

# FCC – Carbon budget study

Dr. Dasaraden Mauree

FCC Week – San Francisco 13/06/2024





**1. Objectives**

**2. Methodology**

**3. Data collection**

**4. Benchmark analysis**

**5. Optimisation strategies**





Objectives

# CERN – FCC

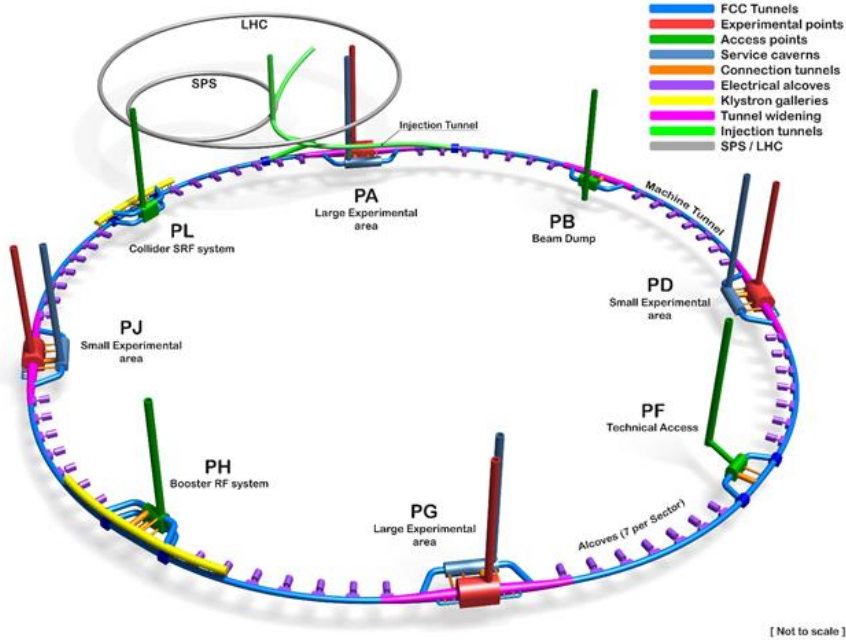
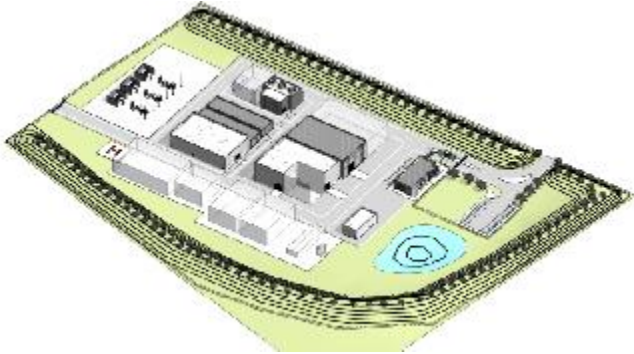
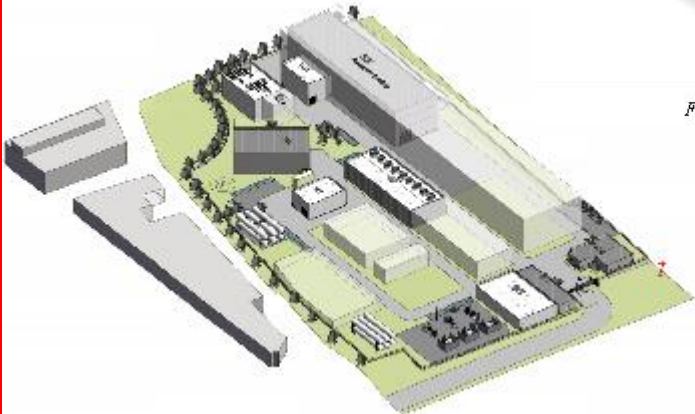


Figure 1 – Schematic model of the proposed sub-surface FCC structures





## Goals of the study

- Establish a credible benchmark for the carbon budget
- Identify main drivers
- Explore realistic optimisation
- Evaluate reduction potential



**1. Objectives**

**2. Methodology**

**3. Data collection**

**4. Benchmark analysis**

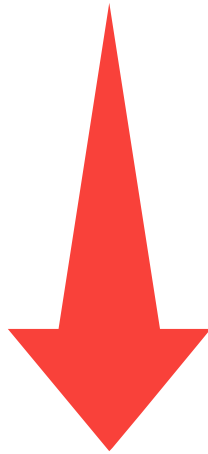
**5. Optimisation strategies**



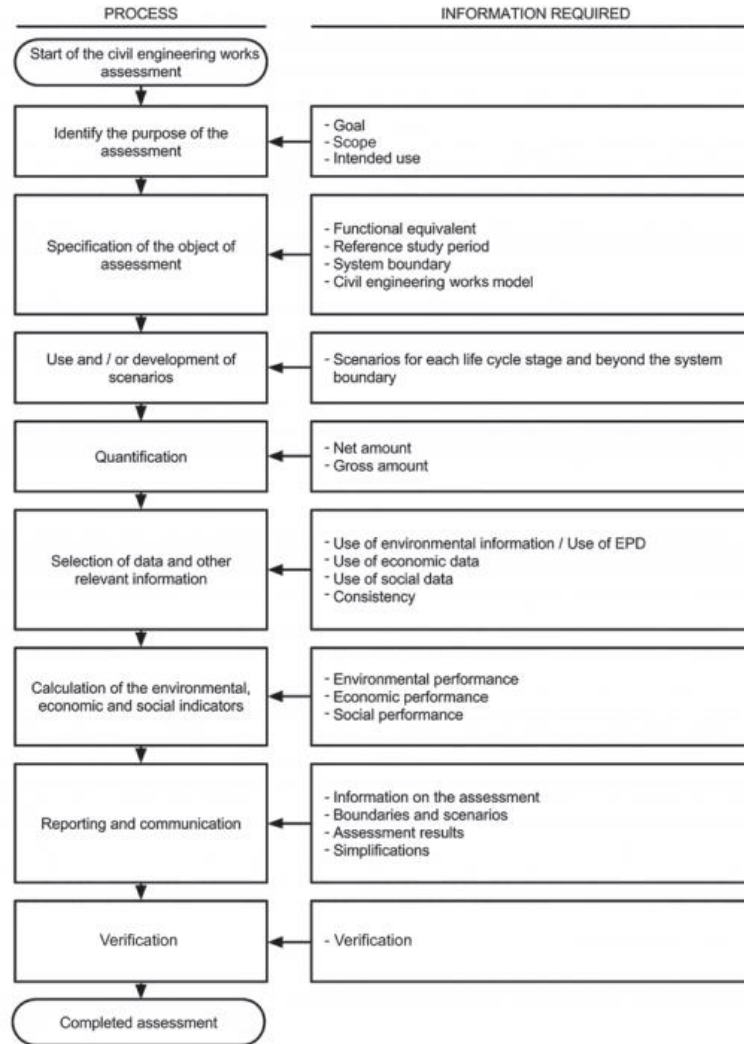


# Assessment process

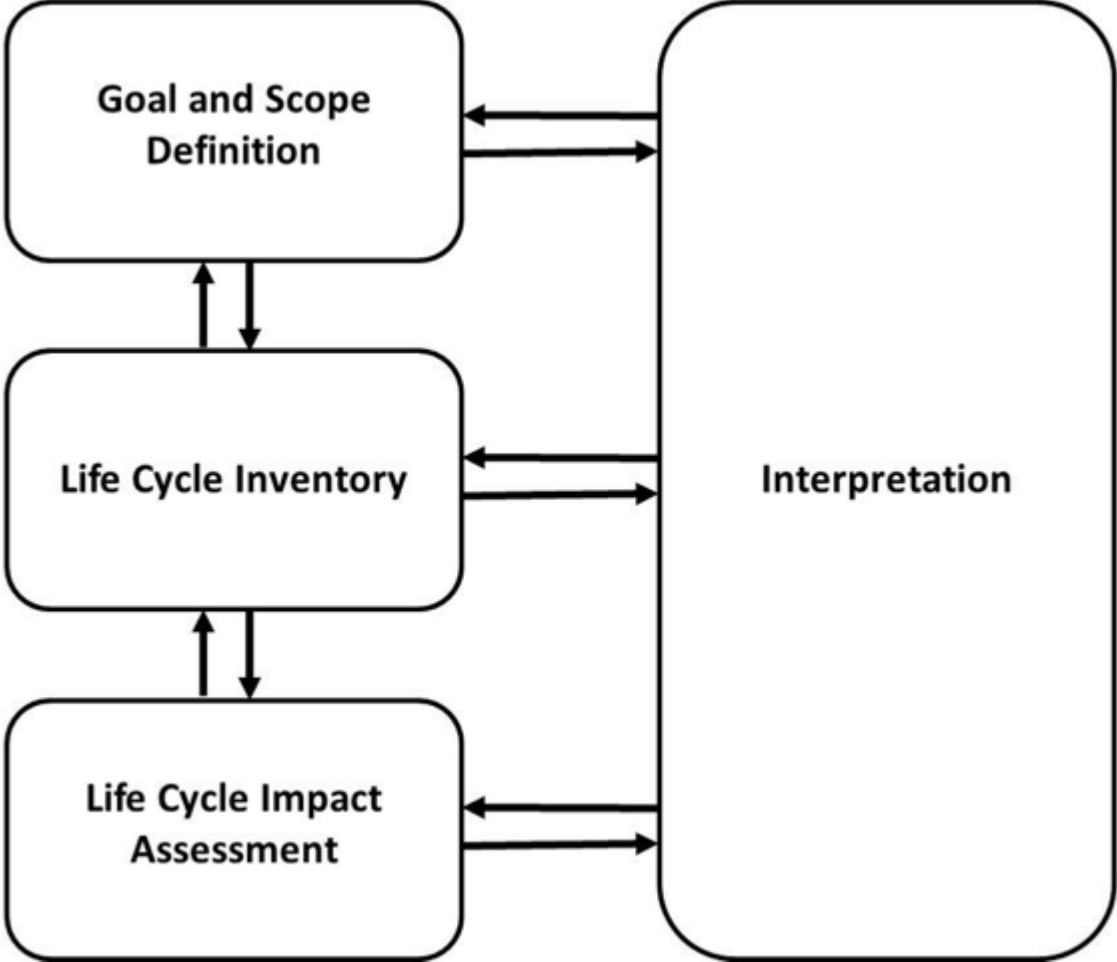
Start of the study



Current stage



# LCA Approach





# Framework for calculation

## EN 17472 :

- EU norm for sustainability assessment of civil engineering work
  - Used as a framework for the life cycle analysis
- Based on the EN15804+A2 Environmental product declaration

EUROPEAN STANDARD

**EN 17472**

NORME EUROPÉENNE

EUROPÄISCHE NORM

February 2022

ICS 91.040.01

English Version

Sustainability of construction works - Sustainability  
assessment of civil engineering works -  
Calculation methods



