1.1 – A sustainable mechanization for the future: first contribution

by *Giuseppe Gavioli (Gavioli Consulting, LLC)*

USA

Abstract

When we speak about sustainability, we should change our perspective; let us think about Earth not just as an “inhabited planet” but more as a “living organism”. Planetary transformations happen across millions of years while living organisms can change at a much higher speed. Gaia may continue living without us in the “short term”.

According to the 6th IPCC report, global warming is under significant acceleration, almost entirely driven by human activity. Reducing GHG emissions to zero is the top priority, not only to be sustainable but to be here tomorrow. So, we have the power, and we must act now.

The urgency to act opens an entirely new technological and economic scenario: agricultural mechanization companies have a tremendous opportunity to evolve as accelerators of sustainability for agriculture and the world. Manufacturers will transform how products are produced and used, dramatically expanding agricultural mechanization connection with biological engineering.

Artificial intelligence, digital platforms, and digital twins will boost the main breakthrough innovations. Energy management is the most effective short-term opportunity; green electrical energy will progressively replace all other energy sources, with a final migration from fossil fuels to renewable sources.

1. Introduction

We are living a critical moment of the human presence on Earth. Our species has developed an enormous power to use and transform natural resources, and the impact of this strength on the planet is now creating risks to our very existence.

The new IPCC Report on climate change states: "It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred", and more: "Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO2 and other greenhouse gas emissions occur in the coming decades" [1].

Global warming is now the most alarming signal, but not the only one, of a destabilized ecosystem rapidly moving out of the Holocene stability into the Anthropocene instability. The Earth is moving to a new set of conditions, very different from the current ones, that can be very harmful to the human species (Figure 1). Furthermore, there is enough scientific evidence that the leading cause of global warming is GHG emissions from human activity (Figures 2 and 3).

We must learn how to become sustainable and start actions to re-establish long-term equilibrium conditions in the global ecosystem.

Sustainability is undoubtedly a big challenge, but it also represents the most significant opportunity to redesign our business models and start exploring extensive new competitive territories.

2. Disequilibrium

When we talk about environmental sustainability, we often refer to the Earth as a planet in the solar system, evolved during millions of years to reach a condition capable of hosting life. The composition and temperature of the crust, an abundance of liquid water, and a thick gaseous atmosphere with a stable content of oxygen all formed an environment ideal to allow for the thrive of multiple forms of life, up to the widespread presence of human beings.

Changes in the planet's characteristics have always been relatively slow compared to the metrics of human life; we are used to measuring them in thousands or even millions of years. This perspective could lead us to think that the coming changes we are causing to the planet with our rapidly evolving presence will slowly show their effects over a period of time of the same order of magnitude.

However, this may be a very wrong and dangerous perspective.

We should instead follow the approach of James Lovelock [2], who introduced the theory of Gaia as a complex living ecosystem composed of the entire biosphere of the planet (all living organisms together with their environment). What he noticed was that Earth was a stable planet made of unstable parts. While the planet core is stable over millions of years because of its nature as a "rock" in the universe, the biosphere is long-term stable as an overall entity, but it can change and evolve its composition and characteristics in a much shorter timeframe.

The biosphere conditions that allow humans to live and thrive are quite narrowly shaped; out of these balanced conditions, human life cannot exist, but other forms of life can continue to form a different Earth's biosphere (Figure 4).

"Our contract with the Earth is fundamental, for we are a part of it and cannot survive without a healthy planet as our home" Lovelock said.

Therefore, let us redefine our metric when we think about the speed of changes on Earth's biosphere caused by human presence and activity; they can be much quicker than the planetary times we usually assume.

Gaia may respond in a much shorter timeframe to our "disturbance" and rapidly move to another equilibrium without us. It is typical of complex systems to reach a state of equilibrium through multiple correlated adaptations of their elements. We have evidence of how much interaction and interdependence exist among the environment and the various forms of life on Earth; everything is linked and correlated, every change causes other changes. Within the equilibrium conditions, the multiple changes mainly interact by negative feedback mechanisms, so compensation and reaction phenomena maintain the overall ecosystem in balance.

However, as soon as the changes are too rapid and too significant, parts of the system can get too much out of balance, and positive feedback may spread quickly to other sub-systems. All that can lead to an avalanche effect that finally moves the entire system out of its equilibrium conditions toward a possible new status that can be very different from the original one.

The positive feedback phenomena typically happen at relatively high speed due to the multiplication effects of correlated changes.

3. Global Priorities

To plan for actions, we need to identify priorities. Among the various causes of the Anthropocene impact on the global ecosystem, three appear to be primarily relevant and urgent to correct: GHG emissions, environmental pollution, and biodiversity destruction.

They are significantly correlated, as each one gives a further boost to the others.

- Greenhouse Gases (GHG) are the main responsible for global warming, which is already well advanced and causing alarming phenomena of more and more frequent extreme climate events. Moreover, excess CO2 in the atmosphere drives progressive ocean water warming and acidification, with a massive impact on marine life, reducing its biodiversity [3]. Most human society activities produce GHG today, so the actions to invert the trend and go to zero GHG emissions must be substantially widespread. The size of the issue is such that an enormous effort will be required across the globe for the next three decades. The broadly accepted global target is to transition to net-zero emissions by 2050.
- Polluting the environment with substances that cannot be absorbed and decomposed by natural transformation mechanisms causes a progressive degradation of life-sustaining conditions, directly impacting biodiversity. The resulting environmental alterations may last forever.
- Biodiversity destruction, also driven by extensive monocultural crop farming and deforestation, is a dangerous trend. The issue is not just losing one or another species in a territory; it is the unstoppable chain of consequences on the environment. Every form of life on Earth is strictly correlated to others and actively keeps the environment in balance. As

soon as a form of life disappears, others start disappearing too or growing beyond equilibrium, causing turbulence that may spread consequences on a wide scale. Think about how much animal and plant lives are intertwined, supporting each other in vital aspects. Moreover, think about the relationship between plants and the atmosphere: the air composition is directly influenced by the vegetal world.

