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# ESG rating construction: an objective and transparent approach

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# Abstract

In the last few years, ESG concerns, short for environmental, social and governance concerns, have been booming, raising the interest of investors, organisations and individuals worldwide. Responsible investments have skyrocketed, with the ESG market capitalisation reaching more than 30 trillion dollars. Considering the impossibility to ignore this megatrend as well as the unprecedented demand for assets with superior ESG performance, institutional investors rely more and more on ESG ratings to assess their investment allocation decisions. Nevertheless, it is still truly difficult to evaluate the portion of a company's value creation attributable to sustainable initiatives, and ESG rating agencies often disagree. Some argue that ESG is not value relevant from an investor standpoint, mainly due to the fact that the lack of standardisation on ESG disclosure involves serious data gaps, inconsistencies and comparability issues. What raters decide to measure, how they measure it, and the materiality they recognise, usually generate confusion, resulting in neither accurate nor transparent evaluations. Since the corporate ethic and reputation is fundamental in determining its shareholders and stakeholders base, there is a strong need to provide a comprehensive assessment which could shed light on the true corporate sustainability conduct, overcoming the divergences.

From here, the study develops a procedure to evaluate in the most objective, transparent and clear way, the corporate long-term performance. By relying on the Global Reporting Initiative Standards, it identifies the company's key performance indicators in a long-term horizon, concerning each of the three ESG pillars, and weights their impact mainly exploiting the United Nations 17 Sustainable Development Goals and specific literature. The proposed model progressively constructs the ESG rating, valuing organisational strengths and weaknesses and considering voluntary data gaps. Precisely, to generate a score which is the most accurate and transparent as possible, it penalises this non assessable information and tries to get round the issue with data prediction.

The study concludes with benchmarking the obtained rating and the evaluations of two emerging agencies, Refinitiv and Sustainalytics.

**Keywords:** ESG, rating ESG, GRI, Sustainable Development Goals, KPI, sustainability



## Abstract in lingua italiana

Negli ultimi anni, le tematiche ESG – acronimo inglese per sostenibilità ambientale, sociale e di governance aziendale – stanno subendo una continua e notevole espansione, suscitando l'interesse di investitori, società e individui in tutto il mondo. La rivoluzione sostenibile sta cambiando i prodotti di investimento e la capitalizzazione del mercato ESG ha raggiunto più di 30 trilioni di dollari. L'impossibilità di ignorare questa crescita senza precedenti ha spinto gli investitori ad affidarsi in misura sempre maggiore ai rating ESG nell'allocazione strategica delle risorse. Ciò nonostante, è ancora difficile valutare quanto un modello di business sia responsabile e le agenzie di rating sono spesso in disaccordo. La mancanza di standardizzazione nella rendicontazione dei dati sostenibili è causa di numerose lacune e divergenze, che ostacolano l'elaborazione di un valore di sintesi circa le potenzialità di un investimento sostenibile. Di contro, l'eterogeneità delle metriche analizzate, le numerose modalità di misurazione e la diversa significatività riconosciuta agli indicatori, inibiscono valutazioni trasparenti, accurate e confrontabili. È necessario porre le aziende sotto una comune lente ESG per fornire una valutazione globale che, in un contesto concorrenziale, aiuti stakeholder e shareholder a orientarsi verso gli investimenti più responsabili.

In questo contesto si inserisce il progetto di tesi. Lo studio sviluppa un algoritmo per valutare nella maniera più obiettiva, precisa e trasparente possibile, la performance aziendale di lungo periodo. Sfruttando i Global Reporting Initiative Standards, identifica gli indicatori strategici di performance aziendale per ognuno dei tre pillar, ambientale, sociale e di governance, e pesa il loro contributo avvalendosi dei 17 Obiettivi per lo Sviluppo Sostenibile delle Nazioni Unite, e della letteratura specifica a riguardo. Attraverso un'analisi progressiva, elabora un giudizio sistematico, valutando gli indicatori di performance disponibili e considerando i dati omessi nella rendicontazione. Penalizzando le informazioni mancanti non valutabili e servendosi dell'analisi predittiva, ottiene uno score esaustivo e bilanciato.

Lo studio termina esaminando le divergenze tra il rating elaborato e le valutazioni di due agenzie emergenti, Refinitiv e Sustainalytics.

**Parole chiave:** ESG, rating ESG, GRI, Obiettivi per lo Sviluppo Sostenibile, KPI, sostenibilità

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# Introduction

Today's worldwide crises are the results of climate change issues, environmental impoverishment, resources exploitation, healthcare emergency, corporate governance frauds, social inequalities and discriminations, which are shaping changes in people habits and mind-sets.

The bankruptcy of Purdue Pharma in 2019 is one of the most dramatic episodes. The pharmaceutical giant was censured for its aggressive marketing campaign, representing a misleading promotion of its opioid painkiller OxyContin. To face pressures of competition, the company maximised its profit at the expense of human health, representing an underestimation of the drug addiction. In this way, Purdue Pharma became the corporate face of the opioid American crisis, which have caused more than 500,000 deaths. The case of Purdue Pharma inevitably shows how ethical marketing is crucial for building a strong company's reputation, as it is able to develop, include, communicate and represent a business's image, reflecting its ESG attitude and responsibility[1]. The Deepwater Horizon oil spill (2010), the Facebook data privacy scandal (2018) and the Enron Corporation accounting fraud (2001) are other noteworthy examples highlighting how businesses are vulnerable to environmental, social and governance risks, since these shape their image and reputation between shareholders and stakeholders too[2].

Since global challenges continue to affect companies' exposure to these issues and their ability to manage them, businesses started to adapt their missions statements accordingly. Corporate managers realised that costs arising from these dangerous scandals could be reduced with corporate social responsibility, combining their first goal of maximising the profit, with environmental, social and governance needs, shortly ESG needs. In an attempt to reduce the above discussed real issues in the long-term, sustainability is not seen as a pure financial return: addressing ESG concerns has become a critical part of the business strategy to limit the company's impact on the natural ecosystem, take care of workforce and customers in compliance with human and labour rights, and ensure the transparency and honesty of management practices.

As such, more and more people tend to purchase products from companies which share their own values, whether paying attention to human well-being, environmental preserva-

tion, diversity and inclusions.

Accordingly, at the start of 2020, surveys estimate 30 trillion dollars in ESG assets, up to a 15% increase over the previous two years, reaching about 36% of total assets under management. To stand out from the crowd from the investor perspective, responsible investing is becoming a very thematic trend which is involving in particular the financial industry. When selecting allocation strategies, investors are increasingly considering responsible initiatives. In this way, the financial channel has inevitably an enormous power in terms of influencing and shaping companies behaviours towards the health and safety of societies and the environment.

Since the valuation of the ESG corporate performance can influence financial decisions, with far-reaching impacts on corporate policies, customer preferences and asset prices, there is a call for an increasingly transparency on businesses sustainable investment practices. More and more investors rely on ESG ratings to obtain a third-party analysis of firms' green quality. This has led to the birth of ESG rating agencies, including the emerging KLD, Sustainalytics, Moody's ESG (previously Vigeo-Eiris), S&P Global (previously RobecoSAM), Refinitiv (previously Asset4), and MSCI.

However, the lack of regulation and standardisation on ESG disclosures generates uneven, poor and often unreliable data collection. As a consequence, not every company reports on ESG issues, and those that attempt are not consistent, questioning the chance to gain a full snapshot of a company's sustainable operations. Kotsantonis, S. *et al.* investigate a sample of 50 companies from Fortune 500<sup>1</sup> list, collecting information about the social issue Employee Health and Safety. They find out roughly 25 different metrics defining the same concern, including the number of accidents with fatal consequence, the rate of injury per 200,000 hours worked, the lost-time incident frequency rate, the injury rate and many others[3]. Data measured differently make measurement inconsistency, and subjective reporting make benchmarking very hard at the evaluation phase. On top to these, rating agencies' scores disagree between other's substantially.

Aiming to develop solutions to tackle the issues arising from ESG rating results comparably, the Aggregate Confusion project by MIT Sloan Sustainability Initiative addresses the difficulty in acquiring high-quality data on sustainable exposures, figuring out a 0.61 correlation between the aforementioned leading ESG rating agencies, against the 0.99 correlation between Moody's and Standard & Poor's credit ratings<sup>2</sup>. This discrepancy undermines the rating first goal of valuing the company's ESG performance, discouraging improvements in sustainable attitudes and distorting the results of corporate social

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<sup>1</sup>The Fortune 500 is an annual list by Fortune magazine which ranks the 500 largest American companies by total revenue for their respective fiscal years.

<sup>2</sup>Moody and Standard & Poor's are two of the three most important worldwide rating agencies which rate the creditworthiness of countries and private companies.

responsibility on asset prices.

In general, even if the players are multiple, ESG scores group several metrics in a single value, by aggregating a measurement and a weight component. The framework typically combines different key performance indicators to form the rater-specific metrics. To find out what drives these mismatches, the Aggregate Confusion project analyses the six ESG rating agencies and discovers that the confusion arises from a multifaceted three-tiered divergence. *Scope divergence* emerges when ratings depend on different sets of metrics. The project finds out several narrow categories not covered by all raters, including Forests, Electromagnetic Fields and Animal Welfare.

*Measurement divergence* emerges when ratings measure the same metric exploiting different key performance indicators. The project gets discrepancies even in the core ESG concerns like Water and Energy. By computing the correlations per raters pair, it discovers the correlation of these two categories to be on average 0.36 and 0.38, respectively. In some other cases, the value found is even negative, showing a complete disagreement.

Finally, *weights divergence* emerges when ratings recognise different significance to the same metric. Via a least squares regression, the project estimates the weights that raters have given to the common metrics. It discovers that also the principal metric weights do not overlap and highlights significant discrepancies between the agencies[4].

Since the approaches used by ESG data providers are inconsistent, investors' decision for portfolio constructions could be altered if the ESG implications are based on rating assessments. Li, F. *et al.* compare Facebook environmental ratings assessed by two distinct data vendors. They do not value the same metrics, and, when metrics are similar, they assign different weights and evaluate them differently. As a result, a provider rates Facebook as a top firm, while, according to the other, it is below average[5]. Moreover, it is also very difficult to understand the precise methodology rating agencies embrace in their measurement. Even if material key issues are usually disclosed, the information about the rating method is very poor, making it more challenging to understand how the vendor assesses ESG issues and compare distinct results.

All these emerging trends suggest a key challenge in quantifying how a firm performs with respect to ESG criteria, putting all under a *common ESG len.* As summarised in the words of Professor Roberto Rigobon<sup>3</sup>, there are needs to create a new universal guidance for giving a chance to businesses, consumers, governments and investors to integrate ESG data into their decisions.

Trying to solve and overcome these divergences, we assess a firm's ESG performance by providing an *objective* and *transparent* snapshot of its impacts on the economy, the

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<sup>3</sup>Roberto Rigobon is a Venezuelan economist. He is the Society of Sloan Fellows Professor of Management and the Professor of Applied Economics at the MIT Sloan School of Management.

environment and the society. In shaping our measuring set-up, we rely on the latest 2021 version of the Global Reporting Initiative Standards (GRIs). The Global Reporting Initiative is a standard-setting organisation which promotes sustainability reporting by defining a comprehensive guidance which provides a view of a company's material issues, their impacts and management. In this way, we generate a common alphabet of disclosure.

We analyse one by one the GRI Topic Standards which are structured into economic (GRI 200), environmental (GRI 300) and social (GRI 400) series, and we split the analysis into the three environmental, social and governance pillars, finding pillars-specific metrics, or key factors, that account for different main topics. Then we group the GRI Standards, identified in the Key Performance Indicators (KPIs), in a way that each group describes a key factor, by integrating GRIs listing with widely acknowledged norms, developed by the United Nations (UN), the International Labor Organization<sup>4</sup>, and the Organization for Economic Co-operation and Development<sup>5</sup>. Precisely, we mainly refer to the UN 2030 Agenda for the Sustainable Development, which collects a set of 17 new targets, called Sustainable Development Goals (SDGs), driving the world's prosperity reducing hunger and poverty, promoting peaceful, just and inclusive societies, supporting partnership and collaboration and safeguarding the environment. We also rely on the Paris Agreement on Climate Change<sup>6</sup>, the Ten Principles of the United Nations Global Compact<sup>7</sup>, the

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<sup>4</sup>The International Labour Organization (ILO) is a UN agency aiming to promote social and economic justice, developing programs and policies in favour of decent work for all women and men, and defining labour standards which take the form of international conventions and recommendations.

<sup>5</sup>The Organization for Economic Co-operation and Development (OECD) is an intergovernmental group with 38 members established to promote global commerce and economic growth. It offers a unique forum and knowledge hub for data and analysis, exchange of experiences, sharing of best practices, and guidance on governmental policies and the development of international standards.

The OECD's 38 members are: Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. OECD welcomed Costa Rica as new member in 2021.

<sup>6</sup>The Paris Agreement is the twenty-first global climate summit – the so-called Conference of the Parties – organized by the UN to face the environmental threat. As first legally binding international agreement on climate change, it marked a breakthrough in the global answer.

The United Nations Climate Change Conferences, known as Conferences of the Parties (COPs), were established in 1992 during Rio Earth Summit. Rio Earth Summit is the United Nations Conference on Environment and Development (UNCED), known as Earth Summit, focusing on ever-increasing economical, social and environmental difficulties toward a global sustainable development. The Conference adopted various documents and agreements as guidelines for member states including the Rio Declaration on Environment and Development, Agenda 21, Forest Principles, the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC).

COPs are annual meetings on climate change issues held by UNFCCC signatory states.

<sup>7</sup>The United Nations Global Compact is a United Nations non-binding pact that encourages businesses to adopt sustainable and socially responsible policies and report on their implementation, stating ten principles for businesses to be followed.

OECD Guidelines for Multinational Enterprises<sup>8</sup>, the United Nations Guiding Principles on Business and Human Rights<sup>9</sup>, the Fundamental Conventions of the International Labour Organization<sup>10</sup> and the OECD Principles of Corporate Governance<sup>11</sup>. Matching all KPIs with a common set of acknowledged metrics, the approach resolves scope and measurement divergences. In this way, data are organised into a common blueprint.

At this stage, we develop a scoring process based on a weighted sum of several key factors, whose weights are framed into the 11 industrial sectors of the Global Industry Classification Standard<sup>12</sup>. The paradigm uses weights to measure each key factor's impact on the overall score, relying on a complex research based on SDGs, specific literature and ESG news sources.

We construct the ESG rating as a *fair* and *relative* comparison with the ongoing industrial scenario, exploiting a bottom-up approach which ends up combining the relative evaluations for each of the three pillars.

Finally, an accurate and transparent approach deals with the issue of voluntary data gaps. In fact, a company may decide not to disclose some data either to hide non-good sustainability actions, or simply to cut costs. The method considers data holes via a penalty algorithm and then tries to fill the gaps with predictive models.

In the end, the algorithm is applied to a manually collected set of 222 Italian listed companies in the FTSE All Share index. The results are finally discussed and, when data are available, they are compared with Refinitiv and Sustainalytics ratings.

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<sup>8</sup>The OECD Guidelines for Multinational Enterprises are recommendations on responsible business conduct issued by governments to multinational corporations operating in or from the countries that have signed on. The Guidelines establish non-binding principles and standards for corporate social responsibility.

<sup>9</sup>The United Nations Guiding Principles on Business and Human Rights (UNGPs) is a set of thirty-one principles for states and companies dealing with human rights prevention in business scenarios, also addressing their violations.

<sup>10</sup>The Fundamental Conventions of the International Labour Organization are a set of conventions and treaties aiming to ensure that work is accessible, productive, and sustainable, in conditions of freedom, equity, security and dignity.

<sup>11</sup>The OECD Principles for Corporate Governance are a set of standards for evaluating and improving the corporate governance.

<sup>12</sup>The Global Industry Classification Standard (GICS) is the industrial taxonomy developed by MSCI and S&P Global.

## Structure of the thesis

The thesis is organised in 5 chapters:

1. **ESG pillars** presents the alphabet of disclosure, organised into the environmental, social and governance pillars. These are broken out into several key factors, and these, in turn, are broken out into a set of GRIs.
2. **Constructing the rating** is the core chapter of the thesis which presents the full rating methodology. It examines one by one all GRIs, distinguishing between considered and overlooked GRIs.
3. **Weights** presents the weights recognised to each key factor concerning the environmental, social and governance pillars, resulting in a very broad research.
4. **Data prediction** presents the predictive models used to fill data gaps.
5. **Computing the rating** discusses the obtained results and compares them with the ratings of Refinitiv and Sustainalytics.

# 1 | ESG pillars

In the following we present the three Environmental, Social and Governance pillars and we discuss the related emerging risks and opportunities. We examine in detail each key factor, listing the corresponding Global Reporting Initiative Standards, or Key Performance Indicators, indicating whether they imply a quantitative or a qualitative disclosure. Concerning the environmental pillar, we mark with a star the KPIs placed in two distinct key factors.

## 1.1. Environmental pillar and key factors

We are into the midst of an unparalleled environmental crisis: natural balance has been disrupted by climate change over the years endangering planet survival. Around the world, storms, floods, wildfires, droughts and floods are boosting, extreme weather is damaging buildings and livelihoods, air pollution is compromising people's health. Climate emergency is destroying the biodiversity threatening the extinction of animal and plant species. Extreme heat is a serious danger both for humans and wildlife: the thermometer in Alaska reached its highest peak in July 2019 killing a wide variety of salmons, warmer waters are causing coral reef bleaching and stronger storms, the Arctic is warming quickly influencing weather all across the world and jeopardizing its ecosystems. To face this critical scenario, the UN organizes the Conference of the Parties (COPs) since decades. The Paris Agreement (COP21) in 2015 aimed to limit temperature rises to well below 2°C, preferably to 1.5°C. Since greenhouse gas emissions are the primary source of global warming, cutting them is the guiding pathway to fight it and to meet the lofty goal of accomplishing net zero emissions by the middle of the century. It is not only about gas release, saving forests from deforestation could help in speeding-up the neutralisation of carbon dioxide (CO<sub>2</sub>) in the atmosphere.

Climate action is much more than that. Industry owns a wide range of possibilities and control on SDGs towards a greener and better future for all. It is becoming more and more crucial investing in green technologies to embrace innovative solutions which minimise the impact on the environment. Renewable energy is one of the most powerful long-term per-

spective measure that today's concerns necessitate, especially because the overall demand for energy services is expected to increase by an order of magnitude by 2050[6]. Recycling is the part one to set up a circular economy which reduces the exploitation of materials, recaptures waste and minimises water, air and soil contamination. As a result, there is a great need of developing efficient sustainable techniques for extracting, processing and using raw materials, which are the backbone of the economy. It is not just an issue of misusing, the ever-growing demand for natural resources is generating serious everlasting environmental problems such as water stress, soil degradation and damages to ecosystem functions. Spikes in agricultural commodity prices, over-fishing, falls in healthcare, hygiene, food and energy security are just few consequences.

In the sections below we structure our environmental analysis into six key environmental factors with the corresponding key performance indicators. We highlight the main topics we focus on, by relying on the seventh, eighth and ninth principles of the UN Global Compact, the Guidelines for Multinational Enterprises and the Sustainable Development Goals. The willed reality develops an eco-friendly sensibility (SDG 11), promoting an industrial system which provides clean energy (SDG 7) and responsible production (SDG 12) with the ever-growing adoption of environmentally sound technologies (SDG 9). Following this direction businesses become a powerful force for achieving SDGs supporting climate action (SDG 13) without threatening life on Earth and below water (SDG 15 and 14), stimulating growth, health and well-being (SDG 3) while respecting the environment (SDG 6).

The six selected criteria at the wheel of the environmental sustainability are: Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions, water, land use and biodiversity, raw materials sourcing, waste and pollution, clean-tech and renewables.

### 1.1.1. Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions

This factor represents the level of gaseous byproducts of industry processes released into the atmosphere.

Greenhouse gases (GHG) trap a significant amount of solar radiation into the atmosphere resulting the major cause of the greenhouse effect. GRI standards address the accounting and reporting of the seven greenhouse gases highlighted by the Kyoto Protocol<sup>1</sup>: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), fluorocarbons (PFCs), sulfur hexafluoride (SF<sub>6</sub>) and nitrogen trifluoride (NF<sub>3</sub>).

Ozone-depleting substances (ODS) are very powerful greenhouse gases which generate the depletion of the atmosphere protective ozone layer. This is one of mankind's major environmental problem since ozone is a good natural greenhouse gas produced by some algae, which absorbs most of the ultraviolet radiation allowing survival on the land surface. This scenario is life-threatening: ultraviolet rays could cause skin cancer and DNA mutations in humans as well as put in danger the wildlife. The Montreal protocol is an international treaty signed in 1987 to phase out the production of most of these substances: the ozone layer is expected to recover by the middle of the century instead of increasing tenfold compared to the current levels.

Finally, we analyse also the impact of other significant air pollutants such as nitrogen oxides (NO<sub>x</sub>) and sulfur oxides (SO<sub>x</sub>) harmful for living beings, environment, climate and materials. These gases are the main cause for acid rain: precipitation releases them on the land damaging plants and agriculture, corroding materials and acidifying water.

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<sup>1</sup>The Kyoto Protocol is an international environmental treaty on global warming adopted during the United Nations third Conference of the Parties (COP3) on 11 December 1997 which came into effect only on 16 February 2005.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	305-1	Direct (Scope 1) GHG emissions	Quantitative	[tCO <sub>2</sub> eq]
	305-2	Energy indirect (Scope 2) GHG emissions	Quantitative	[tCO <sub>2</sub> eq]
	305-3	Other indirect (Scope 3) GHG emissions	Quantitative	[tCO <sub>2</sub> eq]
	305-4	GHG emissions intensity	Quantitative	[ ] <sup>2</sup>
	305-5*	Reduction of GHG emissions	Quantitative	[tCO <sub>2</sub> eq]
	305-6	Emissions of ozone-depleting substances (ODS)	Quantitative	[tCFC-11eq]
	305-7	Nitrogen oxides (NO <sub>x</sub> ), sulfur oxides (SO <sub>x</sub> ), and other significant air emissions	Quantitative	[t]

Table 1.1: GHG, ODS and other significant emissions KPIs.

### 1.1.2. Water

Water is such an important resource both for life and well-being that it is recognised by the United Nations as a human right. It is one of the most significant issues of our time that requires intentional care.

Water stress is becoming a serious problem more and more: billions of people lack proper access to clean water[7] and the situation is predicted to worsen because of the detrimental effects of global warming and population expansion: according to the United Nations, by 2050 world's population is expected to reach 9.4 billion people.

Moreover, water quality is being challenged by rising water temperatures, pollution and contamination. That is the case of Nigeria, Africa's largest economy: the Niger river delta is an oil-rich region in the southern part of the country, where multinational oil firms such as Shell, Exxon Mobil, Chevron Texaco, Total, and Eni, have damaged environment, society, and economy. Crude oil escaping from ancient pipelines that run for hundreds of kilometers into the land is the source of contamination. There were almost 7000 oil spill occurrences between 1976 and 2001, the degradation of the natural environment has pushed the residents of the region into poverty[8].

Among all Sustainable Development Goals, the sixth "Clean water and sanitation" stresses the need of ensuring long-term availability and management both of water and healthcare. Over the past fifty years, according to WWF's Living Planet Index<sup>3</sup> fresh water popula-

<sup>2</sup>The computation of the GHG emissions intensity involves dividing the absolute GHG emissions by the organisation-specific metric, including units of product, production volume, size, number of full-time employees, and monetary units. Accordingly, 305-4 relies on several units measure, thus we overlook it.

<sup>3</sup>The Living Planet Index (LPI) reports world's biodiversity health status by monitoring population's changes relying on time series of population size, density or abundance.

tions have dropped by 83% and around 30% of its ecosystems have been destroyed; as a consequence millions of people can no longer feed on sweet water fishes[9].

Emphasis and delicacy laid on water supply and management make it a material topic.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	303-1	Water interaction with water as a shared source	Qualitative	–
	303-2	Management of water discharge-related impacts	Qualitative	–
	303-3	Water withdrawal	Quantitative	[Ml] <sup>4</sup>
	303-4	Water discharge	Quantitative	[Ml]
	303-5	Water consumption	Quantitative	[Ml]

Table 1.2: Water KPIs.

### 1.1.3. Land use and biodiversity

Covering any living being, biodiversity refers to the variety of living forms that exist on the planet including plants, animals, microorganisms and fungi; it is simply the richness of life on the Earth. From the tropical rainforests to the savannas, from the marshes to the deserts, Earth's ecosystems are the results of 3.5 billion years of evolution. Many aspects of human life such as basic and daily necessities – like food, medicine and fuel – climate regulation, raw materials sourcing and fiber supply – like cotton and wool – rely on biodiversity. Healthy ecosystems provide us with essential services that we take too much for granted: plants absorb the majority of carbon dioxide emissions, living organisms play a significant role in the water cycle, pollinators like birds, bees and other insects account for a third of global crop production.

Nevertheless, ecosystems are attacked from all sides. Climate change is feeding natural disasters which are getting worse and worse putting the extinction of at least one million of plant and animal species around the world. The growth in human population over the last century has resulted in fast environmental changes and catastrophic biodiversity losses around the globe with destruction of habitats, exploitation of resources and pollution. Increased agricultural land usage in nearly 70% of countries, excessive water extraction, rising demand for vegetable oils and irresponsible deforestation all contribute to biodiversity losses. As a result of the increase in agriculture, infrastructure and industrial development, the remaining terrestrial and aquatic biodiversity is restricted to scattered areas[10]. The impact on biodiversity is expected to grow in coming years.

<sup>4</sup>Ml stands for megaliters.

Back in 1992 during the Rio Earth Summit, leaders from 150 nations signed the Convention on Biological Diversity aiming to pledge biological diversity. However, this attempt has failed for nearly three decades. In 2020, relying on the Living Planet Index, WWF painted a frightening picture of the world’s biodiversity ruled by an overall trend of loss: amphibians, birds, fishes, mammals and reptiles dropped by an average of 68% between 1970 and 2016[11]. In this scary scenario, GRI standards encourage the companies to adopt biodiversity-friendly preventative and restoration measures and to rely on the safeguard of the species which are included in the IUCN<sup>5</sup> Red List<sup>6</sup>.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	304-1	Operational sites owned, leased, managed in, or adjacent to, protected areas and area of high biodiversity value outside protected areas	Qualitative	–
	304-2	Significant impacts of activities, products and services on biodiversity	Qualitative	–
	304-3	Habitats protected or restored	Quantitative	[km <sup>2</sup> ]
	304-4	IUCN Red List species and national conservation list species with habitats in areas affected by operations	Quantitative	[#]

Table 1.3: Land use and biodiversity KPIs.

#### 1.1.4. Raw materials sourcing

Raw materials are unprocessed primary commodities at the heart of the production of other goods through appropriate manufacturing and industrial processes.

The rapid human population expansion, the rising levels of economic activity, and the shift to more environmentally friendly technologies are all leading to an exponential increase in resources demand and exploitation. Since the beginning of the 21<sup>st</sup> century, global material flows have recorded major acceleration: it took off in 2002 not as a one-time occurrence, but has persisted[12].

Numerous entities such as the European Commission and the Canadian government, have assessed the warning for raw material sources which is linked with supply risk.

<sup>5</sup>The International Union for Conservation of Nature (IUCN) (formally International Union for Conservation of Nature and Natural Resources) is an international organisation promoting nature conservation and sustainable use of natural resources. It focuses on data gathering and analysis, research, field projects, advocacy, and education.

<sup>6</sup>The International Union for Conservation of Nature’s Red List of Threatened Species (IUCN Red List) is the widest information database on animal, fungi and plant species. It classifies their risk of global extinction into different categories.

Within the supply chain for wind generators, raw materials phase is the major concern. Rare earths<sup>7</sup> are used for the production of permanent magnets which are the key components for the wind turbine generator. In this way, the future penetration into the market of wind energy will be determined by those material supply. In Europe, wind power development is threatened by these material scarcity while China dominates the market[13]. The changeover to a low carbon economy is driving the exacerbation in mining with global mineral extraction expected to reach two to three gigatonnes by 2050[14]. Moreover, the demand for non-fuel feedstocks is expected to rise as the world shifts away from fossil fuels and nuclear fission towards renewable energy sources. This process will result in a significant increase in demand for non-fuel basic materials needed for a variety of purposes such as energy production, storage, transmission, and use.

Some feedstocks are inexhaustible, on the contrary the scarcity of some of them, together with the increasing demand, lead in recent years to a significant price rises. Jeremy Grantham, a former oil analyst and financier, recently wrote in Nature<sup>8</sup> that global raw material prices are rapidly rising. He states this is “a genuine paradigm shift, perhaps the most important economic change since the Industrial Revolution. Simply, we are running out.”[15]

We need raw materials and a responsible metal sourcing to accomplish with the Paris Agreement and also with many of the SDGs. The development of new solutions is required for a responsible recovery such as non-invasive research and low impact technologies. Because of scarcity of materials and uncertain delivery systems, supply chains find challenging to ensure reliable stocks. Due to the limited availability of raw sources such as minerals and the expanding demand for end goods, an extra source of supply is required: recycling permits raw materials from ever-increasing waste streams to be integrated into production processes.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	301-1	Materials used by weight or volume	Quantitative	[t] or [m <sup>3</sup> ]
	301-2*	Recycled input materials used	Quantitative	[%]
	301-3	Reclaimed products and their packaging materials	Quantitative	[%]

Table 1.4: Raw materials sourcing KPIs.

<sup>7</sup>Rare Earth Elements (REE) are a set of seventeen chemical elements including lanthanides, scandium and yttrium used in a wide range of high-tech devices.

<sup>8</sup>Nature is a weekly worldwide journal that publishes the most cutting-edge scientific and technology research.

### 1.1.5. Waste and pollution

Humans are producing far too much waste but they are unable to manage it in a sustainable manner harming the planet. A lot of resources are needed to accomplish their exigencies, oceans and landfills are overflowing with non-biodegradable and non-recyclable waste. Today, with the expansion of consumption patterns, the amount of waste we produce has grown to be truly huge. Until few years ago, all waste was dumped in landfills then, to create a sustainable waste chain, it was established to limit their usage because they pollute the soil putting the underlying aquifer at risk of contamination. The gases produced by the breakdown of organic compounds represent a danger.

Water nowadays is wasted and polluted as a result of anthropogenic activities. In Bangladesh, due to the exponential growth of urbanisation and industrialization, both surface and groundwater are contaminated, poisoned by arsenic and harmed by toxic waste that threatens its potability[16].

Plastic pollution has emerged as one of the most important environmental challenges: the manufacture of disposable plastic items is exceeding our ability to manage it. Consider the case of plastic waste: plastics are made up of long-chain polymer molecules and are extracted as a byproduct from oil, coal, and natural gas. Plastic use is growing at a rate of 5% per year, while global output is estimated to be around 150 million tons yearly. The amount of plastic waste deposited into landfills ranges from 22% to 43% of total plastic waste produced. This is a severe environmental concern because most plastic waste is non-biodegradable, contains harmful compounds and takes up to 500 years to degrade. The majority of plastic is thrown in rivers, with birds and fish bearing the brunt of the contamination. If zooplankton ate micro-plastic debris, their food web would be disrupted, causing even more devastating repercussions[17].

Without a doubt, modern agricultural technologies have contributed significantly to the increase of global food supply. Agriculture, on the other hand, as well as other development-related activities, has been a major source of pollution and waste generation in recent years. These two interconnected agricultural outcomes stem from a variety of activities and materials used to boost efficiency and global agricultural output[18].

In recent years there has been a growing interest in preserving and recovering natural resources from waste, reducing its negative effects on human and environmental health as well as lowering waste production through the optimization of its management cycle. Waste management focuses on the entire waste process which includes collection, transportation and treatment with recycling or disposal of waste materials.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	306-1	Waste generation and significant waste-related impacts	Qualitative	–
	306-2*	Management of significant waste-related impacts	Qualitative	–
	306-3	Waste generated	Quantitative	[t]
	306-4	Waste diverted from disposal	Quantitative	[t]
	306-5	Waste directed to disposal	Quantitative	[t]

Table 1.5: Waste and pollution KPIs.

### 1.1.6. Clean-tech and renewables

clean-technology refers to all methods and products that eliminate or minimise the environmental effect of a specific manufacturing process by increasing energy efficiency, making more sustainable use of natural resources, minimising waste production and reducing emissions. As such, clean-tech is a broad term that encompasses a variety of technologies such as clean energy, recycling, environmental friendly transportation, green chemistry and energy efficient home appliances. Green economy innovation is becoming more and more popular: Cleantech Group<sup>9</sup> underlines that in recent years clean-technology industry has attracted the most venture investments of any sector, outperforming software and biotechnology[19]. British Petroleum<sup>10</sup> recently declared its decarbonization strategy by 2050. As it is reported in BlackRock<sup>11</sup> official website in the section entitled "Sustainability as BlackRock's New Standard for Investing", the multinational investment management corporation declares its decision to exclude from its portfolios thermal coal producers. The letter to the client states "[...] As Larry Fink<sup>12</sup> writes in his 2020 letter to CEOs, the investment risks presented by climate change are set to accelerate a significant reallocation of capital, which will in turn have a profound impact on the pricing of risk and assets around the world [...] We believe that sustainability should be our new standard for investing." Since October 2020, Reclaim Finance<sup>13</sup> has been doing research to determine the exact impact of this announcement. Unfortunately, even with this new

<sup>9</sup>Cleantech Group is a society which provides research, consulting and events to stimulate sustainable growth fueled by innovation.

<sup>10</sup>British Petroleum (BP) is a British oil and gas company. It is one of the world's seven largest publicly traded oil and gas companies well-known as "Big Oil" or "supermajors".

<sup>11</sup>BlackRock is the world largest asset manager, leader in providing investment, advisory and risk management solutions.

<sup>12</sup>Larry Fink is the chairman and CEO of BlackRock.

<sup>13</sup>Reclaim Finance is a young Non-Government Organization (NGO) that has the purpose of "making finance work for the climate". Its main goal is to realise the move away from fossil fuels of the world's largest financial institutions.

policy, the statistics demonstrate that BlackRock continues to be a major investor in coal companies, including those proposing new coal projects. For sure, rapidly eliminating fossil fuel investments is no easy task for a financial giant like BlackRock. Nevertheless, the company's attitude to sustainability must experience a systematic transformation in the following years[20].

Producing renewable energy means the exploitation of natural resources to generate power. In this way, solar, wind, hydro, wave, tidal, geothermal, bio-fuels and many others lead the transition towards a more sustainable and diversified energy system. Renewables, as low-carbon sources of energy, guide the post Paris decarbonization in a scenario where the combustion of fossil fuels for energy accounts for three-quarters of worldwide anthropogenic CO<sub>2</sub> emissions[21]. In this sense, renewables act like a brake to the global warming to reach climate and energy objectives. In addition to that, the use of renewable energy sources is plenty of economic and environmental advantages. They are clean and renewable energies since they do not pollute and they are naturally replenished on a human timescale. Since based on natural sources, they provide widely available and low-cost solutions. Moreover, renewables could materialise energy independence and safer energy supply which are becoming an increasingly topical issue especially with the emergence of Russia-Ukraine conflict. Green energy is the driving force behind global energy transformation, one of the leading strategies towards human and environmental peace and prosperity listed as the seventh goal for sustainable development in 2030 Agenda.

Despite the effects of the COVID-19 pandemic, renewable energy achieved a new record in terms of new electrical capacity in 2020, according to the Renewables 2021 Global Status Report<sup>14</sup>. Although G20 countries, world's biggest polluters, barely fulfilled or even failed their renewable energy commitments, investment in renewable energy capacity climbed, albeit little, and companies continued to set new records for renewable electricity production. The recent success of Australia's renewable energy industry is an example: small-scale solar powered Australia's renewable energy growth in 2021, accounting for 24.9% of the country total renewable energy generation. During the year, the sector added 3.3 GW of new capacity, marking the sixth year in a row that it has established a record for new installed power generation. In 2021, the renewable energy industry in Australia contributed for 32.5% of total electricity generation, up over 5 percentage points from 2020. Renewable energy has almost doubled in the country in the last five years, rising from 16.9% in 2017 to 32.5% this year[22].

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<sup>14</sup>Renewables 2021 Global Status Report is the only worldwide crowd-sourced report on renewable energy covering legislation, markets, and more while providing the most up-to-date global story on renewable energy.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	301-1a.ii*	Renewable materials used by weight or volume	Quantitative	[t] or [m <sup>3</sup> ]
	301-2*	Recycled input materials used	Quantitative	[%]
	302-1	Energy consumption within the organization	Quantitative	[GJ]
	302-2	Energy consumption outside of the organization	Quantitative	[GJ]
	302-3	Energy intensity	Quantitative	[ ] <sup>15</sup>
	302-4	Reduction of energy consumption	Quantitative	[GJ]
	302-5	Reductions in energy requirements of products and services	Quantitative	[GJ]
	305-5*	Reduction of GHG emissions	Quantitative	[tCO <sub>2</sub> eq]
	306-2*	Management of significant waste-related impacts	Qualitative	–

Table 1.6: Clean-tech and renewables KPIs.

<sup>15</sup>The computation of the energy intensity involves dividing the absolute energy consumption by the organisation-specific metric, including units of product, production volume, size, number of full-time employees, and monetary units. Accordingly, 302-3 relies on several units measure, thus we overlook it.

## 1.2. Social pillar and key factors

For a long time, political mainstream focused on economic policy, competitiveness and fiscal stability issues. The social factor has lagged behind as long as the severe social impacts of the financial and economic crisis came forward with increasing insistence, unsettling inclusiveness, gender equality, economic welfare and human rights.

In this scenario, human capital has been slowly recognised as a global wealth and social sustainability comes from the protection of this vital resource. In 2011, the United Nations Guiding Principles on Business and Human Rights established a set of guidelines for States and companies to identify, prevent and correct human rights violations committed in business operations. The European Pillar of Social Rights was set in 2017 to take on themes including equal opportunities and access to the labour market, fair working conditions and social protection and inclusion. Starting from 2021, BlackRock introduces the "Company Impacts on People" category in its Engagement Priorities<sup>16</sup>, calling for a broader and more enhanced attention on companies' impacts on human resource management. Its policy's only goal in interacting with businesses on human rights is to provide value for shareholders and clients, since poor relationships with stakeholders may create negative impacts exposing the company to legal, regulatory, operational, and reputational risks, endangering its social license to operate[23].

Socially sustainable companies focus on the relationship with their employees, the society and the political environment, looking at the workforce as a very valuable asset, and investing in it as critical to their business success. To gain a strategic advantage, they concentrate on workers performance, taking into account many human capital development and protection issues that can increase corporate reputation.

In a competitive environment, a studied and smart use of human resources and an improvement in employee productivity are important and effective plus. Thus, ongoing development activities enhance employee skills and abilities, getting them the necessary technical knowledge and teaching them how to work.

Employment protection legislation has been introduced to give special attention to new hire onboarding which, in turn, can ensure a high level of loyalty, preventing employee turnover, also reducing the expensive process of newcomers recruitment, selection, and training. Employers have legal responsibilities for delivering occupational health and safety, and an inadequate management system is subject to significant fines and penalties. Despite this, many organisations still engage irresponsible practices like inhumane

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<sup>16</sup>The Engagement Priorities is a set of engagement efforts annually identified by BlackRock, aiming to promote sound corporate governance and business models towards a strategy of sustainable long-term returns.

working conditions, discrimination and child labour.

Sustainability is a holistic vision of the reality and its business practices are not only inside the organisation but also outside, extending to the relationship with the community as a whole. Sustainable companies protect consumer privacy, retaining gathered personal data and not disclosing them. Furthermore, supply chain management should bother with its sustainability as well. Finally, along with human capital, sustainable organisations pay careful attention to product labelling, displaying useful information on its composition and disposal.

In the sections below we structure our social analysis into eight key social factors with the corresponding key performance indicators. The Universal Declaration of Human Rights marks rights and freedoms of all people: we are all born equal without any form of social, neither gender (SDG 5) nor race (SDG 10) discrimination or slavery, as it is stated also in the fourth, fifth, and sixth principles of the UN Global Compact and in the Forced Labour, Worst Forms of Child Labour and Discrimination Conventions by ILO. We all have the right to work in just and respectful conditions, ensuring a fair remuneration to guarantee our family a life worthy of a human being, as stressed in the ILO Conventions on Equal Remuneration, Occupational Safety and Health, and Promotional Framework for Occupational Safety and Health. We all have the right to privacy without interference in our private lives.

According to the first, second and tenth principles of the UN Global Compact, all businesses should promote and comply with internationally proclaimed human rights, and ensure they do not fall into violations or corruption actions. In order to promote the inclusive economic growth favoured by full and productive employment and decent work for all (SDG 8), the eight principles we identify are: employment, occupational and customer health and safety, training and education, modern slavery, communities, supplier social assessment, product responsibility, data privacy.

### 1.2.1. Employment

Employment has always characterised everyone's life. This factor focuses on the practices guiding worker's life, from hiring to turnover, paying attention to women's work roles, which have changed significantly over the years, and to the age of the workforce.

In the corporate scenario, age diversity creates a multiplicity of views, opinions and life experiences. An organisational model ensuring a balance between the ability to motivate and engage the most senior workforce, while keeping younger targets recruitment market and development processes active, is a challenge for the near future.

Concerning gender gap, if in 1950 only 29% of women worked outside the home, employed in almost exclusive female occupations, in 2000 this percentage has grown to nearly 75% of women involved in a wider spectrum of jobs[24]. Despite this progress, gender bias remains. Women are frequently thought as having weaker labour force attachment and higher absentee rates than men, especially after having children. Thus, when applying for a job, women are often required to be unmarried and without babies within a certain period of time. Gender wage gap is a normal mean adopted by employers to offset predicted turnover expenditure and to avoid hiring or promoting women into certain roles. According to recent statistics, in Europe there is a 16% gender wage disparity while in the USA the percentage climbs of two points[25].

In this awful scenario, selection biases may be the result of disproportional hiring rates of men and women. Increasing the number of men in a firm could end up with women discrimination, risking the tokenism phenomenon. It occurs in group situations where the numerically dominant members rule and shape the culture of the numerical social minority, known as tokens. Token women at work perceive the organisational atmosphere as unfair to them, feel unhappy and left out in their work with lower self-esteem; the result is the raise in women likelihood of leaving the organisation. Even if it is not necessarily linked with discrimination factors, in 2018 European women employment rate was still 12 percentage points lower than the corresponding men rate. Addressing the size and scope of this inequality is a pressing international matter, requiring both new policy solutions and significant cultural transformations as women carry the majority of the unpaid labour and care responsibilities, limiting their chances for employment and career advancement.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	401-1	New employee hires and employee turnover	Quantitative	[#]
	401-2	Benefits provided to full-time employees that are not provided to temporary or part-time employees	Qualitative	–
	401-3	Parental leave	Quantitative	[#]
	405-1	Diversity of governance bodies and employees	Quantitative	[%]
	405-2	Ratio of basic salary and remuneration of women to men	Quantitative	–

Table 1.7: Employment KPIs.

### 1.2.2. Occupational and customer health and safety

Work has a major impact on community health: just think that people are much more likely to be seriously injured during labour activities than to travel by car or to commit a violent crime. According to ILO, 2.3 million people die each year from work-related illnesses and accidents worldwide, up to more than 6,000 per day and, to make matters worse, updates show a continuous increase in work-related issues.

ILO Constitution provides workers' protection against sickness, disease, and injury from working activities, recognising that they negatively affect productivity and economic and social development. More than 50% of all 387 ILO conventions and recommendations concern with occupational health and safety, including the Occupational Safety and Health Convention (1981), the Occupational Health Services Convention (1985), the Labour Inspection Convention (1947) and the Promotional Framework for Occupational Health and Safety Convention (2006). They call for the creation of a preventive culture as well as an ongoing process of improvement[26]. This depth penetration shows the major relevance of occupational health and safety as central element of ILO activities.

The key factor is of great concern insofar as it has enormous economic repercussions for the company, the nation and the world, including compensation, absenteeism, lost working time, production delays, medical expenses, early retirements, training and retraining. In a world with preventative health and safety culture, the right to a safe and healthy working environment is respected at all levels, with the active participation of governments, employers and employees. In particular, organisations can and must develop occupational health and safety management systems to address the sustainability dimensions, concentrating on reducing worker injuries and health issues as well as providing a safe and healthy workplace. Finally, organisations also have to deal with customers' health

and safety, focusing on the quality of sold products and services.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	403-1	Occupational health and safety management system	Qualitative	–
	403-2	Hazard identification, risk assessment, and incident investigation	Qualitative	–
	403-3	Occupational health services	Qualitative	–
	403-4	Worker participation, consultation, and communication on occupational health and safety	Qualitative	–
	403-5	Worker training on occupational health and safety	Qualitative	–
	403-6	Promotion of worker health	Qualitative	–
	403-7	Prevention and mitigation of occupational health and safety impacts directly linked by business relationships	Qualitative	–
	403-8	Workers covered by an occupational health and safety management system	Quantitative	[#]
	403-9	Work-related injuries	Quantitative	[#] and –
	403-10	Work-related ill health	Quantitative	[#]
	416-1	Assessment of the health and safety impacts of product and service categories	Quantitative	[%]
	416-2	Incidents of non-compliance concerning the health and safety impacts of products and services	Quantitative	[#]

Table 1.8: Occupational and customer health and safety KPIs.

### 1.2.3. Training and education

Each firm operates in a competitive market. The rapid development of information and communications technology, the rising economic knowledge production, the growing internalisation and globalisation, changes to occupational structures and changes to the nature and organisation of work, have forced organisations to find new ways ensuring that workforce's competence overcomes this crowded environment, meeting these challenges and thriving. Since critical business issues, from production technology innovations to new market strategies, also depend on the performance capabilities of the workforce managing them, companies need the development of workplace expertise to achieve an even better performance. The goal of employee development is to create an educated workforce where all people are valued with competence and professional skills growth, ensuring productivity, job satisfaction, competitiveness and well-being. Thus, to define their own

success, companies must rely on the synergy between advanced existing technologies and infrastructures, and reliable and educated human resources.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	404-1	Average hours of training per year per employee	Quantitative	[#]
	404-2	Programs for upgrading employee skills and transition assistance programs	Qualitative	-
	404-3	Percentage of employees receiving regular performance and career development reviews	Quantitative	[#]
	410-1	Security personnel trained in human rights policies or procedures	Quantitative	[%]

Table 1.9: Training and education KPIs.

#### 1.2.4. Modern slavery

Modern slavery is the antithesis of social justice and sustainable development; on the contrary, decent work is the lofty objective of achieving sustainable social progress, fighting work-related exclusion and inequality, while guaranteeing fair wage, job stability and social protection. The concept of decent work came in 1999 when ILO Director-General Juan Somavia, during the International Labour Conference stated that the primary objective of its organisation is providing all men and women with productive work, under conditions of freedom, equality, security and human dignity, against any type of discrimination.

In 2030 action plan's scenario, SDG 8 gives a significant social dimension by mirroring the aspirations of the ILO Decent Work Agenda. SDG Target 8.7, in particular, calls for the efforts of all people to take prompt and effective action stopping forced and compulsory labour, and human trafficking by 2030, while also prohibiting and eliminating all forms of child labour by 2025[27]. In this way, SDG 8 binds decent work and economic growth in a world where an increasingly diverse workforce has brought the challenging duty of creating environments where people with different backgrounds and profiles can collaborate with, learn from, and inspire one another. Some years later, celebrating its 100<sup>th</sup> anniversary in 2019, the ILO adopted its Centenary Declaration for the Future of Work, committing to a world of employment free from violence and harassment. It presented its updated strategy of workers' rights promotion and its struggle for a world without forced, compulsory and child labour.

However, these are still significant issues. The crisis occurred in recent years, including

COVID-19, armed conflicts and climate changes, causing an unprecedented employment and education disruption, growth of extreme poverty, forced migration and complaints of violence, has increased the risk of modern slavery. Nowadays, from Brazilian bananas to Burmese rice, from Turkish hazelnuts to Mexican beans, from Chinese tomatoes to Argentine strawberries and Thai shrimps, many products are responsible for child labour. Moreover, millions and millions of people in Latin America and the Caribbean, Europe, Middle East, and developed countries, together with Indian Dalit and workers from sub-Saharan African countries in Tunisia, are still suffering from forced labour. There are still about 160 million children and 50 million people in child and forced labour respectively. In this awful scenario, the global community must speed up the progress. Besides governments, there is need of a greater involvement of the whole society, starting from businesses, to accomplish the challenging goals for 2030.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	406-1	Incidents of discrimination and corrective actions taken	Quantitative	[#]
	408-1	Operations and suppliers at significant risk for incidents of child labour	Qualitative	–
	409-1	Operations and suppliers at significant risk for incidents of forced or compulsory labour	Qualitative	–

Table 1.10: Modern slavery KPIs.

### 1.2.5. Communities

The key factor measures companies' involvement in solving significant social issues arising, when doing business, from the interactions with different types of political communities[28]. It deals with the protection of locals and indigenous people living or working in areas impacted by businesses' operations somehow. Since taking care of community relations strategies can help shaping industries actions in being more socially, culturally, and environmentally sensitive, nowadays businesses are trying to engage plans for the benefit of local people, establishing a constant dialogue with them and involving them with projects and initiatives for the common good. Community engagement strategy is a series of actions exploited by firms to work in collaboration with and through citizens and groups of people in order to deal with challenges influencing their well-being and shared interests. Involving local communities in planning and decision-making can help companies contribute to beneficial social and economic growth, especially when their operations' impacts are extensive. If on one hand, human interventions are important means in a

socioeconomic perspective, on the other hand they threaten the surrounding populations' environment, amenities and lifestyle, feeding protests and conflicts, and delays up to projects' abandonment. Thus, looking at the scenery with the perspective of local people is needed as productive and safe.

From a sustainable perspective, businesses' impact on state and local communities development needs to be comprehensively evaluated; as required by the Equator Principles<sup>17</sup> "projects affecting indigenous peoples will be subject to a process of Informed Consultation and Participation [which] will need to comply with the rights and protections for indigenous peoples". Therefore, highlighting the specifics of the company's interactions with various political communities in the non-financial reporting provides an additional chance to demonstrate a positive working relationship with them towards sustainability.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	411-1	Incidents of violations involving rights of indigenous people	Quantitative	[#]
	413-1	Operations with local community engagement, impact assessments, and development programs	Quantitative	[%]
	413-2	Operations with significant actual and potential negative impacts on local communities	Qualitative	–
	415-1	Political contributions	Quantitative	[M€]

Table 1.11: Communities KPIs.

### 1.2.6. Supplier social assessment

Over the years, rising public knowledge, stronger government regulations, and market pressure have made it clear that the boundary of companies' responsibility often goes beyond their direct control, up to providers' interdependent units. Arriving to the final product is a long task, passing through deliveries, manufacturing, packaging and transportation issues. Hence, supply chain design is crucial to the success of industrial concerns and its sustainable management is even more. It has been defined as "the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organisational business processes for improving the long-term economic performance of the individual company and its supply chains"[29].

<sup>17</sup>The Equator Principles is a risk management framework, signed by numerous financial institutions, used by financial institutions to identify, evaluate, and manage environmental and social risk when financing projects.

Moreover, to properly handle its stability and effectiveness, companies are involved in assessing supply chain management's risks linked with both internal and external variables. For example, if a supplier operations and production issues depends on water, and it is located in a remote area characterised by water scarcity, this represents a supply chain sustainability risk to the company. Thus, for an industry, controlling and managing information, material and capital flow along the supply chain, as well as the cooperation among firms, while taking into account the three dimensions of sustainable development derived from customer and stakeholder requirements, have been recognised more and more fundamental.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	414-1	New suppliers that were screened using social criteria	Quantitative	[%]
	414-2	Negative social impacts in the supply chain and actions taken	Quantitative	[#]

Table 1.12: Supplier social assessment KPIs.

### 1.2.7. Product responsibility

The opportunity to make informed decisions is necessary to act sustainably; product labelling is an efficient mean for shaping public opinion, impacting consumers' assessments and purchase decisions. Thanks to effective sustainability details on product packaging, consumers can make choices analysing a brand's commitment to produce socially and environmentally responsible items, keeping track of environment's protection, natural resources' conservation and fairly treatment of labour workers.

The French government, for example, pursues laws promoting sustainability data on product life cycle assessment, like production, transportation and packaging information. In this way, at the point of purchase, consumers may consider the environmental impacts of the product they are selecting, such as water consumption and energy-efficiency. Paying particular emphasis on circular economy, starting from April 2022, the country's new rules enforce manufacturers and importers to provide detailed information about products' recycled content, use of renewable resources, durability, compostability, possibility of repair and reuse, recyclability, and presence of harmful substances, through the use of marking, labelling and electronic format.

Over the last decades, stakeholders like investors, consumers, governments, and corporate clients, have been putting more pressure on businesses to publish information about their performance and to produce sustainable friendly goods. In this scenario, some producers

have taken advantage of green marketing, making exaggerated and inaccurate environmental claims about their goods, known as "greenwashing". Therefore it happens that consumers do not receive consistent brand-level sustainability information. In this respect, Coca Cola life is an effort to promote a fake environmental friendly product, strengthening its sustainability care with the use of a natural sweetener and a green label. However, over the last years, in order to accomplish people struggle to incorporate sustainable practises into their consumption habits, governments and consumer advocates are more and more focusing on sustainability labelling.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	417-1	Requirements for product and service information and labeling	Qualitative	–
	417-2	Incidents of non-compliance concerning product and service information and labeling	Quantitative	[#]
	417-3	Incidents of non-compliance concerning marketing communications	Quantitative	[#]

Table 1.13: Product responsibility KPIs.

### 1.2.8. Data privacy

Huge amounts of data from and about current and potential customers are collected to obtain insights and improve offerings and clients' experience across different channels. Although many people voluntarily disclose their personal information in exchange for advantages, like personalised online offers and greater convenience, more and more customers concern about their privacy, mostly as a result of infamous accidents like Alibaba<sup>18</sup>'s and Sony<sup>19</sup>'s data violations. In 2011 Sony PlayStation Network<sup>20</sup> was hacked accounting for about 77 million of stolen data, including personal and financial clients information. Large volume of confidential data were leaked including names, home addresses, emails, birth dates, credit cards, passwords and security questions with relative answers. Since data breaches and privacy issues are set to grow significantly, worldwide governments are adopting tougher measures, such as the European General Data Protection Regulation<sup>21</sup>. Furthermore, even companies are becoming more and more aware: there

<sup>18</sup>Alibaba is a Chinese multinational company composed of a series of companies involved in e-commerce, retail, internet and technology.

<sup>19</sup>Sony is the short name for Sony Corporation, a multinational Japanese company mainly focusing on consumer electronics, videogames and entertainment services.

<sup>20</sup>PlayStation Network is an online entertainment service by Sony.

<sup>21</sup>The General Data Protection Regulation (GDPR) is a European regulation on data protection and privacy.

is a pressing managerial requirement to create an intimate understanding of customer privacy issues' commercial impact, as well as future mitigation solutions. The protection of client privacy is a forward-looking and strategic imperative and firms could adopt a variety of strategies satisfying privacy requirements and using a range of data analytics techniques.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	418-1	Substantiated complaints concerning breaches of customer privacy and losses of customer data	Quantitative	[#]

Table 1.14: Data privacy KPIs.

### 1.3. Governance pillar and key factors

Manipulations and scams have a long history in the business world. Corporate frauds are widespread, costly and multifaceted.

