Farming, Food and Health. First™
Te Ahuwhenua, Te Kai me te Whai Ora. Tuatahi

An ILCD database of three fertilisers for the kiwifruit industry

July 2011

New Zealand's science. New Zealand's future.

An ILCD database of three fertilisers for the kiwifruit industry

Version 1.1

July 2011

Marlies Zonderland-Thomassen, Mark Boyes, Stewart Ledgard

Table of Contents

1. Summary 1

2. Introduction 2

2.1 Goal and scope 2

3. Life Cycle Inventories 4

3.1 Calcium ammonium nitrate (CAN) 4

3.2 Reactive phosphate rock (RPR) 5

3.3 Muriate of potash (KCl) 6

3.4 Manufacturing-to-regional NZ storage 7

4. Life Cycle Impact Assessment 8

5. Life Cycle Interpretation 8

5.1 Reviewing process 9

5.2 Lessons learnt and issues encountered 10

6. Acknowledgements 10

7. References 10

1. Summary

This project aimed to provide a life cycle inventory (LCI) on greenhouse gas (GHG) emissions of imported fertilisers used in New Zealand (NZ) using Life Cycle Assessment (LCA) methodology. The output from the project included a GHG LCI database for calcium ammonium nitrate (CAN), reactive phosphate rock (RPR), and muriate of potash (KCl) in an International Reference Life Cycle Data System (ILCD) format, excluding field emissions from fertiliser use. The manufacturing stage inventory for CAN and KCl was provided by Dr Frank Brentrup from the Fertilizers Europe project in ILCD format. For RPR, an LCI was compiled using information from the NZ fertilisers industry and literature. The NZ weighted average values for 28 GHG emissions covering the cradle-to-NZ regional storage-gate were determined using data from these LCIs in conjunction with data from two NZ fertiliser companies which cover virtually all of NZ's supply, on the international locations from where the various fertilisers were imported from. LCA characterisation factors (IPCC 2007, GWP100) were then used to estimate total GHG emissions for CAN (1.88 kg CO_2-eq/kg), RPR (0.27 kg CO_2-eq/kg), and KCl (0.56 kg CO_2-eq/kg).

2. Introduction

2.1 Goal and scope

The previous carbon footprinting projects of New Zealand (NZ) farming systems have shown that fertilisers can make a significant contribution to GHG emissions from the cradle-to-farm-gate stage of agricultural products. This contribution consists of 1) GHG emissions related to the production and transport of fertiliser and 2) GHG emissions from the application of fertiliser.

In the dairy carbon footprinting project, fertilisers and lime were estimated to contribute about 15% of farm-related GHG emissions or over 50% of farm-related CO_2 emissions [1]. Corresponding values from the lamb carbon footprinting study were 7% and over 70%, respectively [2]. In the kiwifruit carbon footprinting study, the orchard was a less significant part of the total GHG footprint compared to that for animal products but fertilisers and lime still constituted 44% of the orchard-related emissions [3]. A recent study provided a LCA of local and imported fertilisers [4]. This study will build only on the imported fertilisers, because these were partly already available in ILCD format, and the information received from NZ's two main fertiliser companies showed a large part of fertilisers applied in NZ are produced using imported materials.

A recent survey performed by Plant & Food Research in the Bay of Plenty showed in 2010/2011 calcium ammonium nitrate (CAN) was applied in 42.5% of the analysed orchards with an average of 425 kg/ha and a standard deviation of 345 kg/ha. This same survey showed muriate of potash (KCl) was applied in 45% of the analysed orchards with an average of 175 kg/ha and a standard deviation of 114 kg/ha. These amounts are not necessarily put on every year; some orchards might only apply it every other year. This survey also showed a whole range of phosphorus (P) fertilisers were applied. Common P fertilisers used in agriculture are diammonium phosphate (DAP), triple superphosphate (TSP), single superphosphate (SSP), and reactive phosphate rock (RPR). For the imported DAP and TSP, Fertilisers Europe indicated no agreement was reached yet on how to handle allocation of sulphur; therefore, no approved dataset was available for DAP and TSP (June 2011). For SSP, the inventory was based on NZ data using imported phosphate rock and incorporated more complexity and confidentiality issues. Therefore, it was decided for this project to make an LCI of imported RPR.

The goal of this study is to provide a Life Cycle Inventory (LCI) of greenhouse gas emissions (GHG) in an International Reference Life Cycle Data System (ILCD) format of the NZ imported fertilisers calcium ammonium nitrate (CAN), reactive phosphate rock

(RPR), and muriate of potash (KCl). These LCIs will be available for NZ practitioners to use in future carbon footprinting and/or LCA studies of NZ farming systems. Field emissions from fertiliser use are excluded.

The chosen functional unit is kg of fertiliser supplied to regional storage in NZ, which means the LCI of GHG is expressed per kg of fertiliser supplied to NZ regional storage.

For CAN and KCl, cut-off rules for each unit process in the manufacturing stage were: Coverage of at least 98% of mass and energy of the input and output flows and 98% of their environmental relevance. Infrastructure was not included. For RPR, cut-off rules in the manufacturing stage were not specified by the data source. For transport, no cut-off rules were applied, and therefore, the total cradle-to-NZ regional-storage datasets of the fertilisers, also include GHG emissions which have a minor contribution.

