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Climate Change and the Decarbonization of the Steel Industry

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1. Introduction

The need to address climate change has evolved beyond environmental concerns to become one of the main socioeconomic issues in the context of today's global difficulties. This dissertation offers a thorough investigation of the complex relationships between industry dynamics, climate change, and proactive steps to steer industries toward a sustainable, low-carbon future.

Through the academic research and the practical knowledge collected at BCG, I will present a multifaceted understanding of the complex relationship between climate change, industrial emissions, and policy interventions.

In my internship report, I will walk you through my internship at BCG, examining what I did there, what I learned, what challenges I faced, and how this experience has defined my future career plans.

On the other hand, in the section dedicated to the academic research, I will integrate the particularities of the steel industry with the larger context of international efforts to combat climate change.

I will start by analyzing climate change, its origins, and potential economic effects and then move to the landmark Paris Agreement, which currently represents the main effort done to address climate change at the international level. Then, I will shift my focus to the steel industry, which plays a very important role in the economy as well as being a significant source of CO2 emissions. We will briefly explore the strategies that can push a transition to carbon neutrality, also drawing on knowledge I obtained from my internship at BCG, which gave me a unique perspective and helped me fully grasp the difficulties associated with decarbonization in the steel industry. Additionally, we will see how regulatory policies and financial incentives play a crucial role in guiding industries toward reducing emissions and how the EU has emerged as a leader in taking actions to reduce climate change and encouraging decarbonization.

During the later part of the academic research, we will analyze some of these policies, emphasizing their role in influencing the industry's transition to sustainable practices, especially for the steel industry.

To conclude, this dissertation illustrates the connection between academic study and actual practice to provide a comprehensive viewpoint of an extremely urgent and actual problem, climate change, offering at the same time a unique perspective based on my direct involvement and exposure to this issue at BCG.

2. Internship Report

Since March 15, 2023, I have been an intern at The Boston Consulting Group (BCG), a global management consulting firm, in its Milan office. The internship should last 6 months, but since interns don't work in August, it will last until mid-October.

It was an exciting experience from the get-go, entering such a prestigious and competitive firm was intimidating at first, but unlocked a lot of potential that I didn't know I had.

I think that if there was one thing I could take away from this experience, it would be that you have to constantly challenge yourself because you might be underestimating what you could be capable of. And BCG does a perfect job of pushing you to your limits, to go beyond. In fact, the company's motto is "Beyond is where we begin", and over the past 6 months, I have definitely embraced it.

2.1 Overview of BCG

The Boston Consulting Group (BCG) is a global leader in management consulting. For more than 60 years, it has helped the management of businesses in every industry identify and jointly realize factors that contribute to significant, tangible, and enduring results.

Bruce Henderson started the business in Boston in 1963, and the firm currently has more than 100 offices in over 50 countries and a staggering 30,000 employees, generating close to 12 B$ in annual revenues[1]. Since the beginning of his endeavor, Bruce Henderson recognized that this was likely to be a people's business because, unlike traditional businesses, consulting services are only offered by people, and the quality of the service is a result of the quality of the people. Bruce Henderson was extremely determined to create a company that would solve the next most complex business challenges and implement what was beginning to be called "Strategy", and to do so, he wanted to create a culture that could empower its employees to excel[2]. That is also the reason he chose to call the firm Boston Consulting Group rather than using his last name, unlike many other businesses. He wanted to shift the attention from himself to its people, making them feel part of a bigger picture.

[1] About BCG. BCG Global.
[2] Bürkner, H.-P., & Lesser, R.. The history of Boston Consulting Group. BCG Global.

After opening the Boston office, the next one was opened in Tokyo, which represented a big new challenge for the firm, also from a cultural point of view.

The firm works alongside a wide spectrum of clients, from businesses to non-profit organizations and lately, also governments, in order to tackle issues that span from new growth strategies to operational improvements, digital transformations, organizational design, due diligence, and more.

The firm is organized into vertical practices and horizontal practices (also called functional practices). Vertical practices are practices dedicated exclusively to a specific sector, such as consumer goods, financial services, healthcare, energy, technology, industrial goods, and others. These practices consist of consultants with specialized sector expertise and experience. On the other hand, horizontal practices are practices dedicated to a specific function that is executed in an array of sectors, such as PIPE (Principal Investors and Private Equity), Operations, Climate change and sustainability, and others. These practices have deep function knowledge which can deploy to multiple industries.

BCG's Milan Office, situated in the heart of Milan, in front of the Duomo, is the leading consulting partner for companies working in the industrial goods sector in Italy.

More precisely, within the Milan Office, the Industrial Goods practice focuses on supporting clients in the industrial sector, including manufacturing, machinery, automotive, aerospace, and more. BCG has a history of understanding the unique challenges and opportunities that companies in this sector face, and partners with them to navigate complexities and achieve sustainable growth.

2.1 Why Consulting

Coming from a quantitative and financial background, going into management consulting might not seem like the natural career path.

Before joining BCG, during the summer of 2022, I interned at Oxy Capital, a Private Equity firm specializing in investing in overleveraged firms. They acquire majority stakes in these companies, restructure their financial debt and launch a turnaround plan to bring the firm back to profitability, and then make an exit[3].

At the job, I would say that my tasks fall into two categories: the one related to investing activities and the one related to portfolio management, which was very relevant for the success of the investments executed since the firm needs to implement a strategic plan to rescue the company. This 360-degree exposure was very insightful and pivotal to my decision to, later on, join a management consulting firm.

At the fund, the tasks that fell within the investment activities bucket ranged from creating a company profile presentation of potentially attractive investment opportunities to working on an information memorandum as well as building LBO models to value a company and assess the attractiveness of the IRR and MoM forecasted. On the other hand, the tasks that fell into the portfolio management activities, involved strategic plan preparation, frequent calls with the management team, and monitoring of the financial performance of the companies owned, also comparing the actual figures to the budget.

It was very interesting to go beyond the LBO and financial model of a company and actually be involved hands-on in its daily operations, it made the investments and the impact of the firm more tangible. Because at the end of the day, these over-leveraged companies, without the involvement of the fund, would have gone bankrupt and hundreds of people would have lost their job. This would also have resulted in a strong negative impact on the community built around that company.

During the internship, learning about firms and getting involved in their turnaround really inspired me: I wanted to be able to advise companies on their problems and help CEOs and founders shape the future of their companies and their stakeholders.

So, as excited as I was, I decided that I wanted to try a career in management consulting.

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[3] About – Oxy Capital Italia. Oxy Capital.

2.2 Why BCG

After I decided to take an internship in management consulting, I applied to all three of the so-called "MBBs", McKinsey, BCG, and Bain. I was lucky enough to go through the interview process with all of them. To get to know the firms better, I did several networking calls with people working there to understand the working environment and the kind of projects they worked on. My decision regarding which company would be the best fit for me was ultimately based on two areas: culture and type of projects.

Let's walk you through my decision process for the latter. Although at first, these companies seem very similar, at a regional level they have many differences. In Italy, for example, McKinsey is extremely focused on the financial services practice, whereas Bain is on the fashion and luxury ones. On the other hand, BCG is very strong in the industrial goods practice and is well positioned in all of the other practices, making the firm one of the most homogenous ones concerning the type of work you would do as a consultant. As regards the private equity practice, both BCG and Bain are well positioned in the Italian market, although historically and thanks to its worldwide reputation Bain has a slight advantage over BCG.

For me, a finance student just getting out of an internship in private equity, not interested in the financial services practice but also not particularly attracted to a specific industry, I thought that BCG would be the best choice for what regards the type of work I would do, so I could get exposure to a wide range of sectors and topics. Moreover, in case later on in my career I wanted to focus on private equity projects, by being at BCG I would have the opportunity to work in one of the best practices in Italy. So, for what concerned the type of project area, BCG seemed the best fit.

Discovering the culture of the firms was a bit tougher. Last year I was selected to participate in an event organized by Bain & Company called "Bain Talent Hub", a three-day event held at Bain's Milan offices where selected students solved multiple business cases and engaged with Bain's consultants and HR teams. It was a unique opportunity to get to know Bain's culture and at the end of the event, I was positively impressed.