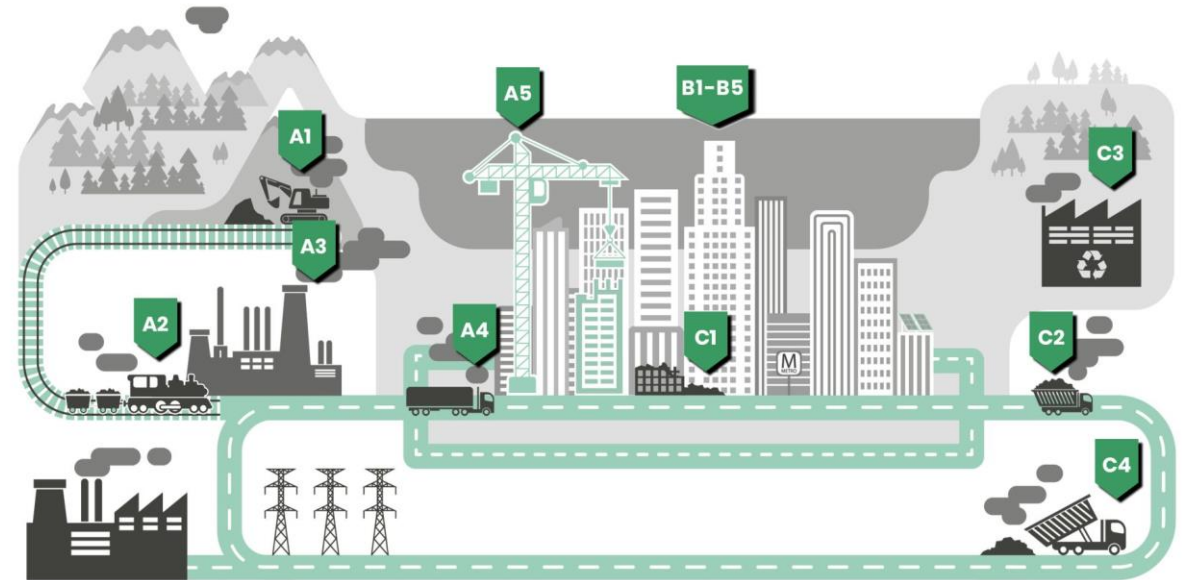


# LCA Approach

## Use of OneClick LCA Tool

- Access to *environmental declaration products* from manufacturers
- Access to local (*KBOB*) and international database (*INIES*)
- Provide calculations for the EN17472

## Sources of embodied carbon across the construction lifecycle



### A1 - A3 Product stage

A1 Raw material extraction  
A2 Transport to manufacturing site  
A3 Manufacturing

### A4 - A5 Construction stage

A4 Transport to construction site  
A5 Installation / Assembly

### B1-B5 Use stage

B1 Use  
B2 Maintenance  
B3 Repair  
B4 Replacement  
B5 Refurbishment

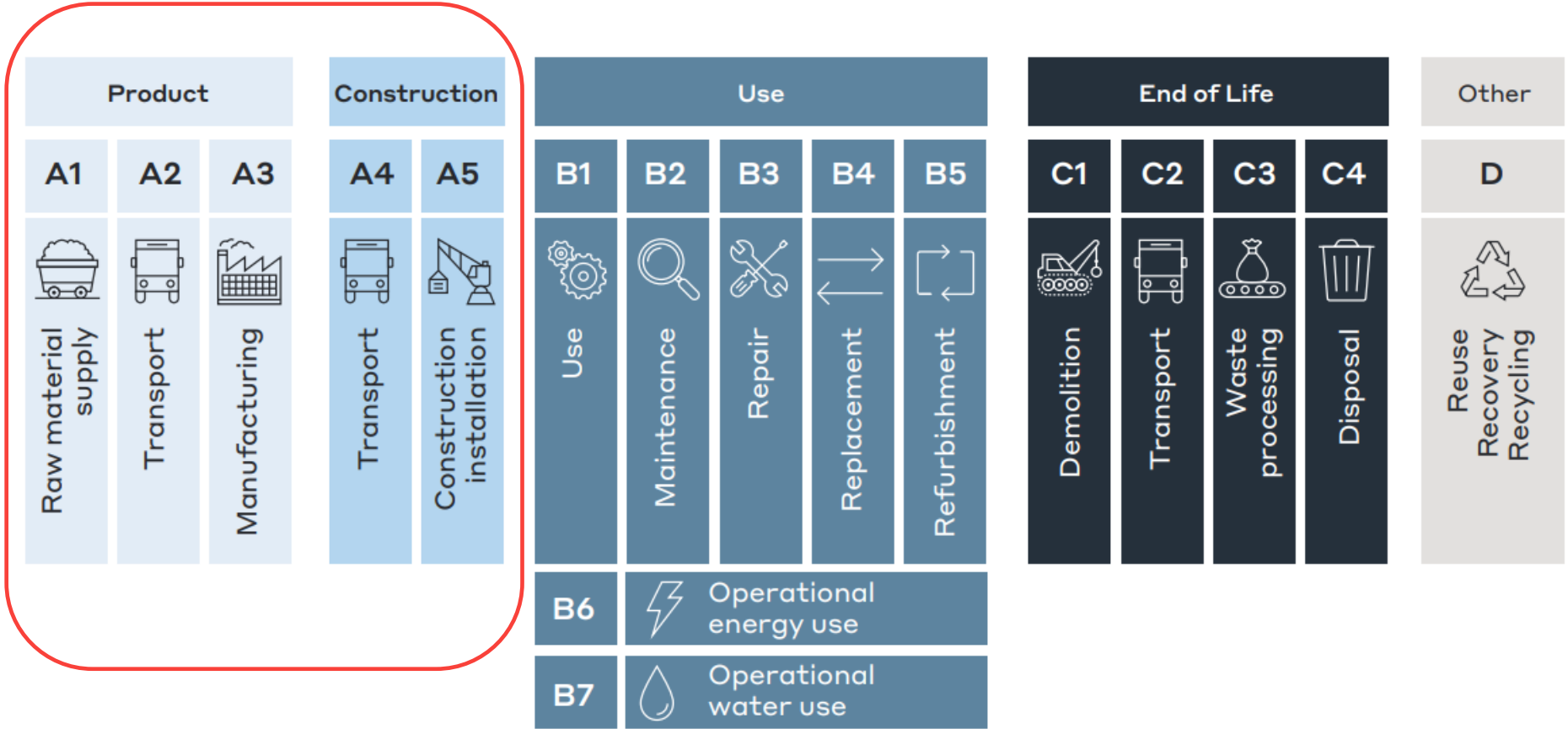
### C1 - C4 End of life stage

C1 Deconstruction & demolition  
C2 Transport  
C3 Waste processing  
C4 Disposal



# Boundary of assessment

**STAGE  
MODULE**





## Selected KPIs

| EPD based on <u>EN 15804+A2</u>                | Reported in OneClickLCA |
|--|-------------------------|
| Climate Change Total                           | X                       |
| Climate Change Fossil                          | X                       |
| Climate Change Biogenic Removals and Emissions | X                       |
| Climate Change Land Use and Land Use Change    | X                       |

|  |   |
|--|---|
| Acidification                                | Data available from EPDs, requires extra work to compile the values |
| Eutrophication Aquatic Freshwater            |   |
| Eutrophication Fresh Marine                  |   |
| Eutrophication Terrestrial                   |   |
| Photochemical Ozone Formation                |   |
| Abiotic Depletion- Minerals and Metals       |   |
| Fossil Fuels                                 |   |
| Water Use                                    |   |
| <b>Particulate Matter Emissions</b>          |   |
| <b>Ionizing Radiation, Human Health</b>      |   |
| <b>Eco-Toxicity</b>                          |   |
| <b>Human Toxicity, Cancer Effects</b>        |   |
| <b>Human Toxicity, Non-Cancer Effects</b>    |   |
| <b>Land Use Related Impacts/Soil Quality</b> |   |



