CREEA - Compiling and Refining Environmental and Economic Accounts

D3.4

Updated and improved data on water consumption / use imported into the EXIOBASE in the required sectoral (dis)aggregation

Authors:
Stephan Lutter (SERI)
Mesfin Mekkonnen (TUT)
Catherine Raptis (ETH Zurich)

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About CREEA

The main goal of CREEA is to refine and elaborate economic and environmental accounting principles as discussed in the London Group and consolidated in the future SEEA 2012, to test them in practical data gathering, to troubleshoot and refine approaches, and show added value of having such harmonized data available via case studies. This will be done in priority areas mentioned in the call, i.e. waste and resources, water, forest and climate change / Kyoto accounting. In this, the project will include work and experiences from major previous projects focused on developing harmonized data sets for integrated economic and environmental accounting (most notably EXIOPOL, FORWAST and a series of EUROSTAT projects in Environmental Accounting). Most data gathered in CREEA will be consolidated in the form of Environmentally Extended Supply and Use tables (EE SUT) and update and expand the EXIOPOL database. In this way, CREEA will produce a global Multi-Regional EE SUT with a unique detail of 130 sectors and products, 30 emissions, 80 resources, and 43 countries plus a rest of world. A unique contribution of CREEA is that also SUT in physical terms will be created. Partners are:

1. Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek (TNO), Netherlands (co-ordinator)
2. JRC -Joint Research Centre- European Commission (DG JRC IPTS), Belgium /Spain
3. Universiteit Leiden (Unileiden), Netherlands
4. Centraal Bureau voor de Statistiek (CBS), Netherlands
5. Norges Teknisk-Naturvitenskapelige Universitet (NTNU), Norway
6. Statistiska Centralbyran (SCB), Sweden
7. Universiteit Twente (TU Twente), Netherlands
8. Eidgenössische Technische Hochschule Zürich (ETH) Switzerland
9. 2.-0 LCA Consultants Aps (2.-0 LCA), Denmark
10. Wuppertal Institut Fur Klima, Umwelt, Energie Gmbh. (WI), Germany
11. SERI - Nachhaltigkeitsforschungs Und –Kommunikations Gmbh (SERI) Austria
12. European Forest Institute (EFI), Finland / Spain

For more information contact the co-ordinator at: arnold.tukker@tno.nl

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Executive Summary

One of the purposes of work package 3 was to improve the water data coverage of the current EXIOBASE (Task 3.4). So far, only modelled data has been used for estimating the water use/consumption of the different sectors. Therefore, the results stemming from the earlier sub-tasks have been used to screen existing databases for the necessary data and to compile the available data in the sectoral (dis)aggregation necessary for the import into the EXIOBASE. Among the different data sources screened were national statistical data, international databases such as Eurostat or AQUASTAT or modelled data such as the data produced with the LPJmL model (Flörke et al., 2013; Rost et al., 2008). The compiled data is then used as a special category of environmental extension to the IO-framework established in the EXIOBASE (compare D7.2). It thus allows for the analysis of different economic activities with regard to their impact on the available water resources.

1 Introduction

The integration of economic data and data on water appropriation within a single framework allows illustrating the interaction between the economy and the environment and helps identifying appropriate measures for the so-called "hot spots" – e.g. sectors with especially high water intensity. In the case of the EXIOBASE this integration is done via the environmental extension water use – a set of country and sector specific data on water use/consumption.

When compiling such a set of data various aspects have to be born in mind: (1) water use vs. water consumption, (2) temporal and geographical disaggregation, and (3) sectoral disaggregation. Taking into account all of these aspects would ensure the most comprehensive set of water extensions. However, despite the importance of the natural resource water, data availability and quality is strikingly restricted.

As a consequence, until the CREEA project the EXIOBASE has contained the following data on water appropriation:

- Green water consumption in agriculture
- Blue water use and water consumption in a limited number of industrial sectors
- Blue water use in livestock husbandry

Hence, the aim of Task 3.4 was to update these data to the new base year 2007 (old base year: 2000) and to review existing datasets for availability of more comprehensive data or data of better quality. While research on water accounting methodologies has increased in the past years, it still seems that data availability is restrained. The fact that Eurostat is about to make comprehensive water accounting obligatory (developing new reporting procedures) and that the UN System of Environmental-Economic accounting for water (SEEA-W; United Nations, 2007) is more and more applied and its used trained makes accountants hope that the data situation will improve in the coming years.

The present report describes the actions undertaken and work done in Task 3.4, in order to come up with a water dataset for the EXIOBASE. Thereby, the focus of the descriptions was set on different aspects according to the dataset described:

In the case of water use and consumption in the manufacturing, electricity producing and livestock sectors a lot of data manipulation had to be done to prepare the original data for the import into the EXIOBASE. On the other hand, in terms of methodology of the compilation of the original data little has changed since the EXIOPOL project, so we refer to scientific publications where the water model is described.

For the data on water consumption in agriculture and N/P emissions to water we use data from the Water Footprint dataset. Here, the methodology is also described very extensively in literature and the aggregation to the EXIOBASE level of detail is relatively straight forward. Hence, we provide a more general description of the methodology as well as of the manipulation of the data for integration into the EXIOBASE.

Finally, in the case of thermal emissions we provide a more extensive description of the methodology, as this approach is relatively new and at the research edge in this area. Calculation details are provided and finally also the aggregation details for the EXIOBASE import are described.

2 Review of existing data sets for water use/consumption

2.1 Selection of criteria and data sources

The first step for updating and – possibly – enlarging the data on water use and consumption used as extensions in the EXIOBASE was to perform an inventarisation of available data sources on water use and consumption disaggregated by economic activities. This process, carried out under the lead of SERI and with contribution of CBS, UTwente and ETH benefitted from the large expertise of the team where everybody is familiar with a large number of data sources and knows the strengths and weaknesses of the different sources from practical work. First, the team compiled a list of criteria following which the different data sources should be evaluated. This list followed the different important aspects of water appropriation as identified in the works in Task 3.4:

- Type of water (blue/green/grey)
- Type of flow (use/consumption)
- Temporal coverage
- Spatial coverage
- Sectoral coverage

In the next step a list of data sources to be evaluated was set up and the responsibilities for review distributed among the partners:

- Eurostat Water Statistics (EUROSTAT, 2013)
- EEA Waterbase - Water Quantity (EEA, 2013)
- UN AquaSTAT database (FAO, 2013)
- UN Water Statistics (UN Water, 2013)
- OECD Water statistics (OECD, 2013)
- Water Footprint dataset (Mekonnen and Hoekstra, 2011)
- LpJmL model data (Rost et al., 2008)
- WaterGAP model data (Alcamo et al., 2003)
- Ecoinvent database (Swiss Center for LCI, 2009)
- ETH data
- Global Crop Water Model (Siebert and Döll, 2008)

2.2 Results of data sources review

2.2.1 Type of water (blue/green/grey)

In the course of the review it became apparent that none of the official statistics, such as Eurostat or the EEA contains data on green or grey water. This is due to the fact that (1) green water quantities are generally modelled and (2) such data are yet not part of the questionnaires sent out. However, especially in the case of

Eurostat the aim is to integrate green water quantities in future questionnaires and, in case an NSI (National Statistical Institution) is not able to fill these cells, to fill the cells with modelled data.
Datasets like the water footprint data, LpJmL or ETH data do encompass blue and green data; hence, for the requirements of the EXIOBASE, the team opted for the usage of modelled green water data – which is relevant especially in the agricultural sector.

2.2.2 Type of flow (use/consumption)

In this category a similar picture was painted: Official statistics present only data on water use. However, also in this regard Eurostat plans to go one step further in the future by integrating calculations of water consumption in different sectors. This will be done on the basis of a physical input-output approach, where for each sector inflows and outflows of water can be quantified and retrieved for the calculation of water consumption values.
With regard to the EXIOBASE it became apparent that for the agricultural sub-sectors only consumption data are available, while for the manufacturing sectors and the domestic sector also use and consumption values can be retrieved.

2.2.3 Temporal coverage

All the reviewed data sources cover the base year (2007); however, some only as average values of specific periods (e.g. AquaSTAT for 5-year periods).

2.2.4 Spatial coverage

In this category, it was clear that European data sources would only be able to cover the European part of the CREEA countries. However, the models in use for the EXIOBASE are mostly based on a grid basis which can be aggregated to the level of detail needed. Hence, coverage of all the relevant CREEA countries is not a problem.

2.2.5 Sectoral coverage

In general, the level of disaggregation of data on water use/consumption regarding product or sector classification is one of the major problems water accountants face. This does not hold true for all the products/sectors though: Modelled data for water consumption in agriculture is normally very detailed (on the plant level) and has to be aggregated to fit to classifications like the EXIOBASE classification. Data for the manufacturing industry, with its large number of sub-sectors and-products in the CREEA classification, is hard to find, however. Here the waterGAP (Alcamo et al., 2003) model offered a disaggregation into 6 groups of manufactured products. However, in the newer version this disaggregation is not applied anymore (Flörke et al., 2013). Still, for the EXIOBASE purposes we decided to use the disaggregation shares as an indication.

2.2.6 Conclusion

The review of existing datasets showed that international water statistics still lack level of detail (See Annex 1 for detailed evaluation). For the application in an EE-MRIO system one is hence forced to use modelled data. Also here, there is still potential with regard to further disaggregation. However, efforts are remarkable. As a consequence, for the EXIOBASE the team had to opt for maintenance of the hitherto used level of disaggregation. Having said this, in the course of WP 8 (Case studies) further options to integrate global data will be examined.

