Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

THE EFFECT OF CEMENT WITH CCS ON GREENHOUSE GAS EMISSIONS

Calculations on a case study

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Loli, A. | SINTEF Community

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THE EFFECT OF CEMENT WITH CCS ON GREENHOUSE GAS EMISSIONS

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Preface

Acknowledgements

This report has been written within the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN). The authors gratefully acknowledge the support from the Research Council of Norway, the Norwegian University of Science and Technology (NTNU), SINTEF, the municipalities of Oslo, Bergen, Trondheim, Bodø, Bærum, Elverum and Steinkjer, Trøndelag county, Norwegian Directorate for Public Construction and Property Management, Norwegian Water Resources and Energy Directorate, Norwegian Building Authority, ByBo, Elverum Tomteselskap, TOBB, Snøhetta, AFRY, Asplan Viak, Multiconsult, Civitas, FutureBuilt, Heidelberg Materials, Skanska, GK, NTE, Smart Grid Services Cluster, Statkraft Varme, Renewables Norway and Norsk Fjernvarme.

The Research Centre on Zero Emission Neighbourhoods (ZEN) in Smart Cities

The ZEN Research Centre develops solutions for future buildings and neighbourhoods with no greenhouse gas emissions and thereby contributes to a low-carbon society. Researchers, municipalities, industry and governmental organisations work together in the ZEN Research Centre in order to plan, develop and run neighbourhoods with zero greenhouse gas emissions. The ZEN Centre has nine pilot projects spread over all of Norway that encompass an area of more than 1 million m^2 and more than 30 000 inhabitants in total.

In order to achieve its high ambitions, the Centre will, together with its partners:

- Develop neighbourhood design and planning instruments while integrating science-based knowledge on greenhouse gas emissions;
- Create new business models, roles, and services that address the lack of flexibility towards markets and catalyse the development of innovations for a broader public use; This includes studies of political instruments and market design;
- Create cost effective and resource and energy efficient buildings by developing low-carbon technologies and construction systems based on lifecycle design strategies;
- Develop technologies and solutions for the design and operation of energy flexible neighbourhoods;
- Develop a decision-support tool for optimising local energy systems and their interaction with the larger system;
- Create and manage a series of neighbourhood-scale living labs, which will act as innovation hubs and a testing ground for the solutions developed in the ZEN Research Centre. The pilot projects are Furuset in Oslo, Fornebu in Bærum, Sluppen and Campus NTNU in Trondheim, Mære Campus, Ydalir in Elverum, Campus Evenstad, Ny by - Ny flyplass Bodø, and Zero Village Bergen.

The ZEN Research Centre is a eight year project ending in 2025, and the budget is approximately NOK 380 million, funded by the Research Council of Norway, the research partners NTNU and SINTEF, and the user partners from the private and public sector. The Norwegian University of Science and Technology (NTNU) is the host and leads the Centre together with SINTEF.

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Summary

Besides using alternative fuels and materials for cement production, capturing and storing CO_2 is necessary to meet climate targets. This report examines the effect of concrete produced with carbon capture and storage (CCS) technology in a construction project. The Vollsveien 9-11 project in Bærum municipality was selected as a case study due to its extensive use of concrete in the load-bearing structural system. Moreover, the building design has selected concrete with minor environmental impacts, such as low-carbon extreme and low-carbon A, to reduce the carbon footprint. The concrete used in the building was replaced with three concrete scenarios with cement from CCS technology: CEM STD-FA Grey, CEM STD-FA EvoBuild, and CEM STD-FA EvoZero. The environmental assessment for the production stage was then compared between the different scenarios at the building scale and for the concrete elements. Additionally, the results were compared with another scenario using industry reference values.

The total impact when applying concrete with CEM STD-FA Grey is 3.3% higher than the original design. This slight increase is due to the extensive use of low-carbon extreme in the original project. However, emissions are reduced when the Evo technology is applied. When cement CEM STD-FA EvoBuild is assumed in concrete production, the overall emissions are 3.6% less than the original project. The value is reduced by 12.1% in the scenario with CEM STD-FA EvoZero. When the concrete industry reference value is assumed, the overall carbon impact of the whole building increases by 13.9% compared with the original project.

When only the effect of concrete elements is compared, the concrete with CEM STD-FA Grey increases the overall impact of concrete elements by 17.4%. However, the values are reduced by 19.8% and 63.1%, respectively, for concrete with cement CEM STD-FA EvoBuild and CEM STD-FA EvoZero, highlighting the significant potential of CCS technology in reducing the carbon emissions compared to the application of low-carbon extreme concrete. The overall emissions of the concrete elements are 72.1% higher when reference values are used in the comparison.

The comparisons at the building level underscore the benefits of cement with CCS technology in reducing the carbon footprint, especially when considering concrete with CEM STD-FA EvoBuild and CEM STD-FA EvoZero in the estimations. These results should assist the ongoing efforts in updating the Environmental Product Declaration (EPD) framework to emphasise and standardise the benefits of the CCS technology.

