



iGEM Team TU Dresden 2017

A Guideline for iGEM-Teams and
Sustainable Scientific Bench Work

GoGreenGuide



es green

iGEM goes green

PUT FORWARD BY THE TU DRESDEN iGEM TEAM 2017.

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Opinions, ideas or suggestions? This guide is under ongoing revision during the iGEM year 2017 and we'd love to hear from you! Drop us an email or open an issue on the GoGreenGuide's GitHub page. You are also welcome to follow the iGEM goes green initiative on social media.

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Both financial and non-financial value drivers contribute to companies' success. Identifying inter-dependencies between value drivers and consequently deduce specific measures to increase the positive impact of ecologic actions and decrease negatives ones are important cornerstones of a sustainable development.

In this context, measuring and evaluating sustainability with various methods provides important information on the base of which decision can be made.

Synthetic biology and its different focuses can achieve important contributions to sustainable development, particularly regarding the reduction of greenhouse gases. The development of novel processes should always be carried out in context of evaluation of sustainability.

Peter Saling, BASF SE, Director Sustainability Methods



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Introduction

How iGEM goes green Came Into Beeing

For more than 10 years now, over 300 teams from all over the world have been attending Boston to participate in the internationally most renowned student competition for synthetic biology: As part of the international Genetically Engineered Machine competition (iGEM) they find solutions to divers contemporary problems by using genetic components and biological systems.

Besides the lab work, a successful team also has to consider the aspects of biological safety, public relations, documentation and finances of their project. However, when we set out to join iGEM with our own research project, we quickly realized being responsible for the safety, resources and outreach of our project was not covering a facet of the competition we feel strongly about: We decided to take one step further by taking responsibility for the environmental impact of our participation in iGEM and especially the related trip to Boston. We want to investigate the ecological footprint of our work as a team and find ways to reduce it.

With the aim to encourage other teams to join us and get involved in sustainability themselves we decided to share our ideas and started the “iGEM goes green” initiative.

About this Guide

While this guide is written by an iGEM team and primarily with other iGEM teams in mind, it still strives to be of value to any other research group or project team interested in suggestions about a more environmentally friendly working routine as well.

However, for the purpose of giving other iGEM teams a general overview of what to expect, chapter 1 is an iGEM-specific chapter focusing on how to participate in iGEM goes green. Any iGEM team not feeling motivated to read an entire chapter on the matter right away is invited to skip forward to section 1.3 for our **GoGreenChecklist** for now.

Chapter 2 deals with possibilities for environmentally-conscious lab work. Due to the high security regulations in biological laboratories it is not possible to simply turn off devices and systems (e.g. ventilation) to save energy. Despite this, we still believe that lab work can be shaped into a more sustainable practice through good planning and the conscientious usage of resources.

For now the chapter only includes basic information we gathered from different sources. Once our lab gets busy enough for it to yield reasonable results we will track our lab consumption of materials and energy for a set period of time to collect the data we need to calculate our ecological footprint and to identify possibilities to organise processes more economically. We will add more suggestions and some insights here once this is done.

As every other research project, iGEM is more than just lab work: Regional meetups are an important and fixed part of every iGEM year and the highlight is the concluding conference in Boston in November, where all teams are presenting their results. Therefore chapter 3 contains notes concerning the sustainable organisation of meetings and conferences. Everybody motivated to pursue the topic of sustainability even further will find ideas going beyond the mere context of scientific research in chapter 4.

Yet even if our lab and the conference were organized in the most sustainable way and we'd all shape our everyday life more environmentally friendly, there is not much we can do to reduce the impact of the transatlantic flights from Germany to Boston and back. Therefore, chapter 5 dedicates itself to possibilities to compensate greenhouse gas (GHG) emission.

Last but not least — and for those who want to go all the way — chapter 6 provides at least basic knowledge on how to estimate a teams GHG footprint.



1. Taking Part in iGEM goes green

1.1 Join the initiative!

Officially becoming a part of iGEM goes green is fairly simple. All you've got to do is:

1. Dedicate a subpage of your team's wiki to your efforts towards a sustainable participation in the competition.
2. Send us the link.
3. Get the go green logo in return and place it on your wiki.
4. Do whatever your team can afford to shape your teams participation in iGEM in a green way.

We are planning on having a map showing all teams involved in iGEM goes green on our Wiki with links to their go green subpages. As the environmental impact and the options for reducing and compensating greenhouse gases vary a lot between teams of different locations, sizes and projects, having specific requirements or comparing teams does not make much sense. Therefore it is entirely up to your team, how much you actually do and what steps towards a green iGEM competition seem feasible to you. You decide whether your team is part of iGEM goes green.

1.2 Set a sign - Plant a tree!

When we first thought about compensating the environmental impact of our flights to Boston - before we started iGEM goes green - our first idea was to plant trees. While we realized we would go beyond the mere compensation of our flights we figured out that the flights alone would need several hundreds of trees to make up for. Still the idea remained and we liked the thought of planting a tree somewhere in Dresden or its vicinity at least as a symbolic act.

And on October 25 2017, our idea finally came true: we planted a *Quercus macrocarpa*, a bur oak, in the forstbotanical garden of the Dresden University! This tree possesses drought and fire resistance and is also capable of tolerating urban conditions. We donated 100€ to cover the costs for tree and care over the next decades. You might get cheaper options by planting a tree in your

own garden, but our focus was laid on the long-term impact.

With that option, our vision of an 'iGEM forest' would have been way to expensive and the forstbotanical garden would have needed to largely expand. Nevertheless, we still want to encourage you to search for a spot somewhere close to your university for planting a tree for your team yourself. At this point we also want to thank the 2017 teams which have been able to plant one or even more trees. You're awesome!

1.3 GoGreenChecklist

To give you a good overview of what awaits you, we wrote this checklist. You can put it up in your teams head quarter or use it to show your efforts on your Wiki's go green subpage.

Required to officially become a part of iGEM goes green:

- Read this guide.
- Create a wiki subpage for your efforts towards a green competition.
- Send us the link.

All set? Great to have you on board! No Wiki yet? Doesn't matter. There is no reason not to start with the actual work already and send us the link later on. Start with the actions toward a greener iGEM and fill your Wiki's subpage with what you are doing. Possible steps and suggestions what to do are listed below. Depending on your teams situation you might not have the possibilities to realize all of this, but don't worry, every little bit counts. Little by little a little becomes a lot!