For CAN and KCl, the LCI of the manufacturing stage was data based on recent industry data supplied by the European Fertiliser Manufacturers Association (EFMA; currently known as Fertilisers Europe) as well as on literature summarised in an ILCD file reflecting the reality in fertiliser fabrication. This project was carried out by Dr Frank Brentrup (from Yara International) who has considerable experience in the use of LCA associated with fertiliser production and use [5]. Life Cycle Inventory data from the Fertilizers Europe project was reviewed and accepted for upload into the public available ELCD database. They have agreed to make the data available for this project. Using the GaBi software system, the foreground data have been combined with LCI models integrating background LCI data on energy supply systems, ancillary processes and materials [6-11]. Therefore, the data set covers all relevant process steps and technologies over the supply chain of the represented "cradle to gate" inventory with a good overall data quality. In cases where no primary data were available, literature data provided by EFMA or calculated data were used. Analyses were used to address the precision and uncertainty of relevant data as well as to justify the inclusion or exclusion of data from the system boundaries. The Fraunhofer Institute for Building Physics (IBP-GaBi), as an independent expert agency, has critically reviewed the manufacturing LCI data profile including data consolidation, development for the various LCI models and the calculation of the associated LCI data sets.

There is no allocation necessary for all three fertiliser manufacturing processes. For allocation of upstream data (energy), the energy data (e.g. refined products like diesel, gasoline, fuel oil and propane) are allocated by mass in relation to the refinery emissions and energy demands are allocated by energy content in relation to the crude oil consumption. All data used in the calculation of the LCI results refer to net calorific value. For the transport of energy carriers, average transport processes with specific parameter settings e.g. transport distances and route (ship, pipeline, rail, road) were used.

3. Life Cycle Inventories

For CAN and KCl, annual average, site specific data from Fertilisers Europe for the year 2006 were used, when necessary complemented by literature information from 1997-2006 [10]. Ancillary processes (e.g. energy carriers) and materials were specified within the GaBi 4 database 2006 and are representative for the years 2000-2005. For RPR, the LCI of the manufacturing stage was based on the ecoinvent database [12]. Annual average data were used based on different literature sources of different years (1993-1997). Year of reference was not specified.

For each fertiliser, the cradle-to-manufacturing-gate stage is outlined below.

3.1 Calcium ammonium nitrate (CAN)

Calcium ammonium nitrate is a fertiliser with 26.5% N-content. It is produced by neutralising nitric acid with ammonia. This is a very heat demanding process. The LCI is based on this „standard‟ CAN, but there is potential to reduce the GHG emissions from such nitrate-based products. Since 2006 N_2O abatement in the manufacturing plant has been a standard technology within the Fertilizers Europe member companies. After neutralising, the ammonium nitrate is then mixed with filler that contains dolomite to produce calcium ammonium nitrate. As result the mixture is either prilled or granulated. The several process steps are neutralisation, evaporation and solidification. This data set also includes the mining process of dolomite. Transport of the dolomite, nitric acid and ammonia to the calcium ammonium nitrate plant is included with the respective fuel demand and assumed by tanker and train. CAN emissions to atmosphere comprise dust and ammonia. Emissions to water include nitrogen. The background system is addressed as follows: Electricity, Thermal energy: The electricity (and thermal energy as by-product) used is apportioned according to the individual country-specific situation. The country-specific modelling is achieved on multiple levels. Firstly the individual power plants in service are modelled according to the current national grid. This includes net losses and imported electricity. Second, the national emission and efficiency standards of the power plants are modelled. Third, the country-specific fuel supply (share of resources used, by import and / or domestic supply) including the country-specific properties (e.g. element and energy contents) are accounted for. Fourth, the import, transport, mining and exploration processes for the energy carrier supply chain are modelled according to the specific situation of each power-producing country. The different mining and exploration techniques (emissions and efficiencies) in the different exploration countries are accounted for according to current engineering knowledge and information obtained by Fertilisers Europe. Figure 1 gives an overview of the relevant unit processes of CAN from cradle-to-manufacturing-gate. The steam supply is modelled according to the individual country-specific situation with regard to the technology efficiencies and energy carriers used. Efficiencies range from 84% to 94% in relation to the representative energy carrier (gas, oil, coal). Coal, crude oil and natural gas used for the generation of steam are modelled according to the specific import situation (see electricity). Newer efficient plants, however, have lower emissions. All relevant and known transport processes used are included. Overseas transport including rail and truck transport to and from major ports for imported bulk resources is included. Furthermore, all relevant and known pipeline and / or tanker transport of gases and oil imports is included. Coal, crude oil, natural gas and uranium are modelled according to the specific import situation (see electricity). Diesel, gasoline, technical gases, fuel oils, basic oils and residues such as bitumen are modelled via a country-specific, refinery parameterised model. The refinery model represents the current national standard in refinery techniques (e.g. emission level, internal energy consumption,...) as well as the individual country-specific product output spectrum, which can be quite different from country to country. Hence the refinery products used show the individual country-specific use of resources. The supply of crude oil is modelled according to the country-specific crude oil situation with the respective properties of the resources.

3.2 Reactive phosphate rock (RPR)

The reactive rock phosphate is a fertiliser with a phosphorus (P) content of 14.5%, equivalent to 33.2% P_2O_5 [13]. The process is based on sedimentary marine phosphorites in Morocco; a Khouribga sedimentary phosphate rock. In order to produce 1 tonne of commercial phosphate rock with a content of 33% P_2O_5, 1.3 tonnes phosphate ore must be mined and beneficiated. In the absence of specific mining information of Khouribga, we used average phosphate rock production in Morocco [12]. Mining in Morocco is in open pit (86%) or underground mines (14%). Figure 2 gives an overview of the relevant unit processes of RPR from cradle-to-manufacturing-gate. After mining, phosphate rock is beneficiated (crushed, washed, and dried), depending on its organic content. Of the phosphate rock in Morocco, 43% are beneficiated by washing and drying, 9% are calcinated, 11% are dry processed (sieving, crushing), and 37% are only dried. For this inventory of dry rock, only 0.3 tonnes waste rock per tonne PR is produced. Diesel and electricity consumption for mining operations were taken from ecoinvent, while using country-specific information [7-10]. Heat (50% natural gas; 50% heavy fuel oil) and electricity consumption for beneficiation were also taken from ecoinvent while using country-specific information for modelling, e.g., by using national grid information.

