



FERRET

A FLEXIBLE NATURAL GAS MEMBRANE REFORMER FOR M-CHP APPLICATIONS

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Public report on production costs and scale up of the membrane production

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1. EXECUTIVE SUMMARY

1.1. Description of the deliverable content and purpose

This deliverable reports the cost analysis of membrane production at lab-scale and semi-industrial scale of three types of thin film (<10 µm thick) membranes: ceramic supported Pd-Ag membranes, ceramic supported Pd-Ag-Au membranes and ceramic supported double skinned membranes. In addition, metallic supported Pd-Ag membranes have been also considered for the semi-industrial scale production cost analysis.

2. Analysis of production costs of the membranes developed in FERRET project

The production cost analysis was carried out for lab-scale and semi-industrial scale membrane production. Three different types of membranes have been considered:

- Thin-film Pd-Ag membranes deposited on porous ceramic supports
- Thin-film Pd-Ag-Au membranes deposited on porous ceramic supports
- Double-skinned Pd-based membranes deposited on porous ceramic supports.

In addition, metallic supported thin Pd-Ag membranes have been also considered for the semi-industrial scale production cost analysis.

The concepts considered in the cost analysis are: supports (that includes the cost for porous supports and the sealing), the selective layer material and the production cost (that includes the costs for the personnel and electricity consumption).

2.1. Lab-scale production

The lab-scale production costs have been defined considering the optimized production procedures a lab-scale. The main assumptions considered for the lab-scale production cost analysis are the following:

- Plating of 1 membrane per batch.
- 20 cm long effective membrane after sealing.
- Pd-Ag and Pd-Ag-Au layers coated by electroless plating (ELP).
- Swagelok connectors.
- Personnel cost.
- Electricity cost.

The results of the production cost analysis for the lab-scale production of the three types of membranes are presented in Table 1 and Figure 1.

Table 1. Cost analysis of the lab-scale membranes production.

	Ceramic supported Pd-Ag membrane		Ceramic supported Pd-Ag-Au membrane		Ceramic supported Double-skinned membrane	
	€/m ²	%	€/m ²	%	€/m ²	%
Support (including connections)	14,280	42.1	14,280	36.1	14,280	50.6
Selective membrane layer	8,020	23.7	10,350	26.1	4,100	14.5
Production (personnel cost and electricity cost)	11,600	34.2	14,970	37.8	9,820	34.8
TOTAL (€/m²)	33,900	100.0	39,600	100.0	28,200	100.0

