Sustainable Leibniz -

Transforming research practices towards environmental sustainability

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On behalf of the Working Group Sustainability of the Leibniz PhD and PostDoc Networks

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Executive summary

The rapid progression of the human-made environmental crisis is undoubtedly the major global challenge of our time. Its consequences, such as harsh weather extremes and the loss of biodiversity and ecosystems, increase social injustice, affect water and food security, and ultimately pose dangers to human health. Therefore, mitigation measures are of utmost importance. The Intergovernmental Panel on Climate Change (IPCC) indicates a very short time frame for action. To limit global warming to 1.5°C (or at most 2°C) above pre-industrial temperatures, all sectors of society, industry, and politics must be transformed to reduce their environmental footprint, which measures process-associated pollution in terms of greenhouse gas (GHG) emissions.

The Leibniz Association and its 97 research institutes and museums cover a large diversity of research topics. These institutes perform highly important and valuable research on the sustainable transformation of our society by studying the consequences of climate change and tipping points, as well as by developing technologies that reduce or reabsorb GHGs. While the Leibniz Association and its institutes can be seen as unique players in terms of offering solutions for mitigating the biodiversity and climate crisis through scientific discoveries, their research in itself is also energy- and resource-intensive and thereby contributes to the environmental crisis. Daily routine operations, such as the use of single-use plastics or high-throughput computing, as well as frequent travel to conferences, all contribute to a significantly higher environmental footprint of researchers compared to workers in other professions. Therefore, the Leibniz Association, together with the Leopoldina, the National Alliance of Research Organisations and the Academy of Sciences, have declared the target to become climate neutral by 2035. With this, they acknowledge their responsibility to mitigate the environmental impacts of their research operations, and have called upon federal and regional governments to improve the regulatory framework and financial means to achieve it. While accepting their role model function, the Leibniz Association must now clearly define what climate neutrality means and how it can be achieved. In this position paper, we, the Working Group Sustainability of the Leibniz PhD and PostDoc Networks, want to offer recommendations on how to rapidly transform the Leibniz Association and its institutes towards sustainability. Therein, we have identified immediate (until 2025) and long-term (until 2035) goals and measures that must be put into action now.

The vague definition of climate neutrality highlights one of the major hurdles of sustainable research: the lack of available data on the environmental footprints of research operations. Therefore, the Leibniz Association and its institutes must first assess their environmental footprints and associated GHG profiles in terms of energy, water, and all other resource consumption (direct and indirect; scopes 1-3, see Box 1) on a regular basis. Based on institute-specific profiles, the largest contributing sectors should be identified, and strategies should be developed to reduce the associated emissions as quickly as possible. As Leibniz institutions exhibit diverse research foci, their environmental footprints will also vary greatly. Here, we describe specific measures in the main common sectors of Energy & building infrastructure, Resource management (Water, Procurement & Waste), Research & administration, Mobility, Event management and Knowledge transfer that will contribute to transforming research processes inside the Leibniz Association towards environmental sustainability (Figure 1, see also List of actions).

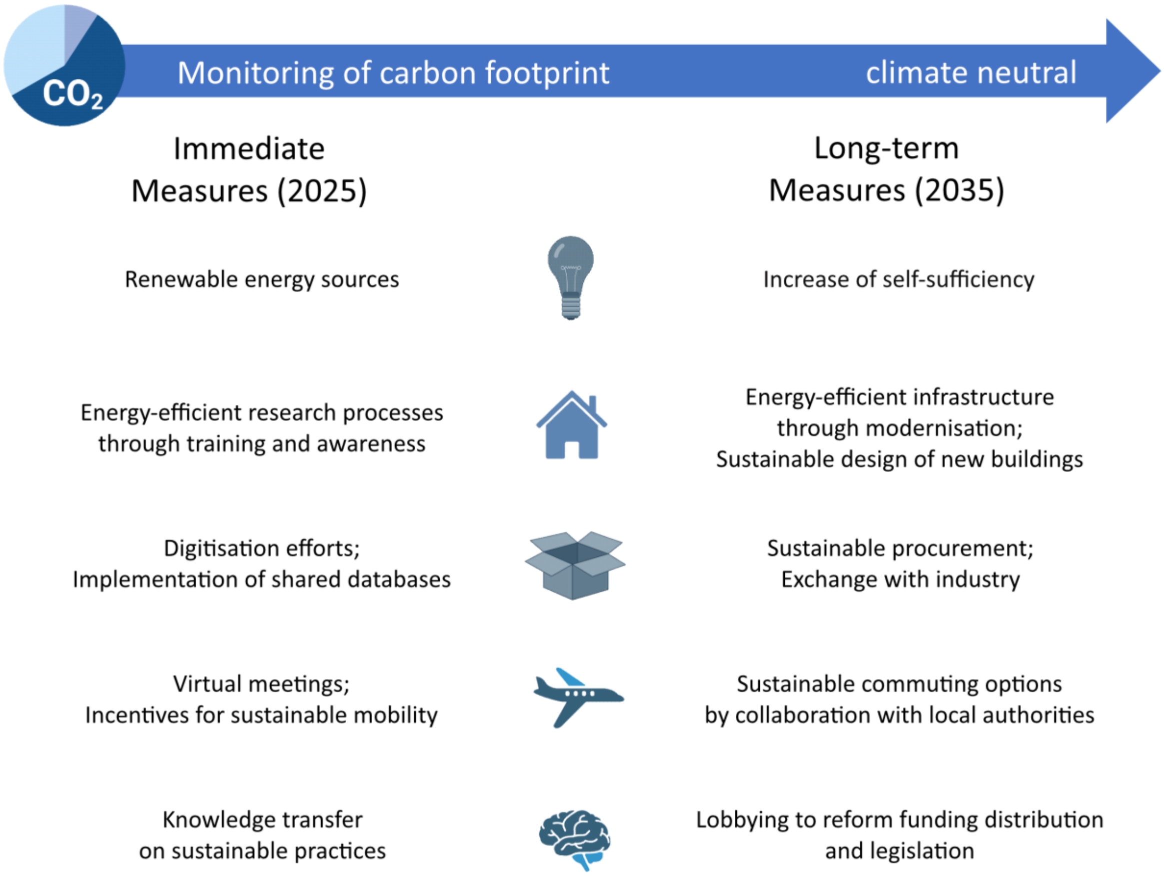

Figure 1.
An overview of immediate and long-term measures to be implemented at Leibniz institutes to reduce their research-associated carbon footprint. Icons were created using BioRender.com.

We see tremendous potential in establishing **immediate measures** at Leibniz institutes, which require no or only limited resources and can lead to a significant immediate reduction in environmental impacts:

1. Switch to **renewable sources of energy and heat** (purchasing contracts).
2. Change the status quo in **resource management:** Institutes can implement inventories, shared databases, centralised procurement, and promote digitisation processes. Institutes can achieve significant reductions in energy consumption by **raising awareness and training staff** in sustainable research operations.
3. Promote and incentivise the attendance of **virtual meetings** and support **sustainable event management** for in-person events.
4. Promote **sustainable mobility** by supporting public transport and biking infrastructure, and incentivising travel by train instead of flying.
5. **Preserve biodiversity** on campus by greening institutes and optimising illumination.

Apart from immediate actions, the Leibniz Association and its institutes must invest in the long-term transformation of infrastructure. This will require allocating both financial and personnel means, and must be preceded by lobbying with funding bodies to include sustainable criteria in selection processes to reward sustainable practices with additional funds. We consider the following **long-term measures** to be imperative to achieve climate neutrality by 2035:

1. Leibniz institutes should aim to increase self-sufficiency with **on-site renewable energy and heat production**.
2. Infrastructure should be transformed by **refurbishing and investing in energy-efficient technology,** and new construction must be designed according to sustainable standards.
3. Many sustainable transformations of the academic system are hindered by legal frameworks. Therefore, the Leibniz Association must lobby policymakers to change the corresponding laws.
    a. Make **sustainable procurement** the default by adding sustainability criteria when considering vendors and products.
    b. Facilitate **infrastructure transformation** by removing bureaucratic hurdles when installing renewable energy and heat sources.
    c. Collaborate with local authorities to improve **employee mobility**.

To establish a *culture of sustainability* in the Leibniz Association, we need an urgent and swift systemic transformation as well as awareness and support from all its employees. To meet self-set goals, the Leibniz Association must prioritise climate action in operations and research processes now, and not solely as a research topic.

Chapter 1. Introduction

1. The state of our environmental emergency

The scale and rate of the progression of the climate crisis are unprecedented, and the influence of humankind, largely owing to the release of polluting gases from burning fossil fuels (coal, oil, and gas), is the main cause and driver. We already experience a global average temperature increase of 1.1°C (in Germany, even 2°C) compared to the pre-industrial period caused by human activities. Resulting environmental changes are already catastrophic today; ecologists are recording an incomparable loss in biodiversity that also puts agricultural production in many parts of the world in danger. Furthermore, because of rising temperatures, the number of natural disasters has nearly doubled in the past 20 years, and repeated droughts have caused drastic shortages in food and freshwater due to soil degradation and erosion. The loss of food and water security in many areas primarily affects the poor and vulnerable, and worsens global economic inequality. As competition for land, food, and water feeds socioeconomic tension and political unrest, global warming poses an immediate threat to international peace. In addition to growing social inequality, rising sea levels threaten to displace millions of people living along coastlines. Such impacts are already occurring today, as 32 million people (one-third of the population) were displaced by floods in Pakistan in September 2022, while the rest of the continent suffered from extreme heat waves. Moreover, the effects of climate change manifest ubiquitously and are not restricted to specific continents. For instance, extreme rainfall events in the Ahr Valley in Germany and other Western European regions in the summer of 2021 resulted in floods with a death toll of over 200 people as well as immense damage to homes, farmlands, and infrastructure. Hence, climate change is a risk multiplier that worsens existing challenges and ultimately drives a global humanitarian crisis. Therefore, we are in an undeniable and unprecedented state of a climate emergency, one which might even lead to "*worldwide societal collapse or even eventual human extinction*."

To mitigate the climate emergency, world leaders have acknowledged that this issue requires international cooperation and coordinated solutions at all levels. As a reaction, they constituted a global framework to limit global warming below 2°C, while pursuing efforts to limit the temperature increase to 1.5°C, known as the Paris Agreement. A total of 195 parties, including the European Union (EU), signed this legally binding international treaty in 2015, committing to reducing their environmental footprint and aiding other countries in adapting to the impacts of the climate crisis. However, according to the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC), providing peer-reviewed reports about the science related to climate change and its consequences, global warming exceeding 1.5°C by 2040 is already unpreventable in all scenarios, and temperatures will likely rise above 3°C by 2100 if there is no immediate societal transformation.

In line with this, the 2019 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assessment report stressed that goals for biodiversity conservation might not be achieved without fundamental and transformative changes across all dimensions of society.

As there are clear warning signals for the future, strategies for ecosystem conservation, implementation of social justice, and economic equality must be developed and adopted to advance on the path of global sustainability, meaning the preservation of life on Earth.

Such urgency for action has been recognised by the United Nations General Assembly, which formulated 17 Sustainable Development Goals (SDGs) in their 2030 Agenda for Sustainable Development. These SDGs provide a *shared blueprint for peace and prosperity for people and the planet, both now and in the future*, by integrating and balancing the three dimensions of sustainability: economic, social, and environmental. As the progression of the environmental crisis will also affect our capacity to tackle and accomplish the social and economic SDGs, the immediate reduction of the environmental impacts of our actions is of utmost urgency. The immediate focus on environmental impacts will in turn help mitigate societal and economic transformation in the long run due to their interconnectivity and is the start of an integrated, holistic approach to navigating a sustainable future.

Environmental impacts are often expressed as carbon footprints that take greenhouse gas (GHG) emissions from processes and/or manufacturing of products into account, even though there are other important environmental impacts unrelated to GHG emissions (e.g., habitat loss, other types of pollution, over-hunting/fishing, etc.). GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases that cause the greenhouse effect and are major drivers of global climate warming. Because of irreversible tipping points and feedback mechanisms, global warming is self-amplifying, which means that the amount of GHGs must be significantly and immediately reduced.

The ultimate goal of environmental sustainability is to achieve climate neutrality, which means a reduction of GHG emissions to zero or even negative values over all three scopes (see Box 1). However, as some processes inevitably emit GHGs, they must be compensated by **carbon offsetting**. However, carbon compensation has several problems (see Box 2). Consequently, as long as compensation does not reflect the actual subsequent costs of damages and environmental impacts cannot be directly offset, the priority should always be to avoid and reduce, while carbon offsetting should be a last resort measure.

Box 1. GHG emissions of an organisation

The GHG emissions of an organisation are categorised into three scopes: scope 1 describes direct emissions from owned sources (e.g. fuel combustion of boilers, furnaces or company vehicles), while scope 2 covers indirect emissions associated with the generation of the purchased electricity (e.g., needed for instruments, heating, and cooling). The most challenging emissions to calculate are included in scope 3, which measures all other indirect emissions associated with employee mobility (commuting and business travel) and resource management (purchased goods and services: energy and water use in supply chains, mining or farming of raw materials, transport emissions, waste disposal, etc.).

Box 2. Carbon offsetting

Carbon offsetting is based on financing climate protection projects in order to compensate for GHG emitting practices. It is based on the principle that GHG emissions contribute to the climate crisis regardless of their origin and can be offset by savings in distant places. Thus, offsetting projects are often focussed on climate action in the global South. This can in turn lead to several ethical and societal issues. Therefore, offsetting should be performed by non-profit organisations (e.g. atmosfair) that support integer projects (certified by Gold Standard CER, VER, CDM, VCS, PlanVivo or MoorFutures), so that greenwashing and green colonialism can be prevented (e.g., building infrastructure in autocratic countries that might strengthen their regimes). Furthermore, projects that negate GHG emissions in Europe (at the source of our emissions) should be preferred as funded by, for example, ForTomorrow, which plants trees in Germany and buys emission certificates from the EU economic market so that companies and power plants have to emit less, or Climeworks which directly captures CO_2 from the air and stores it underground.

In addition to the ethical concerns, carbon offsetting is a theoretical calculation that currently costs 5-28€ per tonne CO_2 emitted. However, the German Environmental Agency (*Umweltbundesamt*) estimates long-term damages up to 680€ per tonne in terms of weather extremes, droughts and infrastructural casualties for future generations. Consequently, as long as GHG emissions cannot directly be offset and compensation strategies do not reflect the actual cost of environmental damages, carbon offsetting should be seen as a last resort measure. Instead, the guiding principle should be to avoid and reduce emissions through other means in the first place.

2. Environmental impacts of academia

Academic research is highly important in the context of the climate crisis as it contributes to further understanding the consequences of climate change and tipping points, as well as aiding in its mitigation by developing adaptation strategies and technologies that can reduce or remove GHGs. Furthermore, academic institutions also carry a special societal responsibility to raise awareness and educate, as well as advise policymakers to allow them to base their decisions on scientific evidence. On the other hand, research organisations must acknowledge their own contributions to the environmental crisis, including global warming. In fact, the majority of higher education facilities carry a large carbon footprint, mostly due to complex infrastructural and high-energy requirements. Most universities and research facilities face difficulties in financing the expensive upgrades that are required to become climate neutral. Conflicting priorities between different stakeholders, accompanied by a multiplicity of decision-making bodies, can make a collective change towards sustainable practices challenging.

Despite all these challenges, examples of sustainable developments inside higher education facilities in Germany already exist: The Leuphana University of Lüneburg became self-sustaining in terms of renewable energy in 2014 and has achieved climate neutrality for heat, electricity, cars and business trips. Several other research facilities are following by declaring that they will become climate neutral by or before 2030, for example, Free University of Berlin (2025), Kiel University (2030), University of Hamburg (2030), Leibniz University Hannover (2031), or setting ambitious resource reduction goals like the EMBL. However, most players in the academic landscape who estimate their carbon emissions and are committed to achieving climate neutrality focus mostly on on-campus emissions (scopes 1 and 2, see Box 1) or include only a few aspects of scope 3 emissions (indirect emissions unrelated to electricity). Nevertheless, complete carbon footprint calculations of the University of Copenhagen have shown that scope 3 contributions (mobility, consumables, building infrastructure, etc.) can account for up to 90% of a university's carbon emissions.

