Carbon History of Holcim Ltd:
Carbon dioxide emissions 1950-2021

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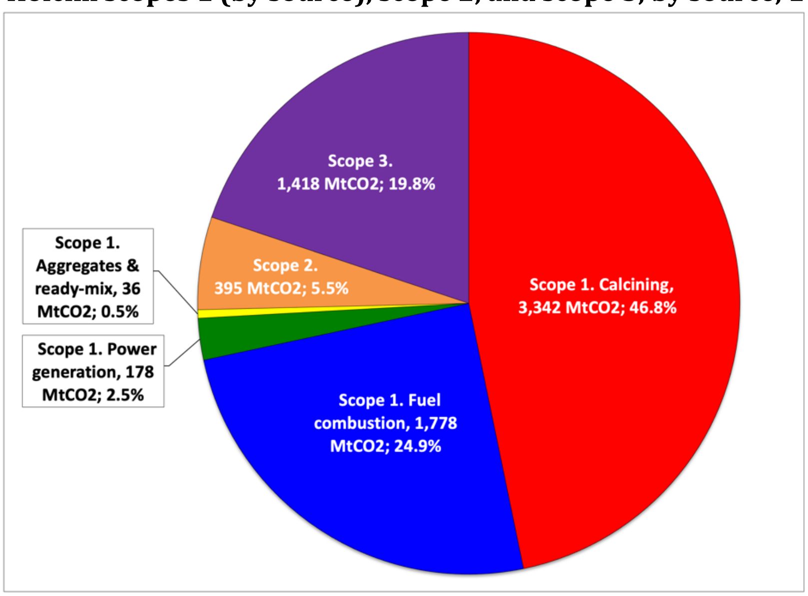
Abstract

Shareholders, regulators, stakeholders, and the public are demanding that leading corporations report on greenhouse gas emissions attributable to a company's operations and its products, and to have those emission inventories verified by a certified third party. Furthermore, and equally important, companies are expected to commit to setting (and achieving) emission reduction targets. Targets are forward looking, to 2030 or 2050, and a base year (often 1990) is selected against which to measure progress. Historical emissions are quantified for the purpose of estimating a company's overall contribution to atmospheric carbon dioxide, for climate modeling, for educating investors, for attribution of carbon dioxide removal obligations, and for potential litigation.

Climate Accountability Institute (CAI) has quantified emissions of carbon dioxide attributable to the cement company Holcim Ltd., the world's second largest by revenue, for the period from 1950 to the present. Our analysis covers emissions for its entire supply chain from quarrying (such as calcite [limestone] and aggregates) to finished product transportation. The boundary definition includes emissions from cement production (calcining emissions, fuel combustion, other scope 1 sources, scope 2 [chiefly purchased electricity], and indirect scope 3).

Figure 25. Holcim scopes 1 (by source), scope 2, and scope 3, by source, 1950-2021.



The company has reported its emissions since 2009, although not comprehensively (as judged by its more comprehensive 2020 performance report).[1] CAI developed a methodology to backcast Holcim's emissions for the same emission sources back to 1950 based on reported annual cement production, and accounting for efficiency gains, increased use of alternative materials, declining clinker factor, and decreased calcining emissions per tonne of cementitious product.

The result of our analysis is that Holcim produced 7.26 billion tonnes (Gt) of cement from 1950 to 2021, and emitted an estimated 7.15 billion tonnes of carbon dioxide ($GtCO_2$) of scope 1, 2, & 3

[1] LafargeHolcim (2021) *Sustainability Performance Report 2020*, February, 22 pp.

emissions. We attribute legacy cement production and associated emissions to the extant company, including that of its merger with Lafarge, in 2015.[2]

Table 3. Holcim and global cement production (Mt) and emissions ($MtCO_2$).

	Holcim		Global		% Holcim of global	
	1950-2021	2021	1950-2021	2021	1950-2021	2021
Cement production	7,264	188	112,112	4,400	6.5%	4.3%
Calcining	3,342	75	44,819	1,700	7.5%	4.4%
Scope 1	5,333	119	na	na	na	na
Scopes 1-3	7,146	156	na	na	na	na
Calcining intensity	0.462	0.392	0.394	0.386	na	na

The history of attributed supply chain emissions (scopes 1, 2, and 3) over Holcim's history from 1950 to 2021 (the companies merged in 2015) are shown in Figure 13:

Figure 13. Holcim cement production and emissions (scopes 1, 2, & 3).

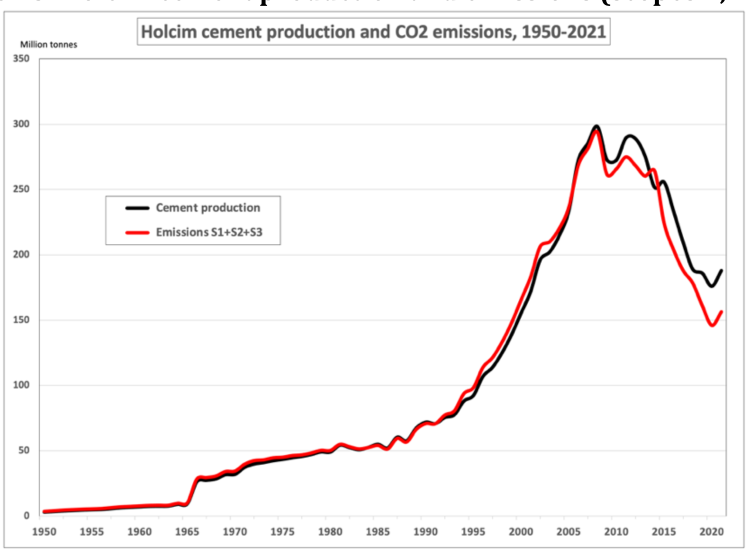
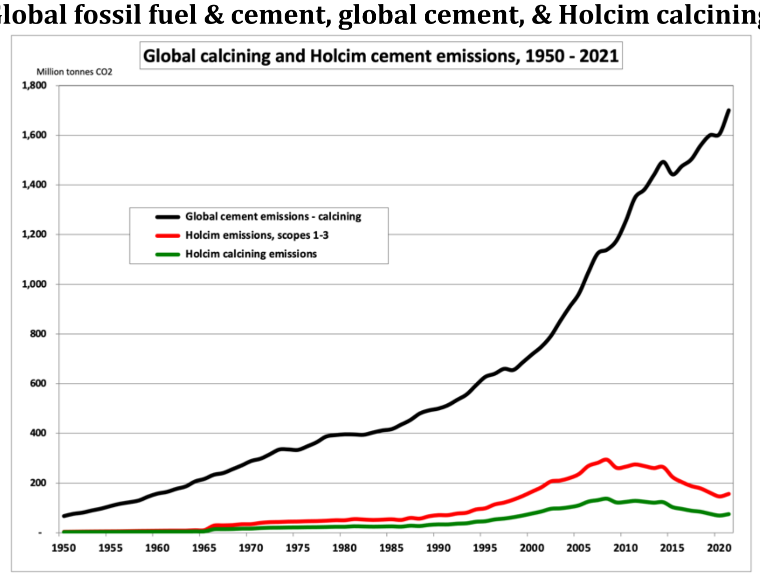


Figure 23. Global fossil fuel & cement, global cement, & Holcim calcining emissions.



[2] We refer to "Holcim" or LafargeHolcim (from 2015 to 2021) by which we include the legacy of each company (e.g., Holcim was founded as Aargauische Portlandcementfabrik Holderbank-Wildegg in 1912, "Holderbank" thereafter).

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INTRODUCTION

The world cement industry produces ~4 billion tonnes (Gt) per year (130 tonnes/second), making it the world's second largest material enterprise, half of coal production (~8 Gt). The industry emits ~8% of global carbon dioxide (CO_2) emissions from fossil fuel and cement (excluding land use and deforestation) (Andrew 2019), roughly 5% from the calcining of limestone ($CaCO_3$), which drives off carbon dioxide, and an additional ~3% from the carbon fuels used to heat the cement kilns to ~1,450 °C. The industry also uses billions of tonnes of sand and gravel (aggregate) used to make concrete and ~17 billion tonnes of water (~17 km^3), equal to ~9% of global water withdrawals (excl. agricultural irrigation) (Miller et al. 2018). Holcim reports using 140 Mm^3 in 2021.

Cement is a versatile building material adapted to many uses for its strength and durability in dams, roadways, bridges, airport runways, harbor facilities, retaining walls, viaducts, canals, coastal defenses, even ship hulls, and buildings of every variety around the world. Cement has been in use for millennia (Rome's Coliseum & Pantheon), though its use lapsed for centuries until revived by the use of iron as reinforced concrete in France in the mid-19th century, and subsequently in such iconic structures as the Empire State Building and the Hoover Dam.

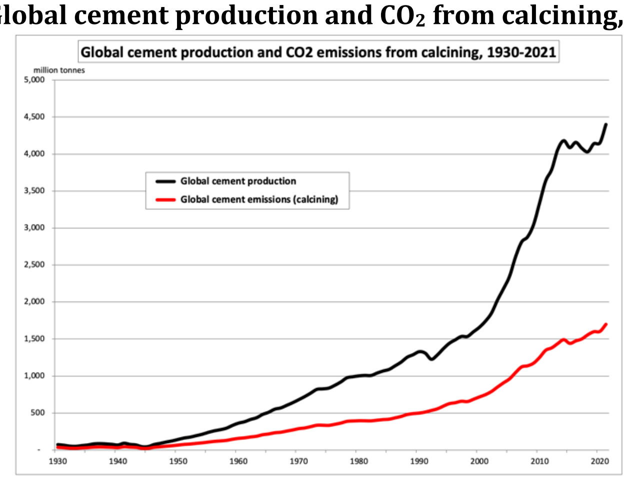
Figure 1a. The Pantheon Dome, Rome

Van Mead (2019).

Figure 1b. Limestone quarry

Photo: Zoonar Gmbh/Alamy. In Watts, 2019

Figure 2. Global cement production and CO_2 from calcining, 1930-2021



Data from Andrews 2019; updated May 2021; chart by Heede.