Maxwell Communications Corporation plc failed in 1991 in the UK, after the theft of nearly 600 million dollars in pension funds. Its owner Robert Maxwell was entirely blamed and he apparently committed suicide. The English Polly Peck International plc failed too in 1991, after a serious debt situation. In this regard, its chief executive Asil Nadir has been accused of fraud and theft. The corporate administrator David Pollock, has said: "You have to come back to the role of the chief executive - the person who runs the business as his own. That is a factor which in hindsight stands out very clearly. True, accounting regulations need to be tightened but the area where one would be looking in terms of predicting is the role played by Mr. Nadir - his dominance as the chief executive and chairman and the lack of control exercised by the rest of the board is critical"[30]. These are very few examples involving highly successful companies run by a very powerful individual, responsible for somehow criminal activities. Following each of these scandals, policymakers questioned the effectiveness of the corporate governance mechanisms. In the UK, their breakdown led to the publication of the Cadbury Report. Similarly, ten years later, US corporate failures such as Enron in 2001 and WorldCom in 2002, led to the first government response, known as the Sarbanes-Oxley Act. Corporate irresponsibility in the Enron Corporate scandal (2001) sparked multiple lawsuits and unprecedented outrage from a wide range of stakeholders, claiming for democratising corporate power structures, improving managerial accountability, and enacting regulatory reform. The corporate governance was weak, people with poor moral character and willingness to commit fraud constituted the board of directors. Furthermore, conflicts of interest harmed the non-executive directors. It is significant that the report on its bankruptcy was entitled "a culture of greed and corruption"[31].

WorldCom filed the largest bankruptcy in the US history in 2002, after several accounting frauds. This accounting scandal highlights the significance of ethical standards and internal checks in the workplace.

According to Cadbury Report by the Committee on the Financial Aspects of Corporate Governance, "Corporate governance is the system by which companies are directed and controlled". Corporate governance should be a balance between different groups, upholding an atmosphere of trust, transparency and accountability, while strengthening the relations between corporate leaders, their shareholders and stakeholders, including State, financial institutions, employees, customers and community. The wave of company frauds

shows that it is more and more fundamental for corporate governance to act sustainably to build the corporate identity.

In this regard, the OECD Principles of Corporate Governance are worldwide considered a benchmark for a sound governance, establishing advised practices with respect to shareholders' rights, stakeholders' part, and board of directors responsibilities. The I principle requires to promote transparent and fair markets, as well as an efficient resource allocation, while influencing the overall economic performance.

Moreover, corporate governance should take care of the division of responsibilities between different authorities, to serve the public interest and to promote the active collaboration between organisations and stakeholders in the creation of wealth and jobs.

For allowing investors to assess the relationship between businesses and the communities in which they operate, companies should disclose policies and performance related to business ethics, social issues, human rights, and other public policy commitments (V principle). Finally, board members should act in the best interests of the company and its shareholders, and adhere to strict ethical guidelines. In this regard, jurisdictions are increasingly requiring boards to oversee the finance and tax planning strategies, while discouraging practises such as aggressive tax avoidance that do not contribute to the long-term interests of the company and its shareholders, with the possibility of resulting in legal and reputational risks (VI principle).

In the sections below we structure our governance analysis into four key governance factors with the corresponding key performance indicators. Coherently with the aforementioned Principles of Corporate Governance, the metrics we introduce are: economic performance and its impacts, market presence, business ethics, tax.

### 1.3.1. Economic performance and its impacts

Value creation is the core of the business model. It should be addressed with and for the stakeholders. The key factor focuses on the way the business serves its own strategic interest and its stakeholders' societal interests. In this context, businesses could buy raw materials locally, encouraging local suppliers and, furthermore, they could provide communities with infrastructural investments, which are not necessarily related to the business operations. An example of effective communities engagement is the Curibamba project. It has been implemented by Enel Green Power<sup>22</sup> in partnership with the rural communities living around the area of the hydroelectric plant it constructed in the Comas, Uchubamba, and Tulumayo rivers basins in Peru. Improvements in the roads, installation of new sewage systems, funding for sports, culture, and education, as well as support for the local farming industry, are necessary for the development of the communities living in this region. The project has generated a number of positive outcomes. It has increased the production on about 80 hectares of coffee plantations and it has built locals' capacity in coffee growing methods via training and technical visits. Moreover, teams of professionals with extensive knowledge of the care of crops and the methods used to produce coffee, periodically visit the farming families to provide them with support, advice, and ongoing training.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	201-1	Direct economic value generated and distributed	Quantitative	[M€] <sup>23</sup>
	201-2	Financial implications and other risks and opportunities due to climate change	Qualitative	–
	201-3	Defined benefit plan obligations and other retirement plans	Quantitative	[M€]
	201-4	Financial assistance received from government	Quantitative	[M€]
	203-1	Infrastructure investments and services supported	Quantitative	[M€]
	203-2	Significant indirect economic impacts	Qualitative	–
	204-1	Proportion of spending on local suppliers	Quantitative	[%]

Table 1.15: Economic performance and its impacts KPIs.

<sup>22</sup>Enel Green Power is an Italian international renewable energy company, subsidiary of Enel power generation firm.

<sup>23</sup>M€ stands for million euro.

### 1.3.2. Market presence

The key factor investigates to what extent the company communicates value back to the community.

Worldwide, wages policies have always brought up several discussions to the table. There have been several attempts in trying to correlate minimum wages with basic human necessities in order to ensure a decent standard of living for everyone. The International Labour Organization refers to the minimum wage as "the minimum sum payable to a worker for work performed or services rendered, within a given period, whether calculated on the basis of time or output, which may not be reduced either by individual or collective agreement, which is guaranteed by law and which may be fixed in such a way as to cover the minimum needs of the worker and his or her family, in the light of national economic and social conditions". The Article 23 of the Universal Declaration of Human Rights says that "Everyone who works has the right to just and favourable remuneration ensuring for himself and his family an existence worthy of human dignity,[...]". The International Covenant on Economic, Social and Cultural Rights provides for the right of "Remuneration which provides all workers, as a minimum, with [...] A decent living for themselves and their families in accordance with the provisions of the present Covenant"[32].

The principle that work is the best way to fight poverty and social inequality does not apply to low-paying sectors. In this context, the ratio between company's and minimum wage is understood as a measure of organisational competitiveness in labour market, saying how the company contributes to the welfare of its employees. Market presence also measures how the company values the local community. Any firm can sustain the local community by making available its skills and valuable resources for improving the population living. Thus, it may contribute to a balanced territorial development, working in partnership with locals and realising shared projects.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	202-1	Ratios of standard entry level wage by gender compared to local minimum wage	Quantitative	–
	202-2	Proportion of senior management hired from the local community	Quantitative	[%]

Table 1.16: Market presence KPIs.

### 1.3.3. Business ethics

Business ethics concerns policies and procedures against fraud, corruption and anti-competitive behaviours, extremely important in shaping the business success. However, in the business world, ethical issues have grown in complexity.

Throughout the late 1990s, the Enron Corporation was one of the world's leading electricity, natural gas, communications and pulp and paper companies. Over a five years period, its annual revenues increased from 9 billion dollars to more than 100 billion dollars, qualifying in seventh place among the most important multinational enterprises in the USA. Buying and selling gas and electricity by exploiting bank loans, it has become both an industrial and a financial empire. It voluntarily disclosed financial statements that hid certain types of information, which caused a financial stock price reaction. Suddenly and without warning, in three months Enron stock price fell from about 90 dollars to less than 1 dollar, and the company went bankrupt in 2001. It has been one of the biggest financial scams.

At a certain level, it hardly matters what the courts decide. No company engaging in similar practises can take heart from any suits that may be dismissed in Enron's favour. A negative perception of corporate ethics has already harmed the company's reputation[33]. Another case in point, is Google's. The United States Department of Justice, along with the States of Arkansas, Florida, Georgia, Indiana, Kentucky, Louisiana, Mississippi, Missouri, Montana, South Carolina, and Texas, filed an antitrust lawsuit against Google on October 20, 2020, for using anti-competitive tactics in its "attempts to monopolise". In favour of a healthy competitive free market, antitrust legislation limits anti-competitive business practises. According to the complaint, Google has forced its users to accept its search engine. This scenario includes agreements with Apple<sup>24</sup> making Google the default search engine on the Safari browser, agreements with device manufacturers making Google's search app preinstalled and unremovable, and agreements prohibiting the pre-installation of other search engines[34].

The consequences of these immoral behaviours can have a wide-ranging impact, harming a company's reputation, as well as undermining public trust in the markets. In this context, business ethics may serve as a powerful mean to gain value between the company's stakeholders inside and outside of the organisation.

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<sup>24</sup>Apple is an American multinational technology company.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	205-1	Operations assessed for risks related to corruption	Quantitative	[#] and [%]
	205-2	Communication and training about anti-corruption policies and procedures	Quantitative	[#] and [%]
	205-3	Confirmed incidents of corruption and actions taken	Quantitative	[#]
	206-1	Legal actions for anti-competitive behavior, anti-trust, and monopoly practices	Quantitative	[#]

Table 1.17: Business ethics KPIs.

### 1.3.4. Tax

The key factor deals with the company's tax administration and compliance issues.

Key factor	GRI	Key Performance Indicator	Category	Unit measure
	207-1	Approach to tax	Qualitative	–
	207-2	Tax governance, control, and risk management	Qualitative	–
	207-3	Stakeholder engagement and management of concerns related to tax	Qualitative	–
	207-4	Country-by-country reporting	Qualitative	–

Table 1.18: Tax KPIs.

## 2 | Constructing the rating

We develop an objective rating methodology which takes shape and significance from businesses sustainable disclosures to think in a benchmarking scenario. It assesses only quantitative information, neglecting unmeasurable qualitative descriptions of impressions and personal point of views, to generate a judgement which is as tangible as possible.

When building financial portfolios, asset allocation centers on the identification of strategic choices meeting investors' demands to select the best assets and investment opportunities. At this stage, isolating the finest option of all the possible ones could help to make a well-planned choice. Thus, the algorithm evaluates a comprehensive ESG information assigning a score between zero and one, which comes down to merely show a company ESG performance in relation with the ongoing industrial scenario.

The algorithm is primarily focused on key performance indicators to grasp how the company manages practices and strategies which govern its sustainable commitment, evaluating either plain indicators or the ratio of different KPIs. Throughout the discussion, depending on its usage, indicator denotes the KPI or its transformed version. For developing the measurement tool, the algorithm learns the global environmental, social and corporate policies status employing a training dataset. Thus, it processes a general rule for each indicator which is consistent with the current scenario. One at a time, it estimates the cumulative distribution function (CDF) which has generated each indicator sample points, by computing the corresponding empirical cumulative distribution function (eCDF) which acts as a tool measuring the company relative performance.

**Measurement tool** we denote with  $K$  a generic indicator taking values in  $D_K$  and with  $m$  its sample size. To ease the notation, in the following its realisations  $(k_i)_{i \in \{1, 2, \dots, m\}}$  are assumed to be in ascending order. Since the set could have repetitions, to indicate the highest number of recurrent elements we introduce the following quantity:

$$n = \max_{i \in \{1, 2, \dots, m\}} n_i \quad (2.1)$$

where  $n_i = \#\{j : k_j = k_i\}$ . Finally, we define the eCDF  $F_K : D_K \rightarrow [0, 1]$  as a step

function jumping high by at most  $\frac{n}{m}$  at each observed point:

$$F_K(k) = P(K \leq k) = \frac{1}{m} \sum_{i=1}^m \mathbb{1}_{(k_i \leq k)} = \frac{\#\{i : k_i \leq k\}}{m}, \quad k \in D_K \quad (2.2)$$

We are modelling the cumulative distribution function of a discrete random variable, since our training dataset is a finite collection of real data. However, since most of the variables take values in intervals of real numbers, we might model them as continuous random variables. Nevertheless, the difference between the step-wise cumulative distribution function and any CDF  $f_K$ , obtained through a continuous interpolation, is at most equal to:

$$\epsilon = \|f_K - F_K\|_\infty = \max_{k \in D_K} |f_K(k) - F_K(k)| = \frac{n}{m} \quad (2.3)$$

Indeed, assuming  $m$  sufficiently large and being  $n \ll m$  reasonably, we get:

$$\lim_{m \rightarrow \infty} \epsilon = 0$$

Thus, as the sample size increases, the difference between the proposed solution and whatever kind of continuous CDF is negligible.

**ESG score** the company ESG rating is calculated as the fair weighted sum of the three environmental, social and corporate governance evaluations:

$$\varphi = \sum_{i \in \{e, s, g\}} \alpha p_i \quad (2.4)$$

where:

- $e, s, g$  are the environmental, social and governance pillars, respectively
- $\alpha = \frac{1}{3}$  is each pillar's weight
- $p_i$  is the score of pillar  $i$

The algorithm implements a nested structure where each pillar contribute is a convex linear combination, arranging the corresponding key factors scores with sector-specific weights, as follows:

$$p_i = \sum_{j=1}^{n_i} w_j \zeta_j \quad (2.5)$$

where:

- $n_i$  is the number of key factors associated with pillar  $i$ ,  $i \in \{e, s, g\}$

- $(w_j)_{j \in \{1,2,\dots,n_i\}}$  is the set of weights associated with the key factors of pillar  $i$  (see Tables 3.1, 3.8, 3.9)
- $(\varsigma_j)_{j \in \{1,2,\dots,n_i\}}$  is the set of scores associated with the key factors of pillar  $i$

In the guidelines of the section below, each key factor  $j$  is matched to the score  $\varsigma_j$  via customised procedures handling its own indicators. Even if grouped in different key factors with different scoring procedures, each indicator  $K$  is mapped with a score  $s_K$  obtained through the evaluation of its eCDF at the company registered value  $k$ . The procedure manages the indicator basing on its definition in this way:

- if  $K$  assesses any sustainable business practice moving the company long-term forward, then  $s_K = F_K(k)$
- if  $K$  assesses a business practice somehow harming environmental protection, social justice or corporate accountability, then  $s_K = 1 - F_K(k)$

By definition, the CDF is a non-decreasing and non-negative function assuming values in  $[0,1]$ . Either way the algorithm values a non-negative contribute differing in the size of the recognised score. Since ratings have a meaning in comparison with the others, the contribute of a good indicator in a sustainable perspective is grasped in such a way that greater values correspond to greater scores, exploiting the CDF as a non-decreasing function. On the contrary, the procedure penalises misconducts delivering a grade which is worth the less the more the size of the danger, being the opposite of the CDF a non-increasing function. In the following each indicator is accurately analysed to get its own assessment, whether positive or negative.

To conclude, being a fair weighted sum of convex linear combinations, the comprehensive ESG score falls in  $[0,1]$ , where 1 and 0 indicate excellent and laggard capacity to fulfill sustainable commitments, respectively.

The grading scale is divided into four ranges from the highest to the lowest values, following the procedure in Table 2.1.

**Training dataset** aiming to construct a fair and relative ESG rating, for powering the overall assessment it is better to provide a sectorial training dataset. We group the companies into 11 different sectors by relying on the Global Industry Classification Standard. Our classification consists on these industrial sectors: Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Healthcare, Financials, Information Technology, Communication Services, Utilities, and Real Estate.

**Data transformation** before proceeding, it is necessary to point out some kind of transformations performed on the dataset.

The industry was born to meet humans needs for goods and services while providing income, guaranteeing an adequate way of living. Natural resources processing and consumption have always supported the industrial production, however, in the current scenario of environmental degradation, economic efficiency cannot ignore supply flow insofar as its interruption could lead to sectors shutdown. As the strict connection between raw materials, industrial products and byproducts stands up from the resources consumption up to the waste generated by the industrial activity, information coming from key performance indicators is more meaningful when linked to the value of the production. Indeed, for carrying out an assessment with respect to the wealth created, before starting, the algorithm performs a transformation both in the training dataset and in the dataset to be evaluated of the environmental pillar. Precisely, it divides the datum by its corresponding economic value generated. The transformation is performed only when the KPI is used as a plain indicator, since the fraction makes it useless.

The transformation is carried out also in the governance pillar to discuss the size of an investment with respect to the company dimension. In the following sections, this transformation is denoted with a tilde.

**CDF critical analysis** it is not enough to compute the CDF corresponding to the available training dataset. Indeed, it is necessary to make sure that CDF attributes correct and accurate results, assigning reliable scores whose variation is consistent with corporate long-term performances. Indeed, we should depict whether the training data distribution is reliable for the purpose of our usage. Consider, for example, a bimodal distribution, which is flat in the middle of the interval and exhibits two distinct peaks at its extremes. Exploiting its CDF, the algorithm correctly matches values placed in the two peaks to increasing scores, but it associates almost constant rates to central values. In situations like this, it is required to proceed cautiously. For addressing the right cause, we must understand whether the presence of a hole in the dataset is due to an incomplete collection of information or not. If refining the dataset, the situation does not change, the hole is simply a representation of the ongoing industrial scenario. Thus, when dealing with CDFs, we should proceed step by step carefully analysing their distributions. In case of small training dataset, it is even the more necessary. Particularly, it is suggested to gather as much information as possible, for avoiding ending up with warped and worthless evaluations.

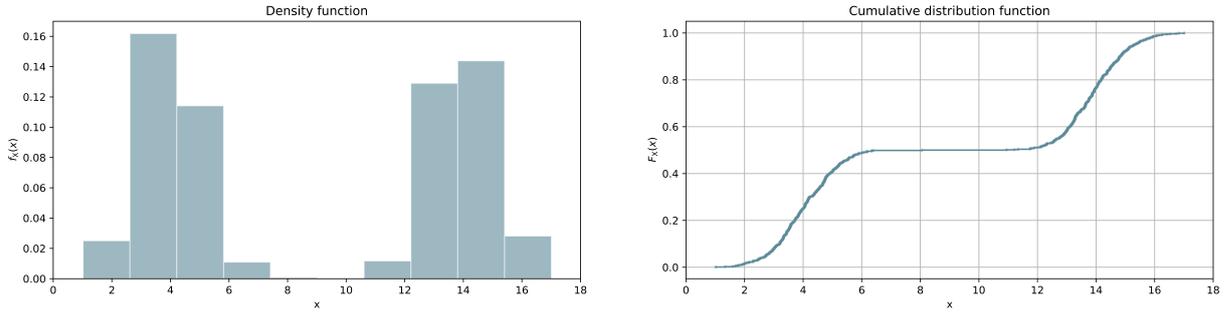


Figure 2.1: Bimodal distribution mixture of  $X_1 \sim \mathcal{N}(4, 1)$  and  $X_2 \sim \mathcal{N}(14, 1)$ .

Values pts.	Letter rating	Rating category	Description
(0.9166, 1]	A+	Excellent	“A” score indicates excellent capacity to fulfill sustainable commitments
(0.8333, 0.9166]	A	Excellent	
(0.7500, 0.8333]	A-	Excellent	
(0.6666, 0.7500]	B+	Good	“B” score indicates good capacity to fulfill sustainable commitments
(0.5833, 0.6666]	B	Good	
(0.5000, 0.5833]	B-	Good	
(0.4166, 0.5000]	C+	Satisfactory	“C” score indicates satisfactory capacity to fulfill sustainable commitments
(0.3333, 0.4166]	C	Satisfactory	
(0.2500, 0.3333]	C-	Satisfactory	
(0.1666, 0.2500]	D+	Laggard	“D” score indicates laggard capacity to fulfill sustainable commitments
(0.0833, 0.1666]	D	Laggard	
[0.0, 0.0833]	D-	Laggard	

Table 2.1: ESG Score Range Chart

## 2.1. Key factor-specific analysis

We discuss the specific rating methodology adopted for each key factor, reviewing and reasoning, one at a time, its key performance indicators. At the end of each section, it is presented the final list of all the indicators used in the key factor analysis, to be reported in the company sustainable disclosure. Exploiting the GRI documentation, we mark with a "r" the indicators which have been somehow revised, that is "revised Key Performance Indicators". Finally, it is provided step by step the algorithm which computes the specific key factor's score.

We examine separately in Section 2.2 all KPIs tracking qualitative information or information ineffective for the purposes of the analysis.

Throughout the discussion we have:

- $K_i$  is the  $i$ -th indicator
- $(K_{ij})_{j \in \{1, 2, \dots, m_i\}}$  is the training dataset for  $K_i$
- $m_i$  is the number of  $K_i$ 's observations in the training dataset
- $n_i$  is the highest number of recurrent elements in  $(K_{ij})_{j \in \{1, 2, \dots, m_i\}}$
- $k_i$  is the value of  $K_i$  recorded by the company to be evaluated

### 2.1.1. Environmental pillar

The environmental pillar consists of 6 key factors, which are examined in the following.

#### Greenhouse Gas (GHG), Ozone-Depleting substances (ODS) and other significant emissions

For weighting together emissions coming from different gases with different climate-changing effects, we exploit the Global Warming Potential.

**Definition 2.1.** The Global Warming Potential (GWP) quantifies the energy that 1 tonne of a generic gas will absorb over a certain amount of time (generally 20, 100 or 500 years) compared with the energy absorbed by 1 tonne of carbon dioxide. In the following we use  $\text{GWP}_t^x$  to indicate the GWP of gas  $x$  over time  $t$ .

To allow comparisons between the effects of various gases on global warming, we use as unit measure the tonnes of carbon dioxide equivalent.

**Definition 2.2.** The tonnes of carbone dioxide equivalent ( $\text{tCO}_2\text{eq}$ ) are obtained multi-

plying the tonnes of gas in a polluting emission with its GWP:

$$m_x [\text{tCO}_2\text{eq}] = \text{GWP}_t^x \cdot m_x [\text{tCFC-11eq}]$$

where  $m_x$  is the mass of gas  $x$ . In this way, one unit of each gas, trapping the same amount of heat in the atmosphere as carbon dioxide, has the same polluting potential.

We concentrate on KPIs 305-1a, 305-2a, 305-3a, 305-5a and 305-6a. The GRI documentation measures all of them in  $\text{tCO}_2\text{eq}$  but 305-6a, which is quantified in  $\text{tCFC-11eq}$ , i.e. tonnes of trichlorofluoromethane equivalent. We use  $\text{GWP}_{100}^{\text{CFC-11}} = 4660$ [35], thus

$$m_{\text{CFC-11}} [\text{tCO}_2\text{eq}] = 4660 \cdot m_{\text{CFC-11}} [\text{tCFC-11eq}]$$

To ease the notation in the following we adopt this convention:

<b>rGRI</b>	<b>revised Key Performance Indicator</b>	<b>Notation</b>
305-1a	Direct (Scope 1) GHG emissions	$x_1$
305-2a	Energy indirect (Scope 2) GHG emissions	$x_2$
305-3a	Other indirect (Scope 3) GHG emissions	$x_3$
305-5a	Reduction of GHG emissions	$r$
305-6ar	Emissions of ozone-depleting substances (ODS)	$y$

For discussing emissions impacts, we perform a two layers analysis distinguishing the emissions the company has actually performed in the reporting period, from those it has avoided, since an objective assessment should recognise the efforts done to make improvements.

Once applied the training dataset transformation, we evaluate *Scope 1*, *Scope 2*, *Scope 3* and *ODS emissions*:

$$K_1 = \tilde{x}_1 \tag{2.6}$$

$$K_2 = \tilde{x}_2 \tag{2.7}$$

$$K_3 = \tilde{x}_3 \tag{2.8}$$

$$K_4 = \tilde{y} \tag{2.9}$$

Since the releases of these harmful chemicals threaten the planet, higher values are penalised. Exploiting the global warming potential, these indicators represent gases with the same power climate-altering, thus we recognise them the same materiality with a fair distribution of weights:  $w_i = 1/4, \forall i \in \{1, 2, 3, 4\}$ . We conclude the first phase of the study by computing the weighted sum of these contributions, acting as the score for the

effective emissions.

The second stage focuses on *GHG emissions reduction* valuing:

$$K_5 = \tilde{r} \quad (2.10)$$

after having computed the training dataset transformation. To classify the size of emissions cuts, we define the quantile function  $Q_{K_5} : [0, 1] \rightarrow D_{K_5}$  which takes the value of the probability  $p$  and assigns  $x$  such that:

$$Q_{K_5}(p) = \max\{x \in D_{K_5} : P(K_5 \leq x) \leq p\}$$

More precisely, the function selects the maximum value of  $x$  leaving at most  $p$  probability to the left and at least  $1 - p$  probability to the right. We compute the quantiles  $Q_{K_5}(1/3)$  and  $Q_{K_5}(2/3)$  to organise the reduction into the three different awarding categories presented in Table A1. Taking the value  $k_5$  registered by the company in the reporting period, it falls into one of these three ranges. Thus, we apply a continuous and increasing reward function  $f_r$  to the computed rating, of the form  $f_r(x) = (1 + r)x$ . Precisely,  $r \in [0, 1]$  is the reward rate and it amounts to 0, 1/20 or 1/10, basing on the selected interval. Finally, we get the adjusted score function  $f_a : [0, 1] \rightarrow [0, 1]$  of the form  $f_a(x) = \min(f_r(x), 1)$  which takes the value of the score calculated in the first phase and returns the final one, stopping  $f_r$ 's growth at 1.

### Algorithm

#### 0. Training dataset

- Take the training dataset and select indicators in Table 2.2:
  - $x_1 = 305-1a$
  - $x_2 = 305-2a$
  - $x_3 = 305-3a$
  - $r = 305-5a$
  - $y = 305-6ar$
- Run the training dataset transformation getting:  $\tilde{x}_1, \tilde{x}_2, \tilde{x}_3, \tilde{r}$  and  $\tilde{y}$

## 1. Emissions generated

- Fix *Scope 1*, *Scope 2*, *Scope 3* and *ODS emissions*:

$$K_1 = \tilde{x}_1$$

$$K_2 = \tilde{x}_2$$

$$K_3 = \tilde{x}_3$$

$$K_4 = \tilde{y}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{1, 2, 3, 4\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{1, 2, 3, 4\}$
- Compute the scores:

$$s_{1.1.i} = 1 - F_{K_i}(k_i) \quad \forall i \in \{1, 2, 3, 4\}$$

- Fix:

$$w_i = \frac{1}{4} \quad \forall i \in \{1, 2, 3, 4\}$$

- Compute the score:

$$s_{1.1} = \sum_{i=1}^4 w_i s_{1.1.i}$$

## 2. Emissions reduction

- Fix *GHG emissions reduction*:

$$K_5 = \tilde{r}$$

- Compute the eCDF associated with  $K_5$  and exploiting Table A1:
  - compute  $Q_{K_5}(1/3)$  and  $Q_{K_5}(2/3)$
  - construct the three awarding intervals  $I_1$ ,  $I_2$  and  $I_3$
  - take the value  $k_5$  registered by the company and select the proper adjusted score function basing on the range to which it belongs
- Compute the Greenhouse Gas (GHG), Ozone-Depleting substances (ODS) and other significant emissions score:

$$s_1 = f_a(s_{1.1})$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	305-1a	Direct (Scope 1) GHG emissions	[tCO <sub>2</sub> eq]
	305-2a	Energy indirect (Scope 2) GHG emissions	[tCO <sub>2</sub> eq]
	305-3a	Other indirect (Scope 3) GHG emissions	[tCO <sub>2</sub> eq]
	305-5a	Reduction of GHG emissions	[tCO <sub>2</sub> eq]
	305-6ar	Emissions of ozone-depleting substances (ODS)	[tCO <sub>2</sub> eq]

Table 2.2: GHG, ODS and other significant emissions rKPIs.

## Water

We concentrate on KPIs 303-3a, 303-4a, 303-5a. The GRI documentation measures all of them in Ml, i.e. megaliters, we convert Ml in  $\text{m}^3$ , i.e. cubic meters, in this way:

$$m [\text{Ml}] \cdot \frac{1}{1000} = m [\text{m}^3]$$

where  $m$  is the body of water.

To ease the notation in the following we adopt this convention:

rGRI	revised Key Performance Indicator	Notation
303-3ar	Water withdrawal	x
303-4ar	Water discharge	y
303-5ar	Water consumption	z

We conduct a two layers analysis focusing on the size of the water supply and water management procedures. For measuring the resource supply, once applied the training dataset transformation, we assess the *total water withdrawn*:

$$K_1 = \tilde{x} \tag{2.11}$$

In order to reduce risks of water shortages, higher values of  $K_1$  are penalised.

GRI 303 defines:

$$z = x - y$$

To discuss a company water handling, we focus on resource consumption and discharge with respect to the global withdrawn. Indeed, considering them in a broad sense could be misleading since their volumes have a meaning when compared. Even if the GRI documentation simply focuses on the water discharge, not claiming an explicit declaration of its composition into pure and contaminated, the procedure wants them for a further discussion. Thus, we require the cubic meters of pure or purified water discharge and the cubic meters of contaminated water discharge. In the following we call them  $y_p$  and  $y_c$  respectively.

We evaluate the *water consumption over the total withdrawn*:

$$K_2 = \frac{z}{x} \tag{2.12}$$

Since the total amount of water consumed is no more available for the ecosystem and the local community in the reporting period, higher values need to be penalised.

We discuss the fraction of water discharge over the total withdrawn to detect its impact on the receiving waterbody. An increased release does not necessarily benefit the environment insofar as hazardous substances could damage the surroundings. Indeed, water discharge is classified basing on whether it is contaminated or not and, if needed, on the application of treatment techniques. We assess the *pure or purified water discharge over the total withdrawn*:

$$K_3 = \frac{y_p}{x} \quad (2.13)$$

and the *contaminated water discharge over the total withdrawn*:

$$K_4 = \frac{y_c}{x} \quad (2.14)$$

Processing before releasing is rated positively as well as pure water and unlike contaminated discharge.

We combine  $K_2$ ,  $K_3$  and  $K_4$  scores via their relative composition:  $w_i = k_i, \forall i \in \{2, 3, 4\}$ . Finally, the obtained score and the evaluation of  $K_1$  (Equation 2.11) are fairly weighted. The company withdrawn is further assessed in connection with the resource availability in the affected area. Thus, the impact of water procurement is not only confined to its volume but it also deals with water security. We make use of the Aqueduct Water Risk Atlas by the World Resources Institute<sup>1</sup> as a mapping tool for inspecting water risk zone by zone all over the world, classifying water stress into five different levels including low, low-medium, medium-high, high and extremely high. We quantify the severity of the water stress in the zone impacted by the company activity, applying a continuous and increasing penalty function  $f_p$  to the computed rating of the form  $f_p(x) = ax + b$ , with  $a, b \in \mathbb{R}$ . In this way, the function is capable of modulating the reduction basing on the previously assigned score. Since scores are non-negative,  $f_p$  maps 0 in 0. Denoting with  $p \in [0, 1]$  the penalty rate, i.e. the size of the reduction associated to a before-penalty score of 1,  $a$  and  $b$  are the solutions of this system of two equations in two variables:

$$\begin{cases} f_p(0) = 0 & \rightarrow & b = 0 \\ f_p(1) = p & \rightarrow & a = p \end{cases}$$

Thus, the penalty curve becomes  $f_p(x) = px$ . Finally, we introduce the adjusted score function  $f_a : [0, 1] \rightarrow [0, 1]$  which receives the old score and returns the final one in this way:  $f_a(x) = x - f_p(x) = (1 - p)x$ .

---

<sup>1</sup>The World Resources Institute is a global research organisation which focuses on seven main topics including cities, climate, energy, food, forests, ocean and water, by committing developing analysis tools to explain current and future risks and improve lifestyle.

We select three different penalty rates to generate different levels of downgrading matched to the severity of the water stress, as classified by the World Resources Institute (see Table A2). We reason as follows:

- the penalty rate of extremely high water stress zones is chosen to prevent a company withdrawing there to get an overall water score classified in A and B rating categories. We select  $p = 1/2$  matching a previous score of 1 to an adjusted  $1/2$ , via a double downgrading (from A+ to C+).
- The penalty rate of high water stress zones is chosen to prevent a company withdrawing there to get an overall water score classified in A category. We select  $p = 1/4$  matching a previous score of 1 to an adjusted  $3/4$ , via a single downgrading (from A+ to B+).
- The penalty rate of medium-high water stress zones is chosen to prevent a company withdrawing there to get an overall water score classified in A+ category. We select  $p = 1/8$  matching a previous score of 1 to an adjusted  $7/8$  (from A+ to A).
- Low and low-medium water stress zones are not penalised.

### Algorithm

#### 0. Training dataset

- > Take the training dataset and select indicators in Table 2.3:
  - >  $x = 303-3ar.i$
  - >  $y_p = 303-4ar.i$
  - >  $y_c = 303-4ar.ii$
  - >  $z = 303-5ar$
- > Run the training dataset transformation getting  $\tilde{x}$

#### 1. Water

##### a. Water withdrawal

- > Compute the *total water withdrawn*:

$$K_1 = \tilde{x}$$

- > Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$
- > Take the corresponding value registered by the company, denoted  $k_1$

- Compute the score:

$$s_{2.1.a} = 1 - F_{K_1}(k_1)$$

b. Water consumption and discharge

- Compute the *water consumption over the total withdrawn*:

$$K_2 = \frac{Z}{X}$$

the *pure or purified water discharge over the total withdrawn*:

$$K_3 = \frac{Y_P}{X}$$

and the *contaminated water discharge over the total withdrawn*:

$$K_4 = \frac{Y_C}{X}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{2,3,4\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{2,3,4\}$
- Compute the scores:

$$s_{2.1.b.i} = 1 - F_{K_i}(k_i) \quad \forall i \in \{2,4\}$$

$$s_{2.1.b.3} = F_{K_3}(k_3)$$

- Fix:

$$w_i = k_i \quad \forall i \in \{2, 3, 4\}$$

- Compute the score:

$$s_{2.1.b} = \sum_{i=2}^4 w_i s_{2.1.b.i}$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{a, b\}$$

- Compute the score:

$$s_{2.1} = \sum_{i \in \{a,b\}} w_i s_{2.1.i}$$

## 2. Water stress

- Get the zone impacted by the company water withdrawal (303-3ar.ii) and use the Aqueduct Water Risk Atlas to detect the severity of the water stress
- Exploit Table A2 to select the proper adjusted score function basing on the the water stress
- Compute the water score:

$$s_2 = f_a(s_{2.1})$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	303-3ar	i Water withdrawal	[m <sup>3</sup> ]
		ii Area impacted by the water withdrawal	–
	303-4ar	i Pure or purified water discharge	[m <sup>3</sup> ]
		ii Contaminated water discharge	[m <sup>3</sup> ]
	303-5ar	Water consumption	[m <sup>3</sup> ]

Table 2.3: Water rKPIs.

## Land use and biodiversity

GRI 304-4 considers animals, plants and fungi species in the IUCN Red List and national conservation list, living in areas affected by industrial activities. The Red List status indicates the likelihood that the considered specie will go extinct in the near future, basing on the current information of population patterns and potential threats. To evaluate the extinction risk based on a specie population size or trends, the GRI indicator classifies the species threatened with extinction into least concern, near threatened, vulnerable, endangered and critically endangered categories, exploiting the IUCN Red List mapping tool. For completeness and consistency with the Red List, we also consider the data deficient category when data are missing. The impact the company has on threatened biodiversity is assessed by demanding all the jeopardized species so that one can classify each reported animal life into its corresponding category. Indicating with  $(y_i)_{i \in \{1,2,\dots,5\}}$  the number of species belonging to the  $i$ -th Red List category, we translate the given taxonomy into a multiplying system exacerbating the value of  $y_i$  in accordance with the severity of the extinction threat. More precisely, we introduce the penalty rate  $\alpha$  which is an integer number greater or equal than one, such that  $\alpha \in \{1, 2, 3, 4, 5\}$  is matched to an increasing serious extinction risk, as indicated in Table A3. We evaluate the *number of IUCN Red List species and national conservation list species with habitats in areas affected by operations multiplied by the penalty rate  $\alpha$  communicating the corresponding extinction risk*:

$$K_1 = \sum_{i=1}^5 \alpha_i y_i \quad (2.15)$$

Since each natural resource has a key role in maintaining the balance of the ecosystem, the conservation of animal, plant and fungi species is critical for humans survival. Thus, we implement an evaluation procedure penalising higher values of threat.

### Algorithm

#### 0. Training dataset

- Take the training dataset and select indicators in Table 2.4:
  - $x = 304-4r$

#### 1. Species threatened with extinction

- Compute the *number of IUCN Red List species and national conservation list species with habitats in areas affected by operations multiplied by the rate  $\alpha$  communicating the corresponding extinction risk*: (see Table A3)

$$K_1 = \sum_{i=1}^5 \alpha_i y_i$$

- Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$
- Take the corresponding value registered by the company, denoted  $k_1$
- Compute the score:

$$s_3 = 1 - F_{K_1}(k_1)$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	304-4r	Total number of IUCN Red List species and national conservation list species with habitats in areas affected by the operations of the organization, by level of extinction risk	[#]

Table 2.4: Land use and biodiversity rKPIs.

## Raw materials sourcing

To ease the notation in the following we adopt this convention:

GRI	Key Performance Indicator	Notation
301-1	Materials used by weight or volume	x
301-1a.i	Non renewable materials used	y
301-1a.ii	Renewable materials used	z
301-2	Recycled input materials used	r

We first measure the *total materials used*, once applied the training dataset transformation:

$$K_1 = \tilde{x} \quad (2.16)$$

Given the global nature of resources exploitation, higher values of  $K_1$  are penalised.

Obviously:

$$x = y + z$$

thus we assess the *renewable materials used over the total materials used*:

$$K_2 = \frac{z}{x} \quad (2.17)$$

and the *non renewable materials used over the total materials used*:

$$K_3 = \frac{y}{x} \quad (2.18)$$

Renewable materials are constituted by natural resources which are spontaneously replenished on a human time scale. Contrary to  $K_3$ ,  $K_2$  is positively rated since, even if consumed, this type of materials results in sustainable strategies. We discuss materials stewardship practices by combining the weighted evaluations associated with each of the two compositions with respect to the total materials used, denoted  $s$ .

We have:

$$s = k_2 F_{K_2}(k_2) + k_3 (1 - F_{K_3}(k_3))$$

Since  $K_2 + K_3 = 1$ , we get:

$$F_{K_2}(k_2) \simeq 1 - F_{K_3}(k_3) \quad (2.19)$$

More precisely, we can write:

$$\begin{aligned} F_{K_2}(k_2) &= P(K_2 \leq k_2) = 1 - P(K_2 > k_2) \\ &= 1 - P(1 - K_3 > 1 - k_3) \\ &= 1 - P(K_3 < k_3) \end{aligned}$$

thus, we conclude that  $F_{K_2}(k_2) = 1 - F_{K_3}(k_3)$  holds in all points but on the training dataset  $(K_{3j})_{j \in \{1, 2, \dots, m_3\}}$  where the difference is at most  $\frac{n_3}{m_3}$ .

Reasonably, we can write:

$$s = k_2 F_{K_2}(k_2) + k_3 F_{K_2}(k_2) = F_{K_2}(k_2)$$

Thus, it is enough to assess the proportion of renewable materials to the overall materials used of any business, regardless of the non renewables.

The procedure also addresses the employment of recycled materials reasoning the *fraction of recycled input materials used over the total materials used*:

$$K_4 = r \tag{2.20}$$

Finally, GRI 301-3 claims the percentage of reclaimed products and their packaging materials over the total products sold. Since materials assessment uses as measuring meter the total materials used, computing the impact of each variable with respect to it, we need the percentage of reclaimed products with respect to the total materials used. Thus, rather than its percentage with respect to the total products sold, we require the total amount of reclaimed products expressed in tonnes. In the following we call it  $p$ . Indeed, we can indicate the *reclaimed products and their packaging materials over the total materials used* as:

$$K_5 = \frac{p}{x} \tag{2.21}$$

Note that  $K_5$  is derived exploiting only the total amount of reclaimed products and their packaging materials, the amount of recycled materials instead is preserved in  $K_4$ .

While diverting from waste, the employment of recycled and recovered materials lower raw and virgin materials' use in products manufacturing, hence they are appreciated.

Considering that renewable, recycled and recovered materials are not necessarily mutually exclusive and that no one is universally recognised to be more advantageous in a sustainable perspective, we exploit a fair weighting system as follows:  $w_i = 1/3, \forall i \in \{2, 4, 5\}$ .

Finally, the obtained score and the evaluation of  $K_1$  (Equation 2.16) are fairly weighted.

### Algorithm

#### 0. Training dataset

- Take the training dataset and select indicators in Table 2.5:
  - $x = 301-1$
  - $y = 301-1a.i$
  - $z = 301-1a.ii$
  - $r = 301-2$
  - $p = 301-3ar$
- Run the training dataset transformation getting  $\tilde{x}$

#### 1. Raw Materials

##### a. Materials used

- Fix the *total materials used*:

$$K_1 = \tilde{x}$$

- Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$
- Take the corresponding value registered by the company, denoted  $k_1$
- Compute the score:

$$s_{4.1.a} = 1 - F_{K_1}(k_1)$$

##### b. Renewable, recycled and recovered materials used

- Compute the *renewable materials used over the total materials used*:

$$K_2 = \frac{z}{x}$$

fix the *recycled input materials used over the total materials used*:

$$K_4 = r$$

and compute the *reclaimed products and their packaging materials over the total materials used*:

$$K_5 = \frac{p}{x}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{2,4,5\}$

- Take the corresponding values registered by the company, denoted  $k_i$   
 $\forall i \in \{2,4,5\}$

- Compute the scores:

$$s_{4.1.b.i} = F_{K_i}(k_i) \quad \forall i \in \{2, 4, 5\}$$

- Fix:

$$w_i = \frac{1}{3} \quad \forall i \in \{2, 4, 5\}$$

- Compute the score:

$$s_{4.1.b} = \sum_{i \in \{2,4,5\}} w_i s_{4.1.b.i}$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{a, b\}$$

- Compute the score:

$$s_4 = \sum_{i \in \{a,b\}} w_i s_{4.1.i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	301-1	Materials used	[t]
	301-1a.i	Non renewable materials used	[t]
	301-1a.ii	Renewable materials used	[t]
	301-2	Recycled input materials used	[%]
	301-3ar	Reclaimed products and their packaging materials	[t]

Table 2.5: Raw materials sourcing rKPIs.

## Waste and pollution

To ease the notation in the following we adopt this convention:

GRI	Key Performance Indicator	Notation
306-3a	Waste generated	x
306-4a	Waste diverted from disposal	y
306-5a	Waste directed to disposal	z

Since a consumer society produces wastes, destabilising the terrestrial biodiversity and polluting air, soil and water, it cannot help but focus on the waste management. Firstly, we evaluate the *total waste generated*, once applied the training dataset transformation:

$$K_1 = \tilde{x} \quad (2.22)$$

In this way we get a metric for the total waste produced by the industrial activity; it is negatively assessed. Following the same way of reasoning as in the discussion on emissions, we proceed the analysis by distinguishing two separate levels, concerning the wastes actually generated in the reporting period from those avoided. The GRI documentation differentiates the total amount of waste generated into directed to and diverted from disposal. The first category mainly refers to the simplest but also the most dangerous remedies of landfilling and incineration. They directly affect humans, ecosystems and species through methane releases and waste burning, respectively, while also interrupting materials life cycle. A careful and effective management of the problem deals with the waste diverted from disposal, involving the development of a circular industrial system cutting the goods directed towards disposal solutions to the advantage of their enhancement through recovery and recycling, in a way that the scraps of a process could become the inputs of another.

We have:

$$x = y + z$$

We indicate the *waste diverted from disposal over the waste generated* as:

$$K_2 = \frac{y}{x} \quad (2.23)$$

and the *waste directed to disposal over the waste generated* as:

$$K_3 = \frac{z}{x} \quad (2.24)$$

The European Union Waste Framework Directive, basing on the implications these processes have on environment and society, defines good practice guidelines for handling components end of life, calling for a hierarchical system of preference including prevention, diversion from disposal and then disposal[36]. As a result, only  $K_2$  is positively rated. We propose the same way of reasoning as the raw materials sourcing key factor (see Equation 2.19), arranging the two types of waste generated with their relative composition obtaining the score  $s = F_{K_2}(k_2)$ . Thus,  $s$  and the evaluation of  $K_1$  (Equation 2.22) are fairly weighted.

Finally, we concentrate on waste generation reduction efforts. In this regard, GRI 306-2a is limited to a discussion about the actions taken to prevent waste generation, starting from the first stages of the production to end of life measures, passing through the value chain. To measure these cuts brought on by circularity measures, we demand its quantification. In the following we call it  $r$ . Once applied the training dataset transformation, we discuss the *waste prevention*:

$$K_4 = \tilde{r} \quad (2.25)$$

Following the same approach as the GHG emissions reduction, we apply an adjusted score function to the computed rating, which accounts for the size of the waste prevented making use of the quantile function  $Q_{K_4}$  (see Table A4).

### Algorithm

#### 0. Training dataset

- > Take the training dataset and select indicators as in Table 2.6:
  - >  $r = 306-2a$
  - >  $x = 306-3a$
  - >  $y = 306-4a$
  - >  $z = 306-5a$
- > Run the training dataset transformation getting  $\tilde{x}$  and  $\tilde{r}$

#### 1. Waste

##### a. Waste generated

- > Fix the *total waste generated*:

$$K_1 = \tilde{x}$$

- > Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$

- Take the corresponding value registered by the company, denoted  $k_1$
- Compute the score:

$$s_{5.1.a} = 1 - F_{K_1}(k_1)$$

b. Waste generated diverted from and directed to disposal

- Compute the *waste diverted from disposal over the waste generated*:

$$K_2 = \frac{Z}{X}$$

- Compute the eCDF associated with  $K_2$ , denoted  $F_{K_2}$
- Take the corresponding value registered by the company, denoted  $k_2$
- Compute the score:

$$s_{5.1.b} = F_{K_2}(k_2)$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{a, b\}$$

- Compute the score:

$$s_{5.1} = \sum_{i \in \{a, b\}} w_i s_{5.1.i}$$

## 2. Waste prevention

- Fix the *waste prevention*:

$$K_4 = \tilde{r}$$

- Compute the eCDF associated with  $K_4$  and exploiting Table A4:
  - compute  $Q_{K_4}(1/3)$  and  $Q_{K_4}(2/3)$
  - construct the three awarding intervals  $I_1$ ,  $I_2$  and  $I_3$
  - take the value  $k_4$  registered by the company and select the proper adjusted score function basing on the range to which it belongs
- Compute the waste and pollution score:

$$s_5 = f_a(s_{5.1})$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	306-2ar	Waste prevention	[t]
	306-3a	Waste generated	[t]
	306-4a	Waste diverted from disposal	[t]
	306-5a	Waste directed to disposal	[t]

Table 2.6: Waste and pollution rKPIs.

## Clean-tech and renewables

To ease the notation in the following we adopt this convention:

rGRI	revised Key Performance Indicator	Notation
302-1a	Energy consumption within the organization from non renewable sources	$x_n$
302-1b	Energy consumption within the organization from renewable sources	$x_r$
302-1e	Energy consumption within the organization	$x$
302-2a	Energy consumption outside of the organization	$y$
302-4a	Reduction of energy consumption	$r_1$
302-5a	Reductions in energy requirements of products and services	$r_2$
305-5a	Reduction of GHG emissions	$r_3$
301-1a.ii	Renewable materials used	$r_4$
301-2	Recycled input materials used	$r_5$
306-2ar	Waste prevention	$r_6$

The analysis is structured in two independent parts focusing on the energy consumption of the company's industrial activity and its clean-tech efforts. We deal with them separately, evaluating their own contribute, then we get the final clean-tech and renewables score as the fair weighted sum.

We first discuss the *total energy consumption within and outside the organisation*, once applied the training dataset transformation:

$$K_1 = \tilde{x} + \tilde{y} \quad (2.26)$$

Being consumption, it is negatively assessed. Then, for valuing the company's sustainable management of the energy resources, we separate the energy consumption from its reduction, as in emissions and waste discussions. More precisely, we demand the quantification of the total energy consumed outside of the organisation, exactly as GRI 302-1a and 302-1b, i.e. differentiating the type of source between renewable and non renewable. In the following we call them  $y_n$  and  $y_r$  respectively. The total energy consumed is made up by a positive and a negative part in a sustainable perspective. Thus, adopting the same way of reasoning as materials and waste key factors, we only assess the good renewable parts, omitting their complementary. We simply compute the *renewable energy consumption within the organisation over the total energy consumption within the organisation*:

$$K_2 = \frac{x_r}{x} \quad (2.27)$$

and the *renewable energy consumption outside of the organisation over the total energy consumption outside of the organisation*:

$$K_3 = \frac{y_r}{y} \quad (2.28)$$

We get the score  $s$  for the type of energy used, as the fair convex linear combination of the two contributes  $F_{K_2}(k_2)$  and  $F_{K_3}(k_3)$ . Thus,  $s$  and the evaluation of  $K_1$  (Equation 2.26) are fairly combined.

To conclude the energy part, we focus on the efforts concerning energy reduction, by discussing measures of energy saving and efficiency, and cuts in the energy requirements of sold products and services. Once applied the training dataset transformation, we introduce the *reduction of energy consumption*:

$$K_4 = \tilde{r}_1 \quad (2.29)$$

and the *reductions in energy requirements of products and services*:

$$K_5 = \tilde{r}_2 \quad (2.30)$$

We use a waterfall model getting the final score via two consecutive steps. These exploit the quantile functions  $Q_{K_4}$  and  $Q_{K_5}$  to construct two adjusted score functions which measure the size of the two reductions (see Tables A5, A6).

The second part of the analysis assesses the company's efforts to adopt solutions reducing or eliminating the environmental impacts of a production process, by improving energy efficiency, making more rational use of natural resources, reducing waste generation and polluting emissions. Hence, we resume KPIs already analysed to measure the company clean-tech attempts. More precisely, we make use of the already defined  $K_4$  and  $K_5$ , together with the *reduction of GHG emissions*:

$$K_6 = \tilde{r}_3 \quad (2.31)$$

the *renewable materials used*:

$$K_7 = \tilde{r}_4 \quad (2.32)$$

the *recycled input materials used*:

$$K_8 = r_5 \quad (2.33)$$

and the *waste prevention*:

$$K_9 = \tilde{r}_6 \tag{2.34}$$

Obviously, these indicators are all positively rated. Since there is no reason to believe that some are more important than others, being all clean-tech struggles, we all recognise the same materiality, concluding with a fair distribution of weights:  $w_i = 1/6, \forall i \in \{4, 5, 6, 7, 8, 9\}$ . We end the subsection by computing the clean-tech and renewables score as the fair weighted sum of the two parts' score.

### Algorithm

#### 0. Training dataset

- Take the training dataset and select indicators in Table 2.7:
  - $x_n = 302-1a$
  - $x_r = 302-1b$
  - $x = 302-1e$
  - $y = 302-2ar$
  - $y_n = 302-2ar.i$
  - $y_r = 302-2ar.ii$
  - $r_1 = 302-4a$
  - $r_2 = 302-5a$
  - $r_3 = 305-5a$
  - $r_4 = 301-1a.ii$
  - $r_5 = 301-2$
  - $r_6 = 306-2ar$
- Run the training dataset transformation getting  $\tilde{r}_1, \tilde{r}_2, \tilde{r}_3, \tilde{r}_4, \tilde{r}_6$

#### 1. Renewables

##### a. Energy consumption

##### aa. Energy

- Compute the *total energy consumption within and outside the organisation*:

$$K_1 = \tilde{x} + \tilde{y}$$

- Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$
- Take the corresponding value registered by the company, denoted  $k_1$
- Compute the score:

$$s_{6.1.a.aa} = 1 - F_{K_1}(k_1)$$

## ab. Energy types

- Compute the *renewable energy consumption within the organisation over the total energy consumption within the organisation*:

$$K_2 = \frac{x_r}{x}$$

and the *renewable energy consumption outside of the organisation over the total energy consumption outside of the organisation*:

$$K_3 = \frac{y_r}{y}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{2,3\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{2,3\}$
- Compute the scores:

$$s_{6.1.a.ab.i} = F_{K_i}(k_i) \quad \forall i \in \{2,3\}$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{2,3\}$$

- Compute the score:

$$s_{6.1.a.ab} = \sum_{i=2}^3 w_i s_{6.1.a.ab.i}$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{aa, ab\}$$

- Compute the score:

$$s_{6.1.a} = \sum_{i \in \{aa, ab\}} w_i s_{6.1.a.i}$$

## b. Energy reduction

- Fix the *reduction of energy consumption*:

$$K_4 = \tilde{r}_1$$

and the *reductions in energy requirements of products and services*:

$$K_5 = \tilde{r}_2$$

- Compute the eCDF associated with  $K_3$  and exploiting Table A5:
  - compute  $Q_{K_3}(1/3)$  and  $Q_{K_3}(2/3)$
  - construct the three awarding intervals  $I_1$ ,  $I_2$  and  $I_3$
  - take the value  $k_3$  registered by the company and select the proper adjusted score function basing on the range to which it belongs

- Compute the score:

$$s_{6.1.b}^{(1)} = f_a(s_{6.1.a})$$

- Compute the eCDF associated with  $K_4$  and exploiting Table A6:
  - compute  $Q_{K_4}(1/3)$  and  $Q_{K_4}(2/3)$
  - construct the three awarding intervals  $I_1$ ,  $I_2$  and  $I_3$
  - take the value  $k_4$  registered by the company and select the proper adjusted score function basing on the range to which it belongs

- Compute the score:

$$s_{6.1} = f_a(s_{6.1.b}^{(1)})$$

## 2. Clean-tech

- Fix the *reduction of GHG emissions*:

$$K_6 = \tilde{r}_3$$

the *renewable materials used*:

$$K_7 = \tilde{r}_4$$

the *recycled input materials used*:

$$K_8 = r_5$$

and the *waste prevention*:

$$K_9 = \tilde{r}_6$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{6,7,8,9\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{4,5,6,7,8,9\}$

- Compute the scores:

$$s_{6.2.i} = F_{K_i}(k_i) \quad \forall i \in \{3, 4, 5, 6, 7, 8\}$$

- Fix:

$$w_i = \frac{1}{6} \quad \forall i \in \{3, 4, 5, 6, 7, 8\}$$

- Compute the clean-tech score:

$$s_{6.2} = \sum_{i=3}^8 w_i s_{6.2.i}$$

### 3. Clean tech and renewables

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{1, 2\}$$

- Compute the clean-tech and renewables score:

$$s_6 = \sum_{i=1}^2 w_i s_{6.i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	302-1a	Non renewable energy consumption within the organization	[GJ]
	302-1b	Renewable energy consumption within the organization	[GJ]
	302-1e	Total energy consumption within the organization	[GJ]
	302-2ar	Energy consumption outside of the organization	[GJ]
		i Renewable energy consumption outside of the organization	[GJ]
		ii Non renewable energy consumption outside of the organization	[GJ]
	302-4a	Reduction of energy consumption	[GJ]
	302-5a	Reductions in energy requirements of products and services	[GJ]
	305-5a	Reduction of GHG emissions	[tCO <sub>2</sub> eq]
	301-1a	ii Renewable materials used	[t]
	301-2	Recycled input materials used	[%]
	306-2ar	Waste prevention	[t]

Table 2.7: Clean-tech and renewables rKPIs.

### 2.1.2. Social pillar

The social pillar consists of 8 key factors, which are examined in the following. Precisely, the sixth, i.e. supplier social assessment, analysing only qualitative KPIs, is not considered.

#### Employment

To measure the company's level of diversity and inclusiveness favouring equal opportunities, we examine both the composition of the workforce by age and gender, and his pay. The GRI documentation requires a detailed workforce reporting, by distinguishing between governance body and employee categories (GRI 405-1), hiring and turnover (GRI 401-1), both by gender and age groups. We summarise this information by discussing the overall balance of the personnel composition, whether at the beginning or at the end of the reporting period, to evaluate the change plans implemented and the achieved final structure. Recalling GRI 405-1, both at the beginning and at the end of the reporting period, we require data concerning the total number of individuals within the organisation's governance body and the total number of employees, by gender and age groups. To ease the notation in the following we adopt this convention:

Indicator	Notation
#individuals in the organisation's governance body	$g$
#employees	$x$
age group under 30 years old	$(30)$
age group between 30 and 50 years old	$(30-50)$
age group over 50 years old	$(50)$
men category	$m$
women category	$w$
beginning of the reporting period	$b$
end of the reporting period	$e$

We define the absolute value of the difference between men and women in the organisation's governance body over the total number of individuals in the organisation's governance body, at time  $t$ :

$$\Lambda_{g,t} = \frac{|g_{m,t} - g_{w,t}|}{g_{m,t} + g_{w,t}}$$

and the absolute value of the difference between male and female employees over the total

number of employees, at time  $t$ :

$$\Lambda_{x,t} = \frac{|X_{m,t} - X_{w,t}|}{X_{m,t} + X_{w,t}}$$

to obtain two ratios pointing out the gender composition asymmetry in the company's team at time  $t$ .

