Climate Change and Post-carbon Alternatives in Transport

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Since the first IPCC report was published in 1990, policy makers have been confronted with the major issue of climate change and its socio-economic impacts. The impact of climate change and its consequences is a complex process that raises several questions. The current shift toward a sustainable future has made various sectors, including transport, the focus of the current urgency to address climate change. Despite this, this matter remains sensitive because it directly affects the daily decisions of countless citizens. While there is no single solution to transforming the transport sector, solutions like clean energy vehicles and fairer public transport can perhaps help us achieve the ambitious goals set by the IPCC. A post-carbon future is also possible by looking back, utilizing wind in sails for transport and riding cargo bikes around the city. Various social innovations and initiatives, such as community transportation and car sharing, together with lively debates about the fair distribution of public space between different traffic users, are already changing the modes of mobility in many metropolises.

Keywords:
climate change,
climate policy,
planetary boundaries,
post-carbon transport,
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1 Introduction

Climate change is no longer just a problem of the future–we are already witnessing its effects today. Some parts of our planet have been visibly affected for decades, and with each passing year, we are seeing more catastrophic consequences in our own region as well. The changes in the Earth's climate, driven by increased human emissions of greenhouse gases, are having a profound impact on the environment. Glaciers and ice sheets are shrinking, ice on rivers and lakes is melting earlier, natural habitats of plants and animals are shifting and changing, and plants are blooming earlier than before … Some changes–such as droughts, forest fires, and other extreme weather events–are occurring even faster than scientists had predicted. In the summer of 2022, we witnessed an almost unstoppable wildfire that devastated the Karst region. We also experienced one of the driest years in Slovenia. According to the Slovenian Environment Agency (ARSO), based on preliminary (and not yet fully verified) data, 2022 was the warmest year on record nationwide, with below-average precipitation and high levels of sunshine. We also witnessed two more severe weather events in 2023: a major hailstorm and one of the largest floods in Slovenia in this century.

Since the release of the first report by the Intergovernmental Panel on Climate Change (IPCC) in 1990, climate change and its socio-economic impacts have become a central topic for policymakers. Climate change and its consequences are highly complex processes that raise a wide range of questions. From an ethical perspective, some of the most pressing issues relate to the balance between mitigation and adaptation efforts, as well as assigning responsibility for past and present greenhouse gas emissions. The fact that climate change is an intergenerational issue is something we can no longer afford to ignore. The well-being and survival of future generations depend now more than ever on the decisions we make today. Thanks to, and because of, the growing pressure for action - both from the top down (such as climate policies at international, national, and regional levels) and from grassroots initiatives - positive changes are happening at the micro level. We are witnessing numerous strategies being implemented that contribute to the transition toward a low-carbon society, the mitigation of climate change, as well as a fairer society and a higher quality of life.

In the following part of this contribution, I would like to shed light on some fundamental concepts related to the climate crisis, such as the Anthropocene, Planetary Boundaries, the IPCC, climate policies, and - most importantly - highlight

some existing solutions in the field of transport that could mark the beginning of the so-called post-carbon society.

2 From humans to climate change

2.1 Anthropocene era

The Anthropocene is the proposed - though not yet officially recognized - geological epoch in which we are currently living. It is considered part of the Quaternary period (from 2.6 million BCE to the present) and is characterized primarily by significant alterations to the Earth's surface, atmosphere, oceans, and nutrient cycles as a result of human activity. An increasing number of scientists argue that the Anthropocene should follow the Holocene epoch (from 11,700 BCE to the present) and that it began around the year 1950. The formalization of the Anthropocene depends on whether the impacts of human activity on planet Earth are - or will become - significant enough to be detectable in the geological strata. Most scientists agree that humanity's collective impact was considerably smaller prior to the Industrial Revolution, that is, before the mid-18th century. After that point, technological advancements enabled humans to initiate large-scale, systematic changes affecting multiple aspects of the Earth's system. Some scientists have proposed that the Anthropocene should begin in the year 1784, when Scottish inventor James Watt significantly improved his steam engine (originally patented in 1781), which coincided with the onset of the Industrial Revolution and the widespread use of fossil fuels (Issberner & Léna, 2018).

The term defining the most recent geological epoch - one in which human activities are believed to have triggered biophysical changes on a planetary scale - was coined in 1980 by American biologist Eugene F. Stoermer. However, it gained widespread popularity in the early 21st century, thanks to Dutch atmospheric scientist and Nobel Prize laureate in Chemistry (1995), Paul Crutzen. The word Anthropocene comes from Ancient Greek: ἄνθρωπος (anthropos), meaning "human," and καινός (kainos), meaning "new." The term is used across a variety of cultural and scientific contexts. It is employed by researchers, poets, philosophers, politicians, and activists - often with different interpretations. While some associate humanity's impact on the planet solely with climate change (such as the warming of the atmosphere, air, and oceans due to the use of fossil fuels), human influence on the transformation of the Earth

extends far beyond climate change alone. Just consider the accumulation of waste, the construction of cities, roads, and other infrastructure.

As noted by Issberner and Léna (2018), from 1987 to 2015, a large-scale multidisciplinary research initiative - the International Geosphere-Biosphere Programme (IGBP) - was conducted, during which an extensive amount of data on anthropogenic changes to the Earth's system was collected. Another research effort, which began as early as the 1950s, involved sampling ancient ice in Antarctica and analyzing the current composition of the atmosphere. This study revealed the accelerated accumulation of greenhouse gases, particularly carbon dioxide. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established with the aim of examining the impact of these phenomena on the climate. In the last sixty years especially, human impact on the planet has reached unimaginable dimensions and speeds. As Rafferty (2023) notes, this period is also known as the "Great Acceleration." It refers to the post-war era, characterized by the rapid expansion and exponential growth of the population, massive consumption of fossil fuels and water, food production, global communication, and the use of vast agricultural lands. This period also marks the beginning of carbon dioxide emissions, global warming, ocean acidification, destruction of natural habitats, species extinction, and extensive exploitation of natural resources. These are clear signs that we have significantly altered our planet.