The Leibniz Association is one of the largest non-university research networks in Germany, with 97 institutes and approximately 20,500 employees, which unites a wide range of academic disciplines. **Therefore, the role and potential of the Leibniz Association in mitigation and adaptation to the climate crisis is tremendous.** The Leibniz Association already aims to bundle the skills of its institutions in the environmental, social, life, spatial, and economic sciences to contribute to our understanding of the environmental crisis and to aid sustainable development through diverse research networks such as Biodiversity, Environmental Crisis, Green Nutrition, Integrated Earth System Research, Knowledge for Sustainable Development and Mobility. Additionally, the sustainable management of its research operations itself has been one of the guiding principles of the Leibniz Association. The Leibniz Association contributed to the LeNa project (Guide to sustainability management in non-university research organisations), which laid the foundation for sustainable development for non-university research organisations. In 2019, the General Assembly adopted a sustainability mission statement that provided a sustainability framework for different action areas, such as strategic development, research practice, personnel management, and infrastructure. Furthermore, the Alliance of Science Organisations in Germany, the Leopoldina, which includes the Leibniz Association, published a pledge to achieve climate neutrality by 2035 in order to meet the 1.5 °C threshold of the Paris Agreement in 2021. Finally, the Executive Board established a Steering Group on Sustainability in 2022, which is mandated to develop strategies and concepts for the whole Association by standardising measures, distributing funding, and supervising pilot projects. While these are meaningful and necessary steps towards climate neutrality, the urgency of the climate and environmental crisis necessitates more resolute and immediate measures to be implemented at all institutes, as we will elaborate in the following.

3. Positioning of the Working Group Sustainability

We, the Working Group Sustainability of the Leibniz PhD and PostDoc Networks, aim to develop strategies to promote sustainable actions within the Leibniz Association, its institutes and beyond.

We believe that, as scientists, we have a social responsibility to acknowledge the environmental crisis as the most crucial threat to the future of biodiversity and humankind and want to actively shape the transformation of the Leibniz Association towards sustainability. We believe that the foundation for sustainable development of the Leibniz Association is laid by means of the LeNa project, the implementation of exchange groups on sustainability (e.g., Steering Group Sustainability and Working Group Sustainability Management), and the set goal of climate neutrality by 2035. However, concrete actions for the whole Association or strategies for individual Leibniz institutes to implement sustainable restructuring are still lacking. We view such changes as imperative and believe that they must involve all individuals in our (research) community. We are committed not only to knowledge production about environmental and climate issues but also to the implementation of this knowledge and consequent measures towards fair and environmental practices in research. We hope that our following statement can open a dialogue between early career researchers and Leibniz administrations in order to evolve our research and lifestyles towards a more sustainable future.

The focus of this position paper is on environmental sustainability because we feel that environmental impacts are too often only considered in terms of economic and societal impacts. The impacts on biodiversity, and on Earth in general, are rarely decoupled from our needs as Humans, even though we bear an ethical responsibility to address all the damages we are causing. Nevertheless, our demands and recommendations carefully consider the interactions between the different pillars of sustainability, and some of them directly relate to social and economic sustainability, as changes in environmental sustainability are often only possible with social and economic transformation.

This position paper echoes similar employee-based bottom-up initiatives within other non-university research organisations in Germany, such as the Max Planck Sustainability Network, the Helmholtz Climate Initiative, and the Fraunhofer Sustainability Network. We, too, want to join these initiatives in the transformation of the academic system towards sustainable research. This transformation should not be shouldered by one organisation alone, but rather be supported by a constant exchange between all players inside our research community, including researchers, administration, funding bodies, industry, and politics.

4. Goals and demands

As the Leibniz Association is committed to form a "*culture of sustainability*," sustainable development has to be achieved at both the Association and the institute level. Special responsibility falls on the Leibniz headquarters to coordinate or develop a general agenda for sustainable change, while individual strategies or concepts must be adapted by the institutes according to their specificities and needs.

Therefore, we call upon the headquarters and the individual institutes of the Leibniz Association (hereafter "the institutes") to respond to the following demands:

1. **The headquarters and the institutes must acknowledge the environmental and climate *crisis* and commit themselves to climate neutrality by 2035, as declared by the Alliance of Science Organisations in Germany.** We believe that the declaration of the current crisis is not just rhetoric but also provides the basis for a subsequent action plan. Therefore, we call for an official acknowledgement of the crisis by the Leibniz Association and its member institutes, including a self-obligation to act. We welcome the declaration of climate neutrality by 2035 as a crucial step towards climate action within the Leibniz Association. However, we regard the declaration as a non-binding pledge whose realisation depends on other stakeholders in the academic system (through financial and legal aid). While we recognise that the Leibniz Association might not be able to fully **commit** to achieving the goal of climate neutrality by 2035, they must **commit** to doing everything in their power to get as close as possible to this goal. They can then act as role models, which might, in turn, start a snowball effect that will propagate through society.
2. **The headquarters and the institutes must provide a definition of climate neutrality.** We believe that it is impossible to set up a concrete action plan without establishing a clear definition of "climate neutrality", which in the ideal sense, would mean zero net GHG emissions for the whole Association. Zero net GHG emissions could be achieved in scopes 1-2 (as seen for other universities); however, the

emissions of all three scopes for all institutes cannot be reduced to zero, but will rather rely on carbon offsetting. Therefore, the rhetoric "climate neutrality' has to be reformulated into clear emission reduction targets (see Demand 4), or compensation strategies have to be put into place. This is the first step in transforming rhetoric into action.

3. **Each institute must assess the environmental impact of all activities carried out, including both research and non-research activities.** We are convinced that setting adequate sustainability targets is possible only with an accurate evaluation of the current environmental impact. Such an assessment should be based on internationally recognised life-cycle-based approaches, as described in the Greenhouse Gas Protocol (for example, the Global Reporting Initiative, Exiobase for procurement, EMAS Audit Scheme, *and Umweltbundesamt*). This will require the allocation of both financial and personnel resources, and is most preferably performed by a credible and independent external agency to ensure neutrality and prevent greenwashing. Based on their GHG profile, every Leibniz institute can prioritise actions on their most impactful sectors, set reduction targets, implement measures, and monitor progress on an annual basis (e.g., against 2018/2019 as a baseline; see Demand 4). The Leibniz Association should then publish a full report of the whole organisation and publicly disclose their yearly emissions (for example, CDP disclosure or a separate tab on their homepage). As the contributions of different sectors to the individual institute's carbon footprints are expected to differ widely (e.g., field researchers are frequent flyers, while laboratory-based scientists use many consumables), annual reports of scope 1-3 emissions will help to identify Leibniz institutes with common challenges (e.g., according to research focus or Leibniz section). If such challenges are transparently communicated, this will offer opportunities for institutes to collaborate and adapt their sustainability strategies, which have to be translated into common goals and specific quantitative reduction targets. Headquarters must provide assessment guidelines to individual institutes such that their results can be aggregated and disseminated at the Association level.
4. Based on the impact assessment, **each institute must develop precise sustainability targets as well as immediate and future action plans**. Climate crisis mitigation policies worldwide have focused far too long on appeasement and little on concrete actions. As a result, many sustainability measures, such as energy use, infrastructure, and purchasing, rely on the voluntary actions of organisations as well as individuals. We maintain that the scientific community must act as a role model and provide concrete and drastic climate mitigation measures from which politicians and society can learn. The targets and action plans of the institutes must be detailed, measurable, and tailored to each institute's circumstances. The impact of the measures must be transparently and systematically analysed and shared with all relevant parties (e.g. Sustainability goals in Sustainability report of the ETHZurich). We must lead by example by taking solid and immediate actions, and "no more empty promises." Commitment to collectively binding reduction goals is the only way in which the Leibniz Association can achieve the goal of climate neutrality by 2035.

5. **The headquarters must make a case for incorporating sustainability measures into the evaluation criteria of the Association.** All actions taken by the Leibniz Association and the individual institutes need to be evaluated for their compliance with climate crisis mitigation measures (see Demand 4), and if not, they need to be adapted accordingly. Currently, the basic principles of the Leibniz Association Senate Evaluation Procedure do not consistently address sustainability and environmental concerns. The Leibniz Senate must include sustainability in the evaluation criteria so that the five major evaluation items (i.e., overall concept tasks, controlling and quality management, cooperation and environment, human resources, and subdivisions) can be assessed accordingly. Consequently, the Senate statement on the Leibniz institutions must evaluate the activities and accomplishments of each member institution through the lens of sustainability. In addition, the Senate must ensure that there is at least one sustainability expert in the evaluation commission.
6. **The headquarters and the institutes must establish sustainability offices to manage and coordinate climate actions.** Human and financial resources need to be allocated to establish sustainability offices at the individual institutes that coordinate activities adapted to local conditions. The sustainability office at the headquarters is encouraged to act as a facilitator and coordinator of collective action among the institutes. The headquarters and individual institutes must support sustainability projects and their dissemination so that they can inspire others. A reward system (e.g., in the form of additional funding from the Leibniz Association to institutes) could be implemented to provide incentives for the institutes to commit to more sustainable actions. Measures that should be implemented at the institutes are described in the following chapters.
7. **The headquarters and the institutes must establish a participatory decision-making process in the sustainability offices** and engage diverse stakeholders, including directors, senior and junior scientists, and administrative staff in the process. This allows for the inclusion of bottom-up initiatives and participatory decision-making, and facilitates communication throughout the Leibniz Association. As highlighted in the 2030 Agenda for Sustainable Development, participation is an integral part of sustainability, as it affects all members of society and requires the engagement of all, and this applies to research organisations like the Leibniz Association as well. Calls for suggestions from the scientific community within the Leibniz Association can raise awareness throughout the institutes and collect innovative ideas.
8. **The headquarters and the institutes must lobby for sustainable measures in science policy and actively engage with politicians and citizens to improve awareness of the current crisis and the need for urgent actions.** Achieving sustainability at the institute and Association level necessitates shifts in policy and regulations that shape how the institutes and Association work. For instance, changes in how we travel for business or how we purchase research equipment are bound to policy and legislation, such as the Federal Travel Expenses Act, Public Procurement Law, or research funding policy of ministries and research foundations (for details,

see Chapter 3 – Section 1. Procurement and Chapter 4 – Section 1. Mobility). As one of the largest research associations in Germany, the Leibniz Association can use its assets and networks to reach policymakers and the broader public, and communicate its activities. Furthermore, establishing and strengthening the alliance between the four German non-university research institutions (Max Planck Society, Helmholtz Association, Fraunhofer Society, and Leibniz Association) will improve the visibility and impact of scientific positions in policymaking.

In the following chapters of this position paper, we describe specific fields of action in the main sectors of Energy & building infrastructures, Resource management (Water, Procurement & Waste), Research & administration, Mobility, Event management and Knowledge transfer that will contribute to transforming research processes within the Leibniz Association towards environmental sustainability (see also List of actions).

While we are aware that the implementation of some actions requires long-term planning, we stress that **climate mitigation must begin now**. Accordingly, the measures we propose hereafter for each sector are classified into two categories:

- **Immediate measures** can be implemented almost immediately, and should be implemented **latest by 2025**. They require no or limited resources at the individual institute level and/or the Leibniz Association level.
- **Long-term measures** require fundamental and/or resource-intensive changes at the individual institute level and/or the Leibniz Association level. They also require policy and legislative changes. Therefore, their implementation requires more time. Nevertheless, they should be implemented **before 2035** because, in our opinion, they are necessary for the climate neutrality of the Leibniz Association.

Chapter 2. Energy & building infrastructure

1. Energy infrastructure

Both the production and consumption of energy are responsible for more than 75% of the EU's greenhouse gas emissions. Therefore, the sources of energy production and its consumption play fundamental roles in tackling the climate crisis and are part of the SDG 7 "Affordable and Clean Energy." Similarly, the energy consumption at research institutes represents a large share of their environmental footprint caused by electric appliances, illumination, air-conditioning, and heating. Therefore, reflecting on both energy sources and energy demand, in general, should be major goals of the Leibniz Association and its institutes.

1.1. Energy sources

According to the 2018 IPCC Special Report (SR15), energy production must drastically shift away from fossil fuels towards renewable sources of energy to achieve the 1.5°C goal of the Paris Agreement. The Leibniz Association is at the forefront of energy research, and has pooled its expertise in the research alliance on energy transitions. While the scientific background for energy transition is laid down by the Leibniz research alliance itself, its principles must be extended to all institutes. Therefore, we urge the Leibniz Association and its institutes to follow their own science and recommendations by transitioning their energy supply exclusively to renewable energy sources.

Off-site renewable energy purchase contracts
All Leibniz institutes should switch to sustainable energy providers that invest in renewable energy projects and have no shareholding in fossil fuel-based power plants (e.g., certified by *Grüner Strom/Gas* label). In terms of gas, partners that generate biomethane from crops that do not compete with food or feed production through anaerobic digestion should be supported, especially if biogenic CO_2 generated during the process is captured, compressed, and stored in locations that do not hamper biodiversity (BECCS). Furthermore, regional sustainable providers of energy and gas should be preferred to develop efficient and smartly managed regional energy grids **(immediate 2025)**.

On-site renewable energy infrastructure
Becoming energetically self-sustainable by building, for example, photovoltaic solar panels on roofs or facades (for example, ZALF since 2020, IZW or ZEW), geothermal energy generators, or even wind turbines (if possible) on campus, should be the guiding principles of Leibniz institutes. Furthermore, external partners could invest in or own renewable power plants installed on institute grounds through subsidies, and Leibniz institutes could lease power from the corresponding plants. As the installation of

photovoltaic power plants on buildings can be complicated by state-specific legislation, such as regulations on the supply to the energy grid, it is imperative that the successful design of power plants on Leibniz infrastructure is highlighted, and such strategies are shared among institutes. In cases where the installation of renewable power plants is hindered by legislation, the Leibniz Association must address policymakers and lobby for changes in the corresponding laws/regulations **(long-term 2035)**.

1.2. Energy consumption

Many studies suggest that the energy transition to renewable sources has to be accompanied by minimising energy demand by reducing consumption to meet the 1.5°C climate targets. Leibniz institutes should therefore monitor their energy consumption over time, so that reduction targets can be set **(immediate 2025)**. Energy audits to identify the largest energy consumers in institutes, buildings, and departments should be performed (e.g., as already done by the DPZ, ZEW, and FMP); based on these results, sustainable strategies for improvement and/or refurbishment (insulation, illumination, heating, etc.) should be established. Ideally, every Leibniz institute should appoint an energy officer or manager or consult external experts. The energy consumption of each building/institute should be assessed on an annual or bi-annual basis and published in Open Access (e.g., CDP or annual report of the Leibniz Association; see Demand 3 in Chapter 1 – Section 4. Goals and demands).

1.3. Energy-efficient buildings

A reduction in energy demand can be achieved by optimising building infrastructure, such as illumination, ventilation, heating, and air-conditioning toward energy-efficiency.

1.3.1. Illumination

Illumination in research buildings can be responsible for 8-25% of the total energy cost and GHG emissions associated with energy. Therefore, it is imperative for Leibniz institutes to install intelligent illumination systems. The energy demand for illumination can be mitigated by **immediate action (2025)** (see Section 2. Building infrastructure) adopting:

- **LED lamps and daylight illumination** (e.g., DZNE Bonn)
- **Smart shading**
- **Motion sensors**
- **Automatic (but user-reversible) shutdowns**
  after common working hours/on weekends
- **Awareness campaigns**
  to shut off lights in rarely used rooms and in the evening

1.3.2. Heating

The energy consumption associated with heating and air-conditioning can make up 16% of an academic institution's environmental footprint. Therefore, the Leibniz Association and its institutes should optimise their temperature control infrastructure and rethink their sources of heating and air-conditioning.