In the following we discuss the adopted procedure while considering the composition of the governance body; the same reasoning is assumed for the group of the employees. We focus on age and gender distinctions, creating two evaluations, each time putting together the assessments on the adopted change plans and the embraced final structure.

Concerning the gender distinction, we assess  $\Lambda_g$  *at the end of the reporting period*:

$$K_1 = \Lambda_{g,e} \quad (2.35)$$

and the *variation in the gender composition of the governance body during the reporting period*:

$$\begin{aligned} K_2 &= \frac{\Lambda_{g,b} - \Lambda_{g,e}}{\Lambda_{g,b} \mathbb{1}_{(\Lambda_{g,b} > \Lambda_{g,e})} + (1 - \Lambda_{g,b}) \mathbb{1}_{(\Lambda_{g,b} \leq \Lambda_{g,e})}} \\ &= \begin{cases} \frac{\Lambda_{g,b} - \Lambda_{g,e}}{\Lambda_{g,b}} & \Lambda_{g,b} > \Lambda_{g,e} \\ \frac{\Lambda_{g,b} - \Lambda_{g,e}}{1 - \Lambda_{g,b}} & \Lambda_{g,b} \leq \Lambda_{g,e} \end{cases} \end{aligned} \quad (2.36)$$

We elaborate assessments encouraging activities aimed at equal chances, protection of diversity and inclusion. For this reason, we penalise high values of  $K_1$  denoting gender disparity. Moreover, we recognise a positive contribute to the company re-balancing efforts in the personnel composition during the considered time frame, favouring large values of  $K_2$ . More precisely,  $K_2$  quantifies the change plans implemented, reasoning as follows:

- if  $\Lambda_{g,b} > \Lambda_{g,e}$  the gender composition of the governance body is somehow unbalanced at the beginning of the reporting period, but it is getting more gender balanced. This scenario is matched to the size of the variation over the maximum achievable improvement.
- If  $\Lambda_{g,b} < \Lambda_{g,e}$  the gender composition of the governance body is getting more gender unbalanced during the reporting period. This scenario is matched to the size of the variation over the maximum possible worsening.
- If  $\Lambda_{g,b} = \Lambda_{g,e}$  the gender composition of the governance body remains unchanged in the reporting period. This scenario is matched to zero to identify a middle situation

in which neither an improvement nor a worsening has been made.

We conclude the governance body analysis by gender, matching  $K_1$  to a continuous and decreasing weight function  $w_1 : [0, 1]^2 \rightarrow [1/2, 1]$  of this form:

$$w_1(x, y) = \frac{1}{2}(e^{-\alpha\sqrt{x^2+y^2}} + 1) \quad (2.37)$$

where  $x = \Lambda_{g,b}$ ,  $y = |\Lambda_{g,b} - \Lambda_{g,e}|$  and  $\alpha \in \mathbb{R}^+$ . Indeed, basing on the initial composition, as well as on the size of the variation in the reporting period, we aim to recognise a different relevance to  $K_1$  and  $K_2$  scores. In the following, we translate our reasoning into inequalities defining half-planes. Thus, we choose the parameter  $\alpha$  in the interval of values satisfying the system of defined inequalities. Precisely, we reason as follows:

- if  $x \simeq 0 \wedge y \simeq 0$  the initial and the end compositions are close to the perfect balance. We prevent underestimating changes in the right neighborhood of zero, by strengthening the final composition rather than the variation efforts. We force the threshold to be equal to 0.9:

$$w_1(x, y) > 0.9 \quad \forall x \leq 0.05 \wedge \forall y \leq 0.05 \quad (2.38)$$

- if  $x \gg 0$  the initial composition is strongly unbalanced, making change plans desirable. Since there is no reason to increase one or other of the indicators, we fairly weight them. Precisely, we force:

$$w_1(x, y) < 0.55 \quad \forall x \geq 0.55 \wedge \forall y \in [0, 1] \quad (2.39)$$

To get a set of values satisfying Eqs.2.38 and 2.39, the mathematical model requires at least an upper bound of 0.55. Note that the Equation 2.37 never assumes exactly 1/2, but it approaches the value at the extremes of the domain.

We attain  $\alpha \in [3.16, 4.19]$ , and we choose  $\alpha = 4$ . Combining the two evaluations, weighting them  $w_1$  and  $w_2$  respectively, we get the score  $s_1$ .

A second analysis mirrors the previous one while focusing on the distinction by age. To investigate the distribution of the governance body individuals in the three different categories, including under 30 years old, 30-50 years old and over 50 years old, we introduce two quantities resembling the unbiased estimators of a population mean and variance.

Firstly, we imagine of fairly dividing the total number of individuals in the organisation's

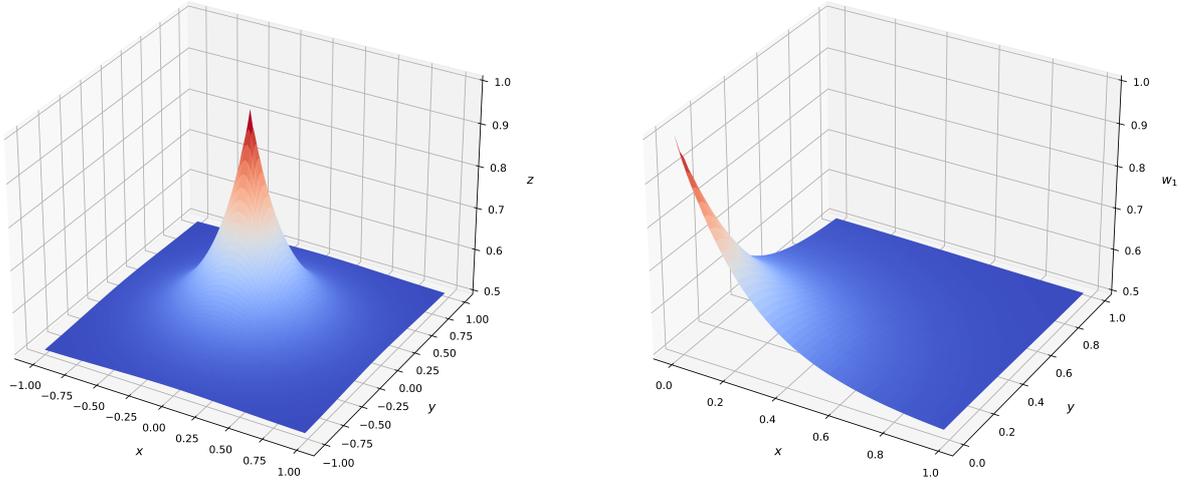


Figure 2.2: The left plot is the graph of the function with  $\alpha = 4$  when  $(x, y) \in [-1, 1]^2$ . The right one is the graph restricted to the region of admissible values, i.e.  $w_1(x, y)$  with  $(x, y) \in [0, 1]^2$ .

governance body at time  $t$ , into the three different classes, defining the pseudo-mean:

$$\mu_{g,t} = \frac{g_t^{(30)} + g_t^{(30-50)} + g_t^{(50)}}{3}$$

Thus, we calculate the pseudo-variance:

$$\sigma_{g,t}^2 = \frac{(g_t^{(30)} - \mu_{g,t})^2 + (g_t^{(30-50)} - \mu_{g,t})^2 + (g_t^{(50)} - \mu_{g,t})^2}{2} \quad (2.40)$$

measuring the dispersion of the categories' values at time  $t$ , with respect to the fair distribution of the individuals in the classes. In the formula we divide by two instead of three to get an unbiased estimator. Finally, we introduce the variable:

$$\Gamma_{g,t} = \sigma_{g,t}^2$$

to quantify the individuals' scatter in the different age groups with respect to the total number of individuals, at time  $t$ . Hence, we evaluate  $\Gamma_g$  at the end of the reporting period:

$$K_3 = \Gamma_{g,e} \quad (2.41)$$

Before proceeding with the analysis, we compute the maximum of Equation 2.40. We fix  $x = g_t^{(30)}$ ,  $y = g_t^{(30-50)}$ ,  $z = g_t^{(50)}$  and  $N = x + y + z$ . Precisely, being the number of individuals within the organisation's governance bodies in a specific age category,  $x$ ,  $y$  and  $z$  can assume only positive or null values. We compute the maximum value taken by the pseudo-variance, that is we solve a constrained maximisation problem of a function in three variables, exploiting the Lagrange multiplier method. We define:

$$f(x, y, z) = \frac{\left(x - \frac{N}{3}\right)^2 + \left(y - \frac{N}{3}\right)^2 + \left(z - \frac{N}{3}\right)^2}{2} \quad g(x, y, z) = x + y + z - N \quad (2.42)$$

where  $f(x, y, z)$  is the pseudo-variance and  $g(x, y, z)$  is the constraint to which  $f$  is subjected. Thus the Lagrangian function is:

$$L(x, y, z, \lambda) = \frac{\left(x - \frac{N}{3}\right)^2 + \left(y - \frac{N}{3}\right)^2 + \left(z - \frac{N}{3}\right)^2}{2} - \lambda(x + y + z - N)$$

We solve the system:

$$\begin{cases} \frac{\partial L(x, y, z, \lambda)}{\partial x} = 0 \\ \frac{\partial L(x, y, z, \lambda)}{\partial y} = 0 \\ \frac{\partial L(x, y, z, \lambda)}{\partial z} = 0 \\ \frac{\partial L(x, y, z, \lambda)}{\partial \lambda} = 0 \end{cases} \rightarrow \begin{cases} \left(x - \frac{N}{3}\right) - \lambda = 0 \\ \left(y - \frac{N}{3}\right) - \lambda = 0 \\ \left(z - \frac{N}{3}\right) - \lambda = 0 \\ x + y + z - N = 0 \end{cases}$$

yielding to  $\lambda = 0$  and to the stationary point  $(x, y, z) = \left(\frac{N}{3}, \frac{N}{3}, \frac{N}{3}\right)$ . Precisely, since  $f(x, y, z)$  is non-negative, and  $f\left(\frac{N}{3}, \frac{N}{3}, \frac{N}{3}\right) = 0$ ,  $\left(\frac{N}{3}, \frac{N}{3}, \frac{N}{3}\right)$  is a minimum point for  $f$ . Given that we have only one stationary point and the domain of the function is compact, there must be a maximum. The maximum is on the extremes of the domain, which is either  $x = 0$  or  $y = 0$  or  $z = 0$ . Being  $f$  symmetric in the three variables, we fix  $z = 0$ . Thus,  $y = N - x$ . We substitute these values in Equation 2.42 getting:

$$f(x, y) = x^2 - Nx + \frac{N^2}{3}$$

We obtain the equation of a concave upward parabola whose minimum corresponds to  $(x, y) = \left(\frac{N}{2}, \frac{N}{2}\right)$ . At the end, we find the maximum of  $f(x, y)$  at the extremes of the interval, either in  $x = 0$  or  $x = N$ . Finally, replacing the value obtained in the pseudo-variance equation, we get the maximum:  $\sigma_{max\ g, t}^2 = \frac{N^2}{3}$ .

Thus, we assess the *variation in the age composition of the governance body during the reporting period*:

$$\begin{aligned} K_4 &= \frac{\Gamma_{g,b} - \Gamma_{g,e}}{\Gamma_{g,b} \mathbb{1}_{(\Gamma_{g,b} > \Gamma_{g,e})} + (\sigma_{max\ g,b}^2 - \Gamma_{g,b}) \mathbb{1}_{(\Gamma_{g,b} \leq \Gamma_{g,e})}} \\ &= \begin{cases} \frac{\Gamma_{g,b} - \Gamma_{g,e}}{\Gamma_{g,b}} & \Gamma_{g,b} > \Gamma_{g,e} \\ \frac{\Gamma_{g,b} - \Gamma_{g,e}}{\sigma_{max,b}^2 - \Gamma_{g,b}} & \Gamma_{g,b} \leq \Gamma_{g,e} \end{cases} \end{aligned} \quad (2.43)$$

Reasoning as before, we weight  $K_3$  and  $K_4$  exploiting Equation 2.37 with the same  $\alpha = 4$ , and we get  $s_2$ .

Considering the employee group, we obtain the scores  $s_3$  and  $s_4$ , assessing  $\Lambda_x$  *at the end of the reporting period*:

$$K_5 = \Lambda_{x,e} \quad (2.44)$$

the *variation in the gender composition of the employees during the reporting period*:

$$K_6 = \frac{\Lambda_{x,b} - \Lambda_{x,e}}{\Lambda_{x,b} \mathbb{1}_{(\Lambda_{x,b} > \Lambda_{x,e})} + (1 - \Lambda_{x,b}) \mathbb{1}_{(\Lambda_{x,b} \leq \Lambda_{x,e})}} \quad (2.45)$$

$\Gamma_x$  *at the end of the reporting period*:

$$K_7 = \Gamma_{x,e} \quad (2.46)$$

and the *variation in the composition by age of the employees during the reporting period*:

$$K_8 = \frac{\Gamma_{x,b} - \Gamma_{x,e}}{\Gamma_{x,b} \mathbb{1}_{(\Gamma_{x,b} > \Gamma_{x,e})} + (\sigma_{max\ x,b}^2 - \Gamma_{x,b}) \mathbb{1}_{(\Gamma_{x,b} \leq \Gamma_{x,e})}} \quad (2.47)$$

To conclude the consideration about the business performance on gender non-discrimination, we also assess equal pay. Recalling GRI 405-2, we introduce the *ratio of basic salary and remuneration of women to men*:

$$K_9 = \max(r, r^{-1}) \quad (2.48)$$

Since the fraction could be both greater and smaller than one, to synthesise a criterion penalising the more values deviate from the unity, in favour of equal pay, we select the maximum. In this way we study a distribution of numbers reaching the minimum in one. In the following its assessment is indicated as  $s_5$ .

Finally, we need to combine all these evaluations, i.e.  $s_1, s_2, s_3, s_4$  and  $s_5$ . Since leadership roles require some experience, they are typically played by older individuals. Indeed, we recognise to all the scores the same contribute but  $s_2$ , which represents the age gap in the governance body, concluding with  $w_i = 0.225, \forall i \in \{1, 3, 4, 5\}$  and  $w_2 = 0.10$ .

### Algorithm

#### 0. Training dataset

➤ Take the training dataset and select indicators in Table 2.8:

- $g_{m,b} = 405-1r.a.i, g_{m,e} = 405-1r.b.i$
- $g_{w,b} = 405-1r.a.ii, g_{w,e} = 405-1r.b.ii$
- $x_{m,b} = 405-1r.a.iii, x_{m,e} = 405-1r.b.iii$
- $x_{w,b} = 405-1r.a.iv, x_{w,e} = 405-1r.b.iv$
- $g_b^{(30)} = 405-1r.a.v, g_e^{(30)} = 405-1r.b.v$
- $g_b^{(30-50)} = 405-1r.a.vi, g_e^{(30-50)} = 405-1r.b.vi$
- $g_b^{(50)} = 405-1r.a.vii, g_e^{(50)} = 405-1r.b.vii$
- $x_b^{(30)} = 405-1r.a.viii, x_e^{(30)} = 405-1r.b.viii$
- $x_b^{(30-50)} = 405-1r.a.ix, x_e^{(30-50)} = 405-1r.b.ix$
- $x_b^{(50)} = 405-1r.a.x, x_e^{(50)} = 405-1r.b.x$
- $r = 405-2ar$

➤  $\forall j \in \{g,x\}$ , compute:

$$\Lambda_{j,t} = \frac{|j_{m,t} - j_{w,t}|}{j_{m,t} + j_{w,t}}$$

and

$$\Gamma_{j,t} = \sigma_{j,t}^2$$

and

$$\sigma_{max\ j,t}^2 = \frac{N^2}{3}$$

where

$$\mu_{j,t} = \frac{j_t^{(30)} + j_t^{(30-50)} + j_t^{(50)}}{3}$$

$$\sigma_{j,t}^2 = \frac{(j_t^{(30)} - \mu_{j,t})^2 + (j_t^{(30-50)} - \mu_{j,t})^2 + (j_t^{(50)} - \mu_{j,t})^2}{2}$$

$$N = j_t^{(30)} + j_t^{(30-50)} + j_t^{(50)}$$

Fix  $\alpha = 4$  and define:

$$w(x, y) = \frac{1}{2}(e^{-\alpha\sqrt{x^2+y^2}} + 1)$$

### 1. Composition by gender - governance body

- Compute  $\Lambda_g$  at the end of the reporting period:

$$K_1 = \Lambda_{g,e}$$

- and the variation in the gender composition of the governance body during the reporting period:

$$K_2 = \frac{\Lambda_{g,b} - \Lambda_{g,e}}{\Lambda_{g,b} \mathbb{1}_{(\Lambda_{g,b} > \Lambda_{g,e})} + (1 - \Lambda_{g,b}) \mathbb{1}_{(\Lambda_{g,b} \leq \Lambda_{g,e})}}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{1,2\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{1,2\}$
- Compute the scores:

$$s_{1.1.1} = 1 - F_{K_1}(k_1)$$

$$s_{1.1.2} = F_{K_2}(k_2)$$

- Fix:

$$w_1(x, y) = w(x, y)$$

$$w_2 = 1 - w_1$$

where  $x = \Lambda_{g,b}$  and  $y = |\Lambda_{g,b} - \Lambda_{g,e}|$

- Compute the score:

$$s_{1.1} = \sum_{i=1}^2 w_i s_{1.1.i}$$

### 2. Composition by age - governance body

- Compute  $\Gamma_g$  at the end of the reporting period:

$$K_3 = \Gamma_{g,e}$$

and the variation in the age composition of the governance body during the

*reporting period:*

$$K_4 = \frac{\Gamma_{g,b} - \Gamma_{g,e}}{\Gamma_{g,b} \mathbb{1}_{(\Gamma_{g,b} > \Gamma_{g,e})} + (\sigma_{\max,t}^2 - \Gamma_{g,b}) \mathbb{1}_{(\Gamma_{g,b} \leq \Gamma_{g,e})}}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{3,4\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{3,4\}$
- Compute the scores:

$$s_{1.2.3} = 1 - F_{K_3}(k_3)$$

$$s_{1.2.4} = F_{K_4}(k_4)$$

- Fix:

$$w_3(x, y) = w(x, y)$$

$$w_4 = 1 - w_3$$

where  $x = \Gamma_{g,b}$  and  $y = |\Gamma_{g,b} - \Gamma_{g,e}|$

- Compute the score:

$$s_{1.2} = \sum_{i=3}^4 w_i s_{1.2.i}$$

### 3. Composition by gender - employees

- Compute  $\Lambda_x$  at the end of the reporting period:

$$K_5 = \Lambda_{x,e}$$

and the *variation in the gender composition of the governance body during the reporting period:*

$$K_6 = \frac{\Lambda_{x,b} - \Lambda_{x,e}}{\Lambda_{x,b} \mathbb{1}_{(\Lambda_{x,b} > \Lambda_{x,e})} + (1 - \Lambda_{x,b}) \mathbb{1}_{(\Lambda_{x,b} \leq \Lambda_{x,e})}}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{5,6\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{5,6\}$

Compute the scores:

$$s_{1.3.5} = 1 - F_{K_5}(k_5)$$

$$s_{1.3.6} = F_{K_6}(k_6)$$

➤ Fix:

$$w_5(x, y) = w(x, y)$$

$$w_6 = 1 - w_5$$

where  $x = \Lambda_{x,b}$  and  $y = |\Lambda_{x,b} - \Lambda_{x,e}|$

➤ Compute the score:

$$s_{1.3} = \sum_{i=5}^6 w_i s_{1.3.i}$$

#### 4. Composition by age - employees

➤ Compute  $\Lambda_x$  at the end of the reporting period:

$$K_7 = \Gamma_{x,e}$$

and the variation in the gender composition of the governance body during the reporting period:

$$K_8 = \frac{\Gamma_{x,b} - \Gamma_{x,e}}{\Gamma_{x,b} \mathbb{1}_{(\Gamma_{x,b} > \Gamma_{x,e})} + (\sigma_{\max,t}^2 - \Gamma_{x,b}) \mathbb{1}_{(\Gamma_{x,b} \leq \Gamma_{x,e})}}$$

➤ Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{7,8\}$

➤ Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{7,8\}$

➤ Compute the scores:

$$s_{1.4.7} = 1 - F_{K_7}(k_7)$$

$$s_{1.4.8} = F_{K_8}(k_8)$$

➤ Fix:

$$w_7(x, y) = w(x, y)$$

$$w_8 = 1 - w_7$$

where  $x = \Gamma_{x,b}$  and  $y = |\Gamma_{x,b} - \Gamma_{x,e}|$

- Compute the score:

$$s_{1.4} = \sum_{i=7}^8 w_i s_{1.4.i}$$

#### 5. Remuneration

- Compute the *ratio of basic salary and remuneration of women to men*:

$$K_9 = \max(r, r^{-1})$$

- Compute the eCDF associated with  $K_9$
- Take the corresponding value registered by the company, denoted  $k_9$
- Compute the score:

$$s_{1.5} = 1 - F_{K_9}(k_9)$$

#### 6. Final

- Fix:

$$w_i = 0.225 \quad \forall i \in \{1, 3, 4, 5\}$$

$$w_2 = 0.10$$

- Compute the employment score:

$$s_1 = \sum_{i=1}^5 w_i s_{1.i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	405-1ar	i Number of male individuals within the organization's governance bodies at the beginning of the reporting period	[#]
		ii Number of female individuals within the organization's governance bodies at the beginning of the reporting period	[#]
		iii Number of male employees at the beginning of the reporting period	[#]
		iv Number of female employees at the beginning of the reporting period	[#]
		v Number of individuals within the organization's governance bodies under 30 years old at the beginning of the reporting period	[#]
		vi Number of individuals within the organization's governance bodies between 30 and 50 years old at the beginning of the reporting period	[#]
		vii Number of individuals within the organization's governance bodies over 50 years old at the beginning of the reporting period	[#]
		viii Number of employees under 30 years old at the beginning of the reported period	[#]
		ix Number of employees between 30 and 50 years old at the beginning of the reporting period	[#]
		x Number of employees over 50 years old at the end of the reporting period	[#]
	405-2ar	Ratio of basic salary and remuneration of women to men	–

Table 2.8: Employment rKPIs. Since rGRIs 405-1br perfectly resemble rGRIs 405-1ar while dealing with the end of the period, they are omitted in the list.

## Occupational and customer health and safety

To ease the notation in the following we adopt this convention:

GRI	Key Performance Indicator	Notation
403-9a.i	Rate of fatalities as a result of work-related injury	$x_1$
403-9a.ii	Rate of high-consequence work-related injuries (excluding fatalities)	$x_2$
403-9a.iii	Rate of recordable work-related injuries	$x_3$
416-2a.i	Incidents of non-compliance with regulations concerning the health and safety impacts of products and services resulting in a fine or penalty	$z_1$
416-2a.ii	Incidents of non-compliance with regulations concerning the health and safety impacts of products and services resulting in a warning	$z_2$
416-2a.iii	Incidents of non-compliance with voluntary codes concerning the health and safety impacts of products and services	$z_3$

We discuss customer health and safety and occupational health and safety, which, in turn, is structured into the analysis of the company's security handling and the damages suffered by workers.

The numerous risks in the workplace make it crucial to provide employees with health and safety education, to ensure awareness of, and adherence to the regulations. The GRI documentation discusses security training in GRI 403-5, without requiring any quantification of the programs taken. Instead, we measure the company's safeguarding of the labour force, by demanding the average number of health and safety training hours per employee, denoted  $h_t$ . Since training activities do not distinguish between men and women, we do not carry out an analysis by gender. We evaluate the *average number of health and safety training hours per employee*:

$$K_1 = h_t \quad (2.49)$$

As a way to assess an adequate warning to workers about potentially dangerous events, higher values of  $K_1$  are positively rated.

Damages suffered by workers differ in work-related injuries and ill health, depending on whether the triggering event is sudden and violent or slow and progressive. In both cases the GRI documentation splits the analysis into different and fading levels of gravity. Recalling GRI 403-10, we demand the rate of fatalities as a result of work-related ill health and the rate of recordable work-related ill health. In the following we call them  $y_1$  and  $y_2$  respectively. Thus, we create two unique indicators weighting the rates faithful to their

severity grade, assessing the *work-related injuries*:

$$K_2 = \frac{3}{4}x_1 + \frac{1}{5}x_2 + \frac{1}{20}x_3 \quad (2.50)$$

and the *work-related ill health*:

$$K_3 = \frac{3}{4}y_1 + \frac{1}{4}y_2 \quad (2.51)$$

Since dealing with workers' damages, these indicators are negatively rated. The fair weighted sum of the two corresponding contributes summarises the score given to the workplace accidents.

We end up the first stage of the study, by fairly weighting the company's efforts to protect its workers from accidents and illnesses, and the events actually happened to the employees, resolving the score  $s$ .

Regarding the second part, customers are entitled to non-hazardous products with no risks to their health. Concerning the health and safety impacts of products and services, GRI 416-2 discusses the incidents of non-compliance with regulations, leading to a fine or penalty, or a warning, and incidents of non-compliance with voluntary codes. We build an indicator summing up these violation episodes. More precisely, we match each of them to a weight which communicates the corresponding severity grade. We negatively assess the *incidents of non-compliance concerning the health and safety impacts of products and services*:

$$K_4 = \frac{1}{2}z_1 + \frac{1}{4}z_2 + \frac{1}{4}z_3 \quad (2.52)$$

The discussion ends fairly weighting occupational and customer health and safety contributes, that is  $s$ , and the evaluation of  $K_4$  (Equation 2.52).

### Algorithm

#### 0. Training dataset

- Take the training dataset and select indicators in Table 2.9:
  - $h_t = 403-5r.i$
  - $h_w = 403-5r.ii$
  - $x_1 = 403-9ar.i$
  - $x_2 = 403-9ar.ii$
  - $x_3 = 403-9ar.iii$
  - $y_1 = 403-10r.i$
  - $y_2 = 403-10r.ii$
  - $z_1 = 416-2a.i$
  - $z_2 = 416-2a.ii$
  - $z_3 = 416-2a.iii$

#### 1. Occupational health and safety

##### a. Employee training

- Compute the *average number of health and safety training hours per employee*:

$$K_1 = h_t$$

- Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$
- Take the corresponding value registered by the company, denoted  $k_1$
- Compute the score:

$$s_{2.1.a} = F_{K_1}(k_1)$$

##### b. Damages suffered by employees

- Compute the *work-related injuries*:

$$K_2 = \frac{3}{4}x_1 + \frac{1}{5}x_2 + \frac{1}{20}x_3$$

and the *work-related ill health*:

$$K_3 = \frac{3}{4}y_1 + \frac{1}{4}y_2$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{2, 3\}$

- Take the corresponding values registered by the company, denoted  $k_i$   
 $\forall i \in \{2, 3\}$

- Compute the scores:

$$s_{2.1.b.i} = 1 - F_{K_i}(k_i) \quad \forall i \in \{2, 3\}$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{2, 3\}$$

- Compute:

$$s_{2.1.b} = \sum_{i=2}^3 w_i s_{2.1.b.i}$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{a, b\}$$

- Compute the score:

$$s_{2.1} = \sum_{i \in \{a, b\}} w_i s_{2.1.i}$$

## 2. Customer health and safety

- Compute the *incidents of non-compliance concerning the health and safety impacts of products and services*:

$$K_4 = \frac{1}{2}z_1 + \frac{1}{4}z_2 + \frac{1}{4}z_3$$

- Compute the eCDF associated with  $K_4$ , denoted  $F_{K_4}$
- Take the corresponding value registered by the company, denoted  $k_4$
- Compute the score:

$$s_{2.2} = 1 - F_{K_4}(k_4)$$

## 3. Final

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{1, 2\}$$

➤ Compute the occupational and customer health and safety score:

$$s_2 = \sum_{i=1}^2 w_i s_{2,i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	403-5r	i Average hours of training on occupational health and safety per employee	[#]
		ii Average working hours per employee	[#]
	403-9ar	i Rate of fatalities as a result of work-related injury <sup>2</sup>	–
		ii Rate of high-consequence work-related injuries (excluding fatalities) <sup>3</sup>	–
		iii Rate of recordable work-related injuries <sup>4</sup>	–
	403-10ar	i Rate of fatalities as a result of work-related ill health <sup>5</sup>	–
		ii Rate of recordable work-related ill health <sup>6</sup>	–
	416-2a	i Incidents of non-compliance with regulations concerning the health and safety impacts of products and services resulting in a fine or penalty	[#]
		ii Incidents of non-compliance with regulations concerning the health and safety impacts of products and services resulting in a warning	[#]
		iii Incidents of non-compliance with voluntary codes concerning the health and safety impacts of products and services	[#]

Table 2.9: Occupational and customer health and safety rKPIs.

<sup>2</sup>It is computed as  $\frac{\# \text{fatalities as a result of work-related injury}}{\# \text{hours worked}}$

<sup>3</sup>It is computed as  $\frac{\# \text{high-consequence work-related injuries (excluding fatalities)}}{\# \text{hours worked}}$

<sup>4</sup>It is computed as  $\frac{\# \text{recordable work-related injuries}}{\# \text{hours worked}}$

<sup>5</sup>It is computed as  $\frac{\# \text{fatalities as a result of work-related ill health}}{\# \text{hours worked}}$

<sup>6</sup>It is computed as  $\frac{\# \text{recordable work-related ill health}}{\# \text{hours worked}}$

## Training and education

The business world experiences continuous and progressive changes. In this scenario, a thriving organisation needs to devote resources for investing in the improvement of its employees' skills and abilities.

The totality of training programs discerns educational and refresher courses on health and safety, and customised solutions based on the specific professional requirements. GRI 404-1 discusses the size of training programs through the average hours of training undertaken per individual, distinguishing by gender and employee categories. We deal with the average hours of training per individual, excluding health and safety training (analysed in Section 2.1.2 - Occupational and customer health and safety) and anti-corruption procedures (analysed in Section 2.1.3 - Business ethics). For the same reason discussed in Section 2.1.2 - Occupational and customer health and safety, we do not introduce gender distinction. Precisely, we classify workers into four distinct categories, including senior leadership, management, professional, operational and technical. Denoting with  $h_s$ ,  $h_m$ ,  $h_p$  and  $h_o$  their average working hours, and rGRI 403-5r.ii with  $h_w$ , we proceed exactly as in equation 2.49 while addressing professional-specific training. We assess the *average hours of training in senior leadership*:

$$K_1 = h_s \quad (2.53)$$

the *average hours of training in management*:

$$K_2 = h_m \quad (2.54)$$

the *average hours of training in professional*:

$$K_3 = h_p \quad (2.55)$$

and the *average hours of training in operational and technical*:

$$K_4 = h_o \quad (2.56)$$

Meeting the needs of ongoing information and updates, the indicators are positively rated. Contrarily to health and safety training courses, this distinction reflects each profession needs and objectives but, in the face of change, they all have the same materiality. Thus we end up with a fair distribution of weights:  $w_i = \frac{1}{4}$ ,  $\forall i \in \{1, 2, 3, 4\}$ .

### Algorithm

#### 0. Training dataset

- Take the training dataset and select indicators in Table 2.10:
  - $h_d = 404-1r.i$
  - $h_q = 404-1r.ii$
  - $h_i = 404-1r.iii$
  - $h_o = 404-1r.iv$
  - $h_w = 403-5r.ii$  (see Table 2.9)

#### 1. Employee training

- Compute the *average hours of training in senior leadership*:

$$K_1 = h_s$$

the *average hours of training in management*:

$$K_2 = h_m$$

the *average hours of training in professional*:

$$K_3 = h_p$$

and the *average hours of training in operational and technical*:

$$K_4 = h_o$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{1, 2, 3, 4\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{1, 2, 3, 4\}$
- Compute the scores:

$$s_{3.i} = F_{K_i}(k_i) \quad \forall i \in \{1, 2, 3, 4\}$$

- Take the corresponding values registered by the company, denoted  $k_i$   
 $\forall i \in \{1, 2, 3, 4\}$

- Compute the scores:

$$s_{3.i} = F_{K_i}(k_i) \quad \forall i \in \{1, 2, 3, 4\}$$

- Fix:

$$w_i = \frac{1}{4} \quad \forall i \in \{1, 2, 3, 4\}$$

- Compute the training and education score:

$$s_3 = \sum_{i=1}^2 w_i s_{3.i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	404-1a.ii	i Average hours of training in senior leadership	[#]
		ii Average hours of training in management	[#]
		iii Average hours of training in professional	[#]
		iv Average hours of training in operational and technical	[#]

Table 2.10: Training and education rKPIs.

## Modern slavery

A fundamental requirement for socially responsible behaviour is the establishment and the successful implementation of anti-discrimination policies. We measure the incidence of employment discrimination episodes, discussing them with respect to the company number. More precisely, addressing GRI 406-1, we refer to an episode only in case of a legal action or a complaint with the organisation or appropriate authorities through a formal process. In view of an universal criterion, we exclude all cases of non-compliance discovered via organisational-specific procedures. Denoting with  $x$  the total incidents occurred in the reporting period and with  $y$  the staff numbers (obtained as the sum of rGRIs 405-1r.b.i, 405-1r.b.ii, 405-1r.b.iii and 405-1r.b.iv), we assess the *total number of incidents of discrimination over the total number of individuals in the organisation*:

$$K_1 = \frac{x}{y} \quad (2.57)$$

Finally, these unwanted behaviours are negatively rated insofar as they humiliate and violate human dignity.

### Algorithm

#### 0. Training dataset

- Take the training dataset and select the indicator in Table 2.11:
  - $x = 406-1ar$
  - $y = 405-1r.b.i + 405-1r.b.ii + 405-1r.b.iii + 405-1r.b.iv$  (see Table 2.8)

#### 1. Discrimination

- Compute the *total number of incidents of discrimination over the total number of individuals in the company*:

$$K_1 = \frac{x}{y}$$

- Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$
- Take the corresponding value registered by the company, denoted  $k_1$
- Compute the modern slavery score:

$$s_4 = 1 - F_{K_1}(k_1)$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	406-1ar	Incidents of discrimination resulting in legal actions or complaints	[#]

Table 2.11: Modern slavery rKPIs.

## Communities

Company activities might clash with the interests of the indigenous residing in the surroundings. Establishing a good relationship involves creating a mutually beneficial partnership where local communities offer resources, as well as prospects of growth to sustain the enterprise, and the company strengthens due diligence on indigenous rights. Insofar as things do not always work out, we exploit GRI 411-1 for quantifying the occurrences of indigenous rights abuses, disclosing episodes only as defined in Section 2.1.2 - Modern slavery. Denoting them with  $x$ , we negatively assess the *number of violations involving the rights of indigenous peoples*:

$$K_1 = x \quad (2.58)$$

### Algorithm

#### 0. Training dataset

- Take the training dataset and select the indicator in Table 2.12:
  - $x = 411-1ar$

#### 1. Violations of indigenous rights

- Fix the *number of violations involving the rights of indigenous peoples*:

$$K_1 = x$$

- Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$
- Take the corresponding value registered by the company, denoted  $k_1$
- Compute the communities score:

$$s_5 = 1 - F_{K_1}(k_1)$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	411-1ar	Incidents of violations involving rights of indigenous peoples	[# ]

Table 2.12: Communities rKPIs.

## Product responsibility

To ease the notation in the following we adopt this convention:

GRI	Key Performance Indicator	Notation
417-2a	i Incidents of non-compliance concerning product and service information and labeling resulting in a fine or penalty	$x_1$
	ii Incidents of non-compliance concerning product and service information and labeling resulting in a warning	$x_2$
	iii Incidents of non-compliance with voluntary codes concerning product and service information and labeling	$x_3$
417-3a	i Incidents of non-compliance concerning marketing communications resulting in a fine or penalty	$y_1$
	ii Incidents of non-compliance concerning marketing communications resulting in a warning	$y_2$
	iii Incidents of non-compliance with voluntary codes concerning marketing communications	$y_3$

Product labeling is a statement of content, connecting producers and consumers while aiming to transparently revealing environmental and social consequences of their actions. The GRI documentation deals with company incidents of non-compliance with regulations, focusing on products and services labeling (GRI 417-2) and marketing communications (GRI 417-3). It faces with different levels of severity including fine or penalty, warning, and a less severe contradiction with voluntary codes. We match each of the two GRIs to an indicator, by grouping their different grades of gravity, weighted on their significance as done in 2.1.2. Thus, we assess the *incidents of non-compliance concerning product and service information and labeling*:

$$K_1 = \frac{1}{2}x_1 + \frac{1}{4}x_2 + \frac{1}{4}x_3 \quad (2.59)$$

and the *incidents of non-compliance concerning marketing communications*:

$$K_2 = \frac{1}{2}y_1 + \frac{1}{4}y_2 + \frac{1}{4}y_3 \quad (2.60)$$

Insofar as the indicators represent information asymmetry between producers and consumers, higher values are penalised.

Finally, we recognise them the same materiality via a fair distribution of weights.

### Algorithm

#### 0. Training dataset

- Take the training dataset and select indicators in Table 2.13:
  - $x_1 = 417-2a.i$
  - $x_2 = 417-2a.ii$
  - $x_3 = 417-2a.iii$
  - $y_1 = 417-3a.i$
  - $y_2 = 417-3a.ii$
  - $y_3 = 417-3a.ii$

#### 1. Incidents of non-compliance with regulations

- Compute the *incidents of non-compliance concerning product and service information and labeling*:

$$K_1 = \frac{1}{2}x_1 + \frac{1}{4}x_2 + \frac{1}{4}x_3$$

and the *incidents of non-compliance concerning marketing communications*:

$$K_2 = \frac{1}{2}y_1 + \frac{1}{4}y_2 + \frac{1}{4}y_3$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{1, 2\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{1, 2\}$
- Compute the scores:

$$s_{7.i} = 1 - F_{K_i}(k_i) \quad \forall i \in \{1, 2\}$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{1, 2\}$$

- Compute the product responsibility score:

$$s_7 = \sum_{i=1}^2 w_i s_{7.i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	417-2a	i Incidents of non-compliance concerning product and service information and labeling resulting in a fine or penalty	[#]
		ii Incidents of non-compliance concerning product and service information and labeling resulting in a warning	[#]
		iii Incidents of non-compliance with voluntary codes concerning product and service information and labeling	[#]
	417-3a	i Incidents of non-compliance concerning marketing communications resulting in a fine or penalty	[#]
		ii Incidents of non-compliance concerning marketing communications resulting in a warning	[#]
		iii Incidents of non-compliance with voluntary codes concerning marketing communications resulting in a warning	[#]

Table 2.13: Product responsibility rKPIs.

## Data privacy

Companies increasingly store consumers' personal information. To protect privacy, organisations are required to inform their customers about how their data is collected and exploit, taking care not to use it for other purposes than those declared. We measure the company behaviour discussing the data breaches occurrences. Denoting them with  $x$ , we negatively assess the *number of identified losses of customer data*:

$$K_1 = x \quad (2.61)$$

### Algorithm

#### 0. Training dataset

- Take the training dataset and select the indicator in Table 2.14:
  - $x = 418-1b$

#### 1. Substantiated complaints

- Fix the *number of identified losses of customer data*:

$$K_1 = x$$

- Compute the eCDF associated with  $K_1$ , denoted  $F_{K_1}$
- Take the corresponding value registered by the company, denoted  $k_1$
- Compute the data privacy score:

$$s_8 = 1 - F_{K_1}(k_1)$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	418-1b	Losses of customer data	[#]

Table 2.14: Data privacy rKPIs.

### 2.1.3. Governance pillar

The governance pillar consists of 4 key factors, which are examined in the following. Precisely, the fourth, i.e. tax, for the reason discussed in Section 3.3, is not considered.

### Economic performance and its impacts

To ease the notation in the following we adopt this convention:

GRI	Key Performance Indicator	Notation
203-1	Infrastructure investments and services supported	x
204-1	Percentage of the procurement budget used for significant locations of operation that is spent on suppliers local to that operation	y

In order to assess the sustainable impact a business can generate, it is crucial to measure the value it brings to the geographic location it covers.

Once applied the the training dataset transformation, we evaluate the *extent of development of significant infrastructure investments and services supported*:

$$K_1 = \tilde{x} \tag{2.62}$$

favouring high values.

The GRI documentation assesses the extent to which the company promotes localism, by supporting and leveraging local suppliers in favour of local solidarity. It is worth to notice that while it is important to recognise a company's sustainable contribution to its local communities, in some occasions it becomes difficult to assess the reasons why a company is not taking advantage of its local supply chain. It might not be just careless. Often businesses need specific products or services which are not offered at their local level, therefore they are forced to benefit from foreign suppliers. The discussion on that matter is wide.

The English economist Alfred Marshall has focused on the industrial organisation. He has defined the localised industry as "an industry concentrated in certain localities". Indeed, firms' geographic concentration always follows precise criteria: the production is always contextualised in the economic, social and environmental scenario of a specific territory. Marshall work has been deepened by the Italian Becattini. Social relations and organisational production networks are the crucial structures determining how an industrial district develops. Among key distinctive features that characterise an industrial district, Becattini has identified a population of businesses, each specialising in a particular

production phase, so achieving a perfect harmony between competition and cooperation. Manufacturers, for example, benefit from being closed to the resources on which they rely[37]. Nevertheless, we cannot consider industrial districts as an universal model of organisation. Thus, addressing both reasons, we introduce a dummy indicator to discuss the *spending on local suppliers*:

$$K_2 = \mathbb{1}_{(y>0)} \quad (2.63)$$

Since it may not be directly up to the company, our aim is not evaluating the size of the expenditure, but rather its presence or not. Being a categorical variable taking value in  $\{0,1\}$ ,  $K_2$  simply investigates whether the company buys its raw materials directly from the local community or not. Indeed, it is assessed in an absolute way, matching a positive answer to 1 and a negative answer to 0, without making a comparison with the ongoing industrial scenario through the application of the CDF.

The discussion ends up fairly weighting  $K_1$  and  $K_2$ .

### Algorithm

#### 0. Training dataset

- Take the training dataset and select the indicator in Table 2.15:
  - $x = 203-1ar$
  - $y = 204-1a$
- Run the training dataset transformation getting  $\tilde{x}$

#### 1. Economic performance and impacts

- Fix the *extent of development of significant infrastructure investments and services supported*:

$$K_1 = \tilde{x}$$

and compute the *spending on local suppliers*:

$$K_2 = \mathbb{1}_{(y>0)}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{1, 2\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{1, 2\}$
- Compute the scores:

$$s_{1.1} = F_{K_1}(k_1)$$

$$s_{1.2} = k_2$$

➤ Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{1, 2\}$$

➤ Compute the economic performance and impact score:

$$s_1 = \sum_{i=1}^2 w_i s_{1.i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	203-1a	Infrastructure investments and services supported	[M€]
	204-1a	Percentage of the procurement budget used for significant locations of operation that is spent on suppliers local to that operation	[%]

Table 2.15: Economic performance and impacts rKPIs.

## Market presence

GRI 202-1 examines the employee gender compensation with respect to the local minimum wage. Focusing on gender pay gap in Section 2.1.2 - Employment (Equation 2.48), we simply discuss the standard entry-level wage to the local minimum wage. In the following we call it  $x$ . Thus, we assess the *ratio of standard entry level wage compared to local minimum wage*:

$$K_1 = x \quad (2.64)$$

Since payments of wages above the minimum show how much the organisation contributes to the economic welfare of its employees, high values of  $K_1$  are positively rated.

A second issue concerns the integration of social engagements towards the society into business operations, which may help to establish good relations with the communities. These advantages cannot be underestimated, mainly for the achievement of trust and good reputation among potential customers. In this scenario, selecting managers who come from local communities, highlights the company positive presence on the market. Indeed, the contact between managers and local communities expresses in the commitment to behave ethically and to favour the economic development, improving the quality of life for workers and their families. However, it is not always possible. In rural area is not always easy to find candidates having the right skillset for covering leadership role within decent organisations. Approaching this reason, since this may not necessarily depend on the company, we exploit a dummy variable to discuss the presence of *senior management at significant locations of operation hired from the local community*:

$$K_2 = \mathbb{1}_{(y>0)} \quad (2.65)$$

matching  $k_2$  to its score.

To conclude, we fairly weight the two variables.

### Algorithm

#### 0. Training dataset

- Take the training dataset and select the indicator in Table 2.16:
  - $x = 202-1ar$
  - $y = 202-2a$

## 1. Market presence

- Compute the *ratio of standard entry level wage compared to local minimum wage*:

$$K_1 = x$$

and the *senior management at significant locations of operation hired from the local community*:

$$K_2 = \mathbb{1}_{(y>0)}$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{1, 2\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{1, 2\}$
- Compute the scores:

$$s_{1.1} = F_{K_1}(k_1)$$

$$s_{1.2} = k_2$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{1, 2\}$$

- Compute the market presence score:

$$s_1 = \sum_{i=1}^2 w_i s_{1.i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	202-1ar	Ratio of the entry level wage at significant locations of operation to the minimum wage	–
	202-2a	Percentage of senior management at significant locations of operation that are hired from the local community	[%]

Table 2.16: Market presence rKPIs.

## Business ethics

To ease the notation in the following we adopt this convention:

GRI	Key Performance Indicator	Notation
206-1a	Number of legal actions pending or completed during the reporting period regarding anti-competitive behavior and violations of anti-trust and monopoly legislation in which the organization has been identified as a participant	$z$

With the adoption of certain business ethics including loyalty, fairness, transparency, diversity and integrity, organisations tend to prevent misconduct or illegal activities. We conduct a two-level study, focusing on anti-corruption policies, and legal actions for anti-competitive and anti-corruption behaviours.

GRI 205-2 discusses anti-corruption policies and requires to report the total number of a company's employees including its governance bodies who follow those procedures. With the same approach as in Section 2.1.2 - Training and education, we demand the followed average hours of anti-corruption procedures, by distinguishing between employees and governance body members, since the latters, being managing directors, have higher responsibilities. have increased responsibilities. In the following we call them  $h_x$  and  $h_g$  respectively. More precisely, we evaluate the *followed average hours of anti-corruption procedures per governance body member*:

$$K_1 = h_g \quad (2.66)$$

and the *followed average hours of anti-corruption procedures per employee*:

$$K_2 = h_x \quad (2.67)$$

Playing a strategic role in preventing corruption, the indicators are positively rated. Finally, we assign  $w_1 = 3/5$  and  $w_2 = 2/5$  to recognise  $K_1$  a major contribute as mostly exposed to risks. This is score  $s$ .

To investigate the business conduct, we focus on lawsuits filed against the organisation, whether for corruption or anti-competitive behaviours. To be precise, we refer to GRI 205-3d, using only quantitative data on corruption episodes. We negatively assess the *public legal cases regarding corruption brought against the organisation or its employees*:

$$K_3 = y \quad (2.68)$$

and the *legal actions pending or completed during the reporting period regarding anti-competitive behaviour and violations of anti-trust and monopoly legislation brought against the organisation*:

$$K_4 = z \quad (2.69)$$

acknowledging  $K_3$  and  $K_4$  the same materiality with weights  $w_i = 1/2, \forall i \in \{3, 4\}$ . Finally, we fairly combine  $s$  with the obtained score.

### Algorithm

#### 0. Training dataset

- Take the training dataset and select indicators in Table 2.17:
  - $h_g = 205-2ar$
  - $h_x = 205-2br$
  - $y = 205-3dr$
  - $z = 206-1a$

#### 1. Anti-corruption policies and procedures

- Fix the *followed average hours of anti-corruption procedures per governance body member*:

$$K_1 = h_g$$

and the *followed average hours of anti-corruption procedures per employee*:

$$K_2 = h_x$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{1, 2\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{1, 2\}$
- Compute the scores:

$$s_{3.1.i} = F_{K_i}(k_i) \quad \forall i \in \{1, 2\}$$

- Fix:

$$w_1 = \frac{3}{5}, w_2 = \frac{2}{5}$$

- Compute the score:

$$s_{3.1} = \sum_{i=1}^2 w_i s_{3.1.i}$$

## 2. Corruption and anti-competitive and monopoly practices

- Fix the *public legal cases regarding corruption brought against the organisation or its employees*:

$$K_3 = y$$

and the *legal actions pending or completed during the reporting period regarding anti-competitive behaviour and violations of anti-trust and monopoly legislation brought against the organisation*:

$$K_4 = z$$

- Compute the eCDFs associated with  $K_i$ , denoted  $F_{K_i} \forall i \in \{3, 4\}$
- Take the corresponding values registered by the company, denoted  $k_i \forall i \in \{3, 4\}$
- Compute the scores:

$$s_{3.2.i} = 1 - F_{K_i}(k_i) \quad \forall i \in \{3, 4\}$$

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{3, 4\}$$

- Compute the score:

$$s_{3.2} = \sum_{i=3}^4 w_i s_{3.2.i}$$

## 3. Final

- Fix:

$$w_i = \frac{1}{2} \quad \forall i \in \{1, 2\}$$

- Compute the business ethics score:

$$s_3 = \sum_{i=1}^2 w_i s_{3.i}$$

Key factor	rGRI	revised Key Performance Indicator	Unit measure
	205-2ar	Total number of governance body members that the organization's anti-corruption policies and procedures have been communicated to	[#]
	205-2br	Total number of employees that the organization's anti-corruption policies and procedures have been communicated to	[#]
	205-3dr	Public legal cases regarding corruption brought against the organization or its employees during the reporting period	[#]
	206-1a	Number of legal actions pending or completed during the reporting period regarding anti-competitive behavior and violations of anti-trust and monopoly legislation in which the organization has been identified as a participant	[#]

Table 2.17: Business ethics rKPIs.

## 2.2. Overlooked KPIs

The procedure would exploit all GRI Standards for synthesising the organisation's contribute to the sustainable development. However, some key performance indicators are statements limited to qualitative features. We translate this information into a quantifiable data wherever possible. Reference is made to GRIs 306-2a (see Section 2.1.1 - Waste and pollution) and 403-5 (see Section 2.1.2 - Occupational and customer health and safety). In most cases it is difficult to track details objectively comparable, since these data are grasped with highly individuality and subjectivity. This limit forces us to leave them out.

Among omitted KPIs, there are also quantitative indicators, analysed in the following.

- 305-4 and 302-3 assess emissions and energy intensity, dividing their total amount by an "Organization-specific metric". Since each company can freely choose its own metric, the indicator does not allow comparisons between different industries. Indeed, relating emissions and energy quantities to the total economic value generated, the algorithm already contextualizes the organisation's effectiveness with respect to the others companies.
- 305-7 assesses nitrogen oxides ( $\text{NO}_x$ ), sulfur oxides ( $\text{SO}_x$ ) and other significant air emissions. It groups tonnes of emissions coming from gases of different nature with characteristic warming potential, whose precise percentage composition is unknown. Thus, the problem stems from the difficulty of translating the unit measure from tonnes to  $\text{tCO}_2\text{eq}$ . However, reporting of 305-7 misses in most cases, as a result of difficulties in estimating reasonable values, rather than a lacking acknowledgement of their hazardous potential. For instance, in our dataset of companies to be evaluated, only 51 out of 222 companies signal it, corresponding to a poor 23%.  
A future development of ESG disclosure regulation could ensure an increasing efficiency in emissions reduction efforts, by introducing more precise rules for nitrous oxides, sulfur oxides and further significant emissions reporting. Quantifying each gas' specific contribute could ensure a more complete and exhaustive rating. Indeed, the new collected data could be added in the evaluation following exactly the same procedure used for KPI 305-6a. This would result in a more detailed scenario in view of the ambitious 2050 climate neutrality.
- 304-3 assesses habitats protected or restored. Since it misses an accurate and comprehensive inventory of worldwide protected areas, it is difficult to include them into an objective analysis.

- 401-1 assesses employee hires and turnover. We overlook this analysis by investigating the overall employee composition at the beginning and at the end of the reporting period.
- 401-3 assesses parental leave by gender. Women typically take care of children. Think that in the USA, only 65.1% of women with babies work, compared to 94.1% of men[38]. In this way, parenthood has a significant impact on women’s employment, making it challenging to balance the demands of a new family with the demands of work. This situation, together with love for children, can lead the woman to choose to stay at home, abandoning her work. The impossibility of distinguishing between the employee’s voluntary decision and the company’s responsibility, avoid us to evaluate it.
- 410-1 assesses the security personnel training in human rights policies or procedures. Organisational formative plans cover multiple areas of specialisation. We summarise all in the average hours of training per employee without an in-depth look (see Section 2.1.2 - Training and education).
- 415-1 assesses political contributions made directly and indirectly by the organisation. Companies may end up acting illegally via donations to government in favour of certain political processes. Being open to charges of corruption, these actions can lead to illicit behaviours which businesses may not disclose, making it impossible to recognise between a positive and a negative evaluation.
- 404-3, 413-1, 416-1 and 205-1 are rule out insofar as they are built on the basis of company-specific assessments, reviews and approaches, not universally recognised.
- 408-1 and 409-1 assess operations at risk of child and compulsory labour concerning suppliers activities, by simply disclosing what is thought to be at risk. Using the company identification process, rather than legal actions or complaints with appropriate authorities, prevents an universal judgement.
- 201-1 assesses the direct economic value generated and distributed. This KPI is managed only as a normalisation factor to measure resources exploitation and investments undertaken by the company, with respect to the economic value generated, saying somehow the corporate dimension (see Chapter 2 - Data transformation). We do not consider the indicator in an absolute sense, since we do not judge the companies’ sustainable performance on the basis of their production capacity.
- 201-3 assesses defined benefit plan obligations and other retirement plans. Since they follow special legislation at national level, the KPI is put aside.

- 201-4 assesses the financial assistance received from government. Being impossible to carry out a sustainable impact assessment, the KPI is ignored.
- 207-1, 207-2, 207-3, 207-4 are grouped in Tax, thus they are left out (see Section 3.3).

### 2.3. Penalty

Missing values plague ESG dataset, making it challenging to judge how well the company handles its material risks and opportunities. In this scenario, investors attention on corporate sustainability has been increasingly demanding better and accurate information. Going back to our sample of 222 companies, we collect data on waste and pollution finding that roughly 45% of the companies disclose waste generated. The remaining part is data gaps. Furthermore, note that Table 3.1 shows waste and pollution as a material issue for 9 out of the 11 industrial sectors.

When a company communicates a little amount of ESG data and this indicates a good long-term performance, ending up with a high ESG score would not be fair neither honest. Moreover, if the lack of data is explicitly considered, companies would be encouraged to provide new additional information, drawing up more accurate non-financial statements. Indeed, the procedure includes ESG data gaps in the measure of the company performance. The set of information needed to value the company sustainable performance is grouped into original and modified GRIs, that is, indicators belonging to the GRI documentation, and indicators that have been somehow revised. Considering original standards, we define a ESG datum gap when its reporting framework exists, thus it is demanded between GRI Standards but it is not appropriately disclosed. In the following, we refer only to the original set of GRI Standards, denoting with  $m_i$  their number in pillar  $i$ ,  $i \in \{e, s, g\}$ . See Tables A7, A8, A9, A10 for the complete list. The penalty algorithm matches any datum gap to a score reduction of  $\alpha_i$  times the comprehensive score of the pillar to which it belongs. Precisely,  $\alpha_i$  is computed such that, when the total number of gaps accounts for half of the required data (or its ceiling function, if it is not an integer number), the procedure reduces by 1/4 a before-penalty score of 1. Indeed,  $\alpha_i$  solves:

$$\left\lceil \frac{m_i}{2} \right\rceil \alpha_i = \frac{1}{4} \quad (2.70)$$

We get the following results:

Pillar	Data gaps - $m_i$	Penalty - $\alpha$
Environmental	19	1/20
Social	32	1/64
Governance	7	1/16

Note that, with data gaps each score obtained as a convex linear combination must be computed with a new convex linear combination where each weight must be divided by the sum of the weights not matching a datum gap.