By combining all this data - first in 2009 and later in 2015 - environmental scientist Johan Rockström (Sweden) and his colleagues from the Stockholm Resilience Centre outlined nine Planetary Boundaries. Four of these nine boundaries have already been exceeded (according to data prior to 2023[1]). These include climate change, loss of biodiversity, species extinction and changes in land cover, as well as biogeochemical cycles - particularly those involving phosphorus and nitrogen (Issberner & Léna, 2018). The Planetary Boundaries framework was updated in September 2023.

It is now clear that our climate is no longer stable and is warming rapidly. Scientists now agree that the main driver of accelerated global warming is human activity. Agriculture, urbanization, deforestation, and pollution have caused dramatic changes to the Earth. However, geologists are still divided on whether humans will leave a

[1] Author's notes.

truly lasting and significant impact on the chemical composition of rocks and fossils beneath our feet. And that is precisely the kind of evidence needed to officially declare a new epoch - the Anthropocene. Humans have existed for such a brief moment in Earth's history that it may still be too early to determine whether our impact will truly be visible in the fossil record millions of years from now.

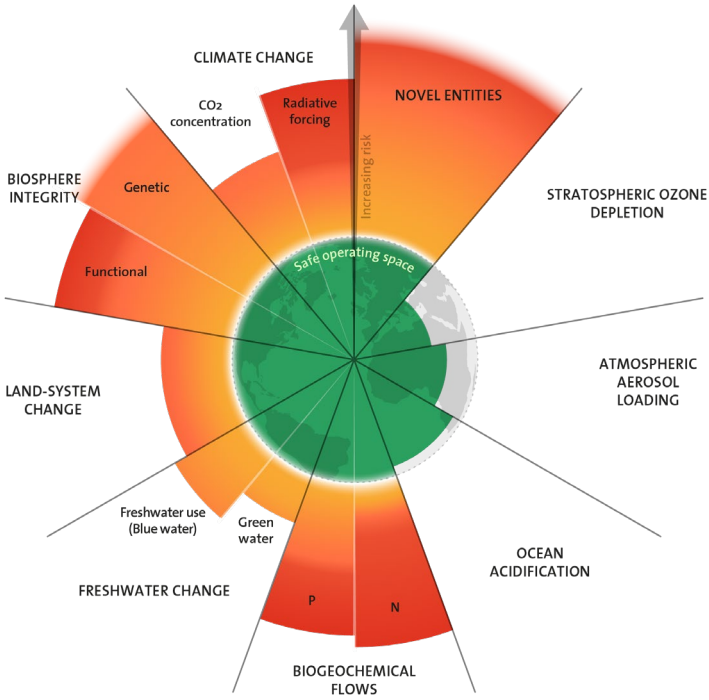

Figure 1.1: The 2023 update to the Planetary boundaries
Vir: Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023

The most recent, third update of the Planetary Boundaries framework was conducted by 29 scientists from eight different countries. The researchers first identified processes in the Earth system that have been crucial for maintaining favorable conditions for humanity over the past 12,000 years. This period is known for its stable and warm conditions on planet Earth. The researchers then assessed the extent to which human activities have altered these processes and determined at what level human intervention increases the risks of potentially dramatic and irreversible changes in the overall conditions on Earth. They also used computer simulations in their research. As noted by the group of scientists in the study *Earth*

beyond six of nine planetary boundaries (Richardson et al., 2023), the findings regarding the exceeded planetary boundaries are as follows:

- Carbon dioxide (CO2) in the atmosphere: The researchers set the planetary boundary for CO2 concentration in the atmosphere at 350 parts per million (ppm), but it has currently reached 417 ppm;
- Land-use change: This mainly refers to deforestation, logging, and the destruction of large forest areas. The current level has surpassed the safe boundary;
- Biosphere integrity: The boundary set for species extinction was to limit it to fewer than 10 extinctions per million species-years (10 E/MSY). However, the extinction rate has exceeded 100 extinctions per million species-years. This boundary has already been surpassed. It is currently estimated that around one million of the 8 million plant and animal species are at risk of extinction. Over the past 150 years, more than 10 percent of genetic diversity, both in plants and animals, may have been lost. Another aspect of biosphere integrity is the energy available to ecosystems, or net primary production (NPP). This represents the difference between the amount of carbon produced through photosynthesis and the energy used for respiration. Humans have appropriated about 30 percent of the energy that supported biodiversity before the Industrial Revolution;
- Freshwater resources: This includes blue water (surface water and groundwater, including drinking water) and green water (the water available to plants). Human impact on blue and green water has been calculated at 18.2% and 15.8%, respectively, exceeding the boundary of 10.2% and 11.1%. Analyses showed that the boundaries for blue and green water were surpassed in 1905 and 1929, respectively;
- Nutrient cycling (biogeochemical flows): Biogeochemical flows already reflect anthropogenic disruptions in the cycles of elements. Currently, the framework focuses on nitrogen (N) and phosphorus (P), as these two elements are fundamental building blocks of life, and their global cycles have been significantly altered by agriculture and industry. The boundary was set at 11 teragrams (Tg) for phosphorus and 62 Tg for nitrogen. The exceeded boundaries are now 22.6 Tg for phosphorus and 190 Tg for nitrogen;
- Creation of new entities: This boundary is now defined by truly novel anthropogenic inputs into the Earth's system. These include synthetic chemicals and substances (e.g., microplastics, endocrine disruptors, and organic

pollutants); anthropogenically mobilized radioactive materials, including nuclear waste and nuclear weapons; as well as human-induced changes in evolution–genetically modified organisms and other direct human interventions in evolutionary processes. New entities serve as geological markers of the Anthropocene. The quantitatively defined planetary boundary for new entities should be maintained at zero. This means zero release of synthetic chemical compounds into the open environment, unless they are certified as harmless and are regularly monitored. This is the goal set by the Montreal Protocol.

