openLCA case study:

Remodelling of a park

Summary

This case study (and others) can also be accessed on the internet: www.openlca.org/documentation.

Keywords: openLCA, LCA, ISO14040, park remodelling, Sellerpark, urban eco-management, ecoinvent database, CML 2001, CO2 fixation, Sankey diagram, parameter and formula use.

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1 Introduction

Usually, a life cycle analysis is done for certain products or services to investigate its environmental impacts. In this case, we want to examine a rather complex matter: the remodelling of a park and its long-term consequences.

1.1 The functional unit

When designing a life cycle analysis you always start by defining your functional unit. Since we want to compare influences on nature and environment of a procedure, the reshaping of a public park area, it is a bit tricky. Basically, we need to create two different life cycle analyses, one for the original and one for the remodelled park, so the functional unit could be called "9000m² of public park area".

Figure 1: Sellerpark before remodelling, 2008 [a]

1.2 The object

The *Sellerpark,* with its about 9000 m² [1], is located between the urban districts *Mitte* and *Wedding* in northwest Berlin. It is bordered by a four-lane street and the *Schifffahrtskanal*, an artificial waterway. It also contains the estuary of the brook *Panke*.

For 50 years the Sellerpark developed quite unnoticed. Trees and bushes grew wildly and there was a lot of space in the embankments for ducks and birds for undisturbed breeding. By mid 2009 the park was completely reconstructed: 59 of the 102 trees were, due to security reasons, chopped down, most of the bushes were removed and a big granite terrace with 4 levels was built around the estuary.

All of this wouldn't be that dramatic if the money for the project, altogether EUR 660'000 [2], wouldn't be part of a fund for the compensation of other interferences in nature. In Germany it is mandatory to rebuild the same amount of biosphere that was not able to be saved in course of a construction process [5, 6]. In this case EUR 130'000 [3] was to be used for the compensation of a newly built road in neighboring district *Moabit*.

Figure 2: Illustrated overview of the park [b]

1.3 System boundaries

Creating a Life Cycle Analysis, one should always be sure of its capabilities. The case study about Sellerpark is now written two years after its actual transformation. Due to this, we have to deal with quite a lot of approximations. Size of trees, used machines, terrestrial modulations and some other processes can only be guessed or estimated. Nevertheless we are sure to be able to give a good clue about the environmental impact. The precision of the method is also limited through the data sets. We are concentrating on certain aspects of the remodelling (the terrace, the wood alteration, etc.), thus we are only able to reconstruct the process partly.

At last, this study has a rather exemplary character, showing the functions and capabilities of the software and sharing an interesting case of urban eco-management.

2 Model description

As already mentioned, we only want to concentrate on the most influential aspects of the remodelling. On the one hand, one analysis will be made for a theoretical untouched park: The development of the natural cover within 50 years before and 20 years after the alteration, plus some work that is usually done in order to keep a park as it is (regular mowing). On the other hand, we will calculate for the remodelled park: the deforestation, the building of the terrace and also the diminished capability of CO_2 fixation due to reduced tree crop will be incorporated. Finally we will compare the two analyses in respect to their long-term Carbon dioxide fixation and the one-time environmental impacts of the reconstruction.

2.1 The Software and database

This case study will be performed with openLCA, an open source Life Cycle Analysis Software. Datasets are collected in the Ecoinvent database which offers reliable data for most of the processes and used products.

www.openLCA.org

openLCA is a really easy-to-use open source Software. Most of the handling will be familiar to you, if you are used to the drag-and-drop mechanisms of *MS Windows.* You can gain insight into the handling of openLCA at the webpage: www.openlca.org/documentation.

In combination with a substantial and detailed database like Ecoinvent you can easily build up a wide scale of processes just by creating your own processes, extracting basic information out of the database, connect and quantify them and finally let the system add up all of its environmental impacts. Due to the complexity of Ecoinvent there can be a huge number of inputs and outputs into the nature by the end of a product's LCA. Impact analysis (*LCIA*) can help you then to evaluate your results in respect to the overall impacts on e.g. *global warming* or *acidification*.

2.2 Biomass

Although there was a great variety in plants that were removed, we will focus only on the deforestation since trees play the major role in the long-term fixation of Carbon dioxide. We know that 59 of the 102 tress of the Sellerpark were cut and 11 were planted instead.

Figure 3: Sellerpark before the deforestation [a]

Figure 4: Sellerpark after the deforestation [c]

Regarding the fact that the trees were not measured in height and volume we can only use data of an "average" tree. In the following table you will find an overview of parameters, applied locally, i.e. per process. With these factors, we will be able to model the yearly growth of trees and also the quantities (in m3) of trees that were cut. We consider that a new tree (a seedling) will grow slowly (7,25 kg/y) during the first 20 years, and then faster (12,5 kg/y).

Name	Formula	Description
density	402	Tree density; kg/m^3
growthseedling	7.25	Growth rate of new trees; kg/y

growthtree	12.5	Growth rate of trees; kg/y
trees	102	Total trees; trees
cuttrees	59	Trees chopped down; trees
newtrees	11	New trees planted; trees
timebefore	50	Time before remodelling; year
timeafter	20	Time after remodelling; year
timeseedling	20	Time of seedling growth; year

2.3 The deforestation

According to the approximation from above 59 old trees (cottonwood, maple, elm, robinia and limetree) were cut down and replaced with 11 new trees. Integrated in the case study should be growth, cut down, chipping, transport and the final waste disposal. Ecoinvent offers a large number of datasets for different kinds of wood, harvesting tools and disposal facilities to choose from.

2.4 The mowing

To ensure a safe use of the park, the grass needs to be mowed. The grass area covers approximately 8000m² and it needs to be done 3 times a year. As some areas are now free under the trees, but also a terrace is set, we will consider that this area stays the same after the remodelling. The following parameters can be considered:

Name	Formula	Description
mowingarea	8000	Area to be mowed; m²
mowingperyear	3	How many time per year is it mowed

2.5 The terrace and seats

On-site research has indicated that approximately 80 m³ of granite have been installed [(4)]. For the modelling of the terrace we will consider the granite extraction (as an Ecoinvent dataset) along with its transport (manufacturer says from China) and the land-excavation on the spot (only for the terrace, because seats were just laid on the ground). Other building machineries and processes will be neglected due to uncertainty.

