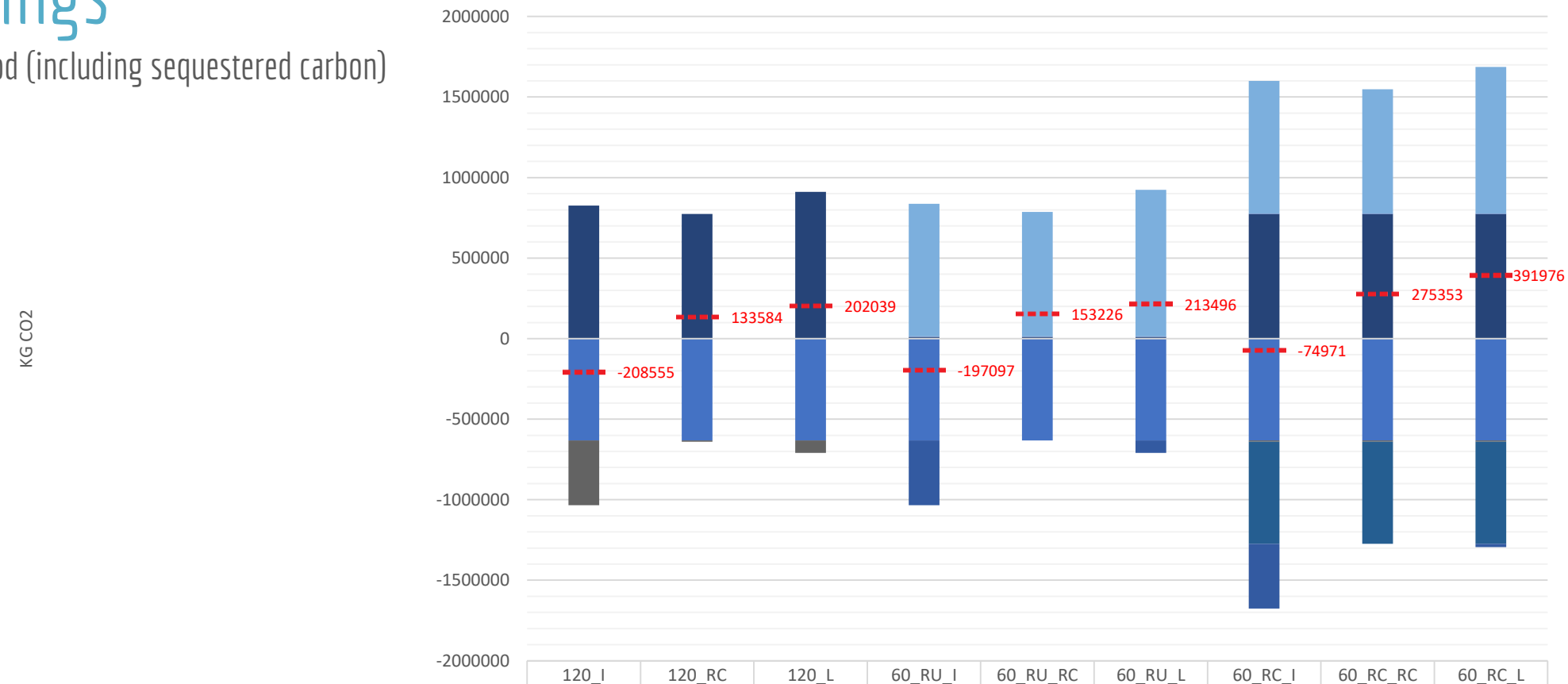
Slab- Concrete with 20% SCM (with carbonation)



	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account					-32570			-32570	
Second Life End of Life (C1'-C4')					17142	18196		17142	18196
Second Life Maintenance and replacement (B1'-B5')									
Second Life Transportation (A4')					5220	5220		5220	5220
Second Life Primary Production (A1'-A3')								228000	228000
First Life External Impacts (D) *A5 not included		-32570						-32570	-32570
First Life End of Life (C1-C4) *A5 not included		17142	18196		15609	15609		17142	17142
First Life Maintenance and replacement (B1-B5) *A5 not included									
First Life Transportation (A4) *A5 not included		5220	5220		5220	5220		5220	5220
First Life Primary Production (A1-A3)		228000	228000		228000	228000		228000	228000

Findings

Slab- Wood (including sequestered carbon)

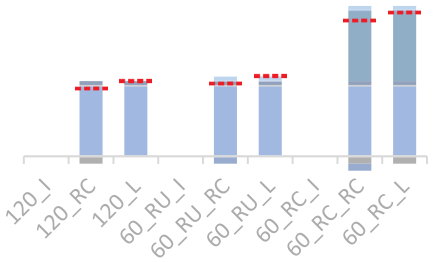


	120_I	120_RC	120_L	60_RU_I	60_RU_RC	60_RU_L	60_RC_I	60_RC_RC	60_RC_L
Second Life External Impacts (D') *can't take this into account				-401932	0	-76980	-401932	0	-20627
Second Life End of Life (C1'-C4')				823327	771719	908969	823327	771719	908969
Second Life Maintenance and replacement (B1'-B5')				0	0	0	0	0	0
Second Life Transportation (A4')				2710	2710	2710	2710	2710	2710
Second Life Primary Production (A1'-A3')							-632660	-632660	-632660
First Life External Impacts (D) *A5 not included	-401932	-8185	-76980				-8185	-8185	-8185
First Life End of Life (C1-C4) *A5 not included	823327	771719	908969	8748	8748	8748	771719	771719	771719
First Life Maintenance and replacement (B1-B5) *A5 not included	0	0	0	0	0	0	0	0	0
First Life Transportation (A4) *A5 not included	2710	2710	2710	2710	2710	2710	2710	2710	2710
First Life Primary Production (A1-A3)	-632660	-632660	-632660	-632660	-632660	-632660	-632660	-632660	-632660

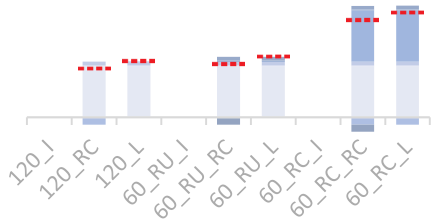
Findings

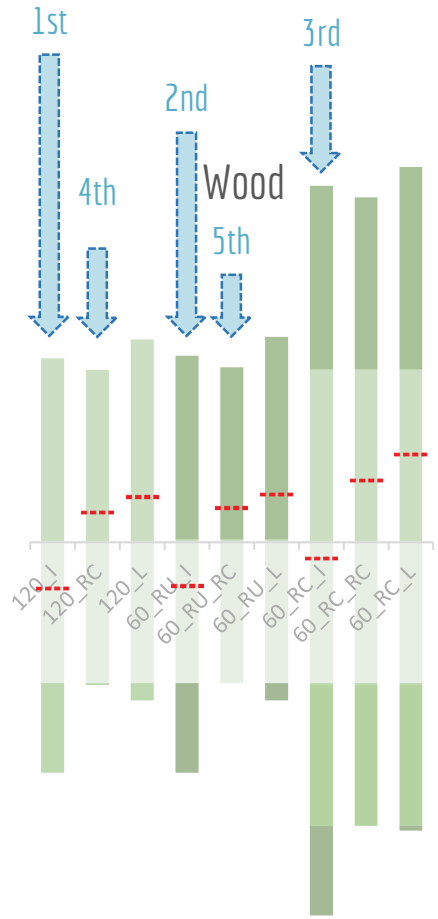
All Slabs- comparison

Concrete-1



Concrete-2 (20% SCM)





