Guideline 3: Methodological guidelines for calculating climate change related indicators of urban/regional food production and consumption

Monitoring impacts of urban and peri-urban agriculture and forestry on climate change mitigation and adaptation

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CONTENT

1. INTRODUCTION

The world is currently witnessing a second urbanisation wave. The global population is reaching a size where cities need to start thinking beyond their immediate interests to consider their role as nodes of human consumption and waste production in a finite planet that is struggling to keep pace with humanity's demands. Cities must acknowledge increasing risks of climate change and ecosystem degradation and build their economies in a manner so that they reduce their contribution to Green House Gas (GHG) emissions –and thus climate change- and respect and rehabilitate the ecosystems on which life depends. If cities are to prosper, they must also embrace the challenge of providing uninterrupted access to water, food, and energy, and improve quality of life for all of their citizens. For such rapid urban growth to be sustainable, in the context of climate change and food security, there is need for "decoupling". Essentially, this means enhancing the quality of life while simultaneously minimising resource extraction, energy consumption, waste generation and safeguarding ecosystem services. Decoupling will depend on how cities are planned and on how city-based energy, waste, transportation, food, water, and sanitation systems are expanded and/or reconfigured (Tuts, 2014[1]).

Urbanisation and climate change are closely linked. CO_2 and other GHG are mainly emitted in urban areas. Within a given city, a substantial proportion of the GHG emissions come from burning fossil fuels in transportation (a large part of it related to food), while another significant percentage comes from energy used for industrial, commercial and domestic consumption. Moreover, poor waste management releases CFCs and gases such as methane into the atmosphere (UN HABITAT Climate Change Strategy 2010-2013[2]).

In addition, feeding an increasingly urbanised world in ways that are sustainable, resilient, healthy and fair, has become a pressing challenge[3]. Although it is recognised that global food systems have had significant progress in increasing/intensifying agricultural production, the number of hungry and malnourished people has hardly reduced (De Schutter, 2014[4]). A focus on international trade, production of export crops and increasing dependency on food imports have reduced local capacity to feed the local population and increased vulnerability to food insecurity, specifically affecting the urban poor (Baker, 2008, Prain, 2010[5]). There is also increasing doubt on the sustainability of intensive conventional agriculture and global distribution systems (loss of agro-biodiversity, erosion, (water)pollution, high GHG emissions; food waste). Food systems (including production, transportation, distribution and consumption of food) contribute to about 30-40% of global GHG emissions. About a quarter of the GHG emissions of the food system are caused by food losses and food wastes. In this regard, there is a clear need to increase the sustainability of our food systems and investigate opportunities for more localised food systems. Indeed, well planned and managed urban and peri-urban agriculture can play a key role in decoupling, as part of the overall urban food system (Tuts, 2014).

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1 Tuts, R., 2014. Cities as Key Actors to act on Food, Water and Energy Security in the Context of Climate Change, in Dubbeling, M. (ed), Urban agriculture as a climate change and disaster risk reduction strategy. Urban Agriculture Magazine 27. RUAF Foundation, Leusden, The Netherlands.
2 UN- HABITAT, Climate Change Strategy 2010-2013, Nairobi, Kenya
3 http://www.fao.org/fileadmin/templates/FCIT/Meetings/WUF_7_City_Region_Food_Systems_2014_05_09_Call_to_Action.pdf
4 De Schutter, Olivier 2014. Report of the Special Rapporteur on the right to food. Final report: The transformative potential of the right to food. http://www.srfood.org/images/stories/pdf/officialreports/20140310_finalreport_en.pdf
5 Baker, Judy L. (2008). Impacts of Financial, Food and Fuel Crisis on the Urban Poor. Directions in Urban Development. Urban Development Unit, World Bank. USA.; and Prain, Gordon and Henk de Zeeuw (2010). Effects of the global financial crisis on the food security of poor urban households . RUAF Foundation, The Netherlands.

The fifth report by the Intergovernmental Panel on Climate Change (IPCC, 2014[6]) projects that in many regions there is likely to be a loss of food production and productive arable lands. Cities with a heavy reliance on food imports would be more significantly affected. Adaptation options and local responses mentioned include support for urban and peri-urban agriculture, green roofs, local markets, enhanced social (food) safety nets and development of alternative food sources.

However and for this to be meaningful, it is important to consider planning at the city-region level – beyond the boundaries of the urban centre itself, including towns, semi-urban areas, and outlying rural lands. At this level, land and water availability and use, production options and volumes, economic and population development patterns, infrastructure and markets (e.g. supermarkets, local farmers markets or other direct consumer markets), business prospects, political relations, and climate variation best play out and are addressed at the city-regional level. Working at a city-regional level allows for better balancing and linking of the urban and peri-urban to rural food supplies. Furthermore at this level there are key opportunities to plan for landscape mosaic patterns that: protect valuable ecosystems and biodiversity hotspots, preserve natural corridors that prevent flooding and landslides, optimise and expand existing transportation network infrastructure, enhance resource efficiency by using and recycling water and energy efficiently, and promote compact cities and planned extensions (e.g. designating low lying areas and flood plains for agriculture to prevent construction and reduce impact of floods) (Tuts, 2014).

The promotion of city-region food systems, and of urban and peri-urban agriculture, also responds to current and projected increases in food prices, as well as the increasing consumer demand for local/regional food and control over their own food system (such as demonstrated by Slow Food or the Buy Local-Eat Local campaigns). Resilience in urban food systems, building upon planning in other sectors, after all requires multiple and diverse sources of food. More localised production in form of urban and peri-urban agriculture is increasingly recognised as one important (but by no means sole) source of food, increasing food security at household level and buffering shocks to food price hikes, market distortions, and imported supplies. Poor and vulnerable city-dwelling families may resort to growing food for home consumption and to generate some income to purchase additional food. Especially peri-urban agriculture has the potential for lowering urban ecological foot(d)-prints and protecting the agricultural land base around cities, while optimising the role of agriculture in providing other urban services (recreation, landscape and water management, urban greening[7]).

City-region food systems may offer new enterprise and marketing opportunities (urban agriculture, farmers markets; local food hubs) for (poor) producers, households, women and youth involved in processing and marketing activities. They can also help develop local identity and collaboration and thus contribute to participatory local government.

In this regard, agriculture must be considered a key land use feature for more resilient city-regions (Tuts, 2014). The extent and contribution of urban and peri-urban agriculture to food security and income generation have been measured more frequently over the past 20 years[8]. However, actual impacts on climate change mitigation and adaptation due to changes in urban and peri-urban food production and consumption are hard to measure on a city level. The implementation of Urban and Peri-urban Agriculture (UPA) measures will take time to fully reach their potential and the actual monitoring of

6 University of Cambridge and ICLEI, 2014. Climate change: implications for cities. Key Findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report. Available from: http://www.iclei.org/fileadmin/PUBLICATIONS/Brochures/IPCC_AR5_Cities_Summary_FINAL_Web.pdf

7 Forster T. and A. Getz Escudero (2014). City regions as landscapes for people, food and nature. Ecoagriculture Partners. http://landscapes.ecoagriculture.org/global_review/city_regions

8 See also a recent (2014) assessment on the extent of urban and peri-urban agriculture in Thebo, A., Drechsel, P, and Lambin, E. (forthcoming) Global assessment of urban and peri-urban agriculture: irrigated and rainfed croplands, Environmental Research Letters.

changes in indicators like GHG emissions, food miles and energy use, are time consuming and costly. However, the effects of different UPA measures like increase in local food production and consumption, as well as enhanced productive waste recycling/improved food waste management can be calculated using a model approach. Coherent packages of UPA measures can be developed and described for different scenarios. The difference in the value of selected climate change indicators for the different scenarios can then be calculated using model calculations.

The methodology proposed can be used to calculate the current impacts of urban and peri-urban agriculture activities on the chosen indicators (the zero-scenario or business as usual).

It can also be used to estimate what the much larger benefits would be if decision-makers up-scaled UPA initiatives (e.g. increased local production) or implemented other related measures related to food transport, consumption and productive use of urban organic waste resources. Scenarios can be formulated as to help make statement along the following lines: "If X per cent of all available and appropriate land were used for urban and peri-urban agriculture for Y food types (or if A percent of different food types were produced locally on available urban and peri-urban land areas), then the reduced food miles per year would be Z. This would translate into X reductions in GHG emissions during a year".

The methodology provided in this manual for calculating these indicators is an adaptation of the well-known Life Cycle Analysis (LCA). Although LCA was developed for single products, in recent years there has been a distinct shift in applying it to larger scale decision contexts. For the calculation of certain indicators a consequential assessment is used, which describes how relevant environmental flows will change in response to possible decisions or scenarios. A limited number of related impact categories have been chosen. These are: climate change, transport and ending resources. The indicators used are GHG emissions, food miles or food kilometres and fossil energy use. When calculating GHG emissions, food kilometres and fossil energy use calculations can be easily arrived at. The functional unit in which the indicators are expressed is the volume of the annual food consumption of a defined urban area (emissions/Tn of food consumer per year).

GHG emissions are an indicator for Global Warming. In this manual GHG are considered as the total of the emissions of methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2), expressed as Carbon Dioxide Equivalents (CDE). The Global Warming Potential of CO_2, CH_4 and N_2O used are: 1, 25, and 298 respectively[9].

Food miles or food kilometres are considered as the distances travelled by food-items from farm gate to consumer. They are generally measured as tonne-kilometres, i.e. the distance travelled in kilometres multiplied by the weight in tonnes for each food item. However, to measure the environmental impact of food kilometres it is necessary to convert them into food vehicle kilometres, i.e. the sum of the distances travelled by each vehicle carrying food[10].

Fossil energy (fuel) use is energy produced from oil, gas and coal, residues of the conversion of once-living organisms that died millions of years ago. As such fossil fuels are considered a non-renewable energy resource.

This methodological guideline will provide measurement and quantification methods to design different urban/regional food production and consumption scenarios and to assess the hypothesis that increased UPA and resource recycling will reduce the food (transport) related emissions, food kilometres and related energy use.

9 IPCC 2007, GWP time horizon 100 years
10 See definition by Watkiss at al., 2005. The Validity of Food Kilometres as an Indicator of Sustainable Development

The manual will describe:

- How to make a basic inventory for scenario development, including
  - Definition of the (peri)-urban area/region
  - Food consumption and distribution, current situation
  - Food production, current situation and potential
  - (Organic) waste management, current situation (optional)

- How to compare (peri-) urban food demand with the (peri)-urban production capacity

- How to design urban/regional food system scenarios

- How to calculate chosen climate change indicators.

2. BASIC INVENTORY FOR SCENARIO DEVELOPMENT

2.1 Basic inventory

In order to develop realistic scenarios for urban/regional food systems, a thorough insight in the actual and possible future situation in the city's food consumption and production is needed. The actual urban food consumption and where this food is currently produced have to be inventoried. Based on the current situation, autonomous developments and projected trends (with regards to urbanisation, land use changes, changes in consumption patterns), possible future scenarios can be designed. For developing scenarios, the inventory can be done in more general terms. For the actual calculation of the indicators for the different scenarios, information to be collected has to be more specific. The main topics for the basic inventory of the current situation would be:

1. Food consumption and distribution, current situation
   - What do people in the city eat? What is the composition of their actual diet and food basket?
   - How much land/surface is needed to produce the current cities' food demand?
   - Where is the city's food currently produced and processed? How much is regional produce and how much is imported from outside the urban and peri-urban area? (for a definition of the urban and peri-urban area see 2.2)
   - How is the food transported to the city?

2. Food production, current situation
   - What food products (crops, fruits, fish, animal products etc.) and how much of these are currently produced in the defined urban and peri-urban area (see also 2.2)
   - How much of the food that is currently produced in the defined urban and peri-urban area is also consumed in this area?
   - What is the potentially available surface area for food production in the urban and peri-urban area?
   - What are the products that can potentially be grown in the urban and peri-urban area? And in which amounts?

3. (Organic) waste management, current situation (optional)
   - How much organic waste is the city producing? (sewage + household waste, garden and other green waste)
   - What is currently done with the waste? (send to the landfill un-separated, burned, separated and recycled, discharged into surface water, ...)

2.2 Defining the urban and peri-urban area/region

Before starting the inventory of the current situation as briefly outlined above, the urban and peri-urban area has to be defined. The physical boundaries of this area determine the amount of food that is consumed by the inhabitants of urban/peri-urban region and the amount of food that currently is or potentially can be produced in this area/region.

There are different aspects and considerations to take in to account when defining this area:

1. Jurisdictional boundaries: municipality, sub-region, province

2. Natural boundaries: rivers, sea, mountain ridges, watersheds

3. Influence of the city on the region (e.g. does the city have a say over land use and agriculture in this entire area; do urban citizens recreate in a certain area) and influence of the region on the city. Physical interactions (for example water infiltration areas that can influence flooding in the city or rural/peri-urban areas sensitive to erosion that affect the city area) or social/cultural interactions (like social/cultural exchange, people coming for shopping/recreation to the city etc.) can be looked at.

4. Transport distance and mode to the city and ease/sustainability of transport to the city (for example when a city is situated along a river, a part of the upstream area may easily provide food for the city by river transport).

5. Production potential/capacity in relation to the city' food demand (for at least fresh products), enclosed production areas like orchards or vegetable production areas or areas that could be converted to food production for the city (e.g. former rubber plantations near Kesbewa, Sri Lanka). For example, 15-30 km from Amsterdam in the Netherlands there is a large vegetable/arable production area called Zuidelijk-Flevoland. This region is part of another province. This production area is however included in the defined Metropolitan Region Amsterdam when looking at local/regional food production areas for the city (see Box 1).

6. Once a certain area/region is defined, the total population in that area is included in the calculations for food consumption, demand, transport etc. As a general rule, an area of 30 to 50 kilometres around the city centre can be included. However and depending on the local context and city size, the above mentioned aspects will shape the urban and peri-urban area in different distances for different directions. The urban and peri-urban area/region should be indicated on a GIS map to facilitate further data collection and geographic referencing of certain production areas and transport routes.

