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Tatiana PERMINOVA, Bertrand LARATTE - New technology to improve the efficiency of photovoltaic cells for producing energy - Procedia Manufacturing - Vol. 7, p.358-363 - 2016

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International Conference on Sustainable Materials Processing and Manufacturing, SMPM 2017,
23-25 January 2017, Kruger National Park

New Technology to Improve the Efficiency of Photovoltaic Cells for Producing Energy

Bertrand Laratte^{a,c,d}, Tatiana Perminova^{a,b}

^aUniversity of Technology of Troyes, ICD-CREIDD, UMR 6281, Troyes, France

^bTomsk Polytechnic University, Geoecology and Geochemistry Department, 634050, Tomsk, Russia

^cArts et Mtiars ParisTech, I2M-IMC, UMR 5295, Talence, France

^dAPESA, Technopole Izarbel, 64210 Bidart, France

Abstract

Due to increasing worldwide energy needs, several technologies have been elaborated to meet this demand. One of these developments concerns solar energy, which has already been in use for several decades. The main solar technologies were developed in the sixties and seventies with monocrystalline and multicrystalline technologies. Subsequently, a new, more efficient, technology with a ribbon system became available.

These different technologies have similar processes and applications. Several Life Cycle Assessment (LCA) studies have been carried out to identify and to compare the environmental impacts of photovoltaic systems and nuclear systems, lignite systems etc. These studies have shown that the main problem with photovoltaic technologies is the decreasing efficiency during the using phase, and that is why some impacts appear higher when compared to other technologies.

However, in order to justify the benefits of this new technology, it is necessary to assess environmental impacts and to compare them with the conventional technologies. The second challenge in this research work is to carry out the LCA. Our proposal shows the preliminary LCA results of this technology, but it also indicates the difficulties and the limitations of assessing the environmental impact of such products. Even if standards, tools and databases exist for completing the LCA, nano-products are quite new and a full LCA study is difficult to conduct due to the lack of information in the actual databases of the Life Cycle Inventory and the characterization factors in the calculation methods.

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Peer-review under responsibility of the organizing committee of SMPM 2017

Keywords: LCA; solar panels; environmental impact; nano material

1. Introduction

World energy consumption has undergone rapid growth and increased by almost 1400 % over the last 20 years. Nearly four-fifths of the energy consumed today comes from fossil fuels, resulting in an increase of around 6% in

CO₂ emissions in 2010. Taking into account the fact that the fossil fuels are limited and highly polluting, the application of renewable energy sources seems to be inevitable.

Many technologies propose “green energy” such as wind power, water power and so on. In this study, we propose assessing the environmental impact of different technologies of solar panels. The efficiency can differ between different technologies; therefore an environmental assessment can be relevant in order to identify the best product.

In recent decades, 3 main categories of solar panels were identified:

- Solar thermal panels;
- Photovoltaic solar panels;
- Photovoltaic thermal panels.

The study made by the NREL (Renewable Energy Laboratory) research team showed the efficiency of different solar cells (figure 1).

