LCA project paper for the course: Environmental Issues in Crop production

CASE STUDIES:
Life Cycle Analysis and Propositions of Environmental-friendly Alternatives for 3 Different Swedish Horticultural Productions.

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ABSTRACT

The Life Cycle Analysis method permits to study a system "from cradle to grave", in order to understand all the environmental impacts which occur with that production. The identification of the environmental hot spots allows us to propose and examine some more eco-friendly alternatives. Our first case study is an apple production in orchard; where we will particularly try to find alternatives for the transportation, the electricity and then work on the possible organic production. The second one is the Iceberg lettuce production in fields; which hot spots are more the cultivation because of the nitrogen leaching, and the packaging. Our last case is the poinsettia production is greenhouses, which has an enormous trouble with the heating and lighting as our productions are situated in Sweden. The alternatives will be discussed and the new results found will authorize some environmental propositions and conclusions.

KEYWORDS

Life Cycle Analysis (LCA), apple production, Iceberg lettuce production, poinsettia production, environmental alternatives, transportation, organic apple production, electricity, nutrients leaching, packaging, heating greenhouses.

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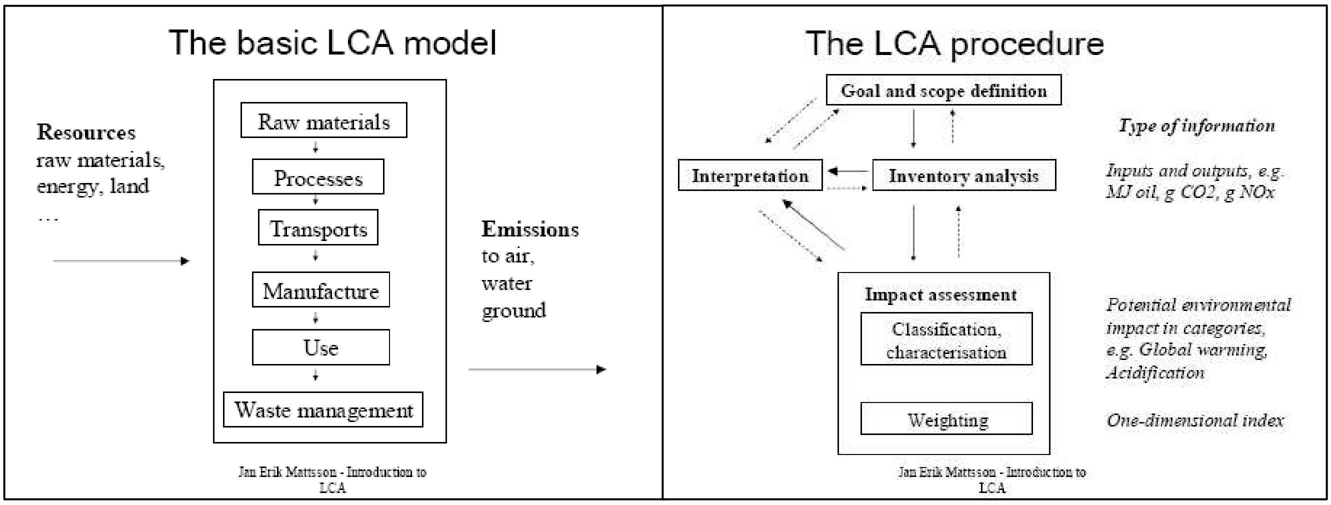
INTRODUCTION

Life cycle assessment (LCA) has been brought forward as an important and comprehensive method for analysis of the environment impact of product and services. In an LCA study, the whole industrial system involved in the production, use and waist management of a product or service is described (Baumann and Tillman 2008). Those figure (1) extracted from J-E. Mattsson's course permits to understand the LCA procedure and model that we applied in our three case studies.

Figure (1); The basic LCA model and procedure



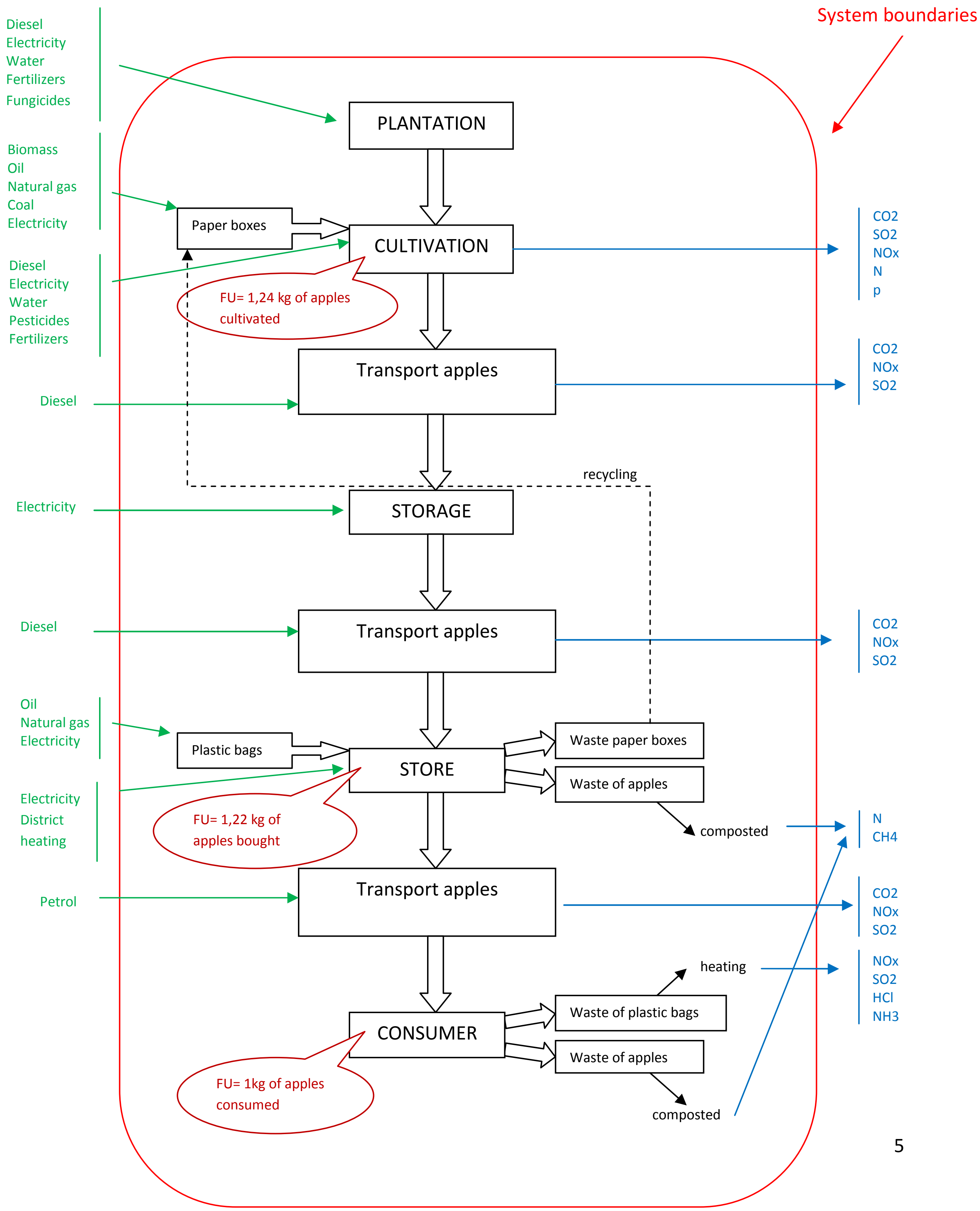
Three different applications of that method have been chosen, as we can work on the broader environmental problems appearing with horticultural productions. In fact, the first case is the apple production in orchards. The main alternatives will be proposed for the transportation and the electricity hot spots. In fact, the energy use induces a lot of environmental troubles. A specific part will be dedicated at the organic apple production study, in order to compare with the environmental impacts of the conventional production. Then the Iceberg lettuce production in field will be considered. In that example, the nitrogen leaching and the packaging are the main issues to deal with. Actually the eutrophication problem is an increasing priority for the agricultural field, especially in the northern country as Sweden, because of the dramatic Baltic Sea illustration.

Finally, as Christmas is coming, the poinsettia production will be observed. And as Sweden is a cold and dark country for the greenhouse productions, we will try to find alternatives reducing the environmental costs of the heating and lighting of those greenhouses.

METHODS, RESULTS AND DISCUSSION

PART I: The apple production in orchard

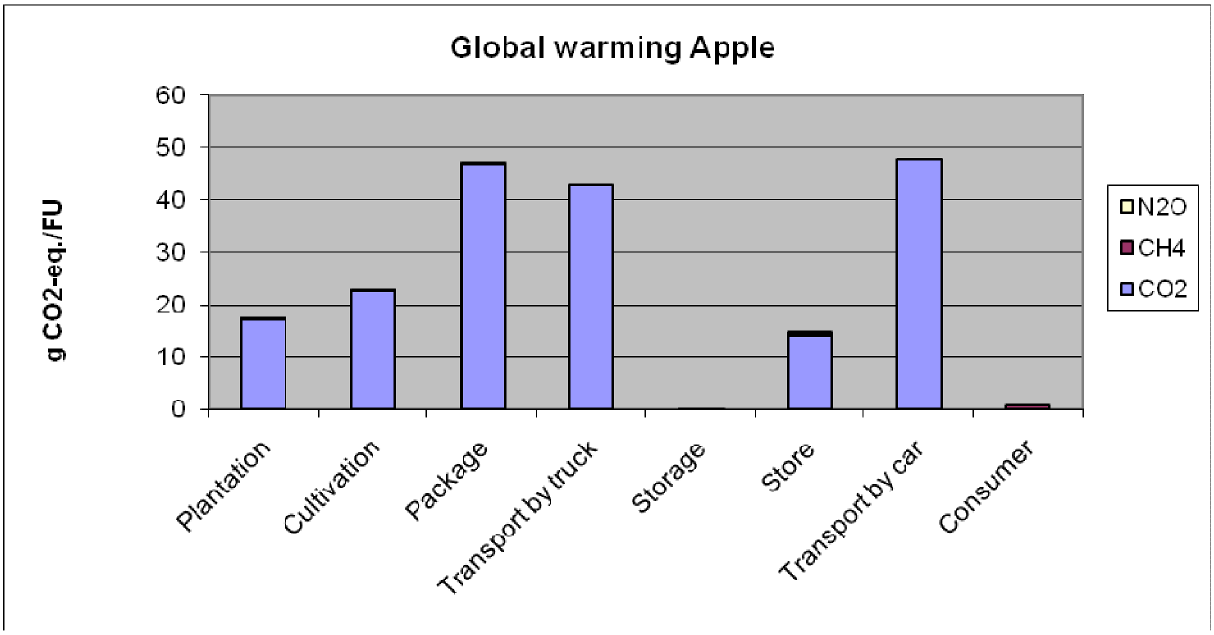
System's description: Figure (2); Apple production flow chart

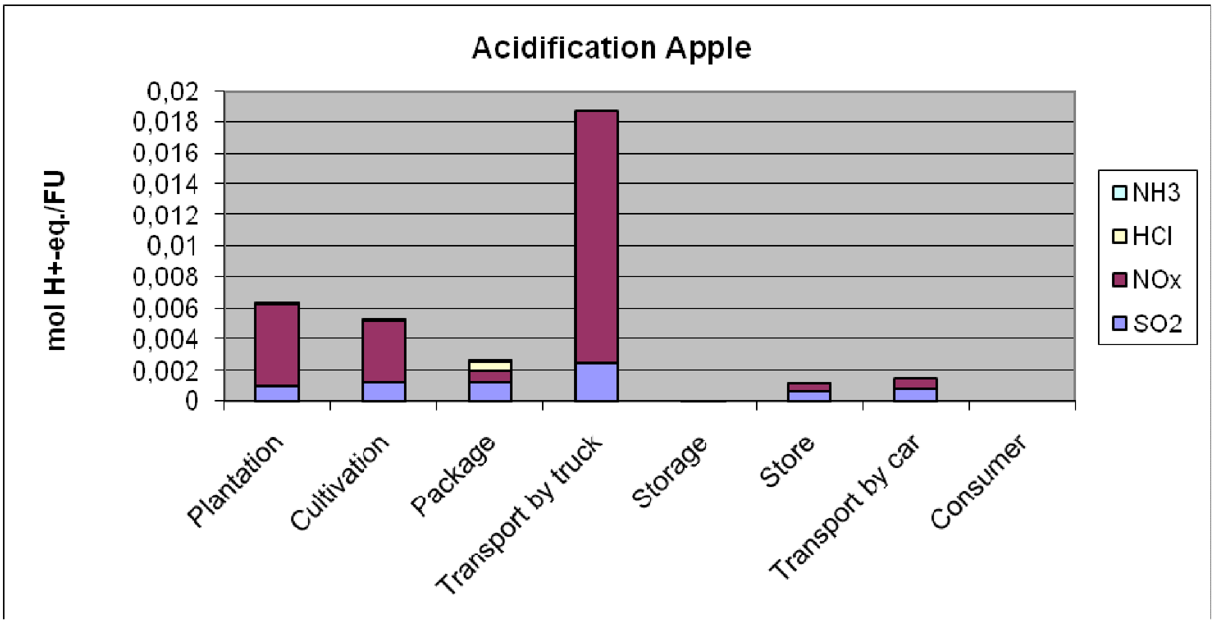


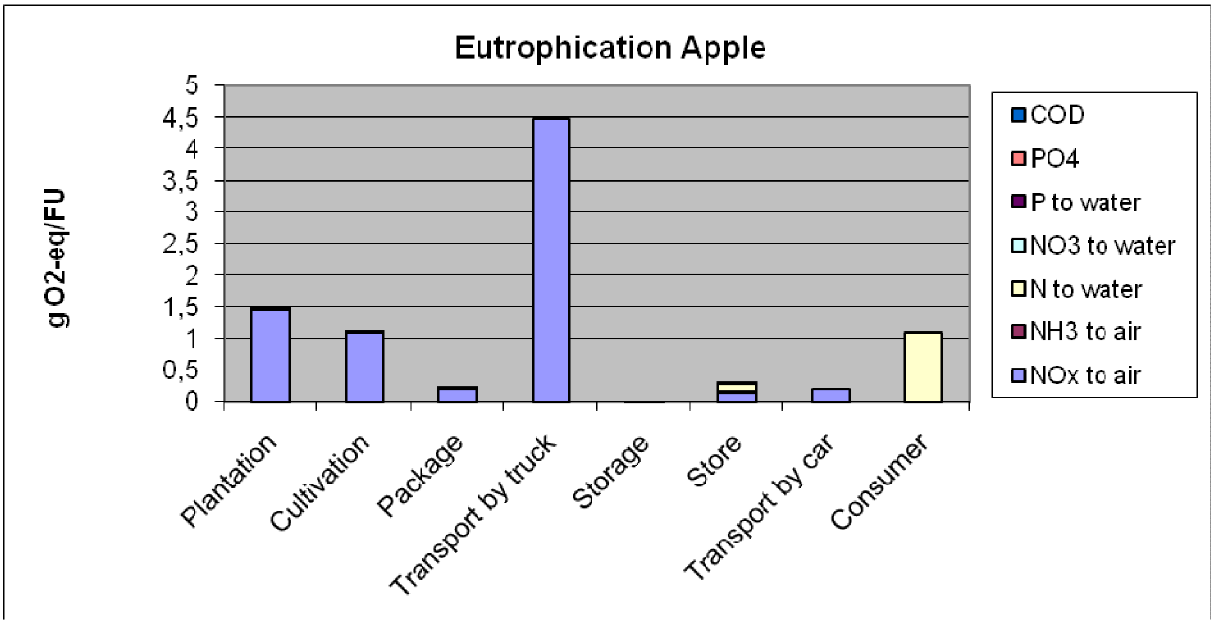
This diagram (Fig. 2) describes main steps in apple production and inputs and outputs to this system which is limited by our system boundaries. As a functional unit of this process 1 kg of consumed apples has been chosen.

This production system of apples is made in different stages: the plantation and cultivation as a growing part, the stocking in storage and store where apples are sold to consumers, the packaging and the transportation. This production chain ends at the consumer, and then the apple residues are wasted (composted). Each part of this production system cause some impacts on the environment. In this paper three groups of global environmental problems represent an environmental footprint of apple production. It is global warming, calculated in grams of CO_2 equivalent per functional unit (FU), acidification calculated in mol of H^+ equivalent per FU, and eutrophication which is presented in grams of O_2 equivalent per FU.

Figure (3-5); State of apple production before improvements







Choice of the hot spots

As we can see in those figures (Fig. 3-5), the most problematic link of this production chain is the transport. Apples are indeed transported by truck between the cultivation and the storage stages, and from the storage to the store. The main impacts are on the eutrophication and acidification processes. But the impact on global warming is also significant; as we can see it is the third biggest emitter of greenhouse gases (GHGs) after the packaging and the car transportation. Therefore some alternatives and improvements to current transport will be presented in that paper. But some other kinds of transportation appear in different stages of the apple production. Concretely, some amount of diesel has been used in plantation and cultivation probably as a fuel to tractors or similar machinery. A discussion on how to decrease the negative environmental effects of diesel will also be done in that paper. Transport by car is a very important source of GHGs too, as we can see on figure (3). This transport is done by costumers on their way to the store, and is therefore nearly impossible to influence.

The second hot spot presented in this paper is the electricity consumption. The theme of discussion is how the environmental impacts of apple production will be changed if cleaner electricity from renewable sources is used.