Box 1: Defining the Metropolitan Region Amsterdam food system

Figure 1 shows a map of the Metropolitan Region Amsterdam (MRA). The light green colour in the figure shows the total area. The definition of this region is based upon cooperation between municipalities and provinces and is not primarily based upon the possibilities for food production. The number of inhabitants in this region is 2.3 million and the surface area adds up to 2580 km2. The maximum distance from the borders of the region to the city of Amsterdam is about 50 km. The area includes some important food production areas for dairy production (grassland) mainly situated at the north of Amsterdam city and for open field arable/vegetable production at the southwest and northeast of Amsterdam city. At the south of the city of Amsterdam there is quite intensive greenhouse cultivation mainly for flowers but also for greenhouse vegetables. There are also some fruit producers included in the area. The area surface is not sufficient to provide the MRA with its entire food need. However extending the area to the north A, north east B and south C would include larger vegetable and arable production areas, all within a range of 50 km of the city of Amsterdam.

Amsterdam is developing its Amsterdam Food Centre more and more towards a logistic centre for regional foods. This centre also develops possibilities for the processing of food, such as a slaughterhouse and a vegetable processing unit for cutting and mixing of salads. Also wholesalers and retailers are increasingly focussing on regional produce. The farmers in the MRA are still partly producing for an anonymous world market. However, there is a development towards more production specifically for the region and for promotion of multifunctional agriculture combining food production functions with recreation, healthcare, home selling etc.

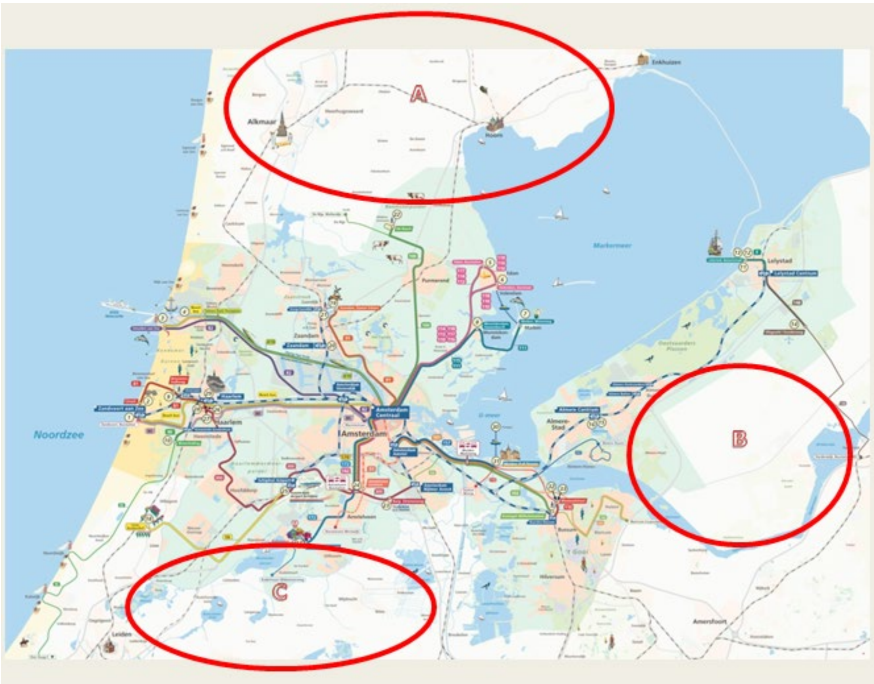


Figure 1. Metropolitan Region Amsterdam

2.3 Food consumption, current situation

What do people in the city eat?

There are various ways to establish the city's food consumption. Preferably this should be based on the daily or yearly household/citizen food consumption (food basket) multiplied by the total number of households/citizens. Differentiating the food basket for various social, ethnic groups might be useful and done if specific policies should be developed for this, but is not necessary. Data on the average diet of a person living in a city are mostly available, either on a national level, regional level, city level or specific for certain social groups (for example with nutrition or health offices or from social and consumption studies). Data on a national level might be corrected for a specific city depending on the composition of the population (social or ethnic groups). The actual diet of people in the city is taken as a starting point, however it is also possible to design a specific diet from a nutrition and health point of view for one of the scenarios. For example in the current Western diet, people often consume too many calories and a high amount of animal proteins. A diet which does not exceed the average daily need for calories and is more focussed on plant proteins would strongly influence the surface area needed for food production.
Another method is to gather data on food production, food imports and food exports of a city from agricultural census and offices, marketing boards and agents, although data on the city's food imports and exports might not be available in enough detail. The choice of approach is dependent on the local availability of such data in statistics or from earlier research projects. A simple example of the average diet of a (Dutch) citizen is given in table 1.

Table 1. Average daily intake of a Dutch citizen

Product	gram per person per day
Potatoes and root crops	96
Vegetables	100
Pulses	3
Fruits	98
Dairy products	391
Cereals and cereal products	219
Meat and meat products	120
Fish etc.	8
Eggs	11
Fats	24
Sugar and sweets	49
Cookies, biscuits etc.	46
Non-alcoholic beverages (soft drinks, fruit juice etc. (excluding milk)	1715
Alcoholic beverages	236
Sauces, spices herbs	36
Soups	58
Divers	21

Such dietary composition as given in table 1, show that some food products are consumed fresh and unprocessed, some products are a mix from various basic products and some products consist for a large part out of water (dairy products like milk and beverages). Furthermore, some products are grouped (vegetables, fruits, cereal products for example) and further detail is needed in order to be able to make specific calculations later on. However from such overview already first choices can be made. Small product groups (like complex processed product groups such as mixed chocolate bars, candy etc.) and beverages like soft drinks (mainly containing water and a bit of sugar and flavourings) might be discarded for further calculations. The reason to exclude such complex processed products is that they contain many different ingredients (partly commodities like sugar and starch) that are sourced from all over the world. This makes it very hard to determine the origin of the products.

Also, for the scenarios we focus on the products that are or can be produced in the defined (peri)-urban area. For some cities it is already clear that certain product (groups) cannot be produced in the (peri)-urban area, this may be because of reasons of limited surface area [11] - or for agro-ecological or climatic reasons. These product groups can thus be discarded. No further calculations for these groups are needed.

From daily intake per person to city demand for primary products

Most consumption data (see table 1) are given in gram per day of daily food intake. These data need to be translated to the annual food demand of the city (see the Box 2 below).

However, daily intake is not the same as the demand for primary products. With almost all products there are losses in the chain from production to consumption. For example the seed or skins of fruits are not eaten. But people also throw away food, because of the decrease in quality in the food chain, because they buy more then they need, etc. Estimations of world food losses add up to some 30%, but the losses in the food chain can sometimes be over 50%!

Processed products that are consumed need to be converted/translated into their primary ingredients. For example for one kg of bread, about 1.15 kg of wheat is needed or for 1 kg of cheese, 10 l of milk is needed.

Box 2: Example calculation- From daily intake per person to city demand and surface area

The daily intake of potatoes and root crops is 96 grams per person per day (table 1). For a defined urban/peri-urban region of 1 million people this adds up to:
0.096 (kg)*365 (days)*1 000 000 (citizens) = 3500 *103 kg per year
Estimated losses in the food chain for potato/root crops are 20% so the actual production demand is
43 800 * 103 kg per year

Average yield of potato and root crops would be (in the Dutch case) 60 * 103 kg per ha per year. So for potato and root crops in this example a surface of 730 ha would be needed to feed the urban/peri-urban area/region with localised production.

Origin of product or product group

For each product (group), information is needed on the current origin of production (and processing) of the product (group). For scenario development, this can be done on a more general level for the different products (groups) - see the example given below in Box 3. Clustering certain products into product groups will simplify the analysis and calculations (see also paragraph 5.5), as there are too many food products to do the analysis and calculations for every single product. Grouping different products into a product group is partly dependant on the local situation. Grouping can be based on products all sharing a similar food chain, similar primary products (dairy products, cereal products), similar origins of production, etc. The amount of products within a group can be dependent on the share of these products in the daily food basket and the similarity in their food chain.

11 Urban and peri-urban production, logically, often concentrate on those activities in which it has a comparative advantage, such as the production of fresh, perishable foods (vegetables, milk, eggs); the production of foods that can be grown under space-intensive conditions (vegetables, small animals) and on those production opportunities where its multiple functions (production next to recreation, education, landscape management) can be promoted.

For example potato products could be grouped in a diverse group of vegetables, in a group of 'root vegetables', as a separate product group potatoes, or even in a sub-groups for fresh, deep frozen and dried products or potatoes. For the Dutch situation, where potato products have a very large share in the food basket, potato products would be a separate group or even divided into different subgroups. The group herbs and spices can be very diverse, but when each single product has a very small share in the food basket, they can be grouped together in one food group.

How is the food transported to the city and consumers?

General information on the transport modes and type of food distribution used will be useful for developing the scenarios. There is a large difference in CO2 emissions between different transport modes (shipping: road: air = approx. 1:6:50). Moreover the type of distribution within the city is relevant. In some (western) cities there are so called 'food deserts' which requires consumers to go by car to do their shopping. CO2 emissions of food transport by consumers can sometimes even exceed the CO2 emissions by professional transport.

Food transport modes will probably change when a larger share of the city's food need is produced in the defined (peri)-urban area. Changes in transport modes can be part of a future scenario, like the future use of more electric powered transport or more transport over water. An example of transport modes per product group is given in Box 3.

Box 3: Example of origin and transport mode

Dairy products for city A: Produced and processed (sterilisation, cheese, yoghurt etc.). Dairy products for city A come for 90% from a region situated 500 km from city A, and for 10% (unprocessed direct selling) in the defined peri-urban area of city A. Transport to the city (500 km) is done with 20 ton trucks. Distribution in the city is done by 2 ton vans with an average transport distance of 10 km.

Fruits for city B: Main products consumed in city B are bananas, apples, oranges and mangos. No processing is done. Bananas, oranges and mangos are grown for 20% in the peri-urban area (home gardens) and for 80% in plantations 200 km from the city. Transport to the city is done by 5 ton trucks (not cooled), distribution in the city by 2 ton trucks with an average transport distance of 10 km.
Apples are all imported, with 3000 km sea transport (5000 GT vessel) to the city harbour, from the city harbour transport to the city markets with 2 ton trucks with an average transport distance of 15 km.

2.4 Food production, current situation

What kind of food and how much of it is currently produced in the defined urban and peri-urban area/region?

It might be useful to distinguish here between home- and community garden production, mainly for own use, and (semi) professional and market oriented production in the urban and peri-urban area. The kind of products and the annual amount of production in home (backyard or rooftop) or community gardens might be difficult to estimate. Information that is gathered for specific projects might be used. Usually the product groups for home/community production are fruits, herbs and vegetables. GIS information on available home or rooftop garden space might be used to estimate the available surface area for food production. Preferably, home/community gardening and (semi)professional production should be distinguished as the production levels of these two types will differ. An expert judgement or land use inventory can be used to estimate how much of this available surface area is on average used for food production (again and if possible distinguish between home gardening and (semi) professional production).

For (semi) professional production, statistical information (agricultural census; land use data) might be available to determine surface area (sometimes even data are available on area per product or product group). Production can be estimated using the average yields per surface unit. The annual production capacity needs to be determined, so seasonality of production needs to be taken in to account (for example, there could be two cultivations of rice in one year or four cultivations of leafy vegetables per year).

The inventory of food production should also include food processing. What kind of processing is already done in the urban area (milling, sterilising, salad cutting, slaughterhouse etc.)? This analysis should include an estimation of the processing production capacity, where the unprocessed products come from and where the processed products are consumed (within the defined area or exported).

How much of the food that is currently produced in the defined urban and peri urban area is also consumed in this area?

Not all food that is produced in the urban or peri-urban area/region is also consumed in this area. Especially production in the peri-urban area might be consumed outside the defined area such as for example coconuts from plantations (Kesbewa, Sri Lanka) or soy and cereal production (Rosario, Argentina). Vegetable and fruits are often to a large extent consumed locally/in the city-region, although again there can be exceptions here (e.g. the production of certain vegetables in Kesbewa peri-urban area might be mainly oriented at the Colombo market located at 23 km from Kesbewa). The percentage of the production in the defined area/region that is consumed within the defined urban and peri-urban area/region needs to be estimated.

What is the potentially available surface area for food production in the urban and peri-urban area/region?

Not all available land that is potentially suitable for food production is already (currently) used for food production. Within the urban area there is often "waste land" that is (temporarily) not used (for example areas set aside for future building), or unused space on balconies, roof gardens, home gardens etc. Similarly production could take place in flood zones; in open spaces (multifunctional land use) or in peri-urban areas zoned for future urbanisation. The estimation of potential surface and production capacity within densely populated city quarters might be difficult. GIS applications and municipal statistics (for example number of houses with or without gardens, houses with suitable balconies rooftops etc.) might provide the needed information.

There might also be areas that were historically used for production (like the abandoned paddy rice fields in Kesbewa, Sri Lanka) but are currently not used any longer and might be restored. Other possibilities could be increasing production surface on floating gardens (see examples from Bangladesh) or using land on river islands (Rosario, Argentina). GIS, satellite images, land use plans and land use studies can be important sources of information.

The inventory should include production areas that are currently used for export products like the rubber plantations around Kesbewa and the soy production areas around Rosario. Changes in land use and product types can be included in the future scenarios.

What are the products that can potentially be grown/produced in the urban and peri-urban area? In what amounts?

Not every food product can be produced everywhere. A distinction in surface area per potential production type is needed. For example rooftops and balconies can mostly be used for herbs and (fruit) vegetables like tomatoes. Home gardens are suitable for fruits and vegetables, but also to keep chicken and sometimes even pigs, goats or cows. Grassland can be used for dairy or other animal production. Paddy rice fields can be used for rice and possible other products in the dry season. The potential annual production of these areas for the different suitable crops or for animal produce (surface area times annual production per surface unit) need to be estimated. Again keep in mind that more cultivations of one crop can be grown in one year.

2.5 (Organic) waste management, current situation (optional)

How much organic waste is the city producing (sewage + household waste, garden and other green waste)?

If possible differentiate between different types of organic waste, like sewage waste (possibly divided in faeces and urine), organic household (food) waste, municipal green waste (tree leaves and grass cuttings), waste from the food chain in production and processing (for example coconut fibres and shells; slaughter residues etc.). The division into groups is dependent on the local situation. It is recommended to at least distinguish sewage and food waste generated before consumption.

The amount of human excrements per person differs per country, but a general guideline could be to calculate with 150 grams of faeces per person a day and 1.7 litre of urine per day. The general data given here can be adapted for the local situation based on locally available data. Human excrements might also be recalculated into N, P, K and C quantities.

