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Environmental Impacts Assessment of the Platinum Nanophase Composite Electrode by Eco-Indicator 99 Methodology

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Abstract

Platinum nanophase composite electrode for hydrogen generation by water electrolysis process has to meet sustainable development requirements even in its development phase by reducing GHG emissions to irrelevance. It is therefore important to determine possible emissions, to estimate the energy consumption and identify key parameters in the improvement of the process used to develop the electrode. Eco indicator 99 was used to assess and determine the types of impacts on the environment of the process of the preparation of the composite electrode and Umberto software was used to develop life cycle assessment inventory (LCIA).

Keywords
Platinum nanophase composite electrode, Environmental Impact Assessment, Eco-indicator 99 methodology

1. Introduction
Platinum nanophase composite electrode is a designed electrode made of nanometre size particles of platinum metal. The electrode allows a high potential of electroactivity when producing hydrogen from water, because of the total participation in reaction of all the nanoparticles when the electrode is used. Nanotechnology method is applied to allow highly efficient electrocatalytic activity of the precious metals like platinum even in very small amounts, incorporated into an electrode. To achieve hydrogen production with zero carbon emission, hydrogen must be produced from a clean source using a clean process such as electrolysis of water in which platinum composite electrode can be effectively used. Hydrogen produced from water by use of platinum nanophase composite electrode might be a considerable stride towards the development of the global development of hydrogen economy. The platinum nanophase composite electrode was developed with the objectives to achieve effectively the generation of hydrogen in considerable quantities, in a low electrolyte environment, with low energy input, and focus on the waste reduction and reuse [1]. Sustainable development of the electrode will need to satisfy the analysis of environmental impact assessments over the process of the preparation of the electrode, and suggest possible improvement.

Taking advantage over the country's wealth in platinum group metals estimated more than 80% of the world reserves [2], South Africa has intended to develop fuel cell technologies to determine the path of its hydrogen economy. South Africa developed a national hydrogen and fuel cell technologies (HFCT) research, development and innovation strategy that is classified as one of the frontier science and technology initiatives for a ten year-plan (2008-2018) [2]. This has fostered research outputs such as the development of platinum nanophase composite electrode [1] that this paper assesses development techniques, from environmental point of view.

2. Basic Assumption in the Objective of the Research
Platinum nanophase composite electrode for hydrogen generation by water electrolysis process has to meet sustainable development requirements even in its development phase by reducing GHG emissions to irrelevance. It is therefore important to determine possible emissions, to estimate the energy consumption and identify key parameters in the improvement of the process used to develop the electrode. This can be resolved through an environmental impacts assessment.

3. Eco-indicator 99 Method of Assessment

Eco-indicator 99 method is a damage oriented method for the life cycle impacts assessment, over a product elaborated or over a process of elaboration. The method is a valuable tool in the improvement of the impact of an existing process or a new process for development of a product. This can only be applied after the development of an inventory analysis through which the input materials are compared to products and emissions are quantified. The Eco-indicator 99 method may be applied to guide to suggest remedies on the environmental impacts of the process.
The method of Eco-indicator 99 was developed [3] to solve the problem encountered in the weighting step of the Life Cycle Impacts Assessment (LCIA) method (Figure 1). Eco-indicator 99 method uses a top-down development considering weighting step as starting point. In this case method consists to modelling damage analysis to the most important impact categories identified as human health, ecosystem quality and resource extraction. Data on weighting and their factors of normalisation are published in the form of tables in reported by Pré Consultants [3-5].

