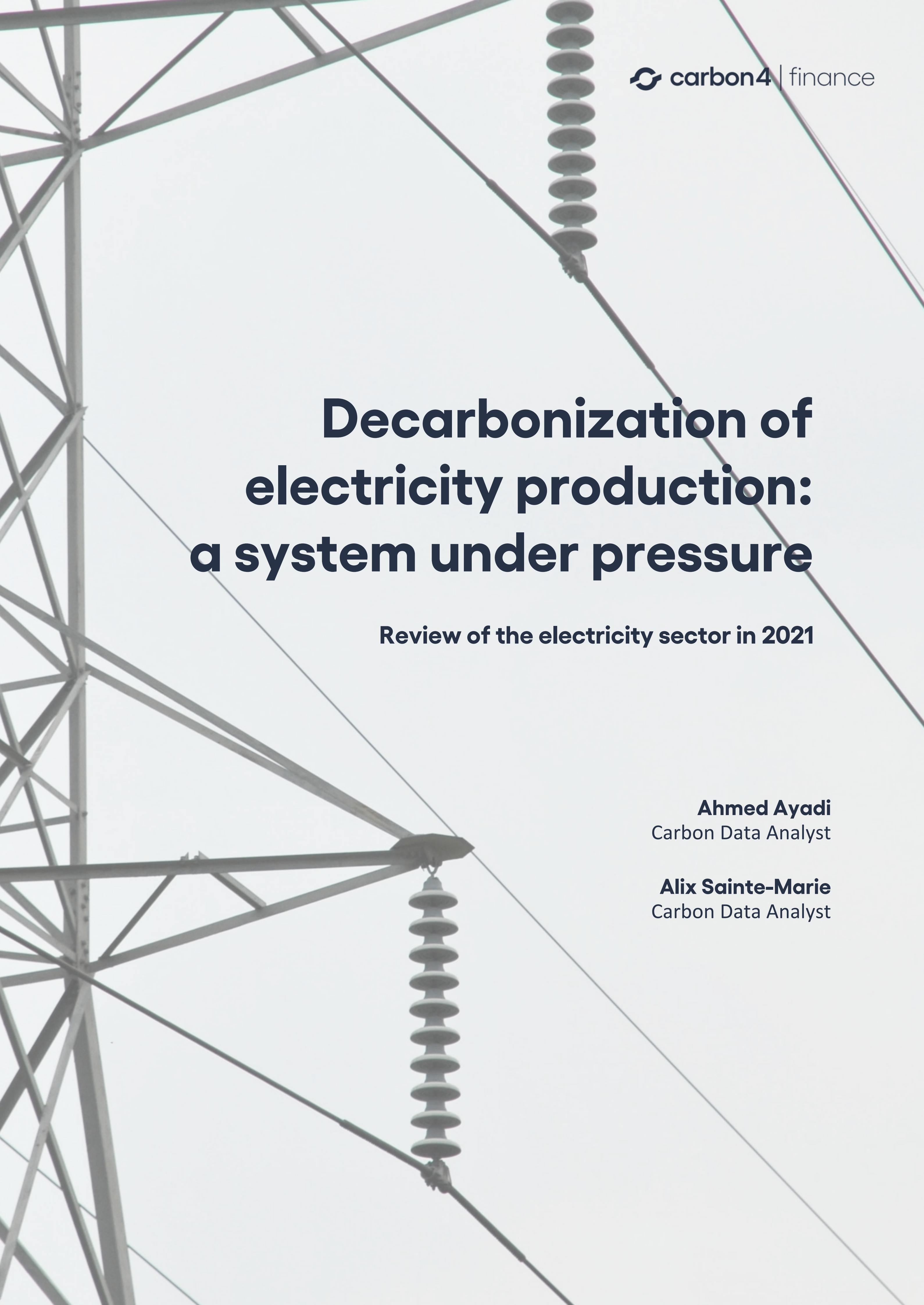

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Decarbonization of electricity production: a system under pressure

Review of the electricity sector in 2021

Ahmed Ayadi
Carbon Data Analyst

Alix Sainte-Marie
Carbon Data Analyst

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Summary

Electricity stands at the forefront of energy transition challenges. While the power sector is responsible for over a third of global energy related GHG emissions, it also holds the key to decarbonization. The electrification of end-use consumption with low-carbon production sources is crucial for decarbonizing the various economic sectors.

Efforts to decarbonize the global power system are multiplying. In 2021, investments in renewable generation exceeded $440 billion, four times the amount invested in fossil-fired power plants in the same year. As a result, the share of renewable energies in the global electricity mix is steadily increasing. This increase has been mainly driven by the development of solar and wind power, which have recorded the highest growth rates in the sector. On average, the combined output of solar and wind farms has risen by 22% annually over the past two decades, and their share of the global electricity mix reached the 10% threshold for the first time in 2021.

Yet, current decarbonization efforts are falling short. The International Energy Agency (IEA) suggests that to align the global economy with the NZE (Net Zero Emissions) scenario and cap global warming at 1.5°C, transition investments need to triple by 2030[1]. Presently, these investments are unevenly distributed, with the bulk concentrated in China and developed nations. Furthermore, despite the growth of low-carbon energies, our reliance on fossil fuels remains undiminished. Coal, alarmingly, is still the dominant source of electricity, contributing to over a third of worldwide production. Even more concerning, 2021 set new highs in coal-fired electricity output, leading to a record level of greenhouse gas emissions from the sector.

Nevertheless, a transition is underway. Renewable energy production costs have significantly decreased in recent years, and the technologies are maturing rapidly with global deployment accelerating. Sector companies, recognizing the urgency of the climate crisis, are reevaluating their business models, and pivoting towards decarbonized production sources.

In this study**, we analyzed 153 companies in the electricity sector using the *Carbon Impact Analytics (CIA)* methodology**. These companies account for over a third of the world's electricity production and more than three-quarters of the sector's global market capitalization. Studying the results of these analyses enables us to assess the features of the energy transition, compare the performance of the various players and evaluate the alignment of their transition strategies with different climate scenarios.

[1] IEA, World Energy Investment 2022.

Key messages

- **Among electricity producers, we observe two diametrically opposed groups:** those who produce exclusively decarbonized electricity on the one hand, and fossil fuel players on the other. Among the integrated players (both producers and electricity transporters and/or distributors), we observe few fully decarbonized profiles.

- **The most polluting players have made marginal reductions in their carbon intensity over the past five years.** While many of these entities have set emission reduction goals, these targets often lack ambition and do not align with the aim of limiting global warming to below 2°C.

- **Some companies stand out as exceptions.** *PGE Polska Grupa Energetyczna* is the most polluting company in the sample (in terms of intensity, expressed in tCO_2 e/MWh produced). The Polish producer has published a highly ambitious transition strategy aimed at moving away from coal (90% of its energy mix) and achieving a 50% share of renewables by 2030, before moving to 100% renewables by 2050.

- **Decarbonization is possible on a producer scale, and certain entities are actively demonstrating its feasibility.** *Ørsted* has registered the most significant decrease in carbon intensity among its peers. The Danish producer has achieved a spectacular transformation of its energy mix in a decade. In 2008, the company generated 80% of its electricity from fossil fuels, with coal contributing 50%. Today, it is the world leader in offshore wind power. Its production mix is over 90% carbon-free.

- **Global electricity decarbonization is in progress, though the momentum differs across regions.** In Asia, the challenge of skyrocketing electricity demand keeps most countries anchored to coal, which represent over half of the total power production. Conversely, Europe and North America have witnessed a significant reduction in coal's contribution to their electricity mix over the last twenty years, with gas—especially shale gas in the U.S.—filling the gap. Meanwhile, the proportion of solar and wind energy in the energy mix is on the rise across all these continents, albeit at varying rates.

- **Grid operators play a crucial role in integrating large volumes of intermittent energy sources, such as solar and wind, which demands flexibility to ensure grid stability.** Some operators are actively pursuing this challenge, formulating comprehensive investment plans to modernize their networks in response. However, others appear less engaged in addressing climate concerns, with the integration of emerging renewable energies being minimal or entirely missing from their strategic priorities.

The challenges facing the electricity sector

A sector at the heart of the energy transition

Over the last few decades, a scientific consensus has emerged on the impact of human activities on the climate. Anthropogenic greenhouse gas emissions are warming the planet at an unprecedented rate[2]. This fact has become undeniable, and efforts to mitigate its effects have intensified.

Energy is the cornerstone of the issue. Fossil fuels have transformed our societies and shaped our world. Today, almost two-thirds of global greenhouse gas emissions are linked to energy[3].

In this context, the electricity sector crystallizes the challenges of the energy transition. On the one hand, the sector is highly emissive. With 14.6 gigatons of CO2 equivalent emitted in 2021, it is responsible for more than a third of energy-related GHG emissions[4]. On the other hand, the development of low-carbon energies represents an opportunity and an indispensable condition for transforming our energy system and reducing our emissions. Indeed, electrification is a fundamental pillar for decarbonizing the various economic sectors. Moving away from fossil fuels requires not only energy sobriety, but also electrification. We need to replace fossil fuel-powered machines with electric alternatives, while rapidly increasing the share of decarbonized electricity in the global energy mix. Considerable efforts will be required, especially as the NZE (Net Zero Emissions) scenario of the International Energy Agency (IEA) assumes a sharp increase in the global electricity demand, which would triple by 2050[5].

The global mix remains unchanged

Electricity is therefore both the problem and the solution. The sector is highly emissive, mainly due to its heavy reliance on coal, which is still the world's leading energy source (see Figure 2). Nevertheless, the development of renewable energies (solar, wind, hydro, biomass and geothermal) has accelerated in recent decades. Since 2000, renewable electricity production (from all sources) has grown at an average annual rate of 4.9%, well ahead of the 2.6% average growth in world electricity production. Growth in renewables was mainly driven by the large-scale development of solar and wind power. Solar production grew by 39% and wind power by 20% annually over the same period. Mature technologies, government subsidies and lower production costs have encouraged investment in these energies. China is now the world leader in solar and wind power, accounting for more than half of the increase in global production in 2021.

