

# **Novel Food for Sustainability: A Case Study of Insect Farming**

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## **Abstract**

In 2015, the United Nation adopted the Sustainable Development Goals to counter environmental and developing problems, and to establish sustainable structures. The global economy, rising wealth, and growing population ask for a higher demand of energy, water, food and other goods that affect the climate and environment. A major contributor to the climate change and general degradation of the environment is the farming and livestock sector. Especially the meat industry is a great consumer of energy, water and space, and it also produce polluting emissions. One solution to challenge the issues of the meat industry is the development of new food sources. One can be insect farming.

This study aims to evaluate the consumption of resources in insect farming and compares it to the common meat sources. As it is a relatively new industry, a qualitative method was used to extract information from interviews and documents. The comparison indicates that insect farming has advantages over the common meat sources in the use of resources for their breeding. Based on this, a change to insect foods seems to be necessary to reduce damage to the environment and climate. However, in the end the question remains whether humans are willing to consume insects or not.

Keywords: Novel Food, insect farming, edible insects, sustainability, SDGs

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# **INTRODUCTION**

## **Research Background**

### **Present Issue**

The last century is characterized by technological progress, an increasing global economy, a rising affluence, and a growing population. However, the continuing upswing and enlargement of living habitats also cause negative effects. The higher demand of energy, water, food and other consumer goods affect the climate and environment. Challenging the consequences is nowadays considered as the most important task in the political and economic spheres.

Humans and industries are liable for the deforestation to make space for residential complexes and multiplexes, and fields to grow food. Moreover, their consumption of energy is highly based on nonrenewable sources that will be eventually depleted, such as oil, natural gases and coal. The growing population and higher demand of resources also lead to an increase in consuming nonrenewable natural minerals and construction materials. Another point is the rising pollution of soil, air, lakes, and seas that are contaminated with sewage, radioactive, materials, toxic chemicals, and other pollutants.

One major contributor to the climate change and general degradation of the environment is the farming and livestock sector. Its consumption of energy, water and space is tremendous, and it also produce a lot of polluting emissions. Technological developments have indeed increased the efficiency in the sector, however, they cannot compensate the effects caused by the growing population and increased living standards.

In order to create food security, the main purpose of the farming and livestock sector, the environment is destroyed and exploited. The growing demand of food results in deforestation

in many parts of the world. Consequences are soil erosion and an increase of greenhouse gases what directly contributes to global warming. Moreover, it leads to the deconstruction of animals' habitats and by that to a loss of biodiversity. This can be also observed in the fishing industry, a further important sector to create food security. Overfishing and the pollution of the oceans have led to an immense reduction in marine life.

Furthermore, poor irrigation practices and poor soil management destroy the soil structure and make it unsuitable for plant growth. Heavy machinery and farming equipment also play part in the destruction of the soil. Besides, fertilizers are used to compensate the soil damaged, and pesticides, fungicides and herbicides are used to ensure the survival of the plants. These procedures do not only kill important soil micro-organisms, but such tools are also polluting in their production.

A further impact to secure access to food is the depletion of fresh water. The poor farming practices, deforestation and pollution result in waster wastage, water contamination, and to the deconstruction of natural water catchment areas.

Especially livestock breeding is a great consumer of energy, water and space. With rising living standards, the eating behavior is changing, and the demand of meat is increasing. The growing population also lead to a higher demand of meats. As a result, livestock breeding is growing and needs more and more resources, and it is also producing more and more polluting emissions.

### **Consequences for Humans**

The consequences for humans are far-reaching and affect their life directly and indirectly. By deforestation, people lose the Earth's green lungs – forests that convert carbon dioxide into oxygen, and they lose natural habitats that can function as recreation areas. The long-term

effects of deforestation can also lead to natural disasters such as flooding and droughts. Greater demand of water often comes along with forest clearing in order to fulfill the needs of agricultural practices and other industry sectors. Especially impoverished areas will then face limited access to fresh water. Moreover, growing industries mean that the release of toxins and chemical by-products increase, too. It is observable that those waste products are often deposited in lakes, soils, and lands where the proper disposal is too expensive, or technologies are not available. In the end, humans eventually suffer from health issues or other impairments.

Everything indicates that interferences with nature, to increase prosperity in short-term, can result in a threat for humans in long-term.

### **Need for Action**

To counter environmental and developing problems, and to establish globally sustainable structures, the United Nation (UN) adopted the Sustainable Development Goals (SDGs). In 2015, all 193 member states agreed on the 17 goals and have set themselves to achieve them by 2030. These 17 goals are divided into 169 targets and calling for collective action- meaning that they can only be achieved if developing, emerging and industrialized countries work together.

The aim of the SDGs is to make the world fairer, healthier, more ecological friendly, more social and more peaceful. This can be already seen in the terms of the goals; the 17 goals in detail:



Figure 1. "Sustainable Development Goals". United Nations Sustainable Development, Last modified 2021. [https://www.un.org/sustainabledevelopment/blog/2016/07/17goals17days-progress-made-on-sustainable-development-goals/#iLightbox\[gallery18522\]/0](https://www.un.org/sustainabledevelopment/blog/2016/07/17goals17days-progress-made-on-sustainable-development-goals/#iLightbox[gallery18522]/0).

The SDGs cover all three dimensions of sustainability: social, economic and environmental. In addition, the SDGs are preceded by five core messages as guiding principles: people, planet, prosperity, peace and partnership.<sup>1</sup> This means, that the SDGs are an important concept to find solutions to deal with the effects of overpopulation, exploitation and the destruction of living space in a proper way.

### Novel Food as possible solution

The United Nation and other organizations have started and supported projects all over the world which go hand in hand with the concepts of the SDGs and meet the needs of the future. Many economic sectors have also start to invest in order to go along with the SDGs. As the

<sup>1</sup> "Nachhaltige Entwicklungsziele", Plan.De, Last modified 2020, <https://www.plan.de/sdg-nachhaltige-entwicklungsziele.html>.

farming and livestock industry is a major contributor to the above-mentioned problems, many changes and implementations of new technologies can be observed there. A further approach is the development of new food sources – so called novel food – to support the SDGs.

The European Union (EU) is a pioneer in defining and regulating novel food. It defines novel food as food which had no major relevance by humans in the EU before 15 May 1997.<sup>2</sup> Novel food is considered as food that is newly developed, innovative, or produced with the use of new technologies or production processes. Furthermore, it also includes food that is traditionally eaten in the outside of the EU.<sup>3</sup>

In recent years, the approval of new food sources by the EU and ongoing developments by the industry have incredibly increased in order to provide possibilities to create new food products which are more sustainable than common food sources. As common livestock farming is a major contributor to negative impacts on the climate and environment, considerable efforts are undertaken to replace them. One alternative can be insects.

Although humans have already eaten insects all over the world for centuries, regulations for an economic breed and insect farming are relatively new. There are just a few companies which operate a breed on economic scale. They are convinced that insects are the food of the future as it goes hand in hand with the United Nation SDGs.

### **Research Motivation**

The present worldwide challenges have many different origins and at least the same number of approaches to challenge them. One origin is the food industry, especially livestock

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<sup>2</sup> "Novel Food", Food Safety, Last modified 2021, [https://ec.europa.eu/food/safety/novel-food\\_de](https://ec.europa.eu/food/safety/novel-food_de).

<sup>3</sup> "Legislation", Food Safety, Last modified 2021, [https://ec.europa.eu/food/safety/novel-food/legislation\\_de](https://ec.europa.eu/food/safety/novel-food/legislation_de).

breeding contributes to the deconstruction of the environment and climate change. As food is essential for humans, possible solutions have to be found in its own rows. One approach can be sustainable Novel Food.

### **Research Purpose**

One innovative food can be edible insects. Edible insects are considered as environmentally friendly so that they have gained a lot of attention in recent years. However, Novel Food does not only need to be environmentally friendly, but it also has to have positive contributions towards economic and social aspects. These three dimensions are all combined in the concept of sustainability. The purpose of this study is to explore the degree of sustainability of edible insects.

### **Research Questions**

This leads to the following research questions:

- To what degree can insect farming reduce global hunger?
- To what extent can insect farming contribute to sustainable economic growth?
- In what way can insect farming contribute to environmental protection?
- Under what conditions is insect farming applicable?

### **Contribution**

The contribution of this study is the connection of edible insects with the three dimensions of sustainability. By that, the study points out the advantages of Novel Food with the example of edible insects. This should help to understand the importance of Novel Food to counter present global challenges, and that it is essential to drive forward in this sector to set up international guidelines for its use so that everyone can benefit from it.

### **Limits**

During the process of writing this paper, two limits have occurred. First, there is only a little literature that analyzed Novel Food in consideration of all three dimensions of sustainability. Second, the process of data collection has been limited as there are only few insect farms in Europe that were able to provide the necessary data.

### **Delimits**

This paper does not take local factors into account that has to be analyzed to point out the feasibility of insect farming. Furthermore, this paper considers edible insects as a substitute product of beef, pork and chicken, and four of their plant-based alternatives, but it does not include other food sources.

# LITERATURE REVIEW

## Problems of livestock breeding

From a global perspective, meat consumption is increasing unabated. At the same time, the world population is growing, so that a significantly higher demand for animal products and the necessary agricultural land can be expected in the coming decades. In many countries, whose traditional cuisine is characterized by only moderate meat consumption, in recent years there has been a change in eating habits on a broad front under the impression of economic prosperity. China can be cited as an example, where meat consumption and the consumption of dairy products are considered status symbols.<sup>4</sup> The corresponding global growth in meat production has far-reaching consequences for the environment and the climate. The need for fodder crops as the basis for meat production is immense. To produce a kilocalorie from meat, several times this nutritional value must be provided in the form of forage plants. In comparison, the direct use of plant-based foods is much more efficient. In addition, cattle herds are responsible for a large part of all methane emissions worldwide.<sup>5</sup> The large-scale production of soy - a plant that is already very nutritious and protein-rich in itself - as animal feed in South America is associated with large losses of area in forests etc. and leads to a rapid decline in soil quality and thus in the long term of yields.<sup>6</sup> Added to this are the questionable use of antibiotics, water consumption, the effects of transport and competition for land use. After all, farm animals are increasingly treated as industrial products, which can be problematic from an ethical point of view.

