Towards Sustainability in Research at D-PHYS/ETH

D-PHYS Working Group CO_2, ETH Zürich

Summary and Suggestions – October 2020

Abstract

In 2020, the Department of Physics (D-PHYS) at ETH Zürich initiated a working group targeted at assessing and reducing the CO_2 emission impact at the department. This document reports on the discussions of the working group and summarises the resulting suggestions. The work and report were endorsed by the department on 2 October 2020.

1 Executive Summary

Climate change is a central challenge of our times. Efforts to avert further damage are going to shape the immediate future of our society, and they will co-determine the long-term development of humankind. Scientists study the earth's climate in detail – how it changes, the causes for its evolution as well as the consequences thereof. They also work towards solutions on the basis of scientific knowledge. However, scientists also take a share in the progressing of global warming by means of their ongoing scientific operations – just as most sectors of society do.

Climate models have long shown, and continue to do so today with greater accuracy and certainty, that global warming is largely caused by anthropogenic CO_2 emissions. Climate impact research asserts that the best way to minimise the effects of global warming is to reduce these emissions as quickly as possible and to achieve a net emission of zero within the next few decades for all gases contributing to the greenhouse effect including CO_2 among others. At the same time, the reduction measures taken so far by the global societies are too hesitant to be appropriate to the seriousness of the situation. This development is perplexing, a research topic in itself, and it calls for crafted measures to enable further progress. Either way, it is inevitable that humankind will adjust to the climate change it conjured – by voluntary efforts or by force of nature. It is beyond doubt, that the point at which we exit the emission curve, i.e. the integral amount of CO_2-equivalent released into the atmosphere, is decisive, and this justifies a sense of urgency. Adapting early is expected to be much easier than late and with even more drastic measures.

Clearly, physics is at the foundation for climate research. However, the basic research carried out at D-PHYS is at a rather fundamental level in view of developing solutions of current relevance to counteract the climate crisis. Worse, the way we advance our research in experiments and by scientific exchange entails CO_2eq emissions, particularly through air travel and production of research equipment. At present, it both is elementary for research and it intensifies global warming. We may feel caught up in this conflict of interests and perceive a very limited influence on this global scale problem. However, by taking several steps into the right direction, we can make an actual difference, at our department, at ETH and beyond. And as these steps are ultimately necessary, it makes perfect sense for us to stay in control by taking them now instead of waiting and assessing and ultimately lagging behind. By taking up the responsibility society entrusts us with, we want to act positively and consistently to address the climate crisis within our professional life, and thus become part of the solution.

To this end, the CO_2 working group was initiated on request of D-PHYS with the aims to:

- assess the climate impact of the scientific operations at D-PHYS;
- propose actions, best practices and recommendations to reduce CO_2eq emissions;
- prepare this report of our work for the attention of the department.

As an overarching goal we aim at a CO_2eq emission path for D-PHYS that *is compatible with the goals of the Paris agreement* (upon scaling to a global level). More broadly, our goal is to enable and facilitate *an environment for research, teaching and work* which encourages sustainable behaviour rather than to disfavour it. There is now the opportunity to establish D-PHYS as a pioneer in adopting a sustainable mode of operations within ETH Zürich and thus to help ETH become a *role model for science* in this regard.

We took as our main task to find and discuss items, actions, recommendations and policies that are suitable to achieve these goals. With respect to the general and specific challenges in counteracting the climate crisis, we have chosen some guiding principles in designing and fine-tuning the suggestions:

- In order to be effective, our focus was on aspects which have a *large impact* on the climate, and over which we have *actual control*. Eventually all other aspects will need to be addressed as well, even if difficult, and by prioritising wisely, we can allocate more time to find solutions for the latter. However, we have to act on items with lower impact as well, especially if they are easy to fix.
- Good measures will be a continued effort that ought to be *carried by everyone* in D-PHYS; ideally their implementation should not rely solely on the commitment of individuals.
- Good measures feature a *simple and intuitive* approach, they ought to be *easy to communicate* so that their impact can unfold beyond D-PHYS with minor efforts.
- Attention is paid to potential and perceived *conflicts of interest* with other aspects of our operations, in particular where our competitiveness may be affected.

This document presents a point of view which the members of the CO_2 working group back broadly and suggestions that we consider useful overall. In the D-PHYS *Departementskonferenz* meeting on 2 October 2020, the work and report were presented to the department. The department subsequently voted to endorse and support the work and this report. The endorsement expresses a broad consensus throughout the department in making our scientific operations more sustainable with regard to their climate impact. This consensus will enable a positive and active role of D-PHYS when facing the challenges of climate change and perpetuate changes at ETH and in our society. The endorsement is not meant to imply that every D-PHYS member will necessarily agree with every item presented in the report or will follow every suggestion in the future.

The document contains detailed reasoning for the point of view and all suggested items. In Section 2, we first provide basics on the climate crisis, and discuss particular challenges towards a sustainable science. In Section 3, we then provide insight into the current status on the different levels from society and ETH to D-PHYS by collecting and presenting relevant data (e.g. on our current CO_2eq emissions and how they distribute between heating, electricity, grey energy and travel). Our suggestions are explained and rationalised in detail in Section 4. We found it useful to classify them in three categories:

- ***actions*** *that we propose to implement as policies of D-PHYS, such as revised emission goals, measures to reduce air travel and promotion of videoconferencing;*
- ***guidelines*** *that are intended for implementation by individuals in the sense of a best practice, e.g. the participation in virtual conferences or sustainable travel planning;*
- ***ideas*** *for further development and long-term implementation by the department or in a larger context, for example ETH-wide, such as possible incentives for sustainable research.*

An overview of the suggested actions of the first category is given in the table below with links to the respective sections in the document.

The results of our work, such as this document, are made accessible via a website:

https://www.phys.ethz.ch/sustainability

Further internal and external resources, such as collected relevant data, tools (e.g. apps developed by other universities to monitor their CO_2eq emission) or news and events, will be announced at this website. For instance, a departmental wiki will serve as a living resource where the experience and recommendations of our pioneering activities can be shared with peers inside and outside of D-PHYS.

List of Proposed Actions

The following table lists all suggested items which are characterised as actions. These are the most natural candidates for a formal implementation by the department.

4.1.A	All scientific meetings, workshops, conferences at D-PHYS offer the possibility of online participation for speakers and participants.
4.1.B	Scientific seminars and colloquia at D-PHYS are open to remote talks.
4.1.C	Committee meetings including doctoral defences are open for external members to participate remotely by videoconferencing.
4.2.A	Members of D-PHYS travel by train to destinations which can be reached by train within 6 hours.
4.2.B	Our guidelines for travel by train are communicated to visitors from continental Europe and UK.
4.3.B	The department agrees on a set of revised goals for the anticipated CO_2 equivalent emission path regarding travel at D-PHYS.
4.4.D	D-PHYS members assess the climate impact of the scientific events they organise (including visitor invitations) in their planning stages.
4.6.D	Courses with sustainability/climate context are made creditable towards physics bachelor/master degrees.
4.7.A	Our aims, strategy and efforts in implementing sustainability in our operations are presented to the external evaluation committee in Autumn 2020.
4.7.C	D-PHYS maintains a mailing list on sustainability where news, events and suggestions can be communicated to interested department members. A departmental wiki on sustainability collects knowledge, implementations and ideas.

Working Group

The working group convened several times between March and June 2020 by videoconferencing. Furthermore, many discussions in small subgroups also involving external actors (ETH sustainability, ETH air travel monitoring project among others) were initiated to discuss various aspects of the topic. This document was written up as a result and a summary of these discussions by members of the working group.

The working group consists of D-PHYS members from all levels and all institutions:

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The current version of this work can be found at:
https://www.phys.ethz.ch/sustainability

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2 Challenges of the Climate Crisis

We start with an outline of the general challenges in the context of the climate crisis including some considerations of our particular situation in science, research and education. This is meant to provide a background to understand the motivations for the subsequent proposals. This introduction is written by informed physicists, and there is no intention to portrait a complete picture of climate change research and related science.

2.1 Global Warming, Paris Agreement and the Climate Crisis

The combustion of fossil fuels and the subsequent release of the produced gas CO_2 into the surroundings change the composition of the earth's atmosphere to the extent that the capacity of the earth's surface to store thermal energy from incident sunlight is enhanced by the so-called greenhouse effect. Unfortunately, this change is permanent and cumulative. In other words, for every amount of released CO_2, the global average surface temperature of the earth increases by a corresponding amount (in linear approximation). Importantly, the released CO_2 naturally remains in the atmosphere for centuries or millennia to come, and thus makes the warming effect persistent. The present global average temperature is already approximately 1°C above pre-industrial levels, and the present global emission rate of CO_2 as well as other gases with relevance to the greenhouse effect, so-called greenhouse gases (GHG), into the atmosphere is sufficient to raise the global surface temperature within few decades significantly further. This global heating will have a substantial effect on the earth's climate system, ecosystems and eventually cause sea levels to rise, all of which bear a large risk of seriously compromising the living conditions for large parts of the global human population.

The above mechanisms and relationships ranging between elementary physics, climate science and extending into agriculture, economy and sociology have been studied and understood broadly for a long time and they are being investigated in greater detail where needed. The scientific findings and projections on this topic have been summarised by the UN-based Intergovernmental Panel on Climate Change (IPCC) in a sequence of assessment reports and special reports (the latest published report is AR5 while AR6 is underway). These results on climate change and its implications have prompted the international community to come to several agreements which were meant to reduce and limit the amount of GHG emissions. The latest and most prominent international agreement is the so-called Paris Agreement of 2015 which has been signed by almost all nations including Switzerland. «*The Paris Agreement's long-term temperature goal is to keep the increase in global average temperature to well below 2°C above pre-industrial levels; and to pursue efforts to limit the increase to 1.5°C, recognizing that this would substantially reduce the risks and impacts of climate change. This should be done by reducing emissions as soon as possible, in order to "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases" in the second half of the 21st century. It also aims to increase the ability of parties to adapt to the adverse impacts of climate change, and make "finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development."*» [Wikipedia, Paris Agreement]. Subsequently, the IPCC composed a special report on Global Warming of 1.5°C (SR15) to address the emission pathways to achieve the 1.5°C degree goal and the risks of missing it. «*Its key finding is that meeting a 1.5°C target is possible but would require "deep emissions reductions" and "rapid, far-reaching and unprecedented changes in all aspects of society." Furthermore, the report finds that "limiting global warming to 1.5°C compared with 2°C would reduce challenging impacts on ecosystems, human* *health and well-being" and that a 2°C temperature increase would exacerbate extreme weather, rising sea levels and diminishing Arctic sea ice, coral bleaching, and loss of ecosystems, among other impacts. SR15 also has modelling that shows that, for global warming to be limited to 1.5°C, "Global net human-caused emissions of carbon dioxide (CO_2) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050."*» [Wikipedia, Special Report on Global Warming of 1.5 °C]

As part of a public, scientific and educational institution, D-PHYS has an obligation to act in accord with the Paris Agreement. Moreover, to do so will be in its own interest. This amounts to investigating the GHG emissions generated by its own operations and to adjust them as far as possible and in balance with its other objectives with which a reduction may be in conflict. Furthermore, D-PHYS needs to understand where it can contribute to research, development and education to facilitate the transition towards a climate neutral society and economy.

However, we are facing a paradoxical situation: On the one hand, (i) the scientific evidence for anthropogenic global heating and the existential risks in continuing on an exponentially increasing GHG emission path is backed by overwhelming consensus within the scientific community; (ii) the goals of the Paris Agreement are considered to be technologically achievable (albeit only with substantial efforts); (iii) the public becomes increasingly aware and concerned of the implications of GHG emissions leading to detrimental climate change. On the other hand, global GHG emissions keep increasing steadily rather than showing any sign of slowing down (the concurrent coronavirus pandemic seems to momentarily suppress a significant amount of GHG emissions, but these will have a lasting impact only if the underlying behaviour changes for good). Evidently, there are conflicts of interest and other effects of diverse nature that slow down progress towards a climate neutral society. These are important to realise and understand so that we can effectively address the issues we encounter at D-PHYS, at ETH and/or in Physics and eventually in the scientific community. Let us point out and illustrate a few of these challenges that may be particularly relevant to the operations of science in general and at D-PHYS/ETH and the legitimate interests that stand behind them.