We also tend to ignore how close and strong is the relationship and interdependence between the atmosphere and microbial fauna. Most of the CO2 absorption and O2 generation is done by bacteria and other microorganisms, in the seas and on the ground; if we alter the presence or just the activity of these forms of life, the Earth's atmosphere will likely change in a way that would not support human life anymore.

The 2020 WWF's global Living Planet Index shows an average 68% fall in monitored populations of mammals, birds, amphibians, reptiles, and fish between 1970 and 2016 (Figure 5). In Central and South America, the Index dropped by a staggering 94% [4].

Livestock now accounts for more than 60% of the biomass of all mammals, with wild mammals comprising just 4% and humans the remaining 36%. At the same time, there is a significant lack of cultivated biodiversity: just four crop species provide two-thirds of human caloric intake [5].

Across the world, people are rapidly decreasing their tolerance of the effects of global warming, pollution, and biodiversity destruction. The sensitivity around these subjects is increasing and becoming one of the most relevant drivers of cultural and behavioral changes.

These significant issues are the first to be addressed with speed and determination.

3.1. Something positive

One positive thing is brought to the scenario by a recent analysis conducted on the effects of the legislation that some years ago banned the ozone-depleting substances, forcing their complete replacement and restoring the continuity of the ozone layer in the atmosphere.

A Nature paper, published in August, found that if production of ozone-depleting substances had continued ticking up 3% each year, the additional UV radiation would have curtailed the growth of trees, grasses, ferns, flowers, and crops across the globe (ultraviolet radiation from the sun puts strain on plants, inhibiting photosynthesis and slowing growth). The Montreal Protocol avoided a catastrophic collapse of forests and croplands, with devastating effects on agricultural yields. [6].

This effect proves that globally coordinated efforts can pay back on multiple forms, restoring the natural equilibrium status of the biosphere.

4. A Paradigm Shift

More than 190 countries have committed to the goals of the 2015 Paris Agreement, which include aggressive reductions in emissions (the main goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels, to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century) [7].

This agreement is a vital sign of governments and institutions' commitment to reach net-zero GHG emissions by 2050, but for the initiative's complete success, it will be necessary to get on board public and private companies of all sizes and from all industries.

Companies need to embrace the global target and take vigorous actions to get dramatic improvements in sustainability. Choosing the correct practices, using the most appropriate tools, and controlling costs and investments will be essential.

Many companies already do sustainability actions today, documenting their plans and results on all sorts of sustainability reports.

What is risky for firms is to concentrate too much on documenting and communicating their sustainability plans, losing focus on customers and global markets.

"There has been notable progress in defining metrics for materiality and sustainability and supporting them with increasingly relevant and better-quality data, but this has inadvertently created an overemphasis on reporting and compliance per se, rather than on strategy, action, and advantage. Instead of measuring action and progress against a strategic plan, ESG metrics have become an end in themselves" [8].

The significant change behind such ambitious sustainability goals will be a true revolution in the economy, technology, and society. Companies will effectively participate in this new future by understanding the possible scope of change, the shift in customer needs, and the opportunities for new business models. Those who will not accept the challenge or will be slow in embracing change will risk profits first and then even survival.

Public demand for sustainability is rapidly growing and will very likely skyrocket in the coming years. Our society will undertake significant transformations: changing behaviors in energy use, transportation, and choosing food and materials. Customers (both consumers and businesses) will want to see facts and certified evidence of product and service sustainability before buying.

Enterprises willing to be effective in sustainability and successfully compete in the market will have to focus more on customer needs and less on optimizing their current business model. When customers start shifting behavior and preferences, the market scenario will change completely; companies will have to explore and understand the unfolding mutation to design new strategies, business models, and competitive products.

5. Precision Agriculture

Agriculture is responsible for generating a lot of GHG today (Figure 6 and 8), but it is also significantly impacted by the consequent global warming. Hotter temperatures can reduce crop yields; for each degree Celsius increase in global mean temperature, wheat yields can fall by up to 6%, rice by up to 3.2%, maize by up to 7.4%, and soybean by up to 3.1% [9].

Other research carried on in Iowa and Kansas by the US Department of Agriculture's National Laboratory for Agriculture and the Environment showed alarming drops in yield of corn and wheat (between -30% to -70%) on growth chambers simulating rising temperatures and altered rainfall patterns expected to hit the areas in the following decades [10].

So, in a moment when agriculture must increase land and crop productivity to produce more food for the rising world population, farmers will have to battle even more against meteorological factors.

Precision agriculture and plant genetics have been so far the best responses to the demand for yield increase, and they will continue to drive improvements in the years to come.

Agricultural mechanization industries are deploying more and more precision farming tools [11] to improve farming practices, increasing productivity, saving energy, and limiting environmental pollution:

- auto-guidance,
- section control,
- variable rate,
- machine and fleet analytics,
- precision irrigation.

Accelerated investments in these tools are the best way for farmers to leap forward in sustainability.

Nevertheless, this effort will have to be supported by adopting additional changes and boosted by introducing new technologies:

- Decouple agriculture from fossil fuels
- Embrace advanced digitalization (AI, digital twin, blockchain)
- Use digital platforms.

This approach will "supercharge" the actions already started or planned by the equipment manufacturers, allowing for a big jump into the sustainable future we desperately need.

