DANTES
DEMONSTRATE AND ASSESS NEW TOOLS
FOR ENVIRONMENTAL SUSTAINABILITY

LCC/LCA Tools
LCA_Battery.xls
- comparing batteries for different applications

(Installation of the battery energy storage system in Fairbanks Alaska. The system consists of 13,760 battery cells and is expected to cut power blackouts by more than 60 percent.)

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ABSTRACT

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

This Dantes report is one in a series of five describing the LCC tools developed by ABB. The others Dantes reports are:

- DANTES - Dry fermentation.doc
- DANTES - LCP tool AX1.doc
- DANTES - Transformer.doc
- DANTES - Wet fermentation.doc

A summary of the experience of developing these tools is presented in the Dantes report

- DANTES LCC-LCA tools.doc

The aim of this report is to describe the "LCA_Battery.xls" tool. The tool was made to make simple environmental and economical evaluations of battery systems.
The batteries can be operated in two configurations; cycles or float. In cycles the battery is unloaded and loaded in distinct cycles and in float the battery is continuously unloaded and loaded depending on the current power need.

The tool allows the user to compare different battery systems for the same application in respect to:

- environmental impact (calculated with selected evaluation methods)
- cost

The environmental evaluation includes only materials in the batteries and the impact of the electric losses. The auxiliary equipment (e.g. transformers, rectifiers, …) are not included.
The user can select evaluation method, country where the electricity is produced and recycling rate of the batteries.

The cost of battery systems is calculated on the kWh price of battery and the total energy lost in the system.

The installed capacity of the battery is calculated on the required power need and the degradation of the battery capacity as a function of the operating conditions.

TABLE OF CONTENT

1. INTRODUCTION

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

The scope of this report is to describe the LCC/LCA tool "LCA_Battery.xls".
The purpose of the LCC/LCA tool "LCA_Battery.xls" is to allow designers to compare the costs and environmental impact of four different battery types and do parameter studies. The results can be used in project evaluation, market communication and sales support, showing the most advantageous battery type.

The intended users of this report are anyone interested in the LCC/LCA tool or the problem area of lifecycle cost/environmental calculation for battery systems.

2. INPUT

All input and all results are presented on one page (see Figure 8.).

2.1 Evaluation methods

There exists different evaluation methods used to calculate the impact of materials in batteries and energy losses. The user can select between:

- Global warming potential
- Acidification potential
- Nutrification potential
- Eco-indicator 99
- EPS 2000

2.2 Electricity types

Environmental impact of the electric losses in batteries depends on the type of electricity used to load the batteries. The user can select electricity from the following countries:

- Austria
- Belgium
- Britain
- Canada
- China
- Czech Republic
- Denmark
- Finland
- France
- Germany
- Greece

- Hungary
- Ireland
- Italy
- Luxemburg
- Netherlands
- Norway
- Poland
- Portugal
- Russia
- Spain
- Sweden
- Switzerland
- Turkey
- United States

2.3 Recycling

It is assumed that only metals are recycled. Recycling rate can be set to different percentages, equal for all batteries. The impact of a recycled material can be calculated as:

$I_{mat} = I_{new} (1-X_{rec}) + X_{rec}*I_{rec}$

where

I_{mat} = the calculated impact of a material with a recycling rate of X_{rec}

I_{new} = the cradle to gate impact of a material

I_{rec} = the impact of recycling the material

X_{rec} = recycling rate (%)

With 0% recycling the impact of a metal is equal to the cradle gate impact of the metal and with 100% recycling the impact of a metal is equal to the impact of recycling the material.

Metals

Metal	I_{rec}/I_{new}	Comment
Aluminium	4%	from Ecolab
Cadmium	5%	as copper
Copper	5%	from Ecolab
Iron	20%	from Ecolab
Lead	5%	as copper
Nickel	5%	as copper
Steel	20%	from Ecolab

2.4 Project data

There are some base parameters

- Required power (in kW) – the effect the battery pack has to deliver

- Life time – for calculating the life time environmental impact and lifetime cost
- Energy cost – in USD/kWh

2.5 Cycling vs. floating

In cycling mode the battery is emptied to a certain extent (Depth of Discharge, DoD) and then the battery pack is recharged and ready. In floating operation the battery is giving energy and is being recharged constantly. The depth of discharge is not as deep as in cycling and there are no recognizable cycles.