2.2 Challenges for Sustainable Science

It is clear that GHG emissions are not dominated by a single activity of our society. In order to make progress towards achieving the goals of the Paris Agreement, all sectors of GHG emissions will need to be addressed. And even though there are still some years or perhaps decades left to ultimately meet these goals, the transition is a *major enterprise*, and planning efforts necessarily *need to take place immediately* in order to *preserve our chances* for a successful transition with moderate *climate risks*. As CO_2 emissions have a persistent effect on the global average surface temperature, it can further be said that *every avoided ton of combusted fossil fuels counts*, namely towards limiting global temperatures and thus in yielding more time for the transition towards climate sustainability.

Clearly, there are conflicts of interest between reducing GHG emissions and running our scientific operations at highest efficiency. We need to acquire equipment and construct scientific experiments, we need energy to conduct them, we need buildings to host experiments and offices, and last but not least we need to interact with colleagues around the globe to collaborate, communicate and exchange our thoughts, ideas and progress. In our current mode of operation, all of these lead to GHG emissions at various levels of magnitude. There is no practical way to eliminate GHG emissions altogether in the near future unless we cease scientific operations (but this is evidently not our intention). Therefore, our main task will be to align the way we conduct research with sustainability while preserving the scientific content and maintaining our agility in research.

We surely need to rely on developments in other branches of technology to achieve an emission-neutral operation for us. Our contribution towards their expedited development can be to actively generate a demand where we can make use of them rather than continuing to rely on traditional methods with higher GHG emissions. And until such sustainable methods have become established and readily available, we may have to invest extraordinary efforts in conducting our research in order to avoid climate-detrimental methods. Finally, there are also aspects where the primary responsibility is on us to adjust our operations.

A serious complication in following these goals is that their weighting and prioritisation is difficult to assess. There is no single scale according to which "sustainability" of a method can be evaluated, and the perceived importance will vary largely with the observer. This adds another factor to a multi-factor decision making process next to the financial budget, time, feasibility and quality to name just a few. It will be tempting to ignore this factor as far as it is not tied to financial aspects in the form of a significant CO_2 pricing or tax. Even though difficult, such complications do not relieve us from the duty to properly take the factor "sustainability" into account in our operations. In fact, as decision-makers in a leading educational institution, we are in the best position to address them.

A relevant point is that there will be implementation costs for most changes of the mode of operation. In order to keep the analysis and implementation at a feasible level, we should focus our attention on those aspects which have a significant effect and which are under our influence. Beyond these, there are many other aspects which will ultimately need to be addressed. Here, we should address lesser issues which can be fixed with manageable efforts along the way, but this should not distract us from keeping our priorities focussed on the big picture.

2.3 Perspectives and Timelines

A very powerful tool towards understanding how to address the challenges of the ongoing climate crisis is to assume a perspective of the future and think backwards towards the present. A worthwhile perspective for the case at hand is one in which our society (and thus our research) has reached a steady state with regard to fossil fuel combustion and GHG emissions. Three distinct scenarios come to mind:

1. Humankind has acted according to the goals of the Paris agreement or has taken a similar path to maintain the global average surface temperature at a tolerable increase. Correspondingly, society operates at a level of net-zero GHG emissions.
2. Humankind has used up all available fossil fuel resources. This society will also have net-zero GHG emissions by definition.
3. The average surface temperature rises by an intolerable amount, leading to a host of adverse effects for society and economy as projected by climate impact research (see also the IPCC reports). In this case, there will be strong incentives or imperatives for humankind to avoid further GHG emissions (otherwise this scenario will ultimately run towards scenario 2).

These steady-state scenarios have in common that society will operate GHG-neutrally, but they differ in the cause for the avoidance of fossil fuels: for 1 it is our own will; for 2 it is the finiteness of resources; for 3 it is environmental deterioration. All of them boil down to the fact that the earth is a system of finite spatial extent, and consequently, the amount of useable resources is finite and so is the capacity to absorb waste products: this implies that eventually (i) society will operate at net-zero GHG emissions, and so will our research – there is nothing we can do about it – but we do have an influence on (ii) the nature of this final state, (iii) how it will be reached, and (iv) how long the transition will take. Let us elaborate:

As society will (i) operate at net-zero GHG emissions, it is evident that we must eventually base our operations on renewable resources rather than fossil ones if we wish to keep our society operational. Finding this sustainable mode of operation follows directly from the finiteness of our planet's system. This is not an optional form of environmentalism – it is a necessity.

The nature of the future equilibrium state (ii) is still widely undetermined. For example, it is of central importance how habitable the earth's ecosystems will be and to what extent they will be able to support the human population – locally as well as globally. And for our most immediate professional concern, this determines the amount and quality of research we will be able to pursue. Scenario 1 is considered our best bet in preserving chances of generally favourable conditions. In scenarios 3 and 2 the potential of humankind will be hugely limited in many regards due to a reduced set of practically available resources and by poor environmental conditions. In this case, humankind may even be forced to engage in widely consequential attempts to alter the earth's atmosphere by means of geoengineering in order to mitigate excessively high temperatures. Along these lines, the ability to productively perform research in physics will likely be compromised as well.

This future state is what we shape by our present actions. Hence, the crucial question (iii) is precisely how we will reach the sustainable state. Ideally, the transition from the present to the future state will be as smooth and adiabatic as possible when bearing in mind the conceivable impact of discontinuities at this scale on humankind.

Perhaps, the most influential factor is the timeline (iv). Unfortunately, science and projections suggest that scenario 1 may only be realised if all necessary steps are taken within very few decades – perhaps there is not even as much time available. Failure to take such decisions swiftly will lead into scenario 3 whose ramifications will also turn into reality within few decades – and in parts have already become apparent at present. Only scenario 2 with an abundance of fossil coal reserves could become reality as far away into the future as a century; however, the accompanying environmental deterioration would seem to make the full exploitation of fossil resources impractical and thus favour the realisation of scenario 3 over scenario 2.

As a side remark, a loose analogy can be drawn to our society's concurrent handling of the developing coronavirus pandemic: In that context we vividly observe that a decisive reaction which is based on analysis of numbers and dynamics in combination with established knowledge of the research experts (in effect, "flatten the curve") has a huge impact how well a given society fares in terms of infections. It shows that it does pay off to listen to the experts and to react in a timely manner.

By construction, a sustainable society will only permit few exceptions of using fossil fuels. At present, a viable scheme is to engage in CO_2 compensation: Here the combustion of fossil fuel in one place or sector is justified by actively bringing forward the avoidance of CO_2 emissions in other places or sectors where this is more easily feasible. Reliance on this practice is questionable and by construction it can only be of reasonable utility within the next decade or so (at around 30 CHF/t with a sharp increase expected for the future). In the long run, a most relevant unknown is whether carbon capture and storage (CCS) techniques will become available at a large scale and whether there will be alternative renewable fuels as energy carriers for transport and the economy. While there are many ideas and prototypes in this regard (at an order of magnitude of 1000 CHF/t for CCS), these are still far from being at the level of large-scale deployment (the future price-tag is estimated at an order of magnitude of 100 CHF/t or lower), and it is questionable whether a significant capacity can and will be reached. Therefore, until these developments are reliably foreseeable, we should not anticipate that they will become available to us and our own operations.

In conclusion, a very relevant question for us is how a sustainable mode of operation for our science can look like. This is how, optimistically speaking, future generations of physicists (including some of us at a later point in our careers) will advance our research. With a clear outlook in mind, it will be possible to develop useful ways of transition towards sustainability. Such a perspective will also naturally motivate the transition and illustrate its necessity: we will reach a state of net-zero emissions, either by our own choice or by force majeure. Our preference must be the former, and with the same spirit of our handling of the coronavirus pandemic at D-PHYS in early 2020, we want to take on a leading role in actively managing the change towards a sustainable science.

2.4 Communication, Fairness and Propagation

It is evident that the actions of any group of individuals will not have a significant direct effect on the global average surface temperature for the better or for the worse. Unfortunately, this insight is often used as an excuse for inaction. Yet, in fact, everyone takes responsibility for the aspects under their control, and the decision-makers in D-PHYS happen to be in a position of elevated influence.

A relevant complication is that established methods making use of fossil fuels often have a different cost-benefit profile than novel methods which respect sustainability: Even though the latter can well be competitive or outperform the former on a global scale, the former often has clear benefits for the individual user. This is because the costs of GHG emissions (estimates by German *Umweltbundesamt* range between 200 CHF/t and 800 CHF/t depending on their precise definition) are realised later and at a global scale rather than being charged immediately to the individual user. Moreover, the implementation of novel methods implies further costs of various kinds. This imbalance of cost-benefit profiles effectively penalises the development and use of sustainable methods and can render their users less competitive in the present playing field.

What this means is that the effectiveness of any sustainability measures implemented by some group depends largely on whether they will influence others to follow with similar measures. Importantly, a broader implementation will also keep the playing field levelled and help maintain a fair competition in science. Thus, for us, it is essential that measures are not merely implemented, but rather communicated prominently to peer groups at ETH, in the physics community and the general public in order to multiply their effect and to increase fairness. As physicists at a leading educational institution, we generally enjoy a high level of trust and recognition, and our department can serve well as role model in this regard and this may eventually discourage others from resorting to climate-detrimental activities. Consequently, our decisions should send a clear message, and thus it makes sense to focus our attention on such measures which can be communicated well and with minimal efforts. In particular, this will be facilitated by paying close attention to a positive framing, e.g. by putting the focus on achievements and innovation.

3 Status Quo

In this section we give an overview of the status quo concerning the climate impact and sustainability goals for D-PHYS and related entities.

3.1 Federal Administration

Energiestrategie 2050, Vorbild Energie und Klima (VBE):
https://www.energie-vorbild.admin.ch/vbe/de/home.html

- initiative towards establishing 10 large institutions and companies as role models and innovators in energy efficiency and climate; ETH domain is one of the contributing actors.
- aim to make actors 25% more energy efficient (reference 2006) during the first phase 2013 – 2020.
- implement 39 defined measures from 3 domains: buildings, mobility, green IT.
- targets are being met or even overshot; second phase 2021 – 2030 is in planning stage.

Klimapaket Bundesverwaltung, *Aktionsplan Flugreisen* (July/December 2019):

- reduce overall domestic CO_2 emissions to 50% (reference 2006) until 2030;
- achieve net-zero GHG emissions due to operations by compensation via emission certificates until 2030;
- incorporates scopes 1, 2 and certain domains of scope 3 (see below for definition): business travel, printing, water, waste; later also IT hardware, catering;
- reduce CO_2 emissions from business travel by 30% (reference 2019) until 2030.

Totalrevision CO_2-Gesetz, Nationalrat (June 2020):

- reduce overall CO_2 emissions to 50% (reference 1990) until 2030;
- achieve 60–75% of CO_2 emission reductions within Switzerland;
- impose surcharge of 30–120 CHF on (return?) flight tickets.

RUMBA (*Ressourcen- und Umweltmanagement der Bundesverwaltung*):
https://www.rumba.admin.ch

- federal departments are responsible to achieve the goals of the *Klimapaket*
- ETH Zürich is a peripheral unit of RUMBA (facilitate monitoring and implementation), but not part of it.

