Tropentag 2023

Innovative integration of renewable energy and agricultural production as contribution on sustainable local development

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INTRODUCTION

As a result of population growth, rising standards of living and industrialization, global energy demand has skyrocketed in recent decades and the use of oil, coal and natural gas has expanded dramatically. Globally, rapid growth in energy consumption results in increased greenhouse gas emissions, leading to serious environmental consequences such as global warming and ozone depletion. This causes the earth's temperature to increase and results in poor environmental conditions for humans. Annual global temperature rose by 0.07 degrees every ten years between 1880 and 1980 (Paygude, Romero, & O. Hartmann, 2021). As a result, in today's world, a shift towards renewable energy is being worked on to reduce CO2 emissions. However, in the implementation of technologies to use renewable energies, the impacts of their implementation in other sectors must be taken into account, such as the extensive use of land for solar and wind farms, competing with the need for land to produce food. This work will present theoretical-practical reflections of the potentialities of the innovative integration and management of renewable energies with agro-productive systems, to achieve synergies that allow increasing food and energy production with sustainable strategies, contributing to local development and reducing gaps in living standards in rural regions of developing countries.

THEORETICAL CONSIDERATIONS

The world needs to grow following the green economy for improving human well-being and reducing inequalities, while not exposing future generations to significant environmental risks and ecological scarcities. The green economy is an enabling component of the overarching sustainable development goals.

The circular economy follows a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials & products for as long as possible.

The green economy, circular economy, and bioeconomy are common concepts in sustainability discussions in policy, scientific research, and business. On the other hand, the water-food-energy-ecosystem nexus seeks to manage resources in multiple sectors, knowing that decisions in one sector can affect other sectors.

The 17 Sustainable Development Goals set forth by the United Nations in 2015 try to address sustainability challenges and the urgency for concerted efforts by multiple societal actors.

In this context the question arises: How can we develop real alternatives that contribute to a green and circular economy, while responding to the demands of the water-energy-food-ecosystem nexus, while promoting the achievement of the SDGs?

The authors of this contribution start from the hypothesis that the innovative integration of renewable energies in rural farming systems, through the sequential implementation of already proven technologies, will allow a real contribution to be made to the use of the previous concepts, as well as to have a significant impact direct to the 17 SDGs.

Agrivoltaic systems (also known as agrophotovoltaic) are still an emerging technology and have enormous potential in the future to increase solar electricity generation and food production with important positive synergies between both sectors, the equivalent use of land is high with LER values (1.35 to 1.73); net sales per hectare increase by more than 30% considering energy and agricultural production; Water savings for irrigation of more than 30% are achieved. At the same time, these systems protect crops from excess solar radiation that exceeds the light saturation point (Kherde, Meier-Grüll, & M. Hartmann, 2021).

On the other hand, the integration of photovoltaic systems in livestock systems allows, in addition to generating electricity, to reduce the heat stress of livestock, which affects their reproduction and production.

Fig. 1: Research facility, agro-photovoltaic for apples
Source: (Kherde, Meier-Grüll, & M. Hartmann, 2021)

Fig. 2: Sunfarming plant of 730 KWp
Source: (Kherde, Meier-Grüll, & M. Hartmann, 2021)

Fig. 3: Vertical agrivoltaic installation in operation Nex2Sun
Fuente: (Paygude, Romero, & O. Hartmann, 2021)

Fig. 4: Photovoltaic systems in livestock pastures and stables
Source: (Paygude, Romero, & O. Hartmann, 2021)

Anaerobic digestion technology also promotes important synergies between the agricultural production system and energy generation, on the one hand it allows the treatment of farm waste such as manure or crop residues, and thus reduce greenhouse gas emissions, at the same time to replace fossil energy farm inputs sell surplus to the grid, as well as agrochemicals by obtaining residual organic material that could be used directly as biofertilizer, or be processed in a vermiculture system to obtain vermicompost and leachates as biofertilizer.

