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Way to go! Improving corporate carbon performance by means of low-carbon initiatives

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Abstract

This paper analyzes a database of 101 annual and sustainability reports of eleven large European firms from the years 2011-2017 in order to reveal low-carbon initiatives and company-level factors which can determine and improve corporate carbon performance. Stüwe, Busse, and Goldhammer (2023) have identified eleven firms as notable cases of carbon performance by means of an innovative benchmarking approach. This research validates their findings and explores these cases. By taking the course of estimated emissions (Stüwe et al., 2023) and reported emissions (from the reports) into account, as well as the model-internal factors described by Stüwe et al. (2023) (industry, firm size and capital intensity), I can reveal further explanatory factors on carbon performance: (1) *strategic company-level factors* (the firms' strategies including mergers and acquisitions or divestments and the choice of the business model and the portfolio) as well as (2) *operational company-level factors* (their low-carbon initiatives including environmental management systems and the staff's behavioral improvements, (changes in) the calculation method, the use of renewable energies and energy-efficiency and structural improvements like N_2O emission abatement technologies or LED technology). This research can support multiple stakeholders like managers or NGOs aiming at an evaluation or improvement of the corporate carbon performance of a firm.

Keywords: Corporate carbon performance, company-level factors, low-carbon initiatives, benchmarking, firm cases

Introduction

Corporations contribute to and are affected by global warming and its consequences (IPCC, 2023). Therefore, many corporations take on the responsibility and foster low-carbon initiatives (Schaltegger & Csutora, 2012). There is a broad body of literature about concepts of such low-carbon initiatives, referring to sustainable cities and urban development (van Doren, Driessen, Runhaar, & Giezen, 2020), carbon management (systems) (He, Luo, Shamsuddin, & Tang, 2021), carbon accounting (Stechemesser & Guenther, 2012), carbon disclosure (Giannarakis, Zafeiriou, & Sariannidis, 2017), carbon footprinting (Wiedmann & Minx, 2008) and carbon performance (Hoffmann & Busch, 2008).

Whereas carbon accounting (Stechemesser & Guenther, 2012) and carbon footprinting allow for the measurement of corporate carbon emissions (Wiedmann & Minx, 2008)[1] and carbon disclosure for their communications (Giannarakis et al., 2017), it is especially the concept of carbon performance (Hoffmann & Busch, 2008) which carries the potential for interpretations and evaluations of companies and their activities in the light of climate change mitigation.

Many scholars (Doda, Gennaioli, Gouldson, Grover, & Sullivan, 2016; Eun-Hee & Lyon, 2011; Kolk, Levy, & Pinkse, 2008; Liesen, Figge, Hoepner, & Patten, 2017; Luo, Lan, & Tang, 2012; Luo & Smith, 2019; Luo & Tang, 2021; Matsumura, Prakash, & Vera-Muñoz, 2013; Tang & Luo, 2014) measure corporate carbon performance simply as carbon output intensity, which "describes the extent to which [a company's] business activities are based on carbon usage for a defined scope and fiscal year" (Hoffmann & Busch, 2008, p. 508). This concept of carbon output intensity has also become part of the standard methodology of the CDP (2017a). The CDP has registered an immense increase of answers to its questionnaire over time (CDP, 2017b; Giannarakis et al., 2017; Matisoff, Noonan, & O'Brien, 2013). Building upon this understanding, Stüwe et al. (2023) proclaimed a more complex model of carbon performance by means of a regression approach of Goldhammer, Busse, and Busch (2017). This regression approach combined the firm size of a company with further regressor variables, i.e. capital intensity, centrality of production and dummy variables for the industry affiliation. Stüwe et al. (2023) were able to confirm the model results of

[1] Carbon footprints measure the amount of carbon dioxide emissions and their equivalents (IPCC, 2014; WRI, 2004) that are "directly and indirectly caused by an activity or […] accumulated over the life stages of a product" (Wiedmann & Minx, 2008, p. 4).

Goldhammer et al. (2017) and, furthermore, developed a new methodology that allows stakeholders (Freeman, 1984) to derive notable cases of carbon performance such as best carbon performance of the year which can support discussions between stakeholders and the firm about the true meaning of a company's carbon footprint. Among the 46 analyzed firm cases for the years 2011 and 2016, they have filtered out twenty notable cases of carbon performance and eleven notable firms.

This research focuses on the low-carbon initiatives of the eleven firms which Stüwe et al. (2023) derived as notable and which have been disclosed in 101 annual and sustainability reports of the years 2011 until 2017.

Aim of this research is to validate the research of Stüwe et al. (2023) as well as to explain qualitatively the notable cases which were derived quantitatively in order to guide academics and practitioners towards climate change mitigation. It aims to find out by which means firms can improve their carbon performance and which factors and initiatives can contribute to a good carbon performance. To filter out these factors and to fill this research gap, I pose the following research questions:

Why are some firms notable in their corporate carbon performance? Which low-carbon initiatives and company-level factors can contribute to good corporate carbon performance?

The subsequent conceptual background offers an introduction to low-carbon initiatives, environmental and carbon management, carbon performance and carbon disclosure. The following methodology section gives an overview of the approach, the database and the procedures of analysis. The results of the analysis follow. The penultimate section discusses theoretical and practical implications of this research, highlights its limitations and identifies opportunities for future research. The article concludes with a brief summary.

CONCEPTUAL BACKGROUND

Low-carbon initiatives

This research aims at revealing low-carbon initiatives and company-level factors that can determine carbon performance of firms. In this context, low-carbon initiatives (van Doren et al., 2020) and carbon management (Tang & Luo, 2014) play dominant roles in the literature. In their research, van Doren et al. (2020) describe low-carbon initiatives within the City of Copenhagen and refer to Bulkeley and Castán Broto (2013, p. 364) who take a look onto "urban climate change initiatives".

Several other papers also emphasize the meaning of low-carbon initiatives for the municipality or city context (Cheng, Yi, Dai, & Xiong, 2019; Genus & Theobald, 2015; Middlemiss & Parrish, 2010). Furthermore, a study by Khan, Godil, Yu, Abbas, and Shamim (2022) examines the influence of low-carbon initiatives onto tourism in Asian countries.

A few studies analyze low-carbon initiatives in the corporate and managerial context: Böttcher and Müller (2015, p. 477), Furlan Matos Alves, Lopes de Sousa Jabbour, Kannan, and Chiappetta Jabbour (2017, p. 225) as well as Lopes de Sousa Jabbour et al. (2021, p. 7107) mention "low-carbon operations practices", "low-carbon operations" or "low-carbon initiatives" which can be understood as corporate responses to current or future contingencies (Sousa & Voss, 2008). Contingencies are outside events or changing contextual factors that affect organisations, over which organisations cannot exert direct control, and which force companies to adapt their structures in order to keep up performance (Donaldson, 2001; Sousa & Voss, 2008). The above-mentioned authors interpret climate change and supply chain disruptions as such contingencies.

In their opinion, those low-carbon operations practices could be products, processes (or production) and logistics (Furlan Matos Alves et al., 2017, p. 225), for example "the production and certification of biodiesel on a commercial scale" (product), "the use of biomass for energy production and proper use of soil, avoiding deforestation in different regions of the country, including the Amazon region" (process) and "exchanges of transport modals and intensified exchange of road with rail" (logistics) (Furlan Matos Alves et al., 2017, p. 229).

Furthermore, Furlan Matos Alves et al. (2017, p. 233) find that "low-carbon management initiatives are [often] started from environmental management systems that already exist". Therefore, they emphasize the meaning of environmental management systems for low-carbon initiatives.

Environmental and carbon management (systems)

Environmental and carbon management (systems) are frequently represented in literature. He et al. (2021, p. 21) describe carbon management as "practices a company undertakes to mitigate its operational GHG emissions". Here, He et al. (2021) give a rather narrow, firm-related definition of carbon management. But, He et al. (2021) also refer to a broader understanding of carbon management like in Tang and Luo (2014): Tang and Luo (2014, p. 84) extend the view on carbon management by considering ten essential elements of a carbon management system, "namely: (1) board function; (2) carbon risk and opportunity assessment; (3) staff involvement; (4) reduction targets; (5) policy implementation; (6) supply-chain emission control; (7) greenhouse gas (GHG) accounting; (8) GHG assurance; (9) engagement with stakeholders; and (10) external disclosure and communication”. They also give a definition of a carbon management system as “a functional tool – a way to implement a firm’s carbon strategy or policy […] to enhance the efficiency of input-use […], mitigate emissions and risks and avoid compliance costs or to gain a competitive advantage” (ibid).

Environmental and carbon management systems are considered helpful in the context of climate change mitigation (Sial et al., 2021; Tang & Luo, 2014). In Tang and Luo (2014), mitigation is measured based on an index, mainly focusing on carbon intensity, Sial et al. (2021) take carbon intensity alone as the dependent variable. Within this research, I analyze 101 annual and sustainability reports in order to find out which role environmental and carbon management and other low-carbon initiatives of the eleven considered firms played in context of their carbon performance.

Carbon performance

This research builds upon different concepts of carbon performance. The basic concept of carbon performance is mainly influenced by Hoffmann and Busch (2008) and the idea to put carbon emissions into relation with the size of a firm. Corporate carbon performance is regarded as carbon output intensity, which “describes the extent to which [a company’s] business activities are based on carbon usage for a defined scope and fiscal year” (Hoffmann & Busch, 2008, p. 508). Many scholars (Doda et al., 2016; Eun-Hee & Lyon, 2011; Kolk et al., 2008; Liesen et al., 2017; Luo et al., 2012; Luo & Smith, 2019; Luo & Tang, 2021; Matsumura et al., 2013; Tang & Luo, 2014) have adopted this concept. Stüwe et al. (2023), point to a more complex approach of carbon performance and they apply further explanatory variables to the carbon footprint, i.e. capital intensity and an industry dummy like in Goldhammer et al. (2017) whose model they support with the directions of the explanatory variables. Goldhammer et al. (2017) as well as Stüwe et al. (2023) find that the higher the size, the higher was the corporate carbon footprint and the higher the capital intensity (as property, plant and equipment devided by turnover), the higher the corporate carbon footprint.

Stüwe et al. (2023) furthermore develop a new methodology that allows for the analysis of notable cases for corporate carbon performance benchmarking and apply it with an exemplary data set of 93 firms for the years 2011 and 2016. This new approach is helpful for a facilitation of carbon footprint related decision making for different stakeholders and related stakeholder discussions. Taking the difficulties of incomplete carbon footprints into account, Stüwe et al. (2023) build their research upon Liesen, Hoepner, Patten, and Figge (2015), thereby, only acknowledging firms which reported complete footprints.

The methodology of Stüwe et al. (2023) allows stakeholders like managers, employees or NGOs to better understand notable cases of carbon performance and support discussions between them and the firms about the companys' carbon footprints and sustainability strategies.

This research aims at extending these discussions further to the importance of low-carbon initiatives and company-level factors. It thus helps stakeholders to qualitatively evaluate a firm's approach towards carbon emission mitigation and sustainability on a more detailed level.

Carbon disclosure

Carbon disclosure can be understood as the connection between carbon management and the stakeholder side of a company. In this context, Giannarakis et al. (2017, p. 1079) state that "environmental disclosure is a managerial tool that can be used to perform managerial expectations". There are two conflicting theories about carbon disclosure: the legitimacy theory (Deegan, 2002; Gray, Owen, & Adams, 1996) and the voluntary disclosure theory (Dye, 1985; Verrecchia, 1983): In the context of the legitimacy theory, firms disclose environmental information in order to stay legitimate and to being able to stay on the market. The theory describes that these firms often have inferior environmental performance and try to protect their business models from criticism of stakeholders (Deegan, 2002; Gray et al., 1996). Giannarakis et al. (2017, p. 1081) here define disclosure as "a means for corporate managers to affect stakeholders' perception of their actual environmental performance".

If firms, however, disclose environmental data voluntarily to distinguish themselves positively from competitors, this can be explained by the other theory, the voluntary disclosure theory. This theory draws a positive link from environmental performance to climate change disclosure (Dye, 1985; Verrecchia, 1983). Disclosure, then, means that "superior environmental performers tend to disseminate more information to distinguish themselves from inferior environmental performers" (Giannarakis et al., 2017, p. 1081). Both views exist parallelly in scholarly discussions.

These theoretical concepts, however, have a shortcoming and emphasize why this research about low-carbon initiatives and corporate carbon performance is so important: While firms disclose their corporate carbon footprints as well as their sustainability strategies and low-carbon initiatives, stakeholders cannot necessarily evaluate those figures and descriptions. Therefore, it often remains unclear, if a corporate carbon footprint of a certain hight is representing a good or a bad carbon performance of a firm, both for internal and external stakeholders (Stüwe et al., 2023). Managers, for example, cannot be certain in which (competitive) context they disclose their carbon footprints and low-carbon initiatives and also other stakeholders do not know who the superior and inferior environmental performers really are. By offering a new methodology to derive good and bad carbon performance as well as other notable cases of carbon performance such as the highest estimated emissions or the largest increase of reported emissions, Stüwe et al. (2023) tackle this problem and allow for evaluation of carbon footprints and firm cases. My research further extends this view and provides an analysis of low-carbon initiatives and company-level factors in the context of carbon performance. This research adds an innovative frame to carbon disclosure and it can help managers to analyze their firm's position on the market in the context of carbon emissions in order to eventually turn the firm from an inferior to a superior carbon performer. It can also lead other stakeholders to evaluate and discuss this competitive position of a firm and the quality of its low-carbon emissions and sustainability strategy.

METHODS

Approach/Design

This research analyzed the explainatory factors of corporate carbon performance and low-carbon initiatives of the eleven firms which Stüwe et al. (2023) derived as notable and which have been disclosed in 101 annual and sustainability reports of the years 2011 until 2017.

I validated the research of Stüwe et al. (2023) and explained qualitatively (Krippendorff, 2004) the notable cases which Stüwe et al. (2023) derived quantitatively. Furthermore, I found out which low-carbon initiatives and company-level factors carried the potential to determine corporate carbon performance. Based on Stüwe et al. (2023) I therefore analyzed the reported and estimated emissions, the model-internal factors size and capital intensity, the firm's portfolio and strategy and their low-carbon initiatives. The model-internal factor industry was taken as given.

Database

Building upon Stüwe et al. (2023) and Goldhammer et al. (2017) I took the eleven notable firms as analyzed cases and also used their data for analyzing the estimated emissions. I found the firms' annual reports and sustainability reports of the years 2011-2017 by online desk research. Some firms had more reports, others less, so that I could analyze 101 reports in total. By analyzing the database of 101 annual reports and/or sustainability reports of the eleven firm from the years 2011-2017, I searched for special characteristics which can explain the different notable cases. Some reports contained more information, some less. Table 1 lists the notable cases of Stüwe et al. (2023) and the amount of reports available for each firm case.

TABLE 1

Notable cases of Stüwe et al. (2023)

Company name	Industry	Criterion and year
Abengoa	C&E	Largest CCP-neutral change Worst carbon performance 2011 Worst carbon performance 2016 Largest decrease of estimated emissions Largest total change
Alstom	Machinery	Largest decrease of reported emissions
BASF SE	Chemicals	Highest reported emissions 2011 Highest estimated emissions 2011 Highest estimated emissions 2016
Dürr AG	Machinery	Largest increase of estimated emissions
Givaudan SA	Chemicals	Best carbon performance 2016
Hochtief	C&E	Largest CCP-effective deterioration
Interserve plc	C&E	Largest increase of reported emissions
Koninklijke DSM N.V.	Chemicals	Largest CCP-effective improvement
Linde Group	Chemicals	Highest reported emissions 2016
Outotec Oyj	C&E	Lowest reported emissions 2016 Best carbon performance 2011
Rotork plc	Machinery	Lowest reported emissions 2011 Lowest estimated emissions 2011 Lowest estimated emissions 2016

Note: CCP = corporate carbon performance; sum of analyzed reports: 101

Procedures of analysis

While Stüwe et al. (2023) carried out a quantitative approach by means of the development of a regression model, this research was conducted as a qualitative analysis based on content analysis (Krippendorff, 2004). First, I found the reported emissions within the reports by searching for the key word "emission" within the reports of 2011-2017. If the carbon emissions were not published within the reports, I analyzed and depicted the carbon emissions of the CDP reports of 2012 (CDP, 2012) and 2017 (CDP, 2017c) used by Stüwe et al. (2023). Then I analyzed the estimated emissions also by using the data of Stüwe et al. (2023) and Goldhammer et al. (2017) for the two years of 2011 and 2016. Furthermore, I analyzed the model-internal factors of Stüwe et al. (2023): size and capital intensity (i.e. property, plant and equipment divided by size) by regarding the financial tables which I found by searching for the key words "consolidated (financial statement)" and "balance sheet". It is important to note that the model of Stüwe et al. (2023) used revenues and sales interchangeably, and so did I. Actually, revenues refer to the total income from different activities, sales is one category of that, more precisely, the amount charged in exchange for a business's products or services (Thakur, 2023).

Then I examined the firms' strategies and their low-carbon initiatives, again by content analysis. Due to the large amount of data, I searched for specific characteristics by using the key words "strategy" and "emission". I coded all findings as sustainability activities and other activities of the firm and then I further narrowed down the findings potentially related to carbon performance. Furthermore, I categorized the low-carbon initiatives along the categories of product, process and logistics initiatives in line with Furlan Matos Alves et al. (2017) and marked the categories within the description of the initiatives. Product and logistics activities were analyzed even though they mostly influence scope 3 emissions and in Stüwe et al. (2023), the sum of scope 1 and 2 emissions were considered. The results of the 20 notable cases were summarized as eleven different firm cases. Therefore, several notable cases could result in one firm case.

RESULTS

Abengoa - introduction

Abengoa is a construction and engineering company with the headquarter in Seville, Spain, (Craft, 2023). Abengoa operates through "more than 600 subsidiaries and investee companies, facilities and offices" (Abengoa, 2011b, p. 13). Stüwe et al. (2023) find Abengoa as the company with the largest neutral and total carbon performance change, the largest decrease of estimated emissions as well as the worst carbon performance in 2011 and 2016 and therefore as a notable case. In the following analysis I find out why Abengoa has been a notable case.

Abengoa – reported emissions

Between 2011 and 2016 the firm drastically lowered its reported carbon emissions by 61,5%. Abengoa's scope 1 and 2 emissions can be seen in Figure 1.

*** Take in Figure 1 about here. ***

Abengoa stated its emissions in terms of direct emissions, direct emissions from biomass and indirect emissions whereas biomass emissions were almost as high as direct emissions. (Abengoa, 2011b, p. 21). Direct emissions, direct emissions from biomass and indirect emissions were all rising from 2010 to 2011 (ibid., p. 40). One reason for this was seen in a “rise in energy consumption in 2011 with respect to 2010 […] primarily attributed to start-up of operations of new plants fuelled by natural gas” (ibid., p. 35). From 2011 until 2014 the scope 1 and 2 emissions increased, with a peak in 2014, right before Abengoa was hit by a financial crisis in 2015 and 2016. Abengoa states in its annual report: “Compared to previous years, there has been an overall reduction of 51 % in energy (direct and intermediate), coinciding with the reduction in activity that the company experienced in 2016. The main decline is in the consumption of natural gas in production of bioethanol, as a result of selling the five plants of Abengoa Bioenergy in the USA and the cessation of activity of the Rotterdam bioethanol plant in the first half of the year” (Abengoa, 2016, p. 54). These were strategy-related divestments which I sum up as the strategic company-level factor “strategy”.

2017 was also a difficult year for Abengoa but “the company’s capability of winning […] contracts in the energy, water, transmission and infrastructure sectors […] [remained] intact” (Abengoa, 2017, p. 4). Possibly due to the further divestments (Abengoa, 2017, p. 5), the emissions of Abengoa further decreased.

Abengoa – estimated emissions

The estimated emissions also dropped substantially, these are the figures that the models of Goldhammer et al. (2017) and Stüwe et al. (2023) generated. The estimated emissions are represented in Figure 2.

*** Take in Figure 2 about here. ***

Between 2011 and 2016 the estimated emission dropped by 92,5 percent. This can be explained by the course of the variables size and capital intensity.

Abengoa - size of the company

The following section will portrait Abengoa’s revenue and sales and it can explain why Abengoa is a notable case. Figure 3 shows Abengoa’s revenues and sales.

*** Take in Figure 3 about here. ***

In 2016, Abengoa listed sales instead of revenues. In 2011, Abengoa listed revenues. It is obvious that size, like reported emissions, has followed the course of the financial crisis, with a drastic reduction from 2014-2016. In total, size has dropped 78,7% from 2011 until 2016.

To find the variable capital intensity, I first look at property, plant and equipment (PPE), which is represented in Figure 4. This figure has dropped by 88,2% between 2011 and 2016 and can be explained by the multiple divestments that Abengoa has carried out due to the crisis.

*** Take in Figure 4 about here. ***

Figure 5 represents Abengoa's capital intensity which has dropped by 44,6% between 2011 and 2016, also due to the crisis.

*** Take in Figure 5 about here. ***

Abengoa – portfolio and strategy

Abengoa's portfolio was described in 2011 as divided into three parts: "Engineering and construction, Concession-type infrastructures […] [and] Industrial production" (Abengoa, 2011a, p. 7). In 2017, however, there seemed to be a new situation for the company: "During 2017, the organisation has furthered its strategic objective of prioritising turnkey engineering projects (EPC) in which the company has technical expertise (know-how), as well as consolidated knowledge to adapt to the company's new situation. Nevertheless, Abengoa continues to take part in concession-type projects, minimising capital investment by signing agreements with strategic partners in which it participates with a minimum investment and mainly performs the engineering and construction of the project" (Abengoa, 2017, p. 7).

The year 2015 marked the beginning of the crisis for Abengoa. Chairman Antonio Fornieles Melero stated in the annual report 2015: "a combination of different circumstances made it impossible for our company to access debt markets and subsequently led to the progressive deterioration of our group's liquidity and financial position. […] [We] had to lower our *cash generation expectations* for the entire year, fundamentally as a consequence of changes in financing conditions in a number of projects in Brazil. This reality, coupled with the negative impact in the return on *significant investments in bioenergy and solar businesses* due to the alteration in market conditions and changes in the regulatory framework […], had a downward impact on our forecasts and created concern regarding the solvency of the company and a sense of lack of confidence within the markets" (Abengoa, 2015, p. 4).

In 2016, the time of crisis for Abengoa went on. The chairman Gonzalo Urquijo stated in the annual report 2016: “2015 and 2016 represent a key stage for us that has undoubtedly marked a turning point in the history of Abengoa. After more than 70 years’ experience, our company faced a major crisis that required us to address a financial restructuring and a rethink of our business model, to ensure that we were able to achieve the Abengoa of the future that we finally see today” (Abengoa, 2016, p. 4). According to a divestment plan, Abengoa started to sell several plants worldwide (ibid.). Therefore, in 2016, Abengoa appeared “with a debt 70 % lower than at the beginning of the [restructuring] process; focused on its core engineering and construction business; resized yet still committed to sustainable development and the environment” (ibid.).

In 2017, Abengoa still suffered from the restructuring of the company. It “reached a restructuring agreement with its creditors in Brazil” (Abengoa, 2017, p. 5) and, again, sold several plants in several countries (ibid.).

Abengoa - low carbon initiatives
As a construction and engineering firm, Abengoa focussed on large-scale projects in the field of energy and water. The sustainability reports of 2011 until 2017 mention many different projects, some with the statement of planned emission reductions. In Table 2, the projects mentioned will be described and categorized into one category of the low-carbon initiatives by including the type of initiative in brackets ([]).

TABLE 2

Low-carbon initiatives of Abengoa

Year	Low-carbon initiatives of Abengoa
2011	The sustainability report of 2011 mainly focused on the power plant “Solana, located 70 km southwest of Phoenix, Arizona, […] [as] one of the **world’s largest thermal solar plants** under construction, […] [which would] boast 280 MW of gross installed capacity (250 MW net) through […] parabolic-trough technology. Solana […] [is aiming at the generation of] enough energy to supply 70,000 US households, while cutting yearly CO2 emissions by 475,000 tons. Solana will include six hours of storage through molten salt technology, enabling it to store energy during cloudy spells and after sunset. This storage capacity will allow Solana to generate enough electricity to meet peak evening

Year	Low-carbon initiatives of Abengoa
	demand during the Arizona summertime” (Abengoa, 2011b, p. 9). **[Process-Renewables-Solar]** Already since 2008, Abengoa was leading a “Greenhouse Gas Inventory” (Abengoa, 2011b, p. 32). In this inventory, Abengoa carried out an analysis of carbon intensity, “a comparative analysis between ratios: tons of CO2 /activity” (ibid., p. 40). Abengoa participated “for the fourth consecutive year in the Carbon Disclosure Project (CDP), **disclosing the company’s complete GHG inventory** and receiving a score of 92 out of 100 on the Carbon Disclosure Leadership Index, and a grade of B on the Carbon Performance Leadership Index” (ibid., p. 43). **[Other-Calculation method]** In 2011, 88.18 % of Abengoa’s (investee) companies were **ISO 14001** certified, therefore had an environmental management system and, also, in 2011, 208 environmental audits were performed (ibid., p. 21). **[Process-Environmental management system]**
2012	In 2012, Abengoa was listed in “the **FTSE4Good sustainability index**, which awarded Abengoa an overall score of 4 out of 5, and 100 out of 100 for its sector (Abengoa, 2012, p. 30). **[Others-memberships and awards]** The firm put effort in improving the calculation of the carbon footprint by “developing an initiative to **calculate Abengoa’s overall footprint** so as to measure and report the resources consumed and the impacts deriving from its business activities” (ibid., p. 38). Furthermore, and for the first time, Abengoa enabled suppliers to directly report their emissions by means of an online tool (ibid.). A sustainability panel examined Abengoa’s sustainability activities and claimed that there were two different calculation methods for Greenhouse gas emission reductions in 2012 at company and at group level which made the figure difficult to understand to readers (ibid., p. 42). Besides a corporate carbon footprint, Abengoa also calculated “the greenhouse gas (GHG) emissions associated with its products and services since 2008 through a management system designed by the company for this purpose and integrated into the ISMS” (ibid., p. 70). **[Other-Calculation method]** In 2012, Abengoa (2012, p. 43) commented on the ongoing increase of emissions (before the crisis) as follows: “As a result of the **natural maturity**

Year	Low-carbon initiatives of Abengoa
	process of the GHG emissions management system, through optimization of emissions accounting and periodic review on all organizational levels, the group companies have been improving the quality of their emissions reporting year after year to reach the current level of maturity". **[Other-Calculation method]**.
2014	In 2014, further carbon reduction initiatives and production facilities came into place: Abengoa started to build the "largest **solar thermal facility** in South America […] [,] a 110 MW solar thermal electric plant employing tower technology and a 100 MW capacity photovoltaic plant in the Atacama Desert, the region receiving the highest solar radiation in the world. The plant […] [was] expected to prevent the release of 870,000 t of CO2eq per annum (Abengoa, 2014, p. 24). Also, the "world's largest single-axis photovoltaic plant - With an installed capacity of 206 MW" (ibid.) came under construction with the hope that the facility would "generate enough energy for 72,000 households while curbing yearly CO2eq emissions by 356,000 t" (ibid.). **[Product-Renewables-Solar]** Furthermore, in Kansas (U.S.), Abengoa "unveiled [Hugoton plant,] the first commercial plant capable of producing **bioethanol from cellulosic biomass**" (ibid.). As the "first second-generation **biofuel plant** […] [this was considered] a huge milestone in terms of innovation since the raw materials or inputs used do not compete with grain otherwise used for food. The facility […] [was] expected to generate upwards of 94 ML of bioethanol a year" (ibid.). **[Product-Renewables-Biofuel]**
2014	Also, in 2014, Abengoa built the "**world's largest biomass plant** - Worth in the region of € 315 million, and boasting an installed capacity of 215 MW of electrical power and 100 MW of thermal power, […] the facility [which runs solely on biomass] will supply electrical power to industrial clients and thermal energy to heat the city of Ghent (Belgium)" (ibid.). **[Product-Renewables-Biomass]**
2017	In 2017, Abengoa built three **thermosolar** plants in South Africa**.** "Thanks to the construction of these three plants […], Abengoa's technology supplies clean energy to more than 220,000 South African homes and prevents the atmospheric

Year	Low-carbon initiatives of Abengoa
	emission of 831,000 tonnes of CO2 equivalent per year” (Abengoa, 2017, p. 4). **[Product-Renewables-Solar]** In addition, the company was planning a plant that would “produce aviation fuels from **Solid Urban Waste (SUW)** with gasification technology in the United States” (ibid.) **[Process-Other technologies]** as well as “Waad Al-Shamal”, Saudi Arabia, “the largest hybrid solar-gas plant in the world; or the Agua Prieta solar field, […] [their] **first solar thermal plant in Mexico**, which will be integrated with a combined cycle to form the country’s first hybrid solar-gas plant” (ibid., p. 5). **[Product-Renewables-Solar]**

Abengoa – concluding analysis

Before the crisis of 2015 and 2016, there was an increase in emissions from 2009 to 2012 which Abengoa explains as a “natural maturity process of the GHG emissions management system” (Abengoa, 2012, p. 43) and which can be categorized as Process-Calculation method and be regarded as a carbon initiative. In this case, as the footprint increased due to the changes, it cannot be called a low-carbon initiative. Indeed, improvements in emissions accounting and periodic reviews on all organizational levels and larger company boundaries can lead to a higher footprint. But there are other cases where the change of calculation method can lead to a lower footprint, too.

In the years 2016 and 2017, Abengoa carried out an intense divestment plan. Abengoa didn’t mention any new sustainability-related projects in the 2016 sustainability report even though it mentioned a large number of carbon initiatives and projects for the other years as parts of Abengoa’s core business strategy. Abengoa’s *firm strategy* was charachterized by substantial divestments due to the financial crisis. During the course of this crisis, reported emissions drastically decreased as mentioned before.

It is obvious that the *model-internal factors* of firm size and capital intensity and therefore the estimated emissions also dropped due to the crisis of 2015 and 2016 that Abengoa went through. It is understandable that Abengoa’s estimated greenhouse gas emissions follow the drop of size and capital intensity as the size of a company and the capital intensity determine the estimated carbon emissions (Stüwe et al., 2023). Therefore, Abengoa showed the largest decrease of estimated emissions. Due to the large overall move of estimated and reported emissions in the same direction, Abengoa was also the company with the largest neutral and total carbon performance change.

Furthermore, it appeared as the worst carbon performance 2011 and 2016. This might be the case because of the discrepancy of estimated and reported emissions in both years. Due to rather low model-internal factors, the estimated emissions were low. The reported emissions were high in comparison. This leads to the assumption that Abengoa had an inherently high emission intensity of its business model compared to other firms in its sector. Its activities appeared very energy-intensive for a construction firm which is supported by the multiple high-energy and large-scale building project that Abengoa has carried out.

These initiatives can be categorized as product low-carbon initiatives as Abengoa sells these technologies to its customers: several of the world's largest thermal solar plants and photovoltaic plants plus hybrid solar-gas plants which all can be categorized as Product-Renewables-Solar, the first commercial plant capable of producing bioethanol from cellulosic biomass (Product-Renewables-Biofuel) and a very large biomass plant (Product-Renewables-Biomass). Even though these renewable technologies can lead to future emission reductions on the side of Abengoa's customers, the building projects cause a lot of emissions for the construction firm itself.

There is one initiative which can be categorized as process low-carbon initiative: the ISO 14001 certification, that is an environmental management system in 88,18% of the investee companies of Abengoa. It can be classified as Process-Environmental management system. It remains unclear if this system really led to carbon reductions but Sial et al. (2021) and Tang and Luo (2014) generally assume so.

Alstom – introduction

Alstom is a machinery firm with headquarters in Saint-Ouen, France (Craft 2022). It appeared as the largest decrease of reported emissions in Stuwe et al. (2023). In the following analysis I find out why Alstom showed the largest decrease of reported emissions and why it has been a notable case.

Alstom – reported emissions

Figure 6 contains Alstom carbon emissions in regards to the CDP reports 2012 and 2017[2] as there was no information regarding the amount of carbon emissions available within the online sources. Therefore, the chart of emissions only shows the emissions reported to the CDP for the years 2011 and 2016. There, one can see a drop of 81,9 % from 2011 to 2016.