Figure 5: The new terrace and seats (c)

openLCA allows to simply quantify masses and transporting distances in order to calculate environmental impacts. The following parameters can be considered:

Name	Formula	Description
granitdensity	2800	Density of granit; kg/m³
groundhole	70	Excavation from the ground; m³
seatsvolume	10	Volume of granit for the seats; m3
shipdistance	19188	Average distance China-Hamburg; km
lorrydistance	290	Average distance Hamburg-Berlin; km

3 Create and compare models

At first, it seems wise to create a subfolder in each category (flow, process, product system, and project). To do so, right click on the folder and "create a child category" (you can call it "Sellerpark" for example). This way, you can easily store together everything you will create.

3.1 The untouched park

3.1.1 Create flows

At first, you need to create a few product flows:

- New park; ref=number of items
- Untouched park; ref=number of items

- Deforestation; ref=number of items
- Grown trees; ref=number of items
- Terrace; ref=number of items
- Seats; ref=number of items
- Natural stone plate, grounded, at site

It might be useful to add also a description, so you can remember they are related to this case study.

3.1.2 Create processes

Two processes need to be created.

<u>Untouched park</u>

- Quantitative reference: Untouched park
- Inputs:

Flow	Category	Unit	Resulting amount
Grown trees	Sellerpark	m3	(timeseedling*growthseedling +(timebefore-timeseedling) *growthtree+timeafter*growthtree)*trees/density
mowing, by motor mower	Agricultural means of production/work processes	m2	mowingarea*(timebefore +timeafter)*mowingperyear

- Outputs:

Flow	Category	Unit	Resulting amount
Untouched park	Sellerpark	Item(s)	1

<u>Growth</u>

- Quantitative reference: Grown trees
- Inputs:

Flow	Category	Unit	Resulting amount
hardwood, standing, under bark, in forest	Wooden materials/extraction	m3	0.5
softwood, standing, under bark, in forest	Wooden materials/extraction	m3	0.5

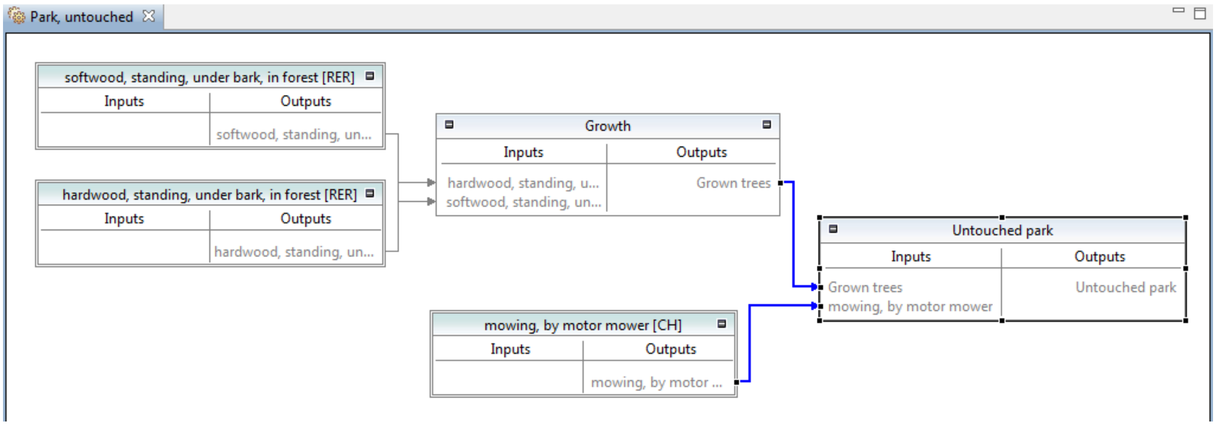
- Outputs:

Flow	Category	Unit	Resulting amount
Grown trees	Sellerpark	Item(s)	1

3.1.3 Create a product system

- Name: Park, untouched
- Reference process: Untouched park
- Ensure you tick the 2 options before clicking “Finish”.

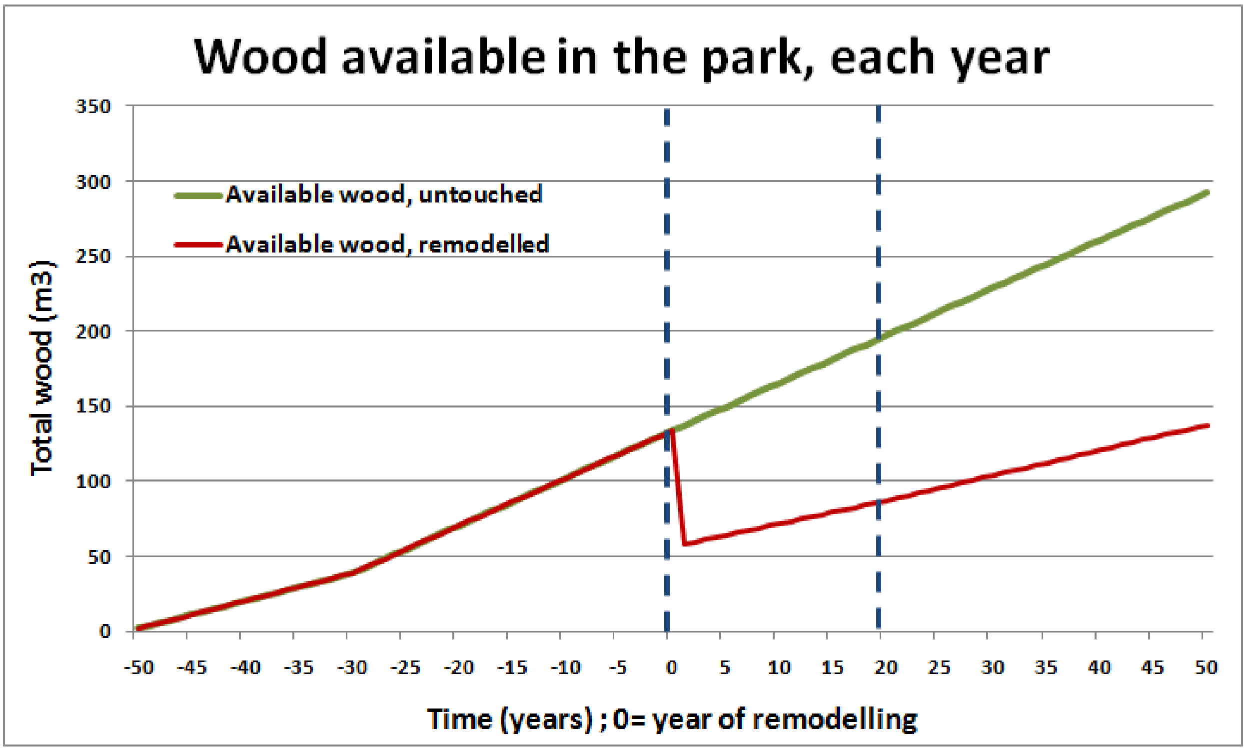
At the end, your first model should look like this:



3.2 The remodelled park

3.2.1 Create processes

As all the flows have already been created, we can directly create new 5 processes. Considering the deforestation as well as the wood growth of old and new trees, the following graph can be considered for the available wood in the park, each year.



