Teachers Teaching with Technology™

T³ EUROPE

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Education for Sustainable Development

Complementary Material and Hints for the UN SDG no 12

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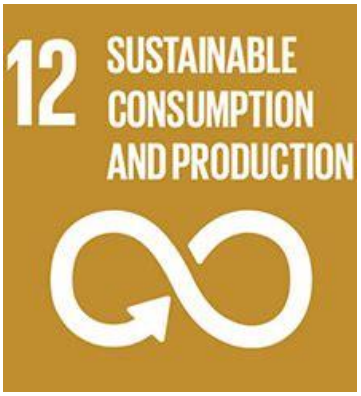


SDG no 12: Sustainable Consumption and Production

Ensure sustainable consumption and production patterns

1. Introduction to the topic

Many high-tech inventions are in favor of our transportations systems, „smart cities“, health system and well-being (many of them invented to „improve sustainability“) are leading to some basic questions:

- From what are all these products made?
- Is it still appropriate to consider (all things being possible in theory) that all ideas have to become reality, meaning: does every idea have to be realized, produced and distributed?

Our actions are based on the foundation of the understanding of what “*Nature*” means. During past centuries, this understanding has changed considerably. Different ideas have been used as an explanation and justification of what “*Nature*” is and what it should be considered as.

Up to the 15th century *Nature* was defined as a status of land untouched by humans. For Galileo Galilei, Nature was everything which did not violate the basic Laws of Physics (—> in this perspective, a car could be considered as Nature). In the middle of the 18th century the verdict was clear: bare *Nature* was something bad – only *Nature* tamed by humans is good and valuable. The “use” of *Nature* by this time was not only but still is demanded by culture - religion and science.

There exist a variety of elemental particles – atoms – out of which everything is made: all organisms, (including of course humans) and non-living objects such as cellphones, tablets, computers, vacuum cleaners, cars, wheelchairs and so on are built from the natural elements, most of them sourced from the Earth’s crust.

Therefore: In order to produce all the billions and billions of objects already constructed by humans, the raw material have to be extracted often on huge mining sites. In other words: each object / product has an ecological backpack- composed of the amount natural resources which were needed to produce it. Most of the product’s ecological backpack is much bigger than the product itself.

With this material you can dive deep into the discussion of material footprint, available reserves on earth and our future perspectives if nothing will change.

As the ecological backpack of each item is a central issue in order to be able to judge if something is sustainable produced or not, you will first get introduced to the concept of **MIPS** (Material Input per ServiceUnit)

To gain a sustainable :-) understanding about the background of every abiotic object we possess, this SDG, too, like all other SDGs, should always be taught and explored in a multidisciplinary way. Therefore STEM-teachers are asked to reach out to their colleagues of different fields to work together:

For this SDG no 12, one can connect with colleagues in subjects like:

History/Geography	Politics	Sociology	Economics
Psychology/Ethics	Biology / Ecology	Philosophy	Religion

(The order of the topics is random and has no implication of a ranking!)

If you click on one of the hyperlinked words, it will lead you to different ideas for multidisciplinary teaching. With such a precious potpourri of fields and competences, you can introduce your students to the very much multifactorial aspects production and consumption. If you get them to reflect on their own consumer-mentality and about their own needs - if they are still appropriate or not- you will have made a great contribution to an individually more conscious way of consumption.

What is this „ecological backpack" MIPS ?

Let's take as the example of an ordinary gold-ring. It might weight about 5g. But – its ecological backpack is about 2000kg. The calculation behind this number originates from the MIPS' concept. It allows to quantify the **M**aterial-**I**nput-**p**er-**S**erviceUnit which is needed to produce any product. Calculations in the 90-ties revealed, that every human being in Germany (including babies) is using up around- 80'000 kg of solid natural resources (once having been part of the soil) per year!

As learnt above, the Gold-ring needed a „Material-Input of 2000kg of „earth", which has to be processed in order to be able to produce a 5g golden finger-ring. You can imagine, that this number is very much dependent on the gold mine and the richness of the gold seams in this specific place. Gold is a very rare element. In the average it is0.0031ppm (parts per million by mass , 10'000 ppm = 1%) (1) only. Actual numbers for gold production worldwide you'll find here (2). Therefore, gold mining means a huge displacement of soil in order to be able to extract the raw material. On average, in a particular gold mine today, about ONE gram of gold will be found in 1'000'000g of earth crust material. In the 20th century, it was about 4g per 1'000'000g of earth.