5.1. Decouple agriculture from fossil fuels

The first and most important action to reduce GHG emissions is to stop burning fossil fuels.

Increasing machine efficiency to save energy is undoubtedly a brilliant start, but it is not enough. It is necessary to progressively eliminate fossil fuels, replacing them with low-emission and zero-emission fuels. We cannot meet the Paris Agreement targets only optimizing the current use of energy: a more dramatic technology change is required.

One step on the way can be biofuels to allow for a certain degree of carbon sequestration for every unit of carbon emission. Biodiesel is a good example, even if it is difficult to produce enough energy crops without a significant land-use change, that may have adverse effects and impact biodiversity.

Better is the use of biomethane because it is typically derived from organic waste. The two main processes to produce biomethane are anaerobic digestion and biomass gasification, with equivalent efficiency (around 65%) [12].

A further step is to use hydrogen to be burnt on endothermal engines or to generate electricity inside fuel cells with zero GHG emissions. Hydrogen is an excellent energy carrier, and its production process through hydrolysis is relatively simple, even if it uses much electric energy. The hydrogen production process should only use electric energy from renewable sources to get close to zero GHG emissions. The progressive cost decrease of green electricity production (from solar cells or wind turbines) is an encouraging trend to implement the green hydrogen production and distribution infrastructure [13].

The next option is to directly use green electricity from the grid (or from local production), stored in batteries, and used to power farm machinery (Figure 7).

The decreasing cost of batteries and their increasing energy density are helping in finding suitable applications in the farm mechanization industry. Electric-powered machines, with batteries on board, will be more and more common in farms and fields. It is also essential to consider decreasing the size and mass of some farm equipment, designing machinery for small-scale, highly automated and specialized operations (replacing some large equipment dedicated to large-scale uniform operations).

5.2. Artificial Intelligence

Artificial Intelligence (AI) is a broad definition for various forms of the augmented ability of software algorithms to learn from data and experience and infer correlations and similitudes. It is one of the most powerful tools available today whose characteristics and performance are rapidly evolving.

A big branch of AI is also going to emulate more and more the ways of handling knowledge through multiple complex connections that are characteristic of the human brain (neural networks).

AI is excellent in the analysis of enormous quantities of data and in developing models and simulations. Machines equipped with AI can perform functions with an unprecedented degree of complexity and independence. Running on high-power low-consumption onboard hardware (processor and sensors), AI supports the implementation of autonomous functions on machinery and robots, opening new possibilities of specific, customized, mission-tailored actions.

Artificial intelligence is also instrumental in maximizing the use of connectivity among different nodes in a network, optimizing the exchange of complex information and the possibilities of collaboration between connected elements.

Therefore, AI is a potent booster of many precision agriculture activities, enabling the invention and development of new machines designed around a new set of customer needs (productivity, selectivity, and sustainability).

5.3. Digital twin

The digital twin is a virtual dynamic model of a real-world object.

Like every virtual model, within the limits of its accuracy and complexity, it offers the possibility to simulate and experiment changes on the model, to study and anticipate the resulting impact on the physical system.

Moreover, when connected to the physical system through various sensors, it also allows for the continuous data collection on the physical object and real-time anticipation of incoming changes in the physical system. Planning and scheduling optimizers can then be rerun in real-time when unexpected events occur.

The subsequent step is to virtually connect the digital twin to machines and robots in the field, for the AI software sends them operative orders and instructions, closing the loop of a highly "intelligent" and automated system.

A complete ecosystem can be realized by connecting the digital twin to various external sources of information (weather data, market trends, customer orders, service providers, and more). In such a way, the digital twin becomes a central tool to implement and manage precision agriculture in a way that boosts its power to incorporate and enhance sustainability [14, 15].

5.4. Blockchain

Crop and food traceability is more and more required to stay in the market and fulfill customer requirements. Consumers are shifting their demand to environmentally and socially responsible products, and they want to know more about the food they buy. Also, the intermediate customers in the economic value chain want information and certification of product quality and characteristics. Transactions and prices on the market are increasingly driven by the availability of data on product life history; in particular, more information is requested on the sustainability of the various value chain steps.

Blockchain technology may help create and maintain public distributed ledgers, where certified authentic data about crops and crop history are stored. That would be a solid incentive to implement sustainable practices, use sustainable materials, and document them. Farm machines can contribute to collect data on operations and materials directly during field operations.

5.5. Digital platforms

A new and vital tool to offer information services is a digital platform. They are essentially software applications structured to create a "platform" acting as a base for several other applications and data services (developed in-house or third-party). These services are usually offered through an online marketplace. The advantage for the users is to see something like an ecosystem of things, sharing a common background or environment, providing multiple services coexistent and connected. Through the mutual influence of customers and providers, the digital platform creates a network that builds a digital ecosystem.

Service providers increasingly apply this concept to offer dynamic groups of data services and software functions integrated into the same environment, where information sharing and network communication are happening in a very natural way.

Digital platforms may be an ingenious way for machine manufacturers to expand the value of physical products, complementing the equipment with a set of information services offered to the same machine users. Instead of offering single data services, manufacturers can propose a digital platform where users can find various data and easy-to-use applications (to process and correlate data), with no separation between the use of the equipment and information management.

"Digital platforms that can track the health of an individual head of lettuce from seed to supermarket and optimize the order in which fields get harvested" [16].

Moreover, the digital platform application may address the needs of an extended population of customers, not only the machine users. An exciting opportunity is to connect multiple categories of value chain actors through services offered by the same digital platform. Every category of users can find in the platform both the information they need and easy ways to share and communicate information with other users.