Remodelled park

- Quantitative reference: New park
- Inputs:

Flow	Category	Unit	Resulting amount
Deforestation	Sellerpark	Item(s)	(timeseedling*growthseedling +(timebefore-timeseedling) *growthtree)*cuttrees/density
Grown trees	Sellerpark	Item(s)	(timeseedling*growthseedling +(timebefore-timeseedling +timeafter)*growthtree)*(trees-cuttrees)/density + timeafter *growthseedling*newtrees/density
Terrace	Sellerpark	Item(s)	1
Seats	Sellerpark	Item(s)	1
mowing, by motor mower	Agricultural means of production/work proc-esses	m2	mowingarea*(timebefore +timeafter)*mowingperyear

- Outputs:

Flow	Category	Unit	Resulting amount
New park	Sellerpark	Item(s)	1

Terrace, building

- Quantitative reference: Terrace
- Inputs:

Flow	Category	Unit	Resulting amount
excavation, hydraulic digger	construction processes/ civil engineering	m3	groundhole
Natural stone plate, grounded, at site	Sellerpark	kg	groundhole*granitdensity

- Outputs:

Flow	Category	Unit	Resulting amount
Terrace	Sellerpark	Item(s)	1

Seats, building

- Quantitative reference: Seats
- Inputs:

Flow	Category	Unit	Resulting amount
Natural stone plate, grounded, at site	Sellerpark	kg	granitdensity*seatsvolume

- Outputs:

Flow	Category	Unit	Resulting amount
Seats	Sellerpark	Item(s)	1

Natural stone plate, transport

- Quantitative reference: Natural stone plate, grounded, at site

- Inputs:

Flow	Category	Unit	Resulting amount
natural stone plate, grounded, at regional storage	Construction materials /others	kg	1
transport, lorry 20-28t, fleet average	transport systems /road	kg*km	lorrydistance
transport, transoceanic freight ship	transport systems /ship	kg*km	shipdistance

- Outputs:

Flow	Category	Unit	Resulting amount
Natural stone plate, grounded, at site	Sellerpark	kg	1

Deforestation

- Quantitative reference: Deforestation
- Inputs:

Flow	Category	Unit	Resulting amount
hardwood, standing, under bark, in forest	Wooden materials/ extraction	m3	0.5
softwood, standing, under bark, in forest	Wooden materials/ extraction	m3	0.5
transport, lorry 3.5-7.5t, EURO4	Transport systems/ road	kg*km	density*50
wood chopping, mobile chopper, in forest	Wooden materials/ extraction	kg	density
disposal, wood untreated, 20% water, to municipal incineration	Waste management/ municipal incineration	kg	density

- Outputs:

Flow	Category	Unit	Resulting amount
Deforestation	Sellerpark	Item(s)	1

NB: The wood, once chopped and chipped is considered as a waste that needs to go to an incineration process. Due to the Ecospold format, openLCA considers waste management processes as **input**.

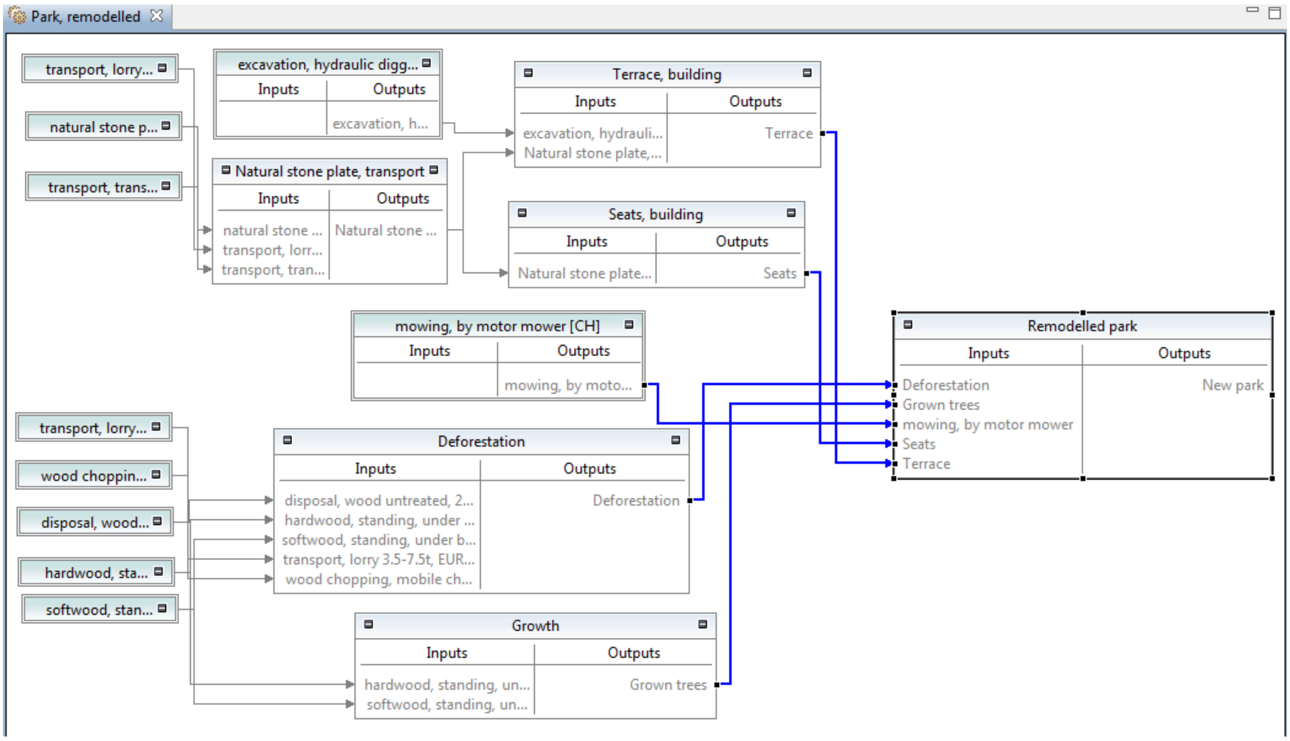
This allows the deforestation process to bear the whole incineration burden. On the other side, if you plan to calculate a mass balance, this will lead you to false results.