China delivered in 2020 the highest amount of gold worldwide with 380'000kg. (2). The damage done by mining activities to the environment is severe. In addition, indigenous peoples are harmed severely, a fact that conflicts directly with the SDG's 1,2,4,6 and 15. The devastation of soil on such extraction sites is irreversible.

Gold is a very rare element on earth. But in order to be able to build cellphones, computers, and many other ICT relevant products, there are, in addition to gold, even more scarce natural resources needed. The so called „*rare earth element*s".

Let's have a look at a cell phone. This is built out of about 60 different raw materials such as Copper, Gold, Aluminum, Iron, Palladium, Silver, Cobalt, Tin, Gallium just to mention a few of them, as well as the rare-earth elements,. Imagine now, how much earth has to be dug, moved and crushed in order to extract all this material! Maybe you want to see a movie about the biggest Gold mine? The largest gold mine, New Guinea.

While watching- just think oof the following questions:

- Whose territory, home, this once was?
- What's happening to the water?
- From where do they extract the huge amount of water needed?
- What about the Carbon Footprint? The CO_2 released? —> Not only from all the trucks, but all these machines had to be built in the first place – and - 98% of Carbon is stored in the soils…

In another Video, you can see the process of crushing the stones in the Copper Mountain Mine, BC (British Columbia), Canada. This will give you a good idea about the input of material which is needed in order to be able to extract new raw-material.

On the following picture you can see a dumping site of a big copper mine in Canada, also in BC, but more south. The process of extraction leaves a lot of material as „trash" behind, the so called tailings, which have to be dumped somehow and somewhere! As an average, you can extract 33g (grams!) of Copper from 1'000'000 gr (1t) of the earth crust. In other words: From ONE (1) ton of the processed stones, 1'000'000g - 33g = 999'967g (999,967kg) are waste. This waste is highly toxic due to the chemicals used for the extraction process. Eventually it is dumped by the thousands of tons as landfill in a valley – an entire ecosystem will be wiped out. The wild and virgin nature of this valley is gone forever. Furthermore, the water will penetrate over the years into the soil and therefore contaminate the surroundings of this landfill. If the contaminated water penetrates even ground water, it will threaten many people and animals in the areas dependent on these water resources.

Copper-mine dump and landfill at „Highland Valley Copper“, Logan Lake, B.C. , Canada ©chrisbuerki-photography.net, 2015

The annual copper production for this mining site from 2021 to 2023 is expected to be between 155,000 tons and 165,000 tons per year! (2)

- Make the calculation with your students! How much waste will be dumped for this projected production? Remember: from 1 ton of the Earth’s crust you can gain only 33g of copper.

Many natural resources are subject to natural cycles. But not every! The chemical elements like gold, silver, copper, tin, rare earth elements and so on will not be created any more. They were assembled during the long process of the formation of the earth-, some 4.6 billion years ago, when the planets were formed by gradual aggregation of the dispersed matter in a molecular cloud, which had aggregated to form the Sun and the planets. (3) Therefore there will be no replacement of the extracted abiotic (not-living) raw-material to construct whatever has to be constructed.

The same is true for our water. Of course, there exists a water-cycle- hopefully well known to everybody. BUT! Water won’t be added- we have to live with the water- esp. the fresh-water which is available and has been available for millions of years. Many production processes consume a very large amount of water!

Want an example?Here we go: for one car, the whole production process consumes 400’000 liters of water. Water, of which most is non-drinkable after the production. Look around you! How much „water“ is driving right now on the streets?

@Chris Bürki, car, ready for exportation, Setubal, Portugal, 2020

This subject turns out to be even more serious, if one becomes conscious about of how low the fresh-water fraction is on Earth. Of course - the Earth is the blue planet. But the theoretically drinkable water is just 2.5% of the abundant salt water. From this 2.5 % of fresh-water, only 0.4 % is at the surface and in the atmosphere and therefore directly usable. Learn more about water and sustainability in the SDG 14.

- How much do we want to push further our ideas of production?
- Can a production be „sustainable“ at all?
- Can consuming be „sustainable“ at all?

