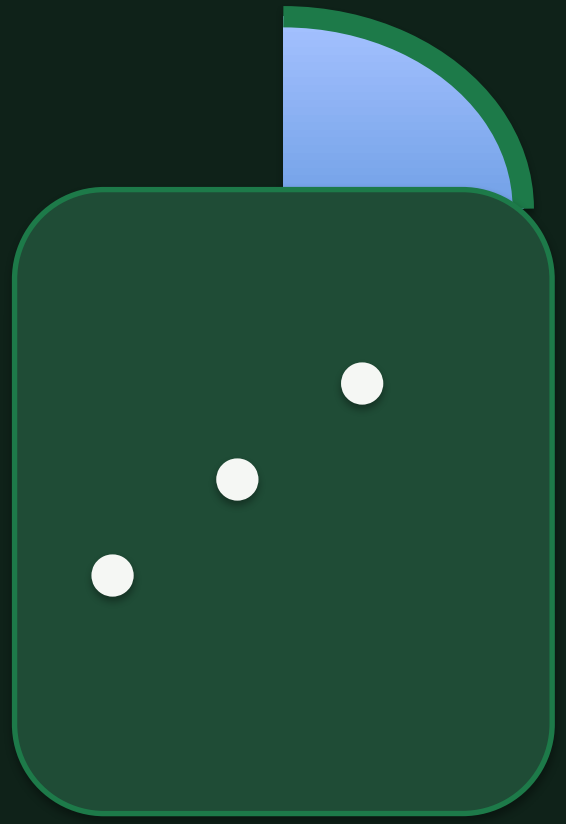
GFIS

Green Fuel Intelligence System



Physics-guided AI digital twin for biogas methane production

A hybrid ML system for methane-yield prediction, stability soft sensing, simulation, and optimization.

2026 Dissertation Prototype

PROBLEM

Biogas plants are nonlinear systems; operators need predictions they can trust.

Process complexity	Temperature, pH, OLR, HRT, TS, VS, C/N and moisture interact over time.
Model gap	ADM1 is mechanistic but heavy; pure ML is fast but can become physically inconsistent.
Operational need	A plant operator needs methane yield, stability warning, and what-if simulation before changing setpoints.

GFIS bridges mechanistic feasibility and deployable AI.

VISION

From dissertation prototype to industrial decision-support platform.

Now

Synthetic AD data
FastAPI + dashboard
SQLite logging

Semester

Model evaluation
Viva demo
Final report artifacts

Plant-ready

SCADA/IoT ingestion
PostgreSQL
Operator dashboard

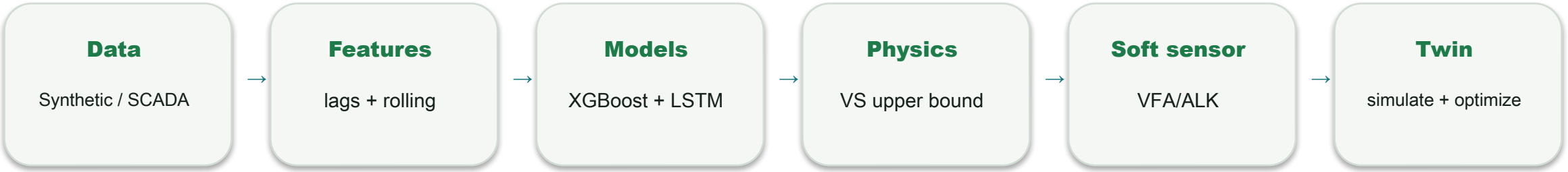
Future

ROS2/Gazebo
Gasification module
Edge deployment

Scope discipline: anaerobic digestion is the implemented core; gasification remains an extensible future module.

PIPELINE

End-to-end machine-learning and digital-twin pipeline.



Prediction output: methane yield with feasibility status.

Stability output: VFA/ALK ratio and Stable / Warning / Critical label.

Audit output: experiments, predictions, and simulations logged to SQLite.

ARCHITECTURE

GFIS is layered so research, software, and deployment stay connected.

Interface	HTML control room • Streamlit • FastAPI
Digital twin	what-if simulation • optimization • logging
AI engine	XGBoost • LSTM • validation-weighted ensemble
Physics + soft sensor	VS methane bound • VFA/ALK stability
Data foundation	synthetic AD dataset • preprocessing • SQLite

DATASET

The synthetic reactor now includes temporal inertia, making it suitable for sequence modeling.