BCG, on the other hand, was the only one of the three "MMBs" to run yearly presentations at Ca' Foscari University of Venice. In Italy, often such companies don't run presentations at public universities, so it was very notable that BCG committed to these events. I found it very representative of their culture: they didn't care which was your background, as long as you were

smart and motivated, they would give you a chance. I also spoke with lots of people from BCG and they confirmed what my idea of the culture at BCG was. Moreover, something that attracted me to BCG was how supportive and innovative its culture was described to me by people working there. For example, BCG is one of the first big management consulting firms, if not the actual pioneer, to have established a practice entirely dedicated to climate change and sustainability. For me, this was very indicative of the innovative spirit of BCG.

Moreover, in Milan, they do a lot of social work. There is a dedicated practice called Social Impact in which BCG performs projects with high social impact potential. On top of doing strategic projects, this practice also organizes pro-bono and charity work. A friend of mine at BCG told me how she had done some learning and gaming sessions with a charity association that supported children who have been estranged from their parents. As someone who likes to give back to the community, I was extremely excited to learn about these opportunities inside BCG (and spoiler, I took part in one of these events and it was amazing!).

For McKinsey, getting to know the firm was very difficult. They didn't run presentations, nor they held events in their Milan office. This, coupled with the fact that the scope of their project was not what I was interested in, made me discard McKinsey. And between Bain and BCG, I decided to go forward with BCG.

2.3 My Team

At BCG, you always start as a Generalist, so I could have been assigned the most diverse project, spanning from Consumer Goods to Sustainability and Climate Change, the newborn practice of BCG entirely dedicated to cross-sector projects around sustainability and climate change issues.
Eventually, I was assigned to the Industrial Goods practice, within the MPI area, that is, "Materials and Process Industry", which focuses on the Steel and Paper Industry.
In my team, we were focused on the Steel Industry and we were 4 people: my manager, a consultant, an associate, and me. We also followed two different projects: operative support to a company under extraordinary administration, and a support strategy for a start-up build with the aim to decarbonize the steel industry.
Both projects were extremely exciting, but my main focus was on the first project, in which I rapidly gained full ownership and independence in doing the work and managing client relationships.
In addition to these two main projects, we worked on multiple business proposals, and I provided support to a vendor due diligence.
To better understand the roles of each of the team members, here is a brief overview of the different roles and the career progression at BCG:
The most junior position is Consulting Intern, which lasts from 3 to 6 months. Then, once you graduate (this is a requirement), you can become a Vising Associate for 5 to 6 months. After that, you are effectively an Associate for a period that can be of 24 months or less than that if you are a “top performer”. Then there is the Senior Associate role (usually 6-18 months depending on your performance), after that, you become Consultant (for 18 months to 36 months), then Project Leader, then Principal, then Partner, and ultimately Managing Director and Partner (MDP), and as an MDP you become an actual shareholder of the company.
Usually, at BCG team are of 2-3 people and are formed by a manager, which can be a Project Leader or a Principal (in my team, my manager was a Project Leader), a consultant, and/or a junior figure which can be a senior associate, an associate or a visiting associate. To provide additional support, sometimes there are also very junior figures such as myself, that is, consulting interns.

2.4 The Projects I Worked on

As already mentioned, during my internship I had the opportunity to work across two main projects, both centered around the steel industry, as well as in several business proposals for future projects. The first project was the main one I worked on, whereas the second one was a project in which occasionally I provided support.
Let's start by going through the projects one by one.

2.4.1 Project #1: Operative support to a company under extraordinary administration

The client is a large steel player, very important for the steel sector and with significant social impact. The company is also one of the few end-to-end steel makers, making it a unique player to work with.
The context of this project was quite complex given the fact that the client was in extraordinary administration (administrative-directed procedure available to large insolvent companies) and given the related social and economic impact of the firm on the stakeholders involved (unfortunately, for confidentiality reasons I cannot go in much more details about the context of this project).
Moreover, there were several ongoing obligations to carry out environmental (and technical) investments foreseen by law.
This project was part of a broader Turnaround strategy initiated several years ago to put the company back on track and to make it profitable and highly growing again. What was also more important was the fact that the turnaround strategy put lots of attention to the environment and stakeholders' management since the pollution of the company affected hundreds of thousands of citizens and the company employed more than tens of thousands of people.
To put a number on the output of BCG's work so far, the majority of the employees kept their job and emissions decreased by 40%.
This was the project in which I was mostly involved, and I mainly worked on monitoring the contractual requirements and the progress of environmental investments, modeling the cash flow of the firm, providing analysis to the CFO of the company, and carrying out activities which other c-level executives assigned me.

2.4.2 Project #2: Support to a newly build company with the aim to enable the decarbonization of the steel sector

The client was a newly established company created with the mission of building a Direct Reduced Iron pant and originated as a kind of "spin-off" from Project #1.

The mission was to support the decarbonization of the steel industry (which contributes 7% of CO2 emissions produced worldwide) by leveraging public funds made available for hard-to-abate sectors (sectors in which is very difficult to reduce CO2 emissions).

The project was divided into different phases ("streams of work"), with the first one being to verify the feasibility of the project to build a Direct Reduction Plant and start Direct Reduced Iron (DRI) production. DRI is a raw material that is used in electric furnaces to produce steel and is obtained using iron ore which then goes through a reduction process that uses natural gas or hydrogen (or any combination of the two). The use of electric furnaces and DRI results in significantly lower CO2 emissions, making DRI a more environmentally friendly option compared to traditional production steel through the blast furnace route which involves the use of coal and which releases a substantial amount of CO2[4] (in the academic research I will talk about the two different ways to produce steel, through electric furnaces that use scrap or DRI and through the blast furnace – converter route (BF-BOF)). If the steel industry is able to combine DRI produced through hydrogen and electric furnaces, we can decarbonize the steel industry[5] in a sustainable way, without being depended on the availability of scarp, which is the alternative raw material to DRI.

In this phase, BCG's work involved supporting the company on all aspects of its activities, providing operative support and steel, energy, and climate & sustainability knowledge thanks to the multiple practices at its disposal.

This project was extremely interesting, not only for the impact it will have on the economy and steel industry but also because I had the opportunity to see how a company is started from scratch and how to properly set it up for success.

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[4] Kinch, D. (2022, June 22). Direct-Reduced Iron becomes steel decarbonization winner. S&P Global Commodity Insights.

[5] Bhaskar, A., Assadi, M., & Nikpey Somehsaraei, H. (2020). Decarbonization of the iron and steel industry with direct reduction of iron ore with green hydrogen. Energies, 13(3), 758.

Although, as I mentioned, this was not my main project, I was still able to learn a lot thanks to the occasional support I provided.

2.4.3 Miscellaneous Projects

In this paragraph I will talk about the "side" projects I worked on alongside the two main ones. We have two macro areas: business proposals and private equity due diligence.

In the first area, we developed some proposals for some potential projects BCG (and in particular the partner of my team) wanted to take part in. These proposals are extremely important because usually, clients who want to initiate a project either go directly to their trusted consultants or provide a brief of the project they would like to launch and ask consultants to provide their "proposals" on how they would develop the project. These proposals are also often followed by an actual pitch to the CEO or management team of the potential client. That's why proposals are very important for the business and given the not-so-favorable market conditions we are facing in 2023, they were considered major. During my time as an intern, I worked on 5 proposals and BCG ended up winning 3 of those.

In the business due diligence area, on the other hand, I supported a team in the concluding phases of a vendor due diligence. Usually, commercial/business due diligence is a type of case that involves a very rigorous research process to understand a single company and the market in which it competes, it differs from a financial due diligence because you don't really analyze the accounting records of the company and don't make adjustments to the main economic and financial indicators such as EBITDA, NFP, etc.

Generally, there are two type of due diligences you can work on as a management consultant: a buy-side and a sell-side (vendor)[6]. A buy-side due diligence is when a private equity firm or another company is interested in buying or investing in a company and hires consultants to assess the attractiveness of the company and the market in works in[7]. A sell-side due diligence, on the other hand, is when a company is looking to sell or raise capital and hires consultants to create a comprehensive report highlighting the history of the company, its achievements, and its role in the market it operates. More simply, in a buy-side due diligence as a consultant you are trying to

[6] Howson, P. (2003). Due diligence: The critical stage in mergers and acquisitions. Gower Publishing.
[7] Howson, P. (2016). Commercial Due Diligence: The key to understanding value in an acquisition. CRC Press.

be objective whether this company is attractive or not, whereas in a sell-side due diligence you work with the company to create a positive story for potential buyers and investors while being as objective as possible.