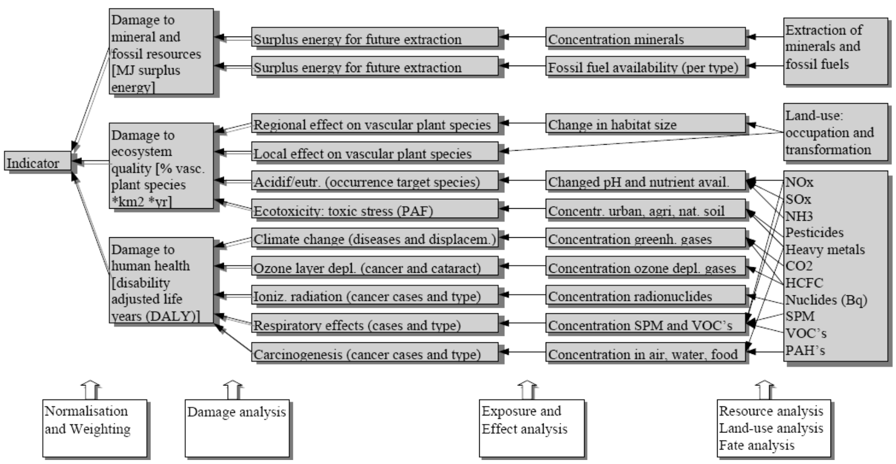

Figure 1: Graphical presentation of the Eco-indicator 99 methodology. Source: [33]

4. Elaboration and Environmental Impacts Assessment of the Platinum Nanophase Composite Electrode

4.1. Descriptive Method in the Platinum Nanophase Electrode

The application of nanometre active components highly dispersed is to favour the development of an efficient electroactive for hydrogen generation by water electrolysis. This can happen by depositing nanophase catalyst metals onto inorganic supports such as the mesoporous matrix support of ultra fine particles. Hexagonal Mesoporous Silica (HMS) is a matrix the kind needed. Such matrix can provide suitable improved catalytic reactivity of the nanophase metals. Furthermore, to prevent the aggregation of unstable and highly dispersed nanophase composite during water electrolysis, a gas diffusion substrate support of porous micro-texture and interfacial interactions may be used; this can be the carbon-supported platinum nanophase electro catalyst (Pt/C), a similar substrate to carbon nanotubes [1].
HMS is a mesoporous molecular sieve generated through hydrogen pathway and first reported in 1996 [6]. It is not commercially available and the challenge would be to produce it. HMS prepared in a laboratory [1] can be synthesized as described by the life cycle inventory shown in Figure 1. We developed Figure 1 through our own analysis and assessment from both, process of elaboration of HMS [7], and published data in the UMBERTO software environment.

4.2. Environmental Impacts Assessment in the preparation of the Hexagonal Mesoporous Silica (HMS) Material

The output of the balance sheet in Table1 above comprises some direct emissions detailed as follows:

- Deionised water used for washing the solid in the process T4 (Figure1), taken as waste water and emission, unless if recycled;
- Ethanol (ETOH) emission when drying and heating HMS in the process T6 (Figure1);

- The collected ETOH in the process T5 when extracting the yellow solid from Soxhlet Extractor is considered as good material since and not a waste or an emission.

The input-output balance sheet established in Table1 is the starting point to establish the Environmental Impacts Assessment of HMS material by Eco-indicator 99 method.

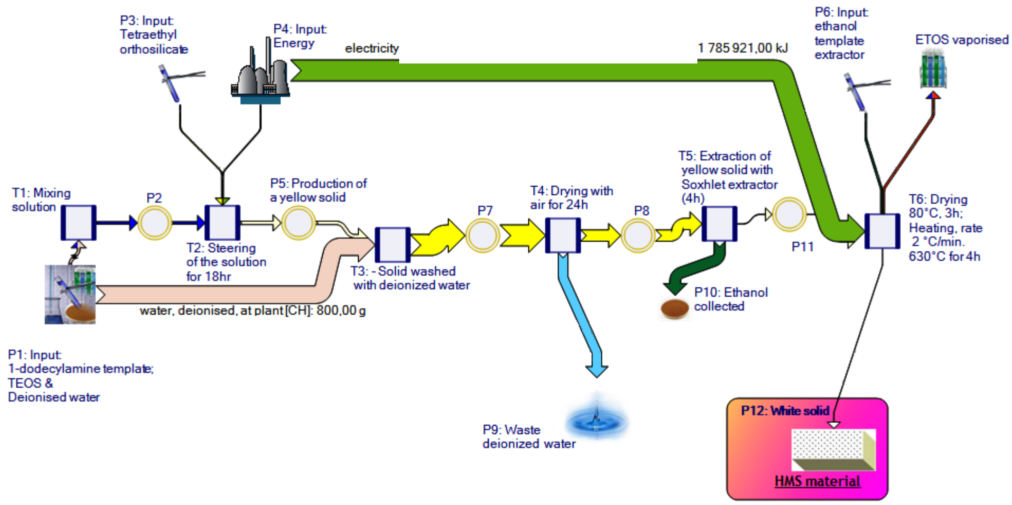

Figure 2: Flow of materials in the preparation of HMS material. (Developed using Umberto software)

Table 1: HMS input/output balance sheet developed using Umberto software.