3.2 ETH Zürich

ETH has a central sustainability office where its overall sustainability strategy is coordinated. This office communicates relevant information to the ETH community and beyond, and it provides resources. On the student side, there is the Student Sustainability Commission (SSC). Furthermore, ETH has an environmental commission, and some environmental activities are coordinated at the ETH council:

- ETH sustainability
  https://ethz.ch/sustainability

- Student Sustainability Commission
  https://ssc.ethz.ch
- ETH environmental commission
  https://ethz.ch/services/en/organisation/boards-university-groups-commissions/umweltkommission.html
- ETH council environmental aspects
  https://www.ethrat.ch/de/themen/umwelt-energie

ETH monitors its environmental impact since the early 2000's and it publishes reports with increasing level of detail also extending into different areas of sustainability:

- ETH sustainability reports
  https://ethz.ch/sustainability-report

CO_2 emissions are grouped into three scopes:

- scope 1, direct emissions, fuel combustion: mostly heating and cooling
- scope 2, indirect emissions, purchased electricity: mostly electricity
- scope 3, indirect emissions: consumption, goods, services

Emission data for scopes 1 and 2 is available in good quality; corresponding data for scope 3 only for selected domains. An estimate of the emissions by domain is given in the following table:

domain	**climate impact**	**GHG emissions**
scope 1: heating	medium *	
scope 2: electricity	low *	
buildings & infrastructure	*high*	
building operations and maintenance	medium	
Versorgungsmedien	low	
scientific machinery	*high-medium*	
ICT hardware, software	medium-high	
Informationsmedien	low	
lab supplies	*high*	
other goods and services	medium	
personnel and business expenses	medium	
business travel	*high* *	
commuter travel	low *	
catering	low	

Data from ETH sustainability reports (marked by asterisk). Preliminary estimates on the other scope 3 domains are provided in the report "Scope 3 Treibhausgasemissionen der ETH Zürich" (2019, unpublished) which is presently undergoing further consultations towards publication. Each barrel represents an estimate of around 5000 t[CO_2eq]/yr GHG emissions. The climate impact column very roughly estimates the relative importance of the respective domains. Please bear in mind that a general difficulty in the collection and presentation of such data is how to precisely attribute the effective GHG emissions. It is however clear that major contributions arise from the domains *buildings & infrastructure, scientific machinery, lab supplies* and *business travel.* Note that many of these goods and services are essential for ETH operations at a basic level, and some of the associated emissions are not controllable well from within ETH.

Some relevant reference data for ETH for the years 2006/2012/2018 is (from sustainability reports):

employees	FTE	6300 / 10200 / 9400
ETH members	FTE	15500 / 17400 / 21400
area	m^2	650000
electricity consumption	kW	9500 / 12800 / 11800
heat provided	kW	8300 / 5800 / 5000
heating renewable fraction	%	18 / 42 / 45
water consumption	m^3	300000
budget basic funding	M CHF/yr	~ 1300 (2018)

GHG emissions due to various domains for the years 2006/2012/2018 (from sustainability reports) in t[CO_2eq]/yr:

heating	11800 / 6800 / 7100
electricity	3000 / 1600 / 1400
business travel	12700 / 17600 / 17000
commuter travel	1700
printing	300
total (of accounted domains)	29900 / 29000 / 28500

ETH is a part of the Swiss federal administration and therefore supposed to achieve net-zero emissions by 2030. This will putatively include selected scope 3 emissions which clearly dominate the scope 1 and 2 emissions (heating, electricity). Planning is in progress.

3.3 Air Travel Monitoring and Goals

In response to the federal initiative VBE, ETH established the Mobility Platform to promote sustainable mobility at ETH Zürich in order to reduce CO_2 emissions and energy consumption:

- https://ethz.ch/mobility

A sizeable fraction of the GHG emissions at ETH is due to business travel:

- Emissions due to travel have been monitored since around 2006.
- Business travel accounts for over half of the GHG emissions at ETH Zürich *when restricted to* the collection of domains for which CO_2 emission data has been available in good quality, see above table.

- Air travel contributes around 93% of overall travel emissions.
- Long distance (above 1600 km) flights account for more than 85% of air travel emissions.
- detailed data and information available at:
  https://ethz.ch/airtravel

In 2017/2018 the ETH departments have set individual reduction goals for air travel and outlined measures towards achieving them:

- The reference year is 2016–2018, reduction targets are to be obtained by 2025, intermediate goals exist.
- Goals are declared as reduction of air travel activity per se which neither includes compensation nor efficiency gains of the airlines due to technological progress. The latter are expected to effectively decrease GHG emissions by some extra 10% until 2025.
- D-PHYS committed to a reduction by 20%. The ETH average goal is an 11% reduction.
- CO_2eq emissions due to flights are accounted in ETHIS since 2019; data is meant to be made available by *Leitzahl* for individual groups to monitor specific trips, their current emissions and their progress in reduction.

In particular due to this monitoring scheme and the definition of quantitative targets which were developed in a bottom-up approach by the departments, ETH Zürich is now widely viewed as a role model in addressing CO_2 emissions related to business travel.

3.4 D-PHYS

Some points of consideration concerning the role of D-PHYS within ETH are as follows:

- D-PHYS has a specific profile within ETH of how research is focussed and conducted.
- Correspondingly, the relative importance of the various emission domains at D-PHYS may deviate from the overall ETH profile.
- Some domains of emissions can hardly be controlled by D-PHYS even though D-PHYS makes direct or indirect use of them; some of them can be controlled centrally at ETH.
- Most research and teaching conducted at D-PHYS does not directly link to the earth's climate and to sustainability (even though the mechanisms of global heating are based on elementary phenomena which are well-understood from the point of view of physics). D-PHYS will thus have a limited scope in advancing sustainable technologies.

Basic data for D-PHYS in 2018 (relative to ETH) are as follows:

employees	FTE	630	6.7%
members	FTE	1380	6.4%
area	m^2	21300	3.3%
budget basic funding	M CHF/yr	48	3.7%

Air Travel

Data obtained in the air travel framework is as follows (average 2016–2018):

unit	FTE	t[CO_2eq]/yr	t[CO_2eq]/yr/FTE
ITP	86	330	3.82
IQE	129	375	2.9
IPA	141	282	2.0
LFKP	111	188	1.68
services, assistants	110	4	0.04
Pauli Center (2019, own data)		39	
departing by 2021	41	236	5.96
D-PHYS	624	1454	2.33
D-PHYS active	583	1218	2.09
D-PHYS researchers	450	1450	3.22
ETH	9207	17256	1.87

Explanations: The 4 institutes summarise the data for the associated research groups. "services, assistants" summarises departmental non-scientific personnel not associated to a *Leitzahl* (within data obtained through the air travel framework). A noteworthy class of research groups are those who will cease operations by 2021 when the air travel framework starts. "D-PHYS active" represents the data for D-PHYS reduced by the former class of departing research groups. "D-PHYS researchers" represents the data for D-PHYS reduced by non-scientific personnel (departmental as well as non-scientific personnel within the institutes and research groups).

ICT equipment and operations

Some rough estimates of ICT-related CO_2 emissions are as follows:

equipment	grey energy t[CO_2eq]	power kW	units	lifetime yr	production t[CO_2eq]/yr	operation t[CO_2eq]/yr
desktop + monitor	0.4+0.4	0.1+0.05	900	5	145	3.3
laptop	0.35	0.01	630	5	44	0.15
server	1.0	0.3	80	10	8	3.0
smartphone, tablet	0.1					

References:

- relevant keywords include "Life-Cycle Assessment" (LCA) and "Product Carbon Footprint" (PCF)
- https://www.apple.com/environment
- https://www.dell.com/learn/us/en/uscorp1/corp-comm/environment_carbon_footprint_products
- https://www.lenovo.com/us/en/compliance/eco-declaration
- https://www.seagate.com/global-citizenship/product-sustainability/enterprise-cap-3-5-hdd-sustainability-report

Some comments:

- Desktops, laptops are operated at working hours (220/365 days, 8h/day = 20%), servers continuously. We estimate the GHG emissions at 0.12 t[CO_2eq]/yr/kW (= 14 g[CO_2eq]/kWh) for the default renewable electrical power mix at ETH
- We assume that every D-PHYS employee has a laptop which is used for work. We thus estimate 1 laptop per employee.
- Production (grey energy) is divided by lifetime; extending the lifetime lowers the figures.
- In conclusion, powering computer equipment causes only minor GHG emissions, whereas grey emissions due to its construction are sizeable.
- In absence of reliable data on the climate impact of (electricity powered) experimental machinery, one may hypothesise that its production often outweighs its operation. There may be exceptions to the rule (e.g. cryostats or capital machinery with very high power consumption), for which a quantitative assessment of grey vs. operational emissions would be worthwhile.

Electric Power Consumption

It is possible to obtain an estimated upper bound for the electric power consumption at D-PHYS by inspection of the electric power meter for the relevant buildings (HPT, HPF, HPP, HPK, HIT). The data from two data sets for 2019 is (the first data set includes HPF, HPP, HPK, HIT, the second one to HPT, HPF, HPP):

building	MWh	kW	t[CO_2eq]/yr
HPT	— / 1739	— / 199	— / 24
HPF	3334 / 3188	381 / 364	46 / 44
HPP	1609 / 854	184 / 98	22 / 12
HPK	747	85	10
HIT	3119	356	43
total	10548	1205	145
ETH total (2018)	103000	11800	1400

These data also include the power consumption of building operations (heating, ventilation, light, elevators) as well as external groups residing in these buildings (while departmental groups in other buildings are not included). Therefore, the resulting total amount of 145 t[CO_2eq]/yr (using a conversion factor of 0.12 t[CO_2eq]/yr/kW) shows that the climate impact of overall electric power consumption (scope 2) is indeed of a lower order of magnitude than most scope 3 emission domains (e.g. business travel presently at around 1450 t[CO_2eq]/yr).

Scope 3 Emissions

Other scope 3 emission data is not available; it could be obtained by individual research groups and will vary largely with the conducted research.

3.5 Peer Institutions

ETH Zürich is a member of several clusters and associations with neighbouring and international universities. Among those are the IDEA league (Chalmers University Gothenburg, RWTH Aachen, TU Delft, Politecnico Milano and ETH Zürich) and the International Alliance of Research Universities IARU (Australian National University, National University of Singapore, Peking University, University of California, Berkeley, University of Cambridge, University of Cape Town, University of Copenhagen, University of Oxford, University of Tokyo, Yale University and ETH Zürich). These unions foster exchange of ideas and concepts among the participants, not only in the fields of research and teaching, but also in the improvement of organisational processes like sustainability development. Using their network, the IARU developed a "Green Guide for Universities" already in 2014, showcasing positive examples of initiatives and changes the member universities have undergone to aim towards fulfilling the 2030 sustainability goals.

ETH is often positioned in high ranks of international university rankings regarding studying and working conditions. ETH also has living commitment to sustainable development, and as part of that, it has become known as a role model in monitoring and setting concrete goals for CO_2 emissions originating from its business flights. Approaches that have proven to be effective in reducing CO_2 emissions at one place can then be adopted at other universities, and the monitoring of data at peer universities will assist this process.

Most prestigious US-American universities focus their CO_2 emission reduction goals on infrastructure (renovation and insulation for buildings, also in student housing, including effective waste management and saving electricity) and local transport (reduce individual car transport). These measures fall under the widely used categories of scope 1 and 2. D-PHYS has only minor impact on these categories, as they are largely managed by central ETH administration.

When looking for programs targeted at sustainability, most universities of similar reputation as ETH do have strategies and goals which areas they want to tackle regarding the reduction of CO_2 emissions, and they often involve several stakeholders, which makes them more likely to be successful (one of the findings in the IARU guide). It is important to differentiate between goals for fossil-fuel neutral, fossil-fuel free and carbon-neutral or carbon-free campuses.

One initiative of the University of British Columbia, Canada, lets researchers sign a voluntary pledge that also includes additional aspects directly aiming at fulfilling the Paris Climate Goals ("Zero Emission University"). This initiative is mainly known in North America, together with No Fly Climate Sci, founded by a US-American climate scientist. No Fly Climate Sci also targets individuals not necessarily affiliated with academic institutions. A similar movement has been initialised in the German-speaking region, called #unter1000machichsnicht. Signing the pledge as an individual means agreeing to a self-commitment of not taking flights for business trips that are less than 1000 km in distance.