# 3 | Weights

In the sections below we select the weights provided with each key factor, driving our analysis and choices issue by issue. In particular, we rely on publicly available information about ESG pillars, as well as on overlays of ESG controversies gleaned from news sources. Recalling that  $n_i$  denotes the number of key factors associated with pillar  $i$ ,  $i \in \{e, s, g\}$  and  $(w_j)_{j \in \{1, 2, \dots, n_i\}}$  are the set of weights associated with its key factors, weights are chosen such that:

$$\begin{cases} 0 \leq w_j \leq 1 \\ \sum_{j=1}^{n_i} w_j = 1 \end{cases}$$

Since each pillar implies a different weight reasoning, we split the discussion into three sections. In the environmental and social pillars, the analysis differs by industry. In general, key factors weights combine how the relative industry contributes to the main concern in comparison with the others (e.g., how emission-intensive the specific industry is with respect to the others), with the time frame in which the concern may materialise. Finally, for what concerns the governance pillar, the discussion is consistent across all sectors.

At the end of each section, it is provided a table with the final ESG sector weights matrix.

## 3.1. Environmental weights

Since each firm has its unique environmental risks and possibilities based on the nature of its activities, our methodology identifies the need for an industrial-specific weighting system. Accordingly with most of rating agencies, even in evaluating the same ESG choice, we develop different assessment criteria: if a material issue strictly deals with the company's main activity, this features a high weight otherwise it is lower. Following this rule, we standardise the efforts of different companies in different industries, allowing for a fairer relative comparison. The route is actually guided by signs on the path left by some existing rating agencies including MSCI and S&P Global which act as starting

point supplying us with their own weighting system. With regards to the 0.61 correlation found between rating agencies' evaluations, we notice that, in some cases, one agency recognises a specific industry's key factor materiality, while the other agency nullifies the same issue to enhance others. Sometimes in these situations we happen to lower a factor's significance simply to recognise also another one's relevancy.

We neglect a particular key factor for the specific industry if it is not significant for the purpose of the analysis.

### 3.1.1. Energy

The energy sector encompasses all businesses involved in energy production and distribution. It includes a broad range of key activities: the upstream area of the oil and gas industry which deals with search, exploration, drilling and extraction phases, known as Exploration and Production (E&P), oil and gas transportation and storage endeavours up to downstream operations of refinement and marketing activities; finally, companies that offer oil and gas equipment and services. The sector also covers industries engaged in the manufacture and mining of coal and other consumable fuels.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** the road to achieving all the objectives of 2030 Agenda is a challenging one. Global warming is the most serious environmental problem related to the energy sector: more than two-thirds of worldwide greenhouse gas emissions come from this industry[39]; consider that in the United Arab Emirates, which are among the world's leading producers and exporters of oil and gas, energy use and production account for more than 90% of total greenhouse gas emissions[40].

In this regard, pressed by the necessity of reducing energy-related releases, the oil and gas business must strike a strategic trade-off between short-term profits and its long-term operating license in order to meet international climate targets set by Paris Agreement. As of today, about 30% of sector production industries – such as BP, ExxonMobil, Shell, TotalEnergies – represent a CEO-led initiative, known as Oil and Gas Climate Organization (OGCI), aimed to collective action on climate change supporting the United Nations conference in Paris. According to the International Energy Agency<sup>1</sup> while some progress has been made in contrasting gas releasing, the entire oil and gas industry has powerful tools to reach an even more outstanding role thanks to its engineering skills, financial resources and project management know-how. In this respect, Dr. Fatih Barol, Turkish economist and energy expert, executive director of IEA since 2015, warned "The first immediate task for all parts of the industry is reducing the environmental footprint of their own operations. As of today, around 15% of global energy-related greenhouse gas emissions come from the process of getting oil and gas out of the ground and to consumers. A large part of these emissions can be brought down relatively quickly and easily." [39]

The high-speed economic recovery after 2020 health crisis drove global coal power generation to a record in 2021 and the overall coal demand to a potential all-time high in 2022. "Coal is the single largest source of global carbon emissions, and this year's historically

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<sup>1</sup>The International Energy Agency (IEA) was founded in 1974 after the oil crisis of the previous year aiming to ensure the security of energy supply. Energy security remains its primary objective even if nowadays it is also involved in sustainable development.

high level of coal power generation is a worrying sign of how far off track the world is in its efforts to put emissions into decline towards net zero" said Dr. Birol (2021). "Without strong and immediate actions by governments to tackle coal emissions – in a way that is fair, affordable and secure for those affected – we will have little chance, if any at all, of limiting global warming to 1.5 Celsius." [41]

In 2021, global energy-related CO<sub>2</sub> emissions climbed by 6% to 36.3 billion tons, the highest level ever recorded. Coal contributed for more than 40% of worldwide CO<sub>2</sub> emissions growth, hitting an all-time high of 15.3 billion tons; instead, CO<sub>2</sub> emissions from natural gas significantly increased to 7.5 billion metric tons [42]. The significant rise was supported by the recovery of the global economy following the COVID-19 crisis, as well as the heavy reliance on coal. According to the IEA, this increase in worldwide CO<sub>2</sub> emissions of more over 2 billion tons was the greatest in absolute terms in history, and more than negated the pandemic-induced reduction of the previous year.

In 2021, even if renewable energy output grew at its fastest rate ever, severe energy market conditions and price's spikes in natural gas exacerbated the rebound in energy demand, leading to greater coal burning. Data show that the global economic recovery from the COVID-19 crisis has not been the sustainable recovery that Dr. Birol predicted during the pandemic's early stages in 2020 when he said "Governments have a once-in-a-lifetime opportunity to reboot their economies and bring a wave of new employment opportunities while accelerating the shift to a more resilient and cleaner energy future" [43].

Emissions-related emergence needs a turning point to safely achieve Paris targets especially in a scenario where the post COVID-19 emissions record has fully outshined Paris strategies to cut emissions. We know there are several ways and alternatives to cut emissions and we recognise that, also because it is a key player in global growth and wealth, the energy sector has a high level responsibility in global warming. In addition, European Environment Agency<sup>2</sup> reports that, since 1990, reduction in energy emissions has occurred at a slower rate than emissions as a whole. In accordance to these considerations, reviewing the 42.33% of MSCI and the 40% of S&P Global, we choose to little enforce the energy sector contribute to Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions resolving a 45%.

**Water** "Energy needs water, water needs energy; and these linkages have enormous significance for economic growth, life and well-being. Water is essential for all phases of energy production, from fossil fuels to biofuels and power plants: energy use is vital for a range of water processes, including water distribution, wastewater treatment and

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<sup>2</sup>The European Environment Agency (EEA) is a European organization involved in monitoring network to control European environmental conditions aiming to support the sustainable development.

desalination. Almost all the weaknesses in the global energy system, whether related to energy access, energy security or the response to climate change, can be exacerbated by changes in water availability. Almost all of the fault lines in global water supply can be widened by failures on the energy side." [44]

Energy sector's reliance on water for what concerns e.g., fossil fuel extraction, transportation and processing as well as power generation, causes vulnerabilities and dangers which are worsened by extreme weather events brought on by climate change. This industry is sensitive to water demand and consumption so that a future increase in water constraints will have an impact on energy costs. Water scarcity is already affecting energy output and dependability, additional limits could jeopardize future projects implementation from both economic and environmental standpoints. What happened at the Parli Thermal Power Station (Maharashtra, India) in 2015 is an example of how water scarcity may lead a 250MW thermal power plant to shut down. Due to the near-complete drying up of the Majalgaon dam, the first of six power producing units stopped working. The facility was forced to stop producing energy due to a malfunctioning cooling system. As a result of the lack of water, each of the remaining five units shut down, forcing a halt in power generation [45].

The energy transition driven by the 2°C climate policy needs to realise its water implications for determining the long-term viability of the resource. The alignment of climate and energy policy has brought to strategies that negatively effect freshwater resources: while a lower carbon policy brings to safer environmental conditions, the technologies used to go towards this direction could worsen water stress and moreover they could be hampered by it. Coal and gas-fired power stations are huge water consumers but also green energy technologies could result in water stress. If wind and solar photovoltaic are low water solutions, others techniques like biofuels, capture, use and storage of carbon or nuclear energy are quite intensive exploiters of this resource.

The energy needed to provide and treat water is the other half of the energy-water nexus: all processes involving transport, distribution and collection of water, water heating and washing require electricity. Furthermore, the depletion of freshwater resources will lead to a greater emphasis on energy-consuming techniques like desalination, the most costly and energy-intensive method of water treatment, used in places where other options are few, such as the Middle East and Australia. During the next twenty-five years, intensification of energy use in the water industry mainly due to desalination processes will bring to more than doubling and within 2040 these projects will represent the 20% of water-related electricity demand.

In the following years there will be a general movement towards more water-intensive energy and energy-intensive water but there exist solutions to avoid stress points. There are

a lot of similarities between SDG 6 (clean water and sanitation) and SDG 7 (affordable and clean energy) that need to be properly managed to attain both objectives. These sectors' strategies and technologies can be much more effective if integrated by collocating energy and water infrastructures and using wastewater built-in energy.[44].

Reference ESG rating agencies disagree in the assessment of water contribute in the energy sector: while MSCI puts a weight of 2.33%, S&P Global recognises a greater value which swings between 10% and 20%. We conclude a considerable 10% weight since nowadays the struggle against climate change is more relevant than ever so that the interconnection between energy and water becomes even more fundamental. This alliance is needed to complete the energy transition in a sustainable manner and to protect planet's water resources.

**Land use and biodiversity** traditional energy technologies, energy transport and distribution, have a negative impact on biodiversity. An example of how oil and gas could jeopardize natural ecosystems comes from the Arctic ocean, an area with abundant oil and gas sources. In a scenario where menacingly warming is already altering and threatening Arctic ecosystems, drilling could pollute and melt polar caps at a higher rate. Nowadays, as a result of climate change, Arctic sea ice has reached its lowest extension setting a new low. Lots of polar bears, which rely on sea ice to travel, hunt, locate mates, and build dens, live in this site together with more than two hundreds other species. WWF is concerned about their habitat's existence and conservation since these animals are already in sharp decline as the entire Arctic melts. Decades ago, the area along the southern Beaufort Sea was declared a National Wildlife Refuge<sup>3</sup> by the United States government since Arctic oil and gas extraction have posed a significant threat to its fragile ecosystems and inhabitants, having a negative impact on fisheries, tourism, and other long-term economic activities.

According to some studies, mining eroded about 40,000km<sup>2</sup> in China and abandoned mine land is growing by around 330km<sup>2</sup> every year. Similarly, in Africa more than 700 million hectares of land is degraded especially because of mining. In these abandoned mined soils, common issues are inadequate plant nutrients, hazardous contaminants, poor physical structure, and extreme soil pH. Moreover, mining causes negative effects on human life such as high incidence of hypertension, lung cancer, lung and kidney disease[46].

Considering that all the energy production methods have an inevitable impact on the natural ecosystem, there needs to be ever growing careful at minimising wildlife exploitation. Understanding the sector's responsibility, we choose to embrace MSCI and S&P Global

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<sup>3</sup>National Wildlife Refuge is a naming used to indicate some protected areas of the United States.

work of weighting its effects on biodiversity more than one-fifth resolving a 25%.

**Waste and pollution** energy production generates a large amount of liquid and solid waste largely different. Some need to be carefully treated and isolated since either toxic or radioactive, some contain precious materials which are retrieved and recycled saving primary resources.

In recent decades, air quality has been deteriorated because of rising human emissions, primarily from the energy production sector. The consequences of air pollution on human health are now undeniable: specifically particulate matter (PM<sub>2.5</sub>) is most commonly linked to cardiovascular and respiratory disease as well as premature mortality. In fact, the fossil fuel cycle has a serious impact on the atmospheric pollution causing global warming with enormous quantity of GHG added daily.

Mining and combustion, especially in the case of coal, generate a great quantity of waste. Coal fly ash, flue gas desulfurization gypsum, spent catalyst containing trace and hazardous elements are all major solid waste from coal-fired power plants[47].

According to estimates, in Poland 0.4–0.5 tonnes of waste are produced for every tonne of coal produced. Consider the example of hard coal: when discussing waste issues arising during the preparation of hard coal deposits, its extraction, and its processing, both environmental and social concerns should be taken into consideration. It is important to organize waste management operations to prevent harm to the environment. Waste dumps could spontaneously catch fire posing a concern also because of deteriorating air quality. The chemism of the organic stuff present on the trash dump may also be impacted by variations in temperature. Additionally, the formation and transfer of phenols and their derivatives to water might result in pollution and a possible risk to the environment[48].

Caution must be exercised and particular attention must be paid in treating waste coming from the energy sector because of the danger these substances represent both for the environment and the life on the Earth. Considering the very risky environmental impact, recovering the work done by reference agencies, we associate to Waste and pollution a weight of 20%.

### 3.1.2. Materials

Companies within the materials sector are involved in the acquisition, development, and processing of many products commonly referred to as raw materials. It incorporates producers and distributors of construction materials (including cement, concrete, glass, plastics, bricks and sand) and building products (like flooring, tiles and furniture). It encompasses manufacturers of containers and packaging (like paper, glass and cardboard containers), extractors of metals and minerals. The sector covers the harvesting of timber and wood used to make paper, commodity chemicals (such as plastic, synthetic fibers and pigments), producers of fertilizers and pesticides, manufacturers of industrial gases and fabricators of iron and steel.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** CO<sub>2</sub> is chemically generated as a waste gas throughout a number of manufacturing processes, including the production of iron, steel, cement, ammonia, and more. About 40% of global emissions are produced by iron and steel manufacture, cement production, chemicals and petrochemicals industries. For instance, cement production, the third-largest source of CO<sub>2</sub> emissions in the world, accounts for 5% of global releases. Moreover, according to Draft Inventory of US<sup>4</sup>, the sector released 40.3 millions tCO<sub>2</sub>eq in 2018[49]. Ammonia production releases 2.6 tons of CO<sub>2</sub> per ton generated; for what concerns steel, instead, the proportion is 1:2.

The use of low-emission energy, sustainable production techniques, carbon capture, and material recycling are just a few of measures that the materials industry should implement in order to reduce harmful releases. However, in some parts of the industry, the use of low-emission energy could only have a limited effect because the primary cause of releases – also referred to as "process emissions" – comes from chemicals reactions rather than from energy use throughout the manufacturing process. For instance, during the production of cement, calcination<sup>5</sup> is responsible for around two thirds of emissions.

In regards to containers and packaging, analysing the entire life cycle of cardboard wrapping in Europe, all significant production process elements, including emissions from fossil and renewable energy sources, raw material extraction and direct land use change, on average 326kg of CO<sub>2</sub> are released for every ton of cardboard packaging produced. For what concerns container and flat glass industry instead, more than 60 million tons of CO<sub>2</sub> are emitted yearly[50].

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<sup>4</sup>Draft Inventory of US refers to the Inventory of U.S. Greenhouse Gas Emissions and Sinks which provides a comprehensive accounting of total greenhouse gas emissions for all man-made sources in the United States.

<sup>5</sup>Calcination is the chemical reaction that takes place when limestone is heated up.

One of the main reasons of global warming and climate change is the increase in the concentration of gases, particularly human atmospheric carbon dioxide. Given that the primary cause of climate change is human activity, an immediate action is needed. In particular, the industrial sector under review, accounting for a sizable portion of the growth in emissions, is strongly responsible for the concerns of pollution. Moreover, since emission reduction is only feasible during specific stages of the manufacturing process, careful thought should be given to the issue. In accordance with S&P, we decide to enforce the 26.81% weight associated to the sector by MSCI, resolving a 35%.

**Water** construction materials like steel, cement, and glass are produced in millions of tonnes annually, making use of water for many operations along the manufacturing chains and leaving it frequently contaminated. Water is also indirectly needed to produce the energy used in the production chain; for instance, when iron ore extraction is fueled by electricity produced at the power plant cooling water is needed[51].

Due to the increased public awareness of the challenges caused by global warming, recent years have seen an increase in studies aimed at resolving the environmental issues that the cement industry faces. The effective use of cement products, particularly in dry areas, depends in large part on resolving the water consumption difficulties related with cement manufacture: large amounts of energy are consumed during cement production, and producing that energy necessitates consuming a lot of water.

Think about Iron and Steel Industry (ISI) in China which generates the bulk of the world's crude steel. Since 1996, the Chinese ISI has struggled with significant water shortages and environmental pollution issues. In China, around 14% of total industrial water use is made up of fresh water utilized by the ISI which, in turn, produces 14.5% of the total wastewater of the country. Moreover, since ISI is energy-intensive, there is a strict link with water shortages and different pollution emissions. Numerous harmful chemicals, including heavy metals, waste oil, and cyanide, are included in the wastewater released from the industry, which significantly degrades the ecosystem[52].

Additionally, mining has a large negative influence on freshwater resources, harvesting timber has an impact on both the quality and quantity of water and chemical industry is a big resource user.

Water management is therefore crucial in production, regardless of the particular process. To create goods, businesses need reliable ways to obtain clean water, monitor water quality, and get rid of wastewater, one of the main drawbacks of industrial production. Consider the quantity of the resource required to produce and refine raw materials like metal, cement, lumber, chemicals, paper, and plastic to see how much water is used in the production of nearly every product we use. Despite rising industrial demand, freshwater

supplies around the world are continuously shrinking. Today more than two-thirds of businesses report being exposed to water concerns, and many corporations like Chinese ISI operate production facilities in regions of the world where water is scarce.

Nowadays, as the need for freshwater management becomes more urgent than ever, similar to the analysis of S&P and MSCI, we resolve an intermediate weight of 22.5%.

**Land use and biodiversity** the extraction of natural resources is inextricably linked to alterations in land cover. In 2001 mining in French Guiana was blamed for the loss of forest cover on an area of roughly 40km<sup>2</sup>, which is nearly 20 times faster than what happened there in 1990. In particular, at the operational site mining frequently grows, encouraging infrastructure expansions like new road networks construction. The pre-mined landscape is fundamentally altered by resource extraction, which results in significant habitat losses for animals, plants, and microbes. Mining contributes to the deterioration of forests and causes habitat fragmentation, isolation, and edge effects, which make it challenging for local species to move from one place to another[53]. Thus, mineral supply chains significantly affect biodiversity.

Mineral resources alive in all key areas of biodiversity so that as human population increases and technology develops, it is expected that conflicts between mining and conservation would worsen. As a result of this acknowledgment, the inclusion of biodiversity in mining industries is now a top priority in internal government discussions about a strategic plan for biodiversity conservation in a scenario where metals have increased by 2.7% yearly since 1970 and other minerals, like sand and gravel for concrete, have grown by nearly five times from 9 billion to 44 billion tonnes.

Negative effects on biodiversity occur over considerable distances, leaving only tolerant species in their wake; the sediment export from Madre de Dios<sup>6</sup>, for instance, affects habitats along connecting rivers in Brazil.

Steel industry in Brazil, even if not on a global scale, destroys a significant amount of habitat when obtaining non-mineral materials[54].

Due to the extensive raw material use, the cement industry has a special responsibility to protect natural resources: the extraction sites of its manufacture companies offer a unique habitat for endangered animal and plant species so that limestone quarries are crucial for the preservation of species and the advancement of biodiversity.

Nowadays Europe uses 400000 tons of pesticides yearly, Italy is the third-highest consumer of chemicals in agriculture among European states. Pesticides and agrochemicals, the main causes of biodiversity loss, also increase pollution, decrease long-term agricul-

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<sup>6</sup>Madre de Dios is a region in Peru where both legal and illegal gold mining raise a number of environmental issues connected to mercury pollution and deforestation, making hydrological and sediment transport processes crucial for any evaluation of environmental impacts.

tural production, create imbalance and fragility.

Activities connected to resource extraction from the environment contribute directly to biodiversity loss causing harm to the vegetation which serves as a habitat for wildlife and flora and increasing the risk of an ecological imbalance. As human population continues to grow, there is an increasing need for more and more resources to be mined. If these priceless resources are continuously harvested, there is a chance that they will likely run out. Since the two reference agencies valuation standards differ a few percent, being aware of the materiality of Land use and biodiversity key factor, we end up with about a middle value. Since the responsibility of the sector in the biodiversity loss and soil fragmentation cannot be disregarded, we associate a 10% weight.

**Waste and pollution** groundwater contamination and deteriorating air quality are just a few of the issues that can result from improper management of the waste coming from mining activities, iron and steel production, cement industry, chemical and petrochemical sectors and so on.

Mining activities produce a significant amount of mining waste worldwide, in particular, it is all about over 100 billion tons of solid waste annually. Concerns about the effects of waste disposal on the surface, in the form of tailings and waste rock, are the main focus of mining environmental management. One of the main issues is related to acid rock drainage, a frequent and problematic situation which may be caused by oxidation of iron sulfides in waste rock dumps and tailings deposits. If not effectively handled, these mining wastes could cause significant risks and considerably add to overall pollution through air routes and water leaching. The numerous characteristics of mining trash, including toxicity, flammability, reactivity and corrosivity provide a serious threat.

In the course of manufacturing steel, a substantial amount of industrial waste is produced: in 2017 more than 400 million tons of iron and steel slag were produced worldwide. Although steel is listed as the most recyclable material in the world, the streams show unsustainable waste management and operating practices, which, as a result, create environmental risks over the materials life cycles and stop progress toward a circular economy. In a steel industry, two main waste streams are produced: general wastes, which are similar to municipal solid wastes and produced indirectly from process activities, and process wastes, which are intrinsically hazardous and come directly from the production of iron and steel. In order to reduce environmental pollution and social effects, like water and soil contamination from poorly controlled industrial waste operations, liquid, gaseous, and solid wastes generated during the manufacturing of iron and steel must be managed specifically[55].

When it comes to the chemical sector, instead, the majority of the solid waste generated

is of metal type, frequently discharged inappropriately into the environment or dumped in landfills. Metals found in solid wastes can combine with groundwater and can have severely harmful impacts on human health. Polymers, such as plastic and polyethylene, can also occasionally be released as solid chemical wastes, adding significantly to environmental contamination. Additionally, the chemical industry produces a sizable amount of solid waste that is generated by packaging and containers. Like other waste-generating industries, petrochemical companies are linked to a number of waste-related environmental issues. Petrochemical wastes, however, typically contain more harmful elements and, as a result, have a higher potential risk to the environment and public health.

The large amounts of waste generated and the obvious danger they pose, force us to give the problem of waste products from the materials sector a worthy consideration: we reserve a weight of 30% in accordance with S&P and MSCI assessments.

**Clean-tech and renewables** being engaged in the discovery, development and processing of raw materials, the materials industry is strictly connect to green opportunities. The development of an integrated system capable of energy conservation, greenhouse gas emission reduction, and waste material recovery offers great potential for the cement industry. One of the greatest technologies allows to produce energy while simultaneously destroying wastes by using them as extra fuel in cement kilns. Recovering the energy value of these wastes for cement manufacturing make it possible to achieve the increase of energy recovery and material reuse. The reliance on waste materials as raw material substitutes in the production of clinker and cement is another possibility being studied. This might result in significant natural resource savings: up to a 38% replacement of limestone and a 72% replacement of clay.

Not only cement production but also the steel one is an example of energy and emission-intensive industry: consuming energy actively causes fuel resources to be depleted, while carbon dioxide emissions contribute to global climate change. China, the largest steel producer worldwide, is an example. Steel industry is under tremendous energy and environmental challenges: in 2018, it accounted for nearly 1 trillion tons of carbon dioxide emissions and about 11% of the total energy consumption of the country. China has implemented a number of green manufacturing rules for the sustainable development of the steel sector, strict energy conservation and emission reduction goals. The adoption of novel emission reduction technology in the industry requires the development of a market for steel manufactured using less carbon intensive production processes, also known as "green steel". However, the average CO<sub>2</sub> emissions per ton of crude steel produced can only be reduced by roughly 25% to 40% using conventional energy efficiency strategies. In this scenario, innovative methods are required to achieve additional reductions, such

as carbon capture, use, and storage, hydrogen or biomass<sup>7</sup> used as reducing agents, or electrolysis (e.g., using electricity to reduce iron ore)[56].

Moreover, the chemical industry produces large volumes of CO<sub>2</sub> and other pollutants because of its dependence on fossil fuels for energy and feedstocks. The growing desire to create a sustainable society is a strong motivation to reduce emissions from the chemical business. In this context, a number of strategies have been identified. Some examples include CO<sub>2</sub> capture and a future switch to renewable carbon feedstocks, adoption of circular economy principles, electrification of the sector using renewable sources, and decreased energy consumption due to technological advancements. Since solar energy is the most abundant form of energy today available to humanity, it can play a key part in these plans to establish a decarbonized chemical[57].

For sure, the search for clean-technologies opportunities is essential for the materials sector, both from an environmental protection perspective and an economic point of view. Consider the case of green steel, which is produced using a process that emits fewer greenhouse gases: since the demand for steel is expected to rise and rise through the end of the 21<sup>st</sup> century, therefore finding a different way to produce steel that releases less GHG into the environment is crucial. Differently from S&P which considers meaningless the Clean-tech and renewables contribute to the materials industry and to MSCI which resolves a weight of 9.23%, we decide to recognise a little but significant weight of 2.5% in view of the possibility of green technological advancements and improvements.

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<sup>7</sup>Biomass is a renewable, organic material coming from animals and plants used to produce a form of renewable energy called bioenergy. It refers to agricultural residues like woody waste products, crops and microbes

### 3.1.3. Industrials

Industrials is the broadest sector comprising most of industries and sub-industries. It regards all companies engaged in manufacturing and distribution of capital goods, durable items used in the production of other goods and services including civil or military aerospace and defense equipment, building components, large-scale contractors, electrical components, power-generating equipment, construction, agricultural and industrial machinery. Companies offering commercial services and supplies regarding office, commercial printing, environmental and facility maintenance, belong to this sector together with companies providing human resource, research, consulting and support services like cleaning and catering, and security services. Finally, it concerns also transportation in all its forms including cargo and passenger flights, ships, rails and trucking also including companies handling transportation infrastructures. Diversified industrial companies and engineering companies are also considered.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** in most countries the aerospace industry is a key economic driver that fosters innovation and social progress. Although the sector is thought to provide both economic and social benefits, it is subject to the growing pressure of public opinion to acknowledge its burden both for society and environment. According to the IEA (2021), the aviation sector is one of the businesses with the highest global carbon emissions[58].

Among all industry categories, the construction sector is the third-largest emissions contributor. Gas emissions from construction-related vehicles and machinery contribute to global warming. In the EU transportation sector, 2% of emissions are caused by construction equipment. Determining and quantifying the inefficiency of current construction operations is crucial to lowering the gas emissions produced by construction activities at construction sites. Increasing operational efficiency of equipment operations had been deemed the most cost-effective method to reduce greenhouse gas emissions. However, there are no many empirical studies looking at potential changes which can be made in daily functioning of equipment fleet, and quantifying the effects of such changes[59].

As a result of a number of economic activities, including the extensive development of transportation infrastructure, vehicle traffic, population and economic growth, demand for transport vehicles has seriously increased endangering the sustainable development. The trillion annual journeys, produced by passenger and freight intensive movements, increased the need for means of transport. In this scenario, environmental concerns led the industry to get lots of attention as, with a contribution of about 23%, it is a significant source of CO<sub>2</sub> emissions[60].

Air transportation carries a variety of chemical and radiative compounds, functioning as high-altitude emissions vector. Nitrogen oxides ( $\text{NO}_x$ ), carbon monoxide (CO), hydrocarbons (HC), sulphur dioxide ( $\text{SO}_2$ ), carbon dioxide ( $\text{CO}_2$ ), water vapour ( $\text{H}_2\text{O}$ ), particulate matter (PM), and other trace compounds are produced by aircraft engines. These substances provide 3.5% of the total anthropogenic-induced global warming. Carbon dioxide emissions accounts for only one-third of the industry's net climate impact, even if it is frequently depicted as the main cause of aviation-related climate change. Water vapour and nitrogen oxides are the main culprits[61].

Sea transportation is one of the cheapest and most common types of cargo shipping. According to the International Maritime Organization<sup>8</sup>, up to 90% of global transcontinental good transportation is carried out by the merchant fleet. In this context, to mitigate the effects of climate change, the policies for the development of the shipbuilding sector need to include a forward-looking evaluation of its potential environmental concerns. One of those issues is marine fouling. Biofouling of ship hulls causes a 70% increase in surface friction and a 50% reduction in operating performance, having a very detrimental effect on its maneuverability and operating qualities. An immediate effect is an increase in fuel consumption, which raises the cost of shipping cargo and also has an impact on the environment due to the additional fuel combustion which, in turn, causes a rise in  $\text{CO}_2$  emissions. About 930 million tons of greenhouse gas emissions are generated by shipping vessels overall. The most reliable method for preventing biological fouling is the creation of biocide-releasing coatings. However, after outlawing of toxic organometallic antifouling coatings, lead-, mercury- and tin-containing, finding new, effective biocidal materials and principles to stop the crucial activity of biofouling has grown into a huge scientific issue that has yet to be resolved[62].

Rail transportation has recently experienced a rebirth to keep up with the steadily rising volume of global freight. According to the International Transport Forum<sup>9</sup>, global rail freight volumes are predicted to increase 2.7% annually between 2015 and 2030, with some nations experiencing much faster growth. This development can be seen in recent infrastructure improvements, such as the "silk railway" initiated by the Chinese government to speed up travels between China and Europe. In addition, transportation contributes around 25% of the world's energy-related  $\text{CO}_2$  emissions and rail travel is frequently viewed as a mean to cut overall emissions from transportation. Emissions refer to all greenhouse gases produced by the burning of fuel and electricity to supply freight

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<sup>8</sup>The International Maritime Organization (IMO) is a specialised organisation of the United Nations controlling shipping.

<sup>9</sup>The International Transport Forum at the OECD is an intergovernmental organisation which promotes a better understanding of how transportation contributes to economic development, environmental sustainability and social inclusion.

transport machinery, including CO<sub>2</sub> and NO<sub>x</sub>[63].

This industry largely contributes to greenhouse gases and other hazardous substances emissions, both for the complexity of its composition and for the type of its employments and applications. Thus, the sustainability of the Industrials sector's growth needs to take into account the associated environmental concerns in long-term planning. Recognising the materiality of the issue, we end up with a middle 30% weight with respect to MSCI's 20.52% and S&P's 40%.

**Land use and biodiversity** Copernicus Programme is the European Union program which uses in-situ and space measurements to keep track of the Earth's environment. Copernicus provides six core thematic services including atmosphere monitoring, land monitoring, marine environment monitoring, emergency management, security, and climate change. The aerospace industry, as part of the Copernicus Programme, is embracing new products which are important for environmental protection, such as earth observations through satellite infrastructure and advanced telecommunications capabilities for monitoring environmental threats and ensuring the efficient use of natural resources. This program depends on a new family of satellites called Sentinels for reliable, fast, and easily accessible information on climate change and related strategies[58].

The transformation of agricultural, forest, and other semi-natural and natural spots for urban and man-made purposes, including city green areas and infrastructures, damages and fragments natural habitats, causing land take and providing significant environmental problems. Since it is necessary to provide a location for economic production, trade, transportation, and consumption activities, the construction industry deals with infrastructures development. Its environmental impact refers to the acquisition, usage, and removal of materials, energy and water, as well as to land exploitation and deforestation. Moreover, the construction process itself has a negative impact on the environment and the neighborhood due to noise, vibration exposure, waste incineration, groundwater contamination, and general soil pollution. Buildings have a significant negative impact on the environment exploiting about 40% of natural resources mined in industrialized countries, consuming 70% of electricity and 12% of potable water generating 45-65% of the landfills' waste. In this scenario, using environmentally friendly construction methods, can help reducing these negative effects. However, the majority of conventional building techniques have the most negative effects on the environment[64].

Besides, population and income growth needs high transportation accessibility. In its turn, transport infrastructure accounts for a major proportion of artificial land take generating soil consumption and encouraging the use of land for purposes like housing and business. Additionally, as transportation options grow, remote regions become accessible

and more appealing as areas near highways, roads, ports, airports, or rivers having a higher likelihood of experiencing new urban development[65].

In an increasingly urbanised world, where it is predicted that two-thirds of the global population will reside in urban areas by 2050, there is a pressing need to create sustainable communities ensuring sustainable consumption and production patterns. Industrialization must be equitable and environmentally responsible, and infrastructure must be resilient. The application of sound urban planning strategies is becoming more and more important since the global biocapacity is decreasing and the ecological footprint is growing.

Our reference agencies disagree in evaluating this sector responsibility: while MSCI considers a 5.24%, S&P recognises a 20.28%. Since we understand the fragility of the scenario, driven by the conflicting forces of urban development and environmental protection, we assign a 15% weight to Land use and biodiversity stressing the need for these two urges to come together.

**Raw materials sourcing** global aviation traffic is expected to double in the next 15 years, with a demand for over 39,000 passenger and freight aircraft.

Due to its outstanding fatigue qualities, high strength-to-weight ratio, and resistance to corrosion, titanium alloys are widely used in the aerospace industry for airframe forged parts, landing gear forgings and aero-engine compressor components. Thus, over the coming decades, there will be large demands for titanium alloys.

Moreover, the ever-expanding automobile sector, to comply with increasingly strict emissions regulations, is replacing steel parts with titanium in vehicles for the lightening of powertrains and exhaust systems. There needs to be a significant change in the economics in order to increase the use of titanium alloys in other industries.

To machine a lot of titanium alloy parts, forgings are used. Such forgings have been made from titanium ore through a number of time-consuming extraction, electron beam or vacuum melting, and forging phases. Most forgings are machined away to swarf in the final phases of component production; in certain cases, up to 95% of a pricey titanium alloy forging is removed during this process and discarded as a low-value waste item. The ferrotitanium industry buys a sizable amount of this titanium scrap at low cost and melts it to create additives for the steelmaking sector. In this scenario, there will likely be an ever-increasing source of titanium scrap and swarf accounting for about 100,000 tonnes per year in the following ten years.

If properly cleaned, sized, and graded, loose titanium alloy machining swarf may be of greater quality than the majority of commercially available titanium alloy powders and, since it is significantly less expensive, powder metallurgy operations could use it as a feedstock[66].

That is not the only thing. Approximately 18.7% of the materials used by aircraft manufacturers are composite materials<sup>10</sup>, and this percentage is expected to rise in the next years. Marine, pipes and tanks, wind energy, construction, and other industries also employ composites, increasing the amount of waste created. Thermoset resin is the most extensively used composite, and it predominantly consists of epoxy resin thus, the recyclability of such epoxy-based thermoset composites is of utmost relevance. The linked problem is that these materials are cross-linking, become rigid upon heating and cannot be remolded thus, recycling and a sustainable approach in its trash management are becoming more and more essential[67].

The use of environmentally friendly construction materials is encouraged to protect the planet. One of the requirements for an environmentally friendly building material is the capacity to reduce CO<sub>2</sub> emissions during its production. Moreover, due to resources' short supply, the cost of construction materials regularly rises. Consequently, there is a constant desire to search for new green construction materials.

Bamboo, for example, is seen as one of the new developing materials with significant economic potential, used as structural member in short-span footbridge, low-rise houses, long span roof, and construction platforms[68].

The most common building material used worldwide is Portland cement concrete, with about 10 billion tons produced annually. With its affordability, durability, and versatility properties, it is used for modern buildings and infrastructures including roads, bridges, tunnels, dams, high-rise buildings, and energy structures. However, the manufacture of Portland cement has negative environmental effects, starting from the release of about 0.8 tons of CO<sub>2</sub> for every ton of cement produced, up to the impacts of quarrying and the consumption of non renewable natural resources. This has led to the search for more environmentally friendly ways to produce high-quality concrete. Recently, newer materials such as geopolymers are used as binding materials replacing Portland cement. Other cement replacement materials are also in use to increase the sustainability, performance and durability of concrete and to offer regional solutions to the growing issue of waste management[69].

Some attempts have been made by the sector in reusing old construction materials as raw materials for creating new parts and in substituting old materials with newer and eco-friendly ones. MSCI identifies a 1.75% weight while S&P does not recognise any materiality. However, to emphasise the efforts done, and to encourage the development of a more efficient management of the used materials, we end up with a 5% weight.

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<sup>10</sup>Composite materials are substances having two or more constituent materials, with properties other than those of their constituents.

**Waste and pollution** as a direct result of increased urbanisation, construction and demolition waste is rising around the world. These materials are the byproducts of the construction of buildings, roads, bridges, and other facilities. Building and civil work operations produce different scrap material, with the entire waste incurred representing around 8% of the total materials employed. This includes insulation, nails, electrical wiring, and rebar, debris, dredging materials, tree stumps, and rubble; materials like steel, concrete, asphalt, asphalt shingles, wood, brick and clay tile as well as lead, asbestos, or other hazardous substances. Nonetheless, trash management issues are still persistent. To prevent the degradation of the natural habitat and the destruction of our priceless resources, effective management of the area is required with reduce, reuse, and recycle strategies[70].

Ambient air pollution is the top environmental health risk factor globally; almost 3.5 million premature deaths occurred worldwide in 2017, due to stroke, ischemic heart disease, chronic obstructive pulmonary disease, lung cancer, lower respiratory infections, and diabetes. The transportation sector is largely responsible; its activities answer for tailpipe emissions, evaporative emissions, resuspension of road dust, and particles from brake and tire wear, releasing particulate matter (PM<sub>2.5</sub>), ozone (O<sub>3</sub>), and nitrogen dioxide (NO<sub>2</sub>). Other significant health effects of the sector include noise and road injuries.

More precisely, the industry is structured into several means of transport with different levels of liability. On-road diesel vehicles use diesel engine, on-road non-diesel vehicles are fueled by gasoline, liquefied petroleum gas (LPG), compressed natural gas (CNG), electricity, and other non-diesel fuels. Non-road mobile sources, like rail transportation, farm machinery, construction machinery and inland shipping, mainly use diesel but also gasoline, LPG, electricity, with rail being its main source of consumption, and other fuels. International shipping, including container and cargo ships, tankers, fishing vessels, ferries, and other service vessels, exploit heavy fuel oil, diesel, and LNG[71]. Air transport whose combustion emissions are increasing air pollution in the form of fine particulate matter (PM<sub>2.5</sub>) and ozone (O<sub>3</sub>), dangerous also because of poor visibility, decreased crop yields, and harm to wildlife and vegetation. The International Civil Aviation Organization<sup>11</sup> predicts that, despite advancements in air traffic control and aircraft technology, emissions from international aviation will continue to rise until 2050.

The scientific community is increasingly interested in air pollution since it is acknowledged as a serious challenge for public health and a major environmental health issue. According to the World Health Organization (WHO), 4.2 million deaths occur annually

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<sup>11</sup>The International Civil Aviation Organization (ICAO) is a specialised agency of the United Nations in charge of developing the principles and the techniques of international air navigation, and promoting the planning and the development of international air transport to guarantee safe and orderly service.

because of ambient air pollution, which has become the fourth-leading cause of death worldwide. Think that 91% of world's population lives in areas where air quality levels are higher than WHO guideline standards. Moreover, in recent years urbanisation has increased dramatically over the world, now reaching a global rate of 55%, causing an excessive amount of garbage from construction and demolition. In this scenario, since it is becoming more and more fundamental to limit any form of environmental contamination, we recognise the sector burden choosing a 25% weight in line with MSCI's 25.76% and S&P's 28.33%.

**Clean-tech and renewables** the aerospace industry will face rising sustainability demands in the next years thus, the adoption of sustainable fuels and innovative materials appears to be directly related to its future. Aerospace companies are developing a number of new technologies and approaches to improve efficiency, such as electronic propulsion, hydrogen-powered aircraft, and cutting-edge electronic guiding systems, while regulatory bodies are raising the standards for eco-friendly efficiency[58].

Moreover, given the rising regulatory compliance which has an impact on the supply chain, particularly in relation to product performance and manufacturability, 77% of aerospace businesses have environmental engagement on their agenda. Delta Airlines, the second largest US airline, recently unveiled a medium to long term project focusing on carbon capture and storage, as well as the usage of sustainable aviation fuels (SAFs) to cut emissions by up to 80%. The company wants to replace at least 10% of its present fossil fuel consumption by 2030. According to the World Economic Forum<sup>12</sup> Report 2020, switching to a carbon neutral aviation is feasible, and SAFs represent the most viable route towards decarbonization in the near future[58].

The use of clean energy in transportation infrastructure benefits from energy efficiency, environmental protection, and policy and technical support, but it also has drawbacks, including uncertain performance, high application costs, and implications for global security. Although its use has seen some success, several key components are still lacking, hampering the spread of clean energy in the industry. Its use can be improved by stimulating the development of clean energy applications and fostering advanced technology research. Moreover, there are still unsolved challenges including industries' struggle to keep up, lack of awareness and raw technology's development[72].

Since transportation has always had an impact on civilizations' growth, considering population growth's pace, modern industrialized nations are needing effective, secure, and

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<sup>12</sup>The World Economic Forum (WEF) is an international non-governmental and lobbying organisation. It works with leaders in politics, business, culture, and other areas to develop agendas for the world, regions, and industries.

cutting-edge transportation systems. With the turn of 21<sup>st</sup> century, the use of clean energy in transportation infrastructure has gained significant attention worldwide, so that the rate of growth in clean energy consumption is rising, making it an essential component of nation's resources.

The industry is making efforts to reduce the environmental impacts of its dangerous activities, trying to improve energy efficiency and embracing SAFs. A renewable energy-based economic development model could emerge in the future and the contribute of the sector is even more fundamental. We choose a 25% weight by averaging MSCI's 46.72% and S&P's 0%.

### 3.1.4. Consumer Discretionary

Companies in the consumer discretionary sector sell non-essential products and services but desirable if one client could afford them. These businesses are typically more susceptible to the economic cycle since, in times of crisis, customers are more inclined to reduce or even delay discretionary purchases. Starting from household goods like housewares, appliances, utensils and furnishings, they also include automobiles manufacturing, leisure and luxury products, footwear and textiles. They finally provide retailing and consumer services such as restaurants, hotels and casinos.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** by 2050, on the planet there will be approximately 9 billion people, and as a result of this growth and the desire for better quality of life, a larger percentage of the population is supposed to be mobile. Thus, sustainable mobility becomes crucial and, as it is written in *Mobility 2030: Meeting the challenges to sustainability*<sup>13</sup>, it is defined as "The ability to meet society's desires and needs to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future." Nowadays, sustainable mobility is a key objective for the automobile industry, although it presents certain challenging problems. Making cars more efficient or altering the fuel type used are the two strategies to reduce emissions. Along with the CO<sub>2</sub> released when driving, an automobile also emits during its manufacture and disposal; in particular, these are less environmentally friendly for electric vehicles than for those with internal combustion engines. Moreover, the amounts of CO<sub>2</sub> emissions generated by electric vehicles differ according to the method used to generate electricity. However, it is clear that electric cars are more environmentally friendly than cars that use gasoline or other petroleum-derived fuels. Since the amount of electricity generated from renewable sources is predicted to increase, electric vehicles should be even less damaging to the environment especially when taking into consideration the initiatives taken by the EU to develop more environmentally friendly batteries.

In July 2021, the European Commission announced a plan to reduce emissions from cars and vans by 15% starting in 2025; this decrease is followed by another one that seeks to attain zero emissions by 2035 by cutting vehicle emissions by 55% and van emissions by 50%, by 2030.

Today, GHG emissions linked to the textile sector are enormous. According to the IEA,

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<sup>13</sup>The Sustainable Mobility project of the World Business Council for Sustainable Development is concluded in *Mobility 2030*. The report offers an overview of world road transportation that takes into account the movement of people, products, and services. It outlines seven goals for sustainable mobility and creates a set of metrics to evaluate how well each alternative is working.

the textile industry emits more than the shipping and aviation combined, primarily as a result of the production of plastic-based yarns. To be precised, fashion's environmental impact is caused by upstream supply chain activities such as material manufacturing, preparation, and processing to a degree of 70% to 90%. One of the most important crops in the world, cotton, for instance, contributes greatly to greenhouse gas emissions, some of which may be prevented or reduced. Coherently, in December 2021, Better Cotton Initiative<sup>14</sup> unveiled the ambitious 2030 strategy and one of five targets. Alan McClay, Better Cotton's CEO, announced "Alongside our 2030 Strategy, we are proud to launch our first ever Climate Change Mitigation Target. By 2030, we aim to reduce greenhouse gas emissions per tonne of Better Cotton produced by 50%."

Nowadays, with the shared objective of lowering carbon emissions inside their value chains and across the fashion industry, About you, Yoox Net-a-porter, and Zalando have teamed up. The three e-tailers are introducing an online learning tool to assist their brand partners in establishing sensible and scientifically-based climate objectives for reducing their GHG emissions. The program, which will be launched in fall 2022 and utilized in 2023, fits into the many pathways established in line with the Science-based Targets Initiative<sup>15</sup> for climate protection. Geoffroy Lefebvre, CEO at Yoox Net-a-porter, said "Our commitment to climate action can only be realised through innovative partnership. This next step prioritises investing in brand partners at different stages in their climate journeys, supporting them to set their science-based targets. By collaborating with ABOUT YOU and Zalando, together we can drive a more consistent approach in our efforts towards reducing the emissions of luxury and fashion,". While David Schneider, Co-CEO at Zalando, added "Decarbonizing supply chains in partnership with suppliers, brands, logistics, packaging partners and now also our competitors is a powerful lever for driving meaningful change in the fashion industry. We aim for 90% of our partners (by emissions) to set science-based targets by 2025, and the new learning platform is a key initiative towards realising this ambitious goal."

Hotels, restaurants and retail stores are all examples of buildings; the energy consumption of these structures accounts for a sizeable portion of the annual worldwide CO<sub>2</sub> emissions.

Consumer Discretionary industry-related emissions are linked with a series of non-essential goods and services that go from the utilization of cars and the production of clothes, to the

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<sup>14</sup>The Better Cotton Initiative (BCI) is a non-profit, multi-stakeholder governance organisation that supports higher standards for cotton growing and practices in 21 countries.

<sup>15</sup>In 2015, the Carbon Disclosure Project (CDP), the United Nations Global Compact (UNGC), the World Resources Institute (WRI) and the World Wide Fund for Nature (WWF) have joined forces to launch the Science Based Targets initiative. Science-based Targets give businesses a well-defined roadmap for cutting GHG emissions, preventing the worst effects of climate change and securing future corporate expansion.

refrigerator activity in a restaurant, and light and gas needed by hotels facilities. Given the urgency of finding a solution to this problem, considering the industry responsible for a considerable portion of daily emissions, we decide to resolve a weight in the middle between S&P and MSCI evaluations. Precisely, we want to lower the MSCI's review by a few percentage points and give a bigger contribute than the one of S&P, resolving a 30%.

**Water** water is largely used by the worldwide automotive industry for a number of production processes. Automotive World<sup>16</sup> stated that more than 39,000 gallons of water are used in the fabrication of a car, depending on whether tire production is included. Surface treatment and coating, paint booths, washing, rinsing, piping, cooling, air conditioning systems, and boilers are among the primary uses of water in the car manufacturing sector. Moreover, wastewater from the auto industry may contain metals, lubricants, and greases, as well as dangerous compounds from leftover paint that, getting into the main water system, may endanger human health and the environment.

The environmental impact of the textile sector is enormous: it entails intensive water use as well as significant chemical use. Large amounts of water are exploited in the creation and disposal of clothing, which also leaves fiber and chemical residue in water sources. About 93 cubic meters of water, or 37 million Olympic-sized swimming pools, are consumed annually for textile manufacturing. Just think to a cotton T-shirt production: it requires 2,700 liters of water, while chemical dyeing, bleaching, and other fabric treatments are responsible for 20% of industrial water pollution worldwide.

Although it's frequently neglected when talking about water conservation, the hospitality sector is a significant resource consumer. Given how many sheets, tablecloths, uniforms, and towels are used in hotels every hour, the constant employment of washers and dryers is reasonable. For what concerns the amount of resource used, just think that daily millions of gallons of water are utilized only to wash towels. In a restaurant, instead, water is needed almost exclusively for cooking, dish-washing, and cleaning. The equipment and procedures used in kitchens account for the majority of the water while, the second greatest resource user, behind kitchens, is the restroom.

Consumer Discretionary industry owns a number of services that require enormous quantity of water for countless daily activities. Given the clear exploitation of the resource by e.g., the automobile industry, the clothing manufacture and the hospitality sector, we completely agree with S&P assessment and we resolve a 20% weight. In fact, in light on the above considerations, we believe that MSCI's evaluation, which gives to Water a

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<sup>16</sup>Automotive world is a combination of exhibitions conferences covering important topics in the automotive industry such as automotive electronics, connected car, autonomous driving, EV/HV/FCV, lightweight, processing technology and MaaS.

8.15% weight, is extremely reductive.

**Land use and biodiversity** soil quality is significantly reduced as a result of cotton farming. Although cotton agriculture has occupied the same amount of land globally over the past 70 years, cotton production has depleted and damaged the soil in many locations. Traditional methods of cotton growing entail using a lot of fertilizers and insecticides which endanger the health of biodiversity, as well as the quality of soil and water. Rivers, lakes, wetlands, and underground aquifers are contaminated by the runoff of pesticides, fertilizers, and minerals. Both their immediate toxicity and their long-term accumulation have an impact on biodiversity. Additionally, the extensive use of pesticides poses health issues for agricultural workers and the surrounding communities. As opposed to conventional cotton, bio cotton is grown organically. Crop rotation, a technique used in organic farming, maintains the health of the soil, enabling plants to develop more robustly and completely without the need of pesticides.

Biodiversity is everywhere and its byproducts can be found even inside hotels and restaurants; e.g., just consider the food, the wood used to make furniture, and the cosmetics in a spa.

In light of the previous considerations, we decide to associate to Land use and biodiversity key factor a positive weight, even if little. Differently from MSCI agency, which ignores its significance, we agree to lower S&P's contribution, resolving a 10%.

**Raw materials sourcing** a significant portion of the environmental effect of the textile and clothing business is due to the manufacturing of raw materials, including cultivating crops for natural fibers. Because its extensive land, water, fertilizer and pesticide requirements, cotton is viewed as being particularly troublesome. Major ecosystems including the Aral Sea in Central Asia, the Indus Delta in Pakistan, and the Murray Darling River in Australia have suffered significantly as a result of water redirection and pollution from cotton production. Since bio cotton uses less water and emits less pollutants than conventional one, the detrimental effects on the environment may be considerably reduced. The 2017 Pulse of the Fashion Industry report<sup>17</sup> found that natural fibers have the highest environmental impact, with silk having a particularly negative impact on the depletion of natural resources and global warming, cotton contributing excessively to water scarcity, and wool to GHG emissions. However, the industry is also experimenting with less popular natural fibers that need less water, fertilizer, and pesticides, like hemp, flax, linen, and nettle.

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<sup>17</sup>In 2017, the Sustainable Apparel Coalition (SAC), the Boston Consulting Group (BCG), and the Global Fashion Agenda partnered to produce the Pulse Report, a qualitative and quantitative analysis of the sustainability performance of the global fashion industry.

Inditex, one of the most famous businesses in Spain and the entire globe, houses the following brands today: Zara, Massimo Dutti, Pull&Bear, Bershka, Stradivarius, Oysho and Zara Home. On July 16, 2019, the Inditex group, which is the third-largest clothing manufacturer in the world by Forbes, announced the sustainability commitment. By 2025, all of the cotton, linen, and polyester used in clothes will be more environmentally friendly, organic, or recycled. Currently, 90% of all raw materials utilized by Inditex brands are made from these three fabrics[73]. As it was declared by Pablo Isla, Inditex's chairman and CEO "Sustainability is a never-ending task in which everyone here at Inditex is involved and in which we are successfully engaging all of our suppliers,".

Although some efforts have already been made to promote environmentally friendly farming, e.g., organic cotton is a more sustainable alternative to cotton, there is still a long way to go. Because of this, differently from S&P agency, we want to give to Raw materials sourcing in the Consumer Discretionary industry a significant weight. By lowering MSCI's contribution, we end up resolving a 10%.

**Waste and pollution** among consumer sectors, the fashion industry is the one that wastes the most. Because of the introduction of fast fashion, which consists of stylish and inexpensive clothing made by international fashion firms, clothes has changed from a durable good to a daily buy. In particular, fast fashion uses a lot of natural resources to manufacture cheap clothing, created by cheap labour, which are worn by consumers for a short time before being discarded. As a result, the industry generates enormous amounts of waste; according to recent analysis, every year \$400 billion worth of clothing is wasted and the average Australian purchases 27kg of new textiles, of which 23kg are disposed of in landfills. Moreover, the fashion industry makes up one-fifth of the 300 million tons of plastic manufactured annually worldwide. Cotton has been replaced by polyester, which is a pervasive type of plastic made from petroleum, as the primary raw material for textile production. Microplastic contamination, which is particularly damaging to marine life, is primarily caused by clothing made of polyester and other synthetic fibers. Man made fibers, which take decades to decompose, are found in two thirds of waste materials and clothes made of polymer decompose in landfills over a 200-year period[74]. The amount of waste recycled is really little. In the end, 87% of the entire fiber input utilized in clothes is burned or dumped in landfills. As a result of the growing concern for environmental and social sustainability, the textile industry, which leaves a significant environmental footprint from cultivation, to textile production, to post-consumer waste disposal, is facing significant challenges. Nowadays, fashion companies have come under fire for actions like dumping mountains of unwanted clothing in Southern landfills and destroying unsold merchandise.

Significant volumes of food waste are produced by the global food service industry. For instance, in the EU countries, every year the sector generates about 11 million tons of food wastes. Inadequate storage, cooking leftovers such as careless handling of food and excessive preparation, surplus servings and residues on plates are among the most common causes of waste.

For what concerns the hospitality sector, instead, according to estimates, a typical hotel guest can produce up to 1 kg of waste per day, which translates to millions of tons of rubbish produced per year globally.

In recent decades, as a result of high population growth rates, increasing global incomes and rising living standards, the manufacture and consumption of non-essential goods have steadily increased, together with the production of waste. Because of the urgency to take action, making a compromising between reference agencies' evaluations, we decide to resolve a 20% weight.

**Clean-tech and renewables** the effects of vehicle emission on environment and human health, both direct and indirect, show that the present transportation systems are unsustainable for environment, human health and economy. As a result of rising GHG emissions and local air pollution, the demand for electrification of mobility is rising quickly. In fact, to provide more environmentally friendly and sustainable mobility options which can help in lowering air pollution, greenhouse gas emissions, and health hazards, electric mobility is a potential technology that can transform the world's transportation sector. It appears that businesses, governments, and consumers are all supporting this technology more and more. However, it must be said that the environmental benefits of electric vehicles depend on a number of variables, including the energy pathway, energy generation profile, type of air pollutants and GHGs, and type of electric vehicles. For instance, a key feature of such vehicles is that the source of transportation-related air pollution is moved from the road to electricity generating plants. The potential for electric vehicles to reduce air pollution and greenhouse gas emissions may not be completely realised if the electricity is produced from non-renewable sources such as coal or oil[75]. The provision of clean carbon-free sources for the production of electricity will be one of the biggest issues of the future. While this is just a minor issue in nations like Norway, Austria, or Sweden which heavily rely on renewable energy sources, it may provide a significant obstacle most other nations, like China, Turkey, and Greece, which mostly generate electricity from coal. Currently, in many countries there is almost no reduction in GHG emissions caused by electric vehicles due to the high CO<sub>2</sub> emissions per kWh of electricity generated. Future legislative plans should guarantee that electric vehicles have strong environmental advantages. Therefore, it must be ensured that the electricity used in those vehicles is either certified green elec-

tricity or that all electricity generated additionally comes from renewable sources. Especially because of their high costs and lack of adequate infrastructure, the use of those vehicles is still extremely restricted. However, just approximately 0.1% of all vehicles are electric vehicles. High purchase costs, a short driving range, a longer charging time than for conventional vehicles, and a lack of adequate charging infrastructure are the main causes of the slow uptake of electric vehicles. However, over the past ten years, major advancements, particularly in the area of batteries, have been made in order to speed up the commercial adoption of such vehicles. According to the Paris Declaration on Electromobility and Climate Change and Call to Action, the target is to have more than one hundred million electric vehicles worldwide by 2030[76].