Feature engineering

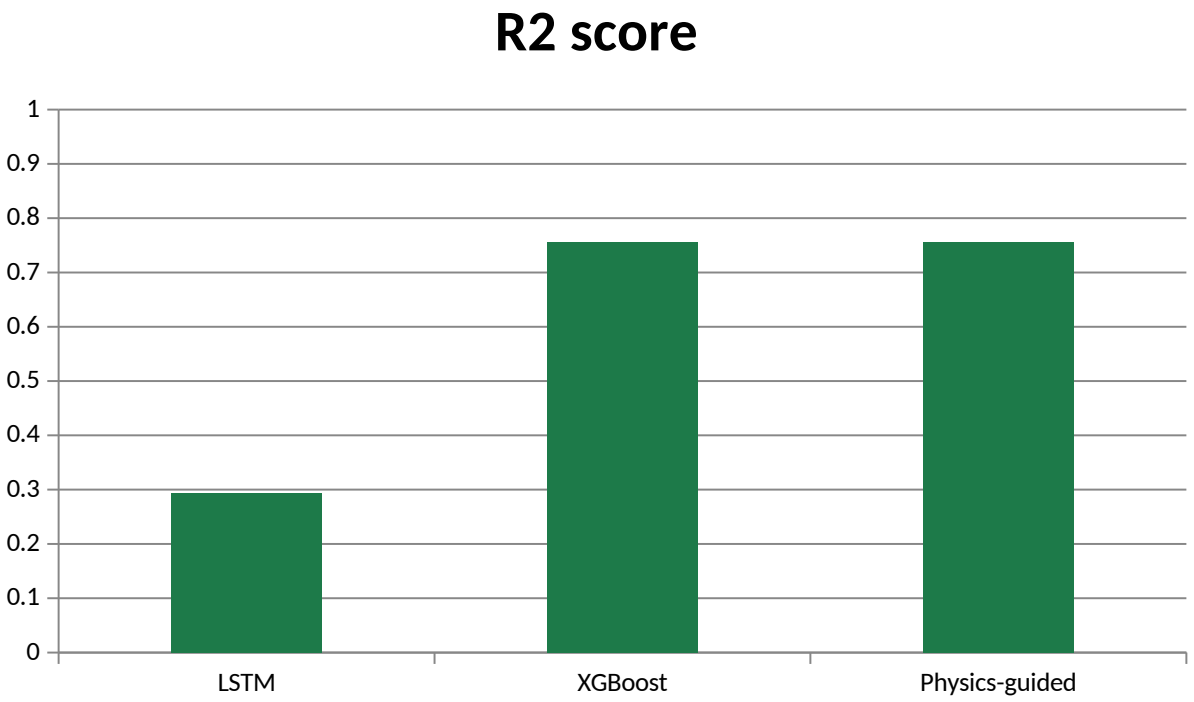
- Missing-value repair
- Standard scaling
- Lag features
- Rolling means
- OLR/HRT and VS/TS ratios

Target outputs

- Methane yield
- Physics violation
- VFA/ALK ratio
- Stability class

RESULTS

Current model comparison on the GFIS synthetic AD dataset.



Physics violations: 0

Best R2: 0.756

The tabular model is strongest on synthetic data; LSTM remains part of the architecture for plant time-series integration.

DEMO

The prototype now has three connected interfaces.

FastAPI	**http://127.0.0.1:8010**	predict • simulate • optimize • evaluate
Streamlit	**http://127.0.0.1:8510**	rapid model dashboard
HTML control room	**http://127.0.0.1:8520**	animated plant simulation

Deployment path: local prototype to Ubuntu VM, Docker, and simulated plant integration.

Local	Ubuntu VM	Docker	ROS2/Gazebo
Python package	22.04/24.04 LTS	API container	sensor topics
FastAPI	venv setup	nginx frontend	actuator topics
HTML + Streamlit	open plant dashboard	mounted data/models	future telemetry bridge

Industrial note: gasification is positioned as a future waste-to-energy module, not the implemented dissertation core.

CONTRIBUTION

What the dissertation can claim now.

A runnable physics-guided AI prototype for anaerobic digestion methane prediction.

A soft sensor for VFA/ALK stability monitoring.

A digital twin workflow with prediction, simulation, optimization, and logging.

A deployment-ready structure covering API, dashboard, HTML site, Docker, Ubuntu VM, and ROS2/Gazebo extension.

A defensible research path from synthetic validation to future real plant data.

Next: real data ingestion, SHAP plots, improved LSTM training, and final dissertation report integration.