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1. Background

Reducing CO_2 emissions is crucial in global efforts to tackle climate change. The cement industry, in particular, is a major emitter, accounting for at least 7% of all the world's CO_2 emissions [1]. While alternative fuels and materials have significantly reduced emissions from cement-based products, capturing and storing CO_2 during cement production is important for decarbonising the cement industry and meeting climate targets [2].

As the name indicates, carbon capture and storage (CCS) is a technological process that captures CO_2 and stores it securely. The process involves a series of technologies that prevent large quantities of CO_2 from being released into the atmosphere [3]. CCS consists of three main steps: capturing CO_2 at the source, compressing it for transportation, and injecting it deep into a rock formation where it is permanently stored [4].

The CCS Brevik project is part of national and international efforts to combat climate change and its impacts. Cement with CCS is in an ongoing production process at the Heidelberg Materials Brevik cement plant, partly financed by the Norwegian government's Longship project [5]. According to the plan, cement with CCS is expected to be delivered from the Brevik cement plant in 2025. The captured carbon, compressed and liquefied with technologies from cooperation partners, is planned to be transported by ship to underground storage.

The cement has the same qualities as cement without CCS but with an increased production cost due to additional carbon capture and storage costs. There is some uncertainty about the willingness to pay for a higher-priced product and the impact of such cement in reducing CO_2 emissions in a construction project. Moreover, EPDs and emission documentation standards have not incorporated the new technology, as standardisation usually takes time. However, it is necessary that the stakeholders involved in the construction industry are familiar with CCS alternatives for cement and can incorporate the derived products from cement with CCS into procurement documents and contracts.

This report aims to study the impact of cement with CCS on emission inventory at a building level and compare it with other concrete solutions in the market. The emission documentation of an ambitious project located in Bærum has been used for comparison. In the analysis, the impact of cement-derived products was replaced with the impact of concrete with CCS to highlight the total impact at a broader level. The effect of industry reference concrete in the Norwegian construction sector was also incorporated into the comparison.

2. Case study: Vollsveien 9-11

The case study building (Vollsveien 9-11) is located in Bærum municipality, in the southernmost part of Granfos's business park. The project derives its name from the construction site address and is intended for office use. The building has based its climate strategy on FutureBuilt ZERO and aims to achieve BREEAM-NOR Outstanding certification [6], [7]. The structure has 8+1 floors and a total area of 19 800 m^2. The construction period is planned for 2020-2025. Existing buildings were demolished or dismantled for reuse, and the ground was stabilised before the erection of the new building to ensure foundation stability.

The structure is designed so that ventilation systems, sprinklers, and electrical cables are located in the holes of prefabricated slab materials, giving a higher level of flexibility and adaptation during the building's operation. The building has a net floor height of 3.2 m, and modular partition walls with high acoustic requirements are selected to utilise the areas for different purposes. The solution makes the entire building process effective and reduces construction waste.

The load-bearing system is mainly made of concrete. This solution is the main reason the case was chosen to compare the effects of different concrete types in the emission calculations. The project has high ambitions in reducing the carbon footprint, and several products are being reused from existing buildings. Low-carbon extreme is chosen for most cast-in-place concrete elements to reduce the carbon impact, while a wide range of materials is chosen based on their environmental impact.

The primary materials in the facade are brick and wood, along with large windows and glass panels that offer good visibility and daylight conditions. The choice of brick and wood as facade materials is closely tied to the historic buildings at Granfos and the expertise in using these materials over the years.

Images of the project are shown in Figure 1 and Figure 2 below:

Figure 1 – Vollsveien 9-11 project from outside (Illustration: A-Lab) [7].

Figure 2 –Vollsveien 9-11 project from inside (Illustration: A-Lab) [7].

3. GHG emission calculations

The assessment and documentation of the building's carbon footprint were performed using Reduzer, a software specialised in calculating the carbon footprint of construction projects [8]. The calculations follow the guidelines of the Norwegian standard NS 3720, which provides a calculation method for greenhouse gas emissions for buildings [9]. The assessment was performed for a service life period of 60 years and includes the modules of production (A1-A3), transport to the site (A4), installation (A5), and replacement (B4). For the comparison, only the production stage (A1-A3) has been considered because emissions related to transport to the site (A4) and installation (A5) are assumed to be the same among the scenarios. The concrete elements are expected to have the same service life as the building and are not intended to be replaced or maintained during the building's lifespan; therefore, the replacement module (B4) is irrelevant for the comparison.

The assessment includes all products of category 2–Building according to the Norwegian standard of building elements and codes for systems in buildings NS 3451 [10]. The calculations do not incorporate elements from outdoor works or other categories such as 3-HVAC installations, 4-Electrical power, 5-Telecommunication and automation, and 6-Other installations. The calculation includes more elements than the minimum requirements of the Norwegian guideline TEK17, which has become mandatory for commercial buildings in Norway since July 2023 [11]. Most of the input data for the estimation was obtained from the software database, which is connected dynamically with the available EPDs or other sources.

