

# Life Cycle Assessment, a tool for improving “wash appliances” performances in the framework of the Ecodesign Directive

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**Abstract** In the framework of the preparatory studies for eco-design requirements for energy using products (EC DG-Energy Tender TREN/D1/40-2005 - Lot 14) [1], authors have done the environmental assessment for Washing-Machines and Dish-Washers, as a part of a more broad study. Standard base cases – as reference models - were identified on average of the 2005 CECED (Conseil européen de la construction d'appareils domestiques) technical database and on the sales data by energy efficiency in 2004 for 21 European countries. Standard base-case characteristics were identified for dishwashers and for washing machines. On these models, LCAs were realized using EuP-Ecoreport v.5 (as required by the call) and SimaPro v.7 software in order to compare their results.

## 1 Introduction

In the framework of the preparatory studies for eco-design requirements for energy using products (EC DG-Energy Tender TREN/D1/40-2005 - Lot 14), authors have done the environmental assessment for Washing-Machines and Dish-Washers, as a part of a more broad study. Standard base cases – as reference models - were identified on average of the 2005 CECED (Conseil européen de la construction d'appareils domestiques) technical database and on the sales data by energy efficiency in 2004 for 21 European countries. Standard base-case characteristics were identified for dishwashers and for washing machines. Standard base-case characteristics were identified for dishwashers, 12 place settings (DW12ps) and for washing machines, 5 kg load (WM5kg). On these models, LCAs were realized according to the ISO14040 standards. For the LCA data processing, the Tender required the use of dedicated software, the EuP-Ecoreport (EuP-ER), implemented on a spreadsheet platform. The authors, in order to verify and validate the results, have done the LCAs using one of the most popular commercial software, the SimaPro7 (SP), too.

Both for dishwashers (DW12ps) and for washing machines (WM5kg) inventory data were collected from European producers: 6 for DW12, 5 for WM5. An inventory data questionnaire has been sent to producers in order to collect data on: Production phase (Bill of materials with scraps, Transport, Processing), Assembling (Energy, water and other materials used), Use phase (Life, electricity consumptions – on/stand-by/off mode, consumables), End of Life (Dismantling, recycling, energy recovery, land-filling - %). As some of data provided from producers were not complete and not compliant with standard foreseen from questionnaires, a control phase and a feedback with producers was necessary. Then, average inventory tables were calculated for each of the three standard base-cases.

Inventory data were, thus, implemented both on EuP-Ecoreport and on SP, according to available data-bases and according to potential offered by the two different calculation tools. In fact, while the SimaPro offers a wide possibility to integrate data and specify details about the inventory phase, the EuP-ER is quite stringent, not allowing many choices from the users. Furthermore, while SP allows respecting ISO14040 standards, EuP-ER is partially compliant, e.g. not allowing the full implementation of the life cycle impact assessment. In conclusion, results of LCAs performed with the two SWs were analyzed and compared, as starting point for eco-design indications for such kind of domestic appliances.

## **2 The standard base cases**

According to the study “Preparatory Studies for Eco-design Requirements of EuPs. LOT 14: Domestic Washing Machines & Dishwashers”, are here below summarized the characteristics of the models chosen as base-cases.

- Standard base case characteristics for dishwasher - 12 place settings machine (DW12ps): energy consumption: 1,070 kWh/cycle (energy efficiency class A/B, EEI=0,648); water consumption: 15,2 litres/cycle; washing performance class: A/B; drying performance class: A or B;
- Standard base case characteristics for washing machine (WM5kg): load capacity: 5,36 kg; energy consumption: 0,998 kWh/cycle (“C” = 0,187); water consumption: 50,7 litres (9,6 litre/kg cycle); spinning speed: 1.129 rpm; automatic load detection; energy efficiency class: A (0,17 < “C” < 0,19); washing performance class: A; drying performance class: B or C.

## **3 Life cycle inventory**

The LCI has been carried out for the following life cycle phase: Production (raw materials, components and assembling); Distribution of products (average distances and types of transport modes); Use phase (average life, specific

consumption, maintenance and repairs); Packaging (type and weight); End of Life - EoL (disposal, thermal valorisation, incineration, dismantling...).

