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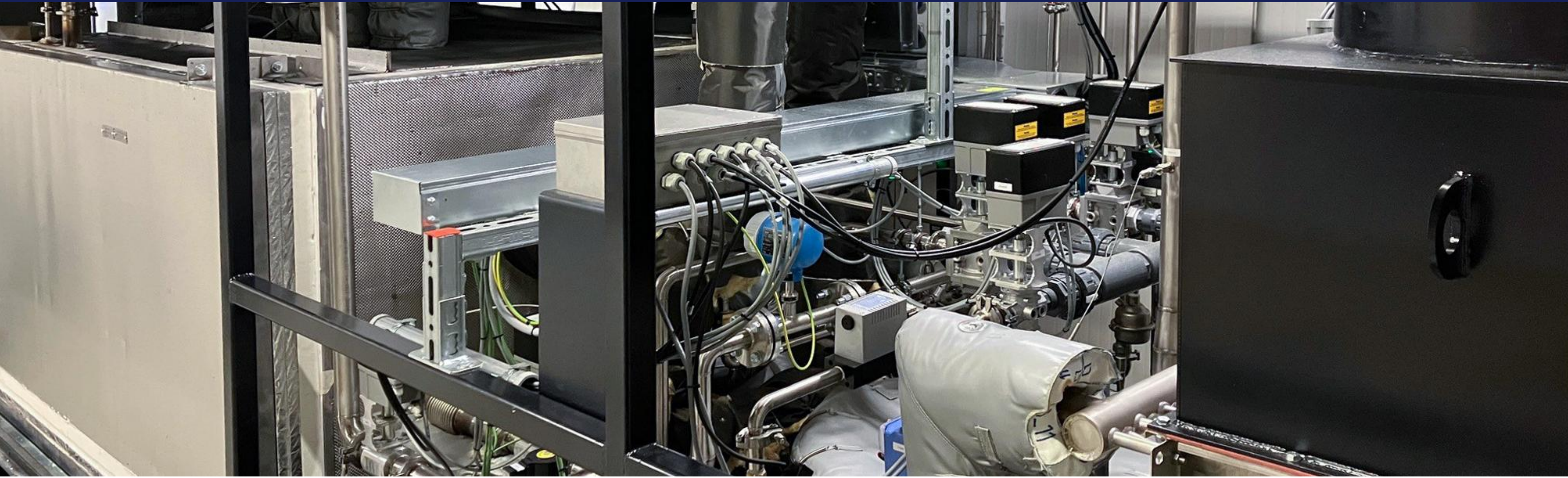
SO-FREE

multi-fuel SOFC industrial integration

From design to testing: BOP, control, safety



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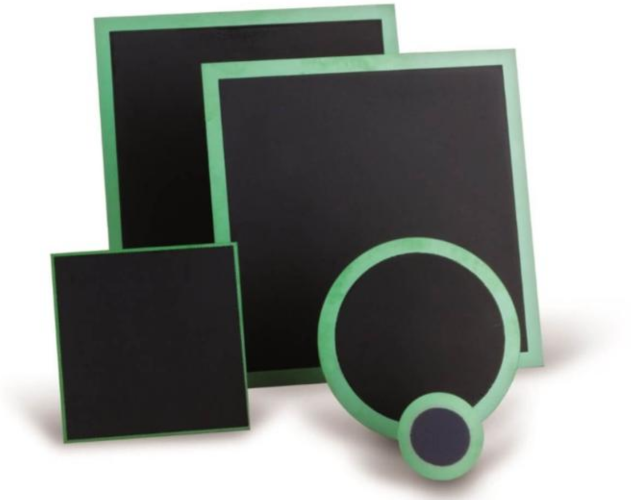
Part 1

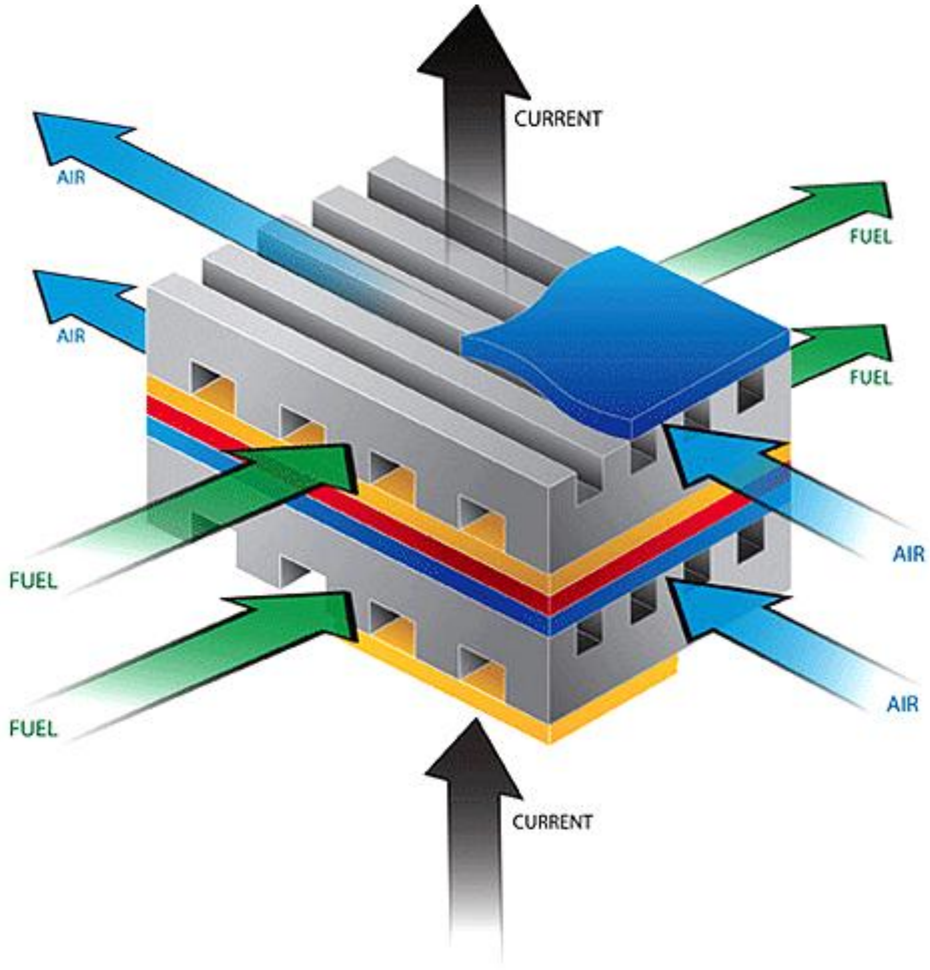
Operting principles

What does a SOFC need and why is it delicate



What is a SOFC

Operating principles



The Operating Window: Constrain to Be Met

Operating principles

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TEMPERATURE	GRADIENTS	FUEL COMPOSITION UTILIZATION	REDOX RISK

Why multi-fuel capability is interesting (and difficult)

Operating principles

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It enables the transition from natural gas to hydrogen, but it requires a system that can adapt to changes in the fuel.