*** Take in Figure 6 about here. ***

Alstom – estimated emissions

The estimated emissions are represented in Figure 7. They drop by 79,7 % because size and capital intensity also dropped.

*** Take in Figure 7 about here. ***

Alstom – size of the company

The sales figures of Alstom and therefore the variable size from 2011 until 2017 are presented in Figure 8. Here, one can see a drop of 63,3 % between 2011 and 2016.

*** Take in Figure 8 about here. ***

The property, plant and equipment figures are shown in Figure 9. They fall by 73,7 % between 2011 and 2016.

*** Take in Figure 9 about here. ***

Figure 10 contains the capital intensity figures of Alstom. They fall by 28,3%.

*** Take in Figure 10 about here. ***

Alstom - portfolio and strategy

Alstom, today, "is a company providing rail transport products and systems. It provides rail transport equipment, systems, services, and signaling for urban, suburban, regional, and mainline passenger transportation, as well as for freight transportation. The company also offers trains, such as metros, tramways, tram-trains, light rail vehicles (LRVs), suburban, regional, and high-speed trains, passenger and freight locomotives, and signaling" (Craft 2022, https://craft.co/alstom).

[2] CDP requests authors to highlight that reproduction of any part of the data by any third party is forbidden.

Several major divestments took place in 2014. Back in 2011, Alstom served another market besides “the rail transport market through its Transport Sector”: “the power generation and transmission markets through its Thermal Power, Renewable Power and Grid activities (“Energy activities”)” (Alstom, 2011, p. 9).

In this context, “on 26 April 2014, the Board of Directors of Alstom received from General Electric (GE) an offer, countersigned by Alstom on 29 April 2014, and updated by GE on 20 June 2014, to acquire its Energy activities. On June 20, 2014, the Board of Directors of the Company unanimously decided to issue a positive recommendation on the GE’s offer” (Alstom, 2015, p. 10). Furthermore, the “Auxiliary components business […] [of Alstom was sold to] Triton, a leading European investment firm […] on 29 August 2014” (ibid., p. 14).

Alstom – low-carbon initiatives

There was no information regarding low-carbon initiatives available within the online reports.

Alstom – concluding analysis

Alstom is nowadays a machinery company that mainly produces trams and trains and equipment. Before 2014, however, Alstom was operating an energy section, within “the power generation and transmission markets through its Thermal Power, Renewable Power and Grid activities” (Alstom, 2011, p. 9). In 2014, Alstom sold this part to General Electrics (GE). Furthermore, Alstom sold the “Auxiliary components business […] [to] Triton, a leading European investment firm […] on 29 August 2014” (Alstom, 2015, p. 14). These divestments lead to the described drops of size, property, plant and equipment and capital intensity of the company between 2011 and 2016. There was no information regarding carbon initiatives or the amount of carbon emissions available within the online sources. Therefore, the chart of emissions only shows the emissions reported to the CDP for the years 2011 and 2016. There, also one can see the sharp drop of emissions overtime as shown in the emission section. Due to the two major divestments it is not a surprise that Alstom was analyzed as a notable case in Stuewe et al. 2022 as the largest decrease of reported emissions.

Alstom divested a large part of its operations in 2014/2015 which explains the large decrease of size and reported emissions of the company. This larger divestment of Alstom's energy business lead to a focus on transportation in 2015: "On November 2, 2015, Alstom and General Electric completed the transaction on Alstom’s Energy businesses [...]. Further to the deal, Alstom (“the Group”) is refocused on its activities in the Transport field" (Alstom, 2016, p. 9). Furthermore, another divestment also lead to lower emissions: Alstom sold the "Auxiliary components business […] [to] Triton, a leading European investment firm […] on 29 August 2014" (Alstom, 2014, p. 14). This explains why Alstom appeared as the notable case of largest decrease of reported emissions in Stuwe et al. (2023).

BASF SE – introduction

BASF SE is a large-scale chemical company based in Ludwigshafen am Rhein, Germany, (Craft, 2023).

In Stüwe et al. (2023) BASF represents three notable cases: the highest reported emissions 2011 as well as highest estimated emissions 2011 and 2016. I analyze BASF's reports to explain why BASF is a threefold notable case.

BASF – reported emissions

Figure 11 shows the course of combined scope 1 and 2 emissions in million metric tons of CO_2 equivalents. One can see a slight downwards trend of reported emissions of -15.1% between 2011 and 2016 on a high niveau, around 22 million metric tons.

*** Take in Figure 11 about here. ***

BASF – estimated emissions

The estimated emissions, shown in Figure 12, behave in a similar manner, with a decrease of -19.2% between 2011 and 2016.

*** Take in Figure 12 about here. ***

BASF – size of the company

The estimated emissions are determined by the model-internal factors size and capital intensity. Figure 13 highlights the course of BASF's sales over the considered period. Size decreased slightly by -21.7% between 2011 and 2016 on a high niveau.

*** Take in Figure 13 about here. ***

At the same time property, plant and equipment, shown in Figure 14, increased by +47.0% between 2011 and 2016.

*** Take in Figure 14 about here. ***

Capital intensity peaked in 2016 and showed a larger increase of 87.8% between 2011 and 2016. Figure 15 represents the capital intensity figures.

*** Take in Figure 15 about here. ***

BASF – portfolio and strategy

BASF, as a chemical company, has a broad portfolio. BASF distinguishes three product categories: "In the Functional Materials & Solutions segment, […] [the firm] bundle[s] system solutions, services and innovative products for specific sectors and customers, especially the automotive, electrical, chemical and construction industries, as well as applications for household, sports and leisure. […] [The] portfolio comprises catalysts, battery materials, engineering plastics, polyurethane systems, automotive coatings, surface treatment solutions and concrete admixtures as well as construction systems like tile adhesives and decorative paints" (BASF, 2017, p. 2). "The Agricultural Solutions segment provides innovative solutions in the areas of chemical and biological crop protection, seed treatment and water management as well as for nutrient supply and plant stress" (ibid.). And "in the Oil & Gas segment, […] [they] focus on exploration and production in oil and gas-rich regions in Europe, North Africa, Russia, South America and the Middle East. Together with […] [their] Russian partner Gazprom, […] [they] are also active in the transportation of natural gas in Europe" (ibid.).

After the earth quake and tsunami disaster in Japan 2011 and Germany's changes in energy policy, BASF stated in the 2011 annual report that "sustainability [will be] more closely than ever" (BASF, 2011, p. 21) integrated into the business.

In 2014 and 2015 price fluctuations of oil and chemical products affected BASF's business as "customers were becoming increasingly cautious. They held back from ordering – in the expectation of further declines in prices for chemical products. Pressure on margins increased in the course of the year" (BASF, 2015, p. 26). In 2015, BASF divested the gas trading and storage business which let sales drop substantially (BASF, 2016). The business year of 2017 had been a success for BASF with an increase of sales. An acquisition took place in December 2016. The Chemetall business "which comprises tailor-made solutions for metals surface treatment" (BASF, 2017, p. 17) was acquired by BASF. Furthermore, BASF announced to be planning to acquire business divisions of close competitors: Solvay's polyamide business and "significant parts of

Bayer's seed and herbicide businesses" (ibid., p. 19). This is seen in line with BASF's overall strategic approach of creating "chemistry for a sustainable future […] [being] well aware of the needs of the fast-growing global population" (ibid., p. 18).

BASF - carbon initiatives

Low-carbon initiatives of BASF from 2011 to 2017 are presented in Table 3.

TABLE 3

Low-carbon initiatives of BASF

Year	**Low-carbon initiatives of BASF**
2011	In 2011, BASF sets new goals for climate change protection. It states that the aim is "to further reduce greenhouse gas emissions in […] [the] production and along the entire value-adding chain. To this end, […] [they] implemented **numerous measures** in […] [the] production in 2011" (BASF, 2011, p. 109). **[Process-structural improvement]** The report, however, does not give details about the production improvement measures.
2012	In the report of 2012, in the context of climate change protection, BASF brings up "measures such as those for the **reduction of nitrous oxide** in […] [the] production [which they have been carrying out] since as early as 1997" as well as "major projects for the efficient generation and **use of steam and electricity**" (BASF, 2012, p. 110). **[Process-structural improvement]** There, BASF describes its attempt to become more energy efficient "as a company in an energy-intensive industry" (ibid.). BASF puts emphasis on "**customers solutions that help reduce greenhouse gas emissions and improve energy efficiency**" (ibid.). In 2012, "about a third of […] [its] annual research spending […] [went] toward the development of these products and processes" (ibid.). **[Product]** Low-carbon initiatives in 2012 also aimed at decreasing "the **continuous flaring of gases** associated with crude oil production in routine operations at all oil production sites by the end of 2012 […] [by which BASF prevented] the emission of around two million metric tons of greenhouse gases per year" (ibid., p. 111) **[Process-structural improvement-gas]** as well as "the startup of particularly **energy-efficient pipelines**, […] [which

Year	Low-carbon initiatives of BASF
	led to] a reduction of 22.1%” (ibid.). **[Process-structural improvement-pipelines]**
2013	Low-carbon initiatives were the use of more energy-efficient pipelines and the more intense **use of waste heat in the transportation network** (BASF, 2013). **[Logistics-Use of waste heat]** In 2013, BASF **certified** the most energy-intensive BASF SE production plants in Ludwigshafen (BASF, 2015, p. 111). **[Process-Environmental management system]** In 2013, “the year-on-year increase in specific emissions was the result of nonoptimal capacity utilization for the **pipeline compressor** stations” (BASF, 2013, p. 112). **[Non: Process-Structural improvement-pipeline compressors]**
2014	In 2014, BASF changed the calculation method. **The company Gascade was no longer fully consolidated in the group’s financial statements**. Instead, it has been considered an associated company and was accounted for using the **equity method** (BASF, 2014). Therefore, after 2014, BASF was “no longer reporting on […] [the] goal to reduce greenhouse gas emissions in the natural gas transport business” (BASF, 2014, p. 134). **[Other-Calculation method]**
2015	In 2015, BASF introduced a “Verbund system” as an important component of its energy efficiency strategy (BASF, 2015, p. 123) which “saved around 17.6 million MWh in 2015, which corresponds to a savings of 3.5 million metric tons’ worth of carbon emissions” (ibid.). According to BASF, the firm was “able to further **optimize the resource and energy consumption** of […] [the] production in numerous projects around the world in 2015. Various process improvements led to steam and electricity savings” (ibid.). **[Process-Structural improvement]** In 2015, BASF planned to “have the energy management at our [other] sites in Germany certified in accordance with **DIN EN ISO 50001**” (ibid., p. 111). **[Process-Energy management system]**
2016	In 2016, “workshops were conducted in all regions to introduce […] [the] **energy management systems**. […] All energy efficiency measures […] [were] recorded and analyzed in a global database and made available to Group sites as best practices” (BASF, 2016, p. 122). **[Process-Energy management system]** In

Year	Low-carbon initiatives of BASF
	2016, BASF stated that over 100 measures were being pursued "to reduce energy consumption and increase competitive ability" (ibid.).
2017	In 2017, BASF used "associated **gas from test production**" for resource-efficient oil production to reduce energy demand and emissions (BASF, 2017, p. 96). **[Process-structural improvement-waste gas]** Furthermore, they "developed a mobile test production unit equipped with three micro gas turbines during the revaluation of the German oil field Suderbruch […] to use the associated gas from test production in plant operations, reducing energy demand by around 40%. This **associated gas from oil production** […] [is thought to be more] efficient and environmentally friendly […] [than] routine operations […]. The resulting lower energy demand reduces CO2 emissions by over 50%" (ibid.). **[Process-Structural improvement-gas from oil]** Also, BASF worked 2017 on their 2015 target to introduce certified energy management systems (**DIN EN ISO 50001**) at all relevant production sites, representing 90% of BASF's primary energy demand. (ibid., p. 115). **[Process-Energy management system]** BASF has "for nearly two decades […] been involved in the **U.N. Global Compact** network […] support[ing] the U.N. Sustainable Development Goals. […] BASF contributes to this with […] [its] lightweight plastics, high-performance catalysts and new battery materials" (ibid., p. 118). **[Other-memberships]** BASF set a **target** to reduce its "greenhouse gas emissions per metric ton of sales product by 40% by 2020, compared with baseline 2002" (ibid., p. 115). In 2017, BASF stated that it reduced this figure by "35.5% compared with baseline 2002 (2016: reduction of 37.2%). Since 1990, […] [the company has] been able to lower […] overall greenhouse gas emissions from BASF operations (excluding Oil & Gas) by 48.3% and even reduce specific emissions by 74.7%. (ibid.). **[Others-carbon targets]** BASF states that, in 2017, "43 sites […] [were] **certified** worldwide, representing 54.3% of […] [its] primary energy demand" (ibid.). **[Process-Energy management system]**

BASF – concluding analysis

In Stüwe et al. (2023) BASF represents three notable cases: highest reported emissions 2011 as well as highest estimated emissions 2011 and 2016. BASF promotes its products as sustainable and adapted to the "needs of the fast-growing global population" (BASF, 2017, p. 18). According to BASF, this contribution to a sustainable development is provided by "lightweight plastics, high-performance catalysts and new battery materials" (ibid.). BASF carries a membership in the U.N. Global Compact network (ibid.). Furthermore, BASF acquired parts of Bayer's seed and herbicide businesses (ibid., p. 19). The company excludes the field of oil and gas when stating its overall carbon emission reduction of 48.3% and reduction of specific emissions of 74.7% between 1990 and 2017 (ibid., p. 115).

The reported emissions of BASF show a slight downwards trend of -15.1% between 2011 and 2016 on a high niveau, which is around 22 million metric tons in 2016. The estimated emissions behave in a similar manner, with a decrease of -19.2% between 2011 and 2016 whereas size decreased but property, plant and equipment increased. As size has the largest influence on estimated emissions, it is not surprising that the estimated emissions decreased when size decreased.

BASF, at the same time, applies the ISO 50001 management system at some sites and shows many different low-carbon initiatives. They can all be characterized by process low-carbon initiatives:

There are, for example, "measures such as those for the reduction of nitrous oxide in […] [the] production [which they have been carrying out] since as early as 1997" (BASF, 2012, p. 110). These can be seen as belonging to the category Process-Structural improvement-Emission abatement technologie-nitrous oxide reduction. Furthermore, BASF saved gases from crude oil production (category Process-Structural improvement-Gas saving) as well as using particularly energy-efficient pipelines which can be considered the category Process-Structural improvement-Pipelines.

In 2013, BASF certified the production plants in Ludwigshafen with an energy management system and 2015 it was planned to certify all other sites in Germany in the future. "All energy efficiency measures […] [were] recorded and analyzed in a global database and made available to Group sites as best practices" (BASF, 2016, p. 122). I categorize this as Process-Environmental management system. Also in 2013, a Process-Structural problem at the pipeline compressors lead to higher emissions (BASF, 2013, p. 112).

In 2014, BASF changed the calculation method. The company Gascade was no longer fully consolidated in the group's financial statements. Instead, it has been considered an associated company and was accounted for using the equity method (BASF, 2014). Therefore, after 2014, BASF was "no longer reporting on […] [the] goal to reduce greenhouse gas emissions in the natural gas transport business" (BASF, 2014, p. 134). This change which can be categorized as Others-Calculation-method should have let to lower emissions ceteris paribus.

BASF is characterized by an inherently energy-intensive business model as around 50% of the group's emissions resulted from steam and electricity generation in own power plants as well as in the energy suppliers' power plants (BASF, 2013, p. 111). It becomes clear that due to this business model and the large sale volumes, BASF SE, "the world's leading chemical company" (BASF, 2011, p. 6), has the highest reported emissions of 2011 and highest estimated emissions in 2011 and 2016 and was therefore classified as a notable case of carbon performance.

It seems surprising that BASF did not have the highest reported emissions in 2016, too. In 2011 BASF had the highest reported emissions but BASF could lower their reported emissions towards 2016. In 2016 a different firm had the highest reported emissions, the Linde Group. Linde Group showed the opposite course of emissions with lower emissions in 2011 and higher emissions in 2016. Therefore, Linde deteriorated and BASF improved reported emissions, so Linde negatively overtook BASF with time and Linde showed the highest reported emissions of the sample in 2016. The course of emissions of Linde is furthermore described in the section about Linde.

Durr Group (Dürr) – introduction

Durr Group is a machinery company with headquarters in Bietigheim-Bissingen in Germany (Durr, 2022). Durr Group appeared as the firm with the largest increase of estimated emissions in Stuwe et al. 2023.

Durr Group – reported emissions

The reported carbon emissions of Durr Group can be found as Figure 16. They increased between 2011 and 2016 by 105% which means they doubled.

*** Take in Figure 16 about here. ***

Durr Group – estimated emissions

The estimated carbon emissions of Durr Group can be found in Figure 17. They increased between 2011 and 2016 by 141 %.

*** Take in Figure 17 about here. ***

Durr Group – size of the company

The revenues of the company have been increasing with time with a peak in 2015. The percentage change betweet 2011 and 2016 has been plus 86%. The revenues are represented in figure 18.

*** Take in Figure 18 about here. ***

Property, plant and equipment, in Figure 19, has increased between 2011 and 2016 by plus 172% with a sharp increase between 2013 and 2014.

*** Take in Figure 19 about here. ***

Between 2011 and 2016 capital intensity increased by plus 46 % with a peak in 2014. This is presented in Figure 20.

*** Take in Figure 20 about here. ***

Durr Group – portfolio and strategy

In 2011, Durr's major technology was the "EcoRP", a "painting robot with over 6,500 units sold in 34 countries" (Durr, 2011, p. 4), with Durr working mainly for the automotive industry (ibid., p. 9). In 2017, Durr Group offered three brands, "Dürr", "Schenk" and "Homag" (Durr, 2017, p. 2). Compared to 2011, in 2017 the company focus was on "digital transformation […]: At Dürr, we want to provide our customers with the most efficient solutions for the digital networking of their production operations" (ibid.). In October 2014, Durr Group purchased the Homag AG, the "world leader in timber processing" (Durr, 2014, p. 8) which was visible in the company figures as described before. "The HOMAG Group belongs to the Durr Group since October 2014. The worldwide leading producer of machines for timber processing is known for exclusive technology and clever product ideas" (ibid., p. 22). In March 2017, Durr divested the "ecoclean group" (Durr, 2017, p. 66).

Durr Group – low-carbon initiatives

Low-carbon initiatives of Durr Group are presented in Table 4.

TABLE 4

Low-carbon initiatives of Durr Group

Year	**Low-carbon initiatives of Durr Group**
2011	In the context of energy savings, Durr focuses on "new buildings and building modernizations […] [as well as] energy-saving construction methods. The prime example is the Dürr campus in Bietigheim-Bissingen […]. There, the sustainable construction and operating concept "Campus Energy 21" combines different processes: from **deep geothermal energy, geothermal heat exchange, combined heat and power plant and photovoltaics to concrete core activation, sensor-controlled lighting and facade insulation**. Compared to a conventional energy supply, […] [it saves] around 40% per year. […] [Two] new locations in Shanghai […] [are supposed to] also perform better than their predecessors in terms of energy" (Durr, 2011, p. 114). **[Process-renewables] [Process-structural improvement]**
2011	A central theme for the Durr Group is "Consumption-optimized products: leading in production efficiency" (ibid.) and the 2011 annual reports states: "The production processes of our customers require a high input of energy, resources and raw materials. As part of our Eco⊕Efficiency system, we work consistently to improve the **consumption efficiency** of our machines and systems. **[Process-structural improvement]** Take car painting, for example: before 2008, between 1.2 and 1.5 megawatt hours of energy were needed to paint a body. By 2010, we were able to reduce this value to around 0.8 megawatt hours through various innovative steps. We are currently building an optimized Eco⊕Paintshop for the BMW Group in Shenyang (China), which will only consume 0.5 megawatt hours per body. […] The EcoDryScrubber paint booth system is at the heart of our Eco⊕Paintshop concept. This **reduces the energy requirement** in the spray booths - and thus also the CO2 emissions - by more than 50%. […] In the long term, too, we consider improving energy efficiency to be one of the most important trends in industrial production. **[Process-structural improvement]** […] The Clean Technology Systems division,

Year	Low-carbon initiatives of Durr Group
	which was founded for this purpose, has already made a pioneering technology acquisition with the Organic Rankine Cycle process, which **generates electricity from waste heat**. We will continue to expand our range of processes in energy efficiency technology” (ibid.). **[Process-structural improvement-waste heat]** Durr also states that “compared to other industrial companies of a similar size, our activities leave a small “environmental footprint”. Emissions and waste generation as well as energy and water consumption at our sites are relatively low.
2011	This is a consequence of the low level of vertical integration that we have as an engineering group, as well as the manufacturing technologies used (Durr, 2013, p. 113). 41% of the locations are certified according to the I**SO 14001 environmental management** standard (ibid.) **[Process-environmental management]**
2013	In 2013, “the Schenck Industry and Technology Park (TIP) in Darmstadt is taking part in a climate protection project run by its energy supplier: the CO2 emissions caused by the location's district heating consumption are **offset by a reforestation program in Canada**. In the future, we will also offset emissions from our gas consumption in the project. **[Others-offsetting]** We are working on reducing our logistics traffic and the resulting emissions. The additional assembly halls in Bietigheim and Radom (Poland) make a contribution. It eliminates the **delivery traffic** to more distant halls that we had previously rented. **[Logistics-reduction of delivery traffic]** We reduce **employee travel** to internal meetings with the help of **video and audio conferencing systems**. In 2013 we equipped all computer workstations with the multimedia online communication system Microsoft Lync” (Durr, 2013, p. 128). **[Logistics-Reduction of employee travel]**
2014	In 2014, Durr Group states: “Although we have expanded our **in-house production** in recent years, the "ecological footprint" of our previous activities remains comparatively small. One reason for this is that the depth of added value is still moderate at 35%. […] The further expansion of our in-house production was decisive for this. **[Process-in house production]** In the case of CO2 emissions, the increased figure for 2014 results from a more precise **recording of fleet vehicles abroad**” (Durr, 2014, p. 124). **[Logistics-recording of fleet vehicles]**

Year	Low-carbon initiatives of Durr Group
2017	In 2017, the majority of the production cooperations were using an environmental management system in line with **ISO 14001**. 10 facilities had a certified energy management system in line with **ISO 50001** and more facilities were carrying out energy and quality audits (Durr, 2017). **[Process-environmental and energy management]** Furthermore, Durr Group stated that - in their opinion - Durr's production and acquisition of goods and services did not lead to "significant ecological impairments" (ibid., p. 49). Durr Group also explained that "when building new buildings, we pay attention to energy-saving technology. For example, we exchange old lighting systems for new **LED systems**, install **modern air conditioning units** or modernize our machinery" (ibid.). **[Process-LED]**

Durr Group – concluding analysis

Durr Group represented the largest increase of estimated emissions in Stuwe et al. 2023. The reported emissions (scope 1 and 2) increased between 2011 and 2016 by plus 105 %, the estimated carbon emissions increased by plus 141 %. Interesting is the sharp increase of emissions between 2014 and 2015 as well as the increase of revenues and PPE between 2013 and 2014. By analyzing the reports, it becomes obvious that these results stem from the purchase of the HOMAG Group in 2014. "The acquisition of the HOMAG Group is also a result of the success within our core business. Dürr is an established supplier of the automobile industry" (Durr, 2014, p. 10). This acquisition explains why the Durr Group showed the largest increase of estimated emissions in Stuwe et al. 2023 and was a notable case. However, Durr Group reported some interesting low-carbon initiatives in the fields of logistics and process-structural improvement: There is the Dürr campus in Bietigheim-Bissingen, Germany, where "the sustainable construction and operating concept "Campus Energy 21" combines different processes: from deep geothermal energy, geothermal heat exchange, combined heat and power plant and photovoltaics to concrete core activation, sensor-controlled lighting and facade insulation" (Durr, 2011, p. 114). Furthermore, Durr reduces delivery traffic by use of additional assembly halls and employee traffic by use of video and audio communication systems (Durr, 2013, p. 128). These measures have a positive effect on scope 3 emissions. I am, however, taking only scope 1 and 2 emissions into account. Durr also established environmental and energy management systems (Durr, 2017, p. 49). The low-carbon initiatives might have improved reported emissions slightly but could not offset the effect of the HOMAG Group acquisition on reported emissions. Due to a higher size and capital intensity, the estimated emissions rose by 141 % and Durr Group showed the largest increase of estimated emissions.

Givaudan – introduction

Givaudan SA is a Swiss chemical company with headquarter in Vernier, Switzerland (Craft, 2023). Givaudan is specialized in the manufacturing of flavours, fragrances, and cosmetic ingredients (ibid.). Givaudan SA showed the best carbon performance in 2016 and is therefore a notable case.

Givaudan – reported emissions

The reported emissions can be found in Figure 21. They decreased over the course of the seven years from 2011 until 2017. Between 2011 and 2016, the scope 1 and 2 emissions decreased by -14.6%. Here, I take only CO_2 emissions into account, as other emissions, i.e. NOx and SO_2, are neglectable due to the relatively small share in total emissions. In 2013, for example, the share of NOx and SO_2 was only 0.17 % and in 2014 0.4% only.

*** Take in Figure 21 about here. ***

Givaudan – estimated emissions

The estimated emissions can be seen in Figure 22. Between 2011 and 2016 they increased by plus 26.6%.

*** Take in Figure 22 about here. ***

Givaudan – size of the company

The sale figures (Figure 23) were increasing with a rise of plus 19.1 % between 2011 and 2016.

*** Take in Figure 23 about here. ***

Property, plant and equipment (Figure 24) was increasing with a rise of plus 5.6 % between 2011 and 2016.

*** Take in Figure 24 about here. ***

Capital intensity was decreasing by -11.4 % between 2011 and 2016.

*** Take in Figure 25 about here. ***

Givaudan – portfolio and strategy

Givaudan is specialized in the manufacturing of cosmetic ingredients (Craft, 2023). The “business relies on the secure supply of more than 10,000 raw materials, of which more than half originate from natural sources. So the efficient and responsible use of resources is essential, as is the assessment and careful management of our impact on the environment“ (Givaudan, 2017, p. 6). Givaudan considers itself to have a leadership role when it comes to climate change action and CDP reporting: “Givaudan’s leadership […] was recognised in 2017 by CDP, the non-profit global environmental disclosure programme. We were awarded the top score of A for reducing GHG emissions and earned an A – for outstanding water stewardship. Overall, Givaudan is among the 120 global companies participating in CDP’s climate change programme to be recognised for leading climate action” (Givaudan, 2017, p. 5).

Givaudan – low-carbon initiatives

Low-carbon initiatives of Givaudan are represented in Table 5.

TABLE 5

Low-carbon initiatives of Givaudan

Year	Low-carbon initiatives of Givaudan
2013	“At our Pedro Escobedo site in Mexico we have switched **from heavy fuel oil as primary energy source to gas**, leading to a significant reduction of CO2 and SO2 emissions. […] Using natural gas supplied by pipe instead of heavy fuel has also eliminated the indirect emissions generated by the ground transportation of the heavy fuel by 100%” (Givaudan, 2013, p. 30). **[Process-natural gas]** “Bio-filters in the manufacturing process are essential to minimise odour emissions and require a high-humidity environment, commonly achieved using steam, which in turn requires energy to heat the water. At Givaudan’s Naarden facility, in the Netherlands, the local **Green Team** converted the process **from steam to a high-pressure water system** based on developing a ‘water fog’. Moistening the air in

Year	Low-carbon initiatives of Givaudan
	this way saves energy because the need to heat water to create steam is avoided. The result is also a reduction in CO2 emissions. […] Producing steam requires 300,000m3 of natural gas per annum, so this innovation is a significant saving on energy costs and carbon emissions. **[Process-structural improvement-high pressure water]** […] Jaguaré [in Brazil] has been measuring its environmental performance since early 2000. With the introduction of our ambitious Company-wide **2020 eco-efficiency goals**, we recognised the need to develop a **clear plan of action** to address areas of inefficiency. A multi-functional team of 12 Givaudan employees, representing our Flavours and Fragrances Divisions, operations, engineering, procurement and EHS began the process by looking at the **site's consumption data**. Site Eco-Efficiency Plans (SEEP) were then created, outlining potential projects and studies regarding **process improvements**. **[Others-carbon targets]** […] At our Ashford factory in the UK, we have developed a site energy map and associated building energy displays to allow anyone to easily identify our energy and water use across the site and use this information as the basis for suggesting reduction initiatives. […] It has also provided an invaluable tool when explaining our energy use to external contacts and for **raising energy-awareness among staff** members. **[Others-staff behavior]** […] **Guidelines** enable our purchasing teams to buy greener energy, moving away from electricity produced from traditional fossil fuels, like coal and oil, to natural gas and renewable energy sources. Highlights of the programme to date include: Germany, which sources 100% of its electricity from green sources, is saving at least 1,900 tonnes of CO2 this year; the Netherlands, with 22% electricity consumption now green as compared to 2012, is saving more than 1,600 tonnes of CO2 per year; and Spain plans to use 100% green electricity by 2014 which will save a projected 2,000 tonnes of CO2 per year (Givaudan, 2013, p. 27). **[Process-Environmental management systems and guidelines]**
2014	"In 2014, the **Eco-efficiency Leadership team (EELT)** continued to encourage **local Green Teams** and **local site Eco-efficiency Management Teams** to further develop and update site plans with **additional saving initiatives** and deliver

Year	Low-carbon initiatives of Givaudan
	improvement initiatives. Plans are in place in most sites, many including two to three year agreed improvement targets. […] The target setting, documentation of improvement initiatives and regular performamce reporting by individual sites are aligned with the requirements and principles of **ISO 14001 Environmental Management System**. To date, five Givaudan manufacturing locations have been certified against the ISO 14001 standard" (Givaudan, 2014, p. 46). **[Process-Environmental management system]** "In 2014, a significant intensity based and absolute reduction of CO2 emissions has been realised. **This is the result of the many initiatives at our manufacturing sites** to reduce energy consumption […] as well as an increased use of electricity produced from renewable sources […]. The latter is particularly the case for our factory in Spain and Japan. […] The strong drop in SO2 emissions is related to the fact that the use of heavy fuel oil in a site was ceased" (ibid., p. 47). **[Process-structural improvement]** "The Green Team in the Shanghai Flavour factory has undertaken a number of initiatives to promote electricity saving. As a result, the site saw a 3% savings in electricity over a two-year period while the production output almost doubled. In addition to **awareness raising activities**, improvements were related to the systematic check of potential savings on electrical appliances and equipment as well as **VFD installation**. The **intelligent control of exhaust fan frequency and timing** also contributed. The success of these initiatives was recognised with an award in September 2014 by local authorities" (ibid., p. 43). **[Process-structural improvement-fan frequency]** "At our Sant Celoni site in Spain, the highest volume ingredient produced is florhydral. With global demand on the rise, the site was faced with doubling production in 2014. They aimed to achieve this ambitious new goal while also lessening environmental impact and increasing eco-efficiency. Manufacturing florhydral is a multi-step process that uses a combination of distillation, blending and other processes. The Green Team analysed data and identified three possible improvements that would make production more sustainable. These included: **using bulk raw materials, as opposed to purchasing 'drums'; changing the gas**

Year	Low-carbon initiatives of Givaudan
	mixing procedures to save on transport; and optimising steps in the production process. Consequently, by reverting to bulk and reducing gas requirements they managed to save 24000 KM/per year on truck transportation of drums and 54000 KM/per year on transportation. Over the course of the year Sant Celoni saved a total of 150MWH of energy while doubling production of florhydral" (ibid.). **[Logistics-changing gas mix]** "In 2014, four energy-saving **workshops** were held in Europe and in Brazil, following the first successful workshop in the US held at the end of 2013" (ibid.). **[Staff behavior]** Givaudan Indirect Material & Service Suppliers (IM&S) has agreed to buy green energy that will meet our electricity needs and reduce our carbon footprint. Electricity accounts for almost 34% of the total energy used by the manufacturing sites, but equates to 50% of our total scope 1 and scope 2 CO_2 emissions. The initiative began in 2011. Highlights of the programme in 2014 were: 100% green electricity at our site in Barcelona, Spain [and] Greener electricity at our sites in Japan and France. The CO_2 emission load per purchased kWh of electricity further reduced by 3.5% compared to 2013 while against 2009 baseline this figure is 13.9%. **Of all electricity purchased almost 33% (24% in 2013) is produced from renewable sources, while 52% is carbon free (46.5% in 2013)** (ibid.). **[Process-renewables]**
2015	Four drivers support our local Eco-efficiency Management Teams and local Green Teams in their on-going success in delivery against these targets: Most of our manufacturing sites have developed their **site eco-efficiency plan (SEEP)** setting individual eco-efficiency targets to be achieved over a period of two to three years. Motivated to achieve these targets, site teams identify **additional saving projects** or improve existing ones on an ongoing basis. Most successful Green Team eco-efficiency projects are rewarded with a dedicated **eco-efficiency Green Team award** that the Company introduced in 2014. The introduction of regular eco-efficiency performance reporting on site, regional, divisional and global level. The implementation of the 'Green Chapter' to capital expenditure project proposals as decided by the Executive Committee in 2014. The chapter has to outline eco-

Year	Low-carbon initiatives of Givaudan
	efficiency aspects, a cost/benefit analysis and a 'price on carbon' of the proposed investment. The target setting, documentation of improvement initiatives and regular performance reporting by individual sites are aligned with the requirements and **principles of the ISO 14001 Environmental Management System**. To date, **five Givaudan manufacturing locations** have been certified against the ISO 14001 standard (Givaudan, 2015, p. 44). **[Environmental management systems]**
2016	"To date, six of our manufacturing locations have been certified against the ISO 14001 standard: Cimanggis, Daman, Pedro Escobedo, Sant Celoni, Vernier and Volketswil" (Givaudan, 2016, p. 34). **[Environmental management systems]** "Energy saving workshops are conducted in order to reduce site ineciencies. Eight workshops conducted so far in 2016 across both business divisions generated average energy savings of 5 – 10% per site" (ibid.). "**Conversion from LPG to natural gas**, Cuernavaca Mexico [:] Significant reductions in CO2 emissions have been achieved by the site by moving from **LPG** to a natural gas supply for its steam boilers and spray dryers. Emissions were cut by 28% during 2016 compared to 2015 and 31% compared to 2009" (ibid., p. 38). **[Process-structural improvements-gas conversion]**
2017	"Among the **winners [of an internal competition of the Green Teams**] was the Dubai Green Team, which put together a programme of events to boost employee health, happiness and well-being – an important element of our Company values" (Givaudan, 2017, p. 5). **[Other-behavioral change and managerial incentives]** "Givaudan is committed to an ambitious climate action agenda; we are determined to play our part in the global effort to limit the average rise in temperature to **less than 2°C** compared to the preindustrial level. Givaudan has set greenhouse gas (GHG) emission targets that have been approved by the **Science Based Targets initiative**, as have many of our largest customers" (ibid., p. 7) **[Others-carbon targets]** "A key element of our strategy for reducing Scope 1 and 2 emissions is the RE100 initiative to convert our entire electricity supply to fully **renewable sources** by 2025. Alongside this, we are leading significant energy consumption reduction

Year	Low-carbon initiatives of Givaudan
	projects across our operations and making improvements through the investment and effort we put into our **energy saving workshops** and the site eco-ecciency plans. Overall **employee awareness** also helps to deliver gains in this area. (ibid., p. 49) **[Others-carbon targets] and [Others-Behavioral change and managerial incentives]**

Givaudan – concluding analysis

As part of the cosmetics industry with a flavour and fragrance division (Givaudan, 2013), it is likely that Givaudan generates high revenues with relatively little throughput of natural resources. Furthermore, it seems like the environmental initiatives which are anchored within the company are structured in a thorough way. The so-called Eco-efficiency Leadership team (EELT) encourages local Green Teams and local site Eco-efficiency Management Teams to develop and update site plans with low-carbon initiatives and other environmental initiatives (Givaudan, 2014). Manufacturing sites are characterized by Givaudan's own management system which allow the sites to have developed their "site eco-efficiency plan (SEEP) setting individual eco-efficiency targets to be achieved over a period of two to three years" (Givaudan, 2015, p. 44). Building upon that, the site teams, i.e. the Green Teams, identify additional environmental initiatives or improve the SEEP. Successful Green Team projects are rewarded with the Green Team award since 2014. Eco-efficiency performance reporting takes place on site, regional, divisional and global level (Givaudan, 2015). Green Teams started initiatives in the fields of processes and logistics (Givaudan, 2014, p. 46) and energy-saving workshops were organized (ibid.). Some of the manufacturing sites have successfully build up an ISO 14001 environmental management system upon Givaudan's system (Givaudan, 2014).