With regards to food waste: about 10 to 15 % of the food that comes into a household is not consumed. This could mean about 130 grams of food waste per person a day. Locally available should be used when available. Otherwise the given international averages can be applied.

The municipality might also have statistics on quantities of organic waste production, market waste and waste from green areas. Markets, processing industries, land fill companies, waste transport authorities may constitute other sources of information.

What is done with the waste (send to the landfill un-separated, burned, separated and recycled, discharged into surface water, ...) ?

There are different ways that waste is treated or dumped. The way it is treated, reused or dumped has implications for the amount of energy use, energy production, GHG emissions and food (waste) kilometres.

Describe per waste group, identified in the previous paragraph, what is done with the waste. If there are different ways in which the waste is managed, divide the amounts over the different chains. For example: the organic household waste is for 20% used as animal feed on household level, for 20% composted at household level and for 60% thrown away un-separated in the dustbin. This residual waste is collected with trucks and ends up un-separated in the landfill. Urine and faeces ends up for almost 100% in the sewage and are dumped in the river and or sea.

3. COMPARING (PERI)URBAN FOOD DEMAND WITH THE (PERI)URBAN PRODUCTION CAPACITY

Resulting from the inventory of the food demand and the potential production in the defined urban and peri-urban area/region, this demand can be compared with the potential production. This comparison gives an indication of which share of the demand of a certain product or product group can produced in the defined area. Often the needed surface area to produce the food for the population in the defined area is larger than the potential available surface area. In the latter case, a choice has to be made which products would be grown in the defined area in one or more of the future urban food scenarios. Different elements can be taken into account for making this choice:

- Storage ability of products and transport costs. In general fresh products with a low shelf life are grown close to the city. Products that can be stored for a long time and can easily be transported by bulk transport (like for example cereals and rice) are very often produced on relatively large scale further away from the city

- Production costs in the current origin and in the defined area (note that differences in cost may be caused by scale of production, labour and energy costs, land prices etc.)

- Availability of (cheap) labour and/or the willingness (of the unemployed) to work in agriculture.

- Products that need to be processed and for which processing capacity is already available or that can easily be set up in the defined area

- Needed craftsmanship/ production expertise and availability of such craftsmanship

- Suitability (climate, soil, water, ...) of the defined area for production of a certain product

- Current and potential future consumer demand (for example for certain specific types of crops/products)

- Land use and zoning plans; city development strategies and other municipal/city-regional policies and plans.

Historically, the production of products that are quickly perishable like vegetables and certain types of fruits were produced close to the city. This also used to be the case with for example fresh milk. However the possibilities to cool products and to transport them relatively quickly over large distances made it possible to import these products from further distances. Products that need a large surface area, that can be transported in bulk and/or are easy storable like cereals, can easily be imported from locations at larger distance from the city.

An example of a calculation comparing food demand with production capacity is given in table 2. The example is based on a Dutch diet and a population of the defined area of one million people. The available production capacity in the defined area is 15 158 hectares. For some product groups all the needed products can be grown within the defined area. Seventy per cent of the fruits could be produced in the defined area, while the other fruits cannot be produced in the area due to climate conditions. The animal products require a lot of surface area and therefore only a small proportion is produced in the defined area. Cereal products have a long shelf life and can be easily and cheaply transported in bulk and are therefore not prioritised for localised production.

Table 2. Example of urban and peri-urban (1 million inhabitants) demand for food and production surface area compared with current production and production capacity in a defined urban and peri-urban area/region.

Product group	City demand[1)] (ton/yr.)	Total surface area needed to cover city demand (ha)	current production (ton/yr.)	Potential production (ton/yr.)	Surface needed (ha) for potential production
Potatoes and root crops	42 048	841	5 000	42 048 (100% of city demand)	841
Vegetables	43 800	1 460	10 000	43 800 (100%)	1 460
Pulses	1 314	329	0	1 314 (100%)	329
Fruits	42 924	1 073	8 000	30 047 (70%)	751
Dairy products	171 258	13 701[2)]	0	17 126 (10%)	1 370
Cereals and cereal products	95 922	19 184	500	19 184 (20%)	3 837
Meat and meat products	52 560	42 048[2)]	500	6 570 (11%)	5 256
Eggs	4 818	2 891	500	1 606 (33%)	964
vegetable oils	10 512	3 504	0	1 051 (10%)	350
Total		85 030		(50% of total city demand)	15 158

Based on a Dutch diet.
Includes fodder, concentrate etc.

4. DESIGNING SCENARIOS

There are different elements in the food chain that have an influence on the sustainability of the food chain and more specifically on the selected climate change indicators. A good understanding of the food chain helps selecting and prioritising relevant measures to make the food chain more sustainable by reducing energy use, food kilometres and GHG emissions.

The food chain consists of various steps. In each step there are direct and indirect inputs of for example energy and losses caused by waste. Between every link of the chain, transport is used in a certain transport-mode. Links can be located on local, regional, national, or global level. Moreover, there is also a time factor between production and consumption which influences the need for storage and/or cooling and the amount of possible food losses. Also the possibility to re-use organic waste (sewage, and food losses) in primary production or even as human food, cattle feed, for energy production amongst others has an impact on selected climate change indicators.

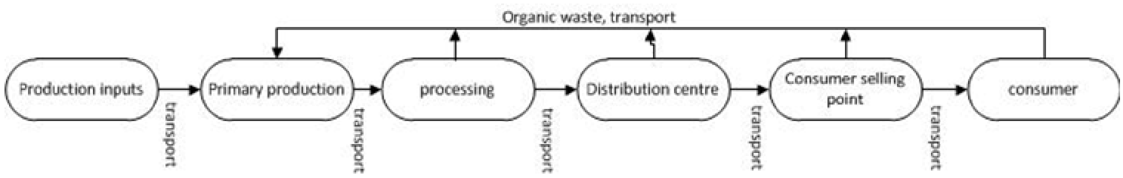


Figure 1. Different steps of the food chain

Scenarios for more sustainable food systems can be focussed on one or more of the different steps of the food chain and/or focus on the composition of the consumer's diet. All the links in the chain are strongly interrelated. Changes in one of the links will have effects on the other links. Scenarios for a more sustainable food system should take these relations into account. For example for processed products: regional primary food production has a different impact on food kilometres if the processing takes place outside the region, as compared to processing inside the region. Another example is the impact on food losses. Longer chains (in distance and in time) have a tendency to cause higher food losses (except when there is a processing/conservation link in the chain).

In designing scenarios for more sustainable food systems one should also take into account aspects like acceptability, technical feasibility, economic effects, effect on climate indicators and communication aspects:

- Acceptability: for example, will consumers accept a change in diet (e.g. eat more locally produced food versus imported food; or change one product that is currently imported –like bananas- for another that can be grown locally- like apples), or would a certain scenario be acceptable for and be supported by policy (e.g. The Ministry of Western Province, in which Kesbewa is located, strongly promotes more localised food production and re-use of organic waste).

- Technical feasibility: for example, is there enough suitable land in the city and city- region to produce certain products; is there enough technical production and processing capacity?

- Economic effects: are there significant effects on: production costs, product price, investments, employment etc.

- Climate indicators: is there a significant effect on climate indicators to be expected and is there enough (reliable) information to calculate/quantify these effects on the indicators?

- Communication value: some changes in the food chain are easy to communicate to the concerned stakeholders and consumers and appeal to the imagination (and just may more easily be socially and politically supported), while other aspects are complicated and hard to communicate (and thus implement).

4.1 Elements of scenarios for urban and city-regional food production and consumption

The transition from global to more local (peri)-urban food production is not the only possible element for a food system scenario. There are various other changes in the food system that can be included in a scenario study. These changes can follow projected trends (like the increasing consumption of animal proteins in some regions) or based on the introduction of specific measures:

- Changes in the consumers diet

- Changes in primary production and processing in the defined urban and peri-urban area (for example shifting towards more organic forms of production)

- Changes in transport modes (for example changing from road to rail or to transport over water)

- Changes in energy sources (from fuel-based to renewable sources for transport, cooling etc.)

- Changes in food losses (reduction of losses in certain parts of the chain)
- Changes in re-use of organic waste.

Not all these changes are directly related to changes in the location of the production and consumption. Some of them can be introduced in any global or local food chain without changing the distance between production and consumption locations. However they can be strongly related and can jointly compose a logical package of interrelated elements and strategies for more sustainable urban food systems. Combining elements and measures can strengthen their total effect. For example, production within or close to a city, logically combines with promoting more sustainable/organic (for example no use of pesticides) and multifunctional forms of production. A smaller distance between production and consumption provides chances for use of other transport-modes (using bicycles instead of cars) and for using other power sources (for example electrical power). Local production also provides other opportunities for the re-use of urban waste.

A zero scenario can be based on the current situation (no changes). Future scenario may be based on projected trends in population increase, land use changes, changes in diets or include certain future interventions that may contain different combinations of measures/ strategies with increasing ambition levels (for example scenario 0 represents the current situation; scenario 1 represents a situation in which 10% of certain products are produced locally; scenario 2 might present a situation in which 50% of certain products are produced and locally, in which 80% of urban organic waste is re-used and where green energy sources are used for part of the transport). See further 4.2

Changes in the consumers' diet

The earlier sections already illustrated the very important influence of the (composition of the) consumers' diet on land-use, energy use and GHG emissions in the food system. Table 2 shows the high land use required for animal products. The energy use and GHG emissions per calorie for animal products can be more than 5 times higher when compared to plant production.

Consumers generally will easily switch from a non-local to a local product if the quality and price are comparable. However it is much more difficult to change the type of food and to promote a shift from eating plant proteins (like beans etc.) instead of meat, or even to change a banana for an apple.

There are various shifts in the food basket possible, these shifts have different effects on the various climate indicators:

- Shift in the origin of the same product: more local/regional origin
- Shift from one product to another within a product group: for example apples instead of bananas.
- Shift from stored unprocessed to fresh unprocessed food
- Shift from processed to fresh products
- Shift from animal to vegetable food products.

Ad 1) Shift in the origin of the same product: more local/regional origin

This shift will have an effect on transport distances, on the possibility to reuse organic waste and possibly on food losses and emissions in primary production. Primary production has a large share in the GHG emission of the total production chain. GHG emissions can differ for different production origins, for example as a result of differences in the type of production, in the efficiency of production or in the yield per surface area.

For scenario development, this measure has to be taken up in the future scenarios. With the assumption that only transport distances change, calculating changes in the selected indicators resulting from these measures is fairly straight forward. The following options outlined below are harder to realise and more complex when calculating the indicators as not only the transport distance is changing but also other aspects of the food chain, like GHG emissions for primary production.

Ad 2) Shift from one product to another within a product group

A shift within a product group can have an effect on the possibility to produce this product regionally (see effects ad 1). For example in a given location, apples can be produced regionally while bananas cannot. Moreover the product can differ in their GHG emissions in primary production and in the food chain. Shifts between products within a product group are to a certain extent easily acceptable for consumers.

Ad 3) Shift from stored unprocessed to fresh unprocessed

This shift has an impact on energy and GHG emissions related to storage. This option implicates most of the time also a change in consumption of non-seasonal products to seasonal products. Consumption of fresh produce can affect the consumption of off-season products that need to be imported or produced with specific production technologies (like production of vegetables in heated greenhouses).

Ad 4) Shift from processed to fresh products

This shift has an impact on energy use and GHG emissions for processing, on food kilometres and on packaging. Processed food is most of the time packed (jars, cans, plastic bags etc.), requiring additional energy inputs. In some cases they also need energy for storage (like for deep frozen products). On the other hand, there can be a reduction in energy use for food preparation as some of these products need less cooking time (for example with sterilised products). Also there can be a reduction of food kilometres.

Ad 5) Shift from animal to vegetable food products

This shift will in general give a large reduction in energy use and GHG emissions for primary production, for processing (slaughter) and for cooling. Possibly there will also be shifts in food kilometres and packaging. The effects are strongly dependant on the way the animals are kept. If the animals are fed with food waste (like for example chicken in home gardens fed on household waste), food processing residues or roughage (for humans indigestible plant products), than the reduction of energy use and GHG emissions will be much smaller.

Changes in primary production

Primary production has a large share in the climate impact of the food chain. The impact of primary production on for example GHG emissions (approx. 40% of the emissions in the total food chain) is in general much higher than the impacts of for example transport (approx. 6% of the emissions in the total food chain). So changes in production methodology, production conditions (for example soil, climate etc.) or yield per surface unit of primary production (on its turn related to production methods) might have a large impact on climate performance. Changes in production location can be related to production methodology or soil and climate conditions. An obvious example is the production of imported seasonal vegetables, produced in a warm climate, compared to production of the same products in heated greenhouses in the region of consumption. Additional fossil energy use and GHG emissions for regional greenhouse production are often higher than the decrease of in energy use and emissions caused by the reduction in transport.

Some changes in production methodology have a logical relation to production in an urban or peri-urban area. Organic production combines very well with production in the urban area and city fringes (to reduce possible health risks and environmental contamination related to use of chemical pesticides for example). Also changing synthetic fertilisers to organic fertilisers combines logically with production in the (peri)-urban area (increased urban organic waste recycling). Production and application of synthetic N-fertilisers cause a high energy use and high N2O emissions.

In conclusion, various aspects of primary production have to be taken into account in designing scenarios and calculating indicators:

- When changing production location, be aware of (accidental) changes in energy use and emissions resulting from differences in production circumstances or methods. The assumption can be made that there are no relevant changes in emissions in primary production unless there are clear differences in production methodology (for example change from open field production to heated greenhouse production, change from conventional to organic production, change from synthetic fertilisers to organic fertilisers).

- Combined with changes in production location, introducing deliberate changes in production methods can be an integral part of the scenario. For example change from conventional to organic production or (partly) replacing synthetic fertilisers by organic fertilisers made from organic city waste.

Changes in transport modes

The choice of the transport mode influences energy use, GHG emissions (shipping: road: air = approx. 1:6:50) and also food kilometres. Changes in transport mode are sometimes interrelated with the change in production origin. If the product is produced a few hundred kilometres away from the location of consumption compared to more localised production, often there is a change from use of heavy trucks to use of light trucks or vans for food transport.