3 Data compilation

The present report describes the actions undertaken and work done in Task 3.4, in order to come up with a water dataset for the EXIOBASE. Thereby, the focus of the descriptions was set on different aspects according to the dataset described:
In the case of water use and consumption in the manufacturing, electricity producing and livestock sectors a lot of data manipulation had to be done to prepare the original data for the import into the EXIOBASE. On the other hand, in terms of methodology of the compilation of the original data little has changed since the EXIOPOL project, so we refer to scientific publications where the water model is described.
For the data on water consumption in agriculture and N/P emissions to water we use data from the Water Footprint dataset. Here, the methodology is also described very extensively in literature and the aggregation to the EXIOBASE level of detail is relatively straight forward. Hence, we provide a more general description of the methodology as well as of the manipulation of the data for integration into the EXIOBASE.
Finally, in the case of thermal emissions we provide a more extensive description of the methodology, as this approach is relatively new and at the research edge in this area. Calculation details are provided and finally also the aggregation details for the EXIOBASE import are described.

3.1 Industrial water use/consumption in manufacturing, livestock, thermal electricity production and the domestic sector

For the EXIOBASE extensions we retrieved data on water use/consumption from the WaterGAP model which was designed to estimate current and future water withdrawals and consumption of the domestic, industrial, and agricultural sectors. While detailed methodological and model descriptions can be found in earlier deliverables for the EXIOPOL project (Lutter and Giljum, 2009) as well as in Flörke et al. (2013) and Alcamo et al. (2003), in the following description we want to focus on the preparation of the data to be used as extensions in the EXIOBASE.

For the use in the EXIOBASE data for the following sectors were used from the WaterGAP model:

- Livestock sector
- Manufacturing sector
- Thermal electricity production sector
- Domestic sector

These data were already delivered aggregated to the different EXIOBASE countries and country groups.

3.1.1 Livestock sector

For this sector the data delivered encompassed blue water use in mio m^3 for the following livestock categories:

- Dairy cattle
- Non-dairy cattle
- Pigs
- Sheep
- Goats
- Buffaloes
- Camels
- Horses
- Chicken
- Turkeys
- Ducks
- Geeses
- total livestock

These data had to be aggregated to the CREEA product classes:

Table 3.1.1a: Allocation of WaterGAP categories to EXIOBASE products

WaterGAP category	**EXIOBASE product name**	**EXIOBASE product code1**	**EXIOBASE product code2**
Dairy cattle	Cattle	p01.i	C_CATL
Non-dairy cattle	Cattle	p01.i	C_CATL
Pigs	Pigs	p01.j	C_PIGS
Sheep	Meat animals nec	p01.l	C_OMEA
Goats	Meat animals nec	p01.l	C_OMEA
Buffaloes	Meat animals nec	p01.l	C_OMEA
Camels	Meat animals nec	p01.l	C_OMEA
Horses	Meat animals nec	p01.l	C_OMEA
Chicken	Poultry	p01.k	C_PLTR
Turkeys	Poultry	p01.k	C_PLTR
Ducks	Poultry	p01.k	C_PLTR
Geese	Poultry	p01.k	C_PLTR

Finally, the different WaterGAP categories were allocated to the specific extension names and codes:

Table 3.1.1b: Allocation of WaterGAP categories to EXIOBASE extenions

WaterGAP category	**EXIOBASE extension name**	**EXIOBASE extension code**
Dairy cattle	Water Consumption Blue - Livestock - dairy cattle	WCB_1.14
Non-dairy cattle	Water Consumption Blue - Livestock - nondairy cattle	WCB_1.15
Pigs	Water Consumption Blue - Livestock - pigs	WCB_1.16
Sheep	Water Consumption Blue - Livestock - sheep	WCB_1.17
Goats	Water Consumption Blue - Livestock - goats	WCB_1.18
Buffaloes	Water Consumption Blue - Livestock - buffaloes	WCB_1.19
Camels	Water Consumption Blue - Livestock - camels	WCB_1.20
Horses	Water Consumption Blue - Livestock - horses	WCB_1.21
Chicken	Water Consumption Blue - Livestock - chicken	WCB_1.22
Turkeys	Water Consumption Blue - Livestock - turkeys	WCB_1.23

Ducks	Water Consumption Blue - Livestock - ducks	WCB_1.24
Geese	Water Consumption Blue - Livestock - geese	WCB_1.25

The final result was a table with the following data detail for every EXIOBASE country (group):

- Country
- Label
- Code
- Year
- Amount
- Product Code 1
- Product Code 2
- Unit

3.1.2 Manufacturing sector

For this sector the data delivered encompassed blue water withdrawals (= water use) as well as water consumption for the manufacturing sector as a whole in mio m^3. In a first step the data were disaggregated into more sector detail using the shares in total water use and consumption of the following sub-sectors from the pre-version of the water gap model:

- Food products, beverages and tobacco
- Textiles and textile products
- Pulp, paper, publishing and printing
- Chemicals, man-made fibres
- Non-metallic, mineral products
- Basic metals and fabrication of metals
- Other manufacturing

Due to the lack of more specific data only one "set of shares" for the total rest of the world was used for the different EXIOBASE rest of the world categories.

In a next step the quantities of water use and consumption in the different sectors were allocated to different product categories according to the physical output data compiled in WP4 (compare D4.2). A rough table shows the allocation:

Table 3.1.2a: Allocation of WaterGAP categories to EXIOBASE products groups

Manufacturing sectors	**EXIOBASE Product groups**
Food products, beverages and tobacco	p15/16
Textiles and textile products	p17/18/19
Pulp, paper, publishing and printing	p21/22
Chemicals, man-made fibres	p24
Non-metallic, mineral products	p26
Basic metals and fabrication of metals	p27
Other manufacturing	p28-36

Finally, the different WaterGAP categories were allocated to the specific extension names and codes:

Table 3.1.2b: Allocation of WaterGAP categories to EXIOBASE extensions

WaterGAP category	EXIOBASE extension name	Extension code
Water Withdrawal food products, beverages and tobacco	Water Withdrawal Blue - Manufacturing - food products, beverages and tobacco	WWB_2.1
Water Withdrawal textiles and textile products	Water Withdrawal Blue - Manufacturing - textiles and textile products	WWB_2.2
Water Withdrawal pulp, paper, publishing and printing	Water Withdrawal Blue - Manufacturing - pulp, paper, publishing and printing	WWB_2.3
Water Withdrawal chemicals, man-made fibres	Water Withdrawal Blue - Manufacturing - chemicals, man-made fibres	WWB_2.4
Water Withdrawal non-metallic, mineral products	Water Withdrawal Blue - Manufacturing - non-metallic, mineral products	WWB_2.5
Water Withdrawal basic metals and fabrication of metals	Water Withdrawal Blue - Manufacturing - basic metals and fabrication of metals	WWB_2.6
Water Withdrawal other manufacturing	Water Withdrawal Blue - Manufacturing - other manufacturing	WWB_2.7
Water Consumption food products, beverages and tobacco	Water Consumption Blue - Manufacturing - food products, beverages and tobacco	WCB_2.1
Water Consumption textiles and textile products	Water Consumption Blue - Manufacturing - textiles and textile products	WCB_2.2
Water Consumption pulp, paper, publishing and printing	Water Consumption Blue - Manufacturing - pulp, paper, publishing and printing	WCB_2.3
Water Consumption chemicals, man-made fibres	Water Consumption Blue - Manufacturing - chemicals, man-made fibres	WCB_2.4
Water Consumption non-	Water Consumption Blue - Manufacturing -	WCB_2.5

metallic, mineral products	non-metallic, mineral products	
Water Consumption basic metals and fabrication of metals	Water Consumption Blue - Manufacturing - basic metals and fabrication of metals	WCB_2.6
Water Consumption other manufacturing	Water Consumption Blue - Manufacturing - other manufacturing	WCB_2.7

The final result was a table with the following data detail for every EXIOBASE country (group):

- Country
- Label
- Code
- Year
- Amount
- Product Code 1
- Product Code 2
- Unit

3.1.3 Thermal electricity production sector

For this sector the data delivered encompassed blue water withdrawals (= water use) as well as water consumption for electricity production with tower cooling and once-through cooling as well as for the electricity production as a whole in mio m^3. In a first step the data were allocated to the different energy products under the assumption of possible water cooling throughout the production process and according to the physical quantities as identified in WP 4 (compare D4.2). The following types of electricity were assumed as being potentially using water cooling:

- Electricity by coal
- Electricity by gas
- Electricity by nuclear
- Electricity by petroleum and other oil derivatives
- Electricity by biomass and waste
- Electricity nec

Please note that in the course of WP 8 (Case Studies) the allocation in the electricity sectos might be adapted according to cross-checks with calculation results.

In the following step product codes and extension codes were allocated:

Table 3.1.3: Allocation of EXIOBASE products to EXIOBASE extensions

EXIOBASE product name	EXIOBASE product code1	EXIOBASE product code1	EXIOBASE extension name	Extension code
Electricity by coal	p40.11.a	C_POWC	Water Withdrawal Blue - Electricity - tower - Electricity by coal	WWB_3.1
Electricity by gas	p40.11.b	C_POWG	Water Withdrawal Blue - Electricity - tower - Electricity by gas	WWB_3.1
Electricity by nuclear	p40.11.c	C_POWN	Water Withdrawal Blue - Electricity - tower - Electricity by nuclear	WWB_3.1
Electricity by petroleum and other oil derivatives	p40.11.f	C_POWP	Water Withdrawal Blue - Electricity - tower - Electricity by petroleum and other oil derivatives	WWB_3.1
Electricity by biomass and waste	p40.11.g	C_POWB	Water Withdrawal Blue - Electricity - tower - Electricity by biomass and waste	WWB_3.1
Electricity nec	p40.11.l	C_POWZ	Water Withdrawal Blue - Electricity - tower - Electricity nec	WWB_3.1
Electricity by gas	p40.11.b	C_POWG	Water Withdrawal Blue - Electricity - once-through - Electricity by gas	WWB_3.2
Electricity by nuclear	p40.11.c	C_POWN	Water Withdrawal Blue - Electricity - once-through - Electricity by nuclear	WWB_3.2
Electricity by petroleum and other oil derivatives	p40.11.f	C_POWP	Water Withdrawal Blue - Electricity – once-through - Electricity by petroleum and other oil derivatives	WWB_3.2
Electricity by biomass and	p40.11.g	C_POWB	Water Withdrawal Blue - Electricity - once-through -	WWB_3.2

waste			Electricity by biomass and waste	
Electricity nec	p40.11.l	C_POWZ	Water Withdrawal Blue - Electricity - once-through - Electricity nec	WWB_3.2
Electricity by coal	p40.11.a	C_POWC	Water Consumption Blue - Electricity - tower - Electricity by coal	WCB_3.1
Electricity by gas	p40.11.b	C_POWG	Water Consumption Blue - Electricity - tower - Electricity by gas	WCB_3.1
Electricity by nuclear	p40.11.c	C_POWN	Water Consumption Blue - Electricity - tower - Electricity by nuclear	WCB_3.1
Electricity by petroleum and other oil derivatives	p40.11.f	C_POWP	Water Consumption Blue - Electricity – tower - Electricity by petroleum and other oil derivatives	WCB_3.1
Electricity by biomass and waste	p40.11.g	C_POWB	Water Consumption Blue - Electricity - tower - Electricity by biomass and waste	WCB_3.1
Electricity nec	p40.11.l	C_POWZ	Water Consumption Blue - Electricity - tower - Electricity nec	WCB_3.1
Electricity by gas	p40.11.b	C_POWG	Water Consumption Blue - Electricity - once-through - Electricity by gas	WCB_3.2
Electricity by nuclear	p40.11.c	C_POWN	Water Consumption Blue - Electricity - once-through - Electricity by nuclear	WCB_3.2
Electricity by petroleum and other oil derivatives	p40.11.f	C_POWP	Water Consumption Blue - Electricity – once-through - Electricity by petroleum and other oil derivatives	WCB_3.2
Electricity by	p40.11.g	C_POWB	Water Consumption Blue -	WCB_3.2

biomass and waste			Electricity - once-through - Electricity by biomass and waste	
Electricity nec	p40.11.l	C_POWZ	Water Consumption Blue - Electricity - once-through - Electricity nec	WCB_3.2

The final result was a table with the following data detail for every EXIOBASE country (group):

- Country
- Label
- Code
- Year
- Amount
- Product Code 1
- Product Code 2
- Unit

3.1.4 Domestic sector

For this sector the data delivered encompassed blue water withdrawals (= water use) as well as water consumption for the domestic sector in mio m³. The only necessary step was to allocate final demand category codes and extension code:

Table 3.1.4: Allocation of WaterGAP categories to EXIOBASE products and EXIOBASE extensions

WaterGAP category	**EXIOBASE final demand code1**	**EXIOBASE final demand code2**	**EXIOBASE extension name**	**Extension code**
Domestic water withdrawal	y01	F_HOUS	Water Withdrawal Blue - Domestic - domestic Water Withdrawal Blue	WWB_4
Domestic water consumption	y01	F_HOUS	Water Consumption Blue - Domestic - domestic Water Consumption Blue	WCB_4

The final result was a table with the following data detail for every EXIOBASE country (group):

- Country
- Label
- Code
- Year
- Amount
- Final demand code 1
- Final demand code 2
- Unit

3.2 Industrial water consumption in agriculture

For the water extensions regarding blue and green water consumption in the agricultural sector Water Footprint data were used (Mekonnen and Hoekstra, 2011). In the following, methodology as well as manipulation procedures are described.

3.2.1 Water Footprint methodology

The global green, blue and grey water footprint of crop production was estimated following the calculation framework of Hoekstra et al. (2011). The computations of crop evapotranspiration and yield, required for the estimation of the green and blue water footprint in crop production, have been done following the method and assumptions provided by Allen et al. (1998) for the case of crop growth under non-optimal conditions. The grid-based dynamic water balance model developed in this study for estimating the crop evapotranspiration and yield computes a daily soil water balance and calculates crop water requirements, actual crop water use (both green and blue) and actual yields. The model is applied at a global scale using a resolution level of 5 by 5 arc minute grid size (about 10 km by 10 km around the Equator) (Mekonnen and Hoekstra, 2010, 2011). We estimated the water footprint of 146 primary crops and more than two hundred derived products. The grid-based water balance model was used to estimate the crop water use for 126 primary crops; for the other 20 crops, which are grown in only few countries, the CROPWAT 8.0 model was used. The steps followed in the calculation framework are schematically shown in Figure 4.2.1.

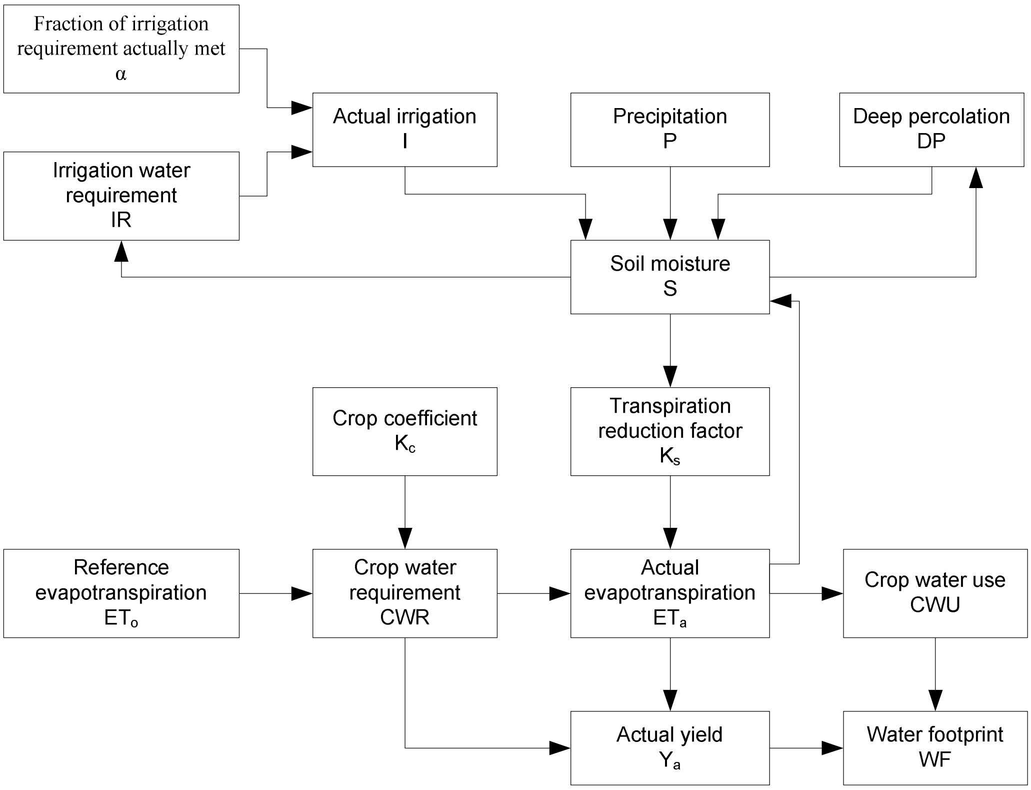

Figure 3.2.1: Simplified representation of the model to calculate the water footprint of a crop.

In the case of rain-fed crop production, blue crop water use is zero and green crop water use (m^3/ha) is calculated by summing up the daily values of ET_a (mm/day) over the length of the growing period. In the case of irrigated crop production, the green and blue water use is calculated by performing two different soil water balance scenarios as proposed in Hoekstra et al. (2011) and also applied by FAO (2005), Siebert and Döll (2010) and Liu and Yang (2010). The first soil water balance scenario is carried out based on the assumption that the soil does not receive any irrigation, but using crop parameters of irrigated crops (such as rooting depth as under irrigation conditions). The second soil water balance scenario is carried out with the assumption that the amount of actual irrigation is sufficient to meet the irrigation requirement, applying the same crop parameters as in the first scenario. The green crop water use of irrigated crops is assumed to be equal to the actual crop evapotranspiration as was calculated in the first scenario. The blue crop water use is then equal to the crop water use over the growing period as simulated in the second scenario minus the green crop water use as estimated in the first scenario.

3.2.2 Water Footprint data sources

Monthly long-term average reference evapotranspiration data at 10 by 10 arc minute resolution were obtained from FAO (2008a). The 10 by 10 arc minute data were converted to 5 by 5 arc minute resolution by assigning the 10 by 10 minute data to each of the four 5 by 5 minute grid cells. Following the CROPWAT approach, the monthly average data were converted to daily values by curve fitting to the monthly average through polynomial interpolation.

Monthly values for precipitation, number of wet days and minimum and maximum temperature for the period 1996-2002 with a spatial resolution of 30 by 30 arc minute were obtained from CRU-TS-2.1 (Mitchell and Jones, 2005). The 30 by 30 arc minute data were assigned to each of the thirty-six 5 by 5 arc minute grid cells contained in the 30 by 30 arc minute grid cell. Daily precipitation values were generated from the monthly average values using the CRU-dGen daily weather generator model (Schuol and Abbaspour, 2007).

Crop growing areas on a 5 by 5 arc minute grid cell resolution were obtained from Monfreda et al. (2008). For countries missing grid data in Monfreda et al. (2008), the MICRA2000 grid database as described in Portmann et al. (2010) was used to fill the gap. The harvested crop areas as available in grid format were aggregated to a national level and scaled to fit national average crop harvest areas for the period 1996-2005 obtained from FAO (2008c).

Grid data on the irrigated fraction of harvested crop areas for 24 major crops were obtained from the MICRA2000 database (Portmann et al., 2010). For the other 102 crops considered in the current study, we used the data for 'other perennial' and 'other annual crops' as in the MICRA2000 database, depending on whether the crop is categorised under 'perennial' or 'annual' crops.

