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LCA of food transports and tomato production

A comparison of different food transport scenarios, including production of tomatoes

Christoffer Krewer, Andreas Emanuelsson, Gustaf Zettergren

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Gustaf Zettergren and Andreas Emanuelsson

Project leader

Christoffer Krewer, SIK
Sustainable Food Produduction
+46 10 516 67 17
christoffer.krewer@sik.se

Project group

Christoffer Krewer
Andreas Emanuelsson
Gustaf Zettergren

Distribution list

Jacob Minnhagen
Göteborgs Hamn AB
403 38 GÖTEBORG

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Background

Port of Gothenburg works actively and with long term commitment to minimize the environmental impact of shipping and contribute to sustainable transports. Climate and pollution are prioritized issues on the agenda. By showing that certain foods flows could be re-routed via the port of Gothenburg, thus reducing the environmental impact of food, it could serve as a basis for acting in the direction of the goals of the port.

SIK – the Swedish Institute for Food and Biotechnology has for many years worked with analyses of food production systems and their impact on the environment and has in the past year also focused more on the transport of foods. The combined knowledge of transport respective food production environmental cost enables a holistic view of the food system as a whole, and together with Life Cycle Assessment (LCA) matters can be seen from new perspectives.

Aim

- Define food logistics scenarios
- Compare the food logistics scenarios with ISO standardised Life Cycle Assessment techniques
- Evaluate scenarios defined by commissioner (Port of Gothenburg)
- Visualize the environmental impact of cooling in relation to other transport activities.
- Assess the magnitude of overall differences in various environmental impact categories; between transport activities and between the different scenarios.
- Visualize the environmental impact of transport in relation to primary production, i.e. cultivation of tomato.
- Identify environmental impact categories relevant for future studies
- Provide a basis for Life Cycle perspective based internal discussions for the commissioner (Port of Gothenburg).
- Provide a pre-study and a foundation for further studies based on Life Cycle Assessment.

Planning and implementation of the project

The project was carried out in January and February 2013

About the report

The report is, together with the final presentation, the main deliverable in this project and will together with the presentation communicate the findings of the project.

Because of this, and since this project is a pre-study this report should not be perceived as a full LCA report, but rather be seen as a starter for working with product oriented sustainability in the field of food logistics.

Methodology

Life cycle assessment (LCA) was used as method for the study. LCA is an acknowledged and standardized method to assess potential environmental impacts over a product life cycle from cradle to grave (described by ISO 14040 and 14044), and the European Commission has concluded it to provide the best framework for describing the potential environmental impacts of products and services currently available. With LCA product environmental impact can be quantified and measured.

The scenarios were finalized and a model of the different scenarios was built. The functional unit was defined as 1 kg of tomatoes, in Falköping. All transports were modelled to being able to carry 27.6 tonnes of tomato, even though different container solutions have different load capacity. The impact categories that were chosen are recommended by the European comission (also called ILCD compliant) and are climate change, ozone depletion, acidification, eutrophication, photochemical ozone formation and mineral, fossil & renewable resource depletion.

Scenarios

The scenarios are described by Figure 1 and Table 1. In the first four scenarios tomatoes are grown in fields around Alicante, and after that transported in different ways to Falköping, Sweden. In the fifth scenario the tomatoes are produced in Sweden, and transported with truck to Falköping.

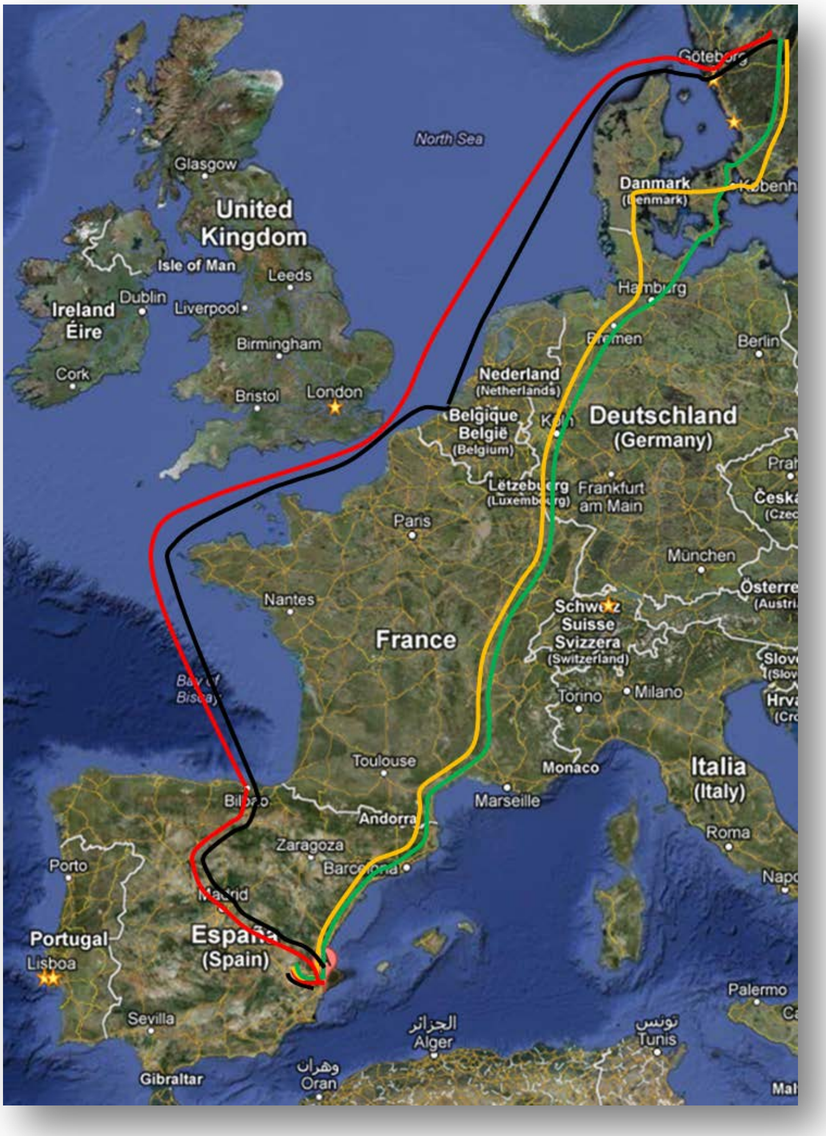

Figure 1: The four transport scenarios, from the left; Scenario 2 (red), scenario 1 (black), scenario 4 (yellow) and scenario 3 (green).