Since 1988, humans have aggressively intervened in what was a relatively stable climate and terrestrial system of the planet (Richardson et al., 2023). Now, we are facing risks and are increasingly approaching irreversible system disturbances. The planetary boundaries are interconnected processes within the Earth's complex biophysical system. This means that simply focusing on climate change is not enough to achieve greater sustainability and resilience. Therefore, understanding the interplay of these boundaries, especially climate change and biodiversity loss, is crucial both in science and practice.

2.3 Climate change and IPCC

Humanity has already witnessed profound climate changes throughout its history, but these occurred more slowly, and the memory of them, in the absence of written records, has been preserved only in myths passed down orally through generations (for example, the myth of the Cosmic Flood) (Allan, 2017). The first known records of observations on changing weather patterns date back to Ancient Greece, while early systematic climate research and the development of modern understanding of climate processes date back to the 19th century. The influence of CO2 in the atmosphere and the related concept of the 'greenhouse effect' was proposed in 1825 by naturalist Jean-Baptiste Fourier. The first calculations on the impact of elevated CO2 concentrations on global temperatures and the associated idea of potential human influence on climate change were developed by Nobel laureate Svante Arrhenius at the turn of the 20th century (Flemming, 2014). With the development of technologies and methods for capturing and processing climate data, alongside the rapid increase in human impact on the environment, the presence of climate change has become increasingly evident and concerning. This, over time, contributed to the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC (2018) was founded under the auspices of the World

Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The IPCC regularly reviews and assesses the various scientific bases related to climate change, its impacts, future risks, and the possibilities for adaptation and mitigation. The IPCC's role is to provide governments at all levels with scientific data that they can use to shape climate policies. It is important to emphasize that, although different governments or organizations may interpret climate change somewhat differently, the definition of climate change provided by the Intergovernmental Panel on Climate Change (IPCC) is widely recognized and accepted within the scientific community and by major international organizations.

In the IPCC Glossary (2018), we find a general definition of climate change, which reads:

"Climate change refers to a change in the state of the climate that can be identified (e.g., using statistical tests) through changes in the average and/or variability of its properties, and which lasts for an extended period, typically decades or more. Climate change may result from natural internal processes or external influences, such as solar cycle modulations, volcanic eruptions, and ongoing anthropogenic changes in the composition of the atmosphere or land use."

It is also worth noting that the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change in Article 1 as:

"Climate change refers to a change in climate that is directly or indirectly attributed to human activity that alters the composition of the global atmosphere and that is observed in addition to natural climate variability over comparable time periods."

The UNFCCC thus distinguishes between climate change that can be attributed to human activities that alter the composition of the atmosphere and climate variability that can be attributed to natural causes (IPCC, 2018).

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) is the sixth in a series of reports that provide a comprehensive review of scientific, technical, and socio-economic information related to climate change. Three Working Groups (WG I, WG II, and WG III) contributed to the report, each focusing on a specific area: the physical science basis (WG I), impacts, adaptation, and vulnerability (WG II), and mitigation of climate change (WG III). The first study was released on August 9, 2021, while the contributions of the second and third

working groups followed on February 28 and April 4, 2022. The final Synthesis Report was published on March 20, 2023.

The IPCC's Working Group I (IPCC, 2023), in its latest report, not only reconstructs past knowledge about climate change and examines current developments, but also explores various possible futures. The five new greenhouse gas emission scenarios used in the report represent potential climate trajectories throughout the 21st century, based on differing levels of greenhouse gas emissions and pathways of socio-economic development.

Five narratives were developed to describe the potential social, economic, political, and technological developments up to the end of the century. These five storylines were used to model different scenarios for the evolution of economic, energy, and land-use systems. Some of these scenarios are constrained by climate targets (referred to as "mitigation pathways"), while others are not ("baseline scenarios"). The results are presented as projected changes for the near future (2021–2040), mid-century (2041–2060), and end of the century (2081–2100), relative to the period 1850–1900, which serves as a reference for the pre-industrial era. As summarized in the Slovenian translation of the latest IPCC Summary for Policymakers (ARSO, 2021), the scenarios begin in 2015 and are as follows: two involve high and very high greenhouse gas emissions (SSP3-7.0 and SSP5-8.5), with CO_2 emissions approximately doubling by 2100 or 2050; one scenario involves intermediate emissions (SSP2-4.5), where CO_2 emissions remain around current levels until mid-century and then decline; and two scenarios involve very low and low emissions (SSP1-1.9 and SSP1-2.6), in which CO_2 emissions decline to net-zero around or after 2050, followed by net negative CO_2 emissions. Emission differences across these scenarios stem from varying socio-economic assumptions, levels of climate change mitigation, and air pollutant emissions. The narratives of these five scenarios are as follows:

- SSP1: Sustainability (Taking the Green Road) – In this scenario, the world gradually but decisively moves toward sustainable development. There would be improvements in education and healthcare systems, and economic growth would focus on lower material consumption and energy intensity.
- SSP2: Middle of the Road – The world follows a path where social, economic, and technological trends continue in a way that is broadly consistent with

historical patterns. Global and national institutions would make slow progress toward achieving sustainability goals, and income growth would occur unevenly across regions.