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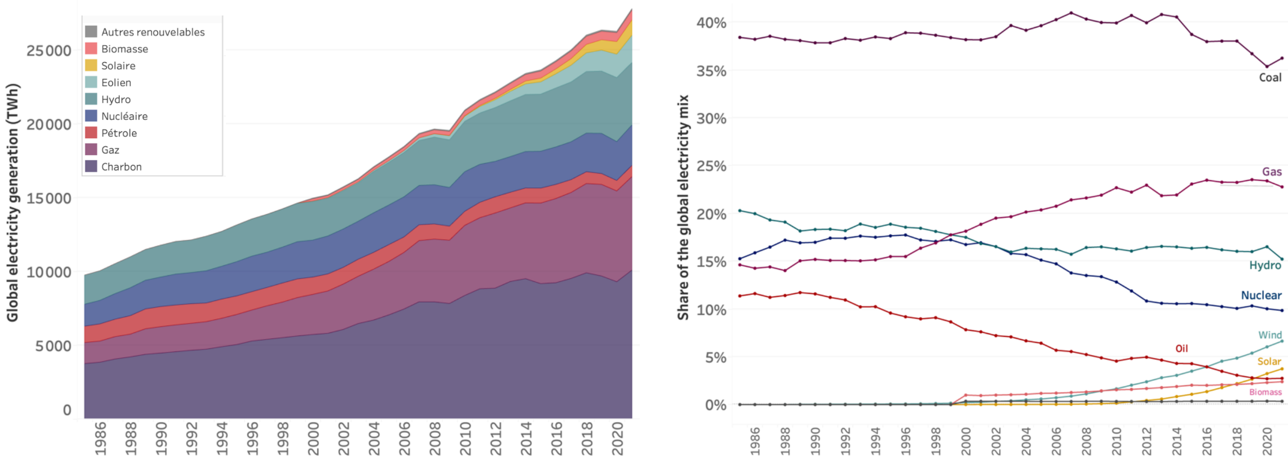
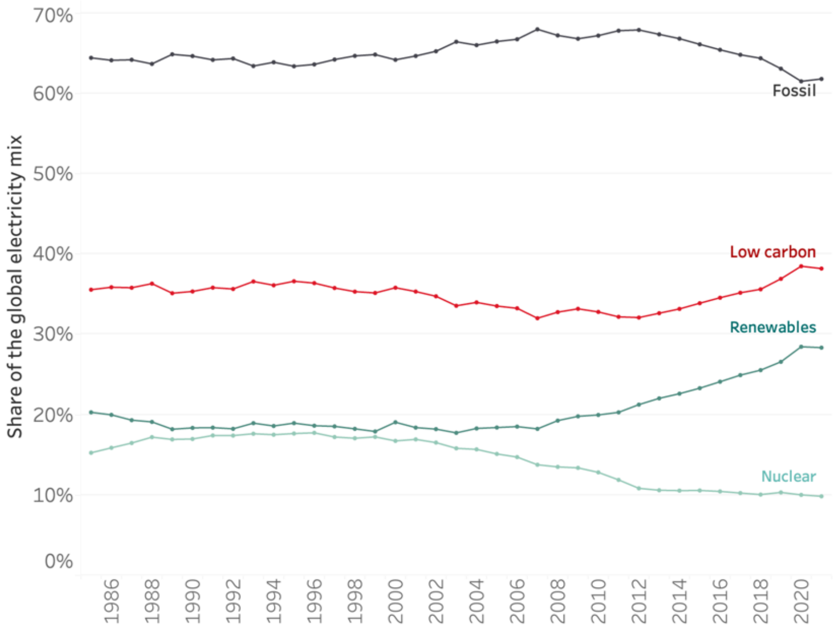
[2] IPCC, Climate Change 2021: The physical scientific basis.
[3] IEA, Greenhouse Gas Emissions from Energy Data Explorer http://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer.
[4] IEA, Global Energy Review: CO2 Emissions in 2021.
[5] IEA, Net Zero by 2050 A Roadmap for the Global Energy Sector.



Source: Our World in Data , Electricity Mix

Figure 1: Global electricity production by source (left) share of each source in the global electricity mix (right)

However, the strong growth in renewable energies has not changed the global electricity mix. Today, almost two-thirds of the world's electricity is generated from fossil fuels (mainly coal and gas). This breakdown has not changed significantly over the last few decades, as the decline in oil has been offset by an increase in gas. On the other hand, the share of low-carbon production methods has increased over the last decade, thanks to the development of renewable energies. However, this increase has been held back by the decline in nuclear power's share of the global mix.



Source: Our World in Data , Electricity Mix

Figure 2: Share of renewables, nuclear and fossil fuels in the global electricity mix

2021: New record for emissions

It's a paradoxical landscape. While efforts to transform the electricity system are multiplying amid the climate crisis, the share of coal and other fossil fuels in the global energy mix has changed little in decades.

The year 2021 is a perfect illustration of this contradiction. For the first time, the share of solar and wind power in the global electricity mix passed the 10% mark. It rose from 9.3% in 2020 to 10.3% in 2021. Nevertheless, this development was not sufficient to cover the rise in electricity demand induced by the global economic rebound following the Covid crisis. Global production increased by over 5%, marking the highest growth rate since 2010. Rising gas prices combined with unfavorable weather conditions for hydroelectricity[6] led to a strong demand for coal-fired power plants. Output from these plants rose by over 9%, covering more than half of the increase in electricity demand. Coal-fired power generation reached a new absolute record, leading to a record level of GHG emissions from the sector.

The challenge of intermittence

The share of renewable energies in global electricity production, while still insufficient, has been rising steadily over the past 15 years. According to IEA projections, renewable energies should cover almost 90% of global production in a scenario where GHG emissions reach net zero in 2050. Combined, solar and wind energies would account for more than half of the production[7].

While the growth of solar and wind energies offers promise, their intermittent nature poses challenges for power grid stability. Maintaining a consistent balance between supply and demand is crucial for the stability of a power system. To achieve this, grid operators utilize operational reserves, predominantly composed of controllable thermal power plants that can swiftly modify output in response to demand fluctuations. As we shift towards a grid dominated by non-dispatchable sources like solar and wind, it's imperative to introduce new flexibility measures to ensure a reliable electricity supply[8]. Multiple strategies can be employed to bolster system stability, including large-scale storage solutions like batteries for daily variations and pumped-storage hydroelectricity for weekly changes, peak power plants fueled by biofuels or fossil fuels equipped with carbon capture, enhanced electrical interconnectivity, and demand-side flexibility, where grid-connected devices adjust according to electricity production and consumption.

Transition risks and opportunities

Electricity is at the heart of the energy transition. In most of the available scenarios, production increases to meet growing demand linked to the electrification of end-use consumption. Governments are encouraging investment in renewable energies to meet their greenhouse gas reduction targets. In many parts of the world, renewable energy producers benefit from financial and tax incentives to ensure their competitiveness. New players are entering the market, attracted by the sector's growth and government incentives.

[6] On a global scale, hydroelectric power plant output fell by 15 TWh despite a 50 GW increase in capacity. Source: IEA, https://www.iea.org/reports/hydroelectricity.
[7] IEA, Net Zero by 2050 A Roadmap for the Global Energy Sector.
[8] RTE, Conditions and prerequisites for the technical feasibility of a power system with a high proportion of renewable energies by 2050.

On the other hand, producers reliant on fossil fuels face heightened vulnerability due to rising carbon pricing, stricter emissions regulations for fossil fuel-fired plants, fuel price volatility, and reputational risks associated with increasing climate awareness.

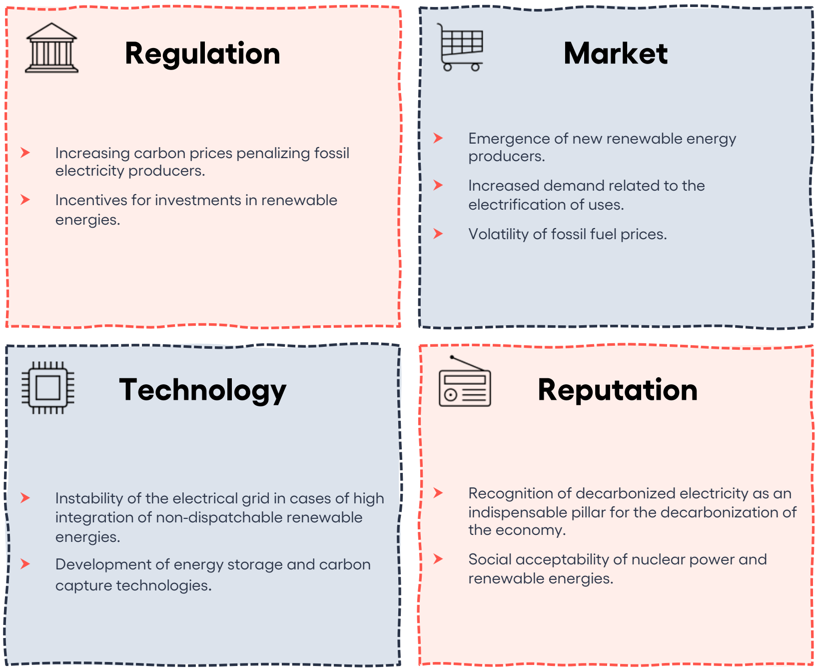


Figure 3: Transition risks and opportunities for the sector

Covered Activities

The analyzed activities encompass the complete value chain of the electricity sector, spanning generation, transmission, distribution, and supply.

Electricity is generated in power plants that convert primary energy sources into electrical energy. Primary energies are thermal (fossil fuels, nuclear, biomass, waste, solar thermal, geothermal), mechanical (hydraulic and wind) and electromagnetic (solar photovoltaic).

As soon as electricity is generated in a power plant, it is transmitted to distribution substations or directly to major consumers (heavy industry, rail transport, etc.) via extra-high voltage (400 and 225 kV) and high voltage (80 and 63 kV) lines. This is known as **electricity transmission.** The use of high-voltage lines minimizes electrical losses during this stage.

Subsequently, the distribution phase begins, delivering electricity to end users. Apart from a few industrial sites directly connected at the transmission level, most consumers receive power after one or two transformer-induced voltage reductions. Electricity is then distributed through medium (20 kV) or low-voltage (400 or 230 V) lines, catering to factories, buildings, and various other consumers.

Electricity supply involves marketing electrical energy to consumers. In essence, suppliers act as pure traders, purchasing electricity either directly from producers or from the electricity market, and then selling it to end users. However, they don't oversee network balancing, production infrastructure, or the physical delivery to their customers. Their primary responsibilities revolve around contract management and billing. While some suppliers might be affiliated with electricity producers (like EDF and Total in France), these two functions operate independently.

Electricity producers often have a secondary activity of **heat production**. Heat is produced in cogeneration plants (simultaneous production of electricity and heat) or in specific plants using a variety of sources (fossil fuels, biomass, waste, geothermal, solar thermal, etc.).

