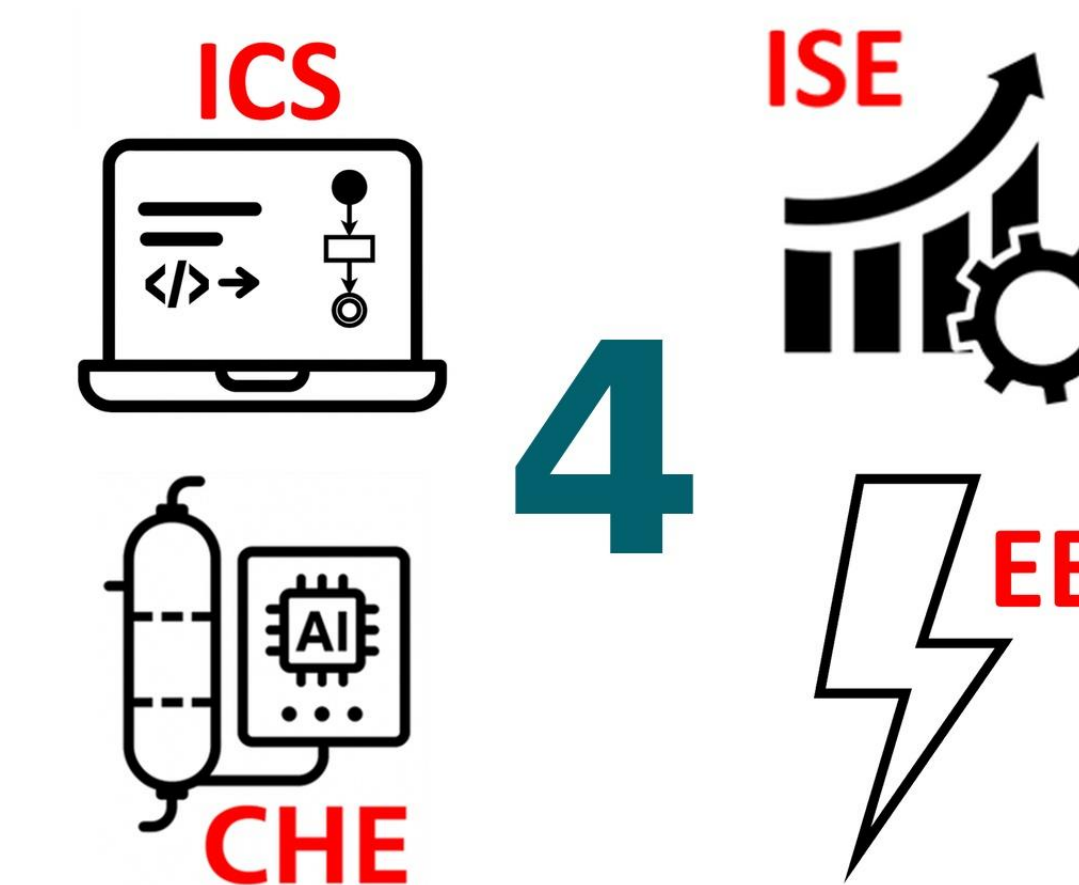


Design of a Digital Twin for a K_2CO_3 -Based Carbon Capture and Methanol Conversion Process Targeting Fluid Catalytic Cracking Unit (FCCU) CO_2 Emissions in Saudi Refineries

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Problem statement

Carbon dioxide emitted from FCC units in Saudi refineries is a major environmental and economic burden, as it is wasted in large quantities without reduction or reuse

Objective

The objective is to reduce CO_2 emissions from FCC units using a digitally enabled K_2CO_3 -based capture system that improves efficiency and monitoring, while enabling CO_2 conversion into methanol to reduce environmental and economic impacts.

