DANTES

DEMONSTRATE AND ASSESS NEW TOOLS FOR ENVIRONMENTAL SUSTAINABILITY

State of the art study of LCA and LCC tools

Dag Ravemark, ABB

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AKZO NOBEL ABB CHALMERS STORAENSO

ABSTRACT

This report was made within the project DANTES that is supported by the EU Life Environment Programme.

This state of the art study of LCA and LCC tools is a starting point for task 4 in DANTES.

The report starts by describing LCA and LCC methods and the methods are compared. No web-based combined LCA-LCC tools where found but one combined LCA-LCC excel tool is described in this report.

Ten of the excel LCC tools found on the internet are described in this report. The LCC tools are developed to address problems in many different areas and a tool developed and structured for one area cannot generally be used in another area. It seems that the LCC method is more problem dependent that LCA method.

LCC, as the method of calculating the total lifecycle cost for equipment over its lifetime are described. One of the costs items in a LCC calculation is environmental cost. What this (internal) environmental cost can be is discussed in the report. What the external environmental costs (cost that occur in society and environment for which the company is not directly responsible) are and how they can be assessed will be developed in an "external cost study" performed in task 4 in DANTES.

No general LCC tool exists and if one is needed for DANTES it has to be developed by the project. Since a full LCC can be very complex it is likely that this DANTES LCC tool should be a small and simple tool for quick cost estimates. Another possible tool/method to develop would be a LCC screening method to identify the most important (largest) cost items during a products lifetime.

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1. INTRODUCTION

This report “State of the art study of LCA and LCC tools” is a starting point for task 4 in DANTES.
LCA stands for Life Cycle Assessment and LCC stands for Life Cycle Cost. LCC is sometimes abbreviated as LCCA, which stands for Life Cycle Cost Assessment.

1.1 LCA

A life cycle assessment (LCA) is a method for estimating the environmental impact during the whole life of a product, from raw material extraction until the product turns into new raw materials or is scattered as waste. LCA is often used to compare different alternatives for materials selection, production methods, recycling and such, in an effort to reduce pollution, health hazards and resource depletion.

1.2 LCC

LCC can be defined as "...the sum of present values of investment costs, capital costs, installation costs, energy costs, operating costs, maintenance costs, and disposal costs over the life-time of the project, product, or measure."

LCC is particularly suited to the evaluation of design alternatives that satisfy a required performance level, but that may have differing investment, operating, maintenance, or repair costs; and possibly different life spans. LCC can be applied to any capital investment decision, and is particularly relevant when high initial costs are traded for reduced future cost obligations.

Life cycle cost analysis (LCCA) is an economic analysis technique that allows comparisons of investment alternatives having different cost streams. LCCA involves estimating the costs and timing associated with each alternative over a selected analysis period and conversion of those costs to economically comparable values considering the time-value of money. LCCA output may be expressed in several different ways, but the most used indicator for highway and airport pavements is present worth (PW), or present value (PV). The PW of an investment alternative is simply the sum of all costs associated with the alternative discounted to today's dollars (Euros,...).

1.3 Comparison LCA-LCC

Both methods are used for studying/evaluating systems and for both methods it important to define the scope of the studied system so it is clear what is included and what is excluded in the study.
If one wants to compare two products/systems (with LCA or LCC) it is important that the studies have the same scope.

2. TOOLS

No combined LCA - LCC web tool where found on the Internet.

The only combined LCA - LCC tool that we know of is ENECO (a excel tool) developed in cooperation by Bombardier Transportation and ABB Corporate research. ENECO is described in chapter 2.1

Two web-based LCC tool was found on the Internet. One is an energy calculator for residential homes, which also calculates cost and payback time for alternative energy systems, and the other is a tool for calculating the optimum time to refurbish equipment. The web-based tools are described in chapter 2.2

The LCC tools that can be found on the Internet are mostly excel-tools. These tools exist in numerous different forms dependent on what problem area or type of question are addressed. Examples of tools are listed in chapter 2.3

2.1 ENECO LCA-LCC tool

ENECO was a spin-off from the RAVEL project. It is an excel tool that combines the LCALight (excel version, developed by ABB) and MiniMarvel (simplified LCC excel tool developed by Bombardier Transportation). The tools were combined to one excel-tool, allowing comparison of life cycle environmental impact and life cycle cost of two different components.