Cement production grew dramatically after World War II, reaching 4 billion tonnes per year in the 2010s, and growing from 125 kg per capita per year in 1960 to 590 kg per capita per year in 2020.[3]

[3] Statista data from United Nations. Cement production data from Andrew 2019. Cement intensity per GDP has fallen from 231 kg/$ in 1960 to 47 kg/$ in 2020. Since 1990, 70% of the growth in cement production has been in China.

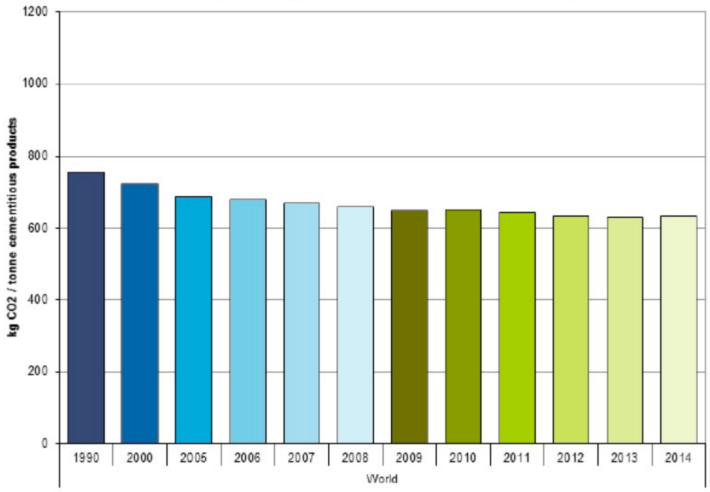
The global cement industry generated $321 billion in revenue in 2018; Holcim had revenues of $29 billion in 2021. The company has 67,400 employees worldwide and operates in 70 countries.

This project

Our objective is to track and document one large cement company — Holcim and its predecessors — over its corporate history since 1950 to the present, and quantify company-wide emissions of greenhouse gases, specifically CO_2. The company has reported its emissions since ~2009. For years prior to company-reported emissions, we estimate emissions from available data, primarily its production of cement (sometimes called cementitious product). See chapter 3 for a description of our methodology, developed for this project.

In general, while cement production has risen dramatically over recent decades, the *rate* of emissions per tonne of cement has declined. That is, the global (and Holcim's) trend has been toward reducing the carbon intensity of cement, on a per-tonne basis. See Figures 3, 8, & 10.

Figure 3. Declining emissions intensity per tonne cementitious



World Business Council for Sustainable Development (2016)

Scopes

The following definition of scopes, as used in the cement industry, is from WBCSD:[4]

> Scope 1 emissions are direct emissions occurring from sources that are owned or controlled by the company. For example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc. (…). Direct CO_2 emissions from the combustion of biomass shall not be included in scope 1 but reported separately, e.g. as Memo-Item.
>
> Scope 2 emissions are indirect emissions from the generation of purchased electricity consumed in the company's owned or controlled equipment. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.[5]
>
> Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company, but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services. Additional examples are listed in ISO 14064-1 8, Annex B.

[4] World Business Council for Sustainable Development (2011) *The Cement CO_2 and Energy Protocol: CO_2 and Energy Accounting and Reporting Standard for the Cement Industry*; also WBCSD/WRI (2004) *Greenhouse Gas Protocol.*

[5] CAI note: a company, facility, or industrial consumer should account for grid losses, and use each utility's carbon factor per *delivered* MWh rather than per generated MWh.

< 3 >

LAFARGE & HOLCIM REPORTING

Production reporting

Lafarge was founded in 1833 (in Le Teil, France) in the limestone quarries of Ardèche by Joseph-Auguste Pavin de Lafarge (originally primarily for plaster, in 1864 he won the contract to supply 0.2 Mt of hydraulic lime for the piers of the Suez Canal). CAI acquired and recorded Lafarge production data in annual reports going back to 1950.

We acquired annual reports for Holderbank Financière Glarus AG from 1966 to 2001 when Holderbank changed its name to Holcim, and annual report for Holcim until the company merged with Paris-based Lafarge in July of 2015. Holcim was founded in 1912 by Adolf Gygi and Ernst Schmidheiny in 1912/1914 in Holderbank, Switzerland.[6] We have located annual reports prior to 1966, but cement production is not reported. In some years, production *capacity* is reported).

We rely on company-reported cement production data for our quantification of emissions prior to Lafarge and Holcim emissions reporting in 2009. Holcim reported cement production of 188 million tonnes (Mt) in 2021, up from 176 Mt in 2020.

Emissions reporting

Holcim reported gross emissions in 2021 of 156.3 million tonnes CO_2, of which direct scope 1 sources (such as process emissions, fuel combustion, etc) account for 119.3 $MtCO_2$, scope 2 emissions (purchased electricity) of 7 $MtCO_2$, and scope 3 supply chain emissions of 30 $MtCO_2$. This is up from its 2020 emissions of 146 $MtCO_2$. See chapter 5, Table 2, and Figure 13 for cement production and attributed emissions over the study period from 1950 to 2021.

The company's Scope 3 methodology was revised to be more "comprehensive and rigorous" in 2020; see Figure 5, and LafargeHolcim note 6a[7]). We quote from the LafargeHolcim *Performance Report 2020* on its methodology with respect to scope 3:

- Scope 3 emission: In 2020, we developed a more comprehensive and rigorous approach to measure the CO_2 emissions from our supply chain. The methodology is aligned with the *Corporate Value Chain (Scope 3) Standard* and follows the *Cement Sector Scope 3 GHG Accounting and Reporting Guidance* of the GHG Protocol and the GCCA Protocol. We decided to take this step because we are committed not only to disclose but also to set actionable targets to reduce our CO_2 emissions, starting with the fuels and transportation categories that account for ~50% of our total Scope 3 emissions. The increased scope (we have estimated emissions from all goods and services purchased in 2020) and accuracy (robust calculation methods and data), resulted in an addition of 9.8 million tons of CO_2 from figures estimated in 2019 (from which: 5.7 million tons of CO_2 from added purchased categories; and ~1 million tons of CO_2 from the upstream and transmission and distribution losses of purchased electricity, and the rest mainly from full volumes of purchased clinker and cement not included in the previous year). We now have a solid foundation that will be the baseline to define actionable 2030 reduction targets, as communicated with our Net Zero Pledge.

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[6] https://www.lafargeholcim.com/our-history Since deleted; see: https://www.holcim.az/en/lafargeholcim-history

[7] LafargeHolcim *Performance Rpt,* p. 5: "Note 6a: In 2020, we introduced a new, more robust methodology for measuring Scope 3 emissions. See the methodology and consolidation section for more details."

Figure 4. Holcim CO_2 emissions scopes 1, 2, and 3.

	Unit	2019	2020	2021
CO_2 and energy				
CEM-specific CO_2 emissions – net (Scope 1)[1]	$kgCO_2/t$	561	555	**553**
CEM-specific CO_2 emissions – net (Scope 1) – 2021 consolidation[1]	$kgCO_2/t$	564	557	**553**
CEM-specific CO_2 emissions – Gross (Scope 1)[1]	$kgCO_2/t$	NR	NR	**581**
CEM CO_2 emissions – electricity (Scope 2)[1]	$kgCO_2/t$	37	36	**34**
CEM CO_2 emissions – electricity (Scope 2) – 2021 consolidation[1]	$kgCO_2/t$	38	37	**34**
Specific heat consumption of clinker production	MJ/t	3,526	3,538	**3,520**
CEM CO_2 emissions – gross (Scope 1)[2]	Mt	113	105	**115**
CEM CO_2 emissions – net (Scope 1)[2]	Mt	108	100	**109**
CEM CO_2 emissions from raw materials	Mt	74	69	**75**
CEM CO_2 emissions from fossil fuels	Mt	34	31	**34**
CEM CO_2 emissions from waste-based fossil fuels (Scope 1)	Mt	5	5	**5**
CEM CO_2 emissions from waste-based biomass fuels (Scope 1)	Mt	3	3	**5**
CEM CO_2 emissions from electricity consumption (Scope 2)	Mt	7	7	**7**
Other segments CO_2 emissions from fuels (Scope 1)	Mt	8	4	**5**
Other segments CO_2 emissions from electricity (Scope 2)	Mt	0.37	0.35	**0.29**
Absolute Scope 1 emissions – gross	Mt	121	110	**119**
Absolute Scope 2 emissions	Mt	8	7	**7**
Absolute Scope 3 emissions[3]	Mt	19	29	**30**

Holcim Ltd. (2022) *Sustainability Performance Report 2021*, page 7.[8]

LafargeHolcim reported the distribution of emission sources in 2020 (after it broadened the boundary and sources included in scope 3), revising its scope 3 estimate upwards by 53% (from 19 $MtCO_2$ in 2019 to 29 $MtCO_2$ in 2020. We apply the relative contributions of scopes 1, 2, and 3 sources posted online in LafargeHolcim's "Our CO_2 footprint." See Figure 5 & Table 1.[9]

CAI developed a methodology for backcasting scope 3 emissions from the company's reassessment of scope 3 sources and emissions reported for scopes 1, 2, and 3 published in LafargeHolcim's *2020 Performance Report*. See chapter 4 on Methodology for discussion.

See Figure 5 below and chapter 5 for details of Holcim's scope 3 reporting by category.

Caveats

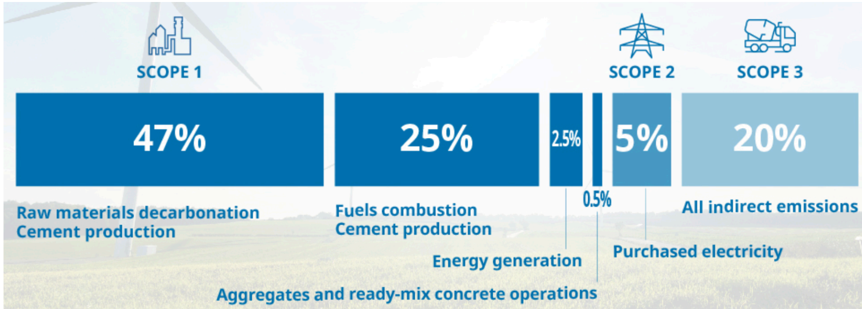
Lafarge cement production data from 1950 to 1962 includes gypsum (for plaster), which we assume is a minor portion of the company's reported production of 3.06 Mt in 1950 (rising to 7.6 Mt in 1962). Lafarge only reports cement production in France for the years 1973-1982, a period when the company had substantial international operations, and we interpolate between reported global production in 1972 and 1983.[10]

[8] Holcim footnote to Figure 4: "In 2020, we introduced a new, more robust methodology for measuring Scope 3 emissions. See the methodology and consolidation section for more details." More on this below.