Original presumed choice

Hollow core concrete
60_RC_RC
609,584

Wood
120_I
-208,555

Wood
60_RU_I
-197,097

Wood
60_RC_I
-74,971

Wood
120_RC
133,584

Wood
60_RU_RC
153,226

Kg CO_2

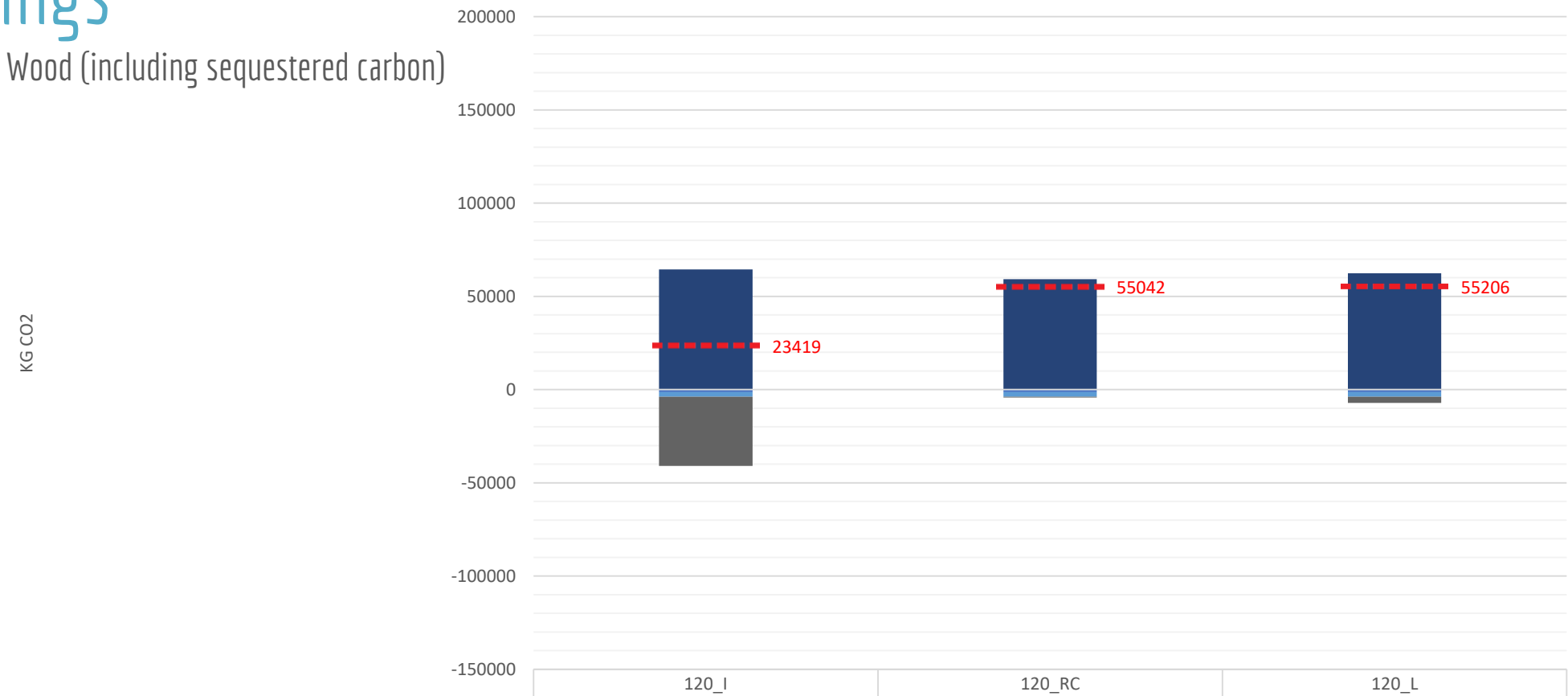
Findings

Awnings- Aluminium

	120_RC	60_RU_RC	60_RC_RC
Second Life External Impacts (D') *can't take this into account			
Second Life End of Life (C1'-C4')		207	207
Second Life Maintenance and replacement (B1'-B5')			
Second Life Transportation (A4')		252	252
Second Life Primary Production (A1'-A3')			80287
First Life External Impacts (D) *A5 not included			
First Life End of Life (C1-C4) *A5 not included	207	207	207
First Life Maintenance and replacement (B1-B5) *A5 not included			
First Life Transportation (A4) *A5 not included	252	252	252
First Life Primary Production (A1-A3)	80287	80287	80287

Findings

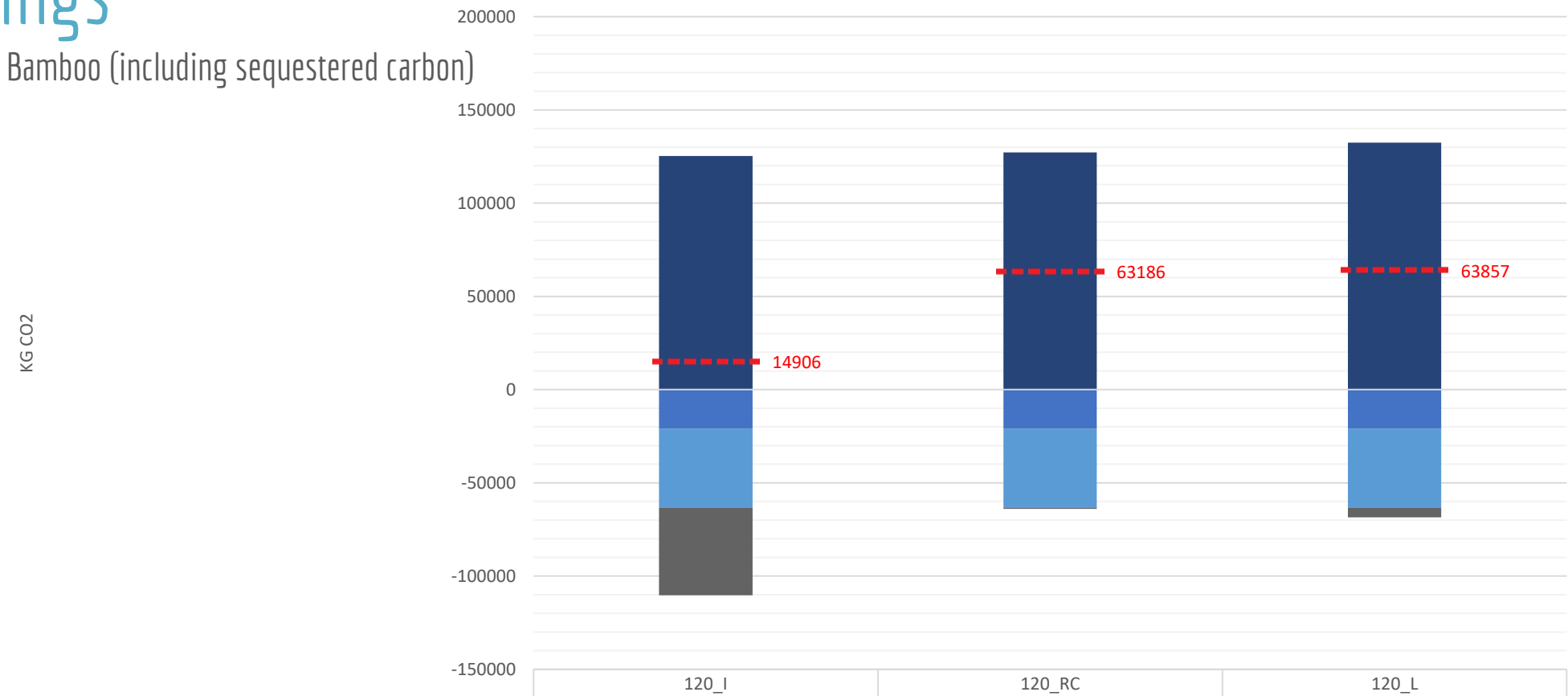
Awnings- Wood (including sequestered carbon)



	120_I	120_RC	120_L
Second Life External Impacts (D') *can't take this into account			
Second Life End of Life (C1'-C4')			
Second Life Maintenance and replacement (B1'-B5')			
Second Life Transportation (A4')			
Second Life Primary Production (A1'-A3')			
First Life External Impacts (D) *A5 not included	-37107	-352	-3313
First Life End of Life (C1-C4) *A5 not included	64178	59046	62171
First Life Maintenance and replacement (B1-B5) *A5 not included	-2581	-2581	-2581
First Life Transportation (A4) *A5 not included	220	220	220
First Life Primary Production (A1-A3)	-1291	-1291	-1291