Input data - LCA part

The user enters data for the components three life cycle phases; manufacture, use and end-of-life phase.

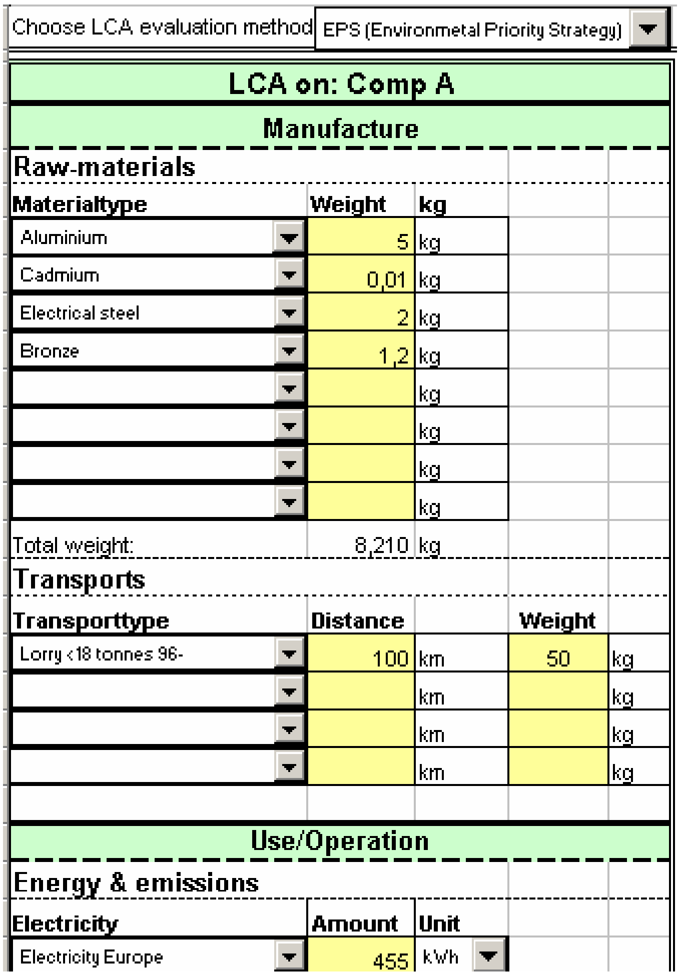
Input data for the manufacture phase are; material type, selected from a dropdown list, and weight, transports, selected from a dropdown list, and distance + weight.

Input data for the use phase are; energy type, selected from a dropdown list, and amount of energy, major emissions, selected from a dropdown list, and weight.

Input data for the end-of-life phase are; recycling rate (in %) of the selected materials.

The user can select five different classification methods and two different evaluation methods to analyze the input data.

The tool allows the user to enter data for two different components to make a comparison of the two.



Choose LCA evaluation method	EPS (Environmetal Priority Strategy)			
LCA on: Comp A				
Manufacture				
Raw-materials				
Materialtype	**Weight**	**kg**		
Aluminium	5	kg		
Cadmium	0,01	kg		
Electrical steel	2	kg		
Bronze	1,2	kg		
		kg		
		kg		
		kg		
		kg		
Total weight:	8,210	kg		
Transports				
Transporttype	**Distance**		**Weight**	
Lorry <18 tonnes 96-	100	km	50	kg
		km		kg
		km		kg
		km		kg
Use/Operation				
Energy & emissions				
Electricity	**Amount**	**Unit**		
Electricity Europe	455	kWh		