These data have been collected and organised according to the “EuP-ER” requirements and taking into account the LCA ISO 14040 standards. As far as possible, LCA has been carried out using not only the EuP-ER software but also the SP7 one.

Primary input data have been collected through direct communication with producers (associated in the CECED) and, when not available, from sector specific or commercial data bases. Inventory data have been gathered through a specific “Bill of materials (BoM) and inventory data template” collection form. Manufacturers have been requested to provide the information listed in the collection form basing them on real appliances, whose characteristics are the closest possible to the identified standard base cases.

### ***3.1 The bill of materials and inventory data collection***

Primary input data came from direct communication with manufacturers and/or, if not available, were collected on sector specific or commercial data base (secondary data). Number of manufacturers providing data are shown in the following table.

**Tab.1: Manufactures providing data for the LCI of standard base cases for DW12ps and WM5kg**

Appliances	Code	Data from manufacturers
1 <sup>st</sup> standard base case characteristics for dishwasher - 12 place settings machine	DW12ps	6
Standard base case characteristics for washing machine	WM5kg	5

Starting from data provided, an “average” model has been elaborated both for DW12ps and for WM5ps. Following paragraphs summarise main data provided characteristics and elaboration assumptions.

#### **3.1.1 Characteristics of data provided from manufacturers of dishwashers**

Data collected for dishwashers presented the following characteristics: Production: Material: data are sufficiently complete; some manufacturers produced data only in terms of “sub-assembled components” (objects) without indications of their material composition; Scrap: generally the data (percentage and EoL) don’t represent all materials used; Processing: given information, also if sometimes exhaustive, are often generic and incomplete and without percentage; Transport: data (average kms and medium) are complete only in some cases; Assembling: the

provided data are generally complete, even if sometimes units of measure are not those required by the inventory data sheets; Use phase: the provided data are sometimes not-complete and units of measure are not those required by the inventory data sheets (generally no indications on cycle/year); EoL: although some producers gave congruent indications, data are difficult to understand and to use. According to the data quality, questions and remarks were sent to the manufacturers and feedbacks were used in order to complete the data collection.

### **3.1.2 Characteristics of data provided from manufacturers of washing machines**

Data collected for dishwashers presented the following characteristics: Production: Material Composition: for some models full indication for each material used have been provided; for other models “objects” are included and data on material composition are available only for some models; Scrap and EoL: for some models no figures have been provided; for other models only generic and incomplete data have been provided; Processing: is always indicated but generally without any indication on %; Data on transport: are complete for most of the models; Assembling: data are generally complete also if sometimes units of measure are not that required in the inventory data sheets; Use phase: data are sometimes incomplete and units of measure are not that required in inventory data sheets (generally no indications on cycle/year); EoL: specific EoL data per material category have been provided only by few producers.

According to the data quality, questions and remarks were sent to the manufacturers and feedbacks were used in order to complete the data collection.

Both for DW12ps and for WM5kg, some general main assumptions were made:

- to use data from other manufacturers when data are not complete or not available;
- to refer to the EU average, mainly for transport and EoL;
- to use 100% for processing when no percentage specification is provided.

### **3.1.3 Final assumptions for the collected data**

Taking into account the “homogeneity” of questions and answers about DW12ps and WM5kg, the following assumptions and simplifications were made for the definition of the “average models” for both product groups: in general, data have been checked and, if necessary, normalised in order to have the same units; for production phase: in the BoM scheme, data have been organised into the following material categories: Ferrous metals; Non-ferrous metals; Plastics; Various materials; Packaging. for manufacturers data, similar or analogous data have been re-organised and re-assembled within the previous material categories; some manufacturers provided data in terms of sub-assembled parts. In these cases, the sub-assembled have been disaggregated (when possible) into the single

material components and, once again, organised in the previous material categories; average data for BoM have been calculated as the mean of the available values; for scrap, the EoL and processing data from the most complete inventory tables have been considered; data used for the average model are not, in general, the mean of the available values but are derived from general considerations regarding the provided values; for transport of materials, average kilometres have been calculated, weighted by the weight of singles components, for each model. The average km value for the average model is a second-level averages, weighted on weights of each model; for Assembling and Use phases: data provided from manufacturers have been checked and normalised, when necessary for the same unit of measure. Data for the average model for the assembling and use phases, has been calculated as the mean of the available values; for EoL: data from manufacturers are often not-homogeneous: only homogeneous and congruent data have been considered to calculate the average model.