If the incineration process were considered as an output of deforestation, it would not be part of the upstream chain that leads to the functional unit. To rectify this, one should add a service flow, looping back to the deforestation.

3.2.2 Create a product system

- Name: Park, remodelled
- Reference process: Remodelled park
- Ensure you tick the 2 options before clicking "Finish".

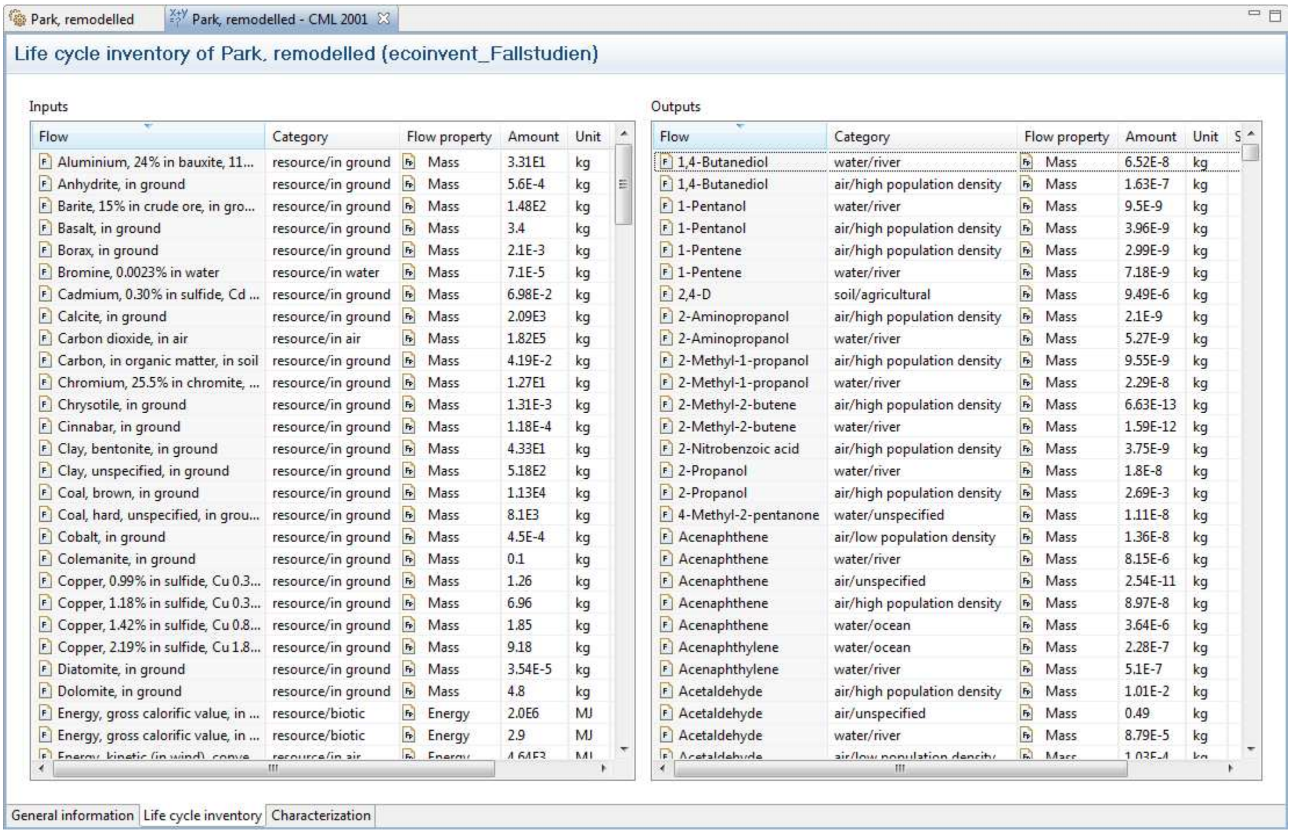
At the end, your first model should look like this:



3.3 Life Cycle Inventory

After finishing the tree-structured process chain, the system will automatically add up all environmental impacts. The *Inventory* is a list of all extracted resources (elementary inputs) and emissions (elementary outputs) that are necessary for the functional unit. In our case, we prepared two different Inventories for the same functional unit "9000 m² of public park area", one remodeled and one untouched.

To do so, simply click on "Results" and calculate. While doing it for each product system, you can reach the list of inputs and outputs of the whole system that looks like this:



Inputs

Flow	Category	Flow property	Amount	Unit
Aluminium, 24% in bauxite, 11...	resource/in ground	Mass	3.31E1	kg
Anhydrite, in ground	resource/in ground	Mass	5.6E-4	kg
Barite, 15% in crude ore, in gro...	resource/in ground	Mass	1.48E2	kg
Basalt, in ground	resource/in ground	Mass	3.4	kg
Borax, in ground	resource/in ground	Mass	2.1E-3	kg
Bromine, 0.0023% in water	resource/in water	Mass	7.1E-5	kg
Cadmium, 0.30% in sulfide, Cd ...	resource/in ground	Mass	6.98E-2	kg
Calcite, in ground	resource/in ground	Mass	2.09E3	kg
Carbon dioxide, in air	resource/in air	Mass	1.82E5	kg
Carbon, in organic matter, in soil	resource/in ground	Mass	4.19E-2	kg
Chromium, 25.5% in chromite, ...	resource/in ground	Mass	1.27E1	kg
Chrysotile, in ground	resource/in ground	Mass	1.31E-3	kg
Cinnabar, in ground	resource/in ground	Mass	1.18E-4	kg
Clay, bentonite, in ground	resource/in ground	Mass	4.33E1	kg
Clay, unspecified, in ground	resource/in ground	Mass	5.18E2	kg
Coal, brown, in ground	resource/in ground	Mass	1.13E4	kg
Coal, hard, unspecified, in grou...	resource/in ground	Mass	8.1E3	kg
Cobalt, in ground	resource/in ground	Mass	4.5E-4	kg
Colemanite, in ground	resource/in ground	Mass	0.1	kg
Copper, 0.99% in sulfide, Cu 0.3...	resource/in ground	Mass	1.26	kg
Copper, 1.18% in sulfide, Cu 0.3...	resource/in ground	Mass	6.96	kg
Copper, 1.42% in sulfide, Cu 0.8...	resource/in ground	Mass	1.85	kg
Copper, 2.19% in sulfide, Cu 1.8...	resource/in ground	Mass	9.18	kg
Diatomite, in ground	resource/in ground	Mass	3.54E-5	kg
Dolomite, in ground	resource/in ground	Mass	4.8	kg
Energy, gross calorific value, in ...	resource/biotic	Energy	2.0E6	MJ
Energy, gross calorific value, in ...	resource/biotic	Energy	2.9	MJ
Energy, kinetic (in wind), conve...	resource/in air	Energy	4.64E3	MJ