1) <u>Transportation</u>

Globally, emissions which rise from diesel engine combustion process cause greenhouse effects; but in a regional scale, they are also involved in the eutrophication and acidification processes. CO_2, CH_4 and N_2O emissions are responsible for global warming, while nitrogen oxides (NO_X) and sulfur oxides (SO_X) emissions cause acidification. Moreover, the NO_X emissions increase the eutrophication level. Some other emissions from diesel combustion exist like CO, HC, PM but they have mainly effect on human health than on the environment.

In our example, the transportation by truck makes significant pressure on environment. If we want to soften it, we can use the following alternatives:

- Use other mode of transport. In this paper it is railway.

- Use alternative fuels. In this paper it is biodiesel (RME).
- Use more efficient engines and high quality diesel.
- Combinations of these alternatives.

ALTERNATIVE I: Railway

Railway is a much more efficient mode of transport than the transportation by truck. The emissions from railway transport are marginal comparing to truck, but there are often problems with the railway network density. In our case study, the distance between cultivation and storage is 15 km and between storage and store it is 270 km. It appears from this that railway can be effectively used only for the second long distance (from storage to store).

In presented calculations the transport distance by train is only 220 km. There is assumption that the store or the storage areas are not situated on the railway network, and therefore is necessary to calculate with some buffer distance. For this illustration, 50 km has been chosen. The energy needed to load or unload the apples, and the other externalities connected with this fragmented process are not included in the calculations.

In Swedish conditions, the absolute majority of railway is electrified. The electricity that is used for traffic and infrastructures comes from renewable energy sources. In 2006, 99.6 percent of the electricity came from hydroelectric power and 0.4 percent from wind power (Banverked 2006). Calculations use only data from hydro-electricity. This data are adopted from Baumann and Tillman (2004), but based on older data from Switzerland (Frisknecht et al., 1996 in Baumann and Tillman, 2004).

ALTERNATIVE II: Biodiesel

The other alternative is the biodiesel use, instead of conventional one, as a truck fuel. The biodiesel in European condition is primary made from RME (rape methyl ester) and can be used pure (100% RME) or blended into conventional diesel fuel at any concentration. In European Union 5% of RME has to be blended into all diesel products.

The usage of biodiesel is not efficient as the railway transport but still it can help to reduce the impacts of apple production on the environment. The big plus of biodiesel is that the CO_2 emissions from engine combustion are almost insignificant, because the same amount of CO_2 will be consumed by rape when it is growing. But the important thing is to be aware of other outputs (emissions) from whole biodiesel production process. Thus, we can say that biodiesel impacts positively on global warming. The SO_X emissions in pure biodiesel are also essentially eliminated. On the other hand the NO_X emissions from pure biodiesel increase on average by 10% compare to conventional diesel (EPA).

In this alternative the pure biodiesel (100% RME) has been used instead of the diesel noted in the excel sheet for plantation, cultivation and of course for truck transport. Diesel which is used for pesticides and fertilizers production hasn´t been changed. Even if biodiesel engine combustion produce more emissions of NO_X compare to conventional diesel (MK3), in the following figures the amount of NO_X has decreased (compare in table 1). It is caused by strange data given for diesel in excel sheet. The value of NO_X emissions from diesel combustion is given at 1,3 g/MJ which is not in concert with 0,594 g/MJ (Aakko et al., 2000 in Bernesson, 2004). It looks that the given value is formulated in the wrong unit, instead of g/MJ_{-fuel} it has been used $g/MJ_{-engine}$. The table which compares diesel fuels is enclosed below.

Table (1); Comparison of diesel fuels – heavy-duty engines

Emissions from :	Diesel (excel sheet) g/MJ fuel	Diesel MK3 g/MJ fuel	Diesel MK1 g/MJ fuel[1]	Biodiesel (100% RME) g/MJ fuel[1]
CO2	74,6	72,6	72,72	9
SO2	0,14	0,14	0,018	0
NO_X	1,3[2]	0,594	0,480	0,644

Source: Baumann and Tillman 2004, Bernesson 2004, Almemark M. et al. 2001

1 - Fuel supply chain included

2 – Strange value

The use of hundred percent biodiesel has some specific problems nowadays and a more common use is the blended variant. In our example the 100% RME has been chosen to show possible future state of transportation and with this connected decrease of environmental impact.

ALTERNATIVE III: Engine efficiency and high quality diesel

The engine technologies are developing to decrease fuel consumption and lower exhaust gas emissions. It is a positive trend which is making our transportation more efficient with each new motor type. This progress is also recognizable for diesel fuels, in fact the diesel standards have been decreasing the amounts of pollutants allowed (SO_X, NO_X, PM...) for a long time.

The diesel fuel contains some sulphur residues which are oxidized in SO_X which cause acidification of the environment. The sulphur content, since January 1st 2005, must not exceed 0.005% (50 ppm) according to EU Directive 2003/17 and the EN590 standard. And all EU countries must secure the availability of 0,001% (10 ppm) fuel e.g. the Swedish Class 1 (MK1). The fuel quality will continue to improve, and from January 1st 2009, all fuel must not exceed 0,001% (10 ppm). (Volvo) A positive fact is that more than 90% of the fuel sold in Sweden is an environmental class 1 (MK1) (Baumann and Tillman, 2004).

Table (2); Legal requirements and limit values for large goods vehicles

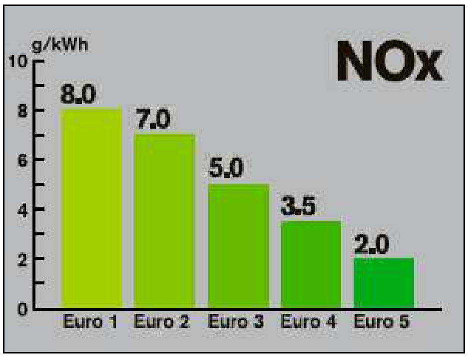
Engine type	Law from	NO_X g/kWh	PM g/kWh	HC g/kWh	CO g/kWh
Euro 2	1996	7.0	0.15	1.10	4.0
Euro 3	2001	5.0	0.10	0.66	2.1
Euro 4	2006	3,5	0,02	0,46	1.5

Euro 5	2009	2,0	0,02	0,46	1.5

Source: Scania, Volvo; 1kWh = 3,6MJ

Each engine has to be approved in accordance with current European Union legislative requirements (tab. 2). This has a positive impact on environment. In our apple production example and also generally, the nitrogen oxide emissions cause major problems with the acidification and the eutrophication processes. The engines of Euro 4 and 5 categories lower significantly the NO_X emissions (Fig. 6), and therefore if we want to improve environmental impact of truck transport, we should think in trucks with these new engines.

Figure (6); NOX emissions according Euro engine types



Source: Scania

Conclusion – Combinations

Transportation by train for long distances seems to be the best variant. Emissions are minimal from this mode of transport, but we still have some emissions from trucks which are necessary because railway transportation cannot cover the whole spectrum of apple transport. To reduce the emissions of truck transport, it is good to use new efficient engines and high quality diesel, biodiesel or some blended combinations. In current conditions, the most environmental friendly solution is to use engines in category Euro 5 as a fuel 100% RME. Summary graphs above (Fig. 11-13) show this combination except calculating with Euro 5, data are presented for standards of Euro 2/3. It means that NO_X emissions can be even lower.

Effective railway transport combined with truck transport based on new efficient engines, and the use of biodiesel as a fuel, should be one of the best alternatives for the apple transportation. Also, a biodiesel usage in plantation and cultivation of apple orchards, and new efficient machineries can significantly reduce current negative impacts on environment.

2) Electricity

Electricity consumption has naturally negative effect on environment, but if some renewable resources are used, those effects can be decreased. Most emissions come from electricity generation based on fossil fuels like oil and coal and natural gas. The combustion of these fossil fuels emits big amount of GHGs and some other important pollutants (NO_X, SO_X). Another possible source of energy is the nuclear electricity generation. In that case, GHGs emissions are not as high as from fossil fuel plants. On the other hand there is a problem with the radioactive waste and also with the fuel (Uranium) which is a nonrenewable source.

In Swedish conditions the electricity is relatively “clean”. The main share of great electricity generations is nuclear power (45,7%) and hydro power (46,0%) (EC). But sometimes, it happens that the coal based electricity from Denmark is bought. This fact can really influence the LCA and final environmental impacts of some product, apples in our example.

In the given excel sheet, the average electricity has been calculated. If we want to reduce ecological footprint of our apple production, we can replace this average electricity by some renewable one. There are few possibilities, electricity from hydro power plants, wind energy, solar energy and from some kind of bioenergy generation. The table below compares these energy sources through chosen categories of pollution, in perspective 2010.

Table (3); Emissions from different types of electricity generation, prediction for 2010

Emission g/MJ:	Hydro power[1]	Wind turbine[2]	Photovoltaic generator	Waste wood steam turbine	Biogas
CO2	2,77	2,83	27,5	8,61	3,05
CH4	0,0058	0,0067	0,06	0,017	-0,0054
N2O	0,0001	0,00005	0,0005	0,0038	-0,206
SO2	0,0047	0,011	0,080	0,087	0,102
NOX	0,01	0,0086	0,094	0,36	0,160

Source: Pehnt 2006
1 – 3,1 MW
2 – 1,5 MW

We can see that electricity from hydropower has the best environmental parameters and therefore has been chosen as an electricity source in our apple production. In the calculations, hydropower data from another source has been used (Frisknecht et al. 1996 in Baumann and Tillman 2004). It is the same data used for calculations in railway transportation.

Graphs show the changes in impact categories when electricity from hydropower plants is used. In calculations, the hydropower electricity replaced average electricity only in apple plantation and cultivation. Other electricity demand in the following steps of the apple production is presented with average electricity and is unchanged.

This electricity improvement and improved transportation figures have been added into summary graphs below (Fig. 7-9), combine hotspots from apple production and shows the “best” solution studied.

3) <u>Organic apple production</u>

As is shown in figure 1, 2 and 3 some environmental effect during apple cultivation such as global warming and use of chemicals is so obvious.

During production, apple orchards are usually face difficulties from establishment of weeds, pests and fungi in large quantity. Most of commonly used pesticides and fungicides are not permitted in organic farming and weed must be removed mechanically and manually (Jönsson 2007). Undoubtedly, economic success in organic apple production depends on location and on the local climatic characteristics.

Pest and disease management

In organic fruits the nutritional and healthy attributes were better as ascorbic acid content
One of the main challenges for organic apple production is susceptibility of apple to fungal diseases like apple scab and powdery mildew and various insects.
In order to evaluate organic apple production we are going to review some of important pest and diseases and the possible solutions in organic pest and disease management.

The organic sections were noted for significantly more scab (Jönsson, 2007). It has been shown that the strong pruning decrease scab considerably due to the improved spray disposition (Holb, 2005). In organic production system only sulfur was applied to treat the major primary scab infections.

Scald occurred only infrequently and with significant variation among years. Generally scald is not very common in Sweden, possibly due to the relatively cool weather during fruit ripening (Jönsson, 2007). In order to control aphids beating tray samples can be used for determination of pest management actions against them. In order to control and restrict codling moths to below damaging levels in the organic section it is possible to use and spray sulphur and fatty acids. Jönsson, (2007) reported that apple suckers and moth caused no damage in apple trees. An alternative for moth damage is kaolin particle film, which was successful against moth (Delate & Friedrich, 2004). They suggest that kaolin clay was effective against insect pests. It is important to apply the insecticides at the optimal time for achieving good control (Jönsson, 2007).

Important resistance management practices to prevent breaking of scab-resistance when scab sources are present in the vicinity are: to use sulfur, a moderately effective fungicide, to treat major primary scab infections; to use chicken wire fences as spatial buffers; and to plant exclusively scab-resistant orchards (Maas, 2007).

IOBC (International Organization for Biological Control) Diseases in Orchard working group advised to take the following measures: 1. Do not plant scab-resistant cultivars together with susceptible apple cultivars, 2. Keep sufficient distances between scab-resistant and orchards with susceptible cultivars, 3. Apply fungicides to treat major primary infections and 4. Apply sanitary measures during winter (Trapman, 2005).

Choice of cultivars:

Disease resistance is one of the primary factors in organic apple production. All over the world, one the main goal in apple breeding programs is to have disease resistance cultivars such as scab resistance or other diseases like mildew, bitter rot. When planting a new orchard, cultivars with strong resistance towards especially scab and bull’s-eye rot may, however, be a better choice.

Among the 16 cultivars investigated for industrial use, ‘Blenheim Orange’, ‘Bramley’, ‘Holsteiner Cox’, ‘Ingbo’, ‘Queen’ and ‘Vanda’ were the most promising cultivars. It has been reported that all of these cultivars had high levels of tree and fruit resistance to pests and diseases, and had fruits that were suitable for mechanical peeling, coring and cutting, were rich in SSC and had good firmness at harvest and after storage. The fruit flesh was white and the skin colour bright and yellowish as preferred in processing (Kaak & Grauslund, 1991). Aroma is one of the cultivars which is recommended for organic growing in Sweden (Juhlin, 2004). A problem with this cultivar is its sensitivity to bull's-eye rot (Schawlann, 1999). Rubinola and Rajka reported to have yield below medium but these cultivars have the highest percentage of first class fruit. Moreover they considered health, attractive, tasty and easy to grow. Rubinola specially is an option as scab-resistant cultivar. For these reasons they appear suitable for organic growing in Sweden.

Scarlet O'Hara with above medium yield and late ripening which keeps well in storage is a promising cultivar for organic growing in Sweden. Results from Jönsson, (2007) suggest that quality of all of these cultivars were acceptable Rubinola turned out to be the best liked cultivar. In addition a rose was observed among the consumers to pay a premium of 0.55 € to buy organic apple. 'K:1160' reported as best liked after 'Rubinola' in one of the two years of the consumer evaluation. Data on yield and fruit quality of 'K:1160' are needed before it can be recommended for organic growing.

Undoubtedly, economic success in organic apple production depends on location and on the local climatic characteristics of orchard (Reig *et al*., 2007). It has been suggested that selection of a suitable site for an orchard is very important in regard to pest and diseases (Holb *et al*., 2001). It is recommended to place the organic orchard far away from other apple orchard to minimize pest and disease migration (Jönsson, 2006).

Soil and Nutrient

It has been reported that the content of potassium and phosphorus is higher in the organic section (Jönsson, 2007). In organic production manure or composted manure could be applied as fertilizers to provide nutrient (Racssko *et al*, 2008). It has been shown that excessive nitrogen fertilization enhances susceptibility to scab (Leser & Treutter, 2006) and reduce firmness (Jönsson, 2007).

As alternation to control decay, disorders and quality lost, it is possible to use O_2, CO_2 and N_2 gases in the store room such as controlled atmosphere.

Hand thinning will help is essential to achieving fruit quality. Treatment with olive oil reduce the fruit set and increased the mean fruit weight without inducing fruit russetting (Alins & Alegre 2005, 2007). Weibel *et al*., (2004) reported that sodium salt is also reducing fruit set. Orchard floor in organic apple system is controlled through mechanical means such as mowing, mulching and flame weeding (Gut & Weibel, 2005). Mulching can provide good weed control within the tree row, but it may necessary to use mouse guards or move mulch away from the base of trees in the fall to prevent winter rodent infestation (CHC, 2003). Keeping hogs at pasture is effective for control of weed and grass growth in orchard. They also preformed well when cleaning up drop apples (Nunn *et al*., 2007). This will receive more attention since in Sweden it is mandatory to keep organic hogs at pasture (Gustafson and Stern, 2003).