H_2

Reforming: no
Volumes/flow: different
Transients: fast

Natural GAS CH_4

Reforming: yes
Steam: required
Thermal balance: sensitive

BIOGAS (CH_4 + CO_2)

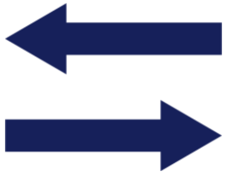
Inerts (CO_2): high
Flow rates: higher
Reforming: variable

AUTOMATIC ADAPTATION

Realigns flow rates + steam + thermal conditions

Stack-agnostic: what does it really mean

Operating principles



Stack A ~600°C

Stack B ~850°C

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Part 2
Design study and design choices

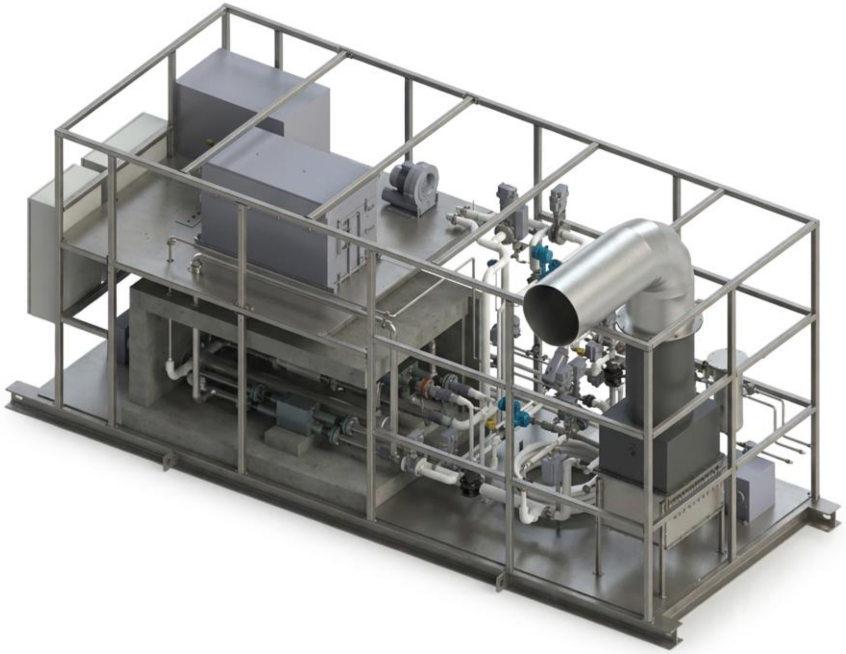
From concept to layout: architecture, control, safety, criticalities

ARCHITECTURE

CONTROL

SAFETY

CRITICALITIES



System architecture

Design study

design choices

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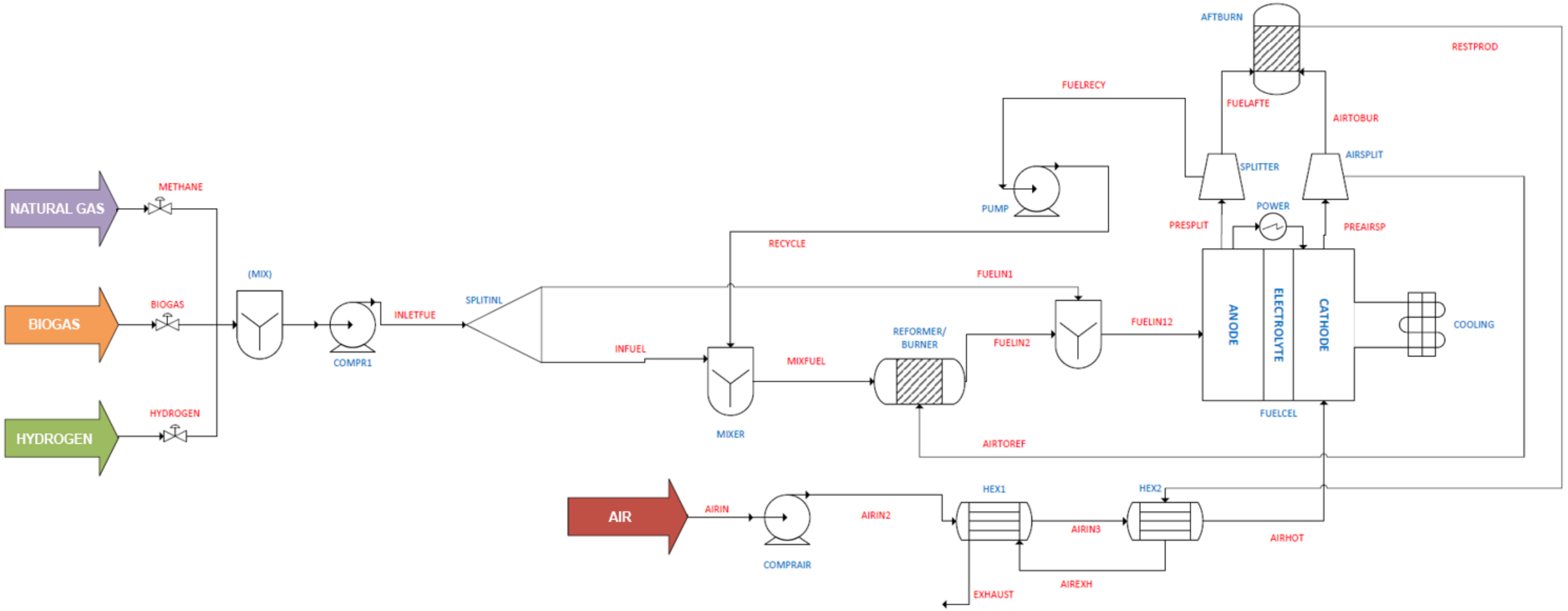
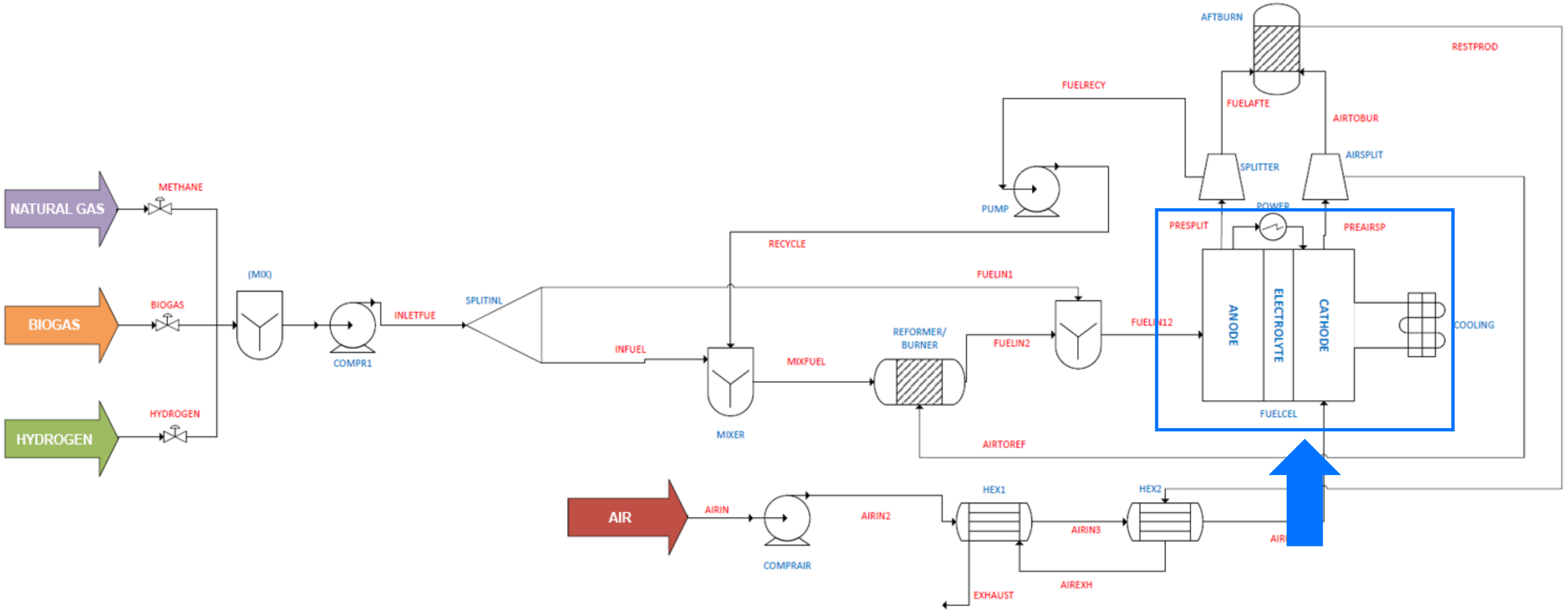


