



Hydrogen recirculation system optimization for PEMFC

SYMBIO - Emilien Sopetti
GTTC 2022

AGENDA

An aerial photograph of a multi-lane highway. A white semi-truck is visible on the road, moving away from the viewer. The highway is flanked by green trees and grass.

1.

Context

2.

Recirculation loop system modeling

3.

Architecture exploration

4.

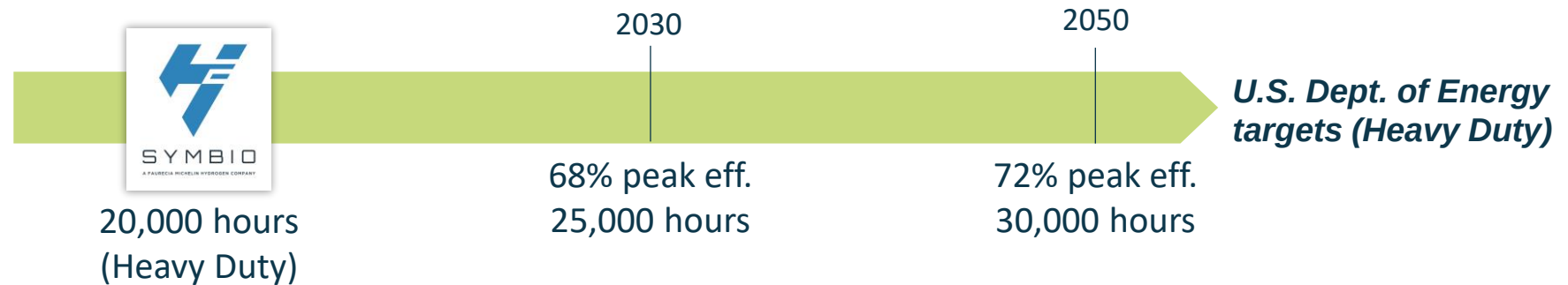
Conclusion

1.

CONTEXT

1/ Context

Fuel cell durability and efficiency are fundamental topics to make the technology competitive.



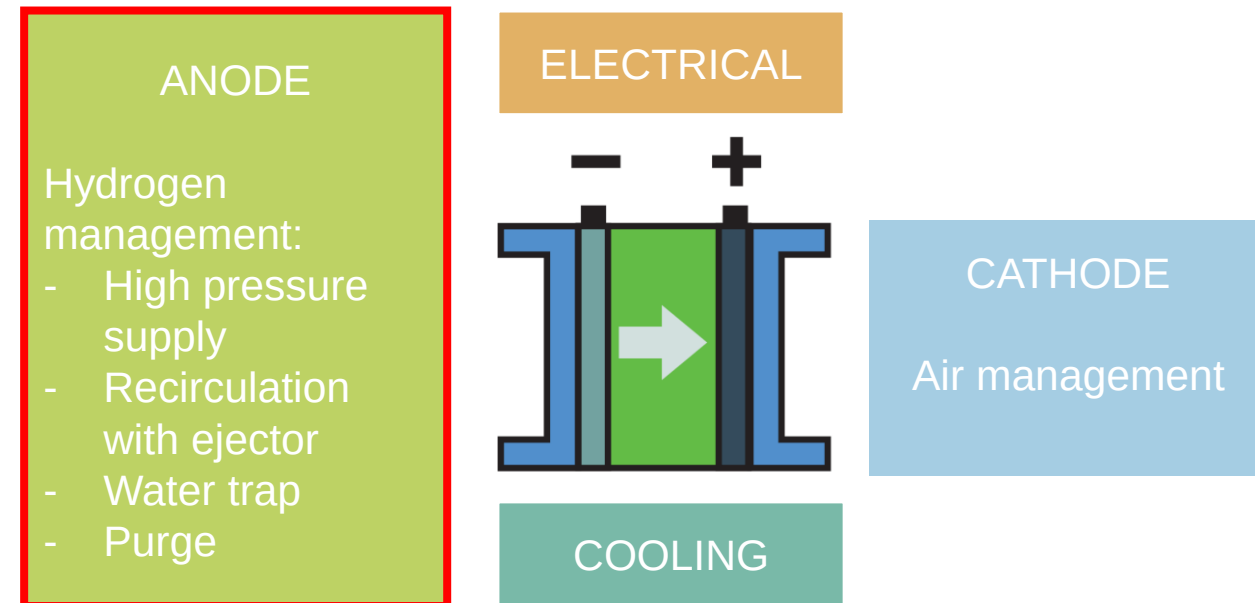
To achieve these goals, one of the keys is the hydrogen recirculation system. It has to:

- Supply sufficient gas quantity on the whole flow field
- Ensure water management
- Sustain defined operating conditions (Pressure, Temperature, Current...)
- Be compact and energy efficient

1/ Context

Area of study: focus on anode loop

- 1) Recirculation is needed to raise the anode stoichiometric ratio & ensure water management.
- 2) Ejector (venturi):
 - ✓ Compact, passive.
 - ⚠ Sizing adapted to stack power range.
- 3) Purge
 - Necessity to purge N₂ and H₂O.

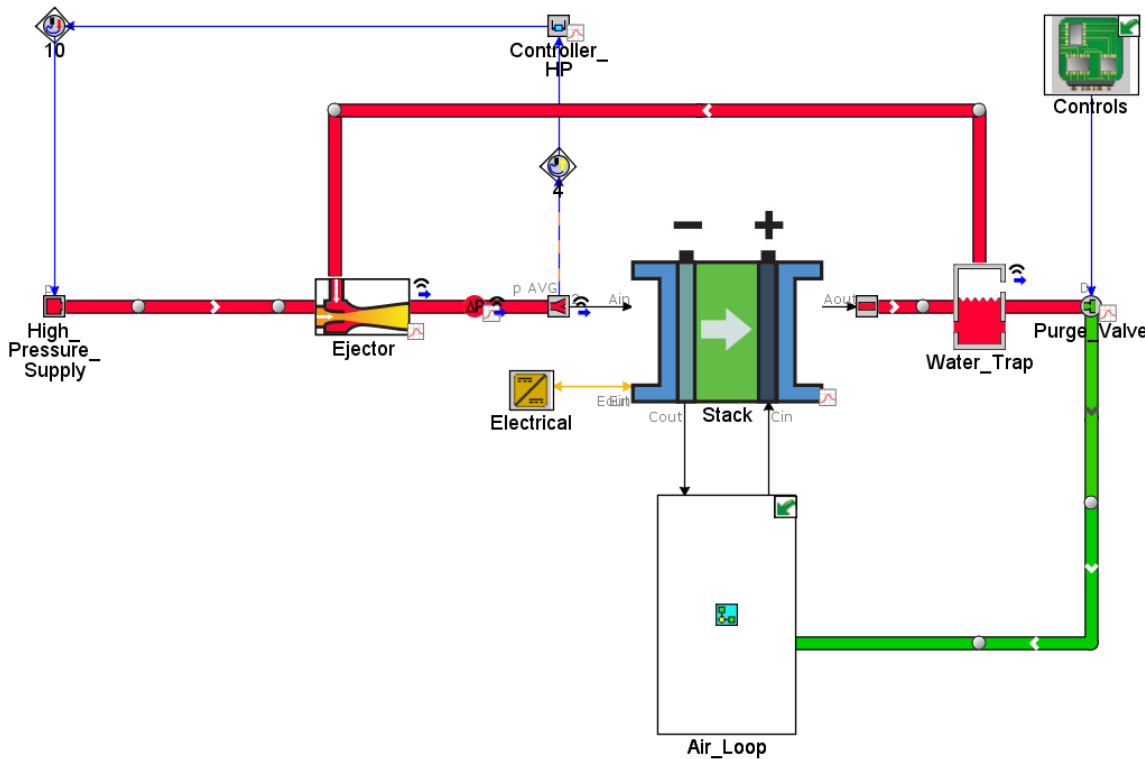


2.

