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Environmental profile of the electricity supplied in Portugal by the main suppliers

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ABSTRACT

The main aim of this study was to assess and compare the environmental profile of 1 KWh of electricity supplied during 2014 by the four main electricity selling companies in Continental Portugal. The study was elaborated based on Life Cycle Assessment methodology and the method chosen for environmental impact assessment was EPD2013. The results show that the ENDESA´s electricity was the worst in terms of acidification, eutrophication, global warming, photochemical oxidation and ozone layer depletion while IBERDROLA´s electricity was the best for those impact categories and the worst in terms of abiotic depletion. Including in the study, the net electricity fed into the Portuguese and UCTE grid at the high voltage level, the conclusion is that the electricity at Portuguese grid presents the worst performance in terms of acidification, global warming and photochemical oxidation while the electricity at UCTE grid presents the worst performance in terms of eutrophication and ozone layer depletion.

KEYWORDS

Electricity, Energy, EPD, LCA, MIBEL, UCTE

INTRODUCTION

World gross electricity production increased from 16813 to 23 406 TWh (tera Wh), a growth rate of 39.2% from 2003 to 2013. In OECD countries the growth rate during the same period was 8 % and in Portugal it was 10.6 % [1].

Electricity net generation in Portugal is volatile year-on-year owing to variable hydropower generation. It was 52 terawatt-hours (TWh) in 2014 and the electricity fuel mix is diverse [2]: hydropower accounts for 30%, followed by wind (23.3%), coal (23%), natural gas (12.5%), biofuel and waste (6.4%), oil (3.2%), solar (1.2%) and geothermal power (0.4%). Portugal's share of fossil fuels in electricity generation was near a median level among IEA member countries and of wind power is the second-highest, behind Denmark. Depending on the technology used for electricity production, there is a large variation of the environmental impacts of 1 kWh of electricity [3].

Portugal and Spain have been integrating their electricity markets into a single Iberian Electricity Market, MIBEL. In July 2006, the Portuguese part of the Iberian Market Operator

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(OMIP), was launched. Since July 2007 the Spanish part of OMIE's has been operating in both countries and in February 2014, it was coupled with the Central and Northern European markets that is an encouraging move towards a wider European approach to the provision of market services [2].
The main electricity selling company in Portugal, in February 2016, in terms of number of customers on the free market was EDP commercial with a market share of 85 %, followed by GALP (6 %), Endesa (3.9 %), Iberdrola (2.1 %) and Others (3 %). In terms of energy supplied the market share was EDP commercial (44 %), Endesa (18 %), Iberdrola (17 %), GALP (8.1 %) and Others (12.9 %). Overall the free market represented close to 90% of total consumption in Continental Portugal [4].
Electricity production is responsible for 32% of total global fossil fuel use, accounting for 132 EJ (exa Joules), and 41%, or 10.9 Gt (giga ton) of energy-related CO_2 emissions [5]. In Portugal, the power generation sector is the largest CO_2 emitter with 15.8 Mt CO_2 in 2013 or 35.2% of the total. However, during the Kyoto period 2008-12, CO_2 emissions from the energy sector have decreased by 14% [2].
Energy consumption in general and electricity in particular have proven to be one of the most important aspects in terms of environmental impacts associated with the life cycle of products. For this reason, it is important to know the environmental impacts associated with electricity production provided by the main traders in Portugal, so that we can make a choice based on environmental data and not only economic.
The main aim of this study was to assess and compare the environmental profile of 1 KWh supplied during a specific year (2014) by those four large suppliers, using the Life Cycle Assessment (LCA) methodology.

METHODOLOGY

The LCA study was elaborated based on ISO 14040 [6] and ISO 14044 [7] standards. LCA is a technique for assessing the environmental aspects and potential impacts associated with a product.

Goal and scope of the study

The main aim of this study is to conduct an academic LCA (cradle to gate) to assess and compare the potential life cycle environmental impacts associated with 1 KWh of electricity supplied by the 4 main companies in Continental Portugal in 2014. Other aim of this study is to compare the results with that presented in the Ecoinvent database for the net electricity fed into the Portuguese and UCTE grid at the high voltage level [8, 9].