System architecture

Design study

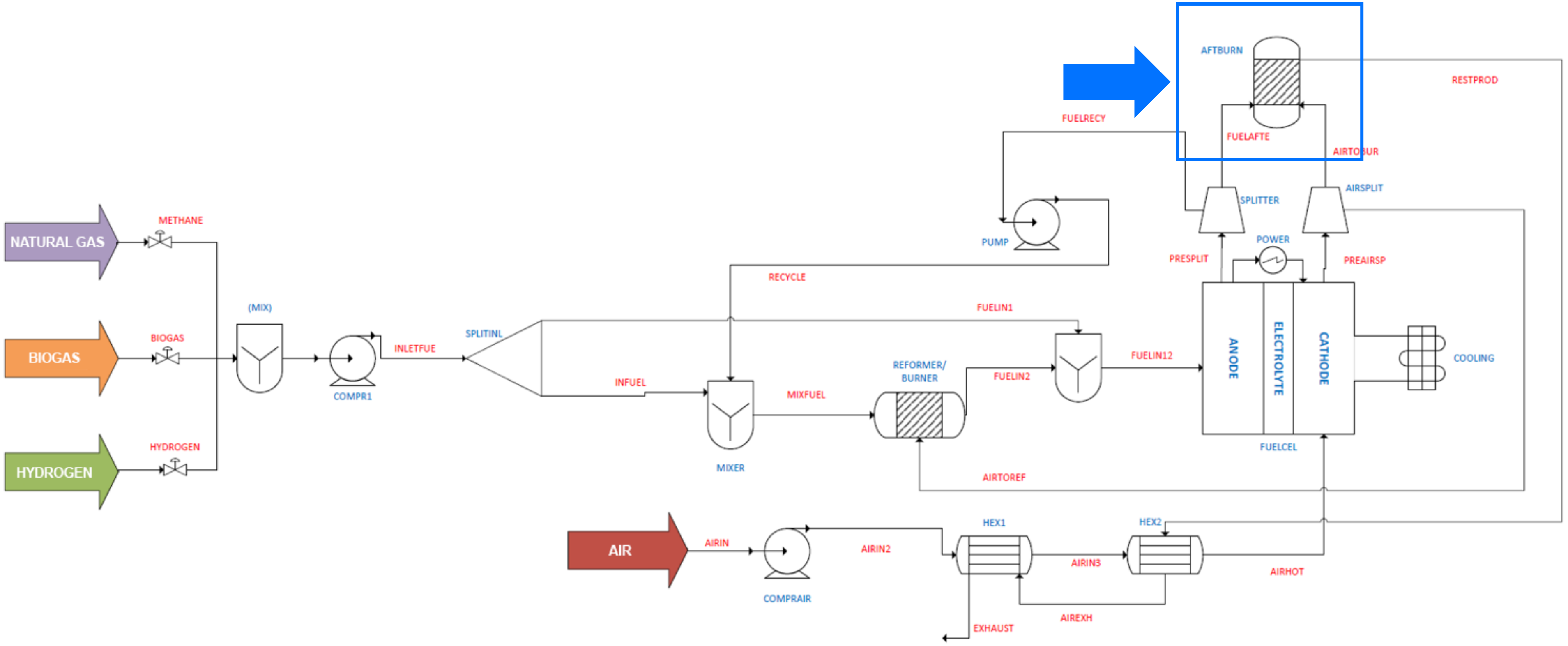
design choices



System architecture

Design study

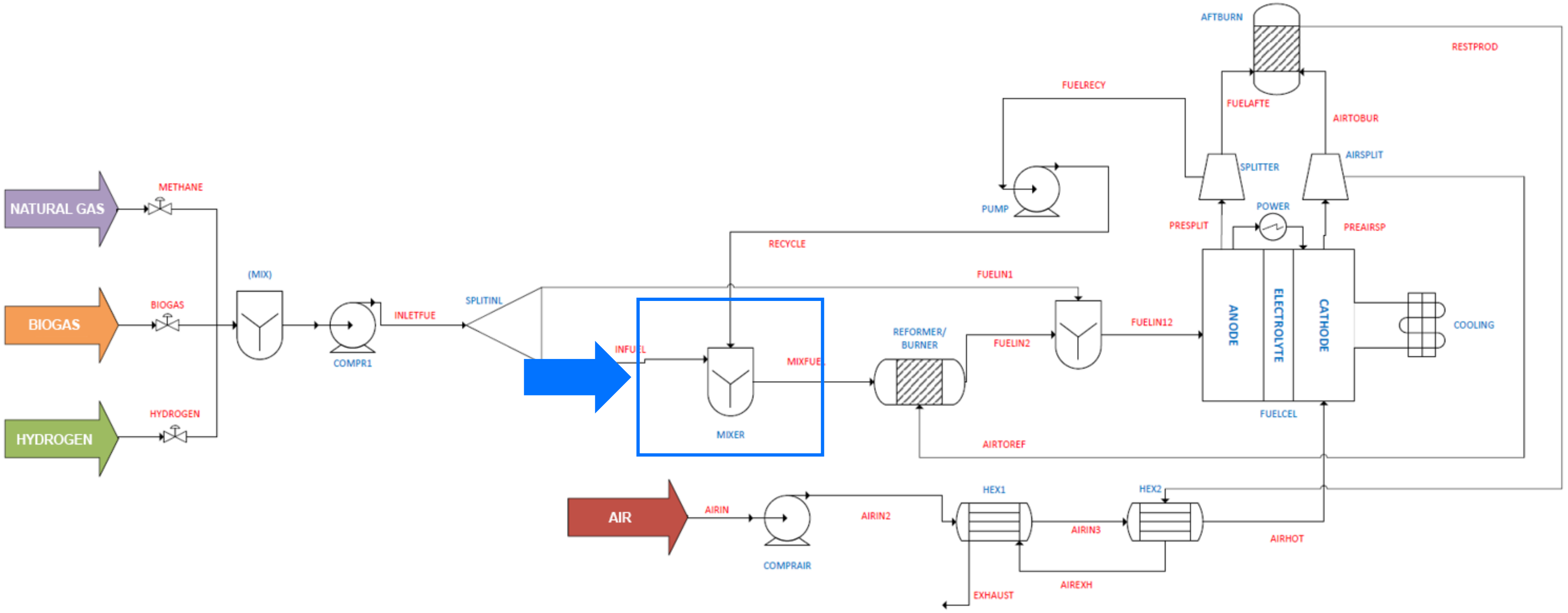
design choices



System architecture

Design study