- SSP3: Regional Rivalry (A Rocky Road) – Rising nationalism, concerns about competitiveness and security, and regional conflicts would push countries to focus on local and regional issues at the expense of broader development. Economic growth would be slow, material consumption high, and inequality would persist or even worsen.
- SSP4: Inequality (A Road Divided**)** – In this scenario, significant inequality in investment in human capital, as well as disparities in economic development and political power, would lead to growing inequality both between and within countries. The gap between developed and developing nations would widen. Developed countries would experience rapid technological advancement, while developing countries would remain reliant on labor-intensive industries and low-tech solutions. The energy sector would see parallel investments in both carbon-intensive fuels (such as coal and oil) and low-carbon energy sources.
- SSP5: Fossil-Fuel Development (Taking the Highway) – In this scenario, the world would pursue sustainability through competitive markets, innovation, and cooperation between societies. Investments in health and education would be high; however, fossil fuels would continue to be heavily exploited. An energy- and resource-intensive lifestyle would become widespread globally. As a result, the global economy would experience rapid growth.

(Summarized from: ARSO – Slovenian Environment Agency: Office for Meteorology, Hydrology and Oceanography. (2021). *Climate Change 2021, Physical Science Basis and the Situation in Slovenia, IPCC Report 2021, Summary for Policymakers with an Added Description of the Situation in Slovenia.*)

The latest IPCC report is intended to serve as the basis for the United Nations Climate Change Conference - COP28, which was hosted by the United Arab Emirates in Dubai starting on November 30, 2023. At COP28, the progress of countries in reducing greenhouse gas emissions since the Paris Climate Agreement of 2015 was re-evaluated.

3 Major international climate policies

Research and findings from both the Planetary Boundaries framework and the IPCC reports are used as the basis for shaping various climate policies and international negotiations. Among the most significant international environmental and climate agreements are the Paris Agreement (which came into force in 2016) and the Kyoto Protocol (in force from 2005 to 2012 and extended for the period 2013–2020), both of which were adopted under the United Nations Framework Convention on Climate Change (UNFCCC). Since 1995, the member states of the Framework Convention have met annually at the Conference of the Parties (COP).

3.1 United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) is one of three conventions adopted in 1992 at the Earth Summit in Rio de Janeiro, when the international community recognized the need for collective action to protect people and the environment and to limit greenhouse gas emissions. It has been ratified by almost all countries in the world. The UNFCCC came into force on March 21, 1994. Today, it has near-universal membership, with 198 countries that have ratified the convention and are parties to it. The UNFCCC states that its objectives are to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC, 2022). The UNFCCC is the first global treaty on climate change and an organized community of member states. The members meet annually to discuss progress and adopt various measures. The Kyoto Protocol and the more recent Paris Agreement are two landmark treaties that resulted from such annual meetings. Since 1995, the parties to the Framework Convention have gathered at annual conferences (Conference of the Parties – COP), where they assess progress in addressing climate change. These conferences also involve negotiations on the content of international climate agreements aimed at reducing greenhouse gas emissions. According to the agreements, industrialized countries were to be the first in line to reduce emissions. One of the agreements was also that the UNFCCC would provide financial support to developing countries to mitigate the impacts of climate change. In this context, it is worth mentioning that the Global Environment Facility (GEF) oversees the system of grants and loans to direct assistance to emerging economies. Industrialized countries are also required to regularly report

on their climate change policies and provide annual inventories of greenhouse gas emissions from 1990 onwards. Developing countries are required to report on their actions to address climate change and their methods of adaptation. The UNFCCC recognizes, however, that the share of emissions from developing countries is likely to increase. Nevertheless, it strives to assist these countries in curbing emissions without undermining their economies. In the early years of the agreement, the UNFCCC emphasized climate change mitigation over adaptation in order to better understand the actual impacts of climate change with greater certainty. Recently, the UNFCCC has also started supporting and financing adaptation policies to the climate crisis. As stated by the UNFCCC (2022) on its official website, work on adaptation is currently taking place within the framework of various convention bodies. The Adaptation Committee, which the parties agreed to establish in accordance with the UNFCCC's Cancun Adaptation Framework, is an important step towards a cohesive approach to adaptation based on the convention.

3.2 Kyoto Protocol

The Kyoto Protocol was adopted on December 11, 1997. Due to the complex ratification process, it only came into force on February 16, 2005. The Kyoto Protocol was designed to operationalize the United Nations Framework Convention on Climate Change (UNFCCC) by binding industrialized countries and economies in transition to limit and reduce greenhouse gas (GHG) emissions in accordance with agreed individual targets. The convention required these countries to adopt policies and measures to mitigate climate change and to report regularly.

