

Deliverable D5.2

Sub system design and optimisation

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1 Acronyms

WP – Work Package

BoP – Balance of Plant

FC – Fuel Cell

HRP – Hydrogen Recirculation Pump

PCV – Proportional Control Valve

2 Summary

The following report builds on the hydrogen loop requirements defined in Deliverable WP5.1 and moves from requirements definition to architecture selection and simulation. Where WP5.1 deliberately assumed a baseline hybrid architecture (HRP + ejector) to ensure the requirements were covered, WP5.2 is responsible for challenging that assumption, quantifying alternatives, and selecting the most appropriate hydrogen recirculation loop architecture for high-power systems. WP5.2 will confirm the previously assumed boundary conditions and where exactly the ejector and HRP will operate.

WP5.1 concluded by making analysis to a range of different architectures assessing all moderately feasible methods of ejecting and entraining hydrogen into the anode of a hydrogen fuel cell. This focussed on a range of parameters, including most of all operating range, scalability and efficiency.

By scoring these against each other, the report identified the following 3 strongest architectures:

1. Ejector only
2. Ejector + Hydrogen Recirculation Pump (HRP) hybrid
3. Passive Variable Geometry Ejector

The core objective of WP5.2 is to assess, compare, and optimise these hydrogen recirculation loop architectures capable of meeting the system requirements defined in WP5.1 and determine:

- Which architecture provides the most robust and efficient solution when evaluated beyond a single nominal operating point.
- How each architecture performs across the range of current densities, particularly around regions where requirements like stoichiometric ratio become most demanding.
- The extent to which architecture level optimisation can reduce complexity, cost, and risk while maintaining system performance.

2.1 Scope of Assessment & Methodological Approach

To achieve these objectives, WP5.2 adopts a sub system level modelling and simulation approach, focusing on the hydrogen recirculation loop rather than isolated component performance. The assessment is conducted within the fixed system boundaries defined in WP5.1, ensuring consistency and comparability between architectural options.

The methodology comprises:

- Definition of candidate hydrogen recirculation architectures operating under identical boundary conditions.
- Application of a consistent ejector capability model across all architectures, ensuring that performance differences arise from architecture selection rather than modelling assumptions.
- System level simulation of mass flow, pressure balance, stoichiometry, and parasitic power across the operating envelope.
- Comparative assessment against both technical metrics (e.g. efficiency, hydrogen utilisation, operating envelope width) and non-technical metrics (e.g. cost, packaging, mass, and technical risk).

3 Simulation set-up & key evaluation metrics

3.1 Modelling approach and boundary conditions

A GT modelling approach was used to compare hydrogen recirculation concepts under a 150 kW fuel cell boundary condition, with cases explicitly including Ejector only, Ejector with hydrogen recirculation pump and dual ejector. A calibrated 150 kW GT Power model was used to study hydrogen recirculation behaviour across a range of current densities. The 150 kW stack represents nominal operation and exhibits a similar maximum operating range to the 210 kW stack defined in WP5.1. The model was therefore suitable for architectural comparison in WP5.2.

This same model was modified in certain modest ways to make all architectural comparisons suitably. The dual ejector architecture can be simulated with each ejector controlled via a one-way control valve. While this best represents the intended architecture, it introduces additional modelling complexity. To characterise the operating range of each ejector size, modelling them individually one by one was an acceptable method.