Changes in transport modes can also be taken up in the scenario. Local production for example, might combine well with electric vehicle transport because of the relatively short distances. Transport by ship/boat might be an option when rivers or canals are bordering or flowing through cities.

Changes in energy sources

Also in energy sources there can be a shift that is interrelated with the production. Home gardens in general use mainly hand labour instead of mechanisation. But there can also be a shift from mechanisation to hand labour related to the scale of production. Another change to be considered is the emission and fossil energy use related to the use of different sources of electricity. In one location, the electricity mainly comes from water/hydro power while in another location electricity is made using fossil energy only. As the latter change in energy mix for electricity, is not a deliberate UPA measure one can decide to assume that the energy mix for electricity is the same for the imported as well as for the more local production origins.

Change of energy sources can also be an option in the scenario. In the previous paragraph already the change to electric vehicles was discussed. But another option would be to combine local production with the use of solar panels, windmills or the use of methane gas (from organic matter fermentation) used for combustion or the production of electricity.

Changes in food losses

Food losses in the food chain can have a large impact on the selected climate indicators. When potentially consumable food is lost, the investments made in energy and all GHG emissions are wasted. Food losses can be related to the length of the food chain and to the conditions under which the food is stored and transported. Energy input in cooling/storage or greenhouse production can sometimes easily be recovered and losses reduced.

Estimations of the world food losses add up to about 1/3 of the total food production. Losses occur in various parts of the food chain. Losses at the level of the consumer and losses at the level of primary production are generally the most relevant.

A short food chain can have lower losses than a long food chain, although hard scientific data is not available to prove this. It also depends on how the long and short food chain is organised. However at least for fresh products with a low shelf life (leafy vegetables, fruits, ..) it would be logical to assume that food losses are lower when transport distances from the production location to the consumption location are shorter. Proxies for these losses are however difficult to give.

Interventions to reduce food losses could also be part of a scenario, including for example the introduction of cooled transport for vegetables, meat, dairy products etc. This intervention would increase energy use and costs for cooling on the one hand, but on the other hand could reduce food losses significantly.

Changes in re-use of organic waste

Changes in the reuse of organic waste can be very well combined with measures to increase local food production. Cities produce enormous amounts of organic waste, either as solid waste from organic residues or as human excrements. In a lot of cases, the solid organic waste still ends up (un-separated) in the landfill where it emits methane and nitrous oxide through anaerobic fermentation. Human excrements often are diluted with water and through the sewage system are dumped in rivers or seas. If the sewage water is purified, the nitrogen compounds are denitrified and broken down to N_2, CO_2 and O_2. On the other hand, agriculture is using synthetic nitrogen fertilisers whose production requires a lot of energy (Haber-Bosch process). The organic matter present in the organic waste improves soil quality and productivity, but also impacts water infiltration and water holding capacity. Increasing soil organic matter can also increase carbon storage in the soil. Input of organic matter is essential for the long term fertility of soils.

There are different measures that could be combined with local production. Household waste can be composted or applied directly in the home garden and used for fertilisation and soil improvement. Organic waste (including waste from green areas such as grass clippings and leaves) can be collected separately and composted or fermented in a central place. Measures for re-using human excrements might be a bit more difficult to realise as there might be hygiene risks or contaminations (medicines) or negative cultural perceptions to be taken care of. However the re-use of (undiluted) urine has relatively low hygiene risks and is more widely accepted.

As already mentioned the re-use of organic waste has different effects on the chosen climate indicators. If measures for re-use of organic waste are included in a scenario, one should include the following aspects in the calculation of climate indicators:

- Avoided methane (and possibly N_2O emissions) from landfills or organic waste dumps

- Reduced fossil energy use for the production of synthetic fertilisers and reduced N2O emission from the production and the field application of synthetic fertilisers
- Additional transport and machines needed for collecting and composting/fermenting organic waste
- Possible energy production from fermenting (bio-gas) or burning organic waste
- Possible carbon sequestration in the soil because of the use of organic fertilisers.

4.2 Examples of possible scenarios

As the aim is to predict the effect of different UPA measures on selected climate change indicators (principally food kilometres, energy use and GHG emissions), at least one of the scenarios should contain interventions that apply to one or more of the UPA measures as described above. The effects of the UPA interventions have to be compared with no intervention and/or the current situation. No intervention may means that autonomous developments/expected trends should be included. One such autonomous development could be that current food production within the defined area is decreasing because of increase in urbanisation.

For the future scenarios with interventions we can design different packages or intensities of UPA measures in combination with other measures that can enhance the effects, like for example promoting more localised production, as well as changes in transport modes or energy sources and setting up food processing in the region. There could be different scenarios of UPA interventions which include different ambition levels. Examples of different scenarios are given below.

If scenario development and modelling is also used to inform other city policies, for example related to urbanisation, climate change and flood risk reduction; or to urbanisation and increasing Urban Heat Island, it is recommended that similar parameters are used. If for example a run-off study sets out to calculate the effects of 50% more urbanisation (and consequently reduction of open and green spaces where water can be stored and infiltrate), it makes sense to use a similar urbanisation and land use scenario for the calculation of indicators of changes in local food production.

Once scenarios are designed, these should be checked again against the criteria already mentioned: acceptability, feasibility, economic effects, communication value and effects on the chosen indicators. As the scenarios are meant to be used for influencing policy, the scenarios might also be evaluated for their political sensitivity. If for example food safety is a hot social and political issue than there could be more emphasis on sustainable and safe food production. The scenarios should also be checked on possible trade-offs or additional positive or negative effects. For example, shorter food chains might reduce food losses, use of compost might increase carbon sequestration, lower energy use for cooling might increase food losses, introducing organic production might decrease crop yields and thus impact emissions/ha etc.

Especially the availability of reliable data to calculate the effects of the different scenarios on the chosen climate indicators can be an important bottleneck. Also predicting autonomous developments might be difficult. Including additional elements like for example electric transportation, can strengthen the intervention package, but take care that every extra element in a scenario also means additional work and additional data to collect.

If there are doubts about availability of data or work load etc., keep it simple. Focus at least on the calculation of the current situation and on a certain growth of the percentage of the consumption that is produced locally. Changes in only the origin of the product but not in the consumers' diet are the simplest and also easily acceptable for consumers. A logical element however to combine with changes in local food production is the re-use of organic city waste.

Box 4: Example scenarios

Let us assume that the basic inventory shows that:

- Currently 10% of the food consumption in the defined urban and peri-urban area/region is produced within the defined area. The product groups that determine these 10% are known.
- Potentially max. 35% of the food consumed in the defined area, could be produced within the defined area without changing the consumers' diet. The product groups that determine these 35% are analysed.
- Historical trends show that over the last 20 years the urban production has decreased with 50%.
- There is a trend that people are eating more meat. The last 20 years, meat consumption has doubled.
- The current situation for organic solid waste is that only 10% is reused and the rest is collected and dumped at a landfill. Half of the volume of all organic waste would be sufficient to provide all (peri)-urban food production with sufficient nutrients.

Based on this information the following scenarios could be designed:

- Zero or baseline scenario: the current situation with 10% consumption (divided over the specific product groups) of locally produced products and 10% reuse of organic waste; no changes in transport modes, food losses etc.
- Autonomous development scenario: assuming a further reduction in food production area of 50% (divided over different product groups) in the defined area and a certain percentage of growth in meat consumption.
- An intermediate scenario: in which 20% (with a certain division over the specific product groups) of the total city consumption is produced in the defined area and in which 25% of the organic waste is reused in (peri)-urban food production as compost
- An ambitious scenario: in which the maximum possible share (35%, with a certain division over the specific product groups) of the consumption is produced in the defined (peri)-urban area. Fifty per cent of all organic waste is reused in food production, which would be sufficient to provide all nutrients for food production.

After designing and possible redesigning (after checking the scenarios for all criteria) the scenarios, each scenario has to be described in detail. This is needed for the calculation of the indicators, but also to be able to substantiate the choices made in the different scenarios. For the above mentioned examples more details would be needed for what the current situation is (like which product (groups) are coming from the region, transport modes used etc.), or what the 20% or 35 % regional production consists of (fruits vegetables, dairy etc.? Details would be needed for different types of organic waste, for possible changes in waste collection and separation etc. See also chapter 2 and 3.

5. CALCULATING CHANGES IN THE CHOSEN INDICATORS FOR THE DIFFERENT UPA

SCENARIOS

5.1 Introduction

When a larger proportion of the food consumed by the urban population, is produced in or close to the city, this could lead to a reduction in GHG-emissions, food kilometres and fossil energy use. As described above, this reduction could be caused by a reduction in food transport distances, less use of cooled storage, processing and packaging (due to higher consumption of fresh products). As also indicated in the previous chapters, there are however various trade-offs possible that make urban or city-regional food production more energy consuming and cause more GHG emissions than transporting food over large distances. This could be the case when the urban production would take place in heated green houses and with high use of imported agrochemicals, while the imported production would be without heating and/or with low input of imported agrochemicals.

To calculate the changes in energy use, GHG emission and food kilometres for the chosen UPA scenarios, we use a methodology called Life Cycle Assessment (LCA). LCA is a method to calculate and compare the environmental impact of a system that provides a product or a service. LCA includes all emissions and consumption of resources from each management stage (or in our case: each part of the food chain), i.e. including emissions from supporting or external production processes . In our case, we want to compare the changes in environmental impact from the designed UPA scenarios compared to the reference or zero scenario. Therefore, we have to include all changes in environmental impact from processes affected by changes caused by the UPA scenarios. This approach is also called change oriented or consequential LCA (Finnveden et al., 2009) .

For a comparative assessment a common unit is applied in the reference and scenarios that expresses the function of the system in quantitative terms, i.e. the functional unit (FU). As the main function of the system considered is to manage the food system for a city we will apply a functional unit of 1 ton of food consumed per year and consequently multiply it with the total food consumption of the city.

5.2 System boundaries

We do not include (or better separately calculate) the inputs for the production and maintenance of machines (like transport vehicles, or tractors), buildings, roads and for the production of inputs (like electricity, fuels etc.) related to the food system, with one possible exception for the production of compost. However in some cases these aspects are already included in the available emission factors/proxies used for example to calculate emissions for transport.

Also the transport of inputs (other than the food itself, compost/organic waste and nitrogen fertiliser) to the food production/processing unit can be disregarded. These aspects have in general a very low contribution to the value of the selected indicators.

Included is the transport of compost/organic waste to the composting unit and from the composting unit to primary food production. Of course transport of food between the different links in the food chain is also included. The last link of the food chain, transport from shop to consumer might also be disregarded if, comparing one scenario to another, no differences in food vehicle transport are to be expected or can be substantiated.

5.3 Working with emission coefficients, data and calculations

Calculating indicators using an LCA analysis has it specific difficulties and pitfalls. Mostly, a very large number of data and interrelated calculations are involved. The individual calculations itself are in most cases not very complicated and are generally easy to comprehend. However the number of calculations that need to be made in the different steps of the food chain is quite high and the calculations are interdependent. A mistake made in one step influences other parts of the calculations. Small mistakes are easily made and can have large consequences on the total result. Pay attention to the following aspects when calculating the indicators.

- Be very precise on the dimensions that are used. Describe/mention in all cases the dimensions of the data even if they seem to be obvious for the one who works with the data. Work with the metric system. For the quantities, distances and numbers we work with on a city level, logical dimensions would be hectare as production surface unit, tons for food quantities, kilometres for distance and year for the time scale.

- Some often occurring mistakes in the dimensions are:

-Mixing up production of a certain surface unit per single cultivation or per year. For a lot of crops more rotations can take place within one year especially in tropical and sub-tropical climates and for crops with a short production cycle such as leafy vegetables (lettuce etc.)
-Often mistakes are made with the dimensions of plant nutrients and fertilisers. N input is often expressed as elementary N per ha. The emission coefficient of synthetic N fertilisers is also expressed in CO_2 eq. per kg of elementary N. However for Phosphorus and Potassium the amounts are mostly expressed as P_2O_5 and K_2O.
-The daily food intake per person is mostly expressed in grams per day. This daily intake per person has to be recalculated to the annual intake of a certain population.
-Agronomic inputs (fertilisers, compost, diesel) are often expressed as input per ha per cultivation. These inputs have to be recalculated to inputs per ton of product. In order to do this one should know the average yield per ha per cultivation.

- Be very consequent in using certain emission factors. Refer to this manual if you use the emission factors from this manual, refer to another source if you have better, more local/regional/national based emission factors. Check very well whether you use the right dimensions of the emission coefficient. For example the CO_2 emission for the combustion of diesel in literature is sometimes expressed per litre and sometimes per kg of fuel.

- If you use a certain emission factor, try to get to understand what this factor is based on. For example in some cases the CO_2 emission for the use of a certain quantity of diesel is based on a 'well to wheel' calculation, but in other cases only on a 'tank to wheel' emission. The 'well to wheel' emission includes also the emissions that are caused in the production of diesel. The 'well to wheel' emission is the emission from the winning of the crude oil to the combustion in the diesel engine. Unfortunately not all literature sources indicate the background of the emission factor they present.

- Organise all your data in a database or spread sheet. This means basic data, emission coefficients etc. Be precise and clear in dimensions, source and uniform description of the type of data (per food group, product, type of transport vehicle etc.).

- Keep a good overview of the calculations, do not take to many steps into one calculation. The use of spread sheets and calculation with spread sheets usually gives quite a good overview of the calculations and the 'in between' product of the calculations. In a spread sheet all the calculations can be related to each other from the basic data to the final result. This makes recalculations (because mistakes were found) easy. The calculation can also be divided into a limited number of separate calculation steps.

In some cases a special model is made for the calculations. Actually the spread sheet approach with interrelated calculations is also a kind of model, however mostly with the basic data, coefficients and calculations all in one file. The model for the calculations can be separated from the needed data input. The advantage of building a model is that it can be used for different basic data, and that a large number of scenarios, variations on scenarios or sensibility for specific uncertainties in the data can be calculated. For example, the effect of more energy efficient cars, the effect of a shorter distance, the effect of the uncertainty of certain data or emission coefficients can be easily included. The model can then be used for all kinds of simulations.