Actions towards a green iGEM competition:

- Make your lab environmentally friendly (suggestions in chapter 2).
- Organize your meetings and meetups environmentally friendly (see chapter 3).
- Track your labs consumption of materials and energy...
 - ...to be able to estimate your teams GHG emission.
 - ...to share the data with us.
- Calculate the GHG emission caused by your teams trip to Boston.
- Calculate your teams total GHG footprint (don't worry, we tell you how to do it in chapter 6)
- Compensate your teams flights, parts of or even your entire emissions (check chapter 5 for options).
- Help to spread the word by sharing and following iGEM goes green on social media and by posting your own updates.
- Involve the public even more by organizing events.

-  Help improving this guide by correcting mistakes or even sending us additional ideas, suggestions or information. Of course you'll be mentioned as a collaborator.
-  Collect the money to plant a tree. Please read up on our tree-planting plans in section 1.2.
-  your ideas: _____

1.4 What's in it for you?

Taking part in iGEM goes green is of course not about winning anything. It is about being a part of change, about setting a sign and shouting out that we do care about our environment. Of course you will gain more than just a good feeling: Sustainability is the future and you will become quite an expert concerning sustainable bench science. You will also get the chance to collaborate in a field outside your actual project by helping us to develop this guide further and to gather enough data to learn something about the average environmental profile of an iGEM team. You will get connected with other teams on a whole new level.

Still, most important is the fact that you will help to reduce the harmful impact of scientific work on the environment. Let's rephrase the question: What's in it for the environment? And that's not really a question, is it?



2. Green Lab

With a high consumption of resources such as energy, water, and chemicals, laboratories are among the university institutions with the greatest impact on the environment. Depending on their size, laboratory buildings consume 3-4 times as much energy as an office building. Thereby, the largest share is accounted for ventilation and cooling systems (~ 60%), followed by the lab equipment (freezer+ other devices) (~ 25%) and most of the rest is lightning. [1]

The total energy consumption is of course dependent on the size of the lab, the research topic, the equipment and its operating times. For calculating how much energy and resulting from that how much GHG your lab produces read chapter 6 about Greenhouse Gas calculation. With some simple “lab hacks” you can avoid waste production, save energy and water and thereby reduce GHG emissions of your lab. If you are not convinced to change your behavior for the environment: sustainable laboratory work saves not only energy and resources, but also money.

- leaf Find out how much GHG and energy your lab consumes!
Check out chapter 6 on Greenhouse Gas calculation!

2.1 Lab equipment

2.1.1 Fume hood

One of the most energy intensive devices in laboratories are chemical fume hoods. The air changing system consists of supply fans that bring air in the fume hood and exhaust fans that pull the air out of the building. A fume hood that runs 24 hours a day, 365 days a year consumes 3.5-times more energy than an average house!

- leaf Close the sash of your fume hood each time you stop working there and remind your lab mates to do the same!
Closing the window in front of the fume hood, known as “sash” can reduce the exchanged air from 600 m^3 to 200 m^3 per hour. Thereby, a lot of energy and money can be saved.

Harvard University started the “Shut the Sash” program in 2005 and even published their own study with data and behaviour tips to reduce the costs and increase the energy efficiency of fume

hoods.[2] The University of Nottingham made a similar 'shut the sash" campaign and could save 5%-25% of energy. [3]

2.1.2 Freezer

Where do you store your biological samples? In the freezer of course. Ultra low temperature freezers are commonly used to store biological samples over a longer time period. Thereby, they can cost more than 1000€ in 'plug load' electricity (i.e. not including their impact on room air cooling systems). This is just one -80°C freezer! How many freezers do you have in your laboratory building? Best saving measure is to reduce the number of freezer running at the same time or make them run more efficiently.

But how to achieve that?

-  Become a sample minimalist
 - Start decluttering your freezer and organize it in a more accessible way. Make sure you know exactly what is inside and dispose any samples that are no longer needed. Do regular inventory checks before it starts getting messy again.
-  Share with a neighboring lab
 - After decluttering you have now a freezer that is only partly filled? Ask your neighbor labs if you can share freezing space with them. Supports socializing as well.
-  Defrost and clean your freezers regularly
 - Opening your freezer gives you an arctic feeling and makes you afraid of polar bear attacks? Time for defrosting!
 - When there is an ice layer covering the coils, the compressor must run longer to maintain its temperature = higher energy consumption.
-  Raise freezer temperatures
 - Raising the temperature from -80 to -70 degrees saves up to 30% of the energy it uses and research shows that many samples can be stored at -70 degree as well. Moreover, the less cooling effort will increase the lifetime of your freezer.
-  Find the right place for your freezer
 - Always remember that cooling the interior also means heating the outside, and this heat needs to go somewhere. So if you store your freezers in a dedicated cold room, the air-conditioning system is adjusted to remove the heated air directly. The room temperature will not be very affected. But if your freezer is in the hallway, you're just heating the whole environment and your air-conditioning has to work against this 24/7. So think carefully and find the right place for your freezers and refrigerators.
-  Store your samples at room temperature
 - Yes, this is possible! Especially DNA and RNA can be stored long-term in a dried state without quality loss. This also applies for bacteria in short-term means and might be soon addressed for other biological samples. Storing the dried samples in well-plates can shrink the container size up to 90%. [4] Stanford University estimated how much savings would be possible if room temperature storage was implemented. For their 9 million to 13 million samples that are potential candidates, room temperature storage would save 2.4 million kWh (1100 tonnes of CO₂ emissions) per year! [5]

2.1.3 Autoclave

A single run of an autoclave can consume up to 900 liters of water, but of course sterilization methods are important for safe working. Still by improving your autoclaving skills, you can reduce energy and water consumption of the device significantly.

Consider the following rules when autoclaving:

- 👉 Do not run the autoclave only half filled but do not overfill the chamber either – Steam Flow is Key!
Whenever you need to run the autoclave, ask your lab mates to combine load and leave a note at the autoclave to remind other people to ask you before autoclaving, too.
- 👉 Turn the unit off and keep the door shut when not in use
Even when not in use, an autoclave uses between 3 to 6 liters per minute for its cooling system only.
You would not leave the door of your refrigerator open, would you?
- 👉 Use energy saving control features
Check the instructions of your device to find out if there is a more ecofriendly mode for your use applicable.
- 👉 Sort your stuff!
Reduce autoclaving needs by sorting your working material. Only required items are autoclaved and other items are run through the dishwasher.