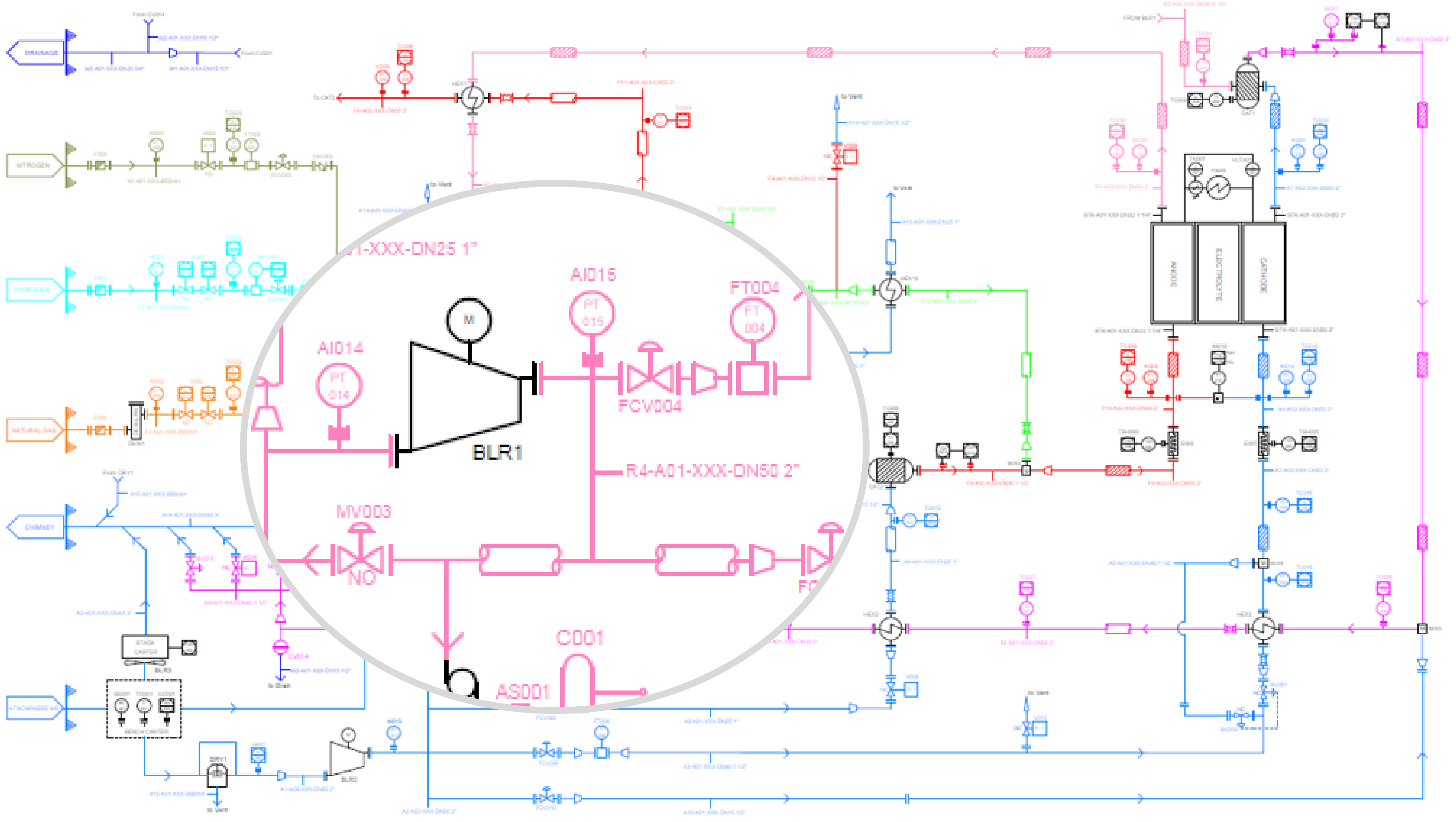
design choices



Architectural choice: anode recirculation

Design study

design choices



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Multi-fuel control: how we keep constraints within limits