Table 1 provides the greenhouse gas assessment for Vollsveien 9-11's production stage. The concrete elements are noted and highlighted separately in the table since they are initially subject to replacement with equivalent representatives made of cement with CCS. The benchmark values for the concrete types are obtained from the revised version of the Norwegian Concrete Association's publication no. 37 - Low-carbon concrete (NB37) [9]. The other non-concrete elements are summarised in the first line. Most elements are described in Norwegian because the software database is primarily built with products from the Norwegian market.

Table 1 – Emission assessment for the Vollsveien 9-11 project – production phase.

Element	**Description**	**Quantity**	**Unit**	**Weight (kg)**	**Emission intensity (kgCO$_2$eq./m^3)**	**Emission intensity (kgCO$_2$eq./kg)**	**GWP A1-A3 (kgCO$_2$eq.)**
21-28	Non-concrete building elements					4 447 770.8	248 208.3
215	"Ferdigbetong, normal styrke, generisk, B20 (var: Bransjereferanse), C20/25 (2900/3600 PSI), 10% (typical) recycled binders in cement (240 kg/m^3 / 14.98 lbs/ft3)"	104	m^3	248 880	200	0.0833	20 740.0
216	"Ferdigbetong, normal styrke, generisk, B30 (var: Bransjereferanse), C30/37 (4400/5400 PSI), 10% (typical) recycled binders in cement (300 kg/m^3 / 18.72 lbs/ft3)"	28	m^3	68 160	245	0.1021	6 958.0
222	"Betongsøyle, low-carbon class A (Contiga)"	313	m^3	782 500		0.1143	89 439.8
223	"Forspente betongbjelke, low-carbon class A (Contiga)"	227	m^3	567 500		0.1157	65 659.8
231	"Betong, B35 M45/MF45, lavkarbonklasse ekstrem (NB37)"	430	m^3	1 032 000	120	0.0500	51 600.0
241	"Betong, B35 M45/MF45, lavkarbonklasse ekstrem (NB37)"	956	m^3	1 896 000	120	0.0500	94 800.0
251	"Betong, B35 M45/MF45, lavkarbonklasse ekstrem (NB37)"	2184	m^3	4 185 600	120	0.0500	209 280.0
251	"Betong, B35 M45/MF45, lavkarbonklasse A (NB37)"	1 025	m^3	2 460 000	210	0.0875	215 250.0
252	"Betong, B35 M45/MF45, lavkarbonklasse ekstrem (NB37)"	780	m^3	1 872 000	120	0.0500	93 600.0
261	"Hulldekke, low-carbon class A, HD200-HD520, X-treme (Contiga)"	1 715	m^2	857 500		0.0863	74 002.3
261	"Betong, B35 M45/MF45, lavkarbonklasse ekstrem (NB37)"	263	m^3	631 200	120	0.0500	31 560.0
281	"Betong, B35 M45/MF45, lavkarbonklasse A (NB37)"	153	m^3	367 200	210	0.0875	32 130.0
	TOTAL						**5 505 510.7**

The four categories of concrete elements are highlighted in the table with colour; specifically, generic cast-in-place concrete for the basement in yellow, prefabricated concrete elements in green, concrete low-carbon extreme in orange, and concrete low-carbon A in red. The cast-in-place concrete in the superstructure is a combination of low-carbon A and low-carbon extreme in accordance with NB37. These types of concrete are prepared by applying various CEM II and CEM III B solutions, which are available on the market today. The cement-based product used for stabilisation of the soil (building element 213) is not indicated as a concrete element because it is considered a part of the soil reinforcement rather than the building itself.

Table 2 summarises the impact of different concrete elements utilised in the project.

Table 2 – Emission assessment of the production phase, highlighting the concrete elements.

Description	**Quantity**	**Unit**	**Weight (kg)**	**Emission intensity ($kgCO_2eq./m^3$)**	**Emission intensity ($kgCO_2eq./kg$)**	**GWP A1-A3 ($kgCO_2eq.$)**	**Percentage (%)**
Non-concrete building elements						4 447 770.8	80.8
"Ferdigbetong, normal styrke, generisk, B20 (NB37)"	104	m^3	248 880	200	0.0833	20 740.0	0.4
"Ferdigbetong, normal styrke, generisk, B30 (NB37)"	28	m^3	68 160	245	0.1021	6 958.0	0.1
"Betongsøyle, low-carbon class A (Contiga)"	313	m^3	782 500		0.1143	89 439.8	1.6
"Forspente betongbjelke, low-carbon class A (Contiga)"	227	m^3	567 500		0.1157	65 659.8	1.2
"Hulldekke, low-carbon class A, HD200-HD520, X-treme (Contiga)"	1 715	m^2	857 500		0.0863	74 002.3	1.3
"Betong, B35 M45/MF45, lavkarbonklasse A (NB37)"	**1 178**	**m^3**	**2 827 200**	**210**	**0.0875**	**247 380.0**	**4.5**
"Betong, B35 M45/MF45, lavkarbonklasse ekstrem (NB37)"	**4 613**	**m^3**	**11 071 200**	**120**	**0.0500**	**553 560.0**	**10.1**
TOTAL						5 505 510.7	100