2.1.4 Electrical devices

There are so many different electrical devices in a lab you only need on certain days or just for some hours a day. What about centrifuges, PCR cyclers, plate readers, heating plates ...?

- 👉 Remember to turn them off every time you finish your task!
You can also add "Turn me off" stickers to the devices to remind your lab mates. Also turn off environmental rooms or incubators when not in use.
The Kirschner's Lab at Harvard Medical School did a case study and revealed that turning off benchtop devices over night can save more than 50 % of energy consumption. [6] [7]
- 👉 Share your devices with others
If your device is not booked 24/7, why not offer it to other scientists? This might cause higher energy consumption for you in the first place, but prevents a potential new electricity guzzler in another lab. Among others, Open IRIS is a free platform to enable resource sharing. Keep it in mind for your next experiment! [8]
- 👉 Look out for labels
We all know different labels, e.g. for organic food or energy efficient devices. There are initiatives to develop sustainability labels for lab products. If you're in the US, make sure to buy freezers that have the energy STAR label. Further labels are the EGNATON-CERT label and the ACT label:
EGNATON-CERT is a work in progress, but there will be a sustainable label for e.g. autoclaves, freezers, washing machines or incubators. Launch of the first certified products is planned in 2018.
The ACT label was developed in the US to label sustainable lab products as consumables, chemicals and reagents and equipment. It is also still in progress (launch 09/2017). Find out

more about the different labels on their websites:

<http://act.mygreenlab.org/0>

<http://www.egnaton.com/en/Home.aspx>

 Give your old devices a second life

Donate old machines, especially to educational institutions such as high schools, instead of throwing them out. Giving away unneeded devices reduces problems like hazardous waste in landfills. For example, an old incubator could be refurbished for use in high schools with cell cultures rather than be broken down in a landfill.

2.2 Lab consumables

Plastic accumulates in ever larger quantities in the oceans, but because of its advantages it is difficult to replace. Plastic materials are also widely used in every day lab work. Due to sterility, products like gloves and pipettes are often used only once. So it is more important than ever to think about waste reduction, recycling and environmental friendly behavior concerning lab consumables.

2.2.1 Tips from A-Z. Let's get started!

 **A Autoclavable glassware**

All sorts of lab equipment are also available as glass ware instead of disposable plastic products. Do you really need one-use plastic pipettes or wouldn't glass pipettes serve the same purpose? As already mentioned in the previous section, autoclaving is an energy and water consuming process. Autoclaving reusable glassware is still more efficient than autoclaving contaminated plastic waste.

 **B Biodegradable materials**

The theory behind bioplastics is simple: Making plastic starting from kinder chemicals, it would break down faster and easier when we compost it. Check out if things like biodegradable gloves are practicable for you!

 **C Consolidate purchase**

Reduce packaging waste and transport ways by combining your orders with other labs, by planning ahead or by ordering from local suppliers. Additionally, if sterility is not an issue, try to buy items that are packed in bulk.

 **D Dry orders**

Order your oligos dry. It saves shipping weight, package material and is more stable.

 **E Eliminate hazardous chemicals**

Minimize the generation of hazardous wastes and find out if you could use eco-friendlier chemicals instead. E.g the MIT Green Chemical Alternatives Wizard assists researchers to find a safer, more environmentally-friendly alternative.

 **F Follow iGEM goes green**

We'll keep you updated about revisions of the Guideline, new tips and ideas and more!

Instagram: https://www.instagram.com/igem_goes_green

Facebook: <https://www.facebook.com/igem.goesgreen>

G Get creative!

Give your package material a second life and reuse card boxes and styrofoam containers. Upcycle them as storage boxes, underlay or hiding place for your cat.

H Have a look if your supplier cares about sustainability

Do they have solutions regarding packaging waste, resource-efficient and sustainable products and what about their company?

Many companies take care on environmental and social issues - have a look on their website, their "sustainability report" or just talk to their representatives. If you have the choice, select the company who cares most on sustainable issues.

I Inspire

Set a good example by making your lab more sustainable and motivate coworkers or other labs to join the movement. #igemgoesgreen

J Journal

Purchase journal abonnements online and do not print articles to reduce paper waste.

K Keep it simple!

Start with simple changes in your daily working routine to make your lab work greener - then you can deal with bigger problems.

L Label your stuff!

Label everything you do clearly, so you and others can be sure what it is and if it is still needed. Also label your bins clearly to support waste separation and recycling.

M Minimize

Order only the amount that you need. Do not buy chemicals in large amounts just because it is cheaper when you will never use it up.

N No excuses!

Start making your lab more sustainable today. There are so many possibilities how to start right away.

O Offer...

... unwanted equipment or unused materials to other labs or student groups.

P Pipette tips

Refill your old tip boxes by purchasing your tips in bulk. It makes great as initiation ritual for new lab members or as pastime during lab meetings. Alternatively, old pipette boxes in the lab make great containers for storage.

Q Quality

Make sure that all your lab consumables are of a high quality.

R Reduce experiments

Reduce the scale of experiments and protocols to the minimum size necessary to achieve research objectives. This can be achieved by good planning and saves chemicals, tubes and other working material.

**Size**

Use appropriate sized vessels to store your samples. You will save plastic, freezer space and money.

**Tubes**

Buy your micro reaction vessels and tubes from recycled plastic. Get them in bags and refill boxes and racks yourself.

**Up-to-date inventory**

Keep an up-to-date list of your lab consumables to avoid duplicate orders.

**Values**

Try to instill green values in coworkers and support green suppliers.

**Waste manager**

Choose a person responsible for waste reduction and informing other people about recycling ways.

**XYZ...**

Have a closer look around your lab. You will probably find more ways to reduce, recycle and refill.

2.2.2 Further important information

Some topics haven't been covered in the alphabet yet, and they also need more space for explanation. What happens to materials after use? And have you heard about Green Chemistry before?

**Green Chemistry**

Green Chemistry, also known as sustainable chemistry, aims to design chemical processes and products in such a way that no hazardous substances are generated. This means that remediation (treating waste streams and cleaning releases), is NOT included. Instead, less hazardous chemicals should be used.