Design study

design choices

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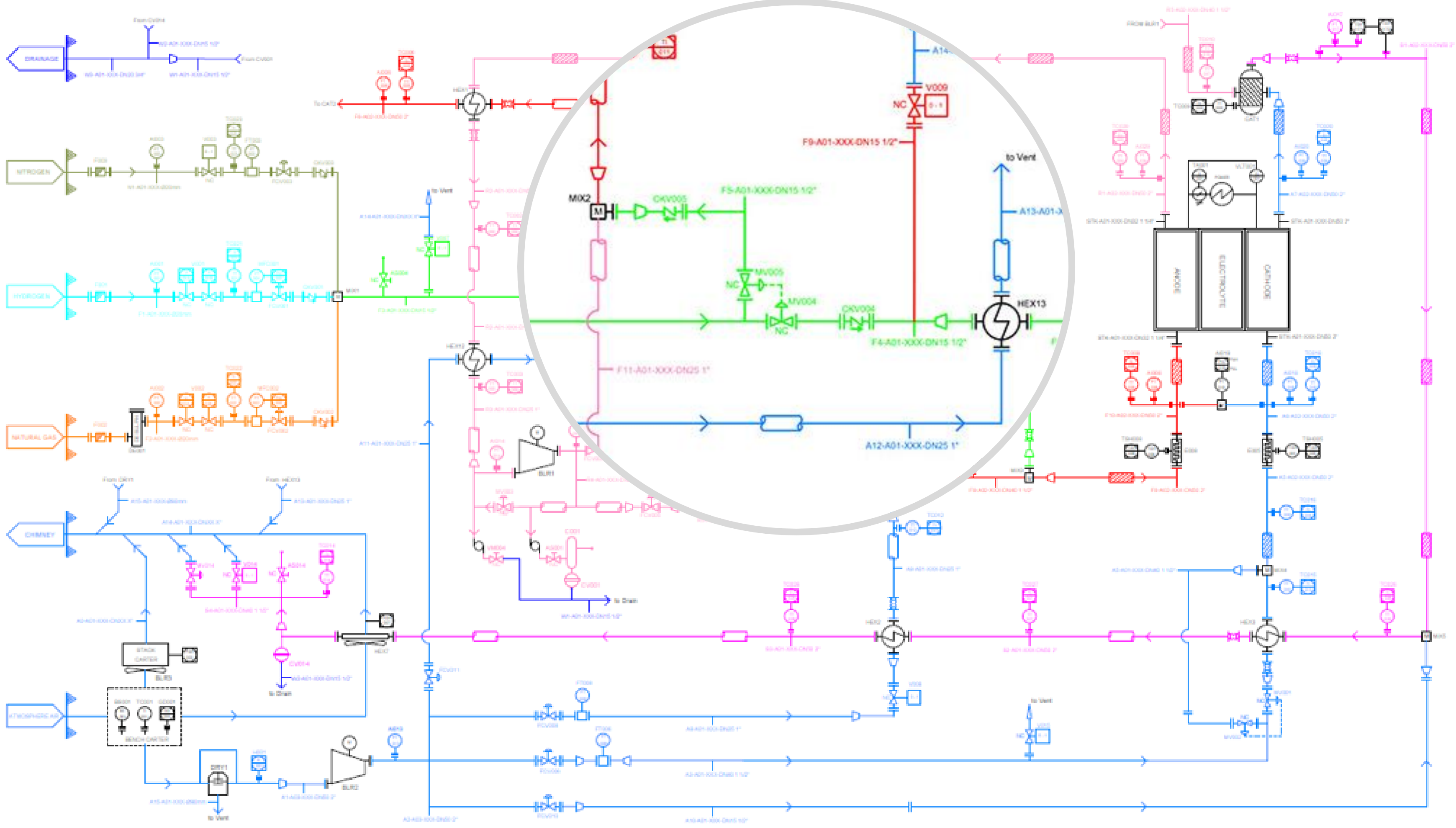
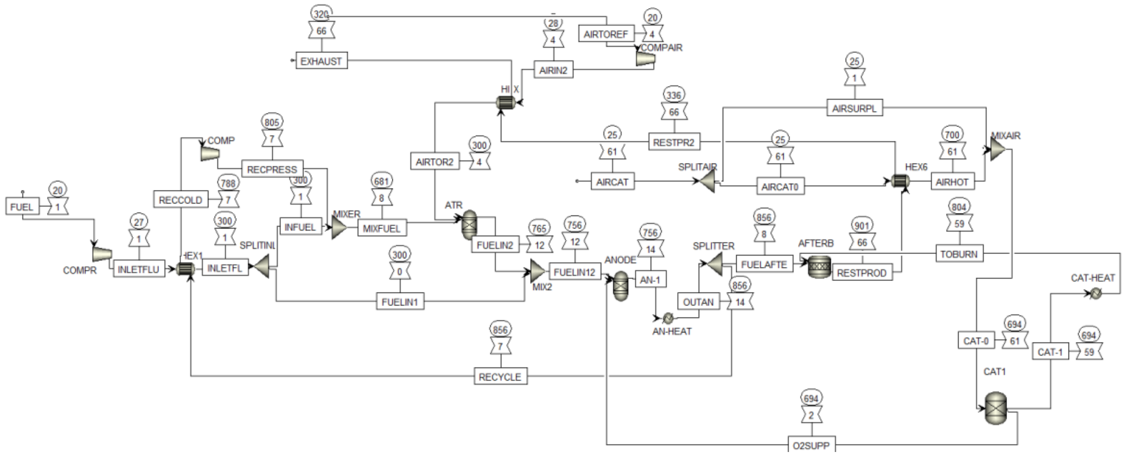


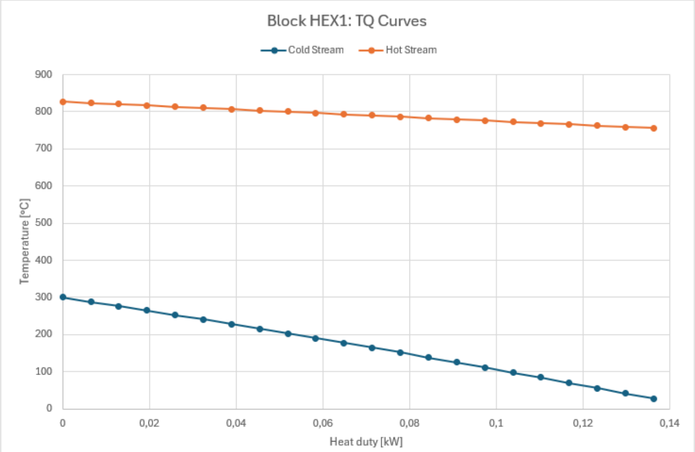
Partner simulations: sizing and design choices

Design study
design choices

Model
→ **Sizing**
→ **Design**
→ **Test**



Heat duty	Cold stream temperatur	Hot stream temperatur	Cold stream pressur	Hot stream pressur	Cold stream vapor fractio	Hot stream vapor fractio	Cold strea	Hot stream status
kW	*C*	*C*	*bar*	*bar*				
0	300	827,277		1,07	1	1	1 OK	OK
0,00648936	288,268	823,884						
0,0129787	276,433	820,489						
0,0194681	264,491	817,091						
0,0259574	252,439	813,69						
0,0324468	240,273	810,287						
0,0389362	227,99	806,881						
0,0454255	215,586	803,472						
0,0519149	203,057	800,06						
0,0584042	190,399	796,646						
0,0648936	177,608	793,23						
0,0713829	164,68	789,81						
0,0778723	151,611	786,388						
0,0843617	138,398	782,963						
0,090851	125,037	779,535						
0,0973404	111,525	776,105						
0,10383	97,859	772,671						
0,110319	84,0378	769,235						
0,116808	70,0609	765,796						
0,123298	55,929	762,355						
0,129787	41,6445	758,91						
0,136277	27,2116	755,463						



- Thermal balances / heat exchangers
- Transients (start-up, switching)
- Operating limits → setpoints and margins