Recirculation loop system modeling

2/ Recirculation loop system modeling

System presentation: model features



Key features:

- Multispecies: H₂O and N₂ crossover prediction, impact on recirculation performance.
- Thermal behavior, condensation.
- Geometry and purge dynamics.

Key outputs:

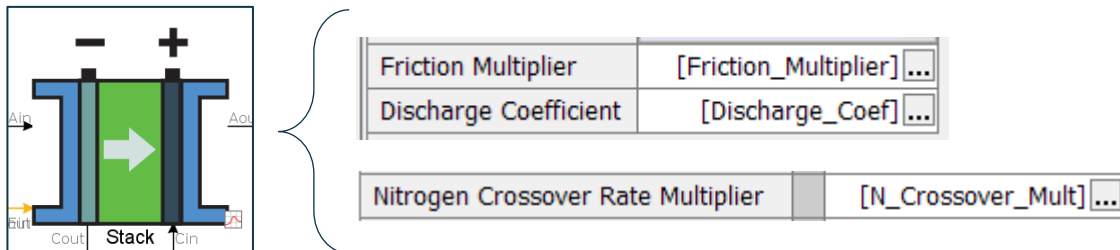
- Stoichiometry, gas composition and humidity, stack flow rate.

2/ Recirculation loop system modeling

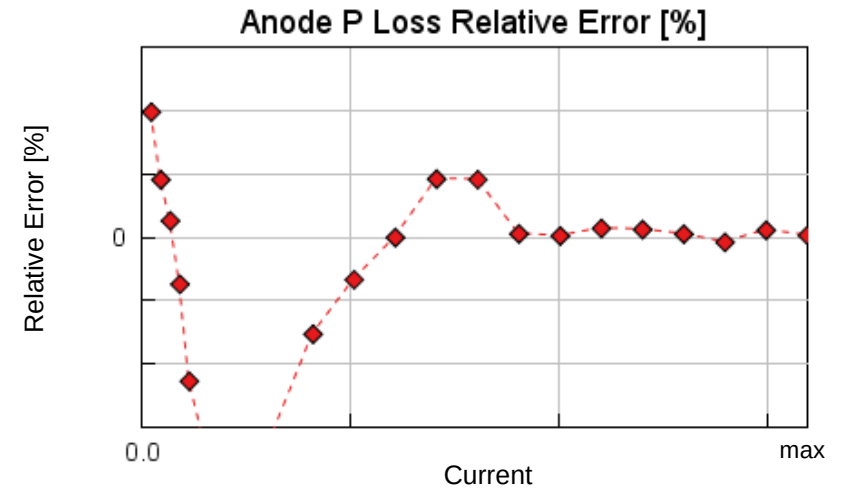
Stack calibration

Correlation:

- Anode pressure loss: maximum error of 11 mbar.
- N2 Crossover: maximum error of 15%