Table 1: The table describes the transport scenarios. The underlined transport mode is the main transport mode of each scenario.

Origin-destination	Cultivation of tomatoes, via Alicante to Falköping
Scenario 1 (black)	Truck, train, vessel via Zeebrygge (Containership), train
Scenario 2 (red)	Truck, train, vessel (RoRo), train
Scenario 3 (green)	Truck, truck, truck w. ferry
Scenario 4 (Yellow)	Truck, train
Scenario 5	Truck

The main characteristics of each transport route in the scenarios are described in Table 2.

Table 2: The table presents main characteristics of the routes in each scenario

Scenario	Routes	Mode	Distances (km)	Time	Data source
1	Production site - Alicante	Road	100	1 h	Estimated
	Alicante - Bilbao	Rail	1016	20 h	Greencargo.se Time is estimated
	Bilbao - Zeebrugge	Water	1254	2 days 0 h (14 knots)	Searates.com
	Zeebrugge - Göteborg	Water	956	1 days 13 h (14 knots)	Searates.com
	Göteborg - final destination (Falköping)	Rail	119	2 h	Greencargo.se Time is estimated
	Total		3445	108 h	
2	Production site - Alicante	Road	100	1 h	Estimated
	Alicante - Bilbao	Rail	1016	20 h	Greencargo.se Time is estimated
	Bilbao - Göteborg	Water	2171	3 days 12 h (14 knots)	Searates.com
	Göteborg - final destination (Falköping)	Rail	119	2 h	Greencargo.se Time is estimated
	Total		3406	107 h	
3	Production site - Alicante	Road	100	1 h	Estimated
	Alicante - Helsingör Helsingborg – final destination (Falköping)	Road	3666 + 302 = 3968	25 + 3 h	Google maps
	Helsingör - Helsingborg	Water	5	1 h	Google maps
	Total		3973	30 h	
4	Production site - Alicante	Road	100	1 h	Estimated
	Alicante - final destination (Falköping)	Rail	3308 ES: 694 FR: 1035 DE: 841 DK: 342 SE: 397	48 h	Greencargo.se Time is estimated
	Total		3408	49 h	
5	Production site – Distribution point	Road	100	1,2 h	Estimated
	Distribution point - Falköping	Road	500	7 h	Estimated
	Total		600	8,2 h	

Transport data

For each route there is one or many datasets describing that certain transport. (a dataset describes an activity with data characteristic for that activity, e.g. a transport with emission data, load factor data etc.)

These datasets were obtained either directly from the Life Cycle Assessment database Ecoinvent v2.2 or created by using both data from the Ecoinvent and the NTM (Nätverket för Transporter och Miljön) database. Sometimes data collected in previous projects at SIK has been used as well, see Table 3.

Table 3: The table describes all transport datasets that have been used in the study.

Routes	Dataset	Source	Load factor	Comments
Production site - Alicante	Transport, lorry 16-32t, EURO3/RER U	Ecoinvent	5,76 tonne	
Bilbao – Göteborg	RoRo ship (1000-2000 lanemeter)	NTM	70%	Weight: 10000 dwt IMO NO_x emission limit: Tier 1 Fuel mix: 100% HFO 1% S Infrastructure processes are obtained from Ecoinvent Fuel production is obtained from Ecoinvent
Bilbao - Zeebrugge Zeebrugge - Göteborg	Containership (Small, 17 knot 350 TEU)	Winther et al (2009)	56%	Infrastructure processes and combustion emissions are obtained from Ecoinvent Fuel production is obtained from Ecoinvent
Göteborg – final destination (Falköping)	Transport, freight, rail/RER U	Ecoinvent/ Green Cargo	60%	See comment concerning trains below
Alicante area - Helsingör Helsingborg – final destination (Falköping)	Transport, truck, 34-40t, NTM	NTM	70%	Diesel B0 – EU Motorway – Swe EURO4 Gradient: 0% Shipment weight: 27,6 tonne Cargo carrier capacity: 26 tonne Fuel consumption: 0,281 l/h
Alicante area – final destination (Falköping)	Transport, freight, rail/RER U	Ecoinvent/ Green Cargo	60%	See comment concerning trains below
Helsingör - Helsingborg	RoRo Carferry (18t goods on 17 lanemeters)	Winther, et. Al (2009)	N/A	
Alicante - Bilbao	Transport, freight, rail/RER U	Ecoinvent/ Green Cargo	60%	See comment concerning trains below

Trains
Ecoinvent dataset is modified with energy consumption from Green Cargo
Country specific electricity production is obtained from Ecoinvent
Weight: 27.6 tonne
Goods density: Average
Type of goods: Container
Train weight: 1000 tonne
Empty return: 50%

Cooling data

For cooling data information from Winther U, et al. (2009) has been used.

Tomato production data

Four different life cycle assessments of Spanish tomato production have been reviewed; Torrellas et al. 2012, Capeletti et al. 2012, Martinez-Blanco et al., and a classified internal case study in the SIK food database (data providers included non-disclosure agreement).

The Spanish studies were complemented with a single Swedish case study; Davids et al. 2011.

The results of the studies with respect to global warming potential can be seen in Figure 2. A Swedish scenario has also been included for a comparison between Spanish and Swedish tomato production.

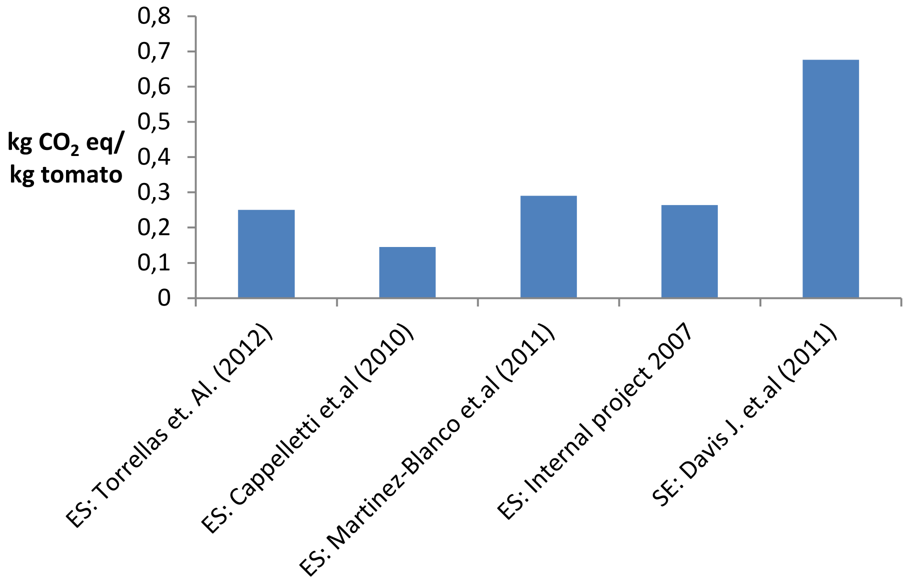

Figure 2: Greenhouse gas emissions measured in kg CO_2 eq. for 1 kg of tomatoes.