**1. Objectives**

**2. Methodology**

**3. Data collection**

**4. Benchmark analysis**

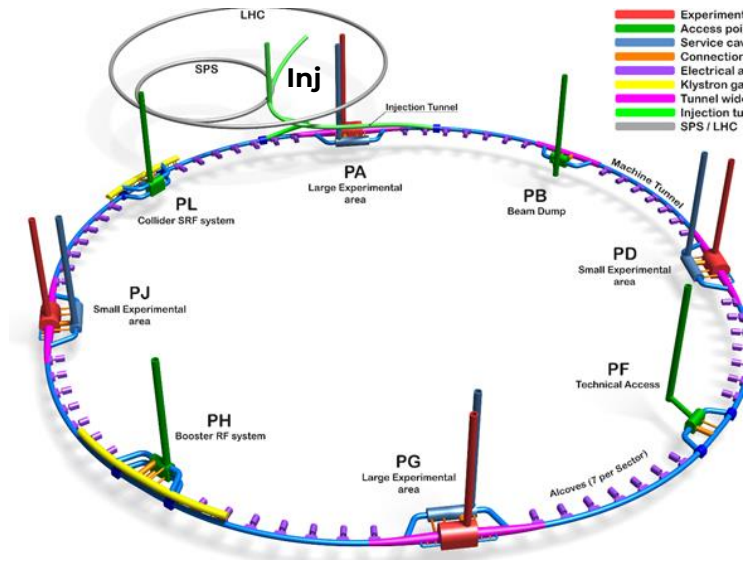
**5. Optimisation strategies**





Data collection

# Subsurface – Bill of Quantities

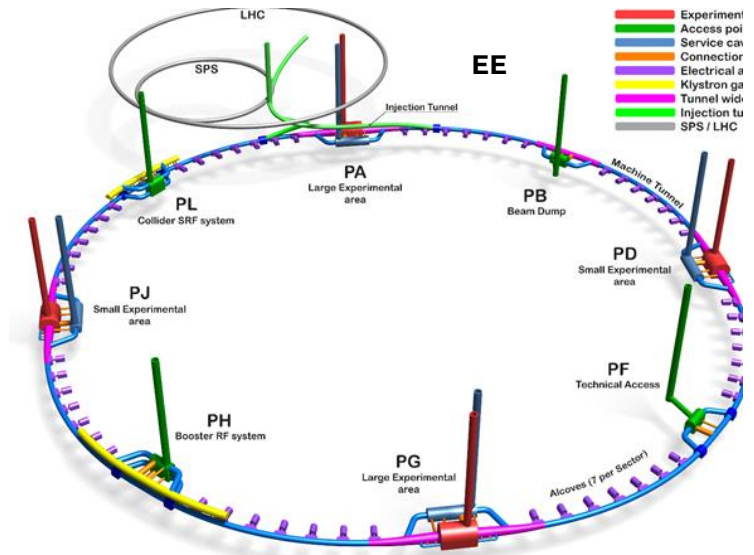


| Description  | Point Mapping     | A          | B         | D          | INJ       | F         | G          | H         | J          | L         | Total       |
|--|-------------------|------------|-----------|------------|-----------|-----------|------------|-----------|------------|-----------|-------------|
|  | kg                |            |           |            |           |           |            |           |            |           |             |
| acier d'armature                                       | Reinforc. Steel   | 11 423 528 | 8 208 711 | 20 428 569 | 2 515 419 | 4 076 864 | 20 974 457 | 6 643 111 | 19 861 207 | 9 842 945 | 103 974 813 |
| Acier  | Int. Str. Steelw. | 951 993    | 1 616 972 | 3 697 711  | 428 652   | 297 888   | 3 737 021  | 581 986   | 3 440 832  | 1 772 421 | 16 525 476  |
| Fibre d'acier  | Steel Fibre       |            | 980 001   | 1 992 659  |           |           | 1 926 355  |           | 1 866 979  | 953 282   | 7 719 276   |
|  | m                 |            |           |            |           |           |            |           |            |           |             |
| Polyéthylène haute densité, épaisseur supposée de 5 mm | Dimple Sheet      | 2 416      | 11 108    | 23 228     | 5 710     | 725       | 23 083     | 2 210     | 21 896     | 11 300    | 101 676     |
| acier, diamètre de 25 mm                               | Rockbolts         | 53 190     | 17 834    | 55 989     | 57 126    | 16 851    | 62 167     | 44 404    | 58 641     | 34 538    | 400 739     |
|  | m2                |            |           |            |           |           |            |           |            |           |             |
| Polyéthylène haute densité, épaisseur supposée de 5 mm | Dimple Sheet      | 30 254     | 45 590    | 91 437     | 30 414    | 10 472    | 91 378     | 41 132    | 85 837     | 56 066    | 482 579     |
| Protection passive projeté                             | Passive Prot.     | 24 681     | 88 209    | 194 244    | 31 752    | 8 414     | 193 471    | 25 427    | 181 400    | 97 574    | 845 172     |
| Polyéthylène haute densité, épaisseur supposée de 3 mm | Waterproofing     | 111 544    | 44 271    | 123 415    | 41 466    | 45 329    | 131 813    | 99 791    | 124 580    | 79 275    | 801 484     |



Data Collection

# Subsurface – Bill of quantities



| Description   | Point Mapping     | A       | B       | D         | EE      | F       | G         | H       | J         | L       | Total     |
|---|-------------------|---------|---------|-----------|---------|---------|-----------|---------|-----------|---------|-----------|
|   | m3                |         |         |           |         |         |           |         |           |         |           |
| Coulis cimentaire   | Annulus Grout     |         | 19 905  | 40 473    |         |         | 39 127    | 1 823   | 37 921    | 20 751  | 160 000   |
| coulis de remblayage  | Backfill Grout    | 6 635   | 3 128   | 7 483     | 2 080   | 2 617   | 7 914     | 6 217   | 7 532     | 4 862   | 48 465    |
| Béton coulé   | Cast Insitu C.    | 74 697  | 19 509  | 73 569    | 11 163  | 23 358  | 80 961    | 34 621  | 73 558    | 29 663  | 421 098   |
| paroi en béton moulé et en acier, densité des barres d'armature 130 kg/m3, béton 40 Mpa | D-Wall C.         | 14 003  | 2 916   | 6 059     | 4 272   |         | 6 883     | 2 083   | 2 999     | 3 749   | 42 964    |
| Béton   | Filter Material   | 24 692  | 2 211   | 24 692    | 440     | 7 887   | 24 692    | 1 317   | 24 692    | 1 317   | 111 942   |
| traitement d'injection  | G. Treatment      | 8 412   | 4 735   | 9 238     | 2 436   | 305     | 9 196     | 2 425   | 8 510     | 5 675   | 50 932    |
| Béton coulé sur place, 30 Mpa et densité des barres d'armature 80 kg/m3                 | Internal Str. C.  | 8 825   | 4 026   | 8 557     | 458     | 5 913   | 9 599     | 3 096   | 10 092    | 3 353   | 53 920    |
| Béton coulé sur place, barres d'armature de 55 kg/m3 et béton de 20 Mpa                 | Invert Insitu C.  | 67 517  | 54 475  | 120 887   | 22 406  | 20 359  | 121 852   | 60 620  | 114 397   | 66 546  | 649 057   |
| Béton préfabriqué, densité des armatures 80 kg/m3. Béton 30 Mpa                         | Invert Precast C. | 268     | 12 297  | 25 042    | 737     | 121     | 24 924    | 827     | 23 415    | 12 348  | 99 978    |
| excavation  | Limestone         |         |         |           |         |         | 141 175   |         |           |         | 141 175   |
| excavation  | Molasse           | 562 457 | 499 592 | 1 248 824 | 336 285 | 165 213 | 1 161 914 | 366 443 | 1 227 428 | 617 754 | 6 185 911 |
| excavation  | Moraine           | 62 721  | 10 473  | 24 925    | 3 636   | 0       | 30 829    | 7 482   | 26 274    | 13 468  | 179 808   |
| Béton préfabriqué, densité des armatures 80 kg/m3, béton 50 Mpa                         | Pre-Cast C.       |         | 55 952  | 113 768   |         |         | 109 983   | 6 195   | 106 593   | 59 143  | 451 635   |
| béton projeté   | Shotcrete         | 28 376  | 9 950   | 28 942    | 22 034  | 7 314   | 32 416    | 16 386  | 30 266    | 13 425  | 189 110   |



## Subsurface - EPDs

| Bill of quantities | Reference material   | Impact CO2       | Database                                     | Country     |
|--------------------|--|------------------|--|-------------|
| Limestone          | Limestone cladding, 30 mm, 78 kg/m2  | 0.06 kgCO2e/kg   | KBOB   | Switzerland |
| Moraine            | Sand, extraction of moraine masses, produced by Helle sandpit, 2690 kg/m3 (NCC Industry AS Stone Materials, Helle plant) | 0.0006 kgCO2e/kg | NCC Industry AS Stone Materials, Helle plant | Norway      |
| Molasse            | Clay soil, loose wet density, 1760 kg/m3   | 0.003 kgCO2e/kg  | One Click LCA                                | Switzerland |
| Invert Precast C.  | Precast concrete elements, high strength, 2770 kg/m3   | 0.35 kgCO2e/kg   | KBOB   | Switzerland |
| Pre-Cast C         | Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 0% recycled binders in cement                      | 0.16 kgCO2e/kg   | KBOB   | Switzerland |
| Steel for concrete |  |                  |  |             |
| Int. Str. Steelw.  | Steel sheets, generic, 0% recycled content (only virgin materials), S235, S275 and S355                                  | 3.91 kgCO2e/kg   | One Click LCA                                | Switzerland |
| Steel Fibre        | Steel fibre for concrete reinforcement, 0% recycled content  | 2.09 kgCO2e/kg   | One Click LCA                                | Switzerland |
| Shotcrete          | Hempcrete sprayed on wall, shotcrete, L=0.0675 W/mK, 330 kg/m3, 502.4kg/m3 (wet) 0.5-3.5 MPa (non-load bearing)          | 0.26 kgCO2e/kg   | One Click LCA                                | Switzerland |



## Subsurface - EPDs

| Bill of quantities      | Reference material  | Impact CO2                  | Database             | Country     |
|-------------------------|---|-----------------------------|----------------------|-------------|
| <b>Invert Insitu C.</b> |   |                             |                      |             |
| <b>Internal Str. C.</b> |   |                             |                      |             |
| <b>Annulus Grout</b>    | Ready-mix concrete, normal strength, generic, C35/45 (5000/6500 PSI) with CEM I, 0% recycled binders (340 kg/m <sup>3</sup> ; 21.2 lbs/ft <sup>3</sup> total cement)                              | 0.29 kgCO <sub>2</sub> e/kg | KBOB / One Click LCA | Switzerland |
| <b>Backfill Grout</b>   |   |                             |                      |             |
| <b>Cast Insitu C.</b>   |   |                             |                      |             |
| <b>D-Wall C.</b>        |   |                             |                      |             |
| <b>Filter Material</b>  | Ready-mix concrete, low-strength, generic, C12/15 (1700/2200 PSI), 0% recycled binders in cement (220 kg/m <sup>3</sup> / 13.73 lbs/ft <sup>3</sup> )   | 0.31 kgCO <sub>2</sub> e/kg | INIES                | France      |
| <b>G. Treatment</b>     |   |                             |                      |             |
| <b>Dimple Sheet</b>     | Laminated high density polyethylene membrane, 0.195 kg/m <sup>2</sup> , UV Facade   | 3.90 kgCO <sub>2</sub> e/kg | IBU                  | Germany     |
| <b>Waterproofing</b>    |   |                             |                      |             |
| <b>Rockbolts</b>        | Reinforcement steel (rebar), generic, 60% recycled content (only virgin materials), A615  | 2.89 kgCO <sub>2</sub> e/kg | One Click LCA        | Switzerland |
| <b>Concrete</b>         |   |                             |                      |             |
| <b>Passive Prot.</b>    | Stone wool (mineral wool) insulation, unfaced, L = 0.031 W/mK, R = 1 m <sup>2</sup> K/W, 31mm, 1.86 kg/m <sup>2</sup> , 60 kg/m <sup>3</sup> , (Range: 51-65kg/m <sup>3</sup> ), 22% slag content | 1.41 kgCO <sub>2</sub> e/kg | One Click LCA        | Switzerland |





## Surface site – Experimental site

| Bill of quantities  | Reference material   | Impact CO2      | Database      | Country     |
|---|--|-----------------|---------------|-------------|
| <b>Prefabricated Concrete</b>                             | Prefabricated reinforced concrete wall, 546.75 kg/m, Voile béton armé (contreventant ou non) préfabriqué PREGA / GA SMART BUILDING   | 0.10 kgCO2e/kg  | INIES         | France      |
| <b>Wire mesh fence</b>                                    | Wildlife fence, galvanized steel mesh, steel posts   | 1.10 kgCO2e/kg  | One Click LCA | Switzerland |
| <b>Wall wire mesh fence</b>                               |  |                 |               |             |
| <b>Concrete C30/37</b>                                    | Hollow core concrete slabs, generic, C30/37 (4400/5400 PSI), 0% (typical) recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3), incl. reinforcement  | 0.13 kgCO2e/kg  | One Click LCA | Switzerland |
| <b>Curtain wall</b>                                       | Aluminium framed stick curtain wall system with clear float glass insulating unit, double glazed, 4-16-4, 36.4 kg/m2   | 3.72 kgCO2e/kg  | One Click LCA | Switzerland |
| <b>metal building envelope and insulation</b>             | Aluminium façade cladding panel, anodized, 7.5 kg/m2, 0% recycled content  | 16.65 kgCO2e/kg | One Click LCA | Switzerland |
| <b>Steel S235</b>   | Steel sheets, generic, 0% recycled content (only virgin materials), S235, S275 and S355  | 3.91 kgCO2e/kg  | One Click LCA | Switzerland |
| <b>Metal-steel-345MPa</b>                                 |  |                 |               |             |
| <b>Steel Decking</b>                                      |  |                 |               |             |
| <b>Metal panel</b>  |  |                 |               |             |
| <b>Metal Flat</b>   | Acoustic wood-wool panel, 25 mm, 460 kg/m3, 11.2 kg/m2, 16% moisture content, Heradesign superfine, Heradesign superfine A2 Heradesign fine, Heradesign fine A2 Heradesign macro Heradesign micro Heradesign plano | 0.48 kgCO2e/kg  | BauEPD        | Austria     |
| <b>Schichtex-Type Rock-Wool Acoustic Insulation Panel</b> |  |                 |               |             |
| <b>curtain wall interior</b>                              |  |                 |               |             |