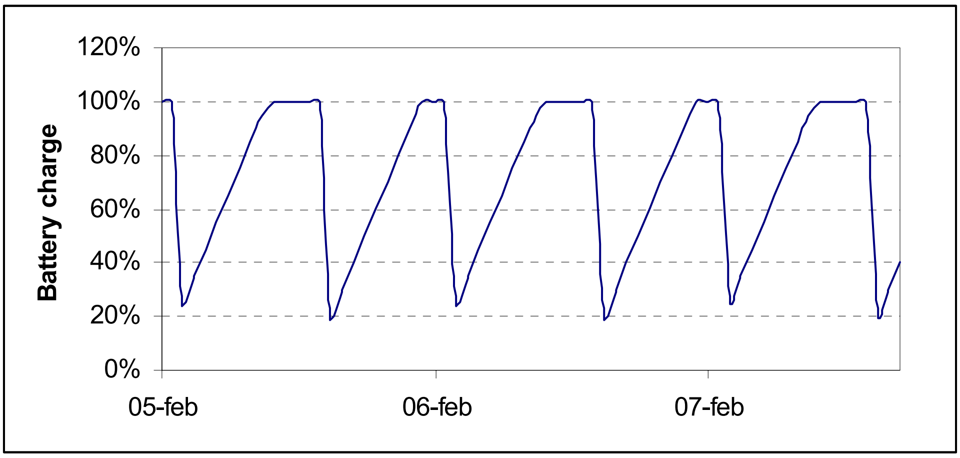

Figure 1 Typical charge pattern for cycling operation

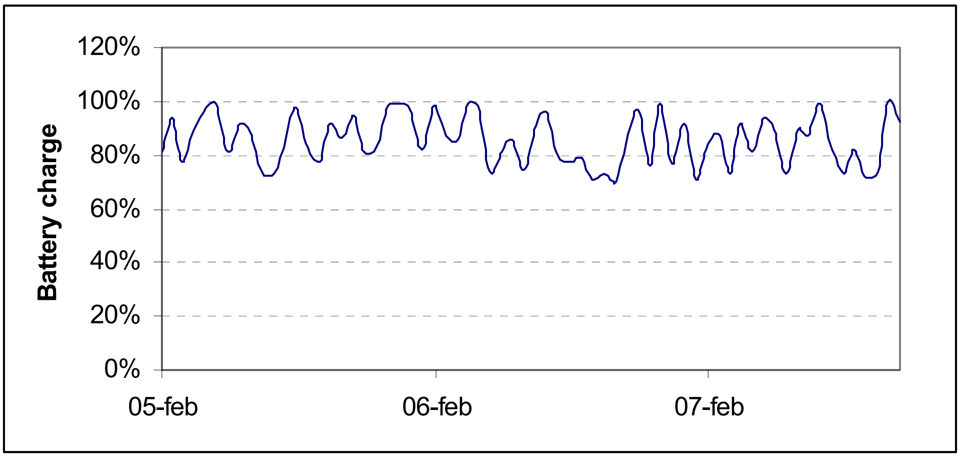

Figure 2 Typical charge pattern for floating operation

2.6 Cycling

- Cycle time (100%) – is the maximum time the battery have to give the "Required power".
- The design energy for the battery is then = (Required power * Cycle time)

- Number of cycles – how many cycles /week the battery is used.
- Depth of Discharge – how much (in percent) of the design energy is used in a normal cycle.

2.7 Float

"Time batteries used as float per week" – is the continuous time that the battery delivers the "Required power" (used for energy loss calculation)
"The needed energy of the battery" – is the design energy for the battery in floating operation.