Specifications & Constrains

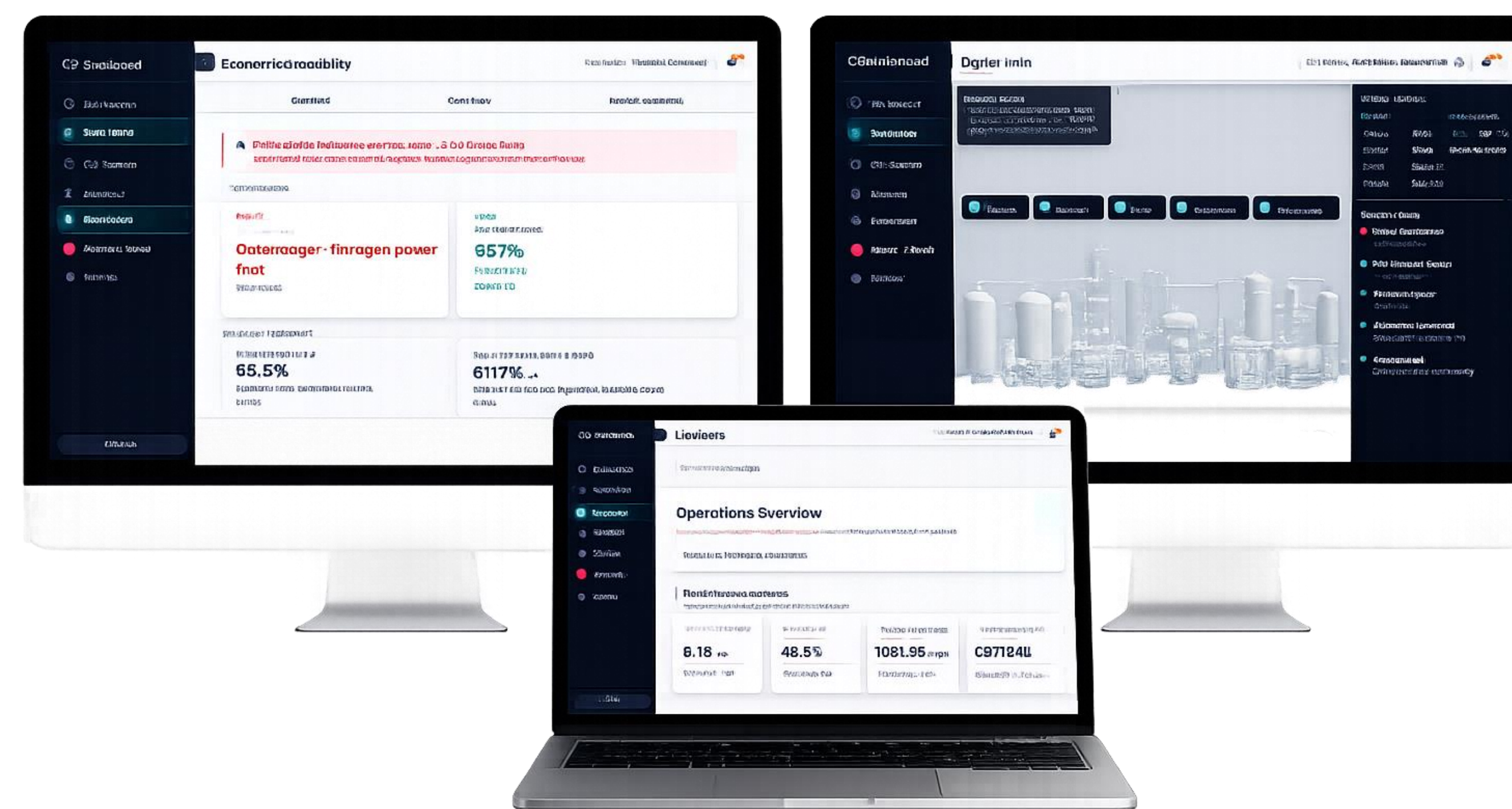