In Europe, many universities already have recommendations in place regarding air travel, which is one of the focuses of the ETH initiative and of our present departmental efforts. They mainly include taking the train whenever the trip is close enough or short enough (between 8–12 hours travel time or below 1000 km or similar thresholds). Furthermore, improving the infrastructure and behaviour in laboratories can have a positive impact on energy consumption as well, as outlined by an example from the University of Copenhagen, presented in the "Green Guide". An information campaign that open fume hoods consume a lot more energy than closed ones combined with stickers on the fume hoods themselves showed a huge improvement on energy consumption. More examples on "green purchasing" are displayed in the IARU guide, a few already suggested by ETH Zürich!

When looking for information on other universities' websites, the ease at which one is able to find relevant information on sustainability strategies, specific goals and recent data from monitoring efforts already gives a feeling for the priority that an institution gives to the topic of sustainability. As a positive example, the University of Copenhagen is actively promoting that they are taking a leading role on developing a sustainable campus.

It is important to get inspiration for successful projects and to make use of the knowledge on how to make projects successful. This includes dealing with challenges that could make an initially good intention fail in the end. Many European universities are facing the same challenges and addressing them in advance can help when setting up a new initiative. The IARU guide highlights projects of different difficulty levels regarding the implementation and the involvement of central organisational units. We have summarised the main focus areas of other European universities within the emerging departmental wiki, where we highlight their plans and sustainability reports.

For instance, knowledge sharing is key when it comes to the implementation of ambitious projects in order to reach the defined goals for CO_2 reduction. The IARU recommends that regular exchange of ideas happens not only between institutions but also between all institutional levels including the departments and research groups.

An outstanding initiative in the UK is the Green Impact Award based at Oxford University. This is an online tool where individual research groups, institutes, or departments can form groups and fulfil certain criteria to win several levels of the Green Impact Award. The tasks include waste management, the installation of a sustainability officer, a garden for biodiversity etc. There are detailed lists of requirements and a monitoring system is established. This award scheme pushes the execution of the smaller projects to gain reputation as a sustainable group/institute/campus. The award is an ongoing initiative, as there are long-term projects and monitoring is established on a regular basis. As the groups in the competition can also be student groups, the award scheme is very inclusive and engages all stakeholder groups (also addressing student housing!). The audits are ensuring that tasks are taken seriously and that the efforts are recognised. This is the most general and complete action that peer universities have set up and made public on their website concerning behavioural change. It does, however, only deal with the scope 1 and 2 emissions like heating, electricity, waste.

The University of Edinburgh has a similar concept of encouraging labs, student groups, etc. to participate in sustainable improvements of their environment. They award the “Sustainability Award” (consisting of three levels) that recognises the completion of several tasks and actions over the course of a year, depending on the type of group joining the competition. The title is awarded for two years, and continuous sustainable improvement is necessary to keep the award. Furthermore, the University of Edinburgh hosts the “Roundtable of Sustainable Academic Travel”, in which ETH Zürich (among other Swiss universities) participates with their initiative on monitoring flight emissions.

In Sweden, 37 institutions have signed on to the “Climate Framework for Higher Education Institutions”, an initiative led by Chalmers and KTH. The initiative acts as the starting point for developing specific climate strategies at those universities who have signed up. The goal is to contribute to national and international measures to keep to the 1.5°C warming limit.

On the level of Swiss peer institutions, EPFL’s “Sustainability Initiative” covers several action areas. These include reducing air travel (based on the ETH framework; the School of Life Sciences has specific suggestions in place), and an open call to fund student projects improving campus sustainability. The main topics at EPFL include Food, Mobility, Energy, Biodiversity, Waste, and Purchasing. Although EPFL claims a goal for their strategy to be “CO_2 neutral by

2020", it is unclear, whether this goal is already met or can be met within the rest of the year. A noteworthy achievement at the Zürich University of the Arts (ZHdK, project based on the ETH air travel framework) is a reduction of their air travel emissions by 40% within merely 2 years.

References

- IDEA League: https://idealeague.org/about/
- IARU Green Guide for Universities: http://www.iaruni.org/sustainability/green-guide
- Zero Emission University: https://zeroemissionuniversity.com/
- No Fly Climate Sci: https://noflyclimatesci.org/
- Green Impact Award: https://www.greenimpact.org.uk/oxford
- Sustainability at Uni Edinburgh: https://www.ed.ac.uk/sustainability
- Climate Framework for Higher Education Institutions: https://www.chalmers.se/en/about-chalmers/Chalmers-for-a-sustainable-future/climate-framework

4 Suggested Actions, Guidelines and Ideas

In a number of meetings between March and June 2020, the CO_2 working group has collected, discussed and refined several approaches to facilitate CO_2-reduction and to promote sustainable behaviour. The purpose of the current section is to collect the items which we suggest to the department.

In our work, we have encountered suggestions of different natures which address diverse aspects of our operations and which display various levels of promise towards inducing a positive effect. Our primary aim was to come up with items on which D-PHYS or individual research groups can act right away. But it naturally also generated items which extend beyond the scope of what we can practically achieve at D-PHYS or items which are not sufficiently concrete for implementation as rules. Nonetheless, many of the latter items are still valuable suggestions, and we felt that we ought to report on our entire work.

With the reasonably large resulting catalogue of items, we decided to categorise them in two ways in order to make them more accessible: The items are collected by the topic area they address, such as videoconferencing, travel, operations and teaching. The secondary categorisation concerns how to interpret the task that is described by the item. In this regard, we use three categories which will be highlighted by different icons and colours:

- ***actions*** *that we propose to implement as policies of D-PHYS, such as revised emission goals, measures to reduce air travel and promotion of videoconferencing;*
- ***guidelines*** *that are intended for implementation by individuals in the sense of a best practice, e.g. the participation in virtual conferences or sustainable travel planning;*
- ***ideas*** *for further development and long-term implementation by the department or in a larger context, for example ETH-wide, such as possible incentives for sustainable research.*

We interpreted the mission of our working group to propose a collection of items to the department. We considered the items presented in this report, viewed in a broad sense, as suitable for implementation. In fact, the actions, some of the guidelines and, to much lesser extent, the ideas could be decided upon by the department for formal implementation. We did not view it as our task to propose whether or not this should be done, which items should be selected or how the resulting rules should be formulated. Instead, we propose to implement the bulk of suggestions as general principles and recommendations. These would be advertised to D-PHYS members (e.g. in a wiki along with suggestions and hints), they would be citable in decision-making, but they are not meant to be enforced. D-PHYS subsequently decided to follow this roadmap by endorsing and supporting our suggestions. This is meant to establish a standard behaviour at D-PHYS without the need for elaborate schemes to monitor and adjudicate.

The ideas which cannot be effective at the level of D-PHYS, could be implementable in related or superordinate entities (e.g., ETH, SNSF, ERC). Members of D-PHYS contribute to these entities and may forward these items according to their capabilities.

4.1 Videoconferencing

It is indispensable to approach a scientific community in which ordinary operations are carried out in a sustainable fashion. We do not even have a choice in this regard.

In our present framework, scientific exchange is organised in the form of workshops, conferences and seminars, all of which are typically conducted in a single location to which the remote participants travel. Visiting these events is a key way for young scientists to obtain recognition in their field, and established researchers benefit from the opportunities to promote their research via these channels. At present, the initiation and continuation of careers in science depends decisively on travel.

However, with current transportation means there is no way that we can keep travelling as much and as far, neither as a community nor as individuals. Hence, we need to find and establish sustainable ways to uphold scientific exchange and to connect and communicate within our community. And in order to protect future generations of researchers, we need to achieve this in such a way that not even the establishment of a career will violate principles of sustainability. For instance, it must not be that young researchers will travel extensively and are thus forced to accumulate an enormous GHG footprint if they want to stand a reasonable chance of finding continued employment in academia, as is currently the case.

It is evident that videoconferencing (VC) will be a vital tool in a future sustainable science environment.

By construction, this technology enables the active participation in all forms of scientific exchange over large distances. Fortunately, the benefits brought forward by VC are strategically aligned with several societal challenges such as inclusiveness, social obligations, financial considerations, work-life balance and others:

- Facilitate the inclusion of scientists from less resourceful universities, developing countries or adverse political circumstances.
- Allow scientists with children or family care duties, scientists with particular disabilities and (at present) scientists with environmental concerns to participate in conferences according to their capabilities and needs.
- Online participation bears substantially lower costs than on-site participation. This fact easily boosts the reach of the event (e.g. the annual international conference "Amplitudes" quadrupled its registrants from 175 to 706 when it moved to a VC platform in 2020).
- At a personal level, attending virtual events (or selected talks) can be less time demanding and jet-lag and travel-related stress is avoided (yet, this can be viewed as lowering the commitment or require participation at night-time).
- Remote delivery of talks may attract a broader pool of potential speakers. Virtual events may thus increase the amount of inter-disciplinary communication.

These benefits on their own are a significant motivation for offering virtual conferences.

It is clear that virtual workshops are not the same as physical workshops, and there are widely-held reservations against this mode of transmission throughout the community. Virtual events cannot provide all of the positive effects of physically being at a workshop and effortlessly connecting to nearby people. They are (probably) less effective in encouraging and maintaining interactions among the participants during breaks and after sessions. Nevertheless, the 2020 coronavirus pandemic vividly demonstrated the power and viability of VC in conducting virtual conferences and webinars with high-profile participants and a large attendance. It will be a challenge to find suitable virtual replacements for the elements that are otherwise eased by physical proximity.

Altogether, we prefer to shape the way in which we conduct scientific exchange by ourselves instead of waiting and being forced. Time is an important factor. For these reasons, we intend to take the lead in enabling VC to become a realistic alternative to travelling to conferences. We all need to gather experience in this regard and get used to virtual conferences. They need to become a habit, and making them a useful experience requires developing new habits. Importantly, virtual conferences need to become recognised and well-attended by established researchers to pave the way for a sustainable career path for youngsters.

We will therefore develop formats for scientific exchange that combine the positive aspects of physical and virtual events. A key element of our strategy is to conduct scientific events at least *in a semi-virtual fashion*, and to *offer the option of remote attendance and remote talks as a matter of principle*. With this inclusive approach we will help establishing a scientific environment operating at net-zero carbon emissions in which the need for physical presence at inter- and transcontinental workshops will increasingly be the exception.

In the following we present measures to approach the aforementioned goals.

4.1.A Workshops at D-PHYS

! *All scientific meetings, workshops, conferences at D-PHYS offer the possibility of online participation for speakers and participants.*

Comments

- As a standard at D-PHYS this principle represents a distributed effort to consider, explore, work out and improve online formats which are inevitably needed to maintain an excellent level of scientific exchange.
- Participation by VC can be available at a fee (for the use of VC infrastructure) which may be different from physical participation fee (e.g., to fund coffee breaks). A typical fee for the use of VC infrastructure at ETH Zürich could be around 400 CHF per hour of online conference including the preparatory testing prior to the meeting with 3 speakers and 1 chair.
- The option for remote participation should be communicated in invitations and advertisements so that the option will be made use of by a considerable fraction of contributors and participants in order to avoid the GHG emissions for their travel.
- Implementation of this standard has a natural outreach component: It will have a broader impact, it will automatically be communicated across the physics community, and we can actively advertise it.

4.1.B Research Seminars and Colloquia

! *Scientific seminars and colloquia at D-PHYS are open to remote talks.*

Comments

- Seminars and colloquia serve a similar purpose as workshops and conferences and due to the implied travel they are subject to similar considerations towards virtualisation. It will therefore be essential to facilitate the transition towards a virtual platform.
- Next to avoiding travel-related CO_2 emissions, invited speakers may have other valid reasons to avoid travelling altogether and/or to avoid spending an extended period of time away from their home or family. These reasons should not represent an obstacle in their ability to present their research.