Have a look at the following table. (5) It will give you a good understanding about which factors are taken into account when calculating the MIPS of a product:

I. Abiotic raw materials

- mineral raw materials (used extraction of raw materials, such as ores, sand, gravel, slate, granite)
- fossil energy carriers (amongst others coal, petroleum oil, petroleum gas) unused extraction (overburden, gangue etc.)
- soil excavation (e.g. excavation of earth or sediment)

II. Biotic raw material

- plant biomass from cultivation
- biomass from uncultivated areas (plants, animals etc.)

(Domesticated animals are already part of the technosphere, and are therefore referred back to biomass taken directly from nature, e.g. plant or animal fodder.)

III. Earth movement in agriculture and silviculture

- mechanical earth movement or
- erosion

IV. Water

(separated according to processing and cooling water)

- surface water
- ground water
- deep ground water (subterranean)

V. Air

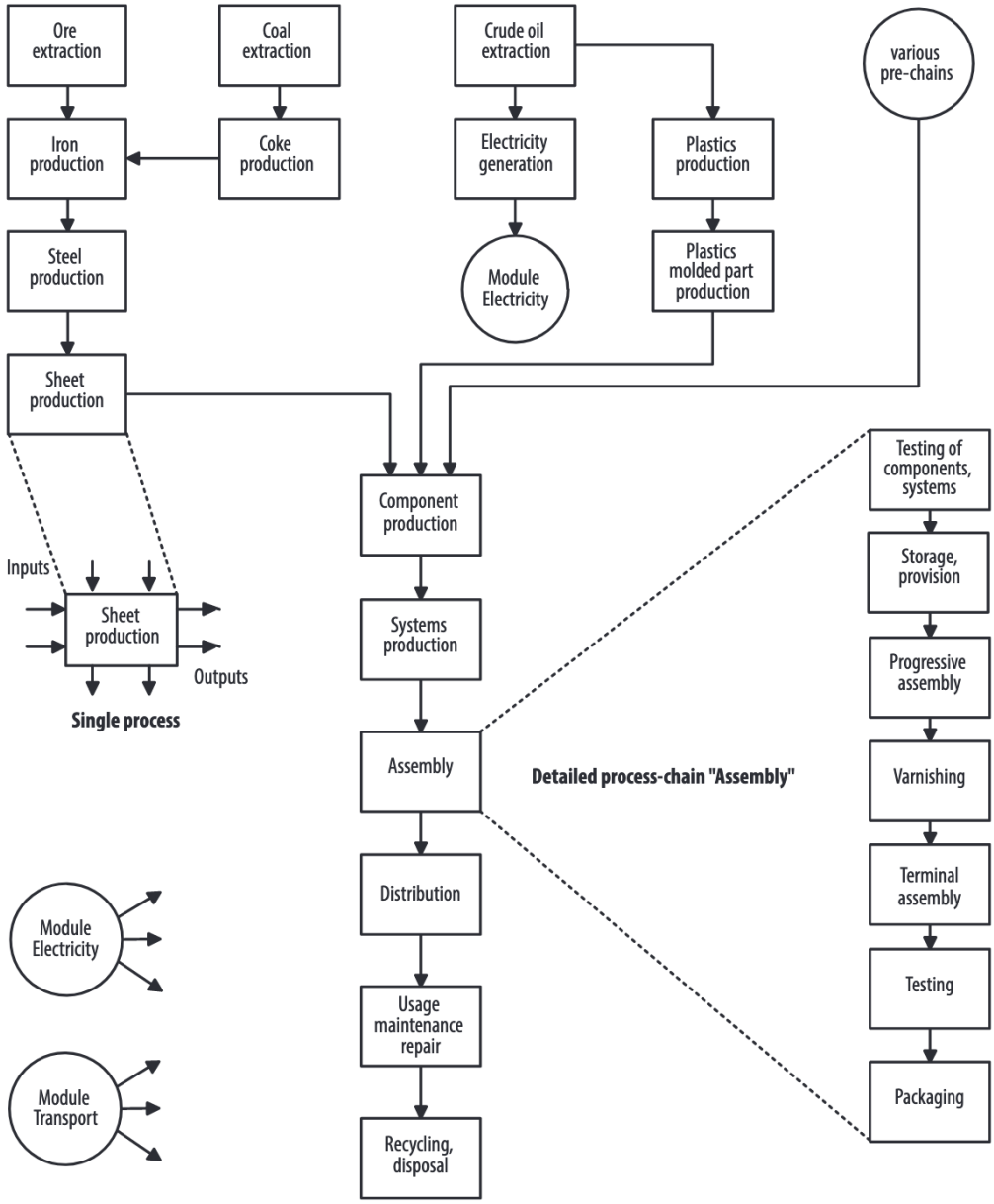
- combustion
- chemical transformation
- physical transformation (aggregate state)

Now: how can one calculate the MIPS?