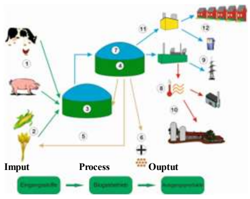

Fig. 5: Scheme of anaerobic digestion integrated into the farm
Source: (https://raming-biogas.de/2-4-wie-funktioniert-eine-biogasanlage/)

Fig. 6: Production of worms and vermicompost in vermiculture systems
Source: (https://lifecoachprafulla.blogspot.com/2019/05/vermiculture-vermicompost-organic-fertilizer.html)

Aquaculture -- also known as fish or shellfish farming -- refers to the breeding, rearing, and harvesting of plants and animals in all types of water environments including artificial tanks, ponds, rivers, lakes, and the ocean. Hydroponics is a method of growing plants using mineral nutrient solutions, in water, without soil. Combined production of fish and hydroponic plants in a recirculating aquaculture system.

Aquaponics = Aquaculture + Hydroponics

The aquaponic system takes opportunity of many synergies between the fish farming and the hydroponic using fish wastes as nutrients, and saving water in a recirculating system where crops improve water quality. The aquaponic system could also be benefited using the worm produced in vermiculture to feed the fish.

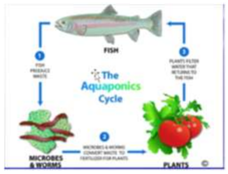

Fig. 7: Scheme of an aquaponics system
Source: (https://slideplayer.com/slide/3501546/)

Likewise, there are other technologies such as vertical agriculture that are already tested or in development to increase food production, which can use renewable energy to cover the lighting demand of plants without the need to import fossil energy from the electrical grid. However, all of the aforementioned technologies are being tested so far only individually or only with the levels of integration they require, thus missing out on the possible synergies that could also occur between them. However, for the authors of this contribution, the innovative and phased integration, partial or total, of these technologies can produce important synergies that contribute to a green and circular economy, promoting the use of bioenergy, addressing the water-energy-food-ecosystem nexus, and promoting local development in rural communities as shown in the following graph.

Fig. 8: Scheme of an innovative and phased integration of technologies that link renewable energies and agricultural production
Source: (Own creation)

Graph 8 shows how technologies that use photovoltaic panels integrated into agricultural systems could be connected to an anaerobic digestion system to treat waste and produce energy, then the digestate could be processed in vermiculture to produce worms to feed fish in aquaponics, as well as vermicompost and leachate to fertilize the soil. The energy produced can cover a large part of the current needs in agriculture, as well as the energy requirements to process agricultural products into everlasting marketable foods. This technological configuration would contribute to achieving all the SDGs.

CONCLUSIONS

The theoretical review and the exchange with practical experiences of the authors allow to conclude that the innovative and phased integration of renewable energy and agriculture technologies will contribute decisively to a green and sustainable economy, focused on the W-E-F-E nexus and promoting local development in rural communities, impacting in all the SDGs.

The mass and energy balances must be further explored, as well as the costs associated with these technological configurations..

REFERENCES

Kherde, S., Meier-Grüll, & M. Hartmann, M. (20. November 2021). IMAGE DATA PROCESSING FOR PLANT GROWTH ANALYSIS IN AGRIPHOTOVOLTAICS(APV) TO BE USED IN APV DESIGNING TOOL. Master Thesis. Berlin, Berlin, Alemania: SRH Berlin University of Applied Science.

Paygude, O., Romero, R., & O. Hartmann, M. (15. August 2021). Performance Analysis of Single Axis Tracker and Fixed Tilt PV System in Agrophotovoltaic at Künzelsau, Germany. Master Thesis. Berlin, Berlin, Germany: SRH Berlin University of Applied Science.

Tongaonkar, T., Romero Romero, O., & Islam, S. (4. December 2021). Comparative Analysis of Solar Photovoltaics Alternatives (Ground-mounted PV, Floating PV, and Agri-PV) in Germany and Cuba. Master Thesis. Berlin, Berlin, Germany: SRH Berlin University of Applied Science.