SETAC-Europe LCA Working Group 'Data Availability and Data Quality'

Energy, Transport and Waste Models

Availability and Quality of Energy, Transport and Waste Models and Data

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Abstract. The subgroup 'Energy, Transport and Waste Models' as part of the SETAC LCA Working Group on Data Availability and Data Quality is finishing its final report with recommendations and references on LCI data concerning energy, transport and waste. To achieve the objectives for each of the models for energy production, transportation and waste management the subgroup has supplied:

- A description of the technical function of LCA and the technical background of existing data, including the influence of using different energy carriers and technologies to reduce emissions
- a data quality description with separate checklists, based on understanding the technology aspects of energy production, transport and waste treatment and LCA thinking. The checklists are meant to be suggestions for data 'providers' of how to improve available data and also the availability of relevant data
- references for available relevant data
- guidelines for what to look for when selecting an appropriate data set

Keywords: Data availability; data quality; energy models and data; SETAC LCA Working Group, Data Availability and Data Quality, Subgroup Energy, Transport and Waste Models; transport models and data; waste models and data

1 Objectives of the Subgroup

The objectives of this subgroup were to:

- supply a reference for practitioners to increase their understanding of the available models and data;
- increase their awareness of the order of magnitude of the differences between data sets caused by system boundaries, allocation rules and level of detail.

2 Energy

Transparent documentation is needed to understand the data and how they can be used.

Inventory data for energy systems should be based upon a life cycle perspective for both energy carrier and power generation facilities (technologies) for each primary energy source. Emissions and resource depletion from extraction and electricity/heat generation should be included and described separately. In principle, construction and demolition of facilities should be included, keeping in mind their proportional importance.

Electricity production inventory data by country, or region, are available from OECD and Eurostat statistics. These analogously collected data can be used for calculation of LCI data for electricity production.

As a basis for discussions on format and transparency, the publications of APME (Association of Plastic Manufacturers in Europe, I. Boustead), ETH [1], Vattenfall [2,3] and results from other national data [4-12] are useful. These publications are used as examples of data sources in this document.

Good LCA data on energy production comprise data on extraction, refining, transport and storage of fuels, electricity production, distribution and consumption. The construction and demolition of power plants, as well as processing and recycling of fuel wastes, are all part of an LCA for electricity production. For nuclear, hydro, wind and solar power the production of the equipment/facility has the largest impact on the environment. In Fig. 1 the model for energy mix formation is shown.

Different energy carriers and energy production technologies are used to produce electricity and heat. The energy mix is a proportional combination of energy carriers and production technologies used in the area that is the subject of the study concerned.

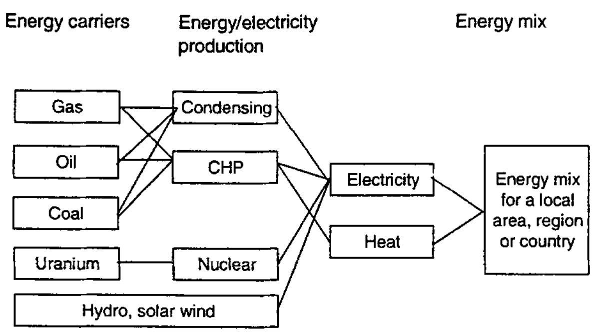

Fig. 1: Energy mix formation

2.1 Data processing

2.1.1 Calculation of energy mix

The energy mix is calculated by taking the percentage contribution from the different energy carriers included in the mix. Emissions and resource depletion for each of the energy carriers are multiplied with the percentage of the energy carrier in the energy mix and added up.

2.1.2 Choice of the mix

The choice of the mix in an LCA is an important issue and many different mixes can be used (the following list is not exhaustive):

- Average mix
- Temporal average mix (time unit : hour, day, night/day, year...).
- Geographic average mix (scale : european, country, regional, site).
- Base load mix, semi base load mix and peak load mix.
- Marginal mix
- Short term (variation in demand on a short term, calculated with no change of the production facility)
- Long term (increase or decrease of the electricity consumption on a long term, calculated with possible change of the production facility)
- Scenario mix (average or marginal mix in ten or fifty years for example as defined in documents of the IEA)

Which mix should be used in a LCA can be discussed. This depends mainly on the scope of the study and, how the electricity is used (specific charge characteristic). It is often preferable to use a purpose-specific model, but an average model will normally be recommended when the exact energy situation is not clear. This is the the recommended course of action for retrospective LCAs (where one examines the current, or historical situation). Marginal modelling can be relevant when the exact system is known, with a specific delivery agreement, or defining/describing new products or production lines (i.e. prospective LCAs). When marginal mix is used, the applied model must be well described (use of models combining the operating ability of the different power plants and the charge characteristic, assumptions). It should be realised that the determination of marginal mix is so complex than it almost only can be done with the help of an expert in clectricity production planning.