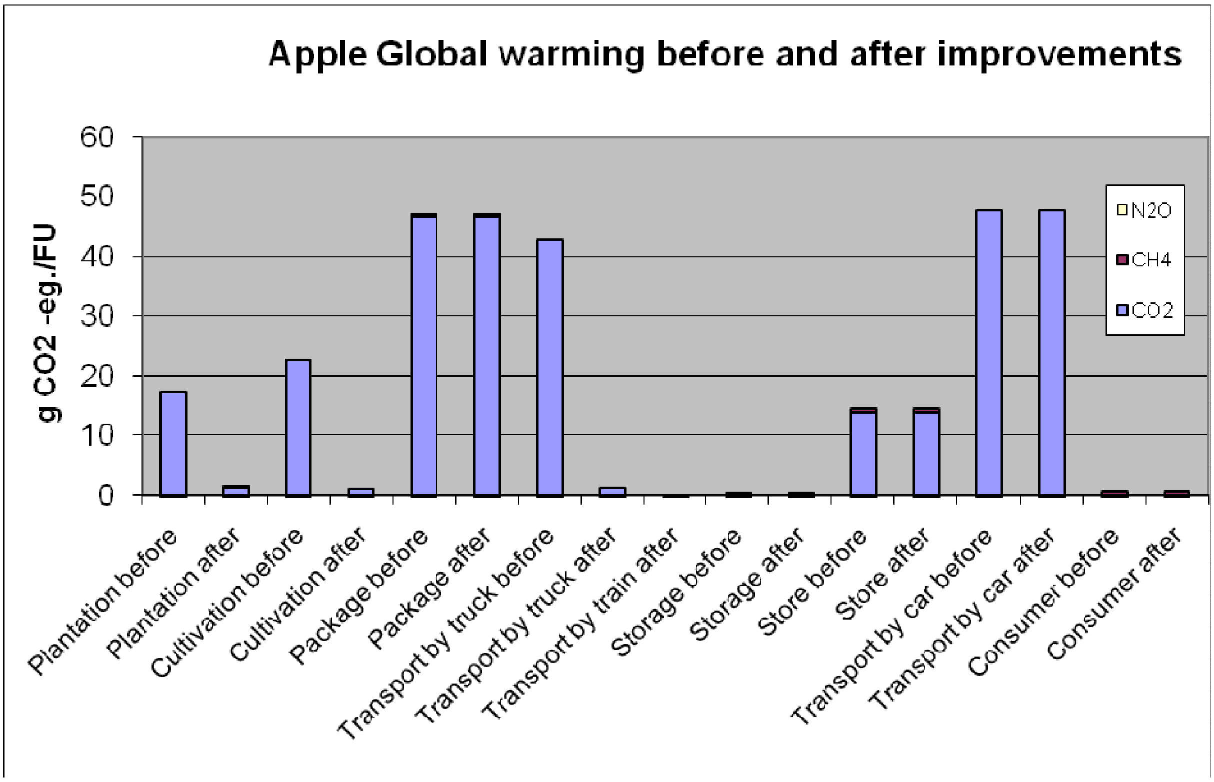
Discussion

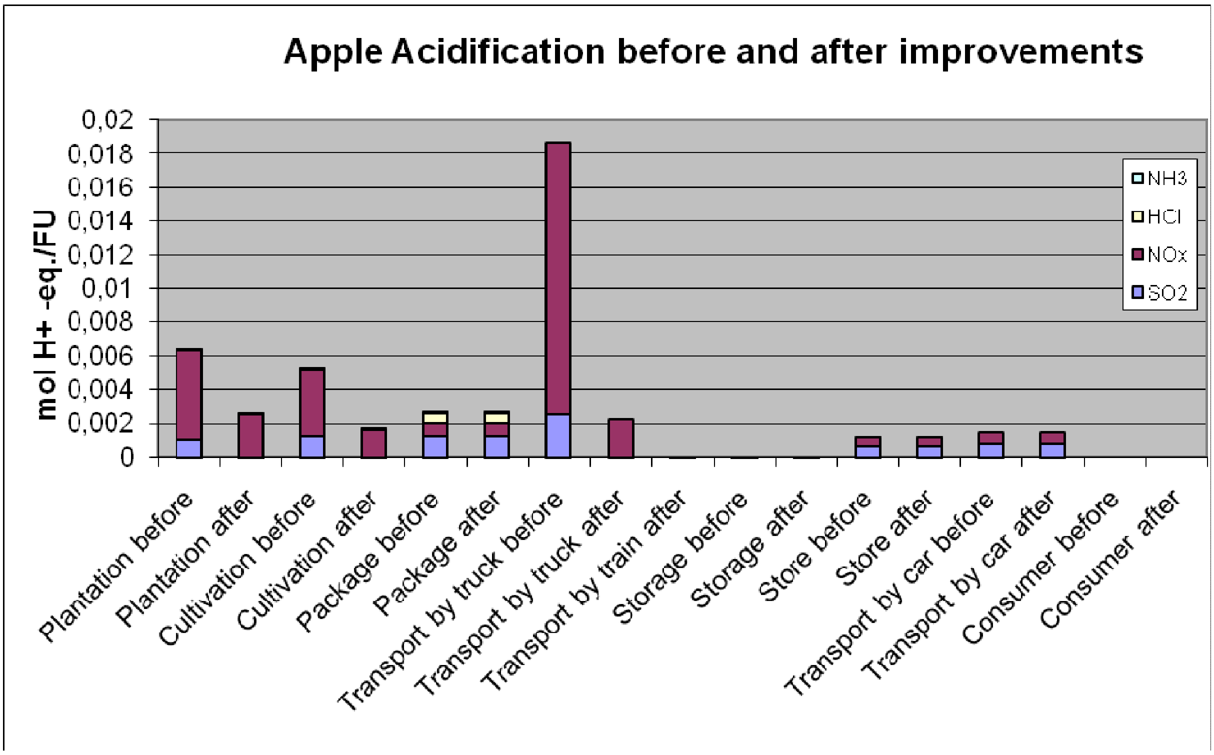
In conclusion Fruit growers must, however, be extremely observant on diseases and pests since these cause severe problems in organic orchards. Collection of beating tray samples, daily supervision of pheromone traps, searches for ants in the trees and control of the foliage for nutrient deficiencies is advised. Thinning of damaged fruitlets should help to minimize damage from brown rot and apple sawfly. The establishment of a healthy balance between pests and predators (with some help from permitted insecticides) should be easier to achieve in an organic orchard if it is placed far away from other apple orchards.

By converting conventional apple orchard to an organic orchard there will be a considerable improvement in environmental impact (Figure 3-5). Global warming effect and

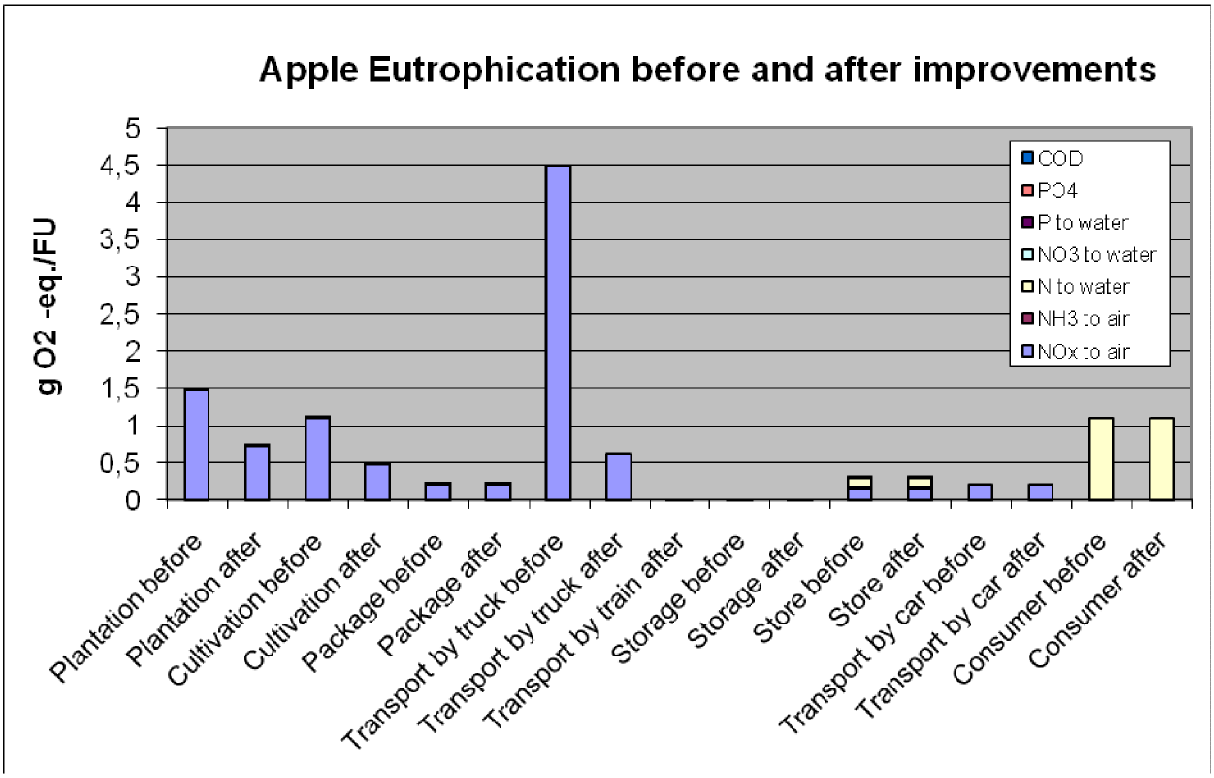
CO_2 emission will get close to almost zero the use of renewable energy sources (Figure 7-9). Even by continues utilization of fossil oil the amount of global warming and CO_2 emission will reduce to almost half of the conventional method. Another reason for this reduction will be the less utilization of machines and diesel in order to spray fungicides and pesticides in organic farming.

Figure (7 -9); Environmental impacts of organic apple production before and after all improvements (alternative transportation and electricity included)





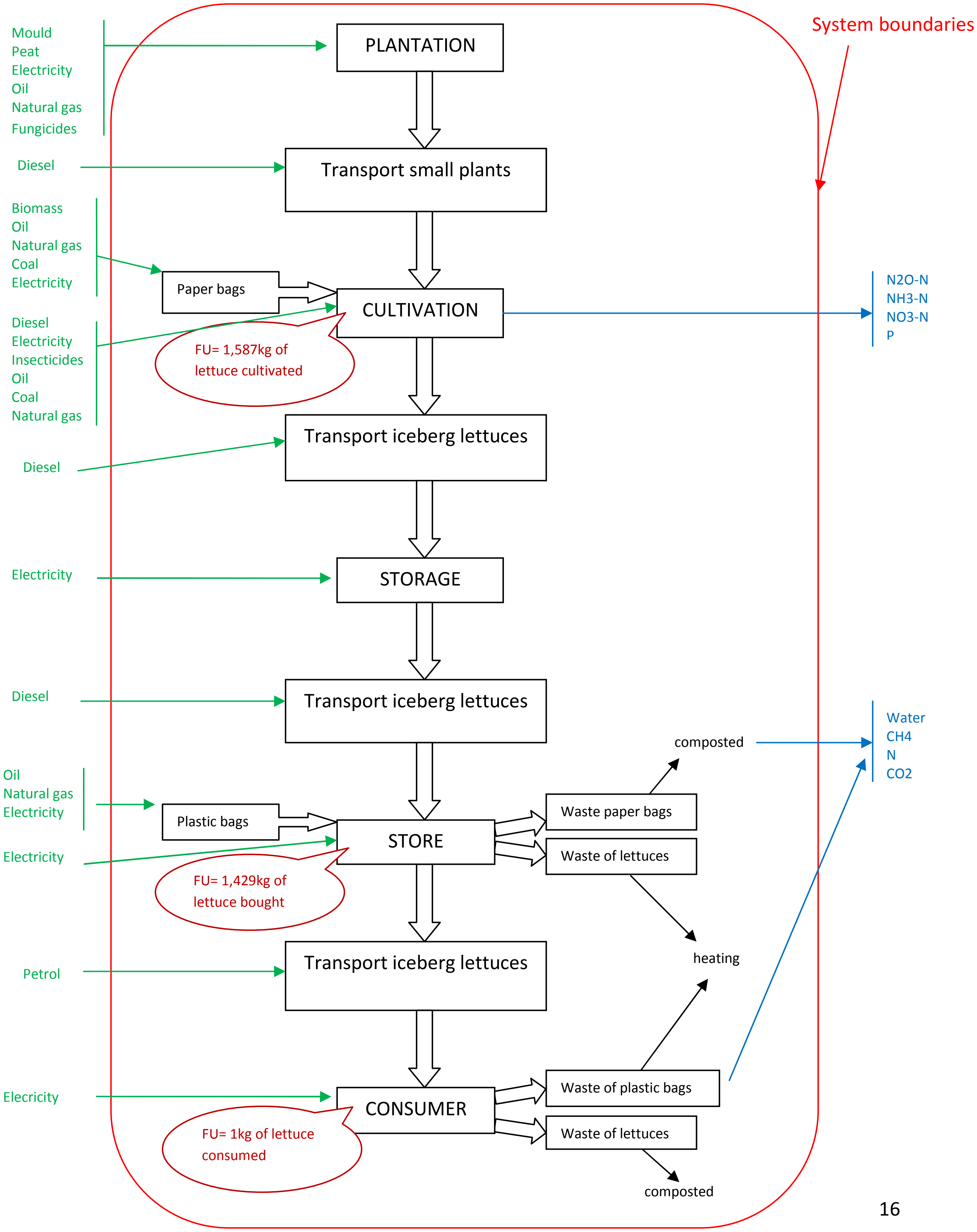
Apple Acidification before and after improvements
mol H+ -eq./FU
0,02
0,018
0,016
0,014
0,012
0,01
0,008
0,006
0,004
0,002
0
NH3
HCl
NOx
SO2
Plantation before
Plantation after
Cultivation before
Cultivation after
Package before
Package after
Transport by truck before
Transport by truck after
Transport by train after
Storage before
Storage after
Store before
Store after
Transport by car before
Transport by car after
Consumer before
Consumer after



Apple Eutrophication before and after improvements
g O2 -eq./FU
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
COD
PO4
P to water
NO3 to water
N to water
NH3 to air
NOx to air
Plantation before
Plantation after
Cultivation before
Cultivation after
Package before
Package after
Transport by truck before
Transport by truck after
Transport by train after
Storage before
Storage after
Store before
Store after
Transport by car before
Transport by car after
Consumer before
Consumer after

PART II: The Iceberg lettuce production in fields

System's description: Figure (10); Iceberg lettuce production flow chart



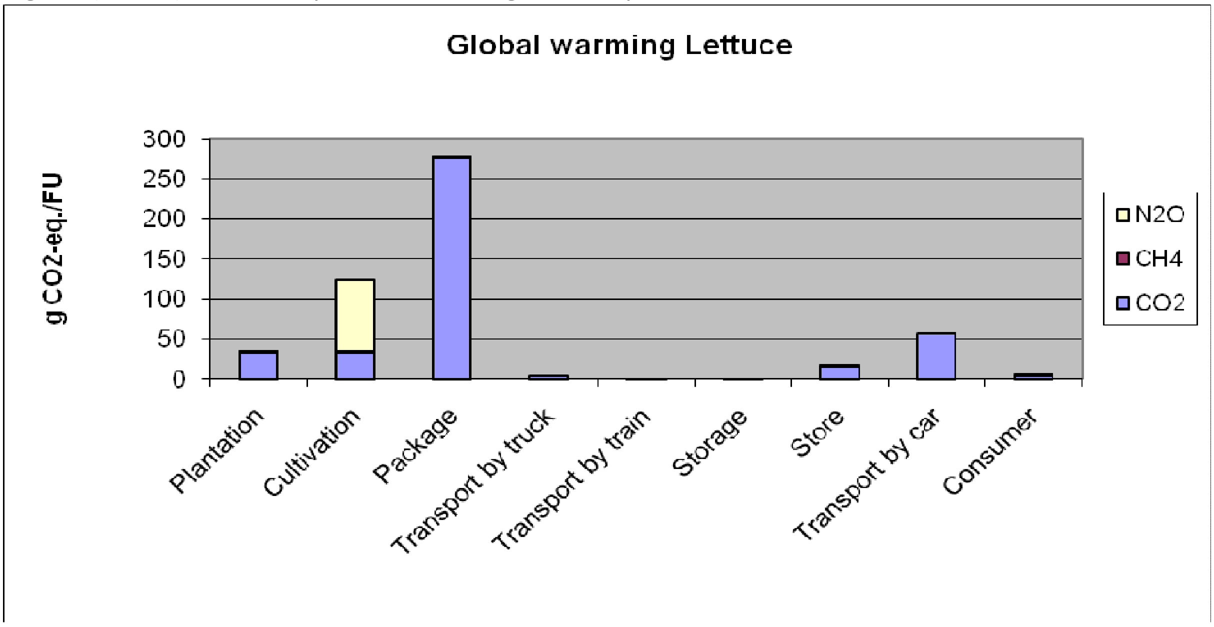
The iceberg lettuce production is the system studied here, in order to understand its impact on the environment and to find better alternatives. This simplified picture shows the different stages of that production, with the inputs and some of the main outputs resulting from that fabrication. We wanted to have the customer point of view that is why the functional unit chosen is 1 kg of lettuce consumed. Indeed, even if the customer buys the lettuce by unit, the price is by kilograms. Actually, if FU=1 head of lettuce have been chosen, the size of the lettuce would have influence our calculations. In order to involve the final purchaser in those results, it was a good solution to describe the amount of emissions produced for 1 kg consumed.