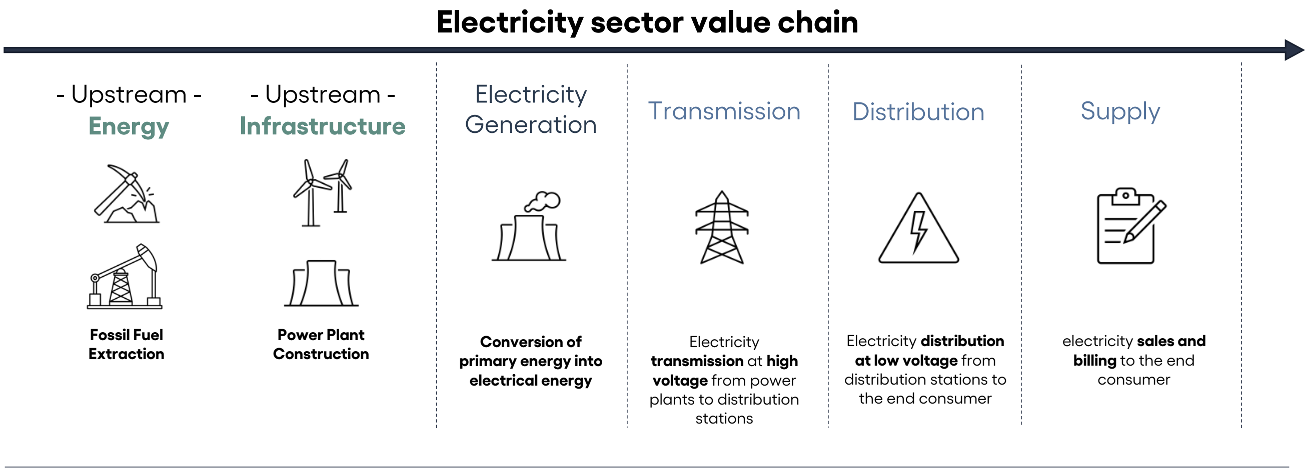


Figure 4: Electricity sector value chain

CIA methodology by activity

When a company is analyzed using the CIA[9] methodology, its activities are segmented based on its revenue distribution. Each segment is assessed using specific criteria and given a score. These individual scores are then combined, with weights corresponding to their revenue contribution, to compute an overall CIA score[10].

For the electricity sector, we distinguish four activities: electricity generation, heat generation, electricity transmission and distribution, and electricity supply. Each activity presents its own specific decarbonization challenges and sources of GHG emissions.

Sources of GHG emissions

Greenhouse gas emissions are the main indicator used to assess the performance of the analyzed entities. Here, we focus on the main sources of emissions specific to each activity. We disregard minority emissions such as those linked to the company's offices and vehicles, or to employee travel.

For each activity, we calculate the scope 1&2 emissions it generates using physical data from the company's public disclosures. This derived value is then cross-referenced with the company's published figures. If the published data is deemed credible, we utilize it for indicator computation and subsequent ratings. If not, our calculated emissions are employed. For scope 3 emissions, we consistently rely on our calculations. Given that published scope 3 emissions data frequently lacks clarity, often omitting scope definitions and calculation methods, our consistent use of calculated emissions ensures uniformity in evaluating all companies within the sector.

Production of electricity and heat

Both activities share analogous emission sources, with thermal power plant combustion being the predominant source of their direct emissions (Scope 1). The emission volume depends on the fuel type and plant efficiency. Coal-fueled plants are the largest contributors, trailed by those using oil. Subsequently, waste incinerators, gas-powered plants, and biomass facilities follow in emission intensity. In contrast, solar, nuclear, wind, and most of hydroelectric facilities typically yield minimal or zero emissions during operation. However, hydroelectric plants situated in tropical regions do emit methane, resulting from the decomposition of organic matter in their reservoirs, which is accounted for in the Scope 1 emissions of the respective companies.

We calculate upstream scope 3 emissions linked to the extraction of fossil fuels used in thermal power plants and to power plant construction. To do this, we use a specific emission factor for each fuel and each type of power plant. We also calculate avoided emissions when the carbon intensity of electricity or heat production (GHG emissions per unit of energy produced) is less than the global intensity required by the IEA's Sustainable Development Scenario (SDS).

[9] The CIA methodological guide is available here: https://www.carbon4finance.com/our-latest-carbon-impact-analytics-methodological-guide2.

[10] Note that for the analysis of a company's decarbonization strategy, transition investments and emissions reduction targets, only its core business is assessed. We do, however, assess the strategy relating to a company's second activity if it represents a significant proportion of its sales.

Transmission and Distribution of electricity

Direct emissions (scope 1) from transport and distribution activities are mainly due to leaks of sulfur hexafluoride (SF_6). SF_6 is an excellent insulator. It is commonly used in medium and high-voltage electrical equipment. Its global warming potential is very high, being 23,500 times that of CO_2 over a hundred years.

Indirect emissions (scope 2) come from electrical losses on transmission and distribution lines. Part of the electricity passing through these lines is lost due to the Joule effect. Emissions linked to the production of this electricity make up the network operators' Scope 2.

We calculate upstream scope 3 emissions (fossil fuel extraction and power plant construction) linked to electricity lost on the grid. We also calculate reduced emissions thanks to the company's reduction in the rate of electricity losses and SF_6 leaks over the last five years.

Supply of electricity

Electricity suppliers do not emit significant scope 1&2 emissions: they are traders and therefore have purely tertiary activities. We only calculate upstream scope 3 emissions linked to the extraction of fossil fuels, the construction of power plants and the production of electricity purchased and resold. We also calculate avoided emissions if the carbon intensity (scope 3) of the electricity sold by the company (average intensity of the company's geographical plate) is lower than the global intensity required by the IEA's Sustainable Development Scenario (SDS).

The following chart summarizes the sources of emissions for each activity:

	Electricity Generation	Transport et Distribution	Electricity Supply	Heat production
Scope 3 Downstream	Emissions related to the extraction of fossil fuels and the construction of power plants	Emissions related to the extraction of fossil fuels and the construction of power plants	Emissions related to the extraction of fossil fuels, the construction of power plants, and the production of electricity.	Emissions related to the extraction of fossil fuels and the construction of power plants
Scope 1&2	• Direct emissions from combustion in thermal power plants • **Methane** emissions from hydroelectric plants in tropical zones	• SF_6 leakage (scope 1) • Grid losses (scope 2)		Direct emissions from combustion in thermal power plants
Emissions Savings	Avoided emissions when the carbon intensity of the company (scope 1, 2, and 3) is lower than that required by the IEA's SDS scenario	Reduced emissions due to the decrease in the rate of electrical losses on the company's network over the past five years.	Avoided emissions when the carbon intensity of the company (scope 3) is lower than that required by the IEA's SDS scenario	Avoided emissions when the carbon intensity of the company (scope 1, 2, and 3) is lower than that required by the IEA's SDS scenario

Figure 5: Sources of GHG emissions included in the CIA methodology for the electricity sector

Calculation of sectoral ratings

As highlighted earlier, a firm's overall CIA rating is dissected into sub-ratings pertinent to each activity. These sectoral scores are in turn subdivided into three pillars: **past performance**, which estimates the company's decarbonization trajectory based on the evolution of its performance over recent years, **current performance**, which measures the company's position at the year of analysis; and **forward-looking performance,** which assesses the company's future decarbonization ambition.

Carbon intensity, which represents the quantity of greenhouse gases emitted per unit of energy generated, is used as a key indicator to measure the performance of electricity and heat producers. The current performance rating of these players depends on their current intensity. To assess their past performance, we track the five-year trajectory of carbon intensity. Leveraging this data, we forecast its progression until 2035, using a compound annual growth rate (CAGR) derived from the past five-year trend. This projection is then compared with the carbon intensity trajectories defined by various IEA scenarios. A company whose intensity evolution is aligned with a net-zero scenario is thus awarded the highest score for this criterion. Finally, for the forward-looking performance rating, we mainly assess the player's emissions reduction target, its investments in new decarbonized capacities and its strategy for transitioning to low-carbon production sources.

Regarding electricity transmission and distribution, companies are mainly evaluated based on two metrics: the percentage of electricity losses within their networks and the intensity of SF6 emissions per electricity unit managed. To evaluate a participant's historical performance, the evolution of these two indicators over the preceding five years is examined, and this data is projected to 2030, facilitating a standardized inter-company comparison. Essentially, this assessment hinges on two variables: an indicator's present value and its evolution rate over the past five years. To illustrate, company A, despite having a higher SF6 leakage intensity than company B, might still secure a superior score if it reduces this leakage more efficiently and if the 2030 projection indicates a surpassing of company B in performance metrics.
For the present performance rating, the average carbon intensity of the company’s operational country or region is considered, alongside its network loss rate. This methodological choice stems from the substantial influence network operators can wield in advancing the energy transition. Indeed, while they may lack direct control over the intensity of electricity moving through their networks, these entities play a crucial role in facilitating the integration of new renewable capacities, thereby aiding in the decarbonization of the electricity mix within their operational domain.

Finally, for electricity suppliers, we employ the average carbon intensity of the company's geographical region to evaluate its present performance. The pertinence of decarbonized electricity purchases (such as PPAs and certificates of origin) poses verification challenges, inhibiting a precise assessment of intensity at the company level. This generates a notable geographical bias within the electricity supply activity. Nonetheless, the impacts of this bias are restrained, considering that this activity constitutes a minority portion of the revenue for the companies under analysis.