Outputs

Flow	Category	Flow property	Amount	Unit
1,4-Butanediol	water/river	Mass	6.52E-8	kg
1,4-Butanediol	air/high population density	Mass	1.63E-7	kg
1-Pentanol	water/river	Mass	9.5E-9	kg
1-Pentanol	air/high population density	Mass	3.96E-9	kg
1-Pentene	air/high population density	Mass	2.99E-9	kg
1-Pentene	water/river	Mass	7.18E-9	kg
2,4-D	soil/agricultural	Mass	9.49E-6	kg
2-Aminopropanol	air/high population density	Mass	2.1E-9	kg
2-Aminopropanol	water/river	Mass	5.27E-9	kg
2-Methyl-1-propanol	air/high population density	Mass	9.55E-9	kg
2-Methyl-1-propanol	water/river	Mass	2.29E-8	kg
2-Methyl-2-butene	air/high population density	Mass	6.63E-13	kg
2-Methyl-2-butene	water/river	Mass	1.59E-12	kg
2-Nitrobenzoic acid	air/high population density	Mass	3.75E-9	kg
2-Propanol	water/river	Mass	1.8E-8	kg
2-Propanol	air/high population density	Mass	2.69E-3	kg
4-Methyl-2-pentanone	water/unspecified	Mass	1.11E-8	kg
Acenaphthene	air/low population density	Mass	1.36E-8	kg
Acenaphthene	water/river	Mass	8.15E-6	kg
Acenaphthene	air/unspecified	Mass	2.54E-11	kg
Acenaphthene	air/high population density	Mass	8.97E-8	kg
Acenaphthene	water/ocean	Mass	3.64E-6	kg
Acenaphthylene	water/ocean	Mass	2.28E-7	kg
Acenaphthylene	water/river	Mass	5.1E-7	kg
Acetaldehyde	air/high population density	Mass	1.01E-2	kg
Acetaldehyde	air/unspecified	Mass	0.49	kg
Acetaldehyde	water/river	Mass	8.79E-5	kg
Acetaldehyde	air/low population density	Mass	1.03E-4	kg

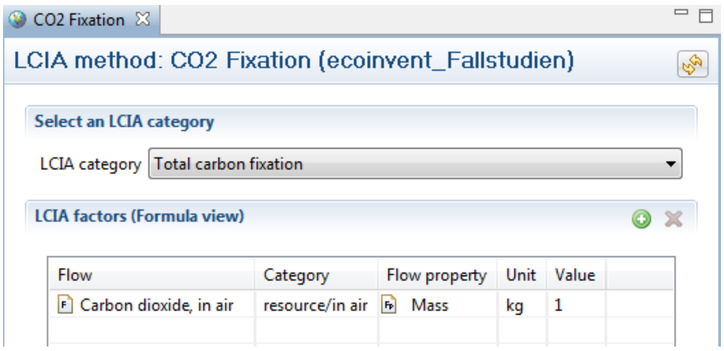
NB: Alternatively, these lists can be exported to Excel spreadsheets to be analysed separately.

3.4 Life Cycle Impact Analysis

The LC Inventory as shown above is not very manageable. Applying a "*Life Cycle Impact Assessment* Method" helps evaluating data. Ecoinvent contains the most important LCIA Methods such as eco-indicator 99, IPCC 2001, CML 2001, IMPACT 2002+, a.s.f... In this case study we want to apply two different methods.

One the one hand we want to compare absorbed Carbon dioxide over a set period of time, thus we have to create our own LCIA method:

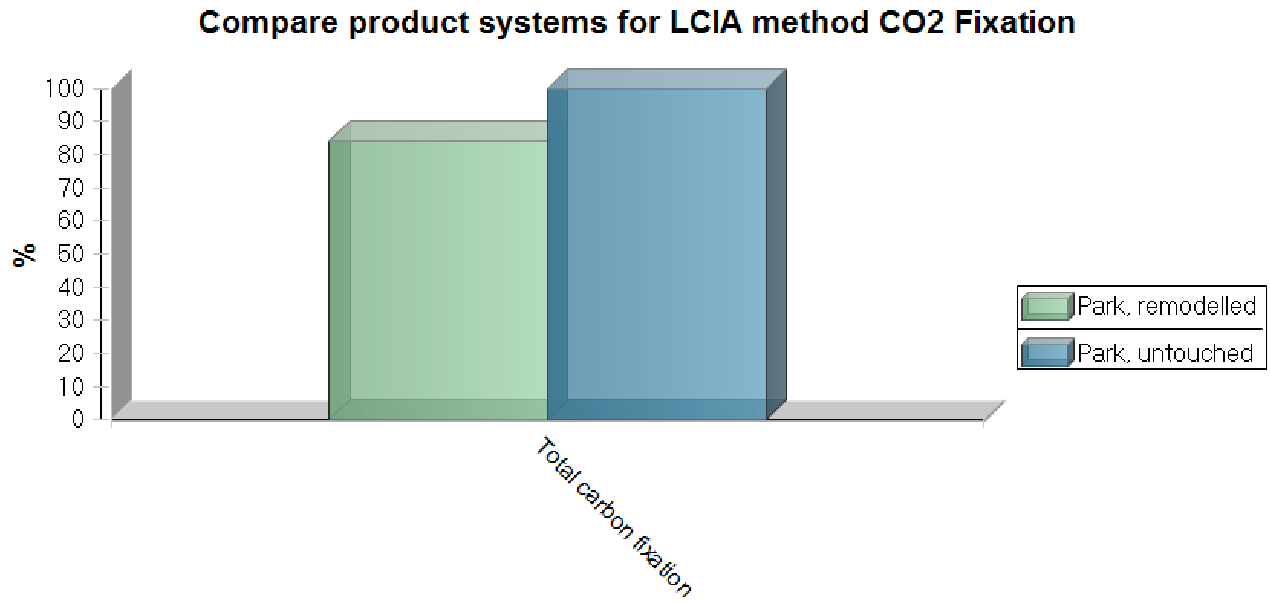
- Create a new LCIA method called "Carbon fixation";
- Add a LCIA category, name it "Total absorbed carbon dioxide" and Unit=kg;
- Add a LCIA factor and flow as seen below:



Flow	Category	Flow property	Unit	Value
Carbon dioxide, in air	resource/in air	Mass	kg	1

This rather easy method weighs every Kilogram of absorbed CO_2 with the factor 1. It can now be applied to the two product systems *"park, remodelled"* and *"park, untouched"*.