Functional unit. The functional unit is 1 KWh of electricity at the station busbar.

System boundary. The system boundary for the product system in study is represented in a simplified way in Fig.1. According to the ISO standards, "for the production and delivery of electricity, account shall be taken of the electricity mix, the efficiencies of fuel combustion, conversion, transmission and distribution losses." As it is a comparative study, it does not include transformation, transport nor distribution losses because the impacts of these processes are the same for all companies.

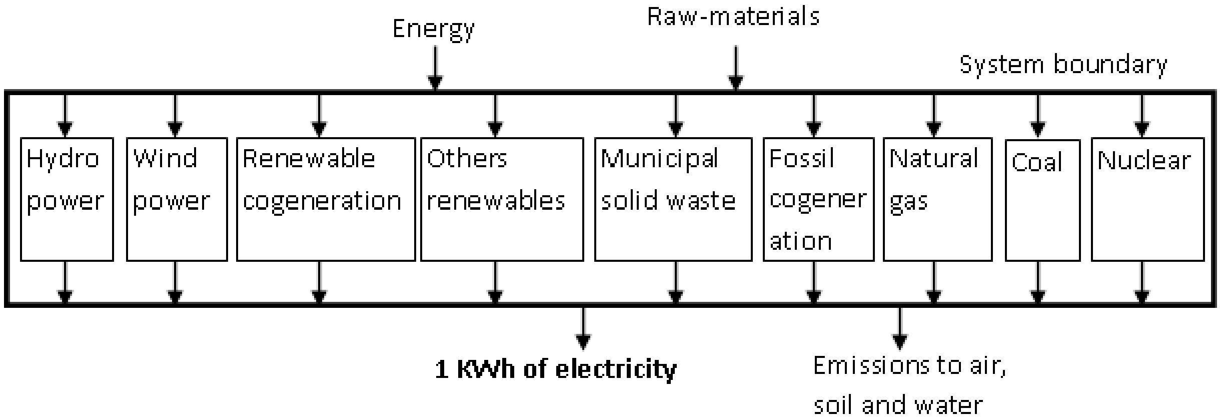

Fig. 1 Product system boundary

Inventory analysis

The inventory analysis and, subsequently, the impact analysis have been performed using the LCA software SimaPro 8.1.0.60 [10] and associated databases and methods.

Data type/data collection. The companies' datasets for electricity mix included in the system boundaries are presented in Table 1. The datasets are valid for the reference year 2014 and were taken from ERSE, [4]. The shares of contributing technologies are in proportion to the annual production of electricity in the supplying transforming activities (electricity generation technologies).

Table 1 Electricity mix in Continental Portugal by company in 2014 (source: adapted from ERSE [4])

Electricity company	Hydro power	Wind power	Renewable cogeneration	Others renewables	Municipal solid waste	Fossil cogeneration	Natural gas	Coal	Nuclear
EDP Serviço Universal	14%	52%	4%	6%	2%	11%	1%	7%	2%
ENDESA	31%	7%	4%	1%	0%	10%	5%	31%	10%
GALP Power	27%	16%	4%	2%	2%	10%	5%	28%	8%
IBERDROLA PT	13%	55%	4%	7%	2%	11%	1%	6%	2%

The following assumptions were made:
The inventory datasets for the background system (such as electricity supplying technologies and their modelling) were obtained from ecoinvent database [8] presented in SimaPro8.1.0.60 software as recorded in Table 2.