Although there are not much reference data for food miles, fossil energy use on GHG emissions for local production or waste recycling, still the results can be compared to the reference data, when the data are expressed as a value per ton of food. There are various reference data for the values of the indicators per ton of product. They provide either averages for all food items, or per individual product or over the total food chain, or per individual link of the chain (especially for emissions in primary production). So the results of the calculation per ton of product can be compared to existing literature data. Also the average contribution of different links of the food chain to fossil energy use and GHG emissions are available in literature. Be aware that in our calculations we only focussed on the changes in the food system! Comparing with literature data shows at least whether the results make sense. If large deviations from literature data are found, check the calculations.

5.4 Step by step approach for calculating changes in the indicators for the different scenarios

The different steps to take in order to calculate the changes in the selected indicators are described briefly in this paragraph. Every step is explained in more detail in the following paragraphs. The steps are described in a logical sequence. However and in practice, one may need to go back to earlier steps, for example when describing and calculating a certain step, information from the previous step may need to be adapted.

For each scenario the following general steps should be described/calculated:

1. The part of the city consumption which is affected by the different scenarios. This means describing the volume of the city consumption for different products/ product groups that have changed in origin, production technique, processing, quantity etc. See the example provided in table 3.

2. If there is a large number of products (> 10-15) for which the consumption has changed in a specific scenario, reduce the number of products to be analysed. Disregard products with a very small quantity, make product groups and choose model products (see further in paragraph 5.5)

3. Per consumed product that has changed (or model product, see previous step), draw/ describe the total food chain for the different scenarios (example figure 3).

4. Analyse the differences in the described food chains (from the previous step) for each of the scenarios. Select these changes in the food chain that have an influence on the indicators to be calculated.

5. Quantify the in the previous step selected aspects of the food chain for the different scenarios, such as transport distances, means of transport, inputs in primary production

etc.

6. Find the relevant proxies for GHG emissions and (fossil) energy use, like GHG emissions and energy use for synthetic nitrogen fertiliser production or the fossil fuel use and emissions for a certain means of transport. The proxies are either given in the appendixes in this manual or can be found in the mentioned databases.

7. Calculate the indicators per scenario for every (model) product per weight unit (mostly tons).

8. Multiply the value of the indicators per model crop with the total consumed weight in the product group (if model crops have been chosen).

9. Add up the value of the indicators for all the products or product groups.

5.5 City consumption affected by scenarios

The changes will mostly be in the origin of the product and in the production inputs (partly replacement of synthetic fertilisers by processed city waste as compost), because these are the main ingredients of our scenarios. However, also the consumption volume of certain products might have changed in our scenarios compared to the zero-scenario. For example, people are expected to eat less beef and more chicken. The production of chicken causes much lower GHG emissions, especially if the chickens would be fed on urban food residues. The change in volume of one product is mostly related to the change in volume of another (if the total food intake in energy, proteins or vitamins should stay the same). Another example could be, less consumption of meat and more of pulses like beans and peas. If the volume of consumption of certain products is changing due to a scenario, than the GHG emissions of the total food chain of these products has to be calculated in order to be able to calculate the effect of that scenario. This gives an extra complication in the calculations, therefore the simplest way is to assume that only origin and production technique/inputs of products change but not the consumed volumes.

Table 3. Example of changes of food consumption due to scenarios

Product group	Scenario 0 City demand[1)] (ton/yr.)	Scenario x City demand[1)] (ton/yr.)	Scenario 0 current/actual (peri)-urban production (ton/yr.)	Scenario x future (peri)-urban production (ton/yr.)	Changes in:
Potatoes and root crops	42 048	42 048	5 000	42 048	Origin of production, production inputs
Vegetables	43 800	43 800	10 000	43 800	Origin of production, production inputs
Pulses	1 314	1 314	0	1 314	Origin of production, production inputs
Fruits	42 924	42 924	8 000	30 047	Origin of production, production inputs
Dairy products	171 258	171 258	0	17 126	Origin of production, production inputs
~~Cereals and cereal products~~	~~95 922~~	~~95 922~~	~~500~~	~~500~~	No changes
~~Meat and meat products~~	~~52 560~~	~~52 560~~	~~500~~	~~500~~	No changes
Eggs	4 818	4 818	500	1 606	Origin of production, production inputs
~~vegetable oils~~	~~10 512~~	~~10 512~~	~~0~~	~~0~~	No changes

Table 3 gives an example of the changes in the food chain for certain product groups. The changes are in origin and in production inputs. No changes in the volume of certain product groups are assumed in these scenarios. The products for which no changes in the food chain occur (such as in this example cereals; meats and vegetable oils), can be disregarded. For further analysis the product groups need to be better specified in detail. For example fruits and vegetables would have to be divided into different fruit and vegetable groups. The subdivision and grouping of products is dependent on differences in their food chain, yields per ha etc. See also the paragraph on product groups below.

Further analysis of the food chain might also bring forward other changes in the food chain than those mentioned in table 3. See further the paragraph 'analysis of changes in the food chain'.

5.6 Simplifying calculations by reducing the number of products to analyse

If only a rather limited number of products is produced in the (peri)-urban area for the different scenarios, the steps in the chain can be identified for each of these products separately (continue in this case with chapter 5.7 on analysis of the food chain). If the number of products grown is large (e.g. more than ten), disregard the crops with a low volume/year, e.g. less than 1 or 2% of the total volume of (peri)-urban production. This could be the case with for example herbs and spices. In order to further reduce the number of products to be analysed, the products can be combined into product groups that have a similar food chain and similar GHG emissions for the food chain (of the crops that will be replaced by (peri)-urban production).

Main factors to take into account when making these product groups:

- Origin of the product: the majority of products in a product group are all imported from the same region. For example 80% of all the leafy vegetables are imported from a region located 400 km from the city.
- Processing: is the replaced product normally undergoing (intensive) processing before being sold or not? Do not take into account simple operations like grading and packaging.
- Is cold storage in the chain for the replaced product normally included or not?
- What is the perishability of the replaced product (see annex 1). This often influences the maximum length of the food chain or the need for processing or refrigerated transport and cold storage. Products with similar perishability often have a similar food chain. Fresh products have higher perishability than processed products; fruits and vegetables generally have higher perishability than grains or root crops.

An example of a division into product groups is given in annex 1.

For each group of crops cultivated, select one or two (if an important group) main products that are most representative for that group (model products or crops). The food chain for the model crop is considered to be valid for the whole product group. The calculated data per ton for the model crop are used to extrapolate data for the total volume of the product group.

5.7 Analysis and quantification of changes in the food chain

For the calculation of the chosen indicators the following changes in the food chain, for the different scenarios, are the most relevant to analyse in more detail:

- Fertiliser/organic matter, energy input and GHG emissions in primary production
- The urban organic waste chain
- Transport distances between different links in the food chain
- Energy use for processing and packaging
- Cooled storage used in different parts of the chain
- Food losses in the product chain
- Energy use in the distribution centres and consumers distribution points.

These different aspects are not contributing equally to energy use and GHG emissions. In general the most relevant differences are production inputs (especially input of synthetic nitrogen fertilisers), transport, product losses and need for cooling. Energy use for light processing as washing and grading, energy use for packaging, energy use at the distribution centre and consumers selling point are mostly relatively small (per ton of product) and therefore might be disregarded.

Again, focus the analysis only on the possible differences between the scenarios. If for a certain aspect no difference in the product food chain for the different scenarios is to be expected, this aspect does not need to be analysed. Examples:

- If all cereals in the different scenarios are imported from the same locations, no calculations on cereals are needed.
- If the production methods in primary production of a certain product (group) is the same for production outside and inside the defined (peri)-urban area (or is assumed to be the same), no calculations for primary production for this product group are needed.
- If the distribution within the defined (peri)-urban area of the products in a product group is the same in all scenarios, for this group no calculations for distribution within the defined (peri)-urban area are needed.

Fertiliser/organic matter, energy input and GHG emissions in primary production

The main aspects that determine GHG emissions, energy use and food kilometres in primary production are:

- Energy use and related GHG emissions for mechanisation and irrigation
- If used, energy use and related GHG emissions for heated greenhouses
- Energy use and GHG emissions for the production and application of synthetic nitrogen fertilisers
- Energy input and GHG emissions for the production and transport of manure, compost and organic matter inputs
- Methane emissions due to digestion in livestock, especially ruminants
- Methane and N2O emissions due to manure storage
- Carbon sequestration due to organic matter inputs in the soil.

The changes in primary production depend on the chosen scenarios. Some of the above mentioned aspects of emissions and energy use are very hard to quantify and/or have a high uncertainty depending on the local circumstances and/or are not likely to be much effected by the scenarios. This is in general the case with the aspects e, f and g. We would advise to disregard these aspects in the calculations. For aspect d, see also the paragraphs on food transport.

Changing the origin of a product to more localised regional production, might have an effect on the scale of production and the mechanisation level for production. Especially for home garden production the level of mechanisation will in general be low. At least quantify the level of mechanisation and the related fuel use per ha for the different scenarios (see Box 5).

Box 5: Quantification of fuel use for mechanisation in primary production

If available, use literature data for the fuel use per ton of product. If not available, categorise the degree of mechanisation in classes (e.g. use of tractor, harvesting machines etc..: none, low, intermediate, high. A proxy for the fuel use per ton of product per class of mechanisation degree needs to be established for the specific product. Examples for a highly mechanised production of wheat and potatoes (Western Europe) would be respectively 14 and 4 kg of diesel per ton of product.

If the use of additional organic fertilisation (manure, compost etc.) based on city waste is included in the scenarios, the use of synthetic fertilisers, carbon sequestration, the transport of fertilisers and organic waste and the methane emissions of landfills could also change (see further next paragraph). For the emissions for the production and application of synthetic fertilisers, standard data are available (see annex 2). The most important is the production and application of synthetic nitrogen fertilisers. Therefore, if changes in fertiliser use are to be expected in a scenario, at least quantify the use of synthetic nitrogen-fertilisers per ha per year and eventually per ton of product for the different scenarios.

The use of organic fertilisers based on city waste also influences the whole cycle of processing and transport of city waste. This will be dealt with in the next paragraph.

Box 6: Quantification of synthetic nitrogen fertiliser input in primary production

If available, use literature data for the synthetic nitrogen fertiliser use per ha for a product. If not available, establish the degree of synthetic nitrogen fertilisation in classes: 0; 0-50; 50-100; 100-150; 150-200; 200-250 kg per ha. (note: this relates to net N weight contained in the fertiliser).

Use the average nitrogen input of the class as the actual nitrogen input per ha (e.g. 0; 25; 75; 125; 175; 225). Use the average yield for primary production in the identified product chains and calculate the nitrogen fertiliser input per ton of product.

The chain of urban organic waste

Recycling of organic waste can be part of a package of measures in a chosen scenario (see discussions in previous chapters above). The use of (additional) processed or non-processed organic waste in primary food production can have a considerable effect on GHG emissions and energy consumption/production. The main effects are caused by:

- Reduction in the use of synthetic fertilisers
- Reduction of methane emissions from anaerobic fermentation of organic material (mostly from landfill)
- Energy use needed for gathering, transport and processing of organic waste
- Energy production from controlled fermentation or burning of organic waste
- Carbon sequestration in the soil due the (additional) input of organic material in the soil.

An example of a complete calculation can be found in: Luske, B. 2010. Reduced GHG emissions due to compost production and compost use in Egypt http://orgprints.org/17480 .

Some of these aspects are however very hard to calculate, have a high uncertainty or have a relatively low contribution to energy use or emissions (aspect c, d and e). To simplify the calculation of the effects of compost use, one can focus on aspect a and b.

For the reduction in the use of fertilisers focus on the production and application of synthetic nitrogen fertilisers and possibly phosphorus fertilisers. These are by far the most important ones in relation to energy use and GHG emissions. See also previous paragraph.

Check at least how much organic waste is produced in the city and how much could be recycled and to what extent this organic waste could replace synthetic nitrogen fertilisers in primary production in the defined (peri-) urban area. The city departments that are responsible for the city waste management usually have data on the production of waste, the type of waste and management of the waste. Knowing the types and management of organic waste, the nutrient content of the waste can be estimated from standard data.

If in the zero-scenario, organic waste would be (partly) dumped in a landfill and in one of the selected UPA scenarios the waste would not be dumped, but used in primary food production, this would possibly lead to a considerable reduction of methane gas emissions from anaerobic fermentation of organic matter. Standard data for avoided methane emissions are given in the annex 2. Not all organic material that is used for fertilisation would have been otherwise dumped at the landfill. So establish also the percentage of the organic material that would otherwise have been dumped at the landfill.

Box 7: Quantification of avoided organic waste dumped at the landfill

Quantify how much (tons per year) of organic waste (either processed as compost or directly) would be used in food production in the (peri)-urban area according to the different scenarios. Mind the weight loss due to composting (50 to 60%)! Define how much of this input of organic waste in food production would otherwise be dumped at the landfill or dumped and stored under (semi) anaerobic conditions in another way. A proxy for methane emissions for organic waste at fermented anaerobic conditions is given in annex 2.

Transport distances between different links in the food chain

Transport distances between the different links in the food chain are very likely to change in the different scenarios. These changes have a direct effect on the chosen indicators. But not only the transport distance will change, it is likely that also the transport mode will change. The transport mode can have a large effect on the energy use and emissions caused by transport. Long distance transport often uses a transport mode with a larger freight size, while for perishable products a faster transport mode is used (for example air freight). Products that are produced within the urban area are more likely to be transported with smaller transport units, like small vans, motorised three-wheelers or other means. So not only the changes in the transport distance have to be analysed but also the change in the modes/means of transport.

We do not include the transport from selling points to the consumer assuming that these will be similar for all the scenarios. However if there are substantial differences between urban/peri-urban produced food and "imported" food in the transport from selling point to consumers you may attempt to estimate these differences and related GHG emissions (locally produced food can be sold at such short distances that there are no fuel costs – with consumers coming by bike or on foot-, whereas most imported food might be sold through central market places and supermarkets to which most clients go by bus or car).

Other factors that have to be taken into account when calculating energy use and emissions for transport are the use of cooled or non-cooled transport, the vehicle load (actual weight transported divided by maximum weight that the vehicle is allowed to carry), and the extra (empty) return kilometres. Extra kilometres are mostly the kilometres that are driven empty, for example for an empty (or only crates) return trip. For example for the bulk transport from production to processing, the vehicles very often have an empty return trip. However, extra kilometres can also be caused by delivery at different locations. For example a truck brings 75% of a load from point A to B (which are 100 km apart), but 25% to point C for which it has to travel an additional 25 km.