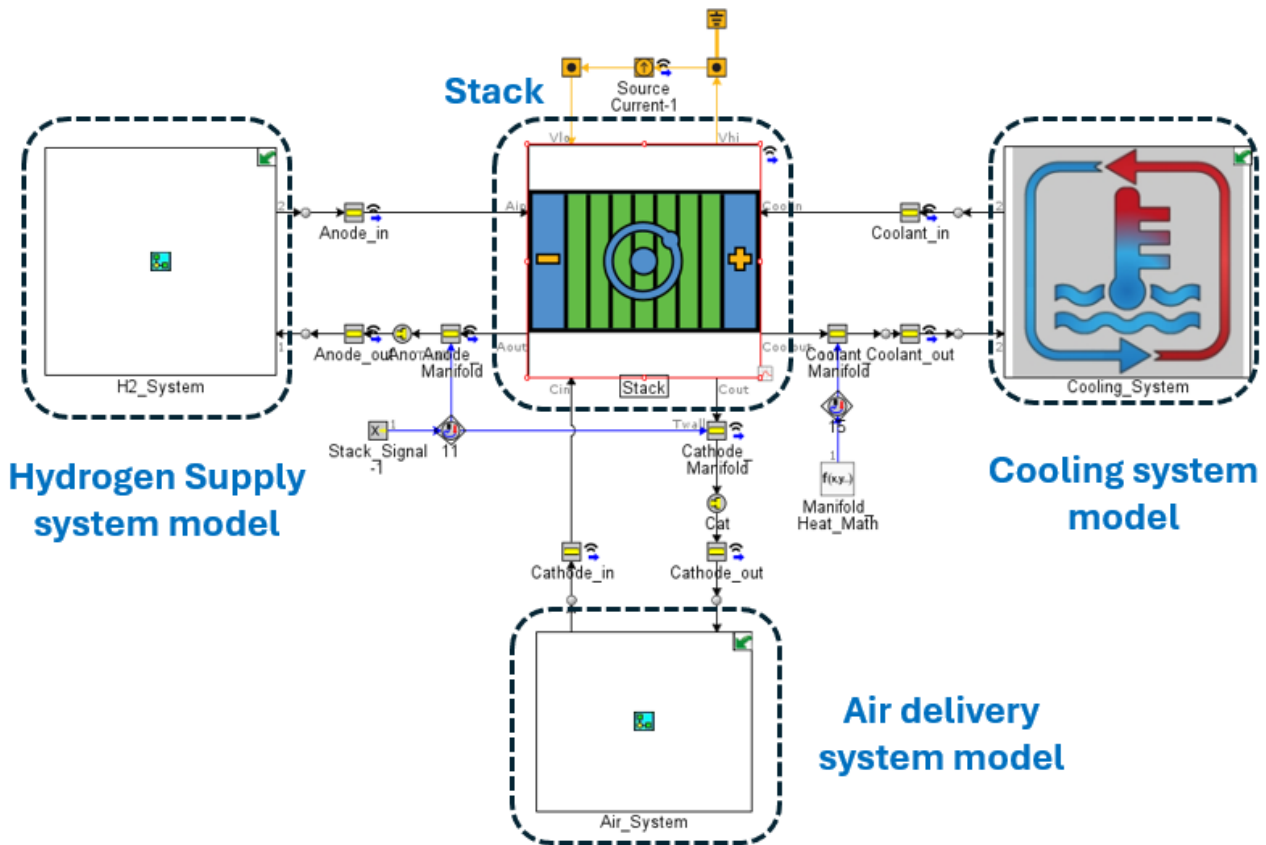


Figure 1: Integrated full system model for 150 kW fuel cell is built based on hydrogen supply system model, stack, air delivery system model, and cooling system model

4 Initial analysis of HRP operation

To ensure that the HRP design selected in this study is feasible for the identified operating conditions, the available pump performance map for the current design geometry was included in the GT-Power system model. For each stack current density operating point, the anode loop was solved in conjunction with the HRP and ejector models to determine the combination of flow rate and pressure rise required to satisfy system recirculation demands as stated in WP5.1. The GT solver then identified a corresponding HRP operating point within the performance map that satisfied these requirements.

The chart below therefore represents the HRP operating speed selected by the system model at each operating point, subject to the constraints of the available pump map. This demonstrates where the selected pump geometry is capable of operating within its map limits. This assessment is intended to demonstrate the feasibility of the selected HRP geometry to support the anode loop across the required stack operating range, rather than to define a final pump control strategy.

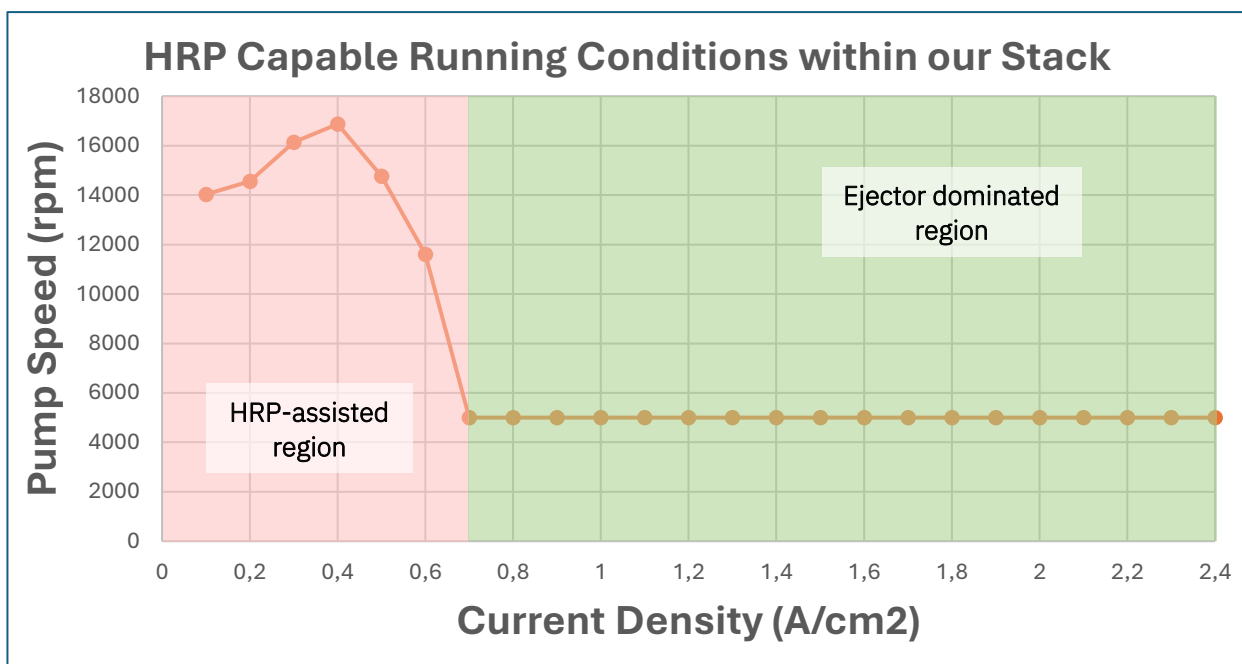


Figure 2: HRP Running Condition at operating range.