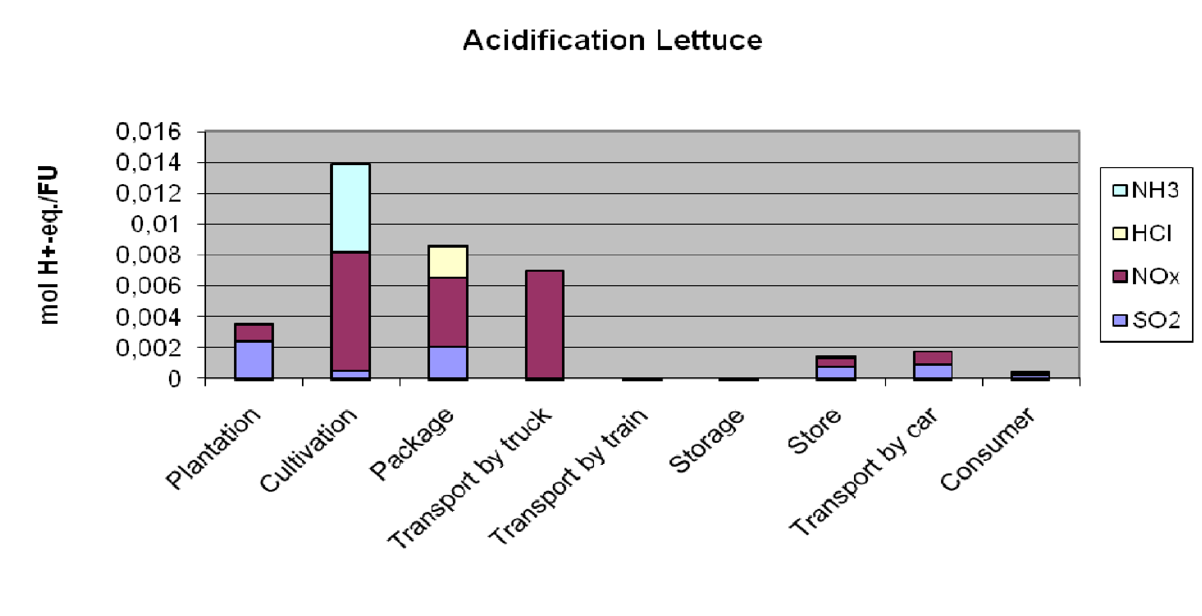
Choice of the hot spots

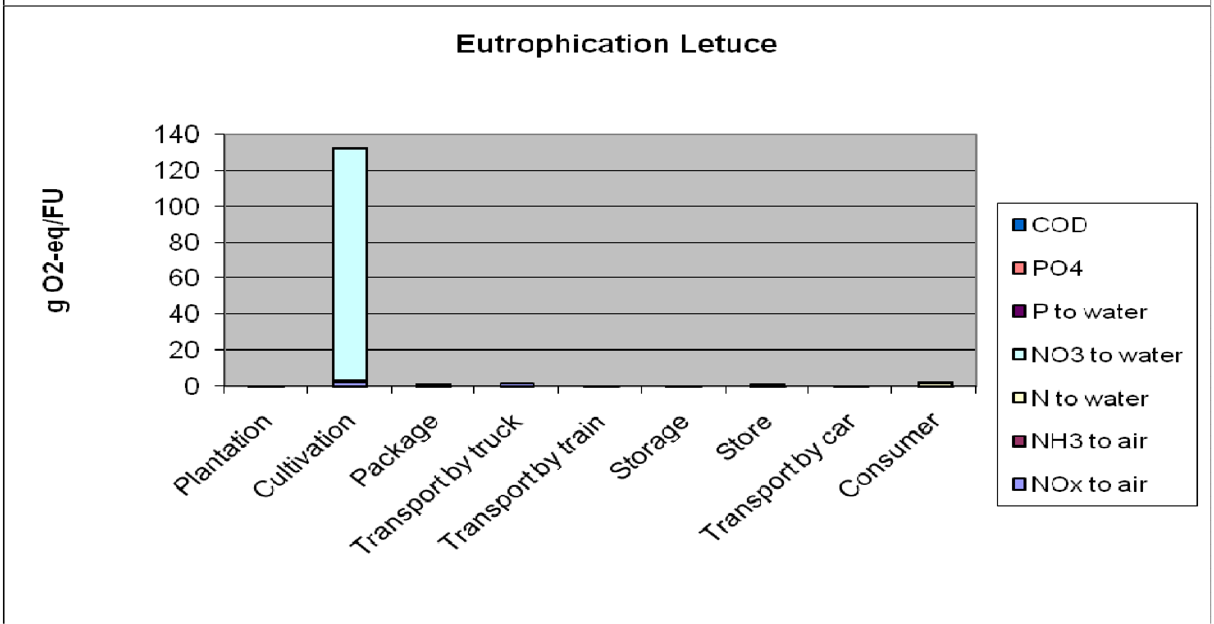
The calculations of the input and output produced was possible with a lot of data giving the amount of resources used and the emissions produced to obtain what was needed for our production system. Then, knowing the environmental impacts of this or that emission, it was possible to estimate the environmental costs. Those costs could then be evaluated for the three major problems: global warming, acidification and eutrophication processes.

In the iceberg lettuce case, we can see that the package is the major hot spot for the global warming problem, followed by the cultivation. The cultivation problems are the leaching of Nutrients, especially the Nitrogen (NO_3 to water, NO_X to air, NH_3, N_2O) impacting on the 3 environmental problems. This leakage is really the particular problem of that kind of production; indeed the vegetable productions in fields use a lot of fertilizers. The nutrient run-off to ground water, then lakes or seas is a difficult issue which really needs to be improved. The transport by truck is also involved in the global warming and especially in the acidification process, but this last hot spot has already been studied for the apple production. So the results could be re-used in that specific case at the end.

Figure (11-13); Initial impacts of Iceberg lettuce production.







1) The Nitrogen Leaching is here the most environmental problem:

Nutrient leaching is the downward movement of dissolved nutrients in the soil profile with percolating water. The leaching risk for a nutrient increases with its mobility in the soil. Among nutrient anions, nitrate is particularly easily leached because it shows negligible interaction with the negatively charged matrix of most topsoil and is, therefore, very mobile in the soil. As a consequence, nitrate leaching can contribute significantly to negative nitrogen balances of agricultural systems. The leaching of NO_3-N occurs in many cool-season vegetables, as the lettuce production system for instance, because N application rates often exceed crop demand. In fact, intensive agricultural practices are considered to be the main cause of the nitrate pollution of groundwater. This Nitrogen can then runoff to rivers, lakes and seas where the Eutrophication processes are leading to really big problems. To avoid that, the Swedish government adopted in 1999 fourteen environmental objectives, out of which, “Zero Eutrophication” (A.Henriksson, 2007). Nitrate leaching is also a significant source of soil acidification and erosion, and can be transformed in global warming gases. This hot spot is truly one of the largest trouble caused by agricultural production in open field areas, that is why we will try to find some alternatives more environmental-friendly. And that trouble in even worst because the lettuce production is often realized in a sandy soil which is particularly known for its nutrient runoff.

Preliminary discussion about the diesel used:

I went to see S-E. Svensson and T. Prade and we discussed about how much diesel is needed for each operations in the field. The comparison of their figures and those from the initial system permits to see that even different experts do not find the same results at all. Of course the tractors have been improved during the last years, but I do not understand how such a difference can be found only because of that factor! (See estimations) That is one of the most difficult things to deal with in LCA, because we have to choose between several data, sometimes so dissimilar that the results can be totally changed. In my study, I will choose to use numbers between those two estimations to obtain more moderated results.

Here are their estimations for the different cultivation steps:

	-ploughing and press of the soil: 20L/ha	20L/ha
	-bed formation, harrow… and fertilization (NPK): 15L/ha	15L/ha
	-transplantation of the lettuce: 5L/ha	5L/ha
(X4)	-mechanic weeding and eventual fertilization (NPK): 3L/ha	12L/ha
(X3)	-pesticides spraying: 1,5L/ha	4,5L/ha
	-harvest: 5L/ha	5L/ha

…………..…………………………………..

Total= 61,5L/ha
Initial total= 250L/ha
Chosen total= 155,75L/ha

If catch crop added:

-ploughing, harrow: 20L/ha	20L/ha
-seeding: 3,5L/ha	3,5L/ha

……………….……………………………………

Total= 85L/ha
Initial total = 345,5L/ha
Chosen total=215,25L/ha

ALTERNATIVE I: Catch crops

One possibility to reduce the nitrogen leaching is to use a catch crop (it can also referred to an intermediate crop but the aim and functions are the same). This crop will catch the nitrogen which is released by the previous one during the autumn, as it is growing. In addition, it will permit to release the nutrients incorporated, as the next spring crop (after the ploughing) can use them. This will reduce the amount of fertilizer that the farmers will have

to add, because the topsoil nutrients will not runaway during the no-exploited period of the year.
Different kind of catch crops have been studied, legume and non-legume (for example clover and ryegrass in T.Rinnofner and all, 2008). The results show that those two types of crops are efficient to reduce nitrate losses, even if the ryegrass is better for that goal. Especially the deep root system plants are good to catch the nutrients. The conclusion of that research for organic farming is that the use of catch crop is good, considering different aspects. Indeed, "they cover the soil, reduce nitrate leaching and erosion, and deliver residues that can improve soil biological activity and increase nitrogen availability for next crops."
During a five year study, at Mellby, the nitrogen leaching has been reduced by 60% on average by the use of Ryegrass (*Lolium multiflorum* L.) catch crop until spring (H. Aronsson, 2000). The conditions of that experimental work are good in our case, because the period of cultivation was approximately the same, as the environmental conditions because localized in the south of Sweden.
And compared with soil tillage in early autumn, the results can be even better: leaching reduced by 80% (only observed for one year). This also show that the ploughing should be done in spring (before the new crop installation), and not in autumn. In fact, when the soil is moved like that, some aggregates are broken and the nutrients are easily released. Then the rain water can bring them away, up to the groundwater, rivers… As the average leakage benefit in that paper is said to be between 50% and 70%, for both spring tillage and the used of a ryegrass catch crop, I will chose to reduce this nitrogen escape by 60%. Truly, this tillage is often done in autumn in Skane because the soil has a large content of clay, which makes the early spring tillage difficult for the farmers. So, even if nothing is said in our initial system, I will consider that the tillage was done in spring, and that no catch crops were used (G. Torstensson and all, 2004).

Results for the catch crop utilization:
Both the catch crop and the spring tillage will decrease the leaching by 60%. Otherwise, the diesel consumption is increased from 155,75L/ha to 215,25L/ha.

ALTERNATIVE II: Change the way of fertilize

-split the spraying in 2 applications, or more:

The little plant, at the beginning of the crop, cannot catch all the nitrogen given by the farmers (with the fertilizers).This can be explained by the lack of synchronization between mineralization and crop uptake too. And if it is raining, a big amount of those nutrients can runs away, which will pollute the groundwater but also, be lost for the growing plants. A solution is to give those contributions in several smaller amounts during the crop growing. One base can be added in the field during the bed formation, and some complements during the growing. Some samples can be analyzed for the period of the growing, in order to only complement the soil if necessary, and with the minimum amount possible. It is notably possible to fertilize at the same time as the weeding is done. In that case, the second or third amount of fertilizer will not cost more diesel consumption, so will not be worst for the environment. The experiments done by the investigators of SLU allow to say that the crop is not significantly altered with only 30 kg N/ha as a starter fertilizer, followed by 50 kg N/ha during the crop. So it is not necessary to fertilize more than that. This examination (G. Torstensson and all, 2004) says that 50 to 70% of the expected requirement must be put just before planting and top up as required during the crop growing (especially for plants with shallow root system). Some of the relevant advices given are the exploitation of sample analysis to know what is already contained in the field, and a good irrigation (in top) too reduce the fluctuations in the field and to give the nutrients more easily available for the plant. Because the lettuce production is mainly done in a sandy soil which has the highest nitrate leaching and the lowest denitrification rates, the utilization of an efficient irrigating system and the split of the fertilizer spraying will reduce the nitrogen leaching (J.M. de Paz & C. Ramos, 2003). Indeed, the nutrient uptake by the plant can be improved by 15-20% if a good irrigation is used, this for an unchanged fertilization.

It is difficult to find figures which could permit to see a relationship between the amount of fertilizer applied and the leakage importance. Although, a linear relation was shown (D.S. Powlson, 1993) between the rainfall and the leaching. In fact, “each additional 10mm of rain increased the loss by 2.6%. (This can also be used as a way to calculate the percentage of Nitrogen lost for the plant, and needed in a second fertilizer application.) But it is different for the relation between the N residual and the rate of N added. The leaching depends a lot on the post-harvest mineralization of crop residues. But the use of a following crop seems utilize the mineral N available, avoiding an important runoff of the nutrients.

-application of less fertilizer using the minimal N method (initially: 175 kg N/ha)

Different methods can be used to know how much fertilizer should be put in the field. For example the utilization of presidedress techniques in USA (S.J. Breschini & T.K. Hartz, 2002) is one way to choose the amount to add, depending on the sample analyses. Some other systems are trying to change the fertilization in the same field, thanks to map utilization. As they can know how much N (or others) they have in this or that part of the field, they can adapt the proportions applied. In fact, we cannot deny that the nutrients are not represented at the same level everywhere in the field, especially if it is a big one. In Sweden, another method is also used not to put too much Nitrogen: the Nmin-method (J.M. de Paz & C. Ramos, 2003 & G. Torstensson and all, 2004), which gives the minimal amount needed by the crop without reducing the product quality.

The important data to remember in south Sweden are: the total N supplied is approximately 260kg N/ha, but only 95kg N/ha of which are harvested as only the heads are sold. This leads to a total N-leaching equal to 95kg N/ha. Fortunately, Nmin calculations can be found (G. Torstensson and all, 2004): Nmin=minimum basic reserve of N in the soil + expected N uptake by the plant = 149kg N/ha as a starter. Then an addition of 15kg N/ha is requested during the crop. Thus, the total Nmin for the lettuce crop is 164kg N/ha if nothing is left in the field, which is not the case especially if a catch crop is used. But with their experiments, as we have seen in the last paragraph, it is possible to only deposit 30 kg N/ha as a starter fertilizer, followed by 50 kg N/ha during the crop (figures I will chose to use).

The figures found in Spain (J.M. de Paz & C. Ramos) are Nmin=72kg N/ha for the lettuce production, even if the traditional advice are 150-200kg N/ha in the code of GAP (Good Agricultural Practice). The GAP notably encompasses rules for nutrient/nitrogen management (A.Henriksson, 2007). It is said that with the Nmin application, the leaching is reduced by 66% while the crop yield is only decreased by 5%. And even if these experiments are not done in the same kind of environment, the amount of N put in the field now (80kg N/ha) in front of the ones put usually (260kg N/ha) are quite similar. That is why I can expect a leaching decrease about 60-70%, reducing the N-dose added in the crop up to 80kg N/ha.

-fertilize on a specific place with the best kind of fertilizer

The Swedish study on iceberg lettuce (G. Torstensson and all, 2004) also proposes to put the fertilizers on a strategic place, so where the plant is localized. Especially when the plants are small because they need a sufficient rate of nutrients easily available, and that method permits a good establishment of the crop. The really good point is that the amount of stimulant spread in the field can be short a lot: 30-40 kg N/ha sufficient if put at the good place add in conjunction with sowing or planting operation. The tractor has to be well equipped for that task, but no more diesels are needed. Otherwise, the farmer has to be careful; actually a bigger application of nutrients in that particular location could lead to salt damage of the newly planted vegetable seedlings. So, the amount of nitrogen put in the field is twice smaller as what we had seen if it was sprayed everywhere, so it seems reliable that the leaching can be reduced by at least 80% in that case.

In addition, all the fertilizers are not as good. In fact, the minerals can be easily released if they are not incorporated in the organic mater of the soil. So it is better to use biomass fertilizers because they liberate the nutrients slowly and are more coordinated with the plant needs. Actually the plant cannot incorporate all those nutrients at the same time, so a continuous supply is better. It is what happened when the catch crop is giving back the nutrients to the economic crop.

Results for the alternative way of fertilize:
I chose a combination of the most efficient figures seen in those paragraphs, in order to improve the environmental impacts of the lettuce production. Finally I will used to fertilize in a specific place, with only 4Okg N/ha (leaching reduced by 80%), and I will irrigate in surface and not by groundwater to improve the plant uptake by 15-20%. Moreover, I will do regular sample analyses not to add to much unneeded fertilizer, and will prefer biomass to minerals stimulants.

ALTERNATIVE III: Organic production and potatoes alternative

In Spain (J.M. de Paz & C. Ramos, 2003) they often produce lettuce from August to November after a potatoes crop from January to May, because this permits not to add any fertilizers. Indeed, the potatoes crop need a lot of Nitrogen but does not incorporate all the Nitrogen available (on average 25 kg N/ha harvested for 52 kg N/ha applied). And the parts of the crop which are not harvested are especially good fertilizers because their nutrients are easily available for the next production. This progressive availability is good because it permits the new crop to use it during its growing, and avoid premature leaching. It is true that the little plants cannot use all the nutrients at the beginning and need them all along their development.

It would also be possible to do that in Sweden, the new potatoes are definitely appreciated with vodka (as a Swedish tradition)! As those new potatoes are harvested before July, it is totally possible to grow iceberg lettuce after that, without any nitrogen addition. The potassium rate is not too bad neither after such a crop (meeting with L. Morgen), but a phosphorus addition will certainly be needed to produce iceberg lettuce. So I can also cut my potassium adding by half.

If we study an organic production, we will perhaps have more weeding interventions on the field. But as the lettuce crop is a fast one, the weeds will not have the time to develop so much. Even if the growing period is a bit longer than a traditional one due to the less amount of fertilizers… few more weeding will be needed. And the insecticides will be changed in a covering, which can be put at the same time as others operations, so which does not need more tractor interventions. We can thus add twice the tractor cost on the environment for the weeding, but delete the spraying interventions; which finally change almost nothing. And, as the organic producers often use the crop rotation system, we can imagine that potatoes will be done before. So we can suppress all the nitrogen, half of the potassium, and all the pesticides used in our initial system; but add 10L of diesel/ha (cultivation). Lars Morgen could not help me to find a relation between the leaching rate and the amount or the way to add the fertilizers, but he showed some diagrams where we could see that if there is a crop in the field, the leaching is really small. Otherwise, it is not possible to say that if we add no fertilizer we will not observe any leaching. In fact, the soil mineralization is going on all the time, even without the additions of stimulant. But if we use always a crop on our field, these minerals will be almost all used (especially if the mineralization is small because of the no addition of fertilizers). That is why; I will assume the choice to reduce the leaching by 90% in that case (except for the P).

Results for that organic alternative:
No pesticides. No N-addition, and half of the K-addition (leaching reduced by 90% except for the P). But maybe the yield will be smaller than a conventional one, which is not taken into account here.