In view of the problems described and the unchecked or increasing consumption of meat, unconventional protein sources are moving into the focus of science and research. The use of

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<sup>4</sup> Tobias Jetzke, Marc B Bovenschulte and Simone Ehrenberg-Silies, "Fleisch 2.0 – Unkonventionelle Proteinquellen", Tab-Beim-Bundestag.De, Last modified 2016, <https://www.tab-beim-bundestag.de/de/pdf/publikationen/themenprofil/Themenkurzprofil-005.pdf>.

<sup>5</sup> Ibid.

<sup>6</sup> Ibid.

insects as food offers great potential. But also, vegetable meat substitutes such as tofu, tempeh or seitan are spreading more and more in local supermarkets and kitchens. Finally, there are efforts to produce meat artificially in the laboratory in order to be able to satisfy the growing demand, decoupled from land use and animal production. The search for environmentally friendly protein sources or meat 2.0 is one of the great future tasks of mankind.

The author of “These maps show where all the world's cattle, chickens, and pigs are” Brad Plumer outlines the relation between the growing population, the increase in wealth, and how it effects livestock breeding.

Livestock breeding describes the reproduction and fattening of farm animals for the production of food and other animal raw materials. In the 21st century, about 980 million pigs, 1.4 billion cattle, and 19.6 billion chickens are raised in the animal industry.<sup>7</sup>

Plumer mentions, livestock breeding has been expanding worldwide. This can be attributed to the growing world population and the increasing prosperity in many emerging and developing countries. In the last 50 years the world population has more than doubled, from around 3 billion people in the early sixties to over 7.6 billion today. Especially regions with high numbers of developing countries and emerging economies have recorded a tremendous growth in population. From 1971 to 2015, the population has been doubled in Asia and more than tripled in Africa, whereas in Europe and North America, the growth in population has been constant.<sup>8</sup> This means that more food, and by that more meat needs to be produced. However, during the same period of time, the meat production has almost increased fivefold, whereas the world population has only more than doubled. So, there are other factors that play a significant

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<sup>7</sup> Brad Plumer, "These Maps Show Where All The World's Cows, Chickens, And Pigs Are", Vox, Last modified 2015, <https://www.vox.com/2014/6/20/5825826/these-maps-show-where-all-the-worlds-cattle-chickens-and-pigs-live>.

<sup>8</sup> Brad Plumer, "These Maps Show Where All The World's Cows, Chickens, And Pigs Are", Vox, Last modified 2015, <https://www.vox.com/2014/6/20/5825826/these-maps-show-where-all-the-worlds-cattle-chickens-and-pigs-live>.

role why more and more meat has been produced. The major reason is the increased income in the last few decades: almost everywhere in the world people have become richer - on average, people's incomes have tripled in the last half century.

### **Sustainability in food industry**

Due to the close interweaving of agriculture, and thus livestock breeding, with the food industry, consumers and environmental law groups expect that it takes responsibility for the origin of agricultural products.<sup>9</sup> The production with agricultural raw materials under the highest possible environmental, animal welfare and social standards is a very important and difficult task, especially in view of the highly competitive pressure in the industry. The food industry is particularly affected by consumer protection issues. The focus here is on food safety as well as the short and long-term health effects of the products and the diet promoted by the industry. Dealing with employees is particularly a problem in sub-sectors affected by labor law violations, such as the slaughterhouse industry and with suppliers from the agricultural sector (e.g., in chocolate or coffee cultivation in so-called developing countries).<sup>10</sup>

As the buyer of most of the agricultural products, the food industry shares responsibility for many environmental problems. In plant cultivation, the greatest pollution is caused by the use of fertilizers and pesticides: the entry of excess fertilizers into surface waters leads to eutrophication and thus to a considerable disruption of aquatic ecosystems. The use of pesticides often has a negative effect on the biodiversity of the cultivated soil and the surrounding area. Pesticide residues that are not completely degraded in plant-based products also pose a health risk when they are consumed. The degradation of humus in conventional

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<sup>9</sup> Jana Gebauer and Stephan Timme, "Branchenkriterien Nahrungsmittelindustrie", Ranking-Nachhaltigkeitsbericht.De, Last modified 2009, [http://www.ranking-nachhaltigkeitsbericht.de/pdf/2009/Branchen\\_PDFs/Branchenpapier\\_Nahrungsmittelindustrie.pdf](http://www.ranking-nachhaltigkeitsbericht.de/pdf/2009/Branchen_PDFs/Branchenpapier_Nahrungsmittelindustrie.pdf).

<sup>10</sup> Ibid.

farming, which leads to the loss of soil substance and a reduction in the water storage capacity of the soil, is also often problematic. The use of genetically modified seeds has come under fire due to the unresolved environmental and health risks. And finally, the climate impacts of agricultural production have recently come under increasing discussion. A fundamental problem in the livestock industry is that the production of a lot of animal products requires many times the amount of plant products (animal feed) and thus large areas. In order to reduce competition for land use, feed utilization can be optimized, but this tends to be at the expense of species-appropriate animal husbandry.<sup>11</sup>

However, so far public criticism of low animal welfare standards in conventional livestock farming has only led to isolated political initiatives such as the ban on cage farming in the poultry industry. Other important issues are methane emissions from cattle farming and the use of antibiotics and hormones in animal feed. In view of these problems, food manufacturers are called upon to advocate animal-friendly and environmentally friendly livestock farming as much as possible.

In addition, cultivation areas are often expanded at the expense of near-natural areas, which leads to a sometimes-drastic reduction in biodiversity in the affected areas and the release of greenhouse gases. Another complaint is the inefficient use of pesticides, which is often done with inadequate occupational safety and with substances that are no longer permitted in the EU due to their negative effects on the environment and health. In view of these challenges, a number of cultivation standards have been developed that the food industry should apply to the raw materials used. The methods of organic farming stand for the highest environmental standards. In addition to the stricter standards of various cultivation associations, cultivation according to the standards defined in the EC organic regulation is the most widespread. The processing of raw materials into food is associated with further ecological effects. One topic is

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<sup>11</sup> Ibid., 10

the efficient use of agricultural raw materials. The food industry causes one eighth of the waste in the entire manufacturing industry. B. re-used as feed or fertilizer or directly and indirectly (through incineration or fermentation) energetically recovered.

It is true that food causes almost a fifth of all greenhouse gas emissions over the course of its life cycle; However, the largest share of this is due to agricultural activities - the emissions caused by processing are comparatively low. Nevertheless, improving energy efficiency and the use of renewable energies, especially in heat generation, are an issue for the industry.<sup>221</sup> Another area of action is reducing the impact of transport, as the industry is responsible for a considerable part of road transport. The reasons for this are the large number of processing steps up to the finished product, the trend towards central production systems to increase cost efficiency and the need to supply retailers just-in-time.<sup>12</sup> Finally, other relevant emissions into the ambient air are primarily dust and odors.<sup>13</sup>

For some years now, food manufacturers have been obliged to ensure the traceability of their products. In order to be able to identify and eliminate a problem in the production chain as quickly as possible, the origin of the raw materials and intermediate products, as well as the handling of these substances from the field to the shelf in the trade, must be fully documented. There are a number of standards for handling food and managing the supply chain. In addition to the ISO 22,000 standard, the various standards developed as part of the “Global Food Safety Initiative” are particularly relevant. In addition to the “BRC Food Technical Standard” of the British Retail Consortium, the “International Food Standard” is particularly relevant in Europe. With regard to hygiene requirements, the HACCP concept<sup>226</sup> is the relevant international

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<sup>12</sup> Jana Gebauer and Stephan Timme, "Branchenkriterien Nahrungsmittelindustrie", Ranking-Nachhaltigkeitsbericht.De, Last modified 2009, [http://www.ranking-nachhaltigkeitsbericht.de/pdf/2009/Branchen\\_PDFs/Branchenpapier\\_Nahrungsmittelindustrie.pdf](http://www.ranking-nachhaltigkeitsbericht.de/pdf/2009/Branchen_PDFs/Branchenpapier_Nahrungsmittelindustrie.pdf).

<sup>13</sup> "Environmental, Health, And Safety Guidelines For Food And Beverage Processing", Ifc.Org, Last modified 2008, <https://www.ifc.org/wps/wcm/connect/f7a7b739-0f08-49ee-8dd8-8e7322884ccf/Final%2B-%2BFood%2Band%2BBeverage%2BProcessing.pdf?MOD=AJPERES&CVID=jkD2z08>.

standard.<sup>14</sup> A particular challenge in this context is the expansion of the use of genetic engineering in agriculture around the world: It is becoming increasingly difficult for manufacturers and their suppliers to comply with the legal limit values when procuring raw materials. Long-term cooperation with direct suppliers may help to cope with the above-mentioned challenges.

Another aspect is the high amount of waste from packaging material. Manufacturers are all more responsible for ecologically optimizing product packaging. In addition to reduce the number of outer packaging, it is also necessary for the material to be easily recyclable.

In order to target these issues, the UN adopted the SDGs.

### **Sustainable Development Goals in the food industry**

The SDGs are based on the Millennium Development Goals that were especially applicable to developing countries. The SDGs are political objectives set up by the United Nations in 2015 and include 17 goals with several sub-targets. In contrast to the MDGs, the SDGs apply to all countries, meaning to developing, emerging, and industrialized countries. The aim of the SDGs is to make the world fairer, healthier, more ecological friendly, more social and more peaceful.