Input/Output - Model: Model HMS

Process	Materia	M	Material	Quantity	Un
T1: Mixing solution	Project	▲	1-dodecylamine-template	10,00	g
T1: Mixing solution	ecoinv	▲	water, deionised, at plant [C	106,70	g
T2: Steering of the solution for 18hr	ecoinv	▲	electricity,	71 280,00	kJ
T2: Steering of the solution for 18hr	Project	▲	TEOS (Si(OC2H5)4)	41,92	g
T3: - Solid washed with deionized	ecoinv	▲	water, deionised, at plant [C	800,00	g
T6: Drying 80°C, 3h; Heating, rate	ecoinv	▲	ethanol from ethylene, at pla	83,24	g
T6: Drying 80°C, 3h; Heating, rate	ecoinv	▲	electricity,	1 785 921,00	kJ
Sums:				1,04	kg
				1 857,20	MJ

Process	Materia	M	Material	Quantity	Un
T4: Drying with air for 24h	Project	▲	Waste deionized water	437,22	g
T5: Extraction of yellow solid with Soxhlet	ecoinv	▲	ethanol from ethylene, at plant [R	500,00	g
T6: Drying 80°C, 3h; Heating, rate 2 °C/mi	Project	▲	waste ethanol template extractor	75,04	g
T6: Drying 80°C, 3h; Heating, rate 2 °C/mi	ecoinv	▲	ethanol from ethylene, at plant [R	10,00	g
T6: Drying 80°C, 3h; Heating, rate 2 °C/mi	Project	▲	1-dodecylamine-template	10,00	g
T6: Drying 80°C, 3h; Heating, rate 2 °C/mi	Project	▲	White solid	9,60	g
Sum:				1,04	kg

Table 2: Form of Environmental Impacts Assessment of HMS by Eco-indicator 99 method

Product or process **Hexagonal mesoporous silica material (HMS)**	*Project* **Platinum nanophase electrocatalyst composite electrode**
Date **08-06-2011**	*Author* **Junior Mabiza**

Inputs to the Production Phase (Materials, Processes, energy)				
material or process	**amount**	**Indicator (weighted damage factor) = (damage factor** x **normalisation) ÷ weight** [2,4]		**result**
1-dodecylamine	0.01 kg	19.9 * (H,A)		0.2
Deionised water	0.91 kg	0.026 **		0.02
Ethanol	0.08 kg	21.17 (H,A)		1.7
Electricity	515.89 kWh	12 **		6190.68
TEOS	0.04 kg	9.6 (H,A)		0.38
Total [mPt]				6193.

Remarks:

- ** refers to indicators obtained from Eco-indicator 99 Manual for Designers [4]
- 19.9* is the indicator of dodecane ($C_{12}H_{28}N_2$) that we supposed having similar effect to the dodecylamine ($C_{12}H_{27}N$).
- 0.026** refers to water demineralised indicator.
- 515.89 kWh = 1857.20 MJ
- TEOS is similar material to esters.
- 12** refers to energy mix outweighed by the energy from non-renewable energy.

Emissions likely after the production phase (Materials, waste, energy)				
Materials or process	**Amount (Kg)**	**Indicator**	**Exposure & Type of damage factor**	**result**
Waste deionised water	0.44	0.026 **	(possibility to recycling)	0.01
Ethanol collected	0.50	**- 21.17**	(Ethanol collected as good material)	- 10.6
Ethanol vaporised	0.09	21.17	Airborne: respiratory effects on humans caused by organic substances (H,A)	1.9
1-dodecylamine	0.01	19.9	Airborne: respiratory effects on humans caused by organic substances (H,A)	0.2
Total [mPt]				- 8.49
Total [mPt] (all phases)				**6184.51**

Interpretation of the Results of the HMS Eco-Indicator 99 Form

6190.68 mPt is the greatest value of indicators of impacts found in table 2 given to electricity consumption. Such a high impact can explain the type and the large amounts of electricity used in the process. The electricity is supplied from non-renewable energy sources. The solutions may be an assessment of the accuracy in the quantification of the useful energy and find available renewable energy sources. Impact of 1.9 mPt second in impact is associated with the ethanol emissions that occur during drying and heating 9.60 g of HMS. There is also the need to control emissions to ethanol and other chemicals.