Performance indicators for the electricity sector are summarized in the following graph:

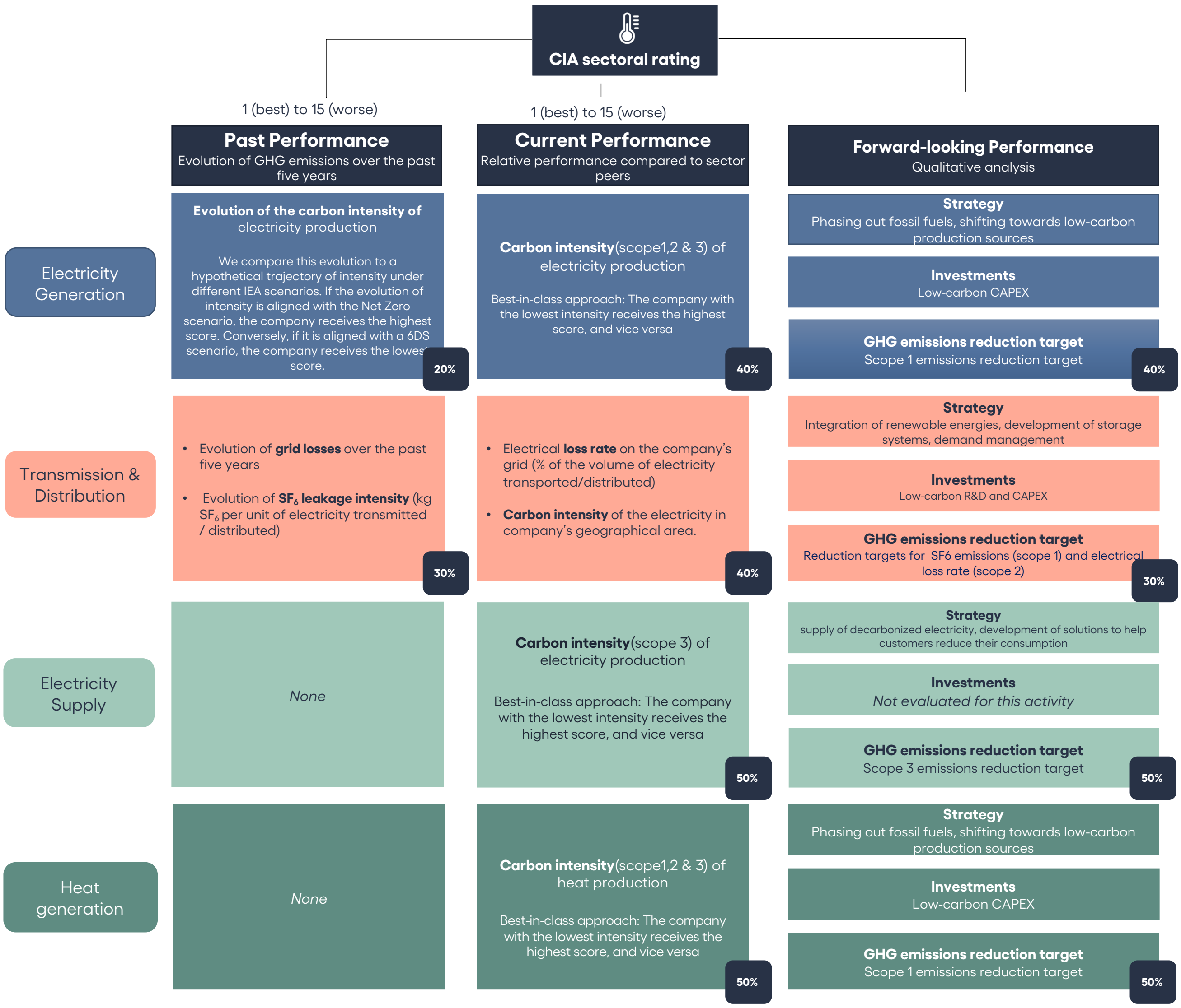


Figure 6: Performance indicators used to calculate sector scores, with the weight of each pillar (past, present, and future) presented as a percentage of the sector score

Representativeness of the sample

The studied sample comprises 153 companies, of which 52 are electricity producers, 19 are transporters and distributors, and 82 are integrated companies combining the two activities. Among the producers, 19 companies exclusively produce renewable electricity.

These companies represent the largest market capitalizations in the sector. Indeed, 79 of the world's top 100 market capitalizations are analyzed, and the sample coverage extends to 76% of the global market value of the electricity sector[11].

The sample mainly represents players from developed and newly industrialized countries. The USA is the most represented country with 34 companies, followed by China with 14 and France with 8.

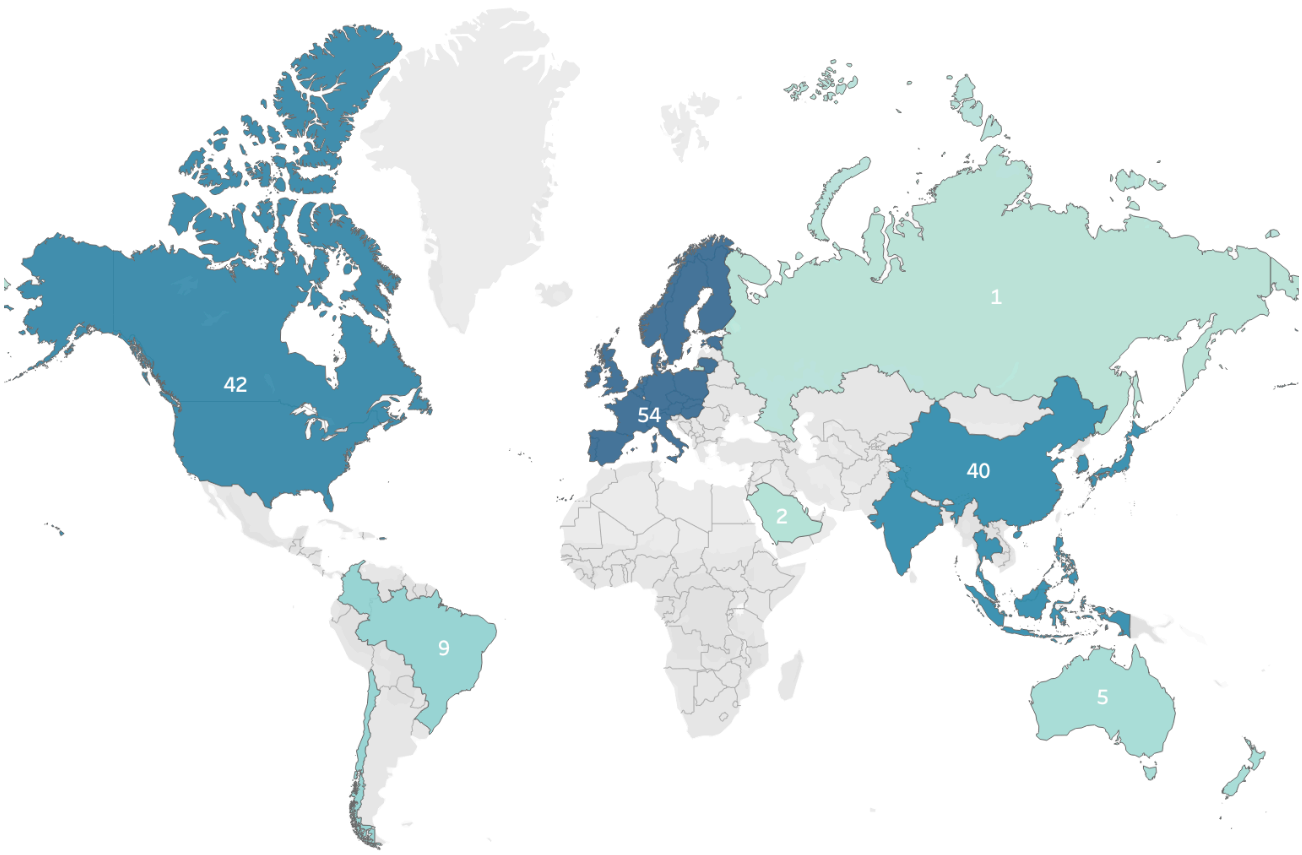


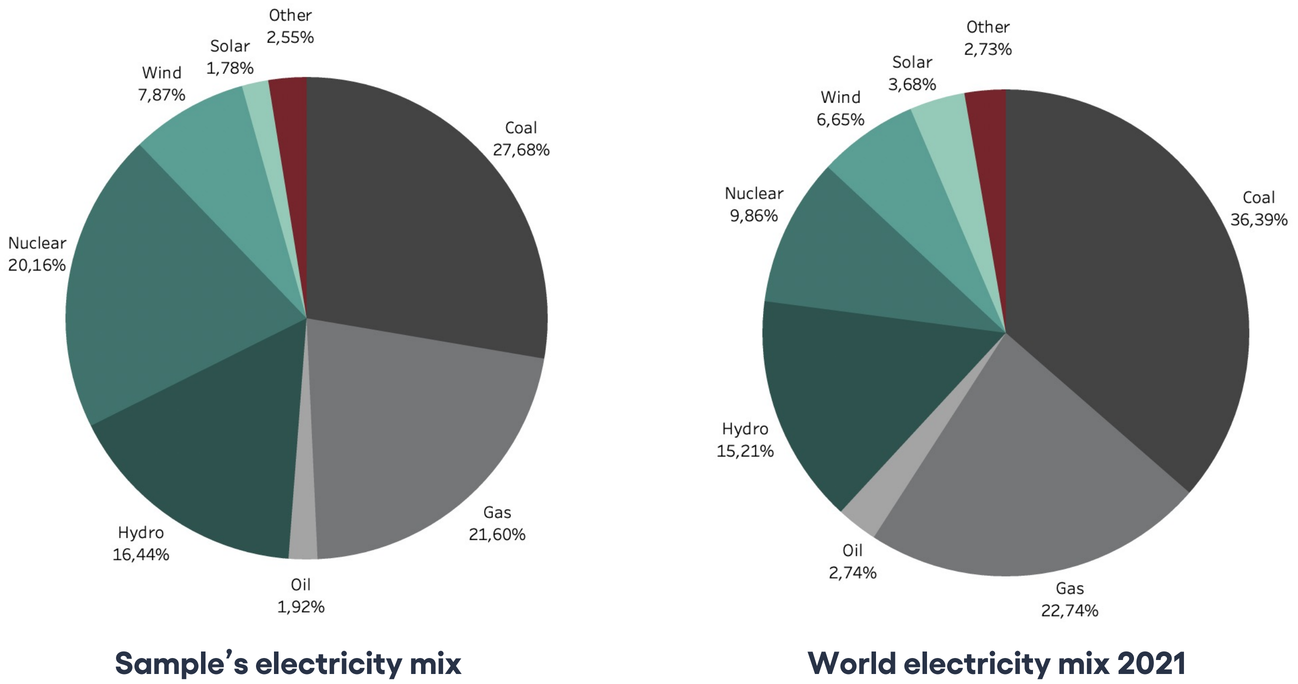
Figure 7: Geographical distribution of the analyzed companies

Entities from developing countries are underrepresented in the sample. The coverage is markedly sparse in Latin America and the Middle East, and entirely absent in Africa and Central Asia. Multiple factors contribute to this situation. For instance, Africa, being the least electrified continent globally, with 43% of its population lacking electricity access, produced 800 TWh of electricity in 2021. This equates to a mere 3% of global production, despite housing one-sixth of the

[11] Sample coverage is determined using data from our financial data provider, FactSet. This is achieved by dividing the sum of the market capitalizations of the companies within our sample by the total market capitalizations of the companies affiliated with FactSet's Utilities segment. The Utilities segment encompasses activities related to the generation, supply, transmission, and distribution of electricity, as well as the distribution of water and natural gas. To confine the calculation specifically to the electricity sector, we have omitted all companies whose predominant activity is the distribution of either water or gas.

world's population[12]. Numerous African nations maintain monopolistic or near-monopolistic standings in the electricity market, and certain regulatory frameworks inhibit sector investment. Consequently, African power producers tend to be either state-owned enterprises or smaller private entities, thereby being omitted from major stock indices, which were our principal sources for constructing our sample.