Furthermore, there are guidelines that enable Givaudan's purchasing teams "to buy greener energy, moving away from electricity produced from traditional fossil fuels, like coal and oil, to natural gas and renewable energy sources" (Givaudan, 2013, p. 27). All these aspects could explain why Givaudan appeared as the best carbon performer of 2016.

Hochtief – introduction

Hochtief is a German construction and engineering firm with headquarter in Essen, Germany (Craft, 2023). Hochtief is a notable case because it showed the largest CCP-effective deterioration of the sample of 92 firm observations.

Hochtief – reported emissions

The reported emissions of Hochtief are presented in Figure 26. Between 2011 and 2016 they increased by 109 %. The data for the year 2012 was not available.

*** Take in Figure 26 about here. ***

Hochtief – estimated emissions

The estimated emissions of Hochtief, shown in Figure 27, declined by - 40.6 % between 2011 and 2016. They are presented in figure KK4.

*** Take in Figure 27 about here. ***

Hochtief – size of the company

Size of the company (in sales) decreased by – 14.5 %. This is depicted in Figure 28.

*** Take in Figure 28 about here. ***

PPE decreased by - 47.3 % and capital intensity by - 38.4 %. These developments are shown in figure 29 and 30.

*** Take in Figure 29 about here. ***

*** Take in Figure 30 about here. ***

Hochtief – portfolio and strategy

In the annual report of 2011, Hochtief is presented as "one of the leading international providers of construction-related services […] [that] deliver[s] integrated services for infrastructure projects, real estate, and facilities" (Hochtief, 2011, p. 5).

With "a wealth of new contracts and project successes all over the globe, […] [Hochtief has] further underpinned […] [its] commitment to developing HOCHTIEF into the world's leading construction group driven by sustained profitable growth" (Hochtief, 2015, p. 9).

In 2016, Hochtief's operations were characterized by two acquisitions: Hochtief has enhanced its "growth prospects via the acquisitions by [the Hochtief Group company] CIMIC of diversified services company UGL and mineral processing business Sedgman" (Hochtief, 2016, p. 9). Hochtief (2016, p. 10) describes that "these companies strengthen […] [its] activities in the services industry". At the beginning of 2016, CIMIC acquired "all the shares in Sedgman, a global minerals processing specialist. With operations in Australia, Asia, Africa, and North and South America, Sedgman [is thought to] bolster […] CIMIC's position in the mining services business" (Hochtief, 2016, p. 10). In October 2016, CIMIC then acquired a majority stake of the Australian-listed UGL, "a leading provider of end-to-end outsourced engineering, asset management, and maintenance services […] [which] serves the segments of rail, transportation and technology systems, energy, resources, water, and defense" (ibid.). Furthermore, Hochtief "improved data collection in 2016", "for greater transparency in reporting on […] [its] progress" (Hochtief, 2016, p. 11).

Hochtief – low-carbon initiatives

The low-carbon initiatives of Hochtief are presented in Table 6.

TABLE 6

Low-carbon initiatives of Hochtief

Year	Low-carbon initiatives of Hochtief
2011	"The buildings we construct in line with sustainability principles stand out for their low energy use. Our energy management specialists develop smart solutions for energy-efficient property and facility operation. We also invest in stepping up the use of renewable energies. Our Group implements **numerous energy conservation and efficiency measures in-house**. **[Process-structural improvements]** And our active climate protection policies have also been recognized outside the company: HOCHTIEF has once again been listed in the **German Carbon Disclosure Leadership Index**" (Hochtief, 2011, p. 59). **[Other-Memberships and awards]** "HOCHTIEF Solutions' **Energy Management business unit saved its clients** in excess of 115,000 metric tons of carbon emissions" (ibid.). **[Product-energy management]** In January 2011, Hochtief started to built a "**geothermal power plant** in the Bavarian community of Dürrnhaar" and "financing was also secured

Year	Low-carbon initiatives of Hochtief
	for the second power plant in Kirchstockach" (Hochtief, 2011, p. 59). **[Product-renewables]**
2012	"All over the world, we construct sustainable buildings noted for their electricity and heat conservation. We contribute to the energy-efficient operation of properties and facilities with our **sustainable facility management services**. As an energy contractor, we conserved 118,000 metric tons of CO2 emissions for our clients in Germany in 2012" (Hochtief, 2012, p. 51) **[Product-energy management]** "An example of these technologies is a **combined heat and power station** that supplies electricity for production" (ibid.) **[Product-sale of innovations]** "In late summer, for instance, we began pile-driving the foundations for the Global Tech I **offshore wind farm** on the North Sea, where 80 wind turbines will be in-stalled. After completion in late 2013, they will be capable of supplying 445,000 homes with environmentally friendly electricity. In addition, we are developing modern pumped storage power plants—planning for the first project in Lower Saxony began in 2012—and researching innovative methods for the **interim storage** of energy on the ocean floor" (ibid.). **[Product-sale of innovations]**
2013	"In the reporting year, HOCHTIEF was again able to chalk up numerous **green building successes**" (Hochtief, 2013, p. 48). **[Product-sale of innovations]** "In the year under review, the proportion of projects with environmental management certification (**ISO 14001**; EMAS/SCC) thus stood at 77.7% in the HOCHTIEF Group" (ibid., p. 49). **[Process-environmental management]**
2014	"In January 2014, at the "Cross City Tunnel" project in Sydney and the "Airport Link" project in Brisbane, Leighton held tunnel energy efficiency work-shops to determine how much energy and greenhouse gas emissions can be saved through **modern ventilation systems**" (Hochtief, 2014, p. 153). **[Product-energy innovations]** "In 2014, Turner analyzed its employees' workplace situation for the fourth year in a row with the **Green Zone program**. Out of 305 offices and construction sites, 159 were identified and certified as Green Zones. In the prior year, it was 146 offices. Improvements targeted by the program include the environmental life cycle

Year	Low-carbon initiatives of Hochtief
	assessment and the working environment. To this end, **employees answer questionnaires** on aspects in five categories covering comfort and environmental quality, recycling and waste disposal, water efficiency, energy and indoor air quality as well as innovation and design" (ibid., p. 154). **[Process-environmental management]**
2015	"The percentage of certified environmental management systems (**ISO 14001**) in the HOCHTIEF Group stood at 68.14% in 2015 (2014: 81.8%). This percentage was down on previous years due to the transformation processes at CIMIC" (Hochtief, 2015, p. 148). **[Process-environmental management]**
2016	"In 2016, we organized the Group's first HOCHTIEF **Energy Award** to further **raise awareness** of the issue among employees. The best ideas and projects submitted, such as the innovation project launched in 2016 to use **LED lighting** on construction sites, are to be turned into measures implemented throughout the Group" **[Other-staff behavior] [Process-structural improvement-LED]** (Hochtief, 2016, p. 150).
2017	"As building is one of the most energy- and emissions-intensive activities, HOCHTIEF believes that it bears a particular responsibility" (Hochtief, 2017, p. 143). "Within our **Innovation Award**, a competition we run throughout the Group, we have also defined an Energy and Environmental Protection category with a view to discovering innovative solutions and forward-looking approaches to environmental and climate-related issues. The awards have shown that enhancements to existing processes always go hand in hand with improvements in safety and sustainability. **[Other-behavioural change and managerial incentives]** **LED lighting** is being used more and more in construction projects, too. Besides the fact that the lights save energy when in operation, their longer life is a major plus point that has a positive impact on costs. HOCHTIEF's major office locations in Germany and selected CIMIC locations have been using green power since as far back as 2010" (ibid., p. 145). **[Process-structural improvement-LED]**

Year	Low-carbon initiatives of Hochtief
	"We aim to further expand our portfolio of sustainable projects in the long term. Capable employees trained to supervise the **certification process** enable us to achieve this aim. A total of 196 **accredited auditors** were employed across the HOCHTIEF Group in 2017" (ibid., p. 146). **[Process-environmental management]**

Hochtief – concluding analysis

Hochtief has enhanced its "growth prospects via the acquisitions by CIMIC of diversified services company UGL and mineral processing business Sedgman" (Hochtief, 2016, p. 9). UGL is a provider of engineering, asset management, and maintenance services (Hochtief, 2016, p. 10). It operates within the segments of rail, transportation and technology systems, energy, resources, water, and defense. (ibid.) Sedgman is a global minerals processing company operating in the mining services business (ibid.). I conjecture that the acquisition increased the inherent emission intensity of Hochtief's business model. Furthermore, Hochtief "further improved data collection in 2016" (Hochtief, 2016, p. 11) – this may indicate that further emissions were included in 2016 that had been omitted in 2011. These aspects explain why Hochtief has appeared as the notable case of the largest CCP-effective deterioration.

Interserve plc – introduction

Interserve plc is a construction and engineering firm (Stüwe et al., 2023) with headquarter in Ruscombe, Great Britain (Craft, 2023).

It showed the largest increase of reported emissions and was therefore a notable case in Stüwe et al. (2023).

Interserve plc – reported emissions

The 2013 report states: "For 2013 our total greenhouse gas emissions were 237,419 tonnes CO2e. This includes the emissions from our international subsidiaries and associates and is the baseline figure from which our SustainAbilities targets will be monitored. The figure can be broken down as 61 per cent Scope 1* (143,825 tonnes), 18 per cent Scope 2* (42,048 tonnes) and 21 per cent Scope 3* (51,546 tonnes)" (Interserve, 2013, p. 39). Furthermore, it sais: "We report using a financial control approach to define our organisational boundary. A range of approaches can be taken to determine the boundaries of an organisation for the purposes of GHG reporting including 'financial control', 'operational control' or 'equity share'. The methodology used to calculate our emissions is based upon the "Environmental Reporting Guidelines: including mandatory greenhouse gas emissions reporting guidance" (June 2013) issued by DEFRA, which make it clear that, in most cases, whether an operation is controlled by the organisation or not does not vary based on whether the financial control or operational control approach is used" (ibid., p. 63).

Scope 1 emissions rose from 29,793.73 in 2011 (CDP, 2012) to 166,235 in 2016 (CDP, 2017c) and scope 2 emissions from 6,640.54 (CDP, 2012) to 44,811 (CDP, 2017c) . That makes the corporate carbon footprint (scope 1 and 2 emissions) rise from 36,434.27 to 211,046. This is a steep rise of emissions of 159 %. It is interesting that Interserve reported those figures to CDP but didn't make them public in their annual reports. Instead, they showed different, much lower figures of 94,351 and 76,072 in their 2016 and 2017 report.

The reported emissions of Interserve plc are presented in Figure 31.

*** Take in Figure 31 about here. ***

Interserve plc – estimated emissions

The estimated emissions, presented in Figure 32, rose by 71% due to increases in size and PPE.

*** Take in Figure 32 about here. ***

Interserve plc – size of the company

The revenues increased by 47 % from 2011 to 2016. The depiction is presented in figure 33.

*** Take in Figure 33 about here. ***

Figure 34 and 35 show the property, plant and equipment and the capital intensity figures. PPE rose by 79 % from 2011 until 2016, capital intensity by 22 %.

*** Take in Figure 34 about here. ***

*** Take in Figure 35 about here. ***

Interserve plc – portfolio and strategy

"Interserve is [considered to be] one of the world's foremost support services, construction and equipment services companies. […] [It] offer[s] advice, design, construction, equipment, facilities management and citizen services" (Interserve, 2017, p. 2). The 2011 annual report offers a statement regarding the environmental strategy of Interserve plc: "In addition to the moral obligation to safeguard the environment, there are clear business advantages in taking a lead on environmental issues. It means we are better placed to help our customers comply with legislation and prepare for a changing climate, and especially it enables us to reduce our customers' costs and their impact on the environment. From cutting down waste and water usage to better use of raw materials and fewer emissions, we keep our environmental impact, and those of our clients, to a minimum" (Interserve, 2011, p. 34). In 2012, Interserve listed its carbon goals as to "reduce carbon emissions from energy used at UK fixed site locations (tonnes CO2e per £million UK revenue) by 2.5% per annum 3.25 tonnes/£m 3.32 tonnes/£m 3.24 tonnes/£m" and to "reduce carbon emissions from fuel used in UK fleet and cars (tonnes CO2e per £million UK revenue) by 2.5% per annum" (Interserve, 2012, p. 35).

The overall target in 2013 was to "cut CO2e emissions by 30% by 2016" (Interserve, 2013, p. 23). Interserve was engaged in an "award-winning defence partnership" at the military site of Corsham, UK, where Interserve fulfilled services for the military (ibid., p. 31).

Interserve plc – low-carbon initiatives

For Interserve, I found only a few carbon initiatives. Therefore, they are presented here in text form and not within a table.

In 2013, Interserve plc proclaimed "notable successes, including reducing the carbon emissions of our Qatar business by 30 per cent, and rolling out a range of **solar powered, water and waste-neutral ambulance facilities in Dubai**" (ibid.). **[Product-sale of innovations]** Furthermore, the annual report of 2013 explains the "**SustainAbilities programme**" with its "focus on procurement, environmental and ethical aspects to supplier **audits**, helping suppliers improve emissions performance through manufacturing improvements and involvement in the 'Surplus Network', which recycles construction waste" (ibid., p. 33). **[Process-Environmental management]**

The "ability to tackle energy efficiency of offices and schools was recognised in the 2013 **Construction News Awards [Others-awards]** for our innovative use of **Passivhaus building**

techniques [Product-Sales of innovations] to create the most efficient building envelope for thermal performance and air-tightness. This was showcased in our Richmond Hill Primary School project which was completed on behalf of Leeds City Council and uses 80 per cent less energy than a conventionally-built, equivalent-sized facility with 60 per cent lower carbon emissions" (ibid., p. 39).

Interserve plc – concluding analysis

Interserve published different figures in their annual reports and in the CDP reports. For the year 2016 the figures of the annual report were combined with the information that the increase between 2015 and 2016 "predominantly relates to the consumption of 6 million litres of gas oil/diesel associated with specific contracts undertaken by The Oman Construction Company LLC and Adyard Abu Dhabi LLC" (Interserve, 2017, p. 105).

While Interserve used the financial control approach in its annual report of 2017, within the CDP report of 2017 it used the operational control approach. In this context, Interserve (ibid., p. 104) stated: "We report using the financial control approach to define our organisational boundary. On this basis, we are including emissions associated with our owned and controlled businesses but not the emissions from our associate companies. GHG emissions from our leased vehicles when used on company business are reported, in addition to emissions associated with our construction sites. This has not been the case in previous years; hence we have retrospectively calculated GHG emissions arising for past years. We have not included data from our Justice division owing to a reliance on estimated data for leased buildings".

The WRI (2004, p. 18) explains that "under the operational control approach, a company accounts for 100% of emissions from operations over which it or one of its subsidiaries has operational control".

Although size increased substantially by 58,9% between 2011 and 2016 and capital intensity increased slightly by 12,8% between 2011 and 2016 (leading to a corresponding increase of estimated and thus, c.p., reported emissions), reported emissions also rose due to a discrepancy of values due to a difference between financial control (CDP 2012) and operational control (CDP, 2017c). "On this basis, we are including emissions associated with our owned and controlled businesses but not the emissions from our associate companies" (Interserve, 2017, p. 104). In the case of Interserve plc, the difference between financial and operational control boundaries determined the notable case of the largest increase of reported emissions.

Koninklijke DSM – introduction

Koninklijke DSM, called DSM, is a chemical company situated in Heerlen, the Netherlands (DSM, 2023b). In Stüwe et al. (2023) it showed the largest CCP-effective improvement.

Koninklijke DSM – reported emissions

The scope 1 and 2 emissions of Koninklijke DSM can be found in Figure 36. They dropped sharply by -68.3 % between 2011 and 2016.

*** Take in Figure 36 about here. ***

Koninklijke DSM – estimated emissions

The estimated emissions are presented in Figure 37. They remained relatively stable and dropped only by 6.3 %.

*** Take in Figure 37 about here. ***

Koninklijke DSM – size of the company

Size of the company, property, plant and equipment as well as capital intensity of Koninklijke DSM are presented in Figures 38, 39 and 40. Size of the company decreased by -12.5 %, PPE by -2.3 % and capital intensity increased by 11.6 %, between 2011 and 2016.

*** Take in Figure 38 about here. ***

*** Take in Figure 39 about here. ***

*** Take in Figure 40 about here. ***

Koninklijke DSM – portfolio and strategy

As a chemical company, the operations and products of Koninklijke DSM are divers. Products are "food and dietary supplements, personal care, feed, pharmaceuticals, medical devices, automotive, paints, electrical and electronics, life protection, alternative energy and bio-based materials" (Koninklijke DSM, 2011, p. 2).

The company describes its “purpose […] [as] to create brighter lives for people today and generations to come” (Koninklijke DSM, 2017, p. 5). Furthermore, “competences in health, nutrition and materials to create solutions that nourish, protect and improve performance” (ibid.) are described. Its “strategy centers on our continuing evolution towards being a health, nutrition and bioscience leader” (DSM, 2023a).

The operations are grouped into four clusters: Nutrition, Pharma, both in the segment Life Science as well as Performance Materials and Polymer Intermediates, both in the segment Materials Science (Koninklijke DSM, 2011, p. 6). “The Polymer Intermediates cluster comprises DSM Fibre Intermediates, the global market and technology leader in caprolactam and the leading acrylonitrile supplier in Europe” (Koninklijke DSM, 2014, p. 12). In 2014, Koninklijke DSM divested a part of its Polymer Intermediate cluster (Koninklijke DSM, 2015, p. 10).

Koninklijke DSM – low-carbon initiatives

The low-carbon initiatives can be found in Table 7.

TABLE 7

Low-carbon initiatives of Koninklijke DSM

Year	**Low-carbon initiatives of Koninklijke DSM**
2012	“DSM’s greenhouse-gas emissions decreased from 4.6 million tons in 2011 to 4.2 million tons in 2012. A **structural improvement** was realized at DFI Nanjing, where an **N2O abatement system** was taken into operation in September 2012. **[Processs-structural improvement]** A significant reduction resulted from lower production volumes at DFI Augusta, and the fact that planet data for DSP are only **consolidated for 50 percent** as of January 2012, compared to 100 percent in previous years. **[Calculation method]** Smaller reductions at several other sites and the **closure** of DSP Zhangjiakou are offset by the contribution of three new reporting sites” (DNP Kingstree, DSP Yushu, DFS Zhongken). (Koninklijke DSM, 2012, p. 65). **[Calculation method]**
2013	Most changes reflect the variations in energy consumption described previously, but the relative increase is significantly less than the increase in energy consumption. This is caused by the fact that greenhouse-gas emissions at DSM Fibre Intermediates in Nanjing (China) decreased by 0.1 million tons, even though the production volume

Year	Low-carbon initiatives of Koninklijke DSM
	and energy consumption of the site increased. This was the result of the **new N2O-abatement system** that was operational through 2013" (Koninklijke DSM, 2013, p. 63). **[Process-structural improvement]**
2014	"In 2014, DSM emitted a total of 4.2 million tons of CO2 equivalents, which is a reduction of two percent compared to its emissions in 2008 (the total reduction target is 25 percent). The main change to DSM's performance in 2013 was related to the deconsolidation of DPP. However, this reduction was offset by mechanical issues in the **N2O abatement system** at DSM Fibre Intermediates in Nanjing (China), which caused an increase in N2O emissions. Other changes were the result of developments in energy consumption. (Koninklijke DSM, 2014, p. 54). **[Process-structural improvement]**
2015	"We are pleased to report that we made further progress in our efforts to reduce the company's environmental footprint, among other things by **improving our energy efficiency and greenhouse-gas efficiency** by around 20%, as well as by reducing our absolute greenhouse-gas emissions (down by 75% versus 2008, with a big impact from the **(partial) divestment** of Polymer Intermediates" (Koninklijke DSM, 2015, p. 10). **[Divestment]** "In 2015, DSM emitted a total of 1.1 million tons of CO2 equivalents, which is a reduction of 75% compared to its emissions in 2008 (the total reduction target was 25% in 2020), which is almost fully attributable to the (partial) divestment of DSM Fibre Intermediates" (ibid., p. 51).
2016	"In 2016, DSM further improved its GHG reporting by implementing the **latest GHG Protocol scope 2 guidance** (2015), updating all of its used emission factors and including all GHG emissions related to electricity and steam generated on-site that is exported to third parties. These improvements in the GHG reporting methodology contributed to an overall increase in our reported emissions" (Koninklijke DSM, 2016, p. 50). **[Calculation method]** "In 2016, DSM emitted a total of 1.5 million tons of CO2eq (location-based), which is an increase of 0.4 million tons compared to 2015. The increase is mainly caused by the inclusion of **recent acquisitions** in DSM's environmental reporting (0.2 million tons CO2eq) **[Mergers & Acquisitions]**, the inclusion of emissions related

Year	Low-carbon initiatives of Koninklijke DSM
	to electricity and steam generated on-site that is exported to third parties (0.1 million tons CO2eq) **[Calculation method]** and the improvements made to the reporting mentioned above. […] A new **high efficiency separation technology** at DSM Nutritional Products in Dalry (UK) combined with higher production volumes, especially of products with a lower specific energy usage, contributed significantly to this improvement. **[Structural improvement]** Additional significant contributions came from our site in Grenzach (Germany), which had a higher utilization rate of its combined on-site **heat and power plant**. (ibid., p. 51) **[Process-renewables-heat and power plant]** Koninklijke DSM has introduced an **internal carbon price** of € 50/t CO2eq "to help guide investment decisions toward low fossil-carbon choices" (ibid., p. 10). **[Other-Staff behaviour & managerial incentives-internal carbon price]**
2017	"Most of the efficiency improvement results are due to a **greater use of electricity from renewable sources** as well as the success of our energy efficiency program. **[Process-renewables]** Changes in GHG **calculation methodologies** can positively or negatively influence the reported performance. In 2017, part of the **improvement** can be explained by better insights into how to determine certain contributions to our GHG emissions" (Koninklijke DSM, 2017, p. 48). **[Calculation method]**

Koninklijke DSM – concluding analysis

In Stüwe et al. (2023) Koninklijke DSM showed the largest CCP-effective improvement. Koninklijke DSM's strategy was characterized by increased utilization of renewable energies, bundled with a divestment of emission-intensive business: "We [...] made further progress in our efforts [...] [in] improving our energy efficiency and greenhouse-gas efficiency by around 20%, as well as by reducing our absolute greenhouse-gas emissions (down by 75% versus 2008, with a big impact from the (partial) divestment of Polymer Intermediates)" (Koninklijke DSM, 2015, p. 10). Furthermore, the use of renewable energies contributed to the situation (ibid., p. 9) as well as "a structural improvement [...] [of] an N2O abatement system" (Koninklijke DSM, 2012, p. 65). Due to the divestment and the structural improvements, the scope 1 and 2 emissions decreased by 68.3 % from 2011 to 2016. As size of the company decreased by only -12.5 %, PPE by -2.3 % and capital intensity rose by 11.6 %, the estimated emissions remained relatively stable and decreased by 6.3%. With a high decrease of reported emissions and stable estimated emissions, the company achieved the largest CCP-effective improvement although, in 2016, there were “improvements in the GHG reporting methodology [that] contributed to an overall increase in [...] reported emissions” (Koninklijke DSM, 2016, p. 50).

Linde – introduction

Linde Group is an industrial gas and engineering company (Linde, 2021) with headquarter in Guildford, United Kingdom (Craft, 2023), and revenues of 17,113 Euro million in 2017 (Linde, 2017b, p. 3). The firm showed the highest reported emissions of 2016 in the analysis of Stüwe et al. (2023). The firm figures are divided into Linde AG and the Linde Group figures.

Linde – reported emissions

The Linde group scope 1 and 2 emissions can be found in Figure 41.

*** Take in Figure 41 about here. ***

The reported emissions rose by 62.3 % between 2011 and 2016. The emissions of the year 2012 were not available, as the reports for that year were not available. Emissions for 2015 were available in the 2016 report (Linde, 2016, p. 87). In the research of Stüwe et al. (2023), Linde showed the highest reported emissions of 2016.

It seems surprising that the other very large firm of the samply, BASF, did not have the highest reported emissions in 2016. In 2011 BASF had the highest reported emissions but BASF could lower their reported emissions towards 2016. Therefore, in 2016, Linde had the highest reported emissions.

Linde – estimated emissions

The estimated emissions are represented in figure 42. The estimated emissions rose by 32.9 % between 2011 and 2016.

*** Take in Figure 42 about here. ***

Linde – size of the company

The following contains the size in sales of Linde (Figure 43), tangible assets of Linde (Figure 44) and capital intensity of Linde (Figure 45). All values rose between 2011 and 2016, group sales by

22.9 %, tangible assets by 41.3 % and capital intensity by 14.9 %. As property, plant and equipment was not available, Stüwe et al. (2023) used tangible assets.

*** Take in Figure 43 about here. ***

*** Take in Figure 44 about here. ***

*** Take in Figure 45 about here. ***

Linde – portfolio and strategy

Linde is a multinational chemical company specialized in gas products. It comprises three divisions: "Gases and Engineering (the two core divisions) and Gist (logistics services)" (Linde, 2011, p. 2).

Within its gases division, "the company offers a wide range of compressed and liquefied gases as well as chemicals, and […] [can be considered a] partner of choice across a huge variety of industries" (Linde, 2017b, p. 4). Furthermore, "Linde's Engineering Division is [considered to be] successful throughout the world, with its focus on promising market segments such as olefin, natural gas, air separation, hydrogen and synthesis gas plants" (ibid.).

One activitiy is the liquefaction and capturing of CO_2: "Europe's largest natural gas liquefaction facility is located off the coast of Norway, near Hammerfest. Linde engineers were selected to build the plant, as well as to capture and compress the CO_2 sequestered from the natural gas. Instead of being left to escape into the atmosphere, the CO_2 can then be fed back into the gas field. Around half of the CO_2 contained in the natural gas – approximately 700,000 tonnes a year – is now […] piped 2.6 kilometres below the ocean floor" (Linde, 2011, p. 7). Linde has "developed various processes to reduce greenhouse gas emissions, capture and store carbon, and recycle CO_2 that would otherwise be released into the atmosphere" (ibid.). Even though the processes are described in detail on Lindes Website (Linde, 2023), it remains unclear how energy-intensity the processes themselves are and how many emissions they cause which Linde has to account for.

Lindes products are used in the "energy sector, steel production, chemical processing, environmental protection and welding, as well as in food processing, glass production and electronics. The company is also investing in the expansion of its fast-growing Healthcare business (medical gases), and is a […] global player in the development of […] hydrogen technologies. […]

[Other market segments include] "olefin, natural gas, air separation, hydrogen and synthesis gas plants" (Linde, 2011, p. 2). In its Group Corporate Responsibility report of 2011, Linde (ibid.) states: "In contrast to virtually all competitors, the company can rely on its own extensive process engineering know-how in the planning, project development and construction of turnkey industrial plants. Linde plants are used in a wide variety of fields: in the petrochemical and chemical industries, in refineries and fertiliser plants, to recover air gases, to produce hydrogen and synthesis gases, to treat natural gas and in the pharmaceutical industry".

In the 2011 sustainability report, Linde describes its general approach to sustainability: Linde's "sustainability management is driven by two strategic goals – to reduce risks and maximise opportunities. This applies both within the company and in our dealings with stakeholders" (Linde, 2011, p. 8). "The Corporate Responsibility Council is the central decision-making authority for Linde's sustainability strategy" (ibid.) According to Linde "the transition to regenerative energy sources and zero-emissions mobility calls for truly innovative carbon management solutions." (ibid., p. 7).

Linde – low-carbon initiatives

Lindes' low-carbon initiatives can be found in Table 8.

TABLE 8

Low-carbon initiatives of Linde

Year	Low-carbon initiatives of Linde
2011	In the sustainability report of 2011, Linde describes how it recycles CO2: "Projects involve feeding **CO_2 to algae**, for example. We have joined forces with algae specialists to develop a range of technologies that provide these cell factories with an optimum supply of CO_2. Special algae cultures use CO_2 to produce ethanol – a climate-neutral fuel for the vehicles of tomorrow" (Linde, 2011, p. 4). Also in greenhouses, **recycled CO_2** is used for "plant growth: Each summer, 350,000 tonnes of carbon dioxide are pumped from an oil refinery near Rotterdam into hundreds of greenhouses in the Netherlands. The amount of **CO_2 recycled [Product-sale of innovations-recycled CO_2]** in this project corresponds to the annual emissions of a large Western European city" (ibid., p. 5).

