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Technical Report

FEL Methodology for Stationary Domestic Electrical Service: PEMFC Technology, Costs and Risk Analysis

C. M. Bautista-Rodríguez[1,*], *M. G. A Rosas-Paleta*[1], *N. Tepale-Ochoa*[2], *D. Sánchez-Grijalva*[1].

[1] Alter-Energías Grupo. Tepetitlán No. 63, Col. Lomas del Sur. CP 72470 Puebla, Puebla.
[2] BUAP. Facultad de Ingeniería Química. Av. San Claudio y 18 Sur - CU. CP. 72590 Puebla, Puebla.
[*]E-mail: celso.bautista@thyssenkrupp.com

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The PEMFC technology is considered as an applicable technology to portable and transportable services; however its application in stationary service has been widely questioned as a viable proposition. This paper develops a FEL study type 1 for a domestic electrical service design. 3 PEMFC prototypes were scaled and compared to supply a stationary domestic electrical service. The integrated method was applied to determine the cost of the technology and the total investment cost +/- 50% at 20 years of useful life for each prototype. Operating costs were estimated considering the consumption of hydrogen from a material balance. It was also developed a cost estimate for electrical production in each case. Finally, a simple method for a risk analyze was developed for this conceptual project. The results show the effect of the cost of materials selected for PEMFC assembly on investment costs and operating costs. This effect is also observed on the production cost when cathodic pressure is applied below 10 psi; however at higher pressures the production cost is influenced by the combination between efficiency of PEMFC assembly and its materials cost. The electrical production costs obtained by PEMFC technology are close at sold price in some regions on the world. This result permits to considerate the PEMFC application in stationary service at medium or long time; however the result of the risk analysis prevents its development by using experimental prototypes.

Keywords: PEMFC: FEL Study, Investment Costs, Operating Costs, Production Costs

1. INTRODUCTION

In the first decade of the third millennium, the operating environment of the so-called black gold has been developed between economic fluctuations, marketing and distribution, as well as environmental disasters (offshore oil spills), global economic crises, energetic crises, social conflicts and even war. Simultaneously, climate change and various environmental problems are related to the generation and consumption of energy. Specially in those places where the combustion of oil resources is not the only method of transformation of energy. In fact, it means the 80% of global energy consumption. Moreover, the commercialization of new clean energy technologies also known as "environmentally friendly" is based on technical and economic competitiveness against conventional technologies. New technologies should prove to be more profitable before entering to technological markets of different societies in the world.

Some of the benefits of the PEMFC are: zero pollutant emissions when using hydrogen as fuel, at the same time it has a silent operation which means a reduction in noise pollution. It also presents a possible link with renewable energy sources like solar or wind power. Some purely technical limitations are still the subject of studies for the application of PEMFC technology. For example, the water management, product of the overall reaction from the active layer of the cathode electrode that is ejected through the stack. Another technical limitation is the materials resistance to corrosion avoiding a reduction in the electrical conductivity of them. Other limitations of PEMFC technology are economics, like the high cost of materials such as catalysts, which are comprised of materials such as platinum, ruthenium, gold, etc. On average, the cost of metals used for electrodes in fuel cells represents approximately 55% of the total cost, which is higher than the cost of any other component such as bipolar plate which represents just the 10%. The gas diffusion layer represents 10% while the polymer membrane represents 7%. Its structural complexity and production are the main causes of its high cost, which amounts to 0.42 USD/cm2 (0.28 Euro/cm2) for Nafion 112 in the first half of 2010 [5-8]. A study of PEM fuel cells have reported in 2007, a fluctuated price in the range of 10,000 to 100,000 Euros / kW for retail sales [1 – 8].

Researchers from the Institute of Quebec (Canada) have published the development of electrode material consisting of iron, nitrogen and carbon (the same elements that make up our hemoglobin) capable of generating an electric current similar to that produced by materials based in platinum. The material and manufacturing cost of the polar plates account for 60% of the total cost of fuel cell. Another important feature is the cost associated to the active area to be used by the Membrane - Electrode – Assembly (MEA). There is an important advance in this direction that the company Nisshinbo Industries in Japan has achieved by making a carbon alloy produced by high current. It has high resistance to corrosion. The cost of this new electrode material is about one sixth of the cost of a conventional platinum electrode. Studies on the amount of platinum electrode show the reduction from 100 to 10 times the load of platinum in the electrodes by using nano-crystalline particles supported on a high specific carbon area and impregnated on an active layer between the electrode and electrolyte conduction proton. Another important cost that PEMFC technology provides is the polymer membrane used as electrolyte, which has the characteristic of being conductive. Its main function is to transport protons generated at the anode to the cathode electrode and prevent the passage of electrons which would develop a short circuit. The structural complexity and production are the main causes of its high cost, which amounts to 0.42 U.S. $ / cm2 (0.28 Euro/cm2) for Nafion 112 in the first half of 2010 [1-8]

The durability of the materials applied to the PEMFC is also an important issue to address, especially when you compare the cost of electricity generated by PEM fuel cells with that generated by conventional methods, such as power plants that use fossil fuels and batteries. Hung Yue reported in 2005 that the PEMFC must reduce its costs by at least five times in order to compete with conventional generators. Moreover, the USA Department of Energy reported in 1995 the cost of electricity at 7.00 USD/Giga Joule (GJ). The estimated price for large plants and the natural gas cost 2.30 USD/GJ the same year. On the other hand, the hydrogen production by electrolysis using hydroelectricity during the same time was reported between 10.00 and 20.00 USD/GJ. The cost of hydrogen is expected to be reduced in the near future through the investigation of public and private institutions focus onits production and storage. Centralized plants that produce hydrogen from natural gas or coal and store it in a compressed form currently charge about 2 USD/kg. Moreover, 1 Kg of H2 is roughly equivalent to the energy of 3.78 L of gasoline, which cost was established during this study (2010) in 1.12 USD/L. Another study estimates the cost of hydrogen for 2030 at 6.2 USD/GJ [9-12].