The analysis shows that concrete-based elements constitute 19.2% of the total emissions of all building elements. Of this, 14.6 % of the emissions derive from the cast-in-place concrete elements in the superstructure (low-carbon A and low-carbon extreme). More than half of the concrete-related emissions (10.1% of the total) are from the presence of concrete low-carbon extreme, which is widely used in the building elements. 4.5% of the total emissions are from low-carbon A, while around 4.1% derive from different prefabricated concrete elements in the project. Standard cast-in-place concrete poured for the foundations is responsible for 0.5% of the total emissions of the building.

4. Effect of concrete with CCS

The impact of concrete elements in Table 2 has been replaced with the impact of concrete elements produced with cement with CCS. The same strength and characteristics of the elements have been considered. Heidelberg Materials has provided the emission intensity values for B35 concrete class A for three different CCS scenarios of cement production: CEM STD-FA Grey, CEM STD-FA EvoBuild and CEM STD-FA EvoZero. In the end, the impact of conventional concrete using industry reference values has been added to provide a comprehensive comparison and overview of different technologies and efforts in reducing the carbon footprint [12].

The concretes applied in foundations with normal strength B20 and B30 account for only 0.5% of the total impact. As a result, they are not replaced with equivalent concrete produced with cement with CCS during the comparison.

The intensity values for the prefabricated elements have been obtained from the EPDs provided by their producer, Heidelberg Materials Prefab Norge. According to the declarations, the prefabricated columns, beams and decks are produced using the industry cement CEM I 52,5 R. The impact of this cement type can be proportionally replaced in the EPDs by the three cement scenarios with CCS, keeping the same impact and ratio of the other aggregates. However, since the impact of all prefabricated elements is, in total, around 4% of the total emissions, the values from EPDs have been used in all comparison scenarios.

Considering the above, the comparison will be focused only on replacing concrete elements of class B35 M45/MF45 (in bold in Table 2). In the project, concrete B35 products were designed into two categories: low-carbon A and low-carbon extreme. Low-carbon extreme concrete, made with cement CEM III/B, is widely used in the project to reduce the carbon footprint. In the comparison, both types of concrete, low-carbon A and low-carbon extreme (in total 5 791 m^3), are replaced with concrete B35 M45 low-carbon A in three different cement scenarios with CCS. The emission intensities for concrete with CCS (Low-carbon B and A) are provided by Heidelberg Materials and given in Table 3. Only the values in the last column (Low-carbon A) are used for the comparison.

Table 3 – Emission intensities for concrete with CCS from Bærum.

Cement type	**Concrete B35 M45 Low-carbon B (kgCO$_2$eq./m^3)**	**Concrete B35 M45 Low-carbon A (kgCO$_2$eq./m^3)**
STD-FA Grey (568)	227	170
STD-FA EvoBuild (328)	137	104
STD-FA EvoZero (34)	26	23

The results for the different concrete scenarios and their impact on the building are given in Tables 4, 5, 6, and 7 below:

Table 4 – Emission assessment of the production phase, emphasising the B35 concrete elements with CEM STD-FA Grey.

Description	Quantity	Unit	Weight (kg)	Emission intensity ($kgCO_2eq./m^3$)	Emission intensity ($kgCO_2eq./kg$)	GWP A1-A3 ($kgCO_2eq.$)	Percentage (%)
Non-concrete building elements						4 447 770.8	78.2
"Ferdigbetong, normal styrke, generisk, B20 (NB37)"	104	m^3	248 880	200	0.0833	20 740.0	0.4
"Ferdigbetong, normal styrke, generisk, B30 (NB37)"	28	m^3	68 160	245	0.1021	6 958.0	0.1
"Betongsøyle, low-carbon class A (Contiga)"	313	m^3	782 500		0.1143	89 439.8	1.6
"Forspente betongbjelke, low-carbon class A (Contiga)"	227	m^3	567 500		0.1157	65 659.8	1.2
"Hulldekke, low-carbon class A, HD200-HD520, X-treme (Contiga)"	1 715	m^2	857 500		0.0863	74 002.3	1.3
"Betong, B35 M45/MF45, lavkarbonklasse A (CEM STD-FA Grey)"	**5 791**	**m^3**	**13 898 400**	**170**	**0. 0708**	**984 470.0**	**17.3**
TOTAL						5 689 040.7	100

Table 5 – Emission assessment of the production phase, emphasising the B35 concrete elements with CEM STD-FA EvoBuild.