As stated by the UNFCCC (2019a) on its website, the Kyoto Protocol was based on the principles and provisions of the convention and followed a structure based on annexes. It only bound developed countries and imposed a heavier burden on them under the principle of "common but differentiated responsibilities and respective capabilities," acknowledging that they are largely responsible for the high levels of greenhouse gas emissions in the atmosphere. The Kyoto Protocol committed most signatories of Annex I (Annex I countries) to mandatory emission reduction targets, which varied according to the unique circumstances of each country. Other signatories of the UNFCCC and the Protocol, which are mostly developing countries, were not required to limit their emissions. The Protocol provided several options for countries to achieve their targets. One approach was the use of natural processes, known as carbon sinks, which absorb greenhouse gases from the

atmosphere. One example of this was tree planting, which absorbs carbon dioxide from the air. Another approach was the international program called the Clean Development Mechanism (CDM), which encouraged developed countries to invest in technology and infrastructure in less developed countries. The Kyoto Protocol, in this way, unfortunately also opened the door to some unethical practices that were exploited by certain corporations and governments for their own benefit (such as land grabbing from indigenous peoples, deforestation, and the planting of monoculture tree plantations, etc.).

At the 18th Conference of the Parties (COP18) held in 2012 in Doha, Qatar, delegates agreed to extend the Kyoto Protocol until 2020 (UNFCCC, 2019a). Although the Kyoto Protocol represented an important diplomatic achievement, its success was far from being realized. Even if the targets were met, some critics argue that the final environmental benefit would not have been significant, as China, the world's largest emitter of greenhouse gases, and the United States, the second-largest emitter, were not bound by the protocol (China due to its status as a developing country and the United States because it did not ratify the protocol).

3.3 Paris agreement

The Paris Agreement is a legally binding international treaty on climate change and serves as an action plan to limit global warming. With the Paris Agreement, countries reaffirmed their commitment to climate action and agreed on new goals to accelerate efforts to limit global warming. It was adopted by 196 parties at the United Nations Climate Change Conference (COP21) in Paris on December 12, 2015. The Paris Agreement entered into force on November 4, 2016, after the condition was met that at least 55 countries, accounting for at least 55% of global greenhouse gas emissions, ratified it. All EU member states have ratified the agreement.

As stated by the UNFCCC (2023) on its website, the long-term goal of the Paris Agreement and the agreement of governments is to limit the average global temperature increase to well below 2°C compared to pre-industrial levels and to strive to limit the increase to no more than 1.5°C. In recent years, world leaders have emphasized the need to limit global warming to 1.5°C by the end of this century. This is also because the IPCC states that exceeding the 1.5°C threshold poses a risk of much more severe and more impactful consequences of climate change, including more frequent and intense droughts, heatwaves, and precipitation. To limit global

warming to 1.5°C, greenhouse gas emissions must peak no later than 2025 and then be reduced by at least 43% by 2030 (UNFCCC, 2023).

The Paris Agreement is an important political achievement that has defined ambitious yet necessary goals to prevent dangerous climate change. For the first time in history, the Paris Agreement united all nations in the effort to combat climate change and adapt to its impacts, with enhanced support for assisting developing countries.

The IPCC, in its Summary for Policymakers (IPCC, 2023), states that the UNFCCC, the Kyoto Protocol, and the Paris Agreement support increasing levels of ambition by countries. The Paris Agreement, adopted under the UNFCCC with nearly universal participation, has led to the development of policies and the setting of targets at national and subnational levels, particularly regarding climate change mitigation and enhanced transparency of actions and support mechanisms. Numerous regulatory and economic instruments are already successfully in use. In many countries, these policies have improved energy efficiency, reduced deforestation rates, and accelerated the adoption of new technologies. In some cases, this has led to the prevention and reduction, or even the elimination, of emissions. At least 18 UNFCCC member countries have been maintaining reductions in greenhouse gas emissions from production and consumption for over 10 years. Unfortunately, this reduction has only partially offset and slowed global emissions growth (IPCC, 2023).

For a better understanding and a detailed review of climate policies (including policies at the European level and in Slovenia), we recommend reading the publication *Politično-zakonodajno ozadje blaženja podnebnih sprememb* (Political-Legal Background of Climate Change Mitigation), published in 2022 by the Slovenian organization Umanotera.

4 Post-carbon transport - examples of alternatives

One of the goals of the UNFCCC and, of course, the EU, is to reduce the negative impacts of transport on the environment. In December 2020, the European Commission published the *Sustainable and Smart Mobility Strategy – Guiding the European Transport System Towards a Green Future*, presenting a vision to ensure that the EU's transport system achieves a green transformation. This strategy outlines various

milestones for achieving the goals of sustainable, smart, and resilient mobility, in relation to the scope and composition of passenger transport and traffic. The UNFCCC, within the framework of the Marrakech Partnership for Global Climate Action, has also set a vision for transportation in a post-carbon society by 2050. According to UNFCCC (2021), by 2050, both passenger and freight transport are expected to be fully decarbonized through the transition to more sustainable and resilient vehicle technologies. While individual countries will need to define their own pathways to decarbonize the transport sector based on existing or potential regulations, challenges, and policy priorities, these shifts will be made gradually and through a series of milestones. Here, low- or fully zero-emission transportation modes (such as trains, public transport, walking, and cycling) and vehicles (e.g., electric, hydrogen, hybrid, biofuel, or ammonia-powered ships and airplanes) are envisioned. This is expected to lead to the complete decarbonization of all transportation modes by 2050.

Many shipping companies are already exploring alternative fuel sources, such as hydrogen, ammonia, or methanol, but the current costs associated with producing "green" fuels are too high to compete with fossil fuels. Wind is a well-known renewable energy source that could be harnessed by shipping companies–after all, it once powered global maritime trade: "Simply put, in order to meet climate and broader environmental goals, vessels must minimize fuel consumption by using slower and more efficient ships that utilize sails and other renewable technologies on board, with any remaining fuel they need being new zero-emission fuels," said John Maggs, Senior Policy Advisor at the organization Seas At Risk, to UNFCCC (2021a).