[9] https://www.lafargeholcim.com/our-co2-footprint Note: Holcim has removed this breakdown of scope 1 sources.

[10] The reported production (in France) totaled 115 Mt 1973-1982, the interpolated estimated global production totaled 207 Mt 1973-1982, thus adding 92 Mt.

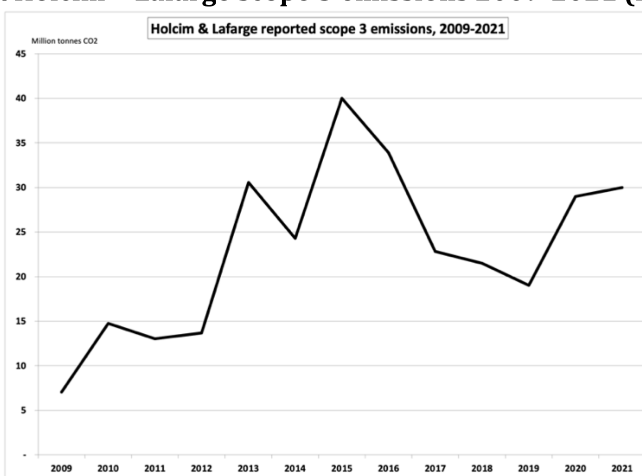
Figure 5. Holcim scopes 1, 2, and 3 sources, by percent[11]



https://www.holcim.com/sustainability/net-zero/our-co2-footprint

Both Lafarge and Holcim typically report on carbon emissions and related environmental data (such as water consumption and discharge, asphalt production, energy consumption and rates per tonne, regulated air pollutant emissions), and have done so since 2009, as reported to CDP. However, as we noted above, the boundary definition for scope 3 emissions was broadened in the 2020 dataset. Furthermore, their pre-2020 reported data is too variable and inconsistent for use in our computations. See Figure 6.

Figure 6. Holcim + Lafarge scope 3 emissions 2009-2021 (reported)



LafargeHolcim reporting on scope 3 emissions for 2018:[12]

1. **Purchased goods and services: 4,127,662 tCO_2**. Purchased goods and services emissions have been assessed according to the Cement Sector Scope 3 GHG Accounting and Reporting Guidance developed by the WBCSD Cement Sustainability Initiative. For this purpose we have assessed the most significant of our suppliers emissions due to clinker bought used in the production process during 2018. For the assessment we have used the global purchase volume by the group multiplied by the estimated emission factor for clinker bought according to the WBCSD-CSI CO_2 Reporting protocol.
2. Capital goods: Not relevant.
3. **Fuel-and-energy-related activities (not included in Scope 1 or 2): 7,512,648 tCO_2**. Fuel-and-energy-related activities (not included in Scope 1 or 2) emissions have been assessed according to the Cement Sector Scope 3 GHG Accounting and Reporting Guidance developed by the WBCSD Cement Sustainability Initiative. Fuel and energy related activities include mainly extraction, refining and transportation of LafargeHolcim raw fuel sources.

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[11] Holcim has apparently removed this chart detailing the distribution of scope 1, 2, and 3 by categories. Nonetheless, we use the scope 1 breakdown to model historical emissions, especially in isolating process emissions from fuel combustion.

[12] LafargeHolcim (2020) *Climate Change 2019*: Submission to CDP, pp. 25-29.

4. **Upstream transportation & distribution: 226,730 tCO_2**. Upstream transportation & distribution emissions have been assessed according to the Cement Sector Scope 3 GHG Accounting and Reporting Guidance developed by the WBCSD Cement Sustainability Initiative. The calculation is based on the transportation of raw material(including bought clinker), MIC and traditional fuels reported in our inventories. All raw materials are assumed to come by truck. The emission factor comes from the reference database used in our verified Product Carbon Footprinting tool.
5. Waste generated in operations: Not relevant.
6. **Business travel: 212,200 tCO_2**. Business travel emissions have been assessed according to WBCSD CSI Scope 3 methodology. The calculation is based on the estimates of domestic and overseas travels of our employees, with an average emission factor per FTE estimated from the data provided by two representative group companies from their travel agent.
7. **Employee commuting: 92,371 tCO_2**. Employee commuting emissions have been assessed according to WBCSD CSI Scope 3 methodology. We assume that all employees commute for 30 km each day and 50% travel by car while the other use public transportation.
8. Upstream leased assets: Not relevant.
9. **Downstream transportation and distribution: 9,304,751 tCO_2**. Downstream transportation and distribution emissions have been assessed according to the Cement Sector Scope 3 GHG Accounting and Reporting Guidance developed by the WBCSD Cement Sustainability Initiative. Downstream transportation and distribution is confirmed in the case of LH and this source includes: i) Transportation of clinker to another company and ii) Transportation of cement, ready mix, aggregates, asphalt and concrete products to retailers.
10. Processing of sold products: Not relevant.
11. Use of sold products: Not relevant.
12. End of life treatment of sold products: Not relevant.
13. Downstream leased assets: Not relevant.
14. Franchises: Not relevant.
15. Investments: Not relevant.
16. Other (upstream): Not relevant.
17. Other (downstream): Not relevant.

Total scope 3 for LafargeHolcim in 2018: 21.48 MtCO_2.

Note that the company expanded the accounting methodology of scope 3 in 2020, which "resulted in an addition of 9.8 million tons of CO_2 from figures estimated in 2019," of which "5.7 MtCO_2 from added purchased categories; and ~1 MtCO_2 from the upstream and transmission and distribution losses of purchased electricity, and the rest mainly from full volumes of purchased clinker and cement not included in the previous year."[13] In the company's Sustainability Performance Reports, Holcim reported scope 3 emissions of 20 MtCO_2 in 2018 (vs 21.5 MtCO_2 reported to CDP), 19 MtCO_2 in 2019, 29 MtCO_2 in 2020, and 30 MtCO_2 in 2021.

None of these scope 3 sources are unique to 2020, and scale with the company's activities, most fundamentally the amount of material throughput, cement production, and transportation thereof. Our methodology discussion follows in chapter 4.

We have assembled a record of Holcim's and Lafarge's history of cement production (Lafarge from 1950, Holcim from 1966-fwd) using annual reports as primary sources. We rely on comprehensive emissions reporting in recent years as a reasonable basis for estimating historical emissions back to 1950 for scope 1, 2, and 3 sources, as discussed in the following chapter.

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[13] LafargeHolcim (2021) *Sustainability Performance Report 2020*, p. 15: Methodology.

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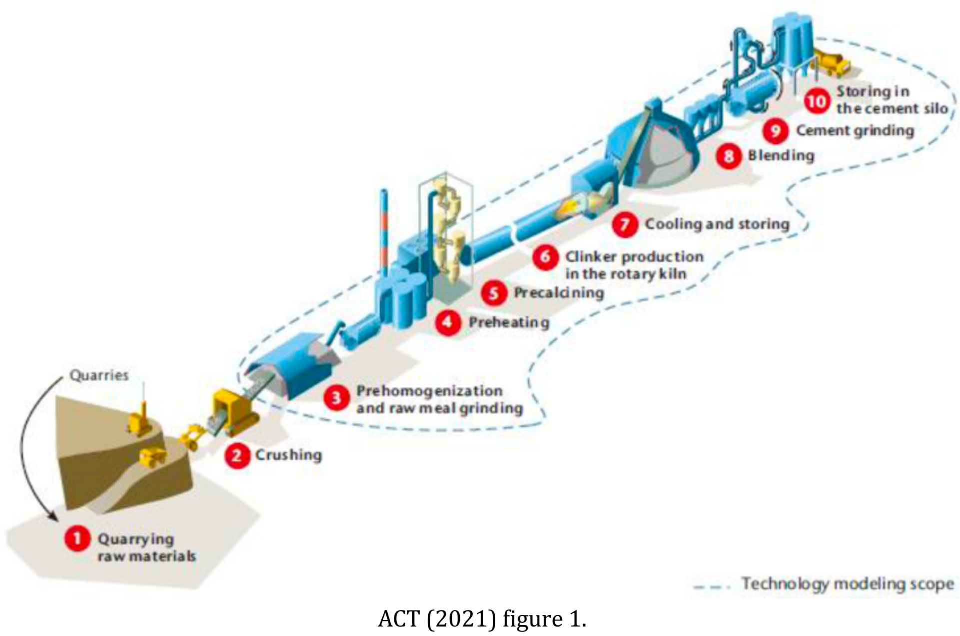
METHODOLOGY

Most multinational cement producers report on several metrics of the carbon dioxide emissions associated with cement production. The World Business Council for Sustainable Development's *Cement Sustainability Initiative* (WBCSD 2011, 2016; transferred to the Global Cement and Concrete Association in 2019) helped establish a protocol for cement producers' emissions inventories. As noted by Dietz & Gardiner (TPI 2019) and Climate Accountability's Institute's *Carbon Majors* project (Heede 2014), company reporting is variable, often incomplete, using varying boundary definitions that can change over time, and are poorly comparable between companies, *except* for the widely reported carbon-intensity factor. In addition, clinker ratios vary geographically and temporally (Andrew 2019), as does use of alternative material inputs, such as fly ash or slag. Cement producers substitute alternative fuels, such as tires, waste materials, and bio-fuels, and improve energy and cost efficiencies, upgrade cement kilns, and are gradually reducing the carbon intensities of the cement production process from quarrying, crushing limestone and aggregates, grinding raw meal, heating and operating kilns, handling dust and ashes, and blending, storing, and transporting millions of tonnes of material at hundreds of facilities operated by Holcim in 70 countries.

Figure 7. Cement-making process chart



ACT (2021) figure 1.

Current and historical emissions reporting

The cement industry has paid attention to the environmental and financial benefits of reducing emissions per tonne of cement and this measure has improved substantially over the last few decades, especially since corporate emission inventories became widespread, spurred by the publication of *The Greenhouse Gas Protocol* (WRI 2004) and the 2011 WBCSD *Cement Protocol* that leading companies use to quantify attributable operational and indirect emissions.[14]

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[14] Other inventory protocols and reporting platform are also in wide use, such as the Global Reporting Initiative (globalreporting.org), International Standards Organization (iso.org), WBCSD's *Cement CO_2 and Energy Protocol*, etc.