In a last study [13], the authors have proposed a PEMFC conventional structural design, comprising gas distribution plates with serpentine channels, Nafion membrane and commercial electrodes. In subsequent studies, we presented the results from an innovative structural design, consisting of the application of a porous gas distributor combining commercial and experimental electrodes. Both PEMFC designs were operated with wet and dry reagents [14-15]. Recently, it was reported a technical study comparing the 3 aforementioned structural designs PEMFC at similar operating conditions [16]. This paper presents the results on a FEL 1 cost study [17] having base on the technical comparison presented, the PEMFC prototypes were scaled to obtain the tension required in a stationary domestic service. Technologies costs have been estimated by using the real cost of PEMFC elements and construction costs by typical index. Later, operating costs were estimated to obtain unit costs for electricity production. Finally these were compared to the cost of energy determined for domestic services in 2010 for Mexico and USA.

2. METHODOLOGY

A front end loading (FEL) is the third stage of a capital project process (CPP). This is the best practice to develop a project scope definition on improved project performance. Historically, the capital project process has been totally driven by the technological owner, however to be successful on Engineering and Construction you must have a definitive capital project process. A FEL I study comprise three sections: i) the costs of technology, ii) construction costs, and iii) study of economic risks [17]. The following criteria were established as a design basis to develop 3 different PEMFC technologies for application on: 1) stationary domestic service at: 140 kW-h and 120 V, 2) life time: 20 years, 3) PEMFC reagents: H_2-Air.

2.1 PEMFC prototypes for design

Typical Design:

The first membrane-electrode assembly (MEA) for the technical comparison (called E1), comprise two polar plates machined with serpentine channels, commercial electrodes (E-Tek) and

Nafion membrane as the electrolyte, its technical and experimental details was reported in the literature [13].

New Designs:

The second structural design (called E2) includes two polar plates with serpentine channels, graphite paper (Toray paper TGPH-090) as a diffusive media and a catalytic coating membrane assembly (CCMA).

The third structural design (called E3) uses a porous medium in recycled graphite as a distribution media for the reactive gases with graphite paper (Toray paper TGPH-090) as a diffusive media and a CCMA as a membrane - electrode system. Technical and experimental details were reported in the literature [14-15]. Table 1 presents the PEMFC structural design considered in this paper.

Table 1. PEMFC characteristics for the study

	E1	E2	E3
Gas Distributors	Polar Plates with Channels	Polar Plates with Channels	Porous Graphite Plate
MEA type	E-tek - Nafion	CCMA	CCMA
Nafion Membrane	115	112	112

2.2 Conditions and Experimental Data

The characterization for the PEMFC designs was conducted in a test bench "Fuel Cell Test System Globe Tech Compu-Cell GT-890-B". The experimental conditions imposed on the PEMFC for the characterization of PEMFC prototypes are shown in Table 2. More details were reported in the literature [13-15].

Table 2. Operating Conditions

Variables (units)	Anode	Cathode
Gas Flow (cc/min)	50	50
Pressure (Psi)	5	5,10,15
Humidification Temperature (°C)	35	35
Cell Temperature (°C)	Ambient	Ambient

2.3 FEL I Methodology

The technology cost was estimated by using an integrated method, similar at the presented in references [23]. This comprises; i) the PEMFC system cost and ii) the peripheral equipment cost such as hydrogen storage system, air blower, and current transformer DC / AC. The PEMFC system cost was the result of a summarized cost for each stack bank prototype and its peripheral equipments. Here, the number of bipolar cells per stack and the number of stacks required for stationary design was estimated from the electrical power developed by each PEMFC prototype (see Table 3) at the operating conditions reported [13-15]. The stack costs includes; costs of commercial materials such as Nafion membrane and electrodes E-tek, also local direct costs such as the amount of raw materials for the manufacture of CCMA, bipolar plates (material and manufacturing) or distribution plates, metal supports, joints, electrical connections. All costs are updated to May 2010.

The +/- 50% Total Investment Cost (TIC) was estimated using factors reported by the U.S. Department of Energy in November 2010 which includes cost estimates for fuel-cell systems [24]. Other parameters considered were instrumentation costs, construction costs, indirect costs, engineering costs and management costs.

Operating costs included in this study were: maintenance costs and costs of hydrogen consumption as raw material, where the consumption of hydrogen and oxygen (from air) was estimated by a material balance in each case. Energy costs were omitted for obvious reasons; also the man power cost was omitted because the PEMFC design has been considered as a fully automated system. Cost factors were those recommended by the references [24-25].

Finally, a risk analyze for a project comprises a review of many issues as: legal and environmental normatively, market conditions, organization, management, taxes, technical risks, economical risk, logistics, credits and others. However, a simple risk analyze was developed, presented and discussed for this FEL I project, this comprises the main issues for this project stage.

4. RESULTS AND DISCUSSION

The technical discussion of structural designs PEMFC compared in this study has been presented in a previous work [16]. Figure 1 shows a comparative graph of the maximum power developed by each of the PEMFC assemblies at cathodic pressure levels applied, maintaining a fixed pressure equivalent to 5 psi at the anode. In the case of E1, an output maximum power by the PEMFC is observed around 10 psi of cathodic pressure.

The developed power by E2 on Figure 1 shows a linear increase in power as a function of the cathodic pressure applied without observing a maximum within this range and the authors suppose that maximum power may be located at pressure levels greater than 15 psi. In the case of E3, there was a slight increase in maximum power output between 5 and 10 psi cathode, however it is observed a sudden increase of power at 15 psi, but this does not exceed the power level reached by E2, only it is approximated.

This behavior supposes a maximum power at values greater than 15 psi applied in the cathodic compartment, considering that the level of pressure has a direct and significant effect on the power developed by the PEMFC, according to the Nernst law.