The fashion industry offers enormous potential for innovation at every stage to support the growth of a green economy. With a market value of over \$1.5 trillion and over 75 million workers, the fashion industry is a vital component of our financial system. Over the last ten years, it has experienced exponential growth and garment output has doubled. 2022, for instance, saw a 25% increase in clothing purchases over 2019. Because of their complexity and interconnection, fashion supply chains need to move from the "take, make, waste" paradigm to a more sustainable strategy. In order to bridge the gap between fast fashion and sustainability, fast fashion firms must launch initiatives including, e.g., conserving water, cutting GHG emissions, reusing materials. The Global Fashion Agenda<sup>18</sup> 2020 featured 94 companies, which together accounted for 12.5% of the global fashion market. Each firm had a number of objectives, such as improving systems, enhancing water efficiency and generating sustainable fibers. Numerous companies also created their own programs. By 2024, Adidas has pledged to only use recycled plastic. H&M, instead, wants to be entirely recyclable and eco-friendly by 2030. PVH, the parent company of Tommy Hilfiger and Ralph Lauren, intends to employ raw materials derived from sustainable sources for cotton and viscose, by 2025 and 2030, respectively. Additionally, France, home to numerous well known fashion brands, during its G7 leadership, led the charge to change the fashion sector into one that is more ecologically friendly[77].

Nowadays the hospitality sector is putting a lot of emphasis on sustainability because it is crucial to the growth of the industry. The rapid expansion of the hotel business significantly accelerates environmental degradation: these structures, in fact, require a lot of energy and water for heating, cooling, and lighting. Recently, in an effort to promote environmental conservation and raise guest satisfaction, certain hotels have incorporated green initiatives. According to a TripAdvisor poll, around 62% of travelers think about

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<sup>18</sup>The Global Fashion Agenda (GFA) supports industry cooperation on sustainability in the fashion industry.

environmental issues before booking a hotel room. Hotels should adopt sustainable practices for two reasons: first, adoption increases resource efficiency and reduces energy and water use; second, this serves as a marketing tool to draw in clients interested in sustainability. Leading worldwide hotel chains emphasise sustainability more and more, and include it into their business strategies. For instance, the Intercontinental Hotel Group<sup>19</sup> reports "our policies and standards set out our position on social, environmental and ethical issues. We embrace our responsibility to focus on ensuring that the growth of our business contributes towards the objectives of the UN Sustainable Development Goals and we believe that by using our power of scale and global reach, we can make the biggest contribution to seven of the goals". Marriott International<sup>20</sup>, instead, highlighted "our sustainability strategy supports business growth and reaches beyond the doors of our hotels to preserve and protect our planet's natural resources"[78].

Because of the numerous opportunities for the Consumer Discretionary sector to improve its environmental footprint, we want to associate to the Clean-tech and renewables key factor a significant weight. By averaging the two reference agencies' contributions, we end up resolving a 10%.

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<sup>19</sup>InterContinental Hotels Group PLC (IHG), also known as IHG Hotels Resorts, is a British multinational hospitality company.

<sup>20</sup>Marriott International, Inc. is an American multinational company that operates, franchises, and licenses lodging including hotel, residential, and timeshare properties.

### 3.1.5. Consumer Staples

Consumer staples provides everyday necessities and services regularly needed for healthy survival. As such, consumer staples are impervious to business cycle and the consistency of consumers demand for its products is the main factor driving the sector development. Its set is very broad; food is one of its main characters including distribution and retailing, agricultural production and packaged food processing. Along with food, the sector includes producers of any alcoholic and non-alcoholic beverages, personal hygiene, household products and tobacco manufacturers. Hypermarkets, super centres and drug stores are also considered.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** the IPCC<sup>21</sup> Special Report on Climate Change and Land warns that about 21-37% of global GHG emissions are generated by the food system. These are the potentially dangerous byproducts of farming, land usage, storage, transportation, packaging, processing, retailing, and consumption. More precisely, emissions come from agricultural and livestock production, land usage including deforestation and peatland, application of nitrogen fertilizers, exploitation of agricultural machines burning fossil fuels, and supply chain activities[79]. Failure to intervene will do the real damage likely increasing emissions by about 30–40% by 2050.

The consequences of warming horribly extend also to plant biology. Because of increasing CO<sub>2</sub> into the atmosphere, the concentrations of protein and minerals in a wide range of plant-based food sources decrease with a significant global effects on human and animal nutrition. According to recent research from Harvard T.H. Chan School of Public Health, the populations of 18 nations may lose more than 5% of their dietary protein by 2050 as a result of a loss in the nutritional content of rice, wheat, and other staple crops[80].

In recent years, agricultural production systems are gaining increasing attention for its global warming potential. Among non-food agricultural crops, grow tobacco for cigarettes production is the most profitable. Being the raw material of tobacco commodities, tobacco is a very important industrial farming; in Brazil it is one of the main agricultural plantations. Considering that tobacco production could rise by 10% by 2030, studying its impacts on the environment is crucial to lowering its footprint. Most of the release lies in the production of tobacco leaves with the application of nitrogen fertilizer[81]. Tobacco manufacturing industries make widely use of steam generator systems mainly fed through fossil fuels. Due to natural gas residues, electric energy consumption, and consumption of diesel, boilers' operation represents a significant contribution to global warming through

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<sup>21</sup>The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body meant for assessing climate change.

its air emissions. Additionally, tobacco smoke emissions from cigarettes alone contribute significant amounts of toxic hazardous substances into the environment. In a single year, direct emissions from smoking contribute tens of thousands of tonnes of known human carcinogens, toxins and greenhouse gases. Carbon dioxide, methane and nitrogen oxides are the three main greenhouse gases released in significant quantities through tobacco smoke.

ESG rating reference agencies agree in recognising the substantiality of the sector contribution to worldwide air emissions weighing it a quarter. By this line of reasoning, also considering the 45% contribute we assign to the energy sector, which is the main emissions provider, we end up recognising a 25% weight.

**Water** water management is a crucial requirement for the supply chain of food and beverage industry. The sector is one of the most water intensive since water is used as a raw material both for growth and production of agricultural products, as well as manufacturing of consumer goods. Comparing all industries worldwide, agriculture, which serves as its primary provider, utilizes the most water, accounting for 70-90% of the world's freshwater supplies[82]. Due to the expansion in output in the sector and the global trade of agricultural goods, countries with limited water resources are forced to boost their food production while also experiencing water stress. Consider that global water use has increased by roughly 6 times over the previous 100 years to support rising food demand and rising standards of living. In this way numerous important freshwater aquifers across the world are being exploited irresponsibly, and some are predicted to reach environmentally dangerous drawdown limits within 21<sup>st</sup> century.

Running dry poses a serious danger to global food security since aquifer depletion frequently occurs in key crop-producing regions. In this scenario, future aquifer recharge is prevented as groundwater levels decline, pumping costs rise, saline water invades and water quality declines, natural springs and dependent river systems dry up, and land permanently sinks. Eventually, overused aquifers can no longer be exploited and pumping must stop. An estimated 90% of the world's population lives in nations that import more than four fifths of their staple food crops from places that irrigate crops by depleting groundwater[83].

In this awful perspective, there needs to address water as a key issue in the food and beverage business to have a favorable impact on this industry's financial performance.

It is not just a matter of shortage: SDGs 6 and 14 emphasise responsible water use addressing its contamination by industrial purpose. Nevertheless, ecosystems are threatened since the agricultural activities: these processes use fertilizers and pesticides deteriorating the quality of the water. Large amounts of potable water are required for food indus-

try material processing, and its vast majority is released as dangerous effluent that is microbially contaminated with strong organic compounds, nutrients like nitrogen and phosphorus, fat, and other substances.

Moreover, the production of soft drinks and other beverages requires a significant quantity of fresh water resulting in waste water generation. Washing bottles, cleaning machinery and equipment, production line losses, filtering wastes, and raw material wastes are the main causes of water contamination via uncontrolled infiltration or voluntary discharge making the water inappropriate for reuse.

By 2050, more than half of the world's population is expected to reside in locations with severe water shortages as a result of rising food demand, climate change, and intensive industrialization. The application of cutting-edge technology interventions has great potential on freshwater resources management. Particularly, the revolution of Industry 4.0 and Agriculture may present fresh chances for the digitalization of water management systems. The management and decrease of freshwater usage in agricultural activities, for instance, is efficiently supported by wireless sensors for measuring soil moisture and precision agriculture techniques. Additionally, expanded IoT<sup>22</sup> networks and data platforms enable water monitoring during production processes, enhancing the effectiveness of industrial water management. The move to smart water management in agricultural, industrial, and urban areas could also be aided by artificial intelligence algorithms and data analytics[84].

We are aware of the delicacy and magnitude of this sector water issue which results its greatest exploiter. At the same time, we live in the age of circular economy and digitalization where technology could help in mitigating these effects reducing freshwater usage and deterioration in agricultural settings. Following our reference agencies guide, we conclude a 25% weight both stressing the danger of water scarcity and the beneficial impact of sensible and sustainable water management practices.

**Land use and biodiversity** the majority of the planet's land surface has been transformed by man's land use.

Although land use patterns differ greatly around the world, their ultimate goal is typically the same: the acquisition of natural resources for urgent human needs, frequently at the expense of the deterioration of environmental conditions. In this way human activities, including the practice of subsistence farming and the intensification of agricultural land productivity, are fundamentally altering the world's landscapes. Over the past thousand

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<sup>22</sup>IoT is the acronym for Internet of Things. It deals with physical objects with sensors, processing power, software, and other technologies that link to and share data with other systems and devices over the internet or other communication networks.

years, people have changed over 43 million km<sup>2</sup> accounting for 75% of the Earth's land surface finding a 0.8 million km<sup>2</sup> net global loss of forest area with about 1 million km<sup>2</sup> increase for agricultural needs. In other words, since 1960 an area as big as twice Germany has changed annually on average[85].

Additionally, humans have changed the hydrological cycle to produce fresh water for agriculture use but also domestic and industry needs. Inputs of anthropogenic nutrients from fertilizers and air pollutants to the biosphere increasingly outpace those from natural sources, having a significant impact on freshwater and coastal ecosystems as well as water quality.

Tropical deforestation in the Brazilian Amazon for the production of beef, sugar cane, and soybeans, in Southeast Asia for the production of oil palm and in Nigeria and Cameroon for the production of cocoa is only an example.

By destroying, altering, and fragmenting habitats, degrading soil and water, and overusing native species, land use has also contributed to a fall in biodiversity. Food systems are the source of about 60% of the loss of terrestrial biodiversity worldwide and 33% of fish stocks overfishing. Commercial fishing, together with other stresses such as coastal eutrophication<sup>23</sup>, deoxygenation, ocean warming, and ocean acidification, become a significant problem for marine ecosystems. Recent research revealed that the use of plastics as packaging is a significant factor in the plight of aquatic life in lakes, rivers, and seas[86]. To face this real problem, the United Nations Convention on Biological Diversity acknowledged that addressing food production and consumption as significant underlying drivers of biodiversity loss is vital to realise its 2050 vision of "living in harmony with nature". According to CBD Aichi Target 4<sup>24</sup>, mainstreaming depends on a shift toward sustainable production and use[87].

Land use change is crucial for addressing global sustainability issues including climate change, biodiversity loss, and food security since it has a significant impact on carbon sources and sinks, causes habitat loss, and supports food production. Land use has become a major topic in many international policy talks because of its capacity to reduce greenhouse gas emissions, particularly those related to agriculture and forests, which have been accepted as being essential to attaining the Paris Agreement's climate targets. Biological worldwide resources are essential to the progress of humanity economy and society. As a result, there is a growing understanding that biological diversity is a valuable

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<sup>23</sup>Eutrophication is the process of enrichment of a body of water by nitrogen and phosphorus nutrients which causes a general degradation of the marine ecosystems. Agriculture has been identified as a key source of nutrient input.

<sup>24</sup>In an effort to save and maintain biodiversity, in October 2010 CBD established the "Strategic Plan for Biodiversity 2011-2020" introducing the 20 Aichi Biodiversity Targets aiming at protecting and conserving natural ecosystems. Aichi refers to the Japanese prefecture where the conference held.

resource for both the present and the future. Nonetheless, the threat to species and ecosystems has never been greater than it is right now and the pace of species extinction brought on by human activity is alarmingly high. The majority of Aichi goals were expected to be met by the end of 2020, however only six can be deemed "partially attained" and none of them can be called finished. Recognising the materiality of these issues, we resolve a 10% for Land use and biodiversity assuming a middle position between S&P (22.5%) and MSCI (2.92%) assessments.

**Raw materials sourcing** due to the increase in global population, there is a greater necessity for food production, which in turn leads to a major need for food packaging materials. Packaging allows for food preservation facilitating its storing, handling and transportation. However, food packaging raises environmental concerns because of its high manufacturing volume, frequently brief shelf life, and issues with waste management and littering.

Reduction, reuse, recycling, but also redesign could lessen the environmental impact of food packing supporting circular economy, even though it might be difficult to recycle used food packaging into new food packaging, especially because of safety concerns. Substances may intentionally or unintentionally come into contact with food; chemicals knowingly introduced often have a technical effect and a performance property. Contrarily, unintentionally introduced compounds are chemicals that are either unidentified impurities or reaction byproducts present in the provided components. In this way, recycled products increase potential sources of contamination and frequently raise quantities and concentrations of chemicals that can leach from the packaging into foods, posing a threat to human health[88].

More than 350 million tons of plastics are produced annually worldwide. One of the most common uses of plastics is in packaging, especially for food. Plastic, in fact, is the most common type of food packaging, followed by paper and board. To limit the production of plastic waste, the European Commission set an ambitious target of 55% of plastic packaging being recycled in 2025 and all plastics being recyclable or reused in 2030. Given that recycling operations typically have lower life cycle impacts than the manufacturing of the virgin materials, several researches conclude that recycling is essential for enhancing environmental sustainability. However, only 14% of all plastic is collected and recycled, and the recycled plastics are typically downcycled into uses with lower value without going through another recycling process[89].

In this context, scientists are looking into the possibilities of employing natural, biodegradable, and renewable packaging materials for food packaging applications to contrast the issue of environmental pollution. Commitment includes investing in bio cutting-edge

packaging materials produced from natural sources such as proteins, lipid derivatives and carbohydrates. Alginates<sup>25</sup> are an example of tasteless and odorless biomaterials with good film-forming properties, low permeability to oxygen and vapors, flexibility, good tensile strength, flexibility, tear resistance, stiffness, water solubility and gloss[90]. Food producers and retailers, reacting to consumer demands for more environmentally friendly solutions, are introducing packaging techniques which use more plant-based materials exploiting natural substances like sugar cane and wood. These are only two examples of renewable and vegetal origin resources which, growing, absorb CO<sub>2</sub> from the atmosphere. Another example of environmentally friendly materials are bioplastics which are plastics made from renewable resources, biodegradable or compostable materials.

Most of food waste generated by commercial or household activities is collected as general waste and it is either burned or dumped while, due to its high organic content, nutrients, and minerals, it has the potential to generate animal feed. Recycling food waste has potential economic advantages leading to a circular economy for the production, consumption, and recycling of garbage. For example, it might be used to generate liquid fertilizer and poultry feed of which is of the same quality as when it was found at the market[91]. Moreover, exploiting less food-competing foodstuffs in animal diets is a potential method for lowering food-feed competition and minimising the environmental effect of livestock. In this way, based on their nutritional characteristics and composition, in some cases identical to fresh forage and grasses, the byproducts generated by the processing of fresh-cut leafy salad crops are an appropriate feed source for agricultural animals, including ruminants[92].

Cigarettes include a number of hazardous compounds as well as plastic fibers which are not biodegradable; they take 3-5 years to decompose. Due to the increasing amount of cigarette waste dumped into the ground, the risk of soil contamination and environmental toxicity increase each year. Researchers found that recycling cigarettes in concrete could be a hit reducing the global littering problem. Moreover, companies could employ this mixture for a variety of things including patios, sidewalks, driveways, and cinderblocks[93].

Due to declining trends and rising costs of natural resources, recent decades have seen a rise in the demand for sustainable methods and more effective exploitation. An increase in recycling has been an important result, so that more things that previously would have been thrown away as garbage are now being reused. With the widespread of the economic cycle, the economy is improved, bringing a number of advantages, including lots of job prospects, cheaper raw material storage costs, less stress and negative environ-

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<sup>25</sup>Alginates are natural polymers extracted from the cell walls of brown algae; they can also be produced by some bacteria.

mental effects, and a decrease in price volatility. Considering the food industry, benefits of recycling exist numerous and disparate thereby leading to circular economy of food production, consumption and waste recycling. In this context, SDG goals include "by 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse". However, increasing awareness among citizens is still important: according to a survey in China on 1050 restaurant owners, only 37.33% of respondents has a high recycling food waste awareness, compared to 62.67% who have a low knowledge[94]. For all these reasons, we end up with a 10% weight assuming a mid-term evaluation compared to the 19.81% of MSCI and the 0% of S&P.

**Waste and pollution** the projected growth of the world population will dramatically increase the burden on natural resources to supply food. In a context of finite resources and climate change, a multidimensional and coordinated global plan is needed to achieve food security without further damaging the quality and variety of ecosystems.

In consumer staples industry the amount of produced waste is an important challenge. Particularly, food waste is a serious issue which requires a combination of technology-based solutions, direct public interventions and incentive structures to change consumer disposal behaviour. The creation of appropriate measures to reduce Food Loss and Waste (FLW) is one of the most crucial concerns in view of sustainable development. FLW issue has been one of the most significant global challenges since the late 2000s, when countries and international organisations started putting policies into place to cut it. SDGs include a target on food waste aiming "by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses". Moving in this direction, in 2015 France introduced a law prohibiting retailers from discarding unsold and unused food; supermarkets were compelled to donate food or give it to charities instead of wasting it.

Every year, a third of all food produced for human use, with a market value of 1 trillion dollars, is lost or wasted throughout the whole supply chain. Large amounts of food are lost during the early phases of production including harvesting, storing, and transport. It might happen that it is wasted not matching the aesthetic requirements of businesses and package sizes. Moreover, food quality preservation during transport can be challenging as it requires special care in packaging and keeping it at the right temperature for storage. Because of this, in nations with inadequate roads and transportation options, food is harmed and by the time it gets to the market, it can no longer be sold. In this way, FLW is posing a severe risk to economy, poverty, food security, environment and natural resources. It is estimated that million tons of food waste in industrialized nations represent almost the 97% of total net production in Sub-Saharan African countries.

FLW is sufficient to address the worldwide concern of meeting the growth in food demand, which may reach around 150–170% of actual demand by 2050 and alleviate malnutrition in one eighth of the world's population.

Additionally, when food waste is disposed in landfills, a sizeable amount gets transformed into greenhouse gases, primarily methane, which has a global warming potential 25 times higher than carbon dioxide[95].

Tobacco industry produces a great deal of industrial and agricultural waste whose disposal represents a significant social, economic, and environmental concern for growers. The annual global consumption of cigarettes is estimated to be around 6 trillion, and the total tobacco production in 2019 was around 6.68 million tonnes. Such a large-scale production generates trillions of chemical waste each year, including nicotine, which had a significant impact on the environment[96]. In this scenario, the industry is facing a severe challenge aiming to recycling and using trash for sustainable development of tobacco processing. The treatment of tobacco waste as trash or its direct incineration harms the environment and depletes resources. Contrarily, recycling this waste will have significant positive economic, social, and environmental effects raising the economic value of biological waste and lowering pollution. High levels of waste biomass are one of tobacco growing byproducts. It is extremely promising to convert biomass waste into high value-added and high-performance carbon materials to maximize resource use and generate sustainable energy. Biochemical and thermochemical processes can transform biomass into fuels and chemicals. In the last ten years, the academic community has paid substantially more attention to the thermochemical process of biomass pyrolysis<sup>64</sup>. Studies are currently concentrated on elucidating the pyrolysis reaction processes and creating new pyrolysis-based production pathways for transportation fuels[97]. Moreover, researchers found that it is possible to exploit tobacco waste biomass for producing eco-friendly, affordable, and high-performing carbon-based electrode materials for electrochemical energy storage devices[98]. Biomass is not the only substance composing tobacco waste; alkaloids<sup>26</sup>, aromatic compounds, protein fractions, phenolic compounds<sup>27</sup>, and solanesol<sup>28</sup> have all reportedly been found in tobacco waste and scientists are becoming increasingly interested in their extraction[99].

In a world where 1 billion people are undernourished and 1 billion people still go without food, it is all the more unacceptable that a third of all food produced each year ends up

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<sup>26</sup>Alkaloids are a family of simple organic compounds found in nature which contains at least one nitrogen atom. Tobacco alkaloids need to be isolated for pharmacokinetic, pharmacological, and toxicological studies.

<sup>27</sup>Phenolic compounds are natural antioxidant compounds capable of modulating hormone metabolism.

<sup>28</sup>Solanesol is an organic compound used both as food additive and drugs ingredient.

in trash cans because of inefficient collection and transportation methods.

Consider that in Spain, each year, 31kg of food are wasted each person on average. In June the government enacted its first law on the prevention of FLW with the goal of reducing food waste disposal and encouraging better food utilization in order to advance the achievement of SDGs halving food waste. Lack of plans to reduce it is analysed by the sanctioning system.

In a scenario where global food production will likely be constrained by environmental and resource issues, recent attention has been focused on FLW reduction as it could help solving interconnected sustainability issues. Improved harvesting practices, on-farm storage, infrastructure enhancements, and packaging are some of the technical possibilities.

In recent decades worldwide consumption of fossil fuels has enormously increased together with environmental problems including GHG emissions and air deterioration. Moreover, depletion of fossil resources and fluctuation of fossil fuel prices have cast a shadow over the world economy. As traditional fossil fuels are gradually replaced, producing carbon neutral and low-emission fuels from renewable sources such as biomass, is becoming more and more crucial. According to the IEA, by 2035 bioenergy could supply 10% of the world's primary energy and biofuels might replace up to 27% of the world's transportation fuel.

Acknowledging the significance of FLW avoidance as a supplemental approach to the pressing issue of global food security and environmental sustainability, and understanding the crucial nature bioenergy is more and more achieving these years, we end up with a 30% for Waste and pollution performance indicator in line with our reference agencies evaluation.

### 3.1.6. Healthcare

Healthcare covers companies involved in production and marketing of medical tools and supplies but also organisations dealing with healthcare technology delivering services primarily to doctors and hospitals like software, internet-based tools, and IT consulting. It is also about biotechnology, pharmaceuticals and drug production.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** while healthcare services are essential for maintaining and enhancing human well-being, they also have a considerable environmental impact putting human health at risk.

Mainly due to operations like patient transportation or space and water heating, the industry contributes significantly to global emissions of greenhouse gases and air pollutants accounting for 4.4% of greenhouse gases and 3.4% of NO<sub>x</sub>. The burning of fossil fuel is the main cause for ambient air pollution which, in turn, kills an estimated 4.2 million people per year. Through on-site fossil fuel energy burning, medical waste incineration, the purchase of energy derived from fossil fuel sources, and the procurement of items that are manufactured and delivered using fossil fuels, many healthcare institutions contribute to ambient air pollution. Fleets of facility vehicles, as well as staff and patient transportation systems, generate air pollution causing smog and poor air quality harmful to human health[100]. Analysing the sector related carbon footprint, 3% of the its total emissions comes directly from the buildings and vehicles of healthcare providers; instead 8% is created by fossil-fuelled electricity and gas used by medical services together with medical or pharmaceutical products used by healthcare providers[101].

According to estimates, if the global health industry were a nation, it would be the world's fifth largest producer of greenhouse gas emissions. Globally, the industry produces more greenhouse gas emissions than aviation and shipping combined. The entire value chain is impacted by the issue: for instance, surprisingly, the pharmaceutical sector has been discovered to produce a lot more emissions than the automotive industry with an emission intensity about 55% higher[102]. The Norwegian system is one of the highest emissions producers per capita in the world, accounting for 4.3% of the country overall GHG emissions. It needs to be more ambitious and assist in creating the low carbon solutions of the future for the health sector in order to help prevent catastrophic climate change[103]. However, in this awful scenario, health services are significantly behind in recognising their own hazardous greenhouse gas emissions and in taking steps to cut them. The National Health Service (NHS) in the UK, taking on its own responsibilities, is the first national health system in the world to establish a plan for becoming carbon neutral by 2040. Among the measures adopted, it includes the use of innovative low-carbon mate-

rials, socio-technical interventions to optimise the way the NHS uses its buildings and on-site renewable energy and heat generation.

In 2021 the former Dutch minister of housing, spatial planning and environment Jacqueline Cramer, wrote that climate change is the biggest health threat of the 21<sup>st</sup> century and healthcare systems need to significantly reduce their emissions in order to help prevent this from worsening. Following this direction, the Dutch healthcare sector set up in 2018 a Green Deal on sustainable healthcare aiming to reduce the negative impact of this industry. In line with the objectives outlined in the National Climate Agreement<sup>29</sup>, a 49% reduction in carbon emissions by 2030, and attainment of carbon neutrality by 2050, will be achieved by working towards energy-efficient buildings, transportation, and procurement, use of renewable energy, as well as a decrease in the amount of energy used by hospitals and other care institutions.

Though being severely affected by shocks and stressors caused by climate change, the health sector has the potential to cut worldwide GHG emissions significantly. Its facilities can address the growing climate emergency building resilience to extreme weather and long-term stresses, reducing and eventually eliminating all environmental contaminants released by its operations so continuing to protect population health. In fact, climate change exacerbates its negative effects on welfare, which include harm to the heart, lungs, and other essential organs. In line with MSCI and S&P evaluations, we assign a 30% weight since to reduce the carbon footprint of healthcare, rapid action is required. There needs to enable healthcare facilities to be environmentally sustainable by optimizing the use of resources and minimising the release of waste into the environment. Planning and purchasing techniques for mobility can be used by health facilities to reduce air pollution and the associated GHG emissions. A radical revamp of care routes is required to make sure that the only patients who visit or stay in hospitals are those whose healthcare cannot be given securely closer to home. Moreover, future hospitals have a significant opportunity to reduce climate change by adopting measure to improve insulation, heating and lighting.

**Water** during the past few decades, a growing and aging population has led to an increase in the use of human pharmaceuticals together with improvements in healthcare. Although there are numerous social advantages of using pharmaceuticals for curative, preventive, and palliative purposes, the rise in consumption has been accompanied by a parallel global contamination of aquatic environments with pharmaceuticals active substances, their metabolites, and transformation products. Some pharmaceutical contam-

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<sup>29</sup>The National Climate Agreement belongs to the Dutch climate policy. To address climate change, numerous Dutch organisations and companies signed this accord whose main objective is cutting greenhouse gas emissions by 49% from 1990 levels by 2030.

inants mostly enter ecosystems through wastewater discharges and are persistent in the water cycle also with the possibility of entering the food chain. Carbamazepine<sup>30</sup> is known to speed up fish embryonic growth disturbing larval behaviour. Since wastewater treatment is insufficient, cytostatic medicines<sup>31</sup> can be found in surface water, groundwater and drinking water with children and nursing women being at higher risk[104]. This issue cannot be overlooked especially in locations with limited water resources, where wastewater is frequently recycled and occasionally utilized in irrigation without being treated[105]. Most waste in the industry is disposed of in landfills. Due to improper landfill construction or the placement of biohazardous waste, material can escape; moreover, sharps and needles can easily tear the lining. In this way, another possibility of water pollution is during rains: the water logging will cause any toxins in the landfill to leak into the surrounding soil, contaminating surface water, groundwater and drinking water. Even though the landfill is far from any surface water, garbage can still leak into the soil and harm groundwater. Landfills must therefore be carefully built in order to keep garbage in a regulated environment. To stop healthcare waste from damaging them and contaminating land and water around them, they should be lined with particular materials such as geotextiles, polymers, and clay membranes[106].

There is a great need to tackle healthcare pollution: by not taking actions, too many pollutants will be part of wastewater streams. Furthermore, the demand for drug and medical care is predicted to rise due to the expected increase in global population. As a result of climate change, water scarcity will occur more often. Those aspects will eventually result in more freshwater pollution.

This issue is a great threat to human health, and the healthcare industry should take responsible action to protect the environment and guarantee that everyone has access to clean water and sanitation. Therefore, we assign a 20% weight to Water, in contrast with MSCI agency, which recognises a very little 1.32% contribution, and slightly lowering S&P's 26.67%.

**Land use and biodiversity** the comprehensive action plan for sustainable development, also known as Agenda 21<sup>32</sup>, points out that human and animal health are closely related. Human health cannot be viewed in isolation since it is strongly influenced by the environment in which people live. In order for people to be healthy, their settings must be

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<sup>30</sup>Carbamazepine, better known by its brand name Tegretol, is an anticonvulsant drug primarily used to treat epilepsy and neuropathic pain.

<sup>31</sup>Cytostatic drugs are substances widely used in the cancer treatment intervening in cell division with the main role of inhibiting or completely blocking the replication of DNA in the tumour cell and triggering cell death when possible.

<sup>32</sup>Agenda 21 is a document produced by the Earth Summit in Rio de Janeiro, thought as an action plan on sustainable development initially within 21<sup>st</sup> century, as its name suggests.

healthy: recent developments have increased awareness of the connections between society and nature, the significance of environmental health for human health, and the potential negative impacts that biodiversity loss may have on human well-being. The disruption in ecosystem function, brought on by biodiversity loss, makes ecosystems less resilient, more susceptible to shocks and disturbances, and less able to provide humans with the services they require. However, the ecological balance has been upset by man activities leading to a rapid decline in biodiversity and the transfer of diseases from animals to humans. Medicinal plants, being both inventive and effective, offer an exceptional alternative treatment, giving people access to affordable medicine as well as the ability to make money and find work from these resources. Plant products are used in traditional treatment but also as a primary ingredient in the creation of modern medicals. Unexplored flora have great promise as a source of new pharmacologically active compounds, with roughly 25% of life-saving pharmaceutical solutions coming from plants. A notable example is the peptide compounds found in the venom of cone snails, a group of predatory snails with over 500 species living on tropical coral reefs. They have developed into crucial instruments for neurophysiological research and could be invaluable in clinical medicine[107]. In this scenario, the loss of natural wild flora is occurring at an alarming rate as a result of the growing demand for medicinal plants and the expansion of the human population, placing persistent strain on the earth's resources and causing the extinction of some species.

Considering that the sources of many drug products are living organisms including plants, animals and marine, by increasing the protection of biodiversity, thanks to the discover of new biomedical relevant compounds, global health will improve. Moreover, these days, maintaining natural products is a difficult task versus a modernized pharmaceutical industry and modified biodiversity. Even though MSCI does not track down any materiality for Land use and biodiversity in the healthcare industry, we embrace the assessment of S&P assigning a 10% weight to the key factor underlying the strength of the nexus between nature and medicine and the essentiality of the establishment of best practices for the sustainable production of natural products.

**Waste and pollution** healthcare waste is regarded as the second most dangerous waste worldwide, only behind radiation one. Inappropriate handling and disposal of medical waste endangers humans and all other living beings but also the environment contaminating soil, air and water.

Illnesses brought on by improperly disposal of medical waste cause at least 5.2 million deaths each year worldwide. Numerous significant public health hazards have occurred as a result of inadequate waste management in the healthcare industry, over the years. In March 2009, after receiving treatment with previously used syringes obtained through

the black market trade of unregulated medical waste, 240 individuals in the Indian state of Gujarat caught hepatitis B. In Afghanistan, in October 2008, the leftovers from a 1.6 million person polio vaccine program were dumped in the city municipal rubbish, endangering those rummaging through landfills for usable goods with infectious diseases[108]. Healthcare waste contains numerous very specific waste types, both hazardous and non-hazardous, including sharps, human body parts, blood, chemical and pharmaceutical products, and medical gadgets. Most of this waste, about 75-90%, is comparable to home trash so being absolutely non dangerous. Chemical waste is only 3% and contains substances such as laboratory and film developing reagents, expired or unused disinfectants, solvents, and heavy metals. The remaining part mainly concerns pharmaceutical trash but also infectious, pathological and radioactive waste so it requires careful handling.

The principal producers of all of this trash are hospitals, outpatient clinics, laboratories, mortuaries, autopsy centers, blood banks, nursing homes, and other medical facilities.

As a result of poor waste management, these negative and destructive pollutants are continuously released by healthcare services with devastating impacts on human health. Moreover, the handling of this hazardous trash offers substantial threat of disease transmission through the exposure of infectious pathogens, to waste employees, healthcare professionals, patients, and the society at large. Due to the volume of waste produced and the highly contagious nature of some contaminants, processing of medical waste and subsequent recycling have become extremely unstable but truly important.

In December 2019, the SARS-CoV-2 virus was the cause of an acute respiratory illness, known as COVID-19, not yet eradicated. Due to the rapid and devastating spread of the virus around the world, a Public Health Emergency of International Concern (PHEIC) has been declared. As a result of the disease's rapid growth in infection rates and high contagiousness, hospitalizations have increased dramatically together with the output of medical infectious solid waste. Since a poor waste management could lead to additional virus spread, in this scenario it has become vital to increase capacity and accuracy handling for medical waste. In case of any problems with incineration or disposal capability, there should be adequate facilities for short-term storage of the trash: it must be kept in sealed containers held in secure locations accessible only to authorised personnel. To prevent the spread of the virus, disinfectant should be applied to both the interior and exterior surfaces and each employee should adhere to the recommended safety precautions[109].

The byproducts of the healthcare industry are hazardous: in order to lessen its negative effects, properly management and appropriate treatment procedures before final disposal are needed. However, lack of funding from the hospital administration, untrained staff handling infectious waste, and outdated technologies and disposal techniques are few ob-

stacles. The World Health Organization in 2015 found that just 58% of the facilities from 24 different selected countries had adequate processes in place to deal with the safe disposal of medical waste. Additionally, the global generation of healthcare waste grows at a pace of 2-3% due to an increase in the population index and expansion of healthcare facilities[110]. To ensure environmental protection and socioeconomic sustainability, secure systems for accurately segregating, collecting, transporting, treating, and disposing are essential. In this way, with effective waste management, waste can be recycled or turned into useful products like energy. In order to promote sustainable growth, national economies can benefit from properly managing healthcare waste, so we review a 40% assuming an almost intermediate position between S&P's 31.67% and MSCI's 68.42%.

### 3.1.7. Financials

Financials sector comprises banks, thrifts and suppliers of a diverse range of financial services including and capital markets, specialised finance and consumer finance services like personal credit, credit cards and leasing financing. The industry also includes asset management, investment banking, trading services, capital market management, financial exchanges, tools and services for financial decision making provision, mortgage REITs<sup>33</sup>, insurance and reinsurance.

With the goal of better comprehending and addressing the financial risks and chances associated with climate change, in December 2017, central banks and supervisors established the Network for Greening the Financial System<sup>34</sup>. In particular, members of NGFS acknowledged this in its initial report "[...] climate-related risks are a source of financial risk. It is therefore within the mandates of central banks and supervisors to ensure the financial system is resilient to these risks."

Recently, the creation of a more environmentally sustainable economy has been aided by the growing attention financial intermediaries and markets are giving to capital going into green projects. Banks are creating new financial services and products to make it simpler for green companies to acquire money, e.g., special banking deals, cheaper interest rates and counseling on environmental issues. Additionally, environmental considerations are increasingly a key factor used by private investors to influence investment decisions. Thus, companies are being evaluated more and more based on eco-efficiency standards, which are seen as indicators for higher profitability. Eco-efficiency stresses the strategic and operational capacity of a company's management to recognise and seize growth opportunities that enhance medium and long-term competitiveness and shareholder value.

Recent documents seem to indicate that investors value the reliability of green bond issuers and the presence of a business climate plan. Within the framework of a conventional asset pricing model, portfolios built in light on environmental performance suggest the existence of a missing element. The greenium, which is the risk premium associated with this green and transparent factor, is found to be negative and highly statistically significant. In fact, assuming nothing else changes, investors accept a lesser return on their investments if they are connected to greener and more accountable companies. This shows that purchasing greener assets is valued since the market considers them as an

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<sup>33</sup>Real Estate Investment Trust (REIT) is a company that owns, manages or finances income-producing real estate.

<sup>34</sup>The Network for Greening the Financial System (NGFS) is a group of 114 central banks and financial regulators with the goal of accelerating the development of green finance and formulating suggestions for the role of central banks in combating climate change.

hedge against negative environmental consequences[111]. Being less hazardous, sustainable investing has a risk advantage rather than a systematic return disadvantage. It differs from traditional investment mostly in terms of what it does not include, such as the oil industry and the manufacturing of illegal weapons. Besides, they dissent not only for moral principles but also on the basis of financial considerations: critical industries from an ecological or social perspective entail more risks and are therefore subjected to stricter regulations, which limits their potential for expansion.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** banks, asset managers, and other financial institutions are accountable for more than only the GHG emissions that result from the routine operations of their offices and branches. Additionally, they are liable for any emissions related to financing, including those from investment, lending, and other financial services. Thus, the transition away from fossil fuels towards net zero, which is necessary to manage the global economy without damaging the planet, will depend heavily on finance. Financial institutions can align their portfolios with the Paris Climate Agreement and increase their transparency and accountability by measuring and disclosing the emissions linked to their lending and investing activities. According to the Science Based Targets<sup>35</sup> project "Financial institutions are the vital link in enabling the rapid and unprecedented economic transformation needed to meet the goals of the Paris Agreement. Through their lending and investing, financial institutions have the power to redirect capital to the sustainable technologies and solutions of the future and to the companies doing the most to prepare for a net-zero emissions economy". Think that a Sierra Club<sup>36</sup> analysis states that the 18 biggest US banks and asset managers financed the production of 1.968 billion tCO<sub>2</sub>eq in 2020.

Since financial institutions regulate global capital flows, they have an enormous responsibility to finance the shift to a low-carbon economy. This means they have the power to mitigate the worst effects of climate change by funding adaptation and mitigation initiatives. For these reasons, we end up associating to Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions a sizable weight of 40%, enforcing the contribution given by MSCI agency but coherently with S&P analysis.

**Water** financial institutions contribute to the usage of unsustainable amounts of water. Even if unconscious, the activities they fund have a significant impact on the state of water resources. Since it is clear that they must reformulate their subpar investment policies to more accurately reflect worries about water sustainability, we end up assigning a 5%

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<sup>35</sup>The Science Based Targets initiative (SBTi) promotes aggressive climate action in the corporate sector by enabling organisations to set science-based carbon reduction goals.

<sup>36</sup>The Sierra Club is the most resilient and significant grassroots environmental group in the US.

weight. We choose to embrace a middle position between our reference agencies moving away from S&P's null contribute and reducing the assessment given by MSCI (20%).

**Land use and biodiversity** biodiversity is impacted by all financial instruments, including loans and investments. Since it is important to recognise the potential effects of economic activity and funding, to encourage financial institutions to support biodiversity, with the same reasoning of the previous section, we resolve a 5% weight.

**Clean-tech and renewables** before COP21, in 2015, Bill Gates and others billionaires in technology and finance declared a daring investment commitment aiming to tackle climate change: they invested billions of their private funds in the creation of breakthrough clean energy technology, radically novel discoveries that would revolutionize energy production and consumption in the 21<sup>st</sup> century. To this end, Breakthrough Energy<sup>37</sup> supports cutting-edge research and development, makes investments in businesses that turn green concepts into clean products and tools, and promotes public policies that quicken the pace at which new ideas are brought to market. As Bill Gates said "My basic optimism about climate change comes from my belief in innovation. The conditions have never been more clear for backing energy breakthroughs. It's our power to invent that makes me hopeful." He added "More than anything, we will succeed because of the network of partners we bring to this effort," "It will take all of us to compel the major market changes we need to create the future we want for the world."

The necessity of an energy transition resulting in the gradual adoption of renewable energy sources has been long recognised by stakeholders and investors. This approach is successful on every level. First, using renewable energy sources could help in keeping energy prices under control. Additionally, investment techniques that adhere to ESG standards are proven to be able to start a positive feedback loop that benefits everyone.

Investors today view renewable energy differently than they did a few years ago, from big international investment banks to wealthy philanthropists like Bill Gates, Jeff Bezos, and Jack Ma. The worldwide attitude toward climate change is generating additional incentives for investment in businesses and initiatives in the renewable energy sector. The significance of money and financial players in the climate change process is now widely accepted. This process necessitates decisions about economic, regulatory, and fiscal policies that are intended to direct the sizeable financial resources needed to significantly change how we generate, transport, and use resources.

Given the urgency and startling currentness of the subject, following MSCI's guideline, in contrast to S&P research which evaluates the topic as irrelevant, we end up with a 50%

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<sup>37</sup>Breakthrough Energy is a fund established in 2015 with the objective of supporting developments to bring the world to net zero emissions.

weight.

### 3.1.8. Information Technology

Information Technology (IT) deals with services and consultancy in software and information management, encompassing data processing, cloud networking and storage, and web hosting, organisations that work on creating and producing business and technical software. The sector also relates manufactures and distributors of hardware and tech equipment like semiconductors, connection devices, resistors and others electronic related products including communication equipment like telephones and cellphones, computers, switchboards and routers.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** in today's scenario, where the world is becoming more and more digital, since the production, usage, and disposal of Information Technology increase, it is vital to address sustainable environmental awareness. Although technological advancements strive to improve quality of life having countless benefits, they are also associated with a number of environmental issues, including rising energy demand and greenhouse gas emissions, environmental degradation and resource waste. As a result, there is a decline in the ecological balance.

According to critics, the tech industry consumes huge amounts of energy increasing greenhouse gas emissions, so being responsible for climate change. Consider that energy-related carbon dioxide emissions account for 60% of global CO<sub>2</sub> emissions[112]. The energy and carbon impact of information technologies have been highlighted by the American journalist Tarnoff who stated in The Guardian "[to] decarbonize, we must decomputerize". These technologies are made up of software and hardware components, including data centers storing and processing data, transmission networks transferring data through fixed or mobile networks, and connected devices exchanging information. GHG are released into the atmosphere as a result of the use of fossil fuels in energy production and consumption and the sector accounts for roughly 4% of global electricity consumption and 1.4% of global carbon emissions. Think that, according to the IEA, Bitcoin mining alone contributes to 0.03-0.06% of all energy-related CO<sub>2</sub> emissions annually[113].

Operating energy consumption is not the only cause of carbon emissions, indeed, the main reasons are hardware manufacture and infrastructure. Although the former's carbon emissions are reducing as a result of algorithmic, software, and hardware advancements, that improve performance and power efficiency, the entire carbon footprint of computer systems is still expanding. In fact, using publicly available industry sustainability data, hardware-manufacturing process rather than system operation, is the main source of carbon emission. Reference is made to the carbon footprint of raw material extraction, manufacture, packaging, and assembly; equipment transportation to its des-

mination; hardware operation and, finally, end-of-life production when the hardware is processed and recycled[114].

In addition to its economic and technical features, environmental considerations have recently become significant when choosing, designing, and utilizing information systems.

In a survey of 360 people, 63.9% say they completely agree with the statement "I am going to prefer a less harmful product for the environment." [112] After these considerations, we assign to the key factor a 20% weight, as MSCI does, even if S&P more than doubles its contribute. Conscious that today there is some sensibility on the environmental issue, this serves as a call to action for scholars studying computer systems and architecture to address the escalating environmental crisis in computing by establishing the groundwork for comprehending and developing more sustainable architectures. Considering that universities are one of the places where information systems are employed extensively, some steps have already been taken in this direction: the Hitit University data center has recently been aiming to lessen its carbon footprint by implementing green technologies. Significant efforts are being taken in this area such as, for example, determining the systems that are appropriate for the energy and signal values of the wireless network devices due to the server virtualization system, cloud architecture and increasing mobile usage needs in campus life[112].

**Water** in technological devices, like computers and smartphones, semiconductors are a key component. With the widespread use of solar energy and connected devices, the demand for chips will rise and rise. However, in order to prevent the contamination of electronic equipment, semiconductors production needs a lot of ultra-pure water: every day, a typical semiconductor manufacturing facility uses 2-4 million gallons of ultra-pure water. For example, in 2015 Intel<sup>38</sup> utilized 9 billion gallons of water. Water supply is necessary for the chemical mechanical polishing procedure, frequently used to flatten the silicon wafer's surface. In this way, a huge amount of wastewater is generated throughout a normal semiconductor production process. The delicate nature of the procedure lies in the heavy metals and the hazardous solvents found in the wastewater issued by the manufacturing. Because of the danger associated with these releases, these businesses have historically had to pay for groundwater pollution clean-up expenses[115].

In order to supply the public with clean and safe water, quality control and management in water resources are crucial. Monitoring, transmission, and administration of field water quality data using information technology and sensor technologies have enormous promise for creating efficient water quality management. The release of various contaminants, like

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<sup>38</sup>Intel Corporation, or simply Intel, is an American multinational corporation and technology company. It is the biggest semiconductor business by market capitalization.

organic matter, dangerous chemicals, and nutrients from domestic, industrial, and agricultural activities into natural water, has brought dangerous effects, such as harmful algal blooms on drinking water supply systems like rivers and lakes. In order to create an effective water resource management strategy and enhance current natural water system management plans, adequate water quality monitoring methods are therefore required. The modern monitoring methods, or "smart water quality monitoring methods", include in situ sensors and information technologies. Recent improvements in IT and sensing technologies in environmental engineering allow for accurate measurements, low-cost transmission and processing of large amounts of environmental data, and decision-supporting processes. Technologies are already widely used in many other domains, such as public health protection and early warning systems for weather-related problems.

Gathering, transmission, and interpretation of the measured data are the main tasks of real time online water quality monitoring systems. Advanced data analysis techniques, like machine learning, also offer useful tools for efficient administration of water quality data such as the prediction of water quality changes. Lately, deep learning is being used more frequently to analyse vast environmental data sets and produce meaningful information for managing water quality[116].

The other big issue related with water are its scarcity and, nonetheless, its waste. To fight water wastefulness, the Brazilian company Sabesp<sup>39</sup> developed the so-called "Programa de Uso Racional da Água". Solutions to reduce water waste consist of several actions like leak detection and repair, replacement of conventional equipment with water saving structures, studies on water reusing and educational lessons. In this context, water monitoring is becoming a key requirement to lower wasteful costs brought on by rising water waste generated by various human activities, such as long showers and car washing. Using an online monitoring tool may help customers make better use of this priceless resource, providing them with useful and warning information. Coelho, E. *et al.* presented a system, named Water Manager, based on hardware and software aiming to monitor residential water consumption performing an online monitoring of user residence water resources. The project has been validated by three experiments saying that the tool provides reliable and useful information aiding decision-making about reduction of water consumption where it is installed[117].

As other sectors, also the IT industry contributes to the delicacy issues of water use and pollution. Moreover, recent advances in IT could help the development of water management techniques whose goals are real time water quality monitor, identify future trends in water quality, and quick reactions to harmful occurrences in water resources. Never-

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<sup>39</sup>Sabesp is the short name for Companhia de Saneamento Básico do Estado de São Paulo S.A, a Brazilian water and waste management firm owned by the state of São Paulo.

theless, even if the analysis of the obtained data is performed by new machine learning approaches, many aspects of water quality monitoring systems still rely on regular-basis manual sample collection and monitoring. Thus, it is crucial to create and use in situ real time monitoring systems combining sensor technologies and sophisticated data processing methods, such as deep learning. Furthermore, in the future, it is even fundamental the development of monitoring systems for newly water contaminants like microplastics and microcystins. The creation of a suitable in situ monitoring system is essential to determine the distribution and circulation of these new pollutants between nations and continents and through rivers and oceans. For all these reasons, consistent with S&P, we end up with a 20% weight little increasing MSCI assessment (9.88%).

**Waste and pollution** in more recent years, technological innovation's adaptability and accessibility have seen enormous sales. As more people across the world use electrical and electronic devices, e-waste<sup>40</sup> is a significant industry that is expanding at a rate of roughly 2 million tonnes per year, of which 34% are communication devices and 14% are electronic items.

The main issue lies in most end users ignorance about how properly recycle or reuse electronics, therefore they frequently dispose them in household trash. Since e-waste is so full of harmful metals and other contaminants, such incorrect disposals are endangering life and ecosystems. According to Rick LeBlanc<sup>41</sup>, a major obstacle to the recycling of e-waste is customers reluctance to participate in recycling efforts since "[...] nearly 75% of old electronics continue to be stored in households because of the unavailability of convenient recycling options." [118] Contrarily, end users are expected to follow official recycling programs since, through the use of the recovered metals, these recycling processes not only assist the environment but also the national economy [119]. E-waste recycling is a gold mine which may produce a wide range of valuable and precious commodities, including silver, gold, platinum, copper, palladium, and other precious metals; the majority of them can be recycled and recovered. According to the United Nations University, global e-waste is worth more than 62 billion dollars in raw materials [120]. Consider the example of circuit boards: besides valuable materials like gold, silver and palladium, they also include a small fraction of expensive materials in short supply like indium and gallium whose concentration is still higher than in natural ores. Cost and scarcity of these materials are significant factors driving the growth of electronic waste management.

E-waste typically contains 30% organic materials, 30% ceramic materials, and 40% in-

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<sup>40</sup>E-waste means electronic waste indicating all old, end-of-life or discarded electrical and electronic equipment.

<sup>41</sup>LeBlanc is a freelance writer, commentator, and consultant on supply chain, pallets, and sustainable packaging.

organic materials. Base metals, noble metals, heavy metals, and rare earth metals are among the inorganic components. The complexity of treating e-waste is increased by the presence of hazardous substances such as brominated flame retardants, lead, cadmium, mercury, nickel, hexavalent chromium, and mercury. Therefore, one of the main difficulties in its managing is the disposal of hazardous trash.

While municipal solid waste management is attempted in many nations, e-waste management planning is frequently disregarded. Significant capital costs are associated with e-waste recycling and treatment facilities so that its management expenditures are rarely allocated and most developing nations treat and manage e-waste informally and illegally. Moreover, due to a lack of enforcement of current laws, significant populations in developing nations continue to be ignorant of e-waste, its policies, rules, and regulations.

To achieve the global Sustainable Development Goals for 2030, a sustainable development system together with e-waste management could be crucial. These goals include reducing deaths and health complications caused by exposure to hazardous and toxic components in e-waste, and extending entrepreneurship skills and capacity-building programs to ensure jobs and access to financial growth. In fact, e-waste recycling helps unemployment in several nations, such as China which employs hundred thousand recyclers at one of its e-waste recycling facilities[120]. The goals also include creating safe and secure working environments reducing environmental hazards posed by open burning, acid and chemical leaching, soil pollution from toxic effluent, and discharge of residues, promoting resource management in both production and consumption.

In line with S&P's evaluation (23.33%), we want to enhance MSCI's 4.32% weight assigned to Waste and pollution, recognising the burden for central and local governments to make effort to improve e-waste management and to promote greater awareness of citizens. We recognise a 20% contribute conscious that customers unwillingness to participate in the recycling process is one of the biggest barriers to the effectiveness of reverse supply chain management. Moreover, to improve present e-waste handling practices towards sustainability, administrations and recycling companies need to put a number of new methods into operation. Think that only 17.4% of the global e-waste generated in 2019 was recycled legitimately, with the remainder 82.6% untreated or processed illicitly[121].

**Clean-tech and renewables** digitalization refers to a range of economic activities using knowledge and information as key production factors, the internet as a vital conduit, and the effective application of information technology as a major force behind efficiency enhancement and optimization of the economic structure. The growth of digitalization has successfully addressed the issues with clean energy technology and encouraged its development, improving the energy structure. Taking the Chinese example, according to

the "China Pollution Cost" report produced by the World Bank and the Development Research Center of the State Council of China, Chinese environmental pollution has resulted in annual economic losses between 100 and 300 billion dollars. This model of pursuing GDP at the expense of resource waste and environmental destruction had a significant negative impact on economic development. As a result, it is essential to support green, low-carbon, and sustainable economic development. When telecommunications industry started penetrating speeding up the development of green technologies in 2013, China's economic and social development started undergone significant changes[122].

Existing studies have not acknowledged the potential influence of information technologies on renewable energy sources. However, in the long/short term, a 1% rise in IT would result in a 0.2-1.1% increase in renewable energy. Therefore, IT can encourage the growth of renewable energy, and policymakers should consider policies fully integrating IT with renewable energy. Because of the intermittent nature of solar and wind energy sources, more renewable penetration in electrical power grid operations had trouble. The use of energy storage systems and smart grids are just some strategies being investigated to raise penetration levels. The European Commission declared in 2014 that information technology has a significant role to play in reducing the energy intensity and enhancing the energy efficiency. ITs have the potential to drastically change how we produce and consume energy, and smart systems built on top of IT have the potential to create a future that is both more sustainable and energy-efficient. In GeSI<sup>42</sup> Smarter 2020 plans, ITs are significant forces for a sustainable future. In GeSI Smarter 2030 plans, more specific IT solutions are suggested to create future energy resources. Real time data on energy harvesting and consumption can be gathered and analysed using monitoring, detection, and diagnosis technologies, which help boost the generation of renewable energy, lower overall energy consumption, and prevent resource waste. Process efficiencies can be improved with the aid of alarm management and automation systems, predictive maintenance, machine learning and pattern recognition technologies. Predictive maintenance and automation in energy consumption can be developed thanks to energy management technologies. Real time data on energy production, distribution, and trading can be accessed remotely through a dashboard or user interface thanks to information and communication platforms, improving the efficiency of the industry. Smart buildings have the potential to greatly reduce emissions, save energy, water, and costs by utilizing the wireless network and smart devices, which can also optimize security, safety, productivity, sustainability, and reliability.

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<sup>42</sup>The Global Enabling Sustainability Initiative (GeSI) is a major source of unbiased knowledge, resources, and best practices aiming to achieve integrated social and environmental sustainability using digital technologies.

Finally, through wireless communication technologies and online platforms on the cloud computing environment, ITs also offer significant advances for the renewable energy sector. Examples of integrating renewable energy with ITs, particularly mobile networks, are sporadic. In a remote location such as Papua New Guinea, rapid cellphone penetration brought to off-grid solar charging systems.

With the co-development of ITs and renewable energy, an online system connecting New York power grid and energy markets and giving real time data for energy cost, energy load, and distribution has been built in New York State through NYISO<sup>43</sup>. Shorter duration forecasting will be feasible if utility level ITs are fully developed and put into place, although one day ahead forecasting is currently feasible.

Due to changing weather, solar power businesses frequently use revenue-grade meters to track energy production and consumption with 97-99% measurement accuracy. This enables solar power providers and users to benefit from performance-based incentives[123].

We put a 40% weight to Clean-tech and renewables by choosing an intermediate position between MSCI (70.37%) and S&P (0%). Technology businesses and related modern technologies quicken economic growth and help to take advantage of new opportunities. Moreover, there exist significantly positive relationships between mobile ITs and renewable energy generations, both in the short and long terms. Thus, if their developments are appropriately coordinated by policy makers, developers and marketing executives, the progress in ITs will play an important role in the promotion of renewables. This becomes even more crucial in a scenario where traditional energy sources like petroleum, coal, and natural gas are phased out in favor of renewable energy sources, and an increasing number of nations are including renewable energy in their total energy portfolios.

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<sup>43</sup>New York Independent System Operators (NYISO) is the organisation engaged in New York electric grid and competitive wholesale electric marketplace management. It controls the movement of electricity throughout the city making sure it is generated in appropriate amounts and transmitted when it is required.