The study by Torrellas et al. (2012) with a climate change of 0.25 kg CO_2 eq/kg of tomato was chosen to represent the Spanish tomato production and the data from this study was used to build a model for comparing impacts from agriculture with impacts from transports.

The study by Davis J. et.al (2011) with a climate change of 0.68 kg CO_2 eq/kg of tomato was chosen to represent the Swedish tomato production.

Results

Figure 3 shows the contribution from the Spanish tomato production and the transport scenarios with regard to global warming potential.

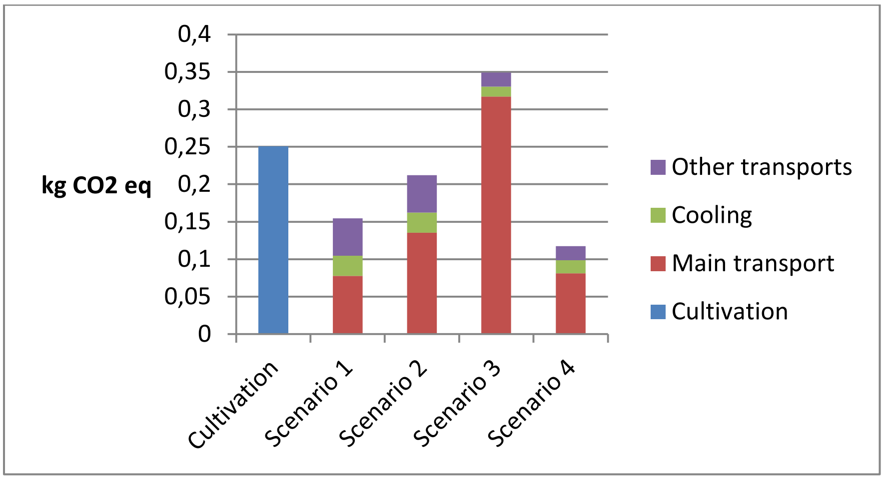

Figure 3: Cultivation of tomatoes in Spain is compared with the transport scenarios with regard to greenhouse gas emissions in kg CO_2 eq./kg tomato. The contribution of the different transports is divided into the categories main transport, cooling and other transports.

Diagrams with one category for each route with its corresponding cooling activity are presented in the appendix (Figure 5 - Figure 12), e.g.:

First transport
Cooling for first transport
Second transport
Cooling for second transport etc.

- for each impact category, resulting in a total of eight diagrams.

This is because eutrophication is divided into three sub categories. In each diagram the contribution of the tomato production will also be represented.

Figure 4 shows the Spanish production with the four transport scenarios compared to the Swedish tomato production with respect to global warming potential.

In order to do the comparison a scenario 5 has been defined with the same first transport as the other scenarios and the same long distance truck as in scenario 4. The distance for the long distance truck was set to 500 km.

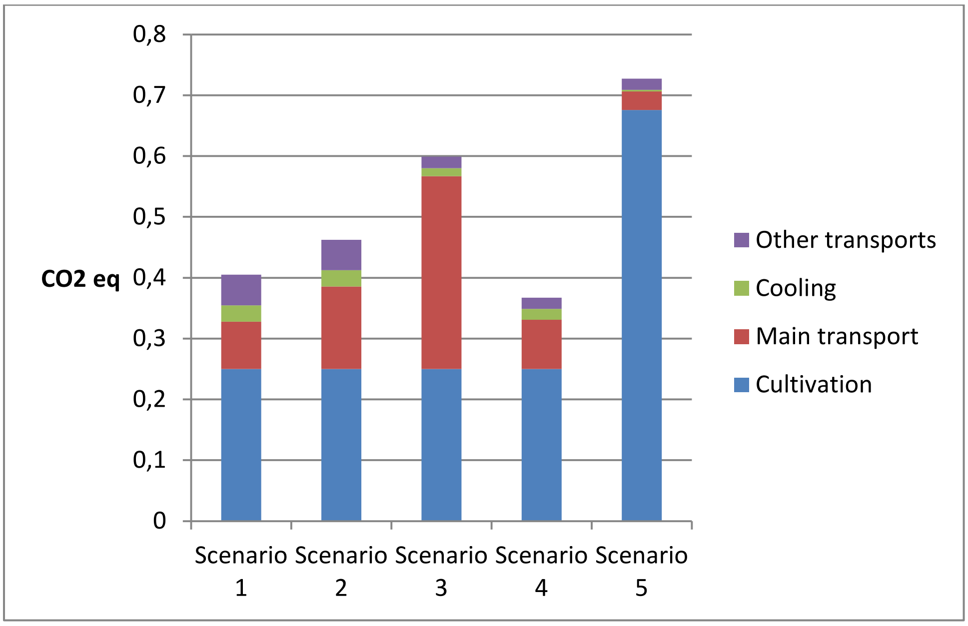

Figure 4: The diagram shows the comparison between the Spanish tomato production with all transport scenarios and the Swedish tomato production with respect to global warming potential

Conclusions and discussion

The tomato production

The studies that have been chosen to represent Spanish respective Swedish production of tomatoes are not representative for the total production of tomatoes in the respective country, but are site-specific or are based on data collected from large producers. Still, the studies show the main features of production in the respective country. Also, when comparing the results from the studies it is important to bear in mind that the tomatoes are grown with different techniques. Furthermore, the studies are carried out with different methodologies, e.g. different system boundaries.

The main difference between the Spanish and the Swedish tomato production, except for the location, is that the Swedish production requires heating. That is also the main reason why the Swedish production shows a much higher contribution to climate change. As can be seen in Figure 4, all Spanish scenarios show a lower global warming potential than the Swedish scenario, which indicates that transports can be a solution to environmental problems in future food production systems. Figure 2 shows that because of the variation of results of tomato cultivation (variation may also be explained by different methodological choices) finding the optimal production may be as important as finding the optimal transport system.