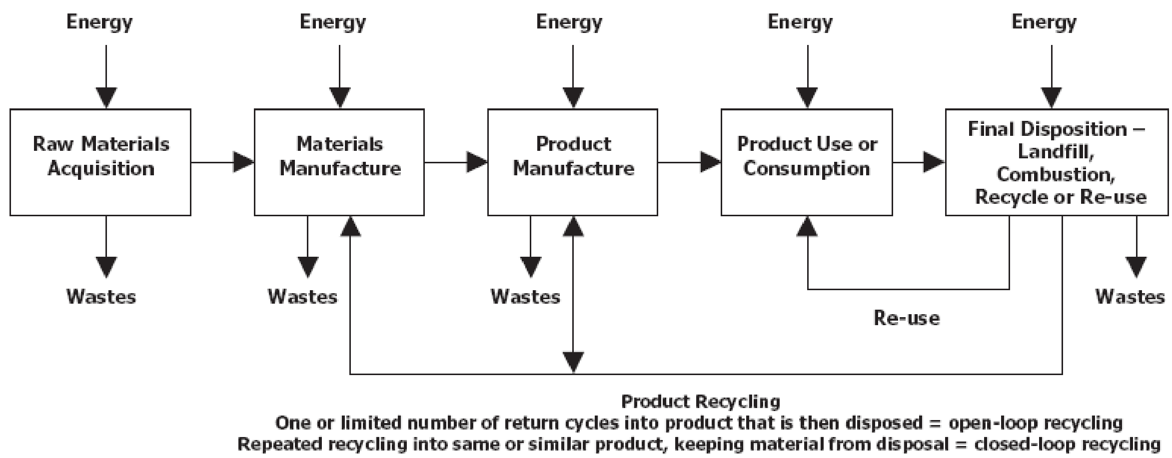
Conclusion and combination of the alternatives

Finally I will use the best alternatives found through that study, which are the organic production after a potato crop, followed by an autumn catch crop and a spring tillage. In addition an efficient surface irrigation will improve the plant uptake by 15-20%. Besides, the regular use of sample analyses is good not to add to much unneeded nourishment, as a preference for biomass fertilizers. The leaching can here be supposed as inexistent.

2) The packaging is a second environmental problem for the lettuce production:

A lot of different LCA have been done about the packaging field in order to find the best substance possible. The main debates are about the rivalry between plastics, papers, paperboards and glass, as for their diverse potential ends of life (www.foodproductiondaily).

Figure (14); General materials flow for cradle to grave analysis of the product



This figure 14 shows the whole system analyzed for a LCA (S.P. Singh & al., 2006). But, it is possible to "doubt on the suitability of LCA results as a justification for a preference for reusable packaging. LCAs do not provide clear support for the argument that levels of reuse should be increased". Moreover, the problem is that the results are often biased, depending on who ordered the analysis. As our environmental impacts are now a social concern, it can in fact become an advertising argument for companies to say that they are acting for our planet (Confederation of Paper Industries, 2008). That is why we will try during all that study to look at the figures in retrospect, and to compare different sources to have a more objective view. But we are not sure that a miraculous solution exists, so we will more discuss the possible improvements which can be done, without really giving the indisputable answer. "What we want to emphasize is the four R's - reduce, re-use, recycle and reject" (query.nytimes.com). The reduction depends mostly on the design and the substance chosen, which we will discuss first. And then the probable end of life for the products will be studied.

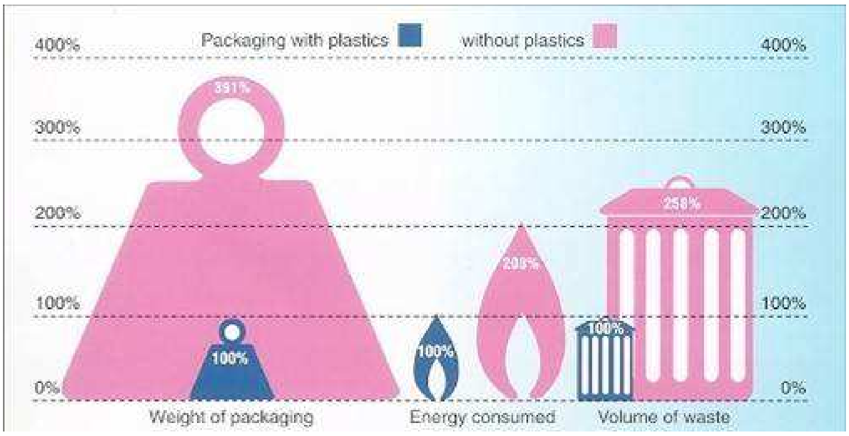
Figure (15); this figure (www.olympus-global.com) shows three stages of that method which gives the best environmental packaging laws.

ALTERNATIVE I: The choice of the best package possible

Different substances can be chose to produce the packaging; I will try to discuss those usable in our case. Remember that in our production paper bags are used to transport the lettuces from the cultivation to the store level, and plastic bags will be used by the customer from the store to his house. The metal package will not be studied as they are not suitable for food transportation. The five indicators usually used to compare the packaging are their effects on global warming, air acidification and eutrophication, as their proportion of no-renewable energy consumption and non-renewable resources (Tetra Pak's bio intelligence service, 2008).

Since the transportation costs are nowadays really expensive, one way to choose the best package is too look at its weight. In that case, glass is bad because heavy, but plastics are good. Besides, according to the UK plastic association, plastics make a positive contribution to all three pillars of sustainability (environmentally, economically and socially). Plastics make an immense contribution to the environmental sustainability through their energy saving potential and intrinsic recyclability and energy recovery options. They provide unparalleled benefits as a packaging material because they are lightweight, resource efficient and offer excellent barrier properties. In that website, it is even said that "if plastics were not used in packaging and other materials were used instead, then waste and energy consumption would double, and weight and costs would quadruple", but this seems a bit too easy (see Figure 37). We although have to tell that some chemical problems can occur with certain plastics, and this is certainly not a good point for a food package. PETE and PVC should be avoided as possible. Then, the Table 4 permits to choose the best plastic bag possible, in HDPE.

Figure (16); The packaging figures if the plastic was not used, from the UK plastic association website



If we look at the study done by Tetra Pak, the results show that the glass is the worst material compared, but the glass is not well adapted for the packages we need in our system (heavy, fragile…) so we will not discuss it. Then Tetra Pak's examination declares that PETE (polyethylene terephthalate) and HDPE (high-density polyethylene) are better but not as the TBA (Tetra Brik Aseptic) or TPA (plastic used for milk bottles). Of course that publication demonstrates that Tetra Pak use the best packaging possible. Their most important argument for the paper board choice is its renewable origin, which decrease a lot its impact on the environment (Tetra Pak's bio intelligence service, 2008).

One figure shows the same conclusion: if the French customers always chose the cardboard boxes (milk or juice), the annual CO2 saving will be of 194 600 tons, so the equivalent of 30 000 travel around the Earth by car in greenhouses gases emissions (www.wwf.fr). But contrary results can be found as in a study (S.P. Singh & al., 2006) focusing on bags used for fresh vegetable and comparing the reusable plastics containers (RPC) and display-ready corrugated containers (DRC). We can learn that, for a lot of factors studied the RPS is better than the DRC.

PLASTIC PACKAGING

SPI #[2]	Plastic Name	$/Ton	Common Uses
2 HDPE	High-density polyethylene	290	Milk jugs, liquid detergent bottles, grocery bags
4 LDPE	Linear low-density polyethylene	340	Plastic films (bread bags, produce bags, shrink wrap)
5 PP	Polypropylene	370	Plastic lids, packaging, automotive, appliances, carpeting
6 PS	Polystyrene	390	Styrofoam, cold food containers, insulation, disposable plates, cutlery, automotive parts, toys, housewares, appliance parts, wall tiles, radio, TV housings, furniture, luggage
1 PETE	Polyethylene terephthalate	850	Soda bottles
Table 4 3 V	Polyvinyl chloride	5100	Construction piping, plastic bottles, upholstery, flooring, wall coverings, sidings

Table 1 - $/ ton is the environmental impact cost of manufacturing each plastic. HDPE, LDPE, PP, and PS have roughly the same environmental impact rating. PETE is about twice as high as these four. PVC is nearly six times higher than PETE primarily because of carcinogenic emissions. The environmental cost of disposal is $4 per ton excluding PETE, which is $5 per ton. Recycling was excluded from analyzing plastic because only 1.8% of packaging plastic is recycled.

Regarding the Environmental Protection Agency (EPA) facts about the paper and plastic grocery bags, the paper production “generates 50% more air pollutants and 70% more water pollutants”, and waste 4 times more energy than plastic’s one. And a plastic bag is almost 10 times lighter than a paper one, so produce less solid waste but takes 4 or 5 years to decompose (against 1 month for the paper). Though, papers are made with renewable resources which are often not the case for plastics. Moreover, the recycling rate for plastics is very low even if it costs less energy; only 1% of plastic bags were recycled against 20% for paper bags according to a research from 2000 (T.E. Ragsdale, 2005).

It finally seems that no winner can be found between paper or plastic bags, the only solution is to re-use them (T.E. Ragsdale, 2005)! So, whatever the package chosen, a resolution could be to ask the consumers to keep their bags several times (plastic bags in our initial system). If they really want to act for the environment, it is easily possible to reduce the costs for those bags by the number of times they are using them! In fact no additional costs exist as they do not have to clean them properly, or to pay more diesels to come in the shop with them…But, how to force them to do so? Maybe signs explaining that fact will be sufficient, otherwise we can make them buy each of their small plastic bags. I am sure that, even if the price is nothing (1 SEK), they will reflect more before wasting it! And if we look at what is done in several communities with "pay as you throw" laws, the amount of waste has decreased in average by 14 to 27 percent per year (K.Marsh & B.Dugusu, 2007). You can hope that effect will be the same on customers.
Although, for the paper bags used for the transport from the cultivation to the store level, a cleaning will be needed to enforce the sanitary laws. Even if that processes are good to save natural resources, they necessitate powerful detergents and difficult logistical system to collect, transport, clean... In that case, the re-use should be more discussed. Unfortunately, not reliable data could be found to answer.

ALTERNATIVE II: The end of life chosen for the package

The package used can take different ways after their utilization. Actually, they can be wasted, land filled, re-used and refilled, composted, recycled, exploited for combustion and incineration… We will now try to see which is the best environmental becoming of those bags.

As we have seen before, the re-use and refilling is a good solution to save natural resources but the several powerful detergents can pollute and the logistic and transportation can generate other costs on the environment (diesel…).
The recycling is also a nice idea not to garbage the raw materials. Nevertheless, various economical factors as the costs for collection, separation, cleaning or processing, and transportation are not negligible. And also, as explained by C. Gruvberger (VA-SYD, Malmö), such products necessitate a market. We can point out a problem appearing with the recycled plastics in our case, because they are often not employed for food packaging then, because of some microorganisms residues. But even if they are not re-usable for food package it is a good choice to recycle them. Actually, they can be recycled 6 times in average before their recycling is less environmental friendly than their combustion. This still permits to compensate bigger impacts than those of the paper production (Tetra Pak's bio Intelligence Service, 2008).
The Composting is only achievable for organic materials, so the plastics are already excluded of that process. It is essentially a valuable alternative to waste disposal for our food or our paper bags, but not as good as the recycling.
The land filling is certainly not the best environmental solution because of the emissions (air, ground…). But our scrap can be combusted and incinerated if they cannot be composted or recycled. Especially the plastics have a high heating value, 38 MJ/kg in average, which compares favorably to the equivalent value of 31 MJ/kg for coal. It is then possible to produce heat or electricity, and also to reduce the waste volume by 70-90% (K.Marsh & B.Dugusu, 2007). Even if the emission rate is not so satisfying (mainly CO and H), this is one possibility to recover energy from those packages. For example in Malmö Sy-Sav plant, Two Energy From Waste (EFW) plants process 400,000 tones of waste a year, producing 950,000 MWh in

hot water for district heating and 145,000 MWh of electricity per annum, or the combined annual energy production saves about 100,000 tones of oil.

In addition, the package design can be transform in order to permit an easier end of life, depending on the end chosen by the company (INCPEN, 2008). This upstream reflection will improve the energy use or recovery efficiency.

Conclusion and combination of the alternatives

One of the most important things is to remember that this packaging, even if impacting on the environment, is necessary to protect our goods (K.Marsh & B.Dugusu, 2007). In fact, the energy put in the product is ten times bigger that the energy put in the packaging, so its protection is very important. In developed countries were this covering is not efficient, it is possible to observe a lot more of food waste (INCPEN 2, 2008). Factories have done a lot of studies and efforts in that environmental way, the customer now also have to help to protect our planet. It is true that “yet, still many people think that recycling is the most important thing they can do to help the environment”, but it is not enough. For instance, using a family car and not a 4x4 for one year save the amount of energy saved by recycling the family’s glass bottles for 400 years (INCPEN 3, 2008)!

Table 5; Results after those two alternatives discussion:

Finally, it seems that no indisputable package can be chosen, especially between paper and plastic bags. The best thing to do is that the customer re-uses them; this will reduce the use of plastic bags by two. Furthermore, different studies showed that the recycling is better for environment than incineration or landfill in general. In one of them, it is written “WRAP considers that it is reasonable to say that recycling 1 tone of paper and cardboard will avoid 1,4 tones of carbon dioxide equivalent compared to landfill, and 0,62 tones of carbon dioxide equivalent compared to incineration”(Confederation of Paper Industries, 2008). Thus I will use the data given in the excel sheets for the recycled paper, unfortunately I cannot find the figures for recycled plastic otherwise my results could be even better. But the energy recovery is also a good alternative if the package cannot be recycled anymore with an environmental benefit.

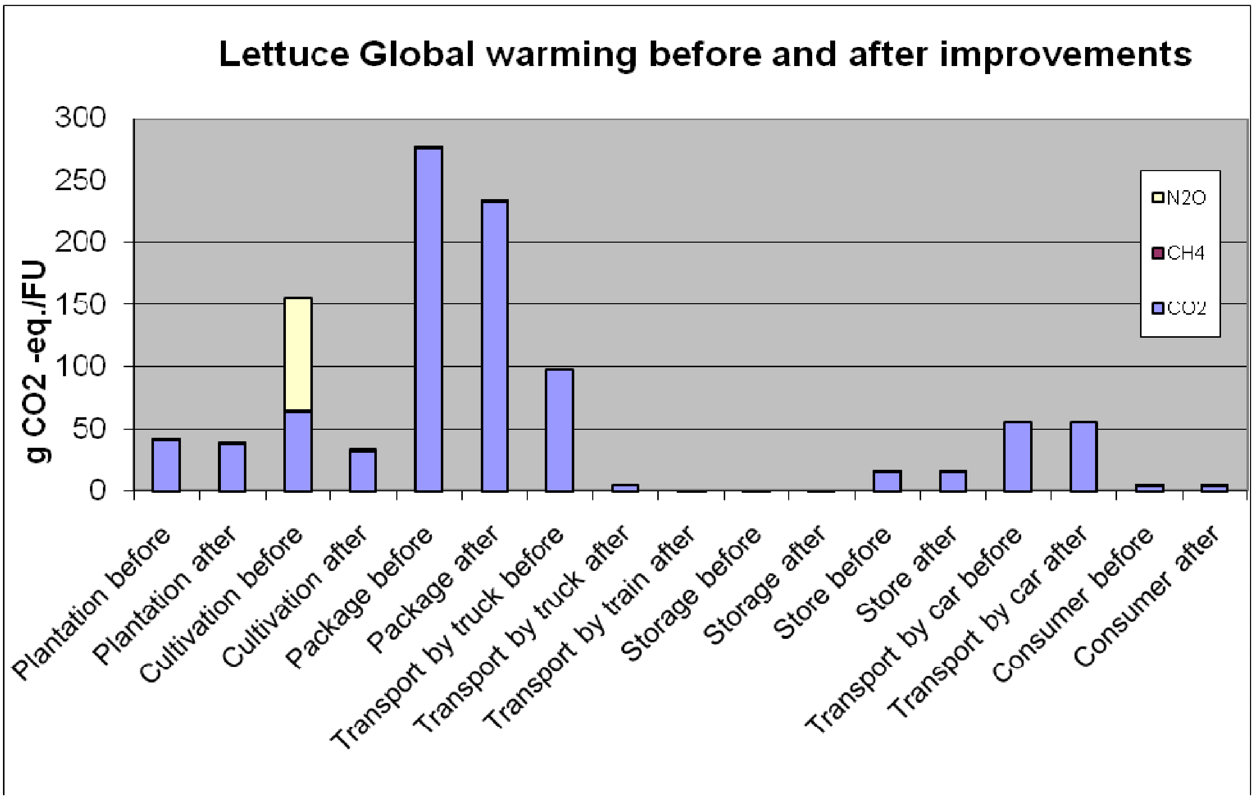
	Initial Package	New Package
CO2	2,77E+02	2,34E+02
CH4	3,78E-01	3,29E-02
N2O	8,09E-02	7,05E-03
SO2	2,04E-03	1,41E-03
NOx	4,45E-03	3,56E-03
HCl	2,10E-03	1,22E-03
NH3	4,75E-06	4,13E-07
NOx to air	1,23E+00	9,84E-01
NH3 to air	1,29E-03	1,13E-04
N to water	6,06E-03	5,27E-04
NO3 to ater	0,00E+00	0,00E+00
P to water	0,00E+00	0,00E+00
PO4	6,75E-03	5,88E-04
COD	7,25E-05	6,31E-06