Connecting the elements of sustainability with the UN's SDGs that defines sustainability on a global governmental scale is another work. One points out, that there are considerable challenges in the food sector when it comes to sustainable development, namely human-induced

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<sup>14</sup> Jana Gebauer and Stephan Timme, "Branchenkriterien Nahrungsmittelindustrie", Ranking-Nachhaltigkeitsbericht.De, Last modified 2009, [http://www.ranking-nachhaltigkeitsbericht.de/pdf/2009/Branchen\\_PDFs/Branchenpapier\\_Nahrungsmittelindustrie.pdf](http://www.ranking-nachhaltigkeitsbericht.de/pdf/2009/Branchen_PDFs/Branchenpapier_Nahrungsmittelindustrie.pdf).

climate change and deforestation.<sup>15</sup> While it can be a source of livelihoods and income for farming communities, it can also be used for land grabbing, which threatens people's rights and wellbeing. In the years since the SDGs were adopted, the agri-food sector has helped feed the growing global population, but has also contributed to obesity, metabolic disease, and malnutrition epidemics.

Several frameworks, guidance documents, and standards have been developed in response to these challenges and opportunities to create guidelines for more sustainable practices in the food industry. However, none of these tools is industry-wide, and they do not provide a comprehensive framework to carry out sustainable practices in the food industry that aligns with the SDGs.

Towards assisting the food sector to align practices with SDGs, CCSI is developing a framework for defining SDG-aligned business practices in the food sector in partnership with the United Nations Sustainable Development Solutions Network.<sup>16</sup> SDG measurement, reporting, and tools will be coherent and rigorous as a result of the project, which will enable responsible, SDG-oriented companies to differentiate themselves clearly from their peers that are engaging in SDG engagement as business as usual.

It is expected that the project helps to implement a consensus for reporting standards, responsible acting, and supply-chain monitoring in order to address the critical areas of the food industry.

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<sup>15</sup> "The Food Sector And The Sustainable Development Goals | Columbia Center On Sustainable Investment", Ccsi.Columbia.Edu, Last modified 2021, <https://ccsi.columbia.edu/content/food-sector-and-sustainable-development-goals>.

<sup>16</sup> Ibid.

A further research describes the different dimension of the SDGs and relates specific goals to the food industry. Along this comes specific targets that play in important role to measure sustainability in the food industry.

The SDGs are categorized into three pillars. The economic pillar, the environmental pillar and the social pillar. All 17 goals can be allocated to one pillar, however, it is to mention that some goals can indirectly also serve another pillar. Furthermore, it is to mention that the goals are dependent on each other and to achieve one goal, the others need to be considered as well. For simplification reasons, each goal is here exactly allocated to one pillar:<sup>17</sup>

#### Economic pillar

- goal 1, No Poverty
- goal 2, Zero Hunger
- goal 3, Good Health and Well-being
- goal 8, Decent Work and Economic growth
- goal 9, Industry, Innovation and Infrastructure

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<sup>17</sup> Marie-Joséphine Amiot-Carlin et al., "Promoting Sustainable Food Systems In Mediterranean Countries: A Framework To Implement Recommendations And Actions.", Researchgate, Last modified 2017, [https://www.researchgate.net/publication/318569791\\_Promoting\\_sustainable\\_food\\_systems\\_in\\_Mediterranean\\_countries\\_a\\_framework\\_to\\_implement\\_recommendations\\_and\\_actions](https://www.researchgate.net/publication/318569791_Promoting_sustainable_food_systems_in_Mediterranean_countries_a_framework_to_implement_recommendations_and_actions).

## Environmental pillar

- goal 6, Clean Water and Sanitation
- goal 7, Affordable and Clean Energy
- goal 12, Responsible Consumption and Production
- goal 13, Climate Action
- goal 14, Life Below Water
- goal 15, Life on Land

## Social pillar

- goal 4, Quality Education
- goal 5, Gender Equality
- goal 10, Reduced Inequalities
- goal 11, Sustainable Cities and Communities
- goal 16, Peace, Justice and Strong Institutions
- goal 17, Partnerships for the Goals

That makes the SDGs to a concept to challenge today's worldwide issues that have arisen on social, economic and ecological levels. Referring to this paper and the caused issues by livestock breeding, the SDGs are an approach to deal with the effects of overpopulation - destruction of the environment and climate change – and to provide a framework for possible solutions.<sup>18</sup>

The issue of sustainability is playing an increasingly important role in the food industry. The focus is on challenges to improve sustainability such as higher energy and resource

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<sup>18</sup> Ibid., 15

efficiency, reduction of greenhouse gas emissions, sustainable procurement of raw materials and coping with demographic and social changes.

In the food industry, specific goals from the environmental and economic pillar are directly linked to it, however, achieving goals from these dimensions would also bring a positive impact to the social pillar in the long run. The specific goals are the following:<sup>19</sup>

- Goal 2, Zero Hunger
- Goal 6, Clean Water and Sanitation
- Goal 8, Decent Work and Economic Growth
- Goal 9, Industry, Innovation and Infrastructure
- Goal 12, Responsible Consumption and Production
- Goal 13, Climate Action
- Goal 15, Life on Land

The second goal, Zero Hunger, aims at the access to enough food for everyone. In the past decades, the number of undernourished people has almost dropped about 50%, however, according to estimates, there were still 821 million people undernourished in 2017.<sup>20</sup> Especially in developing and emerging economies, access to food becomes a great challenge, and as an increase in population is expected, the situation will get worse. In context of this paper, the important targets of the goal are the assurance to safe and nutritious food, sustainable food production, and development of rural infrastructure.<sup>21</sup>

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<sup>19</sup> Ibid., 15

<sup>20</sup> "Goal 2 ZERO HUNGER", UNDP, Last modified 2021, <https://www.undp.org/sustainable-development-goals#zero-hunger>.

<sup>21</sup> Ibid.

More than 40 percent of people have limited access to fresh water, and it is assumed that this figure will rise caused by global warming and growth in population.<sup>22</sup> The use of fresh water in industries and the pollution by them also exacerbate the situation. As mentioned, livestock breeding is one major consumer and polluter. The sixth goal, Clean Water and Sanitation, targets to reduce polluting particles in fresh water, increase the responsible consumption of water, and restore and protect water-related ecosystems in order to minimize water scarcity.<sup>23</sup>

The economic pillar also provides specific targets that should increase sustainability in the food industry. Especially the goals 8 and 9, Decent Work and Economic Growth and Industry, Innovation and Infrastructure, the targets focus on upgrading technology and innovating processes to improve resource management, and to decouple economic growth from degrading the environment.<sup>24 25</sup> Thereby the targets directly address the food industry as it relies on new technologies and innovation to meet the needs for food. In detail, it targets livestock breeding as its growth is coupled with the environmental degradation.<sup>26</sup>

The goal Responsible Consumption and Production targets on the assurance of a sustainable handling and use of natural resources, a proper management with waste and pollutants, and a general reduction of waste products.<sup>27</sup> As the agricultural sector is the largest consumer of fresh water, achieving the targets have a direct impact on livestock breeding as it is the major consumer of agricultural goods. Responsible consumption and production are

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<sup>22</sup> "Goal 6 CLEAN WATER AND SANITATION", UNDP, Last modified 2021, <https://www.undp.org/sustainable-development-goals#clean-water-and-sanitation>.

<sup>23</sup> Ibid

<sup>24</sup> "Goal 8 DECENT WORK AND ECONOMIC GROWTH", UNDP, Last modified 2021, <https://www.undp.org/sustainable-development-goals#decent-work-and-economic-growth>.

<sup>25</sup> "Goal 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE", UNDP, Last modified 2021, <https://www.undp.org/sustainable-development-goals#industry-innovation-and-infrastructure>.

<sup>26</sup> "SDG INDUSTRY MATRIX", Assets.Kpmg, Last modified 2016, <https://assets.kpmg/content/dam/kpmg/xx/pdf/2017/05/sdg-food-bev.pdf>.

<sup>27</sup> "Goal 12 RESPONSIBLE CONSUMPTION AND PRODUCTION", UNDP, Last modified 2021, <https://www.undp.org/sustainable-development-goals#responsible-consumption-and-production>.

driving forces to reduce the ecological footprint and to transit to a sustainable development and green economy.

In the last 30 years, the Greenhouse gas emissions have risen by more than 50%.<sup>28</sup> The resulting global warming hits the agricultural sector, and it has already led to a reduction of food supplies in some regions. But the sector itself is a major contributor to the increasing emissions as the animal industry emits up to 20 percent of the world's greenhouse gases.<sup>29</sup> The 13<sup>th</sup> goal, Climate Action, works hand in hand with the other SDGs to reduce Greenhouse Gases (GHG) by a sustainable natural resource management, implementation of new technologies and the use of innovative processes. The goal aims for the implementation of new development strategies on policy level in order to ensure approvals for new approaches to challenge the climate change.

Goal 15, Life on Land, targets on the effects caused by the increasing demand of space for livestock breeding. With the deconstruction of natural habitats, a source for clean air and water gets lost. Besides, the loss of biodiversity goes along with it. Urgent action has to be taken to counteract the present actions. This goal aims for a sustainable use and restoration of freshwater ecosystems, supports reforestation, and restore degraded land and soil.<sup>30</sup> These measures contribute to the preservation of biodiversity and create natural habitats that counter climate change.

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<sup>28</sup> "Goal 13 CLIMATE ACTION", UNDP, Last modified 2021, <https://www.undp.org/sustainable-development-goals#climate-action>.

<sup>29</sup> Xiaoming Xu, Prateek Sharma and et al, "Global Greenhouse Gas Emissions From Animal-Based Foods Are Twice Those Of Plant-Based Foods", Nature, Last modified 2021, <https://www.nature.com/articles/s43016-021-00358-x>.

<sup>30</sup> "Goal 15 LIFE ON LAND", UNDP, Last modified 2021, <https://www.undp.org/sustainable-development-goals#life-on-land>.

