

INNOVATIVE STRATEGY FOR ENVIRONMENTAL CONTROL OF LIVESTOCK BUILDINGS AND MATERIALS

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Abstract

The efficiency of animal farming is a key requirement for a sustainable agricultural economy, where energy-saving and low-emission solutions are of particular importance. This is especially true for livestock buildings, which have the potential to incorporate low-carbon materials, circularity, and a new approach to waste management. This paper presents a review and analysis of precision environmental control in livestock buildings, with the aim to identify knowledge gaps, research opportunities and technical challenges, and to propose innovative strategies for improving energy efficiency and sustainability in animal farming.

Keywords

Agriculture, environment, innovative, livestock buildings, sustainability

1 INTRODUCTION

Animal farming involves the management and use of farm buildings in such a way as to increase the efficiency and quality of animal production and to optimise human labour inputs. Such efficiency is a key requirement for a sustainable agricultural economy, where energy-saving and low-emission solutions are of particular importance, e.g. in livestock building construction. Animal buildings are one of the main types of structures found on farms. The climate is one of the main limiting factors for production efficiency. Thermal stress events can cause reduced performance, morbidity, and mortality, resulting in significant economic losses and animal welfare concerns [1]. Also, advancements in animal genetics, nutrition and management practices have led to considerable changes in the sensible and latent heat loads of modern livestock buildings. In this context, precision livestock farming control technologies which enable the automatic monitoring of environmental, physiological, and behavioural variables can be used to continuously assess the performance and well-being of livestock in relation to their environment. The Food and Agriculture Organization of the United Nations (FAO) projects that the annual consumption of meat and milk will increase by approximately 50% worldwide between 2015 and 2050 [2]. Since the number of farms is decreasing, the demand for livestock production will be met through intensification, resulting in larger farms. The design of animal facilities combined with appropriate animal housing and management are essential contributors to animal well-being, the quality of animal research and production, teaching or testing programs involving animals, and the health and safety of personnel. An appropriate program provides environments, housing, and management methods that are well suited for the species or strains of animals maintained and considers their physical, physiological and behavioural needs, allowing them to grow, mature, and reproduce normally while providing for their health and well-being [3]. Livestock buildings constitute a fundamental part of any farm engaging in livestock production. The construction industry and the built environment are responsible for nearly 40 percent of global carbon emissions. This needs to change. Solutions including low-carbon materials, circularity and a new approach to waste can have a major impact on improving environmental sustainability [4].

The main goal of this article is to explore innovative strategies for the environmental control of livestock buildings, to analyse the role of materials and technologies in enhancing sustainability, and to propose solutions for reducing the carbon footprint of animal production. This work aims to provide a comprehensive understanding of how environmental innovations can transform livestock management, considering animal welfare, economic viability and environmental impact.

2 ENERGY POSITIVE BUILDINGS AND MATERIALS

Practicing good animal husbandry helps farm animals stay healthy. To reach this goal it is important to monitor the health of animals. Animal health monitoring involves keeping a close eye on livestock for signs of illness to catch problems early and prevent minor dilemmas from becoming significant issues. Daily observation is recommended in most cases. Animal health monitoring is important for keeping records of animal health, such as their weight, feed intake and growth rates. It can help farmers detect diseases early and take preventive measures to maintain animal health [5]. Monitoring the feed and water consumption of animals can help farmers to better adjust the feed amounts and composition to the animals' nutritional needs and to detect and correct any nutritional deficiencies or surpluses. The use of modern methods and innovative technologies to gather data on animal performance can help farmers increase farm productivity and cut costs [6].

Traditional animal farm buildings require considerable external inputs of energy both during their construction phase and then throughout their lifetimes. The energy consumed is often drawn from non-renewable sources that produce significant emissions. If renewable energy solutions and sustainable construction practices are used, such livestock buildings produce more energy during their lifetimes than they consume during their construction and operation. As such, the potential exists to significantly reduce their carbon emissions [7].

3 ECONOMIC AND ENVIRONMENTAL BENEFITS

One of the most compelling aspects of net-positive buildings is their ability to provide both economic and environmental advantages.

