

# Using Life Cycle Thinking and Assessment for Industrial Waste Management Policy Making

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## 1. About life cycle thinking and public policy making

In each stage of the life cycle of a product or a service, natural resources are used and emissions of different kinds are sent to the environment. Life cycle stages may appear quite different, depending on the type of product or service under study. An interesting case is the application of life cycle assessment as a tool (LCA) or life cycle thinking as a concept (LCT) to waste management policy making.

A lot of literature has been produced in different countries and languages describing the methodology and applications of LCA, including a whole set of international standards which have already been revised (the 14040 series). Major research projects have been funded by individual countries in Europe or by the European Commission to further develop different methodological challenges or to adapt and enhance the methodology to certain applications. Several scientific journals are devoted totally or partially to LCA developments and case studies. Scientists and practitioners have organized themselves at international level in working groups, mainly within SETAC and the UNEP/SETAC Life Cycle Initiative for more than fifteen years, and in associations and networks at national level.

While the methodology was being further developed, on the one hand, commissioners of LCA studies from industry have been asking the scientific community to develop quick and easy approaches for internal use in ecodesign. A lot of effort has already been spent into this task. On the other hand, commissioners from public bodies have been asking the same, but with other boundary conditions. Their decisions affect deeply the positioning of competing alternatives in the market. Therefore, if ISO 14044 has to be followed, the LCA studies should be often performed in the so called "full LCAs" manner, with all the variety of additional requirements that the standard is asking when dealing with a comparative assertion intended to be published, including a review panel by interested parties. At the same time, they have found that the scientific community has not arrived to a wide consensus in relation to certain issues like: databases to use, attributional vs consequential LCA, input/output vs process LCA, open loop recycling allocation, etc. Therefore, after big efforts in financial and human resources and after waiting quite long for results, whatever road they take they are always exposed to criticism. Knowing this, practitioners tend to maximize the limitations of their studies giving no clear answers to the politicians' questions, helping some lobbying groups whose message is that LCA can be twisted to whatever result and pressing politicians to follow their opinions based on generalistic assumptions, like the hierarchy in waste management.

No matter how strong this message is, decision makers will probably continue using LCA for strategic long term decisions but they need some new approaches to decision making using life cycle principles but without stopping the decision process. This could be summarized as Life Cycle Thinking (LCT).

Unfortunately little effort has been delivered to life cycle approaches for decision making by the scientific community in comparison to the ones dedicated to LCA as a tool. It might be that,

while LCA has been developed mainly by chemists and engineers, LCT development needs the collaboration of social scientists.

## **2. About waste management plans and life cycle thinking**

Waste management plans are one of the main areas in which new, knowledge-based governance approaches have recently been adopted [1]. In particular, Life Cycle Approaches can play a dominant role in this sense, by providing decentralized, collective-oriented decisions, by means of transmission of knowledge. The European Commission recently recommended that the enlargement countries take an integrated approach based on LCA when making decisions on their waste management systems. Life Cycle Thinking and LCA are explicitly mentioned in a Thematic Strategy on the prevention and recycling of waste and related immediate implementing measures [2]:

*“A first necessary step is to develop a new type of knowledge base taking into account life-cycle information. This knowledge should be used to design environmentally and cost-effective waste prevention and recycling policies. It should help to define what information on waste is relevant to policymaking and to ensure that such information is taken into consideration as an integrated part of policymaking.*

*The main options available are:*

- *[...]*
- *Maximum use of life-cycle assessment (LCA): Undertake a full life-cycle assessment at EU level in accordance with ISO standards on waste generation and management and introduce mandatory LCA for waste management planning;*
- *Move to life-cycle thinking (LCT): LCT is a mindset for policymakers to make every effort to take into account relevant life-cycle aspects. In many cases this means using common sense to look at the wider picture while in others it could mean using assessment tools such as LCAs. To spread LCT in waste policy it is necessary to formulate an environmental objective for EU waste policy and legislation and set a framework for the assessment of waste policies at EU and national levels. This would be supplemented by a knowledge-gathering function at EU level that would inform further developments in EU waste policy.”*

The EU explicitly recommends the use of LCA or Life Cycle Thinking for the formulation of new waste management plans (i.e. in policy formulation) [2]. However, until now the principal use that has been made of LCA in the waste sector has been as a policy implementation tool, in order to detect and improve upon critical points and bottlenecks in the currently employed management strategies. In the next decades, though, the LCA approach is likely to gain wider and wider use in policy formulation and policy evaluation, too. In fact, Life Cycle Thinking can be extremely useful in the difficult task of evaluating and choosing among several often conflicting options, while clearly identifying the inherent trade-offs that each option may inevitably imply in terms of different environmental impact categories. More information on these issues can be found in [3].