Companies in the agribusiness sector have an excellent opportunity to expand their customer base and create more added value, leaving their current boundaries, exploring new customer needs, and offering new solutions. They can leverage their know-how and the vast database they can access, building new business models and boosting sustainability through an integrated offer of products and services.

6. Finance and Sustainability

One of the first economists that started expanding the scope of private companies beyond profit, introducing the concept of social sustainability, was Michael E. Porter in 2011: "The principle of shared value involves creating economic value in a way that also creates value for society by addressing its needs and challenges. Businesses must reconnect company success with social progress" [17].

As the understanding of the importance of sustainability grows, the concept of shared value becomes more concrete and measurable. According to the World Economic Forum, over half of global GDP, around $43 trillion, depends on well-functioning biodiversity. We can think about what natural ecosystems do for the global economy and quantify them as ecosystem services; for example, more than 75% of global food crops (fruits and vegetables) rely on pollinators such as bees, and some 70% of antibiotics and drugs used to fight cancer are natural substances or synthetic products inspired by nature. Moreover, according to the UN's IPCC, natural ecosystems sequester about one-third of global GHG emissions annually instead of allowing them to go into the atmosphere. [5].

In the Living Planet Report, WWF says that biodiversity has significant economic value, which should be recognized in national accounting systems [4].

Recently the concept of "social cost of carbon" is being used to quantify how much additional cost should be added to products and services if we include the real impact that such products have on GHG net emissions increase and their consequences for our society. Another key metric in the fight against climate change is "emissions per dollar of GDP". The declining carbon intensity of economic activity should show our progress on the path to GHG net-zero [18].

The World Economic Forum recommends that private companies restructure their organizations and business models to focus on maximizing the triple bottom line – the company's return on people, planet, and profit [19].

Enterprises must move from an approach focused primarily on the enterprise itself to one that encompasses multiple fronts, including other industries, across a broader ecosystem of participants [20].

Financial institutions and private financers appear to be increasingly sensitive to the sustainability issue; one example for all is the Glasgow Financial Alliance for Net Zero (GFANZ), launched by Mark Carney (UN special envoy for climate action and finance, former governor of the Bank of Canada and the Bank of England) and the COP26 Private Finance Hub. GFANZ, with $70 trillion on the balance sheet, brings together more than 160 firms from the leading net-zero initiatives across the financial system to accelerate the transition to net-zero emissions by 2050.

“One of my messages to the business community is that you can make strategic decisions on climate and expect that the financing will be there for you”, Mark Carney points out [21].

In 2020, investors poured a record US$350bn into sustainable investment funds, more than double the 2019 total. A great deal of capital is being invested into innovation, R&D, technology, and scaling efforts that help bring down the cost of renewable energy production, energy storage, green hydrogen, and other low- or no-carbon innovations [22].

Therefore, companies that embrace the sustainability challenge, with the related uncertainties and risks, can count on a growing amount of financial support from public and private investors, in addition to increasing public subsidies. On the other hand, organizations that hesitate to accept the change and the challenge face relevant risks to see their costs increase and their competitiveness rapidly decline.

8. Conclusions - A Green Future

The rapid progression of global warming, scientifically documented, and the significant concerns about biodiversity destruction are raising the sensitivity of citizens and institutions on sustainability.

More and more organizations, communities, and individuals perceive the urgency of actions and understand the importance of coordinated action plans.

Governments of many countries have started significant initiatives, like Paris 2015 and COP26, that pass the same message; climate change caused by global warming and biodiversity destruction are global emergencies that require immediate attention and joint efforts.

Companies in all sectors must understand the enormous transformations that are going to happen in the markets and the society and must be ready to include sustainability as a critical element of their strategy. The time for pure compliance or limited adjustments is over.

Farm equipment manufacturers have already started an essential evolution of their products, supporting precision and sustainable agriculture with various new offerings. Now is time to boost the efforts and adopt new technologies and energy vectors with decision and passion.

Sustainability represents a unique opportunity for breakthrough innovation, new business models, and a green future.

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FIGURES

Figure 1 – Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850-2020) (Source: [1])