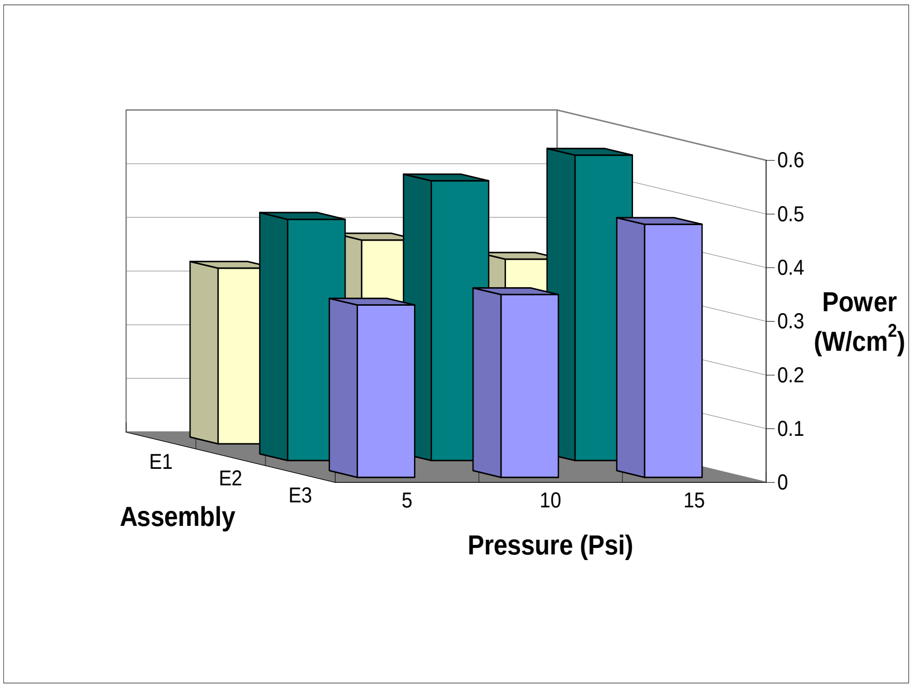

Figure 1. Power developed by PEMFC prototypes at different cathodic pressures.

On the other hand, Table 3 summarizes the electrical characteristics developed by the PEMFC prototypes designed, also it is presented the estimated number of stacks required to supply a stationary domestic service (140 kW-h at 120V) and the end the table shows the normalized total cost by stacks at the cathodic pressure level applied during testing.

Table 3. Electric characteristics and normalized costs for PEMFC technologies

	Cathodic Pressure Level Applied								
VARIABLES	5 psi			10 psi			15 psi		
MEA type	E1	E2	E3	E1	E2	E3	E1	E2	E3
Voltage at Maximum Power (V)	0.76	0.98	0.84	0.88	1.11	0.93	0.81	1.19	1.09
Current at Maximum Power (A)	0.63	1.80	1.61	0.75	2.08	1.70	0.68	2.27	2.36
Power (W)	0.48	1.76	1.36	0.67	2.31	1.58	0.56	2.72	2.58
Stacks Number for Design	159	122	142	137	108	129	148	100	110
Normalized Cost by Stack	1.76	1.18	0.56	1.52	0.88	0.50	1.64	0.74	0.24

Table 3 shows that the number of stacks required by design is inversely proportional to the voltage in the maximum power developed by each PEMFC type when operating at the same experimental conditions. Obviously, the number of MEA required by design will also be inversely proportional to the power developed by the type of assembly. It is noteworthy that the electrical and electrochemical characteristics developed by the PEMFC in operation depend on the physical, chemical and electrochemical of each of the constituent materials. Additionally, these features are associated with a cost, which varies depending on its manufacturing costs and commercial conditions (taxes, money exchange, etc) existing at a regional and international level.

Figure 2 shows a graph of the standard cost of PEMFC technology to study cathode operated pressure conditions in the experimental stage. It is noteworthy that the assembly 1 observes the higher costs for established design conditions. This is mainly due to the costs of commercial electrodes used and the cost of bipolar plates, and also its cost of manufacture (coil) several times higher compared to the cost of the material without machining. In the case of the assembly 2, the cost is significantly reduced due to: 1) the high functionality of this design, i.e., has a higher electrical output compared to other study designs [13-16]. In addition, 2) the cost of the electrodes is reduced by commercial and not only quantifies the cost of materials and workmanship, being necessary to mention that this assembly uses the same type of bipolar plates that in the previous case. Finally, the assembly 3 has the lowest costs of the whole; this is due to the low cost of materials with an efficiency PEMFC assembly lower than 2 and significantly higher than the assembly 1. The selection of materials and structural design applied together allow the results show, the main causes: 1) bipolar plates reduce manufacturing cost significantly, not applied in coil design as a distributor of reactive gases, but applied in this porous plate as a means of distribution of reagents 2) The electrode is experimental and only quantifies the cost of materials. Finally, the E3 MEA has a singular behavior, this prototype has the lowest costs of the group, and this is due to the low cost of materials, however its performance is not the best.