Since my previous internship was in private equity and I have a finance background, I was really interested in discovering more about these types of cases, and what I learned was that generally speaking, every due diligence is going to follow a similar four-step framework:

- Competitive landscape module - in this module you do a lot of expert interviews to get an outside perspective on the company and its competitors
- Market module - here you have to do a market model to understand the size of the market using multiple inputs collected from market reports and interviews (expert interviews as well as internal interviews if it's a sell-side due diligence)
- Company overview module – if it's a sell-side due diligence, here you have to do a lot of internal interviews with the management team of the company, otherwise you keep it high level
- Historical performance and Business plan module – here you analyze the past financial performance of the firm and project and develop its business plan for the coming years based on information shared by the company and collected from outside sources.

Due diligences are usually very short (3-5 weeks) and intense, given the fact that you need to put together a lot of information, and often clients can be very demanding.

2.1 My Role as a Consulting Intern

As an intern, I expected my tasks to be relatively easy and with zero client exposure (given how junior I was), but as soon as I started my internship, my expectations were completely overthrown.

In Project #1, during the first week, I was supported by an associate consultant who explained to me the multiple activities I had to carry out during my internship. It was very important to follow along carefully because after he changed projects, I would have complete ownership of my tasks, with the manager only acting as a supervisor and controlling the accuracy of my work. Most of the activities involved the use of Excel since I had to update the Cash Flow model of the company and run multiple analyses on the information the operating counterparty was sending over relative to its quarterly financial performance, its HR plan, its environmental (and technical) investments, and others.

After performing the analysis in Excel, I had to put everything on PowerPoint and present it to the CFO of the client (after my manager checked them, of course).

Presenting to clients was probably the most difficult part, especially at the beginning, but also the one I enjoyed the most.

These activities represented the bulk of my tasks for Project #1 and the most recurring one, however, occasionally I also run spot quantitative or qualitative analysis the clients asked. The most notable one was research on CO2 accounting and on the EU Cap and Trade System (EU ETS) and several expert calls to understand the procurement strategy of companies producing raw materials very important for steel producers. Talking to experts was also one of the most enjoyable tasks I did because for one hour you had at your disposal an expert who has dedicated years or decades of their life to a certain topic and who can explain to you everything you want to know about that specific topic.

In Project #2, my tasks were more aimed at supporting the current team and less autonomous than the ones I performed on Project #1. I mainly contributed to creating PowerPoint presentations and worked on the financial model of the project, which was similar to an LBO and therefore similar to the one I worked on during my internship in Private Equity.

For what regards the business proposals and the support I provided to the private equity due diligence project, I mainly worked on PowerPoint creating slides and using Excel to derive the data to put on slides and graphs.

2.2 The Workflow

Something very impressive about BCG, especially compared to the past places I interned in, was the fact that everything is very well structured. In particular, during every project, we usually followed the same workflow.

You work on a shared PowerPoint, which is very convenient because you can open it and edit it live, and once you have completed your tasks you share the link of the document with the manager, which will go in and add specific comments on the pages they want to change, making it very clear what to do.

Moreover, as a team, we usually have daily check-in meetings, at 9 am, and usually 5/6 pm check-out calls, to sum up what we did during the day and decide what we want to wrap up before the following morning.

In addition, every week, we have meetings with the senior leadership members of the team. These meetings, called Case Team Meetings (CTMs), are intended to make sure senior membership is aligned in terms of expectations with our output.

Something that at BCG was very encouraged was to speak up and be involved in every one of these meetings (daily check-ins/outs and CTMs).

In terms of tools, we have all of the tools imaginable. On Excel and PowerPoint, which are the main tools used, we have for example multiple add-ons to make creating slides and graphs as efficient as possible.

2.3 What I Learned

During the internship, I experienced tremendous growth, both in technical skills and most notably in soft skills. I had the opportunity to refine my knowledge and expertise in Excel and PowerPoint, but most importantly I really had the opportunity to develop all of my other skills.

I learned how to present in front of C-Level executives and manage Q&A sessions with them, something which I never had the opportunity to work on so early in my career and for which I am immensely grateful, and in which I also used some of the knowledge I collected during my course “Leadership in Finance” at Dauphine.

I learned how to effectively communicate and how to coordinate the expectations of my seniors.

I learned how to work under pressure and to properly organize my tasks efficiently.

I learned how to work in a team, and I really understood the value of collaboration, which is something that at BCG is very encouraged: always think in terms of “we” and not of “I”.

Moreover, I improved my networking skills, and as an introvert, I started to appreciate more the time I spent with others.

Overall, it was a very successful journey for my personal growth. But don’t get me wrong, it was not completely easy. Being someone that likes to run, in running terms it was more like a marathon, with its ups and downs, than a sprint, and I look forward to the other milestones.

But that’s not everything I learned. In fact, I also studied the steel industry, how steel is produced, and its implications on the Italian industrial system and on the EU's ambition to reach net-zero by 2050. Thanks to the courses I took at Dauphine, such as “Economics of Climate Change”, “Green Finance” and “ESG Investing”, I was already prepared on these topics and positively impressed my manager.

I also acquired a lot of knowledge of how businesses in the Italian steel industry work and which are the key success factors to perform well in this sector.

I gained a lot of insights on the current agenda of steelmaking companies to decarbonize their production, the new trend emerging, and the most relevant events that have happened in the past 6 months, such as mergers and acquisitions, joint ventures, announcements of new Direct Reduction Plant to produce Direct Reduced Iron (DRI), Steelmaking plants and supplying agreements, which lately were focused only on green steel, that is, steel obtained with low CO_2 emissions.

2.4 Challenges

As I mentioned, the growth journey was incredible, but it had its ups and downs.

To begin with, getting out of university and entering such a highly competitive role can be difficult, you stop being one of the highest achieving students in the room and start being one of the many talents in the company. It is hard to emerge as one of the top performers because you are surrounded by top performers, and at the beginning, it can be hard to accept this new "reality".

Moreover, since everyone is so good at what they do, you feel a certain pressure to constantly perform well, and falling short of your manager's expectations starts to become a real source of anxiety.

Lastly, the fact that your performance is constantly measured, and you have feedback sessions both with the manager and HR, you start to be very self-aware of what you do.

In my case, I was lucky enough to have very supportive team members, which recognized very soon what I was going through and gave me the right advice on how to get the most out of this experience without overthinking it.

Another very helpful thing was that at BCG, every new joiner has a "Buddy", someone more senior than you who acts like a friend and to which you ask for advice. In my case, my Buddy was very valuable, since he was able to give me the perspective of someone who has been a consultant at BCG for years and has seen many people join and progress their careers inside the firm. He was able to reassure all of my (self) doubts and worries and made me focus on bringing out the best of my skills and providing the best outputs for my team, but most importantly, for clients.

2.5 Future Plans

After these months at BCG, I am extremely grateful for the projects I worked on and the people I worked with. It has been an incredible (growth) journey and I think that consulting met all of my expectations.

Going forward, I see myself staying in consulting, as I think the work can be very interesting and the exposure that you get to solve major business issues for big corporations and interact with C-level executives and CEOs is unparalleled from any other job.

I also found that in very few other spaces other than consulting you get the opportunity to work with extremely diverse and smart people. I feel that in this industry, and especially at BCG, people come from diverse academic and professional backgrounds. In finance, this is not exactly the case since employees tend to be more homogenous, usually with a finance or business background. At BCG I met people coming from a wide array of bachelors/masters, ranging from history to medicine, physics, engineering, and mathematics. I really appreciated the culture that I was starting to be part of, and I felt that the job that we did was very impactful for the clients we worked for.

With my degree in Finance and my interests in this area, I see myself working on projects more centered around corporate finance and private equity, and I plan to get involved in the M&A, Transactions, and PMI Services practice, as well as in the Corporate Finance & Strategy practice.

Going forward, I also feel it could be very exciting to embark on another academic adventure: the MBA. BCG offers the possibility to join Tier 1 MBA programs while covering all the expenses of the program, which is a very attractive opportunity. I see myself joining an MBA such as the one offered by INSEAD so that I can take one year off to network, expand my skills and experiences.

3. Academic Research

In the following pages, we will do a deep dive into climate change, starting with a quick introduction to the topic followed by an in-depth analysis of climate change and the Paris Agreement. Then, we will focus on the steel industry, steelmaking in general, and the EU efforts to push firms towards decarbonization.

3.1 Introduction to Climate Change

Climate change began at the end of the 19th century with the first industrial revolution and Europe has been the first emerging "country" because of that and the use of fossil fuels.