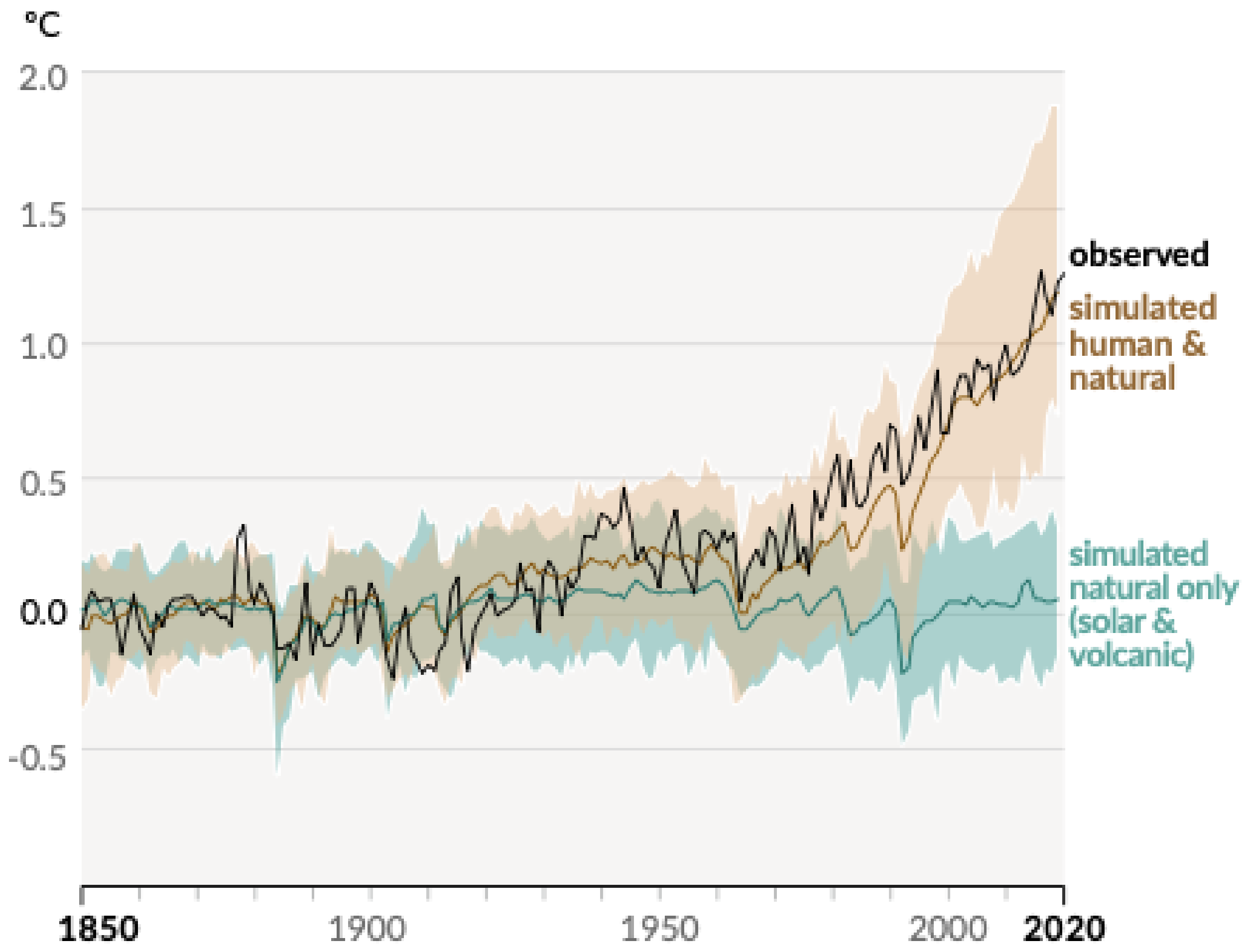


Figure 2 - Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling (Source: [1])

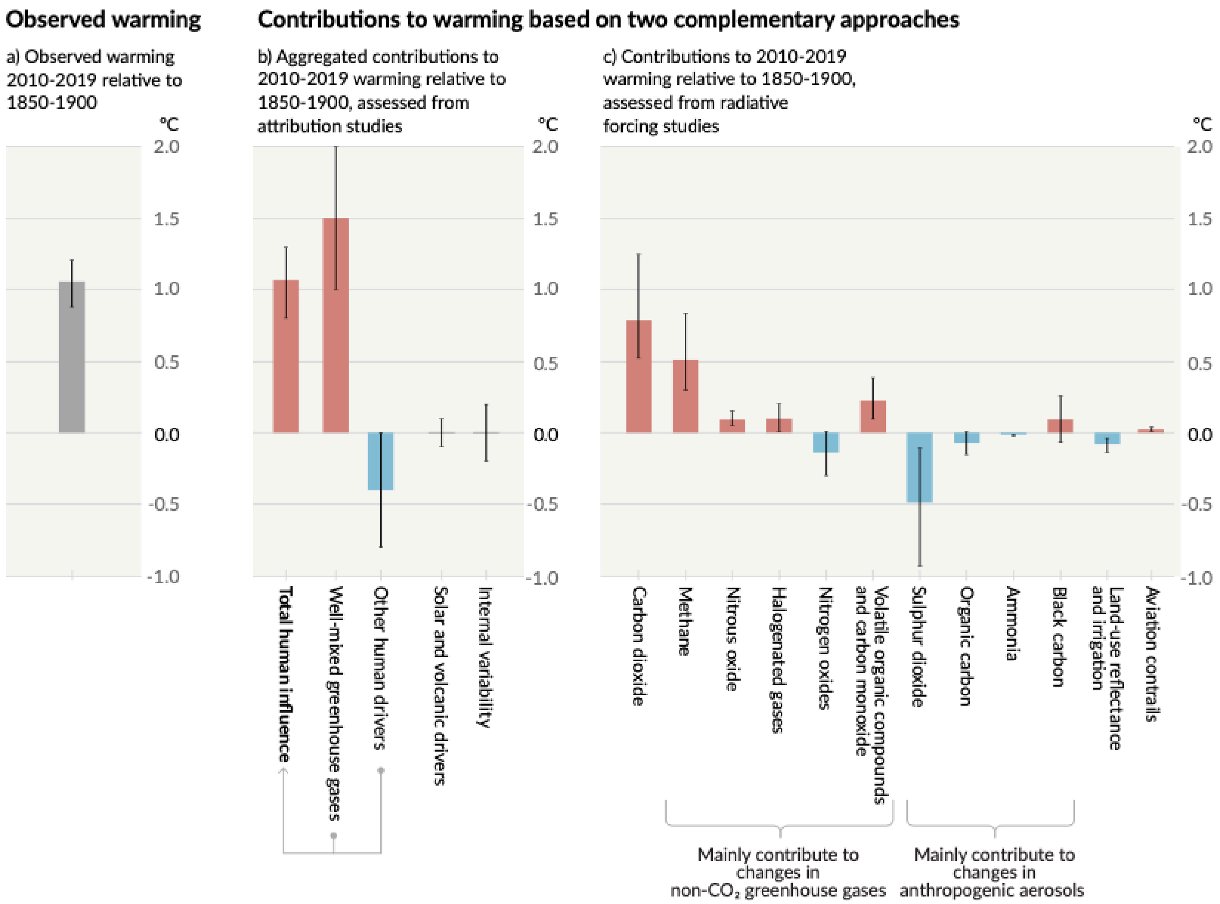


Figure 3 – Resource Extraction and Cultivation Activities Account for Most Pressure on Biodiversity (Source: [5])