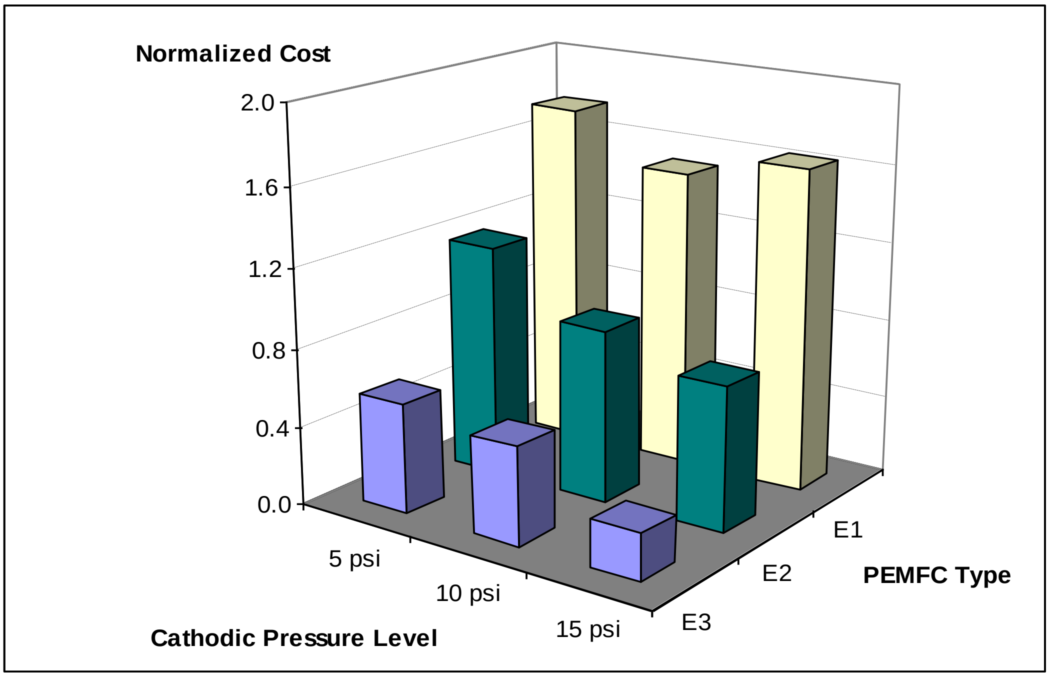

Figure 2. Normalized costs for the designed PEMFC stacks in a domestic stationary service at 140 kW-h and 120 V

Figure 3 shows the percentage cost per element for each PEMFC type, where this value is represented in terms of total cost per stack. For E1 MEA, the Figure 3.a shows almost 60% of the total cost is attributed to the E-tek electrode and over 30% at the bipolar plates (manufactured channels serpentine) while Nafion membrane is only slightly less than 5%. Moreover, experimental electrodes used in E2 show a significant reduction in cost (see Figure 3.b) to just over 10% of the total cost per stack, which increases to almost 75% the cost of bipolar plates being these the same type used in E1. Figure 3.c shows the percentage cost for E3. This graph shows a greater distribution of costs between the basic elements of the PEMFC. This is attributed to significant cost reduction on the electrodes and polar plates because these elements are experimental type, except for the Nafion membrane brand owned by Du Pont ® with 27% of total cost per stack. On the other hand, the distribution of this prototype was made using two elements, the gas diffusers and the bipolar plates. Both elements represent just over 30% of the total cost per stack while the bipolar plates of the above cases reach values of 60% or more.

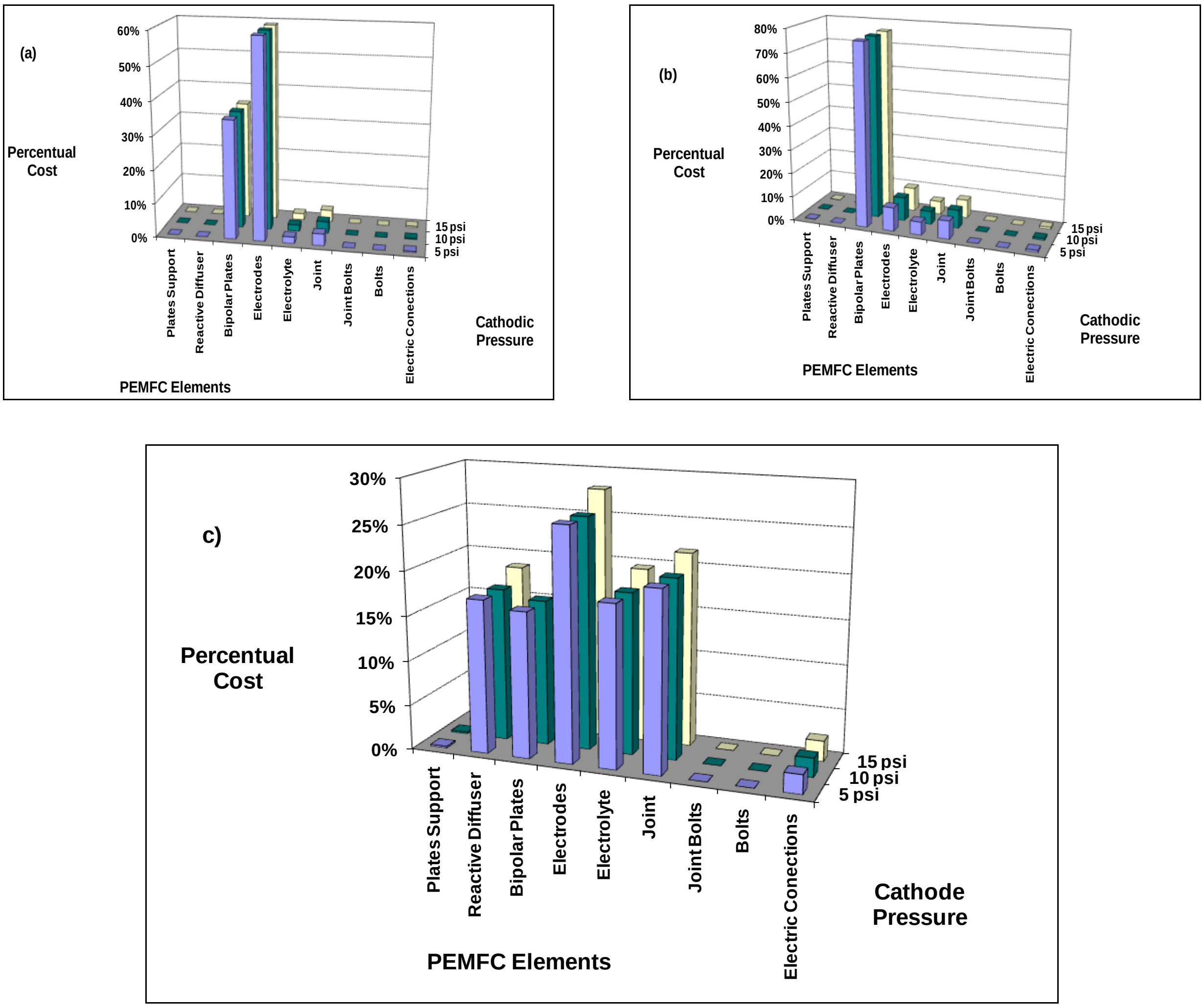

Figure 3. Percent costs for PEMFC elements: a)E1, b) E2, and c) E3 at experimental pressure conditions.