2.8 Data on battery alternatives

- Battery name: Select from pull down menu – when one do not want others to know what types of batteries we are comparing (e.g. competitors)
- Service life (cycles) – how many cycles that the battery can handle (with "Depth of Discharge" = 100%)
- Service life (float) – Years until the battery capacity have been reduced to 80% of the design capacity.
- Electric efficiency – losses in the battery system (combined internal resistance and losses in transformers etc.)
- Installation cost – cost of large scale installation of batteries (in USD/kWh)

3. CALCULATIONS

3.1 Overcapacity when cycling

Installed capacity = X(DoD) * Required capacity
X(DoD) = a multiplying factor depending on the "Depth of Discharge"

X(DoD) = (Cycles per lifetime/Service life) * Depth of Discharge
where Service life is the number of cycles the battery can handle (at 100%) until the capacity is degraded.
For example: Cycles per lifetime = 200, Service life = 100 cycles and DoD = 100%; the installed capacity is 200% of the required capacity.

3.2 Overcapacity when float

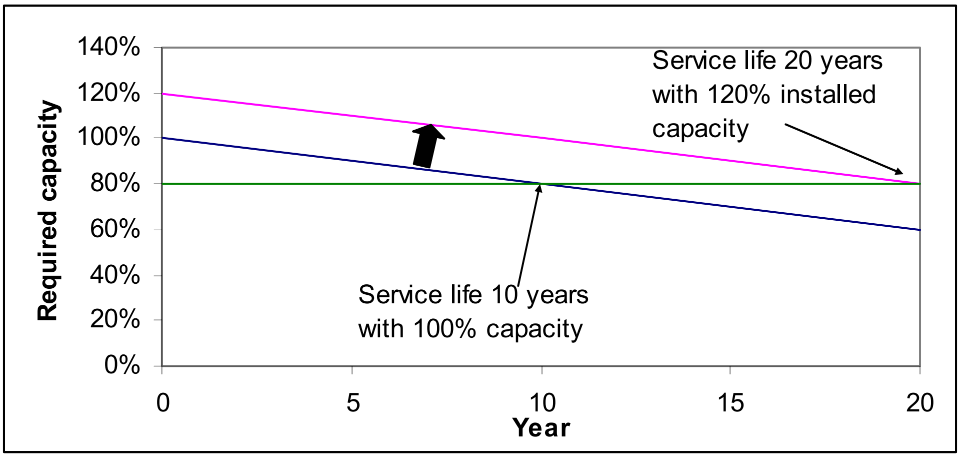

Figure 3 Overcapacity when float

Figure 3 shows a schematic view of the required capacity calculations when the battery is operating as float.
The design capacity 100% has a service life of 10 years (i.e. the original capacity has been reduced to 80% of the original capacity). The required lifetime of the battery is 20 years so the design capacity has to be increased to 120%. The degradation is assumed to be constant over time and independent of capacity.

3.3 Environmental impact

I_j is the environmental impact (per kg for the selected evaluation method) of material *j* and m_j is the mass of material *j*

$$I_{tot} = \sum_j m_j * I_j$$

I_{tot} is the environmental impact of all the materials in the installed

4. RESULTS

Results	SN	SL	MN	XL	
Installed energy	10 000	10 000	10 000	10 000	kWh
Energy density	152,87	3,57	7,40	11,37	kg/kWh
Specific energy	85,6	6,7	7,0		dm3/kWh
Installation weight	1 529	36	74	114	ton
Overcapacity	1,0	1,0	1,0	1,0	times

Figure 4 Tabular result from the indata

- Installed energy – depending on the type, using required capacity and service life to calculate.
- Energy density – in kg/kWh
- Specific energy – dm3/kWh
- Installation weight – weight (mass) of the all the batteries in the installation

- Overcapacity – Installed capacity /Required capacity

Cost result	SN	SL	MN	XL	
Installation cost	14,81	30	5,8	5	MUSD
Energy cost	1,56	0,36	1,30	1,82	MUSD

Figure 5 Tabular cost results

Cost result

- Installation cost = Installed capacity* Installation cost
- Energy cost = Total energy used * (1-efficiency) * Energy cost