Industrial criticalities and design decisions

Design study

design choices

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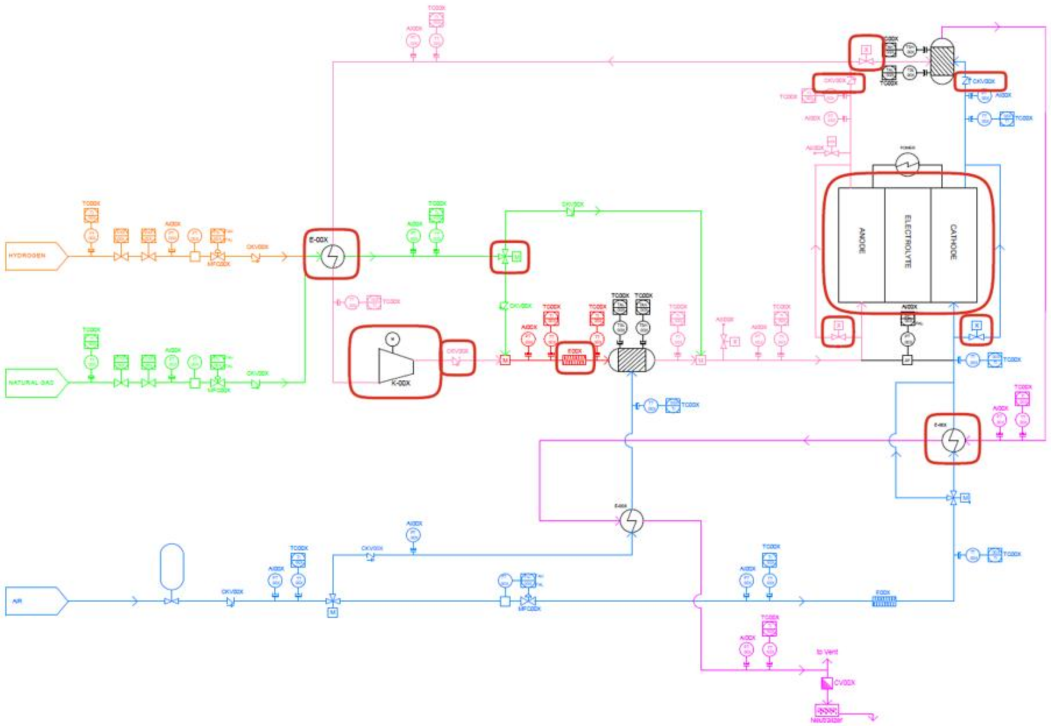
CRITICALITIES

- **Anode recirculation blower** (850 °C, cost, single supplier)
- **Heaters** (electric at high temperatures; ceramic options less efficient)
- **ATEX** (natural stack leakage)
- **Heat exchangers** (pressure constraints, footprint)
- **Solenoid valves** (cost, availability, operating range)
- **Thermal insulation** (high temperature, mechanical structure)
- **Anode off-gas** (composition, temperature)



Safety by design: how we managed risk

Design study

design choices

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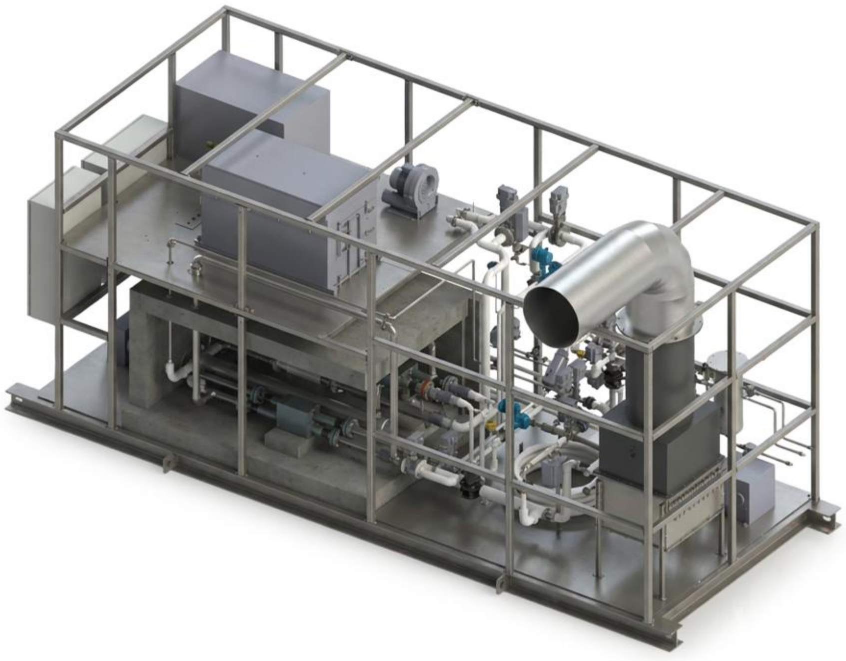
HAZOP
- Deviations
- Causes
- Mitigations

ATEX
- Area classification
- Components requirements
- Segregation

SIS - ESD
- Independent function
- Interlock
- Purge & safe state

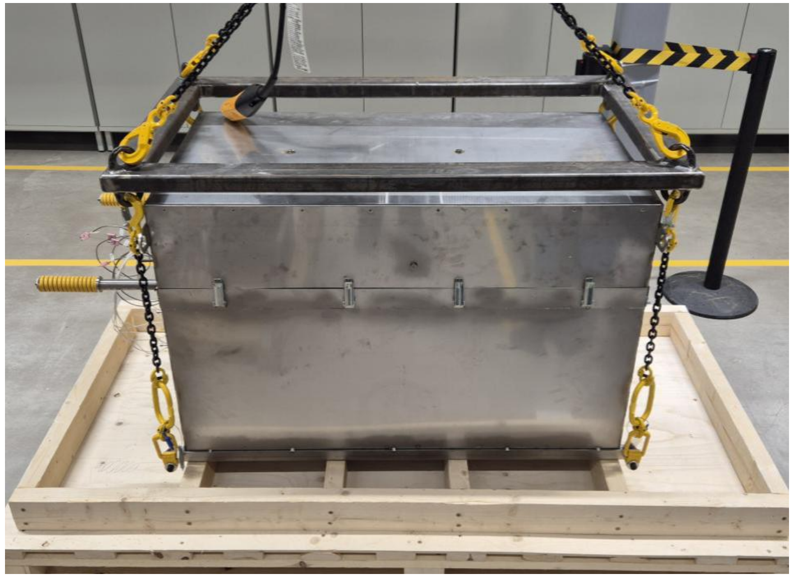
Part 3
Build and commissioning

From procurement to the integrated plant, through to testing



From design to the BoM: component choices and standardization

Build and commissioning



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Plant integration: layout, piping, and thermal management

Build and commissioning

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Automation and operational safety: control + SIS/ESD