2.1.3 Allocation of emissions and resources

In many cases energy has a big influence on the results of LCA which is the main reason why allocation methods must be chosen and reported carefully. The chosen allocation method has to be transparent and suited to the purpose of the study. We refer to the paper prepared by the Scenario Modelling LCIA working group on allocation of multifunctional processes [38]. The allocation methods that can be applied are the energy, exergy and price method. In the working group report these methods are briefly discussed. The main methods for allocation used today seem to be either the exergy or the energy method.

Allocation is especially important where it concerns combined heat and power production plants (CHP). For existing CHP plants a number of methods are used to allocate the emissions and resources to the different energy products produced in the CHP power plants. Choosing different allocation methods, depending on the purpose of the LCIA, leads to different results.

At the present time there is no consensus on which method is correct.

2.1.4 Energy data quality

A generic list of criteria for data quality assessment has been derived from recently published articles [13]:

- statistical representativeness of data
- age of data
- data collection method
- quantitive analysis of flows
- which processes are taken into account
- aggregation level for flows
- mass balance
- geographical representativeness
- temporal representativeness
- technological representativeness
- functional unit definition
- allocation rules
- uncertainty intervals specified

In addition to this list some specifications are more related to the level of detail in the description of data sets like specification of the energy content [LHV (Lower Heat Value) or HHV (Higher Heat Value)] used for each fuel, specification of fuel origin, specification of the electricity 'mix', etc.

The available data varies, depending on energy carrier and technology. When one examines data from the ETH database and the Finnish database SEEP one gets results that are different, due to different characteristics for fuel components.

2.1.5 Units conversion

In LCA studies it is quite often necessary to re-calculate specific emissions with conversion factors for weight units, energy, components and density. The working group report includes an example of a conversion cube, which can be used to re-calculate some common energy units. It is an example of the type of conversion calculations that are required. The reader should note that it includes only some of the units that one is likely to come across and energy content values for fuels do vary. The cube is based on Norwegian LHV values for some common fuels. LCA practitioners should specify if the energy unit corresponds to net energy value or gross energy value. The difference between the two values is around 10% and may be an important reason for mistakes.

2.1.6 Emissions from energy production

Environmental loads are very much influenced by the fuels used, their specific sources, the characteristics of fuel components, and the conversion and emission control technologies applied during energy production. In the working group report a number of examples are given.

3 Transport

A good understanding of the technical aspects of transportation systems is necessary to enable the proper use of LCA data for transport. Inventory data for transport systems should be based upon a life cycle perspective. The final use of fuels in transportation is much more important than oil extraction and fuel production. In the final use the most important parameters are fuel consumption and the loading factor.

3.1 Principles of functional elements and modules in transportation models

The technical and regulatory aspects of transportation systems are described in the Directive 88/77/EEC. The most important cause of variation in energy intensity per km is the choice of means of transportation i.e. ship, rail, road or air transport. Each method of transport has the same modules shown in Fig. 2.

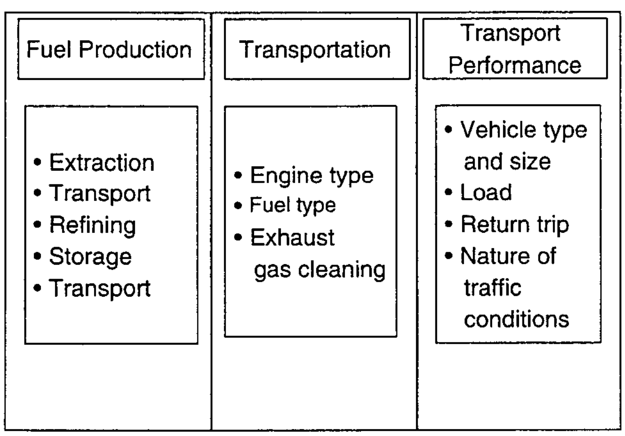

Fig. 2: Modules for transportation systems

3.2 Road transportation

The European Council of Ministers, through Directive 88/77/EEC adopted Type Approval limits for gaseous emissions from vehicles over 3,5 t based on ECE regulation 24.03. In [14] emission limits for heavy-duty motors can be found. Emission factors expressed as g/litre fuel for diesel motors are given for test conditions in the supgroup report.

3.3 Transportation performance

Important causes of variation for energy intensity per km are the size and utilization of the vehicle.

Truck types vary according to type of cargo, as well as the country and regulations. They are classified by weight.

The influence of load depends on the load size, weight/volume ratio and return trip load. Normally between 40% and 70% of the maximum capacity of a truck is used.

