# Upcycling nutrients from food waste and agri-food byproducts into animal feed, fertilizers, and soil amendments, using insects: Creating awareness and technical know-how in Greece

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Fragility of our global food system became evident once more with the COVID-19 crisis followed by war in Europe. While the global food price index has recently seen an all-time high and ~10% of human population suffers from undernourishment, we paradoxically waste over 1 billion tons of food every year, environmental impacts of which contribute to setting the stage for future crises (FAO 2022, 2023, UNEP 2021). Valorizing food waste and agri-food byproducts as sources of nutrients is an obvious way out. Insects and their gut microbes are naturally able to bridge nutrients from organic residues to higher animals. A rapidly growing industry has picked up on this (van Huis & Tomberlin 2018): Selected insect species are reared on food waste and agri-food byproducts. The resulting insect biomass is processed into protein-rich ingredients that can be incorporated into animal feed and human food. The nutrients therefore are upcycled to high-value applications, placing this technology above composting or anaerobic digestion in the biowaste management hierarchy. The material left over from insects is in turn used for amendment of agricultural soils, completing a zero-waste cycle. Recent EU legislation authorize and regulate such use of insects, and an active European sector has come to life, following the strong global trend (IPIFF 2021, 2022). With technological progress, further permissive legislation, upscale and geographical spread as well as increasing public acceptance, insects are set to become key to achieving circularity in our food system (IPIFF 2020).

Greece provides an ideal context for implementing this technology: Annually, estimated 1.5 - 2 million tons of Greek food waste is landfilled (UNEP 2021, EEA 2020), leading to significant greenhouse gas emissions as well as landscape destruction and convicting the country to fines for breaking EU waste management laws. In addition, a rich variety of nutritious byproducts from Greek food-production and -processing businesses remain under valorized. At the same time, the domestic fish, poultry, and swine farming heavily rely on imported feed raw materials – particularly fishmeal and soymeal, associated with environmental damage and unstable prices. Greece therefore features both the critical input providers and the relevant markets, waiting for insects to bridge across them. In this paper, we outline the critical steps to achieve this goal:

I. **Technology adaptation:** For maximal cost-efficiency and environmental benefits, we propose adapting insect-rearing to the local conditions. Particularly:
    - Design of insect-rearing facilities must be adjusted for exploiting the advantages of the Mediterranean climate to minimize energy-intensive active climate control.
    - Cheap and effective insect-diet recipes must be developed based on the specific composition of locally available food waste and the repertoire of Greek agri-food byproducts. A significant portion of these materials are technically and EU-legislatively suitable and can be incorporated into insect diets as such. It is however imperative to also consider technically more challenging materials (e.g., anaerobic digestate, green waste) and to develop pre-processing methods to enable their valorization by insects.
    - Finally, materials that are abundant in Greece but not yet authorized for feed use in the EU (e.g., HORECA- hotel, restaurant, catering food waste) must be systematically explored, with the objective of guiding data-based expansion of the range of input materials for safe and hygienic insect rearing.

II. **Pilot implementation:** The adapted technology must be implemented at pilot scale. This will have multiple benefits:
    - The technical feasibility under the local conditions will be demonstrated and the capital and operational costs will be documented in detail. These can be used to outline concrete business cases for the uptake of the technology in selected scenarios relevant to Greece (e.g., on a small island by the municipality, in rural areas by poultry or swine farmers, as add-on to anaerobic digestion plants).
    - The prototype insect-based animal feed ingredients and soil amendments will be validated in terms of safety and hygiene, based on relevant EU legislation.
    - The quality of the products will be established in controlled feeding and crop production trials.
    - Early adopters will be recruited to evaluate the products under real life conditions.

III. **Making a case for insect-based business in Greece:** The operational pilot facility, the business cases outlined based on the pilot implementation as well as the prototype products must be used to:
    - Increase the awareness for the technology among public, NGOs, regulatory bodies, and policy makers.
    - Promote the products in the respective domestic sectors.
    - Entice public and private stakeholders (e.g., municipalities, waste management bodies, feed manufacturers, livestock farmers) to take up the technology.

We believe that this stepwise strategy can be implemented by an interdisciplinary consortium, and it will create in Greece, a much-needed nucleus of awareness and technical know-how on upcycling nutrients from food waste and nutritious byproducts using insects. Around this nucleus, a new domestic subsector of circular bioeconomy will then grow.

**References**

EEA-European Environment Agency (2020). Bio-waste in Europe - turning challenges into opportunities.

FAO, IFAD, UNICEF, WFP and WHO (2022). The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable. Rome.

FAO Food Price Index. 2023. https://www.fao.org/worldfoodsituation/foodpricesindex/en/

IPIFF-International Platform of Insects for Food and Feed (2020). The insect sector milestones towards sustainable food supply chains.

IPIFF-International Platform of Insects for Food and Feed (2021). An overview of the European market of insects as feed.

IPIFF-International Platform of Insects for Food and Feed (2022). Guide on Good Hygiene Practices.

UNEP-United Nations Environment Programme (2021). Food Waste Index Report 2021. Nairobi.

Van Huis A., Tomberlin J.K. (2018). Insects as Food and Feed. From Production to Consumption. Wageningen Academic Publishers. The Netherlands.