## Surface site – Experimental site

| Bill of quantities       | Reference material  | Impact CO2     | Database      | Country     |
|--------------------------|---|----------------|---------------|-------------|
| Interior Wall            | Precast concrete interior wall elements, 0.18 m, 429.667 kg/m2 (SNBPE)                                    | 0.08 kgCO2e/kg | INIES         | France      |
| False Ceiling            | Standard gypsum ceiling tile, 15 mm, 9.9 kg/m2, absorption coefficient: 0.08, 0.30 W/mK                   | 0.34 kgCO2e/kg | One Click LCA | Switzerland |
| Full diamond grating     | Structural steel profiles, generic, 60% recycled content, I, H, U, L, and T sections, S235, S275 and S355 | 2.12 kgCO2e/kg | One Click LCA | Switzerland |
| Steel Grating            | Asphalt concrete base course, aggregate size 32 mm, 150 kg/m2, thickness 70 mm                            | 0.03 kgCO2e/kg | RTS           | Switzerland |
| CE Floor Wood panel      | CLT wood panels, biogenic CO2 not subtracted (for CML), 710 kg/m3 (BOIS DE FRANCE)                        | 0.22 kgCO2e/kg | INIES         | France      |
| Asphalt + granular       | Reinforcement steel (rebar), generic, 0% recycled content   | 2.29 kgCO2e/kg | One Click LCA | Switzerland |
| Rockacier Insulation 200 | Rock wool insulation, L=0.036 W/mK, R=5.55 m2K/W, 200 mm, 21.6 kg/m2, 108 kg/m3, Lambda=0.036             | 1.13 kgCO2e/kg | INIES         | France      |
| Insulation               | W/(m.K), Rockacier B nu Energy 200mm  |                |               |             |
| Steel fence              | Steel fence, French average, haut. 2,5m, Clôture en acier   | 5.97 kgCO2e/kg | INIES         | France      |
| Steel Door               | Steel external door   | 1.95 kgCO2e/kg | One Click LCA | Europe      |
| Windows                  | Double glazing windows with wooden frame, 30.7 kg/m2, 1.4 W/m2K, biogenic CO2 not subtracted              | 1.80 kgCO2e/kg | INIES         | France      |
| Steel Roof               | Steel sheets, generic, 60% recycled content, S235, S275 and S355  | 2.42 kgCO2e/kg | One Click LCA | Switzerland |



## Surface site – Technical site

| Bill of quantities                              | Reference material   | Impact CO2                   | Database      | Country     |
|---|--|------------------------------|---------------|-------------|
| <b>Concrete C30/37</b>                          | Hollow core concrete slabs, generic, C30/37 (4400/5400 PSI), 0% (typical) recycled binders in cement (300 kg/m <sup>3</sup> / 18.72 lbs/ft <sup>3</sup> ), incl. reinforcement   | 0.13 kgCO <sub>2</sub> e/kg  | One Click LCA | Switzerland |
| <b>Curtain wall</b>                             | Aluminium framed stick curtain wall system with clear float glass insulating unit, double glazed, 4-16-4, 36.4 kg/m <sup>2</sup>   | 3.72 kgCO <sub>2</sub> e/kg  | One Click LCA | Switzerland |
| <b>metal building envelope and insulation</b>   | Aluminium façade cladding panel, anodized, 7.5 kg/m <sup>2</sup> , 0% recycled content   | 16.65 kgCO <sub>2</sub> e/kg | One Click LCA | Switzerland |
| <b>metal prefabricated exterior metal panel</b> |  |                              |               |             |
| <b>Steel S235</b>                               | Steel sheets, generic, 0% recycled content (only virgin materials), S235, S275 and S355  | 3.91 kgCO <sub>2</sub> e/kg  | One Click LCA | Switzerland |
| <b>Metal-steel-345MPa</b>                       |  |                              |               |             |
| <b>Steel Decking</b>                            |  |                              |               |             |
| <b>Schichtex-Type Rock-Wool</b>                 | Acoustic wood-wool panel, 25 mm, 460 kg/m <sup>3</sup> , 11.2 kg/m <sup>2</sup> , 16% moisture content, Heradesign superfine, Heradesign superfine A2 Heradesign fine, Heradesign fine A2 Heradesign macro Heradesign micro Heradesign plano | 0.48 kgCO <sub>2</sub> e/kg  | BauEPD        | Austria     |
| <b>Interior Wall</b>                            | Precast concrete interior wall elements, 0.18 m, 429.667 kg/m <sup>2</sup> (SNBPE)   | 0.08 kgCO <sub>2</sub> e/kg  | INIES         | France      |



## Surface site – Technical site

| Bill of quantities       | Reference material  | Impact CO2                  | Database      | Country     |
|--------------------------|---|-----------------------------|---------------|-------------|
| False Ceiling            | Standard gypsum ceiling tile, 15 mm, 9.9 kg/m <sup>2</sup> , absorption coefficient: 0.08, 0.30 W/mK  | 0.34 kgCO <sub>2</sub> e/kg | One Click LCA | Switzerland |
| Full diamond grating     | Structural steel profiles, generic, 60% recycled content, I, H, U, L, and T sections, S235, S275 and S355   | 2.12 kgCO <sub>2</sub> e/kg | One Click LCA | Switzerland |
| CE Floor Wood panel      | CLT wood panels, biogenic CO <sub>2</sub> not subtracted (for CML), 710 kg/m <sup>3</sup> (BOIS DE FRANCE)  | 0.22 kgCO <sub>2</sub> e/kg | INIES         | France      |
| Metal Roof - Metal Flat  | Reinforcement steel (rebar), generic, 0% recycled content   | 2.29 kgCO <sub>2</sub> e/kg | One Click LCA | Switzerland |
| Rockacier Insulation 200 | Rock wool insulation, L=0.036 W/mK, R=5.55 m <sup>2</sup> K/W, 200 mm, 21.6 kg/m <sup>2</sup> , 108 kg/m <sup>3</sup> , Lambda=0.036 W/(m.K), Rockacier B nu Energy 200mm | 1.13 kgCO <sub>2</sub> e/kg | INIES         | France      |
| Steel fence              | Steel fence, French average, haut. 2,5m, Clôture en acier   | 5.97 kgCO <sub>2</sub> e/kg | INIES         | France      |
| Steel Door               | Steel external door   | 1.95 kgCO <sub>2</sub> e/kg | One Click LCA | Europe      |
| Windows                  | Double glazing windows with wooden frame, 30.7 kg/m <sup>2</sup> , 1.4 W/m <sup>2</sup> K, biogenic CO <sub>2</sub> not subtracted  | 1.80 kgCO <sub>2</sub> e/kg | INIES         | France      |



**1. Objectives**

**2. Methodology**

**3. Data collection**






**4. Benchmark analysis**

**5. Optimisation strategies**





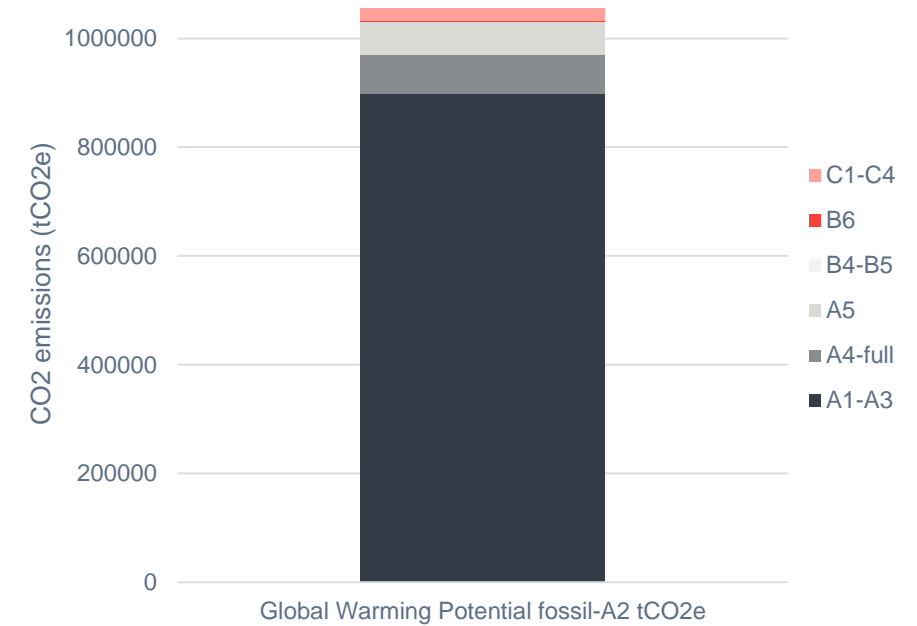
## Subsurface LCA

| No. | Resource   | Cradle to gate impacts<br>(A1-A3) | Of cradle to gate<br>(A1-A3) |
|-----|--|-----------------------------------|------------------------------|
| 1.  | Ready-mix concrete, normal strength, generic, C35/45 (5000/6500 PSI) with CEM I, 0% recycled binders (340 kg/m <sup>3</sup> ; 21.2 lbs/ft <sup>3</sup> total cement)  ? | 435 693 tonnes CO <sub>2</sub> e  | 48.5 %                       |
| 2.  | Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 0% recycled binders in cement (400 kg/m <sup>3</sup> / 24.97 lbs/ft <sup>3</sup> )  ?             | 204 496 tonnes CO <sub>2</sub> e  | 22.8 %                       |
| 3.  | Reinforcement steel (rebar), generic, 60% recycled content, A615  ?   | 126 917 tonnes CO <sub>2</sub> e  | 14.1 %                       |
| 4.  | Steel sheets, generic, 0% recycled content (only virgin materials), S235, S275 and S355  ?   | 62 130 tonnes CO <sub>2</sub> e   | 6.9 %                        |
| 5.  | Ready-mix concrete, low-strength, generic, C12/15 (1700/2200 PSI), 0% recycled binders in cement (220 kg/m <sup>3</sup> / 13.73 lbs/ft <sup>3</sup> )  ?              | 33 971 tonnes CO <sub>2</sub> e   | 3.8 %                        |