Figure 1 Part of the LCA in data sheet of ENECO

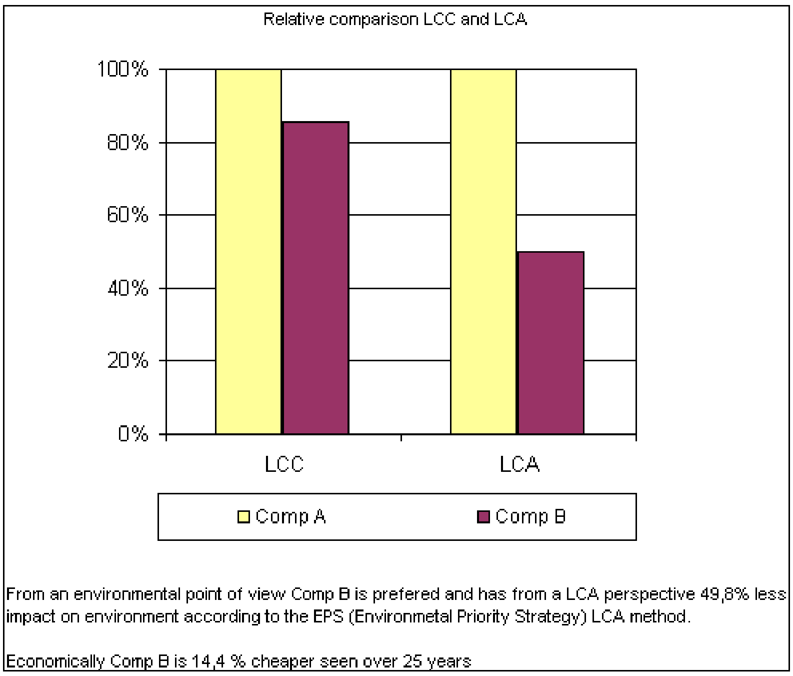
Input data - LCC part

The user enters the purchasing price (cost) of components.
The user enters data for corrective and preventive maintenance and energy use during operation.
Corrective maintenance is repairs that have to be done when the component has broken, so in data are failure rate, cost of repair and the cost of standstill of a train (if it is a stopping failure).
Preventive maintenance is service performed at regular intervals, performed to ensure the failure-free workings of the component, in data are service interval, cost and service work time.

The user has to enter general cost data such as; interest rate, cost of a man-hour, cost of a kWh and general operating data such as; km/year hours of operation/year and lifetime in years.

LCC on: Comp A					
Manufacture					
Identity No.	Name	No. in train	Price		
465221-6654-A	Comp A	1	5221	SEK	
		(1 used in LCA)			
Use / maintenance					
Corrective maintenance					
Repairable	Fail. rate	Unit	Man-hours	Mtrl/Rep cost	
Yes	1	FPMKM	2	2000	
Failure mode	% of failrate	Train fail Category	Cost/ failure		
Train stop	50,00%		30000	SEK	
				SEK	
Preventive maintenance					
Description	Interval	Unit	Man-hours	Material cost	
Service	1	Year	1	500	
Energy					
Energy use	Unit				
500	kWh/year				

Result
The detailed results of the LCA-LCC calculations are presented in tables and the comparisons of the two components are shown graphically.



Evaluation:
The tool is simple to use and the result is easy to interpret. The in data for LCA are simple. The in data for LCC (e.g. failure rates, cost of failures,...) are bit more complex but not overwhelming.

The tool is aimed at the railway manufacture industry and the background assumption is that the user wants to evaluate different components as parts of a train but it can be used in other applications. As an example, for showing the how the tool can be used, Bombardier Transportation compares a low-energy lamp (high price, long life, low energy consumption) with a normal light bulb (low price, shorter life, higher energy consumption).

2.2 Web tools

2.2.1 Konsumentverkets energianalys

A web based calculation tool mainly focusing on reducing the energy use of residential homes but the tool also calculates payback time for selected energy saving measures.
By entering data on the current status of the residential home (location, size, type, year of construction, type of heating,...) the tool calculates the energy, economy and environmental profile of the house compared to an average home (in Sweden) of the same type.
The user can the select some recommended energy saving options and evaluate them and/or evaluate the effect of installing alternative heating methods e.g. different wood ovens or heat pumps or solar pannels (and combinations thereof).
Available at http://www.energikalkylen.konsumentverket.se/main.asp

