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THE DISCREPANCY OF MANAGING DECARBONIZATION & PROFITABILITY

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ABSTRACT. *When looking at scope of the decarbonization effort, the sector(s) being targeted, the timeline for achieving the goals, and the specific decarbonization technologies and approaches being used there are various factors impacting the cost of decarbonization which in effect might put profitability of traditional business models at risk.*

In general, when considering the extended scope of decarbonization (aiming not only at production facility but also involving usage of the products) can involve significant upfront costs to transition from fossil fuel-based energy sources to cleaner alternatives such as renewable energy sources or nuclear power.

Within this paper the cost of decarbonization relate to the cost of transformation. Even tough the cost of not decarbonizing and dealing with the impacts of climate change are not fully estimable, both in economic and human terms, the investment in the transformation involves significant upfront invest. Looking at similar transformation initiatives this paper will provide a framework on what to consider when transforming and which cost buckets with impact on profitability need to be considered including government subsidies, tax incentives, and carbon pricing policies can help to reduce the cost of decarbonization and provide a level playing field

for low-carbon technologies to compete with fossil fuels.
KEYWORDS: *Decarbonization, Transformation, Investments, Profitability*
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INTRODUCTION BASED ON THE HISTORY OF DECARBONIZATION

Decarbonization is a relatively recent concept that has gained prominence in response to the growing recognition of the urgent need to address climate change. While efforts to reduce greenhouse gas emissions and promote sustainability have a longer history, the specific focus on decarbonization is more recent.

- Late 20th century: Concerns about climate change and the need to reduce greenhouse gas emissions begin to gain prominence. The United Nations Framework Convention on Climate Change (UNFCCC) is established in 1992 to provide a framework for international cooperation on climate change [1].
- Early 21st century: The concept of decarbonization begins to emerge as a specific focus of efforts to address climate change. The Stern Review on the Economics of Climate Change, published in 2006, highlights the urgent need to reduce greenhouse gas emissions and transition to a low-carbon economy.
- Mid-2010s: The Paris Agreement is adopted in 2015, providing a global framework for action on climate change. The agreement sets a goal of limiting global temperature rise to well below 2 degrees Celsius above pre-industrial levels, and pursuing efforts to limit it to 1.5 degrees Celsius.
- Late 2010s: Decarbonization becomes an increasingly prominent focus of policy and business efforts to address climate change. The Intergovernmental Panel on Climate Change (IPCC) issues a report in 2018 highlighting the urgent need to reduce greenhouse gas emissions to avoid catastrophic climate change. The concept of a "just transition" to a low-carbon economy, which prioritizes the needs of workers and communities affected by the transition, gains prominence.

The philosophy of decarbonization is based on the recognition that human activities are contributing to the emission of greenhouse gases that are causing climate change. Decarbonization aims to reduce or eliminate these emissions by transitioning from fossil fuels to renewable energy sources, increasing energy efficiency, and adopting sustainable practices across various sectors of society.

At its core, decarbonization is rooted in the belief that human beings have a responsibility to protect the planet for future generations [2]. It recognizes that climate change is a complex and urgent global challenge that requires collective action and collaboration across borders and sectors. Considering the different emission sources it becomes clear that global greenhouse emissions highly vary by country or sector e.g. when looking at a comparison of worldwide emissions per capita in 2021 [3] .

Decarbonization is also closely linked to the concept of environmental justice [4], which recognizes that the impacts of climate change disproportionately affect vulnerable populations [5], including low-income communities, indigenous peoples, and people in developing countries. Decarbonization is seen as a way to address these inequalities by promoting social and economic development while reducing environmental harm.

THEORETICAL FRAMEWORK ON DECARBONIZATION ILLUSTRATED BASED ON THE GLOBAL ROAD TRANSPORTATION

Focusing on the corporate level it becomes clear that there is need to center the findings around single corporations and specific sectors. While energy which lies at the core of industrialization progress represents the biggest proportion. Herein the transportation sector makes up 16,2% as of year 2016 – while mobility as road transportation sums up to ~12% of the global emissions in 2016 and continues to rise when looking at a timeframe of the last 30 years [6].