Renewable district heating ("*Fernwärme*")
If heat is sourced from district heating networks, the Leibniz Association and its institutes must switch their contracts to companies that produce heat from renewable sources (see Section 1.1. Energy sources) or invest in sustainable infrastructure to generate or recycle heat on-site (see below) **(immediate 2025)**.

Self-sustaining heat sources
Heat can be economically generated on-site through geothermal heat pumps, as performed by the IZW, or by biomass heating systems, as illustrated by the ATB, through incineration of campus-grown poplars, which can cut heating-associated greenhouse gas emissions by 35% **(long-term 2035)**.

Heat recovery
Excess heat can be reused by, for example, heat recovery ventilation (as performed by the IHP) to reduce the heating demand of buildings by recovering residual heat from the exhaust gas and pre-heating (or pre-cooling) fresh air. The same principles could be applied to other sectors, for example, by reusing water for cooling servers as a hot water source **(long-term 2035).**

Passive solar heating and cooling
Many simple design techniques can be applied to use the sun's energy for heating or cooling a building at very low cost and with very low environmental impacts **(long-term 2035)**.

Direct temperature control in rooms
Immediate reductions associated with heating workspaces and offices can be achieved by **(immediate 2025)**:

- **Centralised, time-based control of heating**
- **Improved insulation of buildings**
  Together with e.g., greening of roofs and facades (see Section 2.3. Preservation of biodiversity).
- **Creating employee awareness**
  Education about opening windows and doors (if the temperature is controlled individually: no overheating in winter or overcooling in summer).

1.3.3. Air-conditioning and ventilation

Air-conditioning and ventilation have not been a standard building requisite in Germany (especially in old buildings), as only 50% of office buildings are fit with air-conditioning. However, laboratory-based facilities must be equipped with energy-intensive ventilation systems for safety regulations, which can lead to up to 10 times higher energy consumption than in comparable office spaces, as more than half of the energy used in laboratories can be attributed to heating, ventilation, and air-conditioning (HVAC). Laboratory HVAC is driven by "required" air exchange rates, make-up air to offset exhausts like fume hoods or biosafety cabinets, and the airflow to adequately cool space determined by the heat load of equipment.

Air exchange rates

Laboratory German safety regulations state that the air exchange rate in laboratories should be 25 $m^3/m^2/h$, which usually translates to eight full air exchanges/h (6.2.5 TRGS 526/DGUV-I 213-850). However, such fixed ventilation rates were traditionally based on anticipated (not verified) pollutant levels in the air of laboratories (such as volatile organic chemicals), and air contamination can vary greatly depending on the type of chemicals used, as well as the laboratory's occupancy. Due to technological advances, fixed ventilation rates should be revisited, and we urge the Leibniz Association and its institutes to optimise their ventilation infrastructure:

- **Optimisation of air exchange rates during periods of low occupancy**
  During nights (no occupancy), air exchange rates should generally be lowered (e.g., from eight to two air changes per hour, as done by the FMP) **(immediate 2025)**.
- **Demand Controlled Ventilation (DCV)**
  DCV is an active contaminant sensing system that utilises sensors to provide real-time variable-air-volume ventilation control by regulating the air supply and exhaust. Therefore, DCV offers significant energy and cost-saving potential, increases safety, and should be installed in all newly designed laboratory buildings and existing Leibniz infrastructure (see Box 3), if possible **(long-term 2035)**.
- **Assessments of laboratory-specific hazards**
  In terms of safety considerations, no single air exchange rate will be appropriate for all laboratory types. German safety regulations already state that air exchange rates can potentially be reduced if a safety assessment is performed. Therefore, we urge all laboratory-operating Leibniz institutes to re-evaluate the safety assessment of their individual laboratories in terms of handling chemicals, if DCV systems cannot be installed. Narrowing chemical use to certain spaces would allow adjustment of air exchange rates per individual room and could significantly reduce the energy demand for ventilation in accordance with the safety measures needed. This has to be aided by opening up a communication channel between the Leibniz Association and policymakers, as well as institutional bodies that define, control, and assess work safety (e.g., *Landesamt für Gesundheit und Soziales*) **(immediate 2025)**.

Air-conditioning

Laboratories apply air-conditioning in their ventilation systems, as fresh air supply usually has to be "reheated" (see Box 4). This reheat can account for as much as 20% of HVAC costs in laboratories and is therefore a crucial factor in reducing GHG emissions stemming from HVAC. Such a reduction can be achieved by **optimising load variability** when designing laboratories and HVAC systems or by choosing HVAC technology that reduces or abolishes reheat procedures:

- **Decoupling cooling and heating from air delivery**
  Cooling and heating can be decoupled from ventilation by, for example, chilled beam technology (see Box 5) **(long-term 2035)**.
- **Recirculation of excess heat instead of extraction**
  To counteract the energy demand for cooling, excess heat from equipment rooms (e.g., server rooms where air contamination is not possible) should be captured at the source and recirculated instead of being extracted (see Section 1.3.2. Heating) **(long-term 2035)**.
- **Alternative HVAC systems**
  Systems that eliminate or reduce reheat (dual-duct-dual-fan systems, fan coil systems, zone cooling, heating coils, and radiant cooling) should be considered in the design and planning phase of buildings and laboratories **(long-term 2035)**.
- **Investing in appliances with less excess heat**
  For example, water-cooled instead of air-cooled freezers **(long-term 2035).**

Box 3. Demand Controlled Ventilation (DCV)

Studies from operating research buildings have shown that laboratories with DCV systems operate at a lower air exchange rate per hour for 98% of the time, meaning that 98% of time, laboratory air is less polluted than the arbitrary value set by legislation. Furthermore, studies have shown that DCV offers improvements in safety as DCV removes the contaminated air quicker than traditional systems following a spill. Thereby, DCV can also help detect hazards like malfunctioning appliances (e.g., fume hoods). In addition, DCV can be coupled with occupancy/motion sensors and implement unoccupied modes of ventilation after working hours and on weekends. The assessment of pollutant-free air could also aid in setting up air recirculation in order to heat or cool outside air increasing energy-efficiency (see Section 1.3.2. Heating). Economically, the installation of a DCV system can already be profitable after 10 months, as shown for the Texas Children's Hospital Neurological Research Institute (TCH NRI), which calculated savings of $350,000/year.

Box 4. Reheat

Temperature and humidity control in laboratories is often done by simultaneous heating and cooling of the air supply: Air is cooled below its dew point to condense its moisture resulting in dry air. However, the dried air typically has a lower temperature than is desired for air-conditioning spaces, therefore, heat is applied to raise its temperature in a process called "reheat". Furthermore, the cooling and drying of air are usually done at the central air-handling unit, and cooling temperature depends on the zone or room with the highest heat load (due to, e.g., a high number of instruments with excess heat). However, other spaces like rooms or zones with lesser cooling demand (due to less heat load; or rooms with a lot of exhausts like fume hoods) will have to reheat the too-cold air through additional airflow and heating.

Box 5. Chilled Beam Technology

Chilled beam technology eliminates the need for reheat coils and fan energy and can therefore be effectively used to remove heat from space, e.g. excess heat from the equipment. Therefore, equipment-intensive laboratories or data centres with high demand for dissipating excess generated heat are prime candidates for chilled-beam technology, which can reduce energy consumption by up to 30%, while also increasing the net area of usable space and lowering noise pollution. Chilled beam technology has already been successfully installed in research institutions like Vanderbilt University, UC Santa Cruz Biomed department or Stanford University.

Exhausts (Fume hoods and biosafety cabinets)

Fume hoods and biosafety cabinets in life science laboratories are one of the main drivers of energy use, as a single unit has a similar energy consumption to 3.5 four-person households when open. Additionally, fume hoods and biosafety cabinets act as exhausts and influence the airflow that has to be supplied in terms of ventilation. Therefore, rooms with additional exhausts like hoods and flow cabinets must be carefully designed, and models should be chosen according to sustainable standards:

- **Smart building design**
  As fume hoods remove air from a building, they are part of the building's HVAC system and a principal factor in the energy usage of laboratory buildings. Therefore, the installation of hoods has to be carefully planned in terms of the number and sizes of hoods and the spacing between them (diversity factor) to optimise the energy-efficiency of the building's HVAC system **(long-term 2035)**.
- **Variable air volume (VAV)**
  Fume hoods that can adjust the volume of exhausted room air (VAV) should be preferred, as they provide considerable energy savings by minimising the total volume of exhausted air from the laboratory (depending on the usage/opening of the sash). Such VAV hoods can be electronically connected to the general HVAC

system so that the hood exhaust and room supply can be balanced, which can lead to a reduction in energy costs by 85% **(long-term 2035)**.

- **Shut the sash**
  In VAV systems, the air exchange rates and associated energy consumption are significantly decreased when the sash is closed. Shutting the sash when hoods are not in use can be achieved by auto-sash controls or by raising awareness through training and campaigns (e.g., by installing informative stickers), which has been shown to reduce the energy consumption of hoods by 30% **(immediate 2025)**.
- **Limit storage of equipment and chemicals**
  Hoods should not be used as storage space because containers or equipment obstruct the hood's airflow and decrease its efficiency **(immediate 2025)**.

1.4. Sustainable IT

Information technology (IT) is unarguably one of the fastest-growing sectors of our time, equalling the global GHG emissions of air travel due to its extensive energy use, which is expected to expand to 16.4 TWh per year by 2025.

The large environmental footprint of IT is a combination of energy consumption by servers, data storage (clouds), mobile and fixed networks, as well as data centre infrastructure, including air-conditioning, fire hazard measures, and individual appliances like PCs, monitors and screens, TVs, laptops, or smaller devices.

1.4.1. Data centres

Data centre workloads have increased by six-fold between 2010 and 2020, as people produce about 2.5 quintillion bytes of data every day. This exponential growth of unstructured data demands storage capacity. Leibniz institutes should rethink their means of data storage and their data centre infrastructure. The following suggestions should be considered for feasibility, depending on the institute, to reduce their data storage environmental footprints:

- **Assessment of energy consumption**
  Leibniz institutes should calculate their Power Usage Effectiveness (PUE) and Data Centre Infrastructure Effectiveness (DCIE), which indicates how efficiently their data centres use energy in terms of computing vs infrastructure (cooling) equipment. The PUEs of all Leibniz institutes should be published and communicated transparently so that sustainable IT strategies can be adapted Association-wide **(immediate 2025)**.
- **Infrastructure of data centres/server rooms**
  A large energy consumer is the air-conditioning of server rooms to protect appliances from overheating. In recent years, material developments have increased the optimal temperature of server rooms while allowing higher humidity levels. The Leibniz Association and its institutes should be aware of their

server room needs, and they should be run at the highest possible temperature to reduce the energy usage for air-conditioning or humidity filters. Furthermore, the location of server rooms in buildings should be carefully evaluated and chosen based on their efficiency to be maintained at moderate temperatures. If feasible, data centres can also be outsourced to more efficient locations or shared with multiple institutes/campuses (see Data storage/computing below). A criterion for purchasing new data infrastructure should also be focused on high-temperature usage. Sustainable cooling systems (e.g., water or two-phase immersion cooling) should be implemented in new buildings. If possible, excess heat from the server rooms can also be recovered and fed into the building's general heating cycle, making heating self-sustainable (see Section 1.3.2. Heating). A great example comes from the Potsdam Institute for Climate Impact Research, in which the excess heat generated by their supercomputer is used to heat the building in colder months **(long-term 2035)**.

- **Data storage/computing**
  An assessment of the most sustainable data storage and backup servers should be performed as the transition from private local data centres to colocation or cloud services can save energy. If local server storage is needed, the number of servers needed should be carefully re-analysed and optimised **(long-term 2035)**.
- **Colocation and infrastructure sharing**
  If local servers are not a necessity for Leibniz institutes, data centres can be outsourced to infrastructure with more appropriate locations, for example, where air-conditioning is improved, or where data centres can be shared with multiple institutes or even research campuses. A great example of sustainable data centre construction comes from the University of Paderborn, which has installed data centres inside wind turbines to make use of the unoccupied space and directly access the renewable energy generated on-site **(long-term 2035)**.
- **Server-less computing**
  Cloud infrastructure has the advantage of scaling capacity according to the current demand. Furthermore, workloads can be distributed around the globe to fit local time zones (e.g., to daytime when photovoltaics are available) or to be performed in geographic regions with more renewable energy sources. While utilising cloud storage might be a legal grey area, especially in research due to safety concerns (e.g., electronic laboratory books), institutes should consider this step and prepare to advise legislation towards more sustainable options. Special responsibility for rethinking their cloud usage falls on institutes using high-throughput computing, such as machine learning or artificial intelligence applications **(long-term 2035)**.
- **Data handling**
  Data centres can apply data compression, deduplication, and thin provisioning to reduce their data storage, and therefore, energy consumption. Additionally, older data can be archived and/or saved in off-grid media **(immediate 2025)**.

- **Backups**
  The number of backup servers should be limited according to the institute's requirements. Incremental backups should be preferred. The backups can also be saved on the cloud or off-grid media (see above) **(immediate 2025)**.

1.4.2. Training for staff

While restructuring hard- and software to more sustainable means, responsible IT handling practices have to further support a sustainable computing department. Therefore, as this is a fast-changing sector, IT staff should be regularly trained on energy-efficient computing and how to sustainably optimise the institute's network infrastructure. The IT departments should then also perform regular training sessions for all staff members on how to use and handle their computing devices in the most responsible manner **(immediate 2025)**.

1.4.3. Individual usage

Switch-off routines
A running desktop consumes between 30-80 W, while the sleep mode still uses 1-15 W, depending on the computer. Over a long period, the energy usage of the multiple computing devices adds up to significant consumption. Therefore, Leibniz institutes have to spread awareness among their staff to turn off computers, screens, and other plugged-in devices (such as external hard drives or chargers). Furthermore, because screen savers do not save energy, an automatic sleep mode should be enabled. In addition, power strips with manual or time switches that power multiple devices can help automate switch-off routines. Similarly, software or programs that are not in use should be closed after the applications are completed. The background processes should be kept to a minimum. Special responsibility falls on researchers performing computationally intensive tasks, as high-performance computing consumes a significant amount of energy. These individuals should be especially aware of the implications of their computing, and codes should be monitored and optimised for their energy-efficiency **(immediate 2025)**.

E-mail practices
A typical e-mail is responsible for 4 g of CO_2 emissions, whereas attached files require extra storage and longer transmission times, raising the carbon footprint to an average of 50 g. Therefore, it is crucial that Leibniz employees are made aware of sustainable mail practices, which means that the sent, trash, and spam folders are emptied on a regular basis. This can also be performed centrally and automatically. Furthermore, staff members should unsubscribe to mail lists or newsletters that they do not intend to read. Archiving/compression of the remaining emails will also free up storage space. Finally, e-mail signatures should contain only text (rather than photos) to reduce the amount of data sent through each e-mail. Similarly, the amount and size of e-mail attachments should be reduced to a minimum, for example, by using compression or cloud services to share data **(immediate 2025)**.

Data storage
Leibniz employees should prevent saving multiple copies of documents on servers and keep a good inventory of their files. Furthermore, awareness should be raised about data storage formats and their sizes (e.g., JPEG vs TIFF) so that the most sustainable choice can be made according to their applications. Regular cleaning of unused files on servers can help organise the data and reduce the environmental footprint of data storage. In addition, individual staff should assess their most feasible and sustainable way to access their data remotely, either making use of cloud storage, VPN networks, or utilising remote desktops (see Server-less computing in Section 1.4.1.). The local IT department should provide guidelines on the most sustainable practices and aid in the setup and maintenance of data storage. In terms of long-term storage and archiving, clear guidelines must be developed to define how to limit data storage. Additionally, archived former employee data should not be stored on highly efficient media (fast reading/writing speeds) but rather on off-grid media (powered only when needed) **(immediate 2025)**.