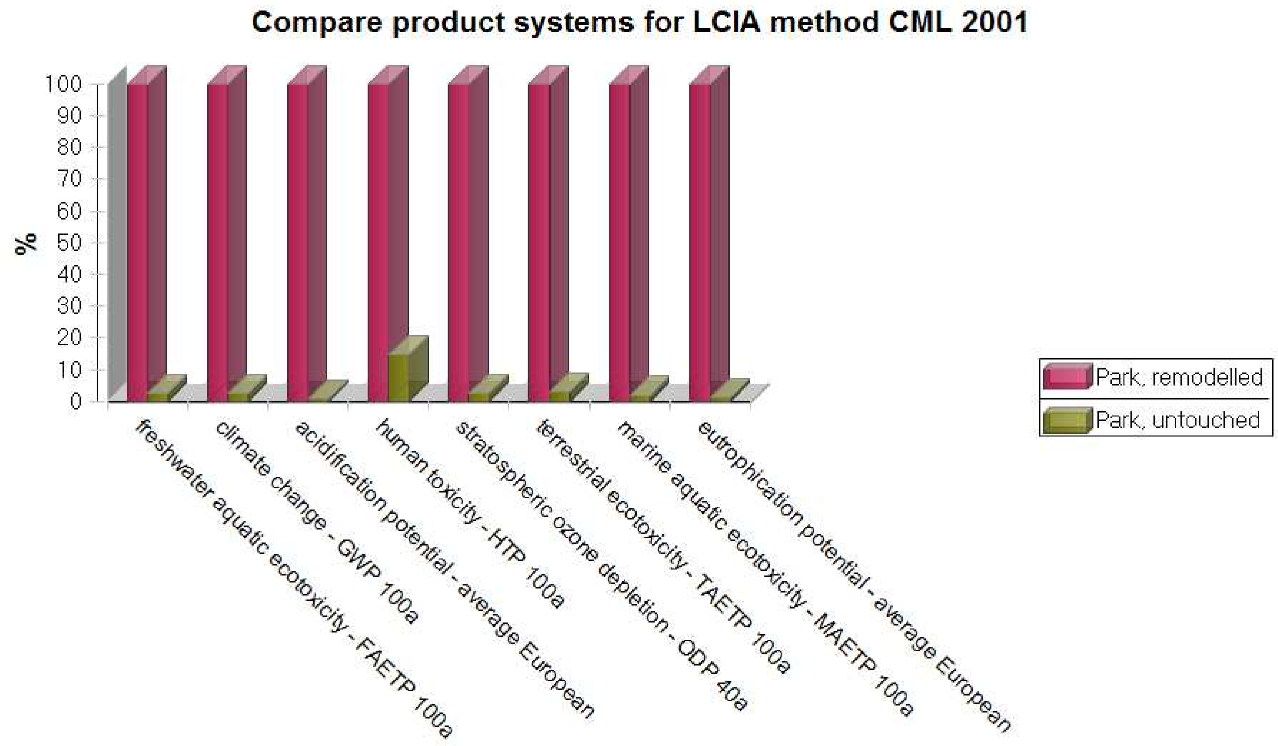
- Click on "Results" of both product systems and then select the CO2 fixation method;
- Create a new project called "Sellerpark – CO2 fixation";
- Add the two product systems and save the project;
- Draw a chart with the CO2 fixation method. It should look like this:



About 20% less capability of Carbon Fixation over a period of 70 years, not to mention emissions in course of the construction producing an alarming result, especially taking into account that in this densly populated area, parks and gardens are rather rare.

On the other hand we want to examine the usual ecobalance indicators. "CML 2001" is a well known LCIA method that evaluates the inventory, considering midpoint categories.

- Click on "Results" of both product systems and then select the CML 2001 method;
- Create a new project called "Sellerpark: untouched vs remodelled";
- Add the two product systems and save the project;
- Draw a chart with the CML 2001 method and the following categories:



In all categories, the remodelled park has much bigger impacts than the untouched park. These results proof the doutable character of the remodelling's good influence on the environment.

__NB:__ In the category "Climate change – GWP 100a", the carbon dioxide saved by the trees is not considered. Otherwise, the value would have been negative.

4 Modification of the functional unit

Now that results clearly show impacts over a period of 70 years (20 after the remodelling), we can wonder what could it be considering 50 years after the change (a total period of 100 years). To try such new model, only a few steps are necessary.

4.1 The untouched park

- Copy, paste and rename the product system "Park, untouched" into "Park, untouched, 100 years";
- In the parameter tab of the product system, add the following data:

Name	Formula	Description
timeafter	50	Time after remodelling; year

In openLCA, there is a classification on parameters' priority. It can be summed up:

Global parameter > Product system parameter > Process parameter

This means that when the LCI will be calculated, the value timeafter=20 from the process will be overwritten by the value timeafter=50.

- Save the change, reload the database and calculate the results.

4.2 The remodelled park

It could be done very easily:

- Copy, paste and rename the process “park remodelled”;
- Change values of parameters and formulas;
- Create a new product system and it’s done.

But, this is not the nice and funny way! The following method is much more interesting:

- In the process “remodelled park”, add the following parameters:

Name	Formula	Description
newwood1	timeafter*growthseedling*newtrees/density	Wood from new trees; if timeafter <=20 years
newwood2	timeseedling*growthseedling*newtrees /density+(timeafter-timeseedling)*growthtree *newtrees/density	Wood from new trees; if timeafter >20 years
oldwood	(timeseedling*growthseedling+(timebefore-timeseedling+timeafter)*growthtree)*(trees-cuttrees)/density	Wood from the old trees (m3)
totalwood	a1*(oldwood+newwood1)+a2*(oldwood +newwood2)	Sum of old and new wood, depending on timeafter (m3)
a1	1	a1=1 when timeafter<=20 years, otherwise 0
a2	0	a2=1 if timeafter>20years, otherwise 0

In Input, change this value:

Flow	Category	Unit	Resulting amount
Grown trees	Sellerpark	m3	totalwood

- Save the change;
- Copy, paste and rename the product system “Park, remodelled” into “Park, remodelled, 100 years”;
- In the parameter tab of the product system, add the following data:

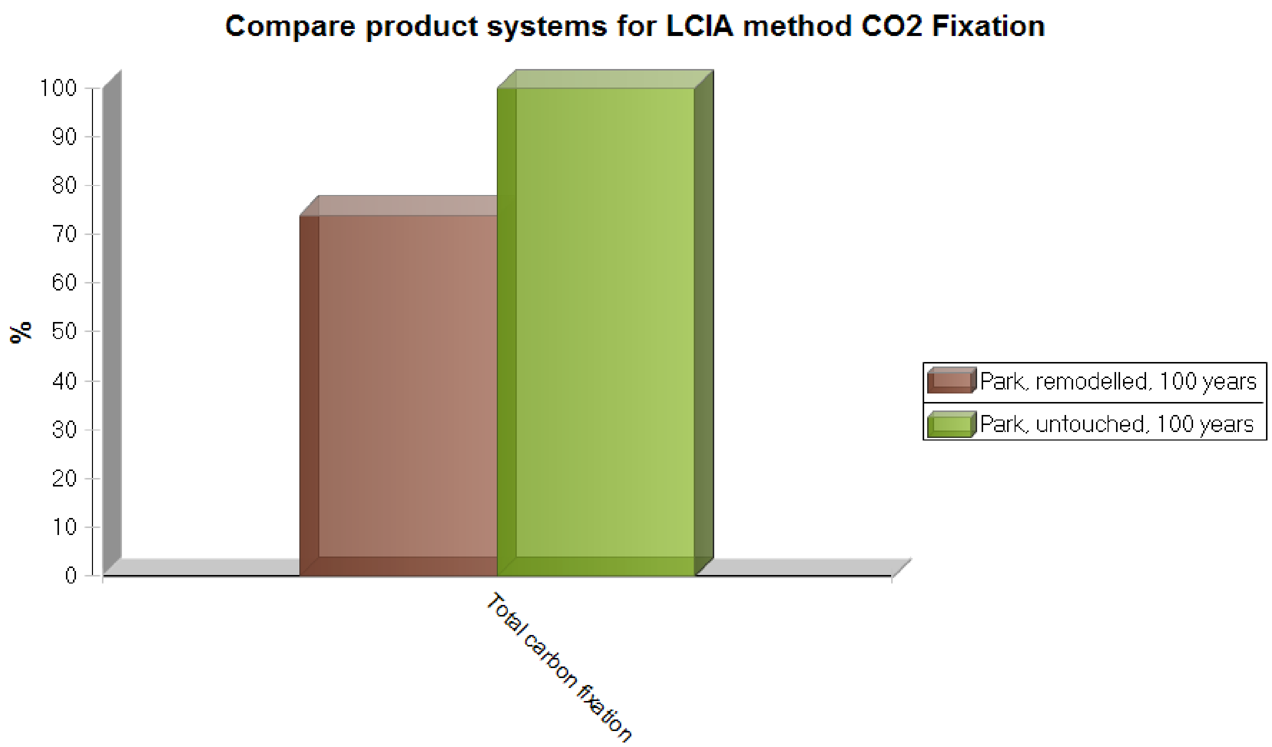
Name	Formula	Description
timeafter	50	Time after remodelling; year
a1	0	a1=1 when timeafter<=20 years, otherwise 0
a2	1	a2=1 if timeafter>20years, otherwise 0

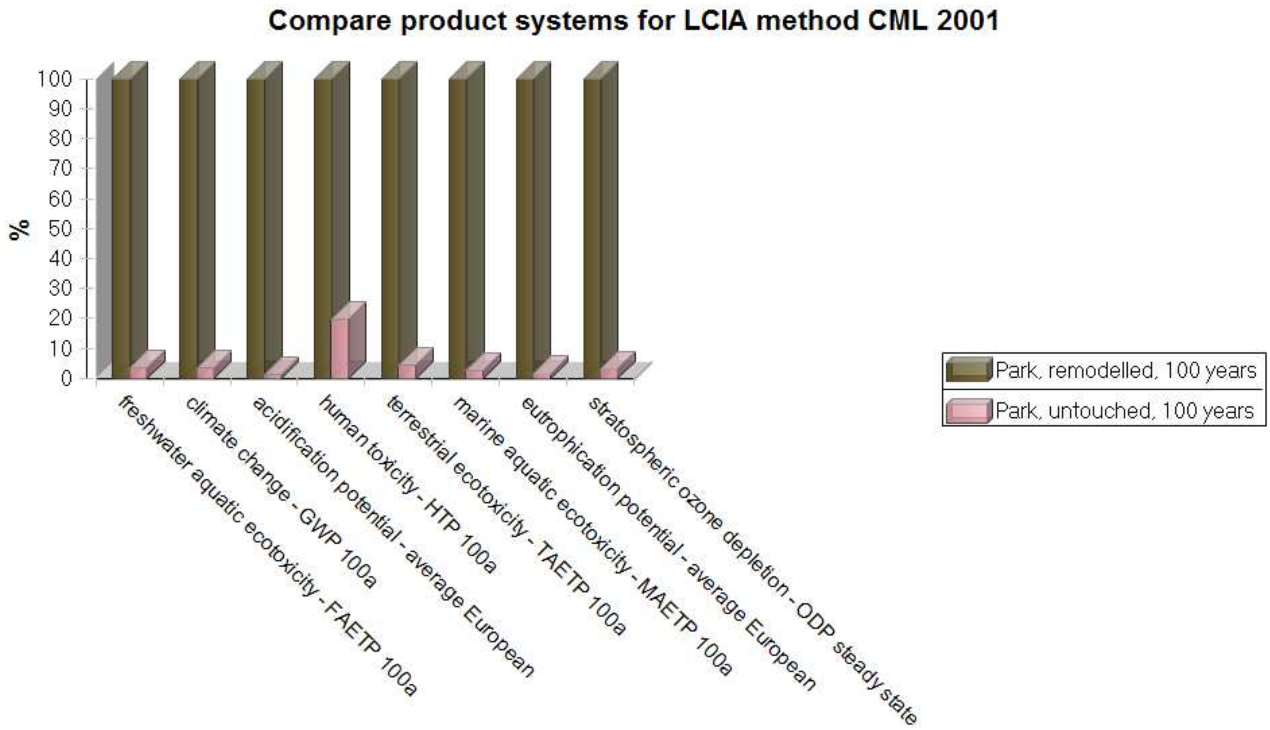
- Save the change, reload the database and calculate the results.

NB: Please, make sure you understand the calculations and the logic behind!

4.3 Comparison

- Create new projects to analyse the CO_2 fixation and the eight CML 2001 categories.