- Hence, the option to deliver talks virtually should be mentioned in the initial invitation.
- Setting up seminars to receive remote talks can be done with some efforts including booking the adequate rooms with the corresponding technical supplies. Recording of talks and/or a live transmission are options which may or may not be advisable depending on the situation or preferences.
- The overall experience of an actual visit vs. a virtual talk will be different, but our experience has shown that the scientific content can be transmitted at comparable quality, and immediate interaction with the speaker works well.
- Our principal scientific communication activity, the Zurich Physics Colloquium, was suspended during the coronavirus pandemic. With some experience, (some of) the scheduled talks could have been transferred to a virtual platform right away towards maintaining an important activity. It would therefore make sense to gain experience by permitting some of the talks to be delivered virtually.
- The reach of local seminars can be widely enhanced by using VC and by advertising the events in community lists or directories (one recent example is the lecture series on Ultrafast nonlinear optics and spectroscopy given by Prof. Giulio Cerullo from Politecnico di Milano in the framework of the EPFL Doctoral Program in Physics in June 2020 with more than 70 participants from the whole ETH domain). VC seminars may also facilitate the active participation of researchers from developing countries in topics of current interest.

4.1.C Committee Meetings and Doctoral Defences

! *Committee meetings including doctoral defences are open for external members to participate remotely by videoconferencing.*

Comments

- As a general rule, remote participation in committee meetings by VC should be offered to external committee members (at least as an alternative to travelling) unless the particular occasion mandates a site visit.
- Allowing external members to join by VC will allow a broader range of experts to participate in these meetings (e.g. in the case of care-taking obligations, teaching duties, travel restrictions); it will also save a significant amount of resources; similar provisions as for remote participation in scientific workshops apply, please see above.
- For doctoral defences, remote participation of external co-referees by VC is explicitly encouraged. In view of the expected change of doctoral regulations to require at least one external university professor as co-referee, this default option will have a significant effect.
- For doctoral defences, it would be worthwhile to consider allowing colleagues and family members to attend the public defence talk by VC.

4.1.D Participation in VC Workshops

\+ *All D-PHYS members make efforts to participate in virtual conferences regularly, at least at one event per year.*

Comments

- There was practically no supply of virtual conferences before the coronavirus pandemic. The demand for such activities promotes and supports the supply.

- A number of shortcomings of virtual meeting and workshops may be mitigated by measures we have not developed and established yet. Therefore we have to gather experience from attending. Participation at VCs will provide very important insights to enhance their functionality, find necessary basic rules, and to get ideas and inspirations for own conferences.
- Department may conduct regular (annual) surveys as an implicit reminder to participate in virtual events and towards collecting and sharing worthwhile experiences in this regard.

4.1.E Credit Points for Doctoral Studies

Doctoral students will earn 3 of their 12 credit points through VC-related activity or service.

COMMENTS

- Useful activities include assisting in setting up or conducting VC components of a workshop (or a research seminar or lecture series), participation in a workshop through VC or delivering a VC talk in a remote seminar or conference.
- Fluency in VC skills will be relevant in the doctoral student's future working environment and it will help her/him to thrive.
- The gathered experience will be exported to other universities and institutes, or branches of the economy and society.
- As usual, supervisors would be in charge of and responsible for awarding credit points.

4.1.F VC Infrastructure

D-PHYS will take care of planning and initialising the installation of major shared VC infrastructure.

COMMENTS

- With an increased frequency of events conducted by VC (fully or in parts), there will be an increased demand for dedicated rooms equipped with VC hardware. Planning efforts for the new HPQ building are taking this into account.
- The ETH unit ID MMS typically takes the lead in installing and maintaining VC infrastructure.
- Depending on future developments and demand, D-PHYS may decide to operate dedicated VC servers and software.
- Standard and supplementary VC equipment should be acquired as needed by individuals rather than preemptively. This strategy worked well in maintaining teaching during the coronavirus pandemic.
- It may make sense to pool specialised equipment for conducting VC events for general use (e.g. dedicated cameras, throwable microphones to enable a reliable transmission of comments and questions from a local audience).
- Conducting a virtual event for hundreds of participants with the assistance and infrastructure of ETH ID MMS can amount to 400 CHF/hour including the software licence and the pre-event test with with 4 speakers/hour.
- It could be a possible incentive for VC pioneers to obtain financial support by D-PHYS for covering the IT costs of the virtual meeting or conference.

4.1.G VC Implementations

+ *D-PHYS discusses and collects hints, suggestions, instructions, best practices and references to optimise the implementation of VC aspects of (fully or partially) virtual events.*

Comments

- Typical drawbacks of virtual conferences and meetings, such as people living in different time zones or connection and bandwidth issues, can be mitigated by a number of measures.
- A D-PHYS wiki may list suggestions and references.

Suggestions

A list of suggestions includes the following items:

- It is good practice to record all talks and to make them available to the participants at least during and somewhat beyond the duration of the workshop. This will compensate for time zone and connection issues.
- Similarly, making talk slides available to the participants ahead of the talk will compensate for ubiquitous connection and bandwidth issues, especially for participants in countries with a less developed networking infrastructure.
- Talks can be streamed to non-interactive services (e.g. YouTube) to have a broader reach and to minimise particular software requirements (may improve bandwidth issues). The option of audio-only transmission (together with the availability of slides) can serve as a backup solution for bandwidth-issues.
- A chat channel (potentially separate from the VC solution) could be used for discussion and interaction.
- Depending on the nature of the event or the preferences of the speaker, talk recordings may be kept indefinitely (for future references) or be removed shortly after the meeting (for confidentiality of current research).
- An international meeting can be organised with a set of hubs to transmit the event to a local community of researchers (e.g. Photonics Online Meetup). This enables on-site interactions while reducing the travel to the local/national level.
- Online collaboration tools (e.g. slack) are good means to subsequently discuss the contents of a talk or session among the participants. This can be a valuable tool, record and reference to replace part of the on-site interactions at breaks and after sessions.
- Random breakout sessions during breaks (small groups of participants are assembled at random into separate rooms of the virtual meeting) may encourage new interactions among participants.
- Monitoring of the various virtual channels can be challenging (raised hands, chat contributions, cyberspace attacks, audio/video control, technical aspects of streaming), and it makes sense to have some people dedicated to specific tasks.
- One may engage a small group of participants to initiate and intensify connections with other participants over the course of the event.

References

Further information and details can be found in the following references:

- Handbook for Nearly Carbon Neutral Conference (University of California at Santa Barbara):
  https://hiltner.english.ucsb.edu/index.php/ncnc-guide/
- Feral conference (online-only conference):
  http://perc.ac.nz/wordpress/feral/
  plus LSE-blog on experience:
  https://blogs.lse.ac.uk/impactofsocialsciences/2019/05/03/running-a-nearly-carbon-neutral-conference-lessons-from-the-feral-conference/
- Handbook for a semi-virtual conference:
  https://static.uni-graz.at/fileadmin/veranstaltungen/music-psychology-conference2018/documents/Semi_Virtual_Conference_Guidelines.pdf
- How to Organize an Online Conference. Nature Reviews Materials 2020:
  https://doi.org/10.1038/s41578-020-0194-0

4.2 Travelling

Presently, commercial flights exclusively use fossil fuels, while trains can easily use renewable energy through the electricity grid.

While it is in principle possible to operate flights with net-zero emissions through the use of non-fossil fuels or solar-to-fuel carbon capture methods, these methods are not yet readily available at the required scale. Until this undetermined point in time, travel by flying contributes substantially to CO_2eq emissions. Compensation schemes may mitigate the impact of CO_2 emissions, but the emission reductions are also needed elsewhere, and it is generally preferable to keep fossil fuels in the ground.

4.2.A Travel by Train

! *Members of D-PHYS travel by train to destinations which can be reached by train within 6 hours.*

\+ *Travel by train to destinations reachable in 6 – 12 hours or up to around 1000 km is encouraged.*

Comments

- The first part reflects a rule by the federal administration with exceptions subject to justification. At this distance, the (useful) time spent on train connections is competitive with the overall time spent on travelling by aircraft.
- Trains should be considered when planning trips (next to the particular situation of the travelling person). Travellers should be given the opportunity to suggest and make use of this mode of travel and to consider and use it as productive working time as far as possible.
- These rules and guidelines give D-PHYS members the *opportunity* to behave in a more sustainable way.
- Night trains can be used to cover long distances; the use of night trains can eliminate one or two days of accommodation at the destination; this can effectively balance higher ticket expenses in lower/single occupancy compartments; book early to find saver tickets (and to ensure the availability of tickets as beds are limited and attractive and sell out soon).

- The type of energy source and its impact on the climate depends on the country and train operator. Within Switzerland, trains are operated by renewable electricity sources with minimal climate impact. For details, see the table below.

4.2.B Visitors at D-PHYS

! *Our guidelines for travel by train are communicated to visitors from continental Europe and UK.*

Comments

- This takes the burden away from visitors to take the initiative on asking whether travel by train would be permissible. This may inspire and tip undecided visitors towards using the train.
- It makes sense to communicate the guideline to intercontinental visitors because they may combine their visit with other destinations in continental Europe and UK which can then be reached by train.
- Communication of these suggestions serves as outreach and towards propagation to peers.

4.2.C Travel Planning and Guidelines

\+ *Aspects of sustainability play a role in planning business travel. Research group leaders provide a written set of guidelines on planning and booking travel for the group.*

Comments

- Tools to compare different travel means to reach a given location are recommended in planning travel. ETH plans to provide a tool to assist in planning (routeRANK) starting Fall 2020.
- Guidelines explain to group members the default procedures of booking travel such as but not limited to: justification, frequency and limitations for travel, how to decide on the mode of travel, means of booking and reimbursement, as well as how to deal with time during travel and time off duty.
- This provides the group members with an authoritative set of guidelines so that they can find an acceptable balance on their own (and it is good practice).
- There may be a default set of guidelines at the level of the department or the institutes which any research group could adopt. However, different groups have different needs and customs and individual guidelines can accommodate for them.
- In order to maximise the scientific gain on intercontinental visits, it makes sense to combine them with visits to other relevant scientific institutions or events in the region (which could be reached by train if possible).
- The expected cumulated gain of a scientific visit should be in proportion to the amount of travel required for this trip. Therefore, few-day cross- and intercontinental trips should be avoided.

Reference Emissions

The climate impact of travel depends very much on the selected means, and for trains it further depends strongly on the country and type of train connection. The following table provides an overview per travelled distance (a factor of 2 is needed for return trips):

mode	g[CO_2eq]/km
flight, with RFI factor	200 – 300
train CH/IC	1
train CH/RE	1
train DE/ICE	20 – 30
train DE/RE	60 – 80
train FR/TGV	8
train FR/TER	4 – 8
train IT/FR	45
train IT/RE	45 – 85
train AT/IC	7
car, single occupancy	100 – 200

Data was collected from atmosfair (for flights) and ecopassenger (otherwise) services by inspecting some reasonable reference connections on the indicated platforms involving several assumptions, and should thus be understood as order-of-magnitude estimates.

References

Further information and details can be found in the following references:

- ETH Zürich's air travel project:
  https://ethz.ch/airtravel
- ecopassenger travel planning comparison platform:
  http://www.ecopassenger.org
- routeRANK travel planning comparison platform:
  https://www.routerank.com/en/
- atmosfair flight emission calculator and CO_2 offsetting:
  https://www.atmosfair.de/en/
- myclimate emission calculator and CO_2 offsetting:
  https://www.myclimate.org

4.3 Travel CO_2 Reduction Path

In 2017/2018, D-PHYS committed to reduce its CO_2 emissions due to business travel within the ETH airtravel project framework by 20% until 2025 using a linear decrease pathway starting in 2019. This decision was taken around two years after the Paris agreement when general awareness for the evolving climate crisis was on a steep increase in the general population and likewise within D-PHYS. At the time the commitment appeared both significant and attainable, but it was not clarified whether it represents a significant (relative) achievement towards the goals of the Paris agreement. The present vantage point has changed the perspective substantially for the following reasons:

- Sample global CO_2 emission reduction pathways towards achieving the 1.5°C goal have been outlined in an IPCC special report. Without going into details, these have in common that GHG emissions should be reduced to ½ no later than 2030–2035, and net-zero emissions should be achieved no later than 2050–2060. The precise timeline depends on the level of global risks we are willing to take.