Video calls/online meetings
While online meetings are usually less resource-intensive than in-person meetings (including travel), turning off the camera in video calls can further reduce the environmental footprint of the meeting by 96%, as streaming in high-definition (HD or UltraHD) consumes high amounts of energy. Therefore, Leibniz employees should be made aware that turning off their cameras or streaming in standard definition can help reduce emissions in both professional and private applications **(immediate 2025).**

Mobile work
Sustainable solutions for mobile work still need to be discussed and implemented. Access to research data from home can be provided by using servers and cloud services (see Section 1.4.1. Data centres). However, because of convenience and software licensing issues, researchers often access their work computers through remote connections. This implies that two computers are turned on instead of one, and usually the work computer is never turned off. Here, deploying software licences in data centres for centralised access could be a part of the solution. Furthermore, remote booting of electronic devices should be implemented to enable the use of work computers on demand. Energy and resource efficiency should also be criteria for the purchase of laptops or other devices for mobile working (see Section 1.4.4. Procurement of IT devices) **(immediate 2025).**

1.4.4. Procurement of IT devices

The production of a single laptop produces approximately 316 kg of CO_2 and consumes 190,000 litres of water and 1,200 kg of Earth's resources, of which some are considered at critical risk of being exhausted in the near future. Additionally, some raw materials are often mined under child labour in regions run by armed militias. Therefore, the production of IT devices is overshadowed by combined economic, environmental, and societal issues.

Thus, Leibniz institutes must carefully evaluate the number of computers and IT devices they need and avoid excess computers. New purchases should be carefully selected in terms of resource-saving and energy-efficiency (labels like EPEAT and ENERGY STAR, laptops are generally more energy-efficient than desktops, etc.). If the re-manufacturing or repair of old devices is feasible, this should always be the preferred option **(immediate 2025)**.

Excess or unused devices should be sold, donated, or recycled (if reuse is not possible) according to electronic waste recycling schemes (see Chapter 3. Resource management) to recover rare metals.

1.5. Appliances

Energy metres
Energy metres should be installed and used to measure energy consumption of individual appliances. This allows identifying outdated appliances and creates visibility for users in terms of operation costs and energy consumption (see below). Furthermore, appliances that use a high amount of energy while "off" or in "sleep-mode" can be identified, replaced, or put on timed smart energy sockets **(immediate 2025)**.

Raise awareness
Based on the identification of energy profiles of equipment (see Energy metres above), their energy consumption and operating costs should be communicated to all users on a regular basis (annual reminders, introductions for first time users). This will raise awareness and inform staff on sustainable practices (e.g., switch-off routines, low-power standby modes) and will also extend the lifetime of appliances **(immediate 2025)**.

Handling instructions
Detailed handling instructions should be prepared and communicated to users to minimise the energy consumption of appliances **(immediate 2025)**, for example:

- Ultra-low temperature freezers can be set to -70°C instead of -80°C. This saves up to 30% of energy without compromising sample storage, extends the freezer's lifetime, and reduces the associated heat load (see Air-conditioning in Section 1.3.3.).
- Closing the sash on fume hoods (see Exhausts in Section 1.3.3.).
- Setting sleep mode of instruments.
- Manual introductions for handling complex equipment (e.g., microscopes).

Booking calendars
Analogue, online, or name tag booking systems should be installed at common appliances so that switch-off routines are implemented, and their use can be tracked **(immediate 2025)**.

Procurement
Energy-efficiency should be a guiding criterion for purchasing new appliances **(immediate 2025)**. For more details, see Chapter 3 – Section 1. Procurement.

1.6. Conclusions

Research is intimately coupled with high-energy consumption due to the energy-intensive nature of research facilities and their instruments. Therefore, it is imperative that the Leibniz Association and its institutes source their energy from renewable sources either through sustainable energy providers or by becoming self-sufficient. Additionally, energy consumption must be monitored and reduced to comply with the 1.5°C agreement. Illumination, HVAC (especially in laboratory-based institutes), and IT procedures are the major sectors contributing to the energy consumption of research institutions that have to be revisited and remodelled for energy-efficiency.

2. Building infrastructure

The building sector is responsible for 40% of Germany's GHG emissions. Approximately 25% of these emissions stem from raw materials and construction processes of new buildings. Thus, in addition to the energy-efficient maintenance of buildings (see Section 1.3. Energy-efficient buildings), the design and construction of new infrastructure must be carefully planned by adhering to sustainability criteria. In the long run, sustainable buildings contribute to the mitigation of the climate crisis while simultaneously having increasing financial benefits due to reduced operating costs caused by, for example, decreased energy and water consumption.

To meet the climate-associated challenges of construction, the *Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen*, and the German Sustainable Building Council (DGNB) have created guidelines and a certification system, the most commonly known being the Assessment System for Sustainable Building (BNB). New infrastructure of the Leibniz Association and its institutes should therefore be built according to these guidelines. It should be aimed at achieving the highest certification levels, for example, the BNB Gold Standard, for all new infrastructures, and the renovation of existing buildings, as done by the IGB for their future research institute.

2.1. Modernisation and renovation

In Germany, the demolition of buildings and infrastructure is responsible for 534 million tonnes of waste annually. Furthermore, new construction processes have a high energy and resource consumption. Therefore, the modernisation and renovation of existing structures should always be favoured over new construction. Such modernisation should include optimised HVAC, insulation, and illumination to increase energy-efficiency (see Section 1.3. Energy-efficient buildings) **(long-term 2035)**.

2.2. Sustainable construction

Construction of new buildings and infrastructure is not only one of the major global drivers of GHG emissions, but also causes soil destruction and habitat loss, stressing the importance of planning construction on the most sustainable terms possible. Sustainable construction can be achieved by smart building design considering biodiversity preservation, the use of long-lifespan renewable and recyclable building materials, and reducing energy consumption and waste streams **(long-term 2035)**.

2.2.1. Building design

Up to 50% of a building's energy consumption is caused by its construction and late dismantling processes, underlining the importance of considering the entire life cycle of the infrastructure during the planning phase. Furthermore, operational costs are heavily impacted by design.

While the BNB or DGNB standards should be fulfilled, we further want to stress specific criteria that should be considered when planning new buildings to increase energy-efficiency and limit the impact on biodiversity destruction:

- **On-site renewable energy sources**
  (See Section 1.1. Energy sources).
- **Optimised HVAC**
  (See Section 1.3.3. Air-conditioning and ventilation).
- **Illumination and natural light distribution**
  (See Section 1.3.1. Illumination).
- **Maximised insulation and passive heating/cooling design**
  (See Section 1.3.2. Heating).
- **Reclaimed water systems**
  (See Section 3.4. Reuse of waste/grey water).
- **Biodiverse building design**
  (See Section 2.3. Preservation of biodiversity).

2.2.2. Raw materials

Cement-based concrete

Concrete production alone accounts for 2% of the German GHG emissions. The production of cement, one of the major components of concrete, is one of the most emissions-intensive industrial processes worldwide, as its burning process requires very high temperatures (1450°C) and directly releases CO_2 due to the calcination of its raw component limestone (1 t of cement releases 587 kg CO_2 eq.). Therefore, the Leibniz Association and its institutes must reduce their use of traditional cement and deploy alternatives on a large scale. To lessen the impact of new buildings, more sustainable forms of concrete should be purchased, such as recycled or cement-free concrete (clay, wool, cigarette butts-based, etc.), cement that underwent carbon capture during the burning procedure, or complete replacement of concrete with wood, if it is sourced from sustainable forestry (see Chapter 5 – Section 1. Sustainable office practices).

Steel

Another critical construction material is steel, whose production accounts for approximately 3% of the German GHG emissions. As steel is needed to guarantee the stability and durability of buildings, Leibniz institutes should predominantly purchase recycled steel or steel produced with renewable energy. Furthermore, alternatives to steel, such as engineered timber or fibre-reinforced plastics, should be evaluated for feasibility and environmental impacts.

Styrofoam
Traditionally, buildings are insulated with Styrofoam, a petrol-based material. Therefore, Leibniz institutes should focus on replacing Styrofoam insulation with ecological re-growing, CO_2 capturing bio composites like straw, wool, plant-based rigid foam or aerogels, cellulose, or greensulate. Green roofs and facades are also good insulators (see Section 2.3. Preservation of biodiversity).

2.2.3 Energy consumption at construction sites

On-site modular battery systems can be deployed and recharged through solar panels, which can power vehicles, electric tools, and security measures to reduce the impact of construction in terms of renewable energy sources.

2.3. Preservation of biodiversity

Ecologists record an incomparable loss in biodiversity on a daily basis and predict the collapse of fragile ecosystems due to anthropogenic activities, such as pollution, habitat conversion, and overconsumption of natural resources through, for example, farming. As both climate and biodiversity crises are intimately linked, biodiversity is part of SDGs 3 (Good Health), 12 (Responsible Consumption), and 15 (Life on Land). Therefore, we call on the Leibniz Association and its institutes to design or refurbish their buildings and/or research campuses towards becoming nature-friendly and areas of wildlife protection, which in turn will not only aid the restoration of ecological balance through species conservation but also improve their employees' quality of life and well-being.

Greening of sites and campuses
As part of the German Sustainability Plan, the *30 Hektar strategy* was implemented to counteract biodiversity loss by sealing wildlife habitats through new construction. The Leibniz Association can support this strategy by greening the facades and roofs of existing buildings (if possible), or by including greened architectural elements in new constructions. Planted roofs or walls and green areas on sites and campuses can serve as functional ecosystems yielding food and nesting grounds for animals while simultaneously protecting against weather and radiation that contribute to carbon sequestration **(immediate 2025)**.

Window fronts
Birds control rodent and insect populations, reduce damage to crops, pollinate plants, and disperse seeds to regenerate habitats. However, due to their low depth perception, birds often collide fatally with the glass fronts or windows of buildings. The Leibniz Association and its institutes can prevent bird strikes by increasing the visibility of glass

through the application of stickers or nettings to windows, and by avoiding interior plants close to glass fronts. Furthermore, installing sunshades, blinds, shutters, or similar measures to protect birds can decrease energy consumption for heating and air-conditioning, while also reducing light pollution (see below). While glass is important for bringing sunlight into buildings, new constructions should be carefully evaluated based on energy-efficiency and glass usage. As a rule of thumb, new building facades should not incorporate more than 30-40% glass in order to protect birds and save energy consumption for heating/cooling **(immediate 2025)**.

Light pollution

Light pollution is closely linked to the number of glass fronts in a building's facade and the amount of exterior light sources. Excessive illumination at night not only disorients birds, bats, and insects, but also drastically affects the circadian rhythm of nocturnal animals. Predators can exploit the attraction to their advantage and shift the food chain balance, which overly affects the species needed for pollination and habitat regeneration. The Leibniz Association and its institute should reduce light pollution by installing motion-activated lighting in lobbies, walkways, and corridors and implementing automated switch-offs after hours, which would also save energy. Furthermore, lights should be shaded so that only the required area is illuminated. In addition, dimmable lights should be preferred, and blue light should be avoided, as it potentially disrupts more species **(immediate 2025)**.

Nesting space

While insect- and bird-friendly habitats can be implemented through the aforementioned greening of buildings, wildflower meadows harbouring native plant mixes or the installation of insect hotels through deadwood or logs can further aid in making campuses more animal-friendly. Suitable locations can be determined through consultation with NABU experts. Furthermore, green areas should be protected by no-walk zones to avoid soil compaction, preservation of dead trees/shrubs, or restricted mowing practices (March-September) to protect populations such as hedgehogs. The use of low risk or no pesticides and the application of non-chemical pest control (if needed) can further support healthy wildlife populations. Additionally, bats are essential parts of many ecosystems, but have suffered a steep decline in their numbers due to the repurposing of buildings, deforestation, light pollution, and wind turbines. As bats do not build nests but use cracks in walls and roofs for roosting, they have become highly vulnerable to the renovation of existing buildings and modern architecture. Therefore, bat boxes can be added to existing structures, whereas new constructions can include bat slits in their new wall design/insulation of buildings **(immediate 2025)**.

De-icing salt

Around 1.5 million tonnes of de-icing salts are distributed on German streets every year. Increased salt concentrations not only harm plant populations but also become enriched in soils over time, leading to infection of animal feet, and can cause erosion of infrastructure. Therefore, we urge the Leibniz Association and its institutes to predominantly use sustainable de-icing alternatives (e.g., certified by the Blue Angel or sand/limestone/clay-based- instead of gravel-based grit) **(immediate 2025)**.

2.4. Conclusions

Building new infrastructure is often coupled with habitat conversion, compromising ecosystems, energy-intensive construction processes, and harmful materials. To counteract this trend, the Leibniz Association and its institutes should modernise and refurbish existing infrastructure as much as possible. If new buildings have to be commissioned, they should be built under sustainable guidelines like the BNB Gold Standard, including self-sufficient and energy-efficient design and construction materials. Furthermore, new and old structures should be transformed and handled to preserve biodiversity. By greening infrastructure and implementing animal nesting areas, fragile ecosystems can be rebalanced, which offers the added benefits of saving energy and increasing the quality of life of Leibniz employees.

Chapter 3. Resource management

The average researcher in Germany can have an up to 60% higher CO_2 footprint compared to other professions, mostly due to the resource-intensive nature of their research. For example, laboratories worldwide are responsible for approximately 1.8 % of global plastic production. Plastics, in particular, have a significant environmental impact as they require petrochemicals to be produced (estimated 2.5 trillion $ in downstream damage), have a long half-life, and degrade into microplastics that pollute soil and water, contaminate ecosystems, and accumulate through food chains.

In addition to the environmental impacts of production, an estimated 11.2 billion tonnes of solid waste are collected worldwide every year, accounting for 5% of global GHG emissions. Additionally, the increasing volume and complexity of waste poses serious risks to ecosystems and human health. Global recycling schemes have already helped reduce waste-related GHG emissions from 40 million tonnes in 1990 to 11 million tonnes in 2015 and conserve virgin resources, energy, water, and ecosystems.

Germany has relatively high recycling rates (55% in 2019 vs 8.5% in the United States) and incinerates most of the rest of its waste. However, these numbers hide the fact that Germany exports recyclable waste to other countries (697,000 t in 2021). In summary, the most efficient strategy for tackling air pollution and contamination of water and soil worldwide is the general minimisation of waste. Avoiding waste and reusing or recycling that cannot be avoided are the major guiding principles of a circular economy.

The Leibniz Association should be responsible for implementing sustainable resource management in each institute. Here, we expand the commonly known 3 R's rule (reduce, reuse, recycle) to propose measures we call on the Leibniz Association to follow in a hierarchical order:

- Sustainable resource management begins with procurement, in which current legislation must be **rejected** and **reformulated** to lay the basis for sustainable purchasing in the future.
- Institutes must be **restructured** in terms of resource management to implement inventories, shared databases and centralised procurement.
- Through smart **re-evaluation** and **rethinking** of the institutes' needs, **reuse** of material, and **repair** and **repurposing** mechanisms, resource consumption can be significantly **reduced**.
- Finally, high **recycling** rates and energy **recovery** from non-recyclable waste streams will transform the Leibniz Association's resource management towards a fully circular economy.

1. Procurement

Consumables and purchases can contribute up to 80% of the GHG emissions of a research institute's environmental footprint. Furthermore, the supply chain-associated emissions of companies supplying these consumables are, on average, 5.5 times greater than their operational emissions. Therefore, it is imperative that the environmental impacts of production, use, and disposal are calculated over the entire life cycle of manufactured goods (scope 3), and that companies transform their supply chains to lower their environmental impact.