### 3.1.9. Communication Services

Communication Services involves companies that distribute content like information, advertising, entertainment, news and social media across networks like internet, cellphones, cables, landlines and satellites. Additionally, it is effective in the creation, distribution, and broadcasting of movies and television shows, as well as music, interactive gaming products, theaters and sport teams.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** among all industries and organisations, the telecommunications sector has experienced rapid global growth. This sector is essential for bringing about an economic revolution. From a sustainable perspective, environmental degradation is one of its more pressing problems even if companies are making significant efforts towards a green and eco-friendly development. 21<sup>st</sup> century is the world of internet, broadband, satellite TV, mobile phones, and other technologies fuelled by Fifth Generation networks, commonly known as 5G. New 5G technology provides a revolutionary communication network with a boost in speed, volume of data, and number of devices with unlimited computing capabilities instantly available to everybody in the world. Thus, last years have seen the emergence of readily available technologies, e-business<sup>44</sup>, e-commerce<sup>45</sup> and e-marketing<sup>46</sup>, online streaming, and social networking platforms. As a demonstration of the enormous potential of this worldwide network of interconnected systems and how easily people become addicted to it, more than 70% of us use internet every day. Google<sup>47</sup> is now the solution to people's need to reserve a seat in a restaurant, to book a hotel room, a flight or a train ticket, to shop online or to order a pizza, so that internet usage has enormously increased over the past ten years.

Moreover, there has been a tremendous increase in data storage, commonly known as Big Data, including personal profiling data, emails, images, audio and video files. More precisely, data centers require big servers to handle this massive data generation, and these servers require a lot of electricity not to overheat. A data center is a collection of

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<sup>44</sup>E-business, also known as electronic business, represents any business or commercial transaction that involves the exchange of information through the internet. For example, it includes e-commerce, electronic publishing, remote work, telehealth and educational technology.

<sup>45</sup>E-commerce, also known as electronic commerce, is a branch of e-business. It is the activity of electronically buying or selling products and services using the internet. Amazon is one of the most famous e-commerce platforms.

<sup>46</sup>E-marketing, also known as digital marketing, is the marketing branch that promotes goods and services using the internet and other online-based digital technologies like desktop and mobile computers, as well as other digital media and platforms.

<sup>47</sup>Google is an American multinational technology company specialised in search engine technology, online advertising, cloud computing, computer software, quantum computing, e-commerce, artificial intelligence, and consumer electronics.

computer servers set up for processing, storing, and distributing a huge amount of data. It is an enormous machine which uses a lot of electricity, produces heat and needs air conditioning or fluids for cooling. Its primary function is the management of user interactions with server-based software tools and web portals.

The use of several search engines, cloud storage and emails, all contribute to CO<sub>2</sub> emissions so that in the next few years, when the global population grows to roughly 2.5 billion people, the carbon footprint of internet will overcome the one of air transport showing how internet is not as green as thought. In fact, internet depends on a huge number of physical servers located in data centers all over the world, as well as miles of undersea cables and routers, needing a lot of energy to run. Most of this energy comes from the burning of fossil fuels which releases CO<sub>2</sub> into the atmosphere. The annual CO<sub>2</sub> emissions from internet use are roughly the same amount that Turkey or Poland would produce from just burning gas, oil, and coal. Think that coal mining factories emit 4 times less CO<sub>2</sub> on average than the world's data centers.

The most popular social media applications include YouTube, Netflix, Facebook, and Tiktok with Netflix being the most used with the highest CO<sub>2</sub> emissions: watching 30 minutes of Netflix has the same carbon footprint of driving 4 miles[124].

As computing becomes more and more widespread, so does its effect on the environment: think that, since 2013, global CO<sub>2</sub> emissions from digital technology have climbed by 450 million tons[124].

However, due to its complexity caused by the billions of computers, laptops, iPads, and smartphones which constitute the global interconnected network, the internet's carbon footprint cannot be rapidly reduced[125].

It has to be said that internet is becoming more and more the backbone of modern communication. In the age of COVID-19, quarantines and lockdowns around the world have led to a significant change in digital behaviour increasing the time spent on such services. Technology broke the isolation enabling people to stay in contact, to work and study remotely, to shop and to stream series and films. Nowadays, in the post COVID world, there are good prospects that this trend does not stop.

However, despite the improvements in human life the internet and technological advancements have brought in many ways, including communication, healthcare, transportation, and entertainment, it has still some negative aspects starting from environmental sustainability. In 2019, the president of The Shift Project<sup>48</sup> said that each byte is the result of mining, metal processing, oil extraction and petrochemicals, manufacture, intermediate transportation, public works burying cables, and coal and gas power generation. As a

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<sup>48</sup>The Shift Project is a French think tank supporting the transition to a post-carbon economy.

result, the global digital system's carbon footprint accounts for 4% of all greenhouse gas emissions while its annual energy consumption is increasing by 9%. The new enthusiasm for the network makes changes towards sustainability all the more important so, assuming a middle position between MSCI's 92.16% and S&P's 50%, we assign a 60% weight to the key factor.

**Water** 5G network architecture is complex. While the efficiency of electronic components is continuously increasing, the amount of transferred data is growing rapidly, driving up energy demand. Besides, operators consider smaller devices to aid the assembly and save space. Thus, more heat energy is concentrated in a smaller region, making cooling more challenging. Overheated electrical components become less reliable, with the possibility of resulting in failures or shorter lifespan. In this scenario, to reduce cooling costs of 5G base stations, water cooling systems have been introduced. The benefits of water cooling over standard air cooling include higher heat transfer coefficients allowing for a significant reduction of annual power consumption, low acoustic noise, environmental friendliness, and a greater likelihood of heat recovery. In 2018, Nokia worked with Finnish telecom operator Elisa and power system provider Efore to implement the first water-cooled 5G base station in Helsinki. Its base station's waste heat has been used for water and space heating in the near buildings[126].

The relationship between network services and water is not over. 5G networks and smart cities will include a significant number of sensors, smart network development for smart management, and real time data analytics for advanced learning. As a result, these networks will promote environmental sustainability and help safeguard and protect public health. As explained in Information Technology's Water section, interconnected smart water sensors, accessible through the internet, can detect leaks, water pollution and contamination; additionally, sensors can also optimize the usage of water in agriculture. For example, the innovative farm Arable uses smart agricultural sensors for taking into account crop and soil conditions as well as weather data to better manage irrigation and increase its effectiveness. Moreover, with order to aid in harvest planning, the systems also track plant stress, nutrients, and pests[127].

Since there is a nexus between water and network industry, as long as systems need water to work and water management could be better controlled with electronic devices, we assign a 5% contribute to this factor by averaging MSCI's 0% and S&P's 10%.

**Land use and biodiversity** significantly more chances for environmental monitoring are now available thanks to drone-shot video, fast connections, and real time AI<sup>49</sup>-driven

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<sup>49</sup>AI is the acronym for Artificial Intelligence.

data analysis in data centers.

Drones can be used to study toxic algae, follow the movement of plastic waste or find oil leaks. In this way, the ability to make prompt decisions to prevent environmental dangers is enhanced by timely information, improving the situational awareness of environmental specialists and researchers.

Drones and drone services market is expected to grow in the upcoming years. Currently, regulations in most countries allow its use while pilot and drone are in visual line of sight. Beyond visual line of sight operations will be allowed providing the drone has a solid command and control link. This link is crucial for offering dependable end-to-end drone communications as well as for ensuring safe drone operations but requires high reliability and wide area coverage. Cellular networks like LTE and 5G are a solution enabling secure and reliable drone control. Concerning 5G, it offers a number of positioning techniques, so this new setup can assist in verifying the claimed location of the drone, following the drone along its flight route, and notifying any potential concerns linked to the availability and dependability of the communication. It can also configure the appropriate security setting and effectively transmit the data from the drone to the user.

Nokia used 5G drones with cameras and sensors to real time detect toxic blue-green algae growth in the Baltic Sea. Whereas algae are typically observed from the shore, in this way drones make it feasible to spot algae blooms in more remote areas. By getting timely information, experts can take rapid action to prevent such environmental concerns. According to Pia Tanskanen, Head of Environment at Nokia, 5G technology has shown to be outstanding in supplying detailed and accurate real time data for computer vision, something that may be used in a range of different fields demonstrating how 5G can significantly improve what we can do for the environment[128].

The Australian startup Myriota and the Australian Institute of Marine Science<sup>50</sup> are able to detect ocean currents, sea surface water temperatures, and ocean's barometric pressure in real time, simply using marine buoys equipped with satellite-connected IoT sensors, so helping researchers in monitoring ocean's changing conditions.

IoT and network systems not only assist men with taking care of the environment. Using 5G geolocation technology, the IUCN tracks whereabouts and migrations of endangered animals.

At the Chengdu Research Base of Giant Panda Breeding in China<sup>51</sup>, 5G is used to monitor

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<sup>50</sup>The Australian Institute of Marine Science (AIMS) is a tropical marine research centre focusing on broad-scale ecology and microbiology study for the protection and sustainable use of the marine environment.

<sup>51</sup>Chengdu Research Base of Giant Panda Breeding is a non-profit research and breeding center for giant pandas and other rare animals.

panda conditions and promote breeding as they only ovulate once a year and they are fertile for twenty-four to thirty-six hours. So, pandas are encouraged to mate by playing back their mating noises previously identified by the technology[129].

Telecommunications sector can benefit the environment developing solutions and tools to preserve Earth degradation, protecting nature and animals well-being. We reserve a 5% to Land use and biodiversity, assuming a middle position between our reference agencies' assessments (MSCI: 0% S&P: 10%).

**Waste and pollution** starting with radar during World War II, human exposure to radio frequency radiation has significantly increased over time. Our generation is heavily reliant on technology. As a result of popularity, extensive use and increasing dependency on wireless technologies, more and more people are exposed to higher and wider frequencies of the electromagnetic spectrum, needed to transmit data through a variety of devices and infrastructures. Thus, in addition to greenhouse gas emissions, electromagnetic radiation from telecommunications equipment contributes significantly to people's health issues. In this way, the continuous rapid growth of the telecommunications industry have raised debates on the human health risks associated with exposure to radio frequency fields, due to cell phones or their base stations and other sources, such as radar or radio and television waves. In this scenario, telecommunications technologies, and especially the emerging 5G, are fueling more and more a heated controversy. To reduce latency, 5G employs high frequency millimeter waves (MMWs), which are mostly absorbed in the superficial layers of the cornea and the first 1-2 millimeters of human skin. Because of capillaries and nerve endings, MMWs' effects may be conveyed via the skin through molecular mechanisms or through the neurological system. Moreover, the addition of this high frequency 5G radiation to an already complicated mix of lower frequencies, will have a harmful impact on both physical and mental health. This is particularly crucial because synergistic toxic exposures and other widespread health risk behaviours are likely to intensify its consequences[130]. However, since 5G technology uses MIMO<sup>52</sup> broadcasting technique, it can establish a direct line of sight connection between antennas and receiver thus, avoiding an omnidirectional irradiation which is conventionally used by 2G, 3G and 4G which can be much more harmful for people living in the area.

Nonetheless, the majority of politicians and decision-makers neglect the consequences of radio frequency radiation exposure both to the environment and human health. In 2011, the International Agency for Research on Cancer (IARC) at the World Health Organization classified non-ionizing radio frequency radiation from cell phones and other wireless

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<sup>52</sup>MIMO stands for Multiple Inputs Multiple Outputs. In wireless technology describes the use of multiple antennas at the transmitter and receiver.

devices as a "possible" human carcinogen, Group 2B. This classification is being disregarded. However, radio frequency radiation is a new type of environmental pollution that is becoming more widely recognised[131]. The main problem is related to the fact that its true health effects won't be fully understood for years or decades since this generation is the first to have had cradle-to-grave exposure to this degree of man-made microwave radio frequencies.

An improved connected society and unheard economic expansion will be the result of high tech companies' IoT global marketing to healthcare systems, businesses, schools and the public. Wireless devices, like cell phones, are often used worldwide, whether for personal or professional usage, so that exposure to radio frequency radiation is commonplace. However, although 5G and the other technologies may have or actually have a wide range of applications and advantages, because of their widely usage, serious adverse effects to human health and ecosystems may emerge. Think, for example, that cell phone radiation affects blood variables and cancer risk[132].

Even though MSCI does not recognise any materiality for Waste and pollution in the Communication services industry, halving S&P's 30% assessment, we end up with a 15% weight, stressing the need for clean and eco-friendly measures lowering sector's hazardous impacts.

**Clean-tech and renewables** due to the widespread usage of telecommunications services and the quick advancement of related technologies worldwide, there is a fierce competition in this market. In this scenario, using eco-friendly machinery and technology can be a mighty competitive advantage. Sector's resolutions on green and sustainable communication services are various, some are listed below.

Starting from 2019, 5G is providing faster and more seamless mobile communication services with low latency bringing great advantages and opportunities to end users, enterprises, and, more generally, the global economy. Thanks to 5G's speed, capacity, and connectivity, there are many opportunities to conserve and maintain the environment. By combining IoT with 5G technology, you can improve energy efficiency, lower greenhouse gas emissions, and expand the usage of renewable energy sources. Moreover, you can lessen food and water waste, air and water pollution, protect wildlife, and, finally, make better decisions about a variety of issues, including waste reduction, industry, agriculture, and pest control. In this way, all aspects of our lives including business, industry, transportation, education, communications and health are being affected by the use of this next generation mobile wireless technology which, compared to the previous ones, is more inclusive, progressive, tested, and potent. In this way, 5G is close to bringing a totally linked world[133].

Green Internet of Things (GIoT) considers energy efficiency at various IoT levels lowering costs and risks to human health. In this way, GIoT enables a smart and sustainable future by reducing carbon emissions and energy use. Some reviewed strategies are green wireless sensor networks including LoRa<sup>53</sup>, Bluetooth, LR-WPAN<sup>54</sup>, WiMax<sup>55</sup>, and WiFi; data rate, transmission range, cost, and energy consumption are taken into account[134].

Telecom firms, manufacturers and suppliers should jointly undertake End-of-Pipe Technologies<sup>56</sup> investments for pollution management. On the other hand, the importance of offering high-speed services and high reliability in the telecommunications industry, as well as the level of competition in this area, makes the supply chain management sustainability so highly vital[135].

To reduce carbon footprint from internet's use, big corporations like Google have recently taken significant action by investing almost 1 billion dollars in renewable energy sources, with its data centers using roughly 50% less energy than standard ones. Following this positive direction, thanks to the establishment of energy-efficient data centers and to its website Yahoo! Green, Yahoo has been made Newsweek<sup>57</sup>'s top 10 rankings of greenest firms in America[125].

As it is impossible to limit internet users, there needs to adopt more green data centers, renewable energy, energy-efficient and eco-friendly practices internet usage. For sustainability goals to be met, performance measurement is crucial and current technology calls for research and enhancements to be improved. To construct smart cities where sensors, cameras, and smartphones will be connected, governments and businesses are looking to 5G, AI, and IoT technology. The connectivity and speed of these networks will enable cities to be better controlled and more efficient and sustainable. For this reason, moving away from our reference agencies evaluations (MSCI: 1.96% S&P: 0%), we assign higher 15% weight to stress the importance of reducing this sector's environmental hazards in a context where, by 2025, there will be 42 billion IoT devices worldwide[134].

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<sup>53</sup>LoRa stands for Long Range communication technology; it is a wireless radio frequency network.

<sup>54</sup>LR-WPAN stands for Low Rate Wireless Personal Area Network; it is the basic scheme for many low rate wireless protocols.

<sup>55</sup>WiMAX stands for Worldwide Interoperability for Microwave Access; it is a telecommunication technology providing wireless transmission of data using a variety of transmission modes.

<sup>56</sup>End-of-Pipe technologies (EOP) denotes methods for removing contaminants from a stream of air, water, waste, product or similar. The name comes from the fact that these techniques are typically used as the final step of a process before the stream is disposed of or delivered.

<sup>57</sup>Newsweek is an American weekly online news publication and digital news platform.

### 3.1.10. Utilities

The Utilities sector provides a variety of daily services linked with gas, electric and water utilities. Gas utilities are involved in the distribution of natural and manufactured gas to residential and industrial customers. Electric utilities produce and distribute electricity, including both nuclear and non-nuclear facilities. Water utilities purchase and redistribute water to the consumers, also including water treatment systems. Multi-utilities operate other diversified activities in addition to those just mentioned. Also, the utilities sector encompasses Independent Power Producers (IPPs), Gas and Power Marketing, integrated energy merchants and renewable electricity manufacturers. The latter ones are involved in electricity generation using renewable sources such as biomass, geothermal, hydropower, solar and wind energy.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** increasing access to energy while also dramatically lowering greenhouse gas emissions is one of the major issues facing humanity in the 21<sup>st</sup> century. The electric sector has been recognised as a prime target for a rapid and deep decarbonization. For the near future, electricity will continue to be produced, primarily using a combination of fossil fuels, nuclear energy and renewables like solar, wind and hydropower. However, to meet the anticipated electricity demand in 2050 while also reducing emissions, most regions will need a different combination of power producing facilities than the current system. Although many low- or zero-carbon technologies can be used, nuclear power plays a significant role. Currently, 11% of the world's electricity comes from nuclear energy. However, the future role of nuclear energy is extremely uncertain for several reasons including rising costs and the persistence of historical issues like disposing of spent fuel, safety of nuclear plants and proliferation of nuclear weapons[136].

To meet the objectives of the Paris Agreement, CO<sub>2</sub> emission from fossil fuel-fired power plants has emerged as a significant concern in the study of power dispatch.

Natural gas is a high-quality, clean and low-carbon energy source. In fact, despite its burning produces carbon emissions, it emits 50% less pollution than fossil fuels like coal and petroleum. Therefore, the transition to natural gas is an effective way for improving energy efficiency and switching to fully renewable energy sources. The growing reliance it is achieving has increased natural gas infrastructures: because of simplicity, affordability, and dependability, pipeline is one of the most used transportation system for delivering huge quantities of natural gas from the source to the final users. A pipeline is characterised by the presence of compressor stations every 60-160km. Since the gas movement reduces its pressure because of the friction with the tube wall, this structure compresses the gas

to preserve speed, pressure and temperature in the pipes all the way.

The Russian Federation is the main European Union gas supplier: its pipelines span the 5,000km between Western Siberia's gas production and Central Europe's gas users. One of the biggest long distance gas network is run by Gazprom<sup>58</sup>, which owns around 153,000km of pipes. Since during gas production and transportation indirect GHG emissions occur, in 2003, measurements on Russian long distance transportation pipelines were conducted to get accurate emissions data. Leaks on machine fittings, compressor stations, and valve nodes on pipelines accounted for two-thirds of the gas released. Ventilation, used for maintenance and repair work, also plays a big role. Thus, recovery projects could boost profitability and effectiveness[137].

Cities are required to constantly provide access to clean water while addressing climate change. Urban water systems cover those facilities that transport, store, and extract water for filtration and distribution, as well as wastewater collection, treatment, and recovery and sludge treatment systems. Operations involving water services emit greenhouse gases directly, including emissions from fuel use, both on-site and during transportation, as well as methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions from the processing of sludge and wastewater. Additionally, the chemical inputs employed to clean water and wastewater entail indirect GHG emissions from energy use[138].

The Utilities industry encompasses a number of activities directly involved in the release of emissions. Starting from the electric sector, which being heavily dependent on coal, is a primary offender, we come to natural gas and water services. Even if this industry is one of the main emissions' responsible, it can make use of numerous sustainable solutions, for instance through renewable energy exploitation. It has to be said that the process of direct combustion and gasification, used to convert biomass into bioenergy for the generation of heat and electricity, are essential to meet climate goals. In fact, compared to non-renewable fossil fuels, biomass has a lower carbon concentration, thus its burning produces less CO<sub>2</sub> which the environment can absorb more readily. Resolving an intermediate position between S&P's 40% and MSCI's 26.36%, we end up associating a 32.5% weight.

**Water** unlike in the past, when water utilities simply needed to ensure service delivery and financial and economic viability, nowadays they also need to be socially and environmentally responsible. However, water losses, often known as Non-Revenue Water (NRW), affect utilities. In their distribution systems, the majority of water companies in the world experiences water leaks, even if many NRW, since preventable, should not happen.

According to water service performance reports from Tanzania Energy and Water Utili-

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<sup>58</sup>PAO Gazprom is a Russian multinational corporation active in the energy-mining industry, particularly in the extraction and selling of natural gas.

ties Regulatory Authority<sup>59</sup>, in 2015-2016 and 2016-2017, NRW reaches 50% for several utilities. Limit NRW is an investment challenge since utilities must make significant infrastructure investments[139]. However, average losses exhibit strong disparity with some nations like Brazil having such index close to 40% while others, like Denmark and the Netherlands having losses' percentages under 10%[140]. The total amount of water lost through distribution networks around the world ranges 15-60% of the total water source, and at 126 billion cubic meters, it is a huge worldwide problem costing around \$39 billion yearly. It accounts for around 9% of the entire amount of incoming water in Germany and 43% in Malaysia. Moreover, in developing countries, because of an antiquated infrastructure, sporadic supply, and unlawful use, the issue of NRW takes on an even new dimension. Water leaks are frequently a serious issue in drinking water supply, resulting in a considerable loss of revenue, limiting the amount of water available to users and posing challenges to the efforts done by the utilities to increase service quality and cover more ground with water networks[141].

Water is essential to modern societies for several purposes: from sanitation to irrigation, satisfying thirst, and maintenance to producing electricity. Deteriorating infrastructures, causing unknown leaks, have become a challenge for water services: spills from pipes account for a large amount of water wastage. Unfortunately, due to the invisibility of the source of the escape, a lot of leaks go unnoticed for years because of worn-out valves and fractured water supply lines. Since we want to resolve a significant weight to stress the need to find a solution for water leaks, following our rating agencies' evaluations (MSCI: 19.83% S&P: 18.75%) we associate a 20% weight.

**Land use and biodiversity** utilities industries largely influence the environment.

Pipelines and electricity lines are two examples of linear infrastructure to blame for habitat loss, fragmentation, and modification in various ecosystems. For instance, although they make up a very minor portion of the entire energy network, across Europe and the US the core network's power lines span at least 300,000km and 250,000km, respectively. Moreover, around the world, the total amount of power lines maintains its 5% annual growth rate, including transmission lines and power distribution lines. Think that 3,560,671km of pipelines transport natural gas, crude oil, petroleum products, and water connecting 124 nations, with an additional 161,118km of pipelines planned and being built to transport hydrocarbons. Therefore, land is cleared of vegetation, soil is frequently scraped or graded, and many man-made structures are built, destroying or significantly diminishing the site's biodiversity. To prevent obstruction of power lines or pipes, tall vegetation is

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<sup>59</sup>Energy and Water Utilities Regulatory Authority (EWURA) is a multi-sectorial autonomous regulatory body which controls both from a financial and technical point of view electricity, oil, natural gas and water sectors in Tanzania.

regularly cut down and road access is frequently kept open to enable for inspection and maintenance of the infrastructure. The resulting corridors are usually planted with grasses or low ground cover to facilitate the observation of pipeline losses from helicopters. The effects brought on by these infrastructures are numerous, including alterations in plant community structure and makeup, and spread of weeds and exotic species. At the end, the pipeline represents a physical or visual barrier to mammals[142].

The Niger Delta is well recognised on a global scale for its non renewable oil and gas resources. To build the pipelines in this area about 4,950,000m<sup>2</sup> of forest were removed and 9,642,000 trees were felled. The pipelines run through lowland, freshwater swamps, mangrove forests and barrier islands; in these locations, 219 plant species and 125 distinct fauna species were found. According to the IUCN conservation status, three of the four Meliaceae species<sup>60</sup> recorded there are threatened, together with 20 mammals, 7 birds, 2 reptiles and 1 amphibian[143].

Nowadays, to satisfy climate targets, energy policies encourage the rapid development of Renewable Energy Sources (RES). RES planning necessitates not only the understanding of industrial needs, but also the agreement on emerging technologies and their consequences.

Bioenergy is one of the many available resources to meet the energy need. It is a form of renewable energy derived from the conversion of biomass. Biomass are organic vegetable and animal materials obtained from firewood, crop and forestry residues, marine algae, and manure and the biodegradable fraction of industrial and municipal waste. This can be converted into biofuel, biogas, biomethane, heat and electricity. However, the process could be dangerous for the natural ecosystem since the unsustainable fuel wood harvest results in land deterioration, burning crop residues removes essential soil nutrients and reduces soil's water-holding ability, and burning cow dung produces a large amount of carbon emissions.

Hydroelectricity is another form of green energy which causes deforestation and loss of wildlife habitat, disruption of river flows and colonization of degrade sites by invasive species.

Among all the RES, wind power has risen to the top with estimates ranging from one-quarter to one-third of worldwide electricity demand by 2050. Wind farms obviously aid climate goals but there is growing evidence of direct negative impacts on biodiversity, including bird and bat collision fatalities, species disturbance and displacement, barrier effects, and noise pollution. Furthermore, despite in terms of power produced per square meter wind farms are less land intensive than other renewables, they still have a significant

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<sup>60</sup>Meliaceae is a flowering plant family of mostly trees and shrubs.

land footprint because of vegetation removal, on-site turbine's building on concrete foundations and unregulated road expansion[144]. In this way, wind farm buildings can have an impact on wildlife species by altering quantity, quality, and configuration of habitat, having a significant impact on total species richness and persistence. Understanding what causes land transformation and fragmentation, and road network growth linked with new facilities, may have an impact on site decisions. A rich literature documents how new wind farms effect transformation and loss of undeveloped lands, with a particular focus on new roads built during the development phase. Studies have been done on the matter focusing on whether characteristics related to the turbines themselves, such as size and spacing, topography and land usage prior to installation, have an impact on the levels of damage induced by the facilities. Using linear models and beta regressions, it is predicted how the previous listed aspects influence three landscape metrics that evaluate factors connected with habitat loss and fragmentation. These metrics are used to measure features of land cover linked with ecological patterns and dynamics such as habitat loss, which is linked with biodiversity decline and species' abundance, size and presence of core areas, which have an impact on the abundance and demography of species that require a minimum space, and connectivity, which influences patterns of species movement in fragmented environments, as well as their spatial ecology and persistence. The geographic setting of a facility, such as topography and pre-construction development levels, turbine characteristics, and newly built roads, could impact levels brought on by new structures. The results back up the intuitive notion that the geographic environment in which energy is created affects types and magnitudes of impacts on natural systems. Besides, it is discovered that the impact of wind farms on undeveloped areas is determined by levels of pre-construction development and new roads, and the design of the farms influences the expansion of road networks. The work suggests that new facilities should be carefully sited and planned to maximize energy production while reducing new roadways and reusing existing ones[145].

Modern society depends largely on the effective functioning of utilities for delivering public services, keeping a high standard of living, and promoting economic progress. In recent years, there has been a significant global expansion of oil and gas pipelines because of the need for trustworthy international energy sources and for the pursuit of energy security. Meanwhile, since facilities and development projects continue to be implemented around the world, biodiversity rich areas are increasingly at risk of experiencing negative impacts, thus all necessary precautions need to be taken.

Oil and gas exploration and production are essential to Nigerian government revenue and are linked to the country's development. However, these processes have led a devastating impact on humankind, biodiversity, and rural livelihoods.

The development of renewable and unconventional energy, whose uptake wants to mitigate the effects of global climate change, is an example of the difficulty of striking a balance between biodiversity protection and economic expansion. RES, in fact, are a possible replacement for fossil fuel energy, but they also involve a series of environmental trade-offs. Since the impact on the environment exists anyway, to assign a significant and appropriate weight to the key factor under consideration, we decide to average the values associated with our reference agencies (MSCI: 9.80% S&P: 17.50%) resolving a relevant 15%.

**Waste and pollution** the nuclear fuel cycle is the collection of industrial processes used in nuclear power reactors to produce electricity from uranium fuel. The process of nuclear fission generates about the 17% of the total world production of electricity. The cycle yearly prevents the release of 2.4 billion tons of carbon dioxide into the atmosphere offering a plentiful source of energy, relatively immune to market changes.

Nuclear waste refers to the byproduct of nuclear fission: it is made up by the fuel that has reached its useful life's end and by a set of materials that have become radioactive during nuclear reactor operations. Due to the extended half-lives and the intricate decay chains required to achieve nuclear stability, nuclear waste is very dangerous and necessitates adequate disposal plans in the long run. Thousands of tons of nuclear trash are generated by 436 reactors around the world yearly. It can be classified into three categories. Low Level Waste (LLW), made up by lightly contaminated objects such as tools and work gear which represents only 1% of the radioactivity; Intermediate Level Waste (ILW) such as filters, steel components from inside the reactor, and some reprocessing effluents having 4% radioactivity; finally High Level Nuclear waste (HLW) which accounts for only 3% of the total garbage produced but it contains 95% of the total radiation. It becomes necessary to provide shielding, personal protection, and remote handling, and to monitor the heat generated. HLW must be treated to reduce its radioactivity or preserved in a safe and isolated environment for hundreds thousands years to avoid radioactive contamination[146].

In recent years, there has been a greater focus on minimising carbon dioxide (CO<sub>2</sub>) emissions from energy production and other industrial operations. In this context, nuclear, as well as renewables, gives its own contribute as carbon-free energy source to the production of electricity, representing a growing part of the world's energy production systems.

The International Atomic Energy Agency<sup>61</sup> estimates that nuclear electricity will continue to rise worldwide up to 2050; nowadays 53 new reactors have been built and 118 are being

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<sup>61</sup>The International Atomic Energy Agency (IAEA) is an international organisation promoting the secure, safe, and peaceful application of nuclear technology while discouraging its use for any military objectives.

designed. However, nuclear waste is one of the most difficult to be handled for modern society. Since it is impossible to avoid waste production, long-term processes are needed to minimise the environmental impact of the industry trash via recovery or neutralization and radioactive waste management systems are essential for maintaining nuclear energy programs around the world. In fact, it could cause risky environmental damages and irreversible harm to humans. Italy is just an example of improper management: despite its nuclear areas closed in 1990, currently these facilities host past radioactive waste for disposal.

Consider the Chernobyl nuclear disaster in 1986: even today the serious consequences like malformations, tumours, pregnancy problems, contamination of plants and animals are still very tangible. Thus, in order to ensure a proper consideration to the issue, coherently with the work done by our reference agencies (MSCI: 20.26% S&P: 23.75%), we conclude a 20% weight.

**Clean-tech and renewables** in today's global context, where economic growth inevitably coincides with increased energy demand, the development of new sustainable production technologies is undoubtedly becoming one of the most important business challenges of the future. Progress in the field of clean-technology is intimately related to the success of the transition from a fossil fuel economy to a sustainable one; therefore clean-tech has been at the forefront of governments' recovery efforts to restructure economies. Besides, green energy could rely on the strength of green chemistry to minimise or even eliminate use and production of hazardous materials while still manufacturing high-quality goods using safe and efficient techniques.

According to Dr Birol (2022), "Energy market developments in recent months - especially in Europe - have proven once again the essential role of renewables in improving energy security, in addition to their well-established effectiveness at reducing emissions." In 2021, according to the IEA's latest renewable energy market assessment, the world has set a record of 295GW of new renewable energy capacity. This year, global capacity additions are forecast to reach 320GW, having the potential of reducing the EU's energy sector reliance on Russian gas[147]. As an example, both this and next year, global solar PV capacity<sup>62</sup> additions are expected to set new records, with the yearly market reaching 200GW in 2023. Renewable energy has overall increased by 200% from 2000 to 2019 in EU-27<sup>63</sup> countries, highlighting an ascendant pathway[148].

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<sup>62</sup>PV capacity stands for photovoltaic capacity. Photovoltaic panels consist of a series of photovoltaic cells converting solar radiation into electricity thus, PV capacity indicates the total amount of installed solar PV generation capability.

<sup>63</sup>The EU's 27 members are: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg,

In the commitment to clean-technologies, President Joseph Biden on November 15, 2021 approved the \$1.2 trillion Infrastructure Investment and Jobs Act, commonly referred to as IIJA or Act. With funding made available by the investment, which includes \$65 billion committed to modernizing the national energy infrastructure, energy and utilities sectors have the chance to strengthen their initiatives to update the grids and promote renewable energy. The fund will be used for projects aimed at cutting carbon emissions, such as building thousands of miles of new transmission lines required for the growth of clean and renewable energy sources. To accelerate the transition to a zero-emission economy, the investment will also support research, demonstration and use of cutting-edge clean energy technologies.

Due to the uncontrolled disposal of municipal and industrial solid waste, land, air, and water are becoming more and more contaminated. Waste removal can have an impact on the cleanliness of the environment also aiding in the preservation of natural resources. Waste-to-energy technologies handle waste incineration, gasification and pyrolysis<sup>64</sup> with energy recovery, and landfill biogas to electricity generation, so converting garbage into power form like hydrogen, biogas, and bioalcohol.

Organic waste, such as agricultural residues, food waste, and animal manure, is becoming more abundant in modern communities and economies, and it may be used to generate energy sources like biogas and biomethane. Biogas provides a clean cooking fuel for households as well as a local source of energy and heat for communities. Besides, switching it to biomethane allows to gain the benefits of natural gas without net emissions. According to Dr Birol “As governments seek to accelerate their clean energy transitions, they should not forget the importance of low-carbon gases such as biomethane and biogas, [...] Among other benefits, biogas and biomethane also offer a way to bring rural communities and industries into the transformation of the energy sector.”[149]

Food waste accounts for 30-60% of all municipal solid waste generated globally. However, because of its high nutrient and organic content, food waste may be used to produce value-added products such as biofuels, biogas and biomethane[150].

New products such as pellet and briquettes<sup>65</sup> are an example of solid biomass. Portugal is involved in pellet production; pellet plants are exploited to mainly export to power plants in Western and Northern Europe substituting fossil fuels. In Uganda, firewood and charcoal accounted for the majority quantity of the country’s total cooking energy

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Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.

<sup>64</sup>Pyrolysis is the thermal decomposition of carbonaceous materials in an inert environment at high temperatures.

<sup>65</sup>Briquettes are made up by organic household waste such as peanut shells and banana peels that are squeezed into little dense products that can be used in place of charcoal and surplus wood gathered from forests.

consumption. Instead, nowadays deforestation has shift the focus on biomass briquettes as the top three East African energy products. Bioenergy production climbed by 8% in 2020, outpacing Net Zero<sup>66</sup> projected growth of 7% through 2030. However, over the past, implementation has been insufficient, with average yearly generation increase falling short of the needed amount. So that, whereas Net Zero Scenario models predict 15GW of new capacity each year between 2020 and 2030, actual additions in 2020 were just 9GW. Since the Net Zero ambition for bioenergy production in 2030 is much higher than the existing sustainable development scenario, the monitoring status in this area has been modified from "on track" to "additional efforts are needed".[151]

Broadly speaking, policies to promote the growth of bioenergy are improving and several significant legislative changes over the last year will have an impact on its growth. In July 2021, Indonesia declared its intention to make co-firing<sup>67</sup> at its coal plants a requirement; in May 2021, India established a National Mission on the use of biomass in coal-based thermal power plants, with the goal of increasing co-firing in coal power plants of 5-10%. Even if bioenergy is less competitive than wind and solar in term of costs, it can supplement intermittent wind and solar sources while helping in reducing waste.

Hans Bruyninckx, EEA Executive Director, has said: "Bioenergy is an important component of our renewable energy mix, helping to ensure a stable energy supply. [...] forest biomass and productive land are limited resources, and part of Europe's natural capital. So, it is essential that we consider how we can use existing resources efficiently before we impose additional demands on land for energy production". In the knowledge that the greatest challenge lies in figuring out where human needs and natural system meet, in a world of finite resources, resource efficiency must not be overlooked. Enhancing resource efficiency means finding ways to achieve more at lower costs to the environment, putting attention to the impacts on water, air, soil and biodiversity.

We recognise the materiality of green energy technologies development for coming years, simultaneously we know that some progress has already been made in this area but we are conscious that Net Zero targets are ambitious ones. In this scenario, there needs to preserve the environmental safety and the Utilities sector could give a huge contribute, relying on numerous commitments made by governments. Think for example that in the US, only 13% of municipal solid waste is employed for energy recovery, while the 53% ends up in landfill sites[152]. Following this reasoning, we steer away from our reference

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<sup>66</sup>To meet climate targets set by the Paris Agreement, carbon emissions need to be halved by 2030 and reach Net Zero goal by 2050.

<sup>67</sup>Co-firing is the simultaneous combustion of two (or more) different types of materials. One of its numerous advantages lies in the possibility of using an existing plant to burn a new fuel, which may be cheaper or eco-friendly. Biomass co-firing, for example, has a significant potential to lower carbon dioxide emissions from power plants.

agencies' assessments which nullify the key factor's contribute, and we resolve a 12.5% weight.

### 3.1.11. Real Estate

Real Estate companies operate in management and development of real estate holdings but also in diversified, industrial, hotel and resort, office, healthcare, residential, retail, and specialised REITs.

**Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions** the yearly status reports released by the United Nations Environment, the International Energy Agency and the Global Alliance for Buildings and Construction<sup>68</sup>, underline the significance of buildings and construction industry in this setting. According to these reports "building construction and operations [account for] 36% of global final energy consumption and 39% of energy-related carbon dioxide (CO<sub>2</sub>) emissions."

In recent reports, the IPCC cited buildings as an important priority area for a variety of reasons. First, 28% of all energy-related greenhouse gas emissions are a result of building activity worldwide. The emissions are produced by processes as the release of refrigerants and blowing agents (HFC and PFC gases), and from the energy needed for cooling and heating, hot water delivery, lighting, ventilation and air conditioning. Given the enormous quantity of GHG emissions that buildings currently produce, they also have a large chance to reduce emissions through increased operational energy efficiency. In this regard, the IPCC declares that "1.5°C-consistent pathways require building [GHG] emissions to be reduced by 80–90% by 2050, new construction to be fossil-free and near-zero energy by 2020", and the need for "an increased rate of energy refurbishment of existing buildings to 5% per annum in OECD<sup>5</sup> countries". On the other hand, given the whole life cycle of a structure, energy consumption and GHG emissions happen for reasons unrelated to how the facility is used. Energy is needed to produce construction materials, to build new structures, to modernize existing ones, and to implement replacement projects. It is also used in transportation, construction, decommissioning, and disposal of materials and buildings[153].

The United Nations Environment Programme states that among the nations that submitted the Nationally Determined Contributions<sup>69</sup>, in accordance with the Paris Agreement, 136 identified environmental and financial costs associated with building emissions and energy efficiency as their top priorities and challenges on the way to achieve the desired

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<sup>68</sup>As a component of the Lima Paris Action Agenda, the Global Alliance for Buildings and Construction (GlobalABC) initiative was unveiled at COP21. It aims to activate all stakeholders, including member states and non-state actors from the buildings and construction sector, to scale up climate initiatives in the sector.

<sup>69</sup>The success of the Paris Agreement and these long-term objectives depends on Nationally Determined Contributions (NDCs). NDCs represent the efforts of each nation to lower national emissions and prepare for climate change effect

objectives. This urgency is clearly obvious in states and cities where the building sector is at the core of decarbonization targets (e.g., New York's Climate Mobilization Act<sup>70</sup>, L.A.'s Green New Deal<sup>71</sup>), as well as at the national level.

Given the obvious need to find a solution to the emissions generated by buildings, unlike MSCI agency, we want to pay attention to Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions released by the considered industry. In agreement with S&P, which resolves a 35% weight, we believe that the Real Estate sector significantly contributes to the rise in atmospheric gas emissions. Thus, by slightly lowering the value fixed by S&P, we end up resolving a 20% weight.

**Land use and biodiversity** real estate industry accounts for a number of environmental effects because of the destruction of natural habitats and the extraction and manufacture of construction materials. As cities grow, urban development can have a substantial impact on natural environments: one of the key factors causing the decline in biodiversity, also known as habitat modification, is the replacement of natural and native ecosystems with urban areas or farmed lands. The way we usually plan cities has shown to be less resilient to the effects of climate change, because of concrete roads and big structures. As a result of the lack of vegetation, for instance, we are more vulnerable to diseases, heat waves, and other harmful effects of climate change. Typical ecological processes like the movement of carbon, water, and essential nutrients have been hampered by the removal of trees and other vegetation and the use of impermeable materials. Resulting from this finding, regulations regarding subsidies and labelling have been implemented to encourage the use of more environmentally friendly building design and renovation techniques e.g., insulation premiums, energy performance labels, subsidies for the installation of green roofs.

Moreover, today urban zones are increasingly being considered as potential habitats for wildlife. These areas can serve as a haven for animals and play a significant role in the urban landscape, from the creation of green spaces like public parks to the building of green walls and roofs. Since there are numerous ways for the urban environment to be developed to promote the integration of biodiversity, we opt to emphasise the key factor's impact. Differently from MSCI agency, which makes it meaningless focusing mainly on Clean-Tech and renewables opportunities, lowering S&P contribution (22.5%), we resolve a 5% weight.

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<sup>70</sup>The Climate Mobilization Act includes a variety of climate policies intended to significantly reduce New York City's carbon emissions, as Green Roofs, Building Energy Efficiency Grade, PACE and Building Mandate.

<sup>71</sup>The L.A.'s Green New Deal, a plan for social and economic reforms, aims to achieve a low-carbon and renewable energy future.

**Clean-tech and renewables** the building sector is essential for the three components of sustainable development: social advancement, economic expansion and effective environmental protection. As a consequence, the economical development of a country is substantially influenced by the building industry which consumes a considerable amount of energy and natural resources. Thus, the industry should actively take part in the national efforts to achieve green growth.

A green building is the end product of extremely cautious design decisions, careful choice of materials and technologies, and rigorous research into the energy absorbing properties of structures. In this perspective, the structure is no longer viewed as only a container but rather as a whole organism in intimate contact with its occupants as well as its surroundings, which it must blend into as much as possible without degrading while reducing its own harmful emissions. Green buildings are an attempt to reduce negative impacts on the planet and resource use while improving beneficial effects over the course of building's existence. The planning, design, construction, and use of buildings are generally acknowledged as being part of green building activities, including minimising harmful environmental effects, improving interior environmental quality and making effective use of energy, water, and materials. It is important to remember that green structure encompasses both sustainability and high performance, which implies that increasing energy efficiency cannot come at the expense of lowering indoor environmental quality or comfort level.

Confirming the importance that green construction is taking on in the modern world nowadays, to assess the sustainability of buildings, many certification programs have been created internationally. The most well-known certifications are the Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Green Star in Australia, and Green Mark (GM) in Singapore. Property developers who wish to take part in the Green Mark Scheme, for instance, must submit an assessment that includes an estimate of the entire environmental performance of the buildings and more. The program encompasses a range of property types, including both residential and nonresidential structures, parks, commercial buildings, hotels, offices and urban districts. The GM program specifically attempts to incentive building owners to adopt sustainable policies and solutions to reduce adverse effects, while developers are encouraged to create new structures that adhere to the goals and objectives outlined by energy and environmental policies[154].

The advantages of building in a more ecologically friendly manner while also being more sensitive to the demands of residents in terms of livability are numerous and beyond dispute. Moreover, the idea of unconditional respect, which guides this new approach to

construction, not only encourages a more careful use of all resources, but also offers real opportunities for cost savings: constructions produced by virtuous cycles are less wasteful by nature, as a result of waste reduction efforts, activity optimization, and increased recycling of components and materials. For these reasons, understanding the importance of developing an increasingly green real estate industry and agreeing that the opportunities to make it real are many, we decide to associate to Clean-tech and renewables key factor a significant weight. With completely different assessments from S&P, which considers the key factor meaningless, we agree to decrease of few percentage points the weight associated by MSCI (99.6%), resolving a 75%.

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Health-care	Financials	Information Technology	Communication Services	Utilities	Real Estate
	$\frac{9}{20}$	$\frac{7}{20}$	$\frac{3}{10}$	$\frac{3}{10}$	$\frac{1}{4}$	$\frac{3}{10}$	$\frac{2}{5}$	$\frac{1}{5}$	$\frac{3}{5}$	$\frac{13}{40}$	$\frac{1}{5}$
	$\frac{1}{10}$	$\frac{9}{40}$	—	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{20}$	$\frac{1}{5}$	$\frac{1}{20}$	$\frac{1}{5}$	—
	$\frac{1}{4}$	$\frac{1}{10}$	$\frac{3}{20}$	$\frac{1}{10}$	$\frac{1}{10}$	$\frac{1}{10}$	$\frac{1}{20}$	—	$\frac{1}{20}$	$\frac{3}{20}$	$\frac{1}{20}$
	—	—	$\frac{1}{20}$	$\frac{1}{10}$	$\frac{1}{10}$	—	—	—	—	—	—
	$\frac{1}{5}$	$\frac{3}{10}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{3}{10}$	$\frac{2}{5}$	—	$\frac{1}{5}$	$\frac{3}{20}$	$\frac{1}{5}$	—
	—	$\frac{1}{40}$	$\frac{1}{4}$	$\frac{1}{10}$	—	—	$\frac{1}{2}$	$\frac{2}{5}$	$\frac{3}{20}$	$\frac{1}{8}$	$\frac{3}{4}$

Table 3.1: Environmental weights matrix

## 3.2. Social weights

The social dimension is a cohesive plot going beyond any sector-based industrial policy, connecting social regulation principles valuing the management of human capital. This universe is not as much closely related to the company's main activity, as to its operations effectiveness in affecting and shaping people's and communities' labour and welfare conditions. Stating "The role of business enterprises as specialized organs of society performing specialized functions, required to comply with all applicable laws and to respect human rights"[155], the United Nations Guiding Principles on Business and Human Rights outlines that in risk management strategies, all companies should embrace human rights due diligence to identify, prevent and mitigate human rights impacts. A culture promoting justice, equality and universal access to human rights, contradicts the high social risk exposure of all industrial federations. In this scenario, focusing on the improvement of the ESG level of social sustainability, all businesses are responsible. If in the environmental pillar we perform a sector-specific analysis, assessing the materiality of one key factor at a time, for the purposes of the social weights setting we pursue a different strategy. We give all the social responsibilities analysed to each industry, assigning only positive weights. We should take the cue from key factors measuring their part in a long-term business scenario with the same cross-cutting score on all industries. However, if social issues' impacts encompass the various market sectors, in some cases, for certain industries they are even more significant than others, requiring a heavier weight. To find out what needs to be highlighted, we combine MSCI guideline with the existing documentation. We continue in the same direction of MSCI, overlooking S&P which develops a social study focusing only on four – of our eight – key factors, including workforce and diversity, safety management, communities, customer engagement. For completeness we point out that, to comply with GRI 400 social serie, we include the key factor modern slavery which neither MSCI nor S&P explore. Following the environmental case, MSCI proceeds the factor by factor analysis. Contrarily, we distinguish between more significant factors and base ones, identifying only two weights types. Thus, we no longer exploit the agency evaluations as initial conditions to start each factor's weight discussion, but simply as guidelines detecting those issues that need to be stressed.

In the following we examine only the key factors for which at least one sector needs greater consideration, focusing on the relevant industries and/or sub-industries as classified in the GICS[156]. Each argument ends up with a final table marketing all the sectors which should pay further attention to the considered issue.

We conclude the section with the final social weights discussion.

### 3.2.1. Occupational and customer health and safety

Since their inception, industrial operations have posed significant hazards both to humans and the environment, thus efforts have been made for reducing these risks and achieving safer operations. Occupational health and safety (OHS) culture is gaining attention all around the world as a way to lessen the likelihood of these catastrophic events.

OHS may have to do with a company leading activity and its support processes, or it can be related with minor actions. Consider construction industry example. From careful engineering calculations to their proper deployment, structures steadiness is an essential process safety need. However, events such as falling from a scaffold, colliding with falling objects, distortions, fractures, cuts or bruises may arise from secondary tasks.

High-risk industries are industries whose business activities result in significant risks, with serious accidents as in mining, chemical production, nuclear power generation, aviation and construction.

**Coal & Consumable Fuels - Metals & Mining** mining is one of the industrial sectors with the greatest incidence of work-related accidents. Although significant strides have been achieved in mining for the management of OHS risks, the sector is responsible for 8% of workplace fatalities, and comparable mishaps and catastrophes keep repeating at mine sites all over the world[157]. The prevailing perception is that mining should be treated differently from other sectors due to the gravity and uniqueness of the faced risks, the historically high rate of work-related deaths, illnesses, and injuries, and its record of periodic disasters involving multiple victims like, for example, the Russian Listvyazhnaya coal mine disaster on 2021 which caused 51 deaths. Thus, some stakeholders have claimed specialised knowledge for an efficient regulatory monitoring and a specific regulatory system.

**Chemicals** the chemical industry is another of the first sectors that must carefully analyse and treat its unavoidable harmful effects. With the increasing shift to chemicals manufacturing, employees are more and more exposed to its detrimental agents causing accidents and chronic professional diseases.

Accordingly, some of these high-risk industries have been leading the way in safety management systems. Especially due to public pressure, the nuclear industry has seemed the most careful for a long time, subsequently followed by chemical and aviation ones.

In particular, many businesses have recently invested in team education to develop necessary abilities for efficient collaboration since, if personal safety training is a commonplace, lots of assessments strongly demonstrated that poor coordination is a substantial cause of unexpected events.

**Energy** due to dangers associated with high temperature, high pressure, and hydrocar-

bons, the likelihood of an event happening in the oil and gas industry is significant.

In March 2005, at the BP Texas City refinery a cloud of hydrocarbons was released from the isomerization unit<sup>72</sup>, wounding 180 people and killing 15.

After one month maintenance, the tower was restarted without the application of the Pre-Startup Safety Review, a collection of operation, safety, service and emergency procedures and equipment, able to identify and correctly manage all dangers. Furthermore, a range of serious problems with safety features were not resolved including a pressure-control valve, a faulty high level alarm, and a defective sight glass. Lack of distress alarms and monitoring tools did not warn the work team about overfilling and overheating of the splitter; the subsequent opening of the safety valves caused the disaster since the massive mass of discharged fluid generated a cloud of flammable vapours, which was ignited by a diesel vehicle causing an explosion[158]. According to the US Chemical Safety and Hazard Investigation Board<sup>73</sup>, there have been numerous technical and organisational faults. American refinery explosion is a concrete example of the great danger represented by an inadequate safety management, cutting across organisation's areas and departments.

**Electric Utilities** in nuclear operations security monitoring is one of the most significant factor, regarding its harmful radiation emissions into the environment and workforce management, especially in emergency situations. In these scenarios, employees should analyse alerts, evaluate readings and detect unusual patterns in many instruments to real time grasping the issue. Frequently, alarms from various systems activate simultaneously, putting even more pressure on the agents. Human error is guilty in the majority of nuclear incidents. Certain workers' limit should be supported by an adequate user interface, even if this does not simplify human labour. Safety measures automation in particular needs to be assisted by operator control. Although first digitalization attempts, most nuclear facilities employ outdated operation and control techniques, lowering efficiency and increasing the risks. However, in Industry 4.0 era, numerous studies focus on artificial intelligence application in many fields of nuclear power plants[159].

Three Mile Island (TMI), Chernobyl and Fukushima Daiichi incidents are the three most significant nuclear disasters of the previous fifty years in order of occurrence, which led to the need for more stringent measures so that security demand has taken on new urgency. TMI, in particular, brought out the awareness that human influence greatly contributes to incidents developing, damaging forever public perception of nuclear energy. Faults in the system and blockage of the pilot-operated relief valve (PORV), resulting in the coolant spill, started the disaster. Furthermore, mechanical failures were compounded by operators

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<sup>72</sup>The isomerization is a process transforming light naphtha, coming from crude oil treatment, into gasoline.

<sup>73</sup>The US Chemical Safety and Hazard Investigation Board is an independent federal agency exploring industrial chemical accidents.

inability to recognise the loss-of-coolant accident<sup>74</sup>. The personnel had not been educated to fully know the PORV behaviour, which would have suggested to seek out additional evidence that the valve was closed in the downstream temperature sensor.

The Nuclear Regulatory Commission<sup>75</sup> sets particular specifications for safety-related equipment, which is by definition the system preventing disasters and whose failure could cause or worsen an accident. Even though NRC and Metropolitan Edison<sup>76</sup> reviewed TMI design, neither party has focused on PORV's lack of safety-related designation, thus it has not been tested under accident conditions, which more likely would not have passed. Broadly speaking, there has been a lack of accuracy in components design and security tools handling.

The accident serves as a lesson for new power plants developers: since the design process, they should guarantee thoroughness of the plant's safety study without relying on utility reviews and regulatory assessments to rectify flaws. One has to wonder whether a system has a safety role and, in that case, it must be developed for both the operational and safety function[160].

**Construction & Engineering - Homebuilding** the construction industry is considered one of the most threatening industries worldwide. Due to its breadth, workers are exposed to all kinds accidents. Poor OHS conditions combined with difficult and dangerous working environment can manifest themselves in an increase in employee illnesses. The industry has reported the highest number of fatalities of any other, and it is also at the forefront of disability cases.

Lack of awareness, inadequate training, insufficient supervision, judgment error and negligence are the main causes. Moreover, tiredness resulting in loss of attention can cause dangerous situations. Difficulties and fatal accidents will unfortunately continue to happen in construction sites, even if training on control and safety measures can help to mitigate and minimise them, while teaching proper practices for machines using. Failing to address such OHS issues is the major concern; however, the sector must concentrate on them insofar as its urgency has tripled compared to other sectors[161].

**Air Freight & Logistics - Airlines** air traffic control is another difficult and challenging profession. A pilot has the primary responsibility to maintain an effective, safe, and orderly traffic flow, preventing crashes. In addition, the working schedule frequently demands irregular hours, making it more difficult to have a good rest, and long periods

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<sup>74</sup>A loss-of-coolant accident (LOCA) is a nuclear reactor failure which can lead to reactor core damage.

<sup>75</sup>The Nuclear Regulatory Commission (NRC) is a US independent agency ensuring public and environment health protection from radioactive material, issuing licences and regulating the civilian use of nuclear energy.

<sup>76</sup>Metropolitan Edison is a US company providing utilities services. At the time of the accident, the company owned the plant together with other two utilities.

in isolation from family and friends. Thus, a pilot's lifestyle is often subjected to severe occupational stress impacting service and health, worsening or even contributing to the appearance of anxiety and depression which, in turn, feed strain, impaired concentration and reduced performance. Occupational stress and overexertion appear in all the workforce, however, if present in the flight crew, they could generate serious security gaps which could lead to irreversible disasters.

In 2012, a JetBlue scheduled passenger flight from New York to Las Vegas, was hijacked to Amarillo, Texas due to the captain nervous breakdown. Seeing the captain's weird behaviour, who started screaming sentences on terrorism and religion, the prime officer closed him out of the flight desk, preventing what could have been a major catastrophe. In 2015, a commercial Germanwings flight from Barcelona to Dusseldorf crashed in the French Alps killing all 150 passengers. The incident was intentionally caused by the prime officer who suffered from mental health problems. He has previously suspended his airline training for a serious depression, with suicidal impulses, then, after passing medical tests, he restarted flying. Following the disaster, it was found a medical certificate stating the pilot's inability to work the day of the incident.

After Germanwings tragedy, the International Civil Aviation Organization<sup>77</sup> and the Federal Aviation Administration<sup>78</sup> reassessed safety regulations, and FAA introduced the Pilot Fitness Aviation Rulemaking Committee made up by a diverse range of individuals, including specialists in aerospace medicine, psychiatry, and psychology, focusing on pilot mental fitness[162]. Despite all, aviation industry continues to be threatened by mental health issues. Personnel education and an improvement in aviation medical care could be a useful way to reduce these events towards safety management systems enhancement.

All working processes and actions involve taking risks. Each day physical and mental accidents take place in the work place, having harmful effects on human and environmental health, but also on businesses, feeding loss of credibility and financial losses. Nowadays we talk a lot about the necessity of identify and assess factors undermining OHS and, to gain reputation and long-term productivity, industries are trying to take into account these issues, particularly those sectors whose operations expose them to a higher risk of accidents including Energy, Materials, Industrials, Consumer Discretionary and Utilities.

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<sup>77</sup>The International Civil Aviation Organization (ICAO) is a UN specialised agency promoting international air travel planning and development to assure its safe and orderly development.

<sup>78</sup>The Federal Aviation Administration (FAA) is the agency of the United States Department of Transportation regulating and supervising civil aviation in the country and in the surrounding international waters.