Findings

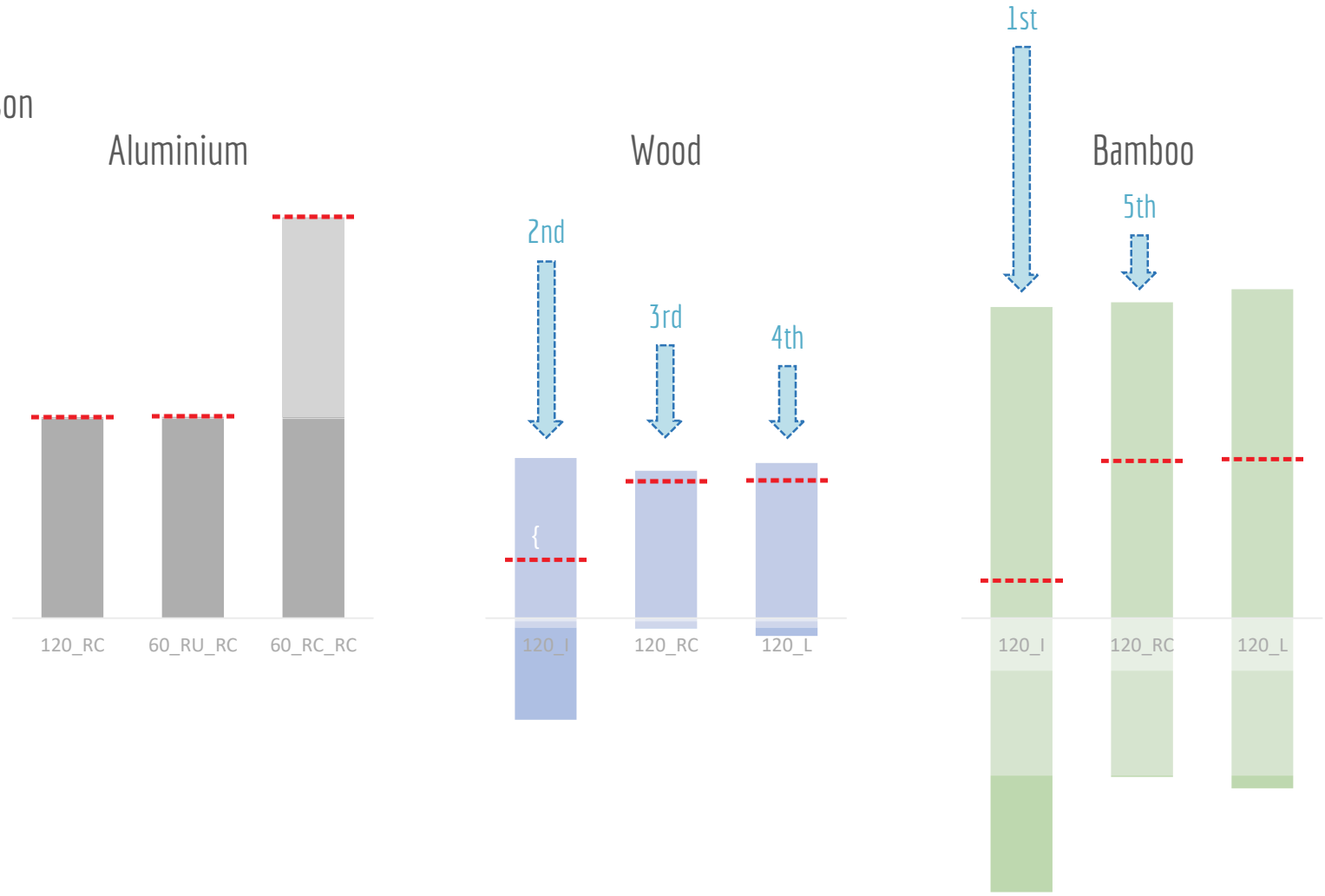
Awnings- Bamboo (including sequestered carbon)



	120_I	120_RC	120_L
Second Life External Impacts (D') *can't take this into account			
Second Life End of Life (C1'-C4')			
Second Life Maintenance and replacement (B1'-B5')			
Second Life Transportation (A4')			
Second Life Primary Production (A1'-A3')			
First Life External Impacts (D) *A5 not included	-46872	-547	-5149
First Life End of Life (C1-C4) *A5 not included	124996	126951	132225
First Life Maintenance and replacement (B1-B5) *A5 not included	-42297	-42297	-42297
First Life Transportation (A4) *A5 not included	227	227	227
First Life Primary Production (A1-A3)	-21148	-21148	-21148