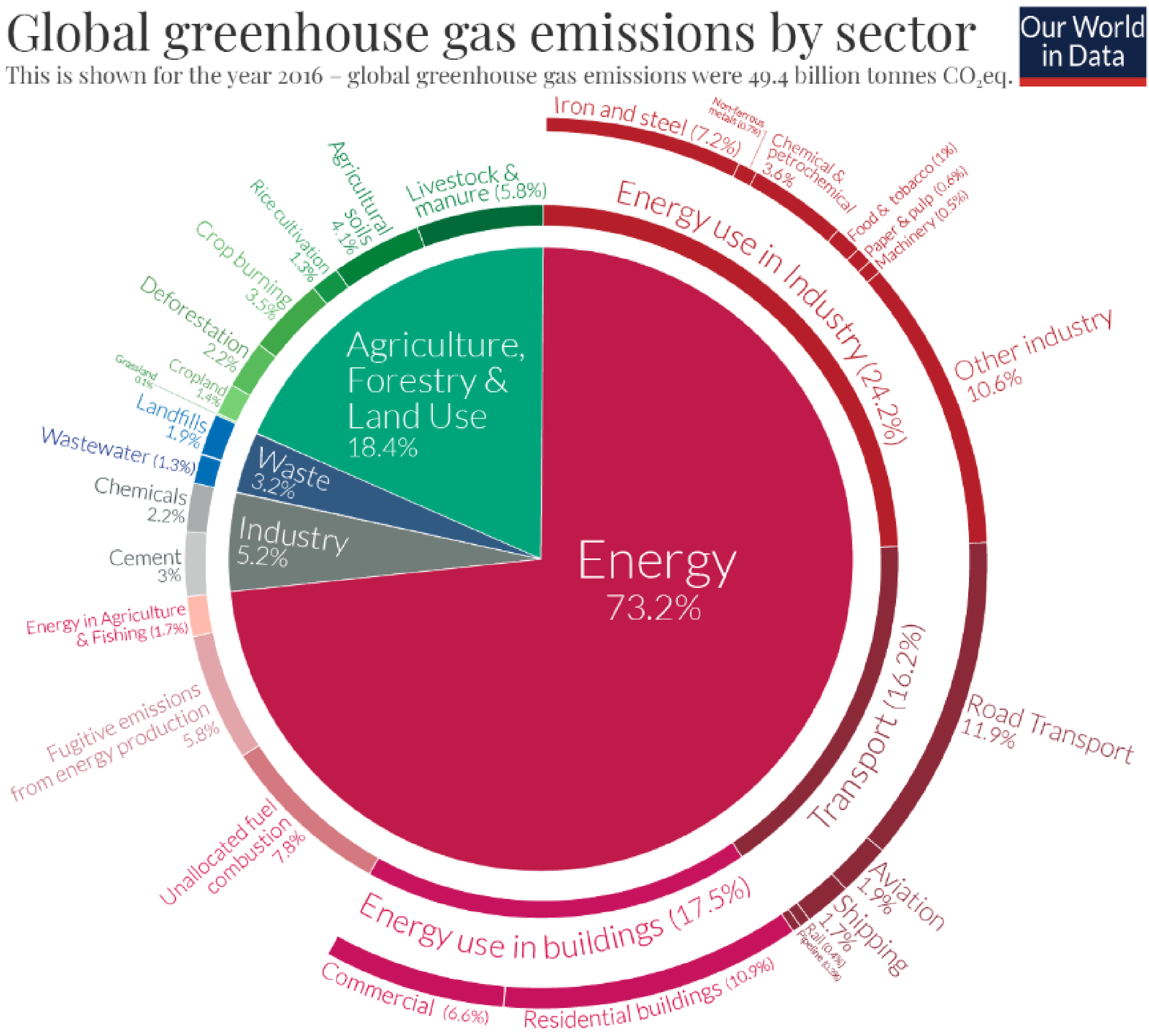

Figure 1. Global greenhouse gas emissions by sector [7]

Source: According to Climate Watch, The World Resources Institute 2020 as shown by Our World in Data for the year 2016 where global greenhouse gas emissions were 49.4 billion tones CO2

Decarbonization is seen as an essential strategy for mitigating the impacts of climate change and creating a more sustainable future. Addressing these emissions bucket requires decarbonizing the entire road transportation value chain. The GHP Protocol [8] provides a starting point to understand where emissions in the road transportation sector are generated when looking at one specific reporting company.