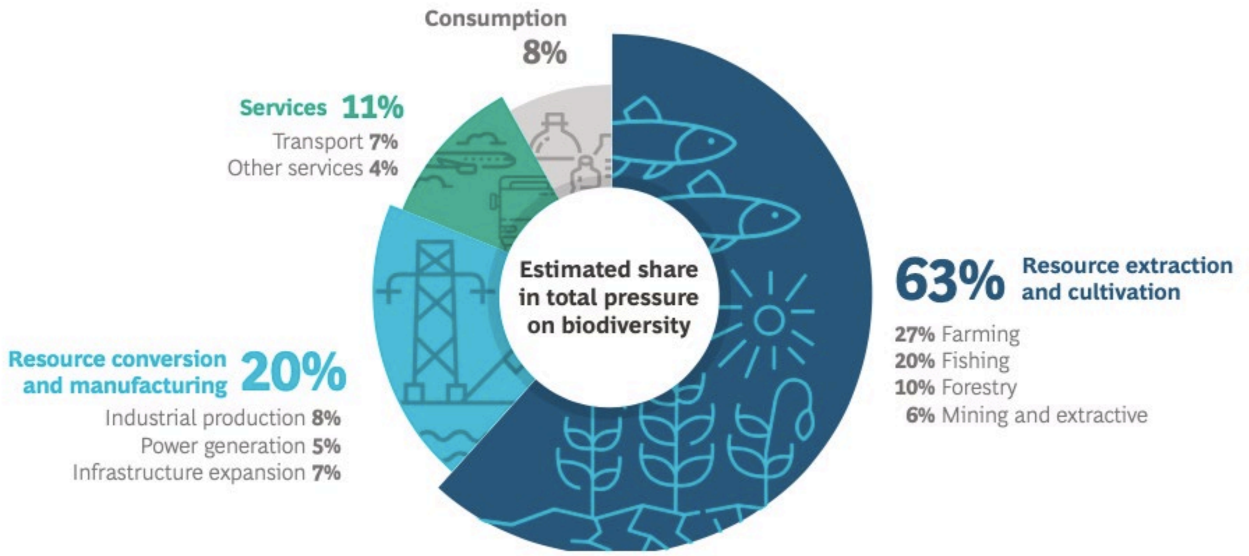
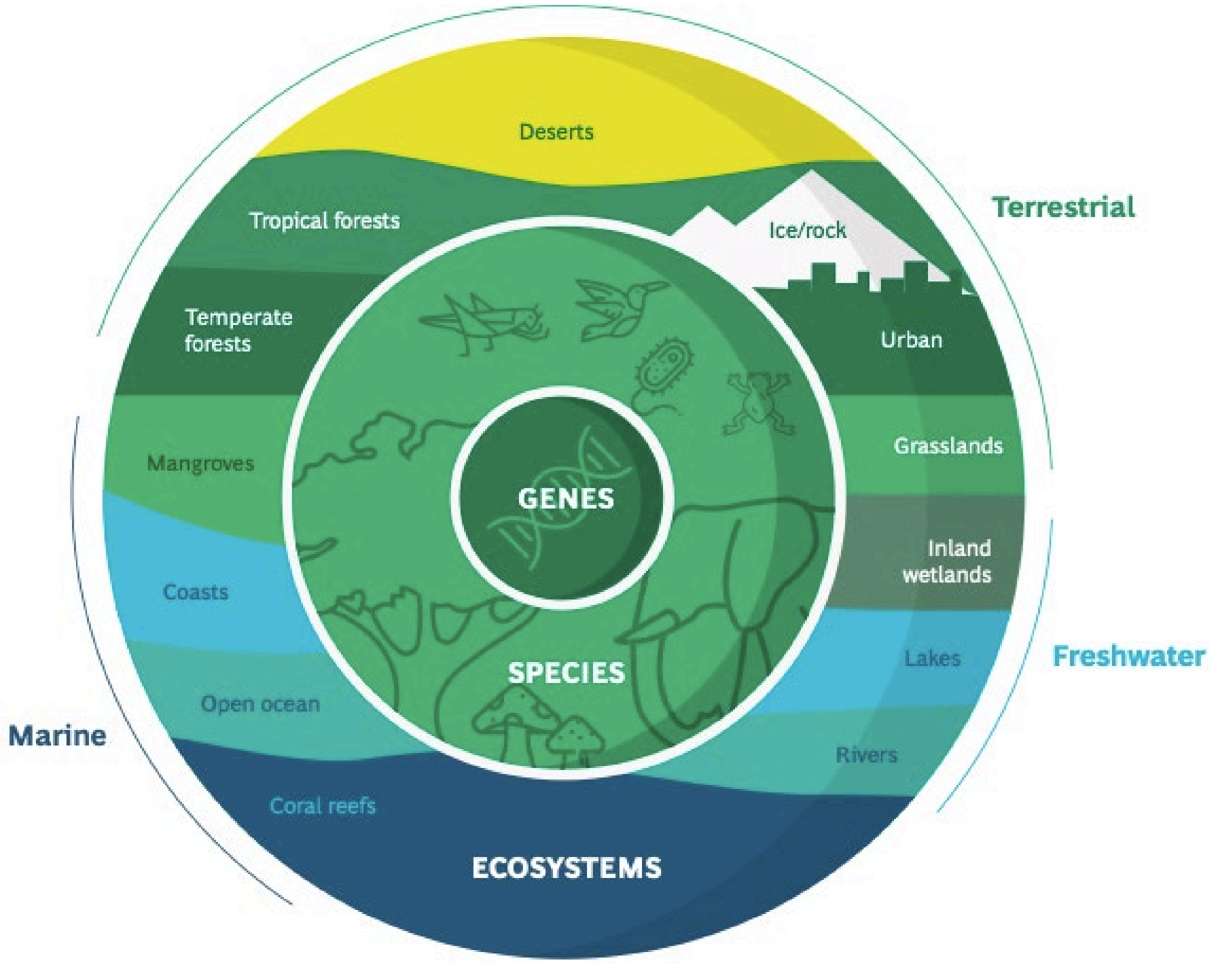