4.1 Graphs

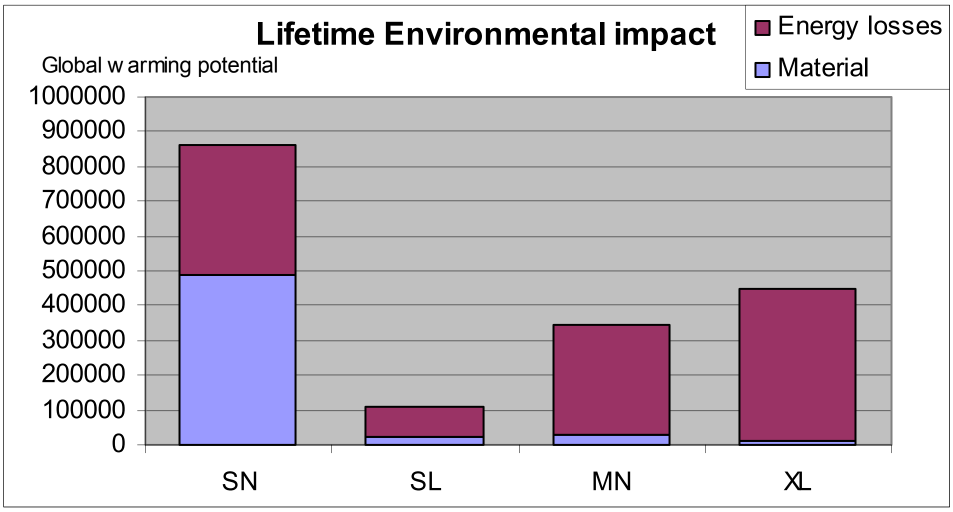

Figure 6 Result, life time environmental impact of different battery alternatives

