The International Journal of Life Cycle Assessment (2019) 24:614–619
https://doi.org/10.1007/s11367-018-1524-y

COMMENTARY AND DISCUSSION ARTICLE

Assessing the availability of life cycle assessments in Austria

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Received: 18 July 2018 / Accepted: 19 August 2018 / Published online: 28 August 2018

Abstract

Purpose This study aims to present the availability of studies that are related to life cycle assessments (LCA) in Austria since 2000. This study also includes a review of available water and carbon footprint studies along with an analysis of the Global Reporting Initiative (GRI) database pertaining to Austria. The review seeks to explore potential research gaps and to identify needs for similar studies in the country while quantifying the number of available studies that are available to the general public or as background information in other LCA studies.

Methods Online searches using Google, Google Scholar, Scopus, and ScienceDirect were conducted using various keywords to find LCA studies. Keywords included: life cycle assessment, LCA, and Austria, as well as water and carbon footprinting. Results were limited to English language studies.

Results and discussion A total of 15 studies that pertain directly to LCAs in Austria were found. In addition, four reports for water footprinting and six reports for carbon footprinting were found, and 77 GRI reports. The majority of the LCA studies were only accessible by way of restricted journals.

Conclusions The majority of the studies focused on the energy and manufacturing sectors. This was expected, due to exports that make up a large portion of the Austrian economy. Nevertheless, LCA research appeared to be driven by academic sources, rather than industry. Therefore, most of the studies were limited to paid subscriptions and thus were not easily accessible by the general public.

Keywords Austria · Carbon footprinting · Environmental management · Life cycle assessment · Water footprinting

1 Introduction

Austria is a landlocked European country with a total area of 84,000 m^2 of mostly mountainous terrain. The country has an open economy consisting mainly of small- and medium-sized enterprises with exports of goods and services accounting for 47% of the gross domestic product (GDP) (Nations Encyclopedia 2018). However, the most important industry in the country is tourism (Österreich Werbung Vienna 2016). Austria produces about 65.3 billion kWh of energy, of which up to 79% is supplied by renewable energy sources (International Energy Agency 2016), indicating that the country has a strong environmental consciousness.

The primary aim of this study was to determine the availability of life cycle-related studies in Austria. The study focused on life cycle assessments (LCA), carbon, and water footprinting studies in particular that are available to the public and non-specialists, as well as LCA practitioners. To satisfy this need, emphasis was placed on data that was both freely available as well as in restricted, paid for academic databases.

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Table 1 Summary of LCA-related results for Austria

	Product	Functional unit	Impact category	Results	Reference
1	Aluminum	kg $year^{-1}$ cap^{-1}	Global warming, abiotic depletion, energy, fossil fuels	Material balances aide in the understanding of aluminum use and recycling within Austria.	Buchner et al. (2014)
2	Battery recycling	400 t of household spent alkaline batteries	Human health, ecosystem quality, resources	Long-term emissions only impact on the human health damage category.	Xará et al. (2014)
3	Bioethanol	One liter gasoline equivalent	Greenhouse gas emissions, renewable, fossil fuels.	Significant reductions of greenhouse gas emissions can be achieved using the renewable fuel source.	Kravanja et al. (2012)
4	Biogas systems	1 MWh useful energy	Greenhouse gas emissions	Biogas systems have lower greenhouse gas emissions than other systems studies.	Pucker et al. (2013)
5	Biopolymer	Impacted square meter surface area per kg material.	Energy, fossil fuels	Biopolymers from whey impact significantly on the environment due to unoptimized production processes.	Koller et al. (2013)
6	Building	A hypothetical two-story office building in Seattle, USA, with 335 m^2 of floor area and lifespan of 60 years	Fossil fuel consumption, global warming, acidification, eutrophication, ozone depletion and smog formation	The usage stage is the primary contributor to the majority of environmental impacts for all scenarios.	Frischknecht et al. (2015)
7	Building design	Building	Global warming, ozone depletion, photochemical ozone creation, acidification, eutrophication, human toxicity, terrestrial toxicity, abiotic depletion, energy demand.	It is difficult to report on individual segmens or stages for building materials. The large distribution in environmental indicators showed that LCA is not a transparent means for building planning	Michlmair (2008)
8	Electricity	One TWh electricity	Fossil fuels, energy consumption, greenhouse gas emissions	Emission accounting methods should be task specific. The consumption based method for accounting performed best	Soimakallio and Saikku (2012)
9	Electricity (biomass production plant)	One kWh	Abiotic, acidification, eutrophication, freshwater toxicity, global warming, human toxicity, land use, marine toxicity, ozone depletion, photochemical oxidation, terrestrial toxicity	The introduction of biomass systems may lead to indirect savings on emissions.	Siegl et al. (2011)
10	Fabrics (dyeing)	1-kg black modal knitted fabric	Climate change, greenhouse gas, abiotic depletion, ozone layer depletion, acidification, eutrophication photochemical oxidant formation, energy consumption, water use.	Spun-dyed fabrics are less damaging to the environment than conventionally dyed fabrics.	Terinte et al. (2014)
11	Food	1-kg food product	Nitrogen formation	Animal-based products are less nitrogen-efficient than plant-based products.	Pierer et al. (2014)
12	Man-made fibers	One metric tonne of staple fibers	Global warming, abiotic depletion, ozone layer depletion, human toxicity, fresh water aquatic ecotoxicity, terrestrial ecotoxicity, photochemical oxidant formation, acidification, eutrophication	Various Austrian fiber studies have better environment profiles than common fibers.	Shen and Patel (2010)
13	Office building	Surface area to volume ratio between various building	Energy consumption, energy efficiency, construction materials.	Energy and construction costs can be optimized using integrated design.	Neururer et al. (2013)
14	Organic dairy products	1 kg of energy corrected milk	Greenhouse gas emissions	Dairy farming is the large greenhouse gas contributor in the European agriculture sector and requires more sustainable practices.	Hietala et al. (2015)