4.3. Environmental Impacts Assessment of the Preparation of the Hexagonal Mesoporous Silica-Support Platinum Nanophase Material (HMS-Pt)

There has been some experiential indication that Chloroplatinic acid can serve as source of platinum metal [1]. This was used to prepare HMS-Pt in which platinum metal is supported upon the mesoporous HMS matrix by incipient wetness impregnation. The reduction of HMS-Pt salt to HMS-Pt metal could be achieved by methanol/formaldehyde solution method or NaH_2PO_2 solution [1]. Figure 3 below describes the HMS-Pt process of preparation.

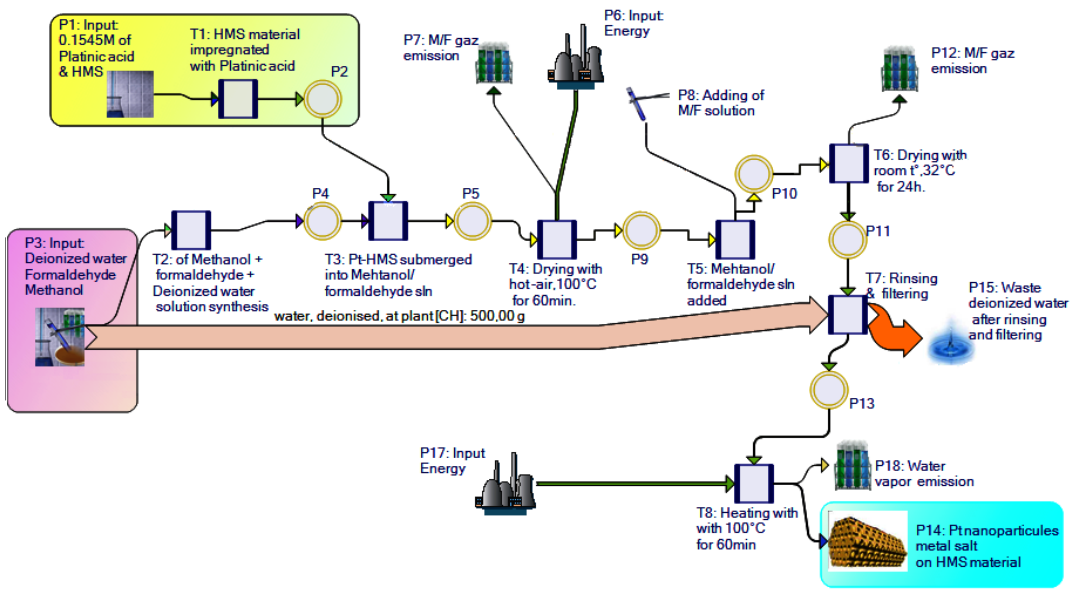

Figure 3: Flow of materials in the preparation of HMS-Pt material. (Developed using Umberto software)

Table 3: HMS-Pt input/output balance sheet developed using Umberto software.

Input/Output per Product - Model: Composite electrode

Selected product: All calculated products

Process (inputs)

Product	M	Material	Quantity	Unit
Process: T1: HMS material impregnated with Platinic acid: 1,95E-03 kg				
Pt metal nanop	▲	0.1545 M of H2PtCl6.H2O	0,27	g
Pt metal nanop	▲	HMS	1,68	g
Process: T2: of Methanol + formaldehyde + Deionized water solution synthesis: 3,86E				
Pt metal nanop	▲	water, deionised, at plant [CH]	0,67	g
Pt metal nanop	▲	methanol, at plant [GLO]	0,72	g
Pt metal nanop	▲	formaldehyde, production mix, at plant [	2,46	g
Process: T4: Drying with hot -air,100°C for 60min.: 1 151,41 MJ				
Pt metal nanop	▲	electricity, mix	1 151 410	kJ
Process: T5: Mehtanol/ formaldehyde sln added: 0,01 kg				
Pt metal nanop	▲	Methanol/formalhedyhe	11,57	g
Process: T7: Rinsing & filtering: 0,84 kg				
Pt metal nanop	▲	water, deionised, at plant [CH]	842,24	g
Process: T8: Heating with with 100°C for 60min: 1 151,41 MJ				
Pt metal nanop	▲	electricity, mix	1 151 410	kJ
Sums:			0,86 2 302,82	kg MJ

