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THE IMPORTANCE OF LOCAL FACTORS FOR INVENTORY ANALYSIS

SANİYE KARAMAN ÖZTAŞ[1] and LEYLA TANAÇAN[2]

[1]*Architecture Dept, Gebze Technical University, Kocaeli, Turkey*
[2]*Architecture Dept, Istanbul Technical University, Istanbul, Turkey*

Life Cycle Inventory (LCI) is an important phase of Life Cycle Assessment (LCA) that provides information on environmental impact assessment of products throughout their life cycle. Local factors have an effect that can influence the results of an LCI. Many developed countries established their own databases for inventory analysis thus eliminating the issues related with locality. In some of LCA studies, data of similar systems or technologies are considered into inventory calculations. However, there might be mistakes in the inventory analysis results because of the differences between the real system and the system used as a source. Environmental impact assessment is an important selection criterion in the construction sector with different kinds of materials. Turkey has lack of environmental data and is one of the developing countries which has not yet generated a database for the construction materials. In this study, it was aimed to discuss the importance of local factors for LCI. Therefore, environmental information taken from Environmental Product Declaration (EPD) of the ceramic tiles manufactured in different geographical context were compared. It was pointed out the urgency of local inventory data and concluded that the gaps may be minimized with industry involvement.

Keywords: Construction materials, Database, EPD, LCA, Locality, Turkey.

1 INTRODUCTION

LCI involves data collection and calculation procedures for the compilation and quantification of inputs and outputs of a product system throughout its life cycle. There are two data systems for inventory analysis. The foreground system (primary data) is defined as the processes of the system that are under control of the decision maker involved in the study (Frischknecht 1998). It includes various sources such as literature, industry survey, industry based data and European average data. Background system (secondary data) is defined as the processes of the system that are not specific to the studied system such as extraction of raw materials, production of the construction materials or electricity. The background system comprises the processes that are operated as part of the system but that is not under direct control of decisions analyzed in the study (Lotteau *et al.* 2015). It includes data such as Ecoinvent, GaBi databases.

An Environmental Product Declaration (EPD) quantifies the environmental impacts of products including the construction materials. According to ISO 14025 (2006) standard, one of the objectives of Type III environmental declarations is to provide LCA based information and additional information on the environmental aspects of products. EN 15804 (2012) standard provides Product Category Rules (PCR) for Type III environmental declarations in the construction sector. The environmental information of an EPD cover all life cycle stages shall

be subdivided into the information module groups. Only the declaration of the product stage modules, A1-A3, is required for compliance with this standard. The declaration of the other modules is optional.

Local factors such as local or regional energy mix, manufacturing technology, kinds of transport and distances etc. are important for LCI. Ignoring these factors affects the accuracy of the inventory analysis. Therefore, several databases about the construction materials have been developed for different geographical context. In addition to the background data such as Ecoinvent database for Switzerland and Europe (2009), European Commission (2015), GABİ Software (2013) for Germany and Europe, and Athena (2013) for US and Canada, local databases such as IBO-Roichtwerte (2016) (the database published by the Austrian Institute for Healthy and Ecological Building) have been developed. However, LCA studies are mostly carried out in developed countries. According to L. F. Cabeza *et al.* (2014), there is no case about LCA in Africa, only one case was found from South America, several papers from Asia; while a lot of cases from North America and Europe were available. Turkey has not yet generated a database for the construction materials. Due to this scarcity of the local data in Turkey, researches often apply non-local databases in their studies. While there is no local database, it is possible to use the information given in EPDs. Nowadays, different construction material producers have declared the environmental impacts of their materials and received an EPD certificate in Turkey. It is a positive step to develop an inventory database.

In this study, it was aimed to discuss the importance of local factors for LCI. Therefore, the environmental information taken from EPDs of the ceramic tiles manufactured in three countries was compared. Also, it was pointed out the urgency of local inventory data and concluded that the gaps may be minimized with industry involvement.