Figure 4 - Biodiversity Is Defined by the Variability in Ecosystems, Species, and Genes (Source: [5])



Sources: IPBES, "Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services" (2019); International Union for Conservation of Nature, Red List of Threatened Species (2019 update); Group on Earth Observations Biodiversity Observation Network; BCG analysis.

Figure 5 – The Living Planet Index (LPI) tracks the abundance of almost 21,000 populations of mammals, birds, fish, reptiles, and amphibians around the world (Source: [4])

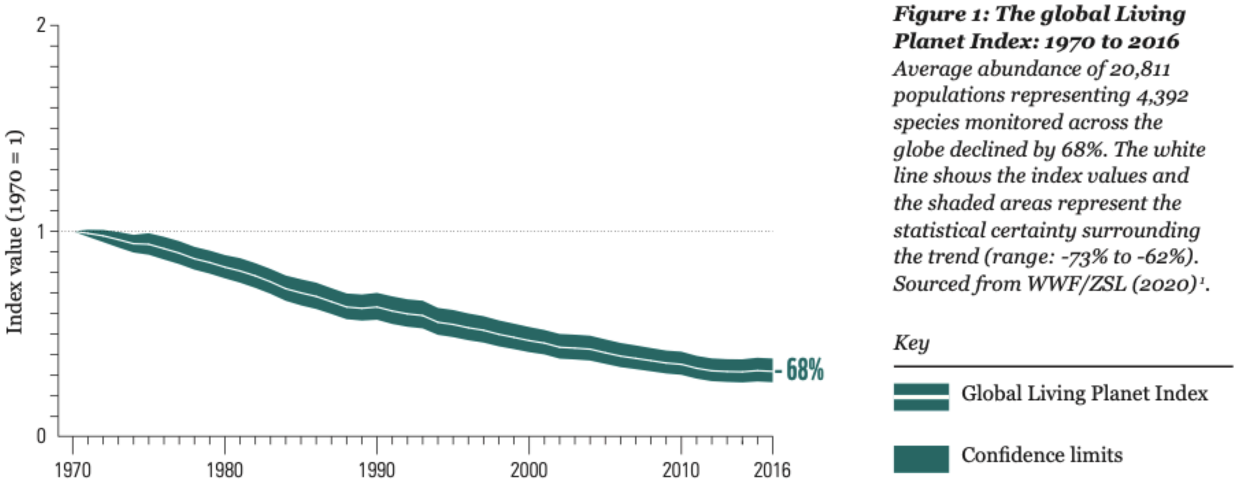


Figure 1: The global Living Planet Index: 1970 to 2016
Average abundance of 20,811 populations representing 4,392 species monitored across the globe declined by 68%. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (range: -73% to -62%). Sourced from WWF/ZSL (2020)[1].

Figure 6 – Global GHG emissions by sector (Source: [23])