Crop coefficients (Kc's) for crops were obtained from Chapagain and Hoekstra (2004). Crop planting dates and lengths of cropping seasons were obtained from FAO (2008b), Sacks et al. (2010), Portmann et al. (2010) and USDA (1994). For some crops, values from Chapagain and Hoekstra (2004) were used. We have not considered multi-cropping practices. Grid-based data on total available water capacity of the soil (TAWC) at a 5 by 5 arc minute resolution were taken from ISRIC-WISE (Batjes, 2006). An average value of TAWC of the five soil layers was used in the model.

3.2.3 Water Footprint data aggregation and allocation

The green and blue water footprint were done at a detailed country and crop level. We have studied 206 individual countries and 146 crops. On the other hand CREEA's classification provide 43 individual countries and 5 major regions. The crops are further grouped into 8 CREEA product and industry classes. Therefore, the final water footprint data were provided after aligning our detailed level of data to CREEA classification. The alignment of the FAO detailed level country and crop list to CREEA classification is shown in the Annex 2 and 3.

3.3 N/P emissions to water

Data compilation on the nutrient (N and P) emission to water was based on the methodology for the calculation of the grey Water Footprint. In the following we describe method and data.

3.3.1 Method to estimate nutrient (N and P) emission to water

Annual soil nutrient balances include the Nitrogen (N) and Phosphorous (P) inputs and outputs at 5 by 5 arc minute spatial resolution. For nitrogen, there are six inputs elements which include application of artificial fertilizer (INfer) and animal manure (INman), wet and dry atmospheric deposition (INdep), biological N fixation (INfix) and nitrogen input from recycled crop residues (INres). The output in the N balance include N withdrawal from the field through crop harvesting, hay and grass cutting, and grass consumed by grazing animals (OUTharv), nitrogen output from crop residues (OUTres), leaching (OUTlea), gaseous losses (OUTgas) and soil erosion (OUTero). For phosphorous, the same approach was followed, with P inputs being artificial fertilizer, animal manures, sedimentation and recycled crop residues. The output in the P balance include P withdrawal with harvested crop, hay grass cutting, and grass consumed by grazing animals, P withdrawal from crop residues and soil erosion. Figure 4.3.1 shows the main elements of the soil surface N and P balance.

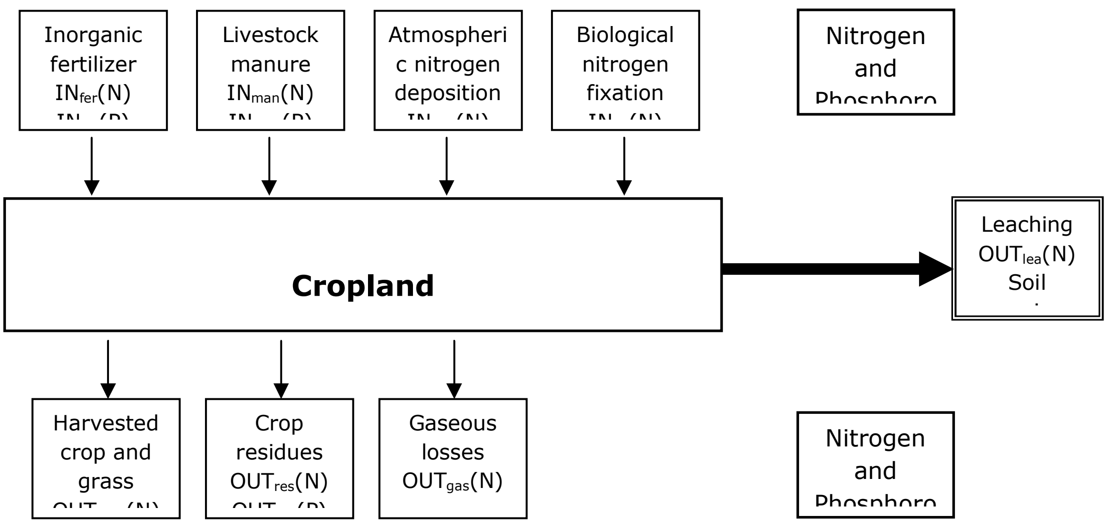

Figure3.3.1: Main elements of the soil N and P balance.

3.3.2 Data to estimate nutrient (N and P) emission to water

Inputs from mineral fertilizers (IN_{fer}):

The fertilizer application rate per crop per country was calculated using three sources of fertilizer data and the spatially explicit data on crop distribution from Monfreda et al. (2008). IFA et al. (2002) provide fertilizer application rate per crop for 88 countries. FAO (2012b) and Heffer (2009) were used to complement data for crops and countries missing from the IFA et al. (2002) data. Since the application rates provided in these data sources is for different years, these were adjusted to fit FAO (2012a) country average nutrient fertilizer consumption per year for the period 2002-2009.

Inputs from animal manures (IN_{man}):

Total manure nutrients (N and P) production within the grazing, mixed and industrial animal production systems for the major livestock categories (cattle, buffaloes, sheep, goats, pigs and poultry) was calculated by multiplying the spatially-explicit global livestock density with animal-specific excretion rates then adjusted for the fraction of manure available for cropland and grassland application (Bouwman et al., 2009; Bouwman et al., 2011; Liu and Yang, 2010; MacDonald et al., 2011). We further estimated the quantity of manure actually applied to crop land.

Inputs from deposition (IN_{dep}):

Atmospheric nitrogen deposition rates (including dry and wet deposition of NHx and NOy) for the year 2000 were taken from Dentener et al. (2006). The 30 arc minute original data were converted to a resolution of 5 arc minute.

Inputs from fixation (IN_{fix}):

Symbiotic relationship between some nitrogen-fixing bacteria and a variety of leguminous plants converts dinitrogen gas (N2) to plant-available forms of N. Some free-living bacteria are also capable of biological N fixation. Following Bouwman et al. (2009), total nitrogen fixation by leguminous crops was estimated by multiplying the N in the harvested product by a factor of two to account for all above and belowground plant parts. Nitrogen fixation by cyanobacteria in irrigated rice ranges from 20 to 30 kg per hectare during the growing seasons (Smil, 1999b). In this study we used an average value of 25 kg of N per hectare. For nonleguminous crops, the nonsymbiotic biological N2 fixation rate is assumed to be 5 kg of N per hectare (Bouwman et al., 2009).

Outputs from harvested crop and grass (OUT_{harv}):

Nutrient (N and P) withdrawal by harvested crops is the most important output of nutrients from the soil system. The N and P withdrawal in the harvested crops is calculated by multiplying the crop production by the nutrient (N and P) content of the crops. Nutrient loss through harvested crop is calculated by aggregating the nutrient withdrawal from each crop harvested and adding the nutrient withdrawal due to grass consumption and harvest.

Outputs from crop residues (OUT_{res}):

Part of the crop residues is removed from cropland and used, for example, as biofuel or for animal feeding. The nutrients withdrawal with crop residue was calculated by multiplying the yield of crop residue by the nutrient content of the crop residue and adjusting this by a removal factor. The nutrient content of the crops and crop residues were taken from Lesschen et al. (2004).

Outputs from gaseous (OUT_{gas}):
Large quantity of nitrogen is lost from animal manures and fertilizers by volatilization of NH3 (Smil, 1999a) and denitrification, NO and N2O emission. We adopted the empirical model of Bouwman et al. (2002a) to calculate ammonia volatilization from the application of animal manure and N fertilizers. We also adopted Bouwman et al. (2002b) empirical models to estimate the NO and N2O emissions.

Finally the quantity of nutrient emission to water is estimated as:

For nitrogen the quantity of nitrogen leached to the water system is the difference of the input and output:

$$Leaching[N] = IN[N] - OUT[N]$$

For phosphorus, following Bouwman et al. (2011) the amount of nutrient emitted to the water system is assumed to be 12.5% of the phosphorus input from of fertilizer and manure application.

3.3.3 Data aggregation and allocation

The estimations of N/P emission to water were done at a detailed country and crop level. We have studied 206 individual countries and 146 crops. On the other hand CREEA's classification provide 43 individual countries and 5 major regions. The crops are further grouped into 8 CREEA product and industry classes. Therefore, the final water footprint data were provided after aligning our detailed level of data to CREEA classification. The alignment of the FAO detailed level country and crop list to CREEA classification is shown in the Annex 2 and 3.

3.4 Thermal emissions

3.4.1 The raw data

Power plant database overview and analysis
The raw data for all calculations of thermal emissions to freshwater from the electricity industry come from the March 2012 version of the commercially available UDI World Electric Power Plants database (WEPP), a comprehensive inventory of electric power generating units with global coverage (Platts, 2012). This database includes key elements of engineering design for over 170,000 power plants worldwide, with a total installed electric capacity of over 10,000,000 MW. The coverage for thermal power plants is > 95% for large units (> 50 MW), except for China, where coverage is estimated to be > 75%. The power plants that are relevant for this analysis in terms of thermal emissions into freshwater

bodies are all the thermal power stations, that is, all the steam driven units, since these require a cooling system. From the (operational) thermal power plants available in the database, the cooling system technology is reported for 74% of the units. This 74% of units contributes 74% of the total gross generating capacity of all steam-driven power plants together.

Power plants included in the calculations:

- Year: all data in the inventory are valid for the year 2012, however the units taken into consideration were the ones that were operational in 2007 (that is, including those which since been taken out of operation), so as to be consistent with the accounting year of the entire CREEA database.
- Only those thermal power plants were considered, for which a cooling system was explicitly identified.
- From these power plants, only those units were retained for which it is explicitly stated that a once-through cooling system is employed (other cooling systems such as cooling towers, or cooling ponds were excluded from the calculations, because the waterborne thermal pollution resulting from these technologies is minimal compared to that from once-through technologies).
- From all units with once-through cooling technologies, those using saline water were excluded (approximately 61% of all units employing a once-through cooling technology), since the sea is considered a heat sink and very local coastal thermal pollution is not considered in this work. The units retained all use either freshwater or brackish water in their cooling systems.