Institutional investors, environmental NGOs, and the overall drive to lower industrial emissions under the Paris Agreement, to which more and companies peg their emission targets, incentivize cement companies to set aggressive targets. Cement companies prefer to reference a relative emission reduction target,[15] such as net kgCO_2 per tonne, rather than commit to an absolute emission target, thus allowing for company expansion, increasing market share, *and* increasing absolute emissions. External observers point out, however, that absolute emission reductions are required (TPI 2019, ACT 2021) if the Paris Agreement is to be met by mid-century.

Company sustainability reports (as well as submissions to both CDP and the WBCSD *Cement Sustainability Initiative*) provide partial data for leading companies, including Holcim and Lafarge. These reports typically provide estimates of absolute emissions (MtCO_2) and relative *intensities* (kg CO_2/t) for recent years; some reports from the late 2000s also showed data for the base year 1990.

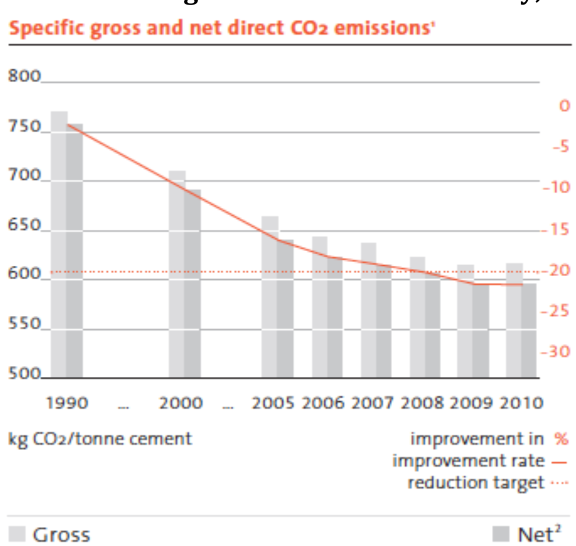
However, a comprehensive picture of the historical emissions for our subject companies — Lafarge and Holcim — is elusive due to the limited reporting noted above. Our research objective is to develop a longer history of emissions attributable to both Lafarge and Holcim (and its predecessor, Holderbank) back to 1950.

Our methodology and objective

This analysis quantifies and backcasts emissions based on company-reported annual production of cement from 1950 to the present. Since neither company provided any detailed source estimates prior to reporting to CDP for 2009 and later, nor complete estimate of scope 3 emissions until 2020, we develop a methodology for estimating scope 1, 2, and 3 emissions based on company-reported cement production and that, crucially, accounts for decreasing clinker ratios and improving process emissions as well as fuel and electricity input improvements annually from 1950 to 2020.

Holcim, typical of the industry, decreased its net emissions per tonne of cement from 755 kgCO_2/t in 1990 to 575 kgCO_2/t in 2014. Lafarge's lowered its rate from 767 kgCO_2/t in 1990 to 572 kgCO_2/t in 2014, for LafargeHolcim: 555 kgCO_2/t in 2020, and Holcim: 553 kgCO_2/t in 2021.[16]

Figure 8. Holcim net & gross emissions & intensity, 1990-2010



Holcim Annual Report 2010, page 42.

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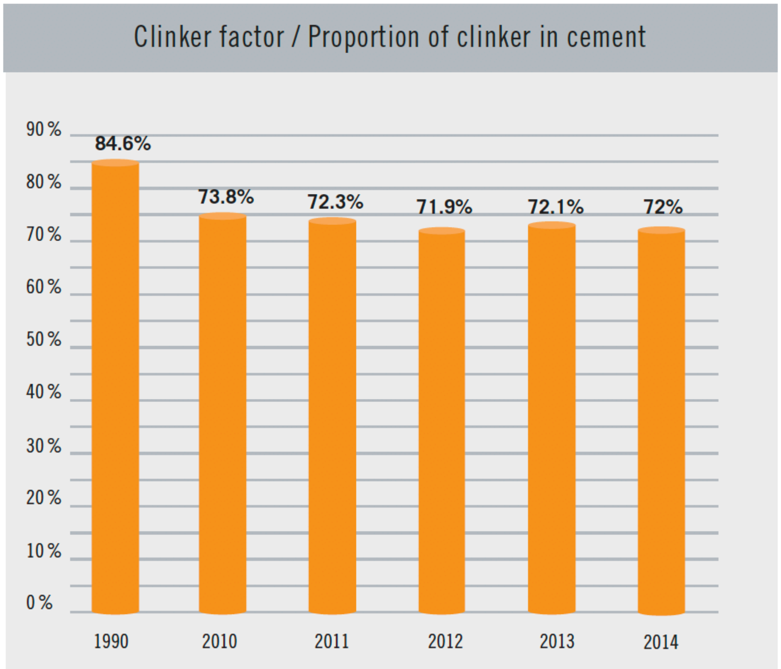
[15] Holcim's 2030 target: 475 kg net CO_2/tonne of cementitious material, a 14.4% reduction from the 2020 datum. Holcim's CO_2-reduction targets have been validated by the Science Based Targets Initiative under the 2 °C threshold.

[16] We caution that some metrics and boundaries are routinely redefined and are not reliable measures over time *within* a company, much less between different companies over time. They are useful as indicators and for targets as long as consistent boundaries and emissions sources are included.

Our analysis is based on reported cement production by Lafarge from 1950 to 2020 and by Holcim from 1965 to 2021. (Companies also report on cement production *capacity*, broadly available historically, but less useful for our purposes than actual production data.) A research team lead by HEKS helped locate, copy, and transmit data from company reports found in university libraries in France and Switzerland.

Figure 9. Lafarge clinker factor



Lafarge Sustainability report 2015, page 12. Holcim reports clinker factor of 70.1 in 2021.

Energy and emission intensity improvements in the cement industry

It is broadly observed that global cement production has increased dramatically since 1950 (Watts 2019; Andrews 2019; Worrell et al. 2013; IEA 2020; TPI 2019), and that energy and CO_2 emissions *rates* per tonne have decreased substantially (CSI 2011; IEA 2020: company reports).

We recognize that emissions per tonne of cement produced was higher in years past, given the higher clinker ratios reported in Andrew 2019 (Fig. 1A). Andrew's discussion pertains specifically to higher emissions intensity per tonne due to historically higher clinker ratios (higher clinker ratios intrinsically increase the carbon intensity of the calcining process).[17]

We assume that a similar trend can reasonably be applied to other scope 1 emission sources, such as the gradual shift from energy-intensive wet kilns to dry kilns, multistage preheaters, low-carbon fuel substitution, process improvements, lower carbon intensity of purchased electricity (scope 2), mining and grinding limestone, materials handling, and other energy and emission sources proscribed as scope 1 emission sources.

In the U.S. total carbon emission intensity declined on average by 0.7% per year from 1970 to 2010, with electricity consumption per tonne relatively stable over the same time period.[18] We do not have global data on fuel combustion emissions and other scope 1, scope 2, & scope 3 emission rates.

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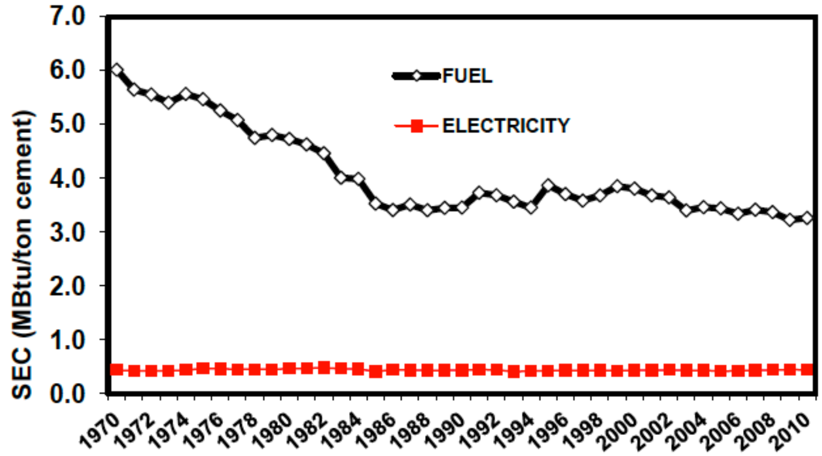
[17] International Energy Agency (2020) *Cement Tracking Report*, June, https://www.iea.org/reports/cement. "Clinker is the main ingredient in cement, and the amount used is directly proportional to the CO_2 emissions generated in cement manufacturing, due to both the combustion of fuels & the decomposition of limestone in the clinker production process."

[18] Worrell et al / US EPA 2013, page 14. "Total carbon dioxide emissions (including emissions from limestone calcination for clinker-making) decreased at 0.7% per year, on average, from 305 kgC/tonne in 1970 to 234 kgC/tonne in 2010."

Figure 10. Specific fuel and electricity consumption per ton of cement produced



Worrell 2013 Figure 7. Specific fuel and electricity consumption per ton of cement produced. Energy is expressed as final energy (or site energy) and excludes power generation conversion losses. Fuels include waste fuel use estimates starting in 1977 (based on PCA data, and after 1993 on USGS reported data).

Climate Accountability Institute's previous work

CAI conducted an analysis of the emissions attributable to the largest oil, gas, coal, and cement producers from as early as 1854 to the present. The original ninety Carbon Majors (Heede, 2014, 2019, 2020) included six cement producers.[19] The Carbon Majors cement methodology quantifies emissions from the industrial process of converting calcite or limestone ($CaCO_3$) to cement clinker in a kiln operating at ~1,450 °C, driving off carbon dioxide in the process. In years past, companies typically *combined* process emissions and combustion emissions into one datum. CAI's objective in the Carbon Majors project was to disaggregate process emissions from the combined total in order to avoid double-counting emissions from cement company use of fossil fuels in scope 1 emissions (direct use of coal or other carbon fuels in kilns) or scope 2 emissions (carbon emissions associated with generating purchased electricity). In recent years many companies, including LafargeHolcim, disaggregate these two scope 1 sources — 47% and 25% of total company emissions, respectively, according to LafargeHolcim data — discussed above in chapter 3, Table 1 and Figure 5.