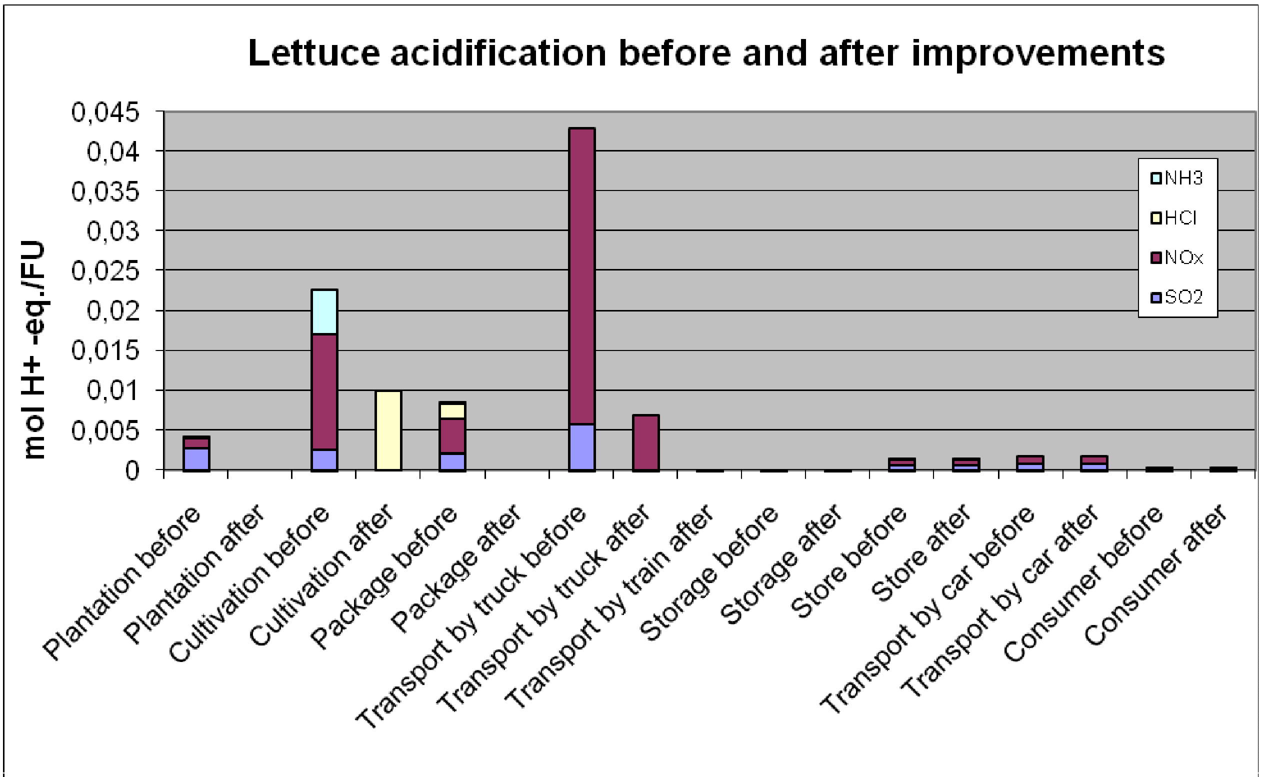
The results are not really visible in a graphics because the changes are not so big. We can nevertheless see a small improvement, but this hot spot seems really difficult to perfect. Those suggestions were maybe not good enough, or the initial system used was already one of the best possible. But as we said, we cannot envisage to reduce too much the packaging costs or the product will be deteriorated, and is it what we want to avoid above all.

3) Conclusion in relation with the other results found in that study

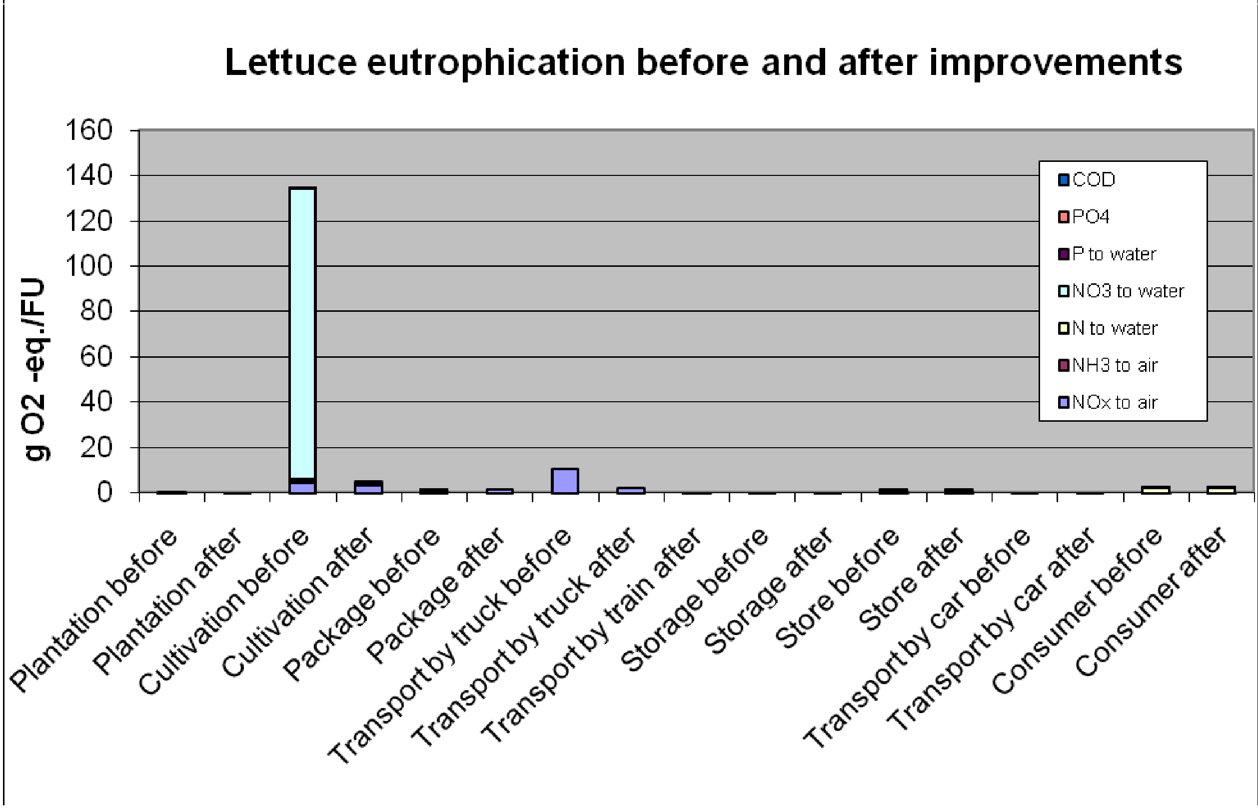
The transport by truck is a very big environmental problem in the iceberg lettuce production too. That is why the alternatives used in the apple production case study can be applied here. The electricity study can also be used in that case to improve the impacts on the environment. The final results are so those ones:

Figures (17-19); Final results after combination of all those alternatives





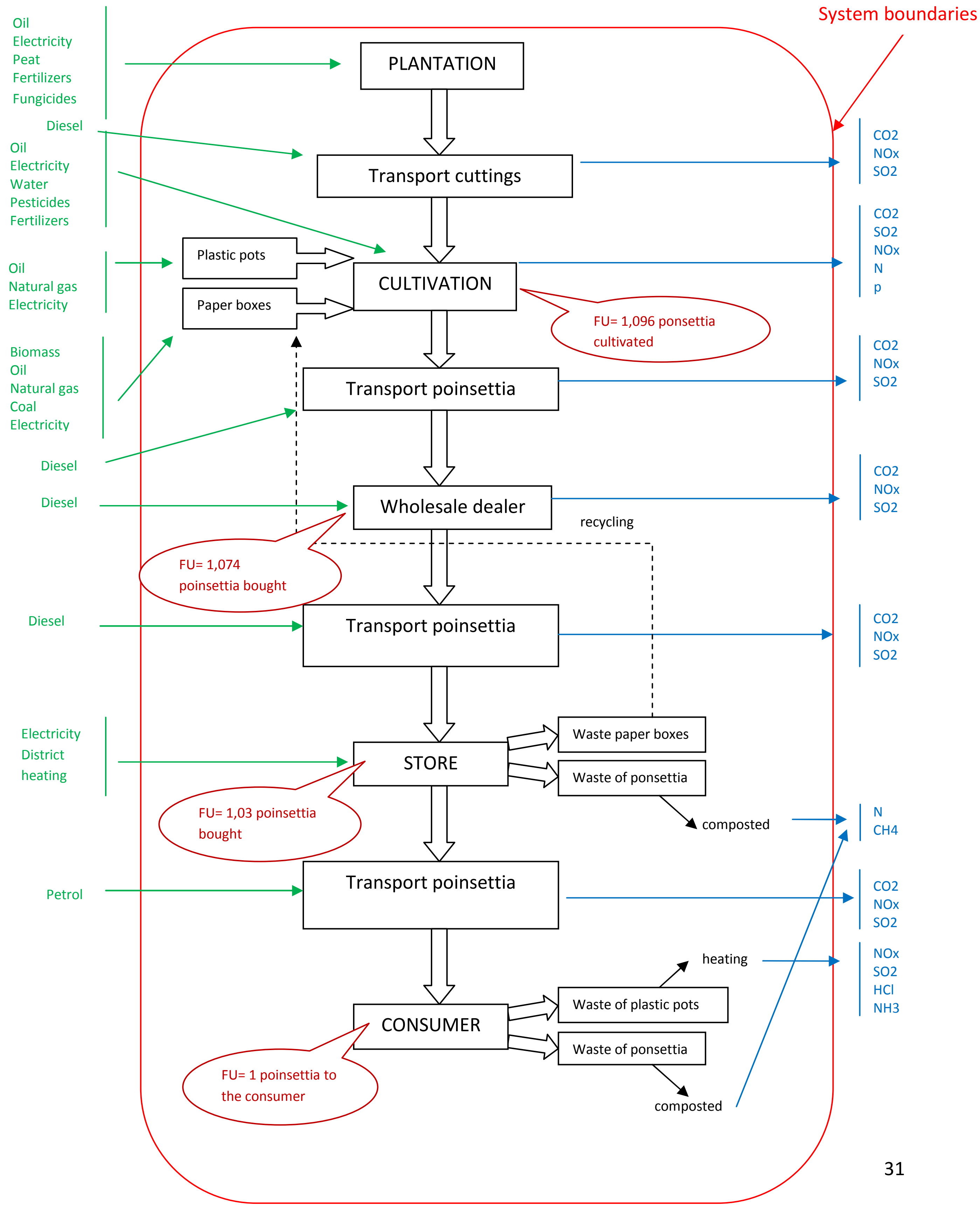
Lettuce acidification before and after improvements
mol H+ -eq./FU
0,045
0,04
0,035
0,03
0,025
0,02
0,015
0,01
0,005
0
NH3
HCl
NOx
SO2
Plantation before
Plantation after
Cultivation before
Cultivation after
Package before
Package after
Transport by truck before
Transport by truck after
Transport by train after
Storage before
Storage after
Store before
Store after
Transport by car before
Transport by car after
Consumer before
Consumer after



Lettuce eutrophication before and after improvements
g O2 -eq./FU
160
140
120
100
80
60
40
20
0
COD
PO4
P to water
NO3 to water
N to water
NH3 to air
NOx to air
Plantation before
Plantation after
Cultivation before
Cultivation after
Package before
Package after
Transport by truck before
Transport by truck after
Transport by train after
Storage before
Storage after
Store before
Store after
Transport by car before
Transport by car after
Consumer before
Consumer after

PART III: The poinsettia production in greenhouses

System's description: Figure (29); Poinsettia production flow chart



Choice of the hot spots

In order to analyze the production process of Poinsettia, LCA was applied to a greenhouse. Results of the LCA analysis show a huge environmental impact (hotspot) during the cultivation of Poinsettia. A considerable environmental impact via global warming was observed during the cultivation and plantation of poinsettias. In this paper we will examine possible ways to improve and reduce this environmental impact.

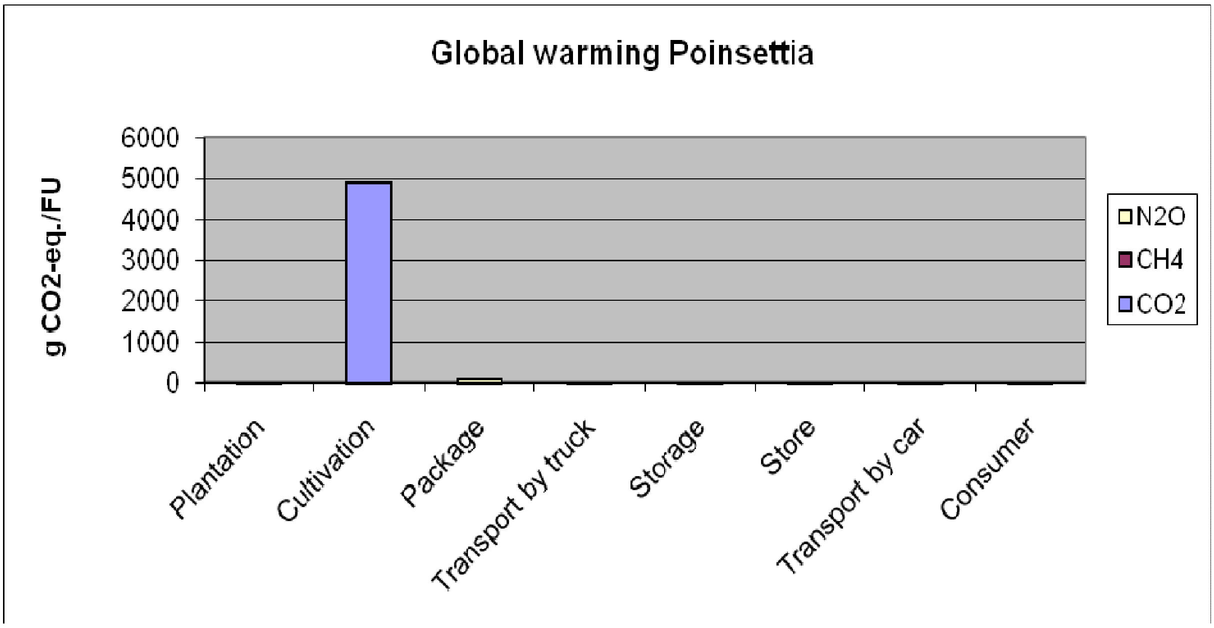
Floriculture production in greenhouse produces a high influence on territory and environment which contributes to creating a significant environmental load caused by large input of matter and energy and by emissions produced (Scarascia and Russo 2007).

Energy is an important production factor in greenhouse crop production. Raising energy prices and fuel scarcity plus sever environmental impact of fossil fuels are the most important issues which growers are face in recent years. All of these issues establish a field research that aimed at new technologies and solutions for energy – friendly green house production system.

Temperature and light are two main factors in production of poinsettia. Main market demand for Poinsettia plant is Christmas and plant must be flower around and before this time. Timing of poinsettia is achieved by controlling day-length and temperature. Poinsettia is a short-day (SD) plant and critical day length for poinsettia reported to be 12.5h (Garner and Allard 1923) and it is advantageous to subject the plant to a day-length well below the critical for early flower formation (Kristoffersen 1994). In order to initiate flower and reduce the vegetative growth negative Dif must be used and the optimum temperature is around 18/21 day/night (Kristoffersen 1994). As it is obvious maintenance of night temperature and heating the greenhouse environment are important factors and they become even more significant in colder region. In north Europe commercial Poinsettia production, growers give 10h light to plants per day by using high pressure sodium lamps (HPS) (Baevre *et al.*, 1994).

Fig.41 shows that during the whole process of Poinsettia from cradle to grave there is considerable environmental impact during cultivation. Global warming as a result of CO_2 emission is so obvious during the cultivation process.

Figure (30); Environmental impact via global warming in poinsettia



During the cultivation most of the CO_2 emission from the fossil fuels contributes to heating system and electricity usage (Table 5).

Table (5); Emission data during cultivation of poinsettia via using oil

Emmsions from	*electricity*	*oil*	*fungicide*	*Insecticide*	*N*	*P*	*K*	*Compost*	*Sum*
CO2	5,01E+01	4,92E+03	1,21E-01	5,24E-04	2,02E+00	2,41E-01	1,97E-01		4,97E+03
CH4	3,13E-01	0,00E+00	6,35E-05	2,43E-07	3,91E-05	6,60E-05	0,00E+00	6,57E-04	3,14E-01
N2O	4,53E-03	0,00E+00	9,20E-07	3,52E-09	5,66E-07	9,56E-07	0,00E+00		4,54E-03
SO2	8,30E-02	1,14E+01	2,74E-04	1,19E-06	9,64E-04	5,10E-04	1,08E-05		1,15E+01
NOx	9,58E-02	7,39E+00	1,86E-04	8,03E-07	3,18E-03	1,85E-03	2,25E-04		7,49E+00
HCl	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00		0,00E+00
NH3	1,40E-03	0,00E+00	2,85E-07	1,09E-09	1,75E-07	2,96E-07	0,00E+00		1,41E-03
NOx to air	9,58E-02	7,39E+00	1,86E-04	8,03E-07	3,18E-03	1,85E-03	2,25E-04		7,49E+00
NH3 to air	1,40E-03	0,00E+00	2,85E-07	1,09E-09	1,75E-07	2,96E-07	0,00E+00		1,41E-03
N to water	5,26E-03	0,00E+00	1,07E-06	4,08E-09	6,57E-07	1,11E-06	0,00E+00	1,10E-03	6,36E-03
NO3 to water	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00		0,00E+00
P to water	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00		0,00E+00
PO4	2,55E-03	0,00E+00	5,17E-07	1,98E-09	3,18E-07	5,37E-07	0,00E+00		2,55E-03
COD	1,26E-03	0,00E+00	2,56E-07	9,77E-10	1,57E-07	2,66E-07	0,00E+00		1,26E-03

ALTERNATIVE I: Construction Improvement

Several obstacles for improvement of sustainable greenhouse system are in energy saving. Most energy conservation practices can be classified as improved maintenance or as major adjustment of the greenhouse construction and heating system (Short, 2004).