Process (outputs)

Product	M	Material	Quantity	Unit
Process: T4: Drying with hot -air,100°C for 60min.: 1,68E-04 kg				
Pt metal nanop	▲	Methanol/Formaldehyde gaz emitted	0,17	g
Process: T6: Drying with room t°,32°C for 24h.: 8,42E-05 kg				
Pt metal nanop	▲	Methanol/Formaldehyde gaz emitted	0,08	g
Process: T7: Rinsing & filtering: 0,83 kg				
Pt metal nanop	▲	Waste deionized water	833,81	g
Process: T8: Heating with with 100°C for 60min: 0,03 kg				
Pt metal nanop	▲	Pt metal nanoparticule-HMS	20,50	g
Pt metal nanop	▲	water vapor	5,05	g
Sum:			0,86	kg

Table 4: Form of Environmental Impacts Assessment of HMS-Pt by Eco-indicator 99 method

Product **Hexagonal mesoporous silica-supported platinum nanophase catalyst material (HMS-Pt)**	*Project* **Platinum nanophase catalyst composite electrode**
Date **08-06-2011**	*Author* **Junior Mabiza**

	Inputs to the Production Phase (Materials, treatments, energy)			
materials or process	**amount**	**Indicator (weighted damage factor) = (damage factor x normalisation) ÷ weight** [2,4]	**Exposure & Type of damage factor**	**result**
Chloroplatinic acid	2.70 E-4 kg	-*		-
Deionised water	0.84 kg	0.026 **		0.022
Electricity	639.67 kWh	12 **		7676.040
Formaldehyde	9.83 E-3 kg	28.8 (HA)		0.283
HMS matrix detritus	1.68 E-3 kg	-*		-
Methanol	7.88 E-3 kg	7.30 (HA)		0.058
Total [mPt]				7676.40

Remarks:

- 0.026** refers to water demineralised indicator [3].
- -* no evident record of weighted damage factor.

	Emissions likely after the production phase (Materials, waste, energy)			
materials or process	**amount**	**indicator**	**Exposure & Type of damage factor**	**result**
waste deionised water	0.834 kg	0.026 **	possible to recycling	0.022
Methanol emission	3.17 E-5 kg	5.44	Airborne: respiratory effects on humans caused by organic substances (E,E)	0.0002
Formaldehyde emission	1.08 E-4 kg	28.8	Airborne :respiratory effects o humans caused by organic substance (E,E)	0.003
Water vapour	0.01 kg	-		-
Total [mPt]				0.025
Total [mPt] (all phases)				**7676.43**

The preparation of HMS-Pt presents likely direct emissions resulting from operations of transformations in heating (Figure3 in T8), drying with hot air (Figure3 in T4) as well as in ambient temperature of HMS-Pt (Figure3 in T6). Other emissions are filtering and rinse with deionized water of HMS-Pt; they can be eliminated unless the deionized water is recycled (Figure 3 in T7).

Interpretation of the Results of the HMS-Pt Eco-Indicator 99 Form

The major impact in the preparation of HMS-Pt comes from the use of electricity. Similar observations are identical to the case of HMS in point 4.2. The conclusions and recommendations are the same. A focus on water vapour (steam) is to be observed, especially in the case of an industrial process, because water vapour emissions can contribute to greenhouse gases.

4.4. Environmental Impact Aassessment to the Preparation of the Carbon-Supported Platinum Nanophase Catalyst (Pt/C)

The carbon-supported platinum nanophase electro catalyst (Pt/C) is a synthetic material with properties analogous to order mesoporous carbon material such as carbon nanotubes. Pt/C can be used as a support of porous micro-texture for gas diffusion. Pt/C will have to serve a delicate structure of ultra-fine particles of platinum support. The support is built from HMS matrix to enhance the electroactivity of the composite electrode. Pt/C nanophase can be prepared through an impregnation-reduction technique of suspension of carbon black in a solvent such as glycol/isopropanol, with a metal precursor $H_2PtCl_6{\cdot}6H_2O$ and a pH-regulator H_2SO_4. Formaldehyde can be used as a reducing agent for the deposition of Platinum (Pt) on material support carbon black [8]. Figure 4 shows the process for the preparation of Pt/C.

