

Hybridization – Unlocking potentials by complementing each other

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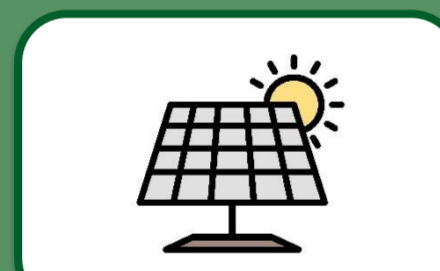
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Background

- ❖ Defined as systems that combine energy generation, storage, and conversion technologies under a decentralized/centralized controlling structure. Hybrid Energy Systems (HES) aim to enhance performance, optimize costs, and improve environmental sustainability by complementing standalone energy solutions (U.S. Department of Energy, 2021).
- ❖ HES systems in their different combinations are highly significant for farms as they provide crucial infrastructure flexibility (Emezirinwune et al., 2024).
- ❖ The project BioSolFarm evaluates the feasibility of hybrid energy systems by analyzing solar photovoltaic (PV), wind energy as well as bioenergy and their combination possibilities in the South Baltic Region. All the information gathered is used to evaluate existing infrastructure and propose new investments based on the enhancement of the farm requirements and the potential for optimization internally.

Methods

- ❖ Data was collected from a selected farm located within the Federal State of Mecklenburg-Vorpommern, Germany in the South Baltic Region.
- ❖ Electricity is generated from both the Combined Heat and Power (CHP) unit of the biogas plant and the solar PV system. The generated electricity is primarily fed into the grid, with a portion being utilized on-site to power the farm's office areas, direct-sale farm shop, milking parlor and milk storage facilities.
- ❖ The heat produced by the biogas plant is used for temperature regulation within the digester and internal heating applications on the farm.



- Solar PV capacity of 1.25 MWp, of which 0.25 MWp is self-owned by the farm, while the remaining 1 MWp is installed on leased rooftops and belongs to an external owner



- Self-owned biogas plant with an installed capacity of 350 kWp for electricity generation and 600 kWp for heat production

- ❖ The system structure aligns with a collocated hybrid energy system integrating multiple renewable energy sources. The owned energy system follows the process flow as illustrated in Figure 2.



Figure 1. Pictures of the feeding wagon, CHP plant, biogas reactors and milking parlor of the studied farm

Results

- ❖ To enhance the system performance of the studied farm, the study suggests several small-scale improvements, including the installation of solar panel optimizers, better utilization of heat for both heating and cooling, and the introduction of flexibilization measures (Figure 2).