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Healthcare	Financials	Information Technology	Communication Services	Utilities	Real Estate
	•	•	•	•	-	-	-	-	-	•	-

Table 3.2: Occupational and customer health and safety relevant sectors.

### 3.2.2. Training and education

Employees are the backbone of the company and managing them is the most significant concern. Although competent workforce strengthens organisations’ human capital improving their own satisfaction, a McKinsey & Company<sup>79</sup> study focusing on occupation and skills development in nine nations, found that 43% of the surveyed businesses stated they were having trouble finding qualified personnel[163].

**Software** being software development highly technical, it requires experience in many software processes, tools and techniques. When hiring or forming project teams, software engineering (SE) companies focus on their need for specific skills and abilities. However, a certain poor skills quality derives from the lack of a well-trained workforce able to deep understand SE, making necessary to fill important information gaps in training future employees[164]. More precisely, there are major knowledge gaps in configuration management, SE models and methods, SE process, design and testing[165]. Improvements in these directions may enhance graduates’ employability and can be achieved through university education and onboarding.

**Real Estate** in making business decisions on real estate purchase, investment, financing, and development, there needs to be comprehensive knowledge for researching, analysing, examining, valuating, forecasting, and mitigating the numerous hazards involved. Environmental and social factors, functional design, future adaptability and sustainability concerns affect real estate. In this scenario, the industry supports practical and applied research and links creation with academia[163].

**Electric Utilities** nuclear energy wave and desire together with the retire of specialised personnel have recently caused a great shortage of professional human resources. Employees deficiency is one of the major challenges for nuclear development, thus countries

<sup>79</sup>McKinsey & Company is a global management consulting firm, founded in 1926, that provides expert services to businesses, governments, and other organisations.

investing in driving nuclear growth should consider mandatory and specific school modules to train the required qualified staff. More precisely, about 16% of the total industry's workforce are experts technical nuclear scientists or engineers with tertiary education. Then, there are employees with engineering knowledge and other support figures. Furthermore, it is important that workers recruiting and training start about five years before nuclear power plant construction to involve them throughout the whole process, from its design to its final testing[166]. Recruitment for positions such as operations, reactor engineering, radiological safety and training could start several years before its effective need. To achieve these rigorous requirements, workforce planning needs to be properly thought out and established at the beginning of human resource development program.

**Healthcare Providers & Services** healthcare facilities are run by trained and qualified personnel handling medical issues from physical to mental illnesses. The sector is knowledge-based and demands high expectations for its employees' insights and skills. Doctors, nurses and laboratory technicians provide highly specialised services to patients including nephrology, cardiology, plastic surgery, neurology, urology, orthopaedics, maternity, paediatrics, geriatrics and many others. To prevent errors which could compromise patients' safety, investments into lifelong learning are essential insofar as healthcare knowledge rapidly evolves. Throughout their entire career, doctors cannot ignore professional updating and are forced to catch up on ongoing developing trends, to maintain high performance, or even improve it. In this scenario, medical facilities have the responsibility to ensure lasting learning providing adequate opportunities improving employee satisfaction and patients safety. Moreover, by law, healthcare structures are forced to monitor workforce's satisfaction with the implemented education system[167].

Personnel development is an integral part of human resources managing insofar as investing in the workforce means investing in the future. Skilled employees enable greater productivity and more high-quality jobs. Moreover, looking at personnel training not only as a preparatory phase for entering the working world but as a continuous process, is vital to keep up with global market changes. This concept of lifelong learning is even more significant in those realities where specific technical skills undergo a continuous evolution. In training and education context, Healthcare, Information Technology, Utilities and Real Estate require increased attention.

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Healthcare	Financials	Information Technology	Communication Services	Utilities	Real Estate
	-	-	-	-	-	•	-	•	-	•	•

Table 3.3: Training and education weights relevant sectors.

### 3.2.3. Communities

In 1980 the Sardar Sarovar Project planned building a dam on the Narmada River in western India, for supplying electricity and agricultural water to downstream regions. As a result, more than 200,000 indigenous people living along the upstream areas were forcibly moved, without sufficient compensation or means of livelihood restoration. The project was strongly criticised worldwide and its construction was interrupted several times due to oppositions and suspension orders.

Multiple and complex human interventions, such as infrastructural megaprojects, mining activities, hydroelectric power plants and biofuels expansion, put under pressure strategic and vital natural resources, threatening worldwide communities. Businesses' services including energy, waste, and water management are frequently linked to environmental issues such as emissions, pollution, resource consumption, and land use; as a result, these activities are expected to assume responsibility for the effects they may have on the comfort and well-being of the local communities where they operate.

In general, if a certain operation or business is viewed as socially unacceptable, its viability may be in danger. When their behaviour falls short of community expectations, companies run the risk of becoming the target of public censure coming in a variety of direct forms, as well as through legal and governmental proceedings. Thus, sectors bearing strong institutional pressures for their environmental impacts' heaviness and gravity, including extractive, construction and utilities industries, require community engagement as a vital mean to obtain public support, particularly when their projects affect indigenous peoples. Civil regulation frequently takes the form of the sway that particular communities have by virtue of a social licence to operate. Therefore, long-term business success necessitates a "social licence to operate", especially in industries with highly visible corporate activities, long time horizons and strong exposure to global markets. Moreover, natives consultation and involvement are frequently demanded by international, national, or re-

gional standards, and their rights are defined by international treaties and conventions, including consultation processes, conservation of natural areas, and natural resources, culture, education and health management. The Indigenous Land Use Agreement in Australia, for instance, claims extractive companies to establish contractual agreements with native groups. However, the main problem is that companies' social, environmental and economic concerns are largely window dressing that has the strategic aim of relieving public worries about their intrinsically destructive character.

**Energy Equipment & Services - Coal & Consumable Fuels - Metals & Mining - Forest Products - Utilities** extractive resources developments including oil, gas, mining and forestry, are labour intensive processes with a profound impact on economy, society, and environment. Through the conversion of natural resources into financial resources, their investment into environmental and social programs, and the growth of social capacities and skills, infrastructure, and business, these developments have the potential to bring economic, social, and even environmental opportunities. Indigenous peoples have not benefited significantly from large-scale resource exploitation on their lands and, moreover, they have suffered the negative effects on their cultures, economics, and societies. If on one hand, extractive resources developments would like to proceed not paying attention on global concerns, on the other hand they find themselves in disagreement with the same challenges, since they run serious financial, reputational, and commercial risks not involving communities.

In recent decades, aboriginal groups have hardly fought to change this situation. In some cases, they have completely opposed development, fuelling conflicts and protests, while in many others, they have sought a fundamental adjustment in the distribution of the benefits and costs associated with resource exploitation.

Mining has probably sparked the most conflicts over land usage of any other sector. Although miners generate significant economic benefits, land demands they make on communities prevent the growth of other potentially profitable industries, including small companies, merchant services, and small-scale fishing. Additionally, heavy mining operations can have a negative impact on the environment, making the area unusable for a variety of other industrial uses, like farming and forestry.

Guidelines for community and stakeholder cooperation have been introduced by sector-specific international organisations such as the International Council on Mining and Met-

als<sup>80</sup>, the Alliance for Responsible Mining<sup>81</sup>, and the International Finance Corporation<sup>82</sup>. Based on the ICMM recommendations, BHP Billiton<sup>83</sup>, for example, has created an indigenous peoples policy statement and a set of actions. Its commitment and policy involves "undertaking participatory and inclusive social and environmental impact assessment; seeking to agree on and document engagement and consultation plans with potentially impacted indigenous peoples; [and] working to obtain the consent of indigenous peoples to BHP Billiton activities consistent with the ICMM Position Statement"[168].

However, this scenario results in worrying failures to integrate sustainability behaviours, examples of which are provided below.

The Canadian Tahoe Resources' Escobal silver mine<sup>84</sup> has been highly obstructed by the Xinka community<sup>85</sup>, due to the mine's negative impacts and the lack of consultation in its development. According to Tahoe, nearly 1.7 billion Canadian dollars were invested in the mine, which, in turn, boosted the local economy. Nevertheless, since Xinka people were not properly consulted before license's issuing in 2013, indigenous protests resulted in significant financial losses and the suspension of the mine's operating licence as of July 2017.

In South America, the Lithium Triangle<sup>86</sup> holds more than half of world's lithium resources, gaining attention because of its key influence on the development of green technologies and cleaner energy sources. Recently, this area has been put under pressure by the annually 20% increase in global lithium production.

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<sup>80</sup>The International Council on Mining and Metals (ICMM) was established in 2001 as a CEO-led leadership organisation aiming to enhance the mining and metals sector's performance in terms of sustainable development.

<sup>81</sup>The Alliance for Responsible Mining (ARM), founded in 2004, is a leading global authority on artisanal and small-scale mining (ASM). It transforms the ASM industry into a socially and environmentally responsible industry, while raising the standard of living for artisanal miners, their families, and communities.

<sup>82</sup>The International Finance Corporation (IFC) is an international financial organisation that supports the growth of the private sector in less developed nations by providing asset management, advisory, and investment services. It is a member of the World Bank Group, a family of five international organisations issuing leveraged loans to developed countries.

<sup>83</sup>BHP Group Limited, previously BHP Billiton, is an Australian multinational natural resources company, one of the world's biggest mining company, involved in the production of iron, steel, copper, silver, aluminum, oil, and gas.

<sup>84</sup>Tahoe Resources Inc. is a mining company involved in the extraction of silver and other precious metals. It was acquired in 2018 by Pan American Silver, another mining firm which is considered one of the world's biggest silver producers. The Escobal mine is a large silver mine located the south of Guatemala.

<sup>85</sup>The Xinka are an indigenous people of Mesoamerica.

<sup>86</sup>The Lithium Triangle is a lithium-rich area that straddles the borders of Chile, Bolivia, and Argentina in the southwest corner of South America. It is a geographic triangle of lithium resources underneath the salt flats.

Indigenous Atacama<sup>87</sup> live in poverty in these lands, theater of a shocking contrast: while local communities struggle to pay for sewage facilities, drinking water, and heating for schools, remote companies profit from their regions' natural wealth. Luisa Jorge, the leader in Susques, which is one of the six communities around the area, remarked "We know the lithium companies are taking millions of dollars from our lands, [...] The companies are conscious of this. And we know they ought to give something back. But they're not." The natives are also concerned about the worsening of the dry land's water shortages, as a result of lithium facilities' high water use.

Since Chile implemented its Indigenous Law in 1993 and ILO Convention 169<sup>88</sup> was adopted in 2008, communities living in Salar de Atacama<sup>89</sup> and the lithium industry are in negotiations. Along with outright opposition, these conversations have also included a range of participation options, including environmental monitoring or benefit sharing in the form of jobs and financial compensation[169].

In this way, benefit sharing is a way to build relationships between indigenous peoples and resource companies on a global scale. The concept was formalised in the Convention on Biological Diversity and emphasises the necessity of sharing the benefits from human and non-human resources use with the parties responsible for providing the access to those resources. Another attempt of benefit sharing was made by Lukoil, a Russian oil company, and Nenets Samoyedic indigenous community. Benefit-sharing agreements in Russia are widely varied and are governed by a confusing and contradictory network of federal, regional, and local regulations as well as less formal agreements between companies and local authorities. Russia houses many isolated indigenous communities, especially in the Arctic and sub-Arctic regions. These peoples are suffering from the direct consequences of their territory's resources exploitation, oil and gas activities, and pipelines construction. Mining and related facilities are nearby villages, thus people drink contaminated water, eat contaminated fish and breathe poisoned air[170]. Commercial oil production started in Russian Nenets Autonomous Okrug<sup>90</sup> and Komi Republic<sup>91</sup> in the late 1980s and early 1990s respectively. Russian Arctic communities have reacted differently to the expansion of the oil industry on their territories. Residents acknowledge the opportunity to profit financially from oil firms, though at the same time their arrival endangers traditional ways of living because of threats to the tundra ecosystem. Thus, in that years, the Nenets protested environmental destruction in their lands. Yasavey, an indigenous

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<sup>87</sup>The Atacama people are indigenous from the Atacama Desert, the Altiplano region in the north of Chile and Argentina, and southern Bolivia.

<sup>88</sup>ILO Convention 169 is the Indigenous and Tribal Peoples Convention (1989), an international agreement aiming to improve the living conditions of indigenous peoples around the world.

<sup>89</sup>The Salar de Atacama is the largest salt flat in Chile.

<sup>90</sup>Nenets Autonomous Okrug (NAO) is a federal subject of Russia in Eastern Europe.

<sup>91</sup>The Komi Republic is a federal subject of Russia in Eastern Europe.

organisation working on cultural preservation and socioeconomic development, assisted in mediating and ending the protests, exploiting its strong links to the local administration. As a result, the NAO created regional legislation on indigenous peoples' rights. Article 29 of the Land Law of the NAO (2005), for example, recognises indigenous' right to claim damages, while the Law on Reindeer Herding (Article 17.4, 2002) allows Yasavey to help communities in achieving agreements with oil companies[171]. Despite these attempts, the path towards full and inclusive benefit sharing is still challenging.

In Canada, instead, according to private participation, impact, and benefit agreements, there are currently numerous northern aboriginal people employed at the operating mines. In this scenario, Diavik diamond mine<sup>92</sup> employed about 36% indigenous workers in 2003. Similar commitments were made by BHP Billiton for its Ekati mine<sup>93</sup>[172].

### **Transportation Infrastructure - Construction & Engineering - Homebuilding**

worldwide population increase drives up the urge for new and upgraded infrastructure to meet electricity, water, transportation, housing, and social needs. Diverse businesses, including mining, extractives, energy, water, sewage, architecture, construction, urban planning, engineering, and social welfare, call for these structures. According to the McKinsey Global Institute<sup>94</sup>, 57 trillion US dollars are required in global infrastructure investments just to keep up with demand. Australian infrastructure industry, in particular, is booming. Furthermore, 100 billion Australian dollars funding will be employed. In this scenario, the interaction between communities and infrastructure projects is significantly challenging. Industry expansion and sizable investments carry with them widespread discontent in Australian communities, which leads to a host of policy questions, accountability concerns, socioeconomic critiques, and dissatisfaction about how locals are involved in projects planning and delivery. In addition, popular opposition raises prices and creates obstacles for providing infrastructure. Over the past ten years, it appears that 20 billion dollars worth of projects have been delayed and cancelled, or shelved after being finished, due to Australian community uprisings. In this context, the Next Generation Engagement Project<sup>95</sup> wants to identify the key engagement issues and gaps in the delivery of new infrastructure, and solve them by conducting applied research with business, the government, and the community[173].

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<sup>92</sup>The Diavik diamond mine is a diamond mine in the North Slave Region of the Northwest Territories in Canada.

<sup>93</sup>The Ekati diamond mine is Canada's first surface and underground diamond mine.

<sup>94</sup>The McKinsey Global Institute is the McKinsey & Company's business and economics research arm, founded in 1990 to gain a deeper understanding of the changing global economy. Its mission is to give leaders in the commercial, public, and social sectors facts and insights they need to make management and policy decisions.

<sup>95</sup>The Next Generation Engagement Project is a pioneering research initiative on a worldwide scale based within the Australian National University Institute.

The situation is anything but simple and resolved; there needs to definitely overcome contradictions between rhetoric and reality around corporate sustainability, with regard to communities respect, engagement and involvement. Investing the necessary time in conflict prevention and resolution, especially when it comes to developing long-term relationships through engagement with local communities, is often in contrast with short-term production goals or aggressive construction timelines. Understanding these issues may also be hampered by a failure to find links between different budget lines like, for example, those between security costs and community relations. In addition to the lack of motivation to engage in indigenous concerns outside of state pressure, and perform poorly when trying to engage the public, industry representatives typically know very little about indigenous land use rights and traditional economies. Following this way of reasoning, the rise of socially responsible investment brings with it new standards for corporate sustainability and relationships with locals should and are more and more scrutinised. Overall, growing societal challenges have an impact on all business sectors. Companies, especially those in Energy, Materials, Industrials, Consumer Discretionary and Utilities sectors, need more and more to address social and environmental issues insofar as they have the greatest bearing on local communities health and well-being.

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Healthcare	Financials	Information Technology	Communication Services	Utilities	Real Estate
Communities	•	•	•	•	-	-	-	-	-	•	-

Table 3.4: Communities weights relevant sectors.

### 3.2.4. Product responsibility

Sustainable consumption is an ongoing challenge worldwide. Every day resources including materials, water, energy and soil, are exploited consuming the supply chain. Growing consumers expectations in global challenges are the outcome of interconnected trends, first of all material interdependence requiring coexistence but also cooperation. People should know that their life needs do not affect future requirements, thus enhancing product labelling could be very useful. Eco-labelling relies on products powers of information and facilitates communication between government, society, industry and producers.

Joining prescriptive regulation and market potential, it is an efficient tool to more directly involve consumers. It differs in verified third-party labels, communicating in a simplified way the results of a rigorous evaluation process, and non-certified claims by producers. In 2008, Windex glass cleaner by SC Johnson<sup>96</sup> showed the addition of a little green label with the words "Greenlist Ingredients – Same Great Product!" alongside a leaf. Only three years later, subjected to two legal actions for greenwashing accusations, the claim was removed. Plaintiffs stated that it was the company to assert the rules dictating which products could and could not bear the green label, even if, apparently, it seemed to have been granted by an impartial third-party[174].

This is an example of how these effective policy communication instruments are not so adequately designed to let people properly meet their desire extent of sustainable consumption. There is a gap between policy goals on sustainable development and effective available environmental and social claims.

**Food Products** in this context, to make fishing more sustainable, changing its consumption is essential insofar as what, when and how we eat, purchase and sell fish impact seafood. In choosing certified fish purchase, consumers' market preference rewards certified fisheries, encouraging more and more activities to undergo the certification and improving global trade. However, despite reaching commitments to provide technical information to a non-specialised audience, the communicated level of sustainable data remains the main issue. There is still room to improve consumers' interests safeguarding in order to face food sustainability, with particular attention to food waste challenge.

In this regard, transparency requirements should be extended to many more products and, moreover, information contextualization should be further examined. For example, when approaching to buy fish, one should know if it is a critical time for the maintenance of viable population size. Only an appropriate and well-developed context allows consumers to make informed and conscious sustainable decisions[175].

Moreover, the food industry is often responsible for false and tricky promises in its advertisements. Danone<sup>97</sup>'s yogurt Activia has been sponsored as "clinically" and "scientifically proven" to boost people's immune system and regulate digestion. Thus, its price was 30% higher than similar products. However, in 2010 the court declared these claims not proven, condemning the company to compensation and ordering to remove the terms from Activia labels. In the same year, Kellogg's<sup>98</sup> Rice Krispies cereals advertising has been interrupted as it was declaring that they strengthen the immune system thanks to "25% daily value of antioxidants & nutrients — vitamins A, B, C and E", and the company was forced to

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<sup>96</sup>SC Johnson is a multinational company selling products for household cleaning and other consumer chemicals.

<sup>97</sup>Danone is a multinational company selling food products.

<sup>98</sup>Kellogg's is a multinational company selling breakfast food and other products to eat.

compensate its damages[176].

**Specialty Retail** the food marketing is not the only one exploiting fake news as a dangerous form of mass persuasion. According to 2020 and 2021 Earthsight<sup>99</sup> investigations, IKEA<sup>100</sup> has been producing wooden chairs exploiting forests of the Carpathian beech, an area housing endangered animals. However, its timber has the most esteemed Forest Stewardship Council<sup>101</sup> certification and IKEA is one of the best companies in its business sustainable management worldwide[177].

**Chemicals - Pharmaceuticals** chemicals are a part of daily life. Consider that more than 100,000 chemical substances are utilised worldwide, with around 1,000 new chemicals introduced to the market each year. Many of them, especially when misused, can represent a real danger being harmful and toxic to human health and the environment. To guarantee their clear and orderly classification, reducing ambiguity and confusion at the user level, the Globally Harmonized System<sup>102</sup> was adopted at the Rio Earth Summit. Companies are made responsible for the security of the compounds they place on the market. More precisely, it includes easily grasping symbols for chemicals production, transportation, use, and disposal. In this regard, Europe established Regulation (EC) 1907/2006 (REACH) and Regulation (EC) 1272/2008 (CLP). CLP complements the earlier and aligns with GHS, guaranteeing the safety handling of these compounds through risks communication. When producing and using these substances, the industry must declare their potential dangers via classification, labelling and packaging standards, and via making use of hazard and precautionary statements, pictograms and signal words. Similarly, a safer use of medicines requires medication labelling to provide consumers and patients with accurate information. Compliance with current regulations are essential tools for the marketing of pharmaceutical products as it cuts prescription errors and inappropriate drug uses.

In 2020, a project by ECHA's Enforcement Forum<sup>103</sup> analysing imported products into the EU, pointed out that 23% of those inspected, containing illegal product quantities or making improper hazard labelling, was not compliant with REACH and CLP regulations[178].

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<sup>99</sup>Earthsight is a non profit organisation investigating on issues of human rights and environmental justice to condemn environmental and social crimes linked to global consumption.

<sup>100</sup>IKEA is a Swedish multinational company which creates and sells ready-to-assemble furniture, kitchen appliances, home accessories, as well as a variety of other home products and services.

<sup>101</sup>The Forest Steward Council (FSC) is a non profit organisation aiming to protect healthy and resilient forests. To this end, it introduced an international forest certification system.

<sup>102</sup>The Globally Harmonized System (GHS) is a an international system of classification for health, physical, and environmental hazards which specifies which information needs to be reported on the labels of hazardous chemicals as well as safety data sheets.

<sup>103</sup>ECHA is the European Chemicals Agency promoting the safe use of chemicals by managing and coordinating processes of registration, evaluation, authorisation and restriction. Its Enforcement Forum is a network of authorities ensuring compliance with regulatory requirements.

Labelling and marketing tools in general are important means to inform the buyer about significant issues concerning the product you want to sell, from its chemical composition to its environmental and social impacts. Industries dealing with product sale exploit these tools to manage the relationship with the client, satisfying the needs of a market with a profit. Simultaneously, activities producing compounds somehow dangerous must convey warning and alert messages. Thus these issues become fundamental in sectors like Materials, Consumer Discretionary, Consumer Staples and Healthcare.

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Healthcare	Financials	Information Technology	Communication Services	Utilities	Real Estate
	-	•	-	•	•	•	-	-	-	-	-

Table 3.5: Product responsibility relevant sectors.

### 3.2.5. Data privacy

In 21<sup>st</sup> century data have become such a fine resource that they have been deemed the oil of our time. Internet and the growing use of IoT make possible solutions collecting unheard volumes of data, thus information security and breaches are among organisations biggest challenges. Think that in 2020, even if companies worldwide registered 3.932 violations accounting for about a 50% down on the previous year, the total number of exposed records was at its highest[179].

**Healthcare** as a result of information and communication technologies developments, healthcare services have improved. Electronic clinical records make medical data always accessible advancing patient care and service efficiency. However, as a side effect, these databases are often accessed by unauthorised users. Compared to other industries, the sector is among the worst picked on: in 2018, 536 of the 2.216 reported violations belonged to healthcare. Moreover, on the dark web a patient's record file could cost hundreds of dollars, accounting for 65% more than in the other sectors. If in the period from 2014 to 2019 the average price of a breached record rose by 3.4%, for the healthcare rose by 19.4%. Since any type of corruption could build up irrevocable damages, the most concerned issue lies in the sensitivity of medical data, thus they require large protection[180].

**Communication Services** the online world collects huge amounts of sensitive infor-

mation. Social networks, in particular, are becoming their hub as when logging in users are often asked to disclose large quantities of their personal details. If you think that Facebook<sup>104</sup> had 3.7 billion users daily online in 2017, it is easy to realise the scale. In this context, self-disclosure is a necessary mean for showing that consumers make aware choices in releasing. However, despite legislative efforts, individuals often give their consent to process personal details freely, ignoring how they will be handled for organisational and/or third parties purposes.

Scandals like Facebook's, Yahoo<sup>105</sup>'s, and LinkedIn<sup>106</sup>'s data breaches show how little users know related risks. Facebook's case, also known as Facebook-Cambridge Analytica scandal, is one of the biggest political outrage occurred at the beginning of 2018, achieved through the Facebook app "mydigitallife" created by Aleksandr Kogan. Kogan is a professor at the University of Cambridge who worked for Cambridge Analytica, a British political consulting closed in 2018 in the course of the scandal. He offered "mydigitallife" as a personality quiz on Facebook that collected its users' information about their identity and social network activities, as liked contents. Thus, the app collected data of more than 87 million people, transmitting them to the political consulting firm, Cambridge Analytica, for the purpose of manipulating the public in view of US elections[181]. In 2013 Yahoo's data violation is one the biggest in history with 3 billion accounts impacted. Digital thieves have stolen names, birth dates, telephone numbers and passwords, protected by an easy encrypted security system. Furthermore they have also taken useful information to hacker users' other accounts such as security questions.

**Financials** to safeguard vulnerable consumers' information, financial organisations must take care of information security at all levels, from data centers to IT, sales, accounting, and HR units. The sector is threatened by rising and changing cybersecurity attacks, particularly the cloud as it collects about the 70% of critical data. For these reasons, suppliers' cloud services must be carefully examined for flaws proving and secured and the IT department must constantly perform network tests to detect vulnerabilities[182]. Before JPMorgan Chase<sup>107</sup> hack in 2014, banks were thought to be protected against cyber attacks thanks to their security investments. The violation is one of the most significant cyber attack in history as it affected 76 million families and 7 million small businesses stealing account holders' names, phone numbers, home addresses and emails. Even if the leak did not go further, the episode is incredibly worrying since the bank is the American

<sup>104</sup>Facebook is an American online social media and social networking service.

<sup>105</sup>Yahoo is an American web services provider.

<sup>106</sup>LinkedIn is an employment-oriented social network used for professional networking and career development.

<sup>107</sup>JPMorgan Chase is an American multinational investment bank and financial services holding company. It is one of the American Big Four banks, together with Bank of America, Citigroup and Wells Fargo. It is the biggest bank in the United States.

biggest and collects highly sensitive financial information.

Since companies are increasingly relying on digitalization and IT-optimized processes, recent years have seen data breaches on the front page, putting more and more business systems at risk. Data breaches are expensive for everyone: users lose personal data, credit cards and accounts, while organisations are sanctioned with ruined reputation and legal costs. In this awful scenario, all businesses must address this issue to guarantee a comprehensive privacy protection, especially those handling the most attractive information like Healthcare, Financials and Communication Services.

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Healthcare	Financials	Information Technology	Communication Services	Utilities	Real Estate
	-	-	-	-	-	•	•	-	•	-	-

Table 3.6: Data privacy weights relevant sectors.

### 3.2.6. Final discussion

In the burden of corporate social responsibilities, all industrial sectors are more responsible for some key factors, implementing one, two or at most three out of eight, further risky social actions and behaviours. We classify the industrial sectors into three different categories  $k_i$ ,  $i \in \{1, 2, 3\}$ , basing on the number  $i$  of their most significant issues (see Table 3.7). We denote with  $y$  the weight given to each of these factors, stressing that they have the same weight across all different categories. Concerning the weights of the rest, insofar as the corporate strategical vision should include all ethical issues, we would recognise the same  $x$  contribute for all industries. Finally, since each sector weights should add up to one for each pillar, to find out the social weights these constraints are incompatible. Imaging to recognise the same 10% weight for all key factors of a generic industry, we still have a remainder 20% to be partitioned among the more significant issues. However, in this way they will unjustifiably receive a different contribute depending on whether they are in a sector of the first, second or third category, thus we proceed in another way. Indicating with  $x_i$ ,  $i \in \{1, 2, 3\}$ , the base weight of a generic factor in category  $i$ , we size the materiality of the further significant issues doubling their weights, i.e.  $y_i = 2x_i$ . More precisely,  $x_i$  and  $y_i$  are the solutions of this system of two equations in two variables:

$$\begin{cases} y_i = 2x_i \\ 1 = (8 - i)x_i + iy_i \end{cases} \rightarrow x_i = \frac{1}{8+i}$$

We end up with these base weights for the three different categories:

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} \frac{1}{9} \\ \frac{1}{10} \\ \frac{1}{11} \end{bmatrix}$$

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Healthcare	Financials	Information Technology	Communication Services	Utilities	Real Estate
i	2	3	2	3	1	3	1	1	1	3	1

Table 3.7: Total more relevant key factors for each industry.

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Health-care	Financials	Information Technology	Communication Services	Utilities	Real Estate
	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$
	$\frac{2}{11}$	$\frac{2}{11}$	$\frac{1}{5}$	$\frac{2}{11}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{2}{11}$	$\frac{1}{9}$
	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{2}{11}$	$\frac{1}{9}$	$\frac{2}{9}$	$\frac{1}{9}$	$\frac{2}{11}$	$\frac{2}{9}$
	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$
	$\frac{1}{5}$	$\frac{2}{11}$	$\frac{1}{5}$	$\frac{2}{11}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{2}{11}$	$\frac{1}{9}$
	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{2}{11}$	$\frac{1}{9}$	$\frac{2}{9}$	$\frac{1}{9}$	$\frac{2}{11}$	$\frac{2}{9}$
	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$
	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$
	$\frac{1}{10}$	$\frac{2}{11}$	$\frac{1}{10}$	$\frac{2}{11}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$
	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{11}$	$\frac{1}{9}$
	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{9}$	$\frac{2}{11}$	$\frac{2}{9}$	$\frac{1}{9}$	$\frac{2}{9}$	$\frac{1}{11}$	$\frac{1}{9}$

Table 3.8: Social weights matrix

### 3.3. Governance weights

The complex network of figures surrounding any type of company requires an entity running the enterprise, which is responsible for the management of the entire conglomerate. Organisational scandals occur and occur, revealing the weaknesses of corporate governance frameworks in addressing the long-term economic growth and the protection of shareholders' and stakeholders' rights. All companies, whether small or large, whether belonging to one sector or another, need to be governed. Indeed, the governance weights are set equal between all industries.

Considering the breakdown of corporate governance issues in the perspective of a sustainable performance analysis, we overlook the key factor tax. Indeed, since taxes payment is unavoidable, we exclude the key factor in the evaluation of the company's governance conduct.

	Energy	Materials	Industrials	Consumer Discretionary	Consumer Staples	Health-care	Financials	Information Technology	Communication Services	Utilities	Real Estate
											
	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$

Table 3.9: Governance weights matrix



# 4 | Data prediction

In an attempt to analyse the corporate ESG performance, inconsistent reporting practices are frequently cited as an issue. Constructing the ESG rating is even more complicated when accurate data lack, and this possibility is not so rare. Indeed, since there is not a global standard for sustainable reporting, data collection is often very poor. As a consequence, gaining a full picture of a corporate sustainable operations is frequently questioned. ESG data providers frequently exploit various gap-filling techniques to deal with huge data gaps, covering a wide range of companies, time periods, and metrics. These strategies entail the arbitrary assessment of a missing data on the basis of customised rules.

## 4.1. Training dataset

We use Refinitiv Eikon<sup>1</sup> to select the most appropriate ESG data item linked to each GRI or rGRI to make up the dataset for a specific indicator in a specific key factor of a specific pillar. We proceed managing all GRIs and rGRIs, trying to seek a model capable of predicting the missing values. However, in many cases, we face certain difficulties: since the software does not adopt Global Reports Initiative Standards to collect ESG information, it is often required to hunt for the data item that best explains the considered rGRI. In addition, qualitative indicators are drop out since not useful. To use as much quantitative information as possible, we pick up also the quantitative data pertaining to a qualitative indicator, if any.

Every association made that is not an ideal match is specified in the following:

- 305-3 Other indirect (Scope 3) GHG emissions: the information is dispersed throughout various data items. Precisely we sum: upstream scope 3 emissions Purchases, upstream scope 3 emissions Capital goods, upstream scope 3 emissions Fuel and Energy related, upstream scope 3 emissions Transportation and Distribution, upstream scope 3 emissions Business travel, upstream scope 3 emissions Waste Generated in Operations, upstream scope 3 emissions Employee Commuting, upstream scope 3

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<sup>1</sup>Refinitiv Eikon is an open-technology solution for financial markets professionals, providing access to industry-leading data, insights, and exclusive and trusted news.

- emissions Leased Assets, upstream scope 3 emissions Other, downstream scope 3 emissions Transportation and Distribution, downstream scope 3 emissions Processing of Sold Products, downstream scope 3 emissions Processing of Sold Products, downstream scope 3 emissions End-of-Life Treatment of Sold Products, downstream scope 3 emissions Leased Assets, downstream scope 3 emissions Franchises, downstream scope 3 emissions Investments, downstream scope 3 emissions Other.
- 305-7 Nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>) and other significant air emissions: we associate the sum of nitrogen oxides emissions, that is NO<sub>x</sub> emissions, and sulfur oxides emissions, that is SO<sub>x</sub> emissions.
  - 303-5 Water consumption: carefully reading the documentation, we discover that the total amount of water consumption can be derived as the exact difference between water withdrawal and water discharge.
  - 306-4 Waste diverted from disposal: since the indicator under consideration has qualitative characteristics, we decide to analyse it cautiously. We conclude that the organisation must keep a record of the steps it has done to prevent waste development, including circularity measures, describe the procedures used to check if waste management companies adhere to their legal and contractual commitments, and, outline the procedures utilized to gather and present waste-related data. We investigate Eikon dataset and the only item that suits is waste recycled.
  - 302-1e Energy consumption within the organization + 302-2a Energy consumption outside of the organization: we associate the total amount of energy consumption, that is energy use total.
  - 302-3 Energy intensity: we estimate it using a ratio of the total amount of energy utilized, that is energy use total, by the average of employees at the beginning and at the end of the fiscal year, that is Employees, Prd/Prd Avg.

In Table 4.1 we list each GRI connected with the related Eikon data item, omitting any indicator for which the amount of available information is insufficient.

Note that, when managing the training dataset to construct eCDFs, as we already mentioned, we divide it by industrial categories. Precisely, Refinitiv Eikon does not consider Communication Services industrial sector, including both company belonging to the Communication Services industrial sector and to the Information Technology one into the Information Technology category.

Unfortunately, our training dataset lacks government pillar's data.

<b>Greenhouse gas (GHG), Ozone-Depleting substances (ODS) and other significant emissions</b>		
<b>GRI</b>	<b>Key Performance Indicator</b>	<b>Data item</b>
305-1	Direct (Scope 1) GHG emissions	CO <sub>2</sub> Equivalent Emissions Direct, Scope 1
305-7	Nitrogen oxides, sulfur oxides and other significant air emissions	NO <sub>x</sub> Emissions + SO <sub>x</sub> Emissions
<b>Water</b>		
<b>GRI</b>	<b>Key Performance Indicator</b>	<b>Data item</b>
303-3	Water withdrawal	Water withdrawal total
303-4	Water discharge	Water discharged
303-5	Water consumption	Water withdrawal total – water discharged
<b>Waste and pollution</b>		
<b>GRI</b>	<b>Key Performance Indicator</b>	<b>Data item</b>
306-3	Waste generated	Waste generated
306-4	Waste diverted from disposal	Waste recycled
<b>Clean-tech and renewables</b>		
<b>GRI</b>	<b>Key Performance Indicator</b>	<b>Data item</b>
302-1e	Energy consumption within the organization	Energy use total
302-2a	Energy consumption outside of the organization	
302-3	Energy intensity	Energy use total / average #employee

Table 4.1: Environmental pillar key performance indicators associated to the closest Refinitiv Eikon data item.

## 4.2. Theoretical background

The linear regression model is:

$$Y = q + mX + \epsilon \quad (4.1)$$

where:

- $Y$  is the model's dependent variable and  $(y_i)_{i \in \{1, 2, \dots, N\}}$  are its realisations
- $X$  is the model's independent variable (or regressor) and  $(x_i)_{i \in \{1, 2, \dots, N\}}$  are its realisations
- $q \in \mathbb{R}$  is the model's intercept, and  $m \in \mathbb{R}$  is the model's regression coefficient
- $\epsilon = Y - (q + mX) = Y - \hat{Y}$  is the model's regression error and  $\hat{Y}$  is the predicted value of  $Y$

**Definition 4.1.** The Ordinary Least Square (OLS) fitting criterion computes the regression coefficients minimising the average quadratic difference between the actual value of  $y$  and the prediction  $\hat{y}$  based on the estimated line. Precisely, given the set of observations  $(x_i, y_i)_{i \in \{1, 2, \dots, N\}}$ , it minimises the Mean Square Error:

$$\min_{(q, m) \in \mathbb{R}^2} \text{MSE}(q, m) = \min_{(q, m) \in \mathbb{R}^2} \frac{1}{N} \sum_{i=1}^N (y_i - q - mx_i)^2 \quad (4.2)$$

yielding the OLS estimators of  $q$  and  $m$ .

OLS requires the following assumptions:

- $\mathbb{E}[\epsilon | X = x] = 0$ , the regressor variable is called exogenous. As an immediate consequence, error terms have zero mean, and they are uncorrelated with the regressors, thus  $\epsilon$  and  $X$  are independent.

Exploiting the Law of Iterated Expectation we prove:

$$\mathbb{E}[\epsilon] = \mathbb{E}[\mathbb{E}[\epsilon | X]] = 0$$

and

$$\begin{aligned} \text{Cov}(\epsilon, X) &= \mathbb{E}[\epsilon X] - \mathbb{E}[\epsilon] \mathbb{E}[X] \\ &= \mathbb{E}[\mathbb{E}[\epsilon X | X]] - \mathbb{E}[\mathbb{E}[\epsilon | X]] \mathbb{E}[X] \\ &= \mathbb{E}[X \mathbb{E}[\epsilon | X]] - \mathbb{E}[\mathbb{E}[\epsilon | X]] \mathbb{E}[X] = 0 \end{aligned}$$

- The observations  $(x_i, y_i)_{i \in \{1, 2, \dots, N\}}$  are independent and identically distributed

- $\mathbb{E}[X^4] < \infty$ ,  $\mathbb{E}[Y^4] < \infty$  i.e., large outliers are rare.

We add two additional assumptions to get the extended least squares assumptions:

- the error term  $\epsilon$  is homoskedastic

**Definition 4.2.** Error terms are said to be homoskedastic if  $\text{var}(\epsilon|X = x)$  is constant, that is the variance of the conditional distribution of  $\epsilon$  given  $X$  does not depend on  $X$ .

Supposing  $\epsilon$  to be homoskedastic, the OLS fitting criterion associates the same relevance to each data point. When dealing with heteroskedasticity, regression coefficients estimates could be inaccurate or incorrect: we can make use of some solutions, including model re-specification, robust standard errors usage and Weighted Least Square modelling.

- Normal distribution of errors: residuals must be normally distributed with zero mean and  $\sigma^2$  variance:

$$\epsilon \sim \mathcal{N}(0, \sigma^2) \quad (4.3)$$

thus the error term is independent on  $x$  and the error variance is constant

### 4.3. Variables transformation

Variables with a large range could make it difficult to manage them. In addition, the skewed distribution of many data collected makes it challenging to grasp useful information. A frequent solution to these issues, could be provided by data transformation handling logarithms. Many examples of usage in literature from allometric scaling in biology[183], microwave imaging systems in medical physics[184], RNA sequences in chemistry[185] emphasise this point.

Lütkepohl, H *et al.* conducted research on if and when using logarithms can help forecasting. Precisely, if someone is interested in predicting the variable  $y$ , they inquire under which circumstances forecasting  $x = \ln(y)$  is more appropriate. Then, changing the  $x$  forecast into a  $y$  forecast can be more accurate than foreseeing  $y$  directly, if the log transformation truly makes the variance more uniform throughout the data sample. However, if the log transformation does not stabilise the data variance, it is preferable to base prediction on the original dataset[186].

We try the log-log transformation by fitting the model which links the logarithm of the explanatory variable to the logarithm of the independent one. Given that the dataset

might contain zeros, we apply a data translation of 1 unit and we suppose that  $\ln(y + 1)$  is generated by a linear model, in this way:

$$\ln(y + 1) = q + m \ln(x + 1) \quad (4.4)$$

where  $m$  and  $q$  are constants. Making  $y$  the subject of the equation we obtain the predictive model:

$$y = (x + 1)^m e^q - 1 \quad (4.5)$$

By flattening data and shrinking larger values, log-transforming makes it simpler to spot patterns. Also, it allows us to easily handle highly skewed variables into ones which are closer to normal, offering access to previously concealed information. As an example, the histogram of direct (Scope 1) GHG emissions shows a strong positive skew which points out that the majority of data are clustered at lower values. Plotting its logarithm, we see a distribution that much more resembles a normal one.

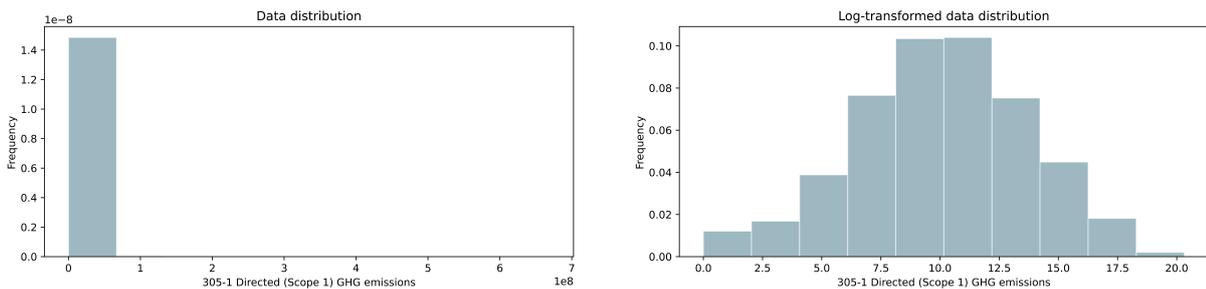


Figure 4.1: Histogram of 305-1 Direct (Scope 1) GHG emissions before and after logarithm transformation.

We also examine exponential relations described by the equation:

$$y^\gamma = mx^\gamma + q \quad (4.6)$$

Since data number several thousands, we fix  $\gamma < 1$  and we test  $\gamma = \frac{1}{7}, \frac{1}{10}, \frac{1}{20}$ . Decreasing the value of the exponent, fixed  $x$ , the variability of  $y$  is of the order of  $10^6$ ,  $10^3$  and 1, respectively.

We evaluate the potential benefits of employing a single methodology for the complete dataset, regardless of pillars and key factors, enabling comparisons between the different quantities under consideration. If a single approach would be able to account for the majority of the variation shown in most of the data, it could be advantageous for the aim of a comparative analysis. ESG log-transformed data make it easier to build well-

established models which have quite high  $R^2$  values, even if the same applies to exponential transformations in most cases. At the end, we choose the log-transformation since it returns better results for a wider variety of cases.

Looking at the graph of the predictive models on a linear scale (see Figure 4.2), we see that, as the value of the variables increases, the regression curve has a lower capacity to grasp the relationship between them. After having normalised each data for the corresponding economic value generated, we re-test the linear regression models with the exponential transformation of the dataset. We avoid making the log-transformation since the values are very small, thus when shifted by 1 unit, their logarithm is almost null. Quantitative findings contradict intuition suggesting that this study may be more insightful than the previous one. To be precise, the linear relation between variables is stronger in the non-normalised case, while in some circumstances, as for the water key factor, it is almost equal. We end up predicting ESG data without dividing by the corresponding economic value generated.

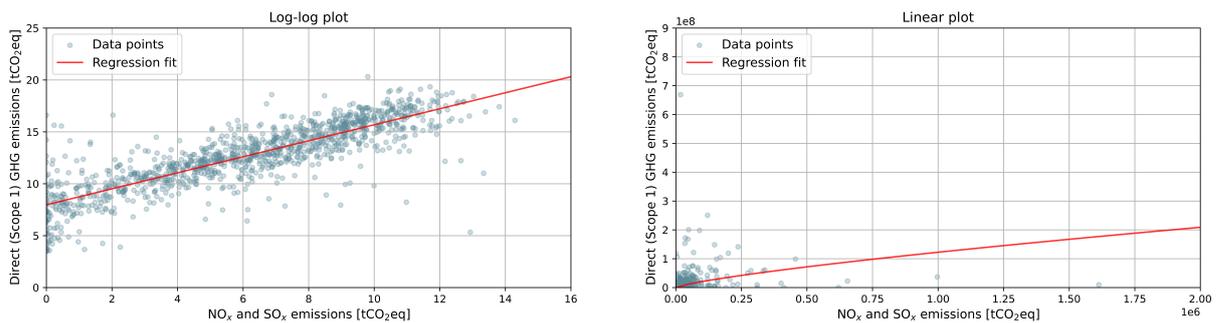


Figure 4.2: Histogram of 305-1 Direct (Scope 1) GHG emissions Ordinary Least Square regression model.

### Algorithm

- Fix a pillar, use scatter plots and create the correlation matrix between the indicators collected in the same key factor to quickly find out the existence of relations:
  - if you can retrieve a potential link between the selected indicators, fixed predictive and explanatory variables and choose the most suitable model.
  - Otherwise, if you cannot reveal any valuable information, go on trying some changes in the variables (e.g., logarithm, exponential) to improve the graph's interpretability and to find the one that best discloses the relations. For each GRI, set the one which is the most correlated as explanatory variable. Then, select the most appropriate relation.
- Analyse quantitative variables' distribution using a boxplot. Look at the measuring scale to better understand values and how they vary over time. Due to the considerable variability of ESG data, pay attention to the median, which is useful when there are many outliers because it accurately captures the phenomenon. Also, observe the box's height and the length of the whiskers, as larger sizes indicate that the variable is more widely distributed than its median value. Finally, take into account the existence of outliers i.e. points that fall below the lower or above the upper whisker, and remove them from the dataset.
- Given the dataset filtered by outliers, fit the model coefficients in a way that the regression line is the closest to the observed data (least square solution). Study the variables under consideration i.e., is there a constraint between them? (e.g.,  $y > x$ ), is the intercept required? So, to quickly check for major errors, overlay the scatter plot of the data over the regression curve
- A quantitative measure of how well data actually fit the regression line would be helpful. Compute the coefficient of determination, denoted  $R^2$ , to determine how much of the data variability is explained by the model:

$$R^2 = 1 - \frac{\text{RSS}}{\text{TSS}} \quad (4.7)$$

where:

- $\text{RSS} = \sum_{i=1}^n (y_i - \hat{y}_i)^2$  (Residual Sum of Squares)
- $\text{TSS} = \sum_{i=1}^n (y_i - \bar{y})^2$  (Total Sum of Squares)
- $y_i$  is the observed data
- $\hat{y}_i$  is the estimated data
- $\bar{y}$  is the mean

thus

- if the result is satisfactory, you get the prediction model.
- Otherwise, it would be useful to insert other predictive variables, exploiting a multiple linear regression model. Make sure the predictor variables are not statistically highly correlated before fitting the model coefficients. Thus, when multicollinearity occurs, it negatively affects the regression analysis and the result is unstable and unreliable.

## 4.4. Regression diagnostics and best fit predictive models

To emphasise the linear relationship between the log-transformed variables, from now on we use the following notation  $x = \ln(x+1)$  and  $y = \ln(y+1)$ . Equation 4.4 can be rewrite as:

$$y = q + mx + \epsilon \quad (4.8)$$

Relating  $x$  and  $y$ , we refer to the model in Equation 4.8 as the two-variable linear regression model or bivariate linear regression model. Precisely, we just deal with linear regression simple predictive model with only one explanatory variable, denoted  $x$ . The log-log model coefficient  $m$  represents the elasticity of  $y$  with respect to  $x$ , i.e. the estimated percent change in the dependent variable for a percent change in the independent one.

After estimating the predictive models coefficients, we verify the previously listed underlying assumptions on data points and residuals. Exactly, we present in detail only the direct (Scope 1) GHG emissions to nitrogen oxides ( $\text{NO}_x$ ), sulfur oxides ( $\text{SO}_x$ ) and other significant air emissions model evaluation. Indeed, for all the others, using the same way of reasoning, we simply report the results in Appendix 5.3.

### Direct (Scope 1) GHG emissions to nitrogen oxides ( $\text{NO}_x$ ), sulfur oxides ( $\text{SO}_x$ ) and other significant air emissions model

We first proceed by visual inspection, plotting the residuals against the independent variable, to detect heteroskedasticity. Since our data sample is large, seeing an "envelope" of uniform breadth makes us think of safely conclude that heteroskedasticity is not severe enough to cause worry (Figure 4.4). Nevertheless, for more careful claims, we exploit the Breusch-Pagan/Cook-Weisberg test, useful to fix any linear form of heteroskedasticity.

**Definition 4.3.** The Breusch-Pagan/Cook-Weisberg test tests the null-hypothesis that

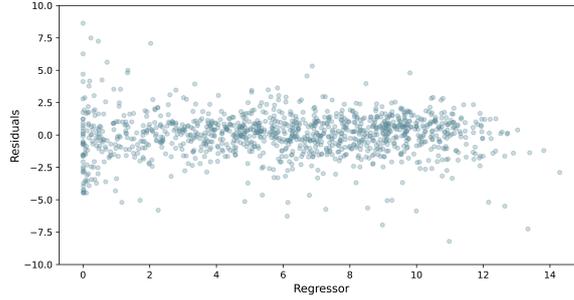


Figure 4.3: Direct (Scope 1) GHG emissions to nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>) and other significant air emissions, Ordinary Least Square regression residuals.

the error variances are constant versus the alternative one that the error variances are the result of a multiplicative function of one or more variables, e.g., the error variances increase with the predictive values of  $y$ .

Precisely,

$$\begin{cases} H_0 : var(\epsilon_i) = \sigma^2 & \forall i \in \{1, 2, \dots, N\} \\ H_1 : var(\epsilon_i) = \sigma_i^2 & \forall i \in \{1, 2, \dots, N\} \end{cases} \quad (4.9)$$

Differently from visual inspection, Breusch-Pagan/Cook-Weisberg test applied to the log-log linear model, returns an unsatisfactory result, forcing us to refuse the null hypothesis with a p-value that tends to zero (p-value = 0.0367). Dealing with heteroskedasticity, we make use of Weighted Least Square (WLS) fitting criterion. Differently from OLS regression, which gives the same relevance to all data points, without caring about the values assumed by the explanatory variable, WLS weights the observations.

**Definition 4.4.** The Weighted Least Square fitting criterion assigns to each pair of data  $(x_i, y_i)$  a weight  $w_i$ , which is positively correlated to the grade of influence it has on the regression line coefficients estimation. Precisely, it minimises the Weighted Mean Square Error:

$$\min_{(q,m) \in \mathbb{R}^2} \text{WMSE}(q, m) = \min_{(q,m) \in \mathbb{R}^2} \frac{1}{N} \sum_{i=1}^N w_i (y_i - q - mx_i)^2 \quad (4.10)$$

where  $\mathbf{w} \in \mathbb{R}^N$ . (Obviously, this includes OLS when  $w_i = 1, \forall i \in \{1, 2, \dots, N\}$ ).

We try different kinds of weights estimating them via the inverse of the residuals variance, the inverse of the predicted value of  $y$  and the inverse of the square predicted value of  $y$ .

**Inverse of the residuals variance:** we set

$$w_i = \frac{1}{\sigma_i^2} \quad \forall i \in \{1, 2, \dots, N\} \quad (4.11)$$

Being each weight inversely proportional to the error variance, it reflects the information contained in the observation, i.e. we assign a large weight to an observation with small error variance, since, containing much more information, it is relatively more meaningful than an observation with large variance. Since our explanatory variable is continuous, we exploit a simple OLS regression to get the residuals we need to compute the weights. Then, we regress the absolute value of the OLS residuals against the model fitted values:

$$|\epsilon| = q_1 + m_1 \hat{y} + \omega$$

where  $\omega$  represents the model's residuals. The resulting fitted values, denoted  $\hat{\epsilon}$ , are estimates of the error standard deviations. Exploiting the WLS with weights  $w_i = 1/\hat{\epsilon}^2$ , we refuse again the Breusch-Pagan/Cook Weisberg null hypothesis.

**Inverse of the predicted value of y:** we set

$$w_i = \frac{1}{\hat{y}} \quad \forall i \in \{1, 2, \dots, N\} \quad (4.12)$$

which cancels out the weighting of higher signal values.

**Inverse of the square predicted value of y:** we set

$$w_i = \frac{1}{\hat{y}^2} \quad \forall i \in \{1, 2, \dots, N\} \quad (4.13)$$

which causes over proportional weighting of smaller signal values.

Only Equation 4.13 allows us to accept the null hypothesis of the Breusch-Pagan/Cook-Weisberg test, as summarised in Table 4.2:

<b>Breusch-Pagan/Cook-Weisberg test summary table</b>			
<b>Model</b>	<b>Stat</b>	<b>p-value</b>	<b>Homoskedasticity</b>
OLS	4.3646	0.0367	no
WLS - $w = 1/\sigma^2$	4.7020	0.0301	no
WLS - $w = 1/\hat{y}$	4.0898	0.0431	no
WLS - $w = 1/\hat{y}^2$	3.8282	0.0504	yes

**Table 4.2:** Statistical test for homoskedasticity applied to Direct (Scope 1) GHG emissions to nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>) and other significant air emissions regression models.

Consistently, we note that the OLS coefficients are close to the WLS ones:

Regression models coefficients			
Model	$q$	$m$	$R^2$
OLS	7.9675	0.7712	0.7110
WLS - $w = 1/\sigma^2$	8.0385	0.7600	0.7000
WLS - $w = 1/\hat{y}$	7.9071	0.7811	0.7100
WLS - $w = 1/\hat{y}^2$	7.8579	0.7903	0.6920

Table 4.3: Direct (Scope 1) GHG emissions to nitrogen oxides ( $\text{NO}_x$ ), sulfur oxides ( $\text{SO}_x$ ) and other significant air emissions regression models estimates.

In the following, we plot the residuals of the WLS with weights  $w = 1/\hat{y}^2$  by order of collection, to verify they are uncorrelated. Coherently, in the right side of Figure 4.4, the error terms are purely random and no relationship can be identified.

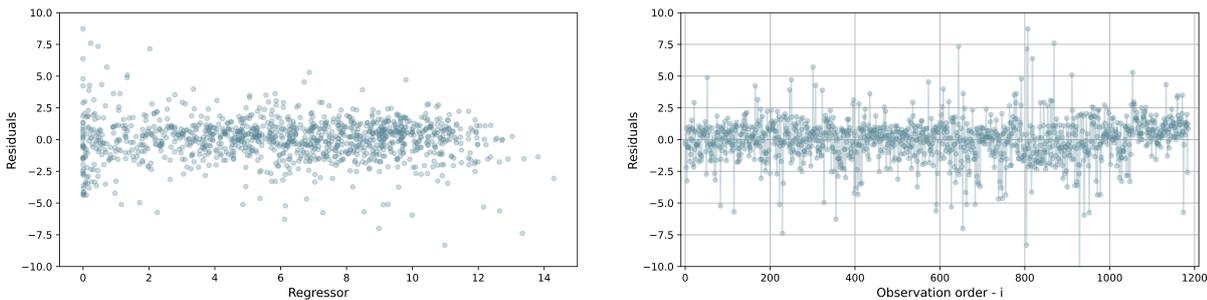


Figure 4.4: Direct (Scope 1) GHG emissions to nitrogen oxides ( $\text{NO}_x$ ), sulfur oxides ( $\text{SO}_x$ ) and other significant air emissions, Weighted Least Square -  $w = 1/\hat{y}^2$  regression residuals.

We proceed with the last checks. In Figure 5.1, we graph the model's residual over the fitted values to verify independence. Then, we investigate the normal distribution of errors through a quantile-quantile plot, also called QQplot. In the statistical tool, the theoretical quantiles of a normal distribution are shown on the horizontal axis, standardized residues quantiles, instead, are shown on the vertical axis. If residues have a normal distribution, their standardized quantiles should coincide with those of the standard normal distribution. Visually, this means that the observed quantiles points should be along the bisector. In the figure below the standardized residues and the corresponding percentiles of a standardised normal distribution are perfectly overlapped, except in the tail values. Moreover, we check the normality assumption exploiting the Shapiro-Wilk test which infers residual normal distribution when the null hypothesis is verified. We perform this test only for accuracy, aware of not getting good results, since Shapiro-Wilk test works well especially with small sample sizes. Finally, for a further and more accurate comparison, we superimpose a standard normal distribution to the standardized residue histogram.