Moreover, the effects of the variation in the cathodic pressure applied during the PEMFC operation don't seem to be significant in the estimated costs for assembly type 1 and 2. This is being attributable to a low variability in the cell number required by the PEMFC stack for each design at the applied cathodic pressure. However, the cell number required for the E3 prototype stack show to be slightly sensitive at the applied cathodic pressure. In this case, the percentage of the element costs is significantly lower for cathodic pressures equivalent to 10 psi. In previous works [13-16] has been presented evidence of a significant change in the PEMFC functional processes, when it is applied a cathodic pressure equivalent to 10 psi. This change is attributed to a higher concentration of oxygen received by the active sites in the active layer of electrode, consequently the number and rate of reaction increases, thus increasing the efficiency and power developed by the PEMFC. However, the percentage cost for the cell number required by the stack when 15 psi is applied in the cathode compartment, is close to those required to 5 psi.

The stack number required by PEMFC design is presented in Figure 4, where E2 have the smaller stack number required for its high efficiency, followed by E3 and E1. This last is presented as the PEMFC technology with the lower efficiency (electric power) and the greater number of stacks to meet the demand of design.

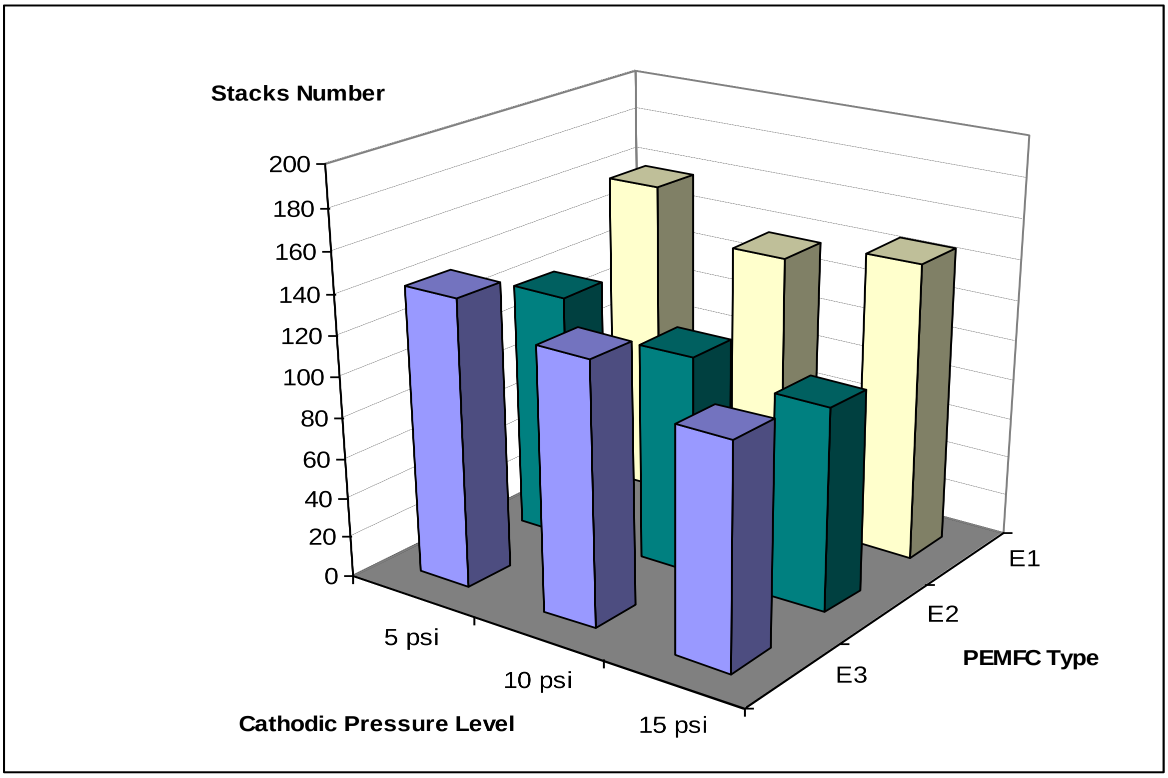

Figure 4. Stack number required by design for PEMFC prototypes

On the other hand, an inverse effect on the behavior of the electrical power generated by PEMFC prototype is observed on the stack number required by design and consequentially on the

PEMFC cost (see Figure 1). This behavior can be attributed to nature of PEMFC elements, cell performance and stack performance to finally determine the unit cost of the PEMFC designed. In other words, the power generated by the PEMFC design will depend on the efficiency of each element used. This performance determines the stack number and cell number required by design. It is associated with the individual nature and cost of materials and also defines the total cost of the PEMFC unity.

The TIC for each PEMFC prototype was estimated using an integrated method in which costs are deferred cost of auxiliary equipment for PEMFC technology. Additionally, direct and indirect costs are also deferred and specialized indexes. They are updated and applied according with references [24-25]. In this work, the costs are presented as normalized values for comparison. Table 4 presents the total investment cost for a PEMFC unit using E1 prototype at 5 psi in the cathodic compartment where it is observed that the costs of ancillary equipment can be considered negligible compared to PEMFC technology costs.

Table 4. Total Investment Cost ± 50% for PEMFC Unit using E1 prototype.