Year	Low-carbon initiatives of Linde
2017	In the 2017 sustainability report, carbon capture and utilization is further described: "In the Al Jubail industrial complex on the Persian Gulf, we constructed the largest **CO_2 purification and liquefaction** plant in the world for the petrochemical group Jubail United Petrochemical Company. Since February 2017, this plant has been operating at full capacity, demonstrating that the large-scale deployment of **carbon capture and utilisation (CCU)** not only makes ecological sense but is also attractive from an economic perspective. The CCU plant separates CO2 before it can escape into the atmosphere and purifies it, so that it can be used as an industrial raw material in the production of methanol and urea. The recycled CO2 comes from two ethylene factories nearby, where it is a by-product of the oxidation of ethylene and oxygen. The plant can also produce 200 tonnes of **liquefied food-quality CO_2** per day, which is transported to food and drink manufacturers. The use of this technology means that around 500,000 fewer tonnes of greenhouse gases are escaping into the air every year" (Linde, 2017a, p. 4). **[Product-CO_2 capture and utilisation]** Furthermore, Linde describes its "**target** of avoiding a total of 6 million tonnes of CO2 emissions from hydrogen and synthesis gas plants (HyCO plants) and air separation plants around the world by 2020" (ibid., p. 6). **[Other-Carbon target]**
2017	In this context, Linde points to efficiency measures in an "**air separation** plant in Ningbo, China, in 2017. The entire plant was reconditioned in order to achieve a more efficient use of energy. Filters and pipes in the sea water cooling system are being cleaned and serviced on a regular basis. **Steam compressors and flow meters** have also been better adapted to the specific needs of the plant, not only optimising its performance, but also reducing its energy requirement. Thanks to these efficiency measures, the whole plant now needs around 8,000 fewer megawatt hours of electricity per year. This has resulted in cost savings of EUR 600,000 for […] [Linde] as the operator of the plant and around 10,000 fewer tonnes of CO2 emissions per year. (ibid.) **[Process-structural improvements-steam compressors and flow meters]**

Linde – concluding analysis

Linde's business model is based on technologies like gas recycling and capturing and establishment of such plants for customers. Even though Linde's technologies may contribute to carbon capturing and storage, they release emissions, too. Linde is a notable case as it showed the highest reported emissions in 2016. Those were 25.8 million t CO_2 equivalents for scope 1 and 2 emissions (Linde, 2017b, p. 223).

For Linde, the CO2 emissions (scope 1 and 2) have been increasing following the trend of the sales/revenues. Linde's operations are based on an inherently high-emission business model: "In contrast to virtually all our competitors, we can rely on our own extensive process engineering know-how in the planning, project development and construction of turnkey industrial plants" (Linde, 2017a, p. 12). Moreover, a change of calculation method in 2014 lead to higher scope 1 emissions: "In 2014, Linde has refined the determination method of the indicator for these GHGs to include additional emitters and emission sources" (ibid., p. 58).

Linde represents its technologies as means of "balancing rising demand for energy with climate mitigation pressures" (Linde, 2023). At the same time, its own processes cause high amounts of emissions. With its gas products, it has become a notable case of the highest reported emissions in the sample of Stüwe et al. (2023) for 2016.

Outotec – introduction

Outotec oyj is a construction and engineering firm (Stüwe et al., 2023) with headquarter now in Helsinki, Finland (Metso Outotec, 2021b). "Metso Outotec was created through the combination of Metso Minerals and Outotec on June 30, 2020 […] [described as] a frontrunner in sustainable technologies, end-to-end solutions and services for the aggregates, minerals processing and metals refining industries globally […] [,] ranked 8th on the 2021 Global 100 list of the world's most sustainable companies" (Metso Outotec, 2021a). Outotec showed the lowest reported emission 2016 and the best Corporate Carbon Performance in 2011.

Outotec – reported emissions

The reported emissions of Outotec are represented in Figure 46. They remained stable (plus 0.14 %) between 2011 and 2016 on a very low level (11,180 t in 2016).

*** Take in Figure 46 about here. ***

Outotec – estimated emissions

The estimated emissions can be found in Figure 47. The estimated emissions (1,139 million Euro in 2016) appear on a higher level but decreased by -7.2 % between 2011 and 2016.

*** Take in Figure 47 about here. ***

Outotec – size of the company

Size (in sales), property plant and equipment and capital intensity of Outotec can be found in figures 48, 49 and 50. Sales of Outotec decreased by – 23.7 % between 2011 and 2016. PPE remained relatively stable within this time period and rose by 5.44 %. Capital intensity increased by 38.1 % in this period.

*** Take in Figure 48 about here. ***

*** Take in Figure 49 about here. ***

*** Take in Figure 50 about here. ***

Outotec – portfolio and strategy

Outotec's core business is "providing resource-efficient solutions for the production of minerals, metals and energy" (Outotec, 2015b, p. 21). According to Outotec "this requires a deep understanding of technology, thermodynamics, chemistry, physics, economics, and all the flows of materials that occur from mines to refined metals and complex products – as well as in subsequent recycling. […] Starting from resource extraction, […] [Outotec uses its] expertise to select the most suitable process for each ore type, aiming to maximize metal yields while minimizing energy and water consumption, waste and landfill. In primary metal processing, […] [it focusses] on methods enabling high recovery of valuable metals, energy recovery, the effective processing of impurities, effluents and by-products, and minimized emissions" (ibid.).

Outotec's "technologies are [...] [a] ferrochrome process, copper flash smelting, alumina calcination, ceramic filters, and the co-generation of electricity in the ferrochrome process, where Outotec's carbon monoxide filter enables the use of process gas in direct electricity generation" (Outotec, 2015b, p. 37).

In the 2011 financial report, Outotec states that "copper represented over 30 percent of […] [the] sales, demonstrating not only the strong global demand but also […] [a] leading position in offering complete solutions for the whole ore-to-metal value chain" (Outotec, 2011, p. 4). Furthermore, Outotec presents its sustainability strategy. "Of the megatrends affecting the mining and metals sector, we consider sustainability the most important, and we see evidence of this not only in mature markets but also increasingly in the emerging markets" (ibid., p. 5). Outotec also states: "We strive to incorporate sustainability into all aspects of our operations, from our own business processes to the solutions we develop for our customers" (Outotec, 2012, p. 5).

Outotec emphasizes the sustainability benefits that its customers derive from its products and services: "Outotec's most significant impact on sustainability occurs indirectly through its customers' operations" (Outotec, 2013, p. 11). Outotec also claims that "the company has developed many breakthrough technologies for metals and minerals processing and is also creating innovative solutions for the renewable energy industry and industrial water treatment (Outotec, 2015a, p. 13). In its business, Outotec focuses mainly on "growth opportunities […] in service business" (ibid., p. 10), meaning that it offers "life-cycle performance for customers' production assets, which helps customers achieve their targets and cope in the tough market environment" (ibid.) and not on forms of energy generation or production of goods.

Outotec – low-carbon initiatives

Table 9 contains the low-carbon initiatives of Outotec.

TABLE 9

Low-carbon initiatives of Outotec

Year	Low-carbon initiatives of Outotec
2015	"In 2015, the **emissions avoided by the metallurgical industry** through the use of five Outotec technologies amounted to 6.6 million tonnes of CO2 equivalent (2014: 5.9 mt CO2-e). These technologies are our ferrochrome process, copper flash smelting, alumina calcination, ceramic filters, and the co-generation of electricity in the ferrochrome process, where Outotec's **carbon monoxide filter** enables the use of process gas in direct electricity generation" (Outotec, 2015b, p. 37). **[Product-sales of innovation-filter]** Furthermore, Outotec offers "renewable and waste-to-energy solutions […] that can treat over 200 different biomass fuels – from waste wood to the lignin sludge generated during bioethanol production. In addition, […]

Year	Low-carbon initiatives of Outotec
	[the firm has] developed an efficient solution to exploit the energy and nutrient potential of certain farmyard wastes and sewage sludge. This solution combines Outotec's fluidized-bed-based **biomass incineration** technology and the **ASH DEC process**, which cleans the **ash from biomass**/sludge incineration and converts the phosphate into a bio-available fertilizer compound" (ibid., p. 38). **[Product-sale of renewable energy-biomass]**
2016	Regarding the savings of energy consumption, Outotec was successful with its customer "at Yamana Gold's gold and copper **mine**, [where] the **identification of flotation issues** led to a turnkey retrofit project that has generated significant improvements in recovery rates, while also reducing energy consumption" (Outotec, 2016, p. 32). **[Product-sale of innovations-mining services]** Outotec also states in its 2016 sustainability report: "When it comes to the efficient mining of precious metals, flotation performance is of the utmost importance" (ibid.) and that "by **modernizing the equipment**, Outotec was able to improve both the productivity and the energy efficiency of the flotation process" (ibid.). **[Product-sales of innovations-mining services]**

Outotec – concluding analysis

In case of Outotec one has to distinguish between the emissions avoided at Outotec's customers and Outotec's carbon footprint itself. Outotec's core business is "providing resource-efficient solutions for the production of minerals, metals and energy" (Outotec, 2015b, p. 21). In that, Outotec focuses via its core business mainly on "service business" (ibid., p. 10) for its customers and not on energy generation or production of consumer goods. Therefore, Outotecs emissions are relatively low. Outotec describes itself as "a technology leader in the minerals and metals processing industry is the capability to deliver technologies and products that are resource-efficient […] [with a] product portfolio [that] covers hundreds of various plant concepts, processes, pieces of equipment and services" (Outotec, 2017, p. 26).

Outotec's carbon emissions remain relatively stable over time, on a very low level. At the same time, revenues are relatively high, leading to higher values of estimated emissions in Stüwe et al. (2023). As a provider of energy-efficient, and environmentally friendly technologies for utilization of natural resources (Outotec, 2011, p. 5), Outotec Oyi may have dedicated substantive efforts to mitigating its own emissions (Outotec, 2012, p. 5): “Our sustainable technologies - whether related to minerals and metals processing or to water, energy, and biomass - reduce the environmental effects of a number of industrial operations, world-wide” (Outotec, 2011, p. 5).

The estimated emissions decreased as size decreased and at the same time, they appeared to be on a rather high level compared to the reported emissions, especially in 2011 when estimated emissions were still very high. That is why Outotec showed the best carbon performance of 2011. It showed the lowest reported emissions of the sample for the year 2016, too. Outotec is operating in the mineral industry where processes lead to great impacts on the natural resources and high revenues but in general do not cause high emissions. In contrast to that, those activities generate high volumes of sale and therefore, high estimated emissions.

Rotork – introduction

Rotork plc is a machinery firm (Stüwe et al., 2023) with headquarter in Bath, United Kingdom (Craft, 2023) and revenues in 2017 of 642.2 million £. Rotork plc showed the lowest reported emission 2011, the lowest estimated emissions 2011 and the lowest estimated emissions 2016 and therefore, was a notable case in Stüwe et al. (2023).

Rotork – reported emissions

The scope 1 and 2 emissions of Rotork plc are represented in Figure 51. The emissions more than doubled and increased by 149 % between 2011 and 2016 but on a very low niveau (14,775 t in 2016).

*** Take in Figure 51 about here. ***

Rotork – estimated emissions

The estimated emissions which can be found in Figure 52, increased, too, by 108 % between 2011 and 2016, on a slightly higher but still very low level (23,112 t in 2016).

*** Take in Figure 52 about here. ***

Rotork – size of the company

Size (in revenue), property, plant and equipment as well as capital intensity of Rotork plc can be found in Figure 53, Figure 54 and Figure 55. Size rose by 31.8 % between 2011 and 2016, PPE by 162 % and capital intensity by 98.9 %. Revenue, for example, was 642.2 million £ in 2017.

*** Take in Figure 53 about here. ***

*** Take in Figure 54 about here. ***

*** Take in Figure 55 about here. ***

Rotork – portfolio and strategy

According to the 2017 annual report, “Rotork is a market-leading solution provider for the actuation, flow control and industrial markets […] [that] provide[s] a world-class service to […] [its] customers. […] [Its] flow control products are used extensively in the oil and gas, water, power and industrial markets, amongst others” (Rotork, 2017, p. 2). Furthermore, the environmental report of 2012 states: “When you turn on a tap or switch on a light, turn on a kettle or put fuel in your car, a flow control product is being used somewhere in the process of delivering that service. We are the only UK listed company with a global presence that is dedicated to this and nothing else” (Rotork, 2012, p. 2).

Rotork plc has been measuring and disclosing its Scope 1 & 2 emissions already since 2003 (Rotork, 2011, p. 32). In 2012, Rotork’s sustainability strategy is focused on pollution prevention: “Rotork is fully committed to the prevention of pollution, compliance with all relevant legal and regulatory requirements and to the continuous improvement of environmental performance. Through Global Compact and FTSE4Good and the other benchmarks we use; we set an example of good, responsible and effective business” (Rotork, 2012, p. 2). Rotork’s strategy of 2020 is three-fold: “Accelerated growth[,] Increased margins [and] Sustainability […] [which is supposed to be tackled by] the Growth Acceleration Programme” (Rotork, 2020, p. 10). Rotork also offers products for the nuclear industry (Rotork, 2011, p. 13).

Rotork – low-carbon initiatives

The low- carbon initiatives of Rotork plc can be found in Table 10.

TABLE 10

Low-carbon initiatives of Rotork plc

Year	Low-carbon initiatives of Rotork plc
2013	In 2013, the UK introduced mandatory greenhouse gas emission reporting for UK companies: "According to the Department for Environment, Food and Rural Affairs (DEFRA) Environmental Reporting Guidelines issued in June 2013, Rotork chose to use 2012 as the base year by recalculating all previous emissions using the new emission factors issued by DEFRA for 2012. […] All future emissions will be compared against data from 2012" (Rotork, 2013b, p. 2). **[Calculation method]** The 2013 annual report describes an increase of energy consumption of "4.73% compared with 2012, slightly below the rate of organic revenue increase. With the inclusion of **new reporting companies** this year, the overall increase was 8.68%" (Rotork, 2013a, p. 40). **[Calculation method]**
2014	Furthermore, there were some "**acquisitions** in USA, Germany, Italy and the new head office in the UK accounted for 3.77% of the increase. **[Mergers & acquisitions]**
2014	There were also increases in business activity with small fluctuations in climate conditions at some facilities also contributing to the increase" (ibid.). The 2014 annual report, then, explains "some of the energy projects includ[…][ing] installing **energy efficient lighting** in our Nottingham (UK), Melle (Germany) and Rochester (USA) facilities. The changes […] reduce […] energy consumption by approximately 50% per fixture. This has allowed some of […] [the] more energy intensive sites, such as Rochester (USA) to cut electricity consumption by up to 30%. Projects like this not only offer reduced energy consumption and the associated reduction in carbon emissions, but also provide a reduction on operating costs for the lighting and reduced maintenance costs" (Rotork, 2014, p. 45). **[Process-efficient lighting]**
2015	Then, the 2015 annual report states that there has been a reduction of energy in the following year also. "Rochester (USA) has shown a reduction of 9.4% in their electricity consumption and Melle (Germany) has shown a reduction of 19.9% in electricity consumption. A number of other **energy reduction projects** which are

Year	Low-carbon initiatives of Rotork plc
	currently being implemented have already started to show their benefits. Bath (UK) has already shown a reduction of 1.8% in electricity consumption against last year and Winston-Salem (USA) has realised a 2.4% reduction in electricity consumption compared to last year. These projects are expected to show greater reductions when they have been completed” (Rotork, 2015, p. 53).
2016	The 2016 report mentions the “**removal of the generator** and **upgrading of the electrical system** at Bifold Marshalsea (UK) and more secure energy supply in India where **generator use** has [been] reduced by approximately 20%. […] **[changes in generator use]** [and that the] UK businesses continue to be certified to ISO50001 with the exception of the Bifold Group” (Rotork, 2016, p. 58). **[Process-Environmental and Energy management system]**
2017	Another reason for the energy consumption reduction was “the use of **solar power** in Chennai **[Solar Power]** which has further reduced the use of the back-up generator” (Rotork 2017, p. 50). Two more sites were certified with the ISO50001 management system (ibid.). **[Process-Environmental and Energy management system]**

Rotork – concluding analysis

Rotork plc is the smallest company of the sample in terms of the predictors and also a service-intensive business. “Rotork is a market-leading solution provider for the actuation, flow control and industrial markets [...] [that] provide[s] a world-class service to [...] [its] customers. [...] [Its] flow control products are used extensively in the oil and gas, water, power and industrial markets, amongst others” (Rotork, 2017, p. 2).

Moreover, a decrease of oil consumption was caused by “the use of solar power in Chennai which has further reduced the use of the back-up generator” (ibid., p. 50). “To support the continued focus on energy management, [...] [the] UK businesses continue to be certified to ISO50001” (ibid.). These developments might have contributed to the fact that Rotork plc showed the lowest reported emission 2011, the lowest estimated emissions 2011 and the lowest estimated emissions 2016 and therefore, was a notable case in Stüwe et al. (2023).

Summary for all firms

I derived strategic company-level factors like mergers and acquisitions and divestments as well as operational company-level factors, the low-carbon initiatives, which influenced corporate carbon performance besides the model-internal factors. Figure 56 depicts these factors and low-carbon initiatives in a more summarized manner for all the firms. Table 11 shows company-level factors and low-carbon initiatives which carry the potential to determine corporate carbon performance for each firm.

FIGURE 56

Analyzed factors overview

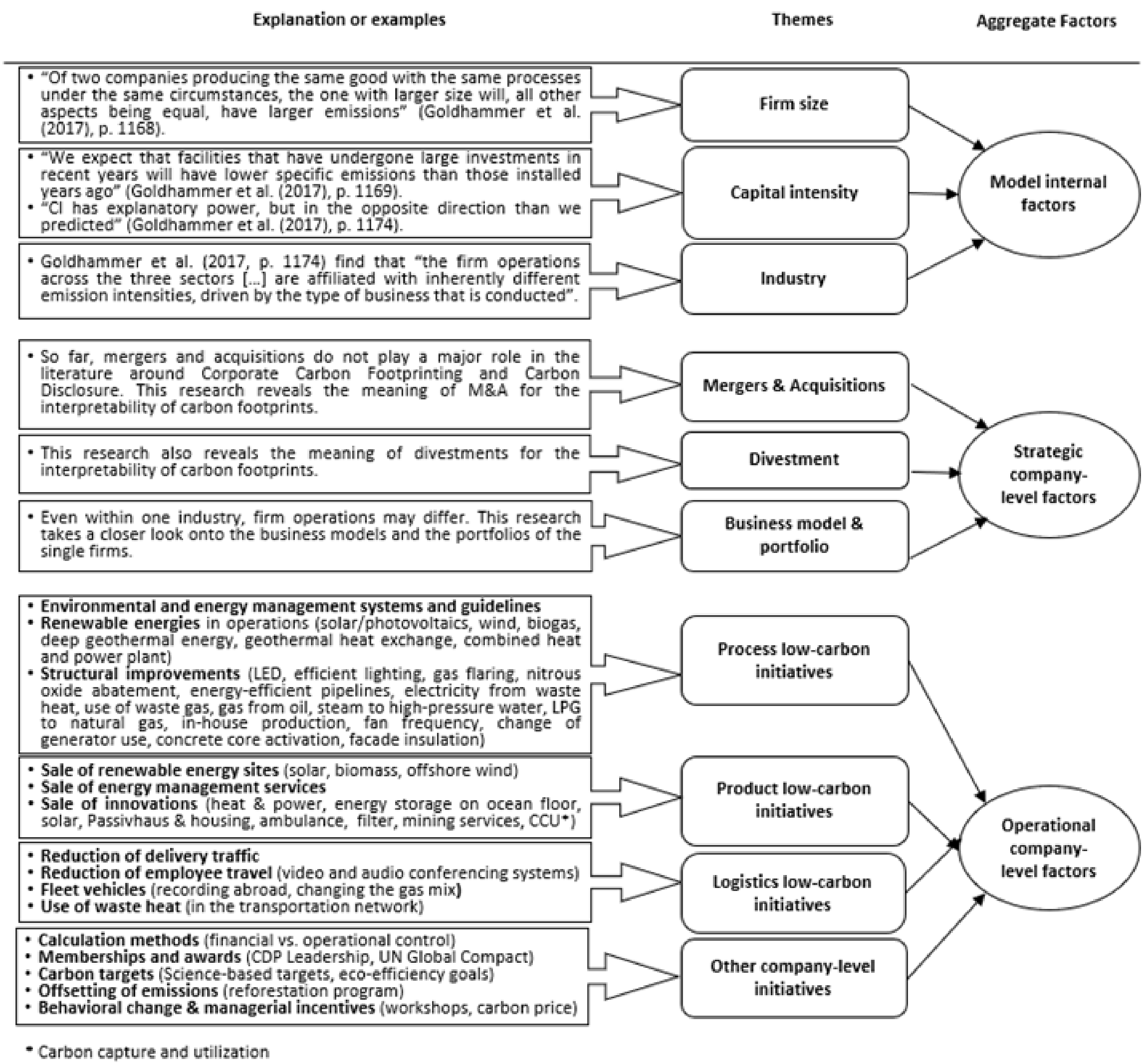

TABLE 11

Analyzed factors for each firm

Company name	Industry	Criteria and years	Course of reported and estimated emissions	Model-internal factors	Mergers & Acquisitions, Divestments, Business Model & Portfolio	Process low-carbon initiatives	Product low-carbon initiatives	Logistics low-carbon initiatives	Other company-level initiatives
Abengoa	C&E	Largest CCP-neutral change, Worst carbon performance 2011, Worst carbon performance 2016, Largest decrease of estimated emissions, Largest total change	Reported emissions decreased, estimated emissions decreased	Crisis lead to lower size and capital intensity	Large divestments took place due to crisis	ISO 14001	Thermosolar, biomass and biofuel plants, Solid Urban Waste (SUW) with gasification technology		Change of calculation method, membership in FTSE4Good sustainability index
Alstom	Machinery	Largest decrease of reported emissions	Reported emissions decreased, estimated emissions decreased	Lower size ad capital intensity	Two major divestments				
BASF SE	Chemicals	Highest reported emissions 2011 Highest estimated emissions 2011 Highest estimated emissions 2016	Reported emissions and estimated emissions decreased on a high niveau	Size decreased slightly on a high niveau, CI increased	Energy-intensive business model	reduction of nitrous oxide, efficient use of steam and electricity, decreasing the continuous flaring of gases associated with crude oil production, energy-efficient pipelines, resource-efficient oil production, DIN EN ISO 50001	customers solutions that help reduce greenhouse gas emissions and improve energy efficiency	use of waste heat in the transportation network	The company Gascade was no longer fully consolidated in the group's financial statements, U.N. Global Compact membership, target to reduce its ghg emissions per metric ton of sales product by 40% by 2020, compared with baseline 2002

Company name	Industry	Criteria and years	Course of reported and estimated emissions	Model-internal factors	Mergers & Acquisitions, Divestments, Business Model & Portfolio	Process low-carbon initiatives	Product low-carbon initiatives	Logistics low-carbon initiatives	Other company-level initiatives
Dürr	Machinery	Largest increase of estimated emissions	Reported emissions and estimated emissions increased	Size and capital intensity increased	Major acquisition in 2014	"Campus Energy 21" combines different processes: from deep geothermal energy, geothermal heat exchange, combined heat and power plant and photovoltaics to concrete core activation, sensor-controlled lighting and facade insulation, Eco⨁Efficiency system to improve the consumption efficiency of machines and systems, EcoDryScrubber paint booth system reduces the energy requirement in the spray booths, Organic Rankine Cycle process generates electricity from waste heat, ISO 14001, ISO 50001, expansion of in-house production, LED systems, install modern air conditioning units or modernization of machinery		reduction of delivery traffic, Reduction of employee travel with the help of video and audio conferencing systems, recording of fleet vehicles abroad	heating consumption are offset by reforestation program in Canada,

Company name	Industry	Criteria and years	Course of reported and estimated emissions	Model-internal factors	Mergers & Acquisitions, Divestments, Business Model & Portfolio	Process low-carbon initiatives	Product low-carbon initiatives	Logistics low-carbon initiatives	Other company-level initiatives
Givaudan	Chemicals	Best carbon performance 2016	Reported emissions decreased, estimated emissions increased	Size increased, Capital intensity decreased, estimated emissions increased	Business model is based on flavours and fragrances: presumably high revenues with little resource throughput	switch from heavy fuel oil as primary energy source to gas-process and from steam to a high-pressure water system-process, guidelines enable purchasing teams to buy greener energy, Eco-efficiency Leadership team (EELT) continued to encourage local Green Teams, intelligent control of exhaust fan frequency and timing, 33% of purchased electricity produced from renewable sources, while 52% carbon free (in 2014), conversion from LPG to natural gas		Changing gas mix of vehicles	2020 eco-efficiency goals, raising energy-awareness among staff members, four energy-saving workshops, internal competition of the Green Teams, targets approved by the Science Based Targets initiative, RE100 initiative to convert entire electricity supply to fully renewable sources by 2025, employee awareness
Hochtief	C&E	Largest CCP-effective deterioration	Reported emissions increased, estimated emissions decreased	Size and capital intensity decreased	Two major acquisitions	numerous energy conservation and efficiency measures in-house, ISO 14001 & EMAS/SCC & Green Zone program (environmental management system), LED lighting, almost 200 accredited auditors employed across the group	Sale of Energy Management and sustainable facility management services to clients, geothermal power plants, combined heat and power station, offshore wind farm on the North Sea, interim storage of energy on the ocean floor, modern ventilation systems		improvement of data collection in 2016, part of German Carbon Disclosure Leadership Index, Energy Award, Innovation Award

Company name	Industry	Criteria and years	Course of reported and estimated emissions	Model-internal factors	Mergers & Acquisitions, Divestments, Business Model & Portfolio	Process low-carbon initiatives	Product low-carbon initiatives	Logistics low-carbon initiatives	Other company-level initiatives
Interserve plc	C&E	Largest increase of reported emissions	Reported and estimated emissions increased	Size and capital intensity increased		SustainAbilities programme with supplier audits,	rolling out a range of solar powered, water and waste-neutral ambulance facilities in Dubai, Passivhaus building techniques,		Construction News Awards, Change of calculation method: financial control in 2017 annual report, operational control in 2017 CDP report
Koninklijke DSM N.V.	Chemicals	Largest CCP-effective improvement	Reported and estimated emissions decreased	Size decreased, CI increased	Partial divestment (big impact from the (partial) divestment of Polymer Intermediates)	N2O abatement system of September 2012, high efficiency separation technology DSM Nutritional Products in Dalry (UK), heat and power plant in Grenzach (Germany), greater use of electricity from renewable sources			data for DSP only consolidated for 50 percent as of January 2012, closure of DSP Zhangjiakou, contribution of three new reporting sites, total reduction target is 25 percent, improvement of GHG reporting, internal carbon price of € 50/t CO2eq, calculation methodologies
Linde Group	Chemicals	Highest reported emissions 2016	Reported and estimated emissions increased on a high niveau	Size and capital intensity increase	Gas business	Adaptation of steam compressors and flow meters	feeding CO_2 to algae and recycling CO_2 for plant growth, largest CO_2 purification and liquefaction plant, carbon capture and utilisation (CCU), liquefied food-quality CO_2,		target of avoiding a total of 6 million tonnes of CO2 emissions from hydrogen and synthesis gas plants (HyCO plants) and air separation plants around the world by 2020

Company name	Industry	Criteria and years	Course of reported and estimated emissions	Model-internal factors	Mergers & Acquisitions, Divestments, Business Model & Portfolio	Process low-carbon initiatives	Product low-carbon initiatives	Logistics low-carbon initiatives	Other company-level initiatives
Outotec Oyj	C&E	Lowest reported emissions 2016, Best carbon performance 2011	Reported and estimated emissions remained relatively stable on a low niveau	Size decreased and capital intensityy increased	Outotec is operating in the mineral industry where processes lead to great impacts on the natural resources and high revenues but in general do not cause high emissions	carbon monoxide filter enables the use of process gas in direct electricity generation, solution to exploit energy and nutrient potential of farmyard wastes and sewage sludge including fluidized-bed-based biomass incineration	identification of flotation issues in gold and copper mine, improvement of both the productivity and the energy efficiency of the flotation process by modernizing the equipment		
Rotork plc	Machinery	Lowest reported emissions 2011, Lowest estimated emissions 2011, Lowest estimated emissions 2016	Reported and estimated emissions increased on a low niveau	Size and capital intensity increased	Rotork plc is a small company specialized in flow control products with low reported and estimated emissions, some acquisitions in USA, Germany, Italy and the new head office in the UK	energy efficient lighting in Nottingham (UK), Melle (Germany) and Rochester (USA) facilities, energy reduction projects, removal of the generator and upgrading of the electrical system at Bifold Marshalsea (UK), ISO50001, use of solar power in Chennai			recalculating all previous emissions using the new emission factors issued by DEFRA for 2012, inclusion of new reporting companies

DISCUSSION

Corporate carbon footprints are difficult to interpret. Therefore, Stüwe et al. (2023) develop a methodology to benchmark such footprints and to increase their interpretability by filtering out notable cases from firm samples. Besides that, Stüwe et al. (2023) illustrate this methodology by applying its scheme to a sample of 46 firms and 92 firm observations for the years 2011 and 2016.

To determine the notable cases, they derive 14 different criteria, such as the lowest and highest reported emissions or the best and the worst corporate carbon performance (CCP). Herein, they show an innovative understanding of CCP and consider not only the explanatory factor size of the firm but also capital intensity (i.e. property, plant and equipment divided by size) and the industry in form of a dummy variable.

This research extends this view by finding strategic and operational company-level factors which lead to notable cases and to a good corporate carbon performance of a firm.

Implications for research

This research validates the work of Stüwe et al. (2023) and qualitatively analyzes the notable firm cases in a longitudinal manner. It aims at finding out what made the cases notable. Stüwe et al. (2023) only derived the cases from two data points (2011 and 2016). This research extends the longitudinal view upon the firm cases by analyzing the annual and sustainability reports from 2011 until 2017 and making sense of the fourteen criteria and eleven selected firm cases.

While Stüwe et al. (2023) focused on model-internal factors such as size, capital intensity and industry, I could derive further factors that explain corporate carbon performance: strategic company-level factors (the strategy and portfolio) as well as operational company-level factors (the low-carbon initiatives of the firm). These initiatives can be categorized into product, process and logistics initiatives (Furlan Matos Alves et al., 2017) and I apply these categories to the initiatives of the notable firm cases.

Having derived these further factors is of high scientific importance as those have not been attributed to the concept of CCP before and this research thus extends the theoretical base about CCP by shedding light onto the factors which contribute to a good corporate carbon performance.

When it comes to strategic company-level factors, divestments and business models that are not energy-intensive can contribute to good carbon performance of a firm. Especially the partial or complete divestment of an energy-intensive part of the business of a firm can contribute to better CCP. As trivial as this may seem, this relationship has not been emphasized in the literature before and therefore, this research extends theory. Regarding operational company-level factors and low-carbon initiatives it turned out that especially environmental management systems, the use of renewable energies, structural improvements such as N2O abatement and LED technologies and the choice of the calculation method can improve corporate carbon performance.

Contribution of this research is therefore that I find initiatives and firm actions that show how a firm can improve its carbon performance or how a firm's carbon initiatives can result in a good carbon performance. It answers the question of why the eleven firms got notable in Stüwe et al. (2023) and the research question which low-carbon initiatives and company-level factors can determine good corporate carbon performance.

Implications for practice

The notable cases of Stüwe et al. (2023) indeed filtered out the aspects in which stakeholders should engage in discussions with firms and this research could deepen this analysis. It allows different stakeholders to lead meaningful discussions with the benchmarked or notable firms.