## Subsurface LCA

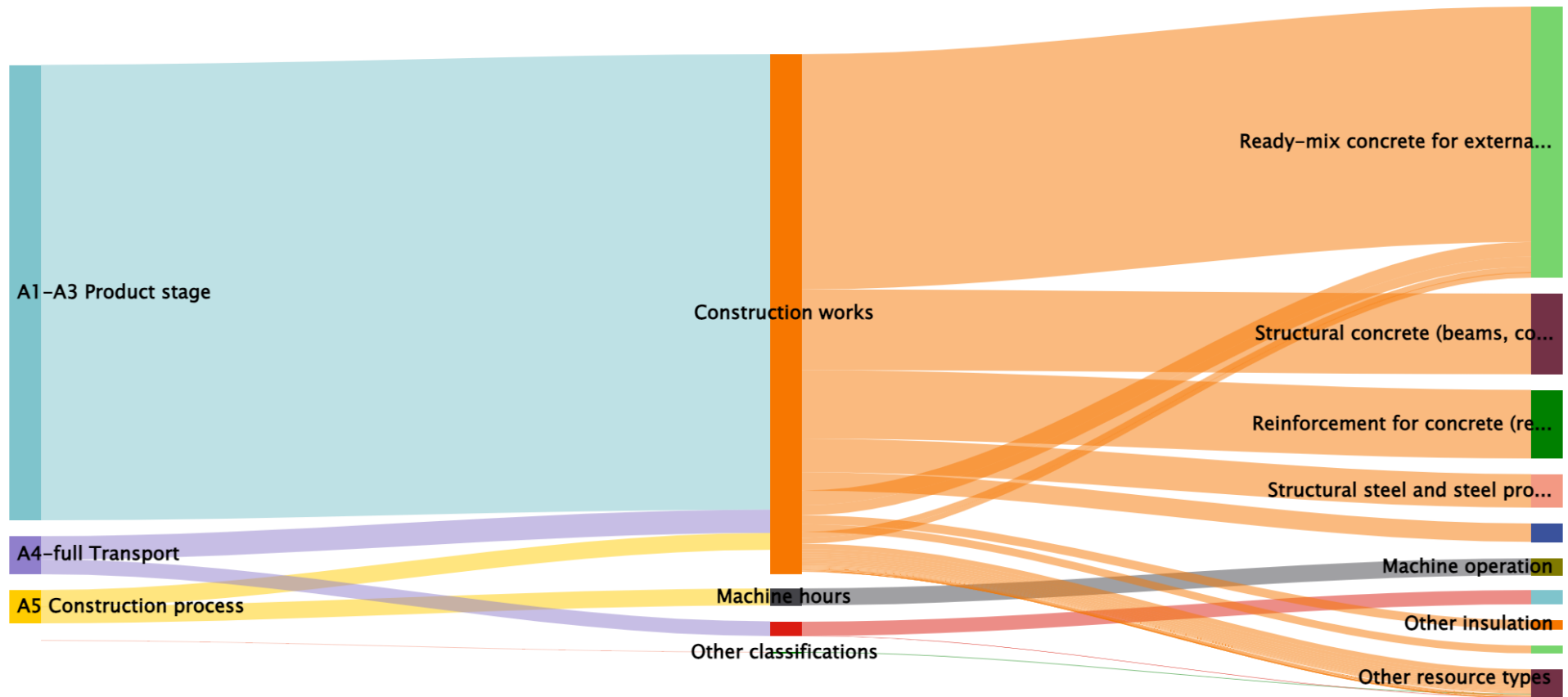
| Stage   | Global Warming Potential fossil-A2 tCO <sub>2</sub> e | Global Warming Potential, LULUC tCO <sub>2</sub> e |
|---------|---|--|
| A1-A3   | 898 670   | 338  |
| A4-full | 70 294  | 2  |
| A5      | 62 485  | 91   |
| B4-B5   | 1   | 0  |
| B6      | 280   | 0  |
| C1-C4   | 23 251  | 7  |
| D       | -303 632  | -141   |





# Subsurface LCA

Sankey diagram, Global Warming Potential fossil-A2







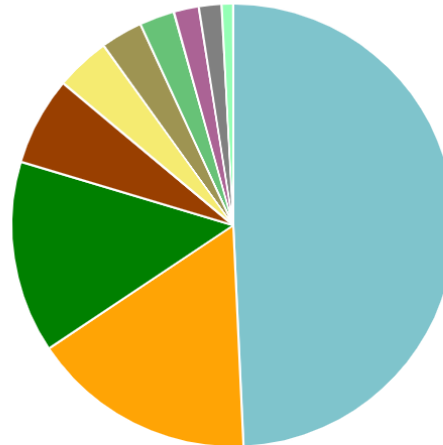
Benchmark analysis

## Subsurface LCA

### Global Warming Potential fossil-A2 kg CO<sub>2</sub>e - Resource types

This is a drilldown chart. Click on the chart to view details

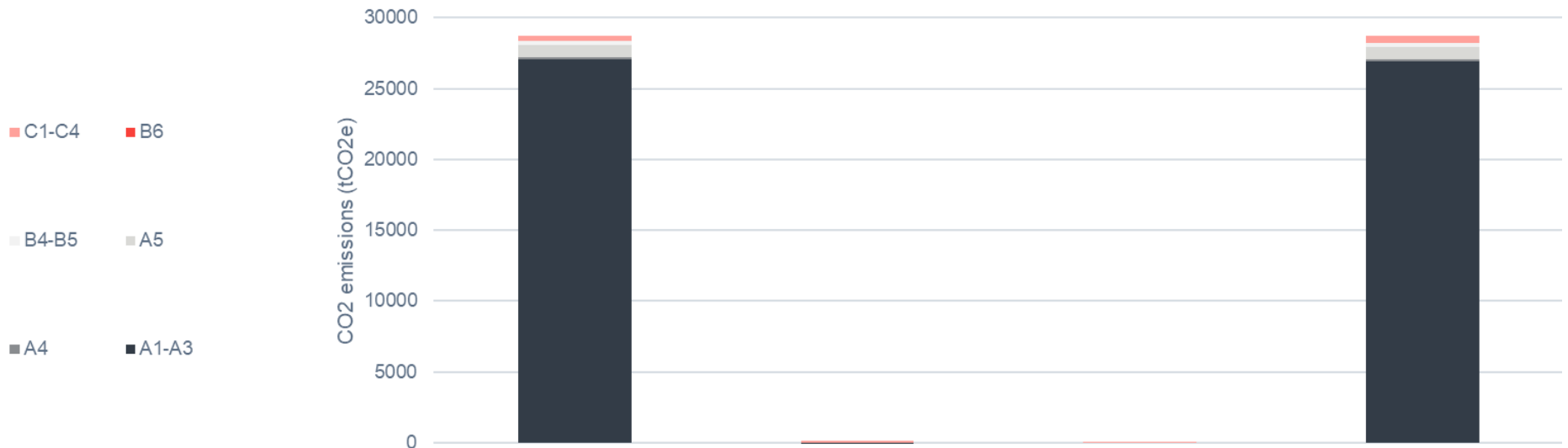
- Ready-mix concrete for external walls and floors - 49.3%
- Structural concrete (beams, columns, piling) - 16.4%
- Reinforcement for concrete (rebar) - 14.0%
- Structural steel and steel profiles - 6.5%
- Ready-mix concrete for lightweight applications (domestic and auxiliary) - 4.0%
- Machine operation - 3.1%
- Sand, soil and gravel - 2.6%
- Other insulation - 1.8%
- Other steel/iron - 1.6%
- Other resource types - 0.8%





## Surface site – Experimental site

| Section | Result category                           | Global warming potential (incl. +A2) tCO2e | Global Warming Potential biogenic tCO2e | Global Warming Potential, LULUC tCO2e | Global Warming Potential total tCO2e |
|---------|---|--|---|---------------------------------------|--------------------------------------|
| A1-A3   | Construction Materials                    | 27059.68738                                | -142.18759                              | 15.19957                              | 26932.69936                          |
| A4      | Transportation to site                    | 164.6605                                   |   | 0.00575                               | 164.66624                            |
| A5      | Construction/installation process         | 852.81811                                  | 0                                       | 0.50762                               | 853.32574                            |
| B4-B5   | Material replacement and refurbishment    | 282.46552                                  |   | 0.00475                               | 282.47027                            |
| B6      | Energy consumption                        | 0.00146                                    |   | 0.0000012                             | 0.00146                              |
| C1-C4   | End of life                               | 344.87604                                  | 142.18759                               | 0.06887                               | 487.13249                            |
| D       | External impacts (not included in totals) | -15801.47352                               |   | -15.26811                             | -15816.74163                         |