The analyzed companies produced 9600 TWh of electricity, equating to a third of the global production in 2021[13]. [13] The subsequent figure illustrates the energy mix of the sample and juxtaposes it with the global energy mix from the same year.



Source: Our World in Data , Electricity Mix

Figure 8: Representativeness of the sample's electricity mix

Nuclear power is over-represented in our sample. Nuclear energy accounts for 20% of the sample's total production, compared with less than 10% of the global electricity mix. This is consistent with the geographical distribution of the companies analyzed as global nuclear production is concentrated in developed and newly industrialized countries, which are present in our sample.

[12] IEA, Africa Energy Outlook 2022.

[13] The analyses are based on the latest business data available. Of the 153 companies in the sample, 140 were analyzed based on 2021 data, and 13 companies were analyzed based on 2020 data.

Results

We analyzed the 153 companies in the sample using the CIA methodology described above. For each of these companies, we calculated an overall CIA score ranging from 1 (best performance) to 15 (worst performance). The following graph shows the distribution of the scores obtained by the various players:

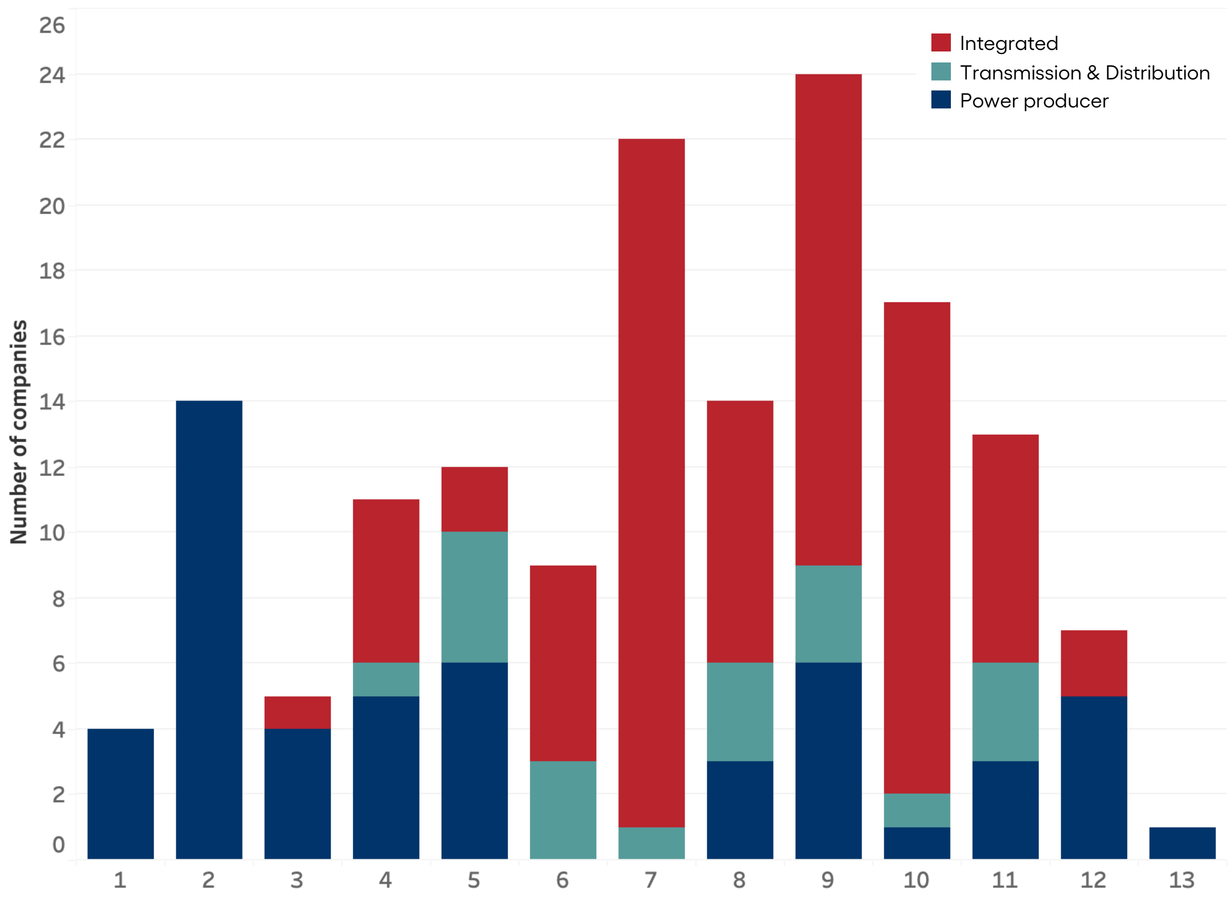


Figure 9: Distribution of overall CIA scores by type of player

Among electricity producers, we distinguish two types of players:
The first group (ratings from 1 to 5) is made up of companies that include a high proportion of decarbonized energy (renewable and nuclear) in their electricity mix. The average carbon intensity of the group is 84 gCO_2 e/kWh. The best-rated players (ratings from 1 to 3) generate **over 90% of their electricity from decarbonized sources**[14].
The second group (scores from 8 to 13) is made up of producers who are significantly dependent on fossil fuels. The average intensity of this group is 660 gCO_2 e/kWh. The worst-rated players (ratings 12 and 13) generate **most of their electricity from coal** (50% to 90% of total production).

Integrated companies show a similar trend. The best-rated players are generally those that have

[14] All the companies concerned, except for ERG SPA, have a decarbonized electricity share of over 90% of their total production volume. Conversely, ERG's electricity mix is made up of renewables (76%) and gas (24%). The company has succeeded in significantly reducing its intensity over the past five years and has achieved a very good forward-looking performance rating given its strategy of moving away from gas and specializing in solar and wind power, which has contributed positively to its overall rating.

managed to integrate a considerable share of decarbonized electricity, while the worst-rated depend on coal and fossil fuels. However, this trend is less pronounced. The integrated players also have electricity transmission and distribution activities, and for some a gas business as well. These activities tend to shift the company's overall rating towards the average, since they have a lesser impact - positive or negative - on the environment than electricity generation. For example, a renewable energy producer that transports gas will see its CIA rating deteriorate, and a coal-fired electricity producer that is also involved in gas transport will see its CIA rating improve.

For transmission and distribution companies, the ratings tend to cluster more closely around the average. Distinctions among these entities are driven by the performance of their electrical networks (in terms of loss rate and SF_6 leakage) and by the significance of their gas transmission and distribution activities. Indeed, out of the 19 companies examined, 5 also operate in the gas sector, which typically exerts a negative influence on the overall score. Furthermore, the lack of information in certain companies' reports (such as non-disclosure of loss rates or SF_6 emissions) adversely affected their ratings.

Classification

The following figure shows the overall CIA rating for a selection of players[15]. For each company, we also visualize the segmentation of its revenue by activity, as well as its market capitalization.

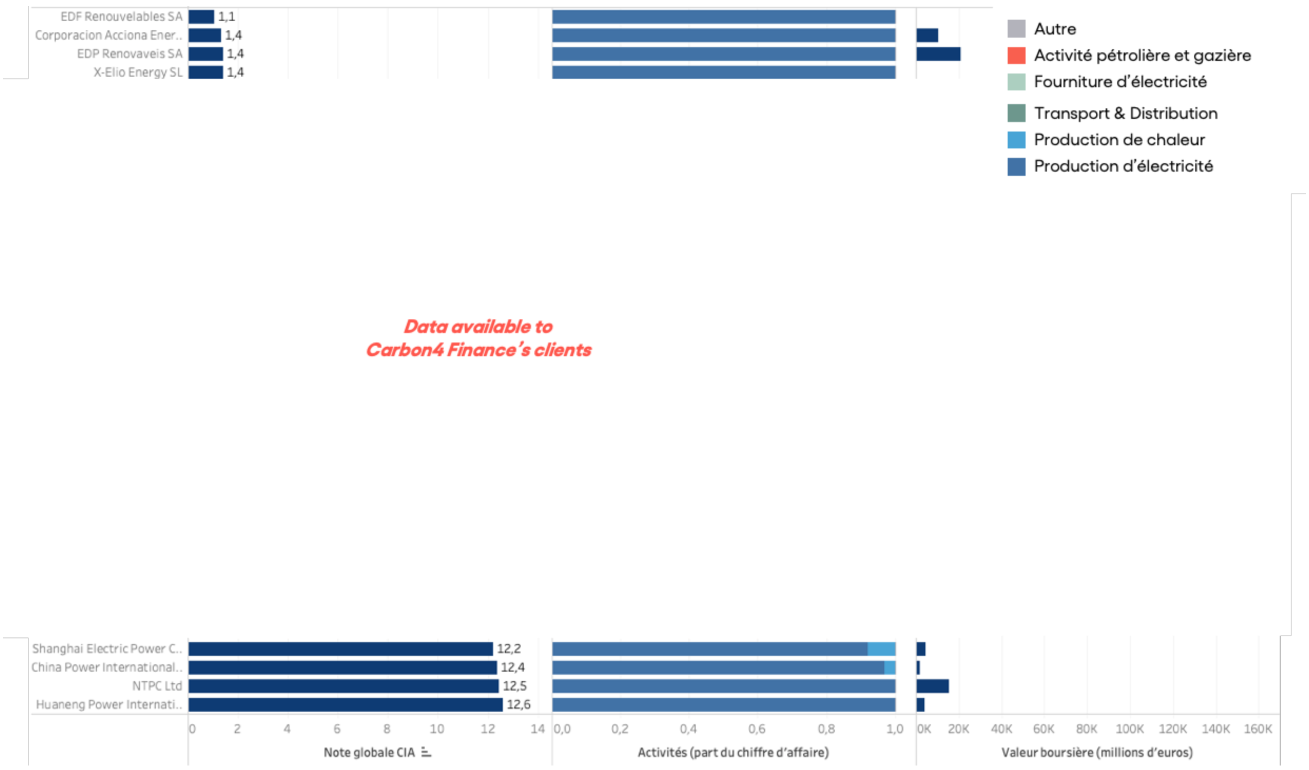


Figure 10: CIA analysis results for a selection of actors. The CIA score (out of 15) is shown next to each bar. As a reminder, a high score indicates poor performance

[15] The selection includes the ten highest-rated companies, the ten lowest-rated companies, the ten largest electricity producers (in terms of production volume) and the ten largest market capitalizations in the sample.