Based on the above a total of 1769 power plants worldwide were retained for further calculations, and their engineering design is described in more detail in the following sections.

Power plant technologies

Table 3.4.1 and Figure 3.4.1 show the distribution of technologies among the 1769 thermal power plants worldwide with a once-through freshwater cooling system that were operational in 2007. The technology of the majority of power plants employ is a straightforward steam turbine, and this group also contributes the most to the total gross generating capacity of all units together (> 90% of the total). The contribution to the total gross generating capacity of the single unit employing an organic Rankine cycle turbine is negligible[1], so this power plant is excluded from further calculations.

[1] And as a consequence, the heat rejected into freshwater is also negligible in comparison.

Table 3.4.1 Summary of technologies and total gross generating capacity of power plants included in the analysis (operational in 2007, with once-through freshwater cooling systems).

Technology	Number of units	Total gross generating capacity (MW)	Approx. % of sum of total gross generating capacity
CCSS Combined-cycle single shaft configuration	6	1.95E+03	0.5
ORC Organic Rankine-cycle turbine	1	3.00E-01	negligible
ST Steam turbine	1476	3.79E+05	91.3
ST/C Steam turbine in combined cycle	92	1.22E+04	2.9
ST/CP Steam turbine in combined cycle CHP (cogeneration)	4	1.96E+02	0.05
ST/S Steam turbine with steam sendout (cogeneration)	190	2.17E+04	5.2
Sum		4.15E+05	

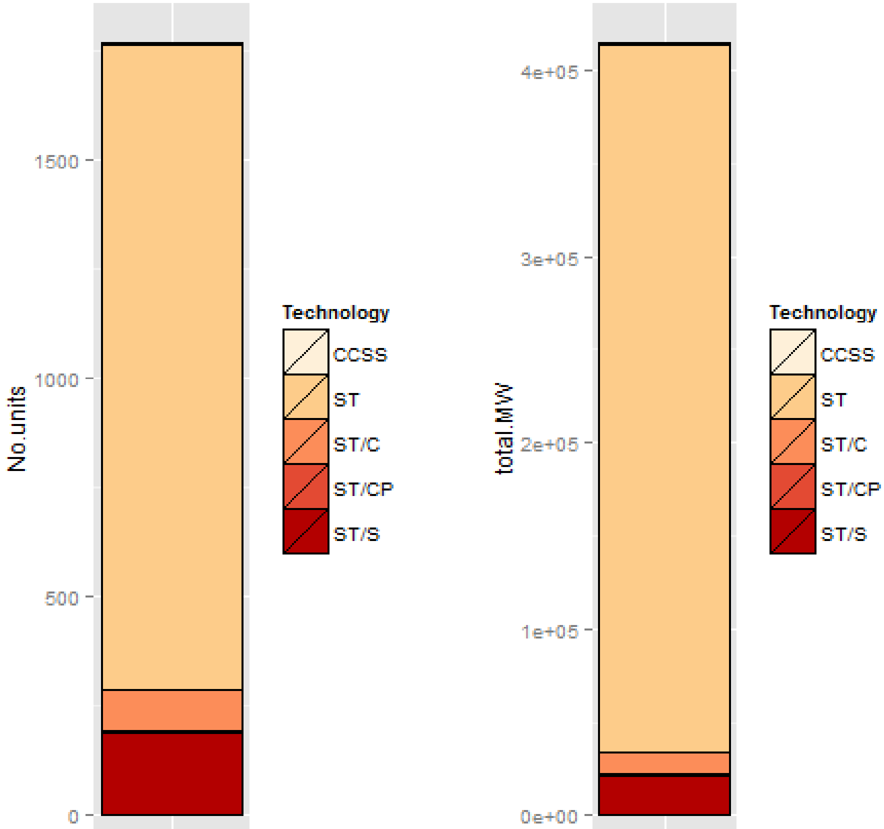

Figure 3.4.1: Left: number of units of thermal power stations per specific technology; Right: total gross electrical generating capacity per specific technology of thermal power station.

3.4.2 Methodology for the calculation of heat rejected to freshwater

The WEPP database provides no explicit information regarding the amount of heat emitted into freshwater bodies via the once-through cooling system. However, the following data are provided:

- Gross generating electrical capacity (W_{gross}, MW)
- Steam pressure at the turbine (p_3, bar)
- Type of steam (subcritical or supercritical)
- Steam temperature at the turbine(T_3, °C)
- Reheat temperature, if applicable (T_{reheat}, °C)

This information, combined with a number of assumptions, permits the estimation of the heat rejected to freshwater via the Rankine cycle, the thermodynamic cycle that describes the performance of steam engines. Given the data available from the WEPP database, the Rankine cycle can be used to predict the efficiency of each power plant, which in turn can be used to predict the amount of heat emitted into freshwater bodies.
The power plants were split into three major categories, depending on the type of Rankine cycle applicable in each case:

- Rankine cycle, subcritical turbine pressure (Figure 3.4.2a).
- Rankine cycle, subcritical turbine pressure, with reheat (Figure 3.4.2b).
- Rankine cycle, supercritical turbine pressure, with reheat (Figure 3.4.2c).

Calculation of thermal efficiency - Rankine cycle, subcritical turbine pressure

Figure 3.4.2a shows the temperature-entropy plot (T-s) for a simple Rankine cycle with superheat. Work (process 1-2) and heat (process 3-4) are provided to the system through the pump and the external heat source (fuel), respectively. The cycle is completed by the production of work at the turbine (process 3-4) and the rejection of heat, in this case to the freshwater body (process 4-1). In an ideal cycle the work produced at the turbine would be isentropic, and the process would follow the line 3-4s, as shown in Figure 3.4.2a. In practice, however, the process is not reversible (there are losses) and is therefore described by the line 3-4. It is assumed in all calculations that follow that pressure drops in the system occur only at the turbine.

The thermal efficiency of the system, η_T, is given by:

$$\eta_T = \frac{(h_3 - h_4) - (h_2 - h_1)}{h_3 - h_2} \qquad \text{Equation 1}$$

where h_1, h_2, h_3 and h_4 are the specific enthalpies at points 1, 2, 3 and 4 of the T-s plot, respectively.

The isentropic efficiency of the steam turbine, η_s , is given by:

$$\eta_s = \frac{h_3 - h_4}{h_3 - h_{4_s}}$$ Equation 2

where h_{4_s} is the specific enthalpy at point 4 of the Rankine cycle under isentropic conditions.

Combining Equations 1 and 2, gives:

$$\eta_T = \frac{\eta_s(h_3 - h_{4_s}) - (h_2 - h_1)}{h_3 - h_2}$$ Equation 3

The elements of Equation 3 are estimated as follows:

- h_1 is found from the temperature table for saturated water, by assuming that the freshwater body temperature is at 15 °C 2. This also allows the estimation of the pressure, p_1, at point 1.
- h_2 is calculated via the following relation: $h_2 - h_1 = \frac{\upsilon_1(p_2 - p_1)}{\eta_{pump}}$, where υ_1 is the specific volume of water at point 1 found from the temperature table for saturated water (by assuming that the freshwater body temperature is at 15 °C), $p_2 = p_3$ (p_3, is given in the database), and η_{pump} is taken to be 0.60 (Balmer, Vapor and Gas Power Cycles).
- h_3 is found from steam tables, using the values for pressure, p_3, and temperature, T_3, at the turbine, which are both given in the database.
- h_{4_s} is found from steam tables, using the entropy calculated at point 3 (isentropic process), and the pressure p_4, which is equal to p_1.
- η_s is taken to be 0.80 (Balmer, 2011), a conservative estimate.

[2] While taking 15 °C to be an average yearly temperature for all freshwater bodies worldwide might appear somewhat crude, in practice, due to the much higher steam temperatures achieved (see Table 3.4.2a), differences on the order of 5-10 °C in the receiving water make little difference in the overall efficiency of the system.

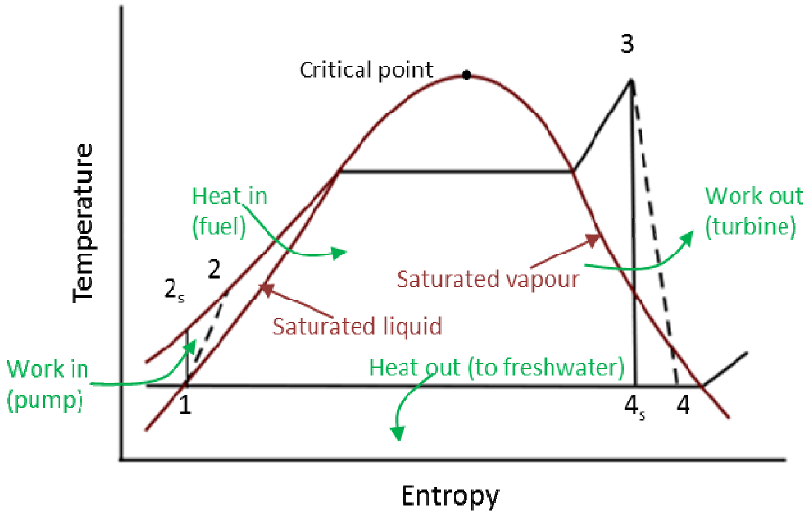

Figure 3.4.2a T-s diagram for the Rankine cycle (subcritical).

Calculation of thermal efficiency - Rankine cycle, subcritical/ supercritical turbine pressure, with reheat

Figures 3.4.2b and 3.4.2c show the T-s plots for the Rankine cycles with reheat, at subcritical and supercritical turbine pressures, respectively. As in the simple Rankine cycle, work (process 1-2) and heat (process 3-4) are provided to the system through the pump and the external heat source (fuel), respectively. Work is given out at the first turbine (process 3-4) after which the temperature of the steam is raised again (process 4-5), allowing for more work to be produced at a second turbine (process 5-6). The cycle is completed by rejecting heat to the freshwater body (process 6-1). It is assumed in all calculations that follow that pressure drops in the system occur only at the turbines.