So the transport distances, the mode of transport, the load and extra kilometres and the type of energy source for transport need to be established. Information about transport modes, loads and extra kilometres can be obtained by interviewing transporters, distributors and wholesalers. Differences in load and extra kilometres between scenarios will complicate the calculations, therefore, if there is no strong evidence or not a logical assumption that loads and extra kilometres change for the different scenarios, you can in that case focus only on the differences in transport mode and transport distance.

Box 8: Quantification of transport distances and transport modes

Quantify for each (model) product chain the transport distance and the transport mode for the different scenarios. Focus on the one or two origins where the main part of the produce is coming from. E.g. if 70% of the product comes from one origin, and the rest is scattered over different origins, than you will focus hereafter on the origin from where the 70% comes from. This origin is used for the total product chain. If there are two main sources with e.g. 35 and 45 % share in the total volume of the "imports" of that product into the city, you take those 2 origins for further analysis.

Divide transport means in classes (including subdivision in type of fuel and cooled transport or not) appropriate for the local situation and in line with annex 2. Transport on foot and by bike can be discarded. Define the load and the extra kilometres per transport class in a certain product chain. If there is no information available use the proxies that are given in annex 2.

Energy use for processing

In general the energy use and related GHG emissions for light processing (washing, grading, cutting, pealing, packing, grinding) are relatively low. Also light packaging or bulk packaging has a relatively low impact on the selected indicators. So differences for light processing and packaging might be disregarded.

For more intensive processing (for example sterilising, forced drying, deep-freezing etc.) and more luxury packaging (for example Pringles) or packing small quantities (for example yoghurt in a 100 to 150 ml cup) energy use and related GHG emissions can be relevant. For some processing types, proxies are given in annex 2. For packaging, the energy use can be related to the production of the basic material of the packaging material (x kg of basic material per ton of product). Energy and emission values for some basic products are given in annex 2. Detailed information about energy use for production of the packaging material and for the packaging itself are often not available, estimations have to be made.

Another difference that might be relevant is the used energy source (manual labour, waterpower, nuclear power etc.) used for the processing in the different scenarios.

Cooled storage during the product chain

A lot of products are or need to be cooled in all or certain links of the product chain. Product cooling can be a relevant aspect related to energy use and GHG emissions. Especially in long storage for products like apples, potatoes etc. energy use can be substantial. This energy use is very dependent on the length of the storage period, the cooling technique sued and the temperature difference with the outside temperature. Therefore standard data area hard to give.

What needs to be analysed (if there are differences in the product chains for the scenarios), is the average temperature under which the product is normally stored, the average outside temperature in the period the product is stored and the timespan (number of days or hours) the product is stored. In general different types of storage could be distinguished for these calculations: deep freeze; long storage (like for apples or potatoes, up to several months); short storage at the producer, distribution centre or retail/shop; storage during transport. For cooling during transport a 10% additional energy use should be added to the vehicle energy use. To simplify the calculations for short storage, the same storage conditions could be assumed for several links of the chain (primary production, distribution centre, retail). For example in the zero-scenario, leafy vegetables are stored in the total chain (excluded in transport) for totally 48 hours under a temperature of 10 o Celsius, while average outside temperature is 22 o Celsius.

Box 9: Quantification of cooled storage

If there are differences between the scenarios in cooling, than quantify the number of days that the product is cooled in a certain way in the total product chain. Distinguish between cooling types (deep freezing, long term bulk storage, temporary cooling in product chain) after harvest at primary production, distribution centre, in shops. Per cooling type define the average cooling temperature, the average outside temperature and if possible the cooling technique. Cooling during transport is already included in the calculations for transport.

Food losses in the chain

Food losses in the product chain can have a strong effect on the selected indicators (see also paragraph 4.1). Food losses can occur in every step of the food chain. Some losses are unavoidable (like banana skins). The losses at food consumption stage are generally the largest. Scenarios with a shorter food chain might have lower food losses, although the availability of data on this topic is often limited. If there are data or experiences available (local/national data or data from pilot projects on household level) that substantiate the assumption that the selected scenarios differ in their amount of food losses, these data can be used in the calculations. Otherwise it is advised to disregard food losses.

Including food losses as a consequence of a scenario also requires collecting additional information on the food chain. Reduction of food losses also means that less food needs to be produced and transported. So to calculate the effect on the indicators, information about GHG emissions and energy use in primary production are also needed.

Box 10: Quantification of avoided food losses

If there are (substantiated) differences in food losses between the scenarios, quantify these differences per product(group) in percentage food loss for every link of the food chain. Reduction of food loss at for example the consumers' level means that the emissions, food kilometres and energy use in the whole chain before the consumer are avoided. Therefore, if there are differences in food losses between the scenarios, also correct the amount of food that has to be produced, transported etc. in the different links of the food chain. For example if the city consumption of a certain product is 5 000 tons per year and the losses are 20% at consumption, than 6 000 tonnes of that product needs to be produced, cooled, transported etc. Use these corrected amounts for the calculation of the selected indicators.

Energy use in the distribution centre and consumers distribution point

Compared to the energy use in the total food chain, the energy use per unit of product at the distribution centre and shop are in general very low. Moreover there is little data available on energy use at these links of the food chain. Cooled storage is however an important aspect of energy use at these links of the food chain. This aspect can be integrated in the total days of cooling during the whole food chain (see also previous paragraph on 'cold storage during the product chain').

5.8 Example analysis

For each product (group) that shows changes in the food chain for each of the selected scenarios, the food chain needs to be described and analysed. Below an example for potatoes and root crops is given. The example for root crops includes most of the possible differences to be taken into account for the different food chains: production inputs, yield, transport, energy use for the different links of the chain and losses in the food chain.

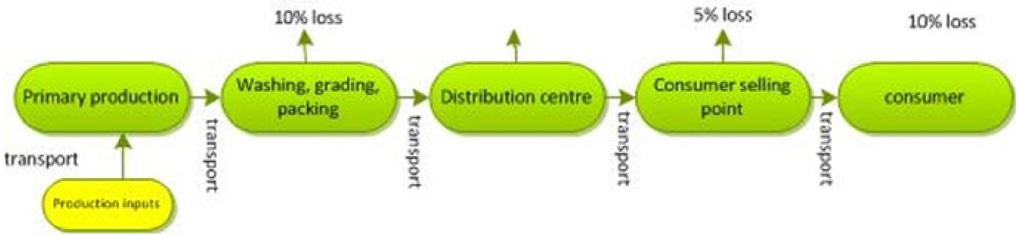
Figure 3 gives an example of the food chains for potatoes and root crops. Potatoes and root crops are placed in one food group because in this example they come from the same imported origin, they have the same production characteristics and follow the same food chain.

Les us assume again that the total city consumption is 42 048 ton per year.

- In the zero-scenario 100 tons are produced in the urban area (home gardens), 4 900 tons are produced in the peri-urban area and the rest is imported.
- In scenario x, 500 tons are produced in home gardens in the urban area, and the rest is produced in the defined peri-urban area.

The food chains (with only a focus on the differences) of the different origins are as follows (see also figure 3) and are further described below:

Food chain of imported potatoes



Food chain of potatoes produced in the peri-urban area

Food chain of potatoes produced in home gardens

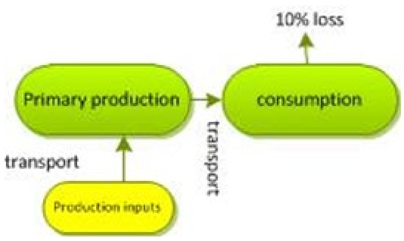


Figure 3. Example of the food chain for imported production, peri-urban production and urban production in home gardens.

Conventional origin imported:

Primary production

- Fertilisation input per ha is 200 kg of N, 50 kg of P_2O_5 and 200 kg of K_2O, the fertilisers are transported to the production site over a distance of 200 km. No organic waste is used as soil improver/fertiliser. Yield is 50 ton per ha per year.

- Energy input for machinery is 4 litres of diesel per ton root crop production.

Storage

The average storage time after primary production and before processing is 2 months at 5 o Celsius (mechanical cooling) in a large cooling house; there is no cooling in the rest of the food chain.

Processing

- The distance between production site and processing (grading sorting packaging) is

50 km. Transport is done by 20 ton non-cooled trucks, there is a full load and the return distance is empty.

- Processing costs 4 kWh of electricity per ton; the potatoes are packed in re-usable crates or in 5 kg bags.
- The packaging used is 1 kg of plastic per ton.
- 10% of the product is lost during processing.

Distribution centre

- The distance between the processing and distribution centre is 500 km, a 20 ton (non-cooled) truck is used with a full load; the return travel is empty.
- Energy use for the distribution centre is 0,5 kWh of electricity per ton.
- The losses in the distribution centre are 0.

Consumers' selling point

- Transport from the distribution centre to the consumers' selling point (shop) is 20 km with a 5 ton truck (non-cooled), the average load is 70% (delivery at different addresses); there is an empty return trip of 20 km.
- The energy use at the consumers' selling point is 0,5 kWh per ton (no cooling).
- 5% of the product is lost at the consumers' selling point.

Consumer

- The transport from the consumers selling point to the consumer is done on foot, no energy use'.
- The energy used for food preparation is the same for all scenarios.
- 10% of the product is lost at the consumer level.

For the peri-urban origin/food chain:

Primary production

- Fertilisation input is 100 kg of synthetic nitrogen fertiliser per ha, the rest of the nutrients is provided by processed organic city waste (12 tons of compost per ha per year). The organic waste is transported over 10 km by a 5 ton truck.
- 50% of the organic matter in the compost would have otherwise been dumped at the landfill. For the production of one ton of compost, 2.5 tons of organic waste is needed. So for the 12 tons of compost applied, 0.5 * 2.5 * 12 = 16 tons of organic waste are diverted from the landfill.
- Energy input for machinery is 4 litres of gasoline per ton root crop.

Storage

The average storage time after primary production and before processing is 2 months at 5 o Celsius (mechanical cooling) in a small cooling house at the primary producer; there is no cooling in the rest of the food chain.

Consumers selling point

- Transport from the production site to the consumers'' selling point (shop) is 20 km with a 5 ton truck (non-cooled), the average load is 70% (delivery at different addresses), there is an empty return trip of 20 km.
- The energy use at the consumers selling point is 0,5 kWh per ton.
- 5% of the product is lost at the consumers selling point.

Consumer

- The transport from the consumers selling point to the consumer is done by foot, no energy use.
- The energy used for food preparation is the same for all scenarios.
- 10% of the product is lost at the consumer level.

For the urban origin home garden/ food chain:

Primary production

- Fertilisation input is all by organic waste and dung, gathered and composted without energy input.
- No energy input for machinery.

Storage

There is no cooled storage.

Consumer

- Transport from production site to consumption site by foot .
- The energy used for food preparation is the same for all scenarios.
- 5% of the product is lost at the consumer level.

5.9 Calculation of the indicators

Introduction

The indicators to be calculated are:

- Food kilometres
- (Fossil) Energy use
- GHG emissions
- Optional: land use (not discussed)

The calculations for GHG emissions and (fossil) energy use are focussed mainly on the differences between the selected scenarios. So if from the analysis it becomes clear that for certain aspects or products there are no differences between the scenarios, the indicators do not need to be calculated for those aspects or products. The calculation is done step by step for each indicator:

1. Per link within a food chain of a product (group) per ton of product
2. For the total volume of the product group per link within the food chain
3. For the total food chain and volume of a product (group)
4. For the total city consumption (all product groups added up).

To be able to calculate the selected indicators, the quantified basic information derived from paragraph 5.7 needs to be multiplied with certain coefficients, like fuel use per ton per kilometre for a certain vehicle and the GHG emissions of the production and combustion of 1 kg of diesel. The values of these coefficients or references are given in annex 2 or in the text.

Before calculating the indicators, the actual food demand from the city has to be (re) calculated for the different selected scenarios. In paragraph 2.3 a rapid calculation of food demand was made. For the different scenarios we might have included changes in food losses or changes in volume between product groups. In paragraph 5.7 we discussed if there are any changes in food losses for certain scenarios (for example because of shorter product chains). So based on the food intake in the different scenarios and based on the analysed food losses in the chain we need to recalculate the city's food demand per product (group). Moreover we have to establish how much of the produce needs to be transported, processed etc. in the whole product chain. If for example food losses occur at the end of the food chain than the lost food has been already transported, if the food is lost at the primary production stage, the lost food has not been transported.

Calculation of food vehicle kilometres

System boundaries

As indicated earlier, we do not include the vehicle kilometres that are made for the production of machines (like transport vehicles, tractors), buildings and the production of inputs (like electricity, fuel etc.), with one exception for the production of compost. Also the transport of inputs (other than the food itself, compost/organic waste and fertilisers) to the food production/processing unit can be disregarded. In general these vehicle kilometres have a very low contribution.

Included are the transport of compost/organic waste to primary food production and transport of food between the different links in the food chain. The last link, transport from shop to consumer might also be disregarded if no differences in food vehicle transport are to be expected (see previous chapters).

Calculation of kilometres per ton per product group for every link of the chain

For every transport between the different links of the food chain the food kilometres per ton of food are calculated separately. Al food kilometres are at this level expressed as kilometres per ton of food product. The calculation for food kilometres includes the transport of the production input like fertilisers and compost.

For every link, except transport of production inputs, the transport vehicle kilometres per ton of food are calculated according to the following formula:

(Transport distance loaded + transport distance empty + detour km) / Average Weight transported per vehicle Distance in km and weight in tons; detour km when additional deliveries are made

The transport of inputs for primary production (compost, fertilisers) is mostly given as input per ha. These vehicle km have to be expressed as km per ton of food. The calculation is as follows:

Needed input per ha * (Transport distance full + transport distance empty + detour km) / (Average Weight transported per vehicle * yield per ha) Distance in km and weight in tons; detour km when additional deliveries are made

An example for potatoes is given in Box 11.