3.3 Muriate of potash (KCl)

Muriate of potash or potassium chloride is a fertiliser containing 60% K_2O, similar to 49.8% K; the product can also be applied as component in multi-nutrient fertilisers. Potassium chloride is produced by shaft mining and beneficiation. This includes the mining of potash salt. The incoming waste from the production is treated as inert material on a landfill site. Muriate of potash is produced in a wide variety of crystal sizes, according to the potash ore and process used. Different applications demand various particle-size distributions obtained by screening. Transport of the potash salt to the potassium chloride plant is included with the respective fuel demand, and it is assumed to be by train. The mining process emits the following GHG substances: Carbon dioxide, Carbon monoxide, Methane, Nitrogen oxides, Nitrous oxide, non-methane volatile organic compounds (NMVOC). The potassium chloride process only emits dust. The background system is addressed as follows: Electricity, Thermal energy: The electricity (and thermal energy as by-product) used is modelled according to the individual country-specific situation. The country-specific modelling is achieved on multiple levels. Firstly the individual power plants in service are apportioned according to the current national grid. This includes net losses and imported electricity. Second, the national emission and efficiency standards of the power plants are modelled. Third, the country-specific fuel supply (share of resources used, by import and / or domestic supply) including the country-specific properties (e.g. element and energy contents) are accounted for. Fourth, the import, transport, mining and exploration processes for the energy carrier supply chain are modelled according to the specific situation of each power-producing country. The different mining and exploration techniques (emissions and efficiencies) in the different exploration countries are accounted for according to current engineering knowledge and information. Figure 3 gives an overview of the relevant unit processes of KCl from cradle-to-manufacturing-gate. The steam supply is modelled according to the individual country-specific situation with regard to the technology efficiencies and energy carriers used. Efficiencies range from 84% to 94% in relation to the representative energy carrier (gas, oil, coal). Coal, crude oil and natural gas used for the generation of steam are modelled according to the specific import situation (see electricity). All relevant and known transport processes used are included. Overseas transport including rail and truck transport, to and from major ports, for imported bulk resources is included. Furthermore, all relevant and known pipeline and / or tanker transport of gases and oil imports is included. Coal, crude oil, natural gas and uranium are modelled according to the specific import situation (see electricity). Refinery products: Diesel, gasoline, technical gases, fuel oils, basic oils and residues such as bitumen are modelled via a country-specific, refinery parameterised model. The refinery model represents the current national standard in refinery techniques (e.g. emission level, internal energy consumption,...) as well as the individual country-specific product output spectrum, which can be quite different from country to country. Hence the refinery products used show the individual country-specific use of resources. The supply of crude oil is modelled according to the country-specific crude oil situation with the respective properties of the resources.

3.4 Manufacturing-to-regional NZ storage

Data on the international locations from where the various fertilisers were imported were retrieved from the two main NZ fertiliser companies (covering a time period from 2002-2010) to determine 1) overseas rail transport, 2) ocean freight transport to NZ ports Tauranga and Christchurch, and 3) transport from NZ ports to regional storages in Te Puke (North Island) and Nelson (South Island). Expert's opinion from these NZ fertiliser companies was used to choose mode of transports. For overseas rail transport, country-specific data from ecoinvent were used [14]. For freight ocean transport, data for the transoceanic freight ship (50,000 dwt) from ecoinvent were used [14]. For transport from NZ ports to the regional storages, the EURO 3 vehicle was chosen (16t-32 t) [14].

For CAN transported as a bulk product, weighted average ocean freight ship distance was estimated at 21715 km [15], overseas rail transport at 190 km, and national truck distance at 116 km.

For KCl transported as a bulk product, weighted average ocean freight ship distance was estimated at 13490 km [15], overseas rail transport at 1877 km, and national truck distance at 102 km.

For RPR transported as a bulk product, weighted average ocean freight ship distance was estimated at 19807 km [15], overseas rail transport at 170 km, and national truck distance at 100 km.

Tables 1-3 present the cradle-to-NZ regional storage greenhouse gas LCI of CAN, RPR, and KCl.

4. Life Cycle Impact Assessment

The Global Warming Potential (GWP100) of all three fertilisers was calculated using characterisation factors established by IPCC 2007 [16]. Table 4 shows total GWP was highest for CAN (1.88 kg CO_2-eq) and lowest for RPR (0.27 kg CO_2-eq/kg). KCl had a GWP of 0.56 kg CO_2-eq/kg. For CAN and KCl, the cradle-to-manufacturing gate stage had the highest contribution to total GWP (88% and 66% respectively), while for RPR, transport contributed most (75%). To facilitate a comparison with other fertilisers, we also expressed GWP per kg nutrient content. Expressed per kg nutrient, GWP was still highest for CAN (7.09 kg CO2-eq/kg N), but lowest for KCl (1.12 kg CO_2-eq/kg K). RPR had a GWP of 1.86 kg CO_2-eq/kg P. Carbon Footprint or Global Warming Potential, however, is a single issue and should be complemented in LCA studies with other relevant environmental impact assessments. For example, fertilisers can have a significant eutrophication potential and energy use [4].