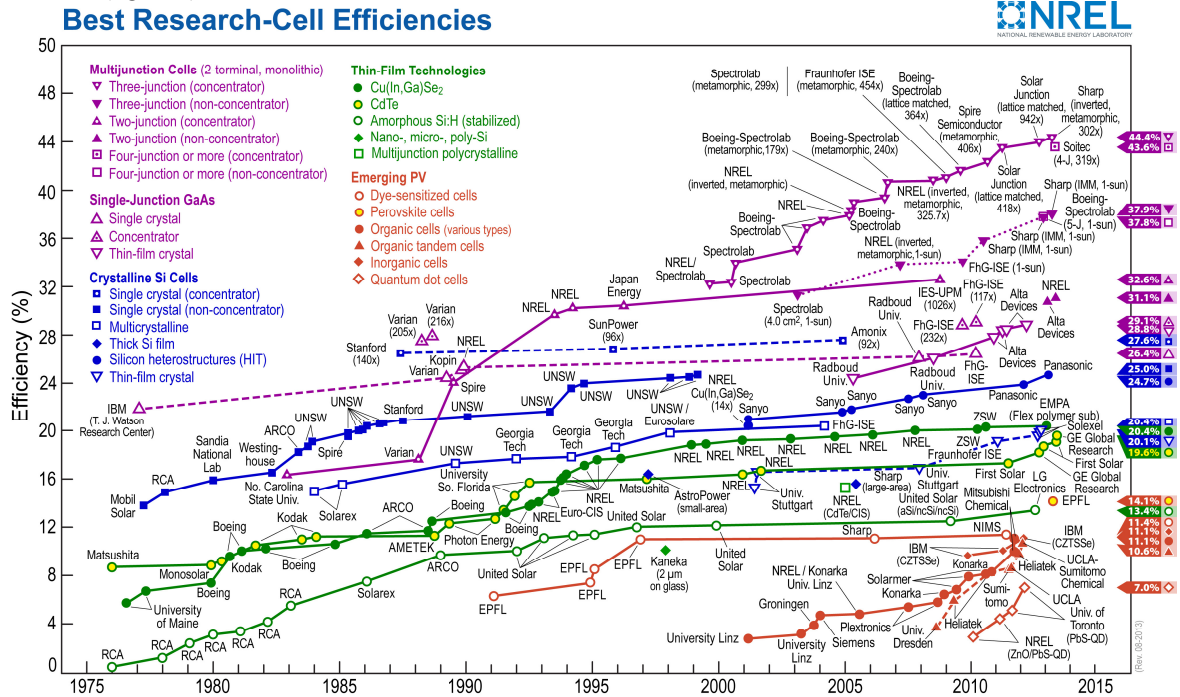


Fig. 1. Best Research-Cell Efficiencies [1]

The University of Technology of Troyes, in collaboration with the University of Reims Champagne-Ardenne, has been developing a new technology with nano yarn for 3 years. This new material could be more efficient than the others. However, the main challenge is reducing the environmental impact.

2. Objectives

The main problem in the evaluation of environmental impact is to determine all the components of products used (known as the inventory). However, some studies have already been done [2]. The objective of the project is to provide a new solution to produce solar energy by guaranteeing the minimum impact of the technical solution. This new technology will ensure higher efficiency compared to existing ones, and will probably be more expensive. The panel could find its use in critical services, e.g. safety systems in mountains or in express-ways.

3. Methods

There are a variety of tools and methods to assess environmental impacts, however LCA is applied for this work. This method is widely used to compare different technologies, and one of its main advantages is that it offers a standard framework [3].

A LCA is based on an inventory of materials that could have an potential environmental impact. Many databases within LCA studies could be used, we decided to use Ecoinvent [4] that proposes a large choice of materials and that is more suitable for the objective of our study.

Then, to assess environmental impacts, some indicators were chosen. The « ReCiPe Midpoint (E) » method [5] is used due on the recommendation of the European commission [6].

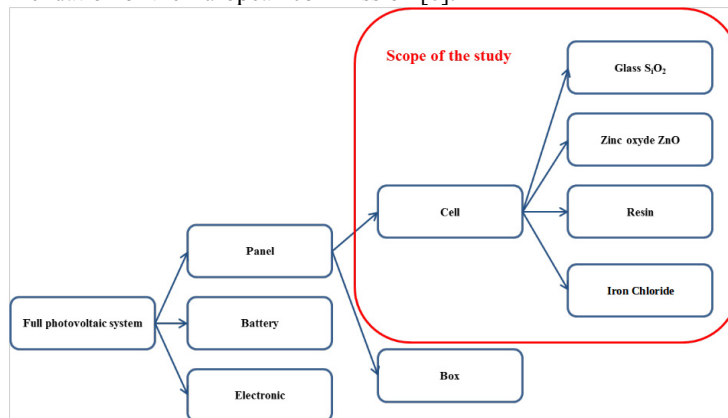


Fig. 2. Scope of the study

Not all the system will be evaluated. Since this study's challenge is to provide new cell technology, only the cells' components were selected.

4. Results

The environmental impact study on the cell nanotechnology that is currently being developed by the LNIO is still at the experimental stage. There is no environmental data of this technology on the market. It was therefore not possible to analyze the entire life cycle of the product, but a study of the manufacturing process was carried out.

For simplicity, we identified five distinct processes (Figure 1). We considered two stages of the cell production: zinc deposit on the substrate by combining steps 0-2, and structuring and engraving by grouping steps 3-5.