Apart from the environmental impacts of consumables, around 24.9 million people were subjected to forced labour worldwide in 2016, and Germany is estimated to import around 30 billion dollars' worth of risk products. Therefore, it is necessary that we apply sustainable and ethical criteria to procurement processes as part of SDG 12 (Responsible consumption and production). In its 2016's national action plan, the German government stated that "*the federal, state and local authorities bear particular responsibility [...] that the use of public funds does not cause or foster any adverse impact on human rights*." As research organisations predominantly operate on public funds, Leibniz institutes have a special responsibility to support sustainable businesses to promote fair working conditions (as defined by the International Labour Organisation). A recent example shows that this is not trivial, as market-leading companies still produce research goods like laboratory gloves under forced labour conditions.

We argue that sustainable procurement must consider fair working conditions as well as resource conservation, environmental protection, and climate change mitigation and urge the Leibniz Association to undertake the following steps:

1.1. Reform through lobbying

Policies to make sustainable procurement the default
Public procurement is governed by legislation, which often means that the price of goods is one of the most important criteria, if not the only one, when choosing suppliers or services. However, apart from the price and quality of goods, both ethical and environmental factors like compliance with environmental laws, avoidance of hazardous materials and waste in the supply chain, and fair labour conditions should be added to the list of relevant criteria. One positive example is the recent change in *Bundesreisekostengesetz*, which now states that environmental aspects can be applied in choosing means of transportation, enabling employees to choose a more expensive train over a flight when travelling for business reasons. Such positive examples need to be translated into corresponding procurement laws stressing sustainable criteria in the selection process. Therefore, we urge the Leibniz Association to **emphasise sustainable**

criteria in offers and contracts, apart from costs, through consultation with both policymakers and funding bodies **(long-term 2035)**.

Building climate resilience in supply chains

Currently, the sustainability of goods or services is not clearly defined. Thus, consumers cannot make informed decisions by comparing vendors on their own to fully understand their consequent share of the supplier's value chain emissions. Although companies have started publishing the environmental impacts of their own production hubs, full impact studies along the entire supply chain upstream of their own operations are often neglected (Scope 3 emissions). Without transparent publication of a product's complete impact study, including energy, water, waste, and working conditions, as part of *Good Manufacturing Practices* for the generation of each source material across its life cycle, the product's sustainability index cannot be fully determined and compared. Some companies have piloted such endeavours, for example, AstraZeneca has developed an internal product sustainability index (PSI) and encourages their suppliers to collaborate with the CDP Supply Chain Programme who reported a reduction of 1.8 billion tonnes of CO_2 eq. through their services. Such assessments must be standardised by legislation. Therefore, we urge the Leibniz Association to argue for the implementation of policies for **mandatory transparent reporting of the environmental and ethical impacts of commercial products,** including their production and, most importantly, their entire upstream supply chain (for example, the USA) **(long-term 2035)**.

1.2. Restructure

Centralised procurement of common materials

At the institute level, procurement should be centralised, so that common materials are purchased from the same most sustainable vendors in order to reward sustainable practices and consolidate orders to reduce packaging materials and delivery emissions. This can be achieved by surveying common consumables in an institute and appointing a central purchasing executive. Such a principle could be further expanded to research campuses, and possibly across Leibniz institutes **(immediate 2025)**.

Institute-wide inventories

Consumables such as reagents, appliances, and instruments should be inventoried in working groups, departments, and at the institute level. By creating such virtual databases, materials can be exchanged between groups, and over-purchasing can be prevented institute-wide (see Appliance lending/exchange platforms in Section 2.2.2.) **(immediate 2025)**.

Digitisation

Digitisation strategies for administrative documents and research processes must be implemented to transform into a paperless organisation (See Chapter 5. Research and administration and Chapter 2 – Section 1.4. Sustainable IT for more details on data storage and backups) **(immediate 2025)**.

1.3. Rethink

To transition to more immediate sustainable purchasing operations, the Leibniz Association and its institutes should **rethink** their procurement strategies by **replacing** consumables and appliances with sustainable alternatives:

Consumables

As consumables often represent daily use items, choosing more sustainable options presents a large opportunity to reduce the environmental impact of a research institute **(immediate 2025)**. The following criteria should be considered:

- Items with **long shelf-lives** should be preferred.
- Single-use items should be avoided.
- Alternative reagents in terms of **safety** for handling and the environment should be evaluated in terms of feasibility (e.g., green organic solvents and solid state vs mercury light bulbs). Generally, the principles of Green Chemistry should be adhered to.
- **Alternative reagents** should be considered in terms of resource consumption during production. For example:
    - Replacing animal-farmed antibodies with synthetic ones.
    - Replacing polypropylene (PP) with polyethylene terephthalate (PET)-based plastics, which are lighter, reduces transport emissions and improves the recovery rate in recycling.
    - Replacement of fossil-based products with plastics made from recycled plant oil.

Appliances

If new instruments or hardware must be purchased, appliances should be evaluated for their quality, energy, and water consumption (production, running, and disposal), durability, and upgradability. Additionally, the final disposal procedure can help differentiate between different vendors and appliances. To make the best choice, certain sustainable labels can be consulted, including the EU energy label (ENERGY STAR), the EU eco-label, ACT (Accountability, Consistency and Transparency) Label, etc. While currently only few companies aim to certify their products through such labels, such visibility will hopefully increase in the future and shift the market toward more transparent production processes **(immediate 2025)**.

Vendors

As long as reports on the environmental impacts of consumables are not standard (see Section 1.1. Reform through lobbying), Leibniz institutes should try to determine if social and environmental standards are met. At the moment, this means opening a communication channel with providers and utilising staff members with specific expertise and knowledge of materials/appliances to aid in the selection. If a sustainable provider has been found, it should be transparently communicated so that other Leibniz (and non-Leibniz) institutes can access them, and good practices can be rewarded. Some vendors have already started advertising more sustainable options in their product catalogues, which should be recognised and tested for feasibility. In addition, companies that aim for "zero waste" in their supply chain by reusing and recycling products or have sought to reduce their packaging (e.g., less Styrofoam) and/or offer take-back schemes of used materials should be supported. Examples include companies such as Corning (packaging), Pan Media (PET bottles), and New England Biolabs (Styrofoam boxes) **(immediate 2025)**.

Communication with sales representatives

Leibniz institutes and their procurement staff can bring sustainability into account by directly discussing with sales representatives or suppliers and inquiring about more sustainable product options. This will help open a communication channel between industry and academia and transform a production market that is based on demand towards positive environmental and ethical development **(immediate 2025)**.

Education

New employees should be introduced to sustainable ordering procedures in training sessions, and institute-specific guidelines should be generated; for example, *Grundlagen der umweltfreundlichen öffentlichen Beschaffung* **(immediate 2025)**.

2. The 3 R's: Reduce. Reuse. Recycle

2.1. Reduce

Before any procurement procedure, the need for a new piece of equipment or the number of consumables to be purchased should be assessed. Inventories (see Section 1.2. Restructure) should be consulted to prevent redundant purchases and piling of consumables that may expire before use (First-in–first-out policy). Following such considerations and monitoring of common consumable consumption, purchasing the right amounts based on demand will be aided through a re-evaluation of one's needs **(immediate 2025)**.

2.2. Reuse

New equipment or materials are not always necessary, as many applications can be performed while reusing existing infrastructure. In addition, repairing or updating the existing equipment often offers economic benefits.

2.2.1. Consumables

As research and consumables vary greatly among Leibniz institutes, every institute and/or department has to assess the most feasible individual reusing schemes. They must be transparently communicated to other departments/institutes, and new employees have to be educated about them. In terms of single-use plastic materials in laboratory-based Leibniz institutes, the following measures should be considered:

Alternatives to plastics
In many cases, single-use items (usually sterile single-use plastics) can be replaced by multi-use glass products that are washed and sterilised after each use. Even though comprehensive full life cycle assessments of the environmental impacts of products sourced from plastics vs glass are still missing, recent studies comparing reuse with single-use scenarios in the laboratory context showed a substantial reduction in the CO_2 footprint of up to 11-fold by reusing glassware. While such studies may be limited to the specific context, they stress that single-use items should be reserved for selected and defined cases. Therefore, single-use plastic applications should be carefully reassessed (in accordance with safety regulations) depending on the environmental impact of single vs multi-use, which includes the production and supply chain of products, transport emissions, energy and water consumption, detergent pollution, and disposal **(immediate 2025)**.

Reuse of plastic materials
Several single-use items can be reused or repurposed. For example, some laboratories have established successful washing routines for single-use plastics, such as falcons,

which can be cleaned and reused if they are not chemically or biologically contaminated. Furthermore, plastic boxes used for shipping consumables can be repurposed as containers for various applications **(immediate 2025)**.

2.2.2. Appliances

Facilities
Institutes should promote facilities that offer shared usage of appliances or specialised services to employees that reduce the number of instruments and consumables by centralising technology and workforce **(immediate 2025)**.

Facility managers
Institutes can implement core facilities as well as central facility managers who oversee shared spaces and resources and maintain up-to-date institute-wide inventories for instruments, reagents, and biological samples. Having a permanent employee who is responsible for specific equipment will also ensure correct usage and thereby prolong the lifespan of these instruments **(immediate 2025)**.

Repairs/upgrades
Before purchasing new appliances, old technology and instruments should be assessed to check whether repairs, refurbishments, or upgrades could provide the same service/quality as a new device. Often, money from research grants cannot be spent on repairing old appliances, which should be covered by host institutes, even if the old pieces of equipment could still be functional. This favours rebuys and redundancy of appliances and should be critically addressed towards funding bodies and policymakers. When appliances can be repaired, hiring repair services should also be performed under the consideration of sustainability criteria. For example, service personnel should be hired regionally so that the travel distance is kept to a minimum, despite potentially higher costs **(immediate 2025)**.

Second-hand
When second-hand appliances can fulfil these requirements, they should always be favoured over new buys; buying (and selling) used devices should be possible and easier. The development of new online platforms might be needed for this purpose (see also Appliance lending/exchange platforms below). Nevertheless, if old or broken equipment is not energy-efficient according to the current standards, replacement with new, more sustainable options (e.g., LED instead of halogen light sources for microscopes) should be carefully considered **(immediate 2025)**.

Appliance lending/exchange platforms
Often, research appliances and technical equipment that are still functional but not needed or that have been replaced by newer models are being disposed of or stored for years. An important tool for promoting resource conservation is to refurbish technology and equipment that is redundant but still functional. Therefore, institutes should have a

central exchange/lending service, which would be based on internal inventories of appliances that could be exchanged between groups and departments, resulting in less overall purchasing. Such an exchange platform has the potential to be extended to local research hubs in bigger cities/research campuses, or even Leibniz-wide and beyond. Therein, unused appliances could be donated and transferred among institutes or gifted to other lower-income research institutions, as already done by the non-profit organisation Equipsent. Such measures would reduce the costs of new purchases and avoid wasting functional equipment **(immediate 2025)**.

2.3. Recycle

The Leibniz Association can significantly reduce GHG emissions using smart **reduction and reuse** paradigms. If materials cannot be avoided or reused, the aim should always be to **recycle** the resulting waste to recover the materials or energy.

The largest components of solid waste are food, paper products, and plastics, which can all be either composted or recycled to be reintroduced into a circular economy. Therefore, it is of utmost importance that waste streams are properly separated in offices and laboratories so that they can be recycled:

Waste separation
As communal or research campus-specific waste management may differ locally, we urge individual institutes to come into contact with their waste contractors. Based on this assessment, local waste management systems should be installed **(immediate 2025):**

- Set up waste bins for biodegradable, paper, plastic/metals, glass, etc. (according to legal regulations) in accessible spots and with proper labelling (bilingual, with visual cues).
- Inform new employees about the recycling system by proper introduction to waste separation and recycling through guidelines and information sheets, with regular reminders for all employees.
- Instruction of cleaning personnel to keep waste separated and enable pickup by recycling companies.
- Collaborate with local waste contractors to elucidate what plastics can be recycled. For example, in laboratories, tip boxes, conical and centrifuge tubes, pipette tips, cleaned reagents, and chemical bottles can often be recycled. Therefore, communication with vendors and recycling companies is crucial for achieving high recycling rates.
- Some companies offer recycling schemes for unusual waste streams, such as KimTech for nitrile gloves, Triumvirate for medical waste, and BASF for Styrofoam. Such programs should be evaluated in terms of their feasibility for laboratory-based Leibniz institutes.

- Monitor the number of different waste streams, identify reduction potentials, and set reduction targets for upcoming time periods.

Compost

We urge the Leibniz Association and its institutes to implement biodegradable waste separation in kitchens and cafeterias to set up on-site composts. Separating compostable waste helps to avoid contamination of other recycling streams, and the resulting compost can be used as a soil fertiliser for plants or flower biotopes on campus/sites (see Chapter 2 – Section 2.3. Preservation of biodiversity) or for energy generation. Furthermore, it should be reconsidered if waste from animal facilities, such as cage litter, could be composted or incinerated for energy recovery (if safety regulations allow it) to cut down on a large waste stream associated with animal-based research **(immediate 2025)**.

Hazardous waste

Waste containing hazardous substances, such as chemical or biological waste from laboratories and electronic waste, poses a special challenge. They can contain organic pollutants that can accumulate through food chains and pose risks to ecosystems and human health. Heavy metals, antibiotics, detergents, or hazardous and toxic chemicals must be handled with special care and disposed of responsibly. While the handling of toxic waste is already highly regulated, there is still potential for optimising disposal through reduction, better streamlining and recycling, and recovery of, e.g., rare metals **(immediate 2025)**.

Energy recovery

Non-recyclable and non-hazardous waste should be subdued to energy recovery. This can be achieved through incineration, gasification, pyrolysis, or anaerobic digestion of organic waste, which converts waste into heat, electricity, or biofuels. Thus, the Leibniz Association and its institutes should collaborate with waste treatment companies and contractors to offer energy recovery from waste **(immediate 2025)**.

Education

Awareness campaigns should be planned to introduce waste separation at the institute level. Best practices should be shared between departments and institutes to aid in establishing collaborations in terms of recycling or take-back schemes. For example, if glove recycling is implemented by one research group, its potential to be expanded institute or campus-wide should be evaluated **(immediate 2025)**.

3. Water

While water covers approximately 70% of the Earth's surface, less than 1% of the available volume can be used as freshwater to sustain the world's ecological balance and biological habitats. Driven by increased consumption due to economic and demographic growth as well as pollution, and critically worsened by the climate crisis (e.g., rising sea levels, droughts, and floods), water scarcity is considered to be the biggest threat to global prosperity, leading to increased potential for competition and conflict. Therefore, the water scarcity crisis is underlined in the UN's Agenda 2030 and SDG 6 to ensure availability and sustainable water management and sanitation on a global scale.

Germany is in a fortunate position to have access to many freshwater sources, which has led to a perception of overabundance, so that cutting down on water consumption is not seen as a necessity. However, the 2 °C temperature increase in Germany since 1900 has already affected rainfall (Ahr floods in 2021) and soil moisture, and has caused eutrophication, droughts, and water scarcity in certain German regions. If the misconception of water overabundance in Germany is not addressed, the progression of the climate crisis and the increasing demand for water will most likely affect the entirety of Germany in the future.

Apart from the threat to natural freshwater sources, the transportation of water from underground basins and its treatment and purification until it exits the tap are energy-intensive processes. Therefore, reducing water consumption, particularly warm water, can save both energy and GHG emissions.

Previous recommendations on resource management (see Sections 1 & 2) also apply to water. Yet, water is a crucial resource that requires additional measures. It is important that the Leibniz Association and its institutes decrease their demand for direct and indirect water usage by monitoring and optimising water consumption and by choosing water-responsible vendors and supply chains through sustainable procurement.

3.1. Direct water consumption

Water metres

Water metres should be installed at water-based equipment in institutes to identify the largest consumers. This will also allow for the identification and replacement of outdated infrastructure/instruments with more sustainable water-saving technologies **(immediate 2025)**.

Aerators

Typical faucets exhibit a water flow rate of 15 L/min. By installing low-flow aerators on faucets, the flow can be reduced to < 5.5 L/min. For example, installing aerators at the UC

San Diego research buildings could save 1-3 million L of water per year **(immediate 2025)**.