The IPCC (Intergovernmental Panel on Climate Change) is the United Nations body for assessing the science related to climate change. Observing the realized evolution of temperatures with models using only natural forces and models using both natural and human forces it's possible to see that even if natural forces can cause an increase in temperature (due for example to volcanic action), based on the observation collected there is no more doubt that the main cause of climate change has been human activity. Now, we are fighting against a generalized increase in temperatures, and depending on the temperatures that will be reached within 2100, the effects may differ. The worst-case scenario (with an increase of temperatures between 2.6-4.8°) may lead to long-term physical risks such as global instability and climate disaster (hot waves, floodings, etc.) whereas in the best-case scenario, there might be some short-term transition risks such as problems connected with stranded assets (I will focus on these concepts later on).

To the question "What are the top 5 risks for the coming decade?" present in the survey made every year by the World Economic Forum and compiled by businessmen, heads of state, and governments, it's interesting to see how ten years ago the environment was not seen as much of a problem and nowadays all of the problems are about the environment[8].

A big step forward in the fight against climate change has been done with the Paris Agreement of 2015 and with the European Roadmap 2050 of 2011. The Paris Agreement is the first-ever universal, legally binding global climate change agreement, adopted at the Paris climate conference (COP21) in December 2015. It sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to

[8] Global Risks Report 2023, World Economic Forum

1.5°[9]. It also aims to strengthen countries' ability to deal with the impact of climate change and support them in their efforts. The European Commission's 2011 Energy Roadmap for 2050 set out four main routes towards a more sustainable, competitive, and secure energy system in 2050: energy efficiency, renewable energy, nuclear energy, and carbon capture and storage. Europe could achieve an economy-wide reduction of GHG emissions of at least 80% by 2050 compared to the 1990[10] but realizing this radical transformation requires fundamental changes to the energy system.

Mitigation and adaptation are the key words to face climate change. Climate change mitigation refers to efforts to reduce or prevent the emission of GHG. Mitigation can mean using new technologies or renewable energies, making older equipment more energy efficient, or changing management practices or consumer behavior. It can be as complex as a plan for a new city, or as simple as improvements to a cook stove design.

Adapting to climate change means taking action to prepare for and adjust to both the current effects of climate change and the predicted impact in the future[11]. Global emissions of GHGs are still on the rise and even with our commitment to cut net global emission to 0 by 2050[12], the concentration of greenhouse gases in the atmosphere will continue to increase for the incoming decades, and average global temperature will rise.

There are many challenges connected with energy transition: the global population without access to electricity especially in Sub-Saharan Africa and Developing Asia, millions of people living in big cities (also known as urban challenge), the correlation between emission, resources, and GPD, the price instability and the potential impact of this instability on average household energy bills, etc.

[9] Nowadays Germany and Italy are around 2.2°, France 2.3°, UK 2.6°, US and Japan 2.8°, Canada 3.1°.

[10] Currently we are at -25%

[11] Chen, W. Y., Suzuki, T., & Lackner, M. (Eds.). (2017). Handbook of climate change mitigation and adaptation. Cham, Switzerland: Springer International Publishing.

[12] In a recent report, the International Energy Agency (IEA), has defined a path to achieve Net 0 by 2050 including: no new oil and gas fields and coal plant projects immediately, electrification will have a major role in this transition, especially in transportation, hydrogen will play an increasing role from 2030. In this context, two-time horizons may be distinguished: 2030-35 (mature low carbon tech) and 2050 (new tech portfolio).

It's extremely important to analyze the relationship between CO2 emissions, material footprint[13] and GDP.

There is a positive correlation between GDP and GHG emissions; in other terms: the higher the emission, the higher the GDP[14]. But limiting the temperature increase to 1.5° in 2050 will require a reduction in CO2 emissions to around 5bn tons (max) compared to the 37 bn tons today[15]. The aim is to return to the 1950 level of emissions by 2050, with a tenfold increase in GDP and a fourfold increase in population between these two dates (is it even possible?).

Fundamentally, the Paris Agreement implies the invention of a new macroeconomic model which will mechanically require drastic adjustments to companies' current business models.

[13] Material footprint refers to the total amount of raw materials extracted to meet final consumption demands. It is one indication of the pressure placed on the environment to support economic growth and to satisfy the material needs of people.

[14] Tucker, M. (1995). Carbon dioxide emissions and global GDP. Ecological Economics, 15(3), 215-223.

[15] CO2 Emissions in 2022. (2022). International Energy Agency (IEA).

3.2 Climate Change: origins and potential economic costs

Climate change represents an urgent and potentially irreversible threat to human societies and the planet; according to the definition given by the United Nations, climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle, but since the 1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil, and gas. Indeed, burning fossil fuels generates greenhouse gas emissions. The general term "greenhouse gas" (GHG) refers to carbon dioxide (which contributes 76% of total emissions around the world), methane (16%), nitrous oxide (6%), and fluorinated gas (2%)[16]. Carbon dioxide, the heat-trapping GHG that is the primary driver of recent global warming, lingers in the atmosphere for many thousands of years, and the planet (especially the ocean) takes a while to respond to warming. So even if we stopped emitting all greenhouse gases today, global warming and climate change will continue to affect future generations. In this way, humanity is "committed" to some level of climate change.

How much climate change? Well, this depends on the current actions in place, but for the sake of this question, we are going to focus on the consequences of climate change. Over the last few years, several studies conducted by researchers and international organizations assessed the possible future effects of climate change. In particular, based on our actions now, the effects in the future may be very different. In the so-called "worst case scenario", a situation in which global temperatures reach a range of +2.6° – +4.8°, the world will be highly exposed to physical risks. However, even in the best-case scenario, a situation in which temperatures will be well below +2°, civil society will bear anyway some kind of risks, in particular transition risks.

As you noticed, we have two main types of risks[17]:

Physical risks are typically defined as risks that arise from the physical effects of climate change and environmental degradation. They can be divided into extreme weather events (or acute risks), which include the increasing, frequency and severity, of natural disasters such as floods, wildfires, cyclones, droughts, etc., and long-term shifts (chronic risks) which refer to the change in trends of weather patterns such as the sea level rise or the average increase in temperatures. The number of climate disasters has increased 2.9 times in the last 30 years.

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[16] Global emissions. (2022, September 8). Center for Climate and Energy Solutions.

[17] Gambhir, A., George, M., McJeon, H., Arnell, N. W., Bernie, D., Mittal, S., Köberle, A. C., Lowe, J., Rogelj, J., & Monteith, S. (2022). Near-term transition and longer-term physical climate risks of greenhouse gas emissions pathways. Nature Climate Change, 12(1), 88–96.

Transition risks, on the other hand, are those risks associated with the transition to a low-carbon economy.

To better explain Transition risks, it is useful to make a comparison between the two types of risks. Physical risks and transition risks have a negative correlation since the intensity of the two types of risks is reversed and they do not have the same temporality. The implementation of demanding public policies on the decarbonization of the economy will increase short-term transition while decreasing long-term physical risks. On the other hand, the absence of climate policies does not entail transition risks but leads to higher long-term physical risks. Spending more now to contain damages caused by the transition risks means spending less in the future for physical risks and many researchers argue it is a good deal[18].

Transition risks have the ability to reduce market value and raise market volatility at the security and portfolio levels since they are financially significant[19]. One example could be stranded assets, which are "assets that have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities": new government regulations that limit the use of fossil fuels (like carbon pricing); a change in demand (for example, a shift towards renewable energy because of lower energy costs[20]); or even legal action[21] against high emitters can cause the company's assets to become stranded (i.e., lose value)[22]. All these drivers will have a huge impact on companies, especially on those sectors which have a relatively high carbon intensity, or those which operate in the supply chains of these sectors. Businesses will need to reshape their production from carbon-intensive to carbon-free methods, and support will need to be provided to communities that are economically dependent on carbon-intensive industries. Without appropriate analysis and planning, there will be an otherwise-avoidable number of stranded assets, plants, and equipment designed for carbon-based production—as climate change alters the value of investments held by banks and insurance companies.

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[18] Gourdel, R., Monasterolo, I., Dunz, N., Mazzocchetti, A., & Parisi, L. (n.d.). The double materiality of climate physical and transition risks in the euro area.

[19] Basel Committee on Banking Supervision. Climate-related risk drivers and their transmission channels. (2021). Bank for International Settlements (BIS).

[20] Renewable power generation costs in 2020. (2020). Irena.org.

[21] Global trends in climate change litigation: 2022 snapshot. (2022, June 29). Grantham Research Institute on Climate Change and the Environment.