Table 1 (continued)

	Product	Functional unit	Impact category	Results	Reference
15	Treated wastewater	One cubic meter of wastewater	Ozone depletion, marine eutrophication, photochemical oxidation, abiotic renewable, fossil fuels, nuclear energy, water, land, climate change, human toxicity, PM formation, fresh water eutrophication, terrestrial toxicity, land occupation and transformation.	Supply chain management and material valorization prevents resource extraction and mitigates diversity loss within wastewater treatment processes.	Schaubroeck et al. (2015)

Additionally, the number of GRI reports was investigated to determine the general environmental reporting practices of industrial players as a pseudo-comparison with what is expected to be an academic outcome of the prior searches.

2 Methods

Online searches were conducted using a similar method as found in (Maepa et al. 2017; Bodunrin et al. 2018; Burman et al. 2018; Croft et al. 2018; Engelbrecht et al. 2018). Google/Google Scholar, ScienceDirect, and Scopus were used to find documents published between 2000 and 2016. Non-exclusive searches using the keywords "life cycle assessment," "LCA," "carbon footprint," "water footprint," and "Austria" were used in order to find articles, reports, and conference papers that contained these keywords. Additionally, the Global Reporting Initiative (GRI) database reports for Austria (2016 only) were included to get a sense of the reporting tendencies of companies.

It is possible that some studies have been overlooked during the search method used here; however, the aim of the review is to assess the availability of easily accessible material to everyday users who would generally employ the above keyword searches and would not be knowledgeable about individual researchers in the country. German language reports were not included in the results and only reports written in English were considered. In addition, other life cycle management studies, e.g., social life cycle assessment and organizational life cycle assessment were excluded as explicit key words.

Table 2 Summary of carbon footprint reports for Austria

	Product	Availability	Source	Reference
1	Fossil fuel	Free	Journal	Gingrich et al. (2011)
2	Food	Free	Conference paper	Lindenthal et al. (2010)
3	Tomatoes	Free	Journal	Theurl et al. (2014)
4	Cucumbers	Free	Conference paper	Raab and Brunklaus (2013)
5	Dairy	Paid	Journal	Hietala et al. (2015)
6	Fabric dye	Paid	Journal	Terinte et al. (2014)

3 Results

The analysis conducted located 15 life cycle assessment-related studies pertaining to Austria (Table 1). The documents covered a wide range of topics. Material production and energy-related studies each comprised four reports and building construction studies yielded an additional three reports. The remainder of the reports is related to battery recycling, wastewater treatment, and the food industry.

In terms of carbon footprint studies, only six reports were found (Table 2). Four of these studies were for the food industry. Four of the six studies were accessible without paid subscriptions. For the water footprinting studies (Table 3), three studies focused on the agriculture and dairy industries while one study was a general countrywide report.

The GRI database search yielded 77 reports from organizations within Austria for 2016 (Table 4). The search included reports for all reporting criteria of GRI-3, GRI-3.1, GRI-4, non-GRI, and GRI-cited reports. Of all the reports, 46 reports (60%) were GRI-4 reports, 22 reports (29%) were non-GRI, and nine reports (12%) were GRI-cited reports.

Table 3 Summary of water footprint reports for Austria

	Product	Availability	Source	Reference
1	Food groups	Paid	Journal	Vanham (2013)
2	Crops	Free	Journal	Thaler et al. (2017)
3	Milk	Free	Conference paper	Hörtenhuber et al. (2014)
4	General countrywide	Paid	Journal	Vanham (2012)