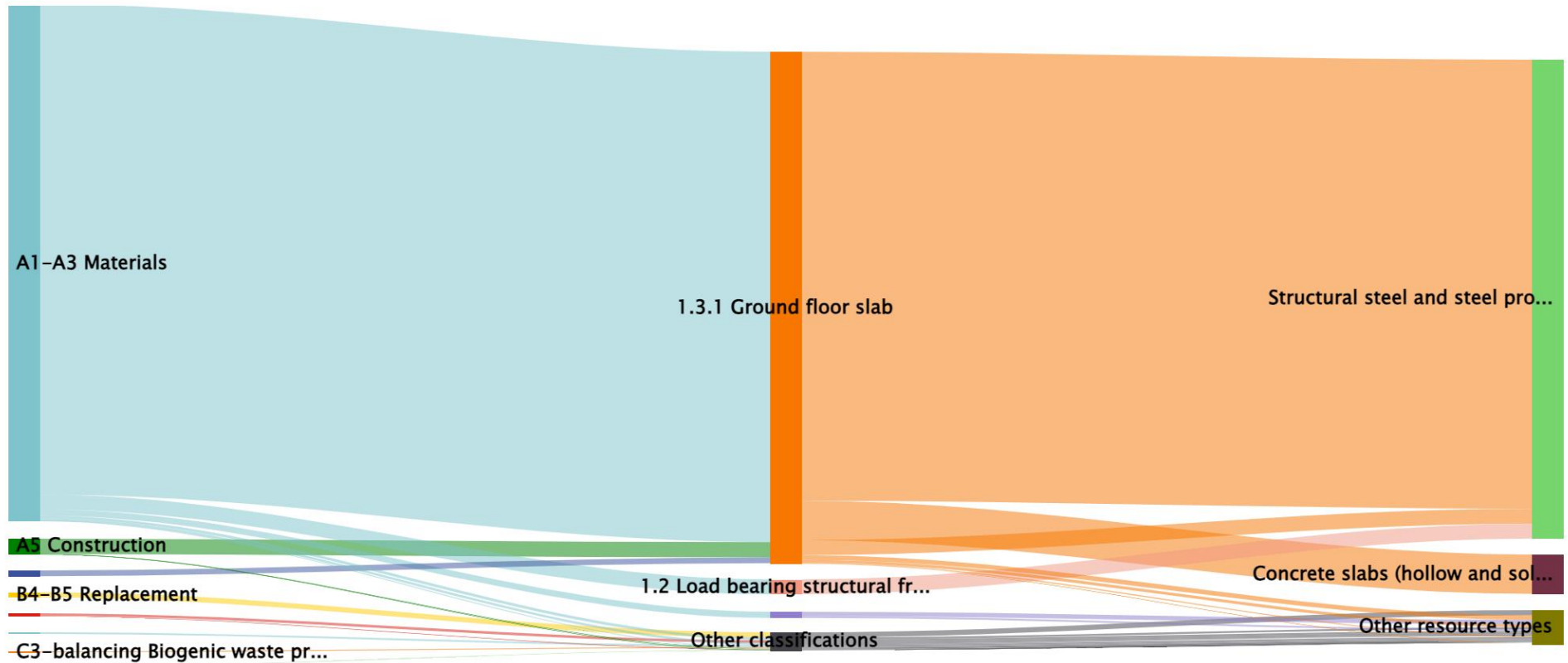




Benchmark analysis

# Surface site – Experimental site

Sankey diagram, Global Warming Potential total



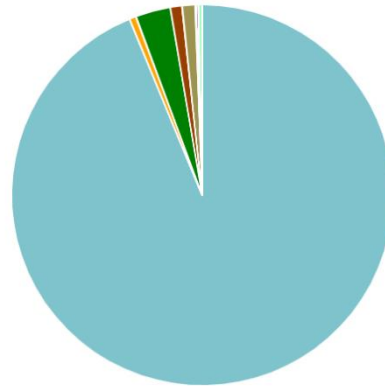


Benchmark analysis

# Surface site – Experimental site

Global Warming Potential total kg CO2e - Life-cycle stages

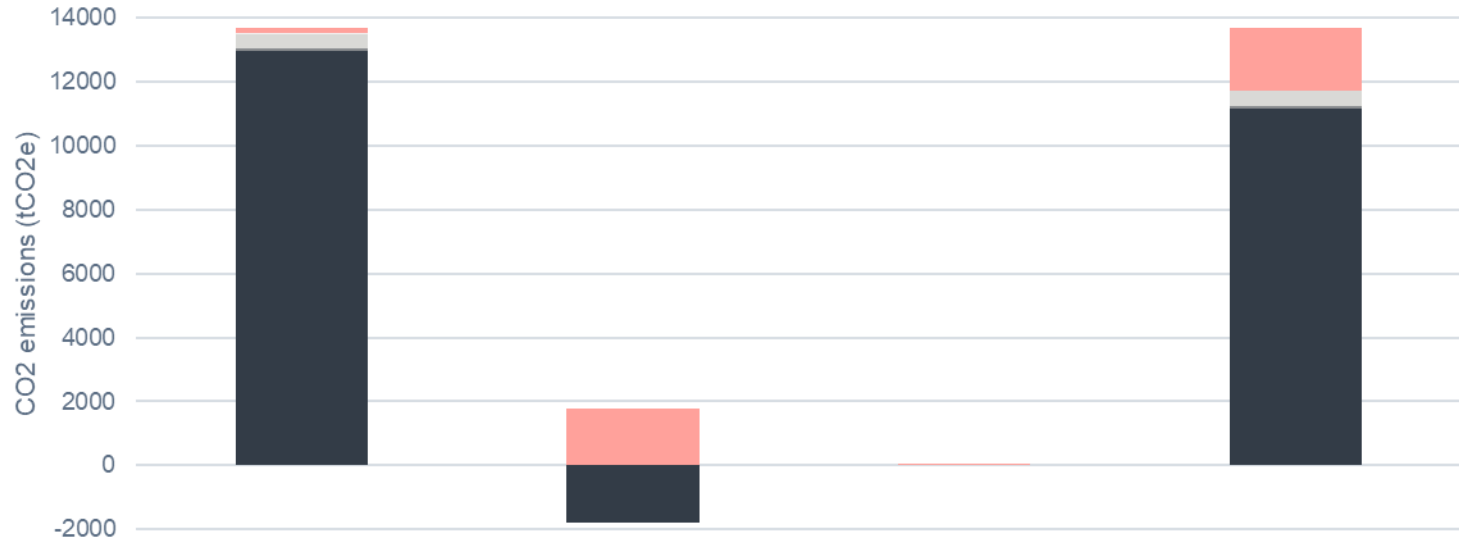
- A1-A3 Materials - 93.8%
- A4 Transport - 0.6%
- A5 Construction - 3.0%
- B4-B5 Replacement - 1.0%
- B6 Energy - 0.0%
- C2 Waste transport - 1.1%
- C3 Waste processing - 0.1%
- C3-balancing Biogenic waste processing - 0.2%
- C4 Waste disposal - 0.0%
- C4-balancing Biogenic waste disposal - 0.3%





## Surface site – Technical site

|       | Result category                           | Global warming potential (incl. +A2)<br>tCO2e | Global Warming Potential biogenic<br>tCO2e | Global Warming Potential, LULUC<br>tCO2e | Global Warming Potential total tCO2e |
|-------|---|---|--|--|--------------------------------------|
| A1-A3 | Construction Materials                    | 12950.77301                                   | -1788.70369                                | 7.14681                                  | 11169.21613                          |
| A4    | Transportation to site                    | 77.69049                                      |  | 0.00271                                  | 77.6932                              |
| A5    | Construction/installation process         | 460.94529                                     | 0  | 0.24027                                  | 461.18556                            |
| B4-B5 | Material replacement and refurbishment    | 11.80165                                      |  | 0.0000585                                | 11.80171                             |
| B6    | Energy consumption                        | 0.00146                                       |  | 0.0000012                                | 0.00146                              |
| C1-C4 | End of life                               | 182.91928                                     | 1788.70369                                 | 0.03509                                  | 1971.65806                           |
| D     | External impacts (not included in totals) | -7455.7389                                    |  | -6.00605                                 | -7461.74495                          |



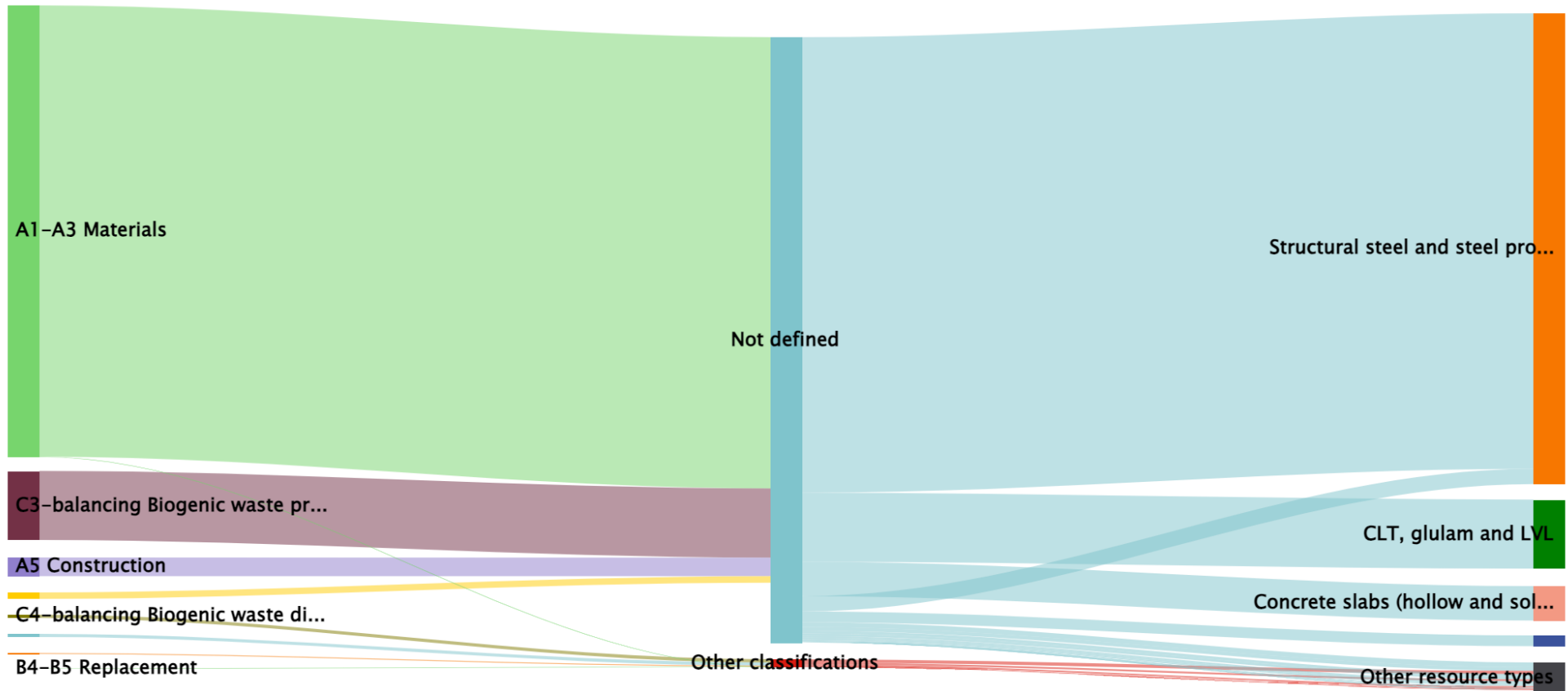


# Surface site – Technical site

Sankey diagram, Global Warming Potential total

FCC – Carbon Budget

30



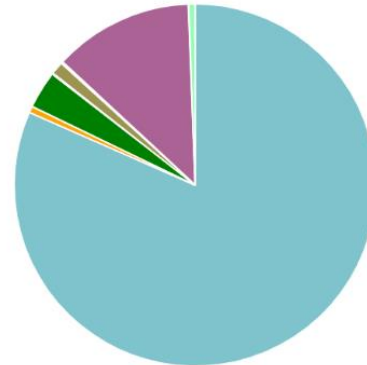


## Benchmark analysis

## Surface site – Technical site

### Global Warming Potential total kg CO<sub>2</sub>e - Life-cycle stages

- A1-A3 Materials - 81.6%
- A4 Transport - 0.6%
- A5 Construction - 3.4%
- B4-B5 Replacement - 0.1%
- B6 Energy - 0.0%
- C2 Waste transport - 1.2%
- C3 Waste processing - 0.2%
- C3-balancing Biogenic waste processing - 12.5%
- C4 Waste disposal - 0.0%
- C4-balancing Biogenic waste disposal - 0.6%