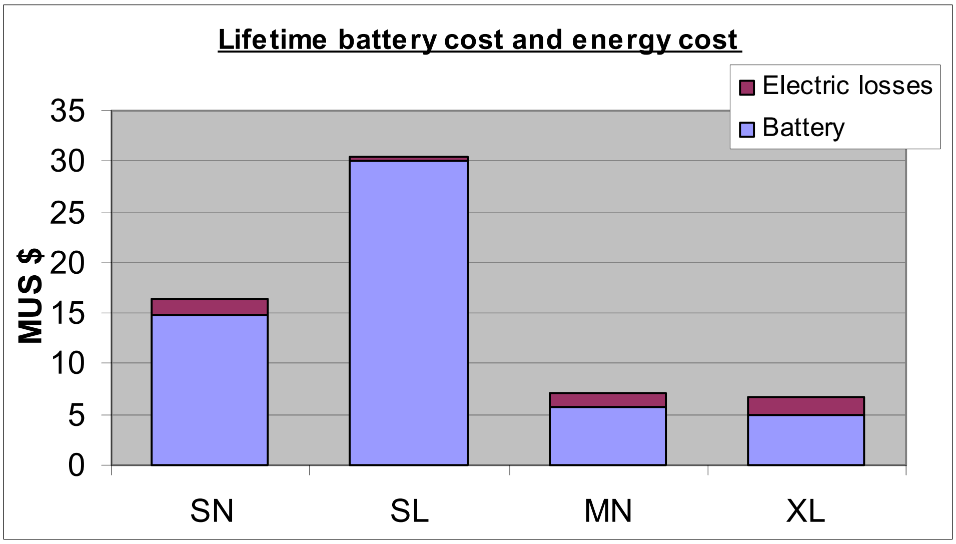

Figure 7 Result, life time cost of different battery alternatives

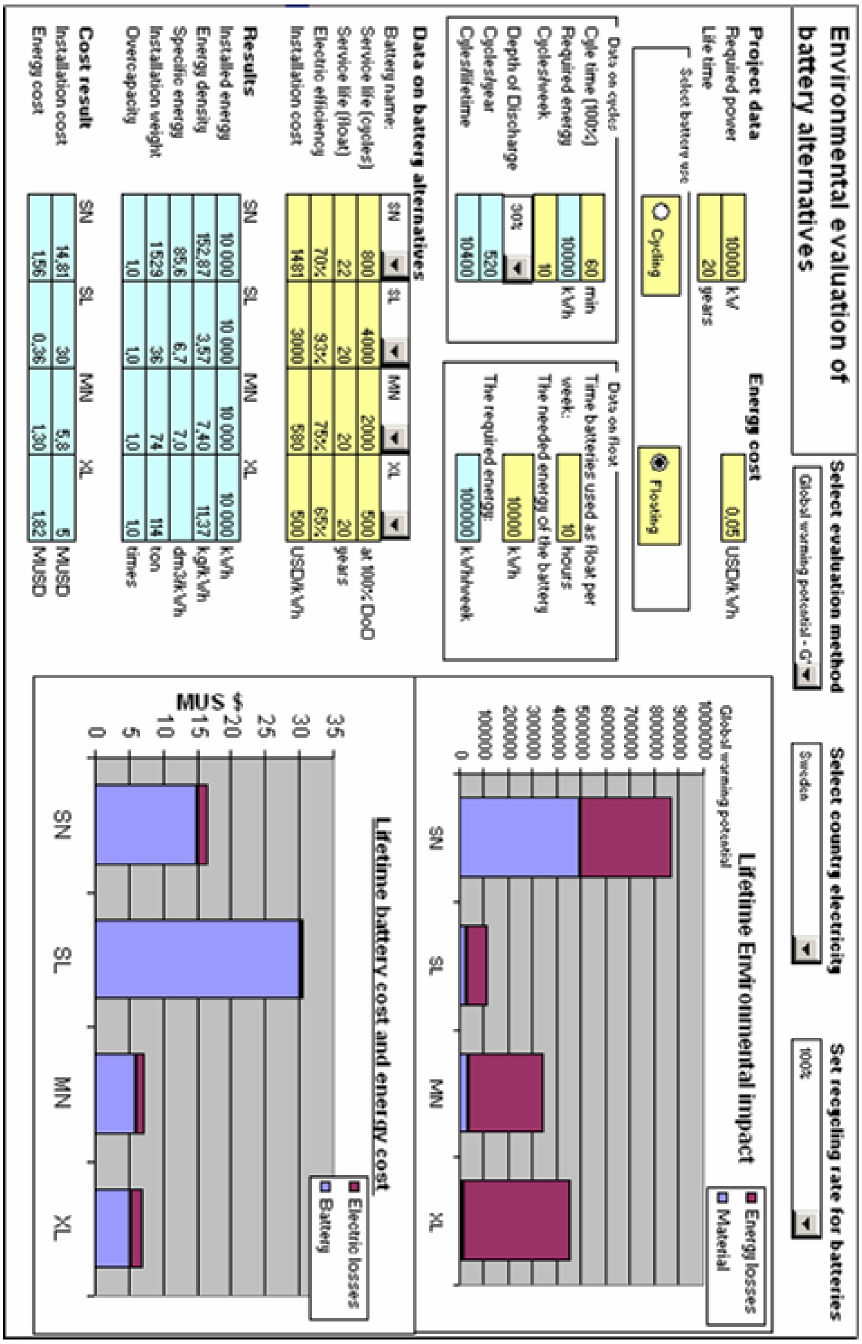

Figure 8 The tool

5. REFERENCES

Environmental impacts of materials and energy are taken from ABBs EcoLab database (file Spine50_2001-11-19.db)

Material	EcoLab activity
Alumina	Al2O3 from Mining to aluminium oxide EAA
Aluminium	Aluminium from Mining to aluminium EAA
Cadmium	Cadmium from Mining to cadmium EIME
Copper	Copper from Mining to 60% primary copper ICA
H2SO4	H2SO4 from Extr to sulphuric acid EIME
Insulation	Glass fibre from Extr to glass fibres EI
Iron	Raw iron from Mining to raw iron UMIP
Lead	Lead from Mining to lead ETH
Nickel	Nickel from Mining to nickel ETH
Plastic	Polypropylene from Extr to polypropylene
Steel	Steel plate from Mining to steel plate IISI
Carbon	Electrode graphite from Mining to electr

Materials where no data was found

- Electrolyte
- Misc.
- Lithium

Material content:
Proprietary information.