Energy-positive buildings offer substantial financial benefits:

- *Lower Energy Bills:* Occupants of energy-positive buildings enjoy reduced or even eliminated energy bills. Excess energy generation can be fed back into the grid, generating income or energy credits.
- *Enhanced Property Value:* These buildings often command higher resale values due to their low operational costs and sustainability features. Investors and homeowners see long-term value in energy-efficient properties.
- *Operating Cost Reduction:* Commercial net-positive buildings significantly cut operational expenses. With lower energy and maintenance costs, businesses can allocate resources more efficiently [8].

4 REDUCING THE CARBON FOOTPRINT

On-farm buildings such as stables, storage sheds, nurseries, breeding enclosures, workshops, milking parlours, barns, silage clamps and others could be optimised with regarding their carbon footprint and wider sustainability to attain the most efficient use in terms of savings. The agricultural industry has suffered from a lack of investment in buildings for many years, which has resulted in the prevalence of buildings with low energy efficiency [9]. A consequence of this is poor animal performance at many farms and breeding units, and this leads to increased production costs. Good design will support good animal health and welfare to the financial benefit of the farm business. For example, the target for most cattle buildings is to ensure a design that maximises ventilation potential on a still day, without exposing the livestock to elevated air speed when the wind is blowing. There are many detailed aspects to consider when looking at the efficiency of cattle buildings.

Net-positive buildings play a crucial role in addressing environmental concerns:

- *Mitigating Climate Change:* By generating more clean energy than they consume, these buildings have significantly lower carbon emissions than those associated with traditional structures. This aligns with global efforts to combat climate change.
- *Resource Conservation:* Energy-positive designs prioritise resource conservation. This extends to water, materials, and land use, reducing the ecological footprint associated with construction and operation.
- *Preserving Biodiversity:* Sustainable building practices often incorporate green spaces and native landscaping, contributing to urban biodiversity and enhancing local ecosystems.

Based on the above, it is clear that the proper management of farm buildings and materials is essential for ensuring long-term sustainability in agriculture. Fig. 1 below shows specific strategies to optimise the use of materials and buildings, thereby achieving better energy efficiency and reducing environmental impacts. The visualisation

contributes to a better understanding of the complexity of this process and provides a clear insight into the implementation of sustainable solutions in practice.

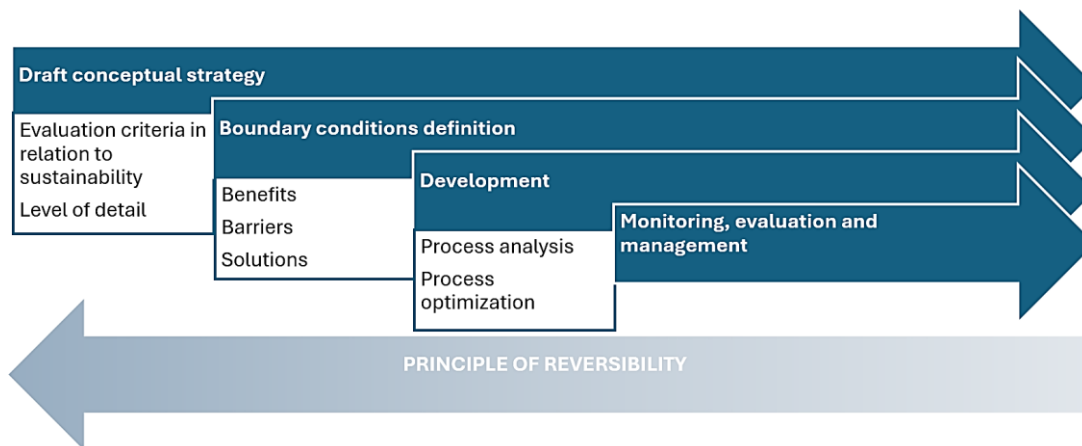


Fig. 1 Strategy for the control of livestock buildings and materials in the context of sustainability.