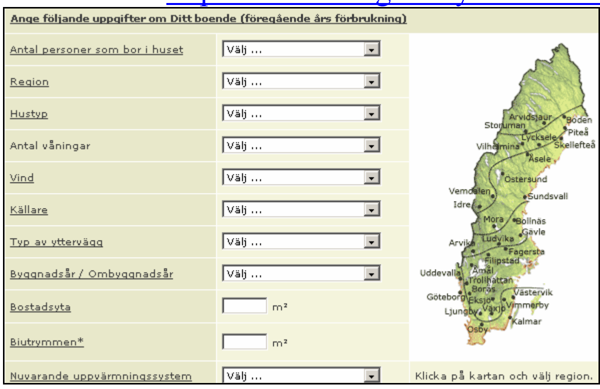


Figure 2 Part of the first page of “Konsumentverkets energianalys” tool

2.2.2 A Ready Reckoner for Maintenance v. Refurbishment Costs

Web tool to calculate the optimum time to refurbish equipment
The assumption is if you do not refurbish the equipment, the time spent on maintenance rises by a percentage. When you refurbish, maintenance time falls back. Risk and cost of an equipment failure are included.
Available at http://www.d-ccl.co.uk/dc/wlcreddyrec.html

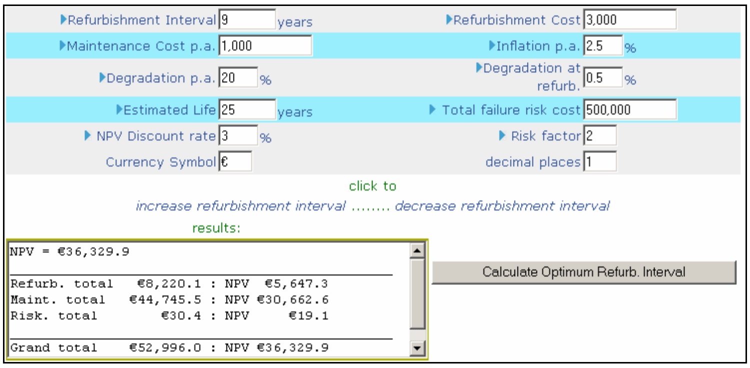


Figure 3 Part of the firs page of the "A Ready Reckoner for Maintenance v. Refurbishment Costs" tool

2.3 Excel tools

The following tools are from a wide range of applications.

- **NORSOK** - oil industry
- **STEM** - residential home
- **Barringer & Associates**, Inc - engineering, manufacturing
- **The Pump Life Cycle Costs** - engineering of pumps
- **CAL-B/C** - infrastructure, highway and transit
- **Bicycle-IV** - power generation
- **LCCA Cal State** - building costs

Showing the wide use of LCC in many different areas. The LCC method can be used to evaluate the cost structure in almost any kind pf project/application.

2.3.1 NORSOK

NORSOK: Norsk sokkels konkuranseposisjon or in English: the competitive standing of the Norwegian offshore sector is the Norwegian initiative to reduce development and operation cost for the offshore oil and gas industry. NORSOK have developed two LCC tools available at http://www.nts.no/norsok/o/
lcc.xls is an attempt to standardize Life Cycle Cost calculation methods for systems and equipment to ultimately help in comparing alternatives.
facility.xls is an attempt to standardize Life Cycle Cost calculation methods necessary to establish the facility design that gives the best field economics.

2.3.2 STEM

STEM (Statens energi myndighet) The Swedish Energy Agency is the central administrative authority for matters concerning the supply and use of energy.
http://www6.stem.se/web/spar.nsf/atkomstsve/07a6cfb3b587810cc12569960043eaf4?opendocument
Ekmil02.xls shows how profitable it is to change the heating system in a residential home (in Swedish)

lcc.xls shows the life time cost saving incurred by changing the lighting systems.

2.3.3 Barringer & Associates, Inc

Barringer & Associates, Inc are consultants for solving reliability problems in industries using engineering, manufacturing, and business expertise

lcc.xls is a simple net present value analysis tool of costs and cost savings, available at http://www.barringer1.com/Anonymous/lcc.xls

LCC_LMTD.xls is a free version of a more complex LCC tool using Monte Carlo simulations to estimate costs of pumps (with simulation of failures). Down load from http://www.barringer1.com/Anonymous/lcc_lmtd.exe (a self extracting zip-file)

2.3.4 Pump Life Cycle Costs

The Pump Life Cycle Costs: A LCC tool for analysis of Pumping System is the result of collaboration between the Hydraulic Institute, Europump, and the US Department of Energy's Office of Industrial Technologies (OIT). The user enters cost data for two alternatives, which are compared at http://www.pumps.org/downloads/LCC_CalcTool.xls