We note the significant presence of oil and gas activities among integrated companies. These activities concern more than half of the integrated players in the sample (48 companies). These are mainly gas transport, distribution and supply activities. We also note that the integrated players represent the largest market capitalizations in the sector.

Focus on power generation

The following graph shows the sector scores for the power generation activity of a selection of players. The selection was made following the same approach described above. We also show the carbon intensity of electricity production (scope 1, 2 and 3 in tCO_2 e/MWh) next to each bar.

Figure 11: Power generation sector scores for a selection of players. A long bar indicates a high CIA score and therefore a poor performance of the player concerned. For electricity generation, the past performance score constitutes 20% of the sector score. Its contribution (green bar) therefore varies between 1 and 3. On the other hand, present and forward-looking performance ratings make up 80% of the sector rating (40% each). Their respective contributions (red and blue bars) range from 1 to 6.

The best-rated companies have very low carbon intensities. They therefore have the best current performance ratings. This group is mostly made up of companies that were founded to produce renewable electricity. In contrast, we find few companies that have made the transition from a fossil-fired to a decarbonized electricity mix. However, in both cases, these players score well on past performance, as they have aligned or are already aligned with a low-carbon economy. In addition, these players' exposure to transition risks is very low and their impact on the climate is positive, resulting in a very good forward-looking performance rating.

Conversely, fossil fuel players reside at the lower end of the scale. Their high carbon intensity results in a poor current performance rating. Having not significantly reduced their intensity over the past five years, these players also receive a poor past performance rating. Moreover, due to the lack of a clear strategy to transition from fossil fuels and pivot their operations toward decarbonized production sources, they attain a deficient forward-looking performance score.

Between these two extremes, some players have begun their decarbonization journey. Their rating varies according to their past and present intensity, but also according to the strategies they are implementing to ensure their energy transition. These strategies are influenced by the constraints of the regional markets in which they operate. Energy policies, regulatory mechanisms and resource availability shape power producers' energy mix and guide their investment choices, leading to disparities in decarbonization efforts on a global scale.

Carbon intensity varies by region

The energy transition is a global challenge to which all players must contribute. However, the decarbonization efforts undertaken in recent years are not homogeneous across the globe. The following graph shows the carbon intensity of electricity production for the analyzed companies, by region. The size of the circles is proportional to each company's production volume:

Figure 12: Carbon intensity of the analyzed companies by region

We observe a regional disparity in intensities. With an average intensity of 0.27 tCO_2e/MWh, European companies are less carbon-intensive than their Asian and North American counterparts (0.56 tCO_2e/MWh and 0.38 tCO_2e/MWh respectively). These values, calculated based on the sample studied, are representative of the overall average intensities of these continents, and reflect a significant difference in their energy profiles.

Asia is highly dependent on coal, which accounts for more than half of its electricity production (45% for the sample analyzed). The abundance of coal in the region has supported the exponential increase in demand for electricity driven by the region's strong demographic and economic growth over recent decades. India and China are the world's biggest consumers. Both, they account for more than two-thirds of the world's coal consumption. More than half of the consumption of the two Asian giants comes from Chinese power plants[16].

Conversely, Europe and North America exhibit a markedly reduced dependence on coal. The contribution of coal to the electricity mix in both continents has witnessed a substantial decline over recent decades. Presently, it constitutes 15% of the European power mix and 18% of the North American mix. Coal has been partially supplanted by gas, especially in the United States, where the surge in shale gas has radically transformed the nation's energy matrix. The advancement of solar and wind power has also played a role in diminishing the share of fuel in electricity production across both regions.

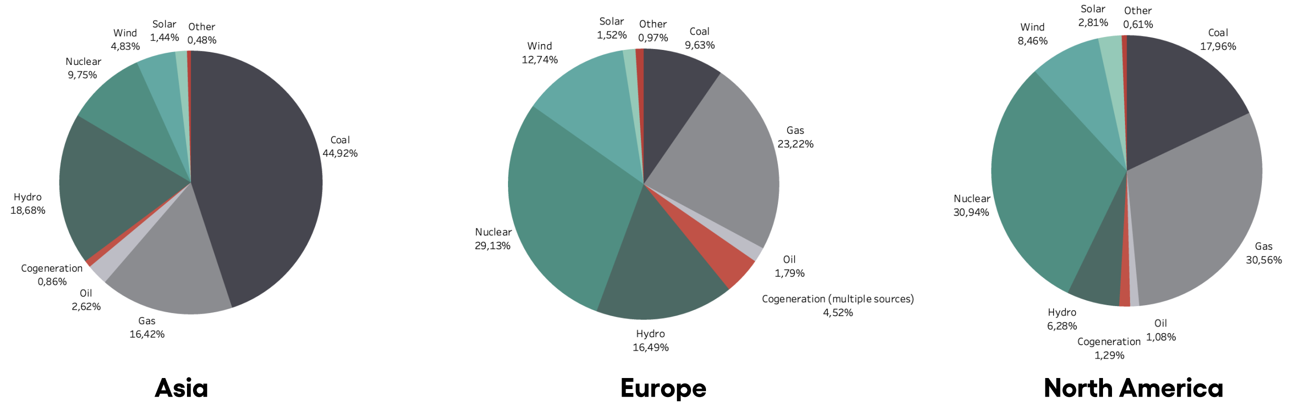


Figure 13: Sample's electricity mix by region

Europe thus stands at the forefront in its pursuit to decarbonize power generation, reflecting efforts to stimulate investments in renewable energies and diminish reliance on fossil fuels. Nevertheless, other historical factors have also molded the European electricity mix. In France, for instance, the 1970s oil crisis catalyzed the nation's nuclear power program. Today, nearly 90% of France's electricity is decarbonized, with nuclear power contributing to 70% of it. The country maintains a remarkably low carbon intensity, attributed not only to recent decarbonization efforts but primarily to the resolve to minimize its vulnerability to fossil fuel imports in the aftermath of the crisis.

To visualize the features of the electricity sector's energy transition, let's look at the evolution of the carbon intensity of the analyzed companies over the last five years. This indicator determines the past performance rating of these players, allowing us to distinguish those who have committed to decarbonizing their electricity mix.

[16] IEA, Coal 2021.

Companies that have committed to decarbonization: carbon intensity reduction profiles

In the sample studied, 124 companies have electricity generation as their main activity (the activity with the largest share of revenue). Among these, 76 companies have either not decreased their carbon intensity over the previous five years or have not released historical data that would allow for the calculation of reduction rates. Within this subset, 25 companies produce decarbonized electricity (constituting over 90% of their electricity mix) and are thus already in alignment with the low-carbon transition. For the remaining entities, diverse profiles with varied intensities are observed.

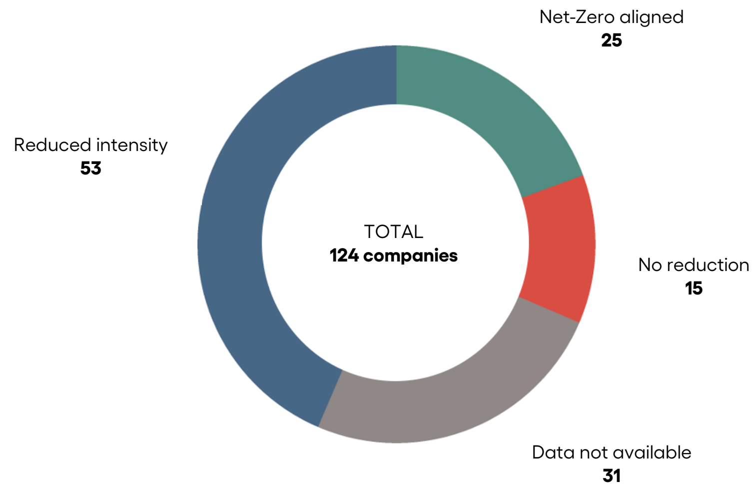


Figure 14: Reduction in carbon intensity of the analyzed companies over the last five years

53 companies in the sample (i.e. 43%) have succeeded in reducing their carbon intensity over the last five years. The following graph shows the average annual reduction rates. The size of the bubbles is proportional to production volume, and their color reflects the current carbon intensity of the players concerned.

Figure 15: Average annual reduction in the carbon intensity of the analyzed players over the last five years

We observe a similar regional trend. European players are the most successful in reducing their carbon intensities. We also note that the most polluting players (yellow and orange) have reduced their intensities very little.

E.ON and Ørsted exhibit the most notable reduction rates, with average annual reductions of 23% and 24%, respectively. E.ON attained this performance through the sale of its fossil fuel operations. In 2016, the company divested its fossil-fired power generation activities to a new entity: Uniper, and subsequently finalized the sale of its stakes in Uniper in 2018. Conversely, Ørsted has undergone a dramatic transformation of its electricity mix within a decade by shutting down most of its coal-fired power plants and converting its cogeneration plants to biomass[17]. In 2008, the company generated 80% of its electricity from fossil fuels, with coal contributing 50%. Today, the Danish manufacturer stands as the global leader in offshore wind turbines, with over 90% of its electricity mix being decarbonized.

It is noteworthy that the two companies achieved this performance through divergent approaches. Ørsted, via the closure and conversion of its coal-fired power plants, aids in decarbonizing the electricity mix in its operational area and hastens the shift away from fossil fuels. Conversely, E.ON has merely relocated the issue: while the company has decarbonized its operations and minimized its transition risk, its divested fossil-fired power plants persist in emitting under the management of another entity. Although the impact of the two strategies on the overall energy transition is markedly distinct, both entities attain the same past performance rating. This illustrates a limitation of the CIA methodology, which does not enable a distinction between these two approaches.

Emissions reduction targets

To illustrate the alignment of electricity producers with the IEA's energy transition scenarios, we examine the GHG emissions reduction targets disclosed by these entities.

Out of the 124 companies primarily engaged in power generation, 25 are already aligned with an IEA net-zero scenario due to their low carbon intensity. Among the remaining entities, 84 companies have disclosed GHG emissions reduction targets for their power plants.