- The Swiss federal administration decided in 2019 to reduce actual CO_2 emissions of its operations including affiliated entities by at least 50% until 2030 and to offset all remaining emissions in order to achieve net-zero emissions. The ETH domain has adopted this goal.
- While the urgency for GHG reductions is already understood in many societies, the actions to implement the necessary changes to counteract the climate crisis are lacking. They are not even foreseeably going to happen, at least not at a sufficient extent, within the next couple of years where they would be needed to keep the accumulated emissions at a reasonable bound. In order to prevent further significant damage to global ecosystems, GHG emissions will then need to be reduced even more deeply and within a shorter amount of time. For this reason, we consider it plausible that even more stringent emission bounds will eventually be imposed than those that are presently needed towards achieving the goal of the Paris agreement. Even though we will not be immediately responsible for such developments, it will be beneficial to anticipate and to be prepared.
- It is evident that a 20% reduction of CO_2 emissions due to flights will merely be the first step, and efforts to reduce will have to continue well beyond 2025. Comparing to the actual needs of the Paris agreement, much more significant reductions within short timeframes are required for the subsequent years.
- At present, a 20% reduction of CO_2 emissions is in fact a small achievement that could be realised momentarily (supposing there is the will to do so) without a noticeable impact on our research.
- Furthermore, a sizeable part of this reduction goal is believed to be realised by increased efficiency of the aircraft fleet and shall happen without action on our side.
- What counts towards the global mean surface temperature are the cumulated CO_2 emissions rather than their reductions within any given year. This insight implies an urgency to achieve emission reductions sooner rather than later.
- Finally, we need an ambitious reduction goal and an efficient monitoring of the progress to motivate us to expedite the transition towards a sustainable science.

For these reasons, our previous commitment is an insignificant goal, and it makes no sense to stick to it. In fact, it will even be counterproductive towards future developments to start with small easy steps and delay the consideration of more difficult steps. Instead we should now impose a realistic goal that will make D-PHYS (and also our community in physics and at ETH) ready for the future.

There are two further factors which should be taken into account in designing a reduction pathway for D-PHYS:

- Due to the coronavirus pandemic business travel is severely restricted throughout 2020, and it is clear that the corresponding emissions for 2020 will be substantially lower than in other years. As further detailed below, we should take the fast and dramatic changes of the last months as an example for what is possible and reflect on what is really needed or could be expendable. But in terms of our long-term goals, such temporary reductions cannot be viewed as an achievement because they have no lasting effect.
- The set of active research groups has changed from the reference period (2016–2018) to the beginning of the reduction period (2019–2025). Incidentally, the departed groups had a substantially higher CO_2eq emission rate, but they will not contribute to the implementation

of the reductions.

4.3.A 2020: Year of Coronavirus Pandemic

The year 2020 with the coronavirus pandemic can be, in terms of the climate crisis, a very valuable learning experience. However, data on CO_2 emissions during the year 2020 shall not be counted towards CO_2 reduction goals (neither the apparent reduction achieved during this year, nor the contribution to the integrated emissions during a longer period). Moreover, the absolute timeframe of reduction goals until 2025 shall remain unchanged.

COMMENTS

- The coronavirus pandemic may lead to a stronger awareness that crises with drastic implications (as is expected for advanced global heating) can become reality, and that we can indeed counteract them by decisive actions even if these are partially unpopular.
- Business travel is suspended during most of the year 2020 (and potentially beyond) due to the pandemic. The corresponding CO_2 emissions during this period will only be a fraction of the amounts of previous years. They bear no meaning towards monitoring the progress in achieving our reduction goals because the underlying reasons for the reductions do not have a lasting effect.
- Counting the shortfall of CO_2 emissions in 2020 towards cumulated emission goals will be a sizeable contribution. This cannot be viewed as an achievement.
- While the temporary suspension of travel has a welcome effect in inhibiting some CO_2 emissions that would otherwise have taken place, the overall dynamic of the economy during and after the pandemic is unclear, and may yet lead to a net surplus or decline of GHG emissions.
- The avoidance of business travel and the cancellation of many conferences and meetings has led to a flurry of activity in videoconferencing within academia, and some conferences are being moved from the real space to a virtual format. This is a valuable opportunity to acquire skills and experience in conducting virtual conferences, to establish the required infrastructure and to gain further insights on sustainability in general. It will be crucial to perpetuate these developments towards sustainable science.
- In view of the experienced boost of VC activity, the emission data for 2020 can serve as a valuable reference point to emphasise the order of magnitude of the potential in emission reductions without ceasing our scientific exchange operations. Therefore the data for 2020 should be listed separately in our monitoring efforts.
- The established view in fighting the climate crisis is that all conceivable reductions should be realised in order to stand a realistic chance of keeping the global average surface temperature at a tolerable level. Consequently, the coronavirus pandemic must not be used as an excuse to delay action.

4.3.B Update Air Travel Project Goals

The department agrees on a set of revised goals for the anticipated CO_2 equivalent emission path regarding travel at D-PHYS:

year	*emission rate ($t[CO_2eq]/yr/FTE$)*	*%*	*integrated since 2021 ($t[CO_2eq]/FTE$)*	*rate per researcher ($t[CO_2eq]/yr/resFTE$)*
2016 – 2018	*2.33*	*100*		*3.26*
2021	*1.63*	*70*	*1.7*	*2.28*
2025	*1.17*	*50*	*7.0*	*1.64*
2030	*0.89*	*38*	*12.2*	*1.25*
2040	*0.45*	*20*	*18.9*	*0.62*

COMMENTS

- We start our efforts with an immediate emission goal of 70% to 1.66 $t[CO_2eq]/FTE$ for 2021. While somewhat ambitious, a reduction by 30% appears well within reach. Furthermore, the resulting rate is comparable to the overall ETH emission rate goal for 2025. It demonstrates that D-PHYS understands the urgency and is willing to be more ambitious than average.
- The relevant emission data for the research groups which will still be active in and after 2021 shows that their reference emission rate is on average 10% below the overall reference emissions. Therefore, a significant amount of the immediate reduction goal by 30% is already realised by the generation change.
- The D-PHYS overall emission rate for 2019 at 2.16 $t[CO_2eq]/yr/FTE$ remained virtually unchanged with respect to the previous year. While these figures are subject to natural temporal fluctuations, the development is worrisome if continued: It points out that altogether the active research groups at D-PHYS have not managed to achieve a reduction for their groups in 2019 despite extensive discussions in the department and widespread coverage of the developing climate crisis in the media. This illustrates that we need to rethink our goals and increase our efforts.
- The goal of a reduction to 38% for 2030 is based on an absolute reduction to 50% for 2006 – 2030 within the *Klimapaket der Bundesverwaltung*.
- The projection for 2040 is mainly included to provide a perspective on emission pathways that align with the goals of the Paris Agreement. They will need to be adjusted to actual progress and needs in implementing net-zero emissions.
- We should aim to stay within the yearly emission goals on average (subject to natural fluctuations) and also within the integrated emissions goals as a measure for our cumulated climate impact.
- Per researcher figures are provided for convenient comparison with individual research groups within D-PHYS in order to account for non-scientific personnel which hardly engages in business travel. These figures are obtained by multiplying by a conversion factor of 1.4 FTE/resFTE, see below for details.

4.3.C Fairness

+ *All research groups aim to have low CO_2 emissions. Research groups with above-average CO_2 emissions will make efforts to achieve above-average reductions. Research groups with below-average CO_2 emissions will make efforts to remain below average.*

Comments

- Few academic fliers are responsible for most emissions (Wynes and Donner, 2018): e.g. Air travel emissions of 1509 individuals across 8 departments at University of British Columbia: 1/3 did not fly, 80% emissions by 25% fliers, 50% emissions caused by 8% fliers.
- To compare the emission rate per FTE between an individual research group with a particular personnel profile and the departmental average, it makes sense to focus on the active research personnel: For D-PHYS this amounts to a factor of around 630/450 = 1.4 by which ETH-wide and departmental emission figures should be multiplied. This effective emission rate may be compared to the research group rate per research FTE which needs to be determined individually.
- The GHG emissions of each research group and their reduction remain in the responsibility of the individual research group. The above principles may help in assessing the progress of a group in comparison to its peers. Different interpretations of details should not be misunderstood as excuses for inaction.

4.3.D Air Travel Monitoring in ETHIS

?

The availability, accessibility and reliability of the relevant CO_2 emission monitoring data for the individual research groups is essential for the development of the air travel project.

Comments

- We discussed with Susann Görlinger, the leader of the ETH air travel project, about its current status and progress. It is now foreseeable that individual research group leaders will soon (summer 2020) be able to access their real-time CO_2 emission data in ETHIS.
- With the monitoring system yet unobserved by us (the eventual consumers of the collected data), one can envision some crucial features or shortcomings that would be decisive on how useful and versatile the systems will be for us. In particular, the following features appear desirable:
  1. prompt availability of data per group for planning purposes;
  2. detailed lists of individual flights in order to verify and properly assign them to projects;
  3. ability to correct and reassign data to its proper originator;
  4. incorporation of data for visitors and guests;
  5. inclusion of CO_2 emission data into financial or academic reports of groups.
- In order for research groups to put their efforts into perspective, the department supplies its overall CO_2 emission data as well as emission data for its institutes in intervals of 3 months to its members.

4.4 Operational Emissions

Research operations directly or indirectly cause GHG emissions (during their production or by usage). Excluding business travel (which we dealt with above) and building infrastructure and operations (which can only be dealt with at the ETH level), these include (their relative impact and thus saving potential is indicated in brackets):

- scientific machinery, lab equipment (high-medium)
- lab supplies and operations (high)

- computers, telecommunication, servers (medium-high)
- office supplies, printing (medium)
- electricity (low)
- catering (low)

There is an evident conflict of interest between reducing GHG emissions and carrying out a high quality and efficient research agenda, but there may be ways to achieve a high standard in both aspects at the same time.

Unfortunately, we do not have good quantitative emission data for most of the above categories even though some of them are estimated to be at an impact level comparable to business travel (high). The above qualifiers for each category provide such an estimate which we can use towards prioritisation. This is an important point as it gives us a handle: We may choose to maintain a high engagement in business travel if we agree to cut back more thoroughly on operational emissions, e.g. by installing experimental equipment which involves less grey energy (emissions due to production, packaging and delivery) or by replacing and upgrading our equipment less frequently. If these options are not desirable, we can do the opposite and make compromises on the amount of business travel. It is our choice.

It is necessary to take on measures for a more efficient equipment use, to raise awareness of the saving potential in everyday lab use. Suggestions for implementation can be found in the Green Guide.

References

Further information and details can be found in the following references:

- IARU Green Guide for Universities:
  http://www.iaruni.org/sustainability/green-guide
- collective "Labos 1.5" (based in France) focussing on operations at scientific laboratories:
  http://labos1point5.org
- Green Impact Award at Oxford:
  https://www.greenimpact.org.uk/oxford

4.4.A Gathering Data and Monitoring

+ *Individual research groups monitor the emissions due to their operations. They gather and supply information (in CO_2 equivalent) on the major contributions upon request.*

Comments

- Laboratories are quite independently managed by the individual groups. The machinery required to run experimental and computational research varies widely with the research field. The associated grey emissions cannot be evaluated from above, only from within.
- To take an inventory of scope 3 emissions represents a substantial effort and should be done only when there is a clearly defined purpose and use for the gathered data. The latter may exist, but it is beyond the scope of this working group to define it.
- It would be useful to have a table to very roughly estimate grey emissions for given types of machinery:
  - Relevant data and references should be collected and maintained in a table within a departmental wiki resource.