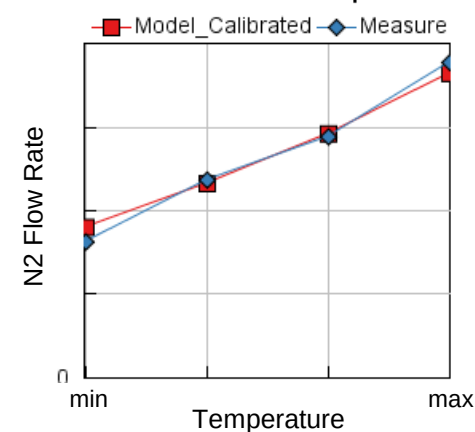


Anode pressure loss calibration

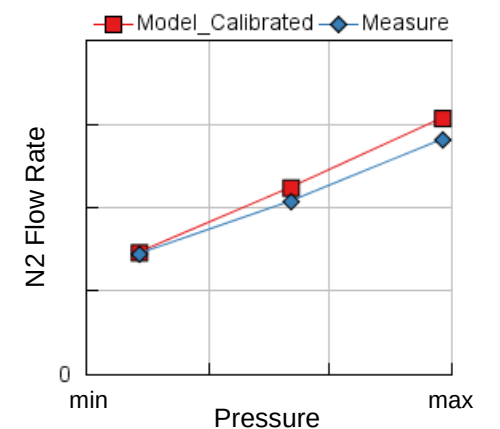


N2 Crossover calibration

N2 Crossover vs Temperature



N2 Crossover vs Pressure

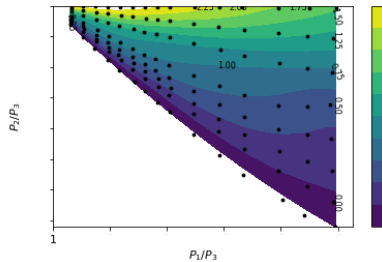


2/ Recirculation loop system modeling

Ejector modeling workflow

1) Testing

Ejector mapping in 100% H₂



2) CFD

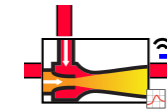
CFD Ejector model validation.

CFD Ejector simulation in H₂/N₂/H₂O mix.

3) GT-SUITE

GT-SUITE ejector model multispecies calibration

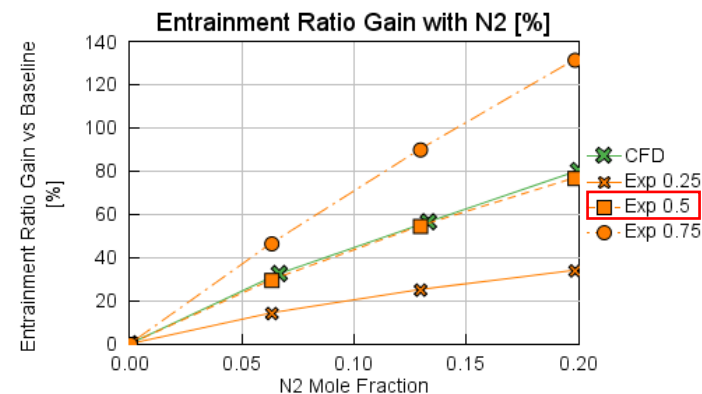
The model extrapolates performance with pressure, temperature, composition.



$$m_{norm} = \frac{m}{P \sqrt{\frac{\gamma}{T} \left(\frac{2}{\gamma+1} \right)^{\frac{\gamma+1}{\gamma-1}}}}$$

Gas Constant Exponent

[Gas_Constant_Exp...]