Findings

All Awnings- comparison



Original presumed choice

Aluminium
60_RC_RC
161,492

Bamboo
120_I
14,906

›

Wood
120_I
23,419

›

Wood
120_RC
55,042

›

Wood
120_L
55,206

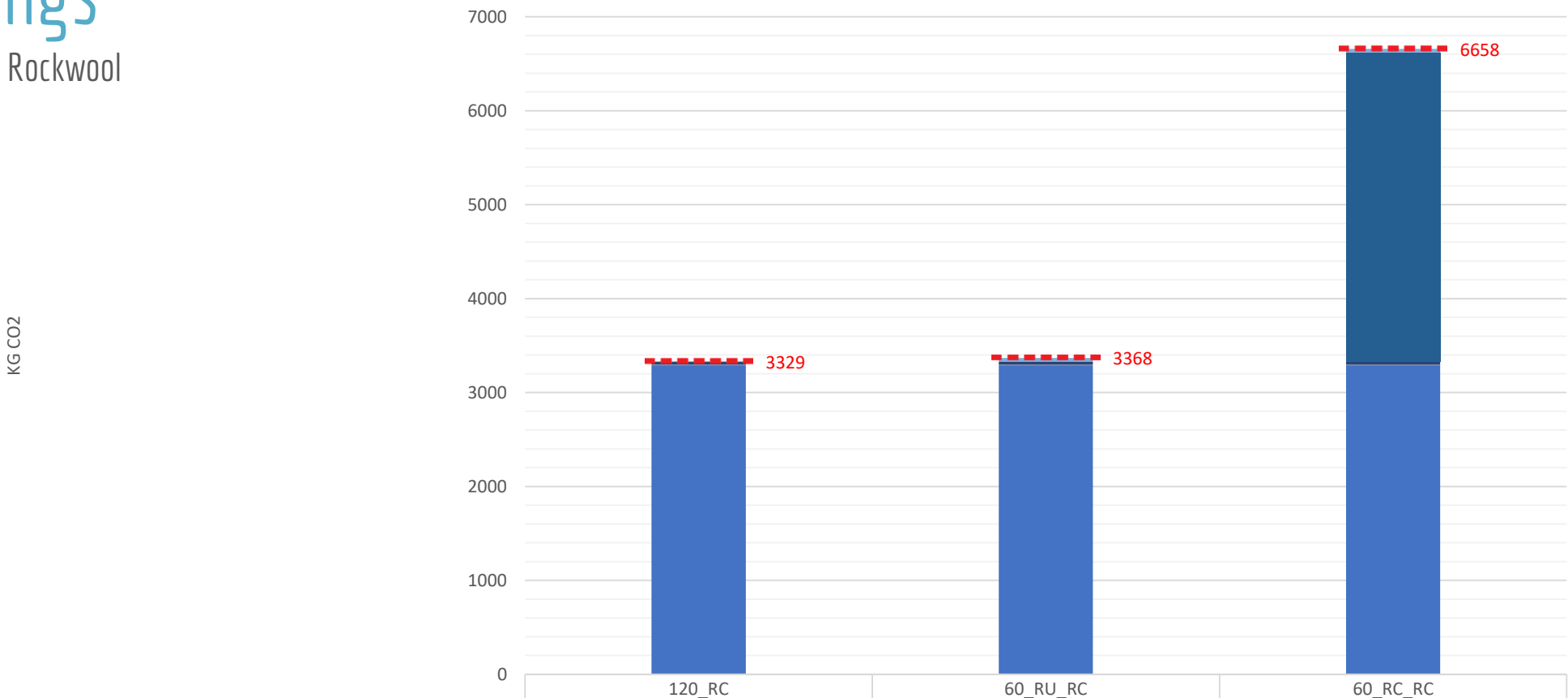
›

Bamboo
120_RC
63,186

Kg CO_2

Findings

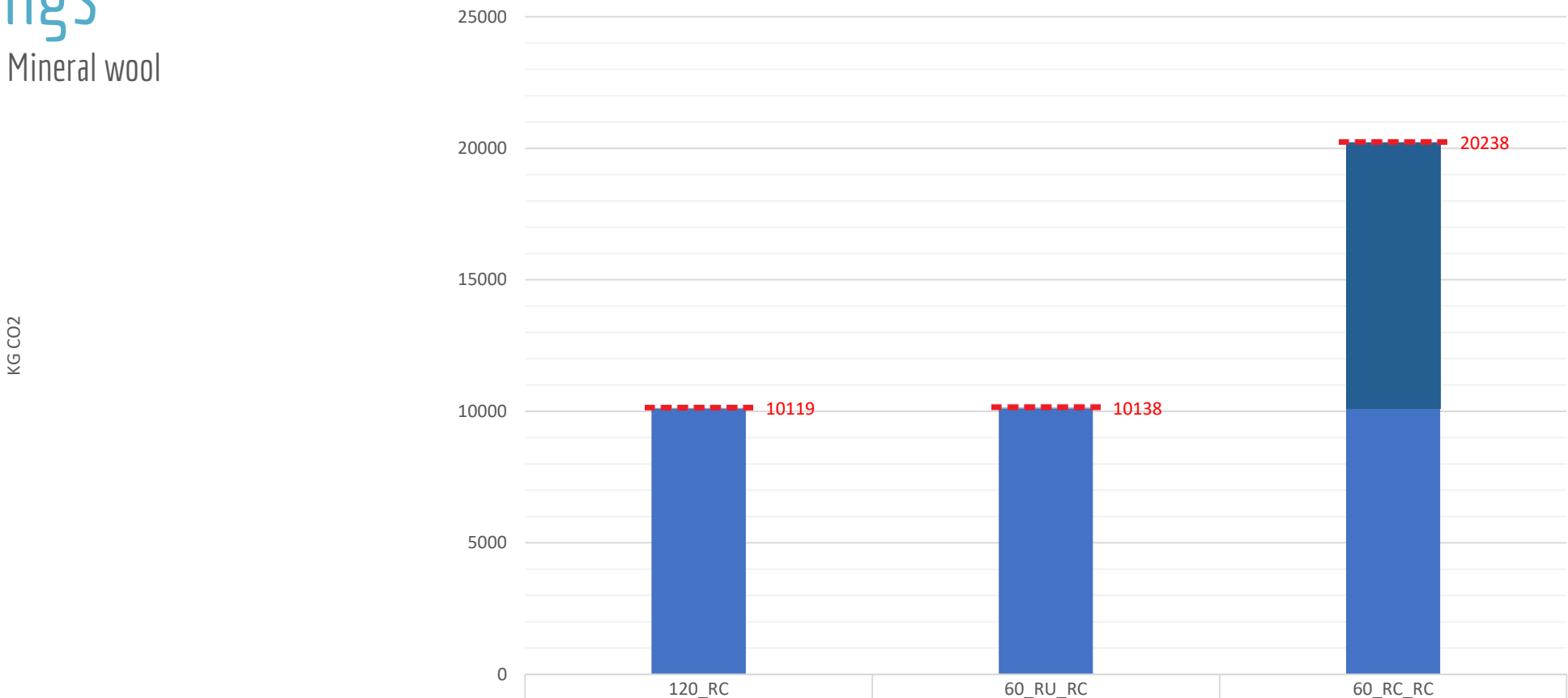
Insulation- Rockwool



	120_RC	60_RU_RC	60_RC_RC
Second Life External Impacts (D') *can't take this into account		0	0
Second Life End of Life (C1'-C4')		34	34
Second Life Maintenance and replacement (B1'-B5')			
Second Life Transportation (A4')		5.7	5.7
Second Life Primary Production (A1'-A3')			3290
First Life External Impacts (D) *A5 not included	0	0	0
First Life End of Life (C1-C4) *A5 not included	34	34	34
First Life Maintenance and replacement (B1-B5) *A5 not included			
First Life Transportation (A4) *A5 not included	5.7	5.7	5.7
First Life Primary Production (A1-A3)	3290	3290	3290

Findings

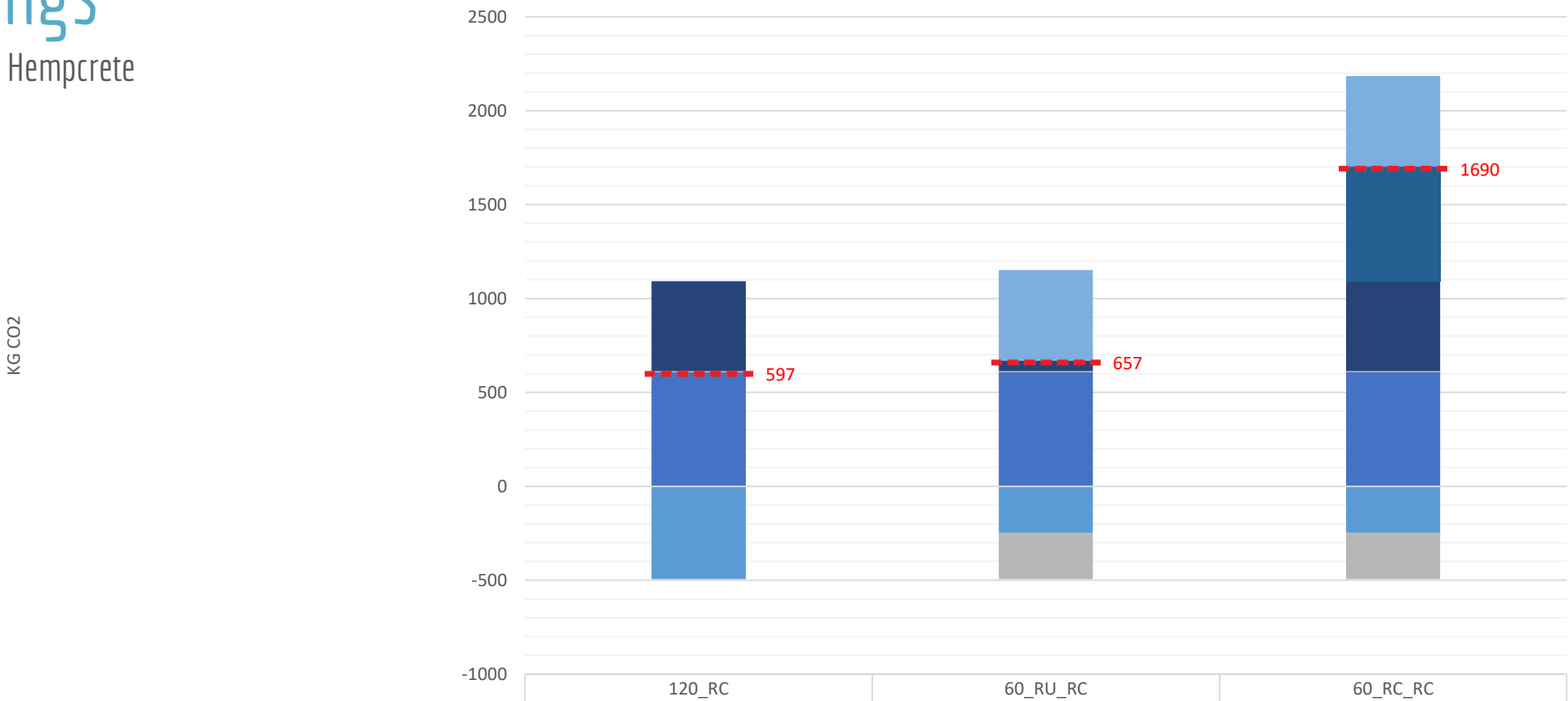
Insulation- Mineral wool



	120_RC	60_RU_RC	60_RC_RC
Second Life External Impacts (D') *can't take this into account		0	0
Second Life End of Life (C1'-C4')		6	6
Second Life Maintenance and replacement (B1'-B5')			
Second Life Transportation (A4')		13	13
Second Life Primary Production (A1'-A3')			10100
First Life External Impacts (D) *A5 not included	0	0	0
First Life End of Life (C1-C4) *A5 not included	6	6	6
First Life Maintenance and replacement (B1-B5) *A5 not included			
First Life Transportation (A4) *A5 not included	13	13	13
First Life Primary Production (A1-A3)	10100	10100	10100