5. Life Cycle Interpretation

The datasets exclude field emissions from fertiliser use. Table 5 shows the assumptions made for each fertiliser and its transport. The “standard” CAN from this study had a high GHG emissions/kg, but there is potential to reduce the GHG emissions from such nitrate-based products due to N_2O abatement in the manufacturing plant. From 2006 this is now the standard technology within the Fertilizers Europe member companies and it reduces the GHG emissions to about 0.75 kg CO_2-eq/kg CAN at the plant gate [4]. This means a reduction of about 40% in this cradle-to-NZ regional storage study which results in a GWP of 1.13 kg CO_2-eq/kg CAN. Fertilizers Europe will publish updated average figures by the end of 2011. The LCI of CAN and KCl are peer-reviewed and for a large part based on primary data, and therefore, of higher data quality than the LCI of RPR. When comparing the GHG emissions of KCl with that of a previous summary of fertilisers in 2008 [17], it shows an increase of 43%. This new LCI is based on recent mainly primary EU-25 data as an average for a range of plants, instead of relatively old published data for an ‘efficient’ plant in the previous study. It is recommended to use the new figures.

5.1 Reviewing process

The datasets and report were reviewed by Prof Dr Brent Clothier, Dr Markus Deurer, and Dr Karin Müller from Plant & Food Research, New Zealand.

The reviewers had the task to assess whether

- the methods used to carry out the LCA follow the international standards ISO 14040 and ISO 14044,

- the methods used to carry out the LCA are scientifically and technically valid and correspond to the state of the art,

- the data used are appropriate and reasonable in relation to the goal of the project,

- the documentation is transparent and consistent.

The review was carried out according to guideline ISO 14044. The three reviewers read the report as well as the ILCD datasets, and in relation to the four points listed above, they provided suggestions. This was followed by a video-conference to discuss how suggestions made by the reviewers had been integrated in the report.

In conclusion, the reviewers found

-that the study on the LCI on greenhouse gas emissions of three imported fertilisers used in New Zealand followed both ISO14040 and 14044.

- that the approaches adopted by AgResearch were indeed scientifically and technically valid.

- that because of AgResearch's good relationship with the NZ fertiliser industry the data were of the highest quality possible. For example, the LCI for the manufacturing of two of the fertilisers (CAN and KCl) were provided in ILCD format by the industry.

- that the report was well written with the rationale and assumptions clearly set out.

Moreover, the report provides additional insight into the lessons learned, and highlights several issues that were encountered, and these will guide approaches that can be adopted for future work.

An earlier version of the datasets and report were also reviewed by Andrew Barber from AgriLINK. The reviewer found minor grammar mistakes, which were already improved in report version 1.0. He also recommended comparing results of KCl with a former study of 2008, which was entered in the interpretation section (5). He also recommended disaggregating the results into different life cycle stages, which was done in Table 4. Another comment was that the dataset excludes field emissions from fertiliser use, which should be made clearer. Therefore, sentences were added in the summary, introduction, section 5, and datasets.

5.2 Lessons learnt and issues encountered

- Thanks to the willingness of the main NZ fertiliser companies we were able to perform these analyses. Detailed information on countries of origin, however, could not be released due to confidentiality issues.
- Although for CAN and KCl ILCD datasets were already available, we were at this stage unable to import the ILCD datasets into the LCA software Simapro. The modelling phase therefore implied more work than thought in advance.
- Our first choice was to make an LCI of the imported P fertiliser TSP. However, because the sulphur allocation issue turned out not to be solved yet, we made an inventory for RPR instead.
- We encountered difficulties when using the relatively new software Open LCA Framework, which was necessary to convert datasets from Simapro into ILCD.
- In future LCA studies of NZ farming systems, besides GWP, other environmental impacts such as eutrophication and energy use should be considered as well as related environmental impacts from the application of fertilisers.
- A part of kiwifruit related GHG emissions comes from lime and other fertilisers as urea, DAP, SSP, and TSP. It is recommended, therefore, to compile an LCI dataset on production and transport of lime and other fertilisers in follow-up research.

6. Acknowledgements

We thank Fertilisers Europe, and especially Dr Frank Brentrup for making available the datasets for CAN and KCl. We also thank Ballance Agri-nutrients and Ravensdown staff for provision of data and advice on the project. In particular, we thank Terry Smith (Ballance) and Murray Mackenzie (Ravensdown) for valuable discussions and provision of specific data.

7. References

[1] Basset-Mens, C., Boyes, M., Ledgard, S.F., 2009. Eco-efficiency of intensification scenarios for milk production in New Zealand. Ecological Economics (68) 1615-1625

[2] McDevitt J, Ledgard S, Lieffering M, Boyes M and Kemp R 2009 Lamb greenhouse gas footprinting project. Report to MAF. AgResearch, Hamilton.

[3] Mithraratne, N., McLaren, S. and Barber, A. 2008 Carbon footprinting for the kiwifruit supply chain: methodology and scoping study. Report to MAF. Landcare Research, NZ. 72p.

[4] Ledgard, S. F., Boyes, M., and Brentrup, F., 2011. Life cycle assessment of local and imported fertilisers used on New Zealand farms. In: 'Adding to the knowledge base for the nutrient manager'. (Eds Currie LD, Christensen CL). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24, Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 13p

[5] Brentrup F and Palliere C 2008 GHG Emissions and Energy Efficiency in European Nitrogen Fertiliser Production and Use. Proceedings No: 639. IFS (International Fertiliser Society), York, UK. 1-28.