CAI developed a methodology that estimated the proportion of process emissions of combined process and fuel combustion emissions that dynamically (not statically) quantifies the proportion of process emissions of the combined total and that this proportion rose from 55.7% in 1990 to 69.8% in 2018 (Heede 2014; Heede 2019).

Process (calcining) and fuel combustion emissions

The methodology developed for the quantification of Holcim and Lafarge historical emissions begins with actual reported absolute gross scope 1, scope 2, and scope 3 emissions (110 $MtCO_2$, 7 $MtCO_2$, and 29 $MtCO_2$, respectively, totaling 146 $MtCO_2$) in the year 2020. The methodology adopts reported scope 1 and scope 2 emissions as submitted to CDP for both Holcim and Lafarge from 2009 to 2014, to LafargeHolcim 2015-2020, and Holcim for 2021.[20] Reported scope 3 emissions is incomplete for prior years, and is therefore ignored (except for the 2020 and 2021 data).

Scope 1 emissions, which are reported in sufficient detail for 2009-2020, are disaggregated into (1) process emissions, (2) fuel combustion, (3) energy generation, and (4) aggregates and ready-mix operations for the year 2020 (Table 1).

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[19] Currently four cement majors: Holcim and Lafarge merged in 2015; HeidelbergCement acquired Italcementi in 2016. Note: results and methodology are available at: https://climateaccountability.org/carbonmajors_dataset2020.html. The Carbon Majors project estimated calcining emissions from 1990 to the present.

[20] Lafarge (Paris) and Holcim (Zug) merged in July 2015.

We calculate the relative contributions of scope 1 sources as reported for the year 2020 and allocated by scope 1 sources in LafargeHolcim's "Our CO_2 footprint" (see Figure 5 in chapter 3).

Table 1. Elements of calculating 2020 emissions, scopes 1, 2, and 3.

Emission sources	Percent of total	$MtCO_2$
Scope 1: process / calcining	47.0	68.9
Scope 1: fuel combustion	25.0	36.7
Scope 1: energy generation	2.5	3.7
Scope 1: aggregates & ready-mix	0.5	0.7
Total scope 1	75.0	110.0
Scope 2	5.0	7.0
Scope 3	20.0	29.0
Total scopes 1, 2, and 3	100.0	146.0

Percent of total from LafargeHolcim "Our CO_2 Footprint," https://www.lafargeholcim.com/our-co2-footprint

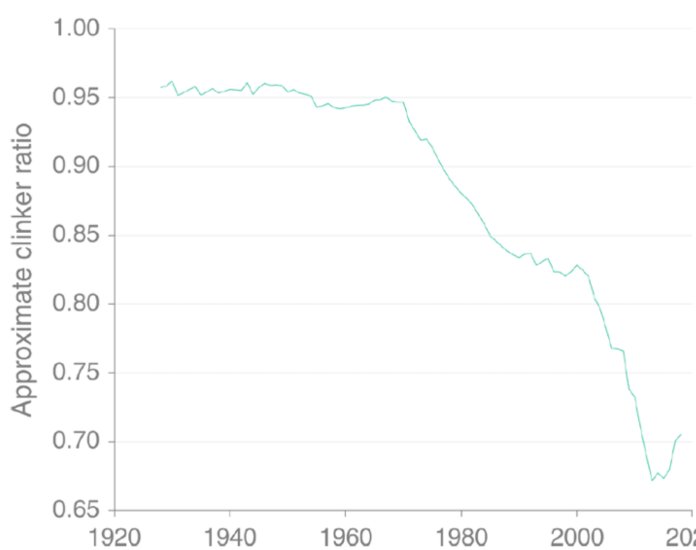
Backcasting

Now we have the two primary datasets: the cement production data 1950-2021 (Fig. 13), and the percentages of each of the four Scope 1 sources as well as scope 2 and scope 3 emissions. The third component is to account for the decreasing clinker factor and thus declining calcining emissions per tonne of cement since 1950. The calculations account for decreasing clinker ratio from 1928 to 2019 (data from Andrew 2019, see Fig. 11), which we indexed from 2020 back to 1950 (Fig. 12).[21] This dataset shows that clinker content was 27% higher per tonne in 1950 compared to 2020.

We use this dataset as a proxy for backcasting not only process emissions but also other sources of scope 1 emissions, such as fuel combustion, and scope 2 and 3 emissions. Energy efficiency gains may have improved at a faster rate, and scope 2 and scope 3 energy use and emissions improved at a faster rate than the reduction in clinker factor and emissions, but we do not have global data to substantiate this trend, and therefore apply the same trend derived from the documented clinker ratio and calcining emissions to fuel combustion and the other scope 1, 2, and 3 sources.

This is subject to revision if better data becomes available for estimating fuel combustion emissions, other scope 1 sources, as well as scope 2 (purchased electricity), and scope 3 sources.

Figure 11. Approximate implied global clinker ratio (Andrew 2019, figure 1A)



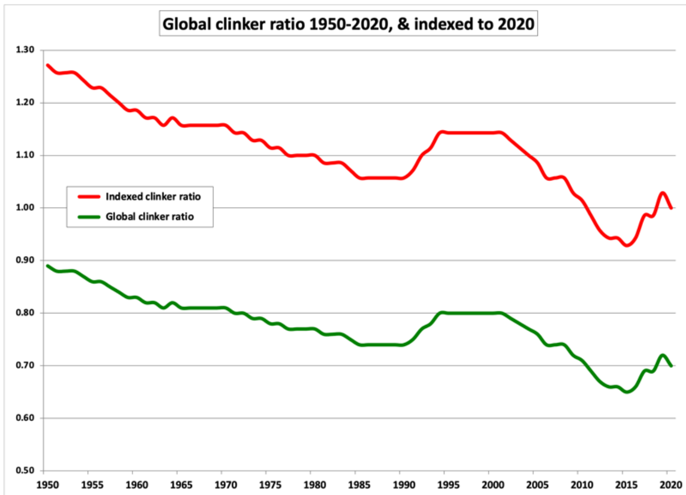
Approximate implied global clinker ratio, derived from emissions estimates and cement production data using default emission factors. The trend up until 1990 is largely a result of the assumptions used in extrapolation.

[21] Personal communication, 21 April 2021. Note: I add an assumed clinker ratio of 0.70 for the year 2020.

Holcim has revised its scope 3 boundary definition and expanded its methodology and thus its quantitative assessment on the basis of a "more robust methodology for measuring scope 3 emissions." See discussion in chapter 3. We adopt the relative contributions shown in table 1, and based on the scope 3 quantity reported for 2020: 29 Mt CO_2 — on the assumption that a "more robust methodology" is equally applicable to previous years' scope 3 emissions. See Chapter 3.

This forms the basis for backcasting emissions in two phases: based on reported scope 1 and scope 2 emissions from 2009 to 2019 to the climate platform CDP, and calculating scope 1 by the individual sources in table 1. (Lafarge and Holcim do *not* report scope 3 emissions for 2009 through 2019 in a consistent manner in the CDP submissions and are ignored in this assessment. See Fig. 6.)

Figure 12. Global clinker ratio and 1950 to 2020 indexed



Our methodology, in sum

In summary, we take the cement production reported by Lafarge for 1950 to 2020 and Holcim for 1965 to 2021, in million tonnes per year (Mt) as our baseline metric. Then we use the specific scope 1, scope 2, and scope 3 emission sources reported by LafargeHolcim for 2020 (Figures 4 & 14-18), apply the same percentage distributions for the four scope 1 sources (calcining process, fuel combustion, energy generation, and aggregates and ready-mix) and scope 2 and scope 3 sources (Table 2). We then calculate emissions for each scope prior to 2009 on the basis of these relative scopes 1, 2, and 3 contributions, and multiply these factors by annual cement production times the indexed clinker ratio from 2008 back to 1950. Our results should be viewed as best *estimates*.

Uncertainties

Only with detailed data from Holcim and Lafarge regarding its historical quantities of carbon fuel combusted in its kilns in hundreds of facilities, data on purchased electricity and powerplant emissions, the nature of its far-flung scope 3 emissions, and a range of related (and unpublished) data can a complete historical inventory of the company's emissions be accomplished. The current methodology is based on company-reported data on cement production, which is fairly but not fully complete (and likely underreported), on global (not company-specific) clinker ratio, on company-reported scopes 1, 2, and 3 for 2009-2019 and the detailed and presumably complete 2020 & 2021 emissions, and on the assumption that fuel combustion and emissions followed the same trend as clinker ratio from 1950 to 2020. One reviewer suggested that combustion emissions may have declined *slower* than the clinker ratio (and calcining emissions), but this point has not been verified.

We cannot assess the overall uncertainties embedded in our historical analysis. Holcim is encouraged to provide additional data, to provide feedback on our methodology and results, and to provide a full record of annual and historical emissions from 1950 onwards.

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RESULTS

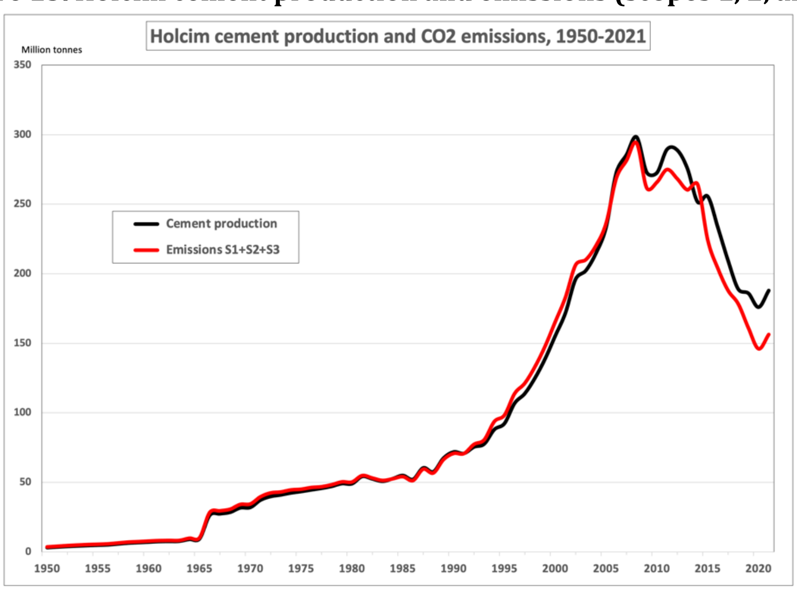
Climate Accountability Institute (CAI) has been commissioned to quantify emissions attributable to Holcim from the company's cement production (calcining emissions, fuel combustion, other scope 1 sources, scope 2 [purchased electricity], and indirect scope 3) from 1950 to the present. The company has reported its emissions since 2009. CAI developed a methodology to backcast the company's emissions for the same sources back to 1950 based on reported cement production, and accounting for efficiency gains, increased use of alternative materials, reduced clinker factor, and decreased calcining emissions. See chapter 3 (company reporting) and chapter 4 (methodology).