For NGOs, customers and the media it is important to know that many firms not only talk about their corporate carbon footprints but also about carbon reductions on customers' sites in their annual and sustainability reports. Therefore, not all low-carbon initiatives necessarily lower the corporate carbon footprint of a firm. Here, it is crucial to differentiate between a firm's corporate carbon footprint and the energy and carbon savings that migh occur at a customer's site due to the use of a product or a technology offered by the firm. Abengoa, for example, mentions the use of solar power. However, the solar technology is not used for Abengoa's production processes but is sold to a customer who then saves carbon emissions by using this technology. Therefore, this initiative counts as product-related, not process-related, here. Furthermore, the logistics low-carbon initiatives often relate to the saving of scope 3 emissions whereas Stüwe et al. (2023) and this research focused on scope 1 and 2 emissions as the calculation of scope 3 emissions is even less standardized than the calculation of 1 and 2 emissions. When considering scope 1 and 2 emissions, it turns out that the process low-carbon initiatives are of highest importance and the distinction of Furlan Matos Alves et al. (2017) into process, product and logistics initiatives can be very helpful for practicioners. I extended this with a further category called "other company-level initiatives" accounting for changes of calculation methods, company memberships and awards, setting of carbon targets, offsetting of emissions, behavioral and managerial incentives such as workshops or publication of an internal carbon price (Figure 56).

Managers who want to improve the CCP of a company can both benchmark a company and can see this research as a guideline to find meaningful low-carbon initiatives and make good company decisions. Especially, divestments of energy-intensive business parts as a strategic company-level factor and process-related low-carbon initiatives such as the use of renewables, energy management systems or LED technology can lead to improvements of CCP.

Limitations and opportunities for future research

While this research derives further factors important to CCP, the extend to which the single factors and initiatives contribute to better CCP remains unclear as this research is of qualitative nature. Furthermore, the methodology of this research is a secondary data analysis based on annual and sustainability reports only. Primary research could supplement this approach, for example interview-driven research which offers firm-internal insights. Especially as the results are limited, firm-inside views as well as innovative qualitative research and an extension of the research of Stüwe et al. (2023) would be beneficial.

The sample size here is only eleven firm cases as those represent the notable cases of Stuwe et al. 2023. It would be interesting to analyze more firm cases and not only from the construction and engineering, the chemical and the machinery industry but also from other industries. In the long run, not only cases of carbon performance could be analyzed but also cases of other environmental performances.

The lack of comparability of carbon footprints can also limit the results. However, the approach of Goldhammer et al. (2017) makes the footprints more comparable by filtering out the different influences on the carbon footprints such as the size, the capital intensity, the industry as well as centrality of production. In Stüwe et al. (2023) centrality of production was dropped as it turned out to be insignificant in the main model and the data situation was not satisfying. Therefore, and because centrality of production had a minor impact, centrality of production was not analyzed in this research.

Further research could analyze quantitatively, if carbon and environmental management systems lead to higher carbon performance and build upon Tang and Luo (2014) as well as Sial et al. (2021) who find that firms with a carbon management system of higher quality have achieved better carbon mitigation. Other new factors and initiatives could be analyzed as well and potentially be included in the model of Stüwe et al. (2023) or similar models by future research.

In this research I assume that there is no wrong reporting and that the reported values were right. If a company reported wrong values, the derivation of notable cases and the analyzes might have let to different results. Also, if the data within the reports is not correctly presented by the firms, this analysis might lead to wrong conclusions.

CONCLUSION

This research validated the study of Stüwe et al. (2023) and qualitatively analyzed the eleven notable firm cases in a longitudinal manner with data from firm reports from 2011 until 2017. It aimed at explaining the notable cases of Stüwe et al. (2023) in more detail and deriving further factors that can explain corporate carbon performance. It derived strategic and operational company-level factors that could contribute to good CCP like divestments of energy-intense business parts, environmental management systems, nitrous oxid abatement or LED, and, therefore, could serve as a guideline for practitioners who want to improve the CCP of a company. For NGOs, customers and the media it could reveal traps around corporate carbon footprints of companies, for example firm reports that present carbon savings of customers instead of the actual corporate carbon footprints.

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TABLES AND FIGURES

FIGURE 1

Reported emissions of Abengoa

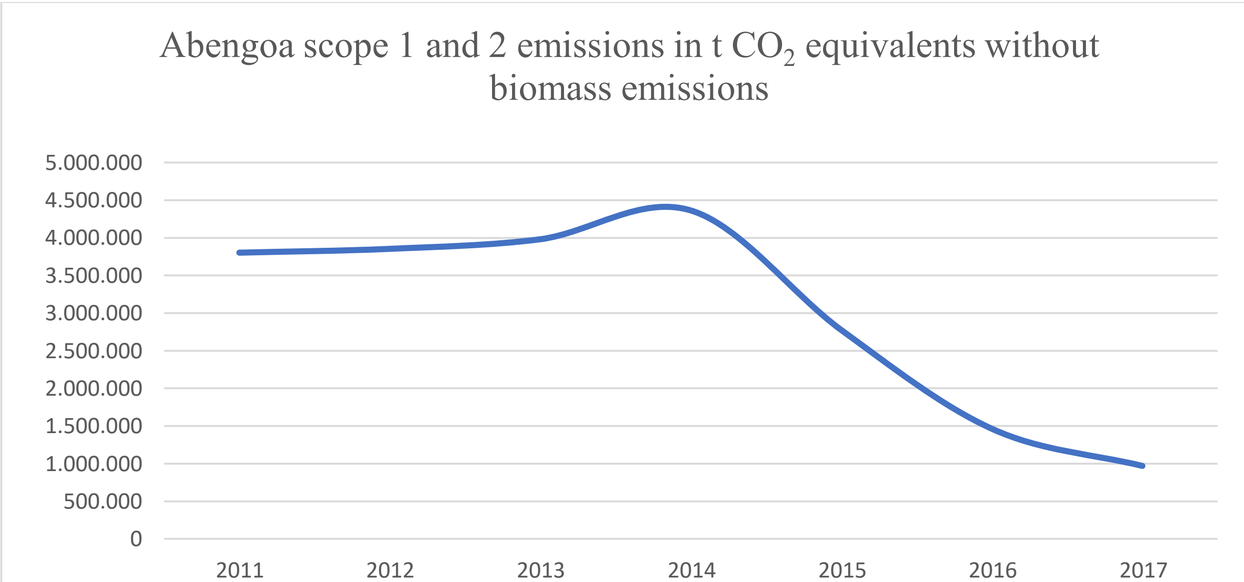


FIGURE 2

Estimated emissions of Abengoa

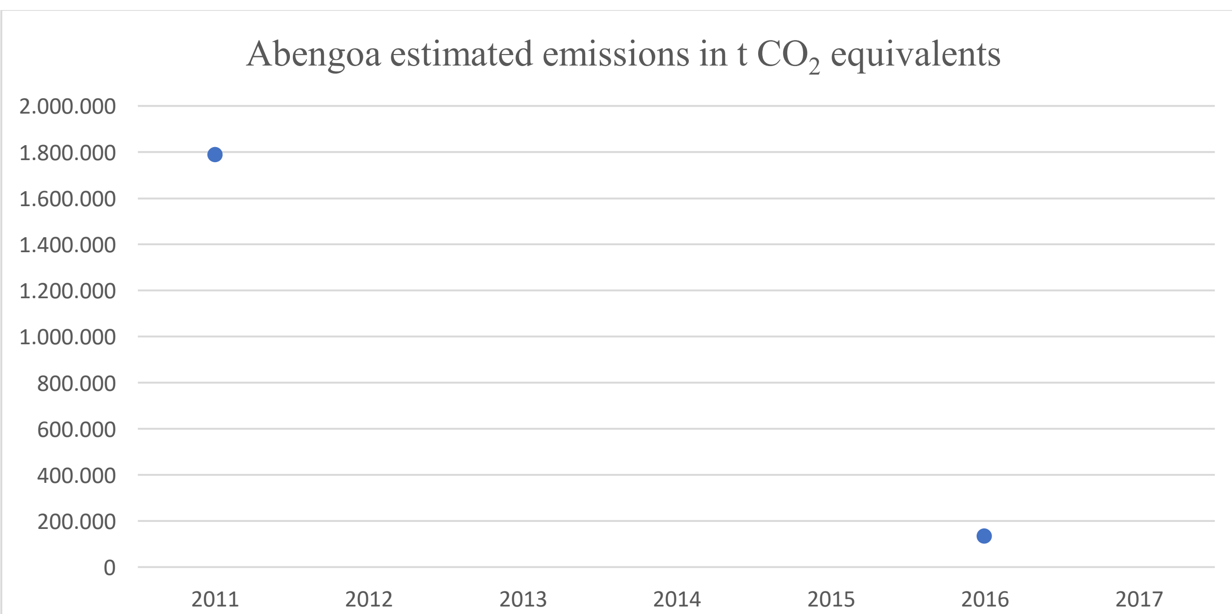


FIGURE 3

Size of Abengoa (in revenues and sales)

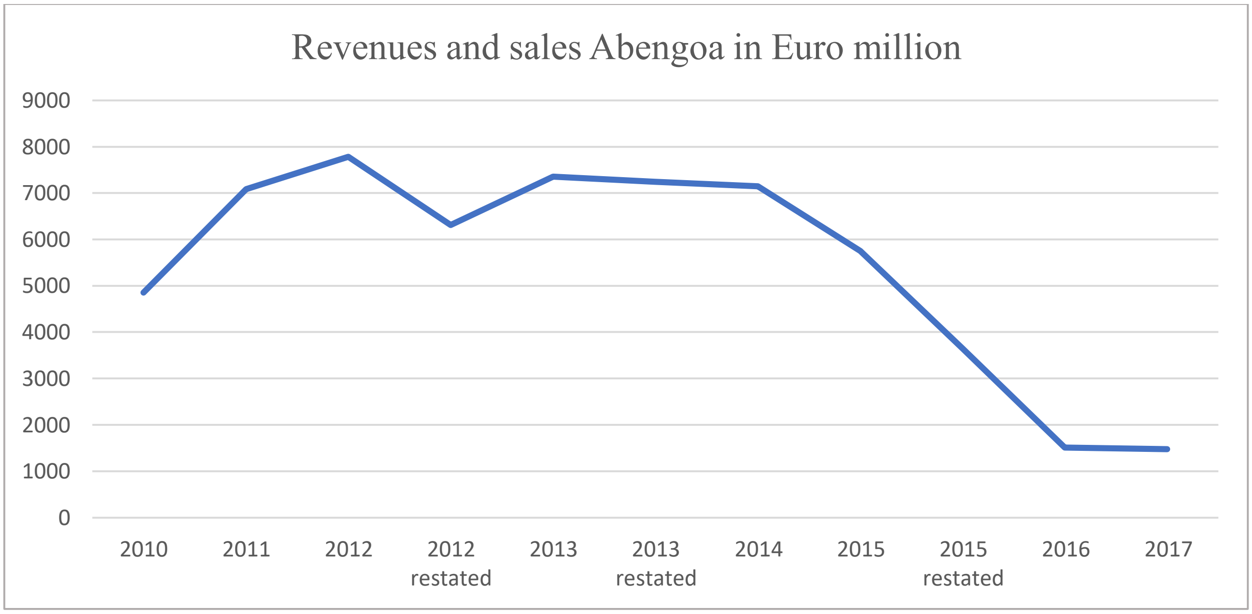


FIGURE 4

Property, plant and equipment of Abengoa

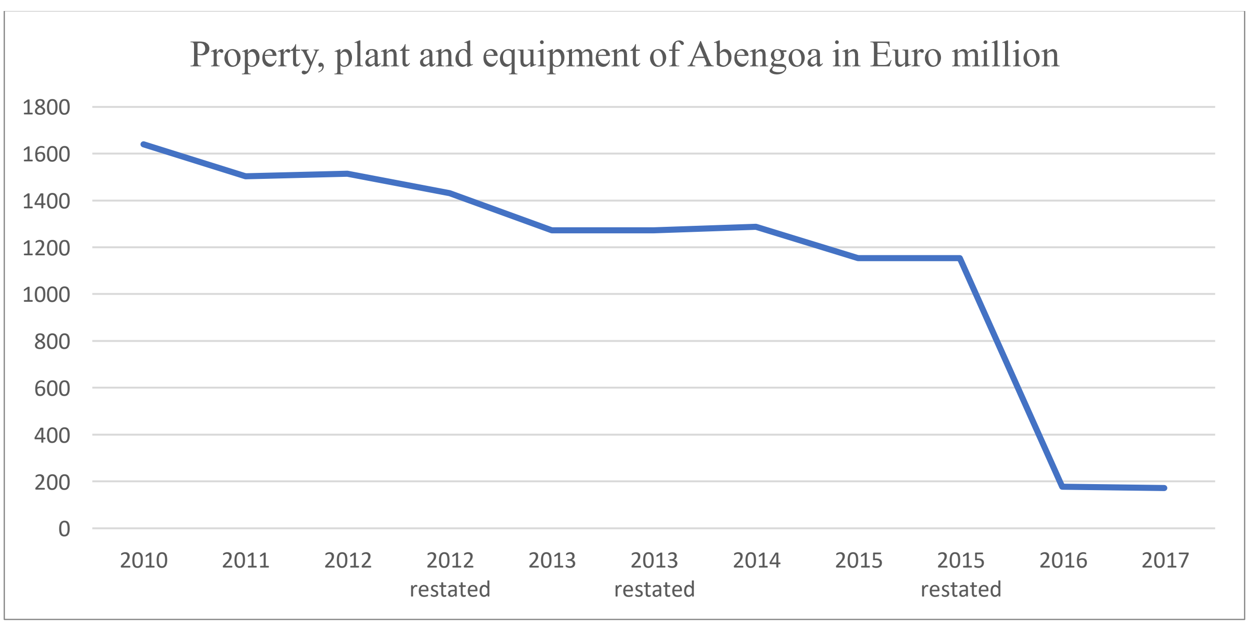


FIGURE 5

Capital intensity of Abengoa

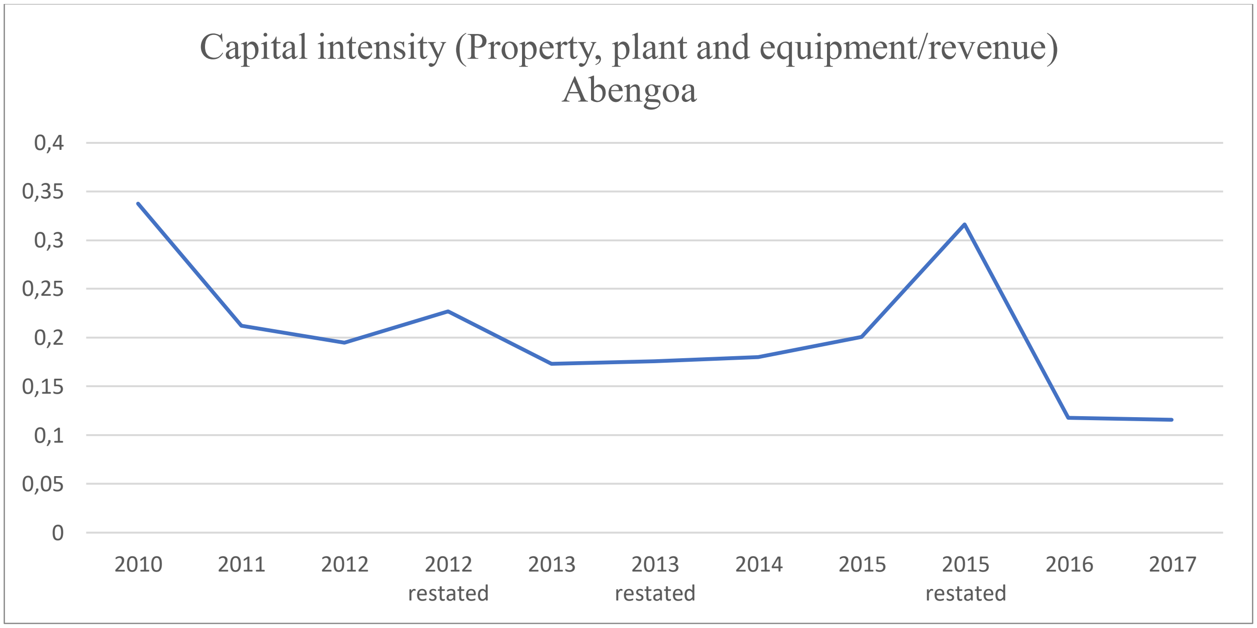


FIGURE 6

Reported emissions of Alstom

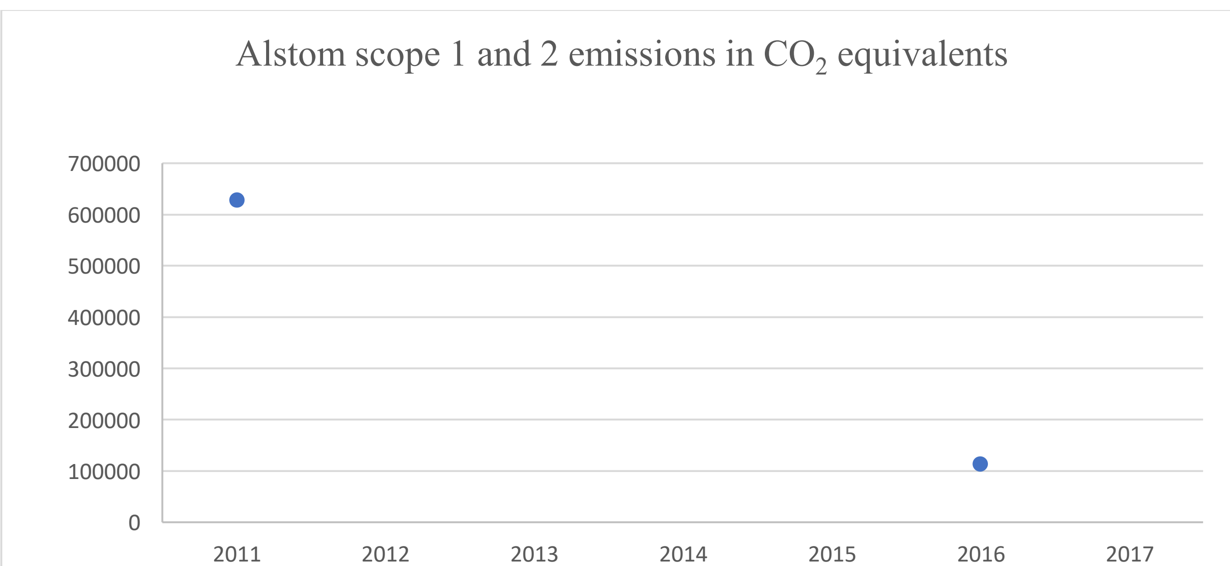


FIGURE 7

Estimated emissions of Alstom

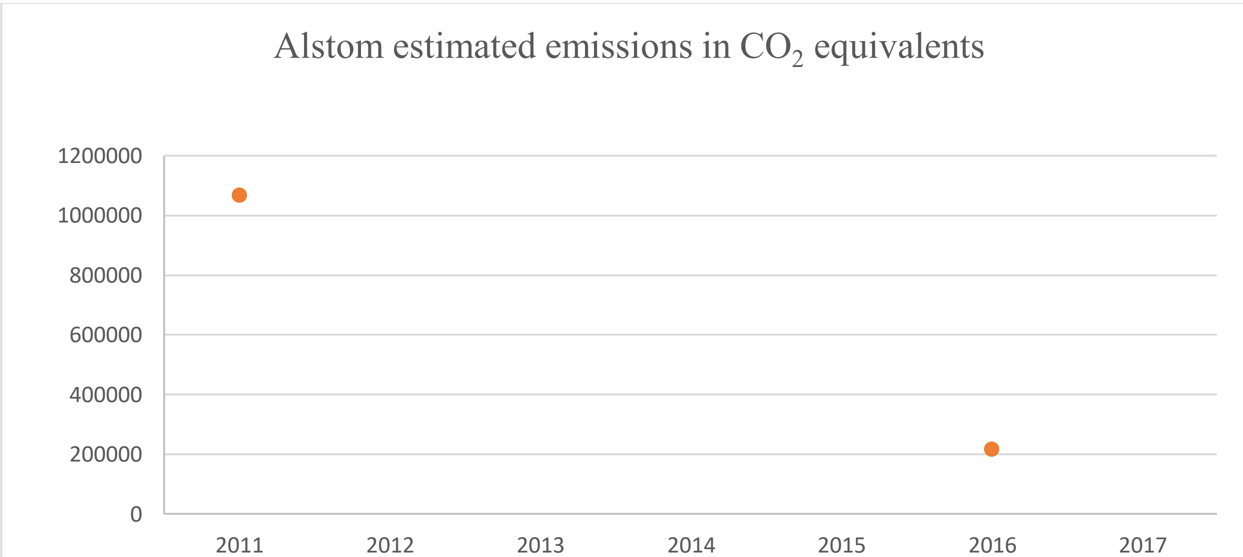


FIGURE 8

Size of Alstom

FIGURE 9

Property, plant and equipment of Alstom

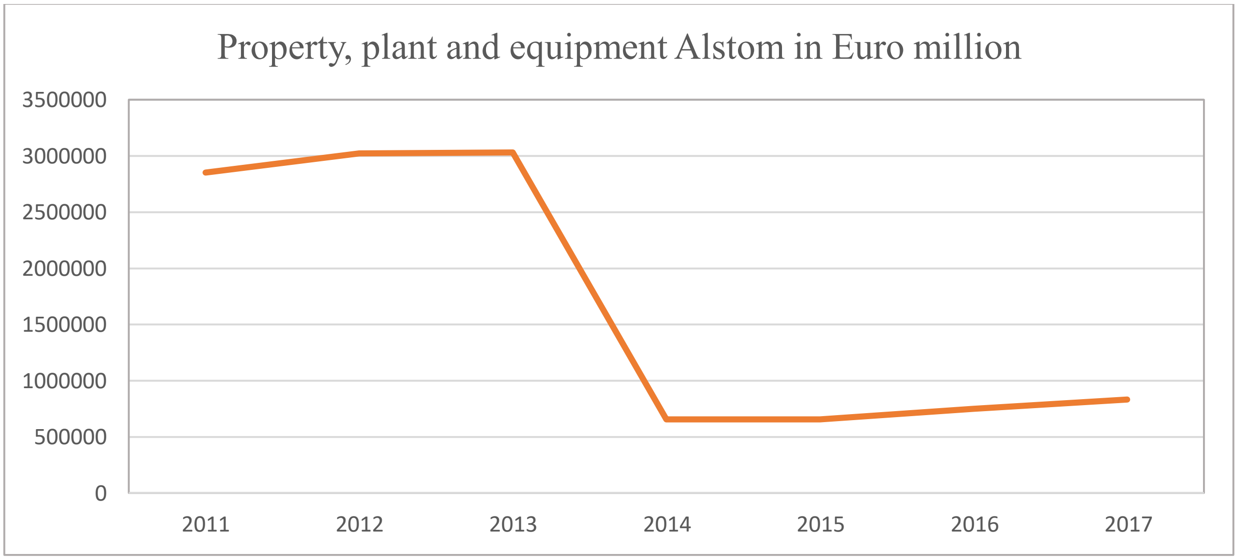


FIGURE 10

Capital intensity of Alstom

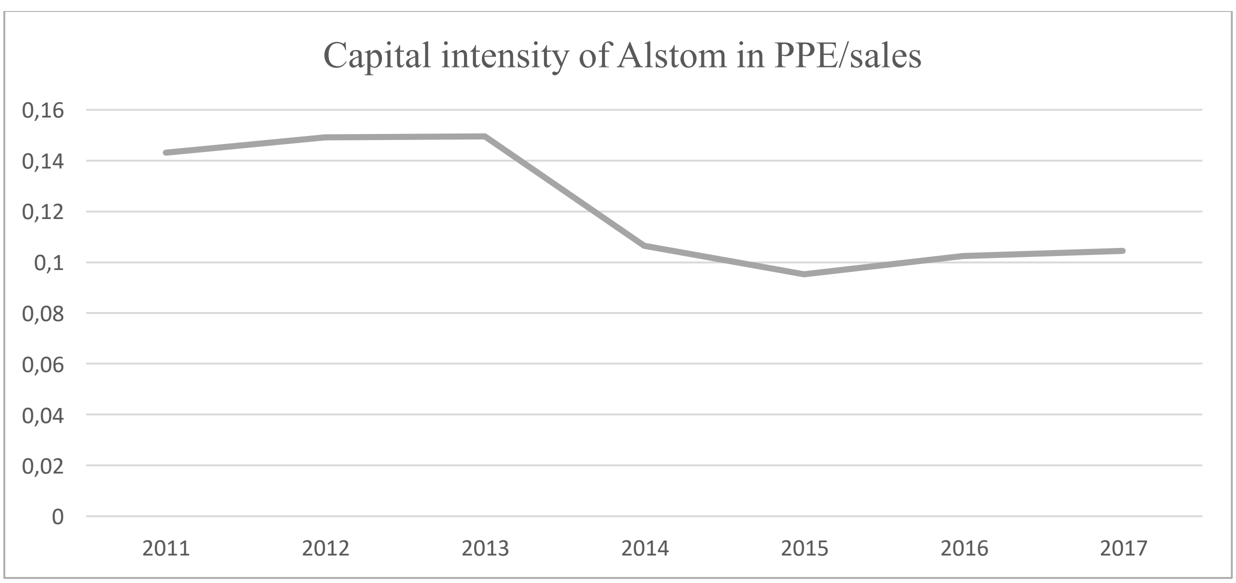


FIGURE 11

Reported emissions of BASF

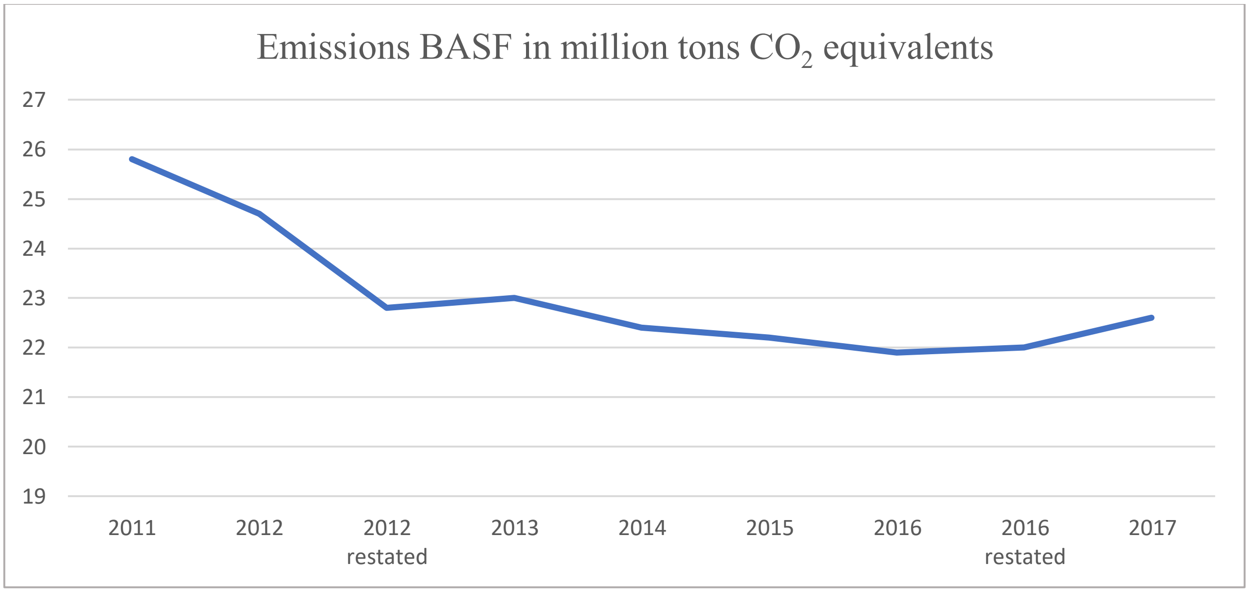


FIGURE 12

Estimated emissions of BASF

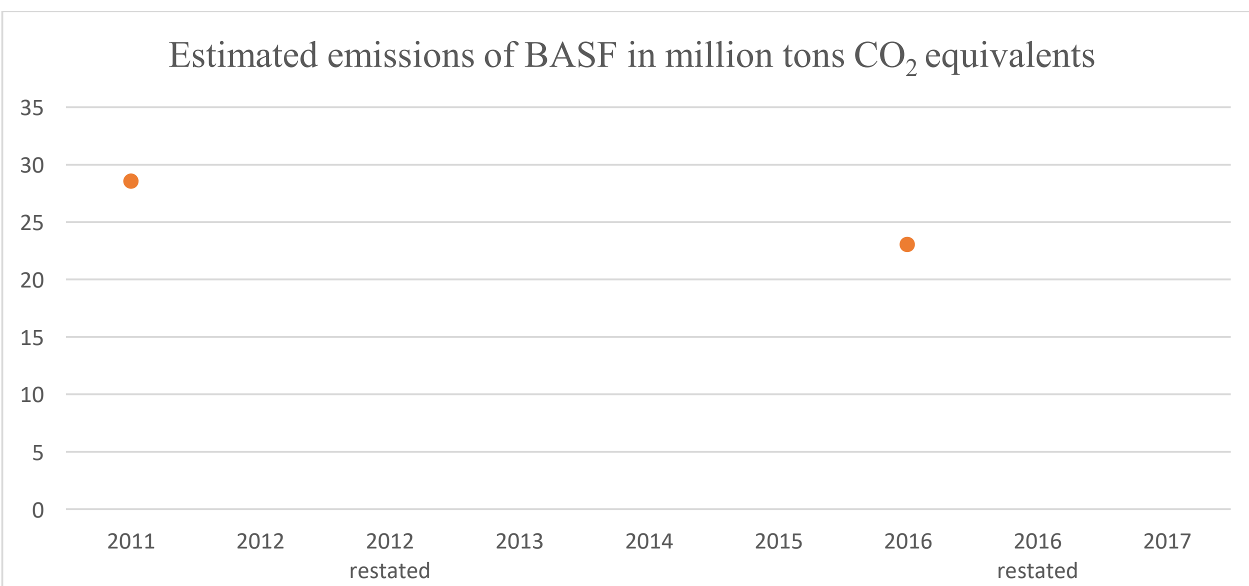


FIGURE 13

Size of BASF (in sales)