## Novel Food

Novel food has the potential to ensure a steady supply of food for a long time, decouple production processes from climatic conditions and decrease production costs. Novel food is consistent with EU policies, in particular the new CAP, as a possible response to the new challenges facing agriculture and the food sector.<sup>31</sup> Nevertheless, if its safety has not been verified, it cannot be claimed to protect the right to food. Therefore, legislation relating to the placement of novel foods on the market focuses on ensuring their safety.

Human life and health are adequately protected by this legislation. Legal instruments are important, but their effective application is also crucial to the safety of these foods. In accordance with the recently adopted solutions, there have been no reports of health hazards related to novel food that has been placed on EU's market.<sup>32</sup> In the area of protecting human health and life, the effectiveness of food law can be best demonstrated by the absence of negative impacts related to its consumption.

As a result of the need to provide a high level of protection for human health and life, the current EU legal instruments for the placement of novel foods on the EU market are very restrictive and impose a wide range of requirements on food business operators. That said, they might contribute to food security, especially if legislators simplify the process of putting traditional foods from third countries on the market. In order for these solutions to be effective, law must be applied uniformly across the EU.

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<sup>31</sup> Volker Heinz and Roman Buckow, "Food Preservation By High Pressure", Springerlink, Last modified 2009, <https://link.springer.com/article/10.1007/s00003-009-0311-x>.

<sup>32</sup> Ibid.

## **Insects as Novel Food**

In recent years, the European Union records more requests to authorize edible insects. The authorization of new food underlies the EU's Novel Food regulations. These regulations ensure the safety for consumers, the proper labelling of the products, and if it is intended that novel food replaces another food, that it will not be nutritionally disadvantageous for consumers. The process also defines the breeding, supply, and waste management in consideration of nowadays and future economic and ecological aspects. The EU defines novel food as food that is newly developed, innovative, or produced with the use of new technologies or production processes. Furthermore, it also includes food that is traditionally eaten in the outside of the EU.

At present, the EU records request to authorize seven insects and two of them have been fully authorized for human consumption in May and October 2021.<sup>33</sup> All other five insects are also allowed to be placed on the market on the basis of an transitional arrangement, until the final decision is given.<sup>34</sup> The authorization of insects as novel food enable its farming on an industrial scale so that an objective analysis of its sustainability is possible.

## **Insects as food source**

Of the currently 1,400,000 known animal species, around 1,000,000 belong to the group of insects - another 6-10 million as yet unknown insect species are suspected.<sup>35</sup> In nature, pollination as well as the breakdown and processing of dead plant material are essential tasks of insects. Insects have served humans in a variety of ways for at least 7,000 years. Honey and

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<sup>33</sup> "Approval Of Second Insect As A Novel Food", Food Safety, Last modified 2021, [https://ec.europa.eu/food/safety/novel-food/authorisations/approval-second-insect-novel-food\\_de](https://ec.europa.eu/food/safety/novel-food/authorisations/approval-second-insect-novel-food_de).

<sup>34</sup> "Insekten Essen: Eine Alternative Zu Herkömmlichem Fleisch?", Verbraucherzentrale.De, Last modified 2021, <https://www.verbraucherzentrale.de/wissen/lebensmittel/auswaehlen-zubereiten-aufbewahren/insekten-essen-eine-alternative-zu-herkoemmllichem-fleisch-33101>.

<sup>35</sup> Arnold van Huis and et al, "Edible Insects: Future Prospects For Food And Feed Security", Fao.Org, Last modified 2013, <http://www.fao.org/docrep/018/i3253e/i3253e.pdf>.

silk are the best-known insect products used by humans.<sup>36</sup> On the basis of archaeological finds it has been proven that insects in the form of eggs, larvae, pupae and in fully grown form served humans as food even in prehistoric times. Especially in warm regions where insects were available all year round, they were an important source of protein. Eating insects is known as “entomophagy”. The name comes from the Greek terms ἔντομον *éntomon*, "insect" and φάγειν *phagein*, "eat."<sup>37</sup>

### **Developing and emerging countries**

Currently, insects are valued and consumed by large parts of the population only in developing and emerging countries. For around two billion people today, insects are a basic and traditional food. 1900 different types of insects are consumed in 113 countries.<sup>38</sup> Beetles, caterpillars, bees, wasps, ants, grasshoppers, grasshoppers and crickets are the most widely consumed groups of insects and are particularly on the menu in Africa, Asia and South America.<sup>39</sup> As a result of westernization, the consumption of insects is beginning to decrease in some developing and emerging countries.<sup>40</sup>

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<sup>36</sup> Ibid., 21

<sup>37</sup> Birgit A. Rumpold and Oliver K. Schlüter, "Potential And Challenges Of Insects As An Innovative Source For Food And Feed Production", Sciencedirekt, Last modified 2012, <https://www.sciencedirect.com/science/article/abs/pii/S1466856412001452?via%3Dihub>.

<sup>38</sup> Arnold van Huis and et al, "Edible Insects: Future Prospects For Food And Feed Security", Fao.Org, Last modified 2013, <http://www.fao.org/docrep/018/i3253e/i3253e.pdf>.

<sup>39</sup> Birgit A. Rumpold and Oliver K. Schlüter, "Potential And Challenges Of Insects As An Innovative Source For Food And Feed Production", Sciencedirekt, Last modified 2012, <https://www.sciencedirect.com/science/article/abs/pii/S1466856412001452?via%3Dihub>.

<sup>40</sup> Matan Shelomi, "Why We Still Don't Eat Insects: Assessing Entomophagy Promotion Through A Diffusion Of Innovations Framework", Sciencedirekt, Last modified 2015, <https://www.sciencedirect.com/science/article/abs/pii/S092422441500151X?via%3Dihub>.

## Western countries

For some time now, eating insects has also been gaining attention in Western countries. Insects are no longer only served in elite restaurants as an "interesting experiment" or are found as casu marzu or German Würchwitz mite cheese as traditional and also very special dishes Place on the plates of western consumers.<sup>41</sup> As early as 1885 Vincent Holt brought up the topic of eating insects in countries where they are not traditionally consumed for the first time with his book "Why not eat insects".<sup>42</sup> The Food and Agriculture Organization of the United Nations (FAO) gave the decisive impetus for the growing interest in entomophagy in recent times with the publication of its paper "Edible Insects - Future prospects for food and feed security", which was downloaded seven million times.<sup>43</sup> In 2014, the former UN Secretary General Kofi Annan advocated eating insects in Western countries as a contribution to counteracting climate change and to a balanced diet.<sup>44</sup> In addition, the participation of 450 people from 45 countries at the "Insects to feed the world" conference, which took place in Holland in May 2014 and was organized by Wageningen University and FAO, demonstrated the worldwide interest in insects as food.<sup>45</sup>

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<sup>41</sup> Sampat Ghosh et al., "Nutritional Composition Of Five Commercial Edible Insects In South Korea", Sciencedirect, Last modified 2017,

<https://www.sciencedirect.com/science/article/abs/pii/S1226861517300924?via%3Dihub>.

<sup>42</sup> Matan Shelomi, "Why We Still Don't Eat Insects: Assessing Entomophagy Promotion Through A Diffusion Of Innovations Framework", Sciencedirekt, Last modified 2015,

<https://www.sciencedirect.com/science/article/abs/pii/S092422441500151X?via%3Dihub>.

<sup>43</sup> Arnold van Huis and et al, "Edible Insects: Future Prospects For Food And Feed Security", Fao.Org, Last modified 2013, <http://www.fao.org/docrep/018/i3253e/i3253e.pdf>.

<sup>44</sup> Matan Shelomi, "Why We Still Don't Eat Insects: Assessing Entomophagy Promotion Through A Diffusion Of Innovations Framework", Sciencedirekt, Last modified 2015,

<https://www.sciencedirect.com/science/article/abs/pii/S092422441500151X?via%3Dihub>.

<sup>45</sup> Arnold van Huis, "Edible Insects Are The Future?", Cambridgecore, Last modified 2016,

<https://www.cambridge.org/core/journals/proceedings-of-the-nutrition-society/article/edible-insects-are-the-future/206E43F1C95FCA2E67EF04950321414E>.

## **Economical meaning**

Entomophagy is an important source of income in some developing and emerging countries. Since edible insects can largely be collected in the wild or bred with limited resources, this also applies to the poorer parts of the population. In South Africa, an estimated 9.5 billion caterpillars are collected annually with a total value of 85 million US dollars.<sup>46</sup> In some places, collection is also uncontrolled and unsustainable. This can lead to exploitation, destruction of forests and extinction of species.<sup>47</sup> To counteract the negative effects of these factors.

## **Summary**

The literature review outlines the importance of novel food to contribute towards more sustainability. At present, food related issues are increasing due to the humans' consumption habits of meat. As population growths and wealth increases the meat consumption will lead to even worse environmental degradation and climate change. Sustainability has indeed a connection to the food industry, however, the whole industry, and especially livestock breeding, has no sustainable approaches. This fact highlights the importance of novel foods as it can contribute positively towards sustainable development.

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<sup>46</sup> Arnold van Huis and et al, "Edible Insects: Future Prospects For Food And Feed Security", Fao.Org, Last modified 2013, <http://www.fao.org/docrep/018/i3253e/i3253e.pdf>.

<sup>47</sup> Birgit A. Rumpold and Oliver K. Schlüter, "Potential And Challenges Of Insects As An Innovative Source For Food And Feed Production", Sciencedirect, Last modified 2012, <https://www.sciencedirect.com/science/article/abs/pii/S1466856412001452?via%3Dihub>.

# METHODOLOGY

## Research Design

The research design for this study is a one-shot case study, using semi-structured interviews in order to gather key figures to ascertain the degree of sustainability of insect farming.

This research design records the current stage of development of insect farms in Europe. To collect key figures, it was necessary to interview operators of insect farms to ensure the data come from companies that are located on the free market and operate under the pressure of it.

A semi-structured interview was selected to guarantee to get on the one hand the key figures that are needed for the data analysis, and on the other hand, to get additional information about the insect farming industry if the interviews allowed to ask for it.