A minimum pump speed of 5000 rpm represents the lowest available operating point in the HRP performance map. At current densities up to approximately 0.7 A/cm² the HRP provides a measurable pressure contribution therefore operating speeds. Beyond this point, ejector entrainment performance improves sufficiently to meet the anode recirculation requirements without additional pressure rise from the HRP. The low operating speed of 5000 rpm indicates the transition from HRP assisted operation, to ejector-dominated recirculation at higher loads.

The pump design and map are therefore suitable for the defined range and the expected operation between the ejector and HRP is confirmed.

4.1 Measures and essential Controls

4.1.1 Stoichiometric Ratio – H₂ supplied Vs electrochemically required (Input to Anode)

$$\lambda_{H_2} = \frac{\dot{n}_{H_2, \text{supplied}}}{\dot{n}_{H_2, \text{required}}}$$

λ_{H_2} = Anode hydrogen stoichiometric ratio

$\dot{n}_{H_2, \text{supplied}}$ = Supplied hydrogen molar flow rate to the anode

$\dot{n}_{H_2, \text{required}}$ = Electrochemically required hydrogen molar flow rate for the ideal reaction

The anode stoichiometric ratio is fundamentally a robustness and durability metric, an anode stoichiometric ratio target is in place to:

- Maintain stable anode pressure levels and flow stability.
- Promote uniform hydrogen distribution to prevent local hydrogen starvation, critical for fuel cell durability.
- Ensure stable anode purge behaviour to support effective water management within the anode loop, preventing flooding or dry-out and protecting anode durability.

The minimum target anode stoichiometric ratio shall be ≥ 2.5 for current densities below 0.2 A/cm^2 .

For current densities $\geq 0.2 \text{ A/cm}^2$, the target anode stoichiometric ratio shall be ≥ 1.4 .

4.1.2 Hydrogen Utilization – Portion of supplied hydrogen converted into electrical power

$$HU = \frac{\dot{n}_{H_2, \text{consumed}}}{\dot{n}_{H_2, \text{supplied}}}$$

HU = Hydrogen utilisation

$\dot{n}_{H_2, \text{consumed}}$ = Hydrogen flow rate electrochemically consumed in the stack

$\dot{n}_{H_2, \text{supplied}}$ = Total fresh hydrogen flow rate supplied to the anode

Hydrogen utilisation represents the fraction of supplied hydrogen that is electrochemically converted into electrical power and is therefore a direct measure of fuel efficiency. While higher utilization reduces hydrogen waste and purge losses, sufficient excess hydrogen must be maintained as stated by stoichiometric ratio.

There is a trade-off where increasing hydrogen utilisation reduces anode hydrogen concentration, which can negatively impact performance. While the magnitude of this effect depends on stack technology, it is generally smaller than the energy losses associated with unused hydrogen, therefore despite this, hydrogen utilisation should still be maximised.

4.1.3 System/Stack Net Efficiency

$$\eta_{\text{sys}} = \frac{P_{\text{stack}} - P_{\text{parasitic}}}{\dot{m}_{H_2, \text{utilised}} + \dot{m}_{H_2, \text{purged}}} \times 100$$

η_{sys} = System or stack net efficiency [%]

P_{stack} = Electrical power output of the fuel-cell stack [kW]

$P_{\text{parasitic}}$ = Total parasitic power consumption (compressor, HRP, auxiliaries) [kW]

$\dot{m}_{\text{H}_2, \text{utilised}}$ = Mass flow rate of hydrogen electrochemically consumed

$\dot{m}_{\text{H}_2, \text{purged}}$ = Mass flow rate of hydrogen lost via purge

System (or Stack Net) Efficiency is the primary metric for comparing anode architectures as it represents the overall effectiveness of the fuel cell system in converting hydrogen into useful electrical power, after accounting for all losses.

5 Simulating GT model

5.1 Operating Points investigated

The GT results were generated across a range of current density points spanning **0.1 to 1.8 A/cm²** for the 150 kW stack. A subset of these operating points was deliberately selected to interrogate the operating limits of the ejector + HRP, rather than the higher current density region where the ejector is consistent between them. This ensured that the architectures were compared against the most critical performance outputs aimed at feasibility and operating range.