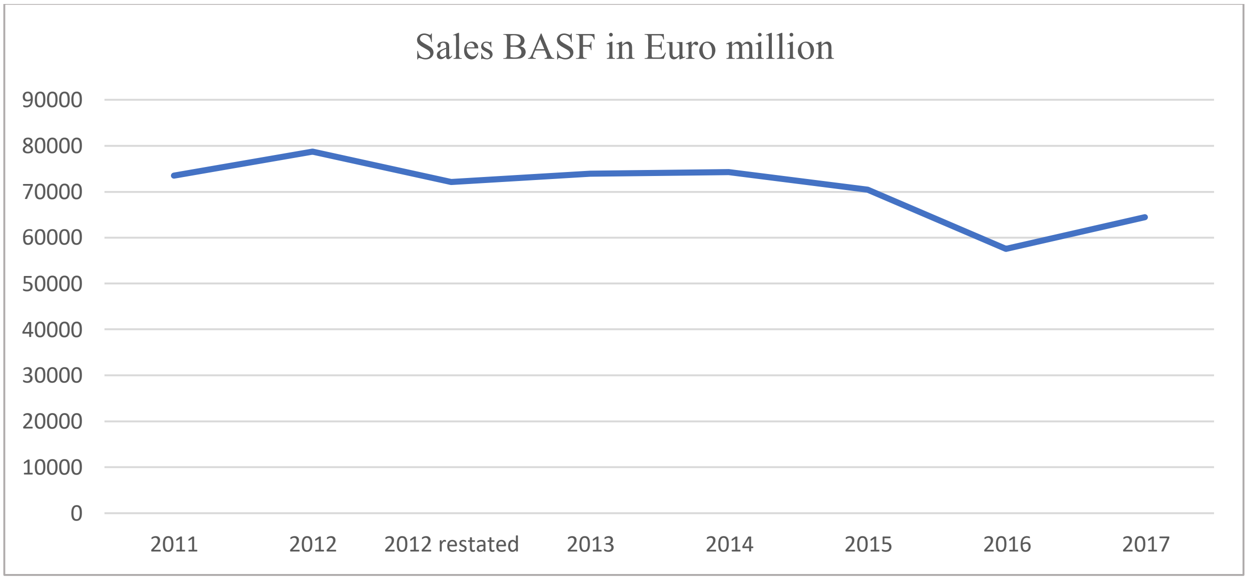


FIGURE 14

Property, plant and equipment of BASF

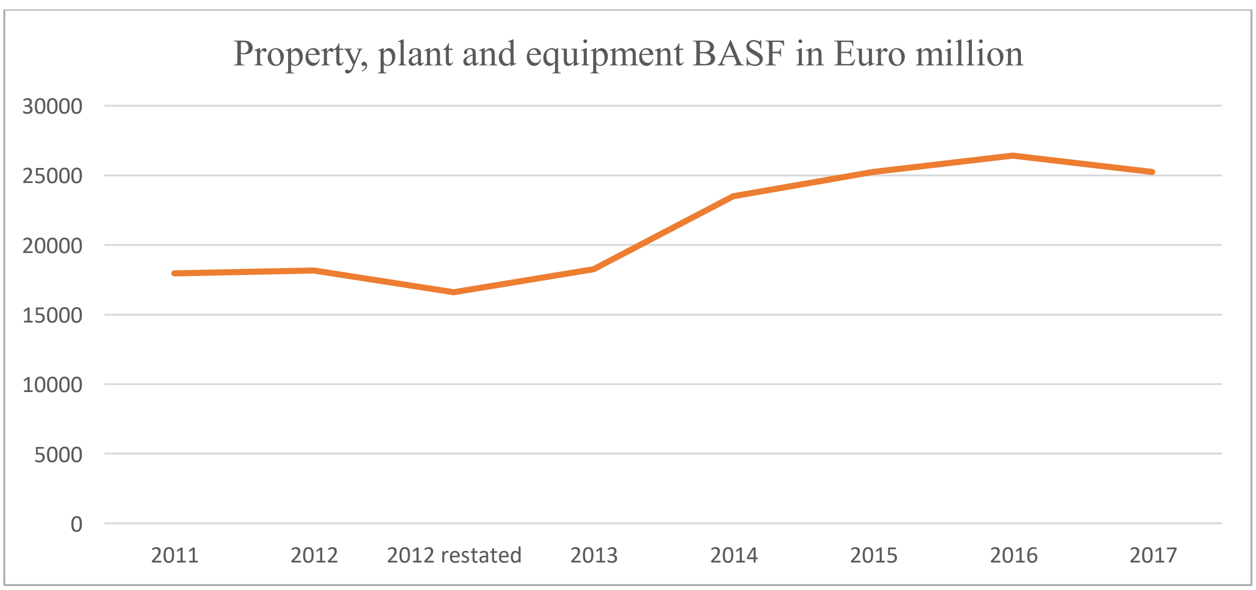


FIGURE 15

Capital intensity of BASF

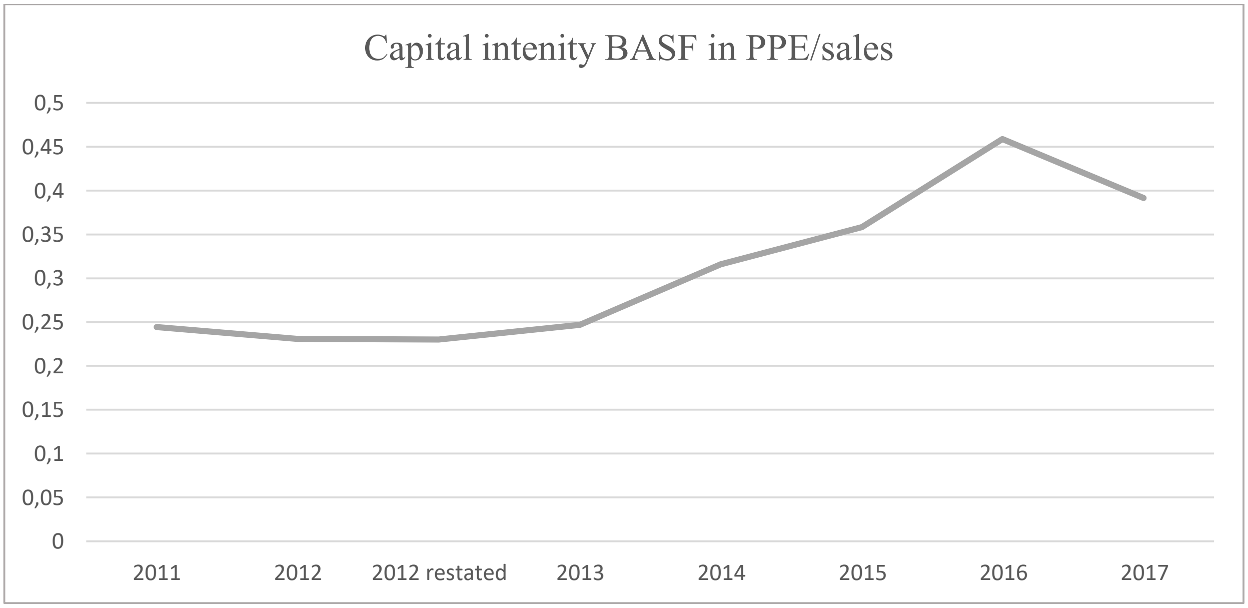


FIGURE 16

Reported emissions of Durr Group

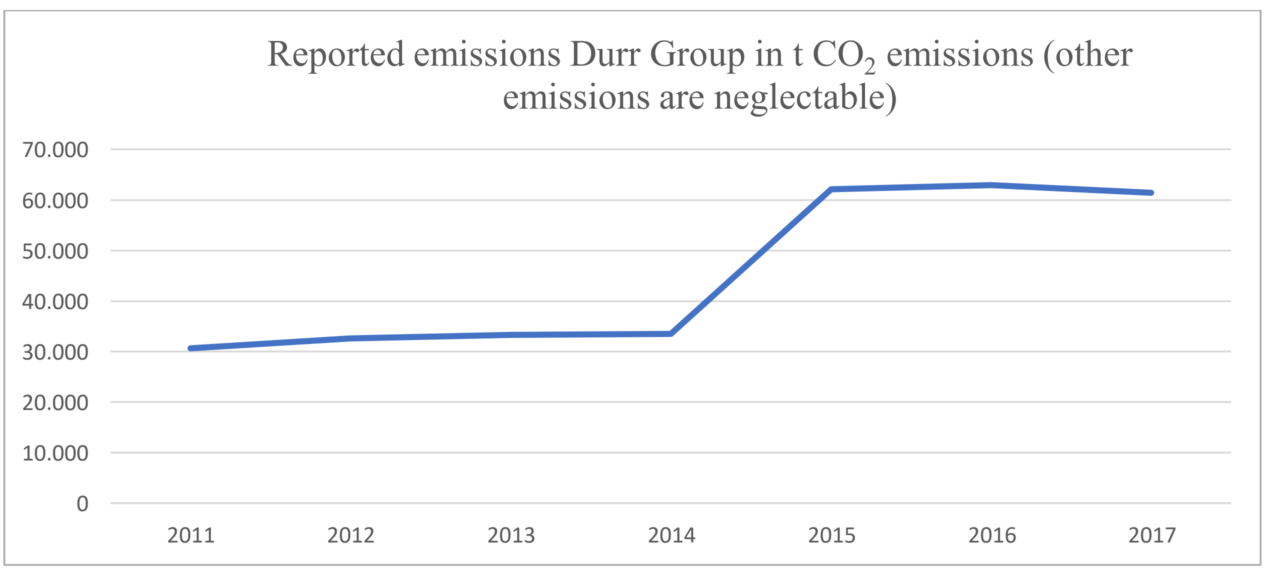


FIGURE 17

Estimated emissions of Durr Group

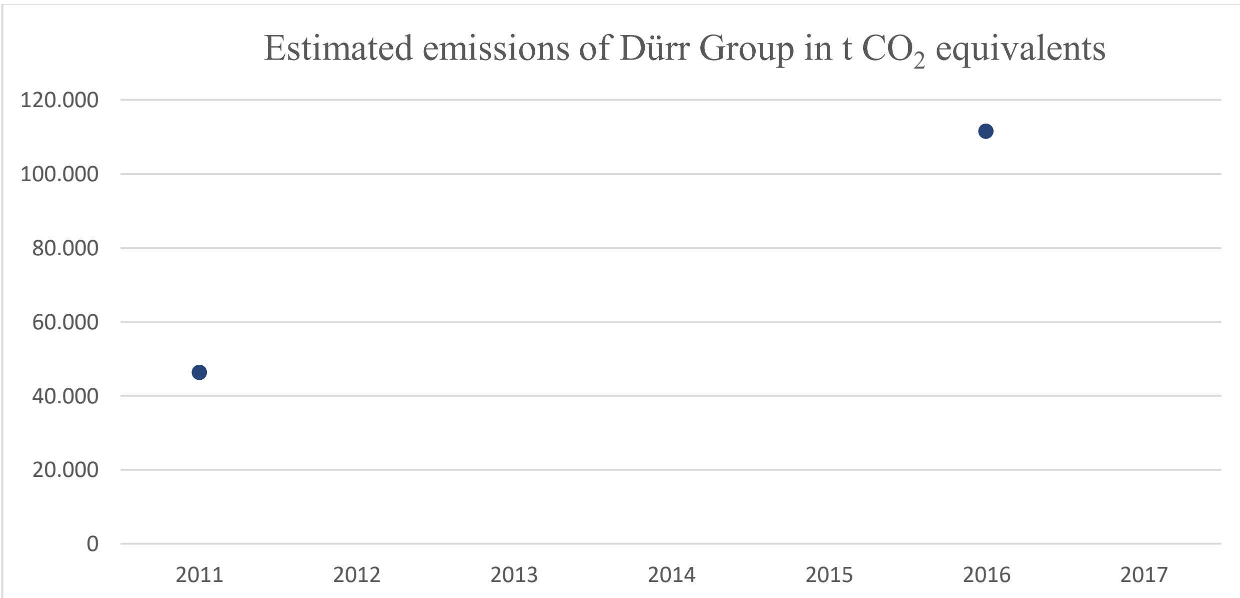


FIGURE 18

Size of Durr Group (in revenues)

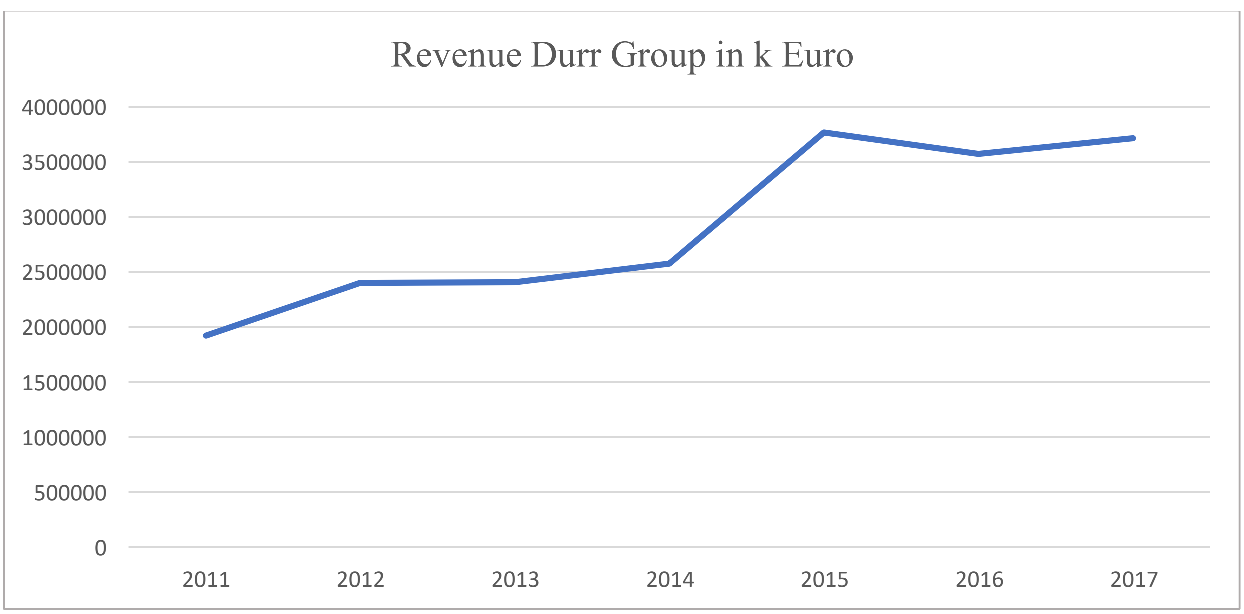


FIGURE 19

Property, plant and equipment of Durr Group

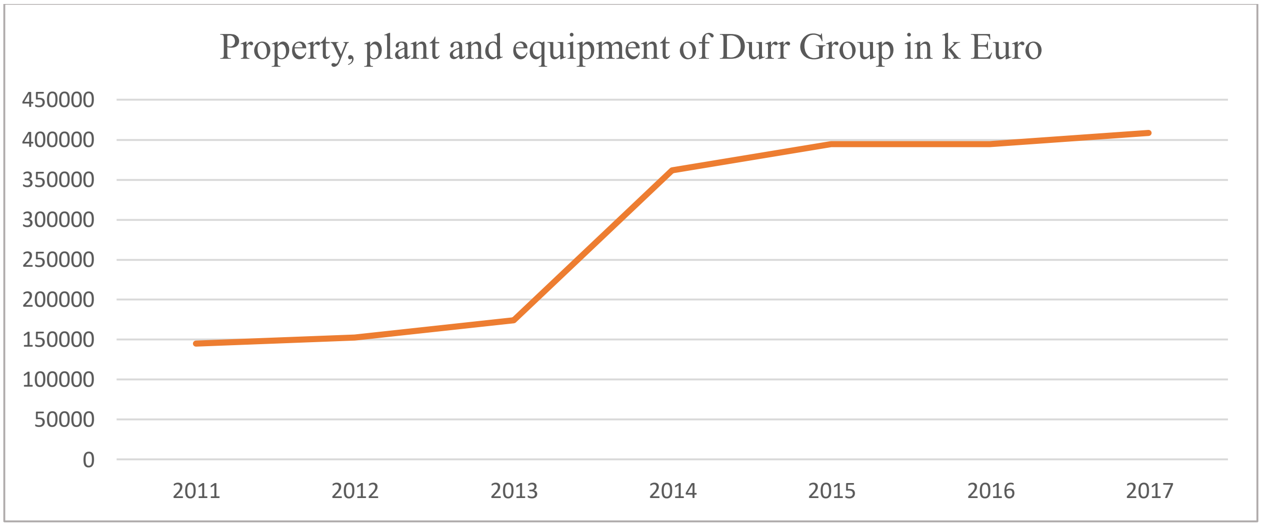


FIGURE 20

Capital intensity of Durr Group

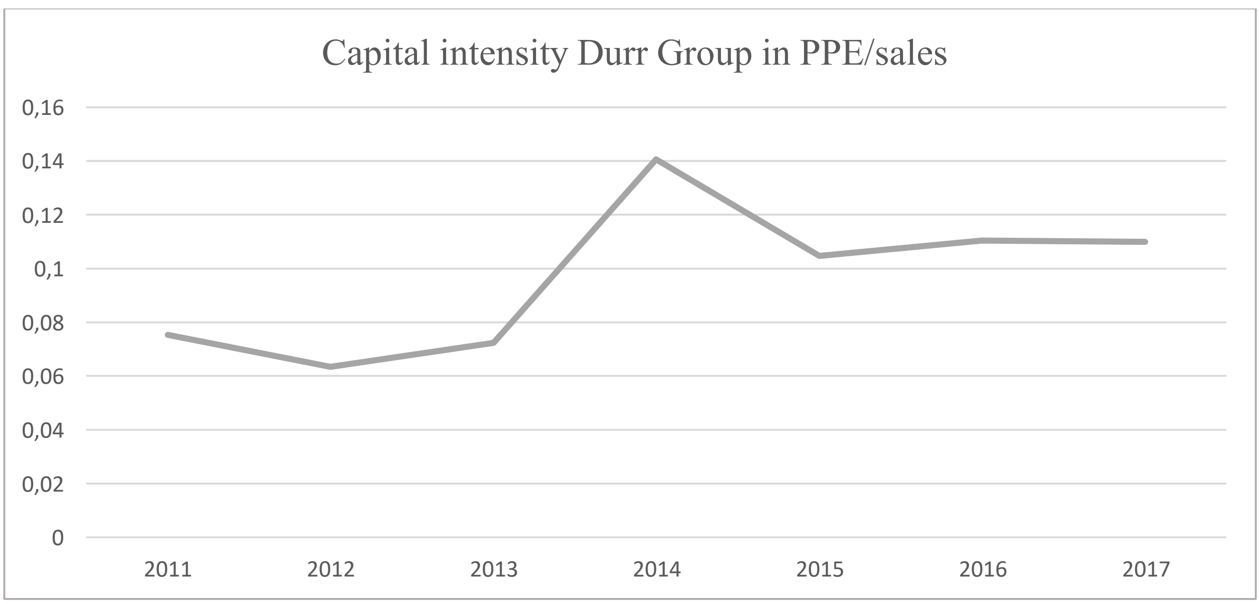


FIGURE 21

Reported emissions of Givaudan

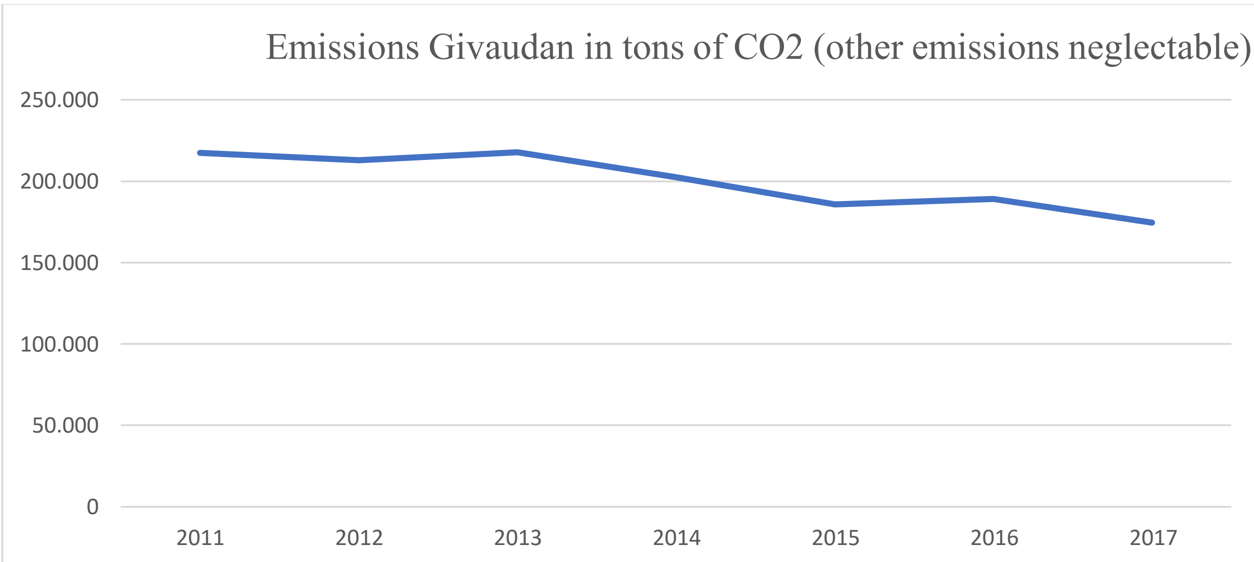


FIGURE 22

Estimated emissions of Givaudan

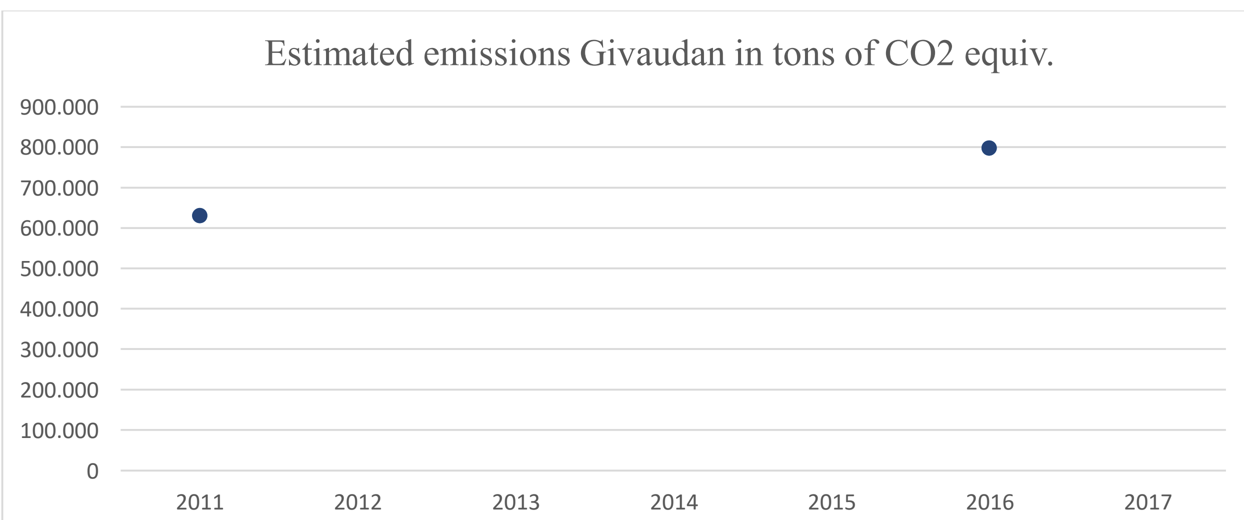


FIGURE 23

Sales of Givaudan

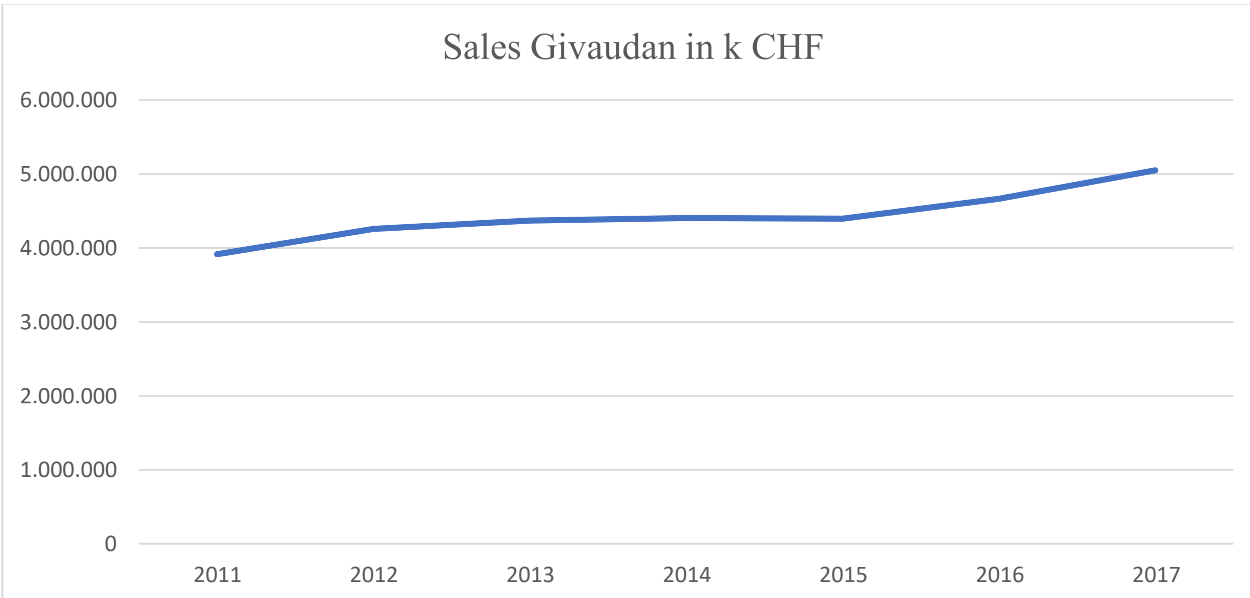


FIGURE 24

Property, plant and equipment of Givaudan

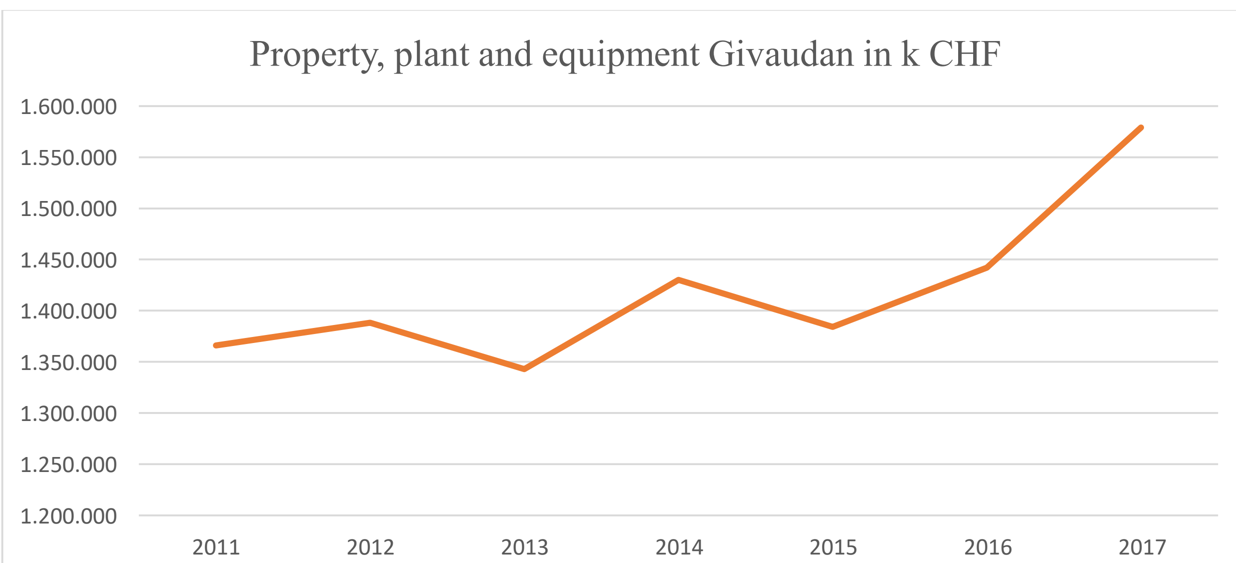


FIGURE 25

Capital intensity of Givaudan

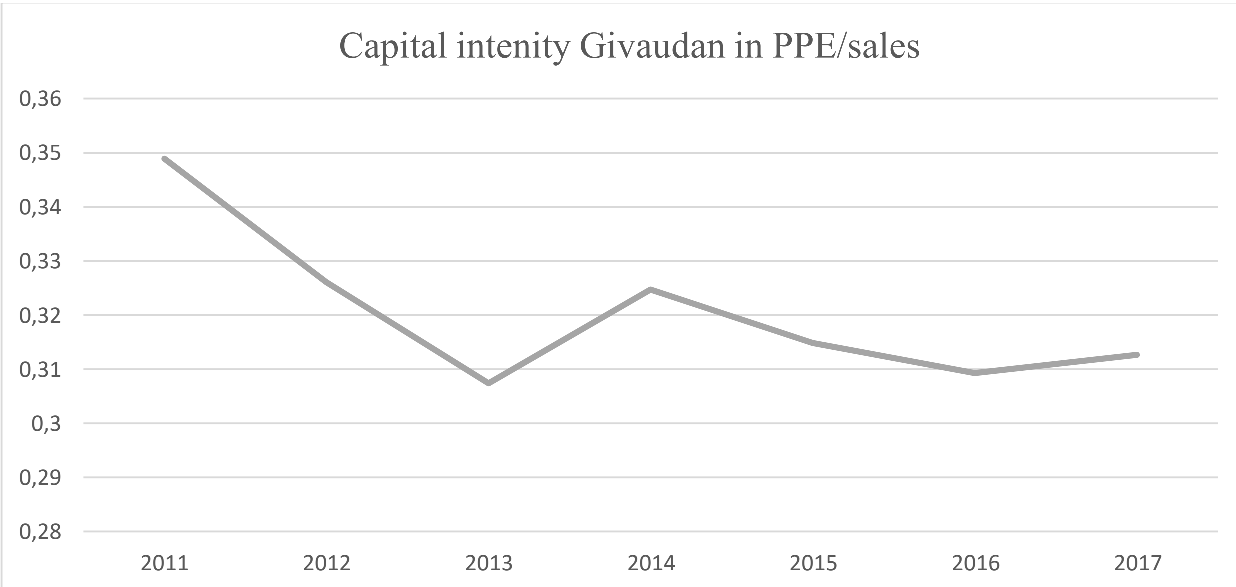


FIGURE 26

Reported emissions of Hochtief

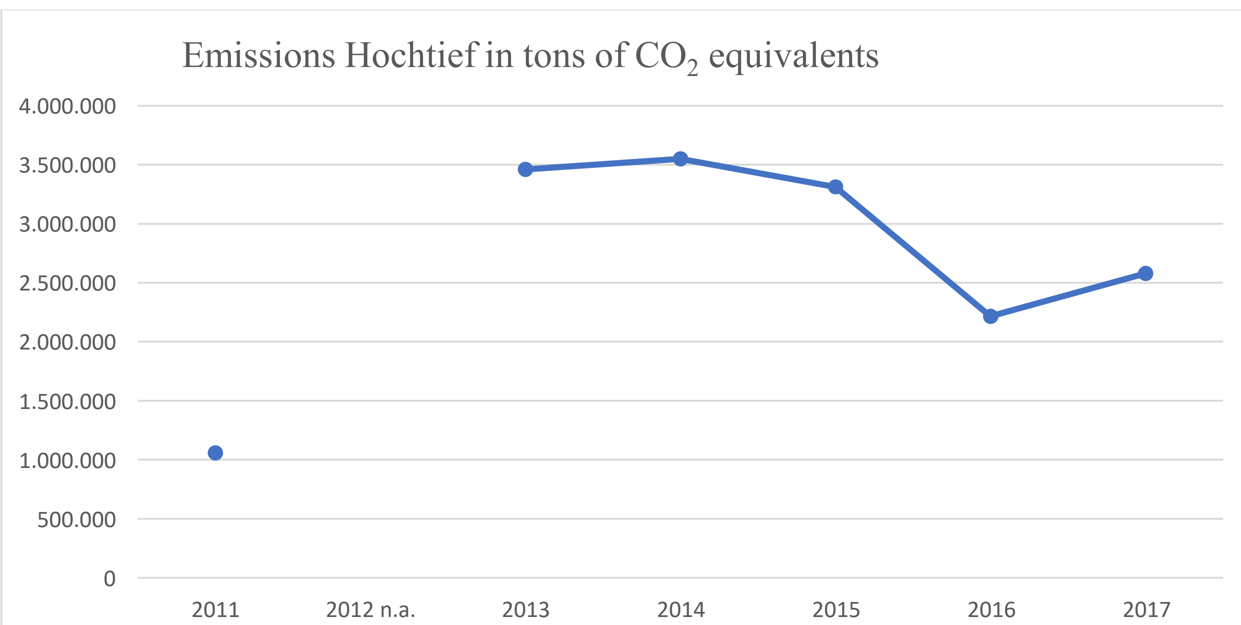


FIGURE 27

Estimated emissions of Hochtief

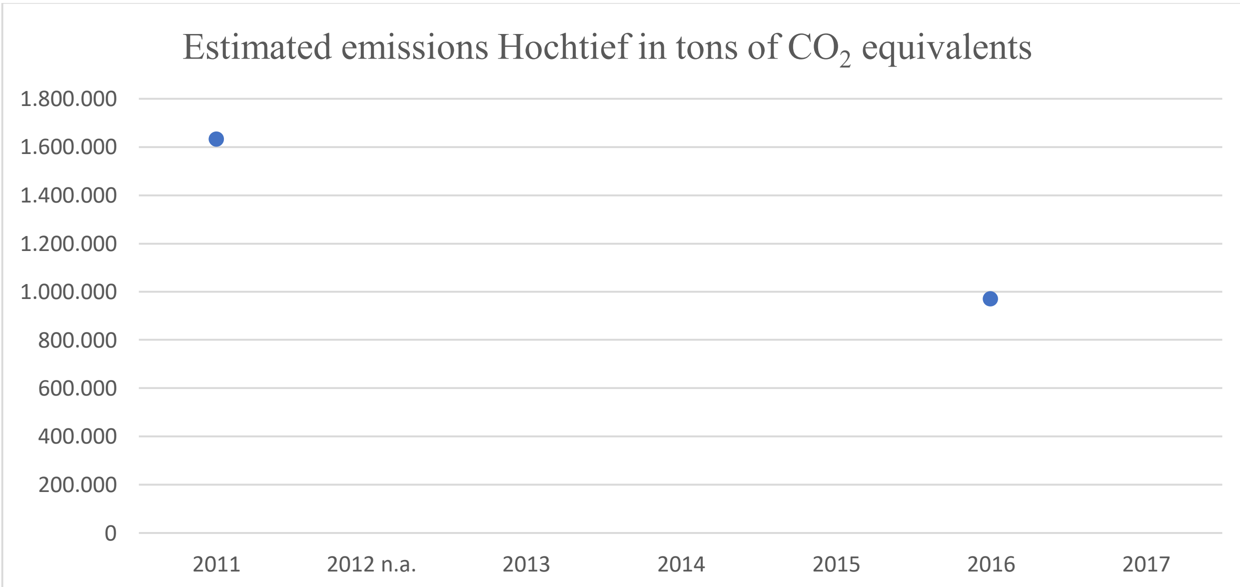


FIGURE 28

Size of Hochtief (in sales)