Table 4 GRI database search results

Industry	GRI-4	GRI-cited	Non-GRI	Total
Aviation	1		1	2
Computers			1	1
Conglomerates	1			1
Construction	3	1		4
Construction materials	2	1	1	4
Energy	3			3
Energy utilities	3	1		4
Equipment	1		1	2
Financial services	9	1	2	12
Food and beverage products	3	1	1	5
Forest and paper products	1		3	4
Healthcare products	1			1
Logistics	1			1
Media			1	1
Metals products	2	1		3
Mining	1			1
Non-profit/services		1	4	5
Other	3	1		4
Real estate	3		2	5
Retailers	1			1
Technology hardware	1			1
Telecommunications	2			1
Tourism/leisure	3		2	5
Universities			1	1
Waste management	1	1	1	3
Water utilities			1	1
Total	46	9	22	77

4 Discussion

Since Austria has a strong industrial background, it was expected that more consideration would be given to power generation and material production. LCA reports on these two sectors accounted for 53.3% (~27% each) of the total LCA studies documented within this review. Additionally, construction accounted for 20%, recycling and wastewater treatment 13.3% (~7% each) and the food industry the remaining 13.3% (Fig. 1a). Of the studies found, 11 (73%) were obtained via paid channels while the remaining four (27%) were freely accessed through online searches (Fig. 1b). Conversely, 67% of the carbon footprinting studies was freely accessible, while 50% of the water footprinting studies was also freely available. Hence, much of the work on LCAs that pertain to Austria is not easily accessible to the public via free channels.

Of the 77 listed GRI entries, the financial services sector was the largest contributor with 12 entries (16%). The constructions and construction materials industries provided eight entries (11%), followed by the energy and energy utilities industries that comprised seven entries (9%). These are the largest contributors to the GRI database, however, combined, they contribute just over a third of the total number of entries, illustrating that there are contributions from a number of diverse industries.

The reports found in this study were all published after 2007; an unexpected result, given that the 12th SETAC Europe Annual meeting was held in Vienna in 2002 and that LCA was highlighted as an important aspect of the meeting (Rebitzer et al. 2002). Some studies before 2007 could be found, for example (Jungmeier et al. 2002; Jungmeier et al. 2003; Unger et al. 2004), but required a modified search method or stricter search restrictions by date, both options of which were outside the scope of this work. Additionally, these studies were not for Austria only or were written by Austrian authors about non-location specific topics. The authors also noted a possible problem with older work, in that PDF documents are less likely to be internally searchable, further limiting a search engine's ability to find appropriate results.

Comparing these findings to a search within the ecoinvent v3.4 database, the authors were able to find 350 datasets.

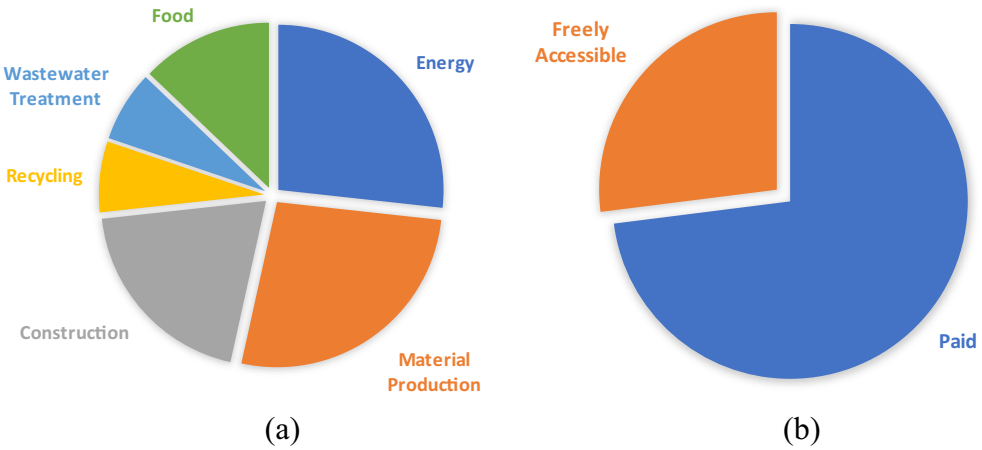

Fig. 1 **a** Relative proportion of LCA-related studies for various sectors. **b** Proportion of paid access studies to free access studies

While this number is a total of allocation and consequential datasets, for unit and system processes, cutoff by allocation and point of substitution, even if the total is conservatively divided by six, this gives approximately 87 datasets. This value is higher than the 15 studies found through online searches. Additionally, the authors noted over 18,000 reports were listed for Austria in the openLCA Nexus (https://nexus.openlca.org). However, only 8286 were freely available and it appeared if many were published in German so not applicable to the aim of this paper.

5 Conclusions

The scope of this review was to evaluate life cycle assessment-related data as they pertain to Austria. It was found that a large number of LCA-related documents were only obtainable by way of paid means, with a few being freely accessible through online searches. Austria's major exports are within machinery, metallurgical products and textiles and this was reflected in the proportion of LCA studies focused on them, especially with the energy consumption in their production processes.

Using the method as presented here, it is noted that a large number of studies were not available by typical searches as would be performed by non-specialists, e.g., Google and that the majority (over 99.5%) were seemingly hidden in either ecoinvent or the openLCA Nexus.

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