Collection of rainwater

New or refurbished buildings can be equipped with rainwater storage tanks. The collected water can be repurposed for applications that do not require a purification step, such as flushing toilets (as already done in the private and public sectors in the US and UK), watering plants, or cleaning (e.g., gardening tools and pavement), which would help to save energy-costly purified tap water **(immediate 2025)**.

Water in laboratory-based research

- **Deionised or ultrapure water**
  Many applications in the natural sciences require deionised or ultrapure (double-distilled) water. However, to make 1 L of deionised water, 3 L of tap water is required in the purification step alongside the accompanying energy consumption. Therefore, employees should be trained to rethink if their application requires deionised or ultrapure water and if they can reduce their usage in terms of volume **(immediate 2025)**.
- **Autoclaves**
  Many biological tasks require sterilised materials, but autoclaves or other sterilisers can use up to 230 L per cycle (old models even 340 L per cycle). Several measures can be applied to reduce the run cycles or water consumption, such as consolidating loads, right-sizing the autoclave depending on the demand, considering the energy and water efficiency for new purchases, and installing water-saving devices on installed autoclaves **(immediate 2025)**.
- **Single-pass cooling**
  Single-pass cooling (in ice machines, autoclaves, and chemical research) is a process that uses water to cool something once. Single-pass systems are extremely wasteful and should be replaced by closed loop or recirculating systems **(immediate 2025)**.

3.2. Indirect water consumption

As freshwater resources are unevenly distributed worldwide, water scarcity is a local crisis. However, international trade is mostly driven by high-income countries that utilise supply chains that often originate in the global South and further drive water scarcity there (which is usually already limited). Organisations and companies manage water consumption in-house but usually neglect the indirect upstream energy and water use of manufacturing products, although the latter is significantly higher (contribution to scope 3 emissions). Therefore, the largest share of water consumption by the Leibniz

Association and its institutes occurs outside Germany, and can be accounted for by virtual water trade calculations.

Water Footprint calculation

To measure the water consumption associated with supply chains, the BMBF-funded research project "Water Footprint for Organisations – Local Measures in Global Supply Chains (WELLE)" identifies an organisational water footprint in order to reduce water consumption and mitigate water scarcity at critical spots. The footprint is designed to analyse water use and its local impacts throughout the production chains of an organisation while considering upstream raw material and downstream water pollution/purification consumption. Based on this assessment, the more sustainable use of water can be supported by rethinking supply chains and procurement. Consequently, to account for indirect water consumption, the Leibniz Association and all its institutes should calculate their water footprints following this or a similar method. However, as most institutes use consumables from many different vendors and suppliers that might not transparently communicate their water consumption for chemicals or other materials, this could result in a superficial analysis **(long-term 2035)**.

Sustainable procurement

To counteract non-transparent supply chains of consumables, the Leibniz Association and its institutes should hold their vendors and suppliers accountable to optimise their water consumption during manufacturing. This can be done by inquiring about the company's water footprint or its virtual water trade and/or taking water consumption/sustainability into account while choosing vendors (certifications/green labels, etc.). In this sense, the Leibniz Association has to advocate to politics and industry that direct (at the production hub) and indirect (along the supply chain) water consumption of commercially available products is transparently reported on (see Section 1.1. Reform through lobbying) **(long-term 2035)**.

3.3. Reduce wastewater and pollution

Sewage or wastewater treatment and purification plants are responsible for 3% of global GHG emissions, as they produce carbon dioxide, methane, and nitrous dioxide during the water purification process due to petroleum-derived pollutants and detergents. Water pollution also drives the water scarcity crisis, as at least one-third of the global water resources are too contaminated to be purified to drinking water quality, and wastewater quantities are estimated to double by 2050. Therefore, wastewater contributes to the climate crisis, and we call upon the Leibniz Association and its institutes to reduce the amount of harmful petroleum-and/or nitrous-based products in their wastewater. This can be achieved by the correct disposal of chemicals, pharmaceuticals, antibiotics, lacquers, or petroleum-based colours, the use of ecological/biodegradable detergents for cleaning and in soaps, and the reduced use of pesticides (e.g., through ecologically sourced food) and microplastics **(immediate 2025)**.

3.4. Reuse of waste/grey water

There should be an increasing trend of wastewater reuse to alleviate water scarcity, as has already been done in countries where freshwater sources are limited. However, there is a lack of national regulations and standards. If economic incentives are provided to establish new techniques to reuse wastewater in applications that do not require high purity (e.g., toilet flushing), in-house water recycling could be installed in newly designed buildings. For example, this was implemented at the Campus for Research Excellence and Technological Enterprise (CREATE), which, through the collection, storage, and treatment of rain and grey water, saves up to 66,000 L of freshwater every year. Therefore, the Leibniz Association should transparently communicate with politicians to improve legislation to ease applications that can recycle wastewater in-house and install corresponding technology in new buildings **(long-term 2035)**.

4. Conclusions

The Leibniz Association can play a crucial role in transforming the research culture into a culture of maintenance in which production demand can be decreased through the repair and reuse of materials and appliances (without sacrificing research integrity). This must be further supported by drastically reducing the number of consumables and increasing recycling rates. Furthermore, a culture of transparency and accountability across supply chains can be formed through sustainable procurement processes. Procurement is responsible for the largest fraction of indirect scope 3 emissions from research institutes because of the lack of transparent reporting on energy and water consumption as well as waste generation. Additionally, publicly funded institutes have a special responsibility to use their funds to support ethical businesses with fair labour conditions and sustainable practices. As the production of consumables is often outsourced internationally, it is imperative that vendors' supply chains are monitored and that the Leibniz Association and its institutes support only businesses that transparently communicate the environmental and social impact of their products along the supply chain. This must be further supported by changes in public procurement laws, which the Leibniz Association has to advocate for. Furthermore, in terms of appliances and consumables, institutes should implement up-to-date inventories enabling exchange on an institute or even Association level, which would save costs and avoid wasting redundant resources. Joint procurement in institutes or science campuses should be promoted to reduce packaging and transportation costs, as well as emissions. Apart from climate change mitigation, sustainable procurement also offers financial savings regarding the life cycle of appliances, promotes social development in terms of fair working conditions and local innovation when sourced regionally, and improves employee morale by setting a positive example.

Chapter 4. Mobility and event management

1. Mobility

The transport sector was responsible for one-fifth of Germany's 2019 GHG emissions. Research organisations like the Leibniz Association contribute to these emissions in two ways: (1) travel to and from work on a daily basis and (2) short and long-distance business trips like conferences/fieldwork/collaborator meetings, etc. Therefore, we call upon the Leibniz Association and its institutes to foster and support, financially as well as structurally, actions to reduce emissions in these areas and recommend the following actions.

1.1. Commuting

The Leibniz Association and its institutes should promote sustainable commuting as much as possible. This discourages the use of individual cars, and offers platforms for carsharing and carpooling.

1.1.1. Bicycle

Riding a bicycle is the most sustainable transportation option. At the same time, it promotes a more active and healthier way of life, and should therefore be incentivised and supported by the Leibniz Association and its institutes by **(immediate 2025)**:

- Promotion of bicycle leasing (e.g., JobRad, or Job.Bike).
- Promotion of local cycling clubs or joining ADFC, e.g., financial contribution to memberships.
- Support for initiatives like "*Mit dem RAD zur Arbeit*" or "*Wer radelt am meisten*".
- Providing repair kits and tools, developing a repair workshop (*Fahrradselbsthilfewerkstatt* like hubSchrauber of the Humboldt University Berlin), contracting a bicycle shop nearby with discounts for Leibniz employees, and/or organising bicycle repair events a few times a year.
- Contributions to the costs (e.g., vouchers or reduced prices through contracting to buy, repair, rent, and/or rent/share a bicycle).
- Collaboration with bike leasing/sharing companies (e.g., Nextbike).

Furthermore, the cycling infrastructure must be improved by **(long-term 2035)**:

- Lobbying for and contributing to better infrastructure (e.g., bicycle lanes, parking, and bicycle rental stations) in cooperation with regional authorities.
- Building safe bicycle parking places on-site with charging points for e-bikes.
- Providing showers and changing rooms.

1.1.2. Public transportation

Employees should benefit from using public transportation rather than cars. JobTickets and financial contributions for BahnCards, for example, are important financial incentives that must be promoted and further developed by Leibniz institutes **(immediate 2025)**.

To use public transport for commuting, the transportation network must be sufficiently dense for quick connections around the institute. If this is not the case, Leibniz institutes must lobby with their local authorities and public transportation companies to improve public transport options, such as bus shuttles during most common commuting times and establishing new bus routes **(long-term 2035)**.

1.1.3. Parking & infrastructure

Once more sustainable alternatives are in place, car parking spaces must be either drastically reduced or converted to bicycle parking spots and/or the price for car parking on-site should be increased. Money generated in this way must be reinvested in sustainable actions. Alongside, e-car loading stations should be installed to incentivise employees to buy/share e-cars **(long-term 2035)**.

1.2. Business trips

1.2.1. Means of transportation

Measures concerning business trips must be discussed and adapted depending on the research field and/or research question; for example, research involving fieldwork requires more travel than laboratory-based research. Therefore, the following measures must be evaluated in the context of research integrity and should never compete with the equal opportunities or career development of early researchers.

Short-distance travel
Travelling by train is the most sustainable option for short-distance business trips and must be mandatory even when it is not the cheapest option **(immediate 2025)**.

Long-distance travel
For longer distances, travelling by train may not be a valid option. A clear threshold (either in kilometres or travel time) must be defined, below which flying is not allowed and not refunded to the researcher. This threshold may differ according to the research field. If flights are needed to conduct interviews or receive data, exceptional thresholds should be adopted. In this case, long stays on-site should be prioritised over many short trips, if compatible with the research design. Additionally, every flight must be compensated (see Box 2) and the number of employees flying must be kept at a minimum.

A restrictive number of “flight certificates” and a reward system could be introduced **(immediate 2025)**.

Travel agencies

When planning trips through travel agencies, only those that comply with certain climate certifications (e.g. EMAS or the ISO 14000 family) and/or organise sustainable travel should be chosen **(immediate 2025)**.

1.2.2. Incentivise online participation

The COVID-19 pandemic has shown that many meetings, seminars, workshops, lectures, and conferences can be held virtually. Virtual events have the advantage of having much smaller environmental footprints and promoting equal participation opportunities for people who are restricted to travel in terms of available funds or their personal situation (e.g., childcare, nursing responsibilities, etc.). This is not to say that all events can be held online, and that there is no benefit to in-person events (see Section 2. Event management). Nevertheless, we must continue to use these online tools in a meaningful way, even after the pandemic is over by **(immediate 2025):**

- Investing in technical means (e.g., high-speed Internet and purchase of webcams/headsets for all researchers).
- Purchasing online conference tools and/or availability of an adequate number of licences.
- Providing training and infrastructure (e.g., dedicated “online meeting” rooms) for employees.

1.2.3. Company vehicles

Company vehicles should be assessed for necessity. If possible, cargo bicycles or trailers for transporting larger/heavier items can replace cars. If cars are needed, they can be rented or shared between neighbouring institutes/companies **(immediate 2025)**. In the **long-term (2035),** only electric vehicles (cars and bicycles) should be supported, or strict limits for gasoline consumption should be set.

1.3. Conclusions

The Leibniz Association and its institutes must promote sustainable mobility in terms of employee commuting and business travel. This increases the attractiveness of public transportation and biking. Such sustainable commuting can be supported by incentives such as JobTickets, and by collaborating with local authorities and transportation companies to offer environmentally friendly infrastructure such as bike paths or bus stops. Furthermore, choosing a train over flying for short-distance business travel should be mandatory, and flights should be limited to a small number per employee per year.

2. Event management

"*A sustainable event is one designed, organised and implemented in a way that minimises potential negative impacts and leaves a beneficial legacy for the host community and all involved.*"

The environmental footprints of events have received increasing attention. Recent developments in virtual meeting alternatives have fuelled critical discussion on the necessity of on-site events and sustainable measures in this context. For example, virtual meetings are clearly more environmentally friendly, much cheaper and less time-consuming for the participants compared to on-site meetings. However, virtual formats can entail technical issues and limit personal contact, which might be disadvantageous for networking. The travel-induced carbon footprint of conference attendees ranges from 0.5 and 3.4 tonnes of CO_2 eq. This does not include contributions from energy and water consumption, and the use of disposable items on-site, which cumulates 1.9 kg of waste per day per attendee. In response to the growing concern for environmental impacts, many organisations and authorities have established sustainable event management guidelines (e.g., Guidelines for the Sustainable Organisation of Events from the Federal Environment Agency or Guide - Sustainable Event Management from the Agency for International Cooperation (GIZ)).

The Leibniz Association and its institutes hold several large-scale events, including conferences, meetings, and public events. Given that many scientific events were either cancelled or postponed due to the COVID-19 pandemic, the number of events is expected to increase in the future. This highlights the urgent need for immediate action for sustainable event management.

2.1. Physical, virtual and hybrid events

Before planning any event, organisers must consider alternatives to a face-to-face event and hold a physical event only if it has a significant impact on achieving the objectives of the event. This may apply to events where active physical engagement and participation of the audience is essential to increase the impact of the event, or where not all participants have access to the infrastructure necessary for a virtual event. Hybrid events (partly physical and partly virtual) should also be considered, as they allow more participants to join while limiting the environmental footprint of the event. Event management guidelines, either at the Association or at the individual institute level, can be useful in decision-making processes **(immediate 2025)**.

If a physical event is necessary, organisers should consider the possibility of bundling this event with other events relevant to the community. This would result in one series rather than separate events; that way, participants travel only once.

2.2. Mobility and infrastructure

- Provide incentives to participants for sustainable transportation (see Section 1. Mobility) **(immediate 2025)**.
- Organise events in central venues with good public transport accessibility and infrastructure for accommodation, dining, and evening recreation **(immediate 2025)**.

2.3. Energy and waste management

- Support venue hosts with sustainable concepts, e.g., use of renewable energy, recycling, composting, carbon compensation, etc. **(immediate 2025)**.
- Avoid single-use items, merchandise waste, and giveaway items, especially plastic products **(immediate 2025)**.
- Provide digital, paper-free information material e.g., QR-code access to documentation **(immediate 2025)**.

2.4. Catering

- Avoid unnecessary waste production, for example, use non-capsule-based coffee machines, and promote reusable and/or biodegradable plates and cutlery in events instead of single-use and/or plastic products **(immediate 2025)**.
- Increase options for vegetarian/vegan/low-carbon footprint meals that are regionally or locally sourced, including seasonal fruits and vegetables **(immediate 2025)**.
- Work with catering companies that create social, economic, and environmental benefits for the local community **(immediate 2025)**.
- Offer leftover food for donations **(immediate 2025)**.
- See also Boxes 6 & 7.

2.5. Communication and education

Communicate with event participants in order to raise awareness for sustainable behaviours. For example, motivating participants to choose low-carbon transportation or meal options with a reduced carbon footprint **(immediate 2025)**.

Box 6. Food production and waste

Food production accounts for more than 25% of global GHG emissions and over 70% of freshwater consumption and is the major driver of biodiversity loss due to habitat destruction. At the same time, approximately a third of produced food is not even consumed, and consequently, food waste accounts for around 6-8% of global GHG emissions. To limit food-associated greenhouse gas emissions and food waste, Leibniz institutes should consult with their associated canteens and cafeterias or food caterers.

Box 7. Drinking water

In most regions in Germany, the water from the tap has drinking quality. Therefore, Leibniz institutes should encourage their employees to drink tap water instead of bottled water which has a much lower climate and social injustice impact. If filtering is required for hygiene reasons, appropriate devices can be installed (e.g. in Berlin through the *Berlin Wasserbetriebe*) that can also add carbonisation for taste. Such measures would decrease the transport of bottled water and reduce emissions and waste as well as save costs, as 1 L of tap water only costs 0.2 cents.