## **3. The problem**

According to the Council Regulation (EEC) No 259/93 of 1 February 1993 on the supervision and control of shipments of waste within, into and out of the European Community, from sentences by the European Court of Justice one may deduce that restrictions to waste shipments to and from Catalonia can be applied, demanding that the environmental gain associated to a specific waste treatment option be larger than the inherent loss due to the same treatment, as established in Directive 2006/12/EC on wastes. Knowing the life cycle environmental impact of certain waste flows could be a proper way to validate waste management practices that are presented as a net improvement for the environment.

The Industrial Waste Management Programme of Catalonia (PROGRIC) is the regional authority's legislative tool to establish the actions to be developed in relation to waste management in this Spanish region. The 2007-2012 PROGRIC gives continuity to the planning tasks initiated in 1994 with the Special Waste Programme and, more recently, to the previous

2001-2006 PROGRIC. In the last two revisions of the latter, the use of a life cycle perspective (and life cycle assessment) for waste policy was called for. The Waste Agency of Catalonia contracted the GiGa research group at Escola Superior de Comerç Internacional (ESCI-UPF) in Barcelona to include a life cycle perspective within the next version of PROGRIC.

It is important to state that the Managing Council of the Waste Agency of Catalonia took this decision also motivated by the complaints of Catalan waste managers, who were claiming that it was more expensive to treat waste in Catalonia than transporting and treating them outside, because the requirements were stronger. Being a responsible Government, it was not adequate that Catalan waste was being sent to places where they were going to be treated in worse conditions than in Catalonia, shifting the pollution problem from home to other regions.

#### **4. The project**

The aim of the project is to prepare a number of simplified mathematical models, applicable in a generalized way to a large variety of waste types, with the aim of helping the decision-making process of whether to allow the transit of specific waste flows from specific industrial plants. The models allow the company to find out the longest distance the waste would be allowed to travel from Catalonia, in order to receive a different kind of treatment from the one it would otherwise receive in Catalonia (many treatment comparisons are possible, but only four have been approached initially). In addition, for certain types of waste flows, like those which include solvents, the model allows the user to calculate the minimum solvent recovery yield needed to justify traveling a specific distance, e.g. from the industrial plant to the solvent recovery plant. Energy consumption has been used as a unified proxy indicator for the whole set of impact categories.

In this study, the environmental impact associated to the transport and treatment of each kind of waste is calculated exclusively as the energy expenditure, as a simplified analysis is pretended, in a quantitative manner. Therefore the energy expenditure is taken as a proxy of the whole group of environmental indicators.

The waste typologies to be considered, in accordance to the geographical location of the study and public body demands, can be classified in four cases:

Case study 1. Liquid and solid waste to be transported outside Catalonia for energy recovery (distillation bottoms, paper and cardboard, plastics, tyres, textiles, flours, etc) when the treatment in Catalonia would be landfilling.

Case study 2. Paint waste to be transported outside Catalonia for solvent recovery when the treatment in Catalonia would be landfilling.

Case study 3. Paint or solvent waste to be transported outside Catalonia for solvent recovery when the treatment in Catalonia would be energy recovery.

Case study 4. Paint or solvent waste to be transported outside Catalonia for energy recovery when the treatment in Catalonia would be solvent recovery.

Parts of the models have been developed as full LCA studies, i.e. transport systems, while others are dealt with by using mean values or proxies. For instance, the energy required to produce any aliphatic solvent can be calculated by using the isopropanol life cycle as a proxy; also, the energy consumption for solvent recovery can be calculated as a mean of literature values. Therefore, the model is not strictly ISO 14044 compliant, although individual parts of it are. In fact, the almost infinite number of cases and combinations would make it virtually impossible to develop such a full model a priori.