Build and commissioning

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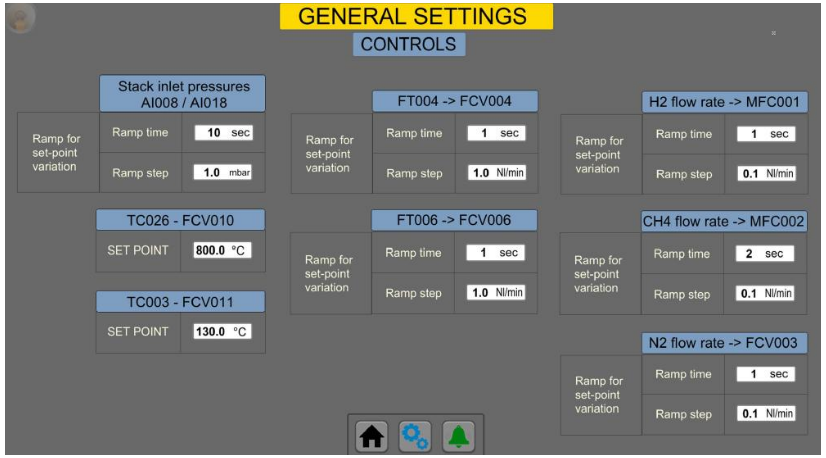
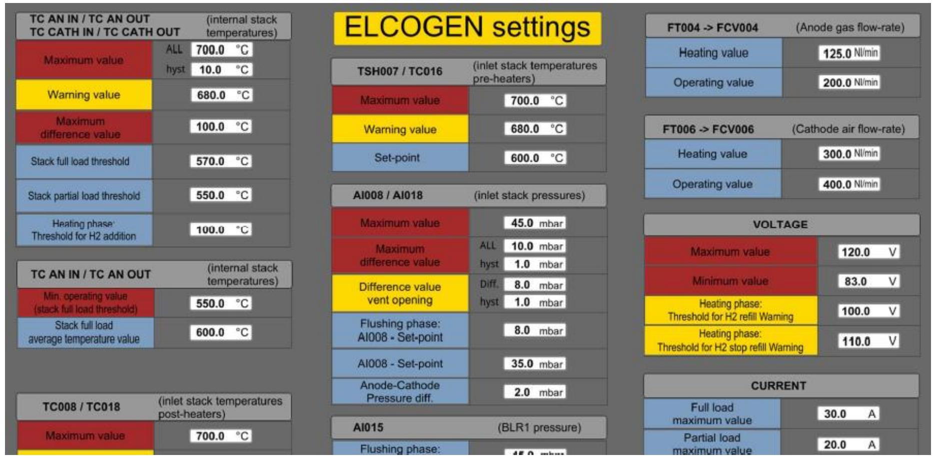
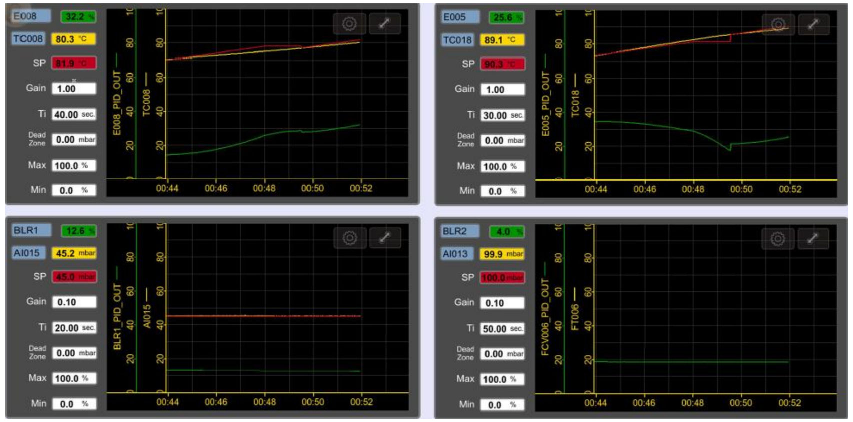
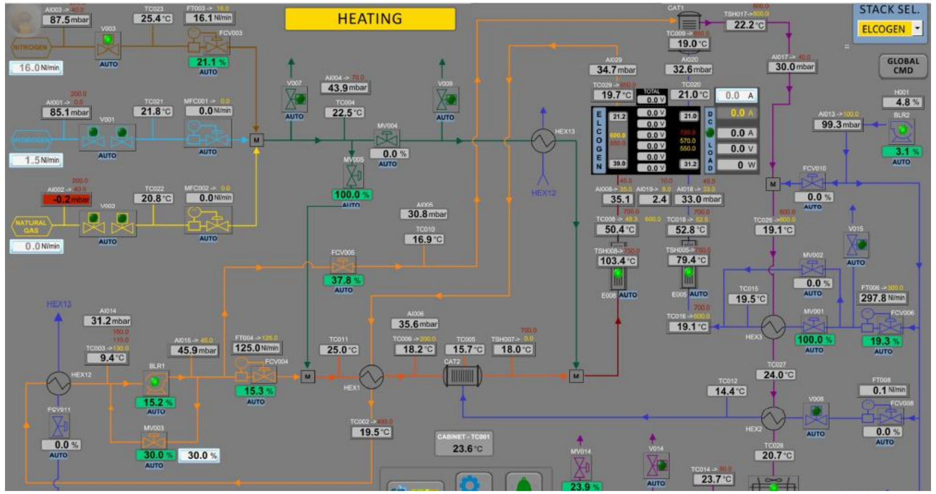