[6] European Fertilizer Manufacturers Association (EFMA): Best Available Technologies for Pollution Prevention and Control in the European Fertilizer Industry, Booklet No. 1 of 8: Production of Ammonia, EFMA, Brussels / Belgium, 2000

[7] European Fertilizer Manufacturers Association (EFMA): Best Available Technologies for Pollution Prevention and Control in the European Fertilizer Industry, Booklet No. 2 of 8: Production of Nitric Acid, EFMA, Brussels / Belgium, 2000

[8] European Fertilizer Manufacturers Association (EFMA): Best Available Technologies for Pollution Prevention and Control in the European Fertilizer Industry, Booklet No. 5 of 8: Production of Urea and Urea Ammonium Nitrate, EFMA, Brussels / Belgium, 2000

[9] J. Davis, C. Haglund: Life Cycle Inventory (LCI) of Fertiliser Production - Fertiliser Products Used in Sweden and Western Europe, the Swedish Institute for Food and Biotechnology, Gothenburg / Sweden, 1999

[10] European Fertilizer Manufacturers Association (EFMA): Average Emissions Year 2006, EFMA Emission Benchmark, Brussels / Belgium, 2006

[11] European Commission, Joint Research Centre - Institute for Environment and Sustainability and DG Environment - Directorate G (2008): European Reference Life Cycle Database, version 2.0. http://lca.jrc.ec.europa.eu

[12] Althaus, H.-J., Chudacoff, M., Hischier, T., Jungbluth, N., Osses, M., Primas, A., 2007. Life Cycle Inventories of Chemicals. Final report ecoinvent data v2.0 No.8. EMPA, Swiss Centre for Life Cycle Inventories. Dübendorf

[13] Rajan, S.S.S., Brown, M.W., Boyes, M.K., Upsdell, M.K., 1992., Extractable phosphorus to predict agronomic effectiveness of ground and unground phosphate rocks. Fertilizer Research (32), 291-302.

[14] Spielmann, M., Bauer, C., Dones, R., Tuchschmid, M., 2007. Transport Services. Ecoinvent report No.14 Swiss centre for Life Cycle Inventories . Dübendorf

[15] www.searates.com

[16] Intergovernmental Panel on Climate Change (IPCC), 2007. IPCC Fourth Assessment Report. The Physical Science Basis. http://ipcc.ch/ipccreports/ar4-wg1.htm

[17] Ledgard, S. F., Boyes, M., 2008. Fertiliser data for MAF GHG footprint projects. report prepared for MAF. AgResearch, Hamilton, New Zealand

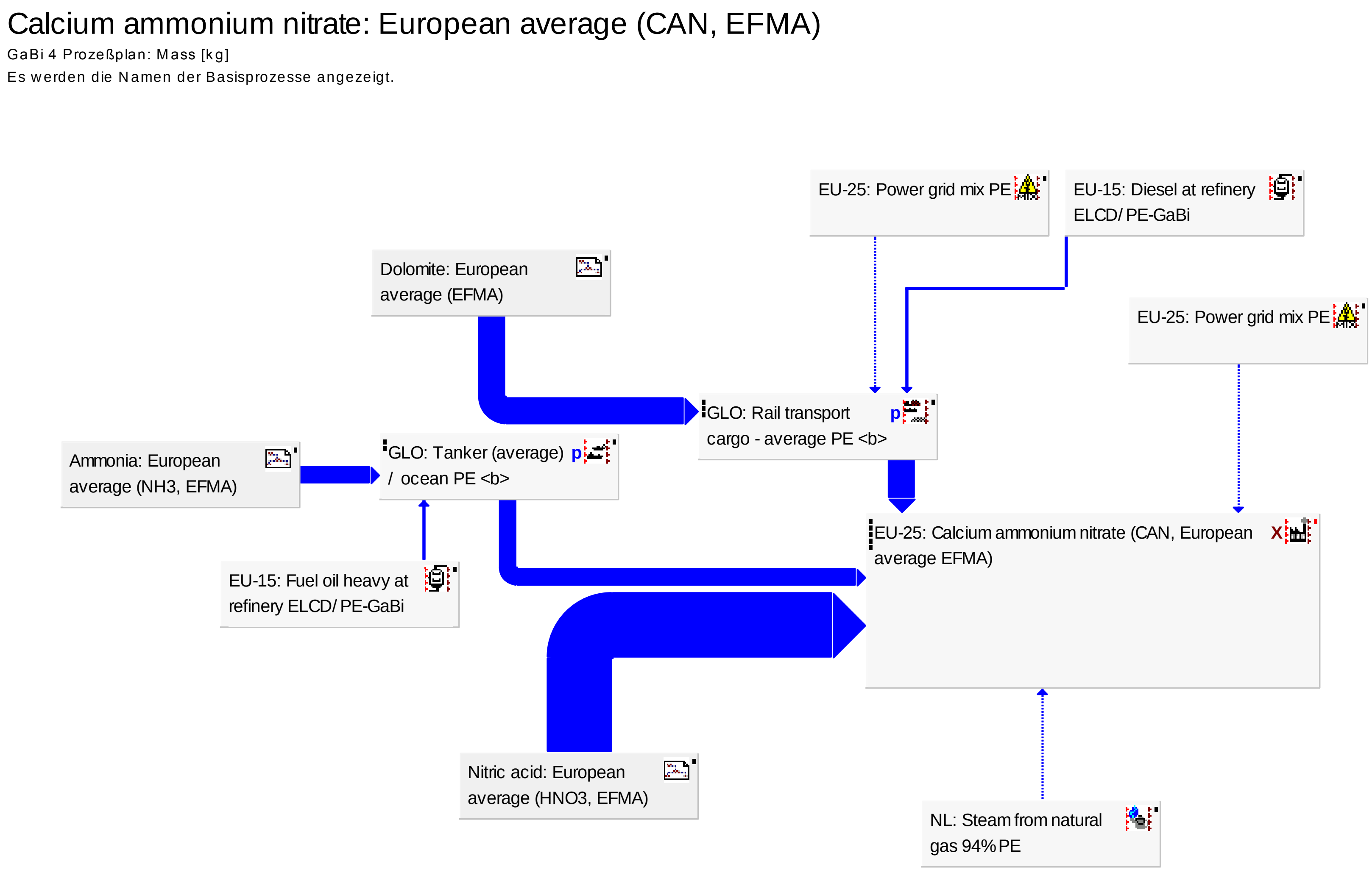

Figure 1 Overview of the relevant unit processesof CAN from cradle-to-manufacturing-gateas defined by Fertilizers Europe (former EFMA) [10]
GLO= Global
NL=the Netherlands