Because of the required simplicity of the models, the legislation will then allow individual users to perform a full LCA of their own specific scenarios, in order to provide an alternative to the result produced by the simplified model, if the latter is not agreed upon.

## 5. The models

**NOTE 1:** Due to the space limitation of the extended abstract, only one case study is presented here, Case study 4, as an example of the whole set of cases.

Case study 4. Paint or solvent waste to be transported outside Catalonia for energy recovery when the treatment in Catalonia would be solvent recovery.

If the transport has to be allowed, the energy gained by recovering the energy from the waste minus the energy required to transport the waste outside Catalonia needs to be higher than the energy gained by recovering the mass of solvent and the energy of the distillation bottom minus the energy needed to perform the distillation. This case is very similar to case study 3 but, as the solvent recovery takes place in Catalonia, there is no energy consumption due to solvent transport back to Catalonia ( $E_{ST}$ ).

$$E_{WC} - E_{WT} > E_{SP} + E_{BC} - E_{SR} \quad (1)$$

where  $E_{WC}$  is the energy obtained through waste combustion  
 $E_{WT}$  is the energy required to transport the waste  
 $E_{SP}$  is the energy required to produce the solvent from virgin material  
 $E_{SR}$  is the energy required to recover the solvent from the waste through distillation  
 $E_{BC}$  is the energy obtained through still bottom combustion  
 $E_{ST}$  is the energy required to transport the solvent

The terms listed are combined within the different equations and are given in MJ per kg of the reference flow chosen, either waste or solvent. All cases have terms in common for which a method of calculation is needed. Some of them are related to transport processes, others to combustion processes and others to production or material recovery ones.

**NOTE 2:** Some information on how to solve the different terms of the equations is given here.

When calculating energy recovered through combustion, it is important to take into account that, thanks to the waste Low Heating Value (LHV), energy will be produced when waste is being incinerated, but part of this energy will be spent to maintain the reactors minimum temperature to allow complete combustion and waste destruction. Therefore, not the whole LHV will be accounted as energy recovered. In Catalonia, the energy needed to allow an adequate performance of the combustion chamber (called threshold LHV,  $LHV_T$ , within PROGRIC) is 11 MJ/kg for non-chlorinated solvents (less than 1% of chlorine) and 15 MJ/kg for the chlorinated ones, for their destruction is more energy demanding. In case study 4, there will be an  $LHV_T$  for the waste as a whole ( $LHV_{T,W}$ ), as well as for the recovered solvent ( $LHV_{T,S}$ ) and for the still bottom ( $LHV_{T,B}$ ), provided it is incinerated to recover energy.

In order to quantify the energy consumption in the solvent recovery process from waste, mean values from Capello et al [4] were taken. These authors make a statistical treatment of data from 150 recovery experiments of 22 different types of solvents via batch and continuous distillation processes and, generally, with less than 10% of solid waste. The model is dependent on the solvent recovery factor, the type of process (batch or continuous), the amount of solid impurities and the range of temperatures of distillation.

In the case of calculating the energy required to produce the solvent from virgin material, given the large variety of solvents and the difficulty on obtaining life cycle information for all of them, isopropanol and toluene were decided to be respectively used as proxies for any aliphatic and aromatic solvents. The decision was taken after acknowledging that they were two of the most used solvents and that their life cycles were well known. With the help of GaBi software modeling and database, life cycle energy consumption for those solvents production was found to be of 52.8 MJ per kg of isopropanol and 66.2 MJ per kg of toluene. The rounded values of 50 MJ per kg of aliphatic solvent and 65 MJ per aromatic solvent were decided to be used.

In Catalonia, the transport of industrial waste is almost only carried out by truck. From the Waste Agency's data sources, the types of trucks were known and their models were found in the GaBi4 and ELCD (European Life Cycle Reference Data System) databases. In order to simplify the model, one of the trucks was chosen, Truck 14-20 tons, which is giving the mean results of the whole set and, at the same time, is the one used more often in Catalonia for waste transport (data provided by the Waste Agency). For this truck, an equation was obtained. If another step of simplification is taken and the mean European value of transport of goods, 85% of fill factor, is used in that equation, then the result for energy required to transport is  $0.943 \cdot 10^{-3}$  MJ/(kg·km). The last step of simplification lead to using the rounded value of  $1 \cdot 10^{-3}$  MJ/(kg·km). This rounded value was demonstrated to be representative, within the precision of the equation, for a wide range of values (0.55 to 1.0) of fill factor.