2 LIFE CYCLE INVENTORY STUDIES FOR TURKEY

Turkey has not yet generated a database for the construction materials. Therefore, there are not many studies related to LCA of the construction materials. Taygun (2005) proposed environmental data sheets to determine inputs and outputs for the construction materials in the context of LCI. Gultekin (2006) proposed open- end model to determine the relation among the construction materials, environmental impacts, and life cycle phases. Çakmaklı (2007) used Athena program that includes European databases for the construction materials in hotel refurbishment projects in Turkey. However, the properties of the material in the database cannot be changed or added by the users in this LCA program. Çamur (2010) studied LCA method for the thermal insulation materials, used GaBi LCA program and literature for the inventory analysis. Mangan and Oral (2015) studied life cycle energy and CO_2 emission analyses for residential buildings in Turkey. GABİ Software (2013), the Inventory of Energy and Carbon (ICE) (Hammond and Jones 2011) and literature were used for LCI. Olmez *et al.* (2016) studied LCA of iron and steel in Turkey. Data were obtained from the three-integrated iron and steel production facilities as a representative sample of Turkish integrated iron and steel industry in terms of manufacturing technologies and production capacity. The information about acquisitions of raw materials, energy and auxiliary materials were not obtained from the facility, but, instead was taken from the inventories in the databases of SimaPro LCA software. Ecoinvent database was preferred primarily. In case the information was not available in this database, the other databases (Dutch Input Output Database 95, ELCD, EU&DK Input Output Database, Industry data 2.0, USA Input Output Database 98 and USLCI) were used. In these studies, it is seen that researches often apply non-local databases in their studies due to the scarcity of local data in Turkey.

Nowadays, different construction material producers have received an EPD certificate. Although it can provide the collection of environmental information for the local database, all environmental data used for EPD are not local. Both of generic and background data are used for EPDs. Construction material producers have taken EPDs from different declaration holders in Turkey and it is seen that different background data have been used. Appropriate LCA data for the construction materials are a prerequisite for the assessment. Thus, building LCAs might be more sensitive to background data selection (Takano *et al.* 2014). Yokoo *et al.* (2013) indicated that the use of different databases causes numerical differences in LCA of the buildings. While inventory database studies are new in Turkey, developing a standardized way provides to allow comparison of the construction materials' environmental impacts.

3 COMPARISON OF THE LOCAL FACTORS ON THE CERAMIC TILES

Differences of materials' composition, manufacturing technology, kinds of transports and distances, electricity grid as well as recycled content as the local factors cause different LCA results of the construction materials produced in various regions or countries. In this study, four EPDs about ceramic tiles including wall and floor tiles are compared in terms of the local factors.

The names of the ceramic tile producers have been omitted to preserve the privacy of the manufacturers of the analyzed. The functional unit of the tiles is 1 square meter. The system boundary of the tiles is "cradle to gate" including life cycle phases from raw material acquisition to the factory gate. All the tiles comply with EN 14411 standard (2006). And typical manufacturing process of the ceramic tiles is broken down into various process steps such as raw materials storage, grinding, atomization, pressing and drying, glazing where necessary, firing and packaging. Data are very much dependent of local technology and of the period it refers to old technology or new technology. Manufacturing technology of the ceramic tiles are similar. For all the tiles produced in three countries, the final product is packed in cardboard boxes, stacked on wooden pallets and protected with PET film. Three producers recycle the total amount of waste water, only the ceramic tile producer in Turkey 1 reuses over 90 % of the treated industrial water in production. Natural gas and electrical energy are two energy sources in the manufacturing process. The kind of transport and distances were taken from the details provided by the plants of the producers. The ceramic tiles produced in Germany and Italy can be reused in line with their original designated use following specific dismantling of buildings or can be crushed and then used in a range of different applications. Reuse of the ceramic tiles produced in Turkey has not declared. Three ceramic producers have preferred IBU, a ceramic tile producer 2 in Turkey have preferred The International EPD system as the declaration holders. These two holders have used different databases for the background data (Table 1). Although all the indicated databases have referred to the same functional unit for the ceramic tiles, some aspects may be different from database to database.

Table 1. The content of the ceramic tiles in four EPDs.

	A ceramic tile producer in Germany	**A ceramic tile producer in Italy**	**A ceramic tile producer 1 in Turkey**	**A ceramic tile producer 2 in Turkey**
Declaration holder	Institute const. and environment (IBU)	Institute const. and environment (IBU)	Institute const. And environment (IBU)	The International EPD system, Sweden
Functional Unit	1 m^2, 15.1 kg/m^2	1 m^2, 19.9 kg/m^2	1 m^2, 18.9 kg/m^2	1 m^2, 22 kg/m^2
System boundary	Cradle to gate	Cradle to gate	Cradle to gate	Cradle to gate

Table 1 (continued). The content of the ceramic tiles in four EPDs.