## **4 Base cases environmental impact assessment**

### ***4.1 Using EuP-Ecoreport – considerations and assumptions***

For the LCA the software EuP-ER v.5 was used and some assumptions and considerations were required and here summarised.

Data requested to manufacturers were larger than those necessary for the implementation of LCA with the EuP-ER, but were adequate to the implementation of the LCA with a more flexible and complete software such as SP. The comparison of results gained with the two software was aimed at complement the results coming from EuP-ER and somehow make a validation through the comparison with the outcome of an internationally recognised LCA SW. In particular, following data are not requested as input in the EuP-ER:

- production phase: data on scrap (percentage and EoL), data on processing and transport of single materials, since those data are defined as assumptions in the EuP-ER; only the setting of the percentage of sheet metal scrap is allowed;
- assembling phase: data on consumption during the assembling phase, which are assumptions in the EuP-ER;
- detailed data on EoL: only the setting of the percentage of land-filled materials, and the percentage of plastics recycled, in terms of materials or thermal utilisation is possible.

In addition, it is worth noting that the in the Data Base available in the EuP-ER many materials are missing. For this reason, only the material composition of the identified average models has been used as input in the BoM of the EuP-ER. For

dishwashers, information about consumables is missing in the EuP-ER, the same occurs also for the detergent and softener for the washing machines.

The materials not mentioned in the Data Base have been re-allocated in the existing material categories. Accordingly, the following assumptions were made:

a) for some materials a direct correspondence with the categories in EuP-ER, data base is possible;

b) for some materials an allocation is possible provided specific assumptions and simplifications are done. The following correspondences were used: Steel strip as Steel Sheet galv.; pre-painted steel as Stainless 18/8; Steel + PA as Stainless 18/8; Bras (Cu + Zn alloy) as Cu Zn 38; Wiring as Cu wire; Zinc die-casting as Cu Zn 38; PP – K40 as PP; PA 66 – GF as PA 6; PC – G as PC; EPDM – rubber as LDPE; POM as HDPE; Wood as cardboard; Gravel as Concrete; Thermostat as Controller board; PPO as PP.

c) for some materials no correspondence is possible; in this case the missing materials' weight is re-allocated in other material categories, according to their percentage. Materials without correspondence are: Plastics, others; Adhesive; Others; Cr; Ni; PBT; Bitumen; Cotton; Cotton + Resins; PPS-GF; Filter; Oil-feet.

#### ***4.2 LCA of wash appliance base cases using EuP-Ecoreport***

Taking into account all the previous assumptions, the EuP environmental profiles for DW12ps and WM5kg models have been evaluated.

Some materials have no correspondence in the categories included in the EuP-ER data base. This occurred for the following weight percentage: 15,5 % for DW12ps; 4,4 % for WM5kg. Assumptions were made for other materials to find a correspondence with existing categories: 12,4% for DW12ps; 4,8 % for WM5kg. This means that between 9% and 29% of the weight of materials in the wash appliances does not have a direct correspondence in the EuP-ER data base. This has to be taken into consideration for the analysis of the appliances environmental impacts in the EuP-ER output. Moreover it is also important to remind that in the EuP-ER database:

- the environmental impact for transport is included in materials environmental impacts; this means that the production phase outputs account also for the impact and consumption due to transport;
- in the “distribution” phase the impact due the packaging includes the transport to retailer;
- the data about detergents or other chemicals (e.g. bleaching) for wash appliances are not taken into account.