Current Density (A/cm ²)	Stack Power (kW)	H ₂ Consumption	Stoichiometric Ratio Target	Component reaction
0.1	10.3	Extremely Low	2.5	HRP Only
0.2	20.1	Low	1.4	Ejector & HRP
0.3	29.5	Low	1.4	Ejector & HRP
0.5	47.0	Low	1.4	Ejector & HRP
0.7	64.4	Low Medium	1.4	Ejector Only
1.2	108.1	Medium	1.4	Ejector Only
1.8	151.0	Medium	1.4	Ejector Only

Figure 3: Points assessed in GT model, WP5.1 reflections and anode Stoichiometric requirements across the Current Density Range.

5.1.1 Stoichiometric and Purging effects on Efficiency

Given that the hydrogen recirculation pump increases recirculation and thus mass flow, this in turn creates more favourable conditions within the anode. However, water transport from the cathode to the anode remains governed by diffusion processes, meaning that water accumulation within the anode is still expected to occur regardless of HRP operation. Additionally, purging (wasting hydrogen) means hydrogen utilisation reduces. So, though a HRP may increase the effective recirculation flow and pressure margin, it is not expected to fundamentally alter purge requirements or efficiency.

In the present study, purge strategy is therefore assumed to be consistent between the ejector only and ejector + HRP architectures, with the same purge fraction applied in both cases. While minor differences in purge behaviour may arise in practice due to changes in anode pressure dynamics, these effects are expected to have a secondary influence on overall system performance. The identification and optimisation of such subtle purge related differences are considered outside the scope of this work and will therefore not contribute to system level efficiency compared later.

5.1.2 PCV and Primary Inlet flow

In the GT Power system model used for this analysis, the ejector primary nozzle is represented using a pipe element rather than a fully resolved converging nozzle. This modelling approach is appropriate for architecture level assessment, as it allows the ejector primary pressure, set by the PCV, to be consistent across all operating points and architectures. As a result, the primary mass flow through the ejector is expected to remain consistent at a given current density, independent of the HRP operation.

The model has also been configured such that, when active, the HRP supplements the anode recirculation loop by providing secondary flow independently of the pressure build up in the ejector. Anode pressure regulation is instead achieved by controlling the ejector outlet pressure to the target anode inlet pressure. This modelling choice isolates the effect of secondary flow availability without introducing artificial ejector pressure rise, ensuring consistent comparison between recirculation architectures.

As primary flow conditions are consistent across architectures, fuel utilisation at the stack level is therefore not expected to change, whereas System Net Efficiency is expected to vary due to differences in HRP parasitic power.

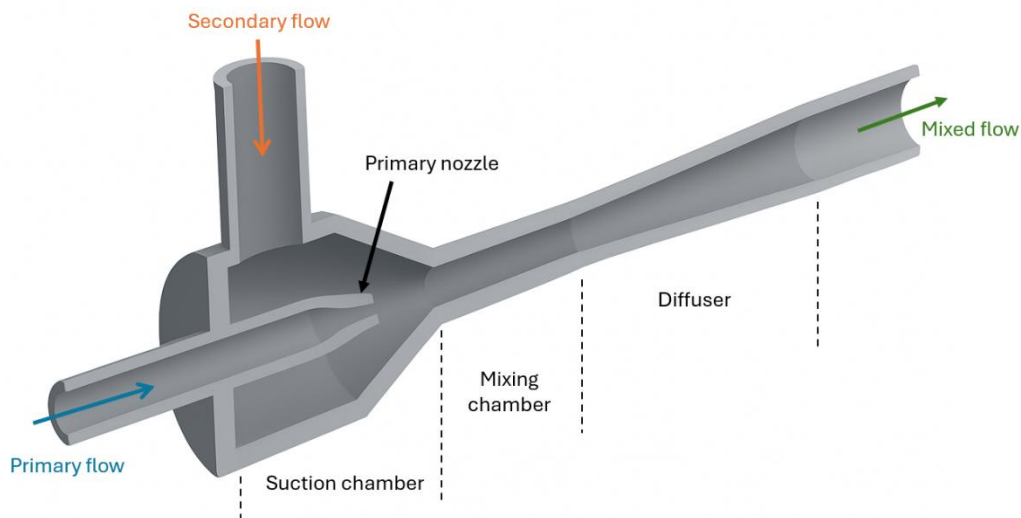


Figure 4: The ejector model used in GT model simulated the primary, secondary and mixing chamber diameters. Not the diffuser chamber increase or specific suction chamber geometry.

6 Ejector Only & Ejector + HRP Hybrid Technical Architectural Comparison

6.1 GT Model Results

As described in 5.1, Operating Points Investigated, the GT Power system model was used to simulate a set of current density operating points. Each point was evaluated independently to assess ejector and stack input output behaviour. The results presented in this section compare key performance parameters, including anode stoichiometric ratio, HRP operating behaviour, and system level efficiency between the architectures.