Findings

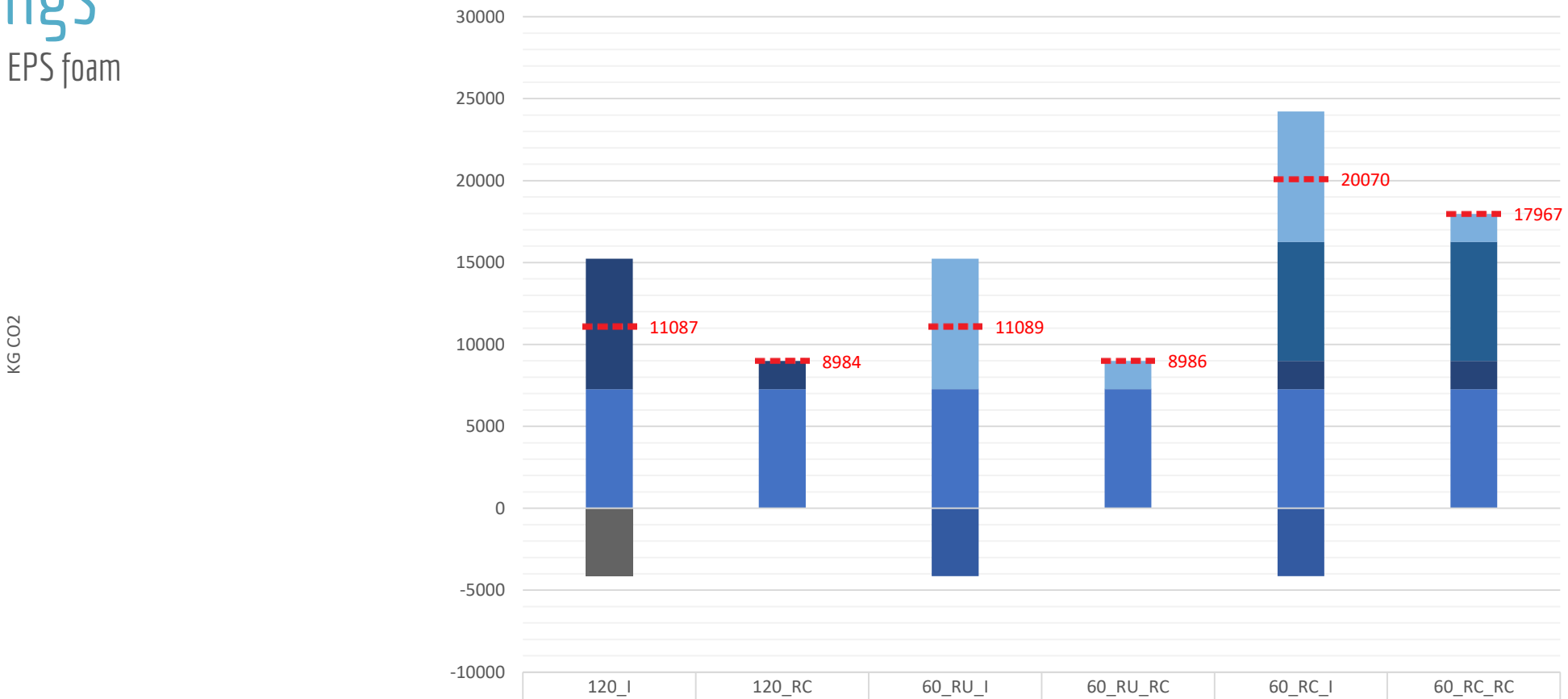
Insulation- Hempcrete



	120_RC	60_RU_RC	60_RC_RC
Second Life External Impacts (D') *can't take this into account		0	0
Second Life End of Life (C1'-C4')		479	479
Second Life Maintenance and replacement (B1'-B5')		-247	-247
Second Life Transportation (A4')		6.2	6.2
Second Life Primary Production (A1'-A3')			608
First Life External Impacts (D) *A5 not included	0	0	0
First Life End of Life (C1-C4) *A5 not included	479	53	479
First Life Maintenance and replacement (B1-B5) *A5 not included	-495	-247	-247
First Life Transportation (A4) *A5 not included	6.2	6.2	6.2
First Life Primary Production (A1-A3)	608	608	608

Findings

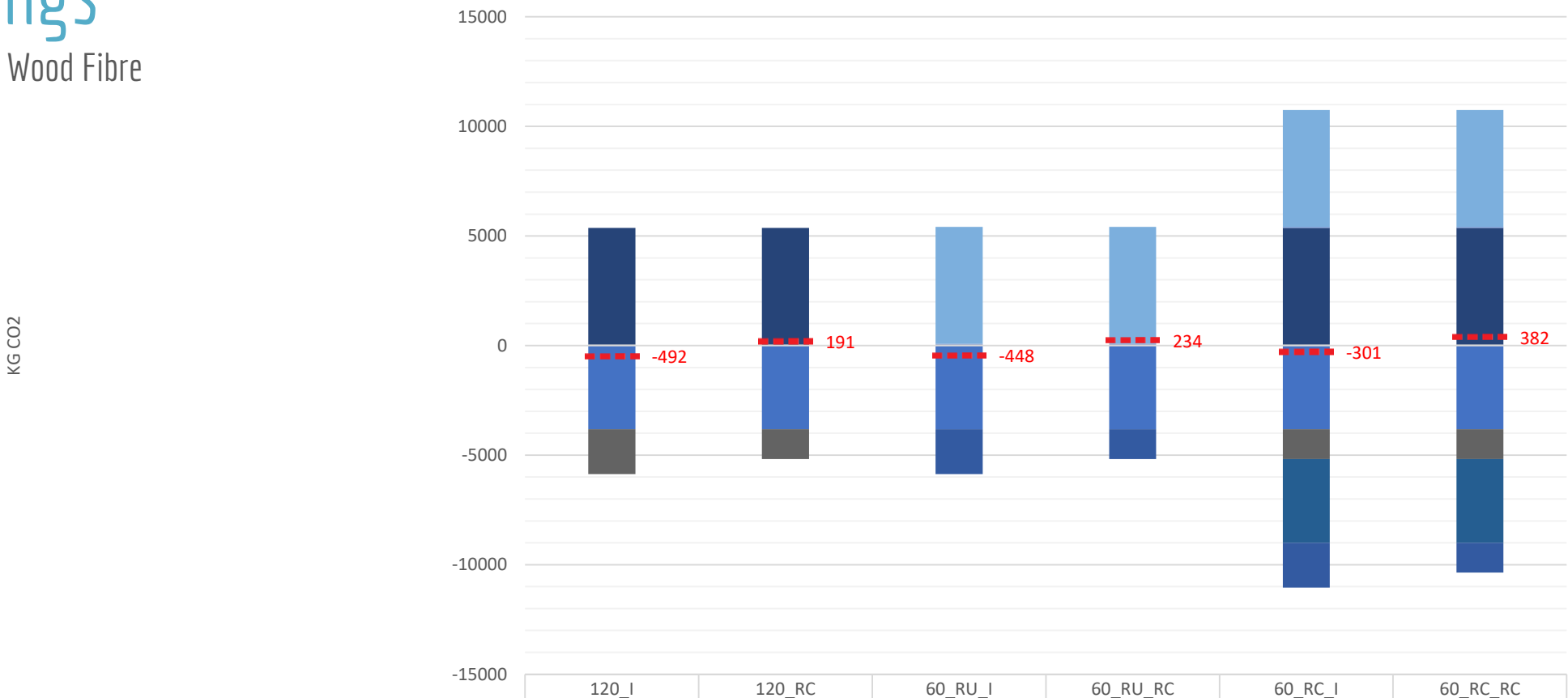
Insulation- EPS foam



	120_I	120_RC	60_RU_I	60_RU_RC	60_RC_I	60_RC_RC
Second Life External Impacts (D') *can't take this into account			-4143	0	-4143	0
Second Life End of Life (C1'-C4')			7957	1711	7957	1711
Second Life Maintenance and replacement (B1'-B5')						
Second Life Transportation (A4')			2.7	2.7	2.7	2.7
Second Life Primary Production (A1'-A3')					7270	7270
First Life External Impacts (D) *A5 not included	-4143	0				
First Life End of Life (C1-C4) *A5 not included	7957	1711	0	0	1711	1711
First Life Maintenance and replacement (B1-B5) *A5 not included						
First Life Transportation (A4) *A5 not included	2.7	2.7	2.7	2.7	2.7	2.7
First Life Primary Production (A1-A3)	7270	7270	7270	7270	7270	7270