The calculation of the emissions footprint is based on globally aligned Standards and Methods, whereas the Greenhouse Gas Protocol Corporate Accounting and Reporting Standard – short GHG Protocol Corporate Standard – is one of the oldest and most established standards for carbon reporting, being created by World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) and already published for the first time in 2001. The scope 3 standard is the widest applicable to corporations [8].

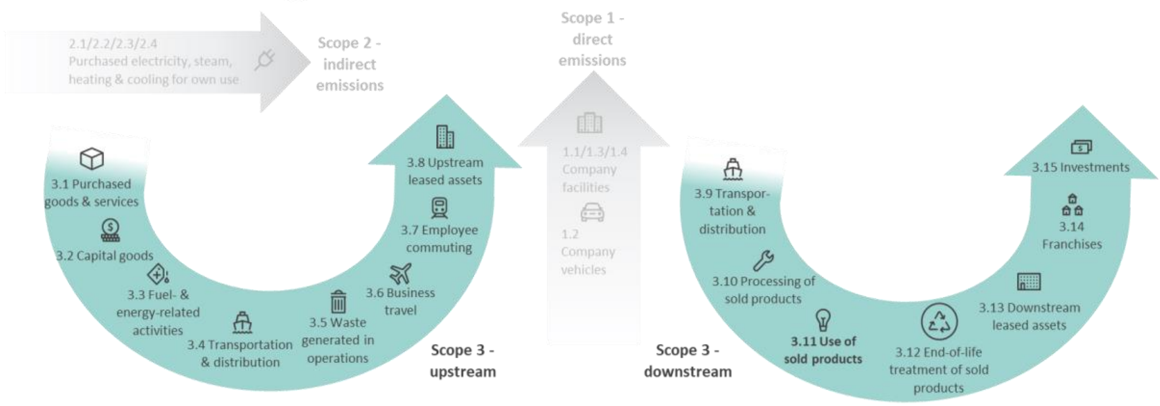

Figure 1. GHP Illustration on Scope 1,2,3 emissions

Source: According to GHG Protocol 2018

In effect the corporate carbon footprint encompasses the company's entire emission allowance along the value chain.

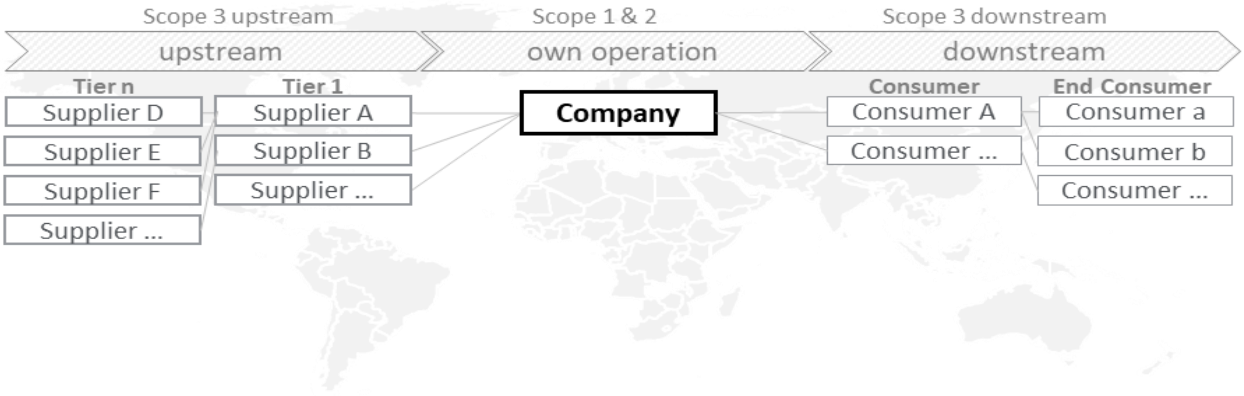

Figure 2. Illustrative Corporate Carbon Footprint Calculation

Looking at the carbon footprint it becomes clear that manufacturers – from supplier to original equipment manufacturer following steps are executed to produce and see and use the mobility products:

- Research and Development which involves the creation of new technologies and products for the mobility industry, such as electric vehicles, autonomous vehicles, and mobility software including features to improve vehicle performance, safety, and efficiency. R&D accounts for testing emissions but also indirect emissions created by labor and infrastructure during this process step of detailing designs and specifications for the various components of the vehicle, including the engine, transmission, suspension, and body etc.
- Inbound Logistics and Supply Chain which involves the management of the movement of parts and components from suppliers to manufacturers as well as management of suppliers and the procurement of raw materials and components necessary to produce the vehicle. Moreover inbound logistics also involves the management of inventory levels to ensure that there are sufficient materials and components available to support production.
- Manufacturing which involved the process of producing the vehicles and their components referring to assembly, painting, but als quality control for all kind of components such as engines, batteries, or tires.
- Outbound Logistics and Supply Chain refers to the distribution to dealerships or consumers once the manufacturing process is ends. This involves the management of the transportation, storage, and delivery of finished products to customers or sales channels. In the automotive industry, this includes the shipment of finished vehicles from manufacturing plants to dealerships or other sales channels, as well as the distribution of spare parts and other aftermarket products. Moreover outbound logistics also involves the management of inventory levels to ensure

that finished products are available to meet customer demand.

- Service and Maintenance which includes the maintenance and repair of vehicles, as well as providing customer support.
- Moreover the indirect functions required to enable core operations are also generating emissions, nevertheless for the purpose of reducing complexity Sales and Marketing, Human Resource, Finance & Controlling, Information Technology, Tax and Legal departments are not taken into account due following course. Here is an example how these indirect functions add to the carbon footprint of a company: Sales and Marketing includes the promotion and sales of vehicles to consumers through advertising, branding, and dealer networks. Depending on the business model this might also include providing loans or leasing options for consumers to purchase vehicles. Leased vehicles need to be reported on an annual basis in the corporate carbon footprint – therefore this might be a lever to the overall emissions footprint.

Apart from the core value chain there are further sources of emissions when considering the development of the infrastructure required e.g. the development of charging stations, roads, and other infrastructure to support the mobility industry.

Moreover the establishment of Mobility as a Service (MaaS) refers to the integration of various mobility services, such as ride-sharing, public transit, and bike-sharing, into a single platform to provide a seamless and efficient mobility experience for consumers which might also be a emission source when looking at the mobility value chain from an end to end perspective: especially when looking at the newest business models evolving around cloud computing, such as the collection and analysis of data related to the mobility industry, such as consumer behavior, vehicle performance, and traffic patterns.

Table 1. Emissions sources per functional area and relevant decarbonization approaches

Functional Area	Description of emission source	Area of decarbonization
Research and Development	**Prototyping and Manufacturing** may involve the use of energy-intensive manufacturing processes for example, the production of carbon fiber components for light weighting may involve energy-intensive processes that produce greenhouse gas emissions. **Testing and Validation** may involve running vehicles on test tracks or in laboratory environments, which can consume energy and produce emissions from testing equipment **Energy Consumption** in the form of electricity, heating, and cooling to power research and development equipment and facilities. Depending on the source of this energy, it may produce greenhouse gas emissions.	Minimize their carbon footprint driven by material and energy consumption during this functional step
Inbound Logistics and Supply Chain	**Transportation** of raw materials and components to an OEM's manufacturing facilities can generate emissions from the vehicles used to transport them, including trucks, ships, and airplanes **Storage and handling** can consume energy and generate emissions from the electricity, heating, and cooling used in these processes **Packaging** materials used to transport raw materials and components can also generate emissions, including greenhouse gases, during their production and disposal.	Optimizing transportation routes, using low-emission vehicles, implementing energy-efficient practices in storage and handling, and using sustainable packaging materials. Work with suppliers to adopt environmentally responsible practices and reduce the emissions associated with the production of raw materials and components.
Manufacturing	**Production** of vehicles and components requires energy in the form of electricity, heating, and cooling, which can generate emissions from the burning of fossil fuels. The emissions produced depend on the type of fuel used and the efficiency of the production process e.g. - Pressing of the vehicle carrosserie	Use energy-efficient production processes, investing in renewable energy sources, reducing the use of hazardous materials and chemicals,