Description	Quantity	Unit	Weight (kg)	Emission intensity ($kgCO_2eq./m^3$)	Emission intensity ($kgCO_2eq./kg$)	GWP A1-A3 ($kgCO_2eq.$)	Percentage (%)
Non-concrete building elements						4 447 770.8	83.8
"Ferdigbetong, normal styrke, generisk, B20 (NB37)"	104	m^3	248 880	200	0.0833	20 740.0	0.4
"Ferdigbetong, normal styrke, generisk, B30 (NB37)"	28	m^3	68 160	245	0.1021	6 958.0	0.1
"Betongsøyle, low-carbon class A (Contiga)"	313	m^3	782 500		0.1143	89 439.8	1.7
"Forspente betongbjelke, low-carbon class A (Contiga)"	227	m^3	567 500		0.1157	65 659.8	1.2
"Hulldekke, low-carbon class A, HD200-HD520, X-treme (Contiga)"	1 715	m^2	857 500		0.0863	74 002.3	1.4
"Betong, B35 M45/MF45, lavkarbonklasse A (CEM STD-FA EvoBuild)"	**5 791**	**m^3**	**13 898 400**	**104**	**0. 0433**	**602 264.0**	**10.6**
TOTAL						5 306 834.7	100

Table 6 – Emission assessment of the production phase, emphasising the B35 concrete elements with CEM STD-FA EvoZero.

Description	Quantity	Unit	Weight (kg)	Emission intensity (kgCO$_2$eq./m^3)	Emission intensity (kgCO$_2$eq./kg)	GWP A1-A3 (kgCO$_2$eq.)	Percentage (%)
Non-concrete building elements						4 447 770.8	91.9
"Ferdigbetong, normal styrke, generisk, B20 (NB37)"	104	m^3	248 880	200	0.0833	20 740.0	0.4
"Ferdigbetong, normal styrke, generisk, B30 (NB37)"	28	m^3	68 160	245	0.1021	6 958.0	0.1
"Betongsøyle, low-carbon class A (Contiga)"	313	m^3	782 500		0.1143	89 439.8	1.8
"Forspente betongbjelke, low-carbon class A (Contiga)"	227	m^3	567 500		0.1157	65 659.8	1.4
"Hulldekke, low-carbon class A, HD200-HD520, X-treme (Contiga)"	1 715	m^2	857 500		0.0863	74 002.3	1.5
"Betong, B35 M45/MF45, lavkarbonklasse A (CEM STD-FA EvoZero)"	**5 791**	**m^3**	**13 898 400**	**23**	**0. 0096**	**133 193.0**	**2.3**
TOTAL						4 837 763.6	100

Table 7 – Emission assessment of the production phase, emphasising the B35 concrete elements with industry reference values.

Description	Quantity	Unit	Weight (kg)	Emission intensity (kgCO$_2$eq./m^3)	Emission intensity (kgCO$_2$eq./kg)	GWP A1-A3 (kgCO$_2$eq.)	Percentage (%)
Non-concrete building elements						4 447 770.8	71.0
"Ferdigbetong, normal styrke, generisk, B20 (NB37)"	104	m^3	248 880	200	0.0833	20 740.0	0.3
"Ferdigbetong, normal styrke, generisk, B30 (NB37)"	28	m^3	68 160	245	0.1021	6 958.0	0.1
"Betongsøyle, low-carbon class A (Contiga)"	313	m^3	782 500		0.1143	89 439.8	1.4
"Forspente betongbjelke, low-carbon class A (Contiga)"	227	m^3	567 500		0.1157	65 659.8	1.0
"Hulldekke, low-carbon class A, HD200-HD520, X-treme (Contiga)"	1 715	m^2	857 500		0.0863	74 002.3	1.2
"Betong, B35 M45/MF45, bransjereferanse (NB37)"	**5 791**	**m^3**	**13 898 400**	**270**	**0. 1125**	**1 563 570.0**	**27.5**
TOTAL						6 268 140.6	100

A comparison of the five different concrete B35 scenarios is shown in Figure 3. The impact of the other building elements, the concrete used for the basement and the prefabricated elements is the same in the charts. The total impact when applying B35 concrete prepared with CEM STD-FA Grey is 3.3% higher than the original design. The slight increase is due to the application of concrete low-carbon extreme, which is widely used in Vollsveien 9-11. When cement CEM STD-FA EvoBuild is used, the overall emissions are 3.6% less than the designed project. The value is reduced further (12.1%) with the scenario with CEM STD-FA EvoZero. In this case, the impact of concrete made with the maximum benefits from CCS is 2.3% of the total emissions of the building.

The last chart visualises the effect when concrete industry reference values are applied for B35. In this case, the overall carbon impact of the building's production is increased by 13.9%.