24 published reduction targets are deemed irrelevant. To assess the relevance of a target, we examine the description provided by the company, ensuring all information essential for assessing the reduction trajectory is available. This encompasses the base year, target year, quantified reduction rate, and the scope of the emissions involved. Neutrality objectives announced without quantified intermediate targets are considered irrelevant.

[17] We do not address the sale of the fossil fuels segment here, which Ørsted sold to petrochemical company Ineos in 2017, as it is not directly related to the electricity sector.

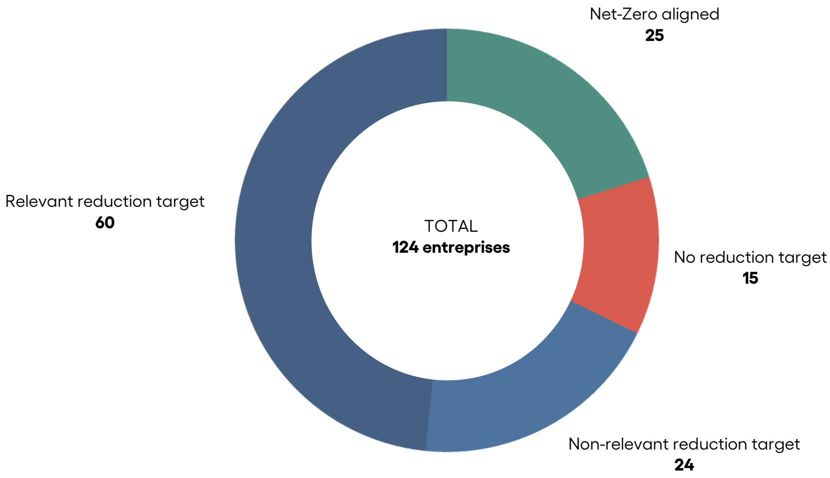


Figure 16: Distribution of the analyzed companies according to their GHG reduction targets

When a reduction target is deemed relevant, we assess it against science-based climate scenarios. This involves calculating the company's targeted carbon intensity, which is the carbon intensity it aims to achieve by meeting its emission reduction target and comparing it with the global carbon intensity of power generation across various IEA scenarios (NZE, SDS, STEPS, and 6DS). Using these scenarios, we estimate the alignment temperature of the evaluated reduction target—i.e., the global warming temperature (in 2100) correlated with the entity's targeted carbon intensity.

The subsequent graph illustrates the distribution of the analyzed entities based on the alignment temperature of their reduction targets. Within each bar, the color represents the current carbon intensities of the companies it comprises:

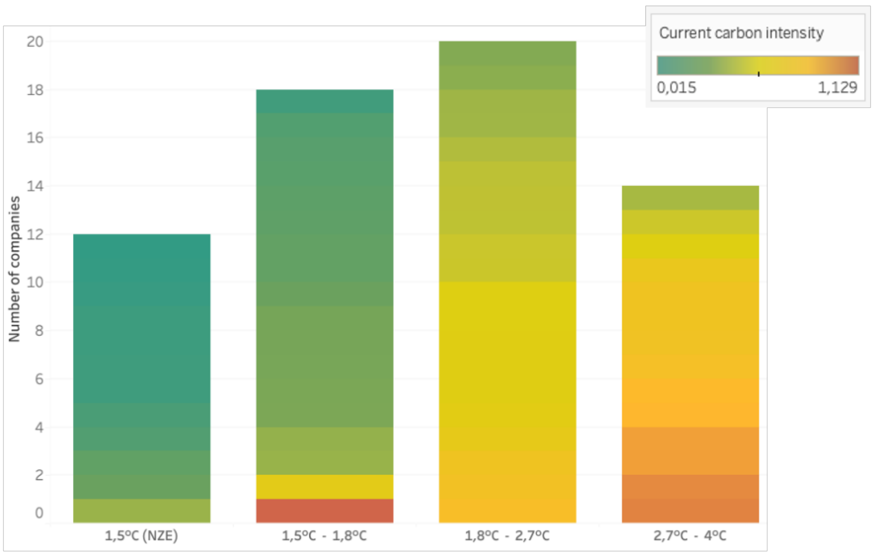


Figure 17: Distribution of the analyzed companies by temperature of alignment of their reduction targets

We observe a correlation between the companies' current carbon intensities and the alignment temperature of their reduction targets. Companies with the lowest intensities (green) tend to have the lowest alignment temperatures. Conversely, companies with the highest emissions (yellow and orange) have not established targets that are ambitious enough to decarbonize their activities.

Nonetheless, there exists a notable exception to this pattern. PGE Polska Grupa Energetyczna, the company with the highest carbon intensity in the sample (indicated in red), and Poland's leading electricity producer, largely depends on coal, contributing to over 90% of its electricity production. However, PGE has laid out a highly ambitious transition strategy. The company sets its sights on achieving an energy mix comprising over 50% renewables by 2030 and aspires to reach 100% renewables by 2050. This shift would diminish emissions from its power plants by 80% by 2030. Should it successfully transition its entire operation to renewables, its carbon intensity would align with the IEA's net-zero scenario.

Decarbonization strategies of the analyzed companies

While emissions reduction targets serve as a pivotal indicator for evaluating the energy transition strategy of the analyzed entities, we also examine other strategic criteria. These include the assessment and management of climate risks, investments in decarbonized production capacities, and the governance of climate-related issues within the company.

The following table delineates the principal characteristics of the strategies of four selected players. EDF and Engie score highly in terms of forward-looking performance, attributed to their substantial investments in decarbonized energies and ambitious reduction targets. PGE Polska garnered an average rating. While the company has unveiled a highly ambitious strategy to pivot away from coal and specialize in renewables, it has not formulated a plan to shut down or convert its coal-fired power plants. Instead, these will be transferred to a new entity managed by the Polish state. Additionally, the company's governance structure offers minimal consideration to climate issues.

Lastly, NTPC, India's premier electricity producer, was assigned a poor rating due to the absence of a transition strategy. The company is heavily reliant on coal (over 90% of its production) and lacks plans to mitigate this dependency. NTPC has set a goal to reduce its carbon intensity by 10% by 2032 which is highly unambitious given its current elevated intensity (0.94 tCO2 e/MWh). For comparison, let’s consider the IEA's 6DS Scenario, which represents a business-as-usual trajectory predicting an average global temperature rise of 4°C relative to pre-industrial levels by the century's end[18]. According to this scenario, the average intensity in India in 2030 is projected to be 0.77 tCO2 e/MWh. Consequently, we ascertain that NTPC's direct emissions trajectory aligns with a temperature rise of 4°C.

[18] IEA, Energy Technology Perspectives 2016.

Company	Forward-looking Performance (/15)	Strategy	Transition Investments *	Time Horizon	GHG emissions reduction target
EDF	1	EDF will cease its coal-based production activities (0.7% of its current production) by 2030. The company is directing its investments towards decarbonized production methods and working on the development of low-carbon technologies (electricity storage, carbon capture and storage.	93%	2018 - 2030	EDF aims for a carbon intensity of 35 gCO2 / kWh by 2030.
engie	2	Engie will shut down its coal power plants (5% of its current production) in 2025 in Europe and in 2027 in the rest of the world. The company is investing only in new decarbonized capacities and aims to achieve 58% renewables by 2030.	100%	2017 - 2030	Engie aims for a carbon intensity of 158 gCO2/kWh (a 52% reduction compared to 2017).
PGE Polska Grupa Energetyczna	7	PGE has established a very ambitious plan to exit coal and decarbonize its electric mix. The company aims for an energy mix of over 50% renewables by 2030, and 100% renewables by 2050. However, PGE has not committed to a closure or conversion plan for its coal plants. These plants will be transferred to a new entity of the Polish state.	50%	2020 - 2030	PGE aims to reduce its GHG emissions related to electricity production by 80%.
एनटीपीसी NTPC	11	NTPC is still investing in new coal power plants and has not established a strategy to decarbonize its electric mix (over 90% coal). The company has not conducted climate risk analyses. Its investments in low-carbon capacities are marginal.	12%	2020 - 2032	NTPC aims to reduce its carbon intensity by 10%.

* Transition investments represent the share of new decarbonized capacities in the capital expenditures (CAPEX) allocated to electricity production.

Table 1: Selected examples of decarbonization strategies from electricity producers

Focus on transport and distribution

Within the sample, 101 companies engage in electricity transmission or distribution. These companies differ mainly in terms of their network's electrical loss rate and their sulfur hexafluoride (SF_6) emissions, but also in terms of their strategies for integrating renewable energies and developing sources of flexibility on the grid.

The two activities present different orders of magnitude for electrical losses and SF_6 leaks. High-voltage transmission lines require more extensive safety and insulation equipment. They therefore have higher SF_6 leakage rates. Conversely, the high voltage on these lines favors their performance and minimizes electrical losses during transport.

Grid losses

Let's examine the loss rates recorded on the transmission and distribution networks of the analyzed entities:

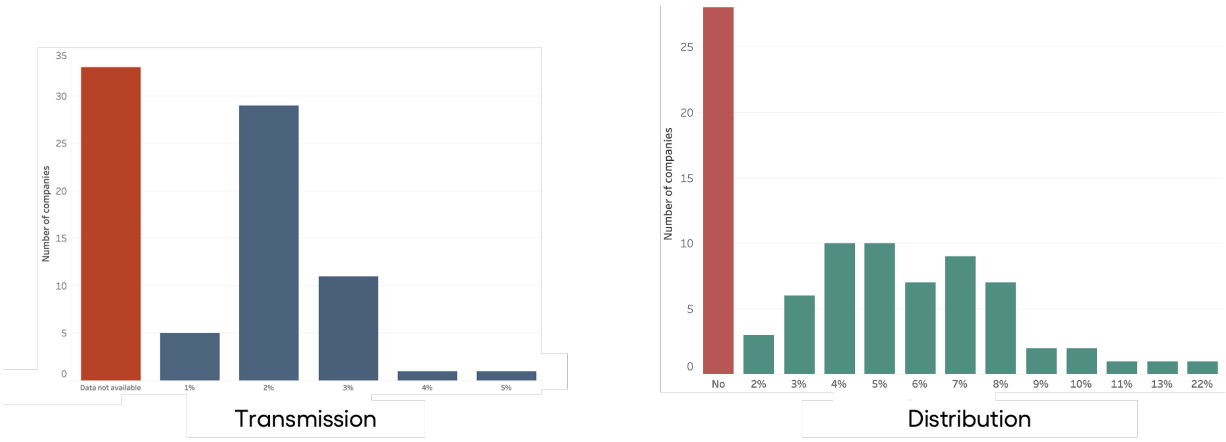


Figure 18: Electrical losses (% of total electricity volume) of the analyzed players

We observe a considerable disparity in loss rates on distribution networks, with the analyzed companies demonstrating varied performances. Consequently, electrical losses serve as a potent indicator for differentiating among these entities. In contrast, electricity transmission companies exhibit homogeneous loss rates, with nearly two-thirds of the entities that published data recording losses around 2%.