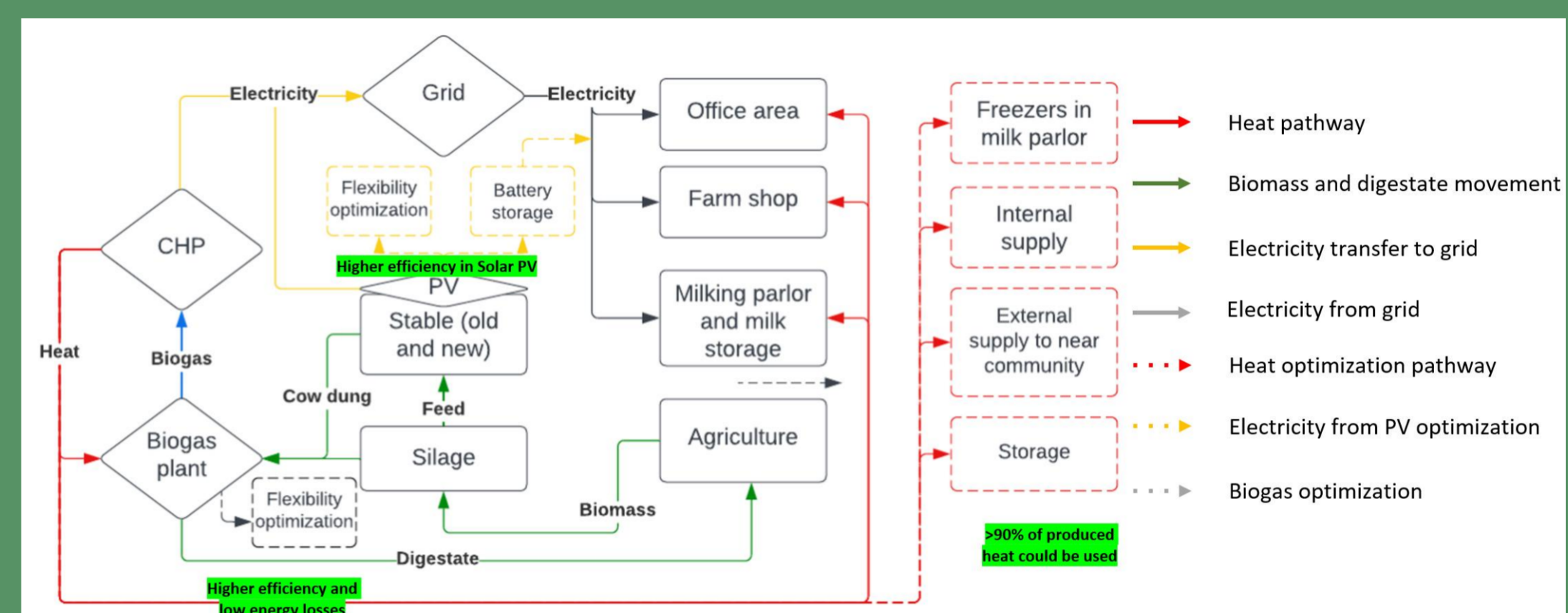


Figure 2. Schematic representation of the existing energy flow at the farm, including electricity and heat utilization from biogas and solar PV, as well as proposed optimization measures

Gap: Lack of performance monitoring and optimization options

Optimization approach:

- Monitoring System Performance:
 - Installation of a monitoring system to track the energy production, voltage, and current to optimize performance of the solar panels
- Energy Storage Integration:
 - Storage of excess solar energy for use during low sunlight or peak demand periods
 - Reducing the dependency on the grid and improving overall energy efficiency
- Energy Optimization:
 - Installation of a power optimizer can increase system performance by up to 25%, particularly under partial shading or mismatch conditions
 - Installation of a three-phase inverter is advised to ensure efficient, balanced power conversion across all three electrical phases

Gap: Lack of flexibilization

Optimization approach:

- Flexibilization of biogas plant:
 - Real-time optimization using automation and control system to adjust the production of heat and electricity according to demand fluctuations
 - Biogas and heat storage solutions
 - Reducing heat loss (loss of >90% (~500 kW_{th}) of heat produced in the CHP unit)
 - Utilization of heat internally for biogas reactor pre-heating, farm heating and drying processes
 - Utilization of heat externally by supplying nearby communities or industries through a local heat network

Discussion

- ❖ This study demonstrates that hybrid energy systems offer a sustainable and economically viable solution for farms transitioning to renewable energy. By integrating biogas, solar PV, and wind energy, and implementing flexibilization measures, farms can optimize energy usage, reduce waste, and enhance profitability.
- ❖ Real-time monitoring, energy storage integration, and smart grid solutions are crucial to maximizing efficiency and economic returns. The results provide a scalable framework for future applications, emphasizing the need for continued research and policy support in agricultural renewable energy transitions.

References

- U.S. Department of Energy, (2021): Hybrid energy systems: opportunities for coordinated research. <https://www.nrel.gov/docs/fy21osti/77503.pdf>
- Emezirinwune, Michael Uzoamaka; Adejumo, Isaiyah Adediji; Adebisi, Oluwaseun Ibrahim; Akinboro, Festus Gboyege (2024): Synergizing hybrid renewable energy systems and sustainable agriculture for rural development in Nigeria. In: e-Prime - Advances in Electrical Engineering, Electronics and Energy 7, S. 100492. DOI: 10.1016/j.prime.2024.100492.