[22] Caldecott, B., Harnett, E., Cojoianu, T., Kok, I., & Pfeiffer, A. (2016). Stranded assets: a climate risk challenge.

To conclude, an important aspect that should be taken into account going into the future is the fact that we should break the historical link between GDP growth and emissions. By breaking this link, transition risks may become more bearable, and stranded assets may become fewer.

3.3 The Paris Agreement

Despite many countries committing to the Paris Agreement, in 2021, after an unusual 2020 where the amount of CO2 dropped dramatically due to lockdowns in many countries of the world[23], CO2 world emissions have been extremely high (kind of rebound). This happened, and it is still going to happen in the future, also because of the increasing needs of developing countries.

From a practical point of view, the challenge of climate change can be measured through the so-called carbon intensity; carbon intensity can be defined as the number of grams of carbon dioxide it takes to make one unit of something (for example the carbon intensity of electricity is the amount of carbon dioxide produced for every additional unit of kilowatt per hour). In this case, the unit is the GDP. Global carbon intensity emission fell by an average of 1.4% per year from 2000 to 2021 but it fell only 0.5% in 2021. To limit global warming to 2°C, an annual decarbonization rate of 6.3% is needed, instead to limit warming to 1.5°C, an annual decarbonization rate of 15.2% is needed. A 77% reduction in carbon intensity is required this decade to limit global warming to 1.5°C[24].

Observing historical emissions of CO2, it's clear that countries which industrialized first such as Europe and USA started growing before other countries and this is why in the past they accounted for more than 80% of total CO2 emissions. Nowadays the situation is changed, Europe and America account for around 50% of the global total emissions and they are going to emit always less. The situation is different for developing countries; for example, China and India will emit more CO2 in the future compared to the past. Africa instead has a limited responsibility.

The Paris Agreement is an international treaty on climate change adopted in 2015 that covers several fields such as climate change mitigation, adaptation, and finance. It's important to understand what's written inside this agreement and what is the difference between the Paris Agreement and the Kyoto Protocol.

The aim of the treaty, as described in Article 2 of the Paris Agreement, is to have a stronger response to the danger of climate change; in particular, the agreement seeks to enhance the implementation of the United Nations Framework Convention on Climate Change (UNFCCC). To be more specific, the Paris Agreement aims to: hold the increase in global average

[23] CO2 emissions have always decreased in correspondence of important international events such as the Oil Crisis, the fall of the Berlin wall and the 2008 crisis.

[24] PricewaterhouseCoopers. (2022). Decarbonisation rates must far outstrip anything seen before to limit warming to 1.5°C, finds PwC's Net Zero Economy Index. PwC.

temperature well below 2°C above pre-industrial levels and to pursue the efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change; increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production, making finance flows consistent with a pathway towards low greenhouse gas emission and climate-resilient development[25].

Each country, through some plans, can determine on its own the amount of contribution to achieving the above-mentioned goals (nothing is mandatory, every country decides for itself). These plans are called Nationally Determined Contributions (NDC)[26] and, as stated in Article 3, they must be an ambitious effort towards achieving the purpose of the agreement and represent a progression over time. These contributions should be set every five years and are to be registered by the UNFCCC Secretariat. The Paris Agreement doesn't prescribe the exact nature of NDCs but, at a minimum, they should contain mitigation provisions, pledges on adaptation, finance, transparency, and others. However, many argue that current pledges seem insufficient to meet the targets of the Paris Agreement[27].

In addition to this, developed countries reaffirmed the commitment to mobiles $100 billion a year in climate finance by 2020 and agreed to continue mobilizing finance at this level until 2025. This money is for supporting mitigation and adaptation policies in developing countries. However, since 2013, this goal has never been reached yet.

Lastly, even if the Paris Agreement is legally binding, there are no punitive economic measures like trade sanctions or embargoes on countries that fail to meet their commitments. However, there is a "name and shame" mechanism that can trigger a reputational risk. The only penalty for falling short in efforts to fight global warming would be failing in front of the whole world to achieve these goals. And that's not necessarily a bad thing, many analysts say. In international

[25] Parties to the United Nations Framework Convention on Climate Change. (2015). Paris Agreement.

[26] Can also be called Intended Nationally Determined Contributions (INDC) but the concept is the same: they are the primary means for governments to communicate internationally the steps they will take to address climate change in their own countries.

[27] Rogelj, J., den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., Schaeffer, R., Sha, F., Riahi, K., & Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature, 534(7609), 631–639.

diplomacy, peer pressure and the risk of losing face can be powerful motivations for a country to keep a promise, particularly on a high-profile issue like climate change. Meeting national emissions pledges will emerge as a key measure of international moral and diplomatic standing after a Paris Agreement, with countries reluctant to respect their targets and risk being treated as undesired.

Despite good intentions, the Paris Agreement still has some problems. For example, since NDCs are decided in autonomy by states, current NDCs would still bring an increase in temperature between + 2.7 and + 3.7. Another problem is that the financing schemes between countries have never been defined, it's not clear who is going to give money to who and how. Again, there has been until now an insufficient pace of carbon technologies deployment, and carbon pricing, which is an important policy tool adopted by a growing number of countries to reduce emissions, is not mentioned in the Paris Agreement.

To solve problems related to financing schemes of developing countries, an interesting solution that has been proposed over the last few years is the use of blockchain. A major problem of financing projects in emerging countries is that money can be used by someone else or for something else since there is no control over it. Blockchains, with their technologies, would solve this problem since data cannot be modified.

The Paris Agreement was also very relevant because it replaced Kyoto Protocol, and there are significant differences between the two, with the Paris Agreement representing a big step forward in the fight against climate change.

The Kyoto Protocol was created in 1997 and ratified in 2005 and it was a legally binding agreement only for developed nations (India and China for example were excluded) whose original commitment was to decrease overall emissions by 5% from 1990 levels. This target, however, has never been changed or reviewed[28].

The Paris Agreement doesn't focus on emissions but has an overall goal for all countries (developing and developed) to limit global temperatures to 1.5°C above pre-industrial levels. New sets of targets are declared every five years.

During COP21 (2015) being a net-zero nation was not even regarded as an issue, whereas now more than 80% of countries try to reach this goal. However, the paradox of the Paris Agreement

[28] Böhringer, C. (2003). The Kyoto protocol: a review and perspectives. Oxford Review of Economic Policy, 19(3), 451-466.

is that all countries agree with the goal in the long term but none of them is doing something important to achieve this result in the short term.

All these topics (climate change, adaption, mitigation, energy demand and supply, CO2 emissions, etc.) have to be taken into account to develop and implement new policies but considering at the same time other pressing issues such as international geopolitical instability, a complex technological portfolio, the historical link between GDP and C02 emissions, the so-called integration challenge, the price instability of commodities (these can be considered also the reasons why it's not that easy to implement the Paris Agreement)

For example, as it has already been said, one of the main challenges to face in the following years is to break the historical link between GDP and CO2 emissions. While some countries (UE, USA, Japan) will need to complete their transition from fossil fuels to green/renewable sources of energy, others (India, China, and Africa) will need to grow and develop without fossil fuels otherwise they will not be able to respect the Paris Agreement. There are different kinds of challenges but probably the most pressing one is creating a new model of growth based on the absence of fossil fuels. In China, the main challenge is to stabilize CO2 emissions (or reduce them) while growing; India and Africa instead will be the first part of the world where GDP per capita is expected to grow without emissions (these countries do not have time to implement fossil fuels technologies and then switch to low carbon technologies).

For the technological portfolio, twenty years ago the main problem was the development of new technologies to face climate change, nowadays there are dozens of technologies (at different stages of the innovation cycle) in competition with each other that can be used to achieve the energy transition. However, the issue now is both how to select them (what is the best?) and to integrate them into our system. Another issue related to the technological portfolio is the so-called climate integration challenge. This challenge can be summarized as being able to combine different technologies. It will be probably necessary to modify the landscape (onshore and offshore wind farms), cities will need to reorganize their own spaces and some sectors could face enormous transformations (such as buildings, transport, and agriculture). However, countries will face not only economic and technological problems but also social challenges (Not In My Backyard (NIMB) phenomenon for example[29]).

[29] Opposition made by residents of a certain area to proposed developments in their local area

Another challenge is the profusion of unconventional fossil fuels. New data provided by geologists showed that the new deposits of unconventional fossil fuels (such as shell gas and shell oil) discovered worldwide could last for centuries. Policies and technologies to achieve a low-carbon transition must be developed not because of the absence or scarcity of fossil fuels (this was a problem 20 years ago) but despite the availability of new fossil fuels.