For both cases (subcritical and supercritical pressure at the turbine), the thermal efficiency of the system, η_T, is given by:

$$\eta_T = \frac{(h_3-h_4)+(h_5-h_6)-(h_2-h_1)}{(h_3-h_2)+(h_5-h_4)} \qquad \text{Equation 4}$$

where h_1, h_2, h_3, h_4 , h_5 and h_6 are the specific enthalpies at points 1, 2, 3, 4, 5 and 6 of the T-s plot, respectively.

The isentropic efficiency of the first steam turbine, η_{s_1}, is given by:

$$\eta_{s_1} = \frac{h_3-h_4}{h_3-h_{4_S}} \qquad \text{Equation 5}$$

where h_{4_s} is the specific enthalpy at point 4 of the Rankine cycle under isentropic conditions.

Similarly, the isentropic efficiency of the second steam turbine η_{s_2}, is given by:

$$\eta_{s_2} = \frac{h_5 - h_6}{h_5 - h_{6_s}}$$ Equation 6

Combining Equations 4, 5 and 6 gives:

$$\eta_T = \frac{\eta_{s_1}(h_3 - h_{4_s}) + \eta_{s_2}(h_5 - h_{6_s}) - (h_2 - h_1)}{(h_3 - h_2) + (h_5 - h_4)}$$ Equation 7

The elements of Equation 7 are estimated as follows:

- h_1 is found from the temperature table for saturated water, by assuming that the freshwater body temperature is at 15 °C. This also allows the estimation of the pressure, p_1, at point 1.
- h_2 is calculated via the following relation: $h_2 - h_1 = \frac{\upsilon_1(p_2 - p_1)}{\eta_{pump}}$, where υ_1 is the specific volume of water at point 1 found from the temperature table for saturated water (by assuming that the freshwater body temperature is at 15 °C), $p_2 = p_3$ (p_3, is given in the database), and η_{pump} is taken to be 0.60 (Balmer, 2011).
- h_3 is found from steam tables, using the values for pressure, p_3, and temperature, T_3, at the first turbine, which are both given in the database.
- h_{4_s} is found from steam tables, using the entropy calculated at point 3 (isentropic process), and the pressure p_4. To estimate p_4 it is assumed that the combination of turbine pressures adopted is such that the output of the high pressure turbine is maximised, without compromising the vapour fraction (that is, without dropping below 85% vapour). This can be achieved by a setup where the pressure ratios $\frac{p_3}{p_4}$ and $\frac{p_4}{p_6}$ are equal, $\frac{p_3}{p_4} = \frac{p_4}{p_6}$, which gives $p_4 = \sqrt{p_3 p_6}$. But p_6 is equal to p_1, giving finally $p_4 = \sqrt{p_3 p_1}$.
- η_{s_1} is taken to be 0.84, for the high pressure steam turbine (Balmer, 2011), a conservative estimate.
- h_4 is found from Equation 5: $h_4 = h_3 - \eta_{s_1}(h_3 - h_{4_s})$.
- h_5 is found from steam tables, using the values for pressure, p_5, which is equal to p_4, and the reheat temperature, T_{reheat}, at the second turbine, which is given in the database.
- h_{6_s} is found from steam tables, using the entropy calculated at point 5 (isentropic process), and the pressure p_6, which is equal to p_1.
- η_{s_2} is taken to be 0.80, for the low pressure steam turbine (Balmer, 2011), a conservative estimate.

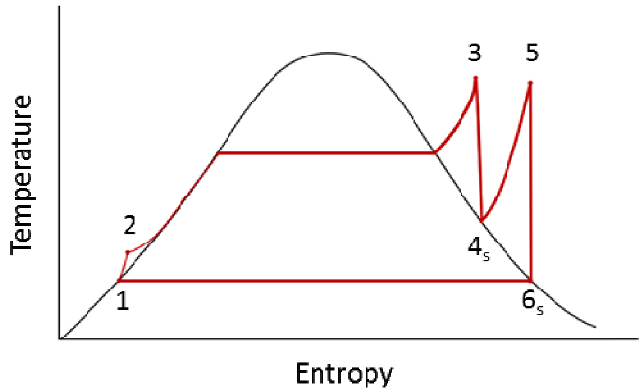

Figure 3.4.2b: T-s diagram for the Rankine cycle with reheat (subcritical)

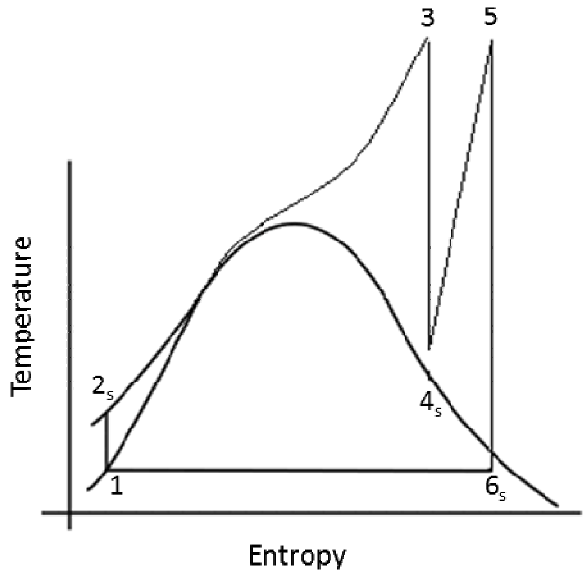

Figure 3.4.2c: T-s diagram for the Rankine cycle with reheat (supercritical)

Estimated thermal efficiencies, per Rankine cycle type and specific power plant technology

Each major group, defined by its type of Rankine cycle, was further divided into subgroups according to the specific technology (defined in Table 3.4.2a). For each subgroup, the median value for the steam pressure, p_3, and the steam temperature, T_3, at the turbine were calculated, as was the reheat temperature, T_{reheat}, where applicable. For each subgroup, the thermal efficiency, η_T, was calculated according the methods described in earlier sections. The results are presented in Table 3.4.2a.

Table 3.4.2a: Summary of median values estimated for key parameters of the Rankine cycle for power plants with once-through freshwater cooling systems.

A. Rankine cycle, SUBCRITICAL TURBINE PRESSURE (Figure 3.4.2a)					
Technology	No. of units	Steam press. (bar)	Steam temp. (°C)		Thermal efficiency (%)
CCSS	3	94	521		**35.4**
ST	498	60	482		**33.9**
ST/C	60	75	488		**34.5**
ST/CP	4	79	513		**34.7**
ST/S	113	60	500		**34.1**
B. Rankine cycle, SUBCRITICAL TURBINE PRESSURE, WITH REHEAT (Figure 3.4.2b)					
Technology	No. of units	Steam pres. (bar)	Steam temp. (°C)	Reheat temp. (°C)	Thermal efficiency (%)
CCSS	3	106	536	536	**38.1**
ST	859	135	538	538	**38.3**
ST/C	32	113	540	540	**38.1**
ST/S	68	128	537	537	**37.8**
C. Rankine cycle, SUPERCRITICAL TURBINE PRESSURE, WITH REHEAT (Figure 3.4.2c)					
Technology	No. of units	Steam press. (bar)	Steam temp. (°C)	Reheat temp. (°C)	Thermal efficiency (%)
ST	119	241	538	538	**38.6**
ST/S	9	236	565	565	**39.3**

Estimation of heat rejected to freshwater bodies

In the final step of the calculations of thermal emissions to freshwater, the gross electrical generating capacity of each unit is adjusted to reflect the thermal output of the cycle, by accounting for the mechanical, η_m, and electrical, η_e, efficiencies of the system (assumed to be 0.95 and 0.98, respectively). Furthermore, a conservative approach is adopted, in that all heat not converted to electrical power is taken as rejected to freshwater; in practice, some waste heat will also be emitted to air. Accordingly, the flow freshwater thermal emissions, $Q_{freshwater}$, are calculated for each power plant via Equation 8:

$$Q_{freshwater} = \frac{\frac{W_{gross}}{\eta_m \cdot \eta_e}(1-\eta_T)}{\eta_T} \quad \text{(MJ/s) Equation 8}$$

where W_{gross} is given for each individual power plant in the database, and η_T has been calculated for each subgroup of power plants via the Rankine cycle, according to their technology (Table 3.4.2a).

All freshwater thermal emission flows were converted to cumulative annual values (MJ/yr) for the CREEA database.

WEPP database-CREEA database country and industry alignment

The final steps of the data preparation involve assigning the 48 CREEA country codes to the countries, as presented in the WEPP database, followed by distributing the results to the relevant industrial sectors in CREEA (Table 3.4.2b).

Table 3.4.2b: Relevant industry sectors in CREEA

EXIOBASE industry name	**EXIOBASE industry code1**	**EXIOBASE industry code2**
Production of electricity by coal	i40.11.a	A_POWC
Production of electricity by gas	i40.11.b	A_POWG
Production of electricity by nuclear	i40.11.c	A_POWN
Production of electricity by petroleum and other oil derivatives	i40.11.f	A_POWP
Production of electricity by biomass and waste	i40.11.g	A_POWB
Production of electricity by geothermal	i40.11.k	A_POWM

Table 3.4.2c shows the distribution of power plants in the WEPP database (with once-through freshwater cooling systems, operational in 2007) according to their fuel, as well as which CREEA industrial sector they were placed in.