	- Assembly the body in white - Painting the vehicle body - Assembly of components in the shopfloor Depending on the source of this energy, it may produce greenhouse gas emissions. **Waste-Related Emissions**: The production of vehicles and components can generate waste materials, including scrap metal, plastics, and other materials, which may be disposed of in ways that generate emissions. For example, the incineration of waste can produce greenhouse gases and other pollutants	implementing waste reduction and recycling programs, and using sustainable materials.
Outbound Logistics and Supply Chain	**Transportation** of finished products can generate emissions from the vehicles used to transport them, including trucks, ships, and airplanes. The emissions produced depend on the type of fuel used and the distance traveled. **Storage and handling** of finished products can consume energy and generate emissions from the electricity, heating, and cooling used in these processes. This includes emissions associated with the operation of warehouses, distribution centers, and other facilities involved in outbound logistics.	Take steps such as optimizing transportation routes, using low-emission vehicles, implementing energy-efficient practices in storage and handling, and using sustainable packaging materials. Additionally, work with dealerships and other partners to encourage sustainable practices and reduce the emissions associated with outbound logistics.
Service and Maintenance	**Operation of aftersales** and **service facilities** can consume energy and generate emissions from the electricity, heating, and cooling used in these facilities. This includes emissions associated with lighting, heating, air conditioning, and the operation of equipment used for service and maintenance. **Transportation** of vehicles to and from aftersales and service facilities can generate emissions from the vehicles used for transportation, including trucks and other vehicles. The emissions produced depend on the type of fuel used and the distance traveled **Generation of waste** materials, including used parts, tires, and other materials, which may be disposed of in ways that generate emissions. For example, the incineration of waste can produce greenhouse gases and other pollutants Moreover **Internal maintenance** of research facilities, transportation and storage equipment as well as production facilities might generate emissions.	Take steps such as using energy-efficient equipment and lighting, implementing waste reduction and recycling programs, and using sustainable materials. Additionally, work with suppliers and service partners to adopt environmentally responsible practices and reduce the emissions associated with the aftersales and service of vehicles.

Source: Research-based structure on functional level considering main supply chain areas of producing companies

EMPIRICAL STUDIES ON THE RELATIONSHIP BETWEEN DECARBONIZATION AND PROFITABILITY

The cost of decarbonization can vary depending on a range of factors, including the strategies and technologies used, the timeline for implementation, and the specific context in which decarbonization efforts are taking place. However, in general, decarbonization efforts are likely to come with significant costs, as they involve transitioning away from fossil fuels and adopting new low-carbon or carbon-free technologies.

The International Energy Agency (IEA) estimates that achieving net-zero greenhouse gas emissions by 2050 would require an average annual investment of around $4.4 trillion in clean energy technologies and energy efficiency measures [9]. This investment would need to ramp up over time, reaching around $5.5 trillion per year by 2030. The IEA notes that while these costs are significant, they are also "far outweighed by the benefits" of reducing the impacts of climate change. Even more as the transport sector emissions have grown faster than almost any other economic sector since the last 50 years – there is a high risk to continue this path if no action is taken [10].

It's important to note that the costs of decarbonization are not evenly distributed across different sectors of the economy or different countries. Some industries, such as the oil and gas industry, may face significant financial losses as the world transitions away from fossil fuels. However, other industries, such as renewable energy, may benefit from increased investment and demand. Additionally, some countries and communities may bear a disproportionate burden of the costs of decarbonization, which can raise issues of equity and fairness that will need to be addressed. Capital investment in energy rises from 2.5% of GDP in recent years to 4.5% by 2030; the majority is spent on electricity generation, networks, and electric end-user equipment [9].

Looking at the mobility or transport sector policies are set in place to promote modal shifts as well as more efficient operations across passenger transport modes. This in effect impacts the product portfolios of the car manufacturers and demands for establishing a new infrastructure for enabling electric vehicles. The mobility sector has traditionally relied on oil products which made up over 90% of the energy needs for this sector to operate [9]. Herein changing the products will directly impact the energy consumption.

Even though there is a general agreement about the need to change the mobility sector towards more sustainable products and operations, currently there is very limited evidence about the impact of the above listed approaches and their impact on the carbon footprint as well profitability. The industry rather focuses on different estimates to establish the relationship between decarbonization and profitability.