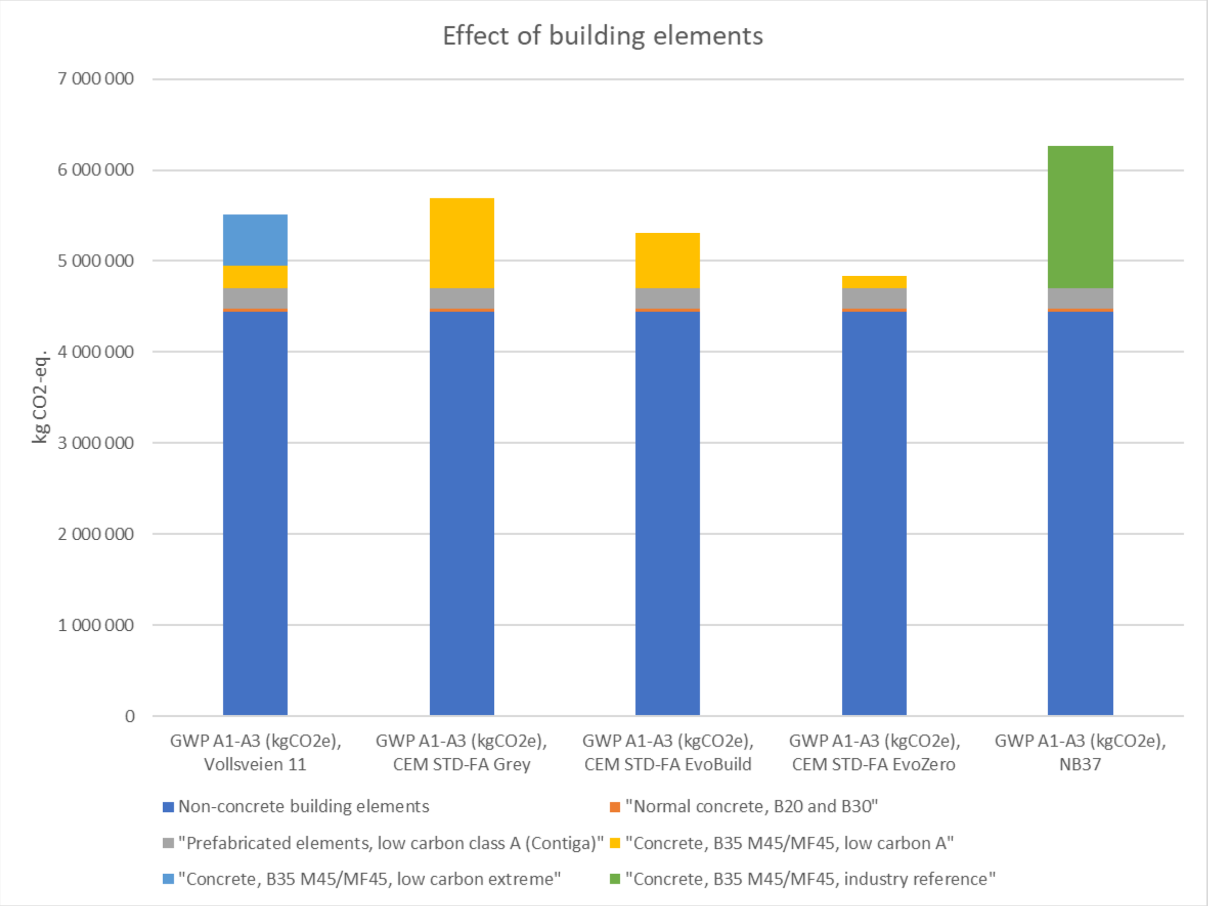

Figure 3 – Embodied greenhouse gas emissions at the building level for the five concrete scenarios.

The differences become clearer when only the impact of concrete elements is visualised in the charts, as presented in Figure 4. The concrete prepared with CEM STD-FA Grey increases the overall impact of concrete elements by 17.4%. The values are reduced by 19.8% and 63.1%, respectively, when the B35 concrete is made with types of cement CEM STD-FA EvoBuild and CEM STD-FA EvoZero. The overall emissions of the concrete elements are 72.1% higher when reference values are used in the comparison.