Cumulatively, from 1950 to 2021, Holcim's scope 1-3 emissions totaled 7.15 $GtCO_2$.

Table 2. LafargeHolcim cement, clinker ratio, and annual emissions by decade, 1950-2021

	Cement prodn Mt	Clinker ratio indexed	Scope 1 $MtCO_2$	Scope 2 $MtCO_2$	Scope 3 $MtCO_2$	Total CO_2 $MtCO_2$
1950	3.0	1.27	2.7	0.2	0.7	3.6
1960	7.0	1.19	5.8	0.4	1.5	7.7
1970	32.0	1.16	25.7	1.9	6.8	34.5
1980	49.0	1.10	37.5	2.8	10.0	50.2
1990	71.9	1.06	52.8	4.0	14.1	70.8
2000	155.5	1.14	123.4	9.3	32.9	165.5
2010	272.7	1.01	198.5	14.4	52.8	265.8
2020	176.0	1.00	110.0	7.0	29.0	146.0
2021	188.0	1.00	119.3	7.0	30.0	156.3
Percent allocation (2021)			76.3%	4.5%	19.2%	100%
Cumulative 1950-2021			**5,332.6**	**395.3**	**1,418.4**	**7,146.3**

Figure 13. Holcim cement production and emissions (scopes 1, 2, and 3)



We applied the allocation factors to Holcim's cement production, after applying the indexed clinker factor (which means that calcining emission intensity was 27% higher per tonne in 1950 than in 2020). Our methodology reflects the distribution of emissions quantified by Holcim:

Calcining 47.2%, combustion 25.1%, energy generation 2.5%, ready mix 0.5%; Scope 1 totals 76.3%, scope 2 is 4.5%, and scope 3 is 19.2%. See Tables 2 and 3.

Results

Our result: Holcim and its predecessors produced 7.15 billion tonnes (Gt) of cement from 1950 to 2021,[22] and an estimated 7.26 billion tonnes of carbon dioxide ($GtCO_2$) from scope 1, 2, & 3 sources.

Figure 14. Holcim cement production & scope 1 emissions, 1950-2021.

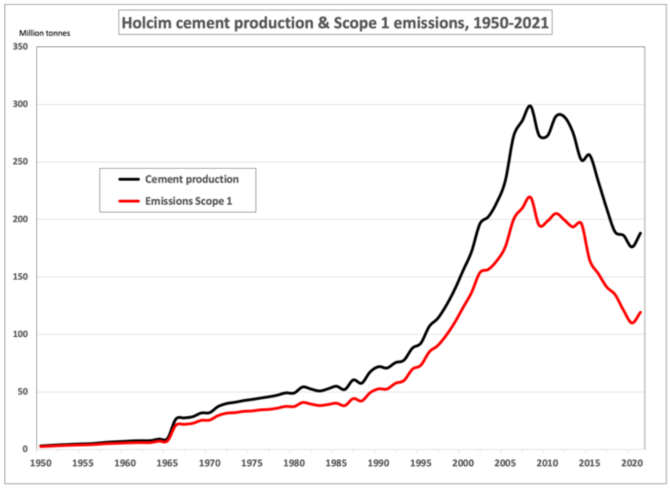
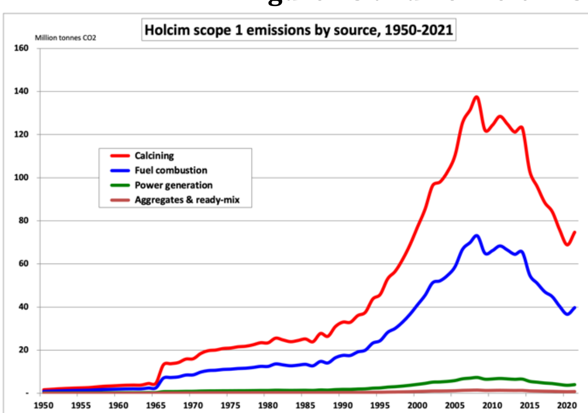


Figure 15 and 16. Holcim scope 1 emissions by category



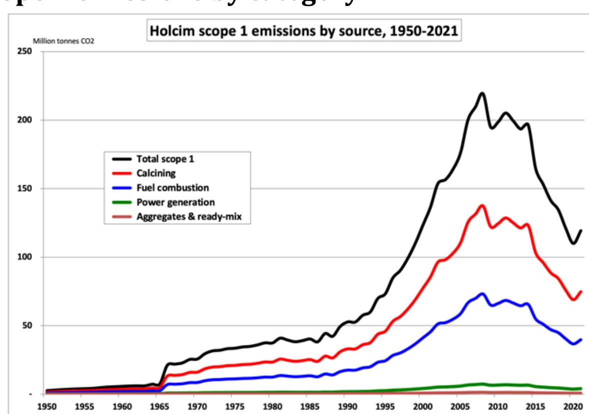
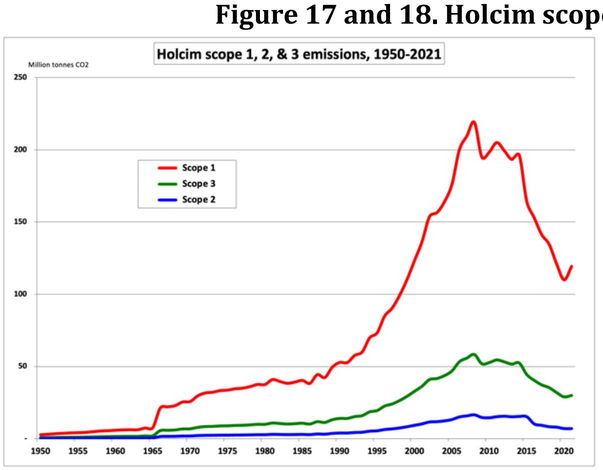
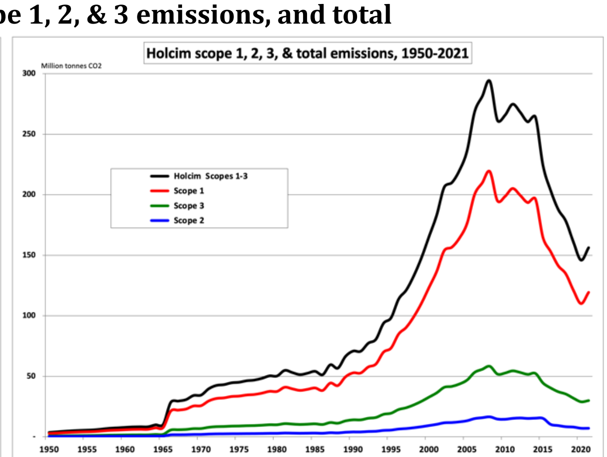


Figure 17 and 18. Holcim scope 1, 2, & 3 emissions, and total





[22] Note that we have company-reported data for Lafarge from 1950, but only from 1966 for Holcim (then Holderbank).

Of this total, scope 1 operational emissions account for 5.33 $GtCO_2$ (74.6%), scope 2 emissions 0.40 $GtCO_2$ (5.5%), and scope 3 indirect emissions 1.42 $GtCO_2$ (19.8%). We estimate historical emissions of scope 1 source by category; of total scope 1 (74.6%), calcining is 46.8%, fuel combustion 24.9%, power generation 2.5%, and ready mix and aggregates 0.5%. See Table 3.

Global emissions are typically based on calcining (process) emissions (Andrew 2019; Global Carbon Project; Friedlingstein 2020), which total 42.33 $GtCO_2$ for the same period 1950-2020, and of which LafargeHolcim accounts for 7.7%.

Table 3. Holcim and global cement production (Mt) and emissions ($MtCO_2$).

	Holcim		Global		% Holcim of global	
	1950-2021	2021	1950-2021	2021	1950-2021	2021
Cement production	7,264	188	112,112	4,400	6.5%	4.3%
Calcining	3,342	75	44,819	1,700	7.5%	4.4%
Scope 1	5,333	119	na	na	na	na
Scopes 1-3	7,146	156	na	na	na	na
Calcining intensity	0.462	0.392	0.394	0.386	na	na

Figure 19. Global cement emissions & Holcim scopes 1, 2, & 3, and Holcim calcining emissions