Findings

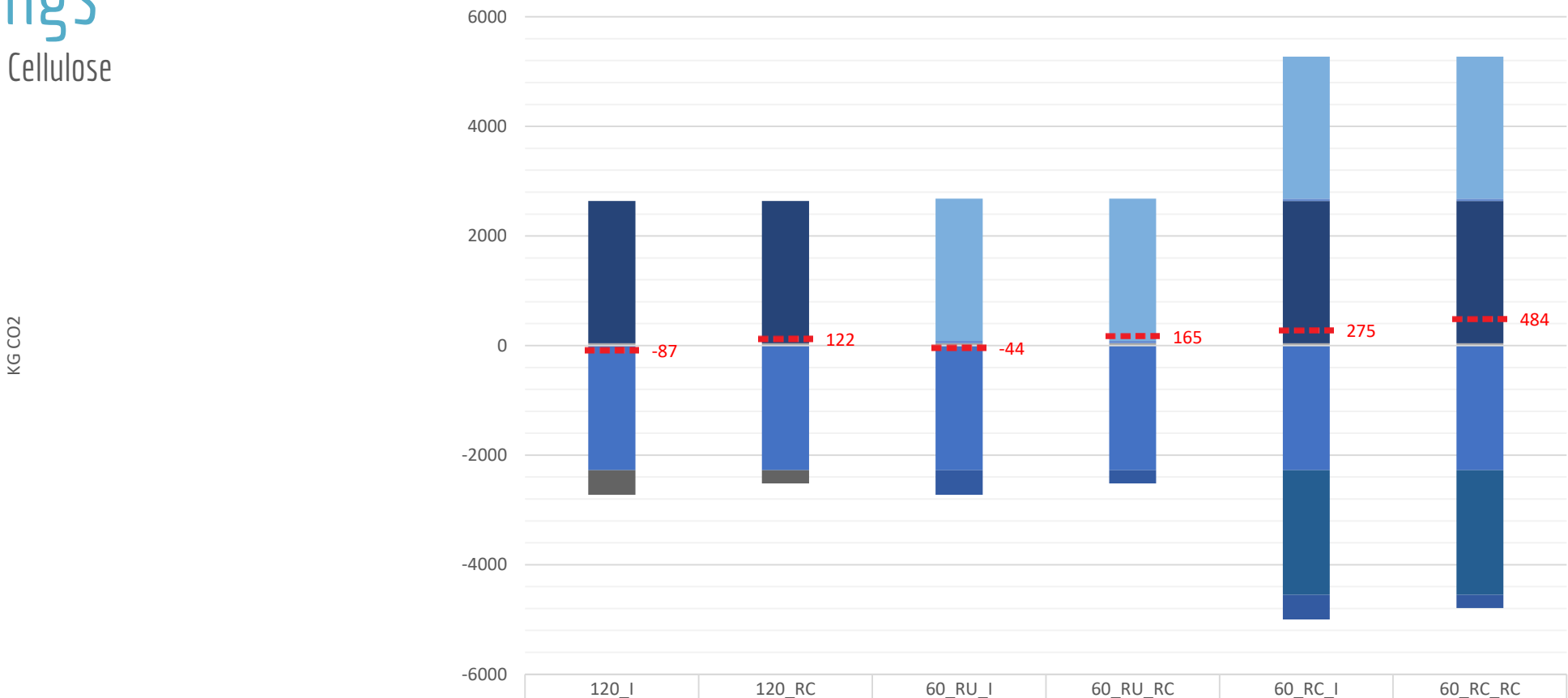
Insulation- Wood Fibre



	120_I	120_RC	60_RU_I	60_RU_RC	60_RC_I	60_RC_RC
Second Life External Impacts (D') *can't take this into account			-2044	-1361	-2044	-1361
Second Life End of Life (C1'-C4')			5328	5328	5328	5328
Second Life Maintenance and replacement (B1'-B5')						
Second Life Transportation (A4')			43.3	43.3	43.3	43.3
Second Life Primary Production (A1'-A3')					-3819	-3819
First Life External Impacts (D) *A5 not included	-2044	-1361			-1361	-1361
First Life End of Life (C1-C4) *A5 not included	5328	5328			5328	5328
First Life Maintenance and replacement (B1-B5) *A5 not included						
First Life Transportation (A4) *A5 not included	43.3	43.3	43.3	43.3	43.3	43.3
First Life Primary Production (A1-A3)	-3819	-3819	-3819	-3819	-3819	-3819

Findings

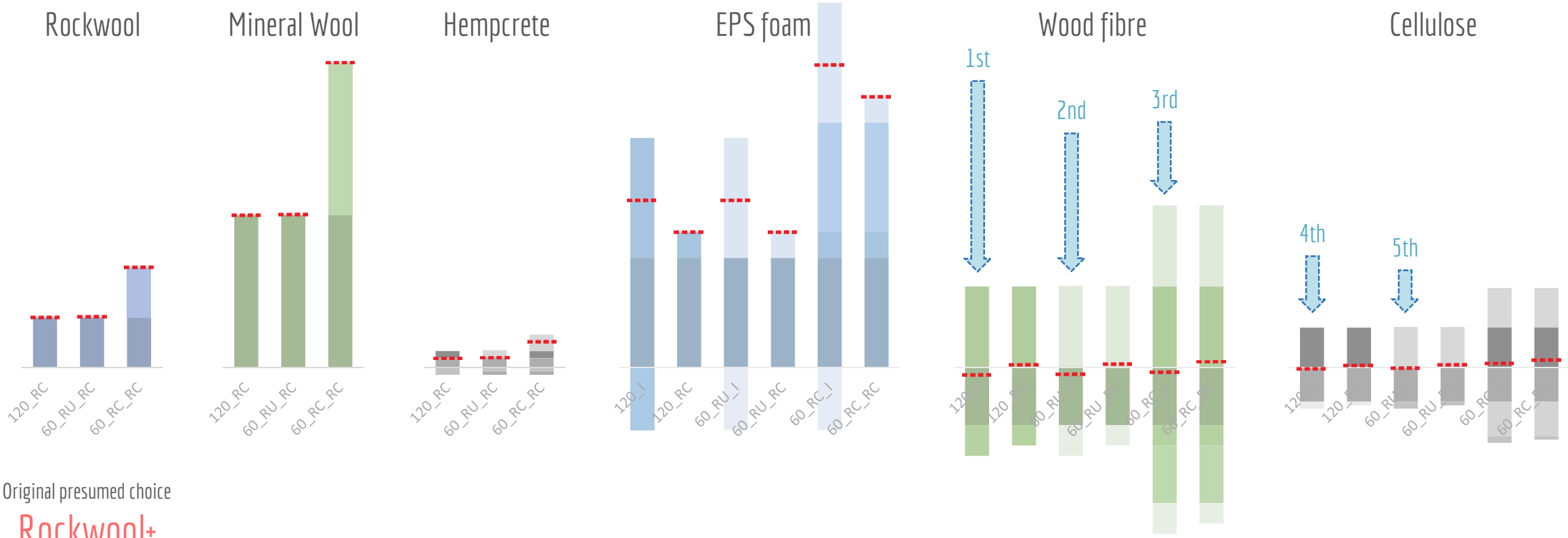
Insulation- Cellulose



	120_I	120_RC	60_RU_I	60_RU_RC	60_RC_I	60_RC_RC
Second Life External Impacts (D') *can't take this into account			-449	-241	-449	-241
Second Life End of Life (C1'-C4')			2594	2594	2594	2594
Second Life Maintenance and replacement (B1'-B5')						
Second Life Transportation (A4')			43.5	43.5	43.5	43.5
Second Life Primary Production (A1'-A3')					-2275	-2275
First Life External Impacts (D) *A5 not included	-449	-241				
First Life End of Life (C1-C4) *A5 not included	2594	2594			2594	2594
First Life Maintenance and replacement (B1-B5) *A5 not included						
First Life Transportation (A4) *A5 not included	43.5	43.5	43.5	43.5	43.5	43.5
First Life Primary Production (A1-A3)	-2275	-2275	-2275	-2275	-2275	-2275