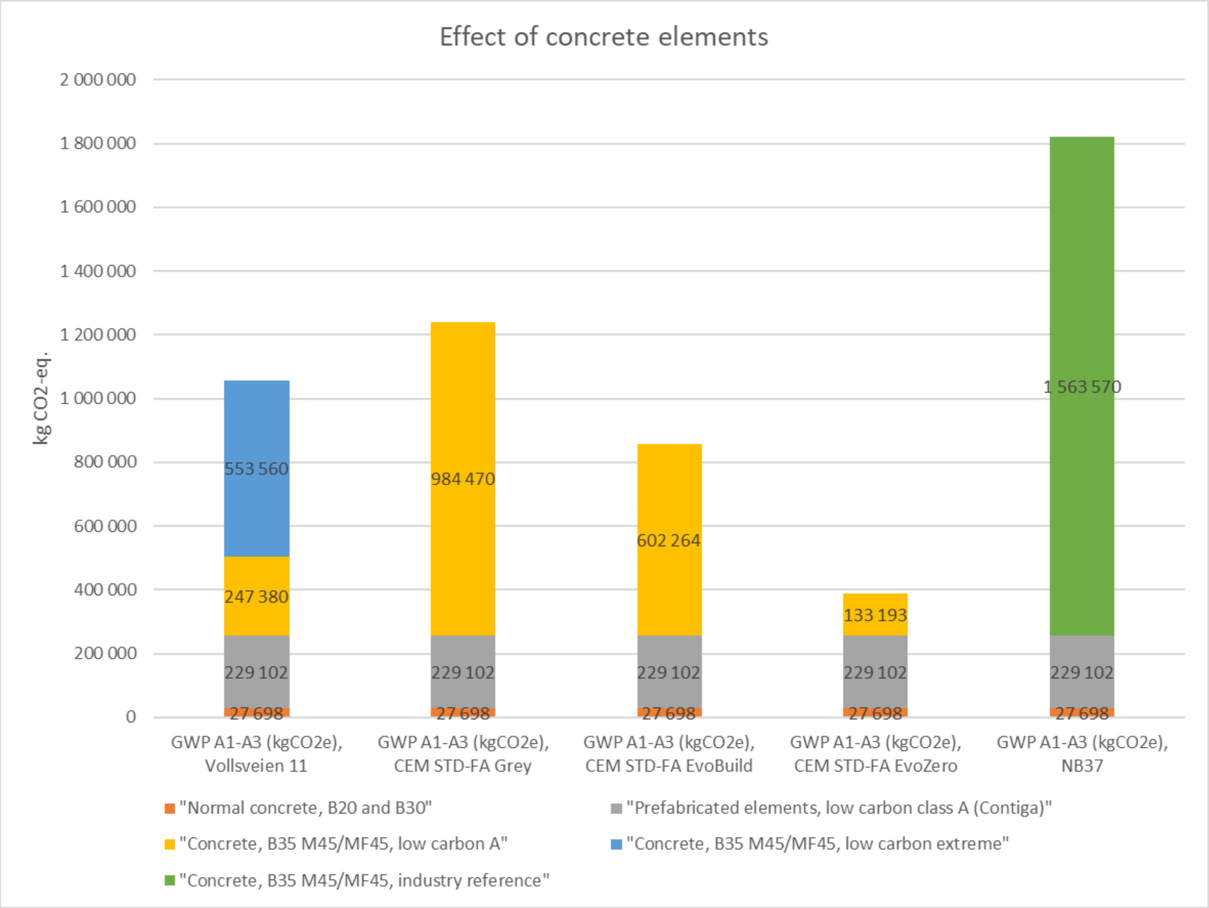

Figure 4 – Embodied greenhouse gas emissions of the concrete elements in five concrete scenarios.

Figure 5 shows the impact of concrete B35 in different concrete scenarios. The comparison highlights the emission fluctuations of the only element that differs in the five scenarios. The carbon impact when the concrete is made with CEM STD-FA Grey increases by 22.9%. This increase is due to the high presence of low-carbon extreme concrete in the original design. However, the impact is significantly reduced when other types of cement with CCS (Evo series) are applied. In such cases, the emissions for the B35 concrete are lowered by 24.8% and 73.4%, respectively. The reduction emphasises the benefits of concrete with CCS even when compared with solutions with already high environmental benefits like low-carbon extreme. Additionally, the last column indicates the impact of the industry reference concrete in the comparison, which almost doubles the carbon footprint compared to the original design. When comparing CCS concrete with the industry reference value, the emissions per unit for concrete B35 made with CEM STD-FA Grey, EvoBuild, and EvoZero are respectively 63.0%, 38.5%, and 8.5% of the industry reference's emissions.