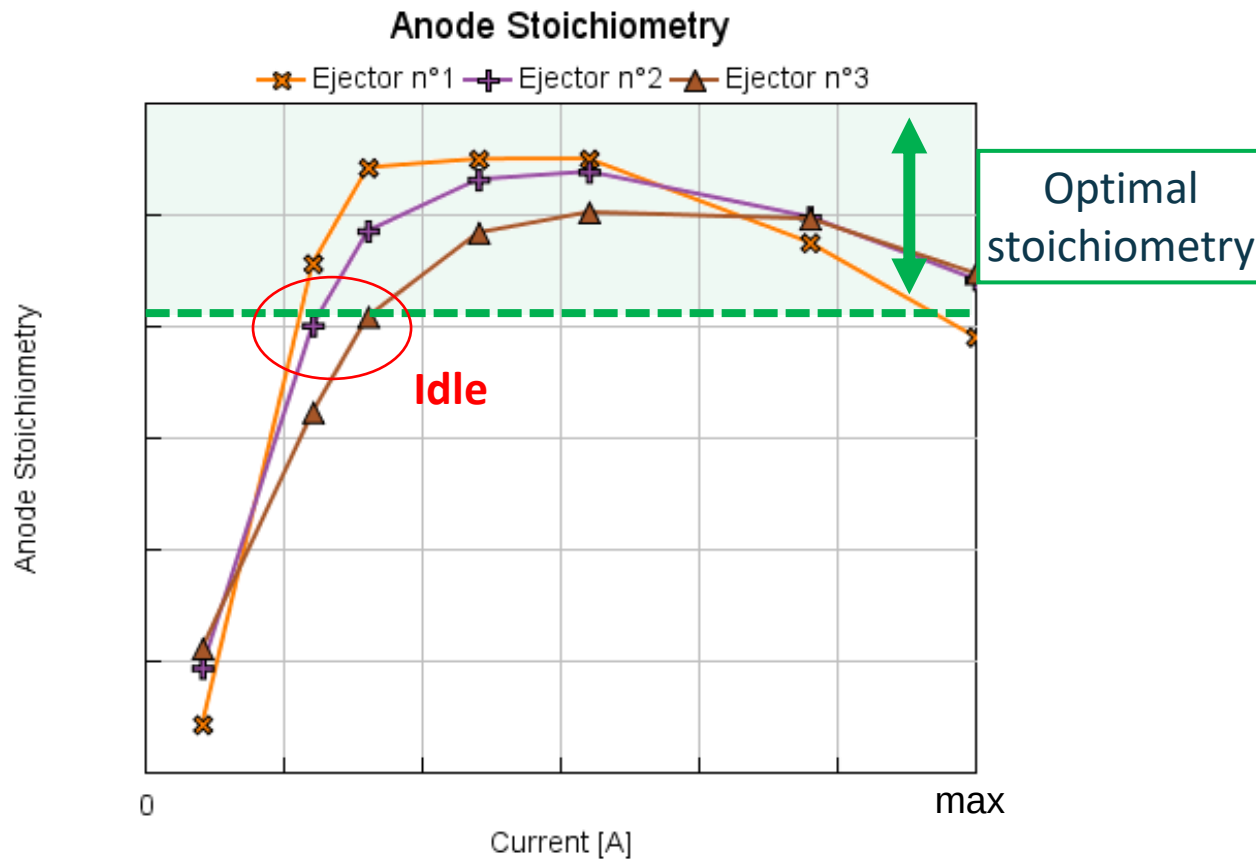
- ✓ Trend is well captured by GT after calibration.
- ✓ Faster than CFD mapping
- ⚠ The calibration is not valid for all the operating range

3.

Architecture exploration

3/ Architecture exploration

Ejector size choice



$$\text{Anode Stoichiometric Ratio} = \frac{\text{H2 Flow Rate at Stack Inlet}}{\text{H2 Consumption}}$$