Findings

All Insulations- comparison



Original presumed choice

Rockwool+ Mineral wool

60_RC_RC

13,500

Wood fibre 120_I

-492

› Wood fibre 60_RU_I

-448

› Wood fibre 60_RC_I

-301

› Cellulose 120_I

-87

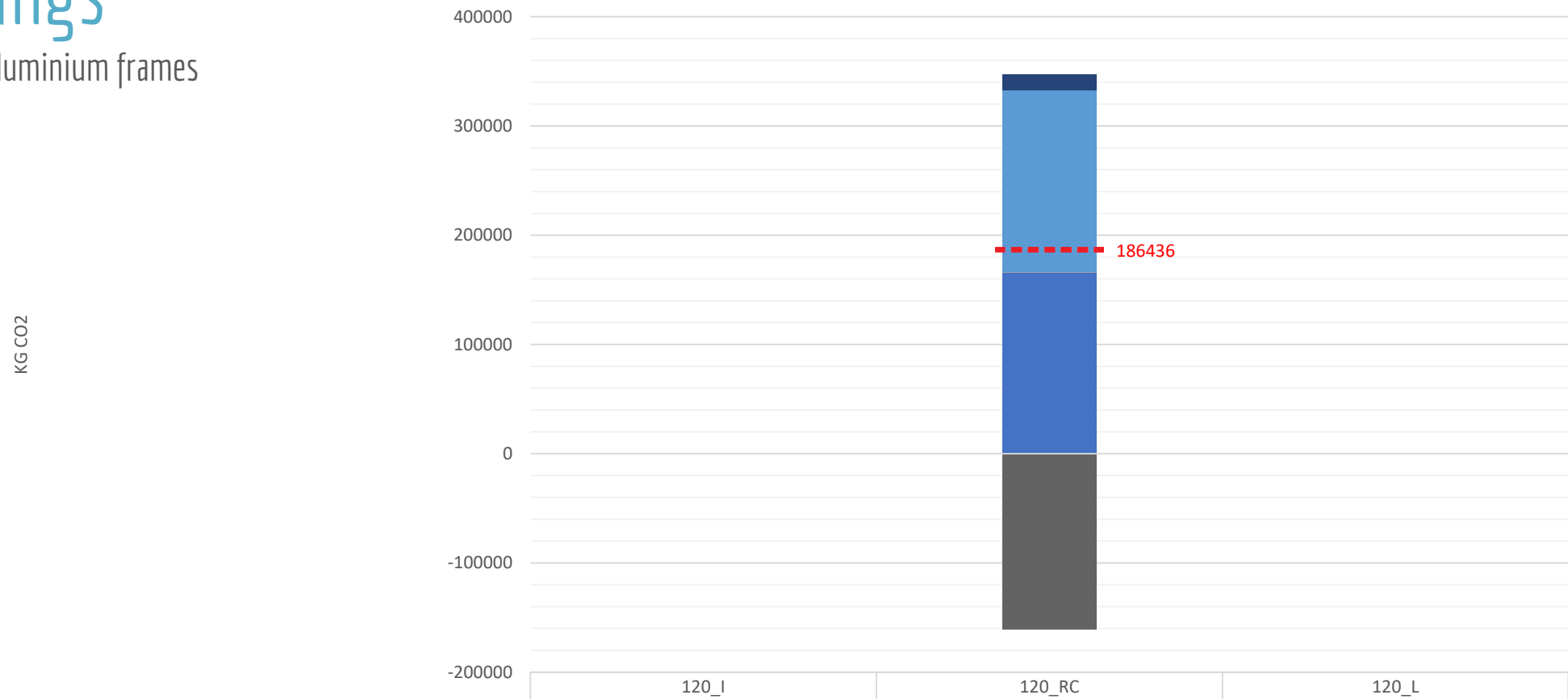
› Cellulose 60_RU_I

-44

Kg CO_2

Findings

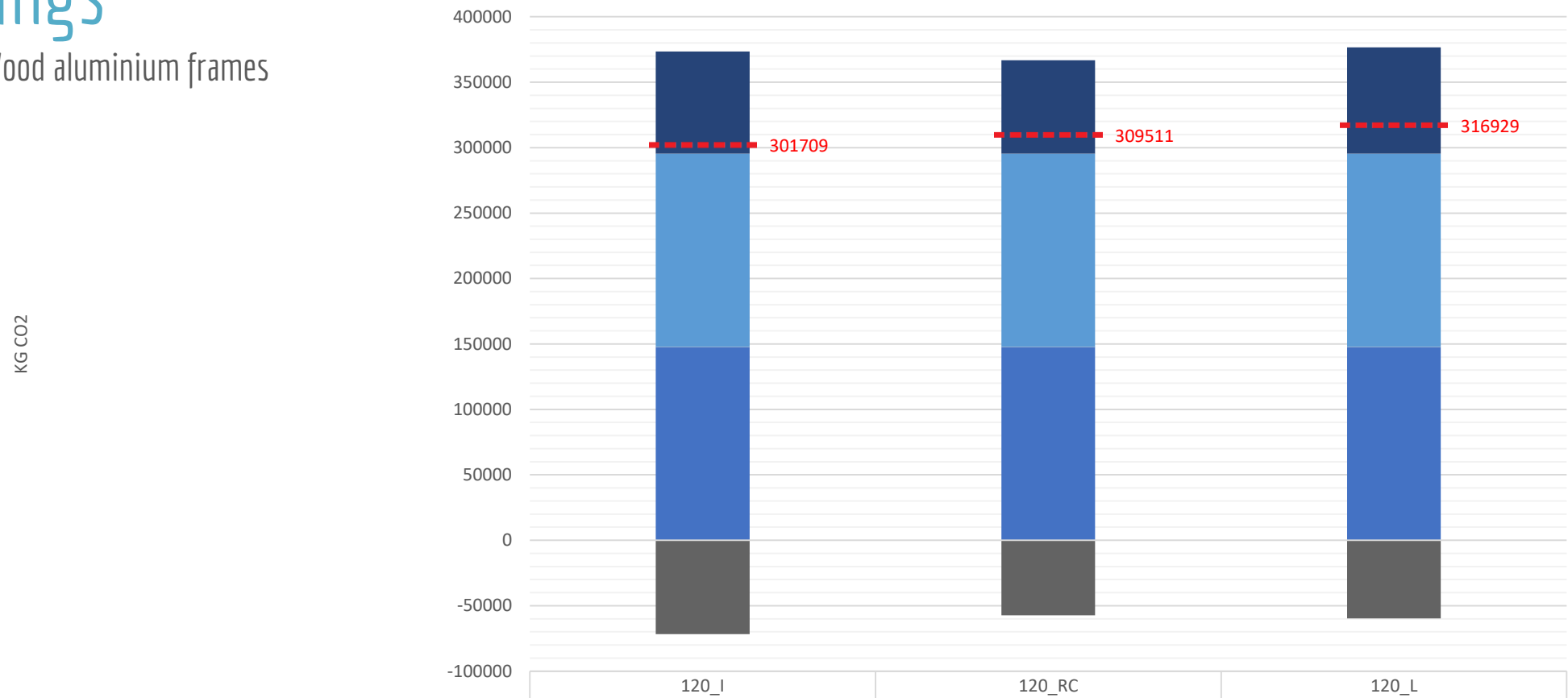
Façade- Aluminium frames



	120_I	120_RC	120_L
Second Life External Impacts (D') *can't take this into account			
Second Life End of Life (C1'-C4')			
Second Life Maintenance and replacement (B1'-B5')			
Second Life Transportation (A4')			
Second Life Primary Production (A1'-A3')			
First Life External Impacts (D) *A5 not included		-160516	
First Life End of Life (C1-C4) *A5 not included		14430	
First Life Maintenance and replacement (B1-B5) *A5 not included		165756	
First Life Transportation (A4) *A5 not included		1010	
First Life Primary Production (A1-A3)		165756	