For more information, click on the links below:

- Find the main 12 principles here:
<https://www.epa.gov/greenchemistry/basics-green-chemistry#twelve>
- If you're planning a synthesis, you can use the "Toolbox" to find the most sustainable synthesis pathway: <https://www.chem21.eu/project/metrics-toolkit/>
- Solvents can be hazardous for your health and the environment. Use less toxic alternatives - this solvent guide can help you to make the right choice: <https://www.chem21.eu/project/chem21-solvent-selection-guide/>
- If you would like to learn more about green chemistry, have a look on the Chem21 online learning platform: <http://learning.chem21.eu/#>

**Green analytics and Green chromatography**

"Green chemistry" was the basis to transfer it to analytics and chromatography and to frame the principles of green analytics:

- Replace and reduce toxic solvents, reagents, preservatives, additives for pH adjustment, avoid derivatization of your samples, minimize waste and reduce your resource consumption during your experiments.

- Miniaturization is key! Minimize your samples size and number of samples! This could be achieved by using microextraction techniques like SPME (Solid Phase Microextraction) or LPME (Liquid Phase Microextraction). Other examples are Nano-LC or capillary electrophoresis (e.g. for DNA-/RNA-electrophoresis).
- To minimize your number of samples, try to get as much information out of your sample as possible - 2D-chromatography is a suitable tool for all scientists working with complex samples (environmental analytics, etc.).
- Integration and automatization of processes also helps in information gathering, minimizes the variability between individual experiments and ensures safer procedures.

Find more information on the principles of green analytical chemistry in the publication of A. Galuszka *et al.* (2013). [9]



Waste separation and recycling

As stated before, hazardous chemicals and substances should be avoided at all costs. However, this is not possible in all cases and waste separation comes into play. Try to divert waste from the landfill by learning which objects can be recycled or composted and which cannot. A safety chart in a laboratory may also be effective for determining where waste should go, what should be recycled, and what should be considered hazardous waste.

Also consider that plastics could be collected separately, recycled and used for eco-responsible durable goods. Does your supplier have a "Take back"-program? Here's a recycling program for gloves and garments: <https://www.kcprofessional.com/brands/kimtech/rightcycle>

2.3 Workspace

Much has been said about how to go about working greener in the lab, but what about the office? Research is also a lot of reading, writing and computer work. Check out your possibilities for a more sustainable desk space.

2.3.1 Paper and printing products

Nearly every office relies on large quantities of paper. On the one hand paper is made from wood, a truly renewable and sustainable resource. However, on the other hand the current demand for paper consumes already 40% of the annual industrial wood harvest. So we exhaust the resource faster than it can regrow. [10] This will not work forever we should start overthinking our paper production and consumption practices now.



Alternatives?

Reduce paper waste by avoiding paper in the first place. Be more aware whenever you use paper and think about whether you really need a paper version of whatever you're up to.



Store manuals, policies and other documents digitally

Consider the environment before printing emails, papers or instructions.



Use both sides of paper

You thought about it and you are absolutely sure that you need a printed version of your document? Then at least make sure that your printer prints double-sided. Use it as default setting for your office printer.



Use recycled paper

Buying a writing pad with 80 sheets of recycled paper instead of a conventional one saves the amount of CO₂ that 353 web queries produce. More advantages of recycling paper compared to paper made from wood:

- The production requires 2-6 times less water.
- The total energy consumption is 3-4 times lower.
- The resource wood is spared. [11]



Reuse unwanted paper

E.g shred it and use it as package material for shipments.

2.3.2 Lights

Turn the lights off whenever you leave a room.



Natural lightning

Try to make use of the cheapest light source and shut the light in your office off as long as there is enough daylight for working. Use the night for sleeping and work during the day.



LED

Save energy and money by switching to LED lights. They are not very expensive anymore and their life span is so much longer than other lights.

2.3.3 Computers

Your computer is running the whole day - even when you are in the lab? Think about when you use your computer the most and switch it off in between.



Computer Sharing

Car sharing is a common trend, so how about computer sharing? Estimate the time you spend in front of the monitor and think about if you really need your own computer. Maybe you can manage to share one with your lab mate.



Give it a nap

Make sure your computer turns to energy saving mode when you are not using it for a short time.

Thanks for reading this chapter. You see, it is not that difficult to make a difference! If you feel motivated to also change some of your personal habits now, check out chapter 4.

Main ideas from this chapter were taken from the Harvard Green Labs Program [1] and the Green Lab Program of the University of California [12].

Do you want to implement many tips but don't know whether your institution will support you in this case? Do they have an environmental or sustainability management staff position ? If yes, get in contact ! Stabilize your project and ideas - in the end it could become a permanent element of your university organisation. Here's an example how to integrate and consolidate a "green lab program":

<http://www.colorado.edu/ecenter/greenlabs>



3. Green Meetups

This chapter concerns especially conferences and is mainly based on the guide for sustainable organization of events by the German Federal Environmental Agency [13]. In the iGEM context teams from certain areas get together for local meetups to create contacts and collaborations. However, even if you do not plan to host a conference of any kind yourself any time soon, this chapter is worth reading. Many aspects will be relevant for simple team meetings or events just as well. Furthermore, if you are attending a conference, reading this chapter will give you a good understanding on how to help shaping it green.

3.1 Transportation

Depending on the distance and mode of travelling, transportation easily becomes a very big issue for sustainable meetings. Try reducing the traffic induced environmental stress of your meeting as much as possible and think about compensating for unavoidable emissions or suggest to do so to the participants of your meeting. There are easy calculation tools for emissions produced by transportation and lots of providers for compensation, check out chapter 6 and chapter 5.

Keep in mind the following:



Make sure public transport is a good option.

- Choose a location that is easily reachable by public transport.
- Organising a shuttle service or shared cars from the train/bus station if the final location is hard to reach without a car.
- Schedule beginning and end of your event according to the operating times of relevant public transport.
- Give “attractive” options for using public transport. Check with the provider if there are any discounts. The tickets could include a bike option in the city etc.



Provide support for planning the journey.

- Inform the participants about environmental friendly travel options, this includes giving them a detail description on how to reach the location via public transport. The best choice can vary in each situation. Guiding principle: bike > a full bus > a full car > train > an empty car with just one person > plane
- Encourage them to share cars. If possible, provide a platform (mailing list, facebook group, etc.) for organizing shared rides.



Considering possible alternatives like telephone or video conferences.

Obviously this is not exactly an option for iGEM meetups, but meetings without a connected social aspect often don't call for a meeting in person.

3.2 Accommodation and Energy

Saving energy is something most people have thought about before, if only for financial reasons. Of course it's a good idea in the context of protecting the environment as well:



Reduce energy consumption.