It will be important also to anticipate the geographical reallocation of energy demand and understand new geopolitical risks; old ways of understanding the world of energy are losing value as countries change roles: for example, the European Union and the United States of America will need less energy compared to now while Africa, South America, India, China, and the Middle East will have a higher demand of energy compared to the past. In other terms, it's necessary to face the problem of the increasing demand for energy in developing countries in a sustainable way. The same reasoning can be done in terms of imports and exports of primary resources; countries like Brazil will pass from being net gas and oil importer to being net gas and oil exporter. The USA is now in a position where they were supposed to be around 10 years ago; recent discoveries of shell gas will bring the nation to become a net gas exporter and to compete against Saudi Arabia. Other geopolitical risks are related to minerals (such as rare earth materials) which are necessary for some technologies (such as PV panels and batteries).

One of the biggest problems of the Paris Agreement is that it doesn't mention Carbon pricing. Two ways through which governments can discourage companies from using fossil fuels are a carbon tax or an emission trade scheme. A Carbon Tax is a tax levied on the carbon emissions required to produce goods and services. Carbon taxes are intended to make visible the "hidden" social costs of carbon emissions, which are otherwise felt only in indirect ways like more severe weather events. In this way, they are designed to reduce carbon dioxide (CO2) emissions by increasing the prices of the fossil fuels that emit them when burned. This both decreases demand for goods and services that produce high emissions and incentivizes making them less carbon intensive[30]. Emission Trading Systems (such as the EU ETS) are "cap-and-trade" systems in which there is a predefined total amount of CO2 that can be emitted ("cap") that is split between companies. Companies that emit less can sell the "right to emit" to companies that emit more. The main problem with carbon pricing is that it cannot be adopted at an international level

[30] The main disadvantage of the carbon tax is that it doesn't provide any information on the expected emissions.

because it could cause severe damage to the poorest people. Over the last few years, some companies started to use an instrument that can be called “internal carbon pricing”. Substantially, firms evaluate projects considering the possible introduction in the future of some forms of carbon pricing, if the project still presents positive cash flows, it can be implemented.

3.4 Overview of the Steel Industry

Now that we know how pressing the climate change issue is, and how we have to act to achieve the targets of the Paris Agreement, let's understand the contribution of the steel industry to climate change.

One of the economic pillars around which the EU is constructed is the steel industry. The European Coal and Steel Community (ECSC), established in 1951 by the Treaty of Paris and signed by Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany, gave rise to the European organization as we know it today. Over the subsequent decades, the objective of facilitating trade among European nations for steel components and finished goods expanded, giving rise to numerous economic and social pacts that eventually led to the creation of the current EU, including the Treaties of Rome and Maastricht, which altered the political landscape of the continent forever. This highlights the significance that steel has always had within European nations and for all of Europe, as it was coal and steel that first sparked the Europeanist spirit of the member states.

In economic terms, the EU steel industry today contributes to the economy with more than 2.5 million jobs (of which 12% direct, 60% indirect and 28% inducted) and generates around 143 million euros of Gross Value Added[31][32].

Global steel demand has been increasing due to population and economic growth and is predicted to keep expanding, notably due to the economies of Africa, the ASEAN nations, and India all experiencing growth, even while demand in China steadily decreases.

The steel demand has more than tripled since 1970 and has continued to rise as economies expand, urbanize, raise their consumption of commodities, and develop their infrastructure[33].

This correlation between steel demand and economic growth is because our society is heavily reliant on steel. Steel is an indispensable material and is used extensively in the building of houses, hospitals, schools, bridges, cars, and trucks, to name a few.

The energy transformation will also depend extensively on steel, which is used in variable degrees in electric vehicles, wind turbines, solar panels, and dams.

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[31] The Gross Value Added (GVA) is the value of output minus the value of intermediate consumption. It measures the contribution to GDP made by a producer, an industry or a sector.

[32] European Steel in Figures 2023. (2023). Eurofer.

[33] Iron and Steel Technology Roadmap. IEA.

In 2022, world steel production was close to 1,900 million tons, with 54% concentrated in China (a great increase compared to 47% in 2012) and 7% in the EU (vs 10% in 2012). China leads also in terms of steel consumption, with 52% compared to 8% of the EU[34].

Moreover, China is by far the main steel exporter while the EU is the main importer.

Every year the World Steel Association publishes a list of more than 100 steel producers with an output greater than 3 million tons per year. Thanks to this list, we can draw several observations. For example, the top 10 steel producers account for just 28% of the global steel output, with the top 25, 50, and 100 accounting respectively 44%, 59%, and 72% of the global output. This reflects a relatively fragmented market and competitive environment.

From the list, we can also see that the main steel producer is currently China Baowu Group, with 132 million tons produced in 2022, followed by ArcelorMittal (which for a long time was the first steel producer) with 69 million tons and Ansteel Group (another Chinese company) with 56 million tones. Another insight we can catch from the list is that Chinese steel players tend to dominate the industry: 6 out of the top 10 steel producers are Chinese.

As a result of rising demand, the steel industry's overall CO2 emissions have increased during the previous years. The CO2 emissions of the steel industry are linked to coal, which is a key component in the production of steel (as we will see in the next paragraph, coal is transformed into coke) since it is used as a reducing agent to release iron from iron ore and to provide the necessary carbon to steel. In the EU, the steel industry is accountable for about 5% of CO2 emissions, whereas globally for about 7%[35] of total CO2 emissions.

[34] World Steel in Figures 2023. (2023). World Steel Association (WSA).
[35] EU climate targets: how to decarbonise the steel industry. EU Science Hub.

3.5 Steelmaking and the new route to decarbonization

Now that we know how many emissions the Steel industry is responsible for, let's cover the production process of steel, which is the main emitting source, and how we can decarbonize steelmaking.

Steel is formed by combining iron and carbon and is produced using either the integrated cycle through a blast furnace-converter (BF-BOF) or using electric furnaces using scarp or DRI.

In the process through the blast furnace, the most important role is played by iron ore and coke.

Unprocessed iron ore is found as both fines and lumps (with the latter being rare and frequently more expensive because it may be utilized right away without any processing). It is necessary to agglomerate iron ore particles, either by creating sinter or pellets. Heat and pressure are used in agglomeration procedures to create nodules (also known as sinter) and pebble-sized particles (known as pellets), which when piled in a furnace allow gases to flow through and around them. These procedures need various amounts of coal, coke, natural gas, and electricity depending on the iron concentration of the iron ore and the quality of the pellets or sinter. The quality of the raw materials employed is very important because the subsequent process of steelmaking is highly dependent on the energy and emission intensities of them[36].

Coke is obtained from coal through a refining process carried out in the coke ovens and has multiple functions: it develops reducing gas for the reduction of iron oxides according to the chemical reaction; it provides the carbon for the steel produced and the heat for the smelting process; it supports the weight of the material loaded in the upper part of the blast furnace; and it acts as a filter for particles and dust.

The charge fed into the blast furnace consists of coke, limestone material, and iron ore.

The blast furnace is characterized by continuous operation, with the charge slowly descending as it is fed; hot air has to be blown (1000-1200 °C) to reach high temperatures. The melting is completed in the lowest part of the plant, where the temperature reaches 2000 degrees. Cast iron and slag are formed, which flow into separate crucibles.

The cast iron produced is in a liquid state, with a carbon content of around 4-5%, and then reaches the converter for transformation to final steel: decarburization (decrease of the % of carbon) and removal of cast iron impurities, mainly sulfur and phosphorus, are required. Many

[36] Geerdes, M., Chaigneau, R., & Lingiardi, O. (2020). Modern blast furnace ironmaking: an introduction (2020). Ios Press.

refining furnaces are based on the conversion process with oxygen (basic oxygen furnace, BOF), in which oxygen is introduced through a lance to promote the oxidation of certain chemical elements such as carbon and silicon[37].

Large-scale equipment and plants set apart the integrated-cycle plants' steel production. These factories rise in areas of substantial size, among the largest in the entire manufacturing sector, as supplemental facilities for processing auxiliary materials and by-products are located in the surrounding area along with the main plants.

On the other hand, due to the simplicity of its equipment and facilities, steel manufacturing utilizing electric furnaces has the benefit of allowing processing in much smaller places and focusing on high output volumes.