**1. Objectives**

**2. Methodology**

**3. Data collection**

**4. Benchmark analysis**

**5. Optimisation strategies**







## Subsurface

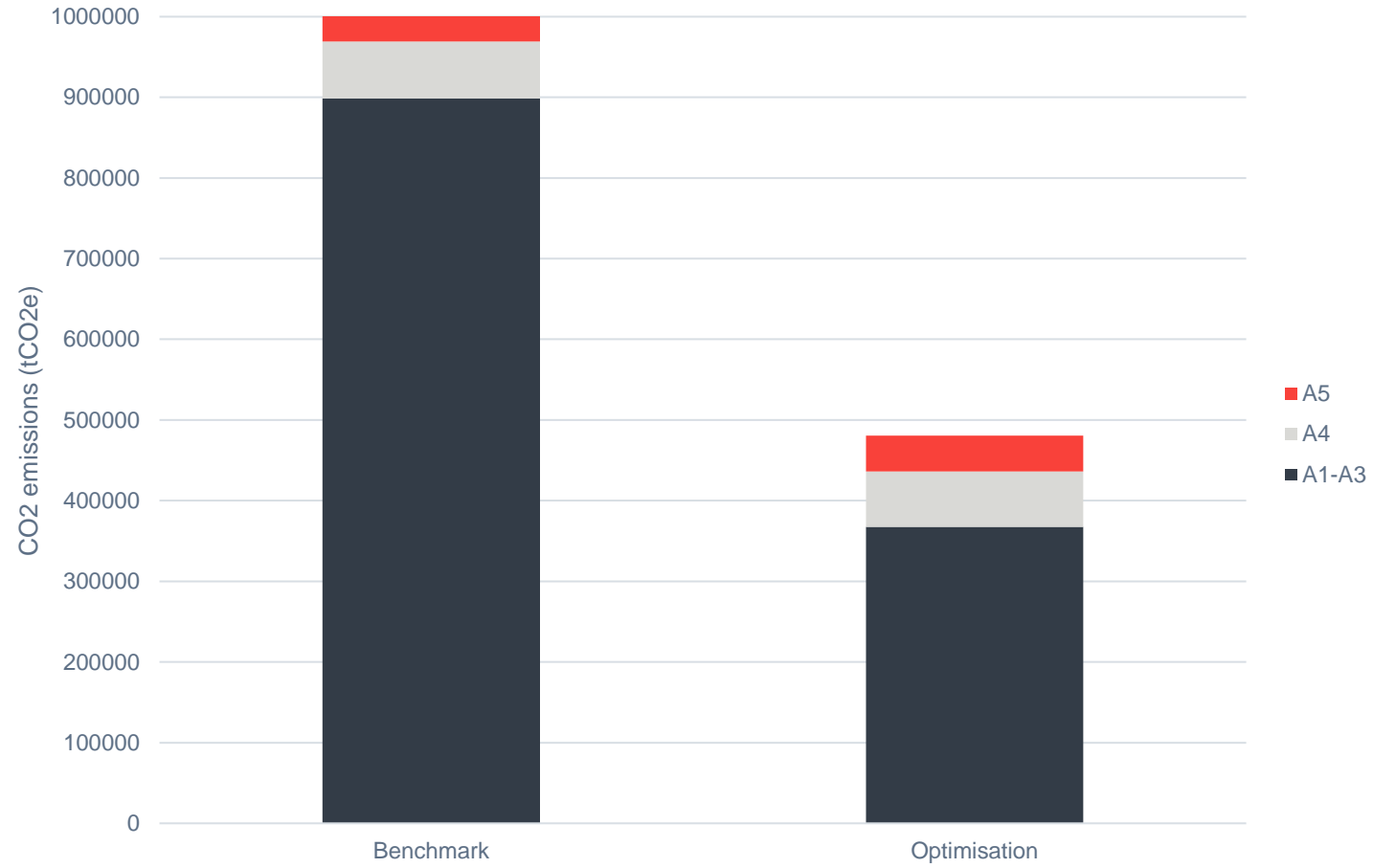
| Benchmark  | Emission CO2                 | Optimised   | Emission CO2                 | Reduction |
|--|------------------------------|---|------------------------------|-----------|
| Steel sheets, generic, 0% recycled content, S235, S275 and S355  | 3.91 kgCO2e/kg               | Steel sheets, generic, 100% recycled content, S235, S275 and S355   | 0.87 kgCO2e/kg               | 77%       |
| Steel fibre for concrete reinforcement, 0% recycled content (One Click LCA)  | 2.09 kgCO2e/kg               | Steel fibre for concrete reinforcement, 100% recycled content (One Click LCA)   | 0.51 kgCO2e/kg               | 75%       |
| Reinforcement steel (rebar), generic, 60% recycled content (only virgin materials), A615   | 1.41 kgCO2e/kg               | Reinforcement steel (rebar), generic, 100% recycled content, A615   | 0.42 kgCO2e/kg               | 70%       |
| Ready-mix concrete, normal strength, generic, C35/45 (5000/6500 PSI) with CEM I, 0% recycled binders (340 kg/m <sup>3</sup> ; 21.2 lbs/ft <sup>3</sup> total cement) | 327.02 kgCO2e/m <sup>3</sup> | Ready-mix concrete, normal strength, generic, C35/45 (5000/6500 PSI) with CEM III/A, 60% GGBS content (340 kg/m <sup>3</sup> ; 21.2 lbs/ft <sup>3</sup> total cement) | 170.36 kgCO2e/m <sup>3</sup> | 48%       |
| Ready-mix concrete, low-strength, generic, C12/15 (1700/2200 PSI), 0% recycled binders in cement (220 kg/m <sup>3</sup> / 13.73 lbs/ft <sup>3</sup> )                | 217.91 kgCO2e/m <sup>3</sup> | Ready-mix concrete, low-strength, generic, C12/15 (1700/2200 PSI), 40% recycled binders in cement (220 kg/m <sup>3</sup> / 13.73 lbs/ft <sup>3</sup> )                | 149.41 kgCO2e/m <sup>3</sup> | 31%       |
| Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 0% recycled binders in cement  | 384 kgCO2e/m <sup>3</sup>    | Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI) with CEM III/B, 75% GGBS content in cement   | 173.00 kgCO2e/m <sup>3</sup> | 39%       |

| Benchmark          | Optimised        |
|--------------------|------------------|
| 1 056 391 tCO2(eq) | 505 005 tCO2(eq) |
| <b>Reduction</b>   | <b>52%</b>       |



Optimisations

# Subsurface





## Surface site – Experimental site

| Benchmark  | Emission CO2                 | Optimised   | Emission CO2                | Reduction |
|--|------------------------------|---|-----------------------------|-----------|
| Hollow core concrete slabs, generic, C30/37 (4400/5400 PSI), 0% (typical) recycled binders in cement (300 kg/m <sup>3</sup> / 18.72 lbs/ft <sup>3</sup> ), incl. reinforcement | 0.13 kgCO <sub>2</sub> e/kg  | Hollow core concrete slabs, generic, C30/37 (4400/5400 PSI), 40% recycled binders in cement (300 kg/m <sup>3</sup> / 18.72 lbs/ft <sup>3</sup> ), incl. reinforcement | 0.09 kgCO <sub>2</sub> e/kg | 31%       |
| Aluminium façade cladding panel, anodized, 7.5 kg/m <sup>2</sup> , 0% recycled content (One Click LCA)   | 16.65 kgCO <sub>2</sub> e/kg | Aluminium façade cladding panel, anodized, 7.5 kg/m <sup>2</sup> , 70% recycled content (One Click LCA)   | 5.80 kgCO <sub>2</sub> e/kg | 65%       |
| Steel sheets, generic, 0% recycled content (only virgin materials), S235, S275 and S355  | 3.91 kgCO <sub>2</sub> e/kg  | Steel sheets, generic, 100% recycled content, S235, S275 and S355   | 0.87 kgCO <sub>2</sub> e/kg | 77%       |

| Benchmark                    | Optimised                   |
|------------------------------|-----------------------------|
| 28 700 tCO <sub>2</sub> (eq) | 7 800 tCO <sub>2</sub> (eq) |
| <b>Reduction</b>             | <b>73%</b>                  |



## Surface site – Technical site

| Benchmark  | Emission CO2    | Optimised   | Emission CO2   | Reduction |
|--|-----------------|---|----------------|-----------|
| Hollow core concrete slabs, generic, C30/37 (4400/5400 PSI), 0% (typical) recycled binders in cement (300 kg/m <sup>3</sup> / 18.72 lbs/ft <sup>3</sup> ), incl. reinforcement | 0.13 kgCO2e/kg  | Hollow core concrete slabs, generic, C30/37 (4400/5400 PSI), 40% recycled binders in cement (300 kg/m <sup>3</sup> / 18.72 lbs/ft <sup>3</sup> ), incl. reinforcement | 0.09 kgCO2e/kg | 31%       |
| Aluminium façade cladding panel, anodized, 7.5 kg/m <sup>2</sup> , 0% recycled content (One Click LCA)   | 16.65 kgCO2e/kg | Aluminium façade cladding panel, anodized, 7.5 kg/m <sup>2</sup> , 70% recycled content (One Click LCA)   | 5.80 kgCO2e/kg | 65%       |
| Steel sheets, generic, 0% recycled content (only virgin materials), S235, S275 and S355  | 3.91 kgCO2e/kg  | Steel sheets, generic, 100% recycled content, S235, S275 and S355   | 0.87 kgCO2e/kg | 77%       |

| Benchmark        | Optimised      |
|------------------|----------------|
| 13 700 tCO2(eq)  | 4 400 tCO2(eq) |
| <b>Reduction</b> | <b>68%</b>     |



Optimisations

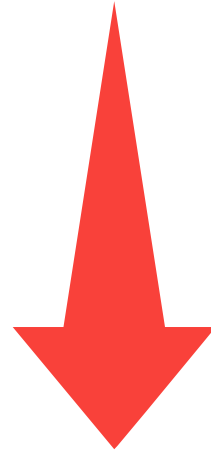
## Overall

| Impact CO2           | Initial            | Optimised        | Reduction |
|----------------------|--------------------|------------------|-----------|
| Subsurface           | 1 056 391 tCO2(eq) | 505 005 tCO2(eq) | 52%       |
| Technical site x4    | 54 800 tCO2(eq)    | 17 600 tCO2(eq)  | 68%       |
| Experimental site x4 | 114 800 tCO2(eq)   | 31 200 tCO2(eq)  | 73%       |
| Total                | 1 170 800 tCO2(eq) | 553 805 tCO2(eq) | 55%       |