2.6. Conclusions

The Leibniz Association and its member institutes hold a number of small-to large-scale on-site events that significantly contribute to their carbon footprints. Environmental pressures mainly originate from travel, energy and water consumption, and waste disposal. We urge the Leibniz Association and its institutes to consider sustainability an essential component when planning and implementing each step of an event, from mobility to resource management and communication. Before planning any event, organisers must consider alternatives to a face-to-face event and hold a physical event only if it has a significant impact on achieving the objectives of the event. If a physical event is necessary, event guidelines or checklists for employees are necessary to facilitate the management of environmentally and socially responsible events.

Chapter 5. Research and administration

As one of the largest research organisations in Germany, the Leibniz Association carries the social responsibility to set an example and minimise its carbon footprint by promoting sustainable office and research practices. Some actions listed above (see Chapters 2-3) already include aspects of administrative and research practices in terms of resource consumption. Here, we stress additional measures that are important for maximising the positive impact of research while minimising its environmental footprint.

1. Sustainable office practices

To understand the need to circumvent paper usage by digitising research and administration, one must understand the impact of paper consumption on the environment: The paper industry annually consumes 500 million m^3 of wood derived from either tree plantations or forests with functioning ecosystems. The erosion of tree-based habitats- (approximately 10 million ha/year) has caused the loss of biodiversity worldwide. Furthermore, forests are carbon sinks; thus, forests in the EU alone absorb nearly 10% of the total EU greenhouse gas emissions every year. Apart from deforestation, paper production also requires large amounts of energy and water, as the production of an A4 paper sheet alone can use up to 13 L of water.

The global paper consumption can be divided into categories: 55% of global paper manufacturing is used for packaging, 26% for printing and writing jobs, and sanitary and newsprint applications account for 8% and 7% of global paper usage, respectively. According to the Paperless Project, 70% of office waste is paper, and approximately 30% of all print jobs are not picked up from the printer, while 45% of printed paper is trashed by the end of the day.

Therefore, we call on the Leibniz Association and its institutes to reduce paper consumption and initiate a transition to paperless offices and laboratories through digitisation.

1.1. Digitisation

The Leibniz Association and its institutes should opt for digital communication and ensure digital access to scientific and administrative content. For administrative purposes, e-procurement, e-invoicing, e-recruitment, and employee self-services should be implemented. Long-term archiving, validity checks (signatures), and formats (e.g., protected PDFs) should be reconsidered and optimised for digital handling. Furthermore, digital access to all information, including all communications (e.g., about upcoming seminars and talks catalogue), documents and contracts should be prioritised and can be aided by increasing document availability on, for example, specialised databases like Intranets or info screens (e.g., QR-code link to Intranet) **(immediate 2025)**.

To shift from paper- to electronic-based processes, employees must be trained internally or granted access to external workshops and training to build awareness and advance their digital skills.

We recognise that digitisation processes will increase the direct energy demand of research and administrative processes in comparison to analogue paper formats and could be seen as contradicting the measures proposed in Chapter 2. Energy & building infrastructure. Nevertheless, we believe that digitisation, when paired with renewable energy infrastructure (on- or off-site) and sustainable IT (see Chapter 2 – Section 1.4. Sustainable IT for details), still offers large environmental benefits and reductions in GHG emissions, when global deforestation and indirect resource consumption of paper production (energy and water) and printing are considered.

1.2. Paper products

Recycling paper

Recycled paper can save up to 70% of water and 60% of energy in contrast to fresh fibres. We call on the Leibniz Association and its institutes to exclusively procure paper certified by the Blue Angel, which is recycled from used carton and paper and is unbleached, thereby reducing the use of chemicals and water pollution during its production **(immediate 2025)**.

Packaging

Paper packaging can be reduced by consolidating orders, utilising take-back and reuse schemes, and choosing vendors with recycled cardboard **(immediate 2025)**.

Printing

Printing colours and toners can directly affect paper recyclability. Toners used for printers should be recycled, and toners with ecological printing colours (e.g., based on plant oils) should be favoured for future procurement. If new printers are required, multifunctional printers (copy, scan, fax, and print in one) should be chosen based on life cycle analysis according to their ENERGY STAR rating, energy-saving modes, and quick-start technology (e.g., evaluating more sustainable options, such as LED UV printers). To prevent accidental printing, manual activation through PINs or transponders can be installed directly at the device, as done by the FMP **(immediate 2025)**.

Sanitary paper

Similar to printing, sanitary paper for bathrooms, toilets, and cleaning jobs should be shifted towards certified sustainable recycled sanitary paper sources (e.g., certified by the Blue Angel). To further reduce paper consumption in bathrooms and toilets, electric hand dryers should replace paper towels, as they have lower carbon emissions per drying (9-40 g vs 56 g of CO_2 eq., respectively). If expenses for electronic hand dryers cannot be covered, another option would be to switch to cloth roller towel dispensers or have personalised washable towels for each employee **(immediate 2025)**.

2. Sustainable research practices

2.1. Third-party funding

Currently, research funds in the form of grants or stipends are allocated based on research quality without considering the environmental impact of the proposed research projects. Furthermore, funding organisations do not reward sustainable practices by, e.g., additional funds. Funding organisations have to collaborate with researchers to establish sustainable criteria for grant allocation without compromising fairness and equal opportunities. Such measures could include mandatory environmental footprint estimations of the project in the proposals, or awarding special funds for sustainable material costs, sustainable means of transportation when travelling, etc. The Leibniz Association must start a dialog with funding bodies to accompany the sustainable transformation of research operations by rewarding sustainable research while preserving freedom, research integrity, and international collaboration. Such incentives are needed to conduct research in a more climate-sustainable way **(long-term 2035)**.

2.2. Publications and journal access

Digital publications

Research extensively relies on both the availability and correct publication of research results. To extend digitisation strategies, publications in digital-only scientific journals, digital-only subscriptions to journals as well as digital-only publication of in-house research papers and/or books should be mandatory **(immediate 2025)**.

Open Access publication

Besides the straightforward direct reduction of resource consumption through digitalisation strategies of publications and journals, scientific data should also be accessible to other researchers and the public. Public accessibility of research data by Open Access publication has benefits in terms of knowledge transfer and equal opportunities. It also presents potential indirect savings in terms of resources and environmental impacts (fewer repetitions to reacquire the data, less printing, etc.), and enables reproducibility and reuse in future research. Even though the Leibniz Association has laid the foundation for Open Science (see Box 8) in the past, Open Access must be integrated into the publication strategy of all its institutes **(immediate 2025)**.

Box 8. Open Science in the Leibniz Association

To address digitalisation the Leibniz Strategic Forum on Digital Change was formed in 2017 and consequently published a report stressing major hurdles and recommendations for improvement: (1) to stimulate individual digital capabilities of all employees; (2) to boost the organisational digital capabilities, by for example hiring experts to perform SWOT analysis in institutes to identify institute-specific instruments, mechanisms and infrastructure for digitisation; and (3) to promote digital capabilities to external players by making research accessible towards the public. In this sense, the Leibniz Association has already made advances in terms of Open Access by generating LeibnizOpen, an Open Access portal, publishing an Open Access policy and creating the Leibniz Research network LeibnizData which provides data management services.

Collaboration with publishing houses

However, similar to other companies (see Chapter 3 – Section 1.1. Reform through lobbying), publishing houses rarely report their environmental impacts over all scopes. Furthermore, the digital infrastructure needed for Open Science will also have a substantially large environmental footprint (see Chapter 2 – Section 1.4. Sustainable IT), but corresponding data availability is scarce, as the ethical advantages often outweigh climate impact considerations. To transform the scientific publication system towards sustainability, publishing houses must report their environmental footprint for subscription vs Open Access publications, and environmental impacts have to be responsibly balanced against ethical values. The Leibniz Association should put emphasis on sustainable criteria in their publication strategies and should collaborate with publishing houses and policymakers to guarantee fair accessibility of research data while simultaneously decarbonising the process of data storage and distribution **(long-term 2035)**.

Negative data publication

By sharing negative or null results, other scientists can learn from the data, guide their projects in different directions, and spare resources by reducing duplications. Therefore, the Leibniz Association should incentivise the publication of negative data by, for instance, implementing funds for negative data publication **(immediate 2025)**.

2.3. Animal-based research

Lots of research in the life and natural sciences still relies on animal models or animal-derived materials. In 2020, approximately 1.9 million vertebrates and cephalopods were used in laboratories in Germany, which, aside from the animal welfare point of view, requires many resources and has a large environmental impact in terms of housing and breeding.

2.3.1. Animal experiments

To reduce GHG emissions associated with animal experiments, the Leibniz Association and its institutes should aim to replace animal experiments with non-animal alternatives if possible, and reduce the number of animals used for experimental purposes.

Leibniz institutes should, therefore, strongly encourage continuing education for sustainable practices in animal breeding (minimising breeding excess) and housing as well as teaching researchers to obtain the same level of information from fewer animals or to obtain more information from the same number of animals **(immediate 2025)**.

Systems to facilitate the sharing of biological samples between different groups (e.g., Animatch or Models in Translational Oncology) should be implemented at the institute level. Additionally, funds should be made available to improve animal housing units to keep them as energy-efficient as possible **(long-term 2035)**.

2.3.2. Animal-derived materials

Although many technological advances have allowed the replacement of animal experiments with human-derived models (e.g., the generation of induced human pluripotent stem cells (iPSCs) or bioprinting of 3D tissues), many standard research methods rely heavily on the use of animal-derived materials (see Box 9), even those that are meant to replace animal experiments (such as culturing of iPSCs). Therefore, we urge the Leibniz Association and its institutes to reduce their use of animal-based products by choosing synthetic alternatives, educating employees on replacement strategies, and aiding in the development of potential alternatives by collaborating with the industry **(immediate 2025)**.

2.4. Collections

All Leibniz Research Museums host valuable collections. Storing these collections requires very specific infrastructure, from storage shelves (e.g., compactus shelving) to controlled temperature and humidity conditions.

Many sustainability aspects should be considered when designing or renovating such infrastructures: temperature control and HVAC, insulation, illumination, space optimisation, packaging/wrapping materials, etc. **(long-term 2035)**. More details on these topics can be found in previous chapters, especially in Energy-efficient buildings (Chapter 2 – Section 1.3) and Resource management (Chapter 3).

Box 9. Animal-derived materials in Cell Biology

The proliferation of eukaryotic cells in culture often requires animal-harvested materials like serum, Trypsin and Matrigel. While some materials can easily be replaced by synthetically generated proteins (Proteases (Trypsin) or antibodies), other materials like serum or Matrigel are still lacking reliable alternatives even though their generation poses both strong ethical and environmental concerns:

- **Serum**
  Laboratories worldwide rely on supplementing foetal bovine serum (FBS) when culturing eukaryotic cells to guarantee cell survival, growth, and division. FBS is harvested from a bovine foetus of slaughtered pregnant cows, which requires over 1 million foetuses every year. There have been developments for replacement products that need to be tested for feasibility in a high-throughput laboratory context.
- **Matrigel**
  Research considered an animal-friendly alternative like bio printing or stem cell research still heavily relies on Matrigel, which is the extracellular matrix obtained from murine Engelbreth Holm-Swarm sarcoma. To this day, the sarcoma is implanted into mice and grown to maximal size before harvest. Over 13,000 publications on PubMed have utilised Matrigel for their experiments (Search 14.09.2022).

3. Evaluation of sustainable practices – audits & certification

To prevent greenwashing and monitor the progress of implemented sustainable measures, audits should be performed by independent professional externals.

This can, for example, be done by implementing sustainability criteria in the 7-annually evaluation of all institutes by the Leibniz Senate (see Chapter 1 – Section 4. Goals and demands). However, in light of our environmental emergency, the time span of 7 years for an audit is too long. Therefore, the Leibniz internal evaluation should be accompanied by more regular assessments like the environmental management audit of the European EMAS Regulation, as done by the ZALF. Similarly, there are no global policies for sustainable development goals in laboratories; however, recommendations for the best sustainable laboratory practices have been made available by different working groups (mygreenlab, laboratory efficiency assessment framework, etc.). The Leibniz Association should urge or incentivise its institutes to participate in such certification programs, in order to identify and implement best sustainable practices in their institutes. Furthermore, certificates can highlight sustainable achievements and offer an opportunity to raise awareness both inside and outside of the Association.

However, as such certifications can be costly, the benefits of audits vs implementing direct measures with the same funds instead should be carefully considered. Nevertheless, consulting with unbiased professionals in terms of energy and resource efficiency, monitoring progress, etc., should become one of the guiding principles of the sustainable transformation of the Leibniz Association **(long-term 2035)**.

4. Conclusions

Both administrative and research operations must transition to more sustainable practices. This means that the Leibniz Association should be transformed into a paperless organisation through digitisation and digitalisation to reduce paper consumption. Furthermore, the Leibniz Association must collaborate closely with funding bodies to prioritise sustainable research practices through financial aid as well as decarbonising their publication strategies through Open Access publication. Special responsibilities fall to laboratory-based institutes to rethink their use of animals and animal-derived products on a daily basis and to research museums to reduce the environmental impacts of their collections. Finally, the Leibniz Association and its institutes should conduct independent audits to monitor the progress of their sustainability strategies, and sustainable certification processes should be encouraged.

Chapter 6. Knowledge transfer

"*Communicating the knowledge gained by Leibniz institutions to industry, policymakers, and society is a key aspect of the Leibniz Association's strategic objectives. Leibniz institutions respond to society's information needs and to topical questions*."

Research must be communicated to other researchers, policymakers, the industry, and the public. Thus, **research findings can inform debates on societal issues such as climate change and biodiversity loss.** Therefore, knowledge transfer has become an important mission of the Leibniz Association. We argue that this mission must include sustainability topics in all transfer formats (museums, magazines, blogs, public lectures, etc.). In doing so, **the Leibniz Association and its institutes can position themselves as major players in solving these challenges**, while also fulfilling their goals according to the UN's Sustainable Development Goals.

We recommend possible actions by the Leibniz Association and its institutes to set the best possible example by communicating sustainability. All these proposed actions can be implemented quickly (**immediate 2025**), with few costs involved.

1. Research on sustainability

We expect that the most straightforward form of knowledge transfer comes from institutes that directly conduct research on sustainability. The environmental crisis is now discussed extensively, and institutes conducting research on sustainability have a special responsibility to communicate about the topic. For example, the Potsdam Institute for Climate Impact Research (PIK) provides policy advice and engages in knowledge transfer activities (e.g., Fokus Transfer and Climate Impacts Online).

Nevertheless, Leibniz institutes or even Leibniz Research Networks (for example, LRN "Knowledge for Sustainable Development") do not necessarily have great visibility for the general public. Sustainability should become central to all forms of outreach (e.g., *Leibniz debattiert*, *Lange Nacht der Wissenschaften*, *Book a Scientist*, etc.).

2. Sustainable research operations

A large part of knowledge transfer focuses on research on sustainability itself, while projects and measures to conduct research in a more sustainable way are much less advertised. We argue that this aspect should be developed, within the Leibniz Association (headquarters and individual institutes) but also towards the general public. Doing so would show citizens that researchers are also concerned about the climate crisis and do their best to reduce the environmental impact of conducting research. This would make the Leibniz Association and its institutes role models for society.

As a simple action, institutes could add a section on their websites listing all sustainable measures in place (or in planning) and how these measures have had (or are expected to have) a positive impact without forgetting negative impacts. For example, the FMP advertises its new Green Initiative, and the ZALF has a section on environmental management on its website. Publicly highlighting the measures taken and increasing visibility may provide ideas and inspire others. These measures could also be collected and listed on the Leibniz Association's website to help other research organisations in Germany and elsewhere to do the same.

3. Research museums

"*With their research-based permanent and special exhibitions at 12 locations across Germany, the museums reach millions of people every year and play an important part in knowledge transfer. Together, the Leibniz research museums increase understanding of science as a process, and allow people to critically evaluate science and society*."

