Edible Cities Network – Integrating Edible City Solutions for social, resilient and sustainably productive Cities

EdiCitNet

Design and Planning Tool – User manual

Version 1.0

EdiCitNet has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 776665.

About this document:

Deliverable lead beneficiary: **UL – University of Ljubljana**

Dissemination Level: **Internal**

Submission Date: **2.8.2023**

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1. Introduction

Design and Planning Tool is a part of the EdiCitNet Toolbox. It can be used either by the individual users, to discover how much food they can produce on their plots, and how much water, nutrients and energy they need, or by the city planners, to investigate the impact of Edible City Solutions (ECS) implementation on city's food production, resources management and sustainability.

The Design and Planning Tool It is accessible through the web page https://ediblecitiesnetwork.com/tools/plannig.

2. Design and plan your own Solution

At first, the user must select among the two options (Fig. 1). The **Individual scale planning** option is to be used by individuals who would like to set up their own ECS and to learn more about the expected yields and resources needed (i.e., water and nutrients). It can also be used by the individuals who already have their own ECSs, to find out more about the optimal yields and to optimize their usage of resources. On the other hand, the **City scale planning** option is to be used by city planners to gain insight into how the implementation of the ECSs in the selected area/s of a city would affect the overall city food production and how it might help close the resources loops.

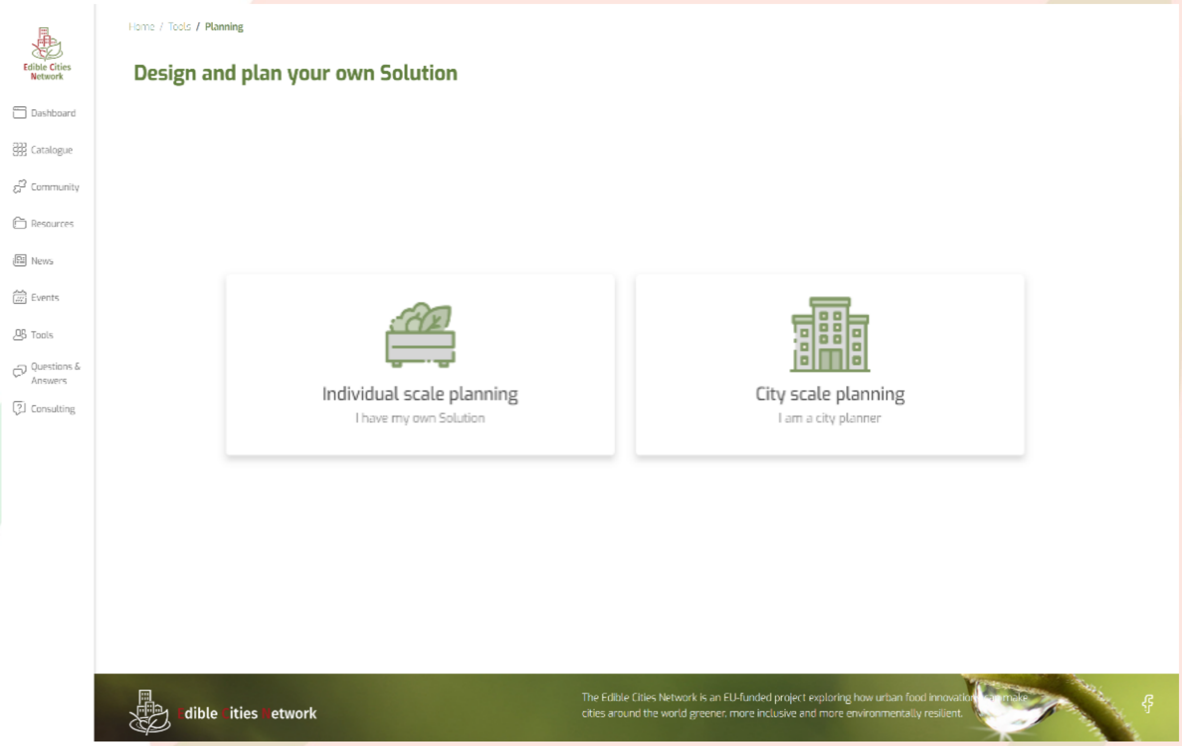


Figure 1: Selection of the ECS planning option

To continue, the user must click on one of the options to select the scale of planning.

3. Individual scale planning

3.1 Please select the city where the ECS is located

Under **Select city**, the user can choose among the list of cities already included in the tool (i.e., Šempeter Vrtojba, Sant Feliu de Llobregat, Ljubljana, Berlin, Rotterdam, Oslo, Andernach, Barcelona, Girona, and Nice; Fig. 2).