The model that was built on the Spanish study was verified by comparing climate change with the result in the study. Not all data in the study could be interpreted and used, e.g. some infra-structure data and waste management of greenhouse building material has been left out. Therefore the result from the model only added up to 0.16 kg CO_2 eq/kg tomato. However, the emissions that are characteristic for agriculture could be included in the model, which is why the model is decided to be adequate enough to be used for comparing impacts between agriculture and transports.

Thus, the value of 0.25 kg CO_2 eq/kg tomato (which is the final result in Torrellas et al. (2012)) was hereafter used for greenhouse gas emissions from tomato production in Spain.

The transports and the tomato production

All transport scenarios to Sweden show a lower global warming potential than the tomato production, except for scenario 3 (truck) which has the highest impact. Scenario 4 (train) shows the least impact. (Figure 3)

Regarding the contribution to climate change among the transport categories, the main transport of each scenario shows the highest impact. The slower transport scenarios 1 and 2 show a higher contribution from the cooling because of the longer transport time. (Figure 3)

Scenario 1 and 2 have a higher impact from other transports since the boats operate a lower fraction of the total distance than the other transport modes. Finally Scenario 3 has a slightly higher contribution from other transports than scenario 4 because of the ferry between Helsingör and Helsingborg. (Figure 3)

Regarding the other impact categories (See appendix) the same relation between impacts as for greenhouse gas emissions can sometimes be seen, but with these exceptions:

- Regarding ozone depletion, cultivation is less dominant compared to the transports
- Regarding photochemical ozone formation, cultivation is less dominant than all of the transports. Scenario 3 is less dominant than scenario 2.
- Regarding acidification, cultivation is less dominant compared to the transports. Scenario 3 is less dominant than scenario 2.
- Regarding terrestrial eutrophication, cultivation is less dominant compared to the transports. Scenario 3 is less dominant than scenario 2. (The reason for the low contribution from the cultivation in this case is because the method only includes emissions to air that will later pollute the ground.)
- Regarding freshwater eutrophication, cultivation is most dominant compared to the scenarios. Scenario 4 is more dominant than the other transport scenarios.
- Regarding marine eutrophication, cultivation is the most dominant contributor. Scenario 3 is less dominant than scenario 2.
- Regarding Mineral, fossil & renewable resource depletion, Scenario 4 is the most dominant compared to the scenarios. This is because the use of rubber tires is weighted high compared to other activities. It is considered beyond the scope of this report to investigate this further.

Next step

The relevance of the defined scenarios needs to be investigated further. Since the environmental impact from the production of food often dominates the total impact, an increase of food waste can easily cut back eventual benefits of using intermodal transports. Therefore the consequences of the increased transport time needs to be assessed, as well as the conditions for maintaining or improving other characteristics such as atmosphere, vibrations etc. Finally, different food will have different requirements on transport which is why further studies could also include other food products than tomatoes.

Cooling datasets for water and rail transports need to be developed further.

The datasets that have been used in the study only represents general transports. If vessel specific data for vessels operating at different speeds could be collected it could enhance the quality and increase the use of this study even further. Actual load factors could also be investigated further. If we would know more about these characteristics we could also assess the improvement potential.

Calculate scenarios with fuels with different sulphur content.

More impact categories that are relevant to either logistics or food production could be included. The ENVIFOOD protocol provides a list of all environmental impacts that should be included in a life cycle assessment of food (Table 4). However, more research is needed to include all of them, and their relevance to the aim of the study also needs to be discussed.

Table 4 The ENVIFOOD protocol list of life cycle impact analysis categories

No	Impact category	End-point	Reference
1	Climate change	Human health and Natural Environment	Bern Model – IPCC ,2007
2	Ozone depletion	Human health and Natural Environment	Steady-state ODPs 1999 as in WMO assessment
3	Eutrophication	Natural Environment	Terrestrial : Accumulated Exceedance (Seppälä et al, 2006, Posch et al, 2008) Aquatic : EUTREND Model (Struijs et al 2009b) as implemented in ReCiPe
4	Acidification	Natural Environment	Accumulated Exceedance (Seppälä et al, 2006 Posch et al, 2008)
5	Human toxicity	Human health	USEtox Model (Rosembaum et al, 2008)
6	Respiratory inorganics	Human health	RiskPoll Model (Rabl and Spadaro, 2004)
7	Ionizing radiation	Human health	Human health effect model as developed by Dreicer et al, 1995 (Frischknechet et al, 2000)
8	Ecotoxicity	Natural Environment	USEtox Model (Rosembaum et al, 2008)
9	Photochemical ozone formation	Human health and Natural Environment	Van Zelm et al, 2008 as applied in ReCiPe
10	Land use	Natural Environment and Natural resources	Soil Organic Matter model (Milà i Canals et al, 2007b)
11	Resource depletion	Resource depletion Natural Environment and Natural Resources	CML 2002 (Guinée et al, 2002)
11b	Water consumption	Natural Environment and Natural Resources	Revised approach to water footprinting. (Ridoutt, B.G. and Pfister, S., 2010)

Reference list

Winther U. et al. (2009): Carbon footprint and energy use of Norwegian seafood products. Report 2009. Nofima. Trondheim

Torrellas et al. (2012): Environmental and economic assessment of protected crops in four European scenarios. Journal of cleaner production 2011.

Capeletti et al. (2012): Life cycle assessment of the tomato production. LCA Food 2010.

Martinez-Blanco et al. (2011): Assessment of tomato Mediterranean production in open-field and standard multi-tunnel greenhouse, with compost or mineral fertilizers, from an agricultural and environmental standpoint. Journal of cleaner production 2011.