	A ceramic tile producer in Germany	**A ceramic tile producer in Italy**	**A ceramic tile producer 1 in Turkey**	**A ceramic tile producer 2 in Turkey**
Base Materials	Clay 60%, feldspar 22%, kaolin 8%, limestone approx. 4%, sand approx. 3%, glazes/refinement approx.4%	Clay 42%, feldspar 35 %, sand 13 %, rhyolite 4%, glaze components, main auxiliary additives	Clay 50-60 %, feldspar 35- 45 %, calcite 3-5 %, kaolin 1-5 %, others < 1%. Auxiliary substances additives	Clay 50-60 %, feldspar 35- 45 %, silica sand 4-8 %, other < 1%.
Generic background data	GaBi database.	GaBi database. European LCI database, The European Federation of Corrugated Board Manufacturers, Perry's Chemical Engineers' Handbook, Ceramic Glaze Handbook, European Ceramic Tile Manufacturers'	GaBi database, European LCI database, European Federation of Corrugated Board Manufacturers and European LCI database, Confederation of European Waste to Energy Plants.	Ecoinvent database
Representative data	9 companies and 12 plants	76 companies and 84 plants	Two production plants in Turkey	Main production plant in Turkey
Temporal data	Foreground data are collected from the production year 2008-2009. The power mix for Germany 2008 is used.	The LCA data were collected in 2014	not older than 2008 for energy carriers and 2010 for all other datasets. Datasets from ELCD are from 2002 and 2006. Foreground data are collected is from the production year 2011	2013- 2014 production figures for ceramic tiles

From Table 2, it can be observed differences of LCA results in terms of the environmental impacts, resource uses and wastes for four EPDs, although the functional units and system boundaries are the same. According to these results, the ceramic tile producer in Germany has a more sensitive approach to the environment except radioactive waste and abiotic depletion potential for non-fossil resources when compared to the others, whereas the ceramic tiles produced in Turkey cause more environmental impacts. However, this comparison may not be accurate because of the differences in the inventory database. It may be due to the following reasons:

- Different background databases such as GaBi and Ecoinvent may cause different results. Therefore, the comparison of the environmental impacts of the tiles from three ceramic producers preferred IBU may be more accurate because of the same background data.
- Local factors such as energy mix of the countries, transportation data, composition of the materials influence the results of LCA. Table 1 indicates that there are differences in the percentage of the materials to produce the ceramic tiles. In addition to the different material composition, a required composition of raw materials includes also recycled wastes to produce the ceramic tile in Germany. Transportation data of the ceramic plants were taken from the data of the production plants. The ceramic tile company in Germany

have declared that a truck with a useful load of 27 tons was assumed as the means of transport. Distances of the transportation data have not been declared for the tiles. The electricity production mix differs depending on time and place. In addition, the reference year for the calculation varies from database to database and data by data. This variation naturally affects the environmental impacts of the material production processes of the ceramic tiles. The ceramic tile producer in Germany used the power mix for Germany.

Table 2. The results of LCA for four EPDs.

		A ceramic tile company in Germany	**A ceramic tile company in Italy**	**A ceramic tile company 1 in Turkey**	**A ceramic tile company 2 in Turkey**
GWP	kg CO_2 eq.	9.7	10.5	16.3	13.3
ODP	kg CFC11 eq.	4.7E-07	0.006E-07	0.18E-07	7.39E-07
POCP	kg ethane eq.	1.6E-03	2.37E-03	3.14E-03	2.27E-03
AP	kg SO_2 eq.	2E-02	2.47E-02	7.40E-02	4.56E-02
EP	kg PO_4^3 eq.	1.9E-03	2.75E-03	6.56E-03	17.6E-03
ADPE	kg Sb eq.	9.9E-05	9.19E-05	3.70E-05	0.59E-05
ADPF	MJ eq.	1.23 E+2	1.57E+2	2.21E+02	2.03E+02
PERT	MJ eq.	0.91 E+01	3.11E+01	1.29E+01	0.005E+01
PENRT	MJ eq.	1.64 E+2	1.62E+02	2.26E+02	2.06 E+02
FW	m^3 kg	0.075	0.03	not declared	0.192
RWD	kg	5.8E-03	4.61E-03	2.07E-03	0
HWD	kg	0.038	2.06	not declared	10.70
NHWD	kg	not declared	0.75	not declared	0.00026

(GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophication potential; POCP = Formation potential of tropospheric ozone photochemical oxidants; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources; PERT = Total use of renewable primary energy resources; PENRT = Total use of non-renewable primary energy resources; FW = Use of net fresh water; RWD = Radioactive waste disposed; HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed.)

4 CONCLUSIONS

Countries have been developed their own database because of the importance of local factors. Databases should be regionally sensitive taking into consideration manufacturing technology, kind of transportation and distances, electricity grid differences for materials produced in various regions. Industrial involvement is important to provide environmental data of the construction materials in the developing countries. The awareness of the environmental issues for the construction materials sector should be raised, and it should be urged the manufacturers of the construction materials to use of LCA.

EPD may provide the developing countries to create their local databases according to product category rules in EN 15804 (2012) standard. Comparability of LCA results based on different background data is one of the main issues for the construction materials which require multiple material data for the assessment. Therefore, national category rules should be created in addition to the rules in standard with the participation of different stakeholders. A standardized way to allow comparison of the construction materials' environmental impacts should be developed. Then, the local database should be developed by harmonizing a generic database to avoid time consuming process and labor intensity.

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