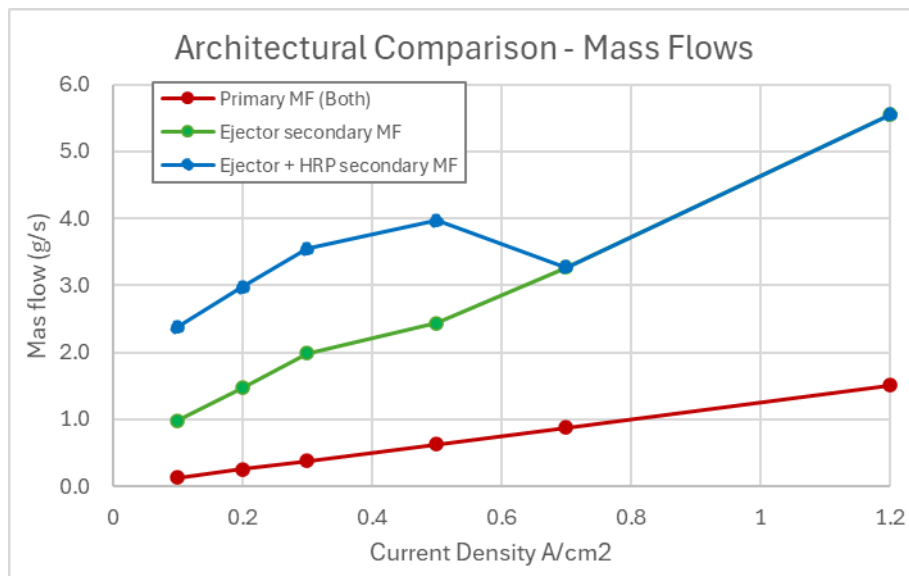


Figure 5: Ejector Vs Ejector + HRP - Mass flow Comparison at fuel cell inlet.

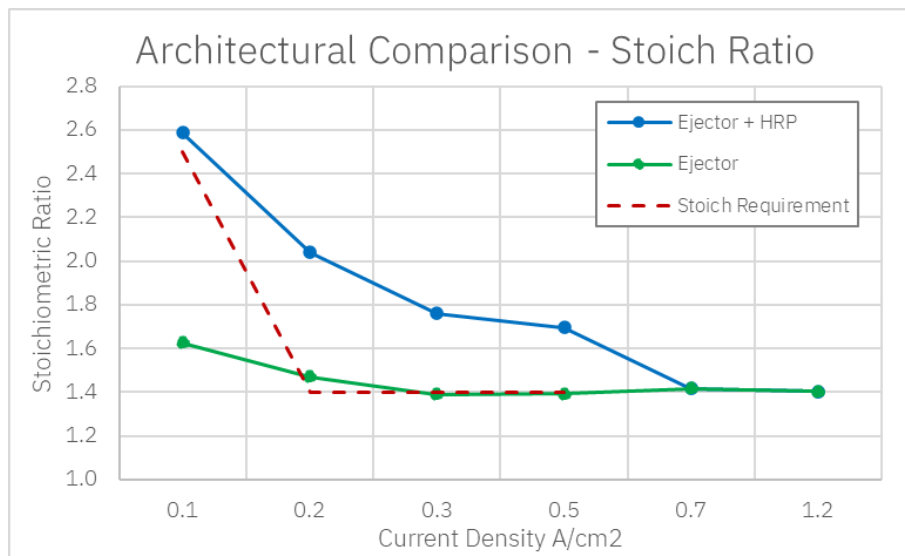


Figure 6: Ejector Vs Ejector + HRP - Stoichiometric Ratio Comparison

Beyond approximately 1.2 A/cm², both architectures converge on all parameters shown, 1.8A/cm² is therefore removed from the charts.

The data above shows why the ejector by itself cannot entrain enough secondary flow at the lower current densities to achieve the required stoichiometric ratio at 0.1A/cm. Though the primary pressure is the same between the 2 architectures, the ejector alone can only entrain a small amount of secondary flow. Whereas the hydrogen pump increases the secondary flow by a significant amount increasing the total flow.

The simulation results indicate that the ejector-only architecture is capable of achieving the required anode stoichiometric ratio down to approximately 0.2 A/cm² under steady state conditions. At these operating points, no stoichiometric shortfall is observed relative to the hybrid ejector + HRP configuration. However, the hybrid architecture demonstrates significantly higher secondary circulation and anode pressure at low current density, providing increased operating margin and robustness where ejector entrainment becomes limited. The HRP therefore does not improve hydrogen utilisation or efficiency at low load, but enables controlled recirculation and stable operation as primary flow momentum decreases.

It should be noted that all results presented here are derived under simulated steady state operating conditions. In real system operation, transient effects and control actions will introduce fluctuations in mass flow and pressure around these steady state values. Based on typical system behaviour, instantaneous flow variations of up to ±10% can be expected. As a result, when the ejector only architecture is shown to just meet the required anode stoichiometric ratio (e.g. ~1.4) at steady state, it is likely that, in practice, the system will periodically operate below this stoichiometric requirement. Targeting the stoichiometric ratio exactly therefore risks short duration anode starvation events and reduces operating robustness. The hybrid ejector + HRP architecture provides additional margin at low current density, mitigating the impact of these transient fluctuations and enabling more stable and controlled operation under real world conditions. The ejector + HRP therefore not only allows us to operate safely at the 0.1A/cm² current density, but also vastly increases the safety margin and robustness at the subsequent conditions up to 0.7A/cm².