The structured part of the interview was used to collect the required key figures related to the environmental dimension of sustainability. They indicate:

- Feed consumption
- Water consumption
- Required space use
- Energy consumption
- Output of emissions

The not structured part was used to ask for statements and figures related to the economic dimension. It was also asked about the operators' estimations of the future development of the insect farming industry.

## Sources of Data

The data for this research originate from primary and secondary data. The secondary data is used to extract key figures of the common livestock breeding of beef, pork, and chicken. Moreover, the data of livestock breeding shows the development of meat consumption and its effects. The information is collected from different websites, from governments' websites like the German Federal Statistical Office or the Federal Office for Agriculture and Food. Furthermore, data was gathered from NGOs such as PETA (People for the Ethical Treatment of Animals) and World Wildlife Fund and the online publication Our World in Data that provides an enormous database.

The empirical data for this research comes from the semi-structured interviews with operators of insect farmers. Inquiries were sent to the largest insect farming companies to ask for an interview. The companies are located in Europe, Germany and the Netherlands. These countries were chosen based on two facts. First, insect farming takes place under the EU's regulations of Novel Food. It is the first standardize regulation that applies in several countries. Based on that, it is considered that the EU's Novel Food guidelines for edible insects are used for orientation by other regional organizations and countries. Second, in both countries are the largest producers of edible insects. Although they are still considered as start-ups as this industry is still relatively new, companies of those countries are the online ones that are able to provide the necessary numbers.

In the end, three operators of insect farms were interviewed that were able to provide key figures for the data analysis. Furthermore, they provided different further information about the business sector.

Information that are important for the data analysis but not given or incomplete by the operators, were supplemented with data from research articles.

## **Instrumentation and Data Collection**

After the decision was made which companies could be the potential interview partners, a request was prepared that firstly points out how the company was found, why there are interests in them, and for what reason they are contacted. Secondly, the content of the research paper was explained, and which data need to be collected from the interview. By that, it was ensured that the interviewees could already prepare the answers before they were contacted for the interview.

Furthermore, an interview protocol was prepared as it was not allowed to record the interviews. The structure of the protocol outlines three parts. The first part asked for the company's numbers of feed consumption, water consumption, space use, energy consumption, and output of emissions. Although these numbers provide enough information to answer the research questions, the second part mentions the research questions ask to the interviewees about their answers. In the last part, different questions were asked that occurred during the interview.

## **Method of Data Analysis**

The data analysis of this research evaluates three issues. The first issue outlines the development of meat consumption and its effect. This is important show the relation between livestock breeding and sustainability and how it will develop if present trends do not change.

The second issue is based on the same indicators of the evaluation of livestock breeding to describe the degree of sustainability of edible insects (Novel Food). That section also

provides a brief overview of the resource consumption of plant-based alternatives to analyze the importance of Novel Food in the context of sustainability.

The third issue compares livestock breeding with insect farming to give a direct overview of advantages and disadvantages of both food sources related to sustainability.

In order to analyze the degree of sustainability of insect farming, this research compares the key indicators (extracted from the SDGs that relates to the food industry: feed consumption, water consumption, required space use, energy consumption and output of emissions, and other aspects with those of livestock breeding, based on 1 kg produced food. Furthermore, plant-based alternatives are also considered, however, this paper does not take into account the consumption of energy and output of emissions as available data could not clearly indicate their relation to the production of 1 kg nuts, pulses, grains and soybeans.

To illustrate the degree of sustainability, this research allocates the different food sources to the rating of 'positive impact', 'neutral impact' and 'negative impact'.

# DATA ANALYSIS

## Outlook of livestock breeding

Based on Plumer's outline of the relation between the growing population, the increase in wealth, and its effect on livestock breeding, it is expected that livestock breeding will expand worldwide in the next decades.

In order to confirm this trend, different data have to be analyzed and linked to each other. The data are meat consumption related to GDP per Capita, development of GDP per Capita, and the development of daily meat consumption per person. The data and figures come from the online publication Our World in Data.

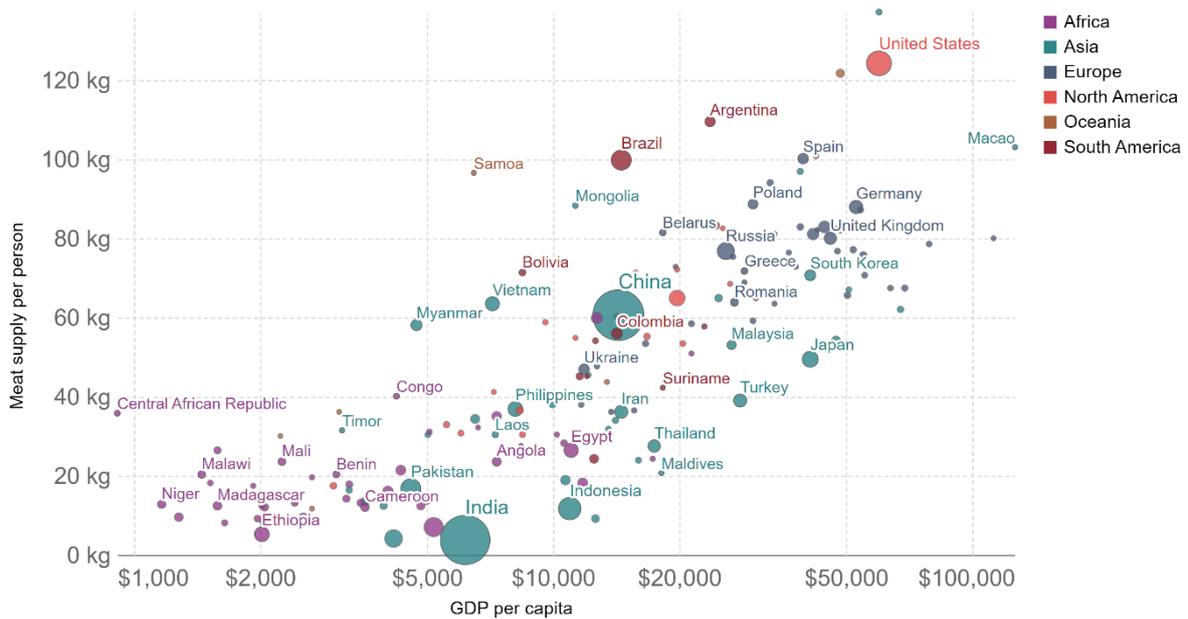


Figure 2. "Meat Consumption Vs. GDP Per Capita". Our World In Data, Last modified 2017. <https://ourworldindata.org/grapher/meat-consumption-vs-gdp-per-capita>.

This figure indicates the relation between meat consumption and GDP per Capita. It shows that a higher GDP per Capita leads to a higher meat consumption. Consequently, the

industrialized countries have the highest meat consumption, however, it is also observable that emerging economies have already a similar meat consumption to industrialized countries, e.g., China, Mongolia, Brazil, and Samoa.

That trace back to the fact that the regions of East Asia and the Pacific, and Latin America have witnessed an increase in their GDP per Capita, what can be seen in the next Figure.

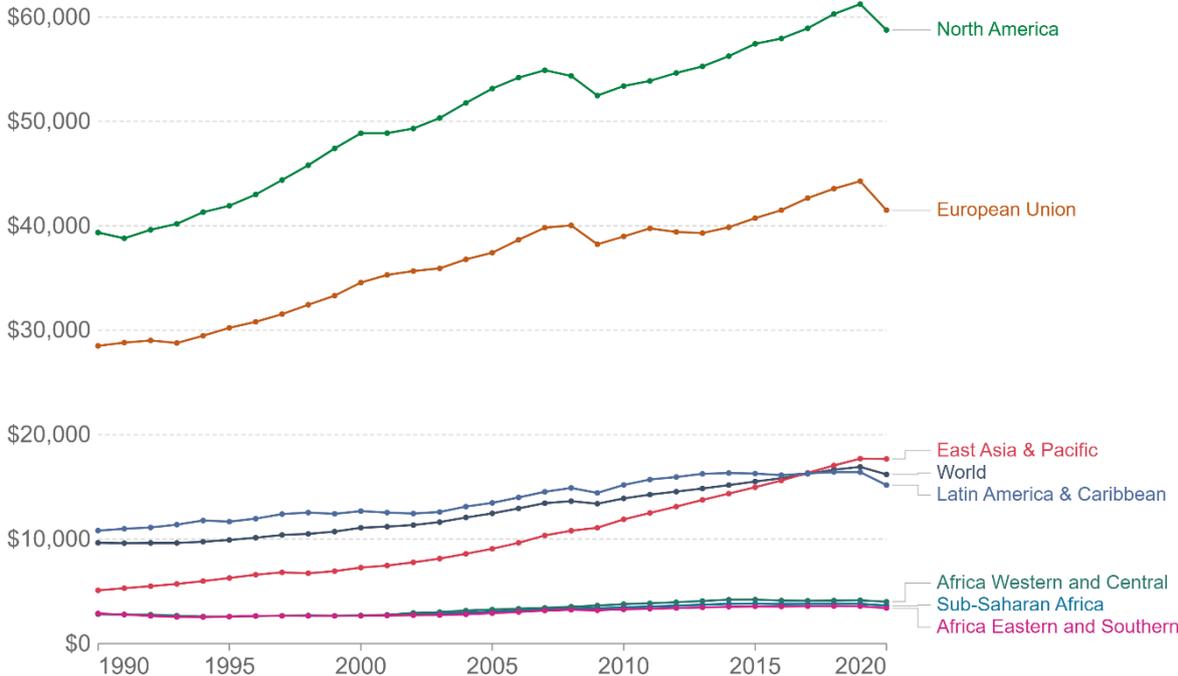


Figure 3. "GDP Per Capita, 1990 To 2020". Our World In Data, Last modified 2020. [https://ourworldindata.org/grapher/gdp-per-capita-worldbank?tab=chart&country=OWID\\_WRL~North+America~Latin+America+%26+Caribbean~European+Union~East+Asia+%26+Pacific~Africa+Western+](https://ourworldindata.org/grapher/gdp-per-capita-worldbank?tab=chart&country=OWID_WRL~North+America~Latin+America+%26+Caribbean~European+Union~East+Asia+%26+Pacific~Africa+Western+)

Although the industrialized regions have experienced the greater growth in GDP per Capita, this increase does not influence the meat consumption at all. It is more important to look at the increase in GDP per Capita in emerging economies and how it affects the meat consumption. The next figure makes it clear. In the last 30 years, the GDP per Capita increased by more than \$10.000 in the European Union and around \$20.000 in North America, however,

the daily meat consumption per person is almost stagnant or even decreasing at the same time. The increase of the GDP per Capita in East Asia and South America has not been as great as in the EU or North America, and even there GDP per Capita in 2020 is still much less than the GDP per Capita of the industrialized countries in 1990, however, the growth has been high enough to reach a level to make the consumption of meat affordable.