One of the key factors in greenhouse structure is to have higher insulation. Good insulation has a huge effect on saving the energy by reduction in heat production and heat maintains during day, night and more considerably during the winter time.

In order to improve the insulation several ways are available which depends on budget, availability, and efficiency. By sealing an old glasshouse it is possible to save 40% in fuel by simple sealing all the laps and bar mountains (Short, 2004). Application of double layer poly ethylene film is another option in order to improve the greenhouse structure. Potential annual energy saving greenhouse modification compared to single pane glasshouse is between 30 to 40% (Short, 2004). In order to have high light transmittance use of double zigzag-sheet could improve this setback. In the case of a zigzag-surface the part of the light that is reflected by the sheet hits again another part of the sheet surface and partly enters the greenhouse in that way after all. The transmittance diffuses light of a double zigzag-sheet with an inclination of 50˚ without colour pigment is 78.8%. For comparison, standard single glass has a diffuse light transmittance of 82% (Breuer and Donneveld, 2000). Adding curtain is another option which is recommended together with double layer polyethylene (Hartmut k. Schüssler, personal communication). Using curtains during night helps to save energy between 20 to 50 percent.

In order to save energy and electricity it is possible to reduce this period till 6h per day (Hartmut k. Schüssler, personal communication). By this strategy it is possible to reduce the use electricity for 4h. Electricity is needed during the warming up process to pump the warm water in the tubes during the night.

As mentioned before, heating system and source of the energy are other important factors. Central heating system with pipes all around the green house is one of the economical and functional systems in order to heat the green house (Hartmut k. Schüssler, personal communication).

As a substitution for oil as a source of energy by using the natural gas it is possible to reduce the CO_2 emission around 30 to 35% (Fig. 31) and the emission data are represented in table 6.

Figure (31); Global warming effect after structural modification and use of natural gas

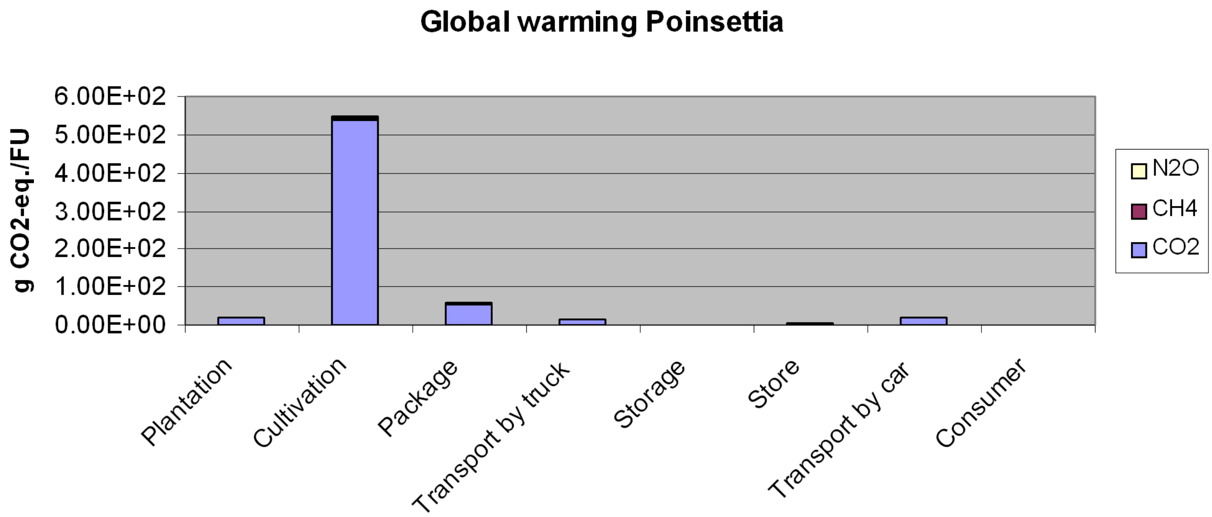


Table (6); Emission data during cultivation of poinsettia after structural modification and use of natural gas

Emmsions from	*electricity*	*Natural Gas*	*fungicide*	*Insecticide*	*N*	*P*	*K*	*Compost*	*Sum*
CO2	4.17E+01	4.94E+02	1.21E-01	5.24E-04	2.02E+00	2.41E-01	1.97E-01		5.39E+02
CH4	2.61E-01	0.00E+00	6.35E-05	2.43E-07	3.91E-05	6.60E-05	0.00E+00	6.57E-04	2.62E-01
N2O	3.78E-03	0.00E+00	9.20E-07	3.52E-09	5.66E-07	9.56E-07	0.00E+00		3.78E-03
SO2	6.92E-02	2.71E-02	2.74E-04	1.19E-06	9.64E-04	5.10E-04	1.08E-05		9.80E-02
NOx	7.98E-02	5.66E-01	1.86E-04	8.03E-07	3.18E-03	1.85E-03	2.25E-04		6.51E-01
HCl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00
NH3	1.17E-03	0.00E+00	2.85E-07	1.09E-09	1.75E-07	2.96E-07	0.00E+00		1.17E-03
NOx to air	7.98E-02	5.66E-01	1.86E-04	8.03E-07	3.18E-03	1.85E-03	2.25E-04		6.51E-01

NH3 to air	1.17E-03	0.00E+00	2.85E-07	1.09E-09	1.75E-07	2.96E-07	0.00E+00		1.17E-03
N to water	4.38E-03	0.00E+00	1.07E-06	4.08E-09	6.57E-07	1.11E-06	0.00E+00	1.10E-03	5.48E-03
NO3 to water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00
P to water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00
PO4	2.12E-03	0.00E+00	5.17E-07	1.98E-09	3.18E-07	5.37E-07	0.00E+00		2.12E-03
COD	1.05E-03	0.00E+00	2.56E-07	9.77E-10	1.57E-07	2.66E-07	0.00E+00		1.05E-03

Moreover, renewable energy use has an enormous effect over global warming and cause a reduction in CO_2 emission around 60 – 65%. Agricultural waists such as straws provide a very effective and beneficial source of energy to be burned and heat up the boiler and eventually the greenhouse. The results of using biofuel or biomass as energy source are represented in figure 32 and table 7.

Keep in mind that, by installing a sophisticated temperature control system it is possible to increase the amount of energy saving to its maximum rate.

Figure (32); Global warming effect after structural modification and use of biofuel

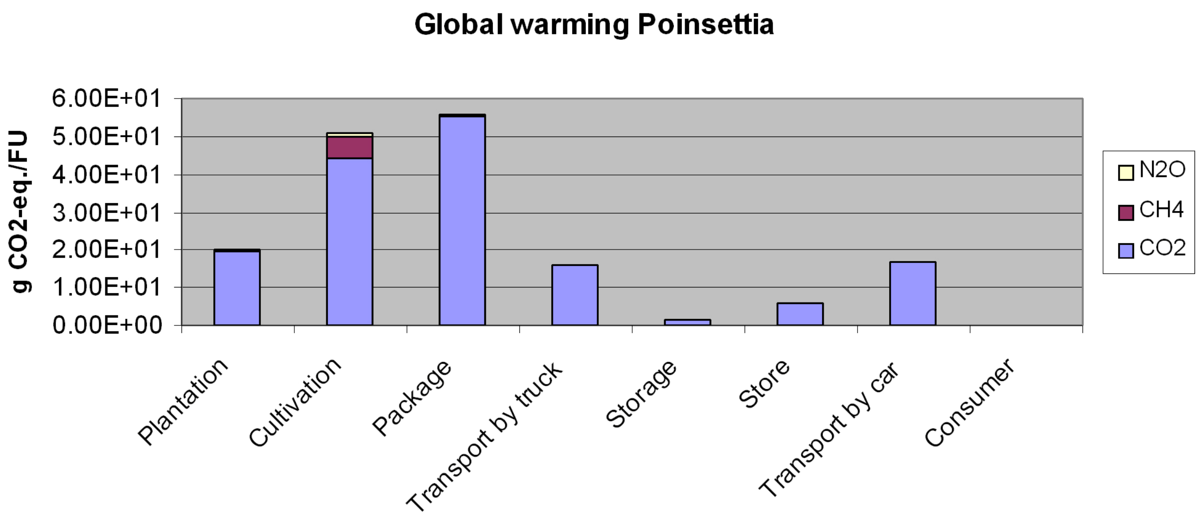


Table (7); Emission data during cultivation of poinsettia after structural modification and biofuel use

Emmsions from	*electricity*	*Biofuel*	*fungicide*	*Insecticide*	*N*	*P*	*K*	*Compost*	*Sum*
CO2	4.17E+01	0.00E+00	1.21E-01	5.24E-04	2.02E+00	2.41E-01	1.97E-01		4.43E+01
CH4	2.61E-01	0.00E+00	6.35E-05	2.43E-07	3.91E-05	6.60E-05	0.00E+00	6.57E-04	2.62E-01
N2O	3.78E-03	0.00E+00	9.20E-07	3.52E-09	5.66E-07	9.56E-07	0.00E+00		3.78E-03

SO2	6.92E-02	2.71E-02	2.74E-04	1.19E-06	9.64E-04	5.10E-04	1.08E-05		9.80E-02
NOx	7.98E-02	5.66E-01	1.86E-04	8.03E-07	3.18E-03	1.85E-03	2.25E-04		6.51E-01
HCl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00
NH3	1.17E-03	0.00E+00	2.85E-07	1.09E-09	1.75E-07	2.96E-07	0.00E+00		1.17E-03
NOx to air	7.98E-02	5.66E-01	1.86E-04	8.03E-07	3.18E-03	1.85E-03	2.25E-04		6.51E-01
NH3 to air	1.17E-03	0.00E+00	2.85E-07	1.09E-09	1.75E-07	2.96E-07	0.00E+00		1.17E-03
N to water	4.38E-03	0.00E+00	1.07E-06	4.08E-09	6.57E-07	1.11E-06	0.00E+00	1.10E-03	5.48E-03
NO3 to water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00
P to water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00
PO4	2.12E-03	0.00E+00	5.17E-07	1.98E-09	3.18E-07	5.37E-07	0.00E+00		2.12E-03
COD	1.05E-03	0.00E+00	2.56E-07	9.77E-10	1.57E-07	2.66E-07	0.00E+00		1.05E-03

CONCLUSION

This LCA project permits to study different cases, dealing with several big environmental problems. The research for new alternatives in order to improve those hot spots allows us to give some advice for those three productions examined. But the main difficulties that we met in that work were to find reliable figures for our alternatives. In fact, the data can vary a lot from one expert to another; the functional unit used is not always the same and the conditions are often really different. That is why a big part of our work has been to compare figures, discuss together and with experts, in order to find the solution we thought be the best possible. Nevertheless, we think be able to give some environmental-friendly propositions for those 3 case study.

In the process of apple production there were several factors that have environmental impacts. In this case of study we chose to examine and introduce some alternatives in order to improve those impacts. In the case of transportation less environmental impact could be achieved by using railway in order to transport apples from storage to store. But still there is some need for using truck for transport. To solve negative environmental impacts caused by this transportation, the best solution is in usage of new efficient engines and biodiesel as fuel. The negative environmental impacts of electricity consumption could be reduced significantly by utilization of some renewable energy. As it has been discussed previously the hydropower energy could be most suitable option.

With raising concerns about negative environmental impact and increasing demand for healthier fruit with low chemical inputs, since 1990 there is a great attention toward organic foods. Moreover organic fruits also presented a better taste, firmness, nutritional fibers and phenolic contents. In addition, organic food showed a lower concentration of nitrate. Organic production of apples has increased in many regions of the world, particularly Europe and North America. But bear in mind that via the organic apple production the amount of harvest will be reduced. So another option which will need further discussion and evaluation is integrated production (IFP). In IFP system synthetic pecticides and fungicide will be used whenever disease or pests were observed.

The examination of the Iceberg lettuce production was the occasion to go into detail with the nitrogen leaching and the packaging problematic. The best alternative for the leaching trouble seems to be the organic production where the crop rotation allows the lettuce production after the potato crop. The tillage should be done in spring, and the irrigation and fertilization stages need to be reflected. Concerning the packaging, no indisputable choice can be done between the paper and plastic bags. But the amount of plastic bags used by the customer can be reduced, and the recycling paper as the best end of life possible for the packages.

As it is obvious the environmental impact of fossil oil consumption drives us toward a renewable and environmental friendly energy sources. From a grower point of view also it is more beneficial cut his or her reliance for fossil fuels. Investment in energy is the important factor which determines the fate of the producer business. As the expenses in energy production getting higher the chances for success is getting lower and there is high risk for driving the farmer or grower out of business. With less invest in energy a farmer or grower will be able to use his or her money in other part of the business.

As we discussed earlier reducing the energy coast and moving toward an extremely cost-effective business will decided by the kind of the energy or fuel sources and efficient consumption. According to the budget and possibilities there is several ways in order to reduce and even stopping our reliance to fossil fuel utilization. In poinsettia production, by a small investment in sealing the greenhouse, installation of double layer glazing (for future buildings) or curtains in order to reduce heat lost and save energy. Further steps could be the installation of heaters and boilers which operate on renewable energy sources such as agriculture and woody waists. Moreover a highly sensitive and sophisticated system to control the temperature and climate will help to reduce the energy consumption to a well efficient level.

REFERENCES

Publications:

A.Henriksson, 2007. *Actions against Phosphorus Losses from Agriculture in the countries surrounding the Baltic Sea*; Agellus Miljökonsulter at SLU Uppsala University (Sweden).

Alegre, S. and Alins, G. 2007. The Flower Thinning Effect of Different Compounds on Organic 'Golden Smoothee®' Apple Trees. Acta Hort. (ISHS) 737:67-69.

Alins, G. and Alegre, S. 2005. Estrategias de aclareo de flores de manzana (*Malus domestica* Borkh.) en producción ecológica. Actas Portuguesas de Horticultura. 6(2):16-21.

Almemark M. et al., 2001. *Miljöfaktabok för Bränslen.* IVL Rapport. Stockholm.

Bævre O. A., Fjeld T., Moe R., 1994. *Poinsettia poduction in the north*. In: E. Strømme (ed.). The scientific basis of poinsettia production. The Agricultural University of Norway. Advisory Service, 1430 Ås, Norway. ISBN 82-90598-12-2.

Banverket, 2006. *Banverket´s annual report 2006*. (http://www.banverket.se).

Baumann H., Tillman A. M., 2004. *The Hitch Hiker´s Guide to LCA. An orientation in life cycle assessment methodology and application.* Studentlitteratur. Lund.

Bernesson S., 2004. *Life Cycle Assessment Of Rapeseed Oil, Rape Methyl Ester And Ethanol As Fuels- A Comparison Between Large- And Smallscale Production*. Swedish University of Agricultural Sciences Department of Biometry and Engineering. Uppsala

Canadian Horticultural Council. 2003. *Integrated Fruit Production Guidelines for Apple.*

Confederation of Paper Industries, 2008. *Environmental labelling, fact sheet*; CPI of UK.

Confederation of Paper Industries, 2008. *Paper and Cardboard Recycling, Greenhouse Gas Benefits Explained*; CPI of UK.

D.S. Powlson, 1993. *Soil Use and Management, Understanding the soil nitrogen cycle*; volume 9, number 3.

Delate, K. and Friedrich, H. 2004. *Organic Apple and Grape Performance in the Midwestern U.S.* Acta Hort. (ISHS) 638:309-320.

EPA, 2002. *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions*. United States Environmental Protection Agency.

European commission (EC); Directorate General for Energy and Transport, 2008. *Sweden – Renewable Energy Fact Sheet.* (http://ec.europa.eu).

G. Torstensson and al, 2004. *Nitrogen Utilization in Potato and Vegetable Growing*; Swedish University of Agriculture and National Board of Agriculture.

Gustafson, G.M. and Stern, S. 2003. *Two strategies for meeting energy demands of growing pigs at pasture*. Livest. Prod. Sci. 80:167-174.

Gut, D. and Weibel, F.P. 2005. *Chapter 25 Integrated and organic weed control in pome and stone fruit*. In: Fundamentals of Temperate Zone Tree Fruit Production. Backhuys Publishers. Leiden, The Netherlands. p.372-377.

H. Aronsson, 2000. *Nitrogen Turnover and Leaching in Cropping Systems with Ryegrass Catch Crops*; Department of Soil Sciences at SLU Uppsala University (Sweden).

Holb, I. 2005. *Effect of pruning on apple scab in organic apple production*. *Plant Disease 89*, 611-618.

INCPEN 2, 2008. *Use your loaf: Packaging PREVENTS Waste*; the Industry Council for Packaging and the ENvironment (INCPEN).

INCPEN 3, 2008.*INCPEN evidence to Lords on Waste Reduction*; the Industry Council for Packaging and the ENvironment (INCPEN).

INCPEN, 2008. *Packguide, a guide to packaging eco-design*; the Industry Council for Packaging and the ENvironment (INCPEN).

J.M. de Paz & C. Ramos, 2003. *Simulation of nitrate leaching for different nitrogen fertilization rates in a region of Valencia (Spain) using a GIS-GLEAMS system*; Agriculture, Ecosystems and environment 103 (2004) 59-73.