4.1 Climate-friendly maritime transport

According to the International Maritime Organization (IMO), international shipping accounts for about 2.2 % of global greenhouse gas emissions. To put it into perspective, if international shipping were a country, it would be the sixth-largest emitter, releasing more CO2 annually than Germany. As Willner (2021) notes, these annual carbon emissions from container ships not only significantly contribute to accelerating climate change (one of the nine scientifically defined planetary boundaries we risk exceeding), but also to ocean acidification (another planetary boundary), which greatly affects biodiversity (the third planetary boundary). All of

this must also be considered in light of chemical pollution (the fourth planetary boundary) coming from ship exhausts.

Today's freight industries are not only plagued by environmental issues but also by complex logistical and economic problems, as highlighted by Willner (2021). Cargo ships that use fossil fuels are generally massive in size, with enormous carrying capacities. However, it is precisely due to these excessive capacities that these ships are unable to adapt to sudden and unexpected changes in the global market. Today, the needs of international cargo ports and specialized markets would be much better served by smaller cargo ships with efficient and fuel-saving consumption, writes Willner (2021). Willner (2021) also emphasizes that the current system of maritime freight transport is becoming increasingly vulnerable due to unpredictable fuel prices, the scarcity of fossil fuels, geopolitical conflicts, wars, instability in the Middle East, Venezuela, and other regions.

When faced with these numerous challenges in the cargo shipping industry, one may wonder: what's next? What should the transition to a new era of shipping, one that is not dependent on fossil fuels, look like, while still preventing significant economic harm? The good news is that change is already underway. Ships powered by wind, solar energy, and hydrogen are offering innovative low-carbon or carbon-free alternatives to fossil fuel-powered cargo vessels. Wind, as the primary source of propulsion, is soon expected to make a comeback in shipping, according to experts. New experimental sail designs include rigid sails, rotating vertical cylinders, and even wind kites.

4.1.1 Fairtransport

From the late 1970s to the early 21st century, the legendary captain Paul Wahlen captained the cargo schooner *Avontuur*. At that time, he was the last captain of a sailing cargo fleet in the Caribbean. In European waters, another sailing cargo operator, the North Sea clipper *Albatros* and its captain Ton Brouwer, were also well-known. These two companies were likely the last in the Northern Hemisphere to rely on wind for shipping. A few years later, everything changed, and sailing cargo vessels made a comeback. Sustainability became mainstream, and shipping by sail began to be promoted online as the ultimate adventure, fulfilling society's desire for a real, authentic experience.

Currently, more than 20 sailing cargo projects are underway, operating from Denmark to the Caribbean (EcoClipper, 2018). The concept has proven to be a successful model even in the 21st century. Two lobby groups have been established: the International Windship Association (IWSA) and the Sail Cargo Alliance (SCA). This can be seen as the emergence of a new economic sector within the domain of maritime freight transport.

In 2006, both *Avontuur* and *Albatros* ceased their cargo operations. Soon after, the newly refurbished sailing ship *Kwai* took over trade between Hawaii and the Cook Islands. Shortly thereafter, another sailing cargo company, *Fairtransport*, was established. Fairtransport operated the vessel *Tres Hombres*, which became widely recognized as the unofficial ambassador of sailing cargo ships. A few years later, the world's oldest cargo ship, *Nordlys*, joined *Tres Hombres* in the fleet. This was followed by the launch of the beautiful ship **Grayhound**, the return of the schooner *Avontuur*, and the conversion of *Luna II* and *Gallant* from passenger ships to cargo vessels. The transportation of goods by sailboats has experienced a resurgence.

As stated on their website (Fairtransport, 2022), the mission of Fairtransport, since its inception in 2027, has been to raise awareness about climate-friendly transport and reducing carbon footprints. With their fleet of sailboats, which operate without engines, they primarily focus on trading ecological and traditional artisan products. They transport goods in a completely sustainable manner, solely using wind energy. In this way, they demonstrate that transport with a nearly zero carbon footprint is possible and environmentally friendly.

In an interview with Sailors for Sustainability (2022), one of the co-founders of Fairtransport, Captain of the ship *Tres Hombres*, Andreas Lackner, states that Fairtransport is the world's largest sailing freight carrier. Their current fleet of seven cargo sailing vessels sails across the Atlantic and the North Sea. Without engines, they rely solely on wind power. Solar panels and wind generators provide energy for their communication and navigation equipment. For emergencies, they also have a generator that runs on recycled cooking oil. Their transoceanic schooner *Tres Hombres* measures 32 meters and has been sailing sustainably, without emissions, since December 2009. It is used for general cargo transport between Europe, the Atlantic and Caribbean islands, and the Americas. Its capacity exceeds 35 tons, and it can accommodate a crew of seven professionals and eight apprentices (training is essential at Fairtransport, as today's sailors need to be taught a combination of

historical and modern sailing skills). In their fleet, they also have the *Nordlys*, a 25-meter ketch - a two-masted schooner, built on the Isle of Wight in 1873 as a fishing vessel. Now, it transports up to 30 tons of cargo between European ports. Additionally, they operate the *De Gallant*, *SV Zeehaen*, *SV Brigantes*, the previously mentioned *Avontuur*, and one of the more well-known vessels, *Hawila. Hawila* is not only used as a cargo ship but also serves as a cultural and educational platform to raise environmental awareness and encourage the global shipping industry to adopt a sustainable, zero-carbon transportation culture (Fairtransport Holding B.V., 2022).