2.3.5 CAL-B/C

This spreadsheet model provides a method for preparing a simple economic analysis of both highway and transit projects.
http://www.dot.ca.gov/hq/tpp/planning_tools/Cal-BC.xls

2.3.6 Bicycle-IV

BICYCLE-IV is a excel tool designed to calculate levelized life-cycle costs of electric power generation plants.
http://www.lanl.gov/projects/cctc/resources/tools/BicycleIV.html

2.3.7 LCCA Cal State

LCCA spreadsheet from Cal State Architecture & Engineering for comparing the cost of two building alternatives.
http://www.calstate.edu/CPDC/AE/Life_Cycle_Cost_Worksheet.xls

2.4 PC-software

2.4.1 IsographDirect

lccWare3.0 is a PC based software for LCC calculation. A free test version (which do not allow saving of the project) can be downloaded at http://www.isograph.com/lccWare.htm

lccWare allows calculation of the life cycle cost of a system. The total cost is made up of several cost categories that the user can define, such as Research & Development, Operation & Maintenance and Disposal. The categories can be further sub-divided. This division of the total cost into sub-categories is known as the Cost Breakdown Structure (CBS). The CBS is represented in lccWare in the form of a tree.

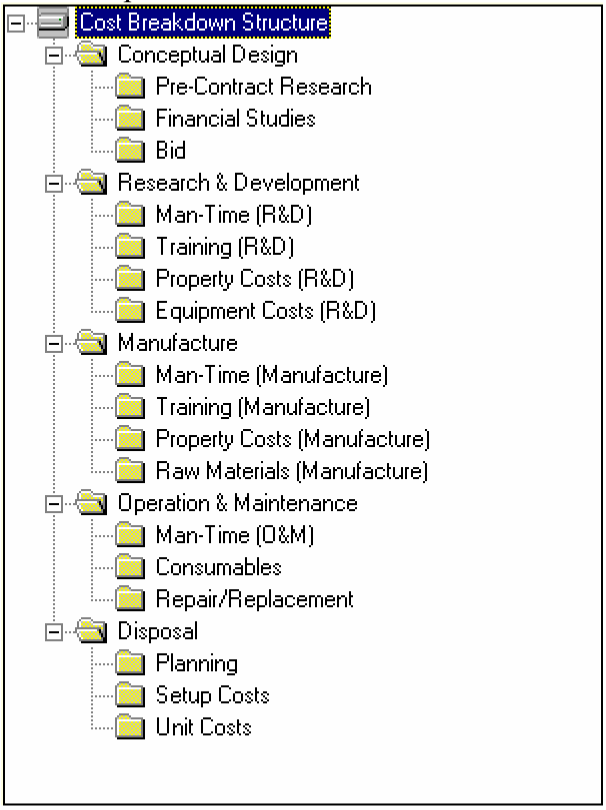


Figure 4 Cost Breakdown Structure in lccWare

The user can assign cost functions to the nodes on the cost tree and lccWare calculates the total life cycle cost.
lccWare3.0 is probably a too complicated specialist tool to be used in DANTES.

3. LCC

LCC is the method of calculating the total cost for equipment over its lifetime from the time of installation to final decommissioning/disposal. When comparing different investment alternatives it is convenient to compare the different LCC- values.

The normally used LCC models for analysis and comparisons of systems are:

- LCC = the sum of all costs incurred by the system in a life cycle view

or divided into different costs

- LCC= the sum of (Initial cost+ Installation cost+ Energy costs+ Operating costs + Maintenance costs+ Downtime costs+ Environmental costs+ Decommissioning costs)

or in short;

- LCC = $C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_{env} + C_d$

Where C = cost element for different cost types.

3.1 Cost parts

The total life cycle cost is calculated as a sum of the costs that arises during the lifetime of a product. Cost of raw material and revenues from the sales of product are usually not included in LCC calculations. Below follows a discussion of the different cost and how they can be calculated.

3.1.1 Initial cost

It is the purchasing price of the component/system. This can be paid immediately or in several down payments over the years.
If the price is paid immediately:
C_{ic} = purchasing price

If the cost is spread over several years (net present value):

$$C_{ic} = \sum_{i=0}^{N} \frac{C_i}{(1+rate)^i}$$

where C_i is cost year i and *rate* is the interest rate.