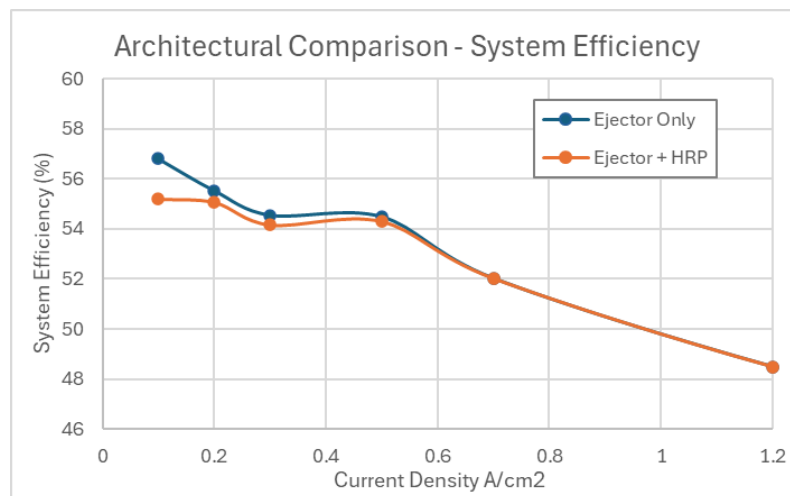


Figure 7: Ejector Vs Ejector + HRP – System Efficiency Comparison

Finally, the results in Figure 7 show that overall system efficiency is not strongly influenced by the inclusion of the HRP across the operating range, with a maximum difference of approximately 1.6% at 0.1 A/cm², reducing to a negligible level at higher current densities. As stated previously, the HRP was not expected to improve fuel efficiency, as the primary hydrogen flow rate was fixed and hydrogen utilisation was therefore unchanged. Purge behaviour was also held constant between the two architectures. Although the inclusion of the HRP introduces an additional parasitic load, its magnitude is not sufficient to cause a meaningful reduction in overall system efficiency.

The primary benefit of the HRP configuration therefore lies not in efficiency improvement, but in enhanced operability and robustness at low current density operating conditions.

6.1.1 Ejector + HRP Contribution to Entertainment and Secondary Flow

In WP5.1, the results indicate that at low current densities the ejector is unable to entrain sufficient secondary flow independently. However, this should not be interpreted as the hydrogen recirculation pump entraining flow in place of the ejector. The HRP is not intended to assist ejector entrainment; rather, it removes the requirement for entrainment at low load by actively supplying the majority of the flow as secondary flow.

Effective ejector entrainment requires a sufficiently high primary-to-secondary pressure ratio (typically of order ~ 1.9 , geometry dependent), which the system struggles to achieve at lower current densities. In this operating region, the HRP provides the dominant contribution to anode recirculation, while the ejector operates outside its effective entrainment regime and behaves primarily as a passive flow path.

In comparison to WP5.1, WP5.2 further suggest that there is no distinct operating point at which the HRP functions entirely independently of the ejector however the HRP does dominate recirculation at 0.1 low current density, with ejector entrainment progressively increasing as load and available pressure ratio rise.

6.1.2 Overall Conclusion

The results therefore show that the HRP does not:

- Improve fuel efficiency
- Reduce hydrogen consumption
- Reduce purge significantly

The HRP does:

- Increase secondary circulation
- Raise anode pressure
- Increase Stoich ratio providing operational robustness
- Increase the operating range reliably

7 VG (Dual Geometry) Passive Ejector

7.1 Dual Ejector Concept

For hydrogen injector applications, passive concepts are more realistic, where geometry variation occurs without actuators or external power input [1]. Instead, performance adaptation is achieved through fixed or self-modulating geometric features. This significantly reduces system complexity, cost, and reliability risk as overviewed in WP5.1.

The dual geometry approach is well suited to hydrogen fuel cell systems, as the primary (large) ejector can cover the majority of the operating range, while a secondary (smaller) ejector is only required at a limited number of low current density operating points where the anode stoichiometric ratio is reduced. In contrast, a continuously actuated VG ejector introduces additional complexity and cost with limited performance benefit. This promotes the use of passive variable geometry ejectors and motivates the following candidate concepts for hydrogen applications, below.

7.2 Passive Ejector Types Suitable for Hydrogen

Single body dual inlet passive ejector

- A single body dual inlet passive ejector uses two differently sized primary inlets that activate with load to provide staged entrainment within a common mixing chamber. It switches between the 2 with pressure.