In the electric furnace route, the main raw materials are scrap or DRI (Direct Reduced Iron). If we take a process that involves the use of scrap only, we witness lower emissions and energy expenditure (4-6 GJ/t of iron produced using 100% scrap compared to 13-14 GJ/t of the BF-BOF process), as recycled material is used and there is no need to produce coke[38]. However, the availability of scrap is insufficient to fill the current large demand for steel. Supply of scrap is constrained by the rate at which steel products reach the end of their useful lives and by the efficiency of scrap collecting and sorting systems, whereas iron ore is mined all over the world (it is one of the most abundant substances on earth). This is also the reason we have the production of iron by direct reduction (DRI), using natural gas (or hydrogen, or any combination of the two), and the subsequent use of EAF. With direct reduction, sponge iron is obtained, called DRI (Direct Reduced Iron) or HBI (Hot Briquetted Iron), depending on the size, which will then be used inside electric furnaces to produce steel, which is fed into the furnace instead of using scarp.

In addition to its practical advantages (e.g., lower energy expenditures), the electric furnace represents a key reality for green production. The increasing success it is experiencing is due, first and foremost, to the attempted decarbonization of steelmaking.

However, globally, steel production remains closely tied to the BF-BOF process, which is responsible for ca. 70% of the steel production in 2022. In Europe, things looking more promising, and the BF-BOF process is responsible for ca. 56% of steel production.

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[37] Miller, T. W., Jimenez, J., Sharan, A., & Goldstein, D. A. (1998). Oxygen steelmaking processes. The Making, Shaping and Treating of Steel-Steelmaking and Refining volume, 475-524.

[38] Madias, J. (2014). Electric furnace steelmaking. In Treatise on process metallurgy (pp. 271-300). Elsevier.

Despite the prevalence of the BF-BOF process, there are more and more realities in which electric furnace accounts for the majority of production; among them, Italy holds the record for the amount of steel produced by electric furnace, present in 84% of Italian steel mills[39].

The most recent estimates show that the CO2 released from integrated cycle steel production is between 2.1 and 2.5 tons per ton of steel, while the use of the electric furnace reduces this value more than tenfold, emitting about 0.1-0.2 tons of CO2 per ton of steel[40]. For these reasons, steel mills need to invest more insistently in production by electric furnaces to confirm their contribution to the fight against climate change and reach the decarbonization of the steel industry at a rate coherent with the targets set by the Paris Agreement.

[39] World Steel in Figures 2023. (2023). World Steel Association (WSA).

[40] To the indicators for the electric furnace, however, must be added those for metallurgical pollution from scrap and charge used in the process, which impact 0.83 tons of CO2 emitted per ton of steel in the system, with production by natural gas. However, the resulting value remains lower than that of blast furnace-related CO2. Recently, alternatives to natural gas are being developed for the electric furnace such as hydrogen, which would reduce scrap pollution to 0.3 tons per ton of steel.

3.6 The EU response to accelerate the decarbonization of the steel industry

The European Union has set the ambitious "net-zero" emissions target for 2050 and this objective was at the heart of the European Green Deal. The intermediate step has been set by the "Fit for 55" package, which aims at reducing emissions by at least 55% by 2030.

To work in this direction, the EU has allocated billions of euros to the green transition thanks to the Recovery Fund and the RePowerEU fund and many European countries have committed billions of euros to the conversion of steelmaking plants.

For example, in February 2023 the EU Commission approved a 460 million euros Spanish measure to support ArcelorMittal Espana in the construction of a hydrogen-based direct reduced iron plant and a new electric furnace that will substitute the current blast furnace in Gijon[41].

More recently, in July 2023 the EU Commission approved an 850 million euros French measure to support ArcelorMittal France in decarbonizing its steel production processes in Dunkirk, where it operates three BF-BOF plants. The state aid will support the construction of a Direct Reduction Plant (which is used to produce DRI) and two electric furnaces which will substitute two of the three existing blast furnaces (BF) and two of the three basic oxygen furnaces (BOF)[42].

Similar state aids were also approved recently by the EU Commission, such as the 2 billion euros German measure to support ThyssenKrupp Steel Europe in constructing a Direct Reduction Plant and two electric furnaces (which will replace the current blast furnace) in Duisburg and accelerating its renewable hydrogen uptake for producing Direct Reduced Iron (DRI) through the Direct Reduction Plant[43].

In parallel, the EU has long been working on another front: regulation. The EU has introduced two very impactful pieces of legislation, especially for the steel industry: the EU ETS and, more recently, the CBAM. With the former being particularly relevant for domestic EU steel producers and the latter for domestic producers as well as importers. The combination of these two policies highly incentivizes a technology shift to EAF production, abandoning the BF-BOF production process and possibly including the use of DRI as raw material, and green hydrogen instead of natural gas to power the Direct Reduction Plant used to produce DRI.

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[41] Press corner. European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_849
[42] Press corner. European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3925
[43] Press corner. European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3928

3.6.1 The EU ETS

The EU ETS is the European Union's emissions trading system. It came into light in 2005 thanks to the EU Directive 2003/87/EC, representing the first such mechanism ever created, and is still one of the European Union's most important tools for combating climate change and reducing CO2 emissions. To date, it represents the second largest cap-and-trade system, after China's, and includes the 27 countries of the European Union and the 3 member countries of the EEA-EFTA (European Economic Area-European Free Trade Association): Norway, Liechtenstein, and Iceland. The EU ETS covers about 40% of the European Union's greenhouse gas emissions, encompassing several sectors, such as energy, manufacturing, and aviation. It regulates emissions of CO2 (carbon dioxide), N2O (nitrogen dioxide), and PFCs (perfluorocarbons) and covers more than 10,000 companies and about 600 aircraft operators.

As already mentioned, the EU ETS is a cap-and-trade system, which involves setting a limit on emissions (cap) allowed within the countries regulated by the ETS for a given period. The cap is given by the issuance of a certain number of emission allowances, or permits, that constitute the "right to emit". Those who fail to meet the maximum target of assigned emissions (assigned amount) must go to the allowance market and buy permits (trade) from those who have produced fewer emissions than the one they have been assigned. Moreover, a certain number of free allowances is also given to high energy-intensive companies that are particularly exposed to international competition and have a higher risk of carbon leakage (i.e., the relocation of production to countries with less stringent emission constraints). These companies work in the iron and steel, cement, chemicals, and pulp and paper industry, among others.

The first steps of the EU ETS can be traced back to 1997[44], with the establishment of the Kyoto Protocol, which introduced emission reduction targets for the 37 industrialized countries participating in the agreement.

Between 2005 to 2007, the so-called "pilot phase" was the first stage and was adopted to test the new carbon market prices and build the infrastructures required for monitoring, reporting, and verifying emissions[45]. The primary goal of the first phase was to ensure that the system operated effectively before 2008 to assure that all of the EU Member States will comply with the Kyoto Protocol's provisions.

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[44] The Kyoto Protocol was created in 1997 but ratified in 2005.
[45] EU ETS Handbook. (2015). European Union.

The second phase (2008-2012) introduced the aviation sector inside the system[46]. The third phase (2013-2020) defined the auction process as the default process for the distribution of the allowances and harmonized the rules concerning the allocation of free allowances.

Over time, the European Emissions Trading Scheme has gradually become more restrictive, through several reforms and is now in its fourth trading phase (2021- 2030).

The last reform of the system was discussed in December 2022 and formally adopted the new legislation in April 2023 and has set more ambitious emission reduction goals, among them reducing emissions to 63% (previously it was 43%) below 2005 levels by 2030. To do so, the rate of cap decrease was also increased, passing from 2.20% annually to 4.3% in the period between 2024 and 2027 and 4.4% from 2028 to 2030.

Moreover, the EU ETS will be extended to the maritime sector and there will be a gradual phasing out of free allowances for certain sectors in parallel with the introduction of the Carbon Border Adjustment Mechanism (CBAM).

The EU ETS has contributed and will contribute substantially to the reduction of GHG emissions and thanks to the recent changes to the system, it will pave the way to reaching the "net-zero" objective of the EU and the Paris Agreement. However, it will also have tangible impacts. A decrease in the cap rate, together with a decrease in the number of free allowances for high energy-intensive sectors (eg., steel) means that the cost of the CO2 will grow larger if demand doesn't decrease (since supply will reduce) and the only way to decrease demand is to produce fewer emissions, that is, to decarbonize the production process. During my internship, something that strokes me was how more stringent policies concerning the EU ETS have been a major driver in incentivizing Steel companies to decarbonize their production process and reduce their emissions: these policies surely had the desired effect.