While all Leibniz institutes should be involved in knowledge transfer, **Leibniz's eight research museums play a special role due to their intense contact with the public**. Therefore, these research museums should be particularly active in sustainability knowledge transfer (e.g., past and present climate, climate change, biodiversity loss, etc.). These topics must become an integral part of all types of outreach formats (exhibits, events, public lectures, blog posts, newsletters, school programs, etc.) at these institutes.

The Museum für Naturkunde Berlin, Museum Koenig Bonn, and the Senckenberg Society for Nature Research have already included these topics in their knowledge transfer programs. Nevertheless, climate change and sustainability are fundamental challenges to our society, as these topics are relevant to all research fields and can be addressed from all perspectives. As such, all other research museums can and should have active knowledge transfer programs on sustainability in general.

4. Education

"Leibniz institutions collaborate intensively with universities – including in the form of Leibniz ScienceCampi."

Although teaching is not the primary task of Leibniz institutes, many Leibniz researchers teach at universities. When developing curricula with university partners, Leibniz institutes and researchers should contribute to the incorporation of sustainability topics (including sustainable research practices and outreach) in all degrees.

Conferences and public lectures on sustainability should be organised to inform researchers and the general public.

Special events (e.g., sustainable weeks) could also be organised as networking events between scientists but also to inform the general public. During these events, institutes, research groups, working groups, and individual researchers can present their research and actions regarding sustainability. The Leibniz conference "*Missions for Sustainability*" is a good example of such an event.

Finally, the Leibniz Association and/or the individual institutes should organise training/workshops on sustainability for their employees, but also for the public. Sustainable use of IT resources should also be addressed during such training/workshops (see Chapter 2 – Section 1.4. Sustainable IT).

5. Conclusions

Research on sustainability must be communicated to other researchers, policymakers, the industry, and the public. Thus, research findings can inform debates on societal issues such as climate change and biodiversity loss. Therefore, knowledge transfer is an important mission of the Leibniz Association. Institutes directly researching climate impacts, mitigation, or sustainability, and Leibniz research museums have a special responsibility to communicate and raise awareness among the public. Furthermore, collaborations with universities should incorporate sustainability to educate future scientists as early as possible. At the same time, sustainable research management, operational strategies, and implemented measures at institutes need to be highlighted and published to help cross-institutional exchange and make the Leibniz Association and its institutes role models for society.

Summary & Outlook

The state of our current environmental emergency calls for an immediate and swift transformation of our society in order to limit global temperature increase, prevent already-now frequent recurrence of natural disasters, and avoid a catastrophic collapse of ecosystems. While the academic system plays an important role in researching human-made environmental impacts and their mitigation, the contributions of the academic sector with regard to its energy and resource-intensive nature cannot be neglected. **The Leibniz Association and its 97 institutes must also reduce their environmental footprints**, as they make up a large portion of the research landscape in Germany. Furthermore, with their expertise in terms of technological advances and the environmental, socio-cultural, and ethical consequences of the climate crisis, they should be at the forefront of developing sustainable research practices.

The first logical step for the sustainable transformation of every institute is to calculate its environmental footprint (over all three scopes; see Box 1) to identify institute-specific sectors with the largest contributions, meaning the largest reduction potential. This also means that environmental footprint assessments need to be standardised and aided by Leibniz headquarters. However, environmental footprints are only a means towards the goal of achieving climate neutrality – identifying where reductions are easily achievable and targeting meaningful and quantitative reduction goals. Thus, concrete actions based on constantly updated evidence must be implemented in parallel, starting now.

In this paper, **we propose immediate (until 2025) and long-term (until 2035) measures for the Leibniz Association and its institutes** to undertake. Due to the decentralised structure of the Leibniz Association, directors and administrations of institutes carry a special responsibility for action because the institutes are largely autonomous/independent in relation to the headquarters. Our recommendations cover the most common energy- and resource-intensive sectors of research institutes like Energy & building infrastructure, Resource management (Water, Procurement & waste), Research & administration, Mobility and Event management.

Nevertheless, as technologies and our understanding of the climate crisis are steadily improving, our recommendations should be viewed as the most feasible measures at the current point in time. Ongoing research will contribute to identifying new fields of action and improved solutions that should then be developed and implemented over time.

Apart from the urgency to reduce the environmental impacts stemming from research operations, the Leibniz Association has a pressing responsibility to ensure climate literacy through **education and knowledge transfer.** The research on sustainability performed at the institutes of the Leibniz Association must be communicated to other researchers, policymakers, industry, and the public to inform debates on societal issues, such as climate change, biodiversity loss, and their mitigation, which goes hand in hand with many of the SDGs. One important means to ensure the accessibility of research data to the public is to support digitisation and Open Access publication in the long term. Knowledge transfer should not only include research on sustainability but must entail successful strategies for transforming research operations. The Leibniz Association, its institutes, and their employees should therefore demonstrate that they too care about our planet, and that they are making every reasonable effort to perform their research in the most sustainable way possible. In other words, they should serve as role models for society. We believe that the sustainable development of the Leibniz Association, as a major player in the German academic landscape, can cause a critical mass effect that inspires other institutions to follow. Yet, this can only work if all members of the Leibniz Association change and communicate their efforts.

We hope that our document will raise **awareness** and help transform the Leibniz Association into a sustainable research organisation. Creating a **culture of sustainability** inside the Leibniz Association will not only lower operating costs and increase employee morale but will also benefit the organisation's reputation.

While a culture of sustainability should be established within the Leibniz Association, its transformation and decarbonisation need to involve all stakeholders of the academic system. As detailed above, there are important interdependencies between stakeholders, and sustainability cannot be established by one actor without the others following along. Therefore, the vision of a sustainable scientific community includes industry, policymakers, funding bodies, publishers, research organisations, administrations, and individual researchers. The pillars of the academic system share the responsibility of transforming framework conditions, such as laws; setting incentives through funding; and optimising infrastructure, materials, and day-to-day operations in terms of environmental sustainability. **While we believe that the Leibniz Association can start a ripple effect in the German academic system and beyond, it must also hold the other actors accountable.** A transformation of the entire academic system without sacrificing core values such as scientific freedom, integrity, and equal opportunities is possible, but it can only be achieved if all actors join in dialogue with the common goal of mitigating our environmental emergency.

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All resources have been cited in the text via hyperlinks. Some of these resources can be accessed via their DOI; below is the list of these resources. Resources without DOI are excluded here because their long-term accessibility is not guaranteed.

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List of actions

<table>
<tr><th>Chapter/Section</th><th>Actions</th><th>Timeframe</th></tr>
<tr><td colspan="3">Chapter 1 – Section 3. Goals and demands</td></tr>
<tr><td rowspan="6">1. Headquarters</td><td>Acknowledge the climate crisis</td><td>Immediate</td></tr>
<tr><td>Commit to climate neutrality or precise GHG reduction goals</td><td>Immediate</td></tr>
<tr><td>Guide and aid institutes with their sustainable transformation by:
Establishing a general sustainability strategy for the Association
Establishing common guidelines e.g., for carbon footprint calculations
Offering financial aid for sustainable measures and setting incentives</td><td>Long-term</td></tr>
<tr><td>Monitor progress of institutes by lobbying for incorporating sustainable criteria in the Leibniz evaluation</td><td>Long-term</td></tr>
<tr><td>Transparently communicate about sustainability inside the Leibniz Association by publishing annual reports including successes and hurdles</td><td>Long-Term</td></tr>
<tr><td>Strengthen the alliance of non-university research organisations to lobby for sustainable research policies and sustainable commercial research products</td><td>Long-term</td></tr>
</table>

Chapter/Section	Actions	Timeframe
2. Institutes	Establish sustainability offices/officers	Immediate
	Assess environmental impact (scopes 1-3) of all activities	Immediate
	Set precise sustainability targets and strategies based on impact assessment	Immediate
	Monitor progression of carbon footprints and effects of implemented measures on an annual basis and make reports accessible to the public	Long-term
	Establish participatory decision-making processes involving all employees at institutes	Long-term

Chapter/Section	**Actions**	**Timeframe**
Chapter 2 – Energy & building infrastructure		
1. Energy infrastructure		
1.1. Energy sources	Switch to renewable energy/gas providers	Immediate
	Increase self-sufficiency by on-site renewable energy infrastructure	Long-term
1.2. Energy consumption	Monitor energy consumption in institutes	Immediate
1.3. Energy-efficient buildings	Optimise illumination by motion sensors and awareness campaigns	Immediate
	Switch to renewable heat providers	Immediate
	Increase self-sufficiency by on-site renewable heating infrastructure or recycling excess heat	Long-term
	Optimise heating by centralised time-based controls and awareness campaigns	Immediate
	Optimise air exchange rates based on occupancy and hazard assessment	Immediate
	Install *Demand Controlled Ventilation* in laboratories	Long-term
	Optimise air-conditioning infrastructure by reducing *reheat*	Long-term
	Educate employees on sustainable handling of exhausts	Immediate

Chapter/Section	Actions	Timeframe
1.4. Sustainable IT	Monitor energy consumption of IT processes	Immediate
	Optimise infrastructure and location of data centres (colocation, server-less, etc.)	Long-term
	Optimise long-term data storage/computing	Long-term
	Train employees on sustainable data handling	Immediate
	Train employees on sustainable e-mail practices	Immediate
	Train employees on sustainable online meetings/video calls	Immediate
	Train employees on sustainable remote data access/mobile work	Immediate
1.5. Appliances	Monitor energy consumption of appliances by installing energy metres	Immediate
	Generate proper handling introductions and instructions	Immediate
	Install booking systems and implement switch-off routines	Immediate
	Invest in energy-efficient models	Immediate
	Raise awareness of energy consumption of individual appliances and their operation costs	Immediate

Chapter/Section	Actions	Timeframe
2. Building infrastructure		
2.1. Modernisation and renovation	Modernise existing infrastructure to improve illumination, insulation, ventilation, air-conditioning, and biodiversity	Long-term
2.2. Sustainable construction	Design new buildings under highest sustainable standards (BNB Gold): • Install renewable energy/heating sources on-site • Optimise HVAC • Optimise illumination and natural light distribution • Maximise insulation and passive heating and cooling • Install reclaimed water systems • Include biodiverse building features	Long-term
	Utilise sustainable building materials	Long-term
2.3. Preservation of biodiversity	Green institutes and campuses	Immediate
	Reduce light pollution from buildings	Immediate
	Increase nesting space for wild animal populations	Immediate

Chapter/Section	**Actions**	**Timeframe**
Chapter 3 – Resource management		
1. Procurement		
1.1. Reform through lobbying	Lobby with policymakers to make sustainable procurement the default	Long-term
	Enforce demand for sustainable products and build climate resilience in supply chains	Long-term
1.2. Restructure	Centralise procurement of common materials and consolidate orders	Immediate
	Implement institute-wide inventories	Immediate
	Establish facilities and facility managers	Immediate
1.3. Rethink	Apply sustainable criteria when choosing consumables, appliances, and vendors: • Reduced carbon footprint; certifications • Reusability • Safety • Take-back schemes	Immediate
	Create demand for sustainable products with sales representatives	Immediate
	Educate employees on sustainable ordering procedures	Immediate

Chapter/Section	Actions	Timeframe
2. The 3 R's: Reduce. Reuse. Recycle		
2.1. Reduce	Monitor consumables ordering and prevent over purchasing	Immediate
2.2. Reuse	Replace plastics with reusable glass items	Immediate
	Reuse single-use plastics when possible	Immediate
	Procure second-hand instruments	Immediate
	Establish appliance exchange/lending platforms	Immediate
	Donate redundant appliances	Immediate
2.3. Recycle	Establish easy to follow waste separation in accessible spots with proper labelling	immediate
	Educate employees on recycling streams and waste separation	Immediate
	Implement composts	Immediate
	Collaborate with waste contractors for energy recovery	Immediate

Chapter/Section	Actions	Timeframe
3. Water		
3.1. Direct water consumption	Install water metres on instruments to replace outdated machines	Immediate
	Install aerators on all faucets	Immediate
	Collect rainwater for gardening purposes	Immediate
	Educate staff on the use of ultrapure and distilled water in laboratories	Immediate
3.2. Indirect water consumption	Monitor the direct and indirect water footprint of institutes	Long-term
	Consider water footprint as a criterion for sustainable procurement	Long-term
3.3. Reduce wastewater and pollution	Reduce disposal of petroleum-based pollutants and detergents	Immediate
3.4. Reuse of waste/greywater	Install reclaimed water systems on institutes and new buildings	Long-term

Chapter/Section	Actions	Timeframe
Chapter 4 – Mobility and event management		
1. Mobility		
1.1. Commuting	Promote bicycle use by financial incentives and community building	Immediate
	Develop bike infrastructure with local authorities	Long-term
	Promote use of public transport by financial incentives like JobTickets	Immediate
	Develop public transport network around institutes together with transport companies	Long-term
	Redesign parking infrastructure towards electric cars	Long-term
	Invest in sustainable company vehicles	Long-term
1.2. Business travel	Make train the default mean of travel for short-distance (<1000km) trips	Immediate
	Define thresholds for business flights per employee	Immediate
	Choose sustainable travel agencies	Immediate
	Incentivise online participation of conferences	Immediate
	Invest in online conference tools and provide necessary infrastructure	Immediate
	Train employees on online conferencing	Immediate

Chapter/Section	Actions	Timeframe
2. Event management		
2.1. Physical, virtual and hybrid events	Consider alternatives to physical meetings and hold face-to-face events only when necessary	Immediate
2.2. Mobility and infrastructure	Organise events in well-connected locations and incentivise the use of public transport	Immediate
2.3. Energy and waste management	Support venues with sustainable concepts	Immediate
	Avoid waste by abolishing single-use, merchandise and giveaway items and providing digital information materials	Immediate
2.4. Catering	Increase vegan options/regionally sourced meals	Immediate
	Corporate with companies that create benefits for the local community	Immediate
2.5. Communication and education	Raise awareness among participants for sustainable behaviour	Immediate

Chapter/Section	**Actions**	**Timeframe**
Chapter 5 – Research and administration		
1. Sustainable office practices		
1.1. Digitisation	Digitise administrative documents and transform towards e-procurement, e-recruiting, and e-invoicing	Immediate
	Make all administrative and scientific information digitally accessible	Immediate
	Train staff on digital skills	Immediate
1.2. Paper products	Switch to recycled printing and sanitary paper	Immediate
	Implement sustainable printing infrastructure	Immediate
2. Sustainable research practices		
2.1. Third-party funding	Lobby with funding bodies to incentivise sustainable research	Long-term
2.2. Publication and journal access	Collaborate with publishing houses to transform towards decarbonised digital publications only	Long-term
	Make Open Access publication mandatory	Long-term
	Promote publication of negative data	Immediate
2.3. Animal-based research	Educate staff on sustainable animal breeding and experimental practices	Immediate
	Facilitate animal/biological sample sharing between groups/institutes	Long-term
	Reduce or replace animal-derived materials in cell biological research	Long-term
2.4. Collections	Optimise infrastructure of collections in research museums	Long-term

Chapter/Section	Actions	Timeframe
3. Evaluation of sustainable practices		
3.1. Audits and certifications	Monitor success of sustainable transformation by independent audits or certification processes	Long-term

Chapter/Section	**Actions**	**Timeframe**
Chapter 6 – Knowledge transfer		
1. Research on sustainability	Communicate about research in sustainability using all forms of outreach	Immediate
2. Sustainable research operations	List all sustainable measures in place (and in planning) on each institute's website	Immediate
	Centralise implemented measures of all institutes on the website of the Leibniz Association	Immediate
3. Research museums	Develop strategies to integrate sustainability in all forms of communication with the public	Immediate
4. Education	Incorporate sustainability topics in university curricula	Immediate
	Hold conferences and public lectures about sustainability	Immediate
	Organise special events, workshops, trainings about sustainable research practices	Immediate