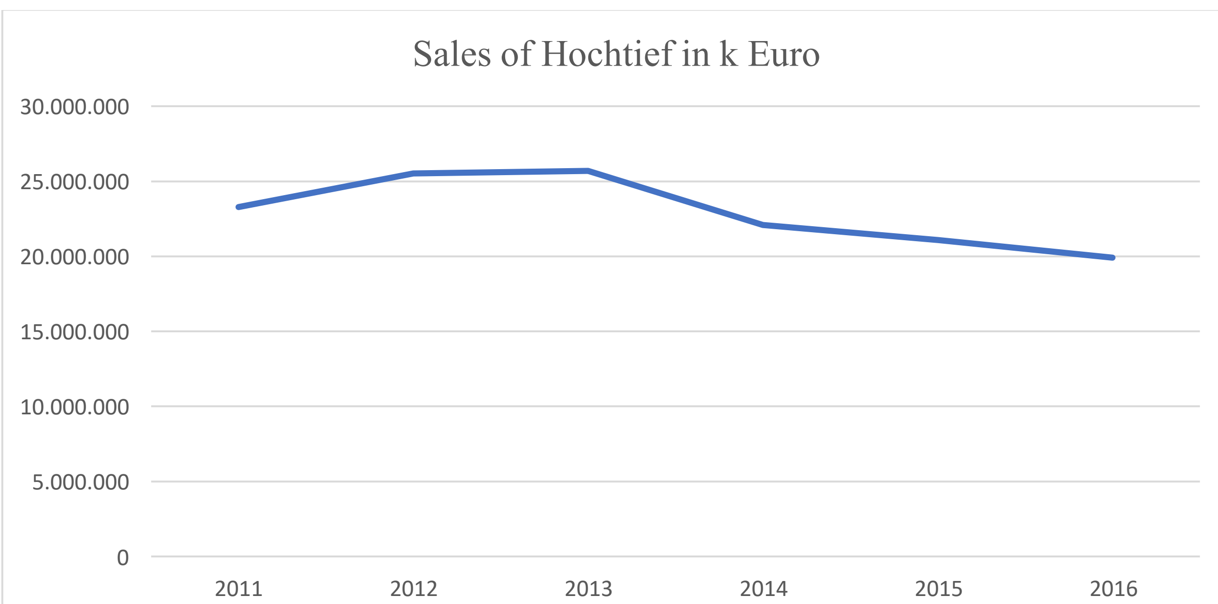


FIGURE 29

Property, plant and equipment of Hochtief

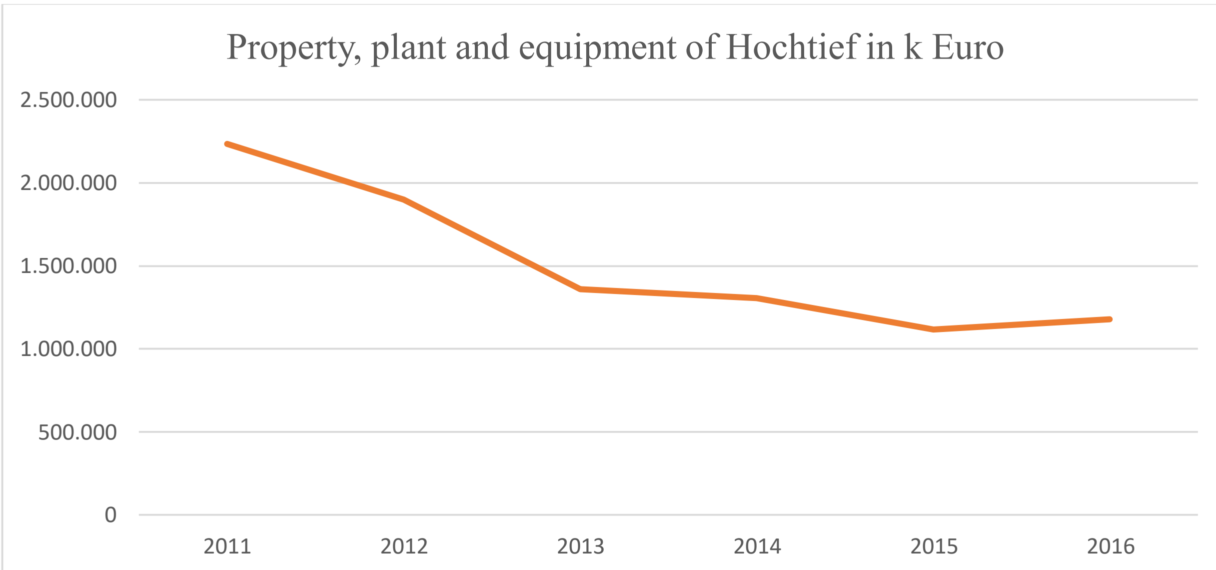


FIGURE 30

Capital intensity of Hochtief

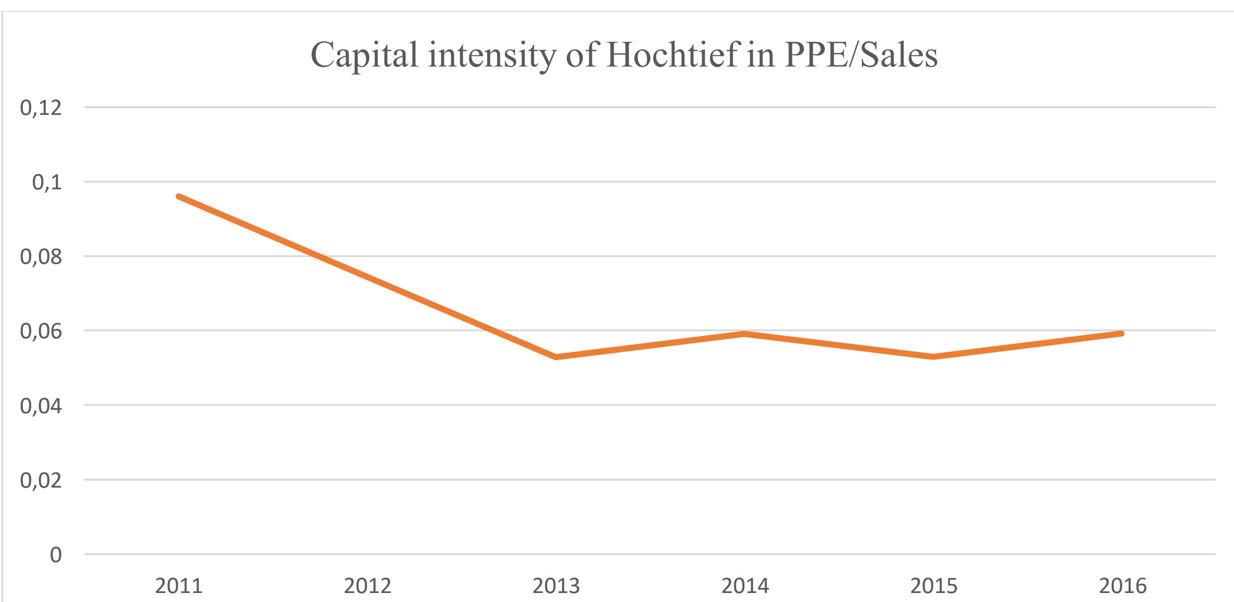
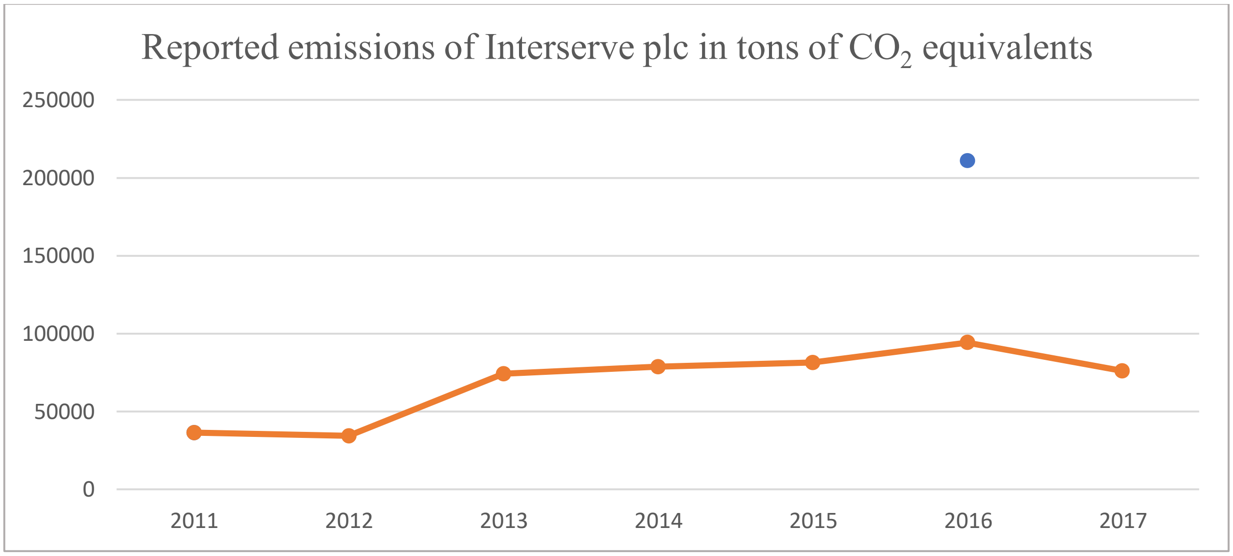


FIGURE 31

Reported emissions of Interserve plc



Note: The upper dot in 2016 represents the emissions from the CDP reporting 2017, the line the figures from the annual reports. In 2011, the dot represents both a value from the 2011 annual report and the CDP report 2012.

FIGURE 32

Estimated emissions of Interserve plc

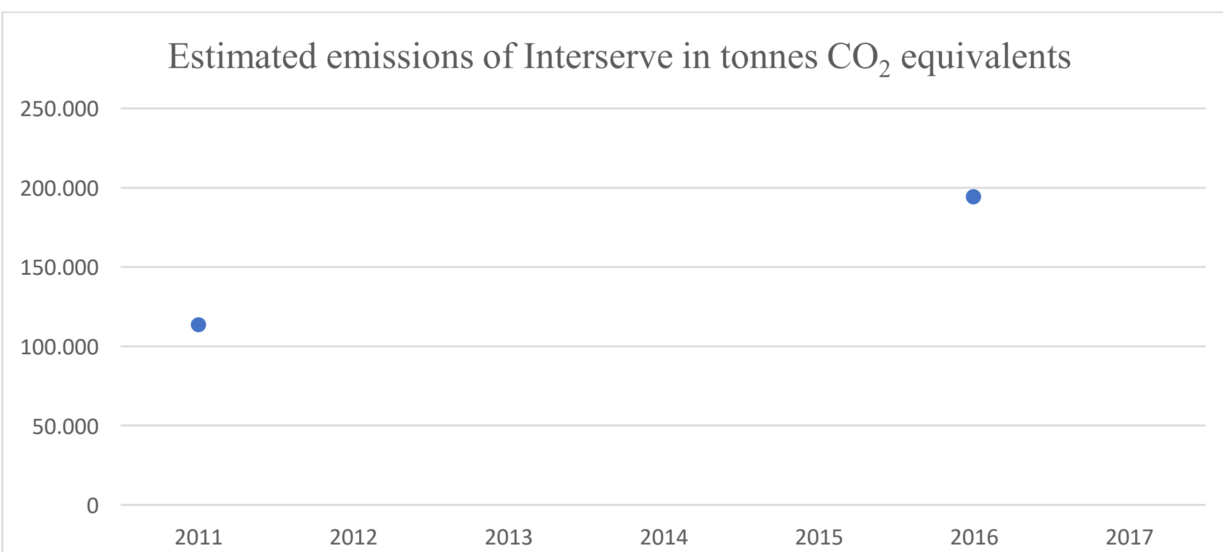


FIGURE 33

Size of Interserve plc (in revenues)

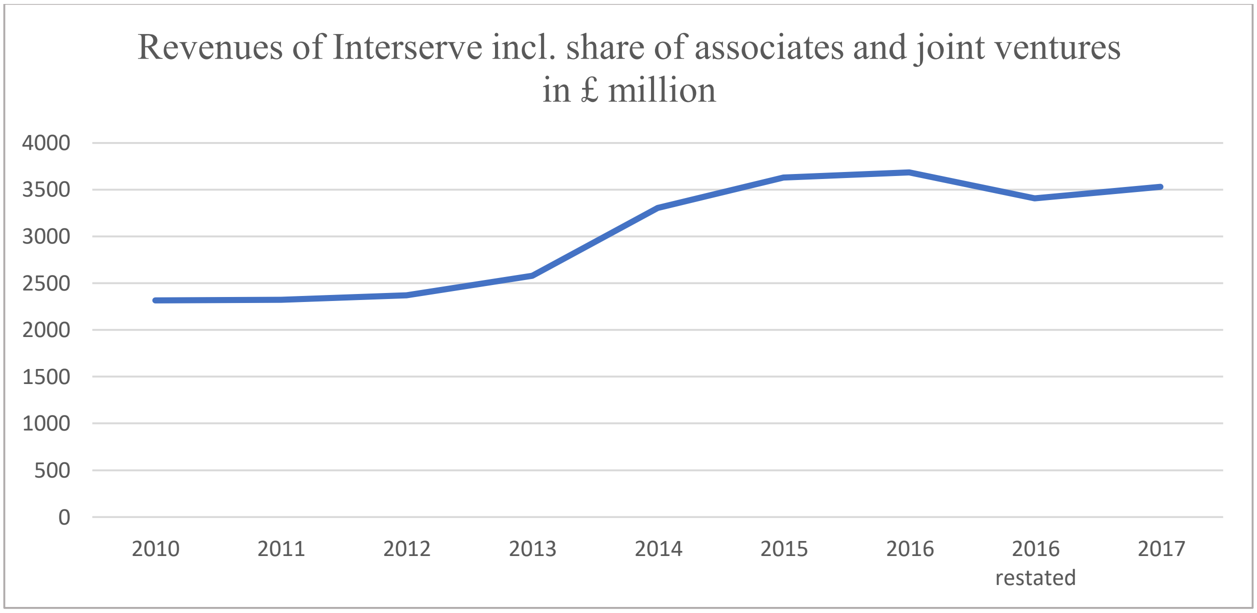


FIGURE 34

Property, plant and equipment of Interserve plc

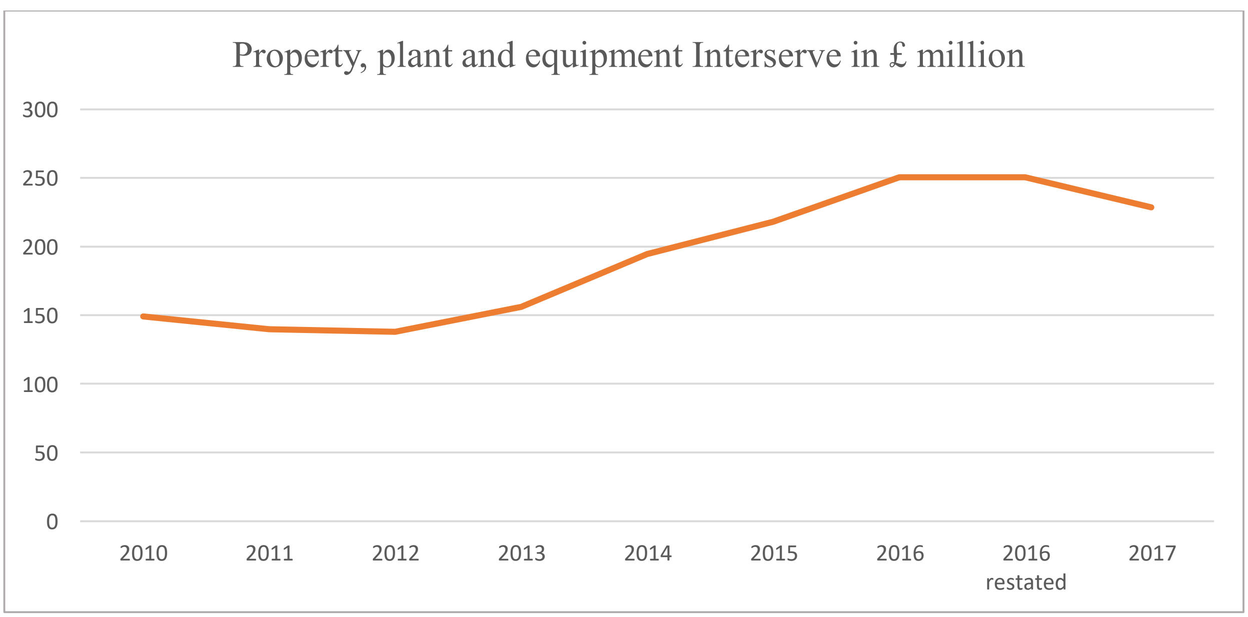


FIGURE 35

Capital intensity of Interserve plc

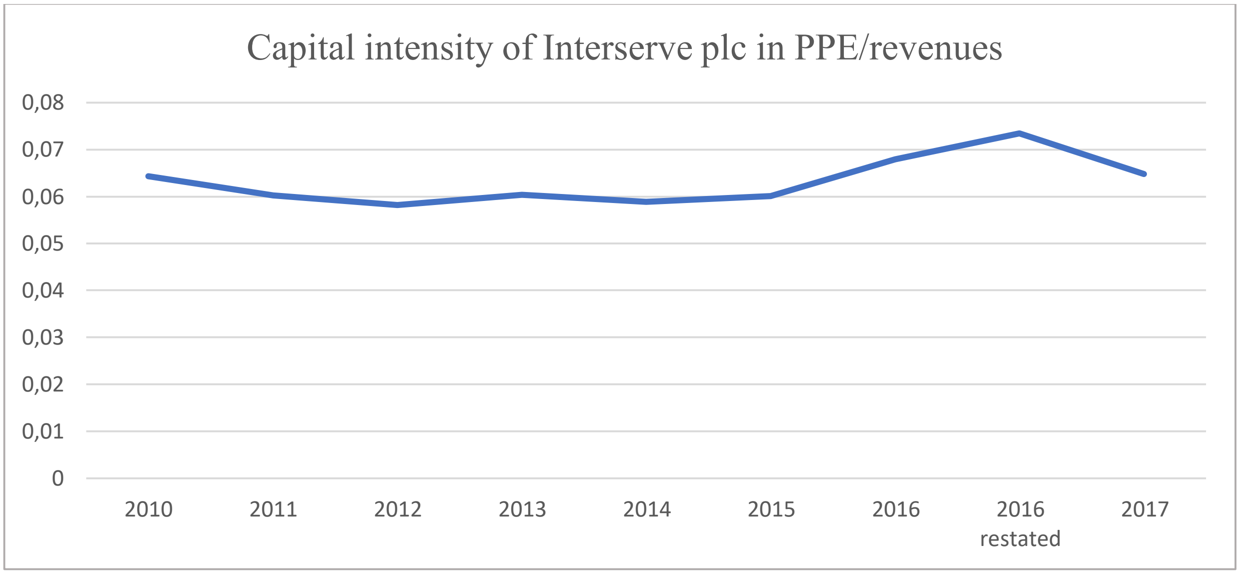


FIGURE 36

Reported emissions of Koninklijke DSM

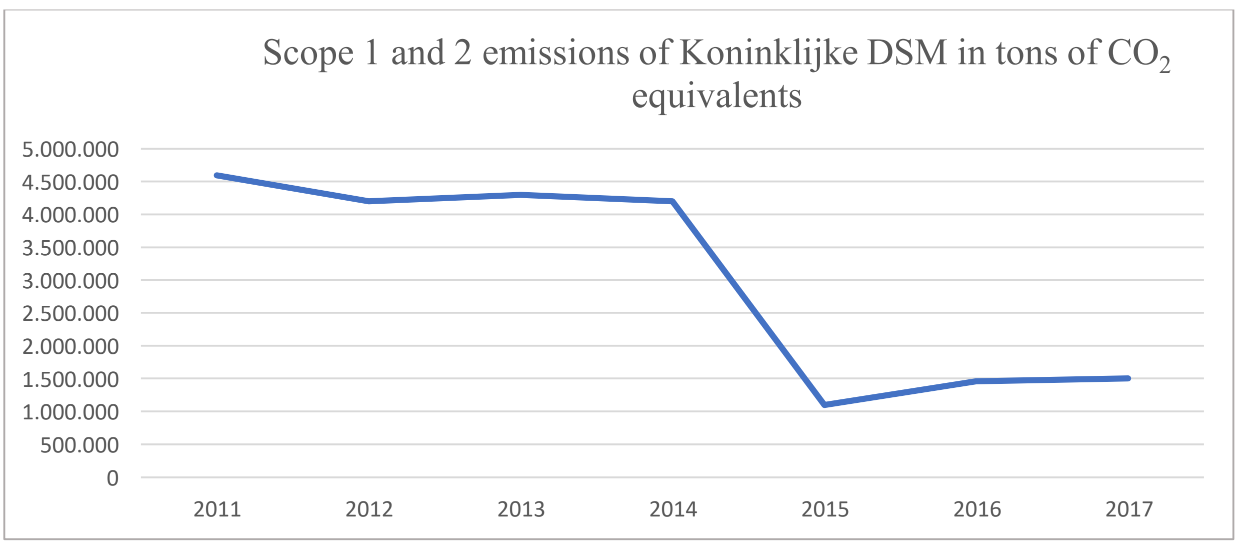


FIGURE 37

Estimated emissions of Koninklijke DSM

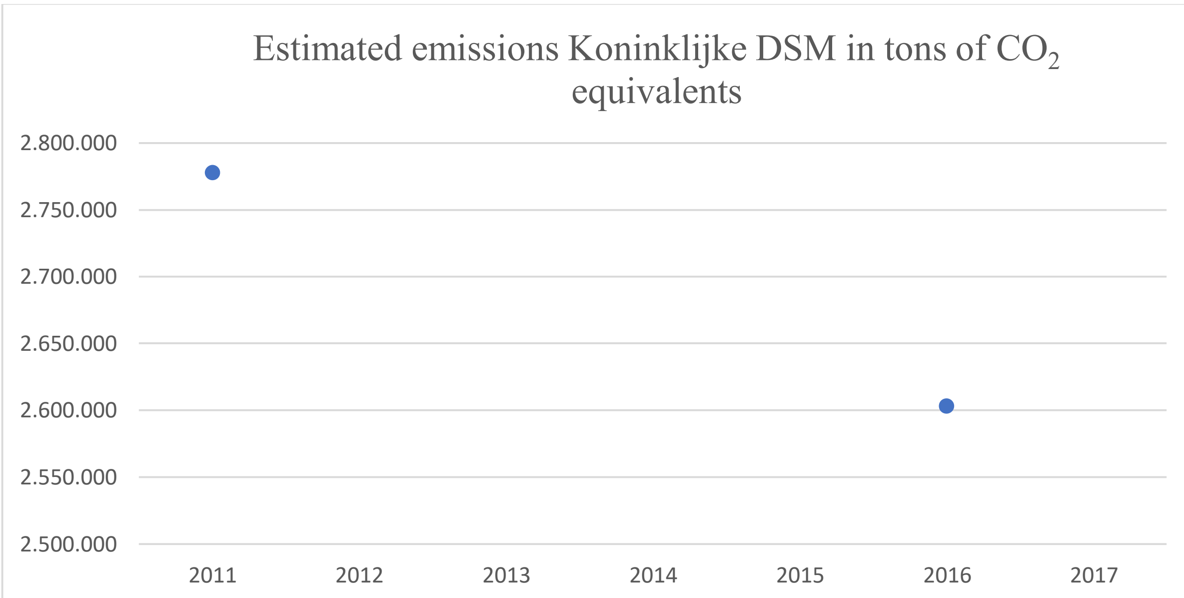


FIGURE 38

Size of Koninklijke DSM (in sales million)

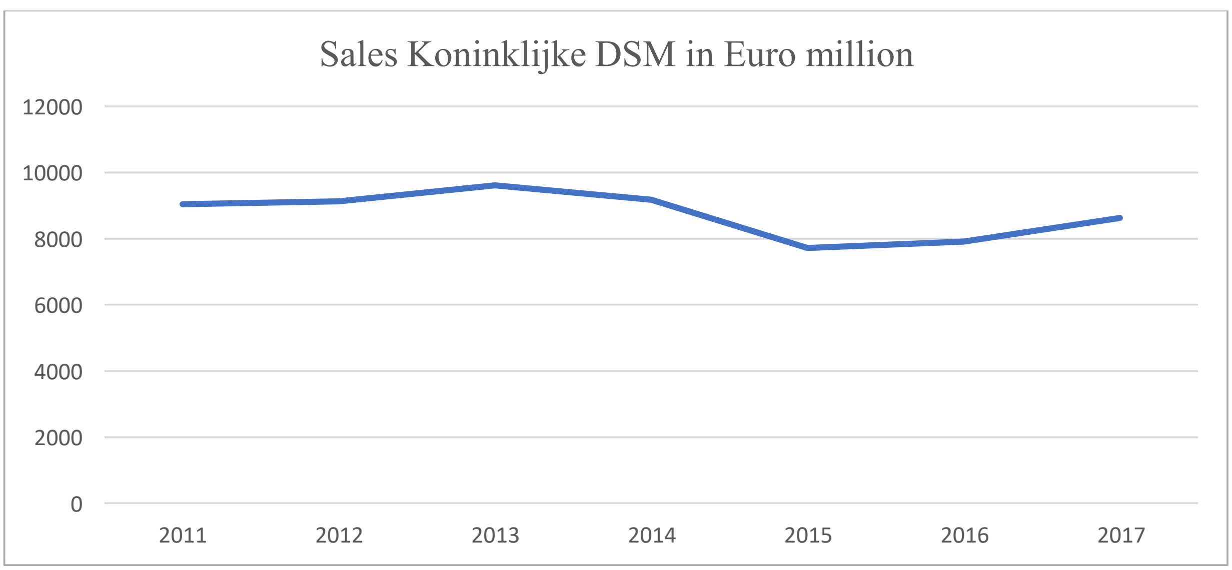


FIGURE 39

Property, plant and equipment of Koninklijke DSM

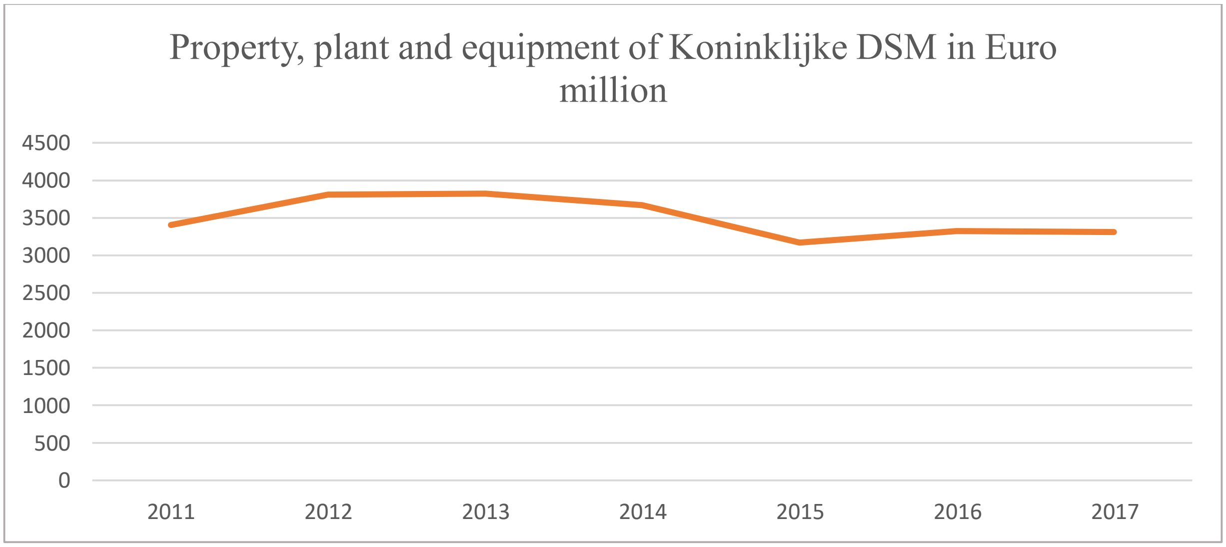


FIGURE 40

Capital intensity of Koninklijke DSM

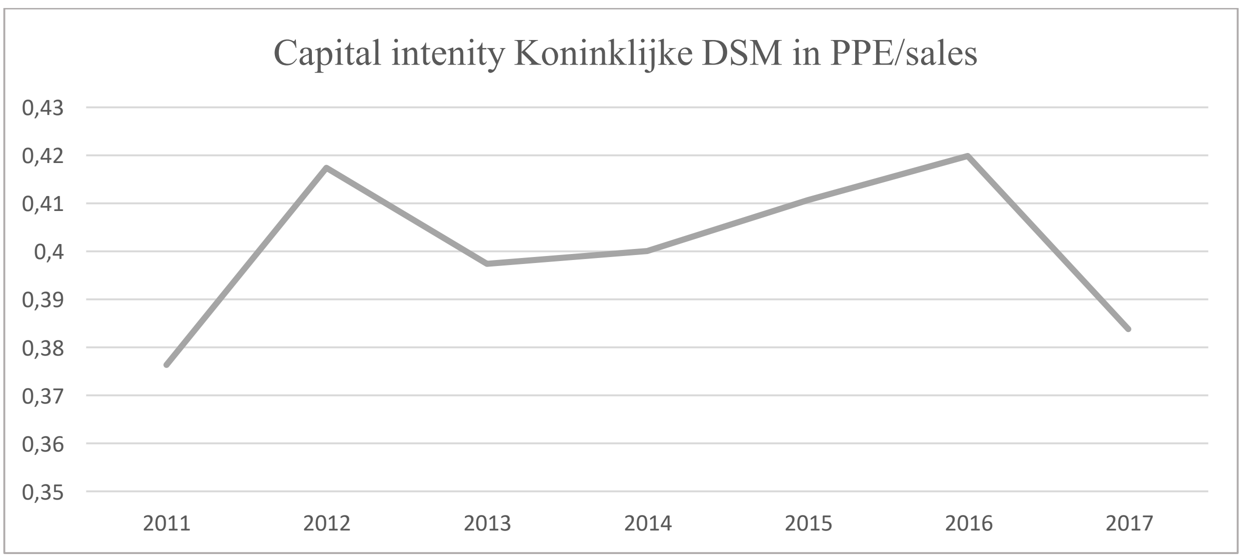
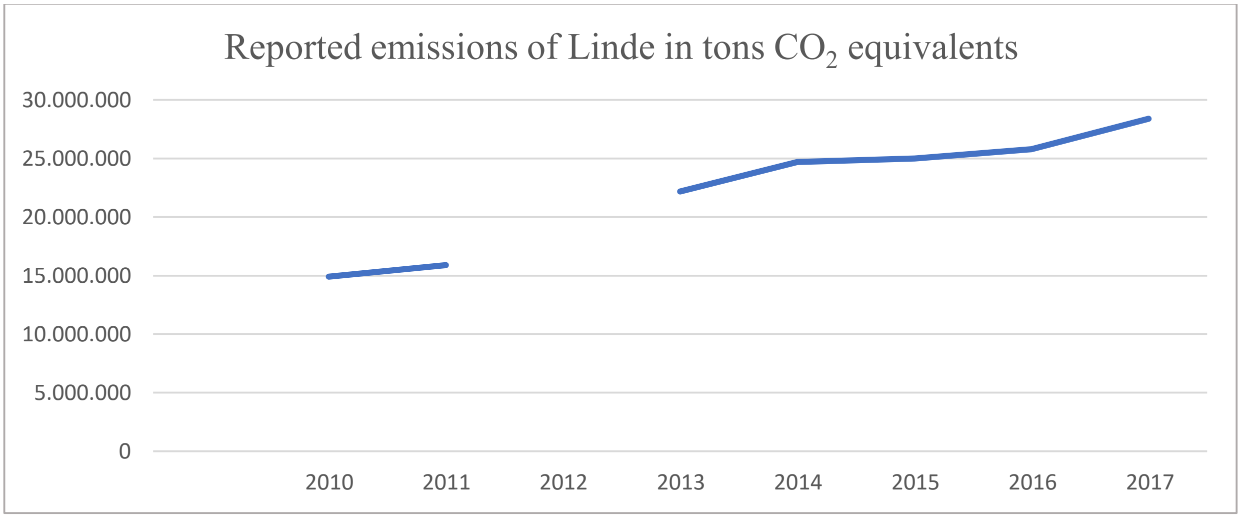


FIGURE 41

Reported emissions of Linde Group



Note: The scope 1 and 2 values of 2012 were not available as the reports of that year were unavailable.