On the basis of the described assumptions on the materials substitution and the EuP-ER database, the LCA resulted in:

- the Production and Use phases are responsible for the majority of environmental impacts;

- for the Use phase, energy consumption and water use are the most relevant elements (for both process and cooling), while for the production phase the wastes are more relevant;
- as far as emissions in air are concerned, the Use phase is most relevant for greenhouse gases, acidification and VOC; while the Production phase yields a higher impact of POP, heavy metals and PAHs; and the Distribution phase is relevant for particulate matter (three times the total of production and use phases);
- as far as emissions to water are concerned, the Production phase is the most relevant for heavy metals but not for eutrophication.

## **5 SimaPro analysis results and comparison with the EuP-Ecoreport outputs**

As explained before, EuP-ER has some limits regarding material's database (lack of data, including detergent for Washing machines), transport (included as a fixed amount in material characteristics) and EoL (only partially considered).

In order to assess the correspondence of EuP-ER results with appliances real environmental impact, a comparison with the output obtained with different and well known LCA software (SimaPro v 7.1) has been performed.

### ***5.1 Steps of the comparison***

#### **a) Correspondence of materials used in wash appliance manufacturing with SimaPro database**

Several databases are available in SP and it is also possible for the user to create specific records. In this way it was possible to significantly reduce the number of data in the inventory data sheet without any loss of correspondence in the SP implementation. Also the number of materials for which assumptions were made to find a correspondence with existing categories has been reduced.

Using SP and its databases, it was possible to find a proper correspondence for almost all materials or processes. Only for the following materials a good correspondence could not be found: for DW12ps - polishing solution and protective layer-cataphoresys; for WM5kg - Ni, phosphate and bleach.

#### **b) Main assumption in SP application**

In order to implement in the SP the inventory data of the DW12ps and for WM5kg base case models the following assumptions were made:

- for Assembling phase: scraps: through the evaluation of the data provided by manufacturers, it was possible to consider the scrap percentage equal to 5% for metals and to 1% for other materials (mainly plastics). Therefore the simulation of assembly has been made on the material gross weight;

processing: manufacturers data gave an average indication for the type of processing needed for each material during the assembly phase (simplified approach); in this way it was possible to find a list of typical processes for different class of materials (steels, iron, plastics, PVCs, expanded plastics). To avoid an over-estimation of the impact deriving from materials processing, as general rule metals have been assumed to be processed as 50% of total weight and plastics as 70%; transport: for each model an average number of km for transport of materials for the assembly phase has been calculated from the collected information. Because of the need in SP to set both the average km (as tkm) and the transport system, the average km has been divided in 70% truck and 30% ship;

- for Use phase: all data collected from manufacturers were used; it was also possible to simulate ad hoc detergents and others washing agents or additives (detergent and softener for the washing machine and detergent and rinsing agent for the dishwasher);
- for EoL phase: the percentage of the different treatments at the EoL have been calculated from the data provided by manufacturers and reported in SP data input. It has to be highlighted that in the EuP-Ecoreport, EoL was an “internal preassembled calculation methodology” as percentage and final destinations of some materials.
- For this life phase, EuP-ER can be considered as a “partially close system”, while in SP it is possible to use other data externally collected. For this reason it was decided to show outputs from SP and EuP-ER “with and without EoL” outputs and to make comparison on outputs “without EoL phase” to reduce the outcome differences.

**c) Adapting Ecoindicator95 environmental impact assessment method to EuP-ER Environmental indicators**

Environmental assessment methods available in SP refer to various databases and are different from those used in EuP-ER. In order to make the environmental indicators more “comparable” a “modified Ecoindicator95 method” has been developed and applied to SP outputs.

## ***5.2 SimaPro vs. Eup-ecoreport output***

### **5.2.1 Dish-washers**

According to SP outputs, the Use and Production phases are the most important from the environmental impact point of view. The same result comes from the EuP-ER outputs. The main difference between the two software is in the evaluation of the environmental impact importance in Use and Production phases. For SP, the Use phase has to be considered the most relevant regarding environmental impact.