Table 3.4.2c: Alignment of WEPP database fuel groups to CREEA industrial sectors

WEPP database fuel category		**Number of units**	**Corresponding CREEA industrial sector:** Production of electricity by…
BAG	Bagasse	3	biomass and waste
BFG	Blast-furnace gas also converter gas or LDG or Finex gas (approx 10% of the heat content of pipeline gas)	10	gas
BIOMASS	Biomass excluding wood chips but including agricultural waste and energy crops	1	biomass and waste
COAL	Coal	1017	coal
COKE	Petroleum coke	1	petroleum and other oil derivatives
GAS	Natural gas	333	gas
GEO	Geothermal	9	geothermal
OIL	Fuel oil	138	petroleum and other oil derivatives
PEAT	Peat	7	biomass and waste
REF	Refuse (unprocessed municipal solid waste)	31	biomass and waste
SHALE	Oil Shale	9	petroleum and other oil derivatives
UR	Uranium	97	nuclear
WOOD	Wood or wood-waste fuel	18	biomass and waste
WSTH	Waste heat[3]	94	gas

[3] The category of fuel termed 'Waste heat' appears in power plants with combined cycle technologies. With no further information, it was assumed that for all relevant power plants, the combination involved a gas turbine, followed by a steam turbine fuelled by the hot exhaust of the gas turbine. Since the primary fuel is gas, this WEPP database fuel group is assigned to 'production of electricity by gas' in the CREEA database.

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5 Annex

No.	Name	Source	Provider	Type of water (b/g/g)	Type of flow (u/c/s)	Temporal coverage	Spatial coverage	Sectoral coverage	Comment
1	Eurostat Water Statistics	http://nui.epp.eurostat.ec.europa.eu/nui/show.do?dataset=env_watqsum&lang=en	Eurostat	blue	use / consumptive use	1970-2009	European Union, Bulgaria, Romania, Turkey, Iceland, Norway, Switzerland, Croatia and Macedonia	public water supply, agriculture, forestry, fishing (total), agriculture, for irrigation purposes, mining and quarrying, manufacturing industry (total), manufacturing industry, for foodprocessing industry, manufacturing industry, for cooling purposes, production of electricity, for cooling purposes, services, Construction and other industrial activities, households	Poor data quality, many gaps!
2	EEA Waterbase - Water Quantity	http://www.eea.europa.eu/data-and-maps/data/waterbase-water-quantity-6	EEA	blue	use	1998-2010	EU-27	6 main sectors - some with sub-sectors (agriculture - irrigation; mining & quarrying; industry - basic metals, cooling, food, textiles, transport; electricity - cooling, hydropower, services, other)	Poor data quality, many gaps!
3	AquaSTAT	http://www.fao.org/nr/water/aquastat/main/index.stm	FAO	blue	use	5-year periods, earliest available data from 1958-62, öatest 2008-2012	5 regions and 150 countries	3 main sectors (agriculture, industry, domestic)	Data of varying quality
4	UN Water Statistics	http://unstats.un.org/unsd/ENVIRONMENT/waterresources.htm	United Nations Statistics Division (UNSD)	blue	supply	most recent year only	~200 countries	1 sector	not detailed enough but perhaps useful for data validation
5	OECD Water statistics	http://stats.oecd.org/Index.aspx	OECD	blue	use	1980-2006 or latest available year	36 countries	Focus on agriculture	poor coverage
6	Water Footprint	http://www.waterfootprint.org/?	WFN	blue/green/grey	consumption	average for 1995-2005	210 countries (grid data for selected crops is also available online)	146 primary crop categories (145 primary crops plus 1 fodder crops groups which covers 14 fodder crops which FAOSTAT had stopped providing data for), only one industry sector, one domestic sector	
7	LpJmL		PiK	blue/green	consumption	1901-2100	All countries	13 crops (1 group tempered climates, 1 group tropical climates)	Crop distribution on the basis of the year 2000; historical data interpolated; future distribution equal to 2000
8	Water GAP		CESR-Kassel	blue	use & consumption, waste water, cooling water	(1900) 1950-2005	170 countries	Domestic, manufacturing industry (6), thermal electricity production (3), irrigation, animal breeding	Consumption calculated via coefficients for water use; dataset not available yet
9	Ecoinvent database		ecoinvent Centre	grey water is a term of a waste water type we do not use this term for pollution in LCA. However, emissions to water are captured and would allow calculation of "grey" water in a sophisticated way (beyond just nitrogen dilution)	use (5 types of sources) + 4 types of processed water as product input	one avergae value	Location specific data. Only country, regional and global values are available and most processes have only one or a few lspecified location. In version 3 (to be released in summer 2012) spatial explicity is improved and can include any spatial unit and even point data.	data on energy supply, resource extraction, material supply, chemicals, metals, agriculture, waste management services, and transport services	No free access - perhaps in the course of CREEA yes.
10	ETH		ETH / scientific publication	blue/green		2000 as reference	country level published	160 crops/crop groups, Power production	including uncertainties. Modeled data
11	University of Frankfurt (GCWM)		University of Frankfurt	green/blue	consumption	1998-2002 ??		20 primary crops plus 2 major crop groups	they have the data but not available online.....

FAO's country listing			CREEA country listing			
FAOSTAT country code	FIPS	Country	CREEA Code	CREEA FIPS	CREEA Name	CREEA Grouping
11	AU	Austria	1	AT	Austria	EU
255	BE	Belgium	2	BE	Belgium	EU
27	BU	Bulgaria	3	BG	Bulgaria	EU
50	CY	Cyprus	4	CY	Cyprus	EU
167	EZ	Czech Republic	5	CZ	Czech Republic	EU
79	GM	Germany	6	DE	Germany	EU
54	DA	Denmark	7	DK	Denmark	EU
63	EN	Estonia	8	EE	Estonia	EU
203	SP	Spain	9	ES	Spain	EU
67	FI	Finland	10	FI	Finland	EU
68	FR	France	11	FR	France	EU
84	GR	Greece	12	GR	Greece	EU
97	HU	Hungary	13	HU	Hungary	EU
104	EI	Ireland	14	IE	Ireland	EU
106	IT	Italy	15	IT	Italy	EU
126	LH	Lithuania	16	LT	Lithuania	EU
256	LU	Luxembourg	17	LU	Luxembourg	EU
119	LG	Latvia	18	LV	Latvia	EU
134	MT	Malta	19	MT	Malta	EU
150	NL	Netherlands	20	NL	Netherlands	EU
173	PL	Poland	21	PL	Poland	EU
174	PO	Portugal	22	PT	Portugal	EU
183	RO	Romania	23	RO	Romania	EU
210	SW	Sweden	24	SE	Sweden	EU
198	SI	Slovenia	25	SI	Slovenia	EU
199	LO	Slovakia	26	SK	Slovakia	EU
229	UK	United Kingdom	27	GB	United Kingdom	EU
231	US	United States of America	28	US	United States	nonEU
110	JA	Japan	29	JP	Japan	nonEU
351	CH	China	30	CN	China	nonEU
33	CA	Canada	31	CA	Canada	nonEU
117	KS	Korea, Republic of	32	KR	South Korea	nonEU

FAO's country listing			CREEA country listing			
FAOSTAT country code	FIPS	Country	CREEA Code	CREEA FIPS	CREEA Name	CREEA Grouping
21	BR	Brazil	33	BR	Brazil	nonEU
100	IN	India	34	IN	India	nonEU
138	MX	Mexico	35	MX	Mexico	nonEU
185	RS	Russian Federation	36	RU	Russia	nonEU
10	AS	Australia	37	AU	Australia	nonEU
211	SZ	Switzerland	38	CH	Switzerland	nonEU
223	TU	Turkey	39	TR	Turkey	nonEU
	TW	Taiwan	40	TW	Taiwan	nonEU
162	NO	Norway	41	NO	Norway	nonEU
101	ID	Indonesia	42	ID	Indonesia	nonEU
202	SF	South Africa	43	ZA	South Africa	nonEU
2	AF	Afghanistan	44	WA	RoW Asia and Pacific	nonEU
5	AQ	American Samoa				
1	AM	Armenia				
52	AJ	Azerbaijan				
16	BG	Bangladesh				
18	BT	Bhutan				
26	BX	Brunei Darussalam				
115	CB	Cambodia				
47	CW	Cook Islands				
66	FJ	Fiji				
70	FP	French Polynesia				
73	GG	Georgia				
88	GQ	Guam				
102	IR	Iran, Islamic Republic of				
108	KZ	Kazakhstan				
83	KR	Kiribati				
116	KN	Korea, Democratic People's Republic of				
113	KG	Kyrgyzstan				
120	LA	Lao People's Democratic Republic				
131	MY	Malaysia				

FAO's country listing			CREEA country listing			
FAOSTAT country code	FIPS	Country	CREEA Code	CREEA FIPS	CREEA Name	CREEA Grouping
132	MV	Maldives				
127	RM	Marshall Islands				
145	FM	Micronesia, Federated States of				
141	MG	Mongolia				
28	BM	Myanmar				
148	NR	Nauru				
149	NP	Nepal				
153	NC	New Caledonia				
156	NZ	New Zealand				
160	NE	Niue				
165	PK	Pakistan				
168	PP	Papua New Guinea				
171	RP	Philippines				
244	WS	Samoa				
200	SN	Singapore				
25	BP	Solomon Islands				
38	CE	Sri Lanka				
208	TI	Tajikistan				
216	TH	Thailand				
176	TT	Timor-Leste				
218	TL	Tokelau				
219	TN	Tonga				
213	TX	Turkmenistan				
227	TV	Tuvalu				
235	UZ	Uzbekistan				
155	NH	Vanuatu				
237	VM	Viet Nam				
243	WF	Wallis and Futuna Islands				
8	AC	Antigua and Barbuda	45	WL	RoW America	nonEU
9	AR	Argentina				
12	BF	Bahamas				
14	BB	Barbados				