Davids et al. (2011): Emissions of Greenhouse Gases from Production of Horticultural Products - Analysis of 17 products cultivated in Sweden. SIK report 828 2011. SIK. Gothenburg

Appendix

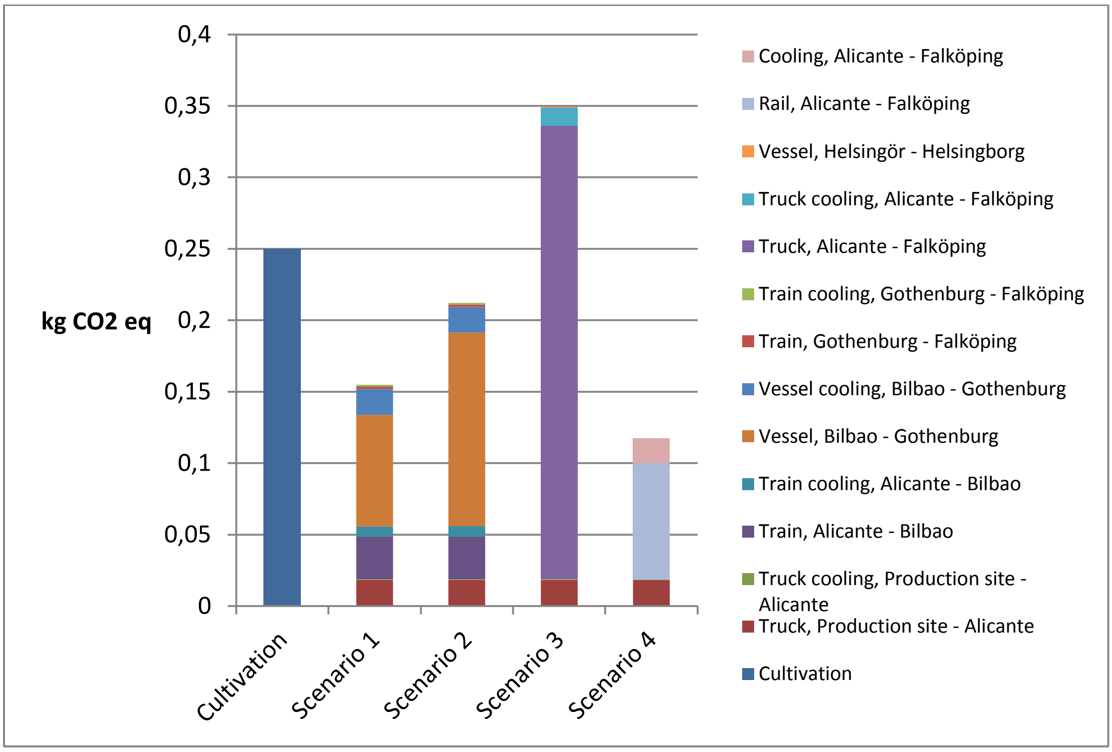

Figure 5: Climate change. The cultivation value is obtained directly from the study and not calculated from the model. The main contributing activities are: In the cultivation, fertiliser production and field emissions; In scenario 1 and 2 combustion of heavy fuel oil; In scenario 3 combustion of diesel; In scenario 4 electricity production and emissions from the train operation.

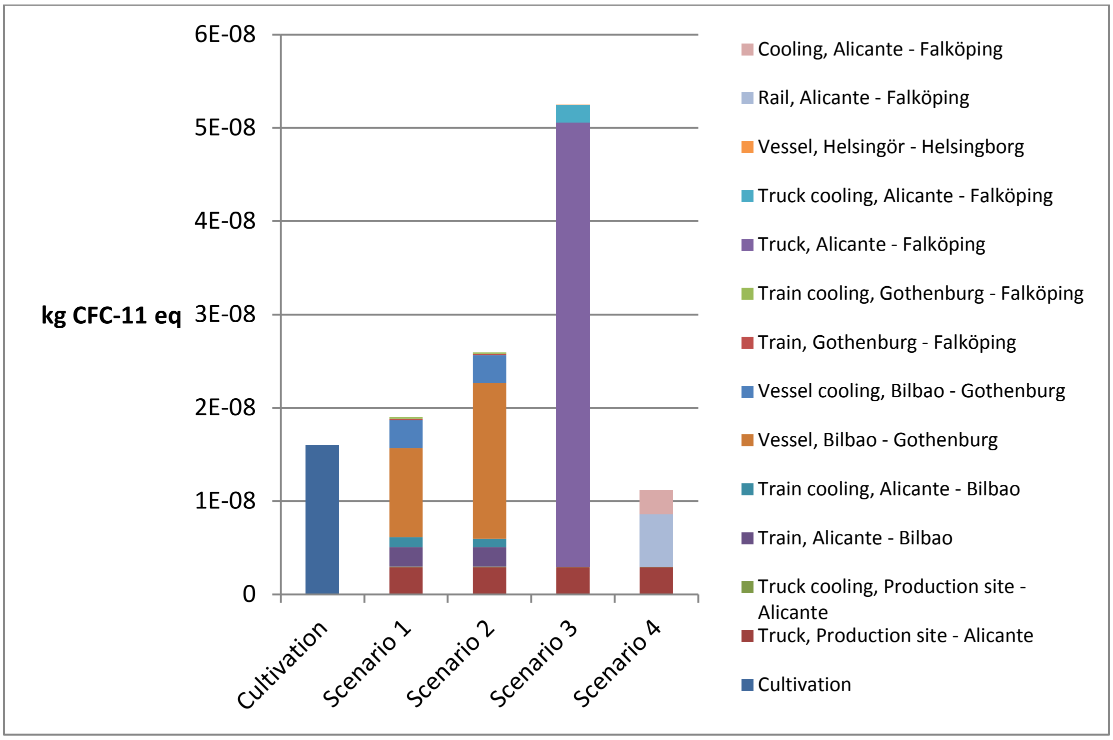

Figure 6: Ozone depletion. The main contributing activities are: In the cultivation, Production of perlite; In scenario 1 and 2 Production of heavy fuel oil; In scenario 3 production of diesel; In scenario 4 electricity production and emissions from the train operation.