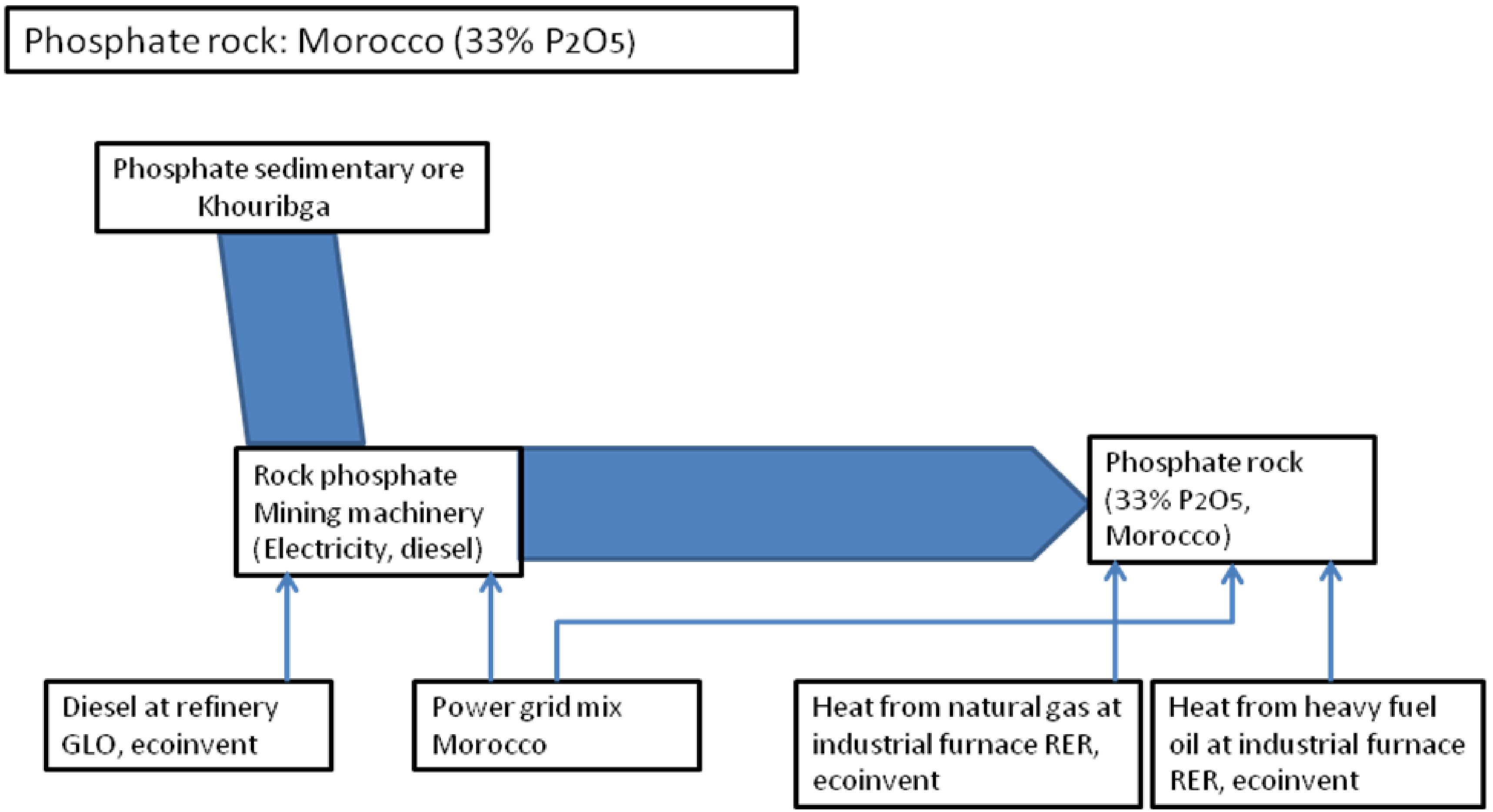

Figure 2 Overview of the relevant processes of reactive phosphate rock (RPR) from cradle-to-manufacturing -gate RER=Rest of Europe GLO=Global