MEA Type E1 at 5 psi of Cathodic Pressure					
	Index Costs		Costs		
CONCEPT	Auxiliary Equipment (%)	PEMFC Unit (%)	Auxiliary Equipment (Normalized)	PEMF Unit (Normalized)	Integrated Costs (Normalized)
EQUIPMENT	100.0	100.0	0.00800	1.76000	1.76800
MATERIALS	36.0	5.3	0.00288	0.09328	0.09616
CONSTRUCTION	5.1	3.4	0.00041	0.06301	0.06342
INDIRECT COSTS	3.5	2.0	0.00028	0.03707	0.03735
ENGINEERING	4.0	3.5	0.00032	0.06486	0.06518
MANAGEMENT	0.4	0.4	0.00003	0.00741	0.00745
TOTAL	149.0	114.6	0.012	2.026	2.038

Table 5 presents the normalized total investment costs for each of the systems under study at the experimental conditions. This table shows the effect of material cost for PEMFC design on the engineering and construction concepts for the project, that are essential for this estimate. It is also observed a dependency between the MEA type (type of PEMFC materials) and the pressure level applied. Both parameters determine the efficiency of the design and partly the cost of the project. In general, the normalized values of the total investment cost for E3 is significantly lower compared to E1 and E2, however the lower TIC value is attributed to the E3 prototype at 15 psi and the maximum value from the table corresponds to E1 at the lower cathodic pressure operated (5 psi). Notable is the difference between the values of the above cases, reaching a magnitude of about 10 times between them.

Table 5. Normalized Total Investment Cost for a PEMFC System at 20 years

	MEA type E1			MEA type E2			MEA type E3		
CONCEPT	5 psi	10 psi	15 psi	5 psi	10 psi	15 psi	5 psi	10 psi	15 psi
EQUIPMENT	1.768	1.524	1.644	1.186	0.885	0.744	0.568	0.505	0.248
MATERIALS	0.096	0.083	0.090	0.065	0.049	0.042	0.030	0.029	0.016
CONSTRUCTION	0.063	0.055	0.059	0.043	0.032	0.027	0.020	0.018	0.009
INDIRECT COSTS	0.037	0.032	0.035	0.025	0.019	0.016	0.012	0.011	0.005
ENGINEERING	0.065	0.056	0.061	0.044	0.033	0.027	0.021	0.019	0.009
MANAGEMENT	0.007	0.006	0.007	0.005	0.004	0.003	0.002	0.002	0.001
TOTAL	2.038	1.756	1.895	1.368	1.021	0.859	0.653	0.584	0.288

Figure 5 shows objectively the impact of the material costs on the Normalized Total Investment Cost; note that the behavior of the columns in the graph is similar to the behavior in Figure 2. A second observation is not negligible; this is the reduction in TIC values in Figure 5 between MEA types within the cathodic pressure level applied, averaging 49% in all cases. However the difference is 67% between E3 - E2 at 15 psi of cathodic pressure. These values will undoubtedly have a strong impact on investment returns and probably on the costs of long-term production.

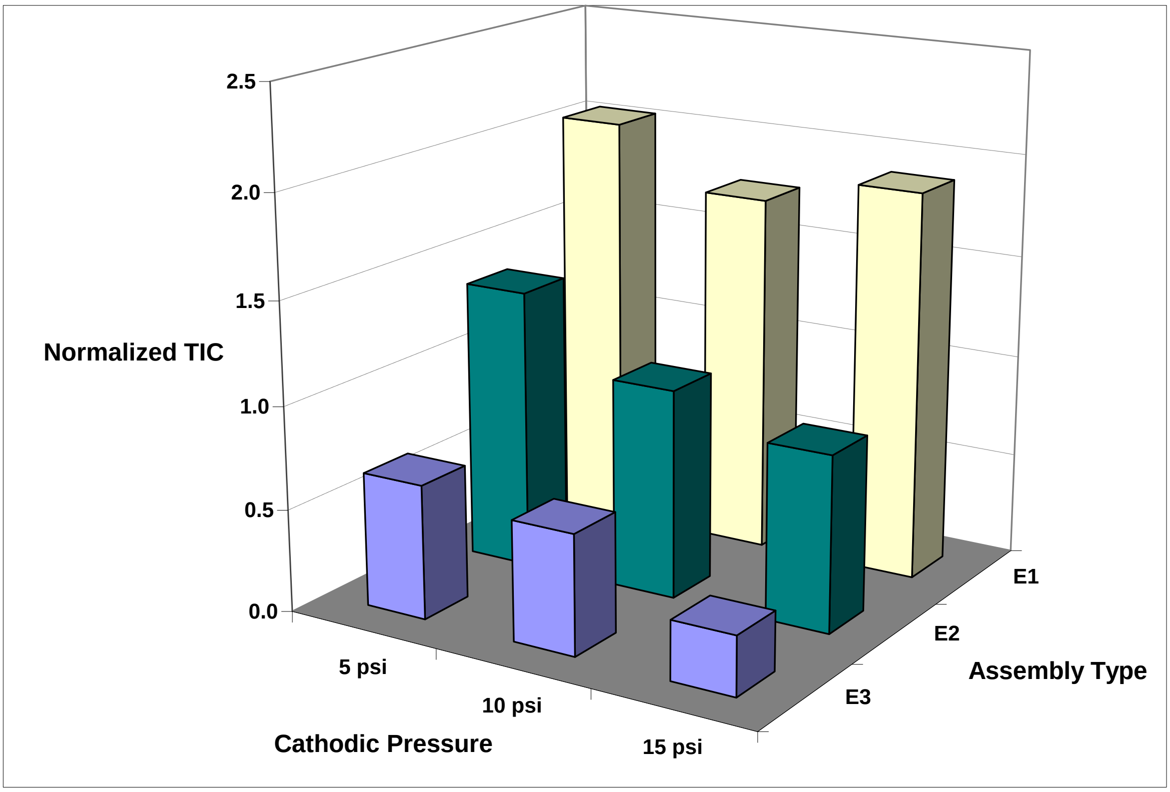

Figure 5. Normalized Total Investment Cost for PEMFC prototypes at pressure levels applied

The operating costs considered for this study include: a) Maintenance Costs by 15% of PEMFC integrated cost, b) Man Hour costs at 0% because PEMFC unit is considered a fully automated, c) Energy Costs also have 0% because PEMFC unit is considered as a fully autonomous system, d) Costs for raw materials where it is considered only hydrogen consumption when considering the use of oxygen present in the air to feed PEMFC design.