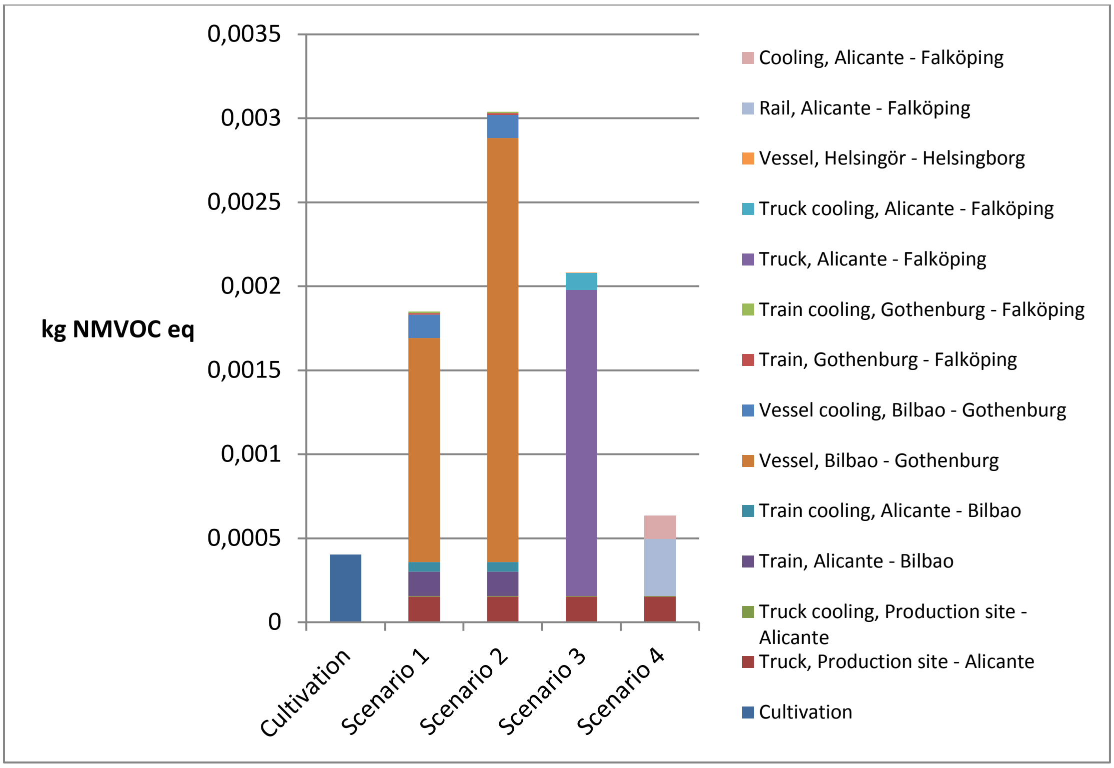

Figure 7: Photochemical ozone formation. The main contributing activities are: In the cultivation no specific activity; In scenario 1 and 2 combustion of heavy fuel oil; In scenario 3 combustion of diesel; In scenario 4 electricity production and emissions from the train operation.

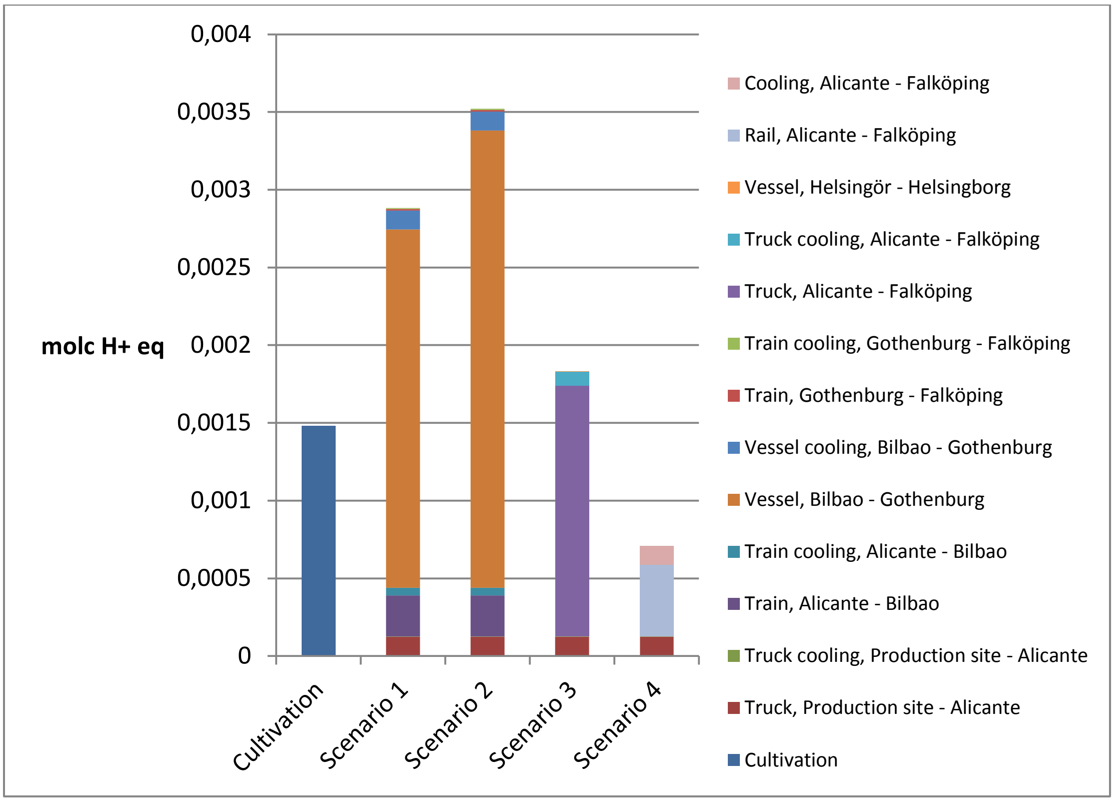

Figure 8: Acidification. The main contributing activities are: In the cultivation field emissions; In scenario 1 and 2 combustion of heavy fuel oil; In scenario 3 combustion of diesel; In scenario 4 electricity production and emissions from the train operation.