    - Data and tables may exist in relevant resources; it is desirable to collect these references.
    - Companies should be asked for a quote when buying major equipment with unknown grey energy.
- Due to the use of electricity from renewable energies at ETH, one may use the comparably low conversion factor of 0.12 t[CO_2eq]/yr/kW for the powering of equipment.
- The need for quantitative monitoring may become obsolete if some form of CO_2 taxation or pricing is imposed by the federal administration.

References

Further information on monitoring can be found in the following references:

- The collective "Labos 1point5" plans to release a tool "GES 1point5" (around July 2020) to assess the climate impact of labs. This may be helpful (after adaption of parameters from French to Swiss situation):
  `http://labos1point5.org`
- Green Impact Award at Oxford:
  `https://www.greenimpact.org.uk/oxford`

4.4.B Optimisation

+ *D-PHYS aims to keep the GHG emissions associated to its operations as low as possible, and more generally aims for fully sustainable operations. The focus is on aspects with a large sustainability impact. Aspects where smaller reductions can be achieved easily with minor side-effects are pursued as well.*

Comments

- Electrical power consumption at ETH is allocated to renewable resources. This means that powering experimental and computational machinery causes only minor GHG emissions.
- Conversely, grey emissions due to the construction of equipment are sizeable.
- It therefore makes sense to plan for long-term use of equipment and to extend the use of existing equipment by upgrades and repairs.
- Modern computing and communication equipment can well be used for 5 – 10 years.
- Decisions on how labs and experiments are run broadly and in detail are taken at all organisational levels. Consequently, the need to pay attention to aspects of sustainability should be discussed with all involved scientists and personnel.

References

Further suggestions and guidelines can be found in the following references:

- ETH active environmental protection:
  `https://ethz.ch/services/en/service/safety-security-health-environment/environment/aktiver-umweltschutz.html`
- ETH guideline "Our Commitment":
  `https://ethz.ch/content/dam/ethz/associates/services/Service/sicherheit-gesundheit-umwelt/files/umwelt/en/Our_Commitment_Our_Measures_web.pdf`

- ETH guideline "Green IT": https://ethz.ch/content/dam/ethz/associates/services/Service/sicherheit-gesundheit-umwelt/files/umwelt/en/12283_Leitfaden_Green_IT_e.pdf

4.4.C Acquisition

Aspects of sustainability (including CO_2 emission estimates for production and operations) are a selection criterion when acquiring scientific machinery and office equipment.

Comments

- The first step towards achieving improvements is to understand the situation.
- The CO_2 footprint of ordered machinery or goods should be enquired when asking a company for a quote. The company may not presently be able to deliver in this regard, but asking is free of charge and emphasises the importance of this aspect for future enquiries and production.
- When comparative bidding is required, key figures with regard to sustainability should be listed among the criteria.

4.4.D Workshop Organisation and Visitors

D-PHYS members assess the climate impact of the scientific events they organise (including visitor invitations) in their planning stages.

Comments

- Scientific conferences, workshops and schools attract a large number of external visitors, either by direct invitation of speakers or by creating an opportunity for scientific interaction. Travel to these events can generate significant amounts of GHG emissions depending on the international composition of its visitors (tens, hundreds or even thousands of t[CO_2eq] to be compared to business travel at D-PHYS at a present emission rate of around 1450 t[CO_2eq]/yr).
- It is important to understand the overall quantitative GHG impact of a planned event as well as a the impact on the ETH emission figures.
- It is noted that scientific meetings are initiated by individual researchers on behalf of the scientific community, while the share of crediting and responsibility is difficult to assess. To this end, D-PHYS members who serve as members of conference series steering committees and organising committees of scientific networks can have a significant influence on designing our scientific operations to be compatible with sustainability (e.g. in the choosing the geographic location of a particular event or by implementing VC elements).
- It makes sense to apply this guideline to external events coorganised by D-PHYS members: This will spread awareness of GHG emissions throughout the scientific community and thus facilitate a change towards sustainable operations.
- The choice of supplied food (lunch breaks, conference dinner) has a direct impact and an indirect impact on the GHG emissions by the workshop: Vegetarian and vegan meals have significantly lower effective GHG emissions than corresponding meat-based dishes (there are also other significant reasons to do so). Supplying such delicious meals in high quality may inspire participants to choose more climate-friendly food options at home or as an organiser of future events.

- Avoiding waste products, e.g. by using ceramics cups and plates during breaks and meals or by minimising the amount of give-aways, has a positive impact on overall sustainability. Besides, it emphasises the highest quality standard of Swiss hospitality and it helps by transmitting a *consistent* message of environmental concern.
- The Pauli Center implemented this guideline in 2018 as a requirement for proposals to support workshops.

References

Further suggestions and guidelines can be found in the following references:

- ETH guideline sustainable events:
  https://ethz.ch/content/dam/ethz/associates/services/Service/sicherheit-gesundheit-umwelt/files/umwelt/en/2018-06_Guideline%20sustainable%20events_ETH.pdf
- ETH guideline sustainable catering:
  https://ethz.ch/content/dam/ethz/associates/services/Service/sicherheit-gesundheit-umwelt/files/umwelt/en/Guidel-Sustainable-Catering_UZH_ETH.pdf
- ETH online tool sustainable events:
  http://nachhaltige-events-eth.ch/?&language=en
- Practical tips for sustainable events:
  https://ethz.ch/services/en/news-and-events/internal-news/archive/2020/01/sustainable-events.html

4.5 Incentives for Sustainable Research

Moving scientific operations towards a more sustainable mode can only be achieved by the community as a whole while pioneering individuals can play an important role in the transformation. At present, individuals can enhance their apparent performance by relying on methods with detrimental impact on the climate (such as excessive travelling to promote their results). Therefore, incentives are required to encourage individuals to align their own behaviour and operations with sustainability goals. Even though these may appear to have no immediate benefit to science, as a community we should appreciate and value the global boundary conditions.

We acknowledge that the following measures are not suitable for implementation in the limited context of D-PHYS at present. Nevertheless, we consider them useful items, e.g. when implemented at ETH altogether or in other science organisations. D-PHYS members may well initiate and contribute to such implementations.

4.5.A CO_2 Taxation

Impose a tax on CO_2 emissions due to operations at D-PHYS.

Comments

- Other departments at ETH have implemented a tax on CO_2eq emissions due to flights.
- Implementation requires accurate data and general agreement on details and procedures.

- Taxation would serve as a motivation to collect accurate GHG emission data for other scope 3 aspects.
- This needs a suitable cause for spending the collected tax funds:
  - We do not intend to generate savings.
  - We could fund a prize to supply benefits to projects with sustainability improvements.
  - We could contribute to CO_2 offsetting, CCS or production of synfuel: E.g. climeworks offers to permanently remove CO_2 from the atmosphere at a price of around 600 – 1000 CHF/t[CO_2eq]. CO_2 offsetting at myclimate is available at around 30 CHF/t[CO_2eq].
  - We could co-fund travel if a sustainable mode of transportation is chosen.
  - We might fund sustainable research projects (including from students), e.g. sustainable projects from the student project house.
- Due to various issues that would need to be resolved, we would currently refrain from imposing CO_2 taxation at the level of D-PHYS. However, a tax could be implemented in the future in order to expedite progress in the ETH air travel project if our progress in CO_2eq reductions will turn out too slow.

4.5.B Prize for Sustainable Research

Establish a prize on research projects which incorporate new ideas to conduct research in a more sustainable mode. Fund additional project members for the best measures to be implemented.

COMMENTS

- D-PHYS is not ideally suited to host such a prize: no appropriate vehicle, no critical mass.
- Such a prize would be open to all research directions, i.e. it would not be restricted to research on topics of sustainability.
- Ideally such a prize would be hosted at SNSF project funding (or other funding agencies like the ERC). It may also make sense at the level of ETH which offers some competitive research funding schemes. Colleagues involved in funding agency committees are invited to forward ideas and thoughts to suitable recipients.
- The establishment of the prize and its awards encourages awareness for climate/sustainability issues.
- The incentive encourages critical thinking and generates new ideas in a distributed fashion. And the advertised sustainability improvements are put into action by the project.
- A prize has a natural outreach component.
- A prize could be financed by a tax on CO_2eq emissions.

4.5.C Award for Implementing Sustainable Operations

D-PHYS (or ETH Zürich) may adopt a version of the UK Green Impact Award including the scheme of award levels, tasks and criteria catalogue.

REFERENCES

- Green Impact Award at Oxford: https://www.greenimpact.org.uk/oxford

Comments

- This is an established scheme developed with experts.
- The success criteria are already defined, however some of the achievement descriptions need to be adopted to the reality at ETH.
- The award requires a pool of auditors to verify the completion of the tasks.
- At the University of Oxford, the tasks can be completed and checked in an online workbook. It might be possible to implement a similar infrastructure at ETH, potentially via ETHIS.
- In view of the necessary infrastructure, this can only be reasonably implemented at the level of ETH Zürich or the ETH domain.

4.6 Education, Training and Knowledge Transfer

This section sketches a vision of sustainability in education at ETH and other institutions within the ETH domain or the IDEA league. Subsequently, it highlights measures that D-PHYS, or more broadly, ETH can adopt to this end. The overall aim here is to introduce sustainability into education and training in a way that helps individuals in taking sustainability into account when making decisions both in their professional as well as personal lives and as responsible members of society. In view of the particular relevance of this topic, this section has been conceived with strong involvement of student representatives.

Sustainability in Education

Sustainability in education has been recognised as a hot topic and is being discussed at the highest university levels. The ETH council is consulting with the student assembly on this matter with concurrent discussions being held at EPFL and other institutions of the ETH domain. Similarly, the homepages of elite institutions world-wide, such as Cambridge or Yale to name just two examples, are announcing ongoing changes to their curricula in this direction.

The reason for this global trend is clear: A central aim of university education is to turn students into *responsible members of society*, who can solve interdisciplinary local and global problems that define this generation, and simultaneously to prepare them for demanding work environments that require highly specialised knowledge and skills. ETH officially accepts this challenge as part of its mission statement.

Undoubtedly, the foundation is laid during primary and secondary education. And indeed, it could be argued that those are the stages during which environmental consciousness should be cultivated. When moving on to university, students will then specialise in their chosen subject. The traditional point of view at ETH is that you will learn about physics in D-PHYS while environmental topics belong in D-USYS. Yet in practice, this approach leaves many of our students only remotely aware of the necessity and approaches to resolve the dire climate situation for humankind. This, for instance, can be inferred from their inability to even state the central aims of the Paris Agreement or their ignorance of the Sustainable Development Goals “SDGs” (let alone knowing the contents). Universities like ETH Zürich are in an excellent position to *fill this knowledge gap* and, going further, make sure that students actively engage with the sustainability topic by strengthening the *critical thinking* approach which ETH Zürich takes pride in.

Importantly, viewing this particular task purely as a clash of priorities and time allocation is a false dichotomy. Much rather, D-PHYS alumni will inevitably be confronted with consequences of the climate crisis in their future careers – be it in technology, science, finance or services. A proper education in this regard will increase their chances of successful work, and incidentally, this will reflect positively on D-PHYS and ETH.

Situation of D-PHYS

In the case of D-PHYS we clearly need to rely on an interdisciplinary approach which is supported by ETH Zürich's belief "that a network of knowledge and skills acquired in an *interdisciplinary environment* best respond to the natural and cultural interdependencies of life". It is evident that the scope of D-PHYS is at a much more fundamental level than most scientific aspects with immediate connection to the climate crisis. Correspondingly, we lack concrete first-hand research expertise in this area and we on our own can only inadequately educate our students in this regard. Yet, physics provides the foundation for the earth's climate, and there is clear demand and a great interest for climate sustainability topics among the present students and young academics. In fact, a curious observation is that among people who actively engage in fighting climate change, many have a solid foundation in physics, or even are physicists by training. This may indicate that physics education is indeed an ideal foundation for understanding nature along with its diverse orientations; perhaps this correlation is related to our deeply rooted understanding that violating the laws of nature is simply not an option.