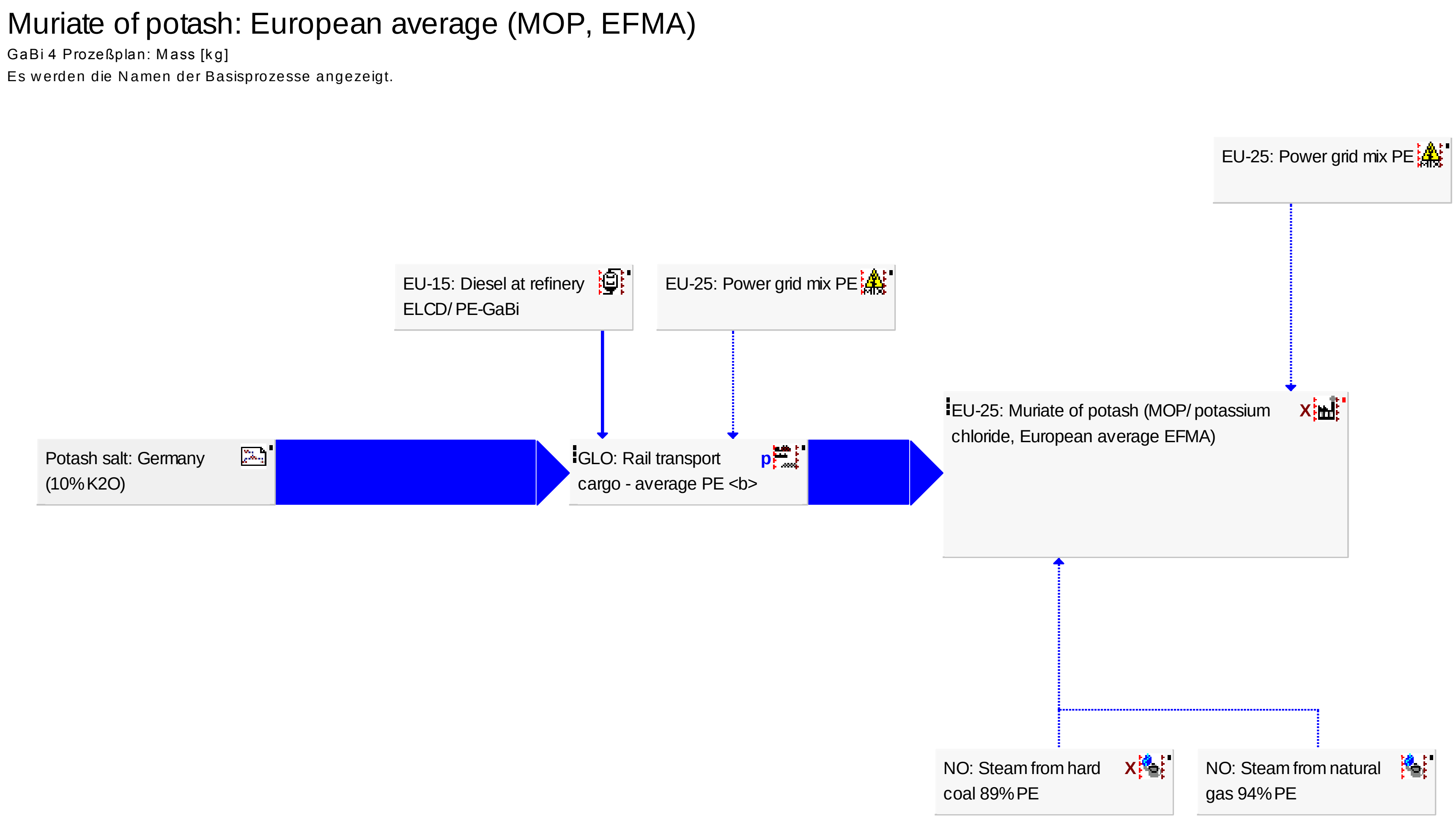

Figure 3 Overview of the relevant unit processes of KCl from cradle-to-manufacturing-gateas defined by Fertilizers Europe (former EFMA)[10]
MOP=Muriate of potash=KCl
GLO= Global
NO=Norway

Table 1 Cradle-to-regional NZ storage green house gas LCI of the imported fertiliser calcium ammonium nitrate (CAN)

Chemical flow	**Input/Output**	**kg/kg CAN**
Carbon dioxide	Input	3.43E-04
Carbon, in organic matter, in soil	Input	7.07E-08
Carbon dioxide	Output	6.60E-01
Carbon dioxide, fossil	Output	2.17E-01
Carbon dioxide, land transformation	Output	1.39E-06
Carbon monoxide	Output	1.27E-04
Carbon monooxide, fossil	Output	4.79E-04
Chloroform	Output	8.39E-12
Nitrous oxide (Dinitrogen monoxide)	Output	3.21E-03
Ethane, 1,2-dichloro-	Output	4.27E-10
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Output	4.74E-08
Ethane, 1,1,1-trichloro-, HCFC-140	Output	2.96E-14
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Output	2.62E-13
Ethane, 1,1-difluoro-, HFC-152a	Output	8.26E-12
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Output	9.23E-09
Ethane, hexafluoro-, HFC-116	Output	3.37E-10
Methane	Output	1.65E-03
Methane, biogenic	Output	5.07E-07
Methane, bromo-, Halon 1001	Output	2.04E-19
Methane, bromochlorodifluoro-, Halon 1211	Output	6.34E-11
Methane, bromotrifluoro-, Halon 1301	Output	2.32E-09
Methane, chlorodifluoro-, HCFC-22	Output	2.37E-09
Methane, chlorotrifluoro-, CFC-13	Output	1.20E-09
Methane, dichloro-, HCC-30	Output	7.93E-13
Methane, dichlorodifluoro-, CFC-12	Output	1.91E-09
Methane, dichlorofluoro-, HCFC-21	Output	1.82E-15
Methane, fossil	Output	1.39E-04
Methane, monochloro-, R-40	Output	8.08E-13
Methane, tetrachloro-, CFC-10	Output	4.09E-11
Methane, tetrafluoro-, CFC-14	Output	2.87E-09
Methane, trichlorofluoro-, CFC-11	Output	8.90E-09
Methane, trifluoro-, HFC-23	Output	5.81E-13
NMVOC, non-methane volatile organic compounds	Output	2.60E-04
Sulfur hexafluoride	Output	1.18E-09
VOC, volatile organic compounds	Output	6.78E-07

Table 2 Cradle-to-regional NZ storage green house gas LCI of the imported fertiliser reactive phosphate rock (RPR)