- Don't heat the conference rooms over 20°C, don't cool them down further than 6 degrees below outside temperature.
- If you have the choice, use energy efficient devices.

However, one thing you probably don't think about much when you plug in a device or turn on the light is where exactly the energy comes from. Green energy makes quite a difference [14].



Think about energy sources.

Ask the accommodations whether they are using "green" energy sources and make it a criterion when choosing the hotel and conference building.

3.3 Food and Catering



Favour organic, fair trade and local products in season.

The positive impact of seasonal products is obvious (short transport routes). However, though you will probably agree that organic and fair trade are great in general, you might wonder how both help reducing emission. To answer that: Fairtrade International developed a Climate Standard and actively works against climate change [15], and organic farming, amongst other benefits, doesn't use the pesticides and fertilizers common in conventional farming which have a far larger carbon footprint [16].



Provide tap water in carafes.

If tap water is drinkable in your country, that is. Aside from the environmental benefits it saves you money and the hassle of transporting all those heavy water bottles.



Reduce the amount of animal products on the menu.

Global livestock causes 14.5 percent of all anthropogenic GHG emissions [17]. That's good reason to reduce the amount of meat, dairy products and eggs involved in your meals. Lamb, beef and cheese have the biggest impact here [18]. Yes, that's right: Cheese is worse than chicken, so going veg isn't enough (though of course it helps).

- Always provide vegetarian and vegan options.
- Cut down on animal products. It's up to you how far you want to go here - however, eating veg or even vegan for a weekend shouldn't be much of a problem for anyone. ;)
- Pay special attention to the source of products like coffee, chocolate and fish.

3.4 Material and Services



Procure and use materials prudently.

- Avoid paper waste: Print on both sites, minimize the number of handouts, and take back and recycle or reuse flyers etc.
- Try to use 100% recycled paper.



Pay attention to the sustainability of providers.

When inviting offers for services or products always state your environmental goals.

3.5 Waste management

Conferences and get-togethers with big enough numbers of people almost always end up with paper floods and mountains of disposable cutlery, plates and cups. We have talked about handouts and flyers before. Of course, there is more:



Reduce waste where you can...

- Use environmental friendly packaging (avoid plastic, prefer reusable containers, buy in bulk).
- Use reusable plates, cutlery and glasses.



...and separate where you can't.

Set up places for waste separation and make them easy to use by clearly stating what goes where and making sure full containers get emptied quickly.

3.6 Communication

Welcome to the most important section of this chapter. You might have read the preceding sections with a bit of unease or doubt, especially when it comes to checking energy sources or having all vegan meals. Understandably. If you haven't, maybe because none of this is new to you and you are excited to realize all this, keep in mind this probably won't be the case for all participants of your meeting. Therefore, no matter how far you decide to go with having a green meeting, make sure the communication is working out. Everyone involved needs to know about your goal to have a sustainable "green" meeting, otherwise it will be hard to make it a success.



Inform participants and public early on.

The goal of having a "green" meeting and the approaches to do so should be made public early on. While this works as a stimulus to reach the stated goals it's also a good advertisement for your meeting and for the green movement in general. Especially the participants should be informed about the green aspects of the meeting beforehand.



Involve the participants.

You won't be successful without their support and cooperation. Provide them with ways to get involved easily. We mentioned providing ways to organize car sharing before. You can think of more! Provide short guidelines on how to save water in the rest rooms for example.



Name a person responsible for the "green" aspects of the event.

That way someone will have the overview about what's going on. Everyone involved in organizing the event as well as participants should know whom to contact with questions.



4. Green Life

Nowadays there are so many lifestyles addressing different aspects of sustainable living. Minimalism, Veganism and Zero Waste are just some catch words here.

In this chapter we collected a few suggestions for developing a more sustainable lifestyle to provide a starting point for everyone who has not yet thought about sustainability in everyday life but feels motivated now to dive into the topic.

4.1 Eating Habits

What we buy and eat influences regional and global structures. Sustainable nutrition means considering the health aspects and the environmental, ecological and social impact of your food [19]. The same facts we already mentioned in chapter 3 are applicable here:

- leaf Reduce the amount of meat, eggs and dairy products on your menu
You do not have to quit everything you enjoy from your meal schedule. But think about reducing your consumption of animal-based food and pay attention to the quality. Global livestock causes 14.5% of all anthropogenic GHG emissions [17]. A plant-based mixed diet produces about 15% less green house gases than an unbalanced meat-based diet. Moreover, the production requires less water and acreage [19].
- leaf Buy regional and seasonal products
Buying regional and seasonal avoids unnecessary food transport. Furthermore it supports regional agriculture and economy.
- leaf Favour organic and fair trade
Though you will probably agree that organic and fair trade are great in general, you might wonder how both help reducing emission. To answer that: Fairtrade International developed a Climate Standard and actively works against climate change [15], and organic farming, amongst other benefits, doesn't use the pesticides and fertilizers common in conventional farming which have a far larger carbon footprint [16].



Drink tap water (if that's safe in your country)

It saves you money, the hassle of transporting all those heavy water bottles and is good for the environment. Also get yourself a reusable bottle for whenever you are on the go. Having your own fancy bottle might even motivate you to drink enough during the day. :)

4.2 Transport

Being mobile is crucial these days for most people, no question here. However, a car is not the only option to get around of course.



Go by bike whenever possible...

Traffic studies show that riding a bike can save up to 138g CO₂ per km and that up to 30% of the car trips in cities could be replaced by bike rides[20]. And it also has more advantages than just being climate-friendly: Riding a bike is flexible, pretty fast (for shorter trips within the city you might even beat public transport sometimes), healthy and makes a good start of the day. You'll feel much more energized and less stressed when you arrive at work or university after a morning bike ride instead of squeezing into the too full morning bus or going by car during rush hour.



...and choose the best alternative when the bike isn't an option

The best choice can vary in each situation. A general guiding principle is: bike > a full bus > a full car > train > a rather empty car > plane.¹ Think about looking for shared rides or offering them yourself, whenever you want to go by car.

4.3 Waste Reduction



Switch to reusable bags

Most plastic bags are used only once to carry home your purchases. But after that it takes decades for the plastic bag to disappear. But even then they don't truly disappear they only break down into tiny pieces you don't see anymore but which will end up in the environment and everywhere in the food chain [21]. And we haven't even talked about the related GHG emission during production yet! So bring reusable bags when going shopping to avoid wasting plastic bags.



Think twice before you buy a new product.