This is a quite complicated calculation. The starting point is always a profound knowledge about the consumer-chain. With each link of this chain, the ecological backpack fills more. And, from the cradle to the grave, all used up resources have to be taken into account.

It will be soon very obvious, that the longer a product is used for, the less harmful it is for the environment. Today, engineers and technicians should invent many new ways of how one can prolong a product's life, politics should prohibit the planned obsolescence of products and people should be conscious that not only having a few things, but having them for a long time makes us as individuals much more „sustainable"; in relation to products and consumption.

The „Wuppertal Institute supplies many tables with products you can take the numbers from. A table for the „Material Intensity Factors“ (MI) you can find here (4)



Production Chain

Sources:

1. Wikipedia: abundance of Gold: https://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth%27s_crust, last accessed, 2021/04/16

2. Weltweite Goldförderung: https://www.gold.de/goldfoerderung/ , last accessed, 2021/04/16

3. Teck, Highland Valley Copper, https://www.teck.com/operations/canada/operations/highland-valley-copper/, last accessed 20201/04/11

4. Geo Studies, Recent Theories about the origin of Earth, https://geostudies.org/recent-theories-about-the-origin-of-earth/, last accessed: 2021/04/11

5. Material Intensity Factors, Wuppertal Institute: https://wupperinst.org/en/a/wi/a/s/ad/365, last accessed: 2021/04/11

6. Calculating MIPS, Wuppertal Institute; https://epub.wupperinst.org/frontdoor/deliver/index/docId/1577/file/WS27e.pdf , p14, last accessed: 2021/04/11

Videos

World largest Gold mine in New Guinea
https://www.youtube.com/watch?v=UrAVuOOlW5Y

Copper Mountain Mine, Princeton, BC, Canada
https://www.youtube.com/watch?v=eOrISAmMtZM

2. How to implement SDG 12 with STEM education?

a. Science

Biology / Ecology

- Investigate different mining sites (maybe in your own country) and try to find out how much effect on the *Biodiversity this site has.*
- For big mining sites as presented, learn more about the natural environment and find out, what is going to happen, if a mine has been given up. For example: Highland Valley Copper at Logan Lake, BC, Canada has an „environmental“ program on how they „re-nature“ mining areas that are not anymore economic. (7)
    - be critical, but fair: now, you know more about sustainability and its original meaning (see introduction paper) what do you think of theactions they take?
    - can you think of other things they should look at or take into account?

Chemistry

- During the past 60 to 70 years, about 100’000 new chemical substances have been synthesized, of which 10% are circulating in our waters. What are the action does your city / village / country take in order to guarantee healthy drinking water?
- For how many substances do they test the local water and how often?
- What do you think: the official number of tested substances; Is it a fair relation to the estimated total amount of substances in our waters?
- Test the water at your school.
- Watch the film: „Chemie im Wasser, die unsichtbare Bedrohung“ (8)
- Investigate, what impact a production of Jeans or a T-Shirt has on the natural re-sources. How many T-Shirts and Jeans do you have?
- Plastic has a huge impact on our planet, too. Dive deep into the chemistry of plastic and find ideas, how to collect and recycle all sorts of plastic in your school. (9)

Psychology / Ethics (more of Ethics)

- „An addiction to distraction is the end of your creative production“ (Robin Sharma):
- Think about: what addiction do you have?
- How many times are you checking your mobile phone?

- Do you have an addiction to consumption?
- As you hopefully by now understand better the impact of production and consumption on our planet- and therefore to our livelihood - can you imagine how to reduce or even renounce consumption?
- Do you need a new mobile phone or TV every year? Yes? Why?
- What feeling makes you want „to go shopping“
- What do you feel about people who are using their products as long as possible and therefore maybe have an „old-fashioned“ appearance?
- How much does (your)/ peer-group influence your consuming behavior?

History / Geography

- Explore, to whom the land belonged before the big mining companies took over and started exploiting the area.
- compare the size of such mining sizes with the surface area of your community. Draw in a local map the size of the area of a big mining location. What are your feelings if you see this? As an example: Yanacocha mine, located in Northern Peru, is 251 km^2

Methodological hint

Hang up a large Map of your country / region. Now let them draw the area of the size of the area occupied /used /owned by big mining companies directly into this map.