Chemical flow	Input/Output	kg/kg RPR
Carbon dioxide	Input	2.33E-04
Carbon, in organic matter, in soil	Input	7.32E-08
Carbon dioxide	Output	3.28E-02
Carbon dioxide, fossil	Output	2.30E-01
Carbon dioxide, land transformation	Output	1.15E-06
Carbon monoxide	Output	9.01E-06
Carbon monooxide, fossil	Output	4.65E-04
Chloroform	Output	6.83E-12
Nitrous oxide (Dinitrogen monoxide)	Output	5.85E-06
Ethane, 1,2-dichloro-	Output	4.39E-10
Ethane, 1,1-difluoro-, HFC-152a	Output	5.36E-12
Ethane, 1,1,1-trichloro-, HCFC-140	Output	2.05E-14
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Output	4.10E-08
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Output	2.29E-13
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Output	1.63E-10
Ethane, hexafluoro-, HFC-116	Output	3.18E-10
Methane	Output	8.66E-05
Methane, biogenic	Output	3.40E-07
Methane, bromo-, Halon 1001	Output	1.82E-19
Methane, bromochlorodifluoro-, Halon 1211	Output	3.59E-10
Methane, bromotrifluoro-, Halon 1301	Output	2.44E-09
Methane, chlorodifluoro-, HCFC-22	Output	1.27E-09
Methane, chlorotrifluoro-, CFC-13	Output	4.16E-13
Methane, dichloro-, HCC-30	Output	2.07E-11
Methane, dichlorodifluoro-, CFC-12	Output	2.70E-12
Methane, dichlorofluoro-, HCFC-21	Output	1.66E-10
Methane, fossil	Output	1.64E-04
Methane, monochloro-, R-40	Output	5.63E-13
Methane, tetrachloro-, CFC-10	Output	4.54E-11
Methane, tetrafluoro-, CFC-14	Output	2.50E-09
Methane, tetrafluoro-, FC-14	Output	2.18E-10
Methane, trichlorofluoro-, CFC-11	Output	3.08E-12
Methane, trifluoro-, HFC-23	Output	4.98E-13
NMVOC, non-methane volatile organic compounds	Output	2.29E-04
Sulfur hexafluoride	Output	8.84E-10

Table 3 Cradle-to-regional NZ storage green house gas LCI of the imported fertiliser muriate of potash (KCl)

Chemical flow	Input/output	kg/kg KCl
Carbon dioxide	Input	1.34E-03
Carbon, in organic matter, in soil	Input	5.43E-08
Carbon dioxide	Output	3.51E-01
Carbon dioxide, fossil	Output	1.89E-01
Carbon dioxide, land transformation	Output	3.62E-06
Carbon monoxide	Output	4.06E-04
Carbon monooxide, fossil	Output	3.87E-04
Chloroform	Output	1.73E-11
Nitrous oxide (Dinitrogen monoxide)	Output	1.23E-05
Ethane, 1,2-dichloro-	Output	3.88E-10
Ethane, 1,1-difluoro-, HFC-152a	Output	3.44E-11
Ethane, 1,1,1-trichloro-, HCFC-140	Output	1.05E-13
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Output	4.17E-08
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Output	2.31E-13
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Output	1.17E-08
Ethane, hexafluoro-, HFC-116	Output	3.50E-10
Methane	Output	4.41E-04
Methane, biogenic	Output	2.03E-06
Methane, bromo-, Halon 1001	Output	1.82E-19
Methane, bromochlorodifluoro-, Halon 1211	Output	2.09E-10
Methane, bromotrifluoro-, Halon 1301	Output	1.70E-09
Methane, chlorodifluoro-, HCFC-22	Output	3.58E-09
Methane, chlorotrifluoro-, CFC-13	Output	1.48E-09
Methane, dichloro-, HCC-30	Output	2.14E-12
Methane, dichlorodifluoro-, CFC-12	Output	2.35E-09
Methane, dichlorofluoro-, HCFC-21	Output	1.98E-15
Methane, fossil	Output	1.61E-04
Methane, monochloro-, R-40	Output	2.83E-12
Methane, tetrachloro-, CFC-10	Output	3.86E-11
Methane, tetrafluoro-, CFC-14	Output	3.00E-09
Methane, trichlorofluoro-, CFC-11	Output	1.09E-08
Methane, trifluoro-, HFC-23	Output	6.29E-13
NMVOC, non-methane volatile organic compounds	Output	2.55E-04
Sulfur hexafluoride	Output	3.94E-09
VOC, volatile organic compounds	Output	1.49E-06

Table 4 Global Warming Potential (GWP) of the imported fertilisers calcium ammonium nitrate (CAN), reactive phosphate rock (RPR), and muriate of potash (KCl) using IPCC 2007 characterisation factors [16]. Field emissions from fertiliser use are excluded in the datasets.

Fertiliser		GWP100 in CO_2-eq/kg fertiliser	GWP100 in CO_2-eq/kg nutrient (N/P/K)
CAN	**- Total**	1.88	7.09
	- Cradle-to-manufacturing gate	1.66	6.26
	-Transport[1]	0.22	0.84
RPR	**- Total**	0.27	1.86
	- Cradle-to-manufacturing gate	0.069	0.47
	-Transport[1]	0.202	1.39
KCl	**- Total**	0.56	1.12
	- Cradle-to-manufacturing gate	0.37	0.73
	-Transport[1]	0.19	0.39

[1] Including overseas transport

Table 5 List of assumptions made for the GHG inventory of the imported fertilisers calcium ammonium nitrate (CAN), reactive phosphate rock (RPR), and muriate of potash (KCl), and related transport.

Fertiliser	Assumptions
CAN	For one country, it was assumed the plant was near the port, so no freight train transport was accounted for.
RPR	The inventory for dry-rock phosphate rock (33% P_2O_5) average Morocco given in ecoinvent is similar to Khouribga phosphate rock (33.2% P_2O_5).
KCl	A certain amount of imported KCl came from Canada. The EU-25 based LCI, however, was used both for KCl imported from Canada as well as KCl imported from Europe.
Transport	It was assumed one NZ fertiliser company imported to the port on the North Island, while the other NZ fertiliser company imported to the port on the South Island. Subsequently, it was assumed only the fertilisers imported to the North Island were transported to the regional storage in Te Puke, while only the fertilisers imported to the South Island were transported to the regional storage in Nelson. Data for the transoceanic freight ship (50,000 dwt) and data of the EURO 3 vehicle from ecoinvent were used.