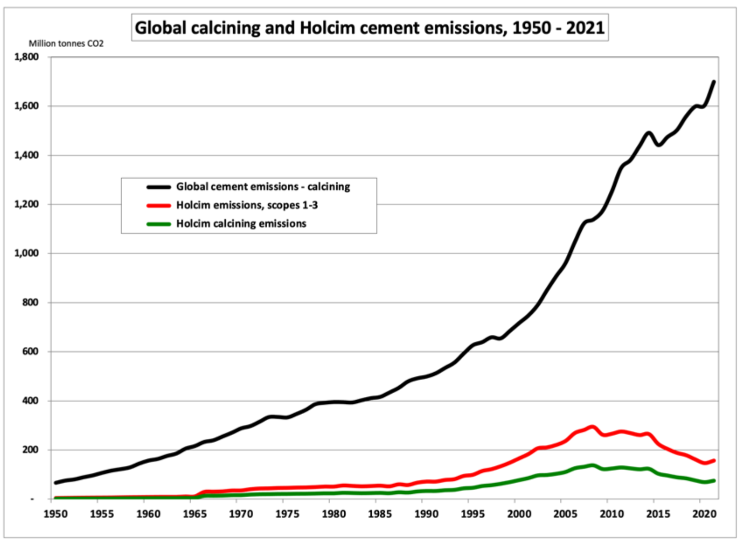
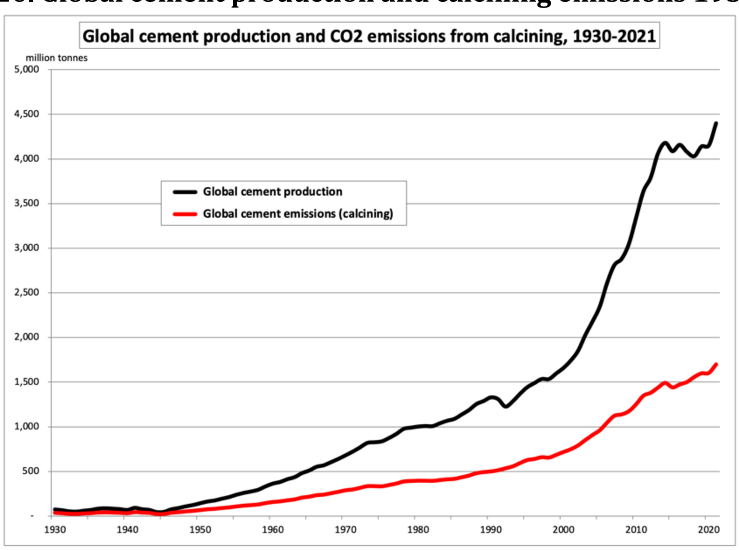
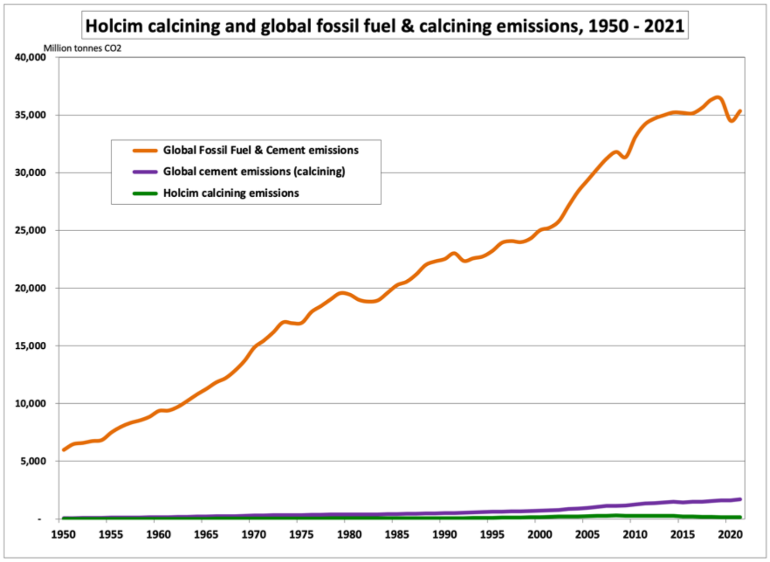


Figure 20. Global cement production and calcining emissions 1930-2021



We chart global cement and Holcim production from 1950 to 2021 (Figures 13, 14). Holcim produced 4.3% of global cement in 2021, and 6.5% of global from 1950 to 2021. See Figure 19 and Table 3. Global cement production and calcining emissions 1950-2021 in Figure 21.

Figure 21. Global fossil fuel & cement, global cement, & Holcim calcining emissions 1950-2021



Cumulatively, over the seventy-one-year period from 1950 to 2021, 112 billion tonnes (Gt) of cement were produced globally, of which Holcim produced 7.26 Gt of cement (6.5% of global). The process of manufacturing cement from limestone (CaC) drives off carbon dioxide. Globally, these "process" (aka calcining) emissions totaled an estimated 44.8 $GtCO_2$ over 1950-2021, of which Holcim (and Lafarge) emitted 7.5%, or 3.34 $GtCO_2$. Figure 21 charts Holcim's calcining emissions, global calcining emissions, and global fossil fuel plus cement emissions 1950-2021.[23] Cumulatively, Holcim scopes 1, 2, and 3 emissions account for 0.477% of global "industrial emissions" (as fossil fuel & cement emissions are called) from 1950 to 2021. Over that period Holcim emissions totaled 7.15 $GtCO_2$, compared to global industrial emissions of 1,499 $GtCO_2$.

[23] Friedlingstein et al. 2020; Boden et al. (2017); Global Carbon Project (www.globalcarbonproject.org).

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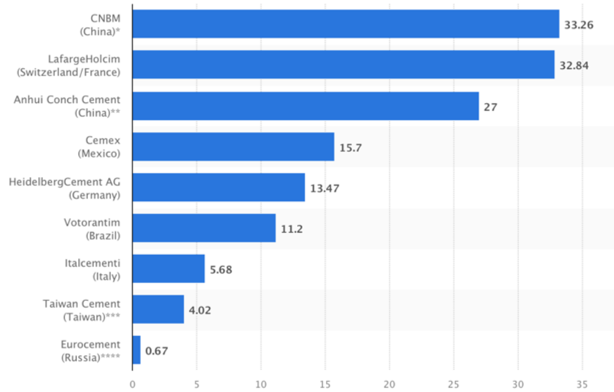
SUMMARY

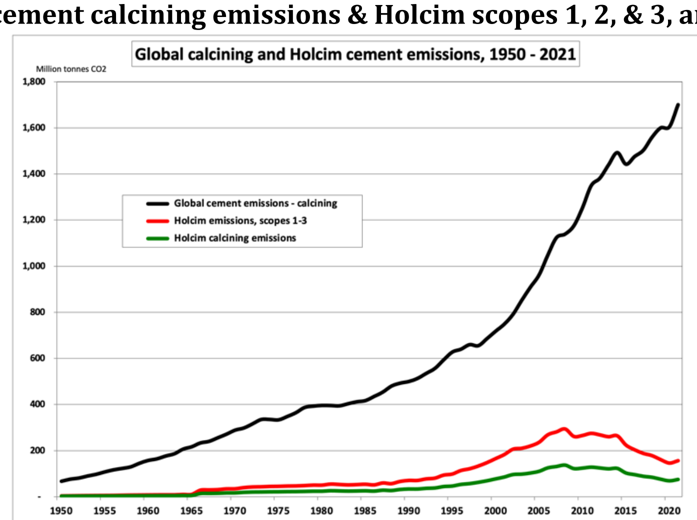
Holcim and its predecessors (Lafarge, and other acquisitions) have been in business since 1883 and has grown to be the world's second-largest cement company by revenue (Figure 22). Holcim and Lafarge annual reports document that the company has produced 7.26 billion tonnes (Gt) of cement from 1950-2021. CAI has analysed Holcim & Lafarge emission estimates and developed a model for estimating the company's process (calcining) emissions, other scope 1 sources, and scopes 2 and 3.

Figure 22. Revenue of leading cement companies, 2020, in billion USD (Statista 2021)



The company has produced 6.5% of world cement over the period of our assessment, from 1950 to 2021 (7.26 Gt of 112 Gt). The company's associated emissions from cement production (calcining, fuel combustion, power generation, aggregates and ready mix, purchased electricity, and scope 3 emissions) amounts to 7.15 $GtCO_2$ over the same period.[24] Figure 23 and Table 3.

Figure 23. Global cement calcining emissions & Holcim scopes 1, 2, & 3, and Holcim calcining



[24] Global assessments of cement emissions estimate that cement production is currently ~8% of global fossil fuel and cement (Andrew 2019), together referred to as "industrial emissions," if both process and fuel combustion emissions are counted. CAI's analysis suggests calcining emissions are 4.14% of total FF & cement, and the other associated emissions account for an additional 4.71%.

Since cement emissions are relatively small compared to fossil fuel emissions, Holcim's portion of cumulative emissions since 1950 is 0.48% of global fossil fuel & cement emissions (or 0.42% of global fossil fuel and cement emissions from 1751 to 2021).[25] See Figures 23 and 24. These calculations do *not* include other anthropogenic sources of greenhouse gases, such as non-CO_2 gases (nitrous oxide, various methane sources, F-gases), and non-energy CO_2, such as from land use, deforestation, agriculture, animal husbandry, etc.

Figure 24. Global fossil fuel & cement, global calcining, & Holcim calcining

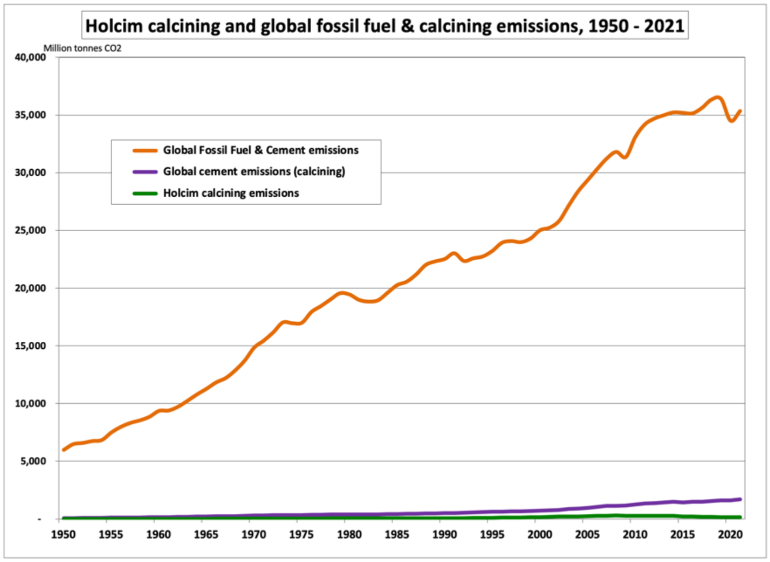
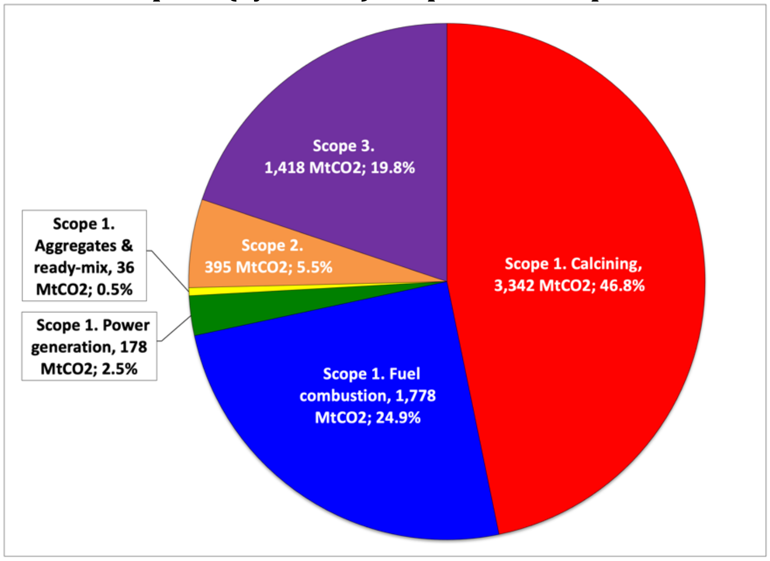


Figure 25. Holcim scopes 1 (by source), scope 2, and scope 3, 1950-2021, $MtCO_2$



[25] CAI uses a dataset from US DOE Carbon Dioxide Information Analysis Center's historical database of fossil fuel (oil, gas, coal, and flaring) and cement emissions from 1751 to 1959; revisions and updates from 1959 to the present are carried out by the Global Carbon Project (www.globalcarbonproject.org). CAI maintains an up-to-date database of global anthropogenic emissions by source. The cumulative total 1751-2021 amounts to 1.72 trillion tonnes CO_2 ($TtCO_2$).