Table 2 Datasets for the background system

Process	Equivalent ecoinvent process

Hydropower	Electricity, hydropower, at power plant/PT U
Wind power	Electricity, at wind power plant/RER U
Renewable cogeneration	Electricity, at cogen ORC 1400kWth, wood, allocation exergy/CH U
Others renewables	Electricity, at cogen with biogas engine, allocation exergy/CH U
Municipal solid waste	Electricity, biowaste, at waste incineration plant, allocation price/CH U
Fossil cogeneration	Electricity, at cogen 200kWe diesel SCR, allocation energy/CH U
Natural gas	Electricity, natural gas, at power plant/UCTE U
Coal	Electricity, hard coal, at power plant/PT U
Nuclear	Electricity, nuclear, at power plant/UCTE U

Life cycle impact assessment (LCIA)

The method chosen for impact assessment was EPD2013 V1.01 [11] ready to use in SimaPro software. All impact categories are taken directly from CML-IA baseline method (eutrophication, global warming, photochemical oxidation, ozone layer depletion and abiotic depletion) and CML-IA non baseline method (acidification).

RESULTS

The following Table 3 shows the contributions, to the impact categories considered in EPD method, of 1 KWh of electricity supplied by the electricity companies in study and by Portuguese and UCTE electric grid and Fig. 2 shows the comparative environmental profiles.

Table 3 Impact assessment results associated with 1 KWh of electricity supplied by the competitors

Impact category	Unit	EDP Serviço Universal	ENDESA	GALP Power	IBERDROLA PT	Portugal (PT)	UCTE
Acidification (fate not incl.)	kg SO_2 eq	9,56E-04	2,94E-03	2,71E-03	8,36E-04	4,25E-03	2,07E-03
Eutrophication	kg PO_4^{3-} eq	2,69E-04	8,33E-04	7,79E-04	2,38E-04	1,03E-03	3,76E-03
Global warming (GWP100a)	kg CO_2 eq	1,53E-01	3,97E-01	3,68E-01	1,39E-01	5,58E-01	5,12E-01
Photochemical oxidation	kg C_2H_4 eq	3,80E-05	1,06E-04	9,78E-05	3,38E-05	1,86E-04	9,53E-05
Ozone layer depletion (ODP)	kg CFC-11 eq	1,03E-08	1,59E-08	1,53E-08	9,94E-09	2,55E-08	6,11E-08
Abiotic depletion	kg Sb eq	1,27E-07	5,54E-08	7,18E-08	1,31E-07	9,14E-08	1,02E-07

The results for Portugal (PT) and UCTE member countries are based respectively on the processes “Electricity, high voltage {PT}| production mix | Alloc Def” and “Electricity, high voltage {UCTE}| production mix | Alloc Def” available in ecoinvent database and represent the net electricity fed into the grid at the high voltage level [12]. Portuguese production mix is valid for the period 2008-2014 and UCTE production mix is valid for 2014.

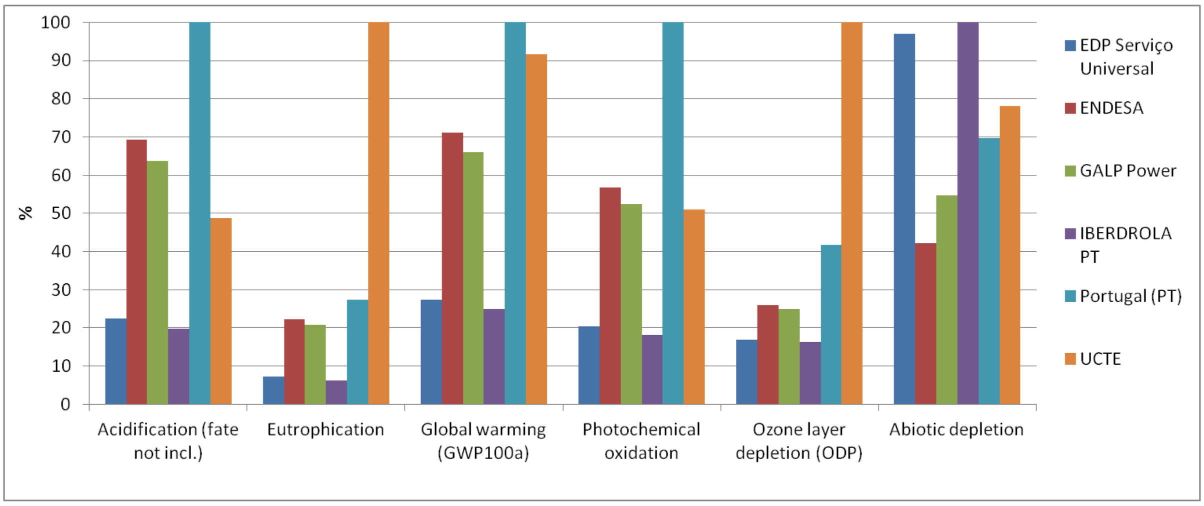

Fig. 2 Comparative environmental profile of 1 KWh of electricity supplied by the competitors