This can be

3.1.2 Installation cost

Startup costs that the operator has to pay that are not included in the purchasing price (for example, staff training cost, material losses,...). The installation cost is assumed to occur the first year of operation.
C_{in} = Installation cost

3.1.3 Energy costs

C_e = energy cost
or

$$C_e = \sum_j E_j * EC_j$$

where E_j is the yearly amount of energy of type j used and EC_j is the cost of energy type j.

Energy types are, for example; electric, oil, coal, gas, renewable, district hating,...
The cost of an energy type (EC_j) includes all costs, e.g. CO2 taxes are included in the energy cost. *Ej* (amount of energy) is assumed to be constant over the operating time and *ECj* (cost of energy) is assumed to increase with inflation.

3.1.4 Operating costs

The yearly operating cost (excluding the energy cost, treated in chapter 3.1.3) consists of: Man-hour cost (for operation)

$C_o = NP * H_{py} * C_h$

where NP = number of persons employed for operation, H_{py} = manhours per year and C_h = Manhour cost.

If the studied system only needs a limited number of manhours

$C_o = NH_o * C_h$

where NH_o = number of yearly manhours needed for operation and C_h = Manhour cost. $NP * H_{py}$ or NH_o is assumed to be constant over the operating time and C_h is assumed to increase with inflation.

3.1.5 Maintenance costs

The maintenance cost (cost of service and planned repairs) consist of:

- Manhour cost (for planned maintenance)
- Spare part

$C_m = NH_m * C_h + C_{spare}$

where NH_m = number of yearly manhours needed for maintenance, C_h = Manhour cost and C_{spare} = cost of spare parts.

NH_m and is assumed to be constant over the operating time and C_h and C_{spare} is assumed to increase with inflation.

3.1.6 Downtime costs

C_s = downtime (stop) cost

$$C_s = SC * HC$$

where SC = hourly stop cost and HS = yearly hours of unplanned stand still.

If the startup cost after a stop is included

$$C_s = SC * HC + nS * SuC$$

where nS = number of unplanned yearly stops and SuC = start-up cost

3.1.7 Environmental costs

C_{env} = ?

This is not CO2 tax since they are in energy costs

And cost of different state permits are in operation and installation cost

Environmental cost will be discussed further in chapter 4

3.1.8 Decommissioning costs

Decommission cost is an estimate of the cost to decommission a plant/unit and this estimate can be expressed as a cost occurring at the end of the lifetime or net present value of the decommission.
C_d^* is the decommission cost that incur at the end of the lifetime. The net present value of this cost is calculated (N being the lifetime in years and rate is the interest rate used for the calculations

$$C_d = \frac{C_d^*}{(1 + rate)^N}$$

If C_d^* is the net present value of the decommission cost

$$C_d = C_d^*$$

4. ENVIRONMENTAL COSTS

The EPA lists a number of examples of environmental costs incurred by firms (ref http://www.epa.gov/opptintr/acctg/pubs/busmgt.pdf).
Not included are the type of costs that occur in society and environment for which the company is not accountable.

4.1 Potentially hidden costs

4.1.1 Regulatory

Regulatory environmental costs incurred in operating a process, system, or facility have traditionally been treated as overhead, they may not receive appropriate attention from managers and analysts responsible for day-to-day operations and business decisions.
The magnitude of these costs also may be more difficult to determine as a result of their being pooled in overhead accounts.
Because these costs may not currently need to be recognized for other purposes, they may not receive adequate attention in internal management accounting systems and forward-looking decisions.
Examples of regulatory costs are:

- Notification
- Reporting
- Monitoring/testing
- Studies/modeling
- Remediation
- Record keeping
- Plans
- Training
- Inspections
- Manifesting
- Labeling
- Preparedness

- Protective equipment
- Medical surveillance
- Environmental insurance
- Financial assurance
- Pollution control
- Spill response
- Stormwater management
- Waste management
- Taxes/fees

4.1.2 Upfront

Costs that are incurred prior to the operation of a process, system, or facility. These can include costs related to siting, design of environmentally preferable products or processes, qualifications of suppliers, evaluation of alternative pollution control equipment, and so on. Examples of upfront costs are:

- Site studies
- Site preparation
- Permitting
- R&D
- Engineering and procurement
- Installation