Fairtransport not only transports goods in the most sustainable way, but also follows strict sustainability principles for the goods they carry. They know the producers of the goods they transport and are confident that their operations are fair, respecting both nature and their workers. *"Furthermore, we only transport luxury goods such as coffee, cocoa, and rum. In this way, we meet special needs without harming the environment. Other products are best produced locally, so transport is not necessary,"* explains Captain Andreas (Sailors for Sustainability, 2022).

Even in the late 1940s, enormous steel sailing ships transported cargo along some of the transoceanic routes. Now, cargo ships powered by fossil fuels will have to make way for high- and low-tech sailing vessels by 2030, which will reduce transportation costs and emissions.

4.2 Around the city: cargo bikes and electric car sharing

The vision framework for transportation set by the UNFCCC within the Marrakech Partnership for Global Climate Action (2020) also envisions nearly fully decarbonized cities. In this vision, cities prioritize walking, cycling, and other forms of active mobility - along with existing public transportation and mobility services utilizing apps - representing a significant portion of urban movement. These changes are expected to occur primarily due to significant shifts in demographics, economic activities, travel patterns, behavior, investments, and policies. Such transformations will be possible through the integration of land-use planning with transportation infrastructure planning, which will reduce the distance traveled per capita. The level of car ownership in urban areas will significantly decrease, thanks to a number of regulations such as tolls and parking fees, traffic restriction schemes in cities, investments in high-quality public transport, green public procurement, and other forms of shared mobility services. Urban transportation will be completely emission-

free, with improved load factors and reduced unnecessary trips, as outlined in the UNFCCC vision (2020).

Some cities have already been implementing the vision of post-carbon mobility for quite some time, using solutions that have either emerged from community-driven initiatives or have been developed in response to specific urban needs. Alongside the rapid rise of digital technologies and increasing demand for better urban logistics, there is also growing pressure to improve the overall quality of urban life. As Vasiutina et al. (2021) point out, the bottom-up approach is gaining momentum due to increasing public awareness of the dangers of global warming - particularly the impact of transportation as one of the main contributors to climate change. Given the growing concern among citizens about the quality of life in their neighborhoods- and increasing calls for city authorities to take appropriate action-the question arises of how to introduce new, environmentally friendly business models and strategies. In response to such grassroots initiatives, many cities around the world have implemented urban transport policies aimed at reclaiming public space for pedestrians and non-motorized vehicles. These policies also seek to limit both the speed and access of heavy motor vehicles in city centers. In addition, city authorities have committed to encouraging residents to shift toward more sustainable modes of transportation. For example, incentives for purchasing electric cars and cargo bikes can include financial support as well as tax reductions. Cycling can be further encouraged through improvements in infrastructure and various community initiatives, as noted by Vasiutina et al. (2021).

4.2.1 Cargo bikes

Urban supply chain management is receiving increasing attention. In recent years, new urban mobility initiatives have been developed to enable more efficient delivery of goods, reducing both delivery costs and negative environmental impacts. Cargo bikes have proven to be a highly effective solution for last-mile delivery in urban centers. This delivery method has low investment costs (making it economical), and the vehicles are versatile, able to navigate densely populated areas and narrow streets with ease, while having near-zero environmental impact (making them ecological). By using cargo bikes, it would be possible to halve the volume of freight transported by polluting vehicles in urban centers, thereby reducing emissions and delivery costs.

As noted by Sesana (2023) in his article for the Italian monthly *Altreconomia*, Vienna introduced a cargo bike sharing project as early as 2017. *Grätzlrad*-a German term that can be translated as "neighborhood bike" is the name chosen by the City of Vienna for this innovative bike-sharing initiative aimed at promoting the use and sharing of cargo bikes in urban environments. The operating model and incentives for sharing these bikes are simple: the municipality co-finances the purchase of the bike for a local business, pub, café, or neighborhood association. They then make the cargo bike available for free rental for a minimum period of two years, in addition to using it for their own needs (deliveries, errands). Local residents can borrow the bike for a day or even just a few hours, depending on their needs. Booking a bike is easy and can be arranged in just a few steps via a dedicated online platform. However, Vienna is not the only city to have promoted the expansion and shared use of cargo bikes in recent years, as Sesana (2023) emphasizes. The European Cyclists' Federation (ECF) has mapped the use of cargo bikes in 125 European cities–from Rotterdam to Copenhagen, and from Salzburg to Brussels–and has compiled the findings on a dedicated website called *"Cargo-bike friendly cities."* On this interactive platform, users can explore data for each city based on seven different indicators, including purchase incentives, sharing system models, urban context, and bike manufacturers (Sesana, 2023).

A cargo bike is a bicycle designed specifically for transporting various types of loads, such as goods or passengers, and was originally developed for this purpose almost a century ago. The first cargo bikes were commonly used for delivering mail, bread, and milk. As noted by Vasiutina et al. (2021), cargo bikes are named based on their design, number of wheels, or intended use. They may be called cargo bikes, transport or "box" bikes, carrier bikes, tricycles and quadricycles, cycle trucks, long johns, and others. Modern cargo bikes are usually equipped with electric assistance. The models vary widely – from simple two-wheel bikes with boxes mounted in the front or back, to more advanced *longtails* and extended bikes capable of carrying weights between 50 and 100 kg. The most advanced multi-wheel bikes or light electric vehicles can even transport loads ranging from 500 to 700 kg.