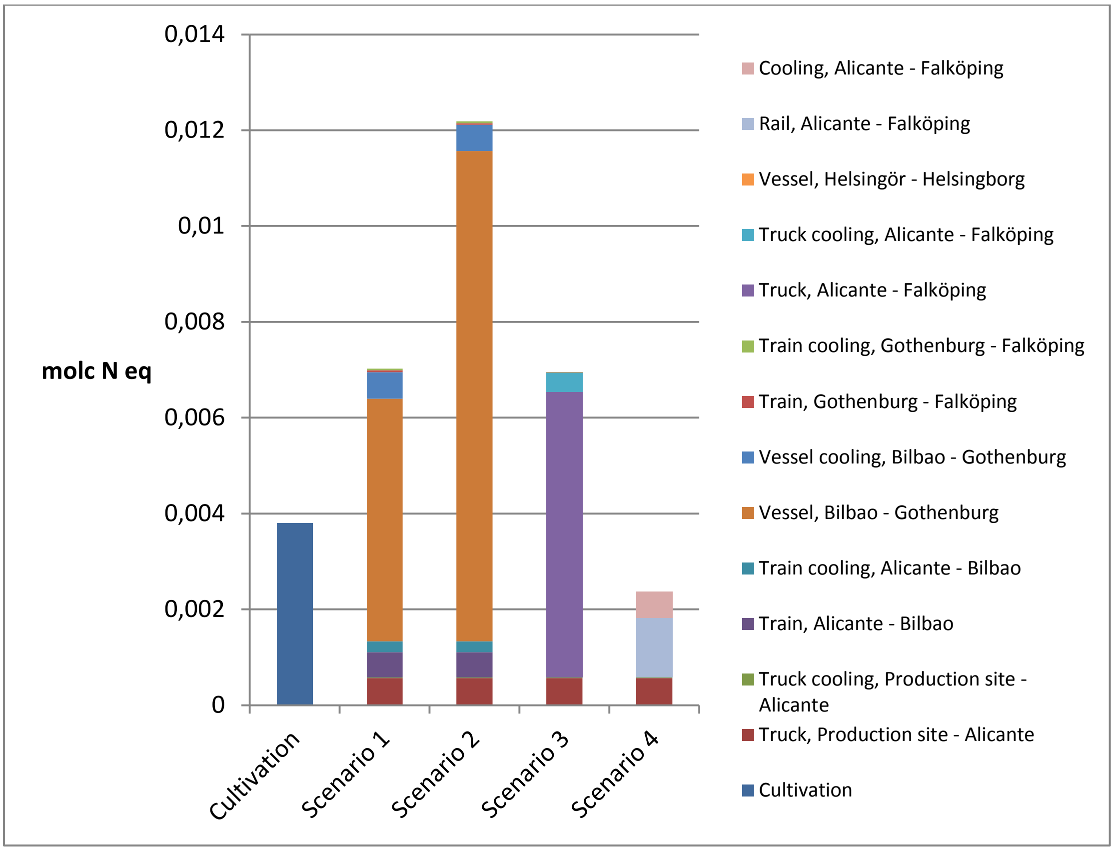

Figure 9: Terrestrial eutrophication. The main contributing activities are: In the cultivation field emissions; In scenario 1 and 2 combustion of heavy fuel oil; In scenario 3 combustion of diesel; In scenario 4 electricity production and emissions from the train operation.

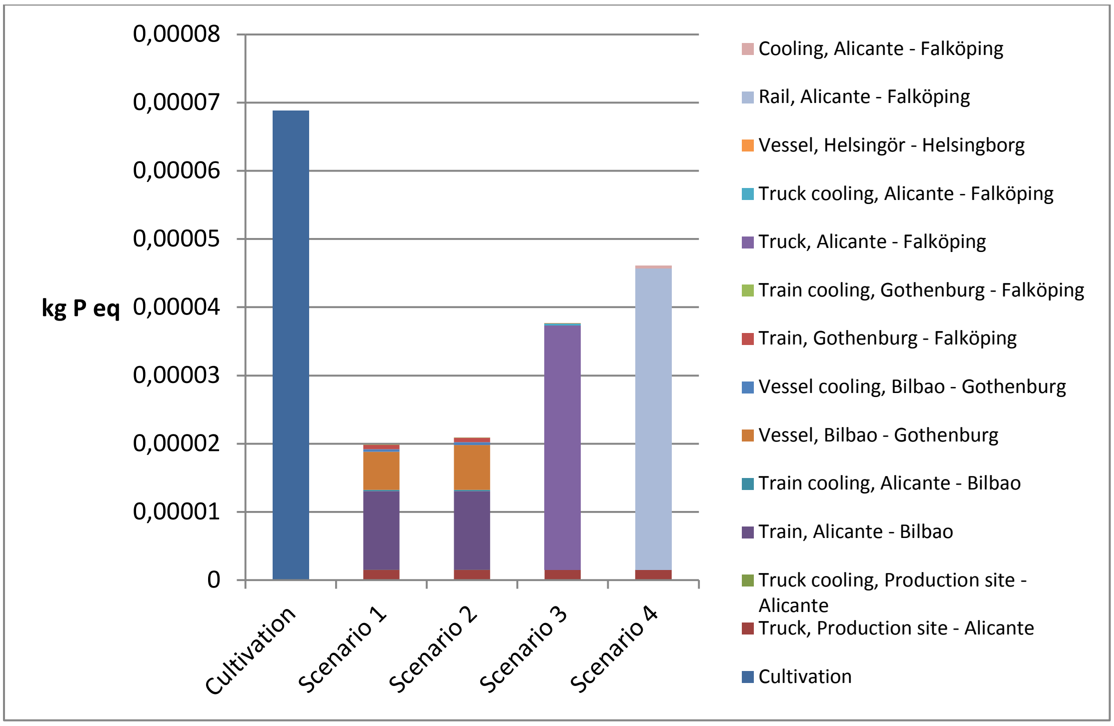

Figure 10: Freshwater eutrophication. The main contributing activities are: In the cultivation production of phosphate fertiliser; In scenario 1 and 2 no specific activity; In scenario 3 no specific activity; In scenario 4 German electricity production.