You might realize your old stuff is still working just fine. When you do buy something new, better spent a little more money and get something lasting instead of any of the cheap stuff that will only end up in landfills too soon.



Avoid plastic wrapping.

Shops that allow you to buy all your groceries in your own reusable containers can be found in some places already. But even in common stores you will find options using less plastic wrapping than others. Also bring reusable bags for veggies and fruits and try to avoid those plastic bags provided in the fruit and vegetable department as much as possible.

4.4 More things to do



Recycle

Recycle old batteries, wires, light bulbs, headphones, and other obsolete devices at electronics recycling drives. These centers can be found in laboratory parks or searched for online.

¹For Germany the "Deutsche Bahn" offers a calculation service: http://www.deutschebahn.com/en/sustainability/environmental_pioneer/umweltschutz_interaktiv/11887484/mobilecheck.html



Whenever choosing services, look for their sustainability

It's no only about buying Eco-labeled clothes or food, also in other life aspects we are spoilt for choice.

Have you ever tried another web search than Google before? No? Now it might be a good time to do: **Ecosia** invests its advertising revenues in planting trees! Have a look and try at <https://www.ecosia.org/>

For the bank sector, the **Fair Finance Guide** is a good help to decide for a bank which is investing in environment, human rights and other sustainability issues. Interested?

<http://fairfinanceguide.org/>

4.5 Further Reading



The lazy persons guide for saving the world:

<http://www.un.org/sustainabledevelopment/takeaction/>



Green blog published by The Green Guide Institute (TGGI):

<http://blog.thegreenguide.com/>



5. Greenhouse Gas Compensation

The first principle for environmental protection from greenhouse gases should always be the reduction and avoidance of emission of those. Nevertheless, some emissions can't be avoided without cancelling the whole project. At this point, compensation comes into play. Let's have a look at the different strategies of compensation!

5.1 Carbon Emission Trading – Reducing Allowed Emissions for Companies

In the 2009 UN Climate Change Conference in Copenhagen an at the most 2°C (3.6°F) rise in average temperature was set. [22] To achieve this aim, calculated emission limits have to be met. Carbon emission trading was introduced by the Kyoto Protocol 1997 and is based on this strategy. Allowances are needed to release greenhouse gases into the atmosphere. A total amount of emissions, the cap, is set and allowances are distributed among companies and installations. The incentive is to reduce emissions to save money. If a company does not need all the bought allowances, it can sell them to other companies. This simple principle allows a market-based control of carbon emissions. [23]

But how to compensate own emissions with this system? The idea is to buy and cancel allowances, making them unavailable for companies. This will lead to reduced emissions and companies are forced to invest into low carbon solutions. [24]

Alright, let's take action at the global carbon market! But wait, there is none... There are 20 different emission trading systems existing, multinational, national and regional ones, making it quite difficult to follow the path. On their website, the International Emissions Trading Association (IETA) offers a good overview and detailed information about the different systems (see <http://www.ieta.org/The-Worlds-Carbon-Markets>). Advantages of Emission Trading Systems are the straight-forwarded method and cheap prices as supporting climate protection projects have to be costly realized and monitored.

Different non-profit organizations have set themselves the target to destroy carbon allowances. Among them are Climakind, Sandbag and CO2compensation.org. All of them buy allowances from the European Union Emission Trade System (EU ETS), mainly because it was the first multinational ETS being established, leading to a nowadays highly reliable and robust system. Furthermore, the

Carbon emissions in the EU ETS were reduced by 3.1% in 2008, global emissions rose 1.9% in the same time period. [25]

However, this does not indicate that other emission trading systems are not reliable, they have less experience and still have to prove that they meet the requirements set from these organizations.

Despite the advantages of emission trading systems, Sandbag highlights weak points and has decided to temporarily close the Destroy Carbon Project. Reasons named are a low carbon price which is not forcing companies to invest into low carbon solutions, and over 3 billion tons of spare allowances in the EU ETS meaning that companies have still enough allowances to consume. After Sandbag, this system has led to even increased emissions in some cases. [26]

In summary, using emission trading systems for compensation of greenhouse gases follows a simple strategy and can be easily applied with cheap prices. Nevertheless, the 100 % effect should not be taken as guaranteed and further information about different emission trading systems, the cap and spare allowances have to be gathered for each individual case.

Interested in alternatives? No offence, but multiple values are important for you? Here comes the second option:

5.2 Support Projects for Reduction of GHG Emissions

Besides emission trading, the Kyoto Protocol introduced Clean Development Mechanism (CDM) and Joint Implementation (JI) as market-based mechanisms that can be also used for compensation [27] By implementation of an emission-reducing project in another country certified emission reduction credits can be earned and traded. The reduced emissions are then subtracted from the allowed ones, allowing countries with high emission of greenhouse gases to compensate. With CDM, the focus is laid on projects in developing countries. A Win-Win situation is created: investing countries have a flexible and cost-efficient way to meet the Kyoto commitments, host countries profit by investment and technology transfer. The variety of organizations and companies offering climate protection projects is huge. Below, three options are introduced.

- **Climate Partner** is a company with multiple services for climate protection. They invest money into certified projects with aims like protecting forests and establishing regenerative energies. For them, the benefit for people is as important as climate protection. Just look at their clean stove project in Peru: poor people suffer from enormous smoke generation while cooking over naked flame. By installing new and efficient stoves, both pollution and emission of greenhouse gases are reduced, less firewood is needed.

Interested? Have a look at their website and choose your favorite project:

<http://www.climatepartner.com/en>

- **Plant for the planet** is an organization initiated and mainly operated by children worldwide. Their aim is to plant 1,000 billion trees around the world to absorb and store 10 billion tons of CO₂. They believe that trees serve as time-buffer to slow down climate change, giving us more time to effectively reduce our emission levels by usage of new technologies and adjusting life styles of industrial countries.

Check out the different planting locations at:

<https://www.plant-for-the-planet.org/en/home>

- **The Wilderness International foundation** has set themselves the target to preserve wilderness from industrial and agricultural damage. They buy land in West Canada to save the largest continuous area of temperate rainforest in the world. This region is endangered by timber and mining industries. GHG compensation is not their preferential aim, nevertheless protecting forest means saving trees which can compensate GHG.

For more details, see: <http://wilderness-international.org/home>

- **CO₂ Neutral Website** is a company that compensates the emissions caused by your website, monitoring both servers and clients visiting it. It holds its own climate projects and more than 2500 companies worldwide are using their services. Have a look on their website: <https://www.co2neutralwebsite.com/>

Convinced? As already mentioned the options for compensation are numerous.