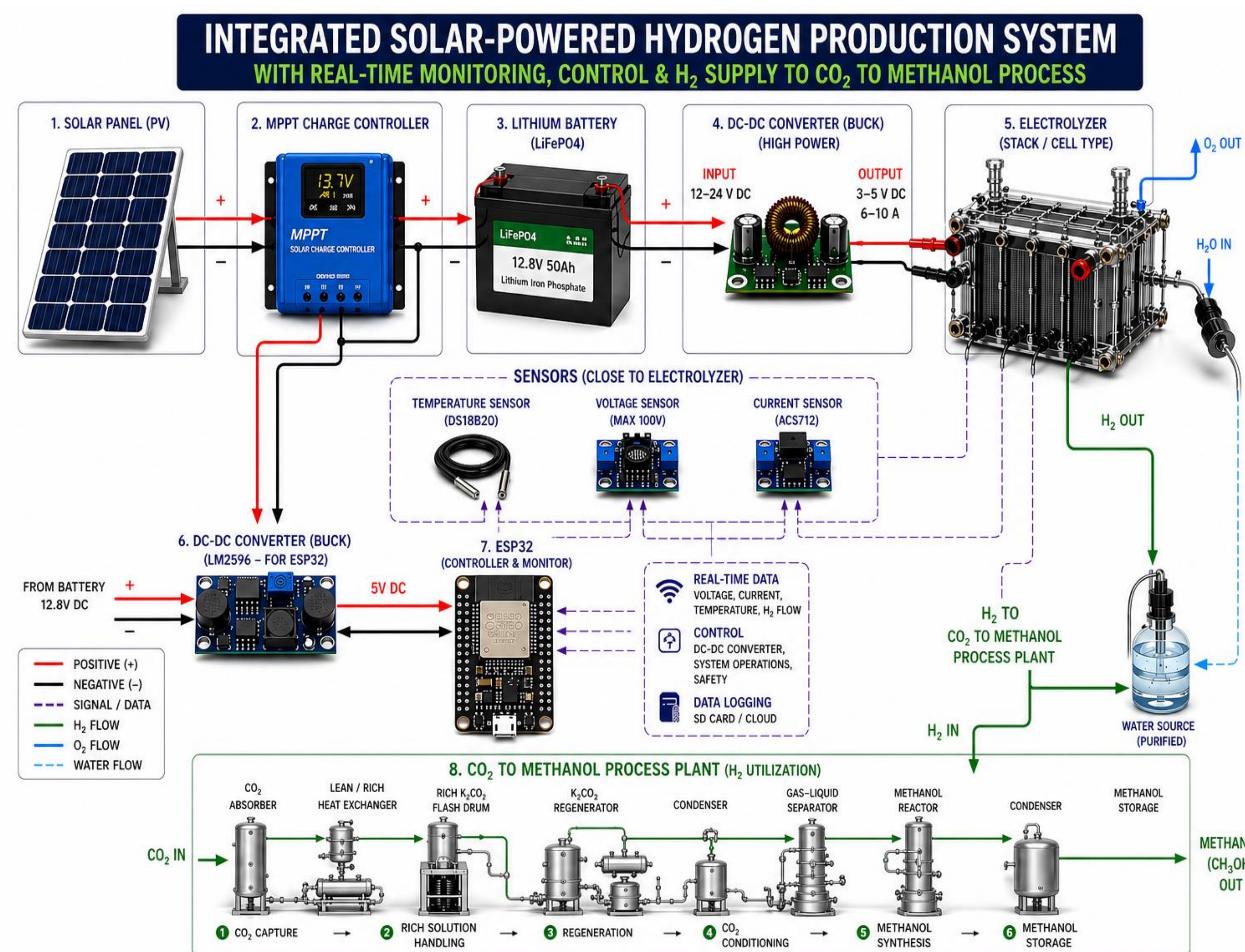
CONSTRAINTS