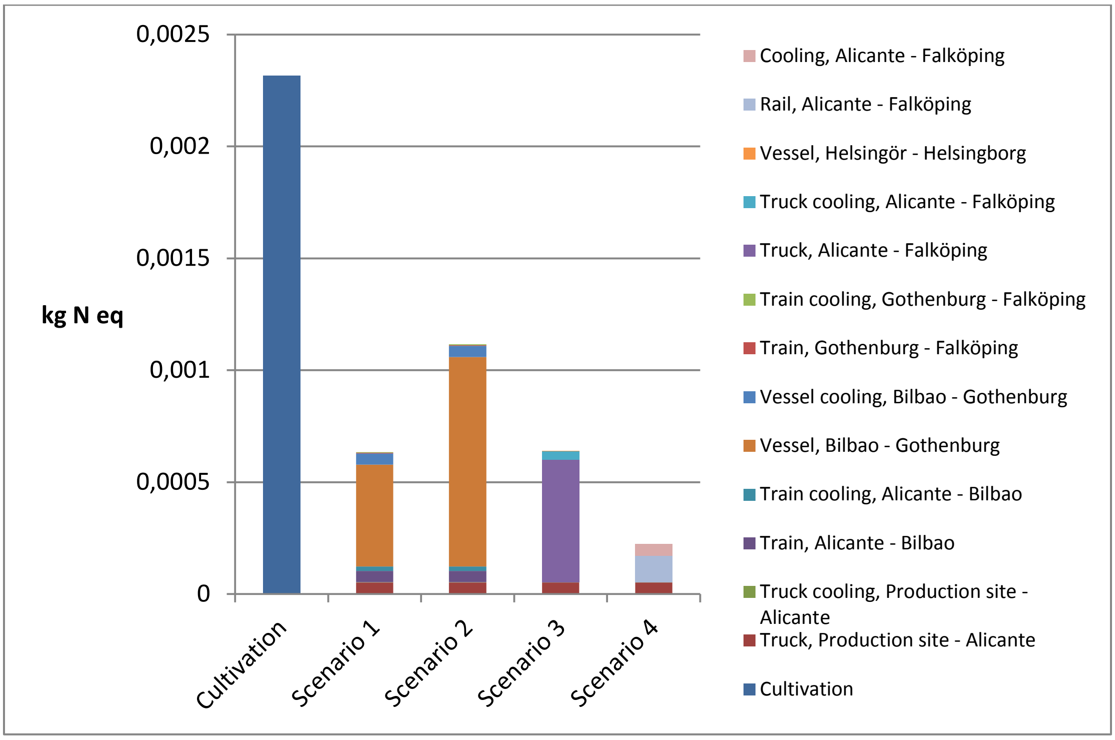

Figure 11: Marine eutrophication. The main contributing activities are: In the cultivation field emissions; in scenario 1 and 2 no combustion of heavy fuel oil; in scenario 3 combustion of diesel; in scenario 4 no specific activity.

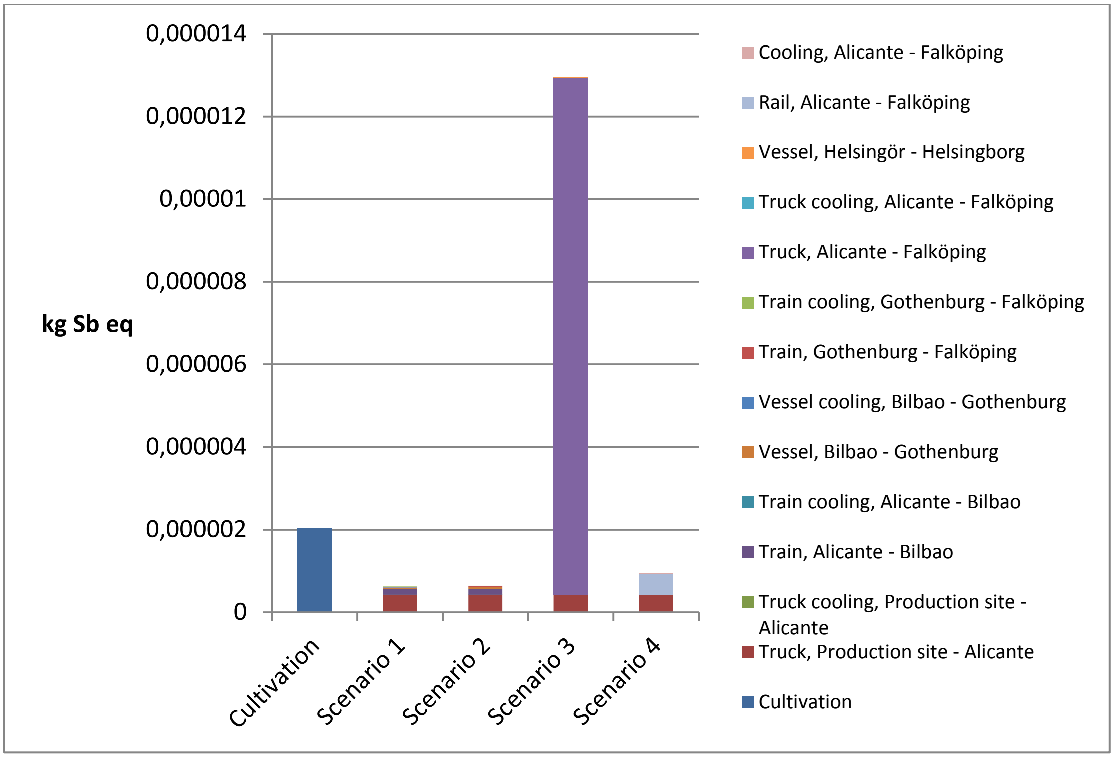

Figure 12: Mineral, fossil & renewable resource depletion. The main contributing activities are: In the cultivation perlite production; in scenario 1 and 2 no specific activities; in scenario 3 no specific activity; in scenario 4 no specific activity.

Table 5: Climate change.

GWP (kg CO_2 eq/kg tomato)	Cultivation	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Cultivation, Spain	0,25	0	0	0	0	0
Truck, Production site - Alicante		0,01847	0,01847	0,01847	0,01847	0
Truck cooling, Production site - Alicante		0,0004395	0,0004395	0,0004395	0,0004395	0
Train, Alicante - Bilbao		0,0297	0,0297	0	0	0
Train cooling, Alicante - Bilbao		0,007204	0,007398	0	0	0
Vessel, Bilbao - Gothenburg		0,078	0,1354	0	0	0
Vessel cooling, Bilbao - Gothenburg		0,01804	0,01782	0	0	0
Train, Gothenburg - Falköping		0,001826	0,001826	0	0	0
Train cooling, Gothenburg - Falköping		0,001081	0,00111	0	0	0
Truck, Alicante - Falköping		0	0	0,3171	0	0
Truck cooling, Alicante - Falköping		0	0	0,01274	0	0
Vessel, Helsingör - Helsingborg		0	0	0,0002583	0	0
Rail, Alicante - Falköping		0	0	0	0,08108	0
Cooling, Alicante - Falköping		0	0	0	0,01729	0
Cultivation, Sweden						0,675891
Truck, production site – Distribution point						0,018469
Truck cooling, production site – Distribution point						0,0004395
Truck, Distribution point - Falköping						0,030142
Truck cooling, Distribution point - Falköping						0,002522
Total	0,25	0,1547605	0,2121635	0,3490078	0,1172795	0,727464

Head Office:
SIK, Box 5401, SE-402 29 Göteborg, Sweden.
Telephone: +46 (0)10 516 66 00, fax: +46 (0)31 83 37 82.

Regional Offices:
SIK, Ideon, SE-223 70 Lund, Sweden.
Telephone: +46 (0)10 516 66 00.
SIK, Forslunda 1, SE-905 91 Umeå, Sweden.
Telephone: +46 (0)10 516 66 00.
SIK, c/o Almi, Box 1224, SE-581 12 Linköping, Sweden.
Telephone: +46 (0)10 516 66 00.

www.sik.se