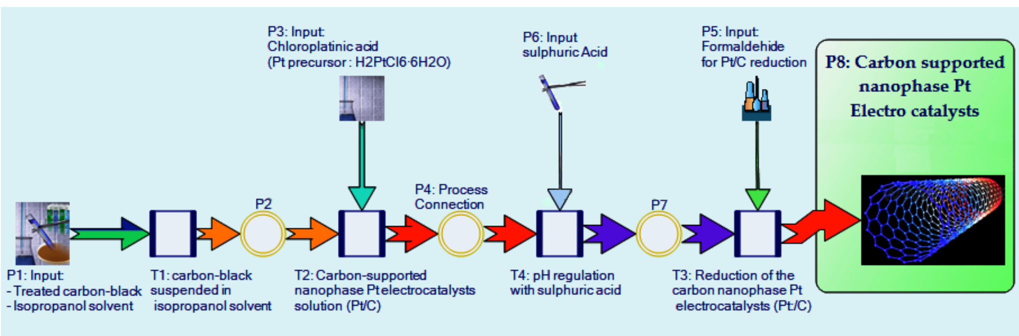

Figure 4: Flow of materials in the preparation of Pt/C material. (Developed using Umberto software)

Table 5: Pt/C input/output balance sheet, developed using Umberto software

Input/Output - Model: Model FC Electro catalyst

Process	Mat	M	Material	Quanti	U
T1: carbon-black suspended in isoprop	eco	▲	carbon black, at plant [G	0,02	g
T1: carbon-black suspended in isoprop	eco	▲	isopropanol, at plant [RE	0,10	g
T2: Carbon-supported nanophase Pt el	Pro	▲	Chloroplatinic acid	0,05	g
T3: Reduction of the carbon nanophas	eco	▲	formaldehyde, productio	0,02	g
T4: pH regulation with sulphuric acid	eco	▲	sulphuric acid, liquid, at	0,03	g
Sum:				2,30E..	kg

Process	Mat	M	Material	Quanti	Unit
T3: Reduction of the carbon nanophas	Pro	▲	Pt/C	0,23	g
Sum:				2,30E..	kg

The output of the balance sheet includes only Pt/C the final product. No obvious emission has been established in the publication of the development process [8].

Table 6: Form of Environmental Impacts Assessment of Pt/C by Eco-indicator 99 method

Product or component **Carbon-supported platinum nanophase catalyst (Pt/C)**	*Project* **Platinum nanophase catalyst composite electrode**
Date **08-06-2011**	*Author* **Junior Mabiza**

Inputs to the Production Phase (Materials, treatments, energy)				
material or process	**amount**	**Indicator (weighted damage factor) = (damage factor x normalisation) ÷ weight** [2,4]	**Exposure & Type of damage factor**	**result**
Carbon black	2.0 E-5 kg	180 **		0.004
Isopropanol	1.0 E-4 kg	7.74 (H,A)		0.001
Chloroplatinic acid	5.0 E-5 kg	-		-
Formaldehyde	2.0 E-5 kg	28.8 (H,A)		0.001
Sulphuric acid	3.0 E-5 kg	22.0 **		0.001
Total [mPt]				0.007
Total [mPt] (all phases)				**0.007**

Interpretation of the Results of the Pt/C Eco-Indicator 99 Form

The Pt/C Form results reveal a series of small impacts of chemicals used, where carbon black is the highest impact with 0.004 mPt. Carbon Black is the main material to prepare Pt/C. Despite its advantage to offer very large surface available for adsorption and chemical reactions, Carbon black accounts a high "weighted damage factor" (Table 6) that identifies it as one of the materials with a very high global warming potential. Environmental precautions may be considered in the production of Carbon black in order to mitigate its "weighted damage factor" which is relatively high due to its production. The improvement on the Carbon black environmental impacts will contribute to the development of the manufacture of the composite electrode.