FAO's country listing			CREEA country listing			
FAOSTAT country code	FIPS	Country	CREEA Code	CREEA FIPS	CREEA Name	CREEA Grouping
23	BH	Belize				
17	BD	Bermuda				
19	BL	Bolivia				
36	CJ	Cayman Islands				
40	CI	Chile				
44	CO	Colombia				
48	CS	Costa Rica				
49	CU	Cuba				
55	DO	Dominica				
56	DR	Dominican Republic				
58	EC	Ecuador				
60	ES	El Salvador				
69	FG	French Guiana				
86	GJ	Grenada				
87	GP	Guadeloupe				
89	GT	Guatemala				
91	GY	Guyana				
93	HA	Haiti				
95	HO	Honduras				
109	JM	Jamaica				
135	MB	Martinique				
142	MH	Montserrat				
157	NU	Nicaragua				
166	PM	Panama				
169	PA	Paraguay				
170	PE	Peru				
177	RQ	Puerto Rico				
188	SC	Saint Kitts and Nevis				
189	ST	Saint Lucia				
190	SB	Saint Pierre and Miquelon				
191	VC	Saint Vincent and Grenadines				
207	NS	Suriname				

FAO's country listing			CREEA country listing			
FAOSTAT country code	FIPS	Country	CREEA Code	CREEA FIPS	CREEA Name	CREEA Grouping
220	TD	Trinidad and Tobago				
234	UY	Uruguay				
236	VE	Venezuela, Bolivarian Republic of				
3	AL	Albania	46	WE	RoW Europe	nonEU
57	BO	Belarus				
80	BK	Bosnia and Herzegovina				
98	HR	Croatia				
64	FO	Faroe Islands				
99	IC	Iceland				
146	MD	Moldova				
186	YI	Serbia and Montenegro				
154	MK	The former Yugoslav Republic of Macedonia				
230	UP	Ukraine				
4	AG	Algeria	47	WF	RoW Africa	nonEU
7	AO	Angola				
53	BN	Benin				
20	BC	Botswana				
233	UV	Burkina Faso				
29	BY	Burundi				
32	CM	Cameroon				
35	CV	Cape Verde				
37	CT	Central African Republic				
39	CD	Chad				
45	CN	Comoros				
46	CF	Congo				
250	CG	Congo, Democratic Republic of				
107	IV	Côte d'Ivoire				
72	DJ	Djibouti				
59	EG	Egypt				
61	EK	Equatorial Guinea				
178	ER	Eritrea				

FAO's country listing			CREEA country listing			
FAOSTAT country code	FIPS	Country	CREEA Code	CREEA FIPS	CREEA Name	CREEA Grouping
238	ET	Ethiopia				
74	GB	Gabon				
75	GA	Gambia				
81	GH	Ghana				
90	GV	Guinea				
175	PU	Guinea-Bissau				
114	KE	Kenya				
122	LT	Lesotho				
123	LI	Liberia				
124	LY	Libyan Arab Jamahiriya				
129	MA	Madagascar				
130	MI	Malawi				
133	ML	Mali				
136	MR	Mauritania				
137	MP	Mauritius				
143	MO	Morocco				
144	MZ	Mozambique				
147	WA	Namibia				
158	NG	Niger				
159	NI	Nigeria				
182	RE	Réunion				
184	RW	Rwanda				
193	TP	Sao Tome and Principe				
195	SG	Senegal				
196	SE	Seychelles				
197	SL	Sierra Leone				
201	SO	Somalia				
206	SU	Sudan				
209	WZ	Swaziland				
215	TZ	Tanzania, United Republic of				
217	TO	Togo				
222	TS	Tunisia				

FAO's country listing			CREEA country listing			
FAOSTAT country code	FIPS	Country	CREEA Code	CREEA FIPS	CREEA Name	CREEA Grouping
226	UG	Uganda				
205	WI	Western Sahara				
251	ZA	Zambia				
181	ZI	Zimbabwe				
13	BA	Bahrain	48	WM	RoW Middle East	nonEU
103	IZ	Iraq				
105	IS	Israel				
112	JO	Jordan				
118	KU	Kuwait				
121	LE	Lebanon				
299	GZWE	Occupied Palestinian Territory				
221	MU	Oman				
179	QA	Qatar				
194	SA	Saudi Arabia				
212	SY	Syrian Arab Republic				
225	AE	United Arab Emirates				
249	YM	Yemen				

FAO classification		CREEA classification					
FAOSTAT crop code	Crop	CREEA product Code1	CREEA product Code2	CREEA Product	CREEA Industry Code1	CREEA Industry Code2	CREEA Industry
27	Rice, paddy	C_PARI	p01.a	Paddy rice	A_PARI	i01.a	Cultivation of paddy rice
15	Wheat	C_WHEA	p01.b	Wheat	A_WHEA	i01.b	Cultivation of wheat
44	Barley	C_OCER	p01.c	Cereal grains nec	A_OCER	i01.c	Cultivation of cereal grains nec
89	Buckwheat						
101	Canary seed						
108	Cereals, nes						
94	Fonio						
56	Maize						
79	Millet						
103	Mixed grain						

FAO classification		CREEA classification					
FAOSTAT crop code	Crop	CREEA product Code1	CREEA product Code2	CREEA Product	CREEA Industry Code1	CREEA Industry Code2	CREEA Industry
75	Oats						
92	Quinoa						
71	Rye						
83	Sorghum						
97	Triticale						
216	Brazil nuts, with shell						
217	Cashew nuts, with shell						
220	Chestnuts						
221	Almonds, with shell						
222	Walnuts, with shell						
223	Pistachios						
225	Hazelnuts, with shell						
226	Areca nuts (betel)						
234	Nuts, nes						
358	Cabbages and other brassicas						
366	Artichokes						
367	Asparagus						
372	Lettuce and chicory						
373	Spinach	C_FVEG	p01.d	Vegetables, fruit, nuts	A_FVEG	i01.d	Cultivation of vegetables, fruit, nuts
388	Tomatoes						
393	Cauliflowers and broccoli						
394	Pumpkins, squash and gourds						
397	Cucumbers and gherkins						
399	Eggplants (aubergines)						
401	Chillies and peppers, green						
402	Onions (inc. shallots), green						
403	Onions, dry						
406	Garlic						
414	Beans, green						
417	Peas, green						
423	String beans						
426	Carrots and turnips						

FAO classification		CREEA classification					
FAOSTAT crop code	Crop	CREEA product Code1	CREEA product Code2	CREEA Product	CREEA Industry Code1	CREEA Industry Code2	CREEA Industry
430	Okra						
446	Maize, green						
461	Carobs						
463	Vegetables fresh nes						
486	Bananas						
489	Plantains						
490	Oranges						
495	Tangerines, mandarins, clem.						
497	Lemons and limes						
507	Grapefruit (inc. pomelos)						
512	Citrus fruit, nes						
515	Apples						
521	Pears						
526	Apricots						
530	Sour cherries						
531	Cherries						
534	Peaches and nectarines						
536	Plums and sloes						
541	Stone fruit, nes						
544	Strawberries						
547	Raspberries						
549	Gooseberries						
550	Currants						
552	Blueberries						
554	Cranberries						
558	Berries Nes						
560	Grapes						
567	Watermelons						
568	Other melons (inc.cantaloupes)						
569	Figs						
571	Mangoes, mangosteens, guavas						

FAO classification		CREEA classification					
FAOSTAT crop code	Crop	CREEA product Code1	CREEA product Code2	CREEA Product	CREEA Industry Code1	CREEA Industry Code2	CREEA Industry
572	Avocados						
574	Pineapples						
577	Dates						
591	Cashewapple						
592	Kiwi fruit						
600	Papayas						
603	Fruit, tropical fresh nes						
619	Fruit Fresh Nes						
236	Soybeans	C_OILS	p01.e	Oil seeds	A_OILS	i01.e	Cultivation of oil seeds
242	Groundnuts, with shell						
249	Coconuts						
254	Oil palm fruit						
260	Olives						
265	Castor oil seed						
267	Sunflower seed						
270	Rapeseed						
280	Safflower seed						
289	Sesame seed						
292	Mustard seed						
296	Poppy seed						
299	Melonseed						
328	Seed cotton						
328	Seed cotton						
333	Linseed						
336	Hempseed						
339	Oilseeds, Nes						
156	Sugar cane	C_SUGB	p01.f	Sugar cane, sugar beet	A_SUGB	i01.f	Cultivation of sugar cane, sugar beet
157	Sugar beet						
161	Sugar crops, nec						
773	Flax fibre and tow	C_FIBR	p01.g	Plant-based fibers	A_FIBR	i01.g	Cultivation of plant-based fibers
777	Hemp Tow Waste						
780	Jute						

FAO classification		CREEA classification					
FAOSTAT crop code	Crop	CREEA product Code1	CREEA product Code2	CREEA Product	CREEA Industry Code1	CREEA Industry Code2	CREEA Industry
782	Other Bastfibres						
788	Ramie						
789	Sisal						
800	Agave Fibres Nes						
809	Manila Fibre (Abaca)						
821	Fibre Crops Nes						
116	Potatoes						
122	Sweet potatoes						
125	Cassava						
135	Yautia (cocoyam)						
136	Taro (cocoyam)						
137	Yams						
149	Roots and Tubers, nes						
176	Beans, dry						
181	Broad beans, horse beans, dry						
187	Peas, dry						
191	Chick peas						
195	Cow peas, dry						
197	Pigeon peas	C_OTCR	p01.h	Crops nec	A_OTCR	i01.h	Cultivation of crops nec
201	Lentils						
203	Bambara beans						
205	Vetches						
210	Lupins						
211	Pulses, nes						
656	Coffee, green						
661	Cocoa beans						
667	Tea						
677	Hops						
687	Pepper (Piper spp.)						
689	Chillies and peppers, dry						
692	Vanilla						
693	Cinnamon (canella)						

FAO classification		CREEA classification					
FAOSTAT crop code	Crop	CREEA product Code1	CREEA product Code2	CREEA Product	CREEA Industry Code1	CREEA Industry Code2	CREEA Industry
698	Cloves						
702	Nutmeg, mace and cardamoms						
711	Anise, badian, fennel, corian.						
720	Ginger						
723	Spices, nes						
748	Peppermint						
826	Tobacco, unmanufactured						
836	Natural rubber						
	Fodder crops						