5 DISCUSSION

Environmental control in agricultural facilities such as livestock farms is key to maintaining optimal conditions for animals. Traditional heating, ventilation, and air conditioning systems can be energy-intensive and have a high carbon footprint. Modern innovative technologies, such as microclimate control systems using renewable energy sources (e.g. solar panels, geothermal energy), or smart sensors for humidity and temperature monitoring, can help to significantly reduce energy consumption and improve animal welfare [10], [11]. Reducing the carbon footprint of agricultural buildings is a key aspect of sustainability [12], [13]. Innovative materials, such as insulation materials made from recycled products or natural fibres, can reduce the energy performance of buildings. Combined with efficient energy management, this approach can significantly reduce CO₂ emissions. The use of renewable energy sources such as solar panels, geothermal energy and wind turbines is becoming an increasingly popular solution in agriculture [14]. These technologies can help not only in reducing energy costs, but also in significantly reducing the carbon footprint that is associated with traditional energy sources such as fossil fuels. The installation of these systems in agricultural buildings can also contribute to energy independence [15].

In the context of the above, it is essential to state that innovative strategies for environmental control in agricultural buildings and the use of environmentally friendly materials and technologies not only have a positive impact on the economy, but also on the environment. These strategies enable us to reduce our carbon footprint, improve energy efficiency and increase sustainability. An integrative approach that combines modern technologies with eco-friendly materials and renewable energy sources is key to the future of agricultural construction.

6 CONCLUSION

The goal of the article was to explore innovative strategies for the environmental control of livestock buildings and the optimization of materials to achieve greater sustainability in animal farming. Based on the analysis, it can be concluded that integrating modern technologies, such as precision farming systems and renewable energy, alongside the use of eco-friendly and circular materials, provides a significant opportunity to reduce carbon emissions, enhance animal welfare, and increase farm profitability. Carbon sequestration and habitat provisioning through building integrated systems are interlinked approaches that could potentially reduce climate change and biodiversity loss attributed to the built environment. Moreover, spatial ecology must give consideration to landscape-level parameters, such as vegetative area coverage, habitat availability, quality and connectivity, as well as specific parameters such as the availability of suitable construction materials from local sources. The need to combat climate change has never been more pressing. Net positive buildings offer a proactive solution by reducing greenhouse gas emissions and mitigating the environmental impact of the built environment. They serve as beacons of sustainable living, setting new standards for eco-conscious construction. Carbon sequestration is a key ecosystem service for climate change mitigation. Mitigating climate change by sequestering carbon in agricultural

buildings and the agricultural sector can lead to the most efficient use of such buildings, and subsequent savings. Animal health and the constant monitoring it requires is a major problem for the livestock sector. Infections in the large groups of animals typical for livestock farming will become increasingly common. However, the detrimental effects that are being seen today are essentially generated by the way livestock has been managed recently, i.e. mostly on a short-term profit basis with no concern for sustainability. Like most other intensive agricultural production systems, intensive livestock production cannot be sustainable and environmentally friendly if it is not integrated with other agricultural activities and sectors of the economy. It must not be forgotten that even though the productivity and efficiency of livestock production is low in developing countries, it can nevertheless be improved with considerably less fossil energy input than is the case in developed countries.