4.5. Environmental Impacts Assessment in the Preparation of the Platinum Nanophase Composite Electrode

The preparation of the nanophase composite electrode may finally be completed, first by the complete reduction of pre-reduced or unreduced platinum salts in the HMS-Pt by a low cost liquid petroleum gas (LPG) by means of calcinations. Then HMS-Pt may be soaked in a NaOH solution to remove HMS matrix by stirring. The resulting nanophase platinum composite material can be cleaned with ultra-pure water and dried in the oven at 100°C. The obtained Pt nanophase powder can after be dispersed and magnetically added in a solution composed of ultra-pure water, isopropanol and a binder/proton-Liquion; from there will result a catalytic ink. The ink is coated upon Pt/C support; this completed the preparation of the platinum nanophase composite electrode [1].

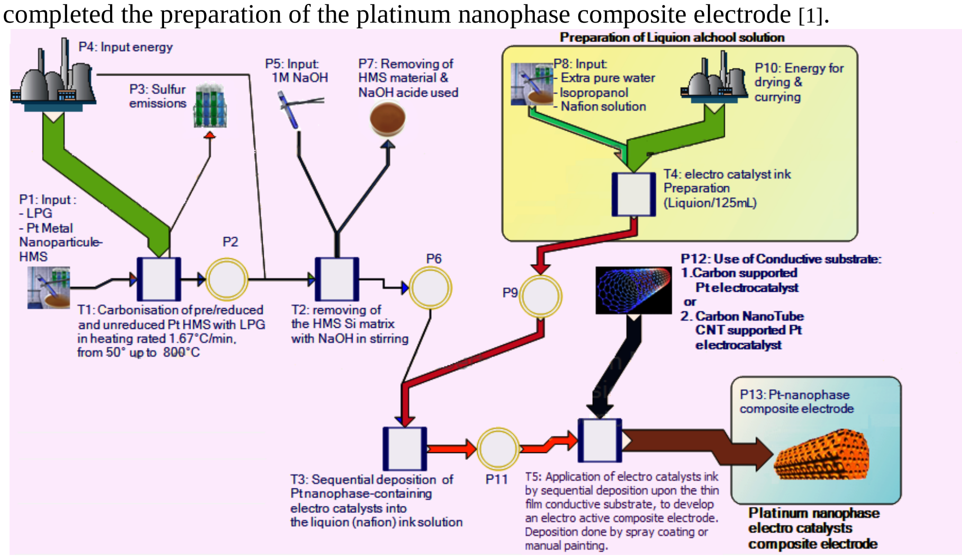

Figure 5: Flow of materials in the preparation of Pt nanophase electro catalyst composite electrode (Developed using Umberto software)

Table 7: Pt nanophase composite electrode input/output balance sheet developed using Umberto software

Product	M	Material	Quantity	Unit
Process: T1: Carbonisation of pre/reduced and unreduced Pt HMS with LPG in heating				
Nanophase co	▲	electricity, ı	364 935,1	kJ
Nanophase co	▲	liquefied petroleum gas, at service statio	13,56	g
Nanophase co	▲	Pt metal nanoparticule-HMS	20,50	g
Process: T2: removing HMS Si matrix with NaOH in stirring the solution: 0,14 MJ, 0,03 k				
Nanophase co	▲	electricity, ı	142,40	kJ
Nanophase co	▲	sodium hydroxide, 50% in H2O, producti	28,00	g
Process: T4: electro catalyst ink Preparation (Liquion/125mL): 341,82 MJ, 0,11 kg				
Nanophase co	▲	water, ultrapure, at plant [GLO]	21,40	g
Nanophase co	▲	isopropanol, at plant [RER]	80,25	g
Nanophase co	▲	Nafion	5,38	g
Nanophase co	▲	electricity, ı	341 820,0	kJ
Process: T5: Incorporation of nanomaterials by sequential deposition in thin films for el				
Nanophase co	▲	carbon black, at plant [GLO]	0,23	g
Sums:			706,90	MJ
			0,17	kg

Product	M	Material	Quantity	Unit
Process: T1: Carbonisation of pre/reduced and unreduced Pt HMS with LPG in heating				
Nanophase composite elect	▲	SOx,CO,NOx emissions	14,06	g
Process: T2: removing HMS Si matrix with NaOH in stirring the solution: 0,04 kg				
Nanophase composite elect	▲	sodium hydroxide, 50%	26,00	g
Nanophase composite elect	▲	waste HMS material re	10,00	g
Process: T5: Incorporation of nanomaterials by sequential deposition in thin films for el				
Nanophase composite elect	▲	Nanophase composite e	119,23	g
Sum:			0,17	kg