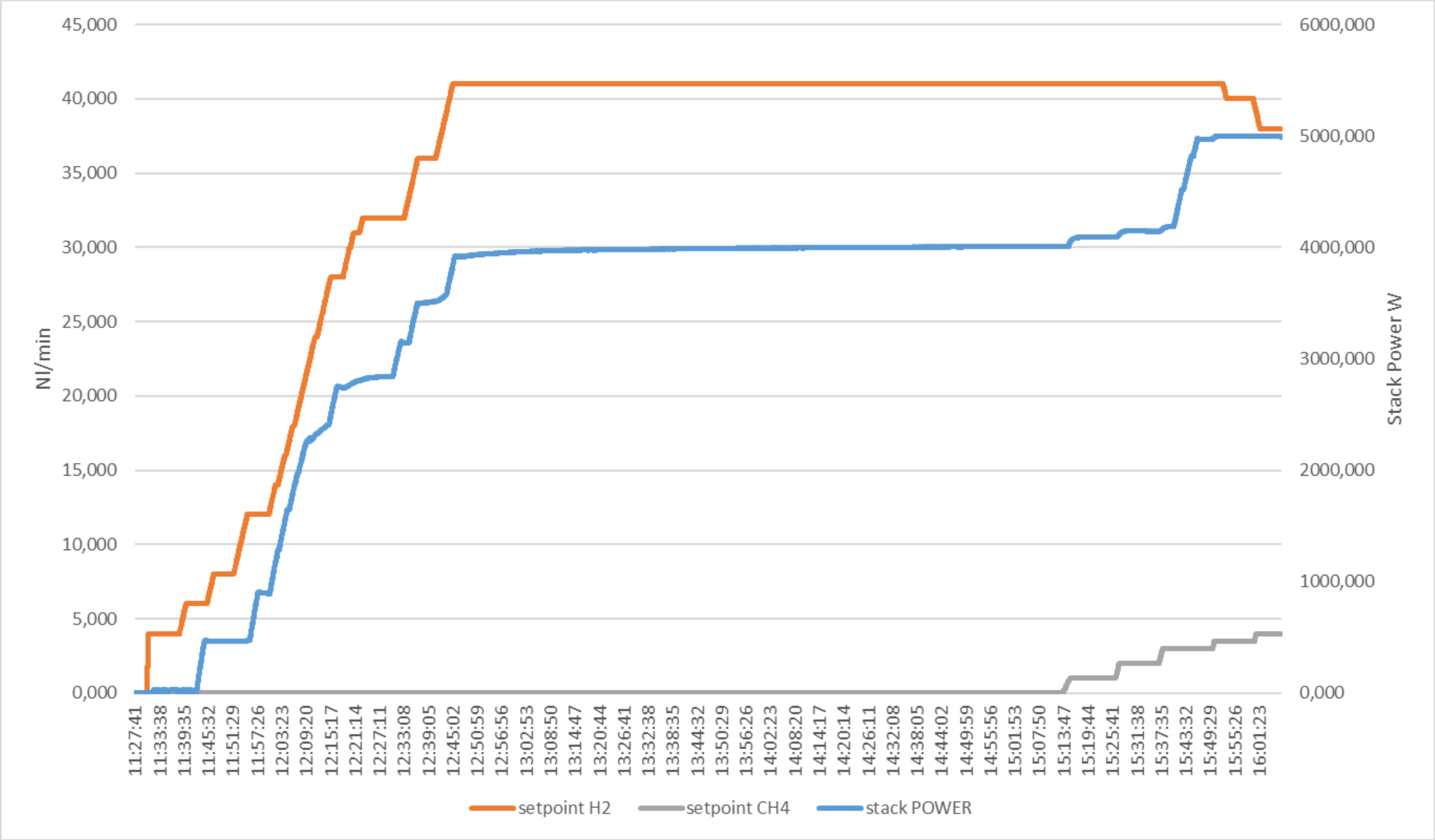






Commissioning & testing: what we are verifying (and how we measure it)

Build and commissioning



Commissioning & testing: what we are verifying (and how we measure it)

Build and commissioning

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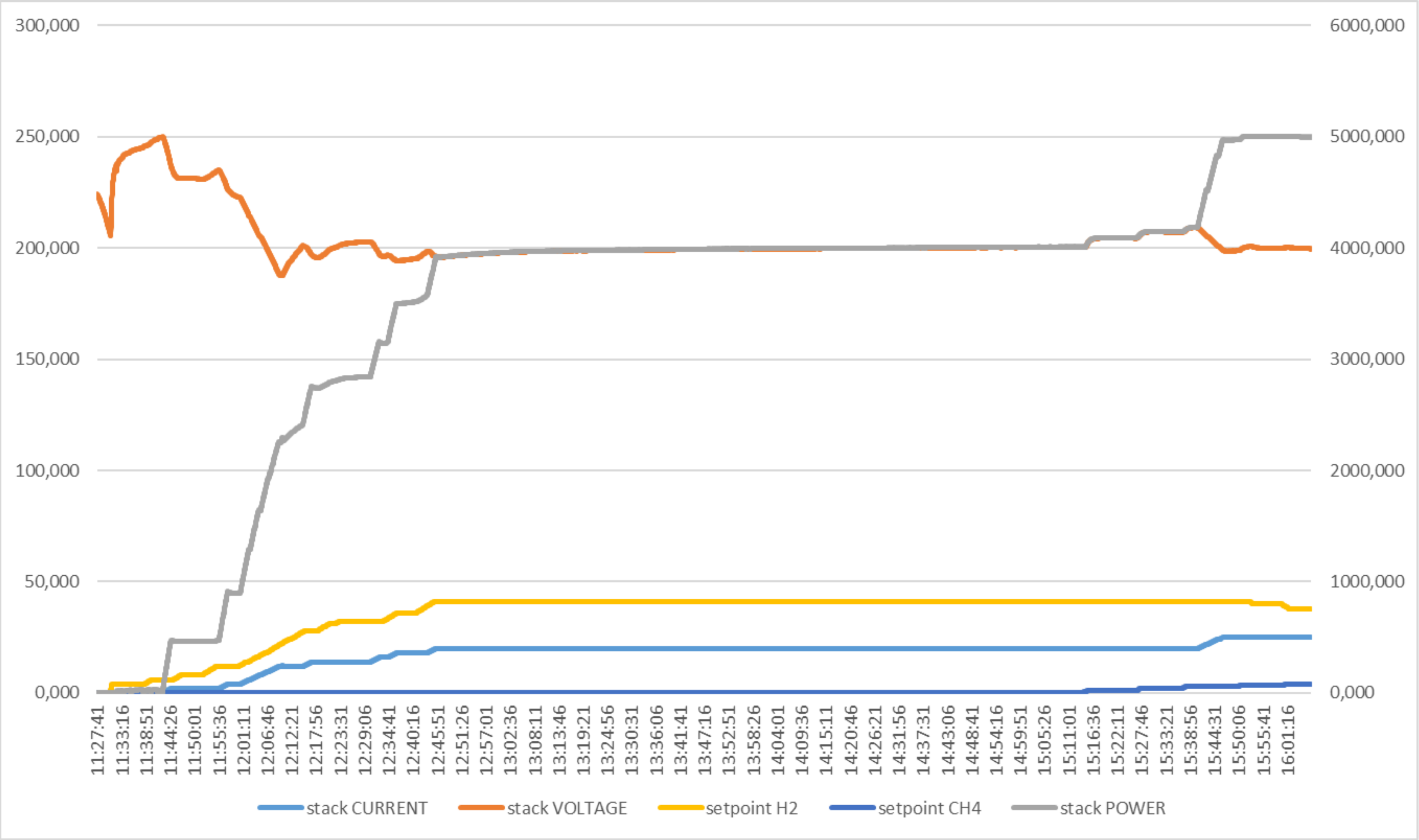

Real-world limits, positive signals

What's slowing things down

- Economics: CAPEX/OPEX and perceived risk are still high in many use cases
- Standards & permitting: certification pathways and responsibilities are not always straightforward
- Operability: lifetime, maintenance, supply chain, and services

What's changing

- Maturation: more standards, more data, fewer one-off solutions
- Consolidation: fewer promises, more verifiable delivery
- Competitiveness is getting closer: often with targeted support, but along clearer trajectories

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Carlo Tregambe PhD
Director of H2 & Energy Innovation

carlo.tregambe@icicaldaie.com