From 1961 to 2013, the daily meat consumption per person has increased from less than 20g to almost 100g in Asia, and from about 100g to more than 200g in South America.

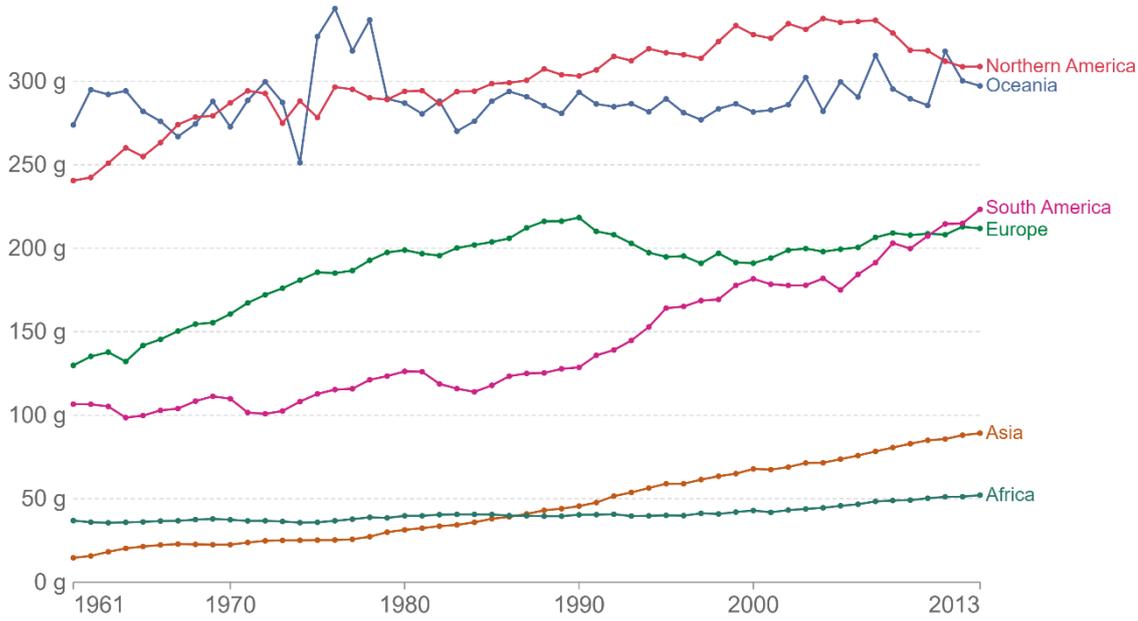


Figure 4. "Daily Meat Consumption Per Person, 1961 To 2013". Our World In Data, Last modified 2017. <https://ourworldindata.org/grapher/daily-meat-consumption-per-person?tab=chart&country=Europe~Asia~Northern+America~Africa~South+America~Oceania>.

Looking at the figures as a whole picture, it indicates that the demand of meat will increase in the next decades if the development in consumption does not change. The annual meat consumption has already increased significantly over the past few decades. While the average worldwide annual consumption was 33.5 kilograms per capita in 1990, it was 42.9 kilograms in 2018.<sup>48</sup> So there are not only more people in the world what results in a higher demand of meat, but also more and more people can afford meat.

This briefly analysis confirmed the expectation from the beginning, that the industry of livestock breeding will expand worldwide.

### **Resource consumption of livestock breeding**

Under the present development and expectations, it is expected that livestock breeding will increase to cover the demand of food. As the world faces global challenges – especially environmental and climate changes – it is indispensable to point out the degree of sustainability in order to justify to expansion of livestock breeding.

The high demand for meats in industrialized countries and the recent increase in GDP per Capita in emerging regions results in a high demand of resources to keep the industry of livestock breeding alive. At the same time, the industry sector produces harmful emissions for the environment and climate. Important factors in livestock breeding are the use of water, demand of animal feed, demand of space, consumption of energy, and the release of Greenhouse gas emissions.

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<sup>48</sup> "Tierhaltung, Fleischproduktion, Fleischkonsum", Statistisches Bundesamt, Last modified 2019, [https://www.destatis.de/DE/Themen/Laender-Regionen/Internationales/Thema/landwirtschaft-fischerei/tierhaltung-fleischkonsum/\\_inhalt.html](https://www.destatis.de/DE/Themen/Laender-Regionen/Internationales/Thema/landwirtschaft-fischerei/tierhaltung-fleischkonsum/_inhalt.html).

On a global average, 1 kg of beef contains 15,400 liters, 1 kg of pork 5,900 liters and 1 kg of chicken meat 4,300 liters of water.<sup>49</sup> Agriculture is responsible for 70 percent of water consumption worldwide. More than half of the world's grain harvest is now fed to animals. In total, 70% of the world's agricultural land is used in some way for animal feed.<sup>50</sup>

Besides, 7 kg of grain is needed to produce 1 kg beef, 4 kg grain for 1 kg pork, and 2 kg of grain is used to produce 1 kg of chicken.<sup>51</sup>

The next number that is considered is the consumption of land. In this paper, the numbers also include the demand of space to produce the feed for the animals. 27 m<sup>2</sup> is used for the production of 1 kg beef. For 1 kg pork, 8.9 m<sup>2</sup> space is required. To produce 1 kg chicken, 8.1 m<sup>2</sup> are used.<sup>52</sup>

Another important factor in livestock breeding is the use of energy. In this paper the unit megajoule (MJ) is used. Here the process is to generate 1 kg of meat. For the production of 1 kg beef about 250 MJ is used, 235 MJ is required for 1 kg pork, and 150 MJ for 1 kg chicken.<sup>53</sup>

Next to the high consumption of resources, livestock breeding also produces a high output of Greenhouse gas emissions. Most Greenhouse gases accrue for land use, farm, animal feed, and transport. They are measured in kg of carbon dioxide equivalents (kgCO<sub>2</sub>eq) what means that non-CO<sub>2</sub> greenhouse gases such as methane are included and weighted by their relative

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<sup>49</sup> "Das Nutztier – Ein Wasserfresser", Weltfriedensdienst, Last modified 2018, <https://wfd.de/thema/fleisch-milch>.

<sup>50</sup> "FLEISCHATLAS", Boell.De, Last modified 2014, [https://www.boell.de/sites/default/files/fleischatlas2014\\_vi.pdf](https://www.boell.de/sites/default/files/fleischatlas2014_vi.pdf).

<sup>51</sup> Tim Worstall, "It Does Not Take 7 Kg Of Grain To Make 1 Kg Of Beef: Be Very Careful With Your Statistics", Forbes, Last modified 2012, <https://www.forbes.com/sites/timworstall/2012/09/03/it-does-not-take-7-kg-of-grain-to-make-1-kg-of-beef-be-very-careful-with-your-statistics/?sh=6a61c7865f0d>.

<sup>52</sup> Harald von Witzke, Steffen Noleppa and Inga Zhirkova, "Fleisch Frisst Land", Wwf.De, Last modified 2011, [https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF\\_Fleischkonsum\\_web.pdf](https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Fleischkonsum_web.pdf).

<sup>53</sup> Cheri B., Shannon L. and Mary J., "How Much ENERGY (In Btus) Is Expended Or Used To Produce 1 Pound Of Beef, 1 Pound Of Chicken, And 1 Pound Of Pork For Retail Consumption?", Wonder, Last modified 2017, <https://askwonder.com/research/energy-in-btus-expended-used-produce-1-pound-beef-chicken-pork-retail-k5gwibwm3>.

warming impact. For the production of 1 kg beef 57.9 kgCO<sub>2</sub>eq accrue, for 1 kg pork there are 6.4 kgCO<sub>2</sub>eq, and 5.3 kgCO<sub>2</sub>eq accrue for 1 kg chicken.<sup>54</sup>

**Table 1. Resources and output of Greenhouse gas emissions for 1kg of meat**

<b>Indicator</b>	<b>beef (beef herd)</b>	<b>pork</b>	<b>Chicken</b>
feed (kg)	7	4	2
water (l)	15,400	5,900	4,300
Land usage (m <sup>2</sup> )	27	8.9	8.1
energy (MJ)	250	235	150
GHG (kgCO <sub>2</sub> eq)	57.9	6.4	5.3

Source: Edited by the Author

**Resource consumption of plant-based alternatives**

In recent years, humans have started to consume more plant-based alternatives. The most well-known alternatives are nuts, pulses, grains, and soybeans. Alternatives are used as their consumption of water and land is less than the resource consumption for the production of beef. Some of the alternatives also have a better water and land efficiency than pork and chicken.

<sup>54</sup> "Food: Greenhouse Gas Emissions Across The Supply Chain", Our World In Data, Last modified 2020, <https://ourworldindata.org/grapher/food-emissions-supply-chain?country=Beef+%28beef+herd%29~Cheese~Poultry+Meat~Milk~Eggs~Rice~Pig+Meat~Peas~Bananas~Wheat+%26+Rye~Fish+%28farmed%29~Lamb+%26+Mutton~Beef+%28dairy+herd%29~Shrimps+%28farmed%29~Tofu~Maize>.