Impacts of the eight categories give slightly the same results (in the same proportion as before). The CO2 fixation difference is ever bigger (almost 30%) between the two models as it was in the previous comparison.

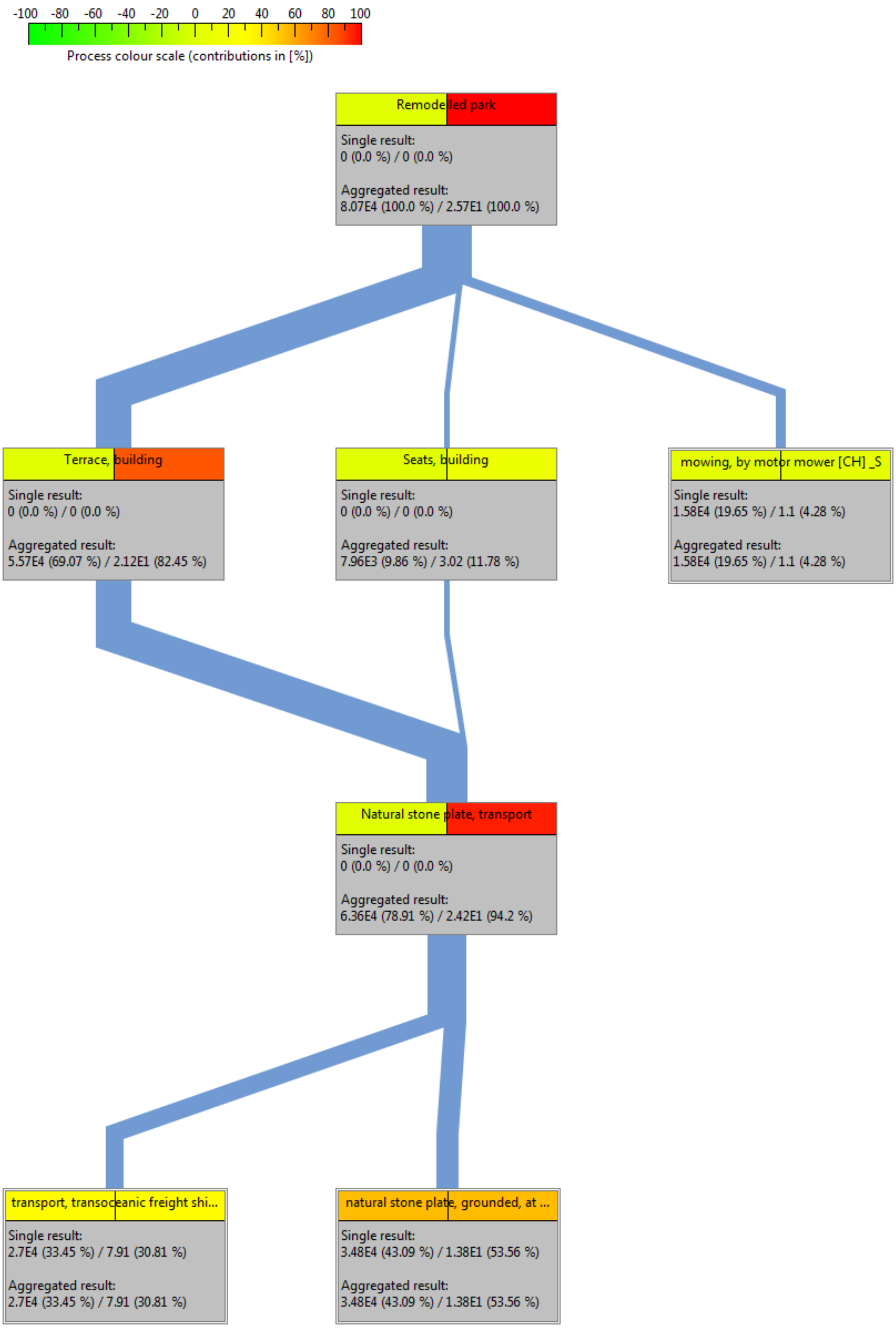
As the time period has been changed and the results are still fairly the same, we can consider that the original assumptions are true.

4.4 Analysis

So, why is there a so big difference between these two models? Thanks to the Sankey diagram, we will be able to find it out:

- Open the process “Park, remodelled, 100 years”, calculate the results and open the “Analysis” with the “CML 2001” method;
- On tab “Sankey diagram”, display it for “Human toxicity – HTP 100a” and “Terrestrial ecotoxicity – TAETP 100a” with 5% cut off:

Product system: Park, remodelled, 100 years
First layer (line width): LCIA category: human toxicity - HTP 100a
Second layer (box colour): LCIA category: terrestrial ecotoxicity - TAETP 100a
Cut off for first layer (in %): 5



Regarding these two categories, impacts come mainly from the production and the transport of the granite from China to Germany. These effects are not local (i.e. only in Berlin), but worldwide, thus they are globally distributed.

5 Conclusion

As expected, the remodeling of the Sellerpark has vast impacts on nature and environment. That is indeed an interesting fact for a biotope compensation project.

Anyway, this case study is rather to demonstrate the capabilities of this LCA software than to judge over absurdity of communal park development. We tried to account for the most environmentally influential aspect of the process. Certainly there are a number of other parts of the remodeling (other plants than trees, newly built park lanes, etc.) that contribute to impacts. From our point of view this neglect may not alter the overall result significantly.

Since the Sellerpark project is already some time ago, we had to juggle with a great number of unknowns – the results may thus differ from reality (which cannot be verified as the "untouched park" has never existed"). Nevertheless it is possible, in line with good preparation, on-site monitoring and accurate measurement, to solve these unknowns and thus create a 100% resilient Eco-Balance.

6 References (in German)

[a] Suzanne Torka, MoabitOnline (www.moabitonline.de)

[b] MoabitOnline

http://www.lehrter-strasse-berlin.net/dateien/Gruen/Sellerpark_Entw-mit-Persp.pdf

[c] GreenDelta[TC] (www.greendeltatc.com)

[1] FIS-Broker, Interactive maps, Berlin

http://www.stadtentwicklung.berlin.de/geoinformation/fis-broker

[2] Press release, City of Berlin

http://www.berlin.de/ba-mitte/aktuell/presse/archiv/20081002.0955.110750.html

[3] townhall meeting, Moabit, protocol

http://www.lehrter-strasse-berlin.net/dateien/BR-Lehrter_Protokolle/2006/BRL-Prot_2006-05-02.pdf

[4] on-site measurements

Law texts:

[5] http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bbe/download/bbe_leit.pdf

[6] http://www.buzer.de/gesetz/8972/index.htm