Variable Primary Nozzle – Needle / Pintle Type (Passive)

- A pressure or flow responsive needle alters the effective nozzle throat area, allowing passive adjustment of entrainment performance without powered actuation.

Multi-Nozzle (Staged) Passive Ejector

- A multi nozzle passive ejector incorporates several fixed primary nozzles of different effective sizes within a single body. As operating pressure and flow increase, additional nozzles become active, providing staged entrainment and extending the usable operating range without powered actuation.

7.3 Modelling Simplicity for Dual Ejectors

Regardless of the specific passive ejector concept selected, we can use a simplified modelling approach, within GT, when assessing the dual ejectors. Instead of interrogating the ejector geometry within the model from a single ejector to a suit a specific type of dual ejector, we can instead double up the number of ejectors on separate lines, with a control valve and assign each one its own geometry. This significantly reduces model size and complexity, while also improving numerical robustness. Should the preferred architecture be agreed, modelling of the specific ejector geometry can be addressed in later work (WP5.4) to support detailed design development and optimisation.

7.4 Passive VG Ejector research

After a deeper analysis between the different VG passive ejector types, that will also be covered in 5.4, the specific ejector we will compare in this report is the **Single body Dual Inlet Passive Ejector**. Given our previous awareness and simulation analysis of the ejector only, we will compare this in detail against the ejector + HRP design. As an analytical assessment of the dual-ejector configuration was not feasible, evaluation of the architecture relied on literature review and insights gained from the ejector-only analysis.

There are still challenges when designing the smaller ejector as part of a dual system. The nozzle diameter required to operate at the lower range would need to be around 1.5 mm. This small ejector size introduces increased manufacturing challenges and higher cost. However, even this ejector would struggle to achieve a stoichiometric ratio of ~ 2.5 at very low current densities of $0.1\text{--}0.3\text{ A/cm}^2$. This results in small, intricate geometries that can be costly, however, advances in additive manufacturing have made such designs more feasible.

Architecturally, single body dual ejector systems are preferred due to their passive operation and zero parasitic power.

The following section reflects and contrasts the main system requirements, which can be scored and help identify the optimal architecture for the project.

8 Comparative Assessment of Hydrogen Recirculation Architectures

This section compares the ejector + HRP and single body dual inlet passive ejector architectures at an architecture level. The concepts are first contrasted qualitatively against key criteria, then scored using a weighted matrix to enable a consistent comparison. The section concludes by identifying the preferred architecture based on overall performance, robustness, and integration trade-offs.

8.1 Assessment Criteria

Scalability

Ejector + HRP

Great Scalability - Pump speed control scales recirculation flow and compensates for high stack Δp . The same core architecture can be applied across different stack sizes and total system powers by adjusting pump capacity, with minimal changes overall. Likely just to the volute and wheel.

Single body dual inlet passive ejector

Moderate Scalability - Passive ejectors scale poorly once you exceed a certain size. Roughly $\pm 30\%$ change in mass flow. Geometry must be re-optimised as stack power, pressure ratio, or flow range changes. [2]

Low current density Capability

Ejector + HRP

Wide range & precise Stoich control - As proven in GT model we know the recirculation pump can accommodate the full range, its wide speed and pressure rise ability means it can cover the 0.1 – 0.7 A/cm² range and progressively targets the desire stack flow and pressure increase.

Single body dual inlet passive ejector

Narrower Stoich Range – Though the ejector can be made smaller, even small ejectors can fail to entrain at current densities below 0.3 A/cm². No active control variable; operation is fully dictated by stack conditions. Because current density does not scale for the different stack powers, this is a limitation in all applications.

Controllable to variation - More reliable transient response and cold/low-humidity operation.

Low Controllability - Sensitive to humidity, temperature, stack degradation, and manufacturing tolerances.

Reliability and Durability

Ejector + HRP

Reliability - Bearings, seals, and rotating elements introduce wear mechanisms and lifetime limits. Increase management.

Single body dual inlet passive ejector

High Reliability – no moving parts or wear mechanisms or seals involved. Very attractive for long life applications.

Complexity - Additional controls, sensors, and failure modes increase BoP complexity.

Cost

Ejector + HRP

High BoM Cost – hydrogen compatible materials, seals, bearings, including a motor and sensors. Around 50 – 70% more expensive than a dual ejector. Estimate cost €1500 to €2000 in volume.

High Integration - There are tight hydrogen leakage requirements.

Moderate for Validation – System level validation can be moderate but its is predictable because stoich is actively controlled.

Single body dual inlet passive ejector

Low BoM Cost – Though the dual inlet ejector is most costly then a single ejector, due to its added complication and small geometric sizes, it is much cheaper than the HRP. Estimate cost €150 to €300 in volume.

Low Integration – Requires only mechanical integration into the anode loop.

High Validation – Extensive CFD and test iteration required. Could be reduced with the Predictive Ejector model.

Package and Weight

Ejector + HRP

Large Package footprint - pump, motor, inverter, mounts, and additional pipework. Also requires electrical routing, service access.