After including all simplifications in the model, two variables were isolated:

- a) the distance "d" that a waste could be transported from the site in which it was generated with an energy expense lower than the energy gain, and
- b) the recovery factor "Rf" below which the waste was allowed to be transported to a treatment plant located at a given distance.

#### Distance "d"

$$d = 1000 \cdot [(LHV_S - LHV_{T,B} + E_{SR} - E_{SP}) \cdot Rf + (LHV_{T,B} - LHV_{T,W})]$$

- The company has to demonstrate that the percentage of chlorine in the still bottom is higher than 1% while the one for the whole waste is lower than 1%, as all other cases were found to make the transport mathematically impossible outside Catalonia, unless a full LCA stated the contrary.

Therefore, a new simplification can be done for case study 4, when  $LHV_{T,W} = 11$  MJ/kg and  $LHV_{T,B} = 15$  MJ/kg:

$$d = 1000 \cdot [(LHV_S - 15 + E_{SR} - E_{SP}) \cdot Rf + 4]$$

- The company will have to deliver certificates by an accredited testing laboratory on the LHV of the solvent or provide a proper reference in the literature.
- If no information is found about the energy needed for the distillation process throughout its lifecycle, then default values can be used (calculated with the simplification after the work by Capello et al):
  - a) 21 MJ/kg for a batch distillation and 15 MJ/kg for a continuous distillation
  - b) 7 MJ/kg for a batch distillation and 5 MJ/kg for a continuous distillation, if the quantity of solid or paste in the waste is lower than 10%. In this case, the company will have to provide a certificate by a testing laboratory.
- If no information about the energy needed for the production process throughout its lifecycle is found, then default values can be used (calculated with GaBi4):
  - a) 50 MJ/kg for aliphatic solvents
  - b) 65 for aromatic solvents
- The company will have to provide certificates (or scientific arguments) by a testing laboratory or by an authorised waste distillation company with an indication on the maximum recovery factor (Rf) expected for their waste.

#### Recovery factor "Rf"

$$Rf = \frac{0,001 \cdot d - (LHV_{T,B} - LHV_{T,W})}{(LHV_S - LHV_{T,B} + E_{SR} - E_{SP})}$$

The terms in the Rf equation are calculated in the same manner as for the distance equation.

## 6. Conclusions

This project has demonstrated to the Catalan Government that a life cycle perspective can be used for policy making at regional level for waste management legislation. A combination of available life cycle data and models, easy to make new life cycle models, and easy (and dirty sometimes) procedures to find the rest of the life cycle information, together with the possibility of “defense” by the company by means of a full LCA was welcome and accepted. Using energy as a proxy indicator was easily accepted from the very beginning.

The problem was very complex, with a lot of waste types, combination of treatment scenarios, different transport systems, models with multiple variables, etc. Starting with a complex model and simplifying it until it was seen applicable by all stakeholders was a good way to go. Even with a very intensive goal and scope definition, it was acknowledged that this kind of projects must be flexible enough to adapt to new alternatives and scenarios found as the project develops and interim results are presented. New projects will have to be proposed with a calendar which allows some learning cycles to re-define / refine its scope.

The results were shown several times, as the project was being developed, to a group of high technicians from all departments within the Agency with some skepticism, in the beginning, and an enthusiastic response to the life cycle principles in the end. During the start-up there was a fear that applicability was not feasible but, seeing that different degrees of simplification are possible and that the company can always go further performing a more complete LCA, this fear was overcome. There was also a feeling from the Legal Department that no limitation to the transport of waste was possible but ways were found also to overcome this issue.

Finally, in a meeting with the General Manager of the Agency and all the Heads of Department, the solution was presented. The politicians could easily understand the philosophy behind the life cycle principles after some explanations. It was widely accepted and they acknowledged its application in EU waste legislation. There was a decision to use the results of the study in Catalan legislation but the way it will be introduced is not clear yet. There were also clear statements about continuing to commission this kind of studies for other types of waste.

The final conclusion by all actors was that the goal was accomplished: the models have enough scientific robustness, they are easy to apply and they comply with the aim of limiting the transport of waste outside Catalonia following the principles of proximity and sufficiency.

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