It's important to highlight that 33 transmission companies (41%) and 28 electricity distributors (31%) have not disclosed data regarding electricity losses on their networks. Due to their lack of transparency, which precludes the estimation of loss evolution, these companies incur a penalty on their past performance score, receiving the lowest score (15/15) for this criterion. For the current performance rating, we utilize the average loss rates of the geographical plates where they operate.

SF_6 leaks

The following figure displays the SF_6 leakage intensities of the transmission and distribution players. The circle sizes are proportional to the volume of electricity transmitted or distributed by each entity. For ease of reading, we have segmented the companies by geographical region:
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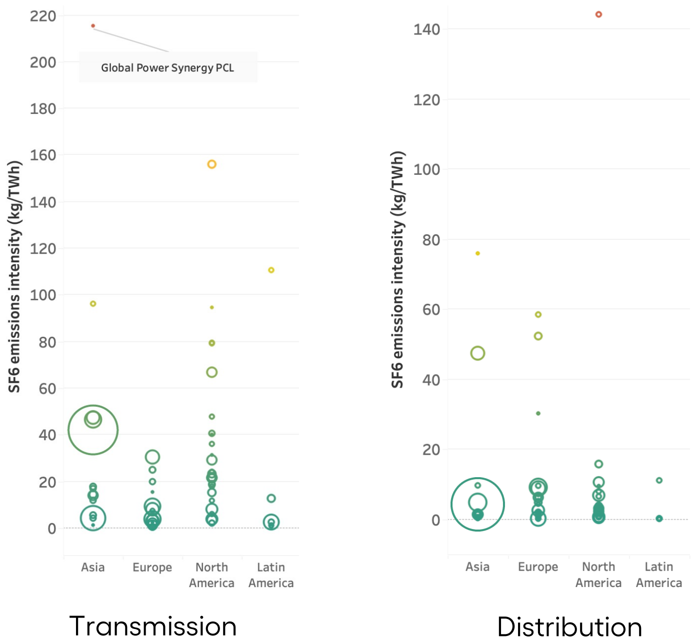

Figure 19: SF6 leakage intensities (kg SF6 / TWh) of the analyzed players

Global Power Synergy PCL (Thailand), with 215 kg of SF6/TWh, exhibits the highest SF6 emission intensity, significantly outpacing other players. In terms of CO2 equivalent, this value equates to 0.005 tCO2e/MWh, thereby being marginal when compared to the intensities recorded by electricity producers.

Nonetheless, the matter of sulfur hexafluoride leaks warrants serious attention. While this gas currently contributes minimally to climate change, owing to its low emission volumes, SF6 is the most potent greenhouse gas, possessing a warming potential 23,500 times greater than that of CO2 over a hundred years. Additionally, its stable molecular structure gives it an extraordinarily long atmospheric residence time of 3,200 years. Therefore, its long-term effect is far from negligible, particularly when considering its escalating use aligned with the surging demand for electricity and the essential expansion of power grids in the upcoming decades. Moreover, even though their impact remains minor, grid operators are subjected to ever-tightening legislation regarding the use of F-gases, as evidenced by the 2016 Kigali amendment to the Montreal Protocol and, more recently, the revision of the EU legislative framework on F-gas emissions approved by the European Parliament in March 2023. Furthermore, alternatives to SF6 already exist (such as Siemens' Blue portfolio and Hitachi Energy's EconiQ™ portfolio). Therefore, managing SF6 leaks and exploring alternatives for insulating electrical equipment emerge as significant challenges for grid operators.

decarbonization strategies

Within the studied sample, 28 companies have electricity transmission or distribution as their core business. The following graph shows the forward-looking performance ratings obtained by these companies:

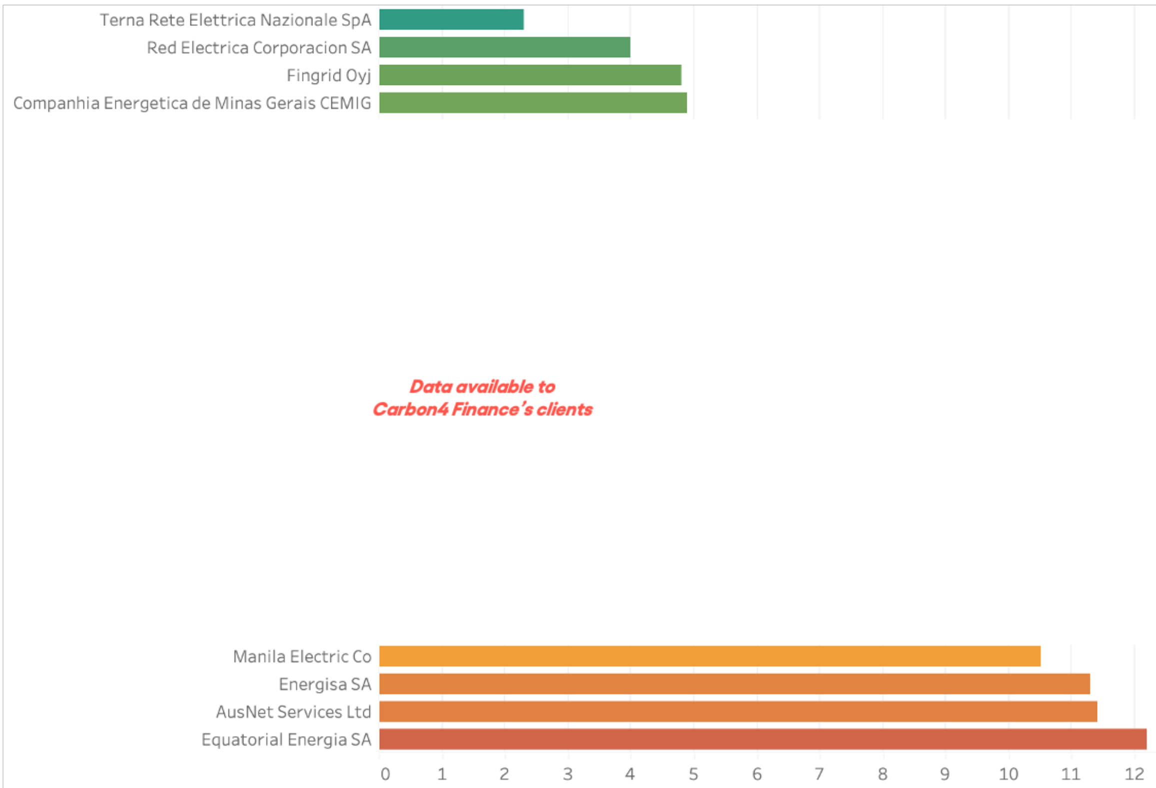

Figure 20: Forward-looking performance ratings for electricity transmission and distribution actors

Let's take a closer look at some examples of transmission and distribution strategies:

Terna obtains the highest rating for forward-looking performance. The Italian company is investing in new regional interconnections and working on strengthening its power grid to adapt it to the integration of new renewable capacities.

Elia Group, the Belgian grid operator, funds research programs aimed at developing alternatives to the use of SF_6 in electrical equipment.

Finally, Equatorial Energia received the lowest score in the sample. The company has not developed a strategy for adapting its network to the energy transition, and the issue of climate change is scarcely addressed in its reports.

Company	Forward-looking Performance (/15)	Strategy	Transition Investments *	Time Horizon	GHG emissions reduction target
Terna	2	Terna is aware of its major role in the energy transition as a grid operator. The company is directing its investments towards the development of regional interconnections and towards strengthening its transmission network to enable the integration of renewable energies. The company is also investing in energy storage systems and demand management.	99%	2021-2025	Terna aims for an SF6 leak rate of less than 0.45%.
elia group	7	Elia mentions investments aimed at strengthening its network to allow better integration of renewable energies. The company aims to cease the use of SF6 in its equipment and is funding a research program to find marketable alternatives to the fluorinated gas.	Non quantified	_	
equatorial energia	12	Climate change is scarcely mentioned in Equatorial Energia's reports. The company does not mention projects aimed at adapting its grid to the energy transition.	Non quantified	_	_

* Transition investments represent the portion of capital expenditure (CAPEX) aimed at adapting the electric network to the energy transition

Table 2: Examples of decarbonization strategies by electricity transmission and distribution operators

Conclusion

The electricity sector is experiencing a profound transformation. Companies are recognizing the imperative to respond to the climate emergency. The development of renewable energies is accelerating at an unprecedented pace, and entities reliant on fossil fuels are starting to question the sustainability of their business models.

The analyzed sample allows us to examine sectoral trends. A spectrum of profiles emerges among the players: some have already aligned with the energy transition or established ambitious targets to decarbonize their operations, while others struggle to begin their decarbonization journey and curtail their reliance on fossil fuels. Additionally, we perceive regional disparities in energy mixes. Asian companies exhibit a greater dependency on coal compared to their European and North American counterparts, and efforts to accelerate the development of decarbonized energies on the continent have yet to sufficiently diminish this dependency.

Output from coal-fired power plants, and consequently the sector's greenhouse gas emissions, continued to rise, reaching a new record in 2022. However, solar and wind power continued to gain ground. Their combined share exceeded 12% of the global electricity mix, and their growth covered 80% of the increase in electricity demand. Current trends suggest that the sector's emissions will peak in the coming years.

Yet, the pace of the transition remains uncertain. While the goal of capping global warming at 1.5°C persists as a theoretical possibility, its actualization will hinge on the rapid implementation of public policies and the trajectory of investments in decarbonized energies. The energy crisis sparked by the invasion of Ukraine has reinvigorated interest and propelled investments in renewable energies[19]. Beyond their crucial role in combating climate change, these energies are emerging as a resilient alternative to fossil fuels, forging a path toward energy security by providing competitive, sustainable, and readily deployable energy sources.

We are navigating a pivotal decade in our planet's history. While decarbonization efforts are amplifying, they still fall short of mitigating the impacts of climate change. Ambitious policies and substantial investments will be imperative to hasten the transition toward a low-carbon economy. The efforts undertaken in the upcoming years will be crucial for the future of humanity.

[19] AIE, Renewables 2022 Analysis and forecast to 2027.

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