Jönsson, Å.H., 2007. *Organic apple production in Sweden: cultivation and cultivars*.. 33p. Thesis (Ph.D.) - Swedish University of Agricultural Sciences, Balsgård.

Juhlin P. 2004. *Äpplesorter för ekologisk fruktodling*. Jordbruksinformation 4, pp 15.

Kaak, K. & Grauslund, J. 1991. *Apple cultivars for manufacturing of stewed apples*. Danish Journal of Plant and Soil Science 95, 449-457.

K.Marsh & B.Dugusu, 2007. *Food packaging-Roles, materials, and environmental issues, Journal of food science*, volume 73, n°3; Institute of Food Technologists (IFT).

Kristoffersen, T. 1994. *Early Norwegian studies of growth and development of poinsettia*. In: E. Strømme (ed.). The scientific basis of poinsettia production. The Agricultural University of Norway. Advisory Service, 1430 Ås, Norway. ISBN 82-90598-12-2.

Leser, C. & Treutter. D. 2006. *Resistance of apple tres to Venturia inaequalis under the influence of N supply*. In: *Pome Fruit Health Research in Europe: Current Status 2006*, Eds. Stich K, Steffek R, Halbwirth H & Persen U., pp. 134-136.

Nunn, L., Embree, C.G., Hebb, D., Bishop, S.D. and Nichols, D. 2007. *Rotationally Grazing Hogs for Orchard Floor Management in Organic Apple Orchards.* Acta Hort. (ISHS) 737:71-78.

Orchards in Canada. *Canadian Horticultural Council*, Ottawa, Ontario: p.13-14.

Pehnt M., 2006. *Dynamic life cycle assessment (LCA) of renewable energy technologies*. Renewable Energy 31. 55–71pp.

Reig, G., Larrigaudière, C. and Soria, Y. 2007. *Effects of Organic and Conventional Growth Management on Apple Fruit Quality at Harvest.* Acta Hort. (ISHS) 737:61-65.

S.J. Breschini & T.K. Hartz, 2002. *Presidedress Soil Nitrate Testing Reduces Nitrogen Fertilizer Use and Nitrate Leaching Hazard in Lettuce Production*; Department of vegetable crops, University of California, Davis, CA 95616.

S.P. Singh & al., 2006. *Life Cycle Inventory and Analysis of re-usable Plastic Containers and Display-ready Corrugated Containers Used for Packaging Fresh Fruits and vegetables*; Packaging Technology and Science, 19: 276-293.

Scania, 2004. *Scania on the environment: emissions from Scania engines*. Scania Communications and Public Affairs. Södertalje. (http://www.scania.com).

Scania, 2004. *Technologies for Euro 4 and Euro 5.* Scania Engine Performance and Economy. Södertalje. (http://www.scania.com).

Schawlann, M. 1999. *Handbok i økologisk fruktdyrking*. Økoringen Vest. 168 pp. Suckling, D., Walker, J. & Wearing, C. 1999. Ecological impact of three pest management systems in New Zealand apple orchards. *Agriculture, Ecosystems & Environment 73,* 129-140.

Short T.H., 2004, *Greenhouse structure and plant growth kontrol system for energy efficient crop production*.

T. Rinnofner and al, 2008. *Effect of catch crops on N dynamics and following crops in organic farming*; Division of organic farming of the University of Natural Resources and Applied Life Sciences of Vienna (Austria).

T.E. Ragsdale, 2005. *Food packaging study, A report on Environmental Impact*; Ashland Food Cooperative (AFC).

Tetra Pak's bio Intelligence Service, 2008. *Synthèse de l'analyse de cycle de vie comparative des emballages de Tetra Pak*, Bio Intelligence Service S.A.S.

Trapman, M. 2005. *Resistance management in Vf apple scab resistant organic apple orchards*. Proc. 12th Intern. Conf. on Cultivation Technique and Phytopathological Problems in Organic Fruit-growing. Weinsberg, Germany 31 January – 2 February. p.108-112.

Van der Maas, M.P. 2007. *Increasing High Quality Production of Organically Grown Apples through a System's Approach Including Management of Vf Scab Resistance.* Acta Hort. (ISHS) 737:105-112.

Volvo, 2006. *Emissions from Volvo´s trucks*. Volvo Truck Corporation 23 January. (http://www.volvo.com).

Weibel, F., Chevillat, V. and Tschabold. 2004. *Nouvelles perspectives pour l'éclaircissage floral en culture biologique du pommier*. Rev. Suisse Vitic. Arboric. Hort. 36:281-286.

Internet websites:

www.foodproductiondaily: http://www.foodproductiondaily.com/Supply-Chain/European-claims-packaging-assessments-inadequate

query.nytimes.com: http://query.nytimes.com/gst/fullpage.html?res=9C0CEFD6153FF932A15753C1A966958260

www.olympus-global.com:

http://www.olympus-global.com/en/corc/csr/annual/2008/eproducts/package.cfm

www.wwf.fr : http://www.wwf.fr/actualites/la_verite_sur_l_impact_environnemental_des_emballages

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APPENDIX:

Production system descriptions for Project work

Production of apple – description of the system and input data

Plantation

The plantation refers to the efforts for building an apple cultivation. How long a cultivation can be used differs, but in this case it is considered to be utilized for 15 years, which is normal for an apple cultivation in Sweden. In the plantation, 6000 MJ diesel per ha and year is used for drainage, soil preparation, plant, pruning and spraying. In one ha 1600 trees are planted. The electricity use to irrigate is 500 MJ and the amount of water is 400 m^3 per ha and year. To protect the trees from fungi, the fungicides Benlate (3 kg active substance per ha and year) and Topas C (2.2 kg active substance per ha and year) are used. The use of fertilizers are 12 kg N, 3 kg P and 16 kg K per ha and year.

Cultivation

The diesel consumption is about 4000 MJ per ha for pruning and spraying. To irrigate the trees, 900 MJ electricity and 800 m^3 water are used per ha. The pesticides used are fungicides (7.56 kg active substance per ha), herbicides (6.64 kg active substance per ha) and insecticides (4.92 kg active substance per ha). The use of fertilizers are 39 kg N, 8,8 kg P and 46 kg K per ha. The yield is 40 000 kg per ha. The apples are packed and transported in paper boxes (see paper box).

Transport, cultivation-storage

The apples are transported by truck and the energy consumption is 1,87 MJ diesel per tkm and the distance between plantation and cultivation is 15 km. The boxes, which the apples are transported in, weigh about 0.5 kg and contain 10 kg apples each.

Storage

The apples are usually stored in cold-storage room for about 20 days before distributed to store. The energy use for cold-storage is 0.00175 MJ electricityper kg and day.

Transport, storage-store

The apples are transported by truck, the same energy consumption as above, and the distance between storage and store is 220 km.

Store

About 2% of the apples are wasted in the store and composted (the emissions when composting are about 0.15 g CH4 and 0.25 g N per kg apples). The electricity use per kg apple is 0.05 MJ for the cold-storage, 0.03 MJ for the refrigerated display case and 0.3 MJ for other use. The district heating per kg lettuce corresponds to 0.2 MJ. In the store the customer puts the apples in a plastic bag (see plastic bag). In one plastic bag one kg of apples are assumed to be put. The paper boxes that the apples were transported in are wasted in the store and used for recycling (see excel sheet; recycled paper box).

Transport, store-consumer

The transport between store and consumer is the most difficult one to estimate, since the parameters are so uncertain. Here we assume that the distance is 5 km, 50% of the transports are done by car and the amount of articles bought each time is 15 kg per kg apples. The petrol consumption is 0,855 litre for 10 km driving. The heat value for petrol is 36 MJ/litre.

Consumer

The waste from one consumed apple is about 18% and this waste is composted (see data above). When the plastic bag is used, it is thrown away at the consumer and used for combustion (see excel sheet).

Plastic bag

The plastic bag weighs 4 g each. To produce one plastic bag 0.2 MJ oil and 0.1 MJ natural gas are used as feedstock. The electricity used in the production corresponds to 0.1 MJ. When the plastic bag is used, it is thrown away at the consumer and used in district heating (see excel sheet).

Paper box

One paper box weighs 500 g and contains 10 kg apples. To produce one kg of paper box from recycled paper, 1.1 kg of recycled paper has to be used (due to the wear of the fibres in the paper). The energy consumption for producing one kg of paper box from recycled paper is 3 MJ electricity, 1.8 MJ oil and 3.8 MJ coal. To produce one “new” paper box from virgin material 4.3 MJ biomass is used as feedstock and the energy consumption is 1.43 MJ oil, 1.43 MJ natural gas, 1.43 MJ coal and 2.14 MJ electricity. The apples are transported in paper boxes from cultivation to store. In the store the boxes are thrown away and used for recycling.

Production of iceberg lettuce – description of the system and input data

Plantation

The cultivation of the iceberg lettuce starts in the beginning of January, when small plants are delivered to the greenhouses. Ready-made mould are used for the plantation and one cubic meter peat is enough to 8000 plants. The energy use is 70 kWh electricity and 90 MJ oil per 1000 plants. To protect the lettuce plants from fungi, 0.5 kg a.s. of Aliette 80 WG (fungicide) are used per cubic meter of peat. The weight of one plant is 0,05 kg. The plants are transported in plastic boxes that are used several times, which makes the environmental impact insignificant and therefore are production of these boxes not included in the study.

Transport, plantation-cultivation

The plants are transported by truck and the energy consumption is 1,87 MJ diesel per tkm and the distance between plantation and cultivation is 20 km. The boxes, which the plants are transported in, weigh about 1 kg and contain 100 plants each. One plant weighs about 0.05 kg.

Cultivation

In one ha 75 000 plants are usually planted and the yield is about 30 000 kg. The lettuce is normally irrigated 8 times, with 10-15 mm water each time. The diesel consumption is about 250 l per ha and the electricity about 360 kWh per ha. The insecticides that are used are 4 l per ha Pyrsol emulsion B, 0.5 l per ha Pirimor and 1.25 l per ha Roxion (totally 0.7 kg a.s. per ha). The use of fertilizers are 175 kg N, 5 kg P and 170 kg K per ha. The emissions from the cultivation are 3.5 kg N_2O-N and 1.5 kg NH_3-N to air and 125 kg NO_3-N and 0.3 P to water per ha. The lettuce is packed and transported in paper boxes (see paper box).

Transport, cultivation-storage

The lettuce is transported by truck, the same energy consumption as above, and the distance between cultivation and storage is 100 km.

Storage

The lettuce is usually stored in cold-storage room for about 2 days before distributed to store. The energy use for cold-storage is 0.01 MJ electricity per kg and day.

Transport, storage-store

The lettuce is transported by truck, the same energy consumption as above, and the distance between storage and store is 300 km.

Store

About 10% of the iceberg lettuce is wasted in the store and composted. (The water content for iceberg lettuce is 96% and the emissions when composting are about 0.15 g CH_4 and 0.25 g N per kg lettuce.) The electricity use per kg iceberg lettuce is 0.05 MJ for the cold-storage, 0.03 MJ for the refrigerated display case and 0.3 MJ for other use. The district heating per kg lettuce corresponds to 0.2 MJ. In the store the customer puts the iceberg lettuce in a plastic bag (see plastic bag). The paper boxes that the lettuce was transported in are wasted in the store and used for district heating (see excel sheet; combustion of paper box).

Transport, store-consumer

The transport between store and consumer is the most difficult one to estimate, since the parameters are so uncertain. Here we assume that the distance is 5 km, 50% of the transports are done by car and the amount of articles bought each time is 15 kg per kg iceberg lettuce. The petrol consumption is 0,855 litre for 10 km driving. The heat value for petrol is 36 MJ/litre.

Consumer

The iceberg lettuce is assumed to be kept in the refrigerator for 5 days by the customer. The useful volume in the refrigerator is 300 l, from which 50% is used and one lettuce occupies about 2.8 l. The refrigerator uses 0.4 kWh electricity per twenty-four hours. About 30% of the iceberg lettuce is wasted by the consumer and composted. The plastic bag is thrown away by the consumer and used for combustion (see excel sheet; combustion of plastic bag).

Plastic bag

The plastic bag weighs 4 g each. To produce one plastic bag 0.2 MJ oil and 0.1 MJ natural gas are used as feedstock. The electricity used in the production corresponds to 0.1 MJ. When the plastic bag is used, it is thrown away at the consumer and used for combustion (see excel sheet).

Paper box

One paper box weighs 700 g and contains 7 kg lettuce. To produce one box 6 MJ biomass is used as feedstock and 2 MJ oil, 2 MJ natural gas, 2 MJ coal and 3 MJ electricity are used. The lettuce is transported in paper boxes from cultivation to store. In the store the boxes are thrown away and then used for combustion (see excel sheet).

Production of poinsettias – description of the system and input data

Plantation

The cultivation of poinsettias starts when cuttings are taken from the mother plants. The cuttings are put in Jiffy7-pots. The Jiffy7-pot consists of dried peat and some coconut. One cubic meter peat is enough for 10 000 Jiffy-potted cuttings. The energy use is 100 kWh electricity and 180 MJ oil per 1000 plants. To protect the poinsettia plants from fungi, 0.16 kg fungicides (active substance) are used per cubic meter of peat. The amounts of fertilizer used are 0.3 kg N, 0.3 kg P and 0.2 kg K per cubic meter of peat.

Transport, plantation-cultivation

The plants are transported by truck and the energy consumption is 1,87 MJ diesel per tkm and the distance between plantation and cultivation is 70 km. The plants are transported in plastic boxes that are used several times which make the environmental impact insignificant and therefore production of these boxes are not included in the study. One plastic box weighs 5 kg and contains 100 plants, which weigh about 0.05 kg each.

Cultivation

The cultivation of poinsettias takes place in greenhouses. The 1000 m^2 greenhouse consist of one layer glass without insulation. 17 600 rooted cuttings will be planted in the greenhouse week 34. The energy use for the greenhouse is 26 500 kWh electricity and 964 800 MJ oil. During the total time of cultivation approximately 50 cubic meter of water are used for the poinsettias and the drainage is estimated to be 30%. If necessary, insecticides are used, i.e. Admiral. With two treatments per season the amount of insecticides will be ca 0.37 gram (active substances) for 17 600 plants. To protect the poinsettia plants from fungi 0.16 kg fungicides (active substance) are used for 17600 plants. Every cultivation pot contains roughly 500 cm^3 substrate. From the substrate every plant is added ca 150 mg N, 43 mg P, and 90 mg K. The irrigation water is estimated to add to the plant ca 527 mg N, 84 mg P, and 407 mg K after the drainage has been deducted. Emissions from poinsettias plantation are very hard to estimate because the emissions to a great part are caused by the irrigation system. About 2% of the poinsettias are wasted during the cultivation and composted (the emissions when composting one poinsettia are about 0.03 g CH_4 and 0.05 g N).

The poinsettias are planted in plastic pots (see plastic pot) and packed in paper boxes (see paper box) when they are transported from the greenhouse. The weight of one poinsettia is assumed to be 0.4 kg.

Transport, cultivation-wholesale dealer

The plants are transported by truck and the energy consumption is 1,87 MJ diesel per tkm and the distance between cultivation and wholesale dealer is 20 km.

Wholesale dealer

The poinsettias are reloaded when they get to the wholesale dealer in the afternoon and are stored in a trailer for the night (about 12 hours). The climate control of the trailer is used during the night and the energy consumption is about 5 liters of diesel per 24 hrs. In the trailer about 5 000 poinsettias can be stored. The poinsettias are transported to the shop the next morning. The heat value for diesel is 36 MJ/liter.

Transport, wholesale dealer - store

The plants are transported by truck and the energy consumption is 1,87 MJ diesel per tkm and the distance between wholesale dealer and store is 200 km.

Store

The electricity use is assumed to be 0.15 MJ and the district heating corresponds to 0.1 MJ per poinsettia. About 4 % of the poinsettias are regarded as non-marketable in the store and composted (see above). The paper boxes that the poinsettias were transported in are wasted in the store and used for recycling (see excel sheet; recycled paper box).

Transport, store-consumer

The transport between store and consumer is the most difficult one to estimate, since the parameters are so uncertain. Here we assume that the distance is 5 km, 50 % of the transports are done by car, the amount of articles bought each time is 15 kg and that two poinsettias are bought one at a time. The petrol consumption is 0,855 liter for 10 km driving. The heat value for petrol is 36 MJ/liter.

Consumer

The loss in the home, i.e. poinsettias that don’t survive until Christmas Eve, is estimated to be 3 %. When the poinsettias have withered, they are composted (see above) and the plastic pots are thrown away and used for district heating (see excel sheet; combustion of plastic pot).

Plastic pot

The plastic pot weighs 18 g each. To produce one plastic pot 0.9 MJ oil and 0.45 MJ natural gas are used as feedstock. The electricity used in the production corresponds to 0.45 MJ. When the plastic pot is used, it is thrown away at the consumer and used for combustion (see excel sheet; combustion of plastic pot).

Paper box

The poinsettias are transported in paper boxes from cultivation to store. In the store the boxes are thrown away and recycled. One paper box weighs 200 g and contains 8 poinsettias. To produce one kg of paper box from recycled paper, 1.1 kg of recycled paper has to be used (due to the wear of the fibres in the paper). The energy consumption for producing one kg of paper box from recycled paper is 3 MJ electricity, 1.8 MJ oil and 3.8 MJ coal. To produce one “new” paper box 1,7 MJ biomass is used as feedstock and the energy consumption are 0,6 MJ oil, 0,6 MJ natural gas, 0,6 MJ coal and 0,9 MJ electricity.