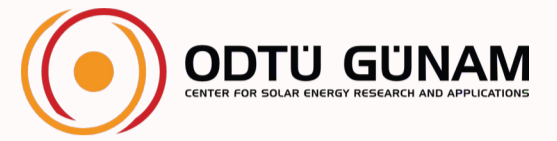




3/ Digital Twin for Solar Biorefinery [GÜNAM]



The Challenge

The solar biorefinery concept combines multiple components — solar collectors, thermal energy storage (TES), hydrothermal reactors, and feedstock handling systems — into one integrated process. However, scaling this system for industrial use is limited by the absence of **digital tools that can simulate, monitor, and optimize** all subsystems in real time.



The challenge is to design and implement a **modular digital twin** that can replicate the biorefinery's thermodynamic behavior, material flow, and energy efficiency under varying solar and operational conditions. This involves connecting sensors, IoT-based data acquisition, cloud computing, and machine learning for predictive maintenance, yield forecasting, and lifecycle optimization.

Although driven by research at **GÜNAM**, this challenge addresses a **clear industrial need**: enabling solar-based biorefineries to operate efficiently, adapt to diverse feedstocks (e.g. fruit waste, livestock residues), and make data-driven decisions for process and investment planning.



Technology Readiness Level (TRL)

4 – Validated in laboratory environment; next steps involve pilot-scale integration and control testing.



Expected Outcomes

- A digital twin platform capable of simulating full solar biorefinery operation
- Enhanced process control, optimization, and predictive maintenance
- Reduced downtime and operational uncertainty for industrial users
- Stronger data-driven investment and sustainability planning



Impact on Operations

Implementing a digital twin will transform how solar-based bioenergy facilities are designed and managed. For industry, this means **greater reliability, reduced operating costs, and higher confidence in scaling complex solar-integrated processes**.



Previous Actions

Key ideas have been validated. Joint development and pilot testing of digital twin architectures; demonstration projects; and co-funded R&D proposals at EU, national, or bilateral levels.



About GÜNAM (ODTÜ-GÜNEŞ Energy Research Center)

GÜNAM — the Center for Solar Energy Research and Applications at Middle East Technical University (METU) in Ankara, Turkey — is the country's leading solar energy research institute and one of the most advanced in the region. Its integrated research infrastructure covers the full solar value chain, from photovoltaics (PV) and solar thermal technologies to energy storage, hydrogen production, and hybrid energy systems. GÜNAM actively collaborates with industrial partners to bridge the gap between research and large-scale applications, providing pilot-scale facilities and technical expertise for technology validation and upscaling. Its work on solar-aided hydrothermal liquefaction (HTL) directly supports the development of **solar-driven, low-carbon fuel production technologies**, addressing real industrial needs for energy efficiency and process stability.

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