FIGURE 42

Estimated emissions of Linde Group

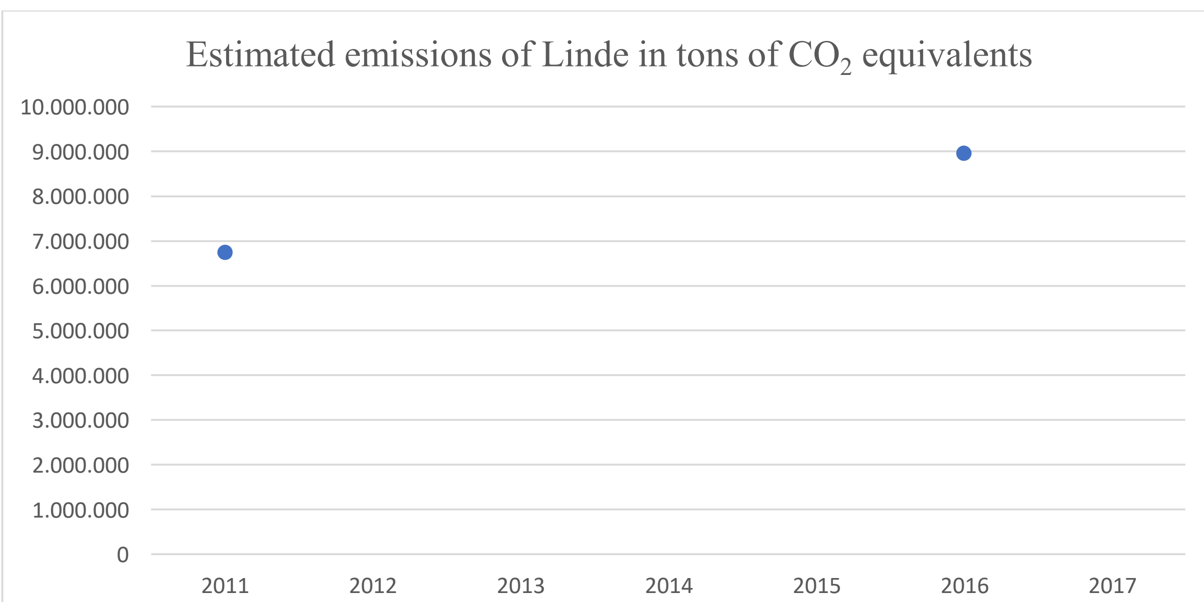


FIGURE 43

Size of Linde AG (in sales) and Linde Group (in Group revenues)

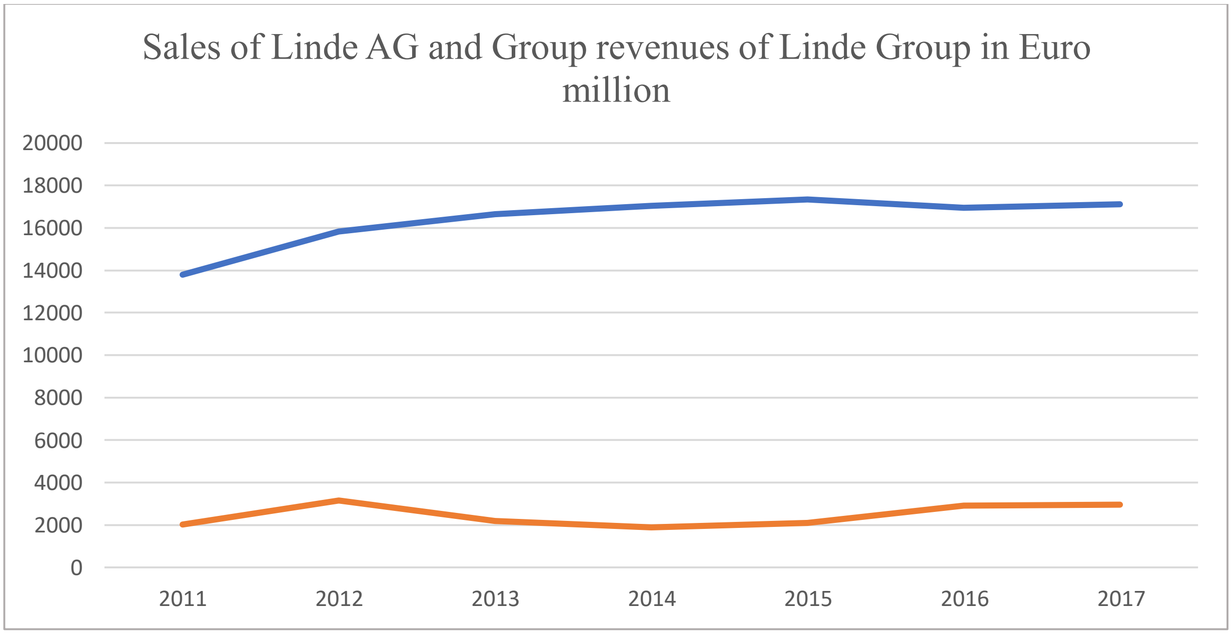
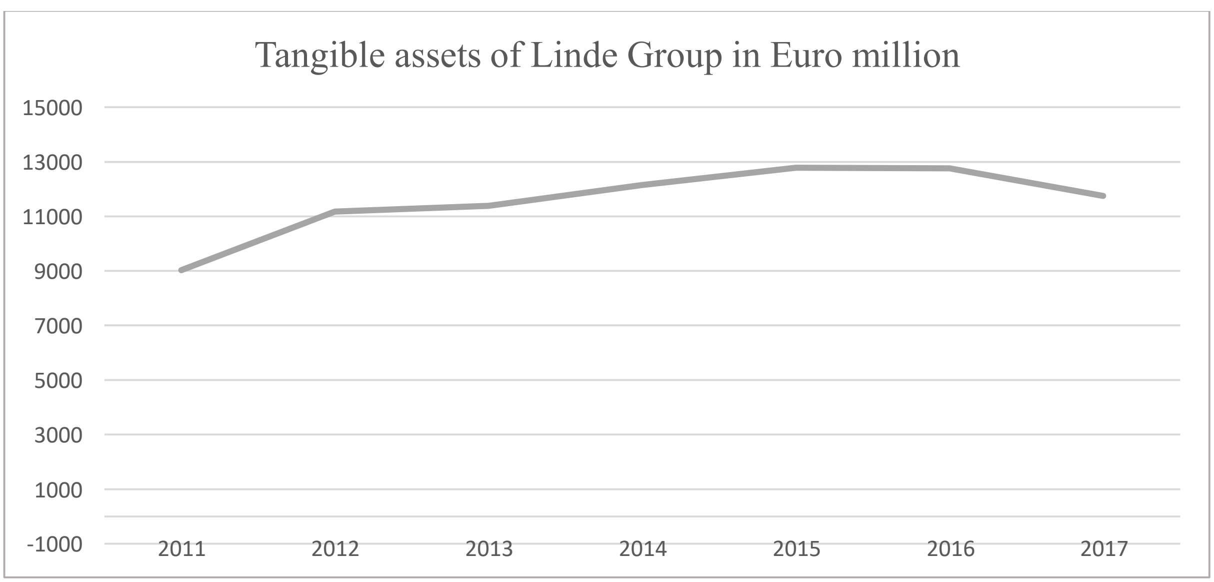


FIGURE 44

Tangible assets of Linde Group



Note: Property, plant and equipment was not available, therefore Stuwe et al. (2023) used tangible assets instead.

FIGURE 45

Capital intensity of Linde Group

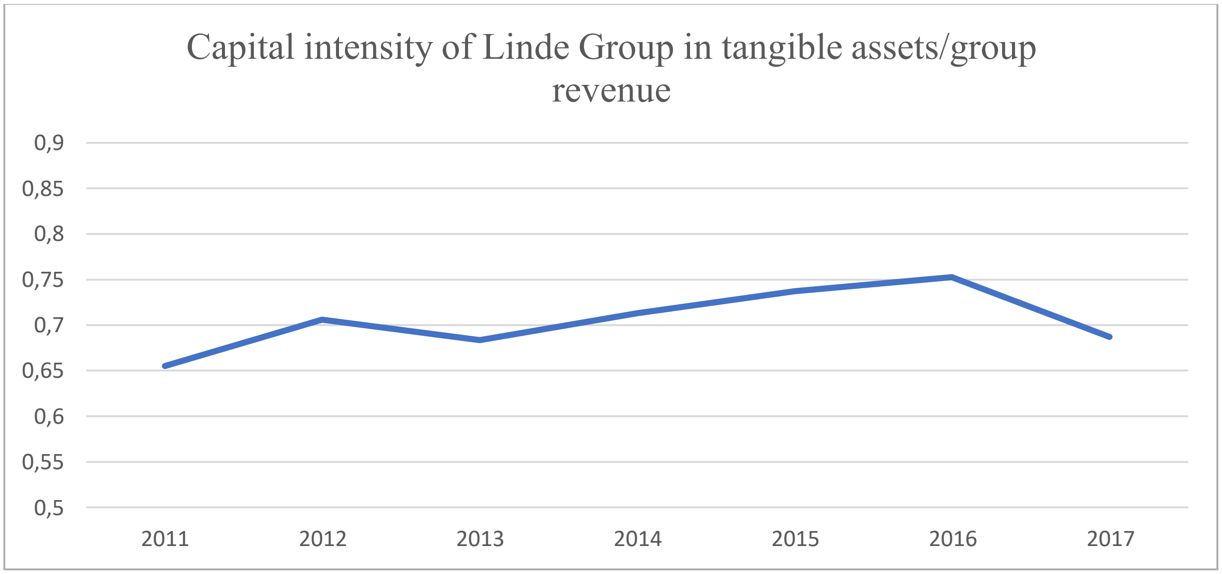


FIGURE 46

Reported emissions of Outotec

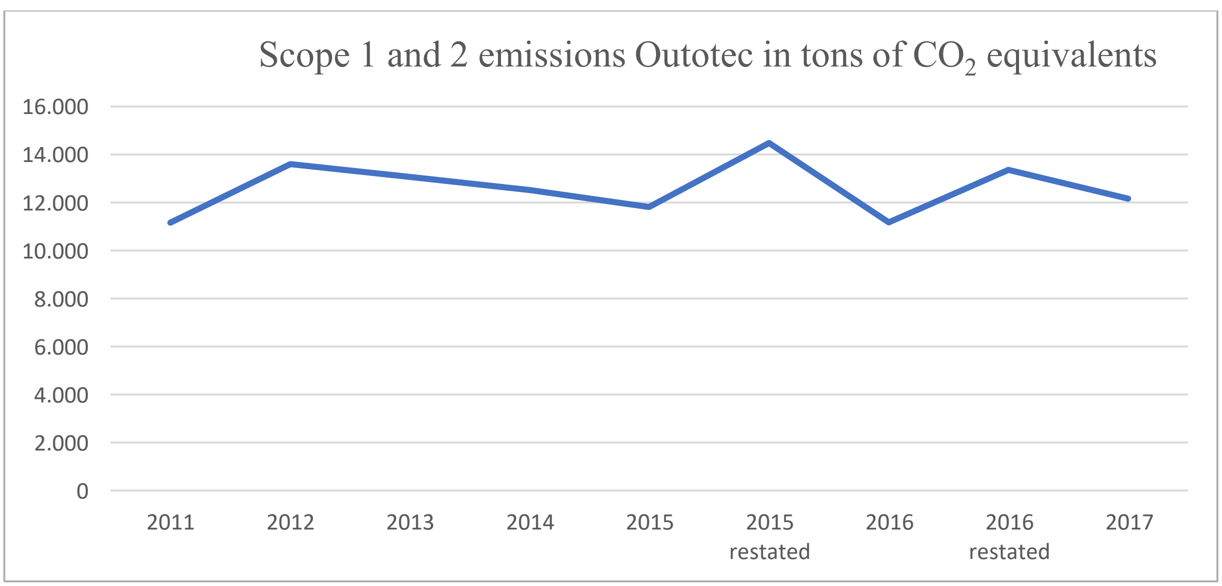


FIGURE 47

Estimated emissions of Outotec

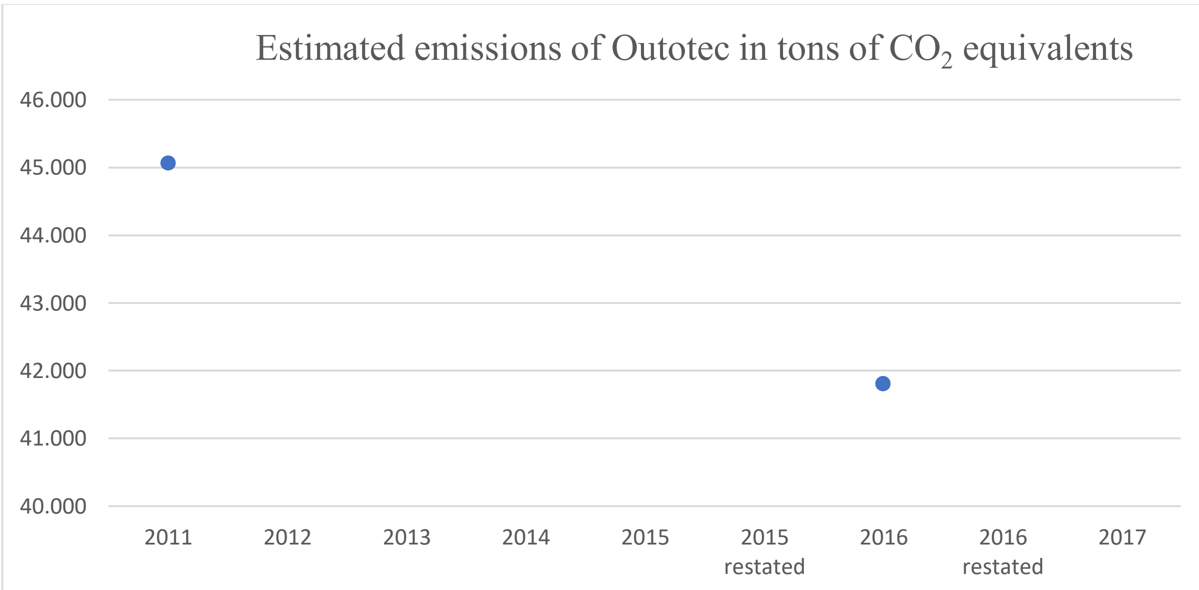


FIGURE 48

Size of Outotec (in sales)

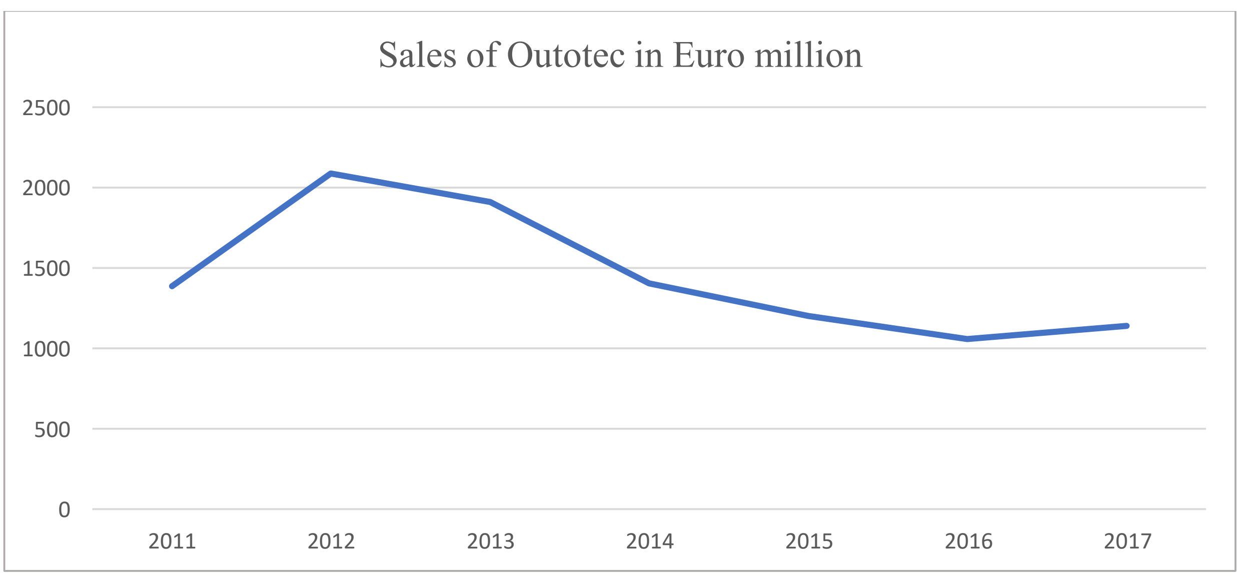


FIGURE 49

Property, plant and equipment of Outotec

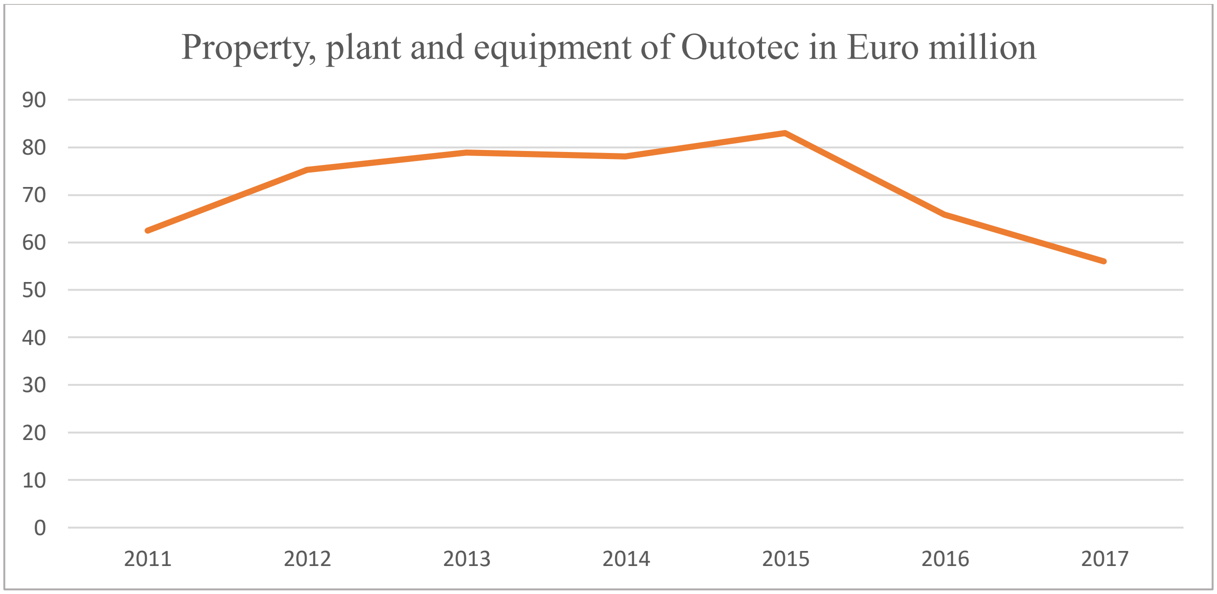


FIGURE 50

Capital intensity of Outotec

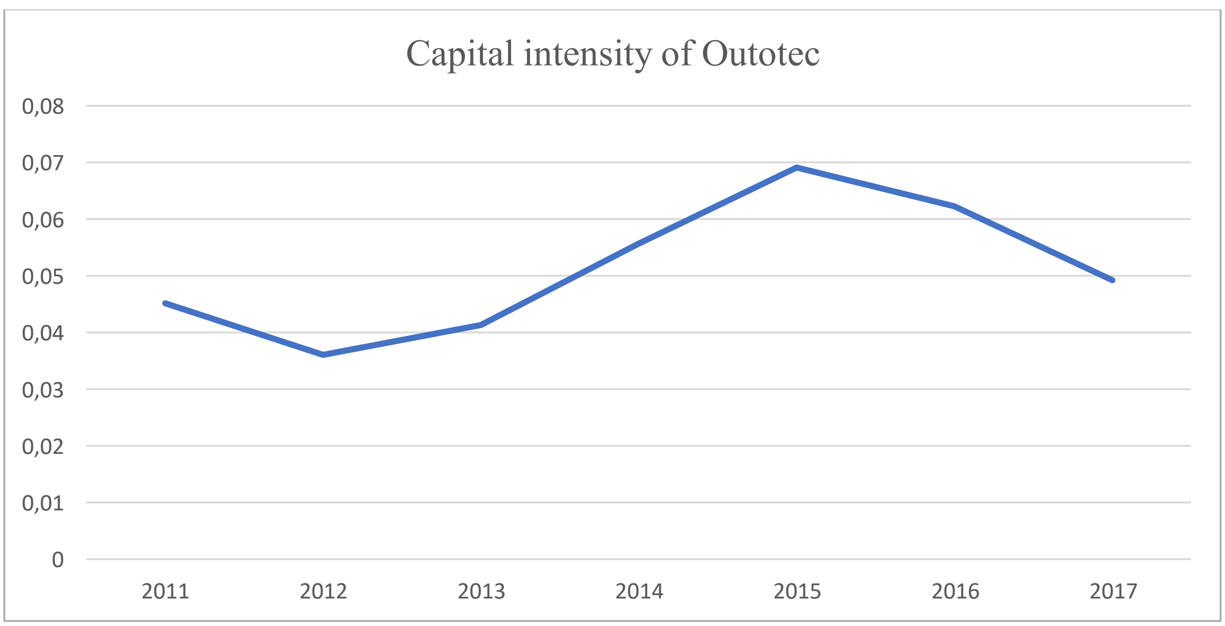


FIGURE 51

Reported emissions of Rotork plc

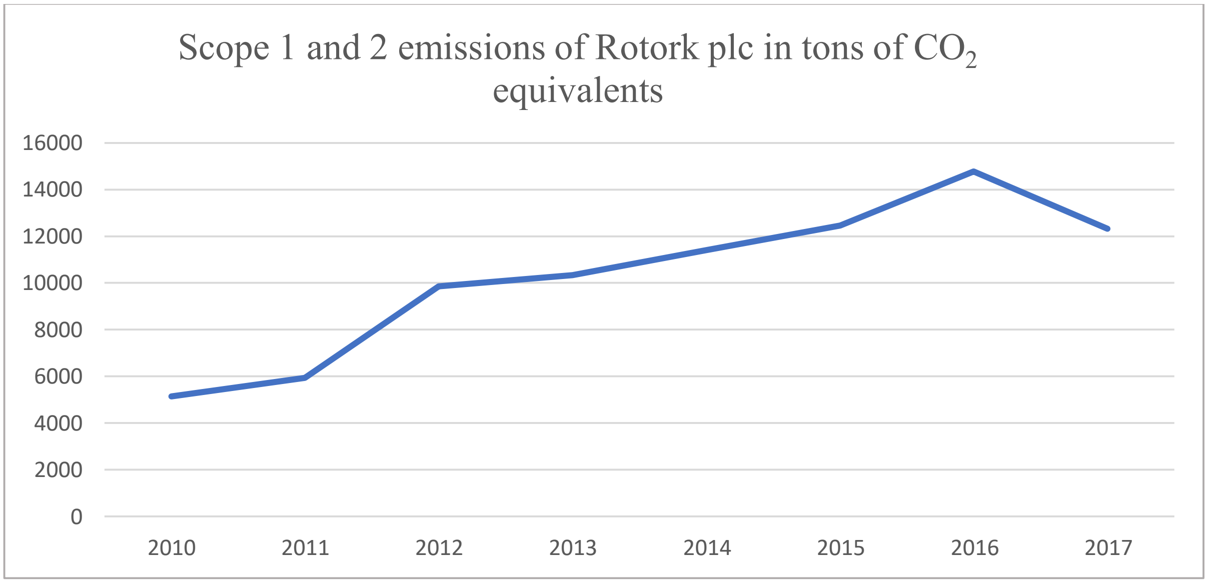


FIGURE 52

Estimated emissions of Rotork plc

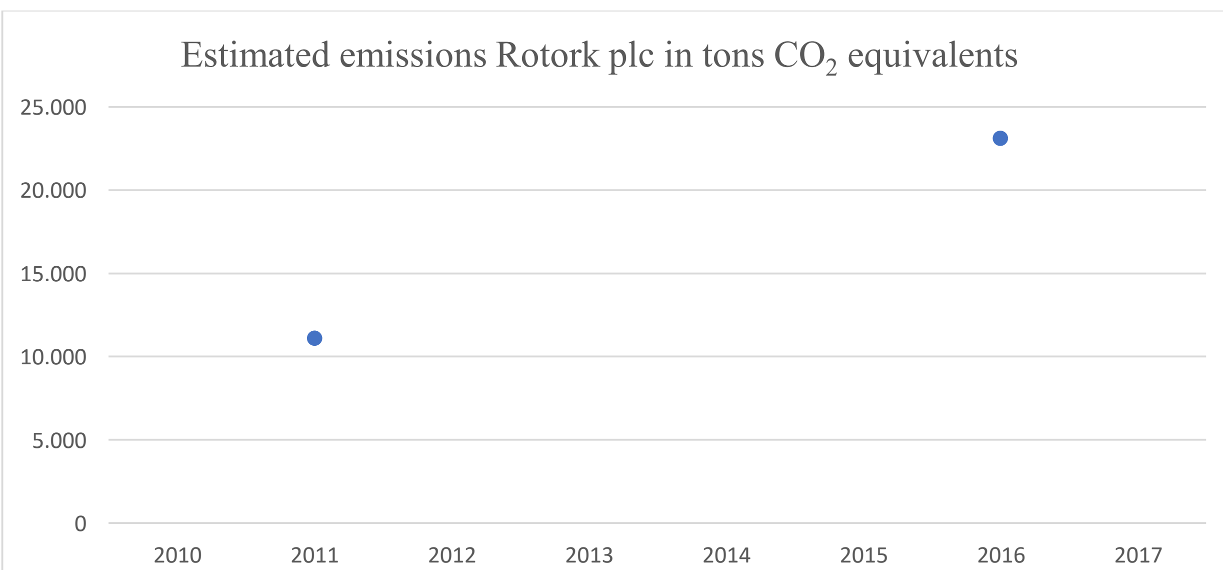


FIGURE 53

Size of Rotork plc (in revenues)

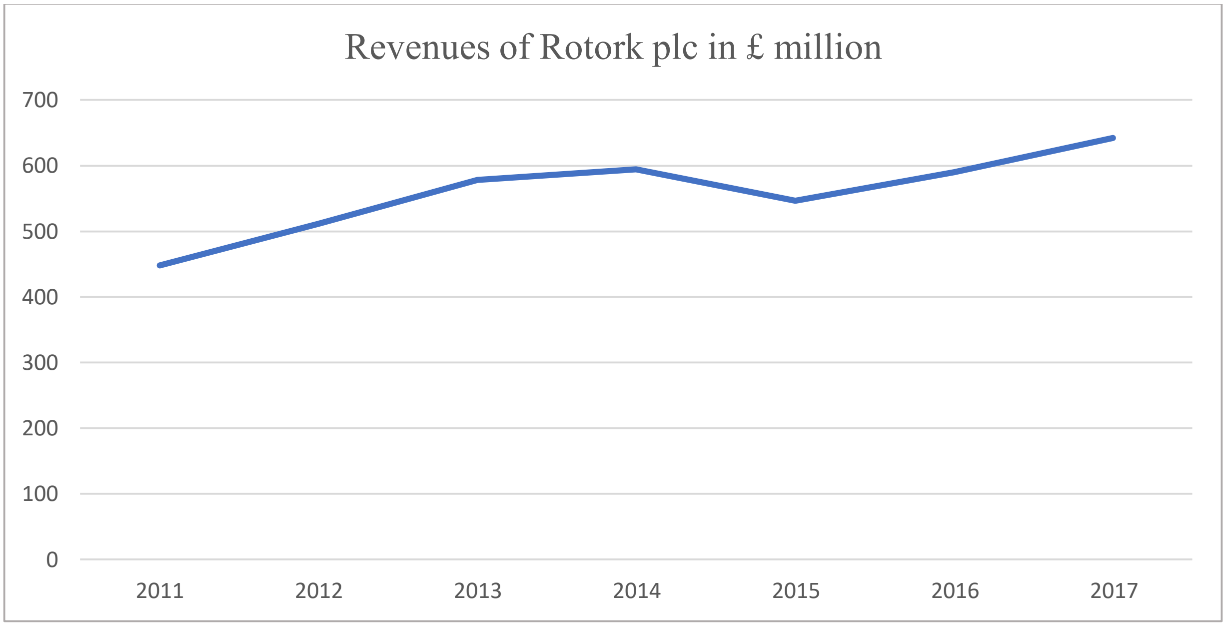


FIGURE 54

Property, plant and equipment of Rotork plc

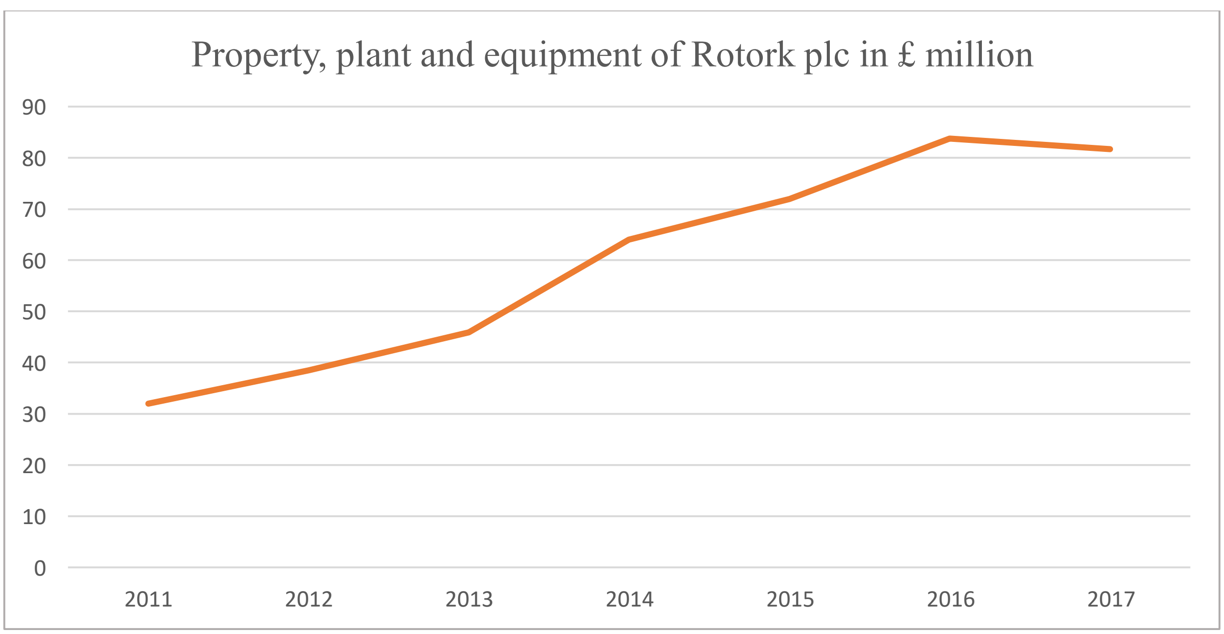


FIGURE 55

Capital intensity of Rotork plc