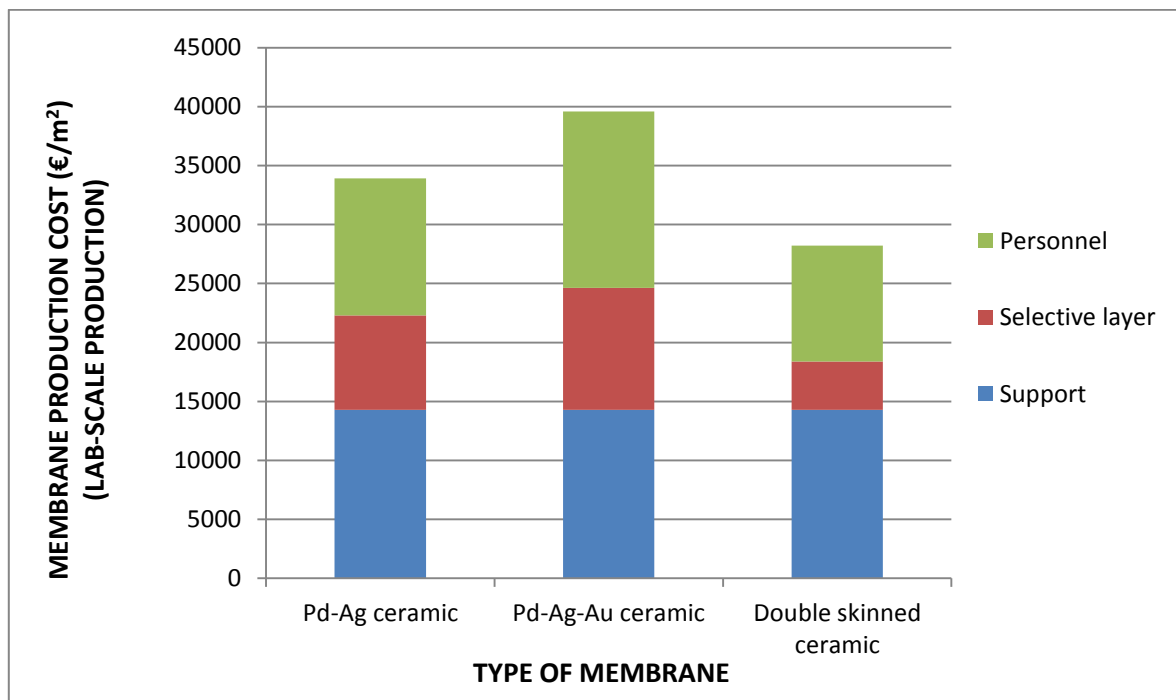


Figure 1. Cost analysis of the lab-scale membranes production.

The cost per square meter of membranes is between 28,000 and 40,000 Euro. The lowest cost have been obtained with the double skinned Pd-based membrane (28,200 €/m²) and the highest cost (39,600 €/m²) with the Pd-Ag-Au based membrane. On the other side, the cost of the Pd-Ag membrane is around 33,900 €/m².

Except for the Pd-Ag-Au membrane that has a support cost ratio contribution of 36.1% (similar to its production cost ratio contribution: 37.8%), the main contribution to the total cost for the other membranes is related to the support (ceramic support plus sealing connections). It is around 42.1% and 50.6% of the total cost for the Pd-Ag and double skinned membranes, respectively. This high contribution to the total cost is mainly due to the high cost of the tubular support when small quantities are ordered. On the other hand, the production cost ratio for the Pd-Ag and double skinned membranes are similar (34.2% and 34.8% for the Pd-Ag and double skinned membranes, respectively), being slightly higher for the Pd-Ag-Au membranes (37.8%). Finally, the lowest contribution to the total cost for all the membranes comes from the selective layer. It is around 23.7%, 26.1% and 14.5% of the total cost for the Pd-Ag, Pd-Ag-Au and double skinned membranes, respectively. As expected, the lowest contribution is found in the double skinned membrane.

2.2. Semi-industrial scale

The main assumptions considered for the semi-industrial scale production cost analysis are detailed hereafter. In this analysis, the metallic supported thin Pd-Ag membranes have been also included.

- Plating of 64 membranes per batch.
- 40 cm long effective membrane after sealing.
- Pd-Ag and Pd-Ag-Au layers coated by electroless plating (ELP) with the same thickness and composition as in the lab-scale.
- Swagelok connectors.
- Personnel cost.

- Electricity cost

The results of the production cost analysis for the semi-industrial scale production of the four types of membranes are presented in Table 2 and Figure 2.

Table 2. Cost analysis of the semi-industrial scale membranes production.

	Ceramic supported Pd-Ag membrane		Metallic supported Pd-Ag membrane		Ceramic supported Pd-Ag-Au membrane		Ceramic supported Double-skinned membrane	
	€/m ²	%	€/m ²	%	€/m ²	%	€/m ²	%
Support	2,000	29.4	6,350	62.3	2,000	25.3	2,000	35.1
Selective membrane layer	3,000	44.1	2,400	23.5	3,775	47.8	1,550	27.2
Production	1,800	26.5	1,450	14.2	2,125	26.9	2,150	37.7
TOTAL (€/m²)	6,800	100.0	10,200	100.0	7,900	100.0	5,700	100.0