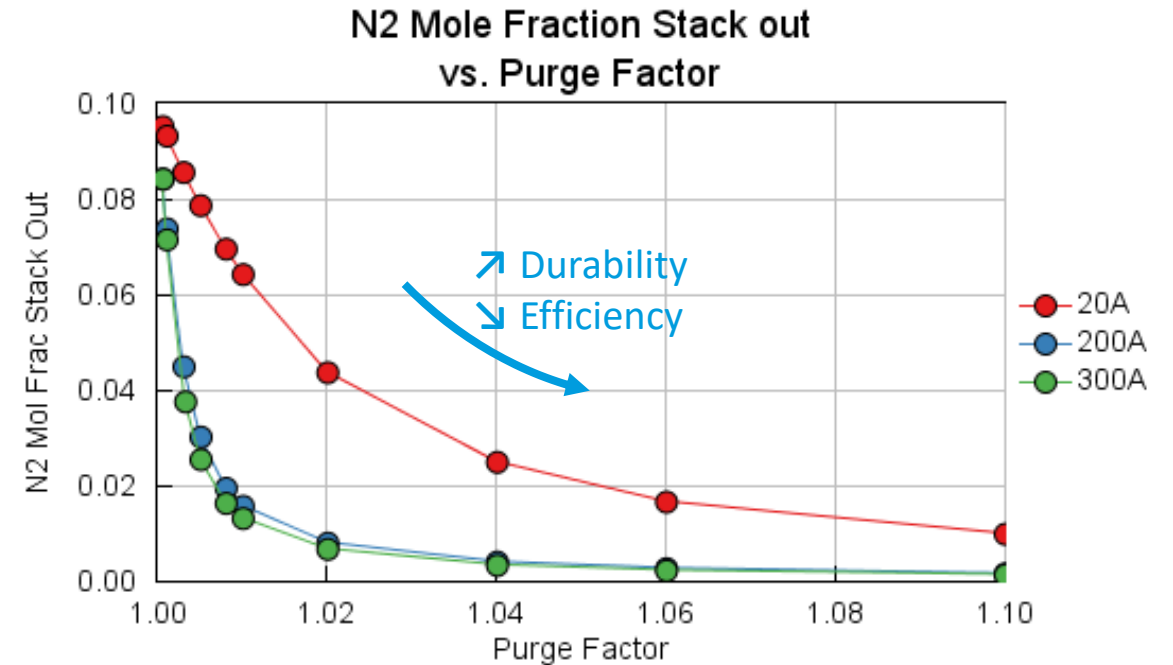
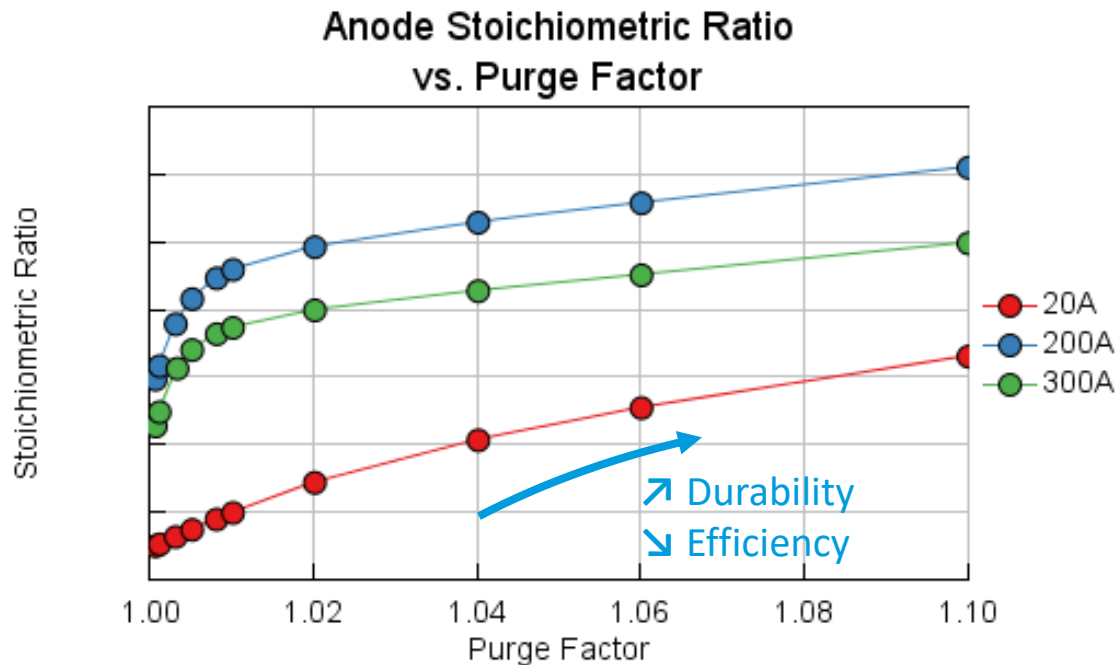
- Ejector sizing will define the idle power of the system.
- Ejector n°2 has a good trade-off between low and high power.