Table 6 shows the normalized values for the Costs of Operation of PEMFC system for 20 years. The observed values show again an important influence from the cost of selected materials on the operating cost. This is explained by the index dependency of total investment cost to estimate the maintenance costs. On the other hand, the cost of raw materials shows little impact on production costs despite of being variable depending on the type of PEMFC technology. The values in Table 6 are presented in Figure 6 where previous observations and discussions are objectively observed.

Table 6. Operating Costs for PEMFC Unit Type E1.

Normalized Operating Cost for a PEMFC System at 20 years									
	MEA type E1			MEA type E2			MEA type E3		
CONCEPT	5 psi	10 psi	15 psi	5 psi	10 psi	15 psi	5 psi	10 psi	15 psi
Maintenance Cost	6.113	5.234	5.650	4.103	3.064	2.577	1.959	1.846	0.864
Men Hour	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Cost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Raw Material (Hydrogen)	0.258	0.204	0.225	0.172	0.149	0.136	0.241	0.228	0.164
TOTAL	6.371	5.438	5.875	4.276	3.212	2.713	2.201	2.074	1.028

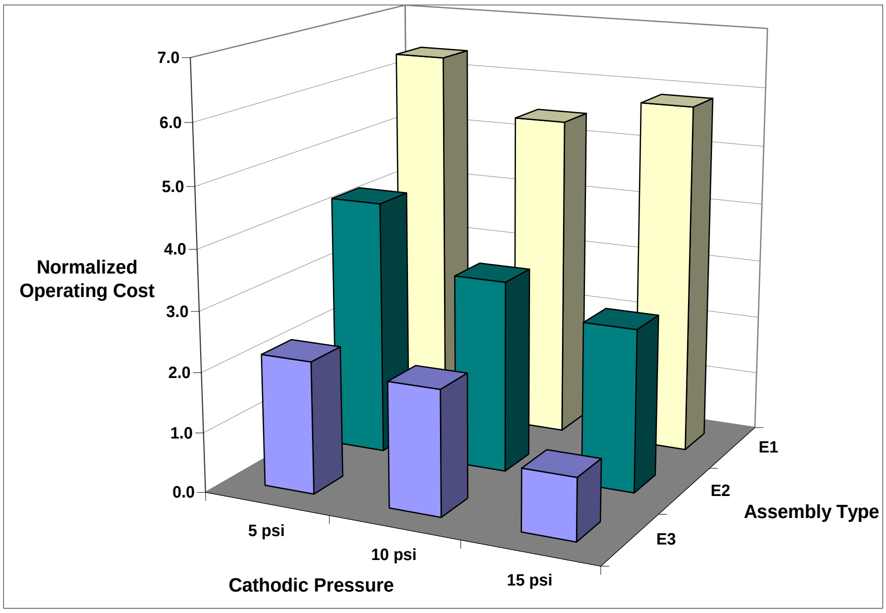

Figure 6. Normalized operating cost for PEMFC designs at experimental conditions

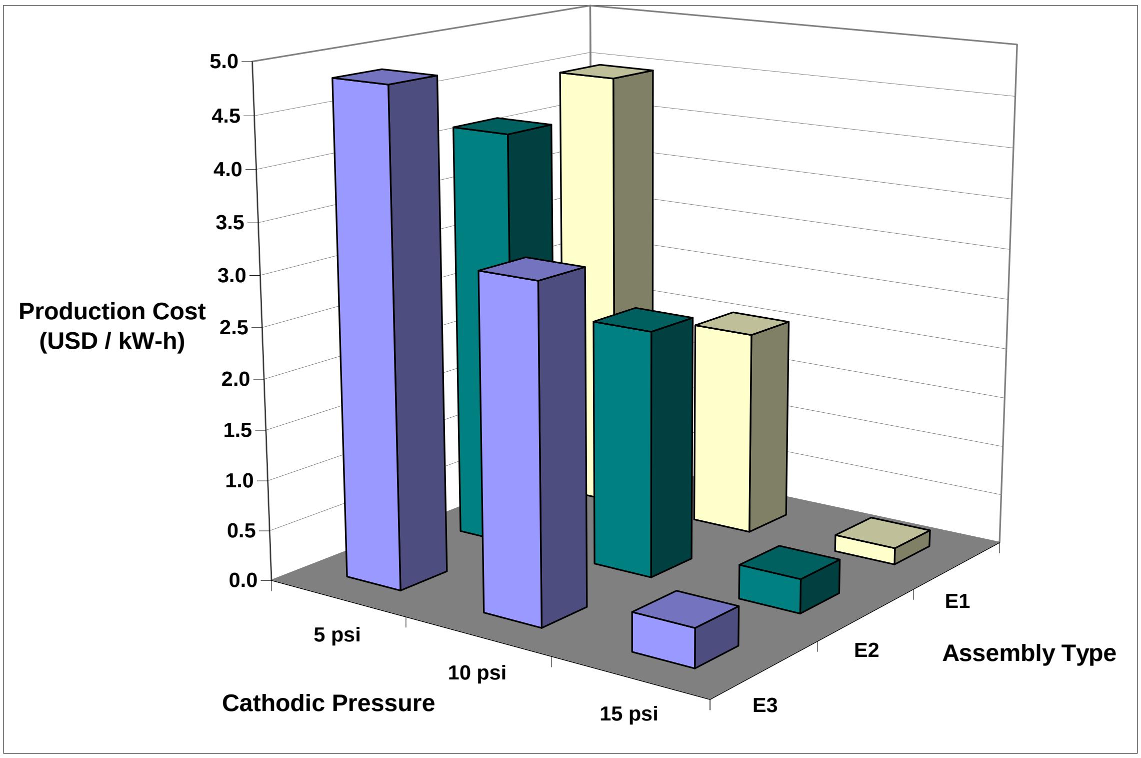

Figure 7. Unitary production cost for PEMFC designs at 20 years

Finally, the estimated production costs at 20 years for the design in the study are presented in Figure 7. In this, the behavior of the columns is remarkably different compared to the previous figures, being attributable to the effect of the efficiencies of each study design and operating conditions applied to the electrical power generated, thus impacting the cost of production unitary. Consequently, it follows a major impact on the sales cost for the stationary domestic service used in the design base.At cathodic pressure values of 10 psi and lower, it is noted a combination of effects between the material costs and efficiencies developed by the prototypes on the production cost. While at higher pressures, the dominant effect is attributed to the efficiency developed for each of the PEMFC prototypes presented in the study. A detailed discussion on the behavior of the power developed by the prototypes is held in previous works [13-16]. The lower cost of production represented in Figure 7 equals to 0.166 USD / kW-h. The value normally considered in cost estimates is 0.08 USD / kW-h, however the cost for this service in Mexico at July 2010 was 0.1201 USD / kW-h [26]. Figure 8 show the electricity prices for domestic service in the European Community during 2000 year, where the average price of the presented values is 0.1653 USD/ kW-h [27]. A risk analysis for the project presented above, requires a selection of types of risks. A list of 13 types of risks projects are presented in the literature [28]. Hhowever for this FEL I project 5 have been considered as the main risk at this stage. These are: i) risks inherent in design development. The main risk for this analysis is the experimental feature of the prototypes used for the project. This feature involves risks in electrical interconnections in series and / or parallel to the correct