Look for local projects and initiatives

Maybe the park in your city needs a refresh and donations to plant new trees are welcome.
Planting your own tree as symbolic action would also please us much.

You see, the possibilities to compensate GHG are versatile and usually easy to perform, it's just some clicks away (#noexcuse). Let's act responsible and sustainable together!



6. Greenhouse Gas Calculation

The calculation of emission of CO₂ and other greenhouse gases is essential to understand the impact our actions have on the environment. Not only the obvious causes (e.g. intercontinental flights), but also the small ones (e.g. electricity) sum up to a final number.

Wait, we don't want to scare you! We are aware that the last sentence might cause readers to immediately stop and go over to the next chapter. We solemnly swear to provide you with a reasonable compromise between simplicity and accuracy to get a good and easy estimation in the end.

An important point to make things easy and feasible is setting boundaries about what should be included in calculations. The whole bunch of production processes of (subsub-) products might be left out, otherwise this calculation will take forever.

For iGEM teams the points labwork, meet-ups and (in our case the largest emission producer) flights should be taken into account. If you feel that an important point is missing, don't hesitate to make a suggestion to us.

6.1 Labwork

With the invaluable help of Toni Kiel from Plant Values¹ we proudly present “The iGEM goes green Emissions Calculator”, an Excel based tool to calculate the part of your team’s carbon footprint that is related to the laboratory work. You can find it online at <https://github.com/igem-dresden/GoGreenGuide/releases>.

To understand the structure and which information need to be implemented in the Calculator, we first have to explain the term “scopes”:

GHG emissions can be classified by scopes that reflect different forms of emission. “**Scope 1**” relates to direct emissions caused, for instance, by burning coal. This scope is not relevant for our calculation as laboratories normally do not produce any direct emissions. “**Scope 2**” relates to indirect emissions caused by the generation of warmth and electricity and “**Scope 3**” accounts for

¹Plant Values is a Dresden-based startup offering sustainable consulting for companies. You'll find their website (in German) here: <https://www.plant-values.de/>

all the other indirect emissions related to your work.

The unit for measuring the global warming potential of the emitted greenhouse gases (GHG) is CO₂, thus your result will be also given in CO₂ units. The different other gases occurring are multiplied with a factor that reflects their harmfulness for our climate. For instance, methane is 12.4 times as damaging as carbon dioxide, so one ton of methane accounts for 12.4 tons of CO₂. Let's have a look at the different sheets included in the Calculator:

6.1.1 General

Here you again find all general information required to understand the Calculator.

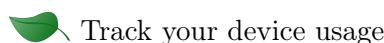
6.1.2 Scope 2

Scope 2 – Heating implements that you heat your lab yourself or it is heated together with the rest of the building. If we want to be precise, air conditioning also belongs here. We haven't been able to find any data about our lab. Instead, only annual consumption data for the whole building, also including office rooms etc., is recorded which is not suitable for our purposes.

For the calculations of the "Scope 2 – Electricity" sheet, it is important to know that the data will always be more precise if you measure the power consumption instead of calculating it, as the stated performance of the equipment is almost always different in reality. The GHG emissions per kWh depend heavily on the energy source you use. It is different in each country and even in each city. The ideal approach would be to identify the GHG emission for the power mix of your city or at least of your country. You can also use the stated data which refers to the average power mix of Germany. In summary that mean: try to get your hands on a powermeter and measure some runs of all your devices! If this is not possible, you don't have any other option than calculating your energy consumption (usually gives higher values).

Answers	Deposited values
Coal	CO ₂ equivalents (kg) per kWh 0.425
Natural gas	CO ₂ equivalents (kg) per kWh 0.251
Oil	CO ₂ equivalents (kg) per kWh 0.30
District heating	CO ₂ equivalents (kg) per kWh 0.11
Wood	CO ₂ equivalents (kg) per kWh 0.054
> Please enter your source here!	> Please enter CO ₂ equivalents here!

Figure 6.2: Do you have data about heating for your lab? If yes, include them in this sheet.



Track your device usage

To monitor how often and with which settings devices were used over a certain time (e.g. two weeks) we hang out lists and asked the users to fill them in whenever centrifuging, shaking etc. It worked out quite nicely!

The screenshot shows a software interface for calculating greenhouse gas emissions. It displays a survey with the following questions:

- 1. What is your energy consumption? (CO₂ equivalent per week [kg CO₂])
- 2. How much energy (Watt) does your device consume in one hour?
- 3. How many hours a week do you use this device?
- 4. Do you have another device in your lab?
- 5. Do you have another device in your lab?
- 6. Do you have another device in your lab?
- 7. Do you have another device in your lab?
- 8. Do you have another device in your lab?
- 9. Do you have another device in your lab?
- 10. Do you have another device in your lab?
- 11. Do you have another device in your lab?
- 12. Do you have another device in your lab?
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- 19. Do you have another device in your lab?
- 20. Do you have another device in your lab?
- 21. Do you have another device in your lab?
- 22. Do you have another device in your lab?
- 23. Do you have another device in your lab?
- 24. Do you have another device in your lab?

Below the survey, there is a summary table:

	measured values	calculated values
measured CO ₂ equivalent (kg CO ₂)	0.476	0.476
CO ₂ emissions (kg CO ₂) from power meter (new German taxes have to be for "Stromverbrauchung" (engl + electricity))	0.476	0.476
CO ₂ measured (kg CO ₂ kWh) (SO2: renewable energy source)	0	0

At the bottom, there are tabs: General, Scope 2 - Heating, Scope 2 - Electricity, Additional devices, Scope 3 - Consumables, Evaluation & Results.

Figure 6.3: All electrical devices you use can be listed here.

If you have other devices we haven't thought of yet, enter their values in the "Additional devices" sheet.