- Discover, if in earlier times, (or still ongoing) there were mining/drilling activities in your country- vicinity, too. Did the landscape change because of the mining activities?

  In Switzerland, for example, we had quite a lot of sites, where different elements had been extracted. In „Ausserferrara“, (in the valley of *Ferrara,* Canton of the Grisons) for example, they extracted Iron ore, Silver, Copper, and Lead out of the soils. The mines only were abandoned in the 19th century (10). More profitable sites were found in many other places of the world. The most obvious heritage of this epoch, lasting for almost 300 years, is, that there are no forests any more. As they heated their furnaces with wood, they were totally de-foresting a big part of this valley. As it is at a quite high altitude with rough weather conditions, the soil was eroded away by wind and by water and this made it impossible, for new trees to regrow. Today, this region is very much appreciated as Alpine meadows and for Ski-touring….

b. Technology

- There are not only mining sites to extract elements from the earth crust, but steadily growing there are mining sites established, to mine crypto currency! Discuss and explore the MIPS of such mining-companies- sometimes using up energy equivalent to that of a small town. The field of crypto-currency is pretty young in comparison with other economical branches. Can this idea be „sustainable“ Look for arguments- always keeping in mind the „MIPS“ (11). Explore the ideas of crypto-currencies with your colleagues of the **Economy** (more Economics)

Methodological hint

Form small groups. Each group is working on a different perspective to this subject. They have to formulate arguments, statements, points of view. In a second round, you can let them go into a dispute/discussion (maybe with audience). (—> ***Puzzle Method***)

- Together with a colleague of the **Philosophy**, discover the reasons, why most societies have the ambition to develop things always further. Why do we have a hard time to „sustain“? From what beliefs does this come from? What did Aborigines do differently? Their Culture and their resources have survived for already 50’000 years. In contrast: we are just using up our resources within some 300 to 400 years

- Did the idea / the „mantra“ of a steady „growth“ became a „Religion“?

- With your colleagues from the **History** department, you could for example, explore the development of Capitalism and later on of Liberalism. With what you have learned: Can those ideas be „sustainable“ at all?

- Who were the owners of the „mining-land“ before big companies started to exploit the region?

- Together with an **Ethicist**: Make an estimation on how many people can profit from a sophisticated technical invention (f. ex. in the health industry) compared to those who suffer health consequences because of its production.

- Together with an **Economist**: Are sophisticated technical inventions really less costly than manpower, if you are taking into account the effective costs which should be paid based on MIPS and based on the fact that many people lose their jobs because of automation?

c. Engineering

- Engineers topics are often to implement new, modern and handsome tools to change many people's lives away from their traditions towards a more modern "western" life-style. Together with a colleague, who teaches **Ethics** (more Ethics) you can explore the tension and impacts on such developments.

- Due to the Covid-19 crisis voices got louder again on implementing robots in homes for elder people and hospitals. Explore the MIPS of such Robots and the **ethical** aspects, too. (13)

- Planned obsolescence of many products is responsible for much additional production and consumption. As Engineers you are ask to overcome such planned obsolescence and produce long-lasting products and materials. Look for products in the student's household „suffering" from planned obsolescence.
    - Explore, how much impact the halt of this practice would make. (14)

d. Math

- The annual production of many sectors is steadily increasing. Once, the physicist Allen Al Bartlett said: *"The greatest shortcoming of the human race is our inability to understand the exponential function."* Let your students explore the dimension of exponential growth. Let them experience what an infinite production and growth on a limited planet will look like.

- In 2019, the copper reserves of Chile were estimated to be at around 200 million tons (15). Calculate, for how long withthe today's yearly production rate these reserves will last. Is this „sustainable" in the sense of the original meaning of „sustained use"?

- It is calculated, that on average, every person on earth would use 2000m^2 of soil surface for being able to live in autarky (self-sufficiency). Make some calculations and extrapolations with this basic idea:
    - What is the estimated surface of agricultural land on our planet?
    - Who is producing food for the biggest part of our population? In which ways?
    - How much precious soil is the production of „things" consuming?
    - How much soil for food production in big cities is missing? —> calculate the proportion of number of inhabitants of a city / metropolis and the 2000m^2 per person which would be needed. —> what are your conclusions?
    - How does the exponential growth of men influence the facts you explored above?