Table 1. The list of chemical components of the cell by steps

Process	Product		Formula	Quantity	State
0: Substrate	Silicon		Si	3,37 g	Solid
	Zinc	Zinc	Zn	0,027 g	Solid
1: Zinc deposition	acetate	Acetic acid	CH ₃ COOH	0,192 g	Liquid
	Ethanol 96%		C ₂ H ₆ O	15,15 g	Liquid
2: Resin deposition	Propylene glycol monoethyl ether		C ₆ H ₁₂ O ₃	0,8 g	Solid
	acetate				
3: Structuring interference lithography	Cresol		C ₇ H ₈ O	0,2 g	Solid
	Tetramethylammonium hydroxide		C ₄ H ₁₃ NO	0,406 g	Solid
	Demineralized Water		H ₂ O	1,96 g	Liquid
4: Chemical etching	Iron	Iron oxide	Fe ₃ O ₄	0,0384 g	Solid
	chloride	Hydrochloric acid	HCl	0,0484 g	Liquid
		Demineralized Water	H ₂ O	0,09 g	Liquid

5: Silicon etching	Chlorine	Cl ₂	0,0093 g	Gaz
	Pure demineralized water	H ₂ O	100 g	Liquid
	Acetone	C ₃ H ₆ O	39,55 g	Liquid
	Pure demineralized water	H ₂ O	50 g	Liquid
	Oxygen	O ₂	0,126 g	Gaz
	Nitrogen	N ₂	0,27 g	Gaz
	Sulfide hexafluoride	SF ₆	1,58 g	Gaz

In order to provide reliable results, our study was achieved in the following way. First of all, we looked at the entire production process from zinc acetate (analysis of all of the products' impacts with zinc acetate). Using the ReCiPe Midpoint method, we obtained the intermediate outcomes presented in Table 2. Secondly, we noted that the solvents (water, ethanol and acetone) accounted for more than 96% of the total mass (Figure 3), and thus did a new simulation without solvents to identify the impact among the products present in very small quantities.

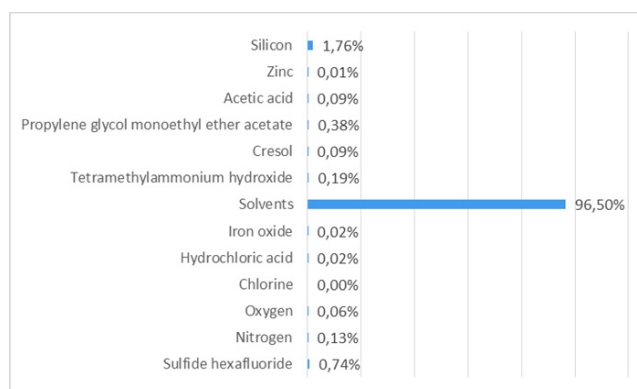


Fig.3. Mass distribution of products in %

Our next step was to study another method of manufacturing the cell, also developed by the LNIO. This alternative method is to remove the zinc from ZnO, which is a replacement for the zinc acetate. For this step, iron chloride was temporarily removed from the process as it accounts for a very high percentage of the ecological impact. This approach ultimately compares two different manufacturing processes, one from zinc acetate and the other from zinc oxide, by separating the solvents and iron chloride. The comparison of the impact results between zinc acetate and zinc oxide is shown in Table 2 and Fig.4.

Table 2. Analysis of impact based on ReCiPe Midpoint method

Indicator	Results					Unit
	<i>All the products included</i>	<i>Without solvents</i>	<i>Zinc acetate</i>	<i>ZnO</i>	<i>Solvents + iron chloride + ZnO</i>	
Climate change	51,50800	54,15401	5,15080 ^{E+1}	4,89912 ^{E+1}	51,50800	kg CO ₂ -Eq
Marine ecotoxicity	3,31098 ^{E-5}	3,45223 ^{E-5}	2,54570 ^{E-8}	0,00000 ^{E+0}	3,30830 ^{E-5}	
Human toxicity	0,00197	0,00200	0,00000 ^{E+0}	0,00000 ^{E+0}	0,00197	
Freshwater ecotoxicity	1,70318 ^{E-5}	9,20795 ^{E-6}	8,64532 ^{E-6}	0,00000 ^{E+0}	7,94468 ^{E-6}	kg 1,4-DCB-Eq ¹
Terrestrial ecotoxicity	4,22539 ^{E-6}	4,34995 ^{E-6}	2,54730 ^{E-8}	0,00000 ^{E+0}	4,19861 ^{E-6}	