Box 11: Example for potatoes

Transport of inputs

-The production of the potatoes is 40 ton (net weight delivered of farm) per ha per year. -For the production of potatoes, 20 ton of compost per ha per year is used and 100 kg of nitrogen as calcium ammonium nitrate (27% N, so 370 kg CAN) -Transport distance of compost is 20 km, transported by a fully loaded 20 ton truck, return trip is empty -Transport distance of CAN is 300 km with a fully loaded of a 20 ton truck and an empty return trip

Calculation food vehicle km:

-Compost -20*(20+20)/(20*40) = 1 km/ton
-CAN- 0.37*(300+300)/(20*40) = 0.28 km/ton

Transport from producer to (light) processor:

-Transport from the producer to the processor is over a distance of 100 km with a fully loaded 20 ton truck, the return trip is empty

Calculation food vehicle km:

-(100+100)/20 = 10 km/ton

Transport from (light) processor to consumer selling point:

-Transport from the processor to the consumers selling point over a distance of 20 km with an average of a 60% load in a 10 ton truck, empty km are 10

Calculation food vehicle km:

-(20+10)/6 = 5 km/ton

Transport from consumers selling point to consumer

-20% of the food shopping is done by car. The average distance is 2 km and the trip to the shop is empty. On average a customer transports 10 kg of food on a shopping trip

Calculation food vehicle km:

-(2+2)/0.01 =400 km/ton (the 20% of the total that is transported will be taken into account at a later step).

The last transport step, between the shop and the customer, shows that, in terms of food vehicle kilometres, consumer transport can have a large impact on the total food vehicle kilometres. It is also advised to calculate the food vehicle kilometres for a different transport mode separately.

From food vehicle kilometres per ton per product (group) to changes in total food kilometres per scenario

We calculated how much of a certain product needs to be transported between every link of the food chain. We also know the number of kilometres per ton for the transport between the different links of the food chain. Now for every step of the chain we can multiply the kilometres per ton with the total amount that needs to be transported. After that the food vehicle kilometres for every step can be added up to give the total food vehicle kilometres for the total food group.

∑_(i=1)^nkm/tonne i*tonne total weigt i

i = transport step in the food chain

We might subdivide the food vehicle kilometres per product (group) in different types / modes of transport or for the stretch of the transport. For example, the impact of transport within the urban area is different from the transport outside the urban area (take into account traffic jams, dust and pollution and possible traffic accidents etc.). Therefore a distinction could be made in food vehicle kilometres within and outside the urban area. Also the impact of a 20 ton truck is very different from for example of a motorised three-wheeler. So food vehicle miles can be subdivided into for example 20 000 km with 20 ton trucks, 5 000 km with 5 ton trucks and 7 000 km with 1 ton vans.

In Box 12 an example calculation for root crops is provided.

Box 12: Example calculation root crops (model crop: potato)

The yearly consumption of root crops in the (peri)-urban area is 50 000 tons per year. At the consumer level, 20% of the produce is lost and at the processing unit 10% of the produce is lost. We use the steps, transport modes and vehicle km per ton in the food chain as described in the previous calculation example for potatoes (Box 11):

1. production inputs – 2. primary production – 3. processing unit – 4. shop – 5. consumer

From processing unit until the consumer 50 000*10 /8 = 62 500 tons need to be transported. From the shop to the consumer 20% is transported by car =12 500 tons

From primary production to the processing unit 62 500 *10/9 = 69 444 tons need to be transported.

(The factor 10/8 and 10/9 are because of the resp. 20 and 10% product loss in these specific parts of the food chain).

Table 4. The total food vehicle kilometres per transport step in the food chain, example potatoes

Transport step	Km/ton[1)]	Weight transported (ton)	Food vehicle km	Transport mode
1-2	1.28	69 444[2)]	88 888	20 ton diesel truck, full load
2-3	10	69 444	694 440	20 ton diesel truck, full load
3-4	5	62 500	312 500	10 ton diesel truck, 60% load
5	400	62 500 * 0.2	5 000 000	Person car, 10 kg load
total			6 095 828	

1) As calculated on the previous page
2) The food vehicle km per ton for inputs were calculated per ton of potato therefore here its multiplied by the total transported weight of the potatoes

This example again shows that if a scenario would have influence on consumer food vehicle kilometres, there will be quite a big effect on the results. Of course a person's car does not have the same impact as a 20 ton truck. Therefore food vehicle kilometres can be divided in different transport classes with a comparable impact.

After calculating the food vehicle kilometres per food group, the total food vehicle kilometres for the different product (groups) per scenario can now be added up. Either as a total, or subdivided into transport modes, and/or in food vehicle kilometres within and outside the urban area.

As a last step we calculate the differences between the zero scenario and the UPA scenario(s).

Calculation of (fossil) energy use

Energy use will be calculated for all the links in the food chain and all transport between the links that are (substantially) changing in energy use per product unit for the different scenarios. The energy use is expressed in mega joule (MJ).

For each aspect that changes in energy use, we can use the data from the analysis in 5.6. These data are combined with energy use coefficients which can be found in the data bases referred to or data that are mentioned in annex 2.

System boundaries

In general we do not include the energy use for the production of machines (like transport vehicles or tractors), buildings and the machines for the production of inputs (like electricity, fuel etc.).

Also the energy use for the transport of inputs (other than the food itself, compost/organic waste and fertilisers) to the food production/processing unit can be disregarded. This energy use is relatively small.

Included are the energy use for transport of compost/organic waste and fertilisers to primary food production and transport of food between the different links in the food chain. The last link, energy use for transport from shop to consumer and energy use for preparation and storage at the consumer might also be disregarded if no differences for the different scenarios are to be expected or can be substantiated.

Calculation of energy use per ton of product

In paragraph 5.7 we quantified the (differences in) the relevant inputs per ton of a product for the different scenarios. These inputs have to be translated to (fossil) energy use. For every input or activity an energy use factor (MJ per unit of input) can be found (in annex 2 or in the relevant databases) or needs to be established. If there is no energy use factor available in annex 2 or databases contact a LCA advisor to find or estimate the energy use factor. The most relevant inputs or activities we have analysed and quantified are:

- Food losses in the product chain
- Mechanisation and irrigation in primary production
- Use of fertilisers and compost
- Cooling and storage
- Transport
- Energy use for processing and packaging
- Energy use in the distribution centre and consumers distribution point.

All inputs and activities have to be translated to the input (per ton of a certain food product) of a certain fossil energy carrier (fuel, gas, coal etc.) or to electricity. This energy carrier has to be related to the energy use in MJ per ton of food product. In some cases the input is already directly translated into energy use per kg input.

Food losses in the product chain

The effect of differences in food losses between the scenarios means that a different amount of food has to be produced, processed, cooled and transported, as described above. This implies differences in energy use, food kilometres and GHG emissions. These differences are only partly accounted for, namely only for these aspects where we established differences for these aspects between the selected scenarios. We calculated a volume to be handled/produced for every link of the food chain because of these losses. However even if there are no differences between the scenarios in inputs, processing cooling etc. per ton of product, still there are differences in total inputs etc. because of the different total volumes that need to be produced/handled. So it needs to be checked if differences in food losses are already accounted for. If not the effects on the indicators need to be calculated separately.

Box 13: Example

For a certain product there are no differences in fertiliser input per ton of product between the scenarios. However, in one of the scenarios the food losses are 10% and in the zero scenario 20%. In this case the fertiliser and mechanisation input for the volume that needs to be produced in this scenario is also 10% lower compared to the zero-scenario.

Mechanisation and irrigation

We established the exact fuel use per ha or per mechanisation class per ha of a product for the different scenarios.

Box 14: Example

200 litre of diesel is used for a highly mechanised potato cultivation with a yield of 50 tons per ha per year. For irrigation we need 400 m3 of water which costs 3 KWh per m3 for pumping. So for mechanisation and irrigation we need 4 litres of diesel and 24 KWh of electricity per ton. These data have to be multiplied with the general energy factor for diesel (46.0 MJ/l; well to wheel) and the local factor for electricity.

Use of N-fertilizers and compost

In paragraph 5.7 we quantified inputs per ha or already per ton of food product.

Box 15: Example:

200 kg of nitrogen fertiliser (as Calcium Ammonium Nitrate) is needed for the production of 50 tons of potatoes. For the production of 1 kg of N (in CAN) the fossil energy use is 41.8 MJ per kg N.

The energy input due to fertilisers per ton of potatoes is: 200 * 41.8 / 50 = 167.2 MJ.

For compost, the calculation is the same by using the energy factors per ton of compost.

Cooling and storage

We quantified the number of days for a certain type of cooling and described cooling temperature and outside temperature. Energy factors might be available for certain types of cooling under certain conditions. These data have to be corrected for the local circumstances. The value given in annex 2 (2.45 KWh per ton per week) is for long bulk storage at 5 oCelsius with an average outside temperature of 10 o Celsius. This is very likely to be a strong underestimation for the situation in (sub) tropical countries. For the estimation/calculation of local energy factors for cooling, contact a LCA advisor.

Transport

We have quantified the type of transport, travelling distance, extra kilometres and load in paragraph 5.7. Now these data have to be used to calculate the fuel use. The fuel use per certain type of vehicle can vary quite a lot due to local circumstances (slopes, road quality, average speed, etc.). In annex 2, for different classes/types of transport, proxies are given for the GHG emissions per ton per kilometre. For the calculation of fuel use, use local data or contact a LCA advisor for estimations of fossil fuel use per ton per km.

The calculation is: fuel use factor, times the number of transport kilometres (single trip). This gives the fuel use per ton of product. Mind the 10% additional fuel use for cooled transport.

Energy use for processing and packaging

Energy use for processing is very much dependant on the type of processing. For intensive processing some proxies are given in annex 2. For light processing a default value of 4 KWh per ton of product could be used.

For packaging a proxy is given of 5 gram of polyethylene film per kg of product (Energy use for the production of polyethylene = 90.5 MJ/kg). This means 5.0 * 90.5 = 450 MJ per ton of product.

Energy use in the distribution centre and consumers distribution point

Energy use at the distribution centre and consumers distribution point is in general relatively low because of the high turnover of products. An important aspect is cooling of products, which is already accounted for in the total estimation of cooling days. For the remaining energy use, no data are yet available.

From energy carrier per ton to (fossil) energy use per ton

The calculations above result in the electricity or fossil energy source per ton of product. These data have to be transferred to energy use in MJ per ton of product. For fossil energy carriers the data are given in annex 2. The data given are from well to wheel, which means that they include the energy use for the production and transport of the fuel plus the energy content of the energy carrier itself.

For electricity, the fossil energy use per KWh depends on the local, regional or national energy mix used for the production of electricity. If for example (all) the primary producers of a certain product are using a windmill or solar panels for pumping up the irrigation water, the fossil energy use is zero (we have excluded the energy use for making the solar panels or windmill). The energy mix for electricity for different national circumstances is given in annex 2.

In a few cases it might not be completely clear what the source of energy is, either fossil or renewable. You have to use your best estimation here.

From energy use per ton to energy use per city per scenario

This calculation follows the same principle as for food kilometres.

- First: multiply the energy use per ton per product for each aspect (primary production, transport, etc.) with the total weight of the product (group). The total weight of the product (group) in a certain link of the chain needs to be corrected for food losses.

- Second: add up the energy for the different aspects (primary production, transport etc.). Within the product(group).

- Third: add up the energy use for the different food groups per scenario.

- Fourth: calculate the differences between the scenarios.

Calculation of greenhouse gas emissions

This calculation follows the same steps as the calculation of fossil energy use. However there are more aspects contributing to the value of this indicator. Some of these aspects have a higher complexity or uncertainty in the calculation of the emissions (or sequestration).

GHG emissions for food systems are not only influenced by fossil energy use, but also by (more or less temporarily) accumulation of carbon (carbon sequestration) and by emissions of CH_4 and N_2O. The GHG emissions are expressed as tons of CO_2 equivalents (the total effect of the different greenhouse gasses) per ton of product and eventually in this study per scenario for the total city.

GHG emissions will be calculated for all the links in the food chain and all transport between the links that are (substantially) changing in GHG emissions per unit of product due to the different scenarios.

For each aspect that changes in GHG emissions, we can use the data from the analysis in paragraph 5.7. These data have to be combined with emission coefficients which can be found in the data bases referred to in paragraph 5.9.5 or data mentioned in annex 2. The emission coefficients are already expressed in CO_2 equivalents as the total of the different greenhouse gasses.

System boundaries

In general we do not include the emission for the production of machines (like transport vehicles, or tractors), buildings and the machines for the production of inputs (like electricity, fuels etc.). However in some cases the emission data that are available already include these indirect emissions.

Also the emission for the transport of inputs (other than the food itself, compost/organic waste and fertilisers) to the food production/processing unit can be disregarded. This energy use is relatively small.

Included are: the emission for transport and processing of compost/organic waste to primary food production and transport of food between the different links in the food chain.

Calculation of GHG emissions per ton of product

In paragraph 5.7 we quantified the (differences) in the relevant inputs per ton of a product for the different scenarios. These inputs have to be translated to GHG emissions. For every input or activity an emission factor (CO_2 eq. per unit of input) is available (in annex 2 or in the relevant databases) or needs to be established. In the case of activities that are using only energy carriers (for example mechanisation and irrigation) we can multiply the input of the energy carrier (as established in par 5.9.3) with the GHG emission factor for that energy carrier. For example: 4 litres of diesel per ton of product multiplied by 3.6 (GHG emission factor for diesel).

If there is no emission factor available in annex 2 or relevant databases contact a LCA advisor to find or estimate the GHG emission factor.

The most relevant inputs or activities that cause changes in GHG emissions we have analysed and quantified are:

- Food losses in the product chain
- Mechanisation and irrigation
- Production and application of synthetic nitrogen fertilisers and compost
- Carbon sequestration due to organic matter inputs in the soil
- Cooling and storage
- Transport
- Processing and packaging
- Distribution centre and consumers' selling points.

All inputs and activities have to be translated to the emission (per ton of a certain food product) of GHG expressed in CO_2 equivalents.

<u>Food losses in the product chain</u>

See paragraph 5.9.3.

<u>Mechanisation and irrigation</u>

We have established the fuel and/or electricity use per ton of product in paragraph 5.8.3. (example: 4 litres of diesel and 24 KWh of electricity per ton of potatoes). The quantified units of energy carriers have to be multiplied by the emission factor. In annex 2 the ghg-emissions per weight unit of energy carrier and electricity per KWh are given.