SOURCES:

7. Teck, Highland Copper Valley, Lake Logan, BC, Canada, Sustainability, https://www.teck.com/responsibility/approach-to-responsibility/sustainability-approach-and-goals/ , last accessed: 2021/04/16

8. Chemie im Wasser, die unsichtbare Bedrohung (Arte Doku): https://www.youtube.com/watch?v=DM-8b3_4mdc (for English, there can be added subtitles:) last accessed: 2021/04/16

9. Waste Management: „Technologies for chemical recycling of household plastics – A technical review and TRL assessment“: https://www.sciencedirect.com/science/article/pii/S0956053X20300465, last accessed: 2021/04/16

10. Erzminen im Hinterrhein, Geschichte: https://www.erzminen-hinterrhein.ch/literatur/geschichte/ , last accessed: 2021/04/17

11. The 5 largest mining sites for crypto-currency: https://coincentral.com/the-top-5-largest-mining-operations-in-the-world/ , last accessed: 2021/04/17

12. Yanacocha mine, second largest Gold-mine in the world: https://www.911metallurgist.com/blog/15-largest-mines-on-earth , last accessed: 2021/04/17

13. OZOBOT: robots in the world: https://ozobot.com/blog/robots-world-theyre-helping-humans-improve-hospitals / last accessed: 2021/04/17

14. International Workshop: Advances in cleaner production. *Planned obsolescence and sustainability, SATYRO, W. C. et al:* http://www.advancesincleanerproduction.net/sixth/files/sessoes/5B/5/satyro_et_al_academic.pdf , last accessed: 2021/04/17

15. 5 Top Copper-mining countries: https://www.nsenergybusiness.com/news/top-five-copper-mining-countries/ , last accessed: 2021/04/17

3. Connecting this SDG no 12 with other SDGs

Methodological hint

Encourage your students, to present the different links and dependencies in a *Concept Map*. This is a powerful tool, not only to show how things are linked together, but it shows you, if the student can make the links and name the dependencies.

Some ideas:

- SDG 01: Poverty —> Poor people are actually consuming very little. (of course, not on purpose- but because they cannot afford it. Would we have a healthier world, if we were all poor?
- SDG 03: Health —> Are the ongoing technical innovations in the health sector (like robots) really a topic we should focus on? For whom is this really in favor? Should the western culture not rethink its relation to death? (—> come together with colleagues from **Ethics**, **Philosophy, Religion**)
- SDG 04: Quality education —> is quality education dependent on still more technology?
- SDG 06: Clean water: the more production and consumption, the lower the water-quality will be.
- SDG 07: Access to clean and affordable energy: is it possible?
- SDG 08: How many working places on production sites are of good quality?
- SDG 09: How could these two fields, consumption and production, become really sustainable?
- SDG 14: Find ways to recycle the excessive use and waste of water for production.
- SDG 15: Land grabbing: what is the impact and how to stop it?

Trying to reduce people's negative impact on our planet with the help of the 17 SDG's, can be a really good idea to make positive impacts. There is a stumbling block to overcome: If enterprises, governments and individuals in their pursuit of following the SDG's are just focusing on one single or may be two SDG's, there will be a huge rebound effect with other goals. So, the crucial point really is, to have always all SDG's in mind, if a new project or idea is launched.

*How the **SDG 11** is affected, if one is only focusing on one of the following goals*:

- **SDG 01, 02:** The bigger the cities, the more people suffering from poverty and hunger, living in slums.
- **SDG 06**: The bigger the cities, the more water consumption, waste and pollution will happen.
- **SDG 07**: Any energy-producing unit has its own MIPS. It's not only about affordable and clean energy. Energy provision itself (renewable or not) has its own energy and CO_2 footprint and has its own MIPS.
- **SDG 08**: Many workplaces - and economic growth as a whole cannot be sustainable
- **SDG 09**: The more buildings, the more infrastructure, the bigger the MIPS.
- **SDG 10:** Mining and inequalities: are still very present.
- **SDG 12**: Especially in cities people are mostly motivated to consume! Most kind of consumption is not sustainable.
- **SDG 15**: Our ongoing thirst to become still healthier is violating the land, pushing away the animals from their original habitat and destroying a lot of native plants.
- **SDG 16:** Scarce resources - not only of raw materials but of land and water, too, will inevitably provoke new conflicts.