power supply, therefore there are risks in the design of support structures for the size and number of stacks. Implications of the above risks are also sizing, specification and construction classification required for the PEMFC system, therefore the management of activities related to this factor are a risk for the development of the project with their cost implications. The second type of risk is the ii) the risk of service quality in the continuous electrical power from complications that can occur for understanding a system developed from experimental prototypes. Another risk is the iii) significant deviation in the estimated cost, for this case the estimate was + / - 50%, where a number of important achievements or activities not considered in the project represent an additional risk. It must also be into account the implications of the first type of risk, where the re-engineering activities could represent significant cost deviations. Finally, an overview at this point involves consideration of iv) the risk of change in the scope of the project or activity limitations (lack of detailed engineering) from the first stage of a FEL 1. The Table 7 presents the analysis of risk, including risk percentages and the resulting assessment for risks considered for this work.

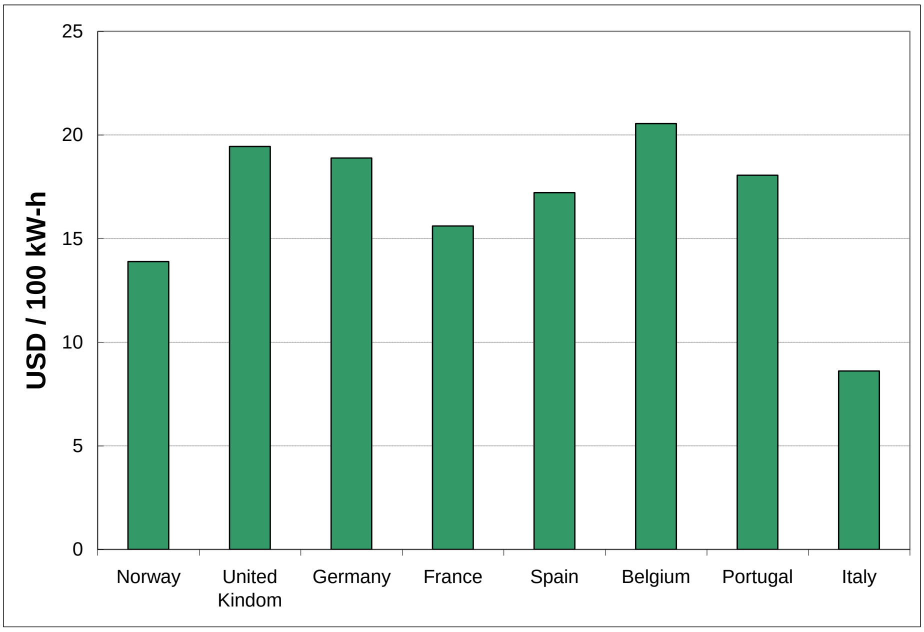

Figure 8. Electricity prices during 2000 year for domestic service in the European Community

Table 7. Risk analysis for FEL 1 a PEMFC design

Risk Analysis for FEL 1 a PEMFC design					
Risk	% Significant	Evaluation	Value	Maximum Value	Probable Value
Development	25%	Low	1	0.75	0.25
Quality	75%	Medium	2	2.25	1.50
Cost	50%	High	3	1.50	1.50
New Scopes	75%	High	3	2.25	2.25
Scope Changes	50%	Medium	2	1.50	1.00
		Total	11	8.25	6.50

Under the conditions described in this paper the risk for this design is remarkably high (79%), being the main cause the consideration of an experimental prototype into a commercial design. Another important cause is the level of the economic valuation applied (+ / - 50%), greater approach requires a basic engineering work and detailed costing of materials with a full development (included in FEL II project).

4. CONCLUSIONS

The nature of the materials selected in the basic structural elements for a PEMFC system is an important factor in PEMFC functionality, i.e., in the electric power generation during the operation. The manufacturing cost of these elements strongly affects the total investment costs for a PEMFC project. On the other hand, the production cost of electricity by a PEMFC system is affected by the combination of three factors, nature and cost of materials, as well as efficiency developed by the structural design. However, an attractive economic return, not only is determined by maximum efficiency, this may be combined with attractive costs in selected materials. Production costs presented in this paper not rule out the viably of PEMFC technology in stationary domestic services, but shows the need of detailed engineering studies for the proper scaling of safe designs with actual service objectives, in order to reduce technical and economic risks in the management of a PEMFC project.

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