Annex A

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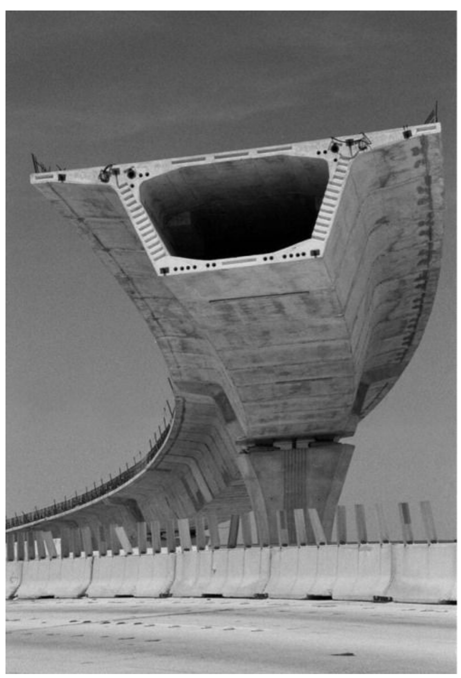
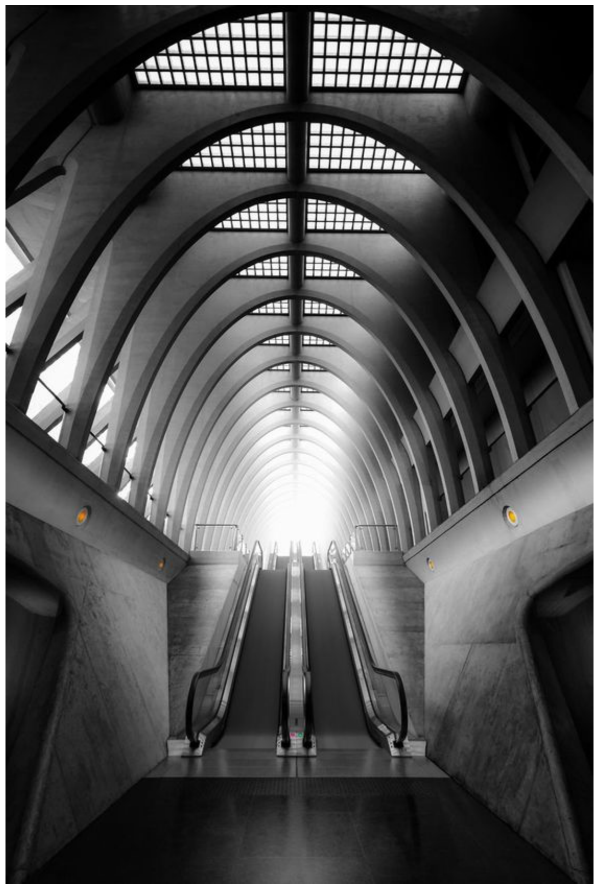




Annex B

Additional material

Figure 26. Cement process, emissions allocation, mitigation options (Chatham House 2018).

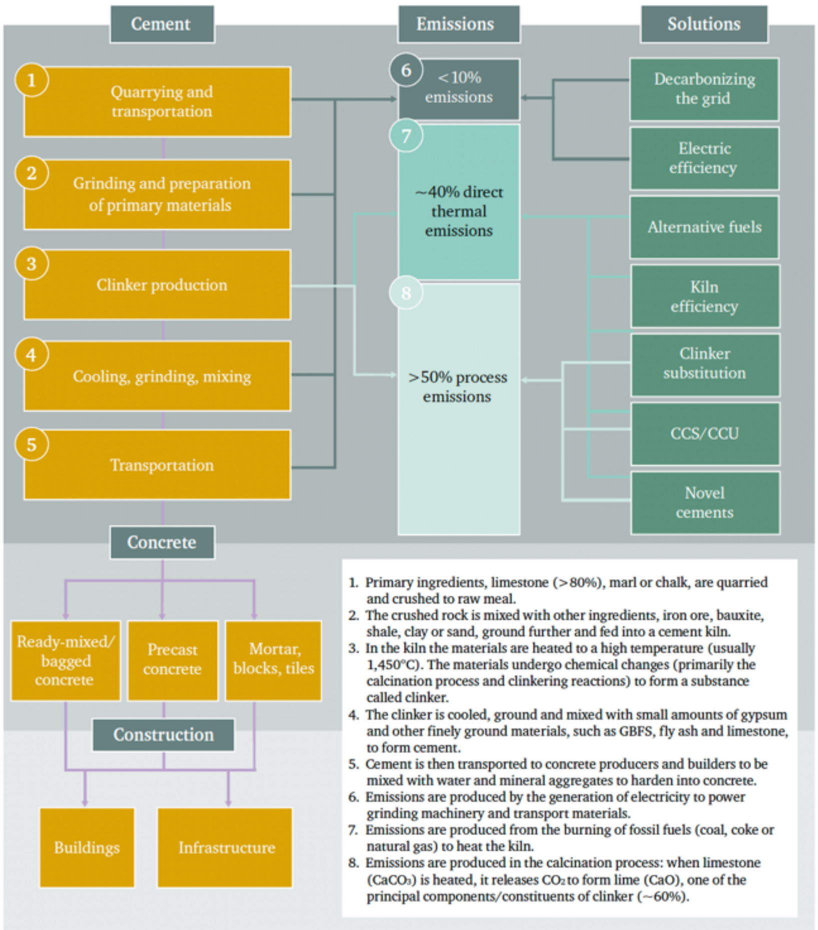
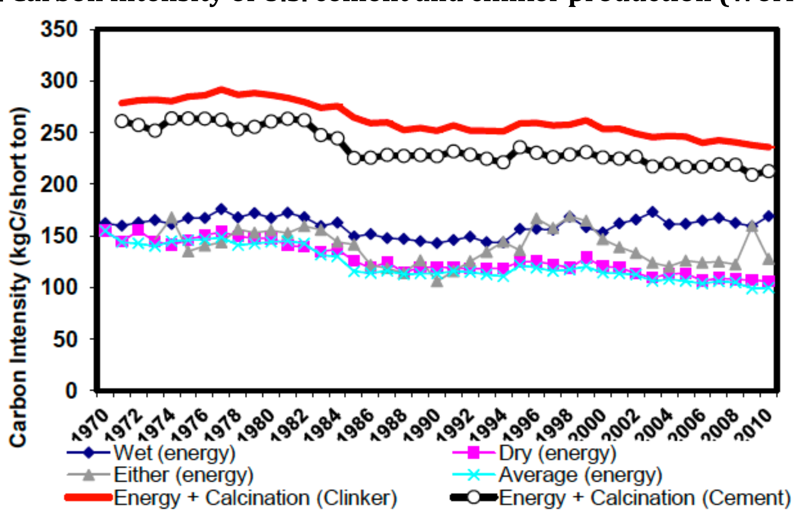
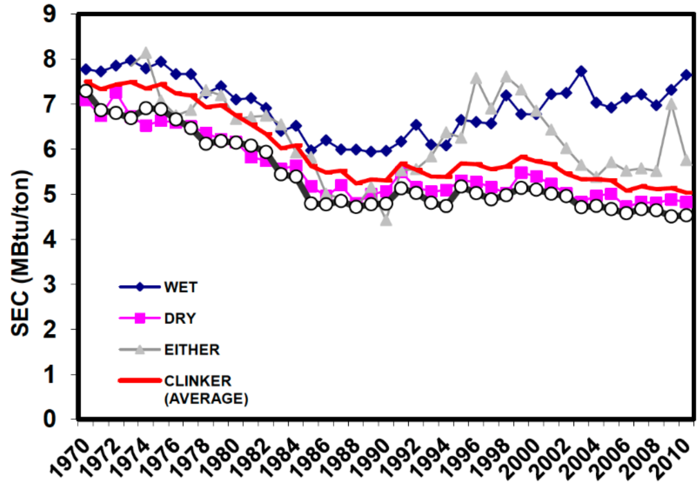


Figure 27. Carbon intensity of U.S. cement and clinker production (Worrell 2013)



Worrell 2013 Figure 8. Carbon intensity of U.S. cement and clinker production, 1970 to 2010 (kgC/short ton of product).

Figure 28. Primary energy intensity of U.S. cement and clinker production (Worrell 2013)



Worrell 2013 Figure 6. Primary energy intensity of U.S. cement and clinker production, 1970 to 2010 (MBtu/sh ton, HHV). This graph excludes use of wastes as kiln fuel between 1977 and 1992, as USGS did not collect this data before 1993.

Formula of calcining limestone (calcium carbonate) into lime (CaO) plus CO_2; cement process schematic. Worrell 2001, page 317: $CaCO_3$ -> CaO + CO_2

$$CaCO_3 \rightarrow CaO + CO_2$$
$$1\,kg \quad 0.56\,kg + 0.44\,kg.$$

Fig 29. cement process schematic (Worrell 2001, Fig. 1). Fig. 30. Highway exchange.