**Table 2. Required space and water for the production of 1 kg food of plant-based alternatives**

<b>Alternatives</b>	<b>Land usage (m<sup>2</sup>)</b>	<b>water consumption (l)</b>
Nuts	12.96	9,063
Pulses	15.57	4,055
Grains	7.6	1,644
Soybeans	3.52	2,523

Source: Edited by the Author

### **Resource consumption of edible insects**

The data for this part come from the three interviews. The operators of the insect farms were not inclined to give out exact numbers but provided a range in which their numbers are located, or compared their numbers with the numbers of the common meat sources. Furthermore, not every interviewee was able to provide all numbers. On the basis of the statements, the numbers are calculated means of their stated ranges, or conversions based on the comparison with the numbers of the common meat industry. All data of the edible insects refer to Meal Worms.

### **Consumption of feed**

The interviewee from Company 1 stated that the consumption of feed is ten time less than the consumption of feed for beef. That corresponds to about 0.7 kg feed. The operator from Company 2 confirmed the data from Company 1. He also stated to the consumption of feed is about 0.7 kg. The operator of Company 3 quoted that he needs about 0.8 kg to 1 kg feed. The mean is 0.9 kg.

### **Consumption of water**

All three interviewees were also able to indicate the consumption of water in their company. The water consumption in Company 1 is 15.500 times less than in the production of beef. That is roughly equivalent to 1 to 1.3 liters, the mean is 1.15 liter. Company 2 indicated its water consumption is about 1 to 2 liters. By that, the mean is 1.5 liter. Company 3 mentioned a water consumption of about 2 liters.

### **Consumption of space**

The operator of Company 1 stated a space requirement that is 12.5 less compared to the beef production. That would be a use of 2.16 m<sup>2</sup>. The operator of Company 2 indicated a space requirement of 2 to 2.5 m<sup>2</sup>, what makes a mean of 2.25 m<sup>2</sup>. Company 3 was not able to share its space requirement. However, all three interviewees said, that the land usage does not play a significant role as insect farming provides the possibility to farm vertically.

### **Consumption of energy**

The interviewee from Company 1 could not state out a number about the consumption of energy as the heat emitted from the insects is used as an energy source in his company. The operator of Company 2 stated a consumption of 120 to 135 MJ, the means is 127.5 MJ. Company 3 mentioned a consumption of energy that is similar to that of chicken. That would be about 150 MJ.

**Output of emissions**

The operator of Company 1 stated that the output of emissions is 100 times less compared to the output in the beef industry. By that, the emissions would be 0.252 kgCO<sub>2</sub>eq. The interviewee from Company 2 quoted an output that is less than 1 kgCO<sub>2</sub>eq. Company 3 was not able to hand out numbers.

In the following table, the means of data are clearly illustrated.

**Table 3. Resources and output of Greenhouse gas emissions for 1kg of edible insects**

<b>Indicator</b>	<b>Company 1</b>	<b>Company 2</b>	<b>Company 3</b>
feed (kg)	0.7	0.7	0.9
water (l)	1.15	1.5	2
Land usage (m <sup>2</sup> )	2.16	2.25	
Energy (MJ)		127.5	150
GHG (kgCO <sub>2</sub> eq)	0.252	< 1 kg	

Source: Edited by the Author

**Table 4. Resource consumption and output of emissions compared with common meat sources and plant-based alternative to produce 1 kg food**

<b>Indicator</b>	<b>Edible insects</b>	<b>beef (beef herd)</b>	<b>pork</b>	<b>Chicken</b>	<b>nuts</b>	<b>pulses</b>	<b>grains</b>	<b>soybeans</b>
<b>Feed (kg)</b>	0.78	7	4	2				
<b>Water (l)</b>	1.93	15,400	5,900	4,300	9,063	4,055	1,644	2,523
<b>Land (m<sup>2</sup>)</b>	2.21	27	8.9	8.1	12.96	15.57	7.6	3.52
<b>energy (MJ)</b>	138.75	250	235	150				
<b>GHG<sup>a</sup></b>	0.63	57.9	6.4	5.3				

Source: Edited by the Author

<sup>a</sup>Stated in kgCO<sub>2</sub>eq

The table indicates the advantages of one food source over the others. Comparing the input of feed to produce 1 kg food, it is clearly apparent that edible insects (0.78 kg) need less than chicken (2 kg), pork (4 kg) and beef (7 kg). The comparison of water consumption shows that the insects need significantly less water (less than 2 liters) whereas common meat sources need at least 4,300 liters (chicken) and plant-based alternatives at least about 1,600 liters (grains). The highest consumption has beef with about 15,400 liters. Insects also have an advantage in land usage. They only need about 2.21 m<sup>2</sup> for the production of 1 kg food. Soybeans have the

lowest land usage (3.52 m<sup>2</sup>) of the plant-based alternatives, and chicken (8.1 kg) has the lowest land usage of the common meat sources. The lowest energy consumption has insects (138.75 MJ), followed by chicken (150 MJ), pork (235 MJ), and beef (250 MJ). The comparison of the output of GHG indicates that insects have an advantage of the common meat sources. In the production of 1 kg food, insects emit 0.63 kgCO<sub>2</sub>eq, chicken 5.3 kgCO<sub>2</sub>eq, pork 6.4 kgCO<sub>2</sub>eq, and beef 57.9 kgCO<sub>2</sub>eq.

## Evaluation of sustainability

The evaluation of the food sources' degree of sustainability is based on the aspects and indicators of each of the SDGs that are already mentioned.

**Table 5. Evaluation of Goal 2, Zero Hunger**

<b>Positive impact</b>	<b>Neutral impact</b>	<b>Negative impact</b>
Insect farming	Plant-based alternatives	Livestock breeding

Source: Edited by the Author

The SDG Zero Hunger aims at the access to enough food for everyone. This goal targeting at the assurance to safe and nutritious food, sustainable food production, and development of rural infrastructure.

Insect farming is allocated as having a positive impact, as compared to the other food sources its consumption of resources is low. Edible insects have the lowest consumption of water and land usage and compared to the common meat sources also advantages in feed consumption, energy consumption and emission of GHG. By that, edible insects contribute to sustainable food production. Furthermore, the interviewees from Company 1 and Company 3 stated, that the implementation of a rudimentary insect farm is relatively easy. Furthermore, the interviewee from Company 3 quoted that the development and maintenance of an insect farm is cheaper than a chicken, pork or beef farm, based on his experience as a farmer. By that, the implementation of insect farms would also contribute to the development of rural infrastructure.

The plant-based alternatives are set as having a neutral impact on the SDG because their consumption of resources is lower than the consumption of common meat sources, however, their water consumption is much higher than that of insects. As fresh water is already a rare resource in some parts, it can be seen critical if plant-based alternative can feed humans in those areas, especially against the background that population will increase.

Livestock breeding has the highest consumption of feed, water, land and energy, and emits the most GHG. Furthermore, land and fresh water will be not available in an amount to feed the future population. In contrast to other food sources, it is also considered as relatively costly. A profit orientated farm under the highest aspects of environmentally friendliness is seldom feasible in areas where it should contribute to a development of a rural infrastructure.

**Table 6. Evaluation of Goal 6, Clean Water and Sanitation**

Positive impact	Neutral impact	Negative impact
Insect farming		Livestock breeding Plant-based alternatives

Source: Edited by the Author

The relevant targets of Clean Water and Sanitation are the reduction of polluting particles in fresh water, a higher responsibility in consumption, and a better protection of water-related ecosystems.

Insect farming contributes positively to Clean Water and Sanitation. First, its water consumption of 1.93 liter to produce 1 kg food is compared to the other food sources very low. Second, the operator of Company 1 stated that only a minimum of pollutants accrues in the breeding process that can get to the ground water if no filters are used.

Although it is pointed out that the consumption of water of the plant-based alternatives is in between edible insects and the common meat sources, it has to be reconsidered under the aspects of this goal. It is arguable that for the planting of the alternatives, fertilizers are used in a similar way than for other crop plants. These further strains the availability of clean fresh water. Besides, an expansion of this industry would lead to a further destruction of water-related ecosystems.

The same counts for livestock breeding but with the fact that its water consumption and output of pollutants is even higher. Especially in countries that are already struggling with water scarcity, the cultivation of animal feed and meat production can exacerbate the water shortage. In addition, the quality of drinking water and groundwater can be impaired. Over 30 percent of the world's freshwater use is used for livestock breeding. This high amount is made up of the irrigation of the feed and the animals' need for drinking water.<sup>55</sup> In addition, livestock breeding pollutes fresh water. For example, from antibiotics, which are used in factory farming. Through the excretions of the animals, which are often spread as liquid manure on fields, antibiotic residues get into the environment and partly into the groundwater. Some of this contamination cannot be filtered by sewage treatment plants or it gets directly into the groundwater and contributes to the fact that the quality and quantity of the available drinking water is decreasing.

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<sup>55</sup> "What Is A Water Footprint?", Waterfootprint.Org, Last modified 2019, <https://waterfootprint.org/en/water-footprint/what-is-water-footprint/>.

**Table 7. Evaluation of Goal 8, Decent Work and Economic Growth**

Positive impact	Neutral impact	Negative impact
Insect farming	Livestock breeding Plant-based alternatives	

Source: Edited by the Author

Decent Work and Economic Growth targets at sustainable economic development to provide jobs and increase in prosperity.

The sale and marketing of edible insects is already seen as relatively normal in some countries. For example, in South Africa, an estimated 9.5 billion caterpillars are collected annually with a total value of 85 million US dollars – with increasing tendency.<sup>56</sup> But also the development of many new businesses in Europe and other western countries will lead to growing industry. That is also confirmed by all three interviewees as they all expected that insect farming will play an important role to feed the world in the future. By that, it will increase job opportunities and especially developing countries can gain from this industry.