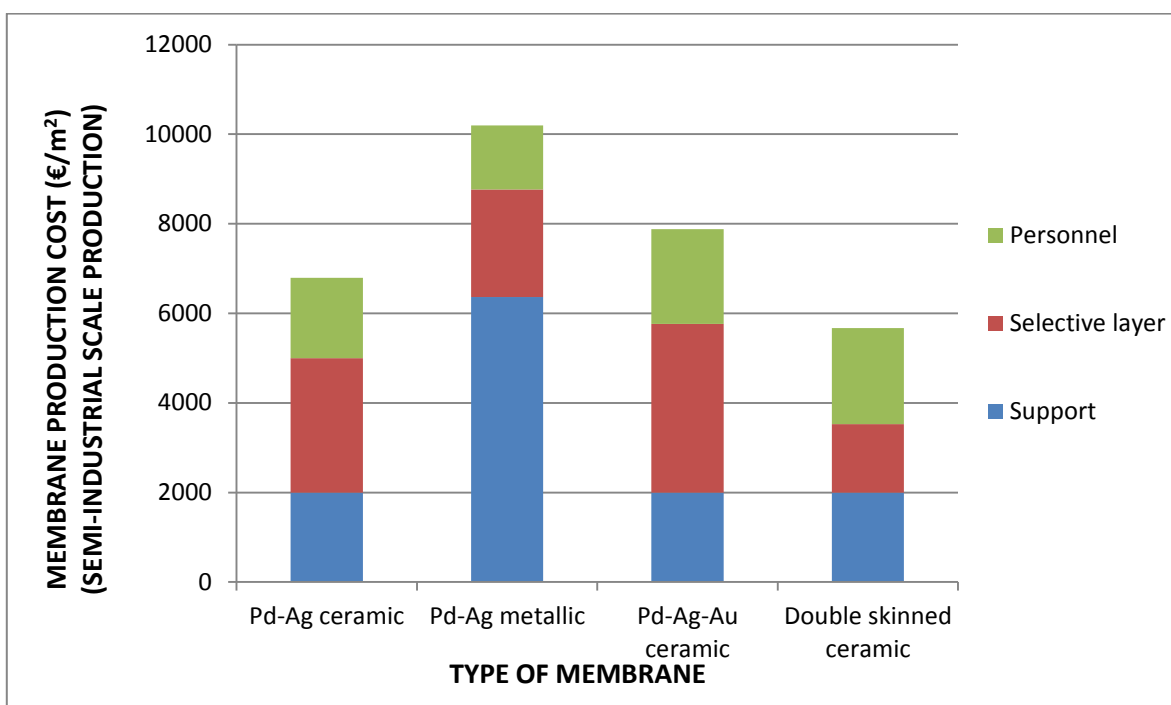


Figure 2. Cost analysis of the semi-industrial scale membranes production.

The cost per square meter of membranes onto ceramic support is between 5,700 and 7,900 Euro. The lowest cost have been obtained on the double skinned Pd-based membrane (5,700 €/m²) and the highest cost (7,900 €/m²) on the Pd-Ag-Au based membranes. On the other side, the cost of the Pd-Ag membrane is around 6,800 €/m². The semi-industrial membrane production reduces the cost to around 20% of the lab scale cost. It is around 20.06%, 19.95% and 20.21% for the Pd-Ag, Pd-Ag-Au and double skinned membranes, respectively.

For the Pd-Ag and Pd-Ag-Au ceramic supported membranes, the main contribution to the total cost is now related to the selective layer material cost, with a cost ratio of around 44.1% and 47.8%, respectively. On the other side, the cost ratio of the supports and the production are similar for these two

types of membranes: i) 29.4% and 26.5% for the Pd-Ag membranes and ii) 25.3% and 26.9% for the Pd-Ag-Au membranes.

For the double skinned membranes, the lowest contribution to the total cost is still related to the selective layer with a cost ratio of around 27.2%. In addition, the double skinned membrane shows similar cost ratio contribution for the supports and production, with a cost ratio of around 35.1% and 37.7%, respectively.

When using metallic supports the cost per square meter of membrane is 10,200 Euro. This means an increase of around 50% of the total cost calculated when using ceramic supports. The main contribution to this cost is related to the supports. While the costs of the selective layer and production decrease, the cost of the supports shows an increase of more than 300% of the cost calculated when using ceramic supports.

3. Conclusions

A cost analysis of the lab-scale and semi-industrial scale production of Pd-based supported membranes has been performed, and reported in this deliverable. Main conclusions of this analysis are the following:

- Semi-industrial production can reduce the cost to around 20% of the lab-scale production costs.
- The cost of the membranes onto ceramic support in semi-industrial production is between 5,700 €/m² and 7,900 €/m². Lowest cost is obtained when producing double skinned membranes (5,700 €/m²).
- The main contribution to the total cost under semi-industrial production is related to the selective layer material cost when manufacturing Pd-Ag and Pd-Ag-Au membranes onto ceramic support. In the case of the double skinned membranes, the selective layer material cost is the lowest contribution to the total cost under semi-industrial production.
- The semi-industrial production cost of the Pd-Ag membranes onto metallic supports is 10,200 €/m², 50% higher than the cost of the Pd-Ag membranes onto ceramic supports.
- The main contribution to the total cost under semi-industrial production of membranes onto metallic support is related to the cost of the support.