6.1.3 Scope 3

"Scope 3" can include a lot of things. This could be the manufacturing of the products you use, the (environmental) cost of their shipping, your business trips, your daily commute and basically everything else you like to take in account. It is important to set the boundaries of your calculation at that point. Our team took in account the consumables and chemicals we use in our daily lab routine. They are interesting factors, as we hope to limit our consumption effectively after identifying the factors that add most to our footprint. The GHG emissions for "Scope 3" are normally measured from cradle to gate, meaning all of the production stages from the raw material up to the finished product leaving the gate of the factory are taken into account. We are not able to include the GHG emissions of the shipping, as these vary too much, but we would still like to encourage you to make collective orders to save on shipping. Neither included in our data are recycling or disposal of the used consumables and here again we would like to motivate you to separate your waste and recycle and reuse as much as possible. If you miss any items on the list of consumables, it is mostly due to the lack of data provided for that specific product. Especially the list of GHG emissions for chemicals is rather short. In many cases the data we do have is actually given for a similar or an intermediate product. Please treat the calculated results accordingly. The result will not reflect your real carbon footprint but it will give you an estimate. This estimate can be used to identify the prominent factors that add to your emissions and can give you an idea about the proportions of the impact the different factors have.

The screenshot shows a software interface for calculating greenhouse gas emissions. It displays a survey with the following questions:

- 2. Electricity - Additional devices
- 2.F.1.1 Do you have another device in your lab?
- 2.F.1.2 What is this device called?
- 2.F.1.3 How many hours a week do you use this device?
- 2.F.1.4 How much energy (kWh) does this device consume in one hour? Hint: Measure the consumption with a powermeter!
- 2.F.2 Do you have another device in your lab?
- 2.F.2.1 What is this device called?
- 2.F.3 Do you have another device in your lab?
- 2.F.3.1 What is this device called?

Below the survey, there is a summary table:

	A	B	C	D	E
	Answers	Energy consumption [kWh] per week	CO ₂ equivalents [kg]		
2.F.1	B: No -> Continue with Scope 3 - Consumables -> Enter its name! 0	0.000			
2.F.2.1	B: No -> Continue with Scope 3 - Consumables -> Enter its name! 0	0.000			
2.F.3	B: No -> Continue with Scope 3 - Consumables -> Enter its name! 0	0.000			
2.F.3.1	B: No -> Continue with Scope 3 - Consumables -> Enter its name! 0	0.000			

At the bottom, there are tabs: General, Scope 2 - Heating, Scope 2 - Electricity, Additional devices, Scope 3 - Consumables, Evaluation & Results.

Figure 6.4: If you used additional devices we haven't thought of, enter their data here.

Track your consumables

Make a tally to see how many pipette tip boxes, reaction tube packages, etc. are needed for a week in the lab. Alternatively, check your orders and see how much stuff is consumed over a (longer) time period.

6.1.4 Evaluation and Results

Have you entered all required data in the Excel sheet? Congratulations! Here's the example of your calculation, we produced about 3520 kg CO₂ by our lab work.

By now, we are also cooperating with Wilderness International, a foundation located in our hometown Dresden, who plan to create an online tool for labwork-based emissions of greenhouse gases. The release is planned for October 2017, so have a look on their website from time to time: <http://wilderness-international.org/>



Wanna help?

The data we will obtain with our measurements can be seen as a general estimation. However, the deviation between different devices and different producers might be huge. Consequently own measurements are advantageous for a precise calculation.

We ask you to track your lab consumption of materials and energy. This will also help us to provide average numbers and gain a better estimation for teams all over the world.

Interested? Just contact us and we will support you and your team!

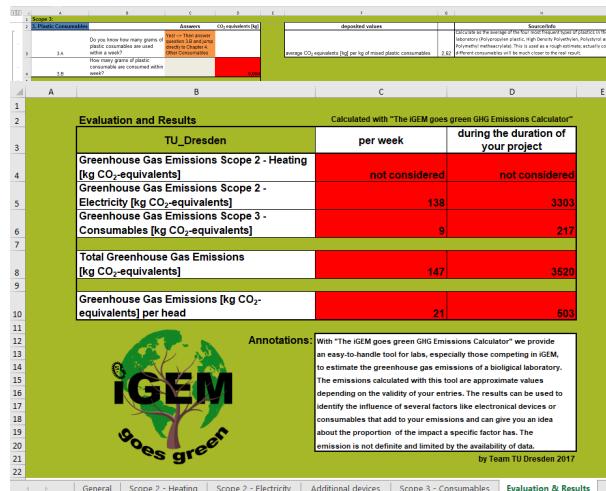


Figure 6.6: Evaluation and Results of the emissions calculation of the TU Dresden 2017 iGEM team

6.2 Meetups

The emissions caused due to meetings and other events strongly rely on duration, number of participants and journey.

"Plant for the Planet" provides a useful online tool with the aim to have carbon neutral events. Therefore, the first step is the calculation of carbon emission, and that is exactly what we are looking for:



Compensate your event

Plant for the planet offers an online tool to estimate how much carbon emissions are caused by your event. Go to <https://www.plant-for-the-planet.org/en/support/carbon-neutral-event> and have the following information ready:

- area of event location
- event duration
- number of participants
- transport (average distance, percentage of means of transport)

6.3 Flights and Travel

Flights cause high emissions of greenhouse gases and therefore should be avoided whenever possible. Is there an alternative to get to the Giant Jamboree in Boston other then by plane (for those who don't live in North America)? By ship? *Joke*

You see, flights usually can't be avoided. Nevertheless, nearly all means of transport (except for cycling and walking) cause emissions and in the end, all have to be taken into account. "Atmosfair",

a German organization for climate protection, focuses on travel and provides a reliable online tool for travel emission calculations.

Below, we want to give a short list why we think the Atmosfair emission calculator is a trustful tool and why we highly recommend to apply it, especially for flights.

- A sufficient amount of independent data from scientific research projects was used to obtain numbers for nearly all combinations of factors. For example, if the user doesn't know the plane type, good estimations can be applied. Furthermore, factors with high impact on emissions are considered in detail, whereas factors with low impact are estimated.
- When burning kerosine, different pollutants having different effects are released (e.g. NO_x, CO₂ and particles). The resulting warming effect is calculated by transforming all effects into CO₂. Here, the "**Radiative Forcing Index**" (RFI) is used. It can only be applied in high altitudes above 9km and is not used for climbing up and landing phases. The calculator strictly separates between those phases.
- The methodology is validated by Germany's Federal Environmental Agency, promising highly reliable calculations.

The detailed description of methods and estimations used in this emission calculator can also be found on their website as pdf file (Documentation_Calculator_EN_2008.pdf). [28]



Compensate your flights

Go to <https://www.atmosfair.de/en/home> and check out your travel emissions. If you want to use a different tool, please check where they got the data from, how it works in detail and which estimations are made. Don't use it before evaluating its trustworthiness!



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