Analyzing SP outputs, energy consumption, greenhouse gas, acidification and VOC are more relevant in the Use phase while POP and PAH are mainly emitted from production phase. This is in agreement with EuP-ER outputs: the main difference being heavy metals, mainly emitted in the Use phase, instead of the Production phase.

Also particulate matter emission is higher in the Use phase, but it should be considered that in SP “distribution phase” is not considered in the same way that in EuP-ER (in which PM10 are higher in distribution phase, due to emissions by diesel motors). The only possible comparison with EuP-ER outputs for water emission is eutrophication: also in this case, according to SP outputs, it has been indicated as more relevant in the Use phase.

Main considerations and remarks on SP vs. EuP-ER outputs for dishwashers are:

- main “classic“ indicators (such as energy resources, greenhouse gas and acidification): the total values reported can be considered in compliance with EuP ones; SP outputs are higher in absolute value mainly due to better input data accuracy (mainly on materials and assembling) and better definition of the environmental impact of the energy sources. It is worth noting that these indicators are in compliance with EuP-ER outputs and it is also confirmed that the Use phase is more relevant than the Production phase, with the same ratio in the two software.
- VOC's and Heavy Metals (water): the difference could be mainly due to the higher number of compounds contributing to the environmental impact considered in SP database as compared with a lower number in the EuP-ER database;
- PAHs: the value in EuP-ER is higher than in SP output; this could be due to the different calculation methodology used in EuP-ER (MEEuP report) and SP (Ecoindicator95 modified);
- Eutrophication: the EuP-ER total value is higher than in SP; the main reason is apparently the type of detergent used. The eutrophication is higher in the Production phase in SP than in EuP-ER, but it should be reminded that in SP the detergent production is taken into consideration;
- for all the other indicators: in general higher values in SP output have been reported; this is probably due to a higher number of data considered in SP, but also to the non-complete harmonisation between SP and EuP indicators.

### **5.2.2 Washing machines**

As in the case of for DW12ps model, according to SP outputs, the Use and Production phases are more important than the other phases for the environmental impacts; this is valid also for EuP-ER outputs, but the main difference lies in the relative importance of the environmental impact between the Use and the Production phases. For SP the use phase is considered the most relevant for the environmental impact.

Analyzing SP outputs, the energy consumption, greenhouse gas, acidification and VOC are more relevant in the Use phase, while POP and PAH are mainly emitted in the Production phase.

This is in agreement with EuP-ER outputs. The main difference lies in heavy metals, mainly emitted in the Use phase, instead of Production phase. Also particulate matter is higher in the Use phase, but in SP the “distribution phase” is not considered in the same way as in EuP-ER (in which PM10 are higher in the Distribution phase, due to emissions by diesel motors).

The only comparison possible with EuP-ER outputs for water emission is eutrophication, where the Use phase is more important according to SP outputs.

Main considerations and remarks on SP vs. EuP-ER outputs for washing machines are the same already described for dishwashers, with the exception of ‘eutrophication’. The EuP-ER total value for eutrophication is higher than in SP: the main reason is that in EuP-ER no data are available for washing machines detergent.

## 6 Conclusions

Beyond the specific results of the LCA performed on the average models for DW and WM, this paper highlights how the availability of data and tools that meet the standard ISO14040, it is essential for the development of reliable LCA studies. In particular, the EuP-Ecoreport software proves to be inelastic to the inclusion of specific data on the processing of materials, conditions of use, transport of materials and transport and conditions for distribution, and on end of life scenarios. The database also is missing many key data on materials used in the production and the use phase. In addition, the phase of life cycle impact assessment stops at the characterization phase, and it do not allow choosing the assessment method.

Comparison between LCA studies performed with the EuP-Ecoreport and with other more complete software requires, thus, the elaboration of specific procedures and LCA results can differ significantly.

## 7 References

- [1] Scialdoni R., Cutaia L., *Preparatory studies for Eco-design. Requirements of EuPs (Tender TREN/D1/40-2005), LOT 14 – sub-tasks 5.2-5.3-6.4*, ISIS - Istitute of studies for the integration of systems, Rome, 2007.