[46] Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community.

3.6.2 The Carbon Boarder Adjustment Mechanism (CBAM)

Climate change, as we have seen in the first paragraphs, is not an isolated issue. It is a cross-border problem concerning the entire world and cannot be solved only by one nation or group of nations. European businesses will have to deal with two major threats if multilateral efforts are not implemented by all nations: the phenomena of carbon leakage and the decline in the competitiveness of their sectors.

Carbon leakage refers to the relocation of production to countries with less stringent emission constraints to reduce the costs associated with the emissions and the policies currently implemented by the EU to decarbonize and meet its carbon reduction targets will increase significantly the risk of carbon leakage (we have seen with the decrease in total number of allowances in the EU ETS the price of CO2 could go up if demand doesn't decrease, harming companies who regularly buy emissions in the market).

With this in mind, the European Commission proposed to create the Carbon Border Adjustment Mechanism (CBAM) arguing that a significant number of trading partners still do not have climate change measures comparable to those deployed by the Union and that the risk of carbon leakage will end up undermining efforts and lead to an overall increase in global emissions.

The European Commission made the legislative proposal for the implementation of a Carbon Border Adjustment Mechanism (CBAM) in 2021. In March 2022, the Council reached an agreement on the text. In December 2022, negotiators of the Council and the European Parliament reached a provisional agreement on CBAM and in April 2023 the Council formally adopted the new rules.

The EU ETS initially served as the backbone of the EU's emissions reduction policy, but growing imports from nations with a more carbon-intensive energy mix have partially offset this reduction. Therefore, despite a 21% decline in EU domestic GHG emissions between 1990 and 2018, net CO2 imports rose by 28% during that same time. In fact, before the introduction of the CBAM, the transitorily free allowances of the EU ETS and particular financial measures targeted at compensating the indirect costs of emissions passed on to the pricing of electricity were the mechanisms utilized to mitigate the risk of emissions relocation for the high-risk sectors. Hence, we can deduce that the introduction of the CBAM pursues two objectives: limiting the possibility of carbon leakage to countries with more favorable emissions constraints and reducing CO2 emissions related to imports of goods to the EU. As President von der Leyen stated "carbon must

have its price – because nature cannot pay the price anymore. The Carbon Border Adjustment Mechanism should also motivate foreign producers and EU importers to reduce their carbon emissions"[47]. Therefore, the carbon price used for imports and the price for carbon on the EU internal market must be equal. Due to the CBAM, importers of carbon goods will need to buy carbon certificates at the same cost as if they were manufactured according to European regulations. With this mechanism, the Union intends to preserve the incentive to reduce emissions even for economic operators from jurisdictions that do not impose a carbon price or have a significant differential to the stringency imposed on European producers. The measure provides for a transitional period, from 2023 to 2025, to allow time for companies to adjust to the procedures and requirements of the CBAM. In this phase, importers need to calculate and communicate the emissions of the imported goods (this means that the companies that export should calculate the emission of their goods) but are exempt from acquiring CBAM certificates. And an implementation period, starting in 2026, in which the phasing-in of CBAM will be coupled with a reduction in free allowances allocated under the ETS. For the steel industry, the CBAM will have significant effects. Free allowances will be reduced between 2026 to 2034 to the point that in 2034 there will be 0 free allowances. Moreover, since the EU is currently a net importer country, internal estimates of my team suggested that the price of imports will rise up to 30%, greatly affecting EU steel imports and the economy overall.

[47] State of the Union Address by President von der Leyen at the European Parliament Plenary on 16 September 2020

4. Conclusion

After starting with a report on my internship at The Boston Consulting Group, in the academic research part, I talked about the complexities of climate change, along with its causes, effects, and potential solutions. I analyzed the Paris Agreement, and why it is currently the most significant international treaty that emphasizes the necessity of international cooperation in resolving climate change and reducing the increase in global average temperatures.

During my internship, I joined a team that worked alongside clients operating in the steel industry, therefore in the dissertation I put a lot of emphasis on how the steel industry contributes to global CO2 emissions (7% of worldwide CO2 emissions), and why finding sustainable routes to decarbonization is urgent and the technology already available.

The main strategy for decarbonizing the steel industry is the replacement of the BF-BOF production processes with electric furnaces combined with hydrogen-based Direct Reduction Plants. These technologies have the potential to transform the manufacturing of steel, lowering its carbon footprint while ensuring the sector's viability without being dependent on the availability of scrap (the other raw material used instead of DRI).

The European Union has been at the forefront of this transition and has implemented financial and regulatory incentives to accelerate the decarbonization of the steel industry, from the introduction of monetary measures through the Recovery Plan and the RePowerEU package to the approval of state aid measures to finance the transition of multiple steel plants to electric furnace production using DRI across Europe.

For what regards the regulatory incentives, since in the Paris Agreement there is no reference to carbon taxes, the EU has introduced its own, very restrictive, pieces of regulation for what regards emissions and carbon taxes: EU ETS and CBAM.

The steel industry has been highly affected by these policies, and during my time at BCG, I can firmly state that these policies have become the main driver for companies to decarbonize their production process to avoid higher future economic costs.

The road to complete decarbonization is still difficult, and it will take ongoing commitment from every level of society. To achieve a “greener” future with low emissions, government regulations, technical advancements, corporate leadership, and consumer awareness must coexist.

However, the EU's strategy for encouraging the decarbonization of the steel industry offers important lessons for other countries looking to reduce climate change while maintaining economic growth. A lot remains to be done, but we are certainly in the right direction.

During my internship, the academic contribution of the courses I took at Dauphine played a major role in getting up to speed with the rest of the team on the issues of climate change and decarbonization. Thanks to the courses in "Economics of Climate Change", "Green Finance" and "ESG Investing", I was able to grasp very rapidly the key issues my team was trying to resolve for clients. Moreover, the concepts learned in these courses came in very handy once I had to go deeper into the topics analyzed during my academic research.

Additionally, thanks to the course "Leadership in Finance", I was able to collect the theoretical (but also practical) knowledge around leadership and public speaking, which at a job such as consulting are extremely important and if well internalized can provide a competitive advantage over your peers.

Last but definitely not least, I would also like to thank Monica Billio, Martine Carré-Tallon, and their amazing collaborators for setting up and coordinating a remarkable double degree program. They did a fantastic job in making the experience very smooth, engaging, and above all, fun.

I have still one month before the end of my internship at BCG, but as I reflect on the transformative journey it has been so far and the aspirations that fueled it, I look forward to the opportunities that lie ahead. I experienced amazing growth, especially in my soft skills and self-confidence but also in my hard skills and problem-solving. Consulting does a tremendous job in giving you the right mindset to face every type of problem and the skill set to succeed in any other career.

As I already stated in the internship report, I believe that the opportunities, the type of work, and the quality of people are unparalleled by any other job. I am grateful for the great time I had at the firm, and I look forward to continuing with this career.

Looking forward to my professional plans, I would like to work on impactful projects, maybe more focused on corporate finance and private equity due diligences, but with positive social and climate ramifications. However, I don't want my path to be limited only to professional challenges: I would like to embark on a new academic experience such as the MBA, preferably at INSEAD. This step would further solidify my skills, increase my network, and mark my dedication to continuous growth.

As I prepare to embrace the road ahead, I remind myself of a quote that says “The beauty of ambition lies not only in the heights to which it propels us but in the path it sets us on”.

My internship at BCG was a pivotal chapter, but the narrative is far from complete, and I look forward to writing the chapters that follow, which will undoubtedly be marked by boldness, resilience, and relentless dedication to making a positive impact on the world.

5. Appendix

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5.2 Internship Evaluation

Perparim Pellumbi: curricular internship review

During his 5 months internship period Perparim has been involved in a critical project consisting in the operative support to a company under extraordinary administration.

During this project Perparim supported the team along the major project workstreams:

- Monitoring of contractual requirements
- Cash flow update and support to the Company's CFO
- Financial and technical monitoring of environmental activities
- Coordination of key stakeholders.

Perparim worked directly with the client to collect and process information, updating the documents and the cash flow model.

Perparim performance has been outstanding on the major dimensions, with a very positive trajectory. Perparim showed a natural propension towards quantitative thinking and problem solving and a very delivery-oriented attitude. He proved to be reliable, always managing the deadline and with a very good propension towards team working.