Often inventory data for transportation systems are expressed per ton kilometer (tkm). In many cases the loading capacity of the vehicle is not determined by the maximum weight allowed but by the maximum available volume. One method to determine if the weight or the volume is determining the loading capacity of the vehicle is: if the volume/weight ratio is less than about 3 m^3/1 metric ton (300 kg/ m^3), then the volume will be the determining factor for the transportation cost, as well as for the environmental impacts. The energy intensity is also determined by traffic conditions. Urban traffic conditions generally lead to higher fuel consumption than motorways.

In [14] it is stated that if the relative fuel consumption for a country road is 1, for the motorway it is 1,15-1,25 times and municipal driving 1,5-1,6 times the country road fuel consumption.

In the working group report, fuel consumption rates for different vehicle types are given, including references [15-19].

3.4 Shipping

For shipping, the engine and fuel type are the main technical parameters affecting the environmental effects. The motor power is typically expressed in kW and the fuel type provides information on sulphur content. Speed is a very important factor in shipping energy consumption.

The main LCA impact is determined by transportation distance, load factor (return trip) and freight weight. In the working group report, a table is presented on the relevance of inventory data for shipping.

3.5 Transportation by rail

Rail transportation can utilise electricity, or diesel engines. The efficiency of electric trains is greater than the efficiency of diesel trains. However, the electricity production efficiency has to be included in the LCA data. The age of the diesel engine influences the emissions from diesel trains.

4 Waste

A good understanding of waste management is necessary to enable the proper use of LCA data for waste treatment. Inventory data for waste should also be based on a life cycle perspective. This means that emissions and resources from transportation and waste treatment are included and described separately. Waste treatment is a complex chain of processes. The structure of the chain depends on the waste source, country, waste treatment, transportation, etc. Providing a simple guideline for data availability and quality for waste is difficult. There are various good publications and case studies from different countries available on the web (see www-address of EPA, ERRA and EU). These can be used as good information sources for models for LCA waste data. Also a lot of information can be found in the proceedings of the international workshop organised on LCA and treatment of solid waste (AFR-report 98, Swedish Environmental Protection Agency [20]). Environmental authorities in different countries have also produced data sets (e.g. SFT 1996).

Waste management can be subdivided into three waste modules as shown in Fig. 3.

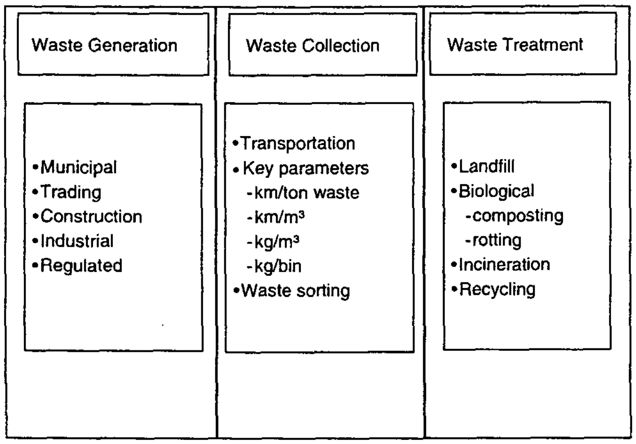

Fig. 3: Waste modules

4.1 Waste treatment

Waste sources determine the type of waste. A waste source can be classified as, for example: municipal waste (mixed waste, sorted biowaste, and sorted/recycled paper, plastics, glass waste), trading waste (mainly packaging and paper waste), construction waste, industrial and regulated waste.

4.2 Waste collection

Waste will always be transported. The collection of waste is a necessary part of waste treatment. There are big variations depending on the type of waste, especially with sorted special waste streams. Key parameters for collection are:

- Truck fuel consumption per km and loading capacity
- Distance to waste treatment location
- Population density

The main processes applied in Western Europe for waste treatment are:

- waste incineration
- landfill
- composting/digesting
- recycling

4.3 Waste incineration

In Western Europe the majority of waste is incinerated. A number of models of the incineration process exist [21-23]. These models can be used to determine the inventory of certain categories of waste. In the working group report a description is given of the model developed by CE, the Centre for Energy Conservation and Environmental Technology, to generate data for the incineration of plastic wastes in municipal solid waste incineration plants.

4.4 Landfill

A landfill model has been developed and verified in [24] and [25]. The model has been made operational in the computer tool PCA-LAND [25].

4.5 Composting/digesting

There is not much data available for these waste treatment processes. In the working group report some references are given for these processes [23,32,33].

4.6 Recycling

The environmental impacts of recycling are strongly related to specific items such as products and materials. There are many studies on recycling of different products and materials. LCA is commonly used to estimate the benefits of recycling. Recycling models are in most cases based on special situations (often specific to a particular site, or region). The data availability and quality should be evaluated by the LCA practitioner for each case. Data on plastics recycling can be found in [22], [26-29] and [36]

In the working group report an overview is shown of the key facts of the European waste situation (EU Focus on waste management 1999 [37]).

To assess the quality of waste data the generic criteria as given above can be applied.

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