Table 8: Form of Environmental Impacts Assessment of the composite electrode by Eco-indicator 99 method

Product or component **Platinum nanophase electrocatalyst composite electrode**	*Project* **Platinum nanophase electrocatalyst composites electrode**
Date **08-06-2011**	*Author* **Junior Mabiza**

	Inputs to the Production Phase (Materials, treatments, energy)			
materials or process	**amount**	**Indicator (weighted damage factor) = (damage factor** x **normalisation) ÷ weight** [2,4]	**Exposure & Type of damage factor**	**result**
Carbon black	0.23 E-3 kg	180.0 **		0.04
Electricity	**195.99 kWh**	12 **		**2351.88**
Isopropanol	80.25 E-3 Kg	7.74 (HA)		1.49
Liquid petroleum gas (composition of:	13.56 E-3 Kg, roughly with :			
90% propane (C_3H_8),	12.20 E-3 Kg	9.95 (HA)		0.12
5% propylene (C_3H_6)&	0.68 E-3 Kg	304.0 (HA)		0.23
2.5% butane (C_4H_{10}) [9]	0.34 E-3 Kg	19.7 (HA)		0.007
Nafion (liquion 1100)	5.38 E-3 Kg	- *		-
Sodium hydroxide	28.0 E-3 Kg	38 **		1.06
Ultra pure water	21.4 E-3 Kg	0.0026 **		1 E-4
Total [mPt]				2353.82

Remarks:

- 0.026** refers to water demineralised indicator [3]
- 0.0026** refers to water decarbonised indicator [3]
- 38 ** refers to Sodium hydroxide indicator [3]
- - * no evident record of weighted damage factor for Nafion.

	Emissions likely after the production phase (Materials, waste, energy)			
materials or process	**amount**	**indicator**	**Exposure & Type of damage factor**	**result**
Sodium hydroxide	0.026 kg	38*		0.14
Waste HMS removed	0.010 kg	-		-

Emissions in carbonizing unreduced HMS-Pt using LPG: • CO_2 (99.87%) • NO_X (0.11%) • SO_X (0.01%) [10]	13.98 E-3 kg 1.54 E-5 kg 1.4 E-6 kg	5.45 2300.0 1420.0	<u>Airborne</u>: Respiratory effects on humans caused by inorganic substances (H,A)	0.11
Total [mPt]				0.25
Total [mPt] (all phases)				**2354.07**

The output of the balance sheet in Table7 above comprises the composite electrode as final product synthesized and some direct emissions detailed as follows:

- LPG can emit SO_X, CO and NO_X through carbonization of HMS-Pt for the temperatures of order of 800°C (Figure 5 in T1), precautions should therefore be taken;
- Sodium dioxide (NaOH) has been used to remove HMS template from HMT-Pt (Figure 5 in T2); it can be an emission to soil, unless it is recycled after removal of the template;
- HMS template waste can be considered emission to soil except if it is recycled. (Figure 5 in T2).

Interpretation of the Results of the Composite Electrode Eco-indicator 99 Form

The preparation of the Platinum nanophase composite electrode was completed with a significant amount of electrical energy. Precautions in the use of electricity taken in point 4.2 are well applicable in this case. 97% of total impact on the finalization of the Platinum composite electrode is provided indirectly by the use of electricity from non-renewable sources. More indirect impact may come from the process of manufacture of LPG, isopropanol, or sodium hydroxide; they are used as presented in Table8 (in Production Phase). Direct emissions are possible in the carbonization of HMS-Pt by the use of LPG. At high temperatures, LPG could probably emit nitrogen oxides (NO_x), carbon monoxide (CO), sulphur oxides (SO_x) as well as particulate matter [9].

Conclusion

The environmental impact assessment of the manufacture of the platinum nanophase composite electrode revealed both direct and indirect impacts. These are assigned to chemicals and electricity from non-renewable sources. However emissions of electricity can be eliminated by using renewable energy sources. Indirect emissions of chemicals can be reduced by suggesting alternatives with less impact and their direct emissions must be treated with precaution. Finally there must be some analyses to develop adequately accurate methods to quantify the energy for the processes involved in the manufacture of the platinum nanophase composite electrode.

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