Yet, it is also clear that education is a long-term investment while the challenges of the climate crisis are becoming imminent. If our efforts in education shall have an effect in tackling the latter, they need to be enacted as soon as possible. Hence we need to deal with the situation with the means presently available to us.

Continued Training and Knowledge Transfer

The university environment lives and thrives on academic exchange through an array of research seminars and colloquium talks. The academic community needs to be up to date with the latest developments in their field, but as scientists we are also very interested in interdisciplinary talks in order to understand better the bigger picture and to update our perspective on it. And also the non-scientific members benefit from inspiring presentations, and the knowledge they gain can come to good use in their work. Likewise, when we encounter challenges in aspects of our work that do not immediately concern our own research, be it administration, leadership or teaching, we typically resort to asking scientific experts of these topics for their research results, experience and advice. It is thus natural to make use of scientific exchange resources in subjects of sustainability and the climate, both as an interdisciplinary effort and towards making informed decisions in our professional life.

References

- ETH mission statement:
  `https://ethz.ch/mission-statement`
- Cambridge Zero:
  `https://www.zero.cam.ac.uk` (information on changes to curriculum at the bottom of the page)
- Yale:
  `https://sustainability.yale.edu/academics-research`
- ETH critical thinking:
  `https://ethz.ch/critical-thinking`

- https://en.wikipedia.org/wiki/Sustainable_Development_Goals
- https://sustainabledevelopment.un.org

4.6.A High-Profile Colloquium Talks on Sustainability Topics

Establish a high-profile talk by a renowned researcher (external or internal) on a key sustainability topic aimed at all ETH members (employees, students) to be held once per semester.

Comments

- This could have a serious impact if supported, implemented and advertised by the ETH school board as an ETH-wide activity.
- This is not reasonably implementable at D-PHYS; the idea has been communicated to ETH sustainability office.
- An existing format is the ETH lecture series “Pioneers in Sustainability” which however is not widely known or advertised:
  https://ethz.ch/en/the-eth-zurich/sustainability/dialog/pioneers-in-sustainability.html
- Encourage discussion of the presented material by following the talk up with an informal apéro.
- This may draw students’ attention to job opportunities with aspects of sustainability.
- This has a natural outreach component, it will encourage discussions among ETH members and will strengthen overall ETH sustainability efforts.
- Until then (or in addition), D-PHYS may reserve one slot of the “Zurich Physics Colloquium” per semester to a topic in an area of sustainability intersecting with physics.

4.6.B Teaching of Climate Crisis Basics

Ensure that future D-PHYS alumni (or more generally ETH alumni) will possess a basic knowledge of aspects of the climate crisis, e.g. by establishing a lecture course on this topic.

Comments

- Contents of the anticipated lecture course include but are not limited to the keywords:
  - Sustainable Development Goals (SDGs)
  - Paris Agreement
  - scope 1, 2, 3 emissions
  - national and international policies and standards
  - relevant mechanisms of society, economy, politics
- Further working knowledge could be acquired in a dedicated living labs project, see below suggestion on PRISMA course.
- This suggestion is not specific to D-PHYS; furthermore, the potential supply and expertise of lecturers at D-PHYS for such a course is low; the idea has been communicated to ETH sustainability office.
- An interdisciplinary course could be delivered by some expert department in the form of a MOOC to all ETH students of a given level.

- Alternatively, we may resort to external MOOCs (see below) and encourage students to participate in them. External MOOCs may also serve as a resource for students with a deeper interest in sustainability.
- In order to expedite the establishment of such a course at ETH level, it would be useful to actively signal a demand and to indicate how to incorporate it into the physics curriculum.
- Communicate the course explicitly as a low-intensity course that provides bites of information with significant societal relevance (and thus is perceived as a refreshing moment in a high-intensity weekly schedule). Make sure to shield students from additional time pressure.

References

- TU Delft sustainability, educational resources:
  https://www.tudelft.nl/en/sustainability/education/
- Sample MOOC:
  https://www.tudelft.nl/en/sustainability/circular-economy-an-introduction/

4.6.C Introduce PRISMA at D-PHYS

Introduce PRISMA as an elective course in the Physics Bachelor degree.

Description

- Pilot project launched by VSETH students (Medea Fuchs, Patrick Althaus); funded by Innovedum; currently based at chair of Prof. Stefano Brusconi (MTEC) .
- Aims to make critical thinking at ETH more hands-on and engaging by providing a one-semester course during which small teams of Bachelor students solve a real-world problem
- Each semester is dedicated to one particular SDG, e.g. SDG 11.
- Sustainable Cities and Communities in HS20; cooperation with Zurich Smart City Lab).
- Each team is coached by a Master student.
- Will provide students with the opportunity of carrying out a living lab project that solves a sustainability issue in their local environment
- Will consolidate facts learnt in the lecture course and understand the relevance of these facts by seeing them in a real-world context

Comments

- This interdisciplinary course has already been accepted as elective course by 10 other departments, including D-MATH, D-INFK and D-ARCH.
- The course fits well with increased flexibility during the 3^{rd} bachelor year achieved by the concurrent bachelor reform.
- This suggestion clearly requires further discussion with the teaching committee at D-PHYS.
- Master and doctoral students serving as coaches will benefit in various ways:
  - Within the PRISMA course, each team of Bachelor students is led by a Master student.
  - In preparation, PRISMA offers coaching training for these master students based on techniques used in the high-profile ETH week.
  - PRISMA coaching would go even further and help master and doctoral students to acquire strong communication, teaching and team-leading skills.

4.6.D Credit Points

Courses with sustainability/climate context are made creditable towards physics bachelor/master degrees.

Comments

- The department may ensure that the rules governing the crediting of courses in humanities and social sciences equally apply to non-physics courses with topics in climate and sustainability. This would naturally include the previously mentioned courses.
- The department may decide on the implementation of a minimum number of credit points in the physics bachelor/master from sustainability topics (requires coordination with the teaching committee at D-PHYS).
- Correspondingly, the learning goals for our degrees may explicitly mention a basic understanding of climate and sustainability as a relevant skill.
- The department may make some relevant internal/external MOOCs creditable.
- Actively encourage enrolment for these courses by highlighting them in the course catalogue and by advertising them, for example, during the introductory lectures at the start of the first semester.
- Creating a demand for such courses will lead to broader availability.

4.6.E Sprinkle Sustainability

Sprinkle aspects of sustainability in established lecture courses, homework exercises including data analysis and programming, student seminars and lab experiments.

Comments

- Include homework exercises or examples using data from climate change research in new "Data Analysis" course in 1st year of Physics Bachelor.
- The physics lab courses may dedicate some experiments to topics with connections to sustainability. A natural point of introduction would be a general revision of experiments such as the present one which has been initiated in response to the coronavirus pandemic. We could attempt to solicit advice from D-USYS, e.g. Prof. Reto Knutti.
- In order to advertise sustainability and reinforce awareness, the SSC could develop a collection of micro-presentations on topics of sustainability (with potential connections to physics) to be delivered by SSC students within the breaks of major physics lectures.
- Illustrate links to sustainability, where appropriate, in activities not explicitly focused on this topic, potentially in the form of supplementary materials for the benefit of interested students.

4.6.F Teaching of Sustainability Topics at D-PHYS

Members of D-PHYS offer specialised lecture courses and other educational formats to engage physics students in sustainability topics.

Comments

- Physics within D-PHYS is mostly carried out as fundamental research. Working expertise in applied physics relating to sustainability and the climate crisis is rare within D-PHYS and experts are hosted at other departments.

- Michael Dittmar offers the two-semester specialised course “Energy and Environment in the 21st century”:
  - This is the only lecture course at D-PHYS with a clear connection to sustainability.
  - It attracts between 40 and 60 registrants.
  - The lecturer will retire in early 2021. The department needs to make up its mind whether the course shall be continued, replaced with an alternative content or whether it has to be dropped altogether.
- Niklas Beisert offers a series of 10-minute presentations “Give the Climate a Break” on the basics on the climate crisis:
  - The presentations are offered to interested students during the breaks of selected lecture courses of the physics curriculum. The format has been introduced within “Quantum Field Theory” in HS19 and an iteration is planned for “*Allgemeine Mechanik*” in HS20.
  - The format provides long-term exposure to the topic and a broad reach with minimal investment on the student side.
  - This format can also involve representation by various ETH institutions involved in sustainability such as SSC, ETH sustainability, as well as presentations by highly committed students.
- The department may consider to offer a student (pro)seminar on topics from the intersection of physics and sustainability:
  - The contents can be designed in collaboration with participating students.
  - Doctoral students and postdocs can be involved in the supervision of seminar students. This represents an opportunity to engage in the subject at a professional level and to satisfy the teaching obligations at the same time.
  - The seminar can serve as a first step in establishing a more formalised course.

4.7 Reporting, Committees and Outreach

A most desirable feature of any implementation that improves sustainability is that its impact will be as broad as possible. This effect can and should be strengthened by reporting and outreach.

4.7.A Evaluation D-PHYS 2020

Our aims, strategy and efforts in implementing sustainability in our operations are presented to the external evaluation committee in Autumn 2020.

Comments

- A relevant observed conflict of interest in implementing sustainability in our operations is an envisioned negative impact on performance. Our performance is evaluated by an external committee of peers in intervals of 7 years.
- We will discuss and solicit feedback on the balancing of aims and conflicts at this opportunity.
- As our peers, the evaluators may take up ideas and export them to their institutions.

4.7.B Reporting

D-PHYS members are encouraged to report on particular implementations of sustainability in established reporting channels.

Comments

- Good ideas will have an unnecessarily limited impact when they are implemented only for a single research group. Ideally they can be taken up by peers and superior instances.
- Successful implementations will easily inspire and convince peers.
- There are numerous reporting channels where relevant items may be communicated such as ETH AAA or funding agency scientific reports.

4.7.C Communication

D-PHYS maintains a mailing list on sustainability where news, events and suggestions can be communicated to interested department members. A departmental wiki on sustainability collects knowledge, implementations and ideas.

Comments

- A mailing list offers an easy, efficient, universal and non-intrusive mode of communication. A wiki is open for contributions by department members and serves as a resource for our community and beyond. Further structures for interaction could be established upon demand.
- The mailing list allows a group of department members to stay in touch and keep each other updated about relevant developments.
- Useful ideas can be spread for swift implementation by interested peers.
- The mailing list and wiki shall be advertised to all department members at regular intervals, e.g. once per semester, potentially with a digest of news items.

4.7.D Roundtables

Organise regular roundtables on sustainability

Comments

- Roundtables offer an occasion at which perspectives on general and current sustainability and related issues can be exchanged in casual atmosphere.
- Roundtables may be scheduled at regular intervals, e.g. once or twice per semester and at a convenient time, e.g., during lunch times. They would be open to students and staff.
- Alternative topics to broaden the scope may be working conditions in academia including study.
- This would be too specific for D-PHYS and better implemented centrally at ETH (both in the centre and at Hönggerberg) or hosted by SSC.

4.7.E Committee Work

D-PHYS members bring up and discuss relevant issues of sustainability (including CO_2 impact) in their work in departmental and external committees.

Comments

- This goes without saying but deserves being emphasised.
- Active discussion of issues of sustainability within groups can activate unused resources and generate new ideas.
- This has an outreach component for external committees and committees involving external members.

4.7.F Alumni Talks

We may invite D-PHYS alumni who are actively involved in the green economy or institutions working on sustainability for career networking talks and events.

Comments

- We can learn from others. Perhaps we are more likely to learn from our own alumni with a physics background and education.
- This will also show a career perspective to our students and non-permanent members.

4.7.G Conference Reporting

Assessing and reporting the CO_2 impact of workshops could be done at the level of common workshop tools (e.g. indico).

Comments

- This suggestion would bring awareness for CO_2 impact and provide an assessment tool to the wider community of our science.
- One option may be to upgrade the indico conference website management tool which is used widely within our community. This could be done by developing an add-on or by encouraging the core development team to do this.
  Indico website: `https://getindico.io`