- Aspen license; steady state first, then dynamic mode (higher complexity)
- Payback period > 4 years is economically infeasible
- CO_2 processed \leq available FCCU flue gas supply per scenario
- Solar DC supply ≤ 100 W, 12–24 V, 5–8 A, efficiency $\approx 23\%$
- Current measurement limited to $\approx \pm 5$ A and sensor noise
- Real-time inputs limited to voltage, current & user-defined conditions
- Digital twin accuracy depends only on input data; no real-world validation
- All simulation inputs from reliable & validated sources
- MongoDB Atlas M0 free tier limited to 512 MB storage

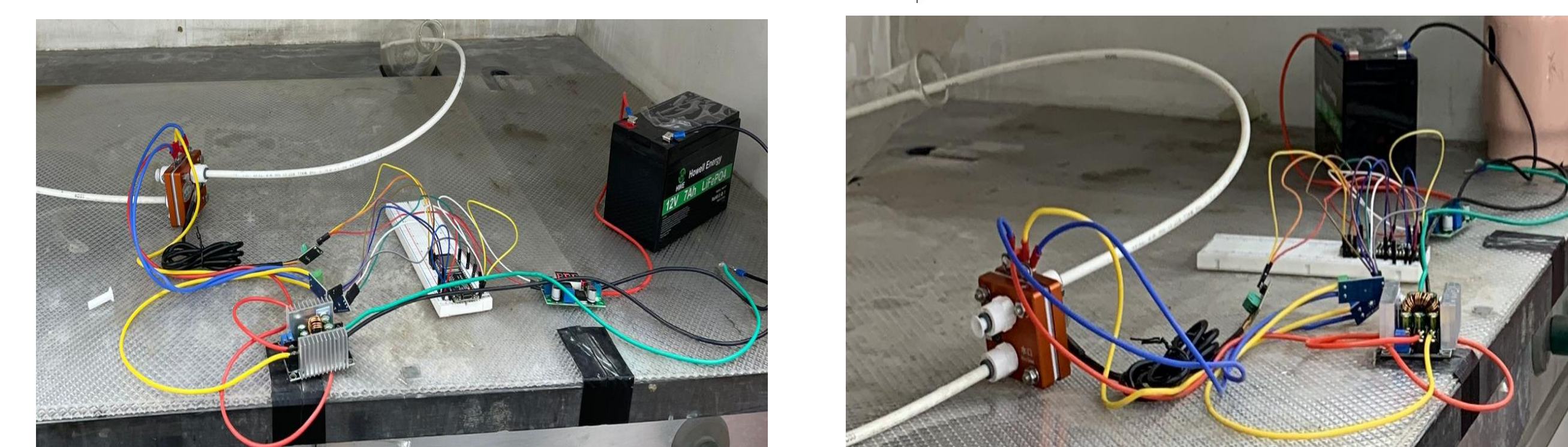
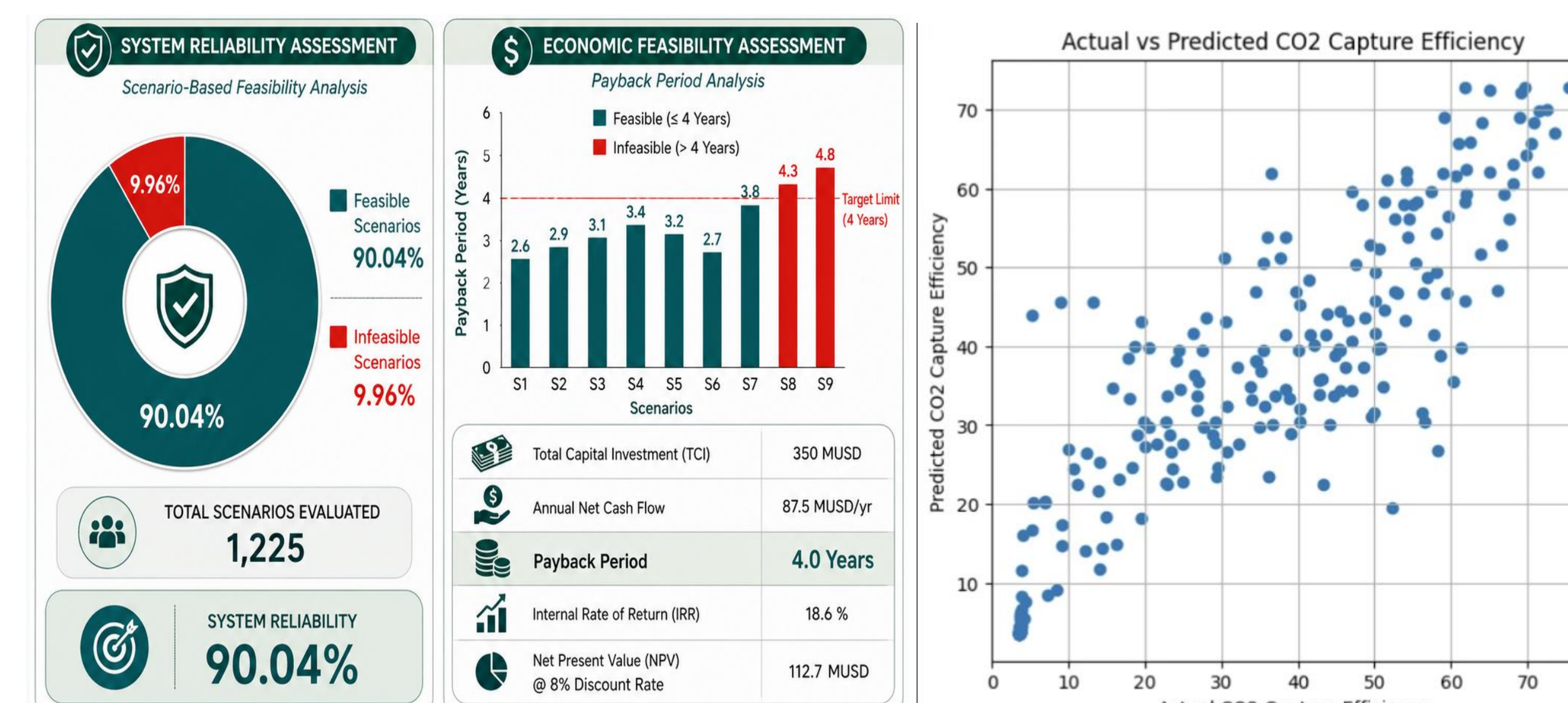
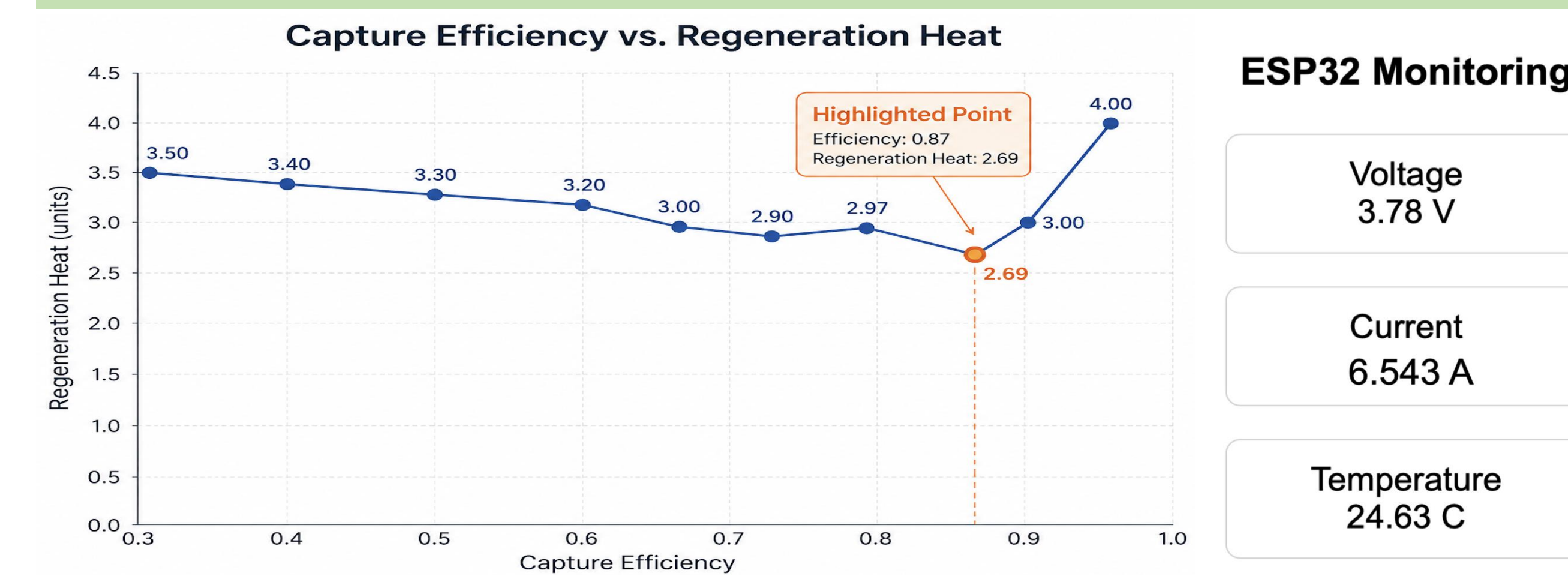
SPECIFICATIONS

- $\geq 75\%$ CO_2 conversion to methanol
- $\geq 85\%$ CO_2 capture efficiency
- $\geq 80\%$ Digital twin prediction accuracy
- $\geq 90\%$ Feasible operation of scenarios
- $\geq 95\%$ of best methanol production objective
- Dashboard shows: CO_2 capture, methanol rate, energy use, economic metrics
- Four user roles: Operator, Engineer, Manager, Admin
- DC-DC buck converter: Input 4–40 V, Output 1.25–37 V
- Electrolyzer: 3–5 V DC, 6–10 A
- Ambient temperature and atmospheric pressure
- User-friendly, clear & real-time responsive UI

Prototype



Testing/ Validation



Conclusion

This work demonstrates an integrated CO_2 capture and methanol conversion system with stable solar-powered operation. Real-time monitoring enhances performance, making the system economically feasible and a sustainable industrial solution.