Signposts indicate the industry is facing a paradox as the demand for mobility is growing with a global rising GDP but sustainable options in terms of products and infrastructure are still limited. Estimated cost for decarbonizing core materials as cement, steel, ammonia, and ethylene would cost $21 trillion through 2050 [11]. Moreover, the transition to a net zero future consistent with the 1,5 degrees Celsius of warming is estimated to exceed the $3 trillion – $4,5 trillion of spending [12].

Focusing on mobility products indicators can be found that forecast some segments of electric passenger vehicles to have a lower total cost of ownership than gasoline-powered vehicles in select regions by 2022 or 2023 [13].

Putting all this information together it requires at least following 3 pillars to drive decarbonization of the mobility sector:

1. Product Portfolio: Electrification of vehicles is one of the most promising strategies for decarbonizing the transport sector. This is because electric vehicles (EVs) – if they use electricity from the grid, which can be generated from a variety of sources, especially renewable energy sources like wind and solar power- produce far fewer greenhouse gas emissions than traditional internal combustion engine vehicles (ICEVs) that run on fossil fuels such as gasoline and diesel.
2. Process and Operations: Electrification of vehicles is not enough but require significant investment in charging infrastructure, renewable energy sources, as well as policy incentives to encourage adoption of EVs by consumers and fleet operators.
3. People mindsets shift towards sustainable consumption and shared mobility.

RESULTS AND DISCUSSIONS

The scientific approach to decarbonization draws on a range of disciplines, including climate science, environmental science, economics, engineering, and policy analysis. It involves interdisciplinary collaboration and the integration of multiple sources of data and evidence to inform decision-making. In effect putting all these factors in practice creates a unmanageable complexity for many actors as decarbonization involves a range of strategies, policies, and technologies. These may include transitioning to renewable energy sources such as solar and wind power, improving energy efficiency in buildings and transportation, promoting sustainable agriculture and forestry practices, and implementing carbon pricing and emissions trading schemes. Therefore this paper is limited to analyzing the sources of emissions of one single company and herein focusing on the core value adding activities, excluding other potential emissions factors as e.g. information technology which becomes more and more relevant in near future.

Further limitations include the cost benefit analysis of selected decarbonization strategies or technologies. Even tough signposts, forecast and predictions are broadly available in the market evidence of the overall decarbonization cost and benefits are missing. There is a general understanding across sectors and countries that reaching a "point of no return" will have significant impact on the future of humanity, nevertheless there is a high uncertainty in what the effects really are. Herein there is rather a fear of a negative impact of climate change which could lead to a range of consequences posing significant risks to human societies and ecosystems:

- Rising temperatures: Greenhouse gas emissions trap heat in the atmosphere, leading to a rise in global temperatures. Missing decarbonization most likely will continue this trend, leading to more frequent and intense heat waves, droughts, and wildfires.
- Sea level rise: As temperatures rise, glaciers and ice caps melt, causing sea levels to rise. Missing decarbonization most likely will continue this trend, leading to flooding of coastal areas and displacement of millions of people.
- Extreme weather events: Climate change can lead to more frequent and severe extreme weather events, including hurricanes, tornadoes, and floods Missing decarbonization most likely will continue these events.
- Food and water shortages: Climate change can lead to reduced crop yields, water scarcity, and other challenges to food and water security. If we do not decarbonize, these challenges will become more severe, potentially leading to widespread hunger and thirst.
- Biodiversity loss: Climate change is already causing widespread species extinction and loss of biodiversity. Missing decarbonization most likely will continue this trend, leading to further ecological imbalances and potentially catastrophic consequences for human societies.

CONCLUSION

In conclusion the covered part of the iceberg is far more threatening than uncovered known factors which are currently only forecasted making it critical to prioritize and accelerate decarbonization efforts across all sectors, especially in energy, industry, and transport. This will require a concerted global effort, including policy incentives, technological innovation, and public awareness campaigns to drive the necessary changes in behavior and investment.

Looking forward there is the ambition to focus on selected decarbonization measurements and link these strategies to cost and profitability to provide rigorous and evidence-based understanding of the causes and consequences of greenhouse gas emissions and climate change. It involves applying the scientific method to develop and test hypotheses, evaluate data and models, and identify effective strategies for reducing emissions and mitigating the impacts of climate change.

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