Optimisations

## Key message 1



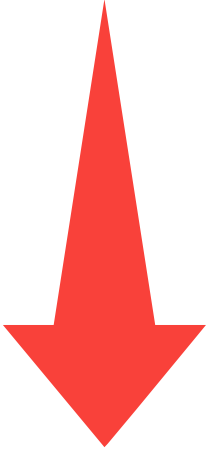
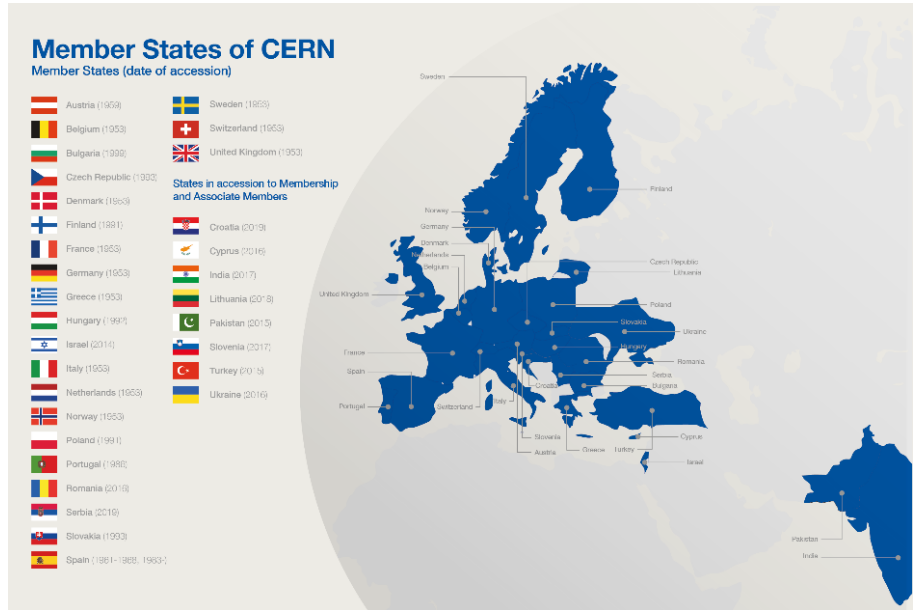
-500 000 tCO<sub>2</sub>

Reduction equivalent to the annual energy use in buildings for Geneva



Optimisations

# Key message 2



GHG emissions corresponds to **1 kg CO<sub>2</sub> / person** of all member states of CERN

Paris climate objective is **2000 kg CO<sub>2</sub> / person / yr** by 2050



## Further improvements (1)

### Cement

- Contact with local cement producers
- Working with them to have a drive low carbon cement production on site



### Steel

- Contact with local steel producers
- Working with them to have a drive low carbon steel production
- Integrate recycled steel
- Integration of renewable energy in their energy mix

### Transport

- Use of only electric or low emission vehicles
- Ensure optimisation of vehicle flow





## Further improvements (2)

### Excavated materials

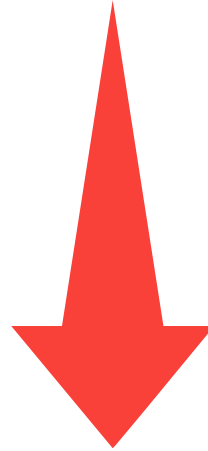
- Possibility to reuse 36% to 48% of the molasse for thermal activation in the production of cement





## Further improvements (3)

### Structure



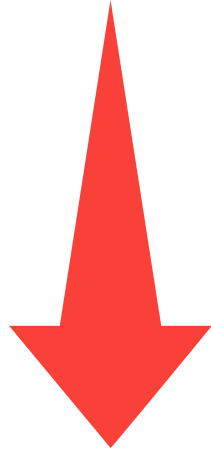
- Reduce thickness of concrete (or type of concrete)
  - **5 cm** of reduction corresponds to **16 %** reduction in CO<sub>2</sub>
- Reduce the quantity of steel in the reinforced concrete
- Reduce the strength of concrete
- Further optimisation of the site experimental and technical sites



## Further improvements (4)

### Surface sites

- Visible part of the infrastructure
- Reduce environmental impact of construction
- Impact of the choice of the sites
- Potential of creating surface sites with very low impact on the environment and not just emissions reduction



# Thank you

@D\_MAUREE

dasaraden.mauree@wsp.com



wsp.com

The WSP team would like to thank CERN, in particular,

- Johannes Gutleber
- Liam Bromiley
- Corentin Lucas Pueyo
- Benoit Bouvet

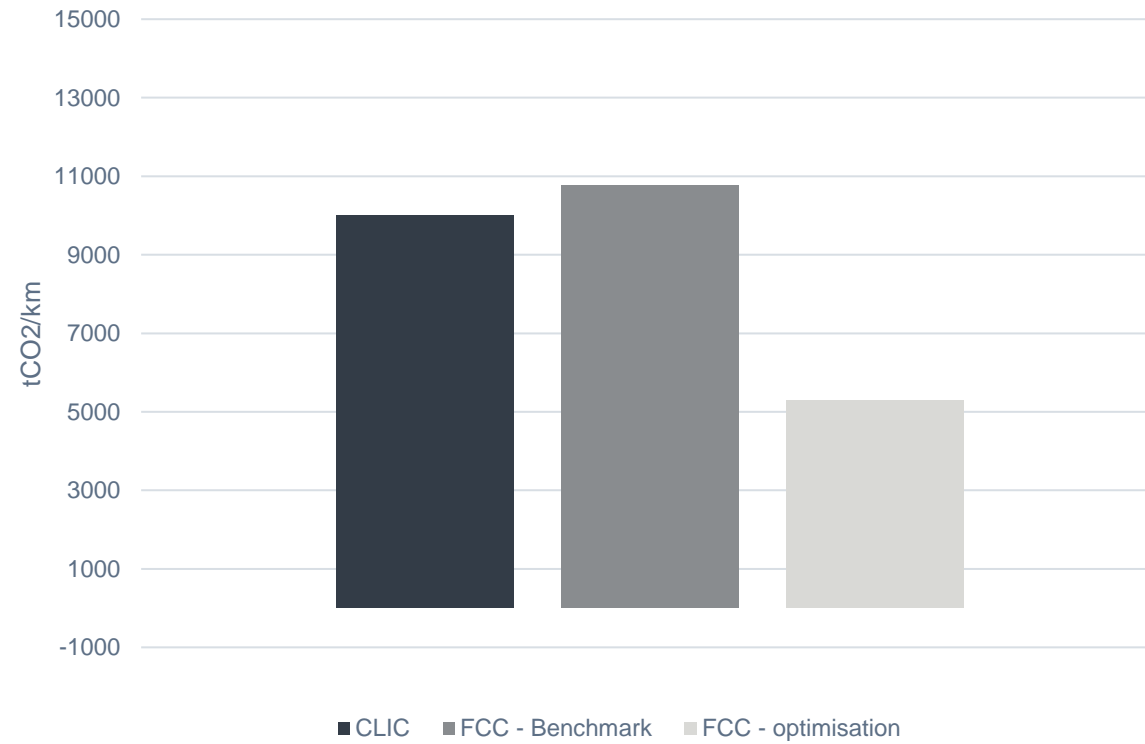
for their help and support in conducting the study.



Optimisations

# Comparison with CLIC

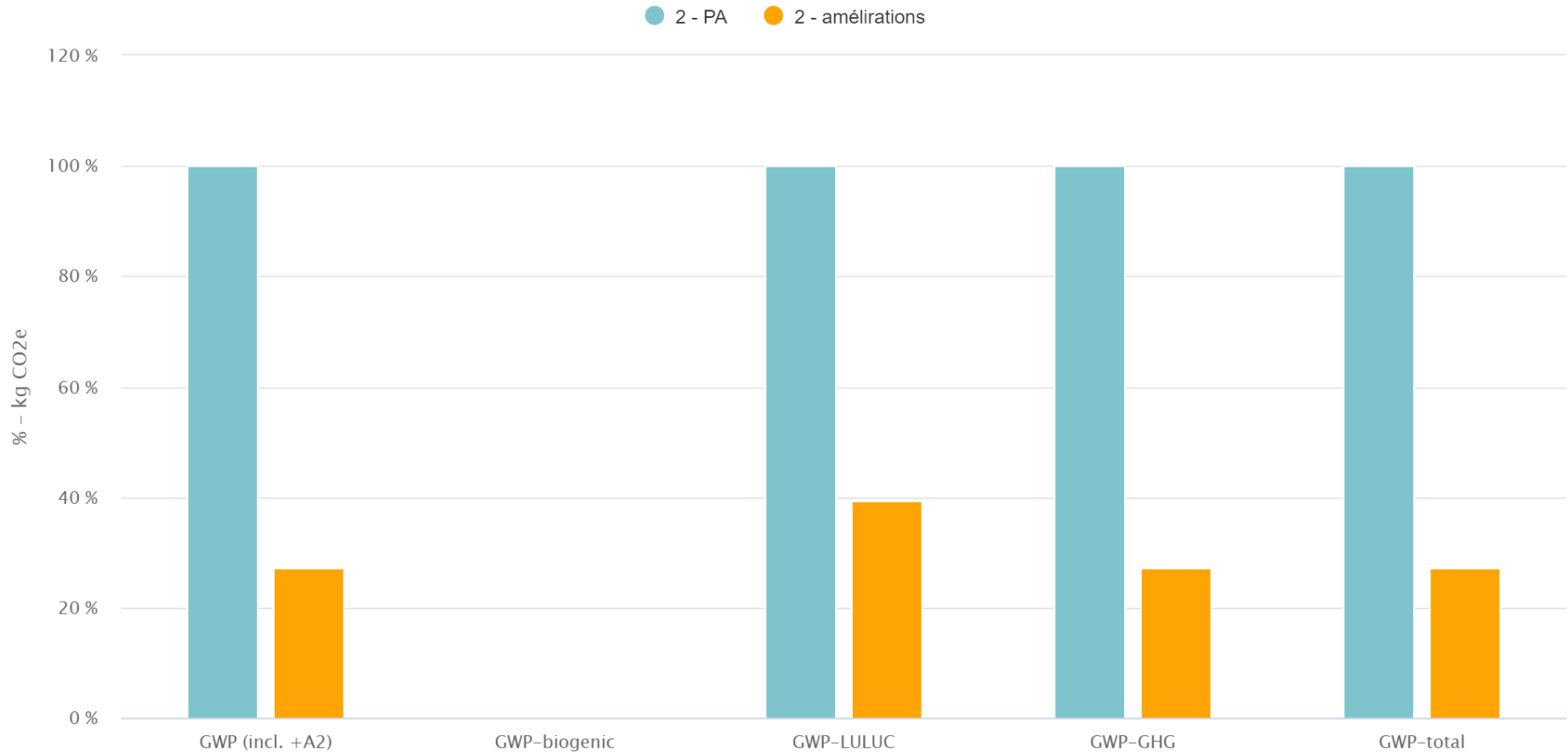
A1-A5 GWP per km, only linear part





Optimisations

# Surface site – Experimental site





Optimisations

## Surface site – Technical site