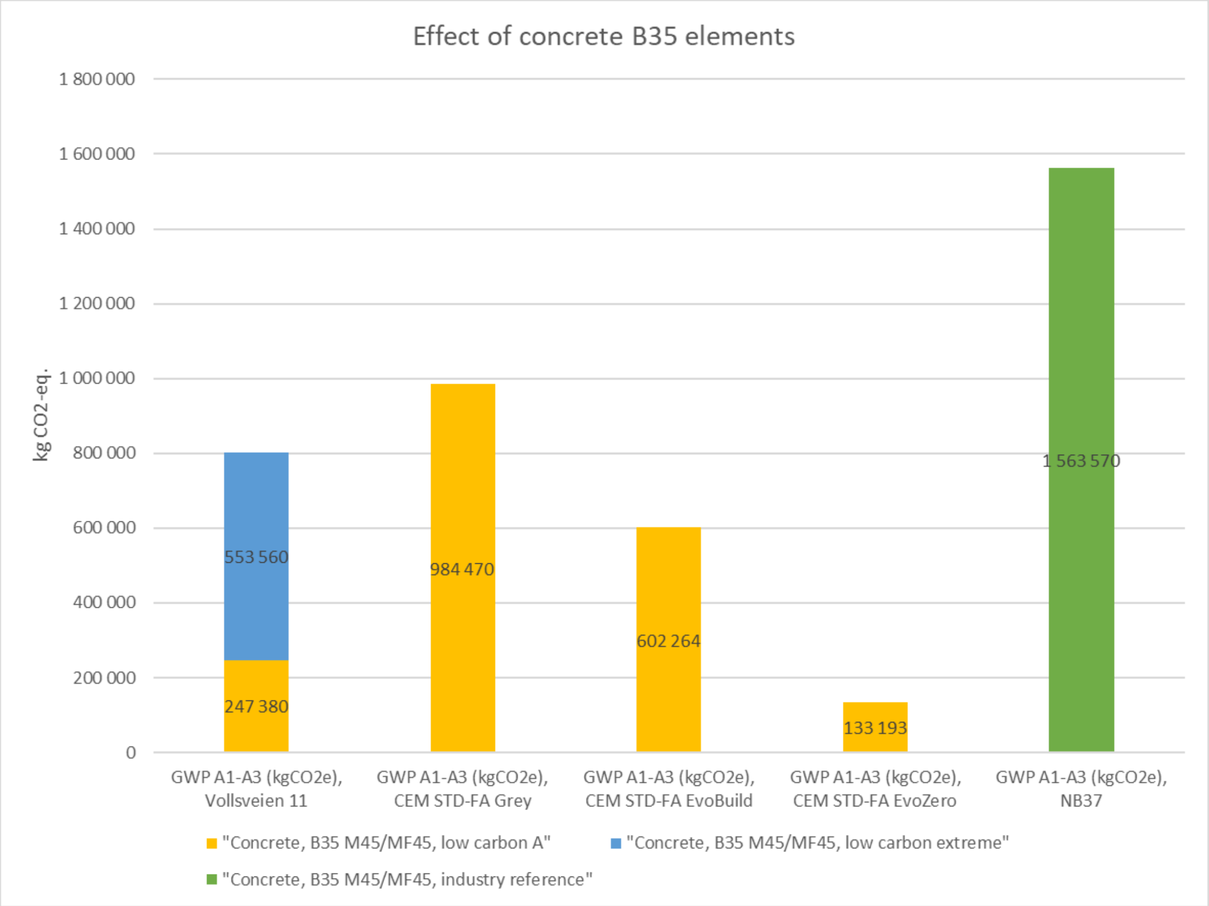

Figure 5 – Embodied greenhouse gas emissions of B35 concrete in five concrete scenarios.

5. Conclusions

This report investigates and compares the effect of concretes with and without CCS technology on a construction project. The results are attained for the Vollsveien 9-11 project in Bærum municipality since the design features a high concrete presence in the load-bearing system. The impact of concrete elements was replaced with three scenarios using CCS technology cement: CEM STD-FA Grey, CEM STD-FA EvoBuild, and CEM STD-FA EvoZero. Only the concrete types of low-carbon extreme and low-carbon A were replaced for the purpose of the study. The prefabricated elements and the concrete applied in the foundations were omitted in the replacement due to small quantities in the design. The environmental assessment for the production stage (A1-A3) was then compared among the different scenarios at the building scale and for the concrete elements. Additionally, the results were compared with another scenario using industry reference values. The revised benchmark values from the NB37 publication were used for the comparisons.

The total impact when using concrete with CEM STD-FA Grey is 3.3% higher than that of the original design. The increase is due to the wide presence of low-carbon extreme concrete in the project's superstructure. However, emissions are reduced when Evo-based types of cement are considered. When cement CEM STD-FA EvoBuild is assumed in concrete production, the overall emissions are 3.6% less than the original project. The value is reduced by 12.1% in the scenario with CEM STD-FA EvoZero. When the concrete industry reference value is applied, the overall carbon impact of the entire building increases by 13.9% compared to the original design.

The effect of different scenarios becomes clearer when only the impact of concrete elements is compared. Applying concrete with CEM STD-FA Grey increases the overall impact of concrete elements by 17.4% compared to the initial design. However, the values are reduced by 19.8% and 63.1%, respectively, when the concrete is made with cement CEM STD-FA EvoBuild and CEM STD-FA EvoZero, despite the high performance of low-carbon extreme in the project. In contrast, the overall emissions of the concrete elements are 72.1% higher when reference values are used in the comparison. The comparisons at the building level show the high potential of cement with CCS in reducing the carbon footprint, especially when utilising cement types CEM STD-FA EvoBuild and CEM STD-FA EvoZero. The results should be followed by an update of the EPD framework for concrete elements to highlight the benefits of the CCS technology in a standardised way.

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