<u>Use of fertilisers and compost</u>

In paragraph 5.7 we quantified inputs per ha. or already per ton of food product. For example 200 kg of nitrogen fertiliser (as Calcium Ammonium Nitrate) is needed for the production of 50 tons of potatoes.

There are various emissions that need to be included. These are the GHG emissions for the production, for the transport to the farm and for the application (direct N_2O emission due to application in indirect N_2O emission due to N losses). The 4 kg of nitrogen fertiliser from the example has to be multiplied with the GHG emission factors which are given in annex 2.

The emissions for compost are a bit more complex. The emissions for compost consist of CO_2 emissions caused by energy use (transport, mechanisation for composting), methane and N_20 emissions during the whole process of composting and application and the avoided methane emissions related to otherwise dumping of the waste in the landfill. The emission factors for the different aspect of compost use are given in annex 2.

Carbon sequestration due to organic matter inputs in the soil

As already mentioned, compost use will cause carbon sequestration in the soil compared to the use of synthetic fertilisers only. However the amount of carbon sequestration is disputable and depends on the circumstances. Estimations in a study for Egypt (citrus production) mention 1355 kg CO_2 eq. per ha.

Cooling and storage

We have already calculated the energy use per ton of product. This number of KWh per ton of product has to be multiplied by the local emission factor in annex 2.

Transport

We have quantified the type of transport, travelling distance, extra kilometres and load. Now these data have to be used to calculate the related GHG emissions. In annex 2, for different classes/types of transport data are given for the GHG emissions per ton per kilometre. If the transport type for a specific product fits into the given type classes, this data can be used. There might be a correction needed for deviating loads and extra kilometres (contact a LCA advisor). If the specific transport type is not available in annex 2, try to find the local data and or contact a LCA advisor.

The calculation is: GHG emission factor, times the number of transport kilometres (single trip). This gives the GHG emissions per ton of product. Mind the 10% additional emissions for cooled transport.

Processing and packaging

For processing we calculated the fuel or electricity use per ton of product in paragraph 5.9.3. This data can be multiplied with the emission factors for fuel and electricity provided in annex 2. The weight of the packaging material is calculated in paragraph 5.9.3. This figure can be multiplied with the emission factor for the specific packaging material used.

Distribution centre and consumers selling point

For the distribution centre and consumers selling point we estimated the electricity use per ton of product in paragraph 5.9.3. This data can be multiplied with the emission factors given in annex 2.

From energy use per ton to energy use per city per scenario

This calculation follows the same principles as for fossil energy use.

- First: multiply the GHG emissions per ton per product for each aspect (primary production, transport etc.) with the total weight of the product (group) in that specific link. The total weight of the product (group) in a certain link of the chain needs to be corrected for food losses.
- Second: add up the GHG emissions for the different aspects (primary production, transport etc.) within the product (group).
- Third: add up the GHG emissions for the different food groups per scenario.
- Fourth: calculate the differences between the scenarios.

Energy and GHG emission factors

Energy and emission factors are given in annex 2. In some cases however energy and emission factors can vary, depending on the country and location. It is important to verify with local experts whether locally validated data are available for each of the factors included in annex 2. To save time, it is recommended to first estimate the reduction in GHG emissions due to food kilometres reduction with help of the proxies supplied in annex 2 and thereafter seek more specific and locally validated data for the factors that make the largest contribution to such reduction.

It is not possible to mention al possible factors for all situations. If data cannot be found in annex 2, databases for LCA's can be consulted. An important and recognised source for energy and emission factors for food and agriculture is Ecoinvent (http://www.ecoinvent.org/ecoinvent-v3/). If no data can be found or if data need to be adapted, inform or consult a LCA advisor.

Special attention should be paid to:

- Electricity use: each country has its own specific mix of energy carriers; the country data in the table might be out-dated or deflated for political reasons. It is better check out locally what the country specific values for these factors are.

- Transport: the proxies given are based on some important assumptions: per trip 75-80% of the full capacity of the transport vehicle is used; for (partial) empty return trips 50 % extra kms are added). Use these proxies if they are in line with the local data or when no local validated data is available. If the general pattern in your case is quite different you will have to search for more precise data in the LCA databases.

- Processing: the energy costs in food processing vary a lot (product processed, processing technology applied, energy carriers used) making it difficult to provide proxies in this case. Three proxies have been included. It is recommended to first define the most important types of processing taking place. Subsequently, you can search for specific values for this factor consulting local experts or in the LCA databases (http://www.ecoinvent.org/ecoinvent-v3/)

- Packaging: if packaging takes place you may use, as a default value, the figure indicated in annex 2. This figure is based on the assumption of 5 grams of plastic per kg product. If the packaging of the product is significantly different and a substantial factor in causing GHG emissions, you may choose a higher amount of plastic (e.g. 10 gr, 15 gr, etc.) per kg product and apply a corresponding higher default value (e.g. 2 or 3 or more times the default value in the table) or seek more specific values for this specific packaging process from local experts or in literature.

6. INCREASE IN LOCAL FOOD PRODUCTION, DIVERSIFICATION OF FOOD SOURCES AND INCOME GENERATION

Scenario development and calculations as described above, will provide data for every scenario on different projected or desired land use/covers for UPAF. This will also provide information on the following indicators:

- Increase in local food production or increase in percentage of local consumption demand met by local production (this is also an indicator of diversification of food sources and increased resilience in food supply).

Although this is not further described in this manual, it is also possible to use these production data to calculate related increase in number of jobs and employment opportunities and the amount of money that is retained in the local economy in the city region (see Box 1 below). Such increased income, employment and economic resources are important to further enhance city and household capacity to recover from potential climate change disasters.

Box 1. Scenarios for local food production

Cleveland, USA

Given current policies and bylaws and available area, crop yields, and human intake, three distinct scenarios were developed to determine the potential level of food self-reliance for the City of Cleveland, USA. Scenario I, which utilizes 80% of every vacant lot, can generate between 22% and 48% of Cleveland's demand for fresh produce (vegetables and fruits) depending on the vegetable production practice used (conventional gardening, intensive gardening, or hydroponics), 25% of both poultry and shell eggs, and 100% of honey. Scenario II, which uses 80% of every vacant lot and 9% of every occupied residential lot, can generate between 31% and 68% of the needed fresh produce, 94% of both poultry and shell eggs, and 100% of honey. Finally, scenario III, which adds 62% of every industrial and commercial rooftop in addition to the land area used in scenario II, can meet between 46% and 100% of Cleveland's fresh produce need, and 94% of poultry and shell eggs and 100% of honey. The three scenarios can attain overall levels of self-reliance between 4.2% and 17.7% by weight and 1.8% and 7.3% by expenditure in total food and beverage consumption, compared to the current level of 0.1% self-reliance in total food and beverage by expenditure. The analysis also reveals that the enhanced food self-reliance would result in USD $29 M to $115 M being retained in Cleveland annually depending upon the scenario employed. Money retained was calculated based on total food expenditures. This study provides support to the hypothesis that significant levels of local self-reliance in food, the most basic need, is possible in post-industrial North American cities. It is concluded that while high levels of local self-reliance would require an active role of city governments and planners, public commitment, financial investment, and labour, the benefits to human health, the local and global environment, and the local economy and community may outweigh the cost (S. S. Grewal and P.S. Grewal, 2011. Can cities become self-reliant in food? Cities, Elsevier).

New York State, USA
An analysis done for New York State (NYS) in 2004, revealed that:

-New Yorkers spend over USD $43 billion dollars annually for food.
-New York farmers and food producers generate about USD $18.1 billion in revenues—and much of that revenue comes from export for out-of-state sales.
-The market gap between what New York consumers spend for food at home and away from home (restaurants, etc.) exceeds USD $34.5 billion—money that New Yorkers export all over the world for food.
-New York food producers—both farmers and food manufacturers—captured just 10% of NYS consumer food expenditures, they would increase NYS food system revenues by over USD $8 billion dollars.
-If New Yorkers increased consumer food expenditures by 10% for food produced by New York farmers and another 10% for food manufactured in New York, that money could fuel local and regional economic development by generating USD $16.5 billion in total income and over 17,000 jobs through regional multiplier effects.

(H. Herrera, 2004. New York State Food System Fact Sheet, The Economic Potential of Regional Food Systems. The Center for Popular Research, Education and Policy and NYSAWG, New York).

Annex 1. Potential storage life for certain food groups

<u>Fruits</u>

1.Very short storable: (less than 2 weeks): Apricot, blackberry, blueberry, cherry, fig, raspberry, strawberry;

2.Short storable: (2-4 weeks): Avocado, banana, grape, guava, loquat, mandarin, mango, melons, nectarine, papaya, peach, plum; minimally processed fruits

3.Medium storable: (4- 8 weeks): Apple and pear (some cultivars), orange, grapefruit, lime, kiwifruit, persimmon, pomegranate

4.Long storable (8-16 weeks): Apple and pear (some cultivars), lemon

5.Very long storable (> 16 weeks): tree nuts, dried or canned fruits and other well processed fruits

<u>Vegetables / roots & tubers</u>

1.Very Short storable (less than 2 weeks): Leaf lettuce, asparagus, bean sprouts, broccoli, cauliflower, green onion, , mushroom, muskmelon, pea, spinach, sweet corn, tomato (ripe); cassava

2.Short storable (2-4 weeks); Artichoke, green beans, Brussels sprouts, cabbage, celery, eggplant, head lettuce, okra, pepper, summer squash, tomato (partially ripe); minimally processed vegetables

3.Medium storable (4- 8 weeks): table beet, carrot, radish, cocoyam

4.Long storable (8-16 weeks): Potato, dry onion, garlic, pumpkin, winter squash, sweet potato, taro, yam

5.Very long storable (> 16 weeks): dried or canned vegetables and other well processed vegetables

Source: Kader A.A. Postharvest handling in Preece J.E. and Raed P.E., 1993. The biology of horticulture; An introductory text book, New York, John Wiley & Sons, p 353-377

Annex 2. Proxies for GHG-emissions due to energy use in production, transport, processing, packaging and cold storage

Emissions related to energy use in food production (irrigation pump, tractor, heating etcetera)	kg CO2 eq.	Emission per:	Remarks/assumptions
Gasoline	3.61	Kg	well to wheel
Diesel	3.6	kg	well to wheel
Coal	2.69	kg	well to wheel
Gas	1.87	m3	well to wheel
Electricity (including emissions related to delivery to distribution points; data 2002)			
Nepal	1047	MWh	check locally, see also: http://www.nef.org.uk/greencompany/co2calculator.htm
Sri Lanka	941	MWh	check locally
Burkina Faso	1045	MWh	average of data available for West African countries; check locally
Emissions related to transport	**kg CO2 eq/ton/km**		
aeroplane (freight)	1.6575		extra km factor for return trip 150%; average load estimated at 75%
sea vessel deep see 30 000 tonnes	0.0150		extra km factor 150%; load 80%
sea vessel 8000 tonnes	0.0300		extra km factor 150%; load 80%
river vessel 5500 tonnes	0.0320		extra km factor 150%; load 80%
river vessel 1350 tonnes	0.0590		extra km factor 150%; load 80%
Train	0.0030		
truck > 24 tonnes	0.0920		extra km factor 150%; load 75%
truck 5-10 tonnes (diesel)	0.1757		extra km factor 150%; load 75%
light truck 2-5 tonnes (diesel)	0.2500		extra km factor 150%; load 75%
Van 500 -2000 kg (diesel)	0.3200		extra km factor 150%; load 75%

person car max 300 kg load (gasoline)	2.0000		extra km factor 200%; load 50%
Motorised three-wheeler max 150 kg load (gasoline)	0.9778		extra km factor 200%; load 75%
Additional emissions and energy use due to cooling during transport	10%		first calculate energy use/ghg emission during transport, than add 10%; no extra energy use for cooling in air freight
Emissions related to electricity use for cold storage	**kWh/ton/week**		conversion to CO_2 emissions according to national emission per kWh
	2.45		bulk storage
Emissions related to packaging	**kg CO_2 eq./kg product**		
default value for packaging	0.0281		per kg product if packaging is used, assumption an average of 5 grams of plastic per kg product
Emissions related to processing	**kWh / kg product**		conversion to CO_2 emissions according to national emission per kWh
Heat treatment (blanching/ pasteurisation/ sterilisation)	2.08		Based on Duthil and Cramer 2000
Freezing	1.39		Based on Duthil and Cramer 2000
Drying (excluded sun drying which is zero)	4.17		Based on Duthil and Cramer 2000
Emissions due to production of synthetic fertilisers	**kg CO_2 eq./kg N**		All data in this section taken from: ISCC 205 GHG Emissions Calculation Methodology and GHG Audit
N-fertiliser	5.88		
Urea	3.31		
Ammonium nitrate	8.55		
Ammonium sulphate	2.69		
Ammonium nitrate phosphate	5.27		
Diammonium phosphate	2.8		

Calcium ammonium nitrate	8.66		
P2O5-fertiliser (emission per kg P2O5)	1.01		
K2O-fertiliser(emission per kg K2O)	0.57		
CaO-fertiliser(emission per kg CaO)	0.13		
Pesticides (emission per kg active ingredient)	10.97		
Field emissions - N fertiliser application	4.87		
Emissions compost production and application	**ton CO2-eq./ton**		General comment: Emissions for composting are very much dependant on the composition of the waste materials and on the quality of the composting process. The data given below are valid only for a well-managed process of composting using a combination of garden and household waste
Field emissions compost application (excluding machinery for transport and application)	0.0477		Dekker et al 2009
Emissions for machinery use for field application of compost	0.0027		Dekker et al 2009
Emissions in production of compost (household and garden waste, 35% moisture, professional bulk composting, well aerated, excluding machinery and transport for waste collection)	0.0622		Tauw et al, 2007

Emissions for collection of household and garden waste by truck	0.0062		Dekker et al 2009
Emissions for machinery use for composting	0.0434		Tauw et al, 2007
Emissions for different composting methods and duration:	**tonnes CO2-e/ tonne (general)**		
Anaerobic digestion	0,02		tonnes CO2-e/tonne (general)
Emissions due to co-composting	0.01 – 0.03		tonnes CO2-e/tonne (general)
	0,5 – 1,0		Equivalent to 500 -1000 kg CO2 eq per ton product based on methane emissions
Emissions in landfill from organic wastes			Soil and More

Note: Composting will have a beneficial effect on carbon sequestration in the soil. This positive effect is not included in the calculations.

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