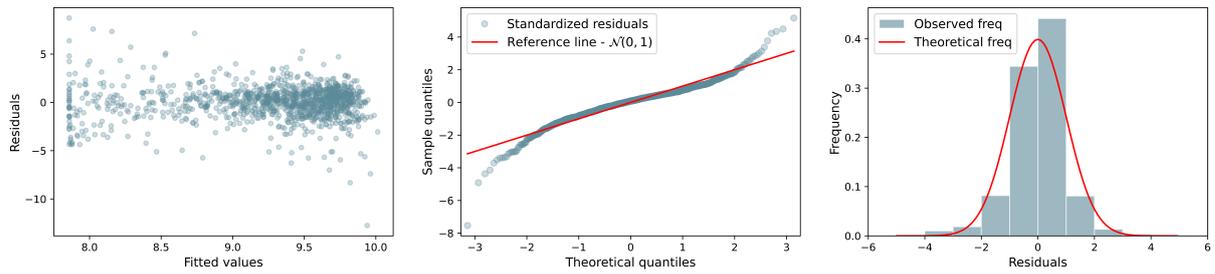


Figure 4.5: Direct (Scope 1) GHG emissions to nitrogen oxides ( $\text{NO}_x$ ), sulfur oxides ( $\text{SO}_x$ ) and other significant air emissions Weighted Least Square -  $w = 1/\hat{y}^2$  regression residuals.

In the following we report a summary figure of all the analysed regression models.

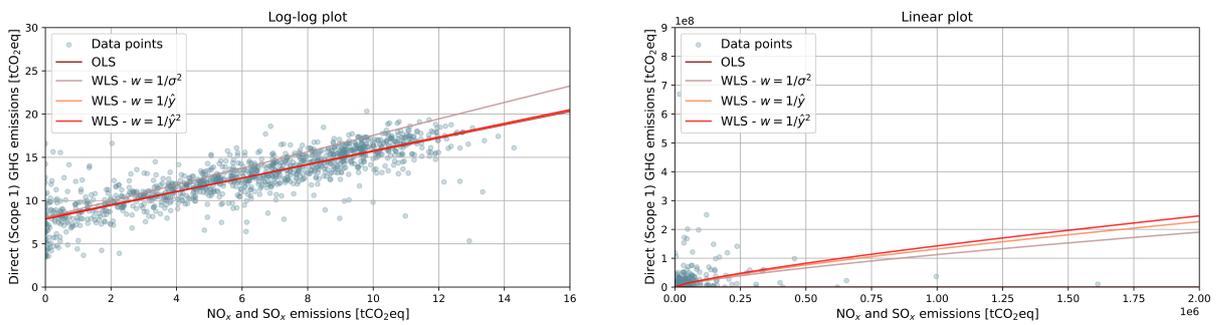


Figure 4.6: Direct (Scope 1) GHG emissions to nitrogen oxides ( $\text{NO}_x$ ), sulfur oxides ( $\text{SO}_x$ ) and other significant air emissions regression models.



# 5 | Computing the rating

## 5.1. Dataset to be evaluated

To test our evaluation criterion, we manually collect companies' sustainability data, directly from the non-financial statements published on companies web pages. These data concern 222 Italian listed companies in the FTSE All Share index. The baseline of our analysis is 2020. In the tables below we collect all the retrieved GRIs, divided by pillar, highlighting the ones used in the evaluation.

Note that, as explained before in Section 4.1, we are forced to collect both company belonging to the Communication Services industrial sector and to the Information Technology one into the Information Technology category. In this way, we evaluate companies belonging to these two industrial categories exploiting the same eCDF.

Environmental pillar		
GRI	Key Performance Indicator	Unite measure
305-1a	Direct (Scope 1) GHG emissions	[tCO <sub>2</sub> eq]
305-2a	Energy indirect (Scope 2) GHG emissions	[tCO <sub>2</sub> eq]
305-3a	Other indirect (Scope 3) GHG emissions	[tCO <sub>2</sub> eq]
305-7a	Nitrogen oxides (NO <sub>x</sub> ), sulfur oxides (SO <sub>x</sub> ) and other significant air emissions	[t]
301-1a.i	Non renewable materials used	[t]
301-1a.i	Renewable materials used	[t]
301-2	Recycled input materials used	[%]
303-3a	Water withdrawal	[m <sup>3</sup> ]
306-3	Waste generated	[t]
302-1a	Fuel consumption within the organization from non-renewable sources	[GJ]
302-1c	Energy consumption within the organization	[GJ]
302-3	Energy intensity	—

Table 5.1: List of environmental pillar KPIs collected for the dataset to be evaluated.

Social pillar		
GRI	Key Performance Indicator	Unite measure
401-1a	New employee hires by age group	[#]
401-1b	New employee hires by gender	[#]
401-1c	Employee turnover by age group	[%]
401-1d	Employee turnover by gender	[%]
403-9a.i	Number of fatalities as a result of work-related injury	[#]
403-9a.iii	Rate of recordable work-related injuries	[#]
404.1a.i	Avg hours of training per year per employee by gender	–
404-1b	Avg hours of training per year per employee per employee category	–
405.1a	Diversity of governance bodies by gender	[%]
405-1b	Diversity of governance bodies by age group	[%]
405-1c	Diversity of employees by gender	[%]
405-1d	Diversity of employees by age group	[%]
405-2	Ratio of basic salary and remuneration of women/men	–

Table 5.2: List of social pillar KPIs collected for the dataset to be evaluated.

Governance pillar		
GRI	Key Performance Indicator	Unite measure
201-1a	Direct economic value generated	[M€]
201-1b	Economic value distributed	[M€]
205-2	Total percentage of governance body members that have received training anti-corruption	[%]
205-3	Confirmed incidents of corruption and actions taken	[#]
206	Legal actions for anti-competitive behavior, anti-trust, and monopoly practices	[#]
207-4b.viii	Corporate income tax paid on a cash basis	[M€]

Table 5.3: List of governance pillar KPIs collected for the dataset to be evaluated.

## 5.2. Comparison with the ratings of Refinitiv and Sustainalytics

We recall that our training dataset (see Section 4.1) lacks government pillar's data. Consequently, we are forced to limit our study to one pillar at a time (environmental and social) without carrying out a comprehensive analysis.

We make use of data coming from two of the major ESG rating providers, Sustainalytics and Refinitiv, manually collecting Sustainalytics evaluations from Yahoo Finance and Refinitiv ones from Refinitiv Eikon. Unfortunately, due to data accessibility issues, there is very little information available on Sustainalytics ratings.

To make comparisons, we apply some adjustments to the raw data: first, we only take into account rating scores submitted at the end of the year, second, a scale ranging from 0 to 1 is exploited to translate different rating scores given by various agencies. We apply specific attention to the providers. Sustainalytics does not disclose how score is determined at a pillar level, presenting only the methodology used to compose what it defines ESG Risk Score, that is the size of an organization's mismanaged ESG risk. The greater the ESG Risk Rating score is, the more of this risk is not handled. Additionally, we are unaware of the range of potential values that each pillar scores may assume. The overall and individual pillar scores, instead, are provided by Refinitiv on a scale from 0 to 1, precisely, a score close to 1 means strong ESG practices. Environmental ratings and associated sample characteristics are presented through descriptive statistics in Tables 5.4, 5.7. In the highest part of the table we report the analysis carried out for the full sample of companies rated by the algorithm or by any of the two agencies: we provide evaluations for 118 companies, Refinitiv for 117 companies and Sustainalytics for 18 companies. In the lower part of the table, instead, we report results simply analysing the restricted data sample. We stress that the following analysis is constrained by data availability.

To discuss the results, we distinguish two different cases:

- *data samples as snapshots of reality*: accepting that data samples are a valuable representation of reality, we can make absolute considerations between the three rating agencies different assessments.
- *Non uniform data distribution in the range of acceptable values*: relaxing the assumption of uniform distribution of data, we can only make claims which are relative to the maximum value reached by the sample. Precisely, an higher average score means that values are more concentrated around the maximum, while a lower average score indicates that a large amount of ratings are smaller than the maxi-

mum.

**Environmental pillar:** we can note that the average values of ESG ratings, obtained exploiting the three different evaluation methods, are quite dissimilar: our rating criterion associates the smallest mean score (0.3511), while Sustainalytics the highest one (0.6802). We continue with the examination of the restricted sample to verify whether the difference is related to the various companies examined. Once more the average values differences are substantial, the maximum value is reached by Refinitiv (0.7800) and the lowest one by our algorithm (0.5195). This result tells us that, for the environmental pillar, the algorithm issues the average lowest value of ESG rating.

Environmental pillar	Algorithm	Refinitiv	Sustainalytics
	<i>Full sample</i>		
No. of firms	118	117	18
Mean	0.3511	0.5713	0.6802
Median	0.3192	0.6106	0.6756
Standard deviation	0.2074	0.2447	0.2520
<i>Common sample</i>			
No. of firms	16	16	16
Mean	0.5195	0.7800	0.6436
Median	0.4852	0.8007	0.6145
Standard deviation	0.2590	0.1789	0.2437

**Table 5.4:** Descriptive statistics of the Environmental ESG rating in 2020 for our algorithm and the two rating agencies.

Exploiting a correlation analysis, we quantify the differences between the three assessments. We report in Tables 5.5, 5.6 the Pearson's correlations for both the full and common samples ESG rating scores. If for the pairs Refinitiv-Algorithm and Sustainalytics-Refinitiv scores the full sample correlation is negative (-0.2290 and -0.2190, respectively), for the couple Sustainalytics-Algorithm, instead, it is significantly positive (0.3530). Also correlation values calculated on the restricted sample for the pairs Refinitiv-Algorithm and Sustainalytics-Refinitiv are negative. The average correlations are 0.0317 for the full sample and -0.0173 for the common sample. At the end, Sustainalytics and the algorithm exhibit the highest level of agreement between them.

	Algorithm	Refinitiv	Sustainalytics
<i>Full sample</i>			
Algorithm	1		
Refinitiv	-0.2290	1	
Sustainalytics	0.3530	-0.2190	1

Table 5.5: Pearson’s correlation between our algorithm and the two rating agencies environmental scores – full sample.

	Algorithm	Refinitiv	Sustainalytics
<i>Common sample</i>			
Algorithm	1		
Refinitiv	-0.3430	1	
Sustainalytics	0.3530	-0.0620	1

Table 5.6: Pearson’s correlation between our algorithm and the two rating agencies environmental scores – common sample.

**Social pillar:** proceeding with the social pillar, once again, the average values are quite dissimilar. Considering the common sample, unlike the environmental pillar, Refinitiv combines the smallest average value (0.6869), while our algorithm the highest one (0.7559). Narrowing to the common sample, differences remain, with the minimum average value attributable to Sustainalytics (0.7370) and the maximum one attributable to Refinitiv (0.8862).

	Algorithm	Refinitiv	Sustainalytics	
<b>Social pillar</b>	<i>Full sample</i>			
	No. of firms	159	117	18
	Mean	0.7559	0.6869	0.7364
	Median	0.8041	0.7193	0.7652
	Standard deviation	0.2222	0.1948	0.2018
	<i>Common sample</i>			
	No. of firms	16	16	16
	Mean	0.7839	0.8862	0.7370
	Median	0.8931	0.9202	0.7744
	Standard deviation	0.2313	0.0936	0.2028

Table 5.7: Descriptive statistics of the Social ESG rating in 2020 for our algorithm and the two rating agencies.

Correlations are confirmed to be quite low with a mean value of 0.0863 for the common sample and a lower value of 0.0777 for the restricted sample (see Tables 5.8, 5.9).

	Algorithm	Refinitiv	Sustainalytics
<i>Full sample</i>			
<b>Algorithm</b>	1		
<b>Refinitiv</b>	-0.0430	1	
<b>Sustainalytics</b>	0.2410	0.0610	1

Table 5.8: Pearson’s correlation between our algorithm and the two rating agencies social scores – full sample.

	Algorithm	Refinitiv	Sustainalytics
<i>Common sample</i>			
<b>Algorithm</b>	1		
<b>Refinitiv</b>	-0.0890	1	
<b>Sustainalytics</b>	0.2410	0.0810	1

Table 5.9: Pearson’s correlation between our algorithm and the two rating agencies social scores – common sample.

We focus on the results: referring to the environmental pillar, our algorithm associates significantly lower scores when compared to the two considered rating agencies. When performing evaluations, we exploit the *water discharge to water withdrawal* regression model to get estimates of water discharge. Then, we compute the difference between the total amount of water withdrawn and the one discharged to get the water consumed.

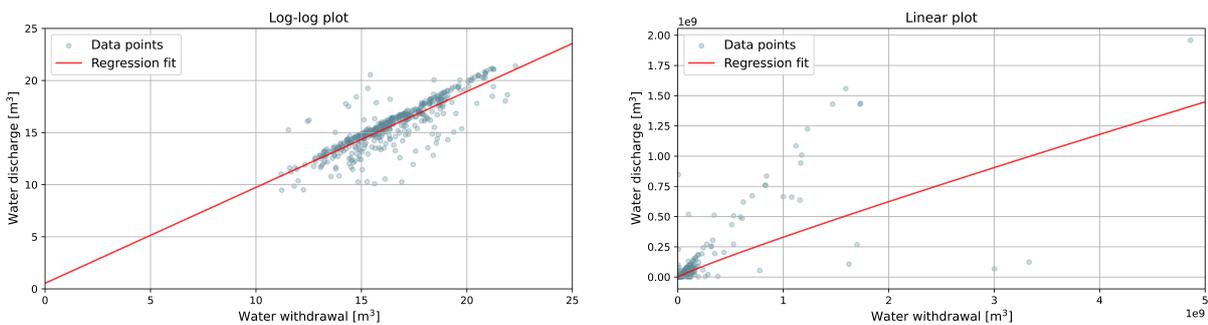


Figure 5.1: Water discharge to water withdrawal Ordinary Least Square regression model.

We can notice that, increasing the total water withdrawn, the regression line struggles to predict the water discharge, that is increasing the value of  $x$ , the regression line provides to the average observed values of  $y$  a downward trend. As a result of gap filling, we assess a total amount of water consumed that, growing the total amount of water withdrawn, tends to be larger than observed values. Since the algorithm assigns decreasing scores with increasing water consumption, water key factor scores become lower. To investigate this issue, we re-compute environmental scores excluding the forecast of the water con-

sumption. Coherently, the algorithm average environmental ESG rating is higher than before (0.3657). However, in this case, the predictive model is good (with an high value of  $R^2$  and verifying regression hypothesis), and that's why we decide to use it. Indeed, it is preferable to use as many indicators as possible to obtain complete and true assessments, but attention is required. Prediction models are a key tool for taking advantage of all the information provided by sustainability reports, but they should be handled cautiously. Unsuitable regression curve estimates may alter scoring results.

For what concerns the social pillar, instead, the algorithm issues higher mean rating values. Moreover, the correlation analysis provides higher relations in the social pillar assessments than in the environmental ones (with mean correlation values of 0.0863 and 0.0317, respectively). Quantitative ESG ratings analysis are largely consistent with the reasons behind our research: existing rating agencies evaluations differ remarkably. However, it is challenging to focus on reasons, since they are numerous and significant. Difficulties arise not only from the different choices of indicators and the resulting relevance associated with them, but also from the limited amount of public information about rating agencies evaluation criteria.

### 5.3. Algorithm ESG scores

Company name	GICS	Let	Num	Let	Num
A2A S.p.A.	Utilities	D+	0.2140	B	0.6552
AbitareIn	Real Estate	-	-	A+	0.9844
Acea S.p.A.	Utilities	C-	0.2667	A	0.8627
Aedes SIIQ S.p.A.	Real Estate	-	-	-	-
Aeffe S.p.A.	Consumer Cyclical	B	0.6232	A+	0.9688
Aeroporto G. Marconi Bologna S.p.A.	Industrials	D+	0.1914	A+	0.9259
Alerion Clean Power S.p.A.	Utilities	-	-	-	-
algoWatt	Industrials	-	-	-	-
ALKEMY S.p.A.	Consumer Cyclical	-	-	A+	0.9644
Ambientesis	Industrials	D-	0.0095	A	0.9015
Amplifon	Healthcare	B	0.6369	A+	0.9688
Anima Holding	Financials	C+	0.4705	B	0.6147
Antares Vision	Industrials	-	-	-	-
Aquafil	Consumer Cyclical	D	0.1021	A+	0.9688
Ascopiave S.p.A.	Utilities	B	0.6111	A-	0.8010
Assicurazioni Generali	Financials	-	-	-	-
Atlantia S.p.A.	Industrials	D-	0.0018	C+	0.4286
Autogrill S.p.A.	Consumer Cyclical	C-	0.3200	A+	0.9688
Autostrade Meridionali S.p.A.	Industrials	-	-	-	-
Avio S.p.A.	Industrials	-	-	-	0.7644
Azimut Holding	Financials	-	-	A	0.8834
B&C Speakers S.p.A.	Information Technology	-	-	-	-
Banca Carige	Financials	-	-	B+	0.6829
Banca Farmafactoring S.p.A.	Financials	C	0.4016	A+	0.9844
Banca Finnat Euramerica	Financials	-	-	-	-
Banca Generali S.p.A.	Financials	C+	0.4825	B+	0.6843
Banca Ifis S.p.A.	Financials	-	-	A-	0.8018
Banca Intermobiliare S.p.A.	Financials	-	-	-	-
Banca Mediolanum S.p.A.	Financials	D-	0.0124	A+	0.9844
Banca Monte dei Paschi di Siena S.p.A.	Financials	D-	0.0030	B+	0.7304
BPER	Financials	D-	0.0032	B-	0.5576
Banca Popolare di Sondrio	Financials	D	0.1362	B+	0.7051
Banca Profilo	Financials	-	-	-	-
Banca Sistema S.p.A.	Financials	-	-	-	-
Banco BPM S.p.A.	Financials	D	0.1212	D-	0.0425

Company name	GICS	Let	Num	Let	Num
BasicNet S.p.A.	Consumer Cyclical	-	-	A+	0.9688
Bastogi	Industrials	-	-	-	-
Be Think, Solve, Execute S.p.A.	Information Technology	B-	0.5769	B+	0.7480
Beghelli	Information Technology	D	0.1034	A-	0.8101
BF S.p.A.	Consumer Staples	C+	0.4657	A+	0.9202
Bialetti Industrie	Consumer Cyclical	C-	0.3027	B+	0.7360
Biesse S.p.A.	Industrials	C+	0.4588	A	0.8918
Bioera	Industrials	-	-	-	-
Borgosesia	Consumer Cyclical	-	-	-	-
Brembo	Consumer Cyclical	D	0.1465	A+	0.9578
Brioschi	Real Estate	-	-	-	-
Brunello Cuccinelli S.p.A.	Consumer Cyclical	B-	0.5615	A+	0.9688
Buzzi Unicem S.p.A.	Materials	D+	0.2431	D-	0.0766
Cairo Communication S.p.A.	Communication Services	C-	0.3004	B-	0.5638
Caleffi S.p.A.	Consumer Cyclical	-	-	-	-
Caltagirone Editore	Communication Services	-	-	-	-
Caltagirone S.p.A.	Materials	D	0.1308	B+	0.6815
Campari	Consumer Staples	C-	0.3056	A+	0.9202
Carel Industries S.p.A.	Information Technology	C	0.3820	A+	0.9126
Cellularline S.p.A.	Information Technology	-	-	B	0.6547
Cembre S.p.A.	Industrials	D+	0.2692	A-	0.8089
Cementir Holding	Materials	D+	0.2151	A+	0.9688
Centrale del Latte d'Italia	Consumer Staples	D	0.1231	B-	0.5121
Cerved Group S.p.A.	Information Technology	C	0.3892	B	0.6216
Class Editori	Communication Services	-	-	-	-
CNH Industrial	Industrials	C+	0.4418	A-	0.8382
COFIDE S.p.A.	Consumer Cyclical	D+	0.1739	B	0.6316
COIMA RES SIIQ	Real Estate	-	-	A+	0.9688
Compagnia Immobiliare Azionaria	Real Estate	-	-	-	-
Conafi	Financials	-	-	-	-
Credito Emiliano S.p.A.	Financials	D+	0.1841	A+	0.9844
CSP International	Consumer Cyclical	D+	0.2050	B-	0.5786
D'Amico	Industrials	D+	0.1745	A	0.9015
Danieli	Industrials	D	0.1152	A+	0.9688
Datalogic	Information Technology	-	-	B	0.6357
De Longhi	Consumer Cyclical	B-	0.5059	A+	0.9711
DeA Capital	Financials	-	-	-	-
DiaSorin	Healthcare	D	0.1407	A+	0.9844

Company name	GICS	Let	Num	Let	Num
Digital Bros	Communication Services	–	–	–	–
DoValue	Financials	D+	0.2096	A+	0.9844
Edison Rsp	Utilities	–	–	B	0.6637
EEMS	Information Technology	–	–	–	–
El.En. S.p.A.	Healthcare	B–	0.5797	A+	0.9844
Elica	Consumer Cyclical	–	–	A+	0.9511
Emak	Industrials	C	0.3874	A–	0.7846
Enav	Industrials	C	0.4141	A	0.9015
Enel	Utilities	C	0.2066	C+	0.4285
Enervit	Consumer Staples	–	–	–	–
Eni	Energy	C	0.3280	A+	0.9688
ePRICE	Consumer Cyclical	–	–	–	–
Equita Group	Financials	–	–	–	–
ERG S.p.A.	Utilities	C–	0.3040	A+	0.9688
Esprinet	Information Technology	B+	0.7208	D–	0.0457
Eukedos	Healthcare	–	–	–	–
Eurotech	Information Technology	–	–	–	–
Exor	Consumer Cyclical	–	–	–	–
Exprivia	Information Technology	–	–	A	0.9126
Falck Renewables	Utilities	C	0.3809	A	0.8686
Ferrari	Consumer Cyclical	C	0.3439	A+	0.9578
Fidia	Industrials	–	–	–	–
Fiera Milano	Industrials	C–	0.2589	B+	0.7164
FILA	Industrials	–	–	C–	0.2830
Fincantieri S.p.A.	Industrials	D+	0.2474	C+	0.4985
Fine Foods & pharmaceuticals	Consumer Staples	–	–	–	–
FinecoBank	Financials	C–	0.2814	A–	0.7673
FNM S.p.A.	Industrials	D+	0.1948	A+	0.9405
FullSix	Communication Services	–	–	–	–
Gabetti	Real Estate	–	–	–	–
Garofalo Health Care S.p.A.	Healthcare	C–	0.2613	A+	0.9688
GasPlus	Energy	–	–	–	–
Gefran S.p.A.	Information Technology	D+	0.1766	B	0.6211
Geox	Consumer Cyclical	C+	0.4948	–	–
Gequity	Financials	–	–	–	–
Giglio Group S.p.A.	Communication Services	–	–	–	–
GPI S.p.A.	Industrials	A–	0.7150	B+	0.6951

Company name	GICS	Let	Num	Let	Num
Gruppo MutuiOnline S.p.A.	Financials	-	-	-	-
GVS	Industrials	-	-	A	0.9015
Hera S.p.A.	Utilities	C-	0.2696	C-	0.2925
I Grandi Viaggi	Consumer Cyclical	-	-	-	-
IGD - SiiQ	Real Estate	-	-	B+	0.7242
Il Sole 24 Ore	Communication Services	D	0.1489	C	0.3778
illimity Bank	Financials	C	0.3372	A+	0.9844
IMMSI S.p.A.	Consumer Cyclical	A-	0.7719	D+	0.2248
IndelB	Information Technology	D+	0.1787	C+	0.4755
Intek Group	Materials	-	-	-	-
Interpump Group S.p.A.	Industrials	C-	0.2939	A-	0.7894
Intesa Sanpaolo S.p.A.	Financials		0.1239		0.9488
INWIT	Communication Services	D-	0.0539	B	0.6103
IRCE	Industrials	D+	0.1923	A-	0.7738
Iren S.p.A.	Utilities	D+	0.2449	A-	0.7615
Italgas S.p.A.	Utilities	B-	0.5505	A-	0.8300
Italian Exhibition Group	Communication Services	D	0.1277	A	0.8921
Italmobiliare	Consumer Staples	C+	0.4195	B+	0.7383
ItWay S.p.A.	Information Technology	-	-	-	-
IVS Group	Consumer Cyclical	-	-	B	0.6585
Juventus Football Club	Communication Services	-	-	-	-
La Doria S.p.A.	Consumer Staples	C+	0.4599	c+	0.4782
Landi Renzo S.p.A.	Consumer Cyclical	D+	0.2146	A+	0.9644
Lazio S.p.A.	Communication Services	-	-	-	-
Leonardo S.p.A.	Industrials	D+	0.2266	B+	0.7212
LU-VE S.p.A.	Industrials	D+	0.2427	B	0.6365
LVenture Group S.p.A.	Financials	-	-	-	-
Maire Tecnimont S.p.A.	Industrials	C-	0.3253	B+	0.7421
MARR S.p.A.	Consumer Staples	D+	0.1734	C	0.3514
Mediaset S.p.A.	Communication Services	C	0.4071	A-	0.8101
Mebiobanca S.p.A.	Financials	D+	0.2172	B	0.6820
Moncler S.p.A.	Consumer Cyclical	B-	0.5739	A-	0.7974
Mondadori Editore S.p.A.	Communication Services	-	-	C+	0.4987
Mondo TV S.p.A.	Communication Services	-	-	-	-
Monrif S.p.A.	Communication Services	D+	0.1680	C+	0.4822
Neodecortech S.p.A.	Materials	C+	0.4837	B	0.6166
Netweek S.p.A.	Communication Services	-	-	-	-

Company name	GICS	Let	Num	Let	Num
Newlat Food S.p.A.	Consumer Staples	D	0.1301	B-	0.5121
Nexi S.p.A.	Information Technology	D	0.0851	C+	0.4192
Nova Re S.p.A.	Real Estate	-	-	-	-
Openjometis S.p.A.	Industrials	-	-	C-	0.3325
Orsero Group S.p.A.	Consumer Staples	C	0.3665	A-	0.7597
OVS S.p.A.	Consumer Cyclical	C-	0.2521	A+	0.9688
PharmaNutra S.p.A.	Healthcare	-	-	-	-
Philogen S.p.A.	Healthcare	-	-	-	-
Piaggio & C S.p.A.	Consumer Cyclical	D	0.1044	A-	0.8265
Pierrel S.p.A.	Healthcare	-	-	-	-
Pininfarina S.p.A.	Consumer Cyclical	D+	0.1766	A-	0.8114
Piovan S.p.A.	Industrials	C	0.3975	A	0.8431
Piquadro S.p.A.	Consumer Cyclical	B-	0.5133	A-	0.8114
Pirelli S.p.A.	Consumer Cyclical	D-	0.0738	A-	0.7538
Piteco S.p.A.	Information Technology	-	-	-	-
PLC S.p.A.	Industrials	C+	0.4133	A	0.8967
Poligrafica San Faustino S.p.A.	Communication Services	-	-	-	-
Poste Italiane S.p.A.	Industrials	C+	0.4676	C+	0.4617
Prima Industrie S.p.A.	Industrials	-	-	B-	0.5468
Prysmiam S.p.A.	Industrials	D+	0.1994	C	0.3789
Rai Way S.p.A.	Industrials	D	0.1502	B	0.5885
Ratti S.p.A.	Consumer Cyclical	D+	0.2107	A-	0.7915
RCS MediaGroup S.p.A.	Communication Services	C	0.3459	B-	0.5813
Recordati S.p.A.	Healthcare	C-	0.2917	A+	0.9844
Reno De Medici S.p.A.	Materials	C-	0.2889	B	0.6274
Reply S.p.A.	Information Technology	-	-	-	-
Restart S.p.A.	Real Estate	-	-	-	-
Retelit S.p.A.	Communication Services	C	0.3603	C+	0.4202
Risanamento S.p.A.	Real Estate	-	-	-	-
Roma S.p.A.	Communication Services	-	-	-	-
ROSSS S.p.A.	Industrials	-	-	-	-
Sabaf S.p.A.	Industrials	D	0.1445	B	0.6348
Saes Getters S.p.A.	Information Technology	-	-	-	-
Safilo Group S.p.A.	Healthcare	C-	0.3316	A+	0.9844
Salcef Group S.p.A.	Industrials	C-	0.2678	A	0.9064
Salvatore Ferragamo S.p.A.	Consumer Cyclical	B-	0.5388	A+	0.9578
Sanlorenzo S.p.A.	Consumer Cyclical	B-	0.5024	A-	0.8048
Saras S.p.A.	Energy	D	0.0858	A+	0.9214

Company name	GICS	Let	Num	Let	Num
Seco	Information Technology	D+	0.2340	B+	0.7178
Seri industrial	Utilities	C	0.4151	A+	0.9844
Servizi Italia S.p.A.	Industrials	D	0.1490	B+	0.6676
SeSa S.p.A.	Information Technology	B-	0.5543	C	0.3759
SIT S.p.A.	Industrials	C-	0.2689	A	0.9064
Snam S.p.A.	Utilities	C	0.3689	C+	0.4829
Società cattolica Assicurazioni	Financials	C-	0.3200	A+	0.9844
Softlab S.p.A.	Communication Services	-	-	-	-
SOGEFI S.p.A.	Consumer Cyclical	D+	0.1711	A+	0.9179
Sol S.p.A.	Materials	C+	0.4181	B+	0.7356
Somec	Industrials	-	-	A+	0.9688
Stellantis	Consumer Cyclical	C+	0.4546	A	0.8580
STMicroelectronics	Information Technology	D	0.1105	A+	0.9844
Tamburi Investment Partners	Financials	-	-	-	-
TAS	Information Technology	-	-	B	0.5994
Technogym S.p.A.	Consumer Cyclical	D-	0.0237	A+	0.9245
Telecom Italia	Consumer Cyclical	C-	0.3037	B	0.6547
Tenaris	Energy	D+	0.2271	A+	0.9688
Tenra S.p.A.	Utilities	B+	0.6689	B+	0.6763
Tesmec	Industrials	D+	0.1928	A-	0.7797
The Italian Sea Group	Industrials	-	-	-	-
Tinexta	Information Technology	-	-	A	0.9126
Tiscali	Communication Services	C-	0.2950	A	0.8716
TITANMET	Financials	-	-	-	-
TOD'S	Consumer Cyclical	C-	0.3321	A	0.9046
Trevi Finanziaria Industriale S.p.A.	Industrials	-	-	C	0.3419
Triboo S.p.A.	Communication Services	-	-	-	-
TXT e-solutions S.p.A.	Information Technology	-	-	A	0.8921
UniCredit S.p.A.	Financials	D	0.0913	A+	0.9844
Unieuro S.p.A.	Consumer Cyclical	-	-	B-	0.5751
Unipol S.p.A.	Financials	C-	0.3244	A-	0.8134
UnipolSai S.p.A.	Financials	D	0.1161	A	0.8834
Valsoia S.p.A.	Consumer Staples	-	-	A+	0.9688
Webuild S.p.A.	Industrials	D	0.1647	C+	0.4694
Wiit S.p.A.	Information Technology	C-	0.2946	C	0.4137
Zignago Holding S.p.A.	Consumer Cyclical	D-	0.0562	C+	0.4516
Zucchi S.p.A.	Consumer Cyclical	A	0.8424	C	0.3784



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# Appendix A

## Greenhouse Gas (GHG), Ozone-Depleting Substances (ODS) and other significant emissions

GHG emissions reduction: $f_a(x) = \min(f_r(x), 1)$ , $x = s_{1.1}$	
Reduction intervals - $k_5$	Reward rate - $r$
$I_3 = (Q_{K_5}(0.66), 1]$	0.10
$I_2 = (Q_{K_5}(0.33), Q_{K_5}(0.66)]$	0.05
$I_1 = [0, Q_{K_5}(0.33)]$	-

Table A1: GHG emissions reduction chart.

## Water

Water stress: $f_a(x) = (1 - p)x$ , $x = s_{2.1}$			
Water stress	Penalty rate - $p$	Score	Adj score
Low	-	from A+ to A-	unchanged
		from B+ to B-	unchanged
		from C+ to C-	unchanged
		from D+ to D-	unchanged
Low-medium	-	from A+ to A-	unchanged
		from B+ to B-	unchanged
		from C+ to C-	unchanged
		from D+ to D-	unchanged
Medium-high	$\frac{1}{8}$	from A+ to A-	↓ from A to B
		from B+ to B-	↓ from B to C+
		from C+ to C-	↓ from C+ to D+
		from D+ to D-	↓ from D+ to D-
High	$\frac{1}{4}$	from A+ to A-	↓ from B+ to B-
		from B+ to B-	↓ from B- to C
		from C+ to C-	↓ from C to D+
		from D+ to D-	↓ from D+ to D-
Extremely high	$\frac{1}{2}$	from A+ to A-	↓↓ from C+ to C
		from B+ to B-	↓↓ from C to D+
		from C+ to C-	↓ from D+ to D
		from D+ to D-	↓ from D to D-

Table A2: Water stress penalty chart.

## Land use and biodiversity

IUCN Red List: extinction risk	
Red List category	Penalty - $\alpha$
Data deficient	1
Least concern	1
Near threatened	2
Vulnerable	3
Endangered	4
Critically endangered	5

Table A3: Guidelines for the application of the extinction risk.

## Waste ad pollution

Waste prevention: $f_a(x) = \min(f_r(x), 1)$ , $x = s_{5.1}$	
Prevention intervals - $k_4$	Reward rate - $r$
$I_3 = (Q_{K_4}(2/3), 1]$	0.10
$I_2 = (Q_{K_4}(1/3), Q_{K_4}(2/3)]$	0.05
$I_1 = [0, Q_{K_4}(1/3)]$	-

Table A4: Waste prevention chart.

## Clean-tech and renewables

Energy consumption reduction: $f_a(x) = \min(f_r(x), 1)$ , $x = s_{6.1.a}$	
Reduction intervals - $k_3$	Reward rate - $r$
$I_3 = (Q_{K_3}(0.66), 1]$	0.10
$I_2 = (Q_{K_3}(0.33), Q_{K_3}(0.66)]$	0.05
$I_1 = [0, Q_{K_3}(0.33)]$	-

Table A5: Energy consumption reduction chart.

Reduction in energy requirement: $f_a(x) = \min(f_r(x), 1)$ , $x = s_{6.1.b}^{(1)}$	
Reduction intervals - $k_4$	Reward rate - $r$
$I_3 = (Q_{K_4}(0.66), 1]$	0.10
$I_2 = (Q_{K_4}(0.33), Q_{K_4}(0.66)]$	0.05
$I_1 = [0, Q_{K_4}(0.33)]$	-

Table A6: Reduction in energy requirement chart.

## Penalty

Governance pillar	<b>Economic performance and its impacts</b>		
	<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>
	203-1a	203-1a	Infrastructure investments and services supported
	204-1a	204-1a	Percentage of the procurement budget used for significant locations of operations that is spent on suppliers local to that operation
	<b>Market presence</b>		
	<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>
	202-1a	202-1ar	Ratio of the entry level wage at significant locations of operation to the minimum wage
	202-2a	202-2a	Percentage of senior management at significant locations of operation that are hired from the local community
	<b>Business ethics</b>		
	<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>
	205-2a	202-2ar	Total number of governance body members that the organization's anti-corruption policies and procedures have been communicated to
	202-2b	202-2br	Total number of employees that the organization's anti-corruption policies and procedures have been communicated to
	205-3d	205-3dr	Public legal cases regarding corruption brought against the organization or its employees during the reporting period
	206-1a	206-1a	Number of legal actions pending or completed during the reporting period regarding anti-competitive behavior and violations of anti-trust and monopoly legislation in which the organization has been identified as a participant

Table A7: GRI economic Standards (GRI 200) exploited in the algorithm.

Note that the first column indicates the original code, while the last ones indicate its corresponding in the new documentation.

<b>Greenhouse gas (GHG), Ozone-Depleting substances (ODS) and other significant emissions</b>		
<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>
305-1a	305-1a	Direct (Scope 1) GHG emissions
305-2a	305-2a	Energy indirect (Scope 2) GHG emissions
305-3a	305-3a	Other indirect (Scope 3) GHG emissions
305-5a	305-5a	Reduction of GHG emissions
305-6a	305-6a	Emissions of ozone-depleting substances (ODS)
<b>Water</b>		
<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>
303-3a	303-3ar.i	Water withdrawal
303-5a	303-5ar	Water consumption
<b>Land use and biodiversity</b>		
<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>
304-4	304-4r	Total number of IUCN Red List species and national conservation list species with habitats in areas affected by the operations of the organization, by level of extinction risk
<b>Raw materials sourcing</b>		
<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>
301-1	301-1	Materials used
301-1a.i	301-1a.i	Non renewable materials used
301-1a.ii	301-1a.ii	Renewable materials used
301-2	301-2	Recycled input materials used
<b>Waste and pollution</b>		
<b>GRI</b>	<b>rGRI</b>	<b>revised Key performance indicators</b>
306-3a	306-3a	Waste generated
306-4a	306-4a	Waste diverted from disposal
306-5a	306-5a	Waste directed to disposal
<b>Clean-tech and renewables</b>		
<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicators</b>
302-1a	302-1a	Non renewable energy consumption within the organization
302-1b	302-1b	Renewable energy consumption within the organization
302-4a	302-4a	Reduction of energy consumption
302-5a	302-5a	Reductions in energy requirements of products and services

Table A8: GRI environmental Standards (GRI 300) exploited in the algorithm.

Note that the first column indicates the original code, while the last ones indicate its corresponding in the new documentation.

<b>Employment</b>			
<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>	
405-1a.i	405-1br.i	Number of male individuals within the organization's governance bodies at the end of the reporting period	
405-1a.i	405-1br.ii	Number of female individuals within the organization's governance bodies at the end of the reporting period	
405-1b.i	405-1br.iii	Number of male employees at the end of the reporting period	
405-1b.i	405-1br.iv	Number of female employees at the end of the reporting period	
405-1a.ii	405-1br.v	Number of individuals within the organization's governance bodies under 30 years old at the end of the reporting period	
405-1a.ii	405-1br.vi	Number of individuals within the organization's governance bodies between 30 and 50 years old at the end of the reporting period	
405-1a.ii	405-1br.vii	Number of individuals within the organization's governance bodies over 50 years old at the end of the reporting period	
405-1b.ii	405-1br.viii	Number of employees under 30 years old at the end of the reporting period	
405-1b.ii	405-1br.ix	Number of employees between 30 and 50 years old at the end of the reporting period	
405-1b.ii	405-1br.x	Number of employees over 50 years old at the end of the reporting period	
405-2a	405-2ar	Ratio of basic salary and remuneration of women to men	
<b>Occupational and customer health and safety</b>			
<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>	
403-9a.i	403-9ar.i	Rate of fatalities as a result of work-related injury	
403-9a.ii	403-9ar.ii	Rate of high-consequence work-related injuries (excluding fatalities)	
403-9ar.iii	403-9a.iii	Rate of recordable work-related injuries	
403-10a.i	403-10ar.i	Rate of fatalities as a result of work-related ill health	
403-10a.ii	403-10ar.ii	Rate of recordable work-related ill health	
416-2a.i	416.2a.i	Incidents of non-compliance with regulations concerning the health and safety impacts of products and services resulting in a fine or penalty	
416-2a.ii	416-2a.ii	Incidents of non-compliance with regulations concerning the health and safety impacts of products and services resulting in a warning	
416-2a.iii	416-2a.iii	Incidents of non-compliance with voluntary codes concerning the health and safety impacts of products and services	
<b>Training and education</b>			
<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>	
404-1a.ii	404-1a.ii.i	Average hours of training in senior leadership	
404-1a.ii	404-1a.ii.ii	Average hours of training in management	
404-1a.ii	404-1a.ii.iii	Average hours of training in professional	
404-1a.ii	404-1a.ii.iv	Average hours of training in operational and technical	

Table A9: GRI social Standards (GRI 400) exploited in the algorithm.

Note that the first column indicates the original code, while the last ones indicate its corresponding in the new documentation.

<b>Social pillar</b>	<b>Modern slavery</b>		
	<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicator</b>
	406-1a	406-1ar	Incidents of discrimination resulting in legal actions or complaints
	<b>Communities</b>		
	<b>GRI</b>	<b>rGRI</b>	<b>revised Key performance indicators</b>
	411-1a	411-1ar	Incidents of violations involving rights of indigenous peoples
	<b>Product responsibilities</b>		
	<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicators</b>
	417-2a.i	417-2a.i	Incidents of non-compliance concerning product and service information and labeling resulting in a fine or penalty
	417-2a.ii	417-2a.ii	Incidents of non-compliance concerning product and service information and labeling resulting in a warning
	417-2a.iii	417-2a.iii	Incidents of non-compliance with voluntary codes concerning product and service information and labeling
	417-3a.i	417-3a.i	Incidents of non-compliance concerning marketing communications resulting in a fine or penalty
	417-3a.ii	417-3a.ii	Incidents of non-compliance concerning marketing communications resulting in a warning
	417-3a.iii	417-3a.iii	Incidents of non-compliance with voluntary codes concerning marketing communications resulting in a warning
	<b>Data privacy</b>		
	<b>GRI</b>	<b>rGRI</b>	<b>revised Key Performance Indicators</b>
418-1b	418-1b	Losses of customer data	

**Table A10:** GRI social Standards (GRI 400) exploited in the algorithm.

Note that the first column indicates the original code, while the last ones indicate its corresponding in the new documentation.

## Appendix B

In the following we list the regression models we analyse highlighting the row which corresponds to the model we select.

### Direct (Scope 1) GHG emissions to NO<sub>x</sub>, SO<sub>x</sub>, other significant air emissions regression model

Recalling that:

- 305-1a Direct (Scope 1) GHG emissions
- 305-7a Nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>) and other significant air emissions

Model	Dependent variable	Explanatory variable	Fitted coeffs		Statistic
	$y$	$x$	$q$	$m$	$R^2$
OLS	305-1a	305-7a	7.9675	0.7112	0.7110
WLS - $w = 1/\sigma^2$	305-1a	305-7a	8.0385	0.7600	0.7000
WLS - $w = 1/\hat{y}$	305-1a	305-7a	7.9071	0.7811	0.7100
WLS - $w = 1/\hat{y}^2$	305-1a	305-7a	7.8579	0.7903	0.6920

Table B1: Direct (Scope 1) GHG emissions to NO<sub>x</sub>, SO<sub>x</sub> and other significant air emissions regression models estimates – logarithm transformations.

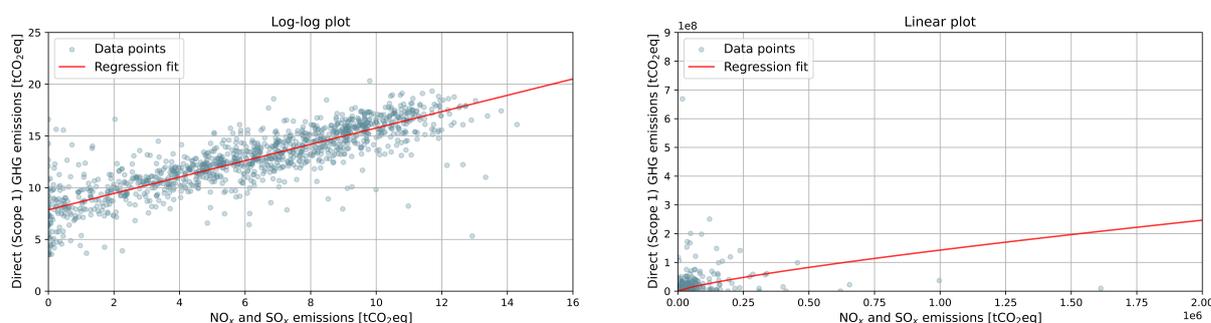


Figure 2: Water discharge to water withdrawal Weighted Least Square -  $w = 1/\hat{y}^2$  regression model.

## Water discharge to water withdrawal regression model

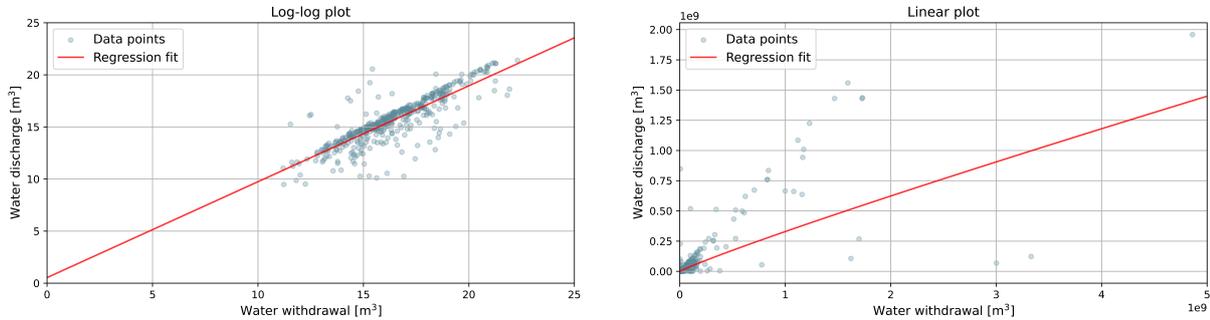


Figure 3: Water discharge to water withdrawal Ordinary Least Square regression model.

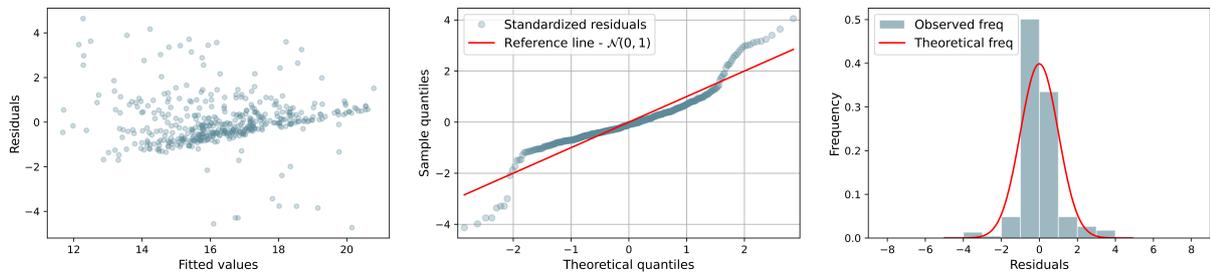


Figure 4: Water discharge to water withdrawal Ordinary Least Square regression residuals.

Breusch-Pagan/Cook-Weisberg test summary table			
Model	Stat	p-value	Homoskedasticity
OLS	0.0309	0.8606	yes
WLS - $w = 1/\sigma^2$	0.0263	0.8712	yes
WLS - $w = 1/\hat{y}$	0.0263	0.8712	yes
WLS - $w = 1/\hat{y}^2$	0.0236	0.8779	yes

Table B2: Statistical test for homoskedasticity applied to water discharge to water withdrawal regression models.

Since tests results return p-values greater than 85% for all the regression models, we proceed by choosing the most appropriate regression line analysing the other assumptions that the residues should fulfill. Precisely, none of the models considered accepts Shapiro’s null hypothesis, rejecting normal distribution of errors, but as anticipated, we can relax this assumption because of the large size of the dataset. At the end, we select the simplest model, the Ordinary Least Square model.

Recalling that:

- 303-4a Water discharge
- 303-3a Water withdrawal

Model	Dependent variable	Explanatory variable	Fitted coeffs		Statistic
	$y$	$x$	$q$	$m$	$R^2$
OLS	303-4a	303-3a	0.5345	0.9206	0.7040
WLS - $w = 1/\sigma^2$	303-4a	303-3a	0.6503	0.9135	0.6930
WLS - $w = 1/\hat{y}$	303-4a	303-3a	0.6258	0.9150	0.6960
WLS - $w = 1/\hat{y}^2$	303-4a	303-3a	0.7172	0.9093	0.6870

Table B3: Water discharge to water withdrawal regression models estimates – logarithm transformations.

## Waste generated to waste recycled regression model

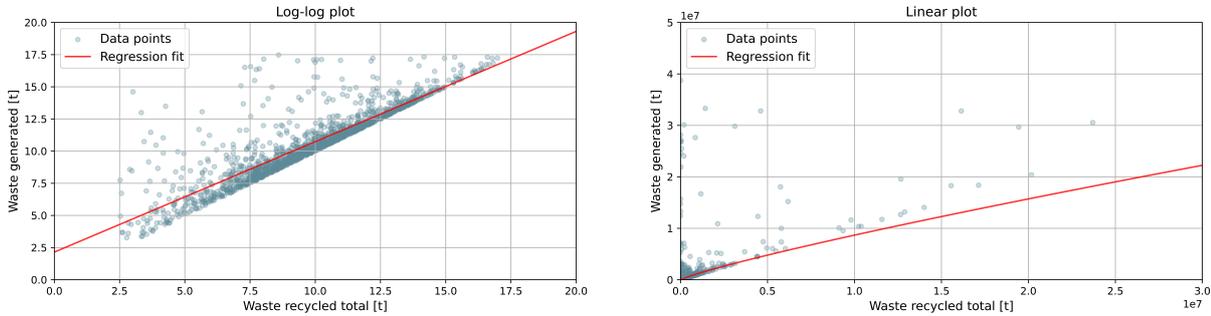


Figure 5: Waste generated to waste recycled Ordinary Least Square regression model.

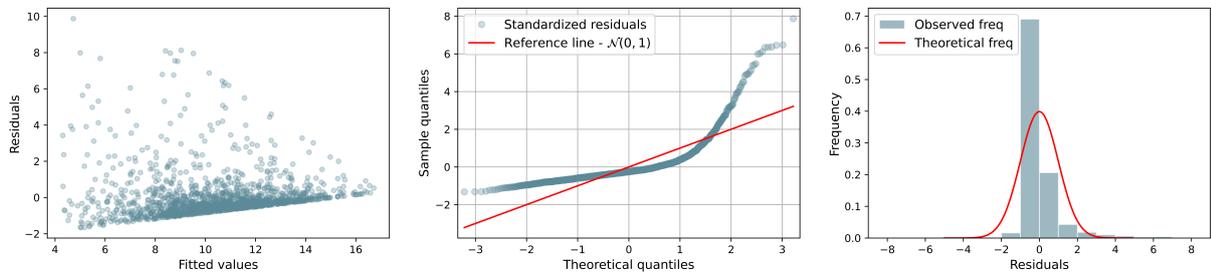


Figure 6: Waste generated to waste recycled Ordinary Least Square regression residuals.

Breusch-Pagan/Cook-Weisberg test summary table			
Model	Stat	p-value	Homoskedasticity
OLS	48.1791	$3.8902 \cdot 10^{-12}$	no
WLS - $w = 1/\sigma^2$	48.1791	$3.8902 \cdot 10^{-12}$	no
WLS - $w = 1/\hat{y}$	48.8269	$2.7958 \cdot 10^{-12}$	no
WLS - $w = 1/\hat{y}^2$	45.6158	$1.4388 \cdot 10^{-11}$	no

Table B4: Statistical test for homoskedasticity applied to waste generated to waste recycled regression models.

Since none of these regression models verifies homoskedasticity assumption, we are forced to rule the prediction out from the analysis.

Recalling that:

- 306-2a Waste recycled
- 306-3a Waste generated

Model	Dependent variable	Explanatory variable	Fitted coeffs		Statistic
	$y$	$x$	$q$	$m$	$R^2$
OLS	306-3a	306-2a	2.1489	0.8578	0.7730
WLS - $w = 1/\sigma^2$	306-3a	306-2a	1.8106	0.8910	0.9350
WLS - $w = 1/\hat{y}$	306-3a	306-2a	2.3931	0.8326	0.7400
WLS - $w = 1/\hat{y}^2$	306-3a	306-2a	2.6547	0.8035	0.6930

Table B5: Waste generated to waste recycled regression models estimates – logarithm transformations.

## Energy consumption to energy intensity regression model

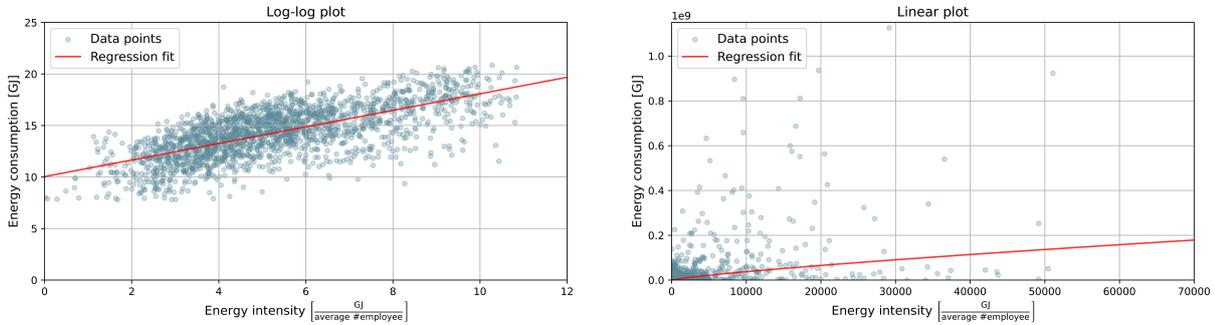


Figure 7: Energy consumption to energy intensity Ordinary Least Square regression residuals.

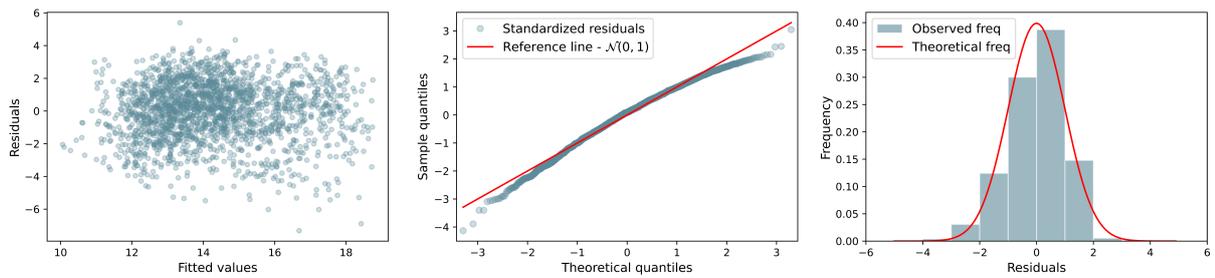


Figure 8: Energy consumption to energy intensity Ordinary Least Square regression residuals.

Breusch-Pagan/Cook-Weisberg test summary table			
Model	Stat	p-value	Homoskedasticity
OLS	14.9218	0.0001	no
WLS - $w = 1/\sigma^2$	16.0233	$6.2566 \cdot 10^{-5}$	no
WLS - $w = 1/\hat{y}$	16.4811	$4.9138 \cdot 10^{-5}$	no
WLS - $w = 1/\hat{y}^2$	18.3397	$1.8482 \cdot 10^{-5}$	no

Table B6: Statistical test for homoskedasticity applied to waste generated to waste recycled regression models.

Since none of these regression models verifies homoskedasticity assumption, we are forced to rule the prediction out from the analysis.

Recalling that:

- 302-1e + 302-2a Energy consumption
- 302-3ar Energy intensity

Model	Dependent variable	Explanatory variable	Fitted coeffs		Statistic
	y	x	<i>q</i>	<i>m</i>	<i>R</i> <sup>2</sup>
OLS	302-1e + 302-2a	302-3ar	10.0446	0.8029	0.4730
WLS - $w = 1/\sigma^2$	302-1e + 302-2a	302-3ar	9.9773	0.8158	0.4740
WLS - $w = 1/\hat{y}$	302-1e + 302-2a	302-3ar	9.9498	0.8209	0.4750
WLS - $w = 1/\hat{y}^2$	302-1e + 302-2a	302-3ar	9.8514	0.8405	0.4760

Table B7: Energy consumption to energy intensity predicted models – logarithm transformations.



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