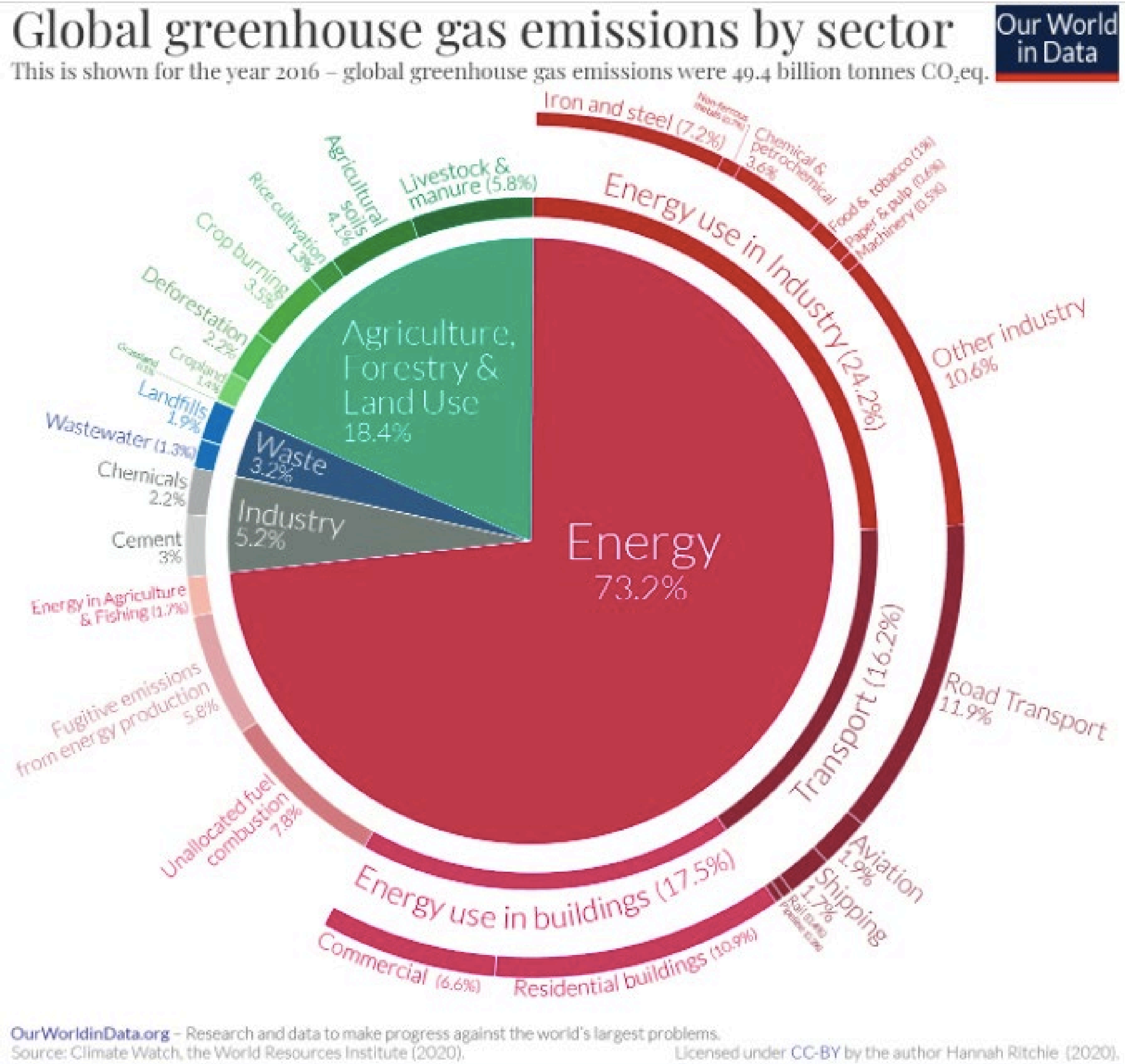


Figure 7 – New vectors for molecules and electrons (Source: [22])

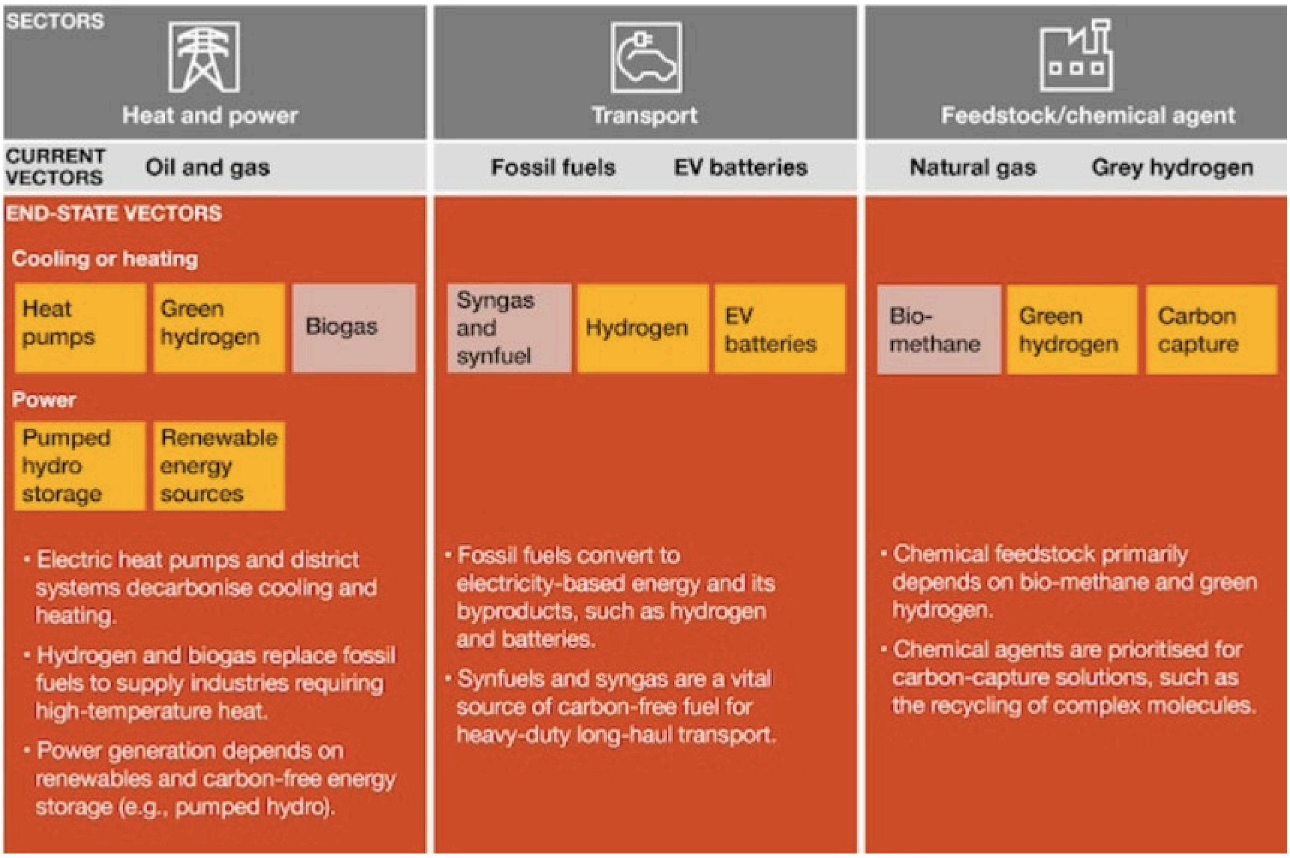


Figure 8 - The environmental impacts of food production (Source: [4])