Livestock breeding and plant-based alternatives are considered to have a neutral degree of sustainability under the aspects of this goal. Both industries will be there in the next decades and based on the growing population and increase of wealth, they will record an economic growth. However, especially livestock breeding has to change to meet the concept of sustainability. The interviewee of Company 2, a former breeder of cattle for the organic meat production, stated that meat will become a luxury product again but in exchange it will have a better ecological footprint.

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<sup>56</sup> Arnold van Huis and et al, "Edible Insects: Future Prospects For Food And Feed Security", Fao.Org, Last modified 2013, <http://www.fao.org/docrep/018/i3253e/i3253e.pdf>.

**Table 8. Evaluation of Goal 9, Industry, Innovation and Infrastructure**

Positive impact	Neutral impact	Negative impact
Insect farming	Livestock breeding Plant-based alternatives	

Source: Edited by the Author

Goal 9, Industry, Innovation and Infrastructure aims at an improvement of resource management by focusing on upgrading technology and innovating processes.

Edible insects are Novel Food and by that considered as an innovative food source. The interviewee from Company 3 pointed out that there is a huge variety of end products that can be made by insects such as flour, butter, pasta, etc. Furthermore, edible insects can be produced in vertical farms and under non-consideration of climatic conditions. By that, the infrastructure of the food production can change as it allows to be realized much closer to the customers.

Some researchers deal with innovative approaches to improve the ecological footprints of livestock breeding and plant-based alternatives. Key fields are for example the reduction of methane output of cattle or to reduce the water consumption of crops. However, the progress that is made in the sector of edible insects is much higher in the recent years. By that, livestock breeding, and plant-based alternatives are considered to have neutral impact on this goal.

**Table 9. Evaluation of Goal 12, Responsible Consumption and Production**

Positive impact	Neutral impact	Negative impact
Insect farming	Plant-based alternatives	Livestock breeding

Source: Edited by the Author

The goal Responsible Consumption and Production targets on the assurance of a sustainable handling and use of natural resources, a proper management with waste and pollutants, and a general reduction of waste products.

As already pointed out, edible insects have advantages in all aspects that are considered in this research. Thereby, the contribution of insect farming is highly sustainable compared to the other food sources.

Besides, edible insects can be fully utilized whereas slaughterhouse waste is often produced in the common meat industry.

Plant-based alternatives are allocated to have a neutral impact as they waste products can be fully return to the environment if they are planted under organic aspects, however, a sustainable handling of resources is not observable in its excessive forms.

**Table 10. Evaluation of Goal 13, Climate Action**

Positive impact	Neutral impact	Negative impact
Plant-based alternatives	Insect farming	Livestock breeding

Source: Edited by the Author

Climate Action aims at the reduction of GHG by a sustainable natural resource management, implementation of new technologies and the use of innovative processes.

Under the aspect to reduce GHG, edible insects have a great advantage over livestock breeding. However, in the production process of 1 kg food of edible insects, GHG are still emitted. The operator from Company 1 indeed mentioned that the company produced energy from the heat that is emitted from the insects what reduced the consumption of energy from external sources, however, he also mentioned that this procedure is highly technological and costly in its development. It is sustainable in the long-term, but not affordable for everyone so that its contribution is yet too little.

Plant-based alternatives have an advantage here as they can store carbon that they remove from the atmosphere by photosynthesis in plants. Furthermore, certain crop plants that are used to be alternatives produce more oxygen than they need to use and release it to the atmosphere.<sup>57</sup>

Livestock breeding is largely responsible for climate change. A new study attributes up to 20 percent of the world's greenhouse gases are emitted by the animal industry.<sup>58</sup> The emissions

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<sup>57</sup> Joost T van Dongen, "Sauerstoff In Pflanzen – Wie Ein Lebenselixier Gleichzeitig Stressfaktor Und Signalstoff Sein Kann", Mpg.De, Last modified 2011, [https://www.mpg.de/4982054/Pflanzen\\_Sauerstoff](https://www.mpg.de/4982054/Pflanzen_Sauerstoff).  
<sup>58</sup> Xiaoming Xu, Prateek Sharma and et al, "Global Greenhouse Gas Emissions From Animal-Based Foods Are Twice Those Of Plant-Based Foods", Nature, Last modified 2021, <https://www.nature.com/articles/s43016-021-00358-x>.

arise, on the one hand, directly through the digestive process or the excretions of the animals, and on the other hand, indirectly through the deforestation of the forests for the planting of animal feed and pastureland. By that, livestock breeding is considered to be not sustainable.

**Table 11. Evaluation of Goal 15, Life on Land**

Positive impact	Neutral impact	Negative impact
Insect farming		Livestock breeding Plant-based alternatives

Source: Edited by the Author

Life on Land aims for a sustainable use and restoration of freshwater ecosystems, supports reforestation, and restore degraded land and soil.

One major advantage of insect farms is that they can be operated in vertical farm. By that, the base area is significantly smaller than the base area of livestock breeding. That enables to operate them in urban areas where a deconstruction of natural habitats has already taken place. A further deconstruction is not necessary. Although additional space is required to grow the insects' feed, it is much less than compared to the plant-based alternatives. The low land usage and consumption of water enable the restoration of freshwater ecosystems and reforestation.

A central aspect of the environmental impact is the great need for agricultural land for livestock breeding. These not only include grazing land, but above all arable land for growing animal feed. More than 83 percent of the agricultural land is used for animal husbandry and feed.<sup>59</sup> In order to meet the high demand for space, natural habitats are being destroyed around

<sup>59</sup> "9 Gründe, Warum Umweltzerstörung Durch Tierprodukte Entsteht", PETA, Last modified 2021, <https://www.peta.de/themen/umwelt/>.

the world. For example, since 2011, 800,000 hectares of rainforest have been destroyed in the Amazon region.<sup>60</sup> This destroys the natural habitats of many species. Furthermore, the cultivation of animal feed in industrial agriculture, which is characterized by monocultures, does not offer any space for biodiversity.

The floors also suffer from this pollution. The increasing need for food and the growing demand for meat reduce soil fertility through overuse. Monocultures for feed and overgrazing lead to soil compaction and erosion.

Similar problems also occur in plant-based alternatives. Their high demand of land usage and water destroy natural ecosystems and the usage of fertilizers harm the soil in long-term.

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<sup>60</sup> Idib., 47

## CONCLUSION

First of all, the data analysis shows that the present food industry contributes to the destruction of the environment and climate change with its great share of livestock breeding.

The most dramatic effects are:

- negative effects on climate change,
- high land consumption and the associated destruction of natural habitats such
- high water demand and water pollution,
- emissions of greenhouse gases (CO<sub>2</sub>, methane).

With the comparison of the different food sources, edible insects, livestock breeding and plant-based alternatives, the research questions can be answered. Moreover, the paper gives a brief outlook of insect farming's effects on the three dimensions of sustainability.

### **Response to research questions**

RQ1: To what degree can insect farming reduce global hunger?

The comparison of the different food sources shows that edible insects have the potential to contribute positively to the reduction of global hunger. Edible insects have a low consumption of resources, and it is possible to farm them everywhere where humans are as their requirements are low compared to plant-based alternatives and livestock breeding. As they are farmed completely indoor, the location is completely independent from climate conditions. Only the supply of water and feed has to be ensured. Furthermore, the implementation of an insect farm is relatively easy and cheap compared to livestock breeding. In combination, these are important and needed features to reduce global hunger.

RQ2: To what extent can insect farming contribute to sustainable economic growth?

In Africa and many parts of Asia, edible insects are already part of the daily food consumption, and by that already implemented on local markets. In western countries, many startups occurred to farm insects. From the interviews it is observable that an economic growth is expected within the next years. Giving edible insects the potential to reduce global hunger, the expansion of this industry will increase, providing jobs and bringing prosperity. With an innovative and technological process in insect farming, farms can be operated highly economic friendly without reducing economic outcomes.

RQ3: In what way can insect farming contribute to environmental protection?

Insect farming can contribute positively to environmental protection in several ways. First, insect farms consume less water compared to other food sources. Furthermore, its output of pollutants to the fresh water is very low if no filters are used what ensures an easier access to water. Second, as feed consumption is also very low and insects can be breed in vertical farms, the land usage is minimal. A replacement of livestock breeding would decrease land usage what then can be reforest and restored to natural habitats again. By that, it also protects the biodiversity. Third, insect farms produced only a fraction of emissions. Lastly, the waste outcome of edible insects is also very low as the insects can be fully processed.

RQ4: Under what conditions is insect farming applicable?

Based on the interviewees' expertise, insect farming is applicable almost everywhere. Resource consumption is low, and no expertise is need to breed insects. It is pointed out that a rural insect farm is easy to develop compared to common farms, however, to answer the

question in a more appropriate way, a research that focus on the development of insects farms has to be done.

### **Closing words**

This research provides new and interesting insights into insect farming. It stands out that insect farming under the EU's Novel Food guidelines is relatively new and cannot answer all aspects of sustainability yet, however, it can be already seen the high potential of this sector. Especially based on the fact that the interviewees were not willing to provide detailed numbers – although they all stated that these numbers are existing – it indicates that all have great expectations in the industry, and it will be highly competitive as long as only a few insects are approved to be consumed by humans.

Moreover, this research is only able to give a detailed analysis of insect farming on the environmental dimension of sustainability. For the economic dimension, the research indicates positive developments from insect farming, but as it is a relatively new industry with only a view firms, a detailed analysis is not yet possible. That also applies to the social dimension. There is still data missing to make a proper evaluation, however, it is to be expected that the positive impact on the environment and economy will also lead to a positive impact on the social dimension.

This paper does not provide an evaluation if edible insects are accepted as a food source globally. If they are not accepted worldwide, the industry will not play a key role to challenge the present issues.

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