Recent studies confirm the enormous potential of cargo bikes as a sustainable alternative to traditional delivery vehicles, according to Vasiutina et al. (2021). At the same time, people's willingness to shift to more environmentally friendly means of transportation–especially for last-mile delivery–can be observed in just over 60% of the studies reviewed. Nearly 50% of scientific sources advocate for the adoption of

cargo bikes. According to the findings of the *CycleLogistics* project, almost half of all urban freight transport in the EU could be carried out using cargo bikes (Vasiutina et al., 2021). Of course, financial incentives and other initiatives to promote the use of cargo bikes in cities are not enough on their own. There also needs to be sufficiently wide bike lanes–between two to four meters in each direction–so that those riding cargo bikes can do so safely and without obstructing other road users, says Anna-Karina Reibold from the European Cyclists' Federation (Sesana, 2023).

"Cargo bikes have great potential to transform our cities by reducing motor vehicle traffic, congestion, noise, and air pollution. Local authorities can help unlock this potential by providing policies and infrastructure, incentives, services, and other forms of support," said Jill Warren, Executive Director of ECF, to Altereconomia newspaper (Sesana, 2023).

4.2.2 Electric car sharing in cities and SPARK

The challenges related to mobility and transportation in urban areas have become one of the priority areas for policies aimed at improving the quality of life for citizens. Inefficient traffic system organization and distorted mobility development reveal a scenario that is becoming increasingly critical day by day. We are witnessing numerous traffic jams, air pollution, noise pollution, high energy consumption, traffic accidents, overcrowding of public spaces with cars, uneven distribution, and rising costs (fuel, parking fees), etc. All of this contributes to the fact that our cities no longer offer a high quality of living. One of the alternative methods that is undoubtedly interesting and already in use is carsharing. *Carsharing* complements public transportation and often involves walking or cycling as well. It is one of the most prominent examples of the sharing economy and a modern, sustainable form of mobility. Significant progress in sustainable development policies and the shift towards electromobility has led to increased interest in the use of electric vehicles among carsharing providers.

As Turoń and others (2019) mention in their study on electric vehicles in carsharing systems, the basic idea of carsharing is to limit the number of vehicles in cities and reduce people's need for car ownership. Carsharing systems include services based on the principle of short-term vehicle rental. Initially, carsharing systems were based on the option of renting a vehicle and returning it to the same location (the return system). Later, the possibility of returning the cars at different locations designated by the service provider was introduced. Finally, the possibility of so-called free-

floating rentals was implemented, allowing users to pick up and drop off cars anywhere within the operational area of a specific carsharing provider. Currently, the most commonly used carsharing model is this type of rental system. Users can take a car from where it is parked (anywhere) and park it anywhere in the city at their final destination. The first carsharing system was established in the market in 1948. However, the main development of carsharing systems began after 2006. In 2008, European automotive giants like Daimler and BMW created carsharing services. Due to the growing demand for these systems, by 2009, there were already 14 operators offering carsharing services (Turoń et al., 2019).

One such operator is the company and platform SPARK, which is an example of good practice in the carsharing of electric vehicles in the cities of Vilnius (Lithuania) and Sofia (Bulgaria). This system provides affordable, environmentally friendly mobility solutions through the use of free-floating carsharing models. The use of cars is tied to a mobile app, through which users can find and reserve a car they wish to use. With the app, users can view the route to the selected vehicle, reserve it, unlock and lock the car, and also receive a bill for use. Each ride is charged by the minute or per day, with costs including insurance, technical maintenance, and charging. Charging is free at one of SPARK's charging stations, or users can charge the vehicle at home (a cable is provided). Parking is also free in any paid parking zones in Vilnius and Sofia. SPARK has a network of 85 charging stations in Vilnius and a total of 88 electric vehicles in Vilnius and 63 in Sofia. To date, the SPARK service has been used approximately 225,000 times in both Vilnius and Sofia, covering 2,000,000 kilometers, which has helped save 400 tons of CO2 emissions, according to Kaveckis (2018).

Kaveckis (2018) also emphasizes that car-sharing of electric vehicles reduces traffic congestion, lack of parking spaces, pollution, and noise levels in urban areas, which are major issues for any modern city. This contributes to sustainable mobility plans in cities and should encourage municipalities to develop networks of charging stations. Additionally, it highlights the importance of promoting the greater use of electric vehicles, which represent the future of the automotive industry.

5 Conclusion

A large part of human history has been dedicated to improving ways and abilities to move, with inventions followed by improvements and new innovations. Testing and innovating versions of bicycles, sails, and engines has led to significant progress in transportation. However, to rapidly adapt transportation systems to the upcoming energy challenges, more than just adjusting existing systems will be needed. New revolutions in transportation will be necessary to make the use of fossil fuels irrelevant. Part of this is figuring out how we can change things like current cars and trucks, which significantly contribute to atmospheric warming and, consequently, climate change. To achieve resilience to the already evident impacts of climate change and prevent the worsening of negative effects, we must radically reduce emissions across the entire global economy and protect and restore the natural ability to absorb emissions that are already in the atmosphere. For a successful post-carbon green transition, we will need a new revolution in transportation, as well as an understanding of the dynamics of this revolution, or the fundamental change in transport and mobility in general. This fundamental change in the given situation would mean a significant reduction (or increase) in traffic activity, and a new mode of transportation would become so widespread that at least one-tenth of the population would use it. The changes will need to be far-reaching and bold enough to break established organizational structures and user expectations.

Although humans are responsible for the climate crisis, it's important to remember that human ingenuity can also be a source of positive change, which is a source of optimism. Furthermore, we already have many tools and innovations at our disposal to build a better and brighter future–from the potential creation of alternatives to air travel and greater investments in public transportation, to the transition to electric vehicles and cleaner modes of long-distance travel. However, as the latest IPCC report clearly states, we no longer have time–now is the moment to act.

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