	Idle (minimum) power	Optimal power range
Ejector n°1	Reference	Reference
Ejector n°2	+ 14%	+5%
Ejector n°3	+ 50%	-9%

3/ Architecture exploration

Purge calibration (1/2): sensitivity study

? Purge factor = overconsumption factor due to H₂ loss at the purge



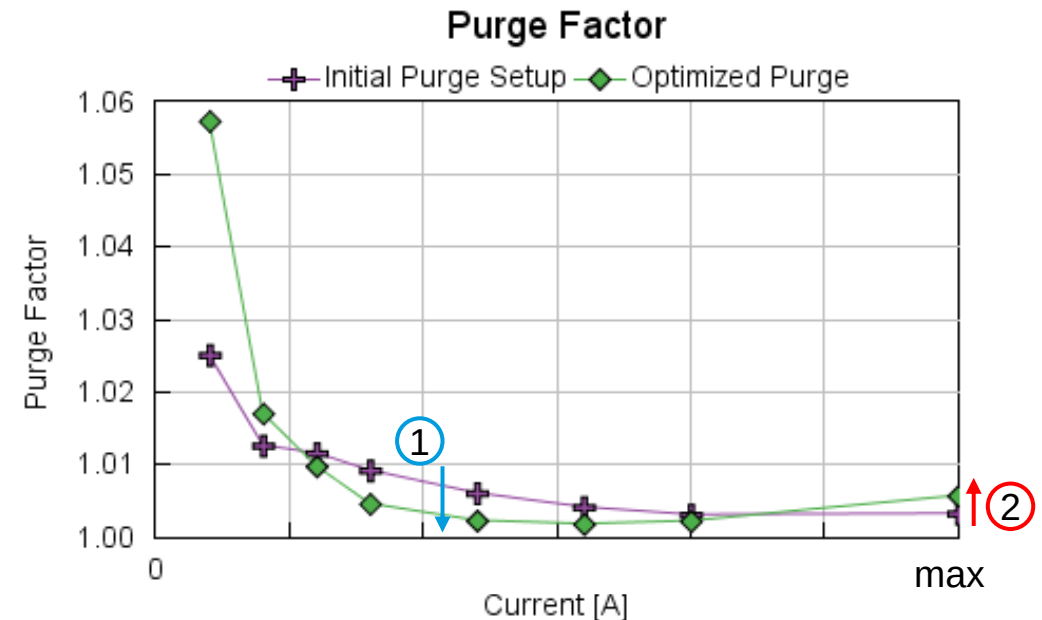
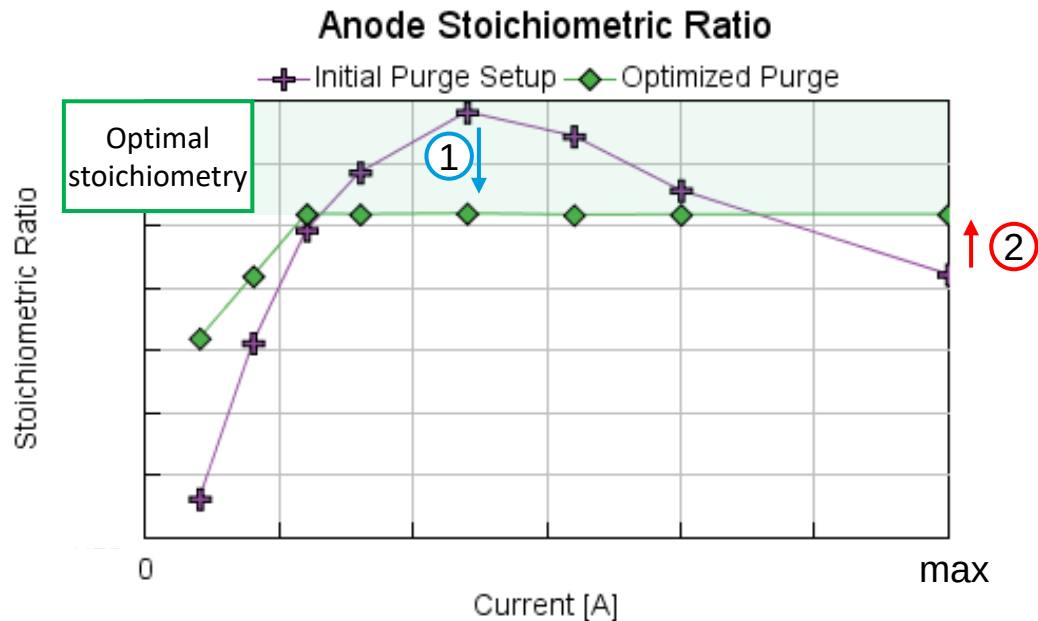
The purge strategy is a trade-off:

- High purge factor to limit N₂ concentration / raise the stoichiometry.
- Low purge to avoid rejecting H₂ and to lower the consumption.

3/ Architecture exploration

Purge calibration (2/2): optimization result

? Purge factor = overconsumption factor due to H₂ loss at the purge

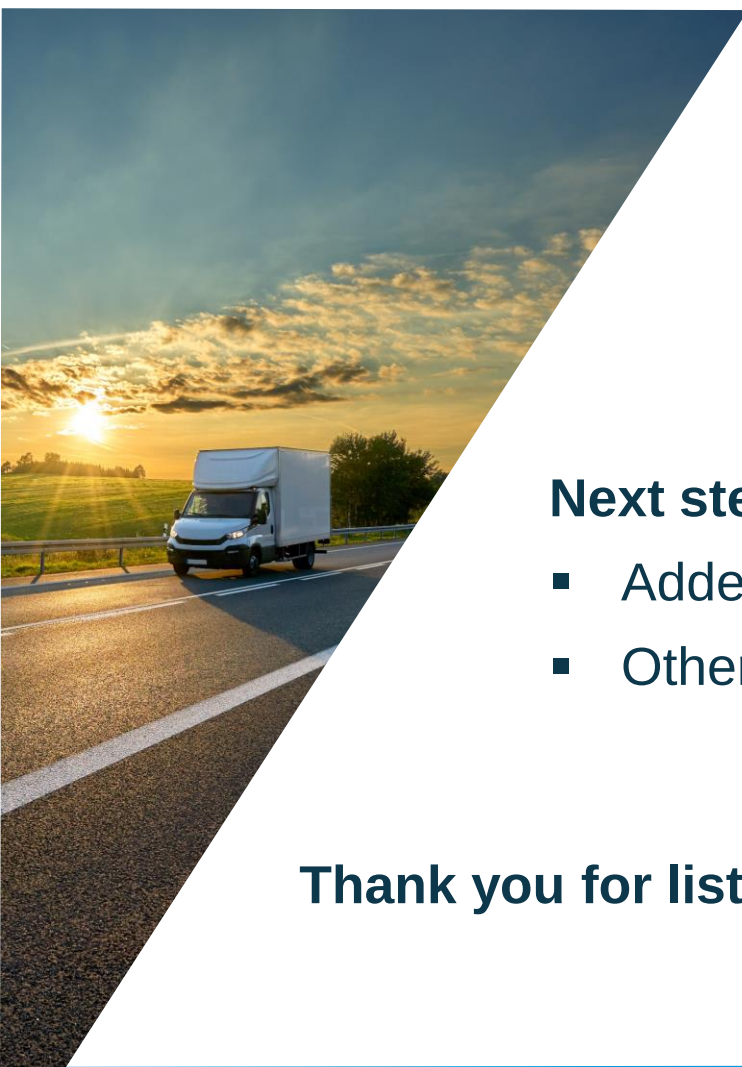


Once the stoichiometric ratio criteria is met, consumption is optimized (①).
Maximum power is calibrated to reach the optimal stoichiometry (②).

4.

Conclusion

4/ Conclusion



Key results:

- Good correlation of the model with test data.
- Virtual system architecture and calibration to reach performance and durability targets.

Next steps:

- Added complexity.
- Other system architecture exploration.

Thank you for listening!



SYMBIO

A FAURECIA MICHELIN HYDROGEN COMPANY

BUILDING
A POSITIVE
FUTURE