Findings

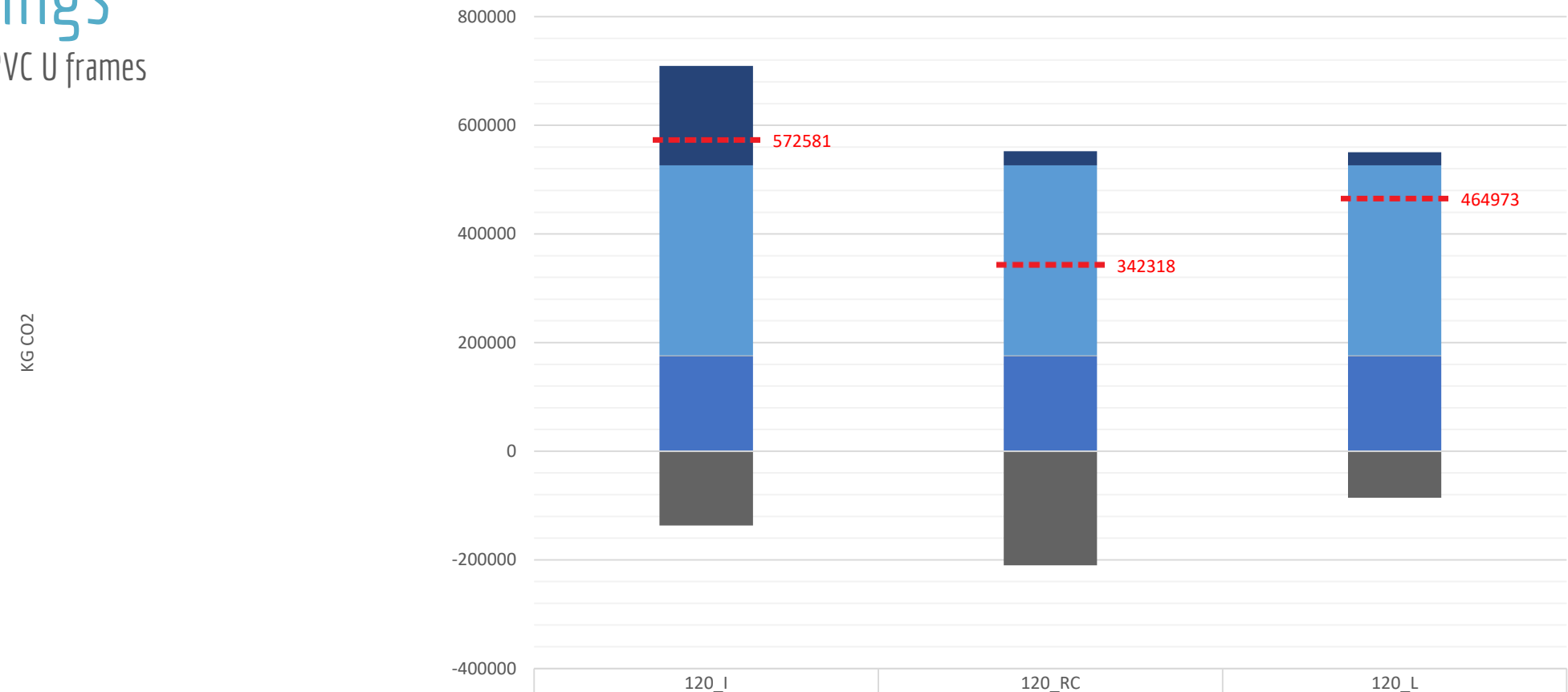
Façade- Wood aluminium frames



	120_I	120_RC	120_L
Second Life External Impacts (D') *can't take this into account			
Second Life End of Life (C1'-C4')			
Second Life Maintenance and replacement (B1'-B5')			
Second Life Transportation (A4')			
Second Life Primary Production (A1'-A3')			
First Life External Impacts (D) *A5 not included	-71793	-57228	-59773
First Life End of Life (C1-C4) *A5 not included	78085	71322	81285
First Life Maintenance and replacement (B1-B5) *A5 not included	147598	147598	147598
First Life Transportation (A4) *A5 not included	220	220	220
First Life Primary Production (A1-A3)	147598	147598	147598

Findings

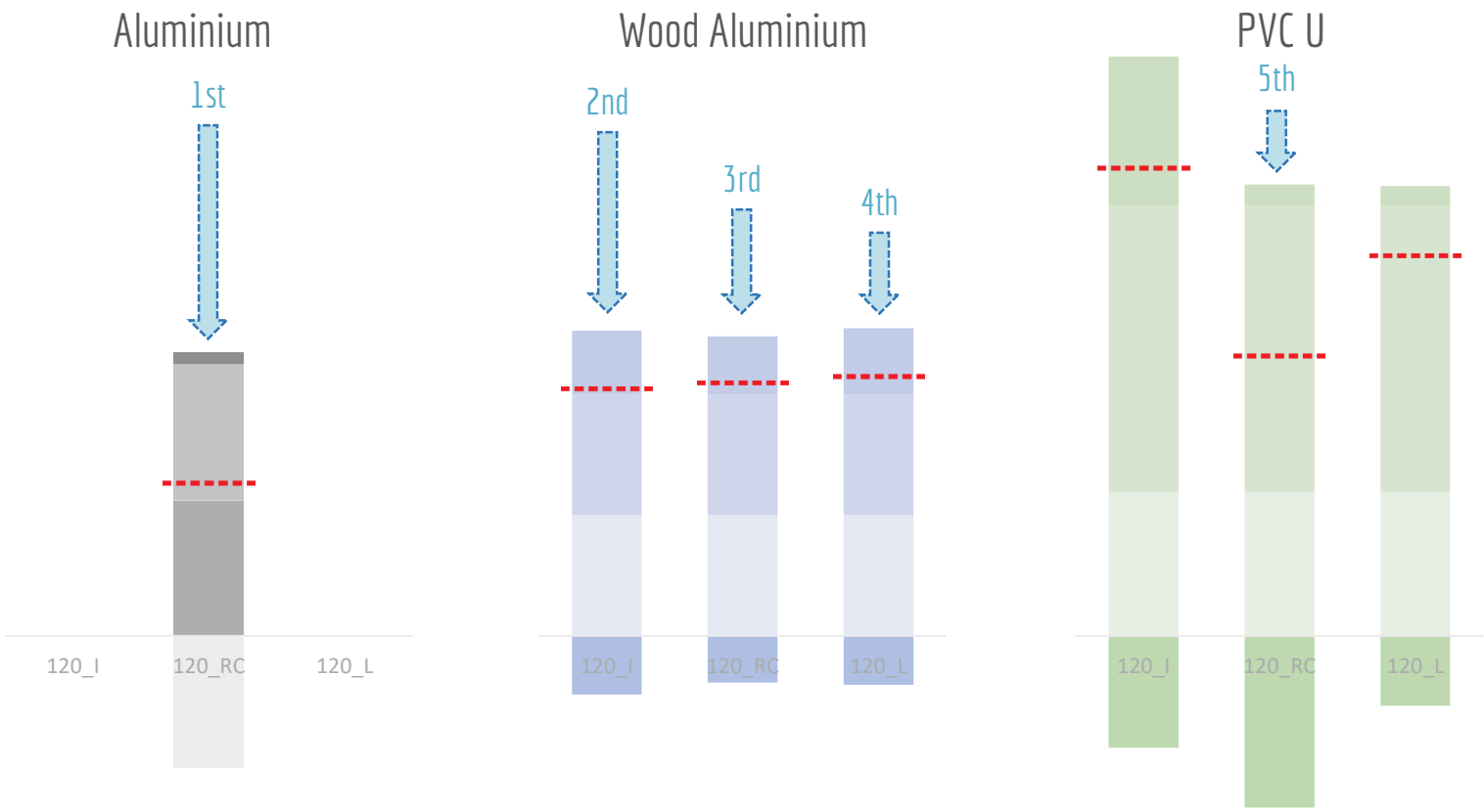
Façade- PVC U frames



	120_I	120_RC	120_L
Second Life External Impacts (D') *can't take this into account			
Second Life End of Life (C1'-C4')			
Second Life Maintenance and replacement (B1'-B5')			
Second Life Transportation (A4')			
Second Life Primary Production (A1'-A3')			
First Life External Impacts (D) *A5 not included	-136839	-210032	-85468
First Life End of Life (C1-C4) *A5 not included	183210	26140	24231
First Life Maintenance and replacement (B1-B5) *A5 not included	350000	350000	350000
First Life Transportation (A4) *A5 not included	1210	1210	1210
First Life Primary Production (A1-A3)	175000	175000	175000

Findings

All Façade- comparison



Original presumed choice

Aluminium
120_RC
186,436

Aluminium
120_RC
186,436
›
Wood-Alu
120_I
301,709
›
Wood-Alu
120_RC
309,511
›
Wood-Alu
120_L
316,929
›
PVC U
120_RC
342,318

Kg CO_2