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References

- [1] BUCHERER, Michael., Jan HOLZHAUSEN, Franz J. CONRATHS and Carolina PROBST. Infrastructure of animal farms: key constructional elements in terms of biosecurity based on experience from Germany. *Berliner und Munchener Tierarztliche Wochenschrift* [online]. March 2021, 134, pp.1-12. [Accessed 17/12/2024]. ISSN 0341-6593. Available at: <https://doi.org/10.2376/1439-0299-2020-37>
- [2] THORNTON, P.K. Livestock Production: Recent Trends, Future Prospects. *Philosophical Transactions of the Royal Society: Biological Sciences*, [online]. March 2010, 365, pp. 2853-2867. [Accessed 17/12/2024]. ISSN 1821-4339. <https://doi.org/10.1016/j.gloenvcha.2020.102056>
- [3] PEDERSEN, S. Climatization of animal houses: a biographical review of three decades of research. *DIAS Report Livestock*. [online]. October 2005, 66, pp.83. [Accessed 17/12/2024]. ISSN 1397-9892. Available at:
- [4] MIN, Ji., Gongxing YAN, Azher M. ABED et al., The effect of carbon dioxide emissions on the building energy efficiency. *Fuel*. [online]. October 2022, 326, 15, pp. 124-842. [Accessed 17/12/2024]. ISSN 1873-7153. Available at: <https://doi.org/10.1016/j.fuel.2022.124842>
- [5] VLAICU, Petru Alexandre., Mihail Alexandru GRAS, Arabela Elena UNTEA et al., Advancing Livestock Technology: Intelligent Systemization for Enhanced Productivity, Welfare, and Sustainability. *AgriEngineering*. [online]. May 2024, 6, pp. 1479-1496. [Accessed 17/12/2024]. ISSN 2624-7402. Available at: <https://doi.org/10.3390/agriengineering6020084>
- [6] NEETHIRAJAN, Suresh. Recent advances in wearable sensors for animal health management. *Sensing and Bio-Sensing Research*. [online]. February 2017, 12, pp.15-29. [Accessed 17/12/2024]. ISSN 2214-1804. Available at: <https://doi.org/10.1016/j.sbsr.2016.11.004>
- [7] BARIS, Ahmet. Impact of feed quality on livestock productivity. *Journal of livestock policy*. [online]. September 2023, 2, pp.1-8. [Accessed 17/12/2024]. ISSN 2525-4685. Available at: <https://doi.org/10.47604/jlp.v2i1.2112>
- [8] BARTKOWIAK, Anna, M., Energy-saving and low-emission livestock buildings in the concept of a smart farming. *Journal of water and land development*. [online]. October 2021, 51, pp. 2083-4535. [Accessed 17/12/2024]. ISSN 2083-4535. Available at: <https://doi.org/10.24425/jwld.2021.139935>
- [9] SOW, Sumit, Ranjan SHIVANI, Behera BISWARANJA et al., Maintaining agricultural sustainability through carbon footprint management. *Current science*. [online]. November 2023, 125 (9), pp. 939 - 944. [Accessed 17/12/2024]. ISSN 0011-3891. Available at: <https://doi.org/10.>
- [10] YOUNAS, H. (2023). Optimizing Livestock Microclimates: BES Models, Challenges, and Sustainable Solutions. *International Journal of Agriculture and Sustainable Development*, 5(3), 150-162.
- [11] ASCIONE, F. (2017). Energy conservation and renewable technologies for buildings to face the impact of the climate change and minimize the use of cooling. *Solar Energy*, 154, 34-100. DOI: <https://doi.org/10.1016/j.solener.2017.01.022>
- [12] MINOOFAR, A., GHOLAMI, A., ESLAMI, S., HAJIZADEH, A., GHOLAMI, A., ZANDI, M., ... & KAZEM, H. A. (2023). Renewable energy system opportunities: A sustainable solution toward cleaner production and reducing carbon footprint of large-scale dairy farms. *Energy Conversion and Management*, 293, 117554. DOI: <https://doi.org/10.1016/j.enconman.2023.117554>
- [13] XU, Z., SUN, D. W., ZENG, X. A., LIU, D., & PU, H. (2015). Research developments in methods to reduce the carbon footprint of the food system: a review. *Critical reviews in food science and nutrition*, 55(9), 1270-1286. DOI: <https://doi.org/10.1080/10408398.2013.821593>
- [14] RAHMAN, M. M., KHAN, I., FIELD, D. L., TECHATO, K., & ALAMEH, K. (2022). Powering agriculture: Present status, future potential, and challenges of renewable energy applications. *Renewable Energy*, 188, 731-749. DOI: <https://doi.org/10.1016/j.renene.2022.02.065>
- [15] TOMASZEWSKA, B., AKKURT, G. G., KACZMARCZYK, M., BUJAKOWSKI, W., KELES, N.,

JARMA, Y. A., ... & KABAY, N. (2021). Utilization of renewable energy sources in desalination of geothermal water for agriculture. Desalination, 513, 115151. DOI: <https://doi.org/10.1016/j.desal.2021.115151>