High mass – The pump mass is estimated at approximately 6.0 kg, with only minimal additional local pipework required where it is integrated into the existing secondary recirculation flow.

Single body dual inlet passive ejector

Very compact - Single integrated component, negligible compared to single ejector.

Very low mass – Negligible additional weight

8.2 Conclusions

8.2.1 Scaling factors

Scalability (1.2): When considering the specific scaling range up to 700 kW and 1050 kW, picking one architecture for all shows highly beneficial for the project, this allows cost saving and reduced complexity when increasing the amount of stacks.

Low Load Capability (1.0): Though important the separate Reliability & Durability increases the weighting in this area.

Package and weight (0.8): Though weight can be more important for the airplane applications, package and weight is overall not as important as the other criteria.

8.2.2 Final Ranking

	Ejector only	Ejector + HRP hybrid	Single Body Dual Inlet ejector	Scaling factor
Fuel Efficiency	4	3	4	1
Operating range	2	5	4	1
Scalability	2	5	3	1.2
Low Load Capability	1	5	3	1
Reliability & durability	5	3	4	1
Cost	5	2	4	1
Package & Weight	5	2	4	0.8
Risk & Failure modes	2	4	3	1
Score	25.4	29.6	28.8	

Figure 8: Final scoring for the recirculation architectures for the BoP applications.

Though the scoring is very close between the top 2 architectures, the HRP + ejector architecture offers superior low load stoichiometric robustness, while the single body dual inlet passive ejector provides a lower cost, low complexity solution with reduced control authority at very low current density.

The architectural preference ultimately depends on whether system priorities favour the guarantee of low load operability or reduced cost, mass, and integration complexity. The scoring presented reflects a cross-application assessment. While preferences may vary between individual applications, a single architecture must be selected to support manufacturing efficiency and scalability, and therefore the evaluation has been applied generically across all cases.

Ideally, the smaller ejector within the dual ejector system would have been investigated in more detail to better define its low load operating range. However, findings from the literature support prior expectations, indicating that the smaller ejector would still struggle to maintain the required anode stoichiometric ratio at low current densities. Given the emphasis of this project on robust low current density operation, the HRP based solution was therefore selected as the preferred option.

9 Predictive Ejector Modelling Approach

9.1 Predictive Ejector Model for Architectural Comparison

Traditional passive ejector assessment typically relies on single-point sizing at a selected operating condition, often mid to high load. While appropriate for component procurement, this approach introduces sensitivity to the chosen design point and geometry when applied across a wide operating envelope. For system level architectural comparison, this can bias conclusions, as fixed geometry ejectors are forced to operate outside their design point and performance reflects geometry choice rather than architectural capability. This effect was, however, minimized by explicitly defining the operating regions where ejector only operation is feasible and where additional recirculation support is required, in Deliverable 5.1.

A predictive model:

- Applies a consistent ejector capability model across all architectures,
- Uses identical system boundary conditions for all concepts,
- Evaluates how ejector performance varies across the operating range rather than at a single design point.

9.2 Predictive Ejector Model for Ejector Sizing

A predictive modelling approach is more appropriate than a single point approach, as it supports ejector sizing by accounting for performance and efficiency across the full operating range.

Specific benefits:

- Support robust ejector sizing by identifying geometries that maximise operating range coverage, rather than optimising around a single design point.
- Reduce reliance on empirical or experience-based judgement when attempting to extend ejector performance beyond nominal conditions.
- Compare idealised ejector capability against specific ejector designs across multiple applications and architectures without requiring bespoke ejector designs for each case.
- Efficiently assess ejector feasibility across different stack sizes or power nodes using a consistent, boundary-condition-driven methodology, improving reuse and scalability.

This capability can also address limitations where 2023 GT-Power model restricted the ability to evaluate smaller ejector concepts.

9.3 Conclusion

While the predictive ejector modelling approach represents a more robust tool for architecture comparisons, the GT Power modelling approach applied in this deliverable was considered appropriate for the objectives of WP5.2. Development of the predictive ejector model was initiated within WP5.2; however, full implementation was not completed within the available scope. As a result, the architectural comparisons presented here are based on single-point selected ejectors, consistent with the 2023 GT Power modelling approach.

Subject to scope and resource availability, the predictive ejector modelling framework could be further developed in WP5.3 and subsequently applied to ejector sizing activities in WP5.4, but consideration as to what level of improvement it can have will have to be assessed.

10 Scaling the Model in WP5.3

WP5.3 will focus on scaling the model, extending the analysis from 350 kW and subsequently consider the changing parameters and the feasibility of scaling to 700 and 1050 kW. Though comparison of the 150 kW stack is appropriate for the architectural comparison, Task WP5.3 is required to understand how sensitive the system is to scaling. This includes the impact of increased absolute hydrogen mass flow on pressure losses, HRP operating points, efficiency etc. Scaling offers challenges because trend-based assessments are made to make assumptions rather than more absolute calibrated models.

11 References

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