CONCLUSIONS

The main conclusion of the study is that the electricity supplied by ENDESA was the worst in terms of acidification, eutrophication, global warming, photochemical oxidation and ozone layer depletion while the electricity supplied by IBERDROLA was the best for those impact categories representing between 28 to 62% of ENDESA´s impacts. For the same impact categories, the environmental profile of GALP Power electricity was slightly better than ENDESA´s electricity and EDP Serviço Universal electricity was slightly worse than IBERDROLA´s electricity. In terms of abiotic depletion, IBERDROLA electricity was the worst (100%) followed by EDP Serviço Universal electricity (97%), GALP Power electricity (55%) and the best was the ENDESA electricity (42%).
If we compare those results with that for net electricity fed into the grid at the high voltage level available in ecoinvent database for Portugal and for UCTE countries, we can conclude that the worst in terms of acidification, global warming and photochemical oxidation was the electricity at Portuguese grid and in terms of eutrophication and ozone layer depletion was the electricity at UCTE grid. In terms of abiotic depletion, IBERDROLA electricity maintained the worst performance.

REFERENCES

1. IEA statistics. Available at: http://www.iea.org/statistics/statisticssearch/. Accessed: 1 April 2016.
2. © OECD/IEA, *Energy Policies of IEA Countries*, Portugal, 2016 Review, IEA Publishing,. Licence: www.iea.org/t&c, 2016 (2)).
3. Itten R., Frischknecht R. and Stucki M., *Life Cycle Inventories of Electricity Mixes and Grid*, Treeze Ltd., fair life cycle thinking, Kanzleistr. 4, CH-8610 Uster, 2014.
4. ERSE, *Data suppliers*, Regulatory Authority for Energy Services (in Portuguese). Available at:http://www.erse.pt/pt/desempenhoambiental/rotulagemenergetica/comparacaoentrecomercializadores/Paginas/default.aspx. Accessed 5 April 2016.
5. Taylor P., Lavagne d'Ortigue O., Trudeau N. and Francoeur M., *Energy Efficiency Indicators for Public Electricity Production from Fossil Fuels*, IEA Information paper, OECD/IEA, July 2008.

6. International Standard Organisation (ISO) (eds), Environmental management – Life cycle assessment – principles and framework, EN ISO 14040:2006, ISO, Geneva, 2006.
7. International Standard Organisation (ISO) (eds), Environmental management – Life cycle assessment – requirements and guidelines, EN ISO 14044:2006, ISO, Geneva, 2006.
8. Treyer K. and Bauer C., Life cycle inventories of electricity generation and power supply in version 3 of the ecoinvent database-part I: electricity generation, *Int J Life Cycle Assess* (on-line version), 2013.
9. Treyer K. and Bauer C., Life cycle inventories of electricity generation and power supply in version 3 of the ecoinvent database-part II: electricity markets, *Int J Life Cycle Assess* (on-line version), 2014.
10. PRé 2014, SimaPro Software, version 8.0.4, PRé Consultants, Netherlands [online]. Available at: www.pre.nl. Accessed 6 May 2016.
11. SEMC, International EPD Cooperation (IEC), General Programme Instructions for Environmental Product Declaration EPD, Version 2.01, Swedish Environmental Management Council, 18 September 2013.
12. PRé, SimaPro Database Manual, Methods Library, Version 2.8, PRé Consultants, Netherlands [online]. Available at: www.pre-sustainability.com. Accessed 6 April 2016.