4.1.3 Voluntary (Beyond Compliance)

Voluntary environmental costs incurred in operating a process, system, or facility lies close to the image and relationship costs. The costs of these actions are real but the values of them are less tangible. The reasons to have them are based on company policy.
Examples of voluntary environmental costs are:

- Community relations/outreach
- Monitoring/testing
- Training
- Audits
- Qualifying suppliers
- Reports (e.g., annual environmental reports)
- Insurance
- Planning
- Feasibility studies
- Remediation
- Recycling
- Environmental studies
- R & D
- Habitat and wetland protection
- Landscaping
- Other environmental projects
- Financial support to environmental groups and/or researchers

4.1.4 Back-End

Back-end environmental costs may not be entered into management accounting systems at all. These environmental costs of current operations are prospective, meaning they will occur at more or less well defined points in the future.
Examples of back-end environmental costs are:

- Closure/decommissioning
- Disposal of inventory
- Post-closure care
- Site survey

4.2 Image and relationship cost

Some environmental costs are called "less tangible" or "intangible" because they are incurred to affect subjective (though measurable) perceptions of management, customers, employees, communities, and regulators. These costs have also been termed "corporate image" and "relationship" costs. This category can include the costs of annual environmental reports and community relations activities, costs incurred voluntarily for environmental activities (e.g., tree planting), and costs incurred for P2 award/recognition programs. The costs themselves are not "intangible," but the direct benefits that result from relationship/corporate image expenses often are.
Examples of image and relationship costs are:

- Corporate image
- Relationship with customers
- Relationships with investors
- Relationship with insurers
- Relationship with professional staff
- Relationship with workers
- Relationship with suppliers
- Relationship with lenders
- Relationship with host communities
- Relationship with regulators

4.3 Contingent costs

Costs that may or may not be incurred at some point in the future are termed "contingent costs". They can best be described in probabilistic terms: their expected value, their range, or the probability of their exceeding some dollar amount. Examples include the costs of remedying and compensating for future accidental releases of contaminants into the environment (e.g., oil spills), fines and penalties for future regulatory infractions, and future costs due to unexpected consequences of permitted or intentional releases.
Because these costs may not currently need to be recognized for other purposes, they may not receive adequate attention in internal management accounting systems and forward-looking decisions.
Examples of contingent costs are:

- Future compliance costs
- Penalties/fines
- Response to future releases
- Remediation
- Property damage
- Personal injury damage
- Legal expenses
- Natural resource damages
- Economic loss damages

5. INPUT TO A LCCLIGHT TOOL

If one wants to make an LCCLight tool (similar to LCALight), what input would then be required to make the tool usable (not to much input data) and non-trivial (the result are easier obtained with the tool that with a pocket calculator)?

5.1 General input

Global data those are valid during life cycle ($ means arbitrary monetary unit)

General

- Interest rate (%)
- Manhour cost ($/h)
- Manhours per manyear (h/year)
- Electric energy cost ($/kWh)
- Cost of other energy types ($/MJ)

Product/component specific

- Lifetime (years)
- Hours of operation (h/year)

5.2 Specific cost input

Initial cost

- Initial cost/purchasing price ($)

Installation cost

- Installation cost ($)

Energy cost

- Electric energy need (kWh/year or kW when in operation)

Operating costs

- Manyears or manhours to operate

Service costs

- Service frequency (no service/year)
- Manhours to do service (hour)
- Cost of spare parts ($)

Breakdown cost

- Breakdown frequency (/year or /h)
- Manhours to do repair (hour)
- Cost of spare parts ($)
- Cost of standstill ($)

Decommission cost

- Decommission cost ($)

6. CONCLUSION & RECOMMENDATIONS

LCC tools are made for a special application/problem area and there does not seem to be one LCC tool for a general type of problem. Therefore, in DANTES we cannot hope find one general tool to include in our platform. What one could develop is a simpler support tool to do cost analysis and/or a sensitivity analysis tool that helps users to identify the major costs during the life cycle.
The continuation of this task has to be closely related to the external cost study (DANTES task due 03-1/9).

Recommendations

- If we want a LCC tool, we have to develop it ourselves
- A full LCC is too detailed what we need is a simple tool that can make a quick cost estimate.
- We must find a model/method to identify critical cost components
- And further clarify links between LCA-LCC (and develop translation keys?)