¹ Corresponds to the equivalence of the 1,4-Dichlorobenzene

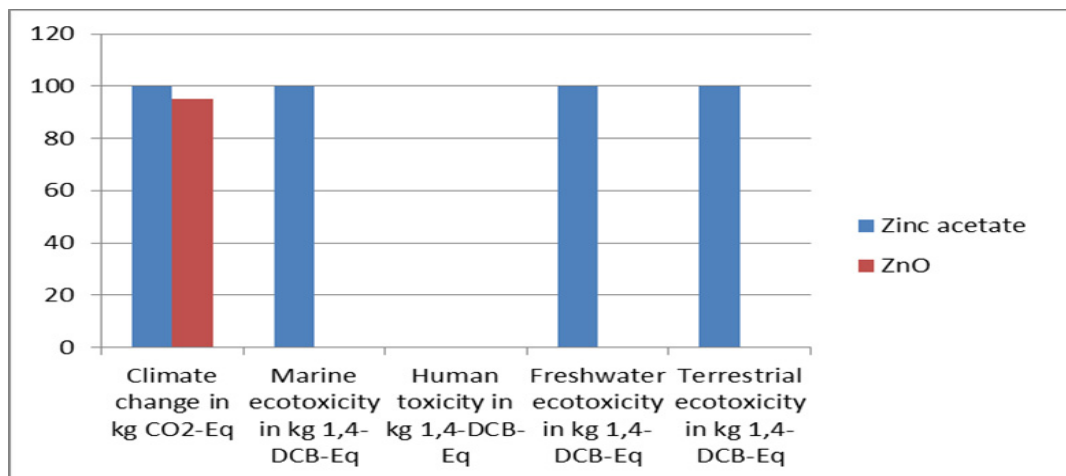


Fig.4. Comparison of results between zinc acetate and ZnO

At this last step of our study we combined all the products, retaining the manufacture method starting from ZnO - comprehensive impact analysis with solvents + iron chloride + ZnO (Table 2).

4. Discussion

Our first results show that the use of zinc acetate has much more impact on nature than zinc oxide. Therefore it is better to use the latter during the LNIO cell manufacture process. According to data from ReCiPe, the silicon substrate, resin, tetramethyl ammonium hydroxide, oxygen and nitrogen do not have significant environmental impacts. This has to be validated using other databases, since the production of the silicon substrate requires very high temperatures.

One of the main points of LCA is the inventory, but in the case of a new technology described, it is quite difficult to obtain it. A review was done to find a characterization factor of the missing data, but we still need more information to improve the results [7].

The second issue is the assessment method (ReCiPe) which does not provide characterization factors for nano components. An assessment based on the data on conventional materials introduces uncertainties into the final environmental impact results.

The environmental assessment should be also carried out with other LCA methods and models to compare the results. One of the models of interest for our study is USEtox [8], which aims at identifying toxicity impacts of chemicals. This model determines impacts on ecosystems and human health at different scales (e.g. global, continental...) within a variety of environmental compartments.

Acknowledgements

We would like to thank Patricia Kaufmann, Naël Ammoury, Fabrice Getas, Timothe Puzio and Pierre Soria.

References

- [1] http://www.nrel.gov/ncpv/images/efficiency_chart.jpg
- [2] B.Laratte, B.Guillaume, Epistemic and methodological challenges of dynamic environmental assessment: A case-study with energy production from solar cells, *Key Engineering Materials*, 572 (2014) 535-538
- [3] ISO 14040: Environmental Management, Life Cycle Assessment, Principles and Framework; International Standard Organization: Geneva, 2006.

- [4] <http://www.ecoinvent.org>
- [5] M. Goedkoop et Al., ReCiPe 2008: A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level, 2012
- [6] ILCD Handbook: recommendations for life cycle impact assessment in the European context; Publications Office of the European Union: Luxemburg, 2011.
- [7] J Kim, JL Rivera, TY Meng, B Laratte, S Chen, Review of life cycle assessment of nanomaterials in photovoltaics, 133 (2016) 249-258
- [8] www.usetox.org