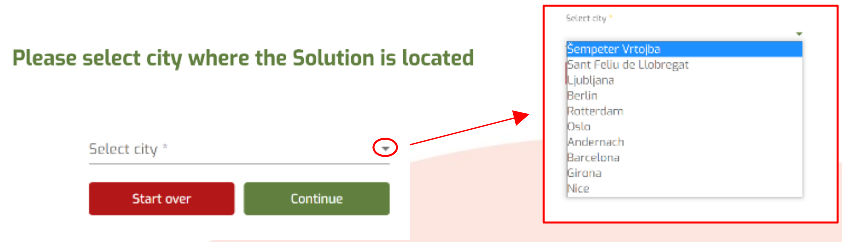


Figure 2: City selection

The selection of the city is important because it is linked to the climate data (i.e., precipitation and reference evapotranspiration) used to calculate water demand. For most cities, the mean monthly climate data were obtained from the AQUASTAT Climate Information Tool, displaying average monthly values of climate variables for the period 1961-1990, obtained by interpolating data from different climate stations. Thus, they can only indicate climatic conditions. For more accurate assessments, it is advisable to use locally measured data and long-term statistics.

To continue, the user must click the **Continue** button.

3.2 ECS scenario setup

In the ECS scenario setup window (Fig. 3), the user must select or specify the following features:

- **Pick ECS method:** Current options are green plot (on the ground), greenhouse, hydroponics, or substrate-based, so in this version, the tool only focuses on the ECSs used to grow vegetables. Based on the selected ECS method, the resources demand and irrigation options are being calculated.
- **Pick product type:** Currently, the user can choose among different vegetable types, depending on the preferred ECS method. For example, in the case of a greenhouse, only eggplants (aubergines) and tomatoes can be selected, while in the case of a green plot (on the ground), the user can choose among more than 40 vegetable types and three typical garden mixes, obtained from the results of the (Glavan et al., 2015) funded by the European Union. Within the project, the researchers investigated urban food production in London, Milan and Ljubljana, representing different climate conditions. The project results revealed the ten most common vegetable types grown in a particular city, and their yields which were used in three preset garden mixes (see Tables 1-3).
- **Growing period (in months):** The growing period is a time required from planting to harvest (under optimal growing conditions). This field is automatically filled in based on the selected vegetable type but can be changed by the user. If one of the garden mixes has been selected as the product type, the longest growing season among the vegetables included in the mix is assigned.

Table 1: Ljubljana garden mix (FoodMetres project results)

Ljubljana garden mix	Vegetable type	Yield for all gardens included in the research (kg/year)	% of the annual yield
1	Potato	2572.60	24.6
2	Tomato	1598.90	15.3
3	Lettuce	1492.97	14.3
4	Onion	840.00	8.0
5	Cabbage	781.50	7.5
6	Zucchini	732.00	7.0
7	Carrot	653.86	6.3
8	Pepper	650.00	6.2
9	Cucumber	581.00	5.6
10	Chicory	551.50	5.3

Table 2: Milan garden mix (FoodMetres project results)

Milan garden mix	Vegetable type	Yield for all gardens included in the research (kg/year)	% of the annual yield
1	Tomato	359	20.0
2	Cherry tomato	349.89	19.5
3	Zucchini	324	18.1
4	Chicory	130.75	7.3
5	Eggplants	130.5	7.3
6	Cabbage	128.83	7.2
7	Salad	115.23	6.4
8	Pepper	93	5.2
9	Onion	83.5	4.7
10	Pumpkin	79	4.4

Table 3: London garden mix (FoodMetres project results)

London garden mix	Vegetable type	Yield for all gardens included in the research (kg/year)	% of the annual yield
1	Potato	950.99	23.1
2	Squash/Pumpkin	892.92	21.7
3	Zucchini	448.6	10.9
4	Tomato	397.12	9.6
5	Chard	301.76	7.3
6	Cucumber	257.66	6.2
7	Lettuce	251.23	6.1
8	Beetroot	217.75	5.3
9	Beans	205.81	5
10	Onion	199.96	4.8

- **Beginning of growing season (month no.):** The growing season is the portion of the year in which local climate conditions (i.e., rainfall, temperature, daylight) permit normal plant growth. The default value for the beginning of the growing season is 3 (i.e., March) but can be changed by the user.
- **End of growing season (month no.):** The end of the growing season depends on the climate conditions. The default value is 10 (i.e., October) but can be changed by the user. The beginning and end of the growing season are needed to calculate the possible number of plantings per growing season.
- **Area the ECS will be applied to (in m^2):** In the case of growing vegetables, the user must specify the area used for growing a particular vegetable type.

The user can add more products (e.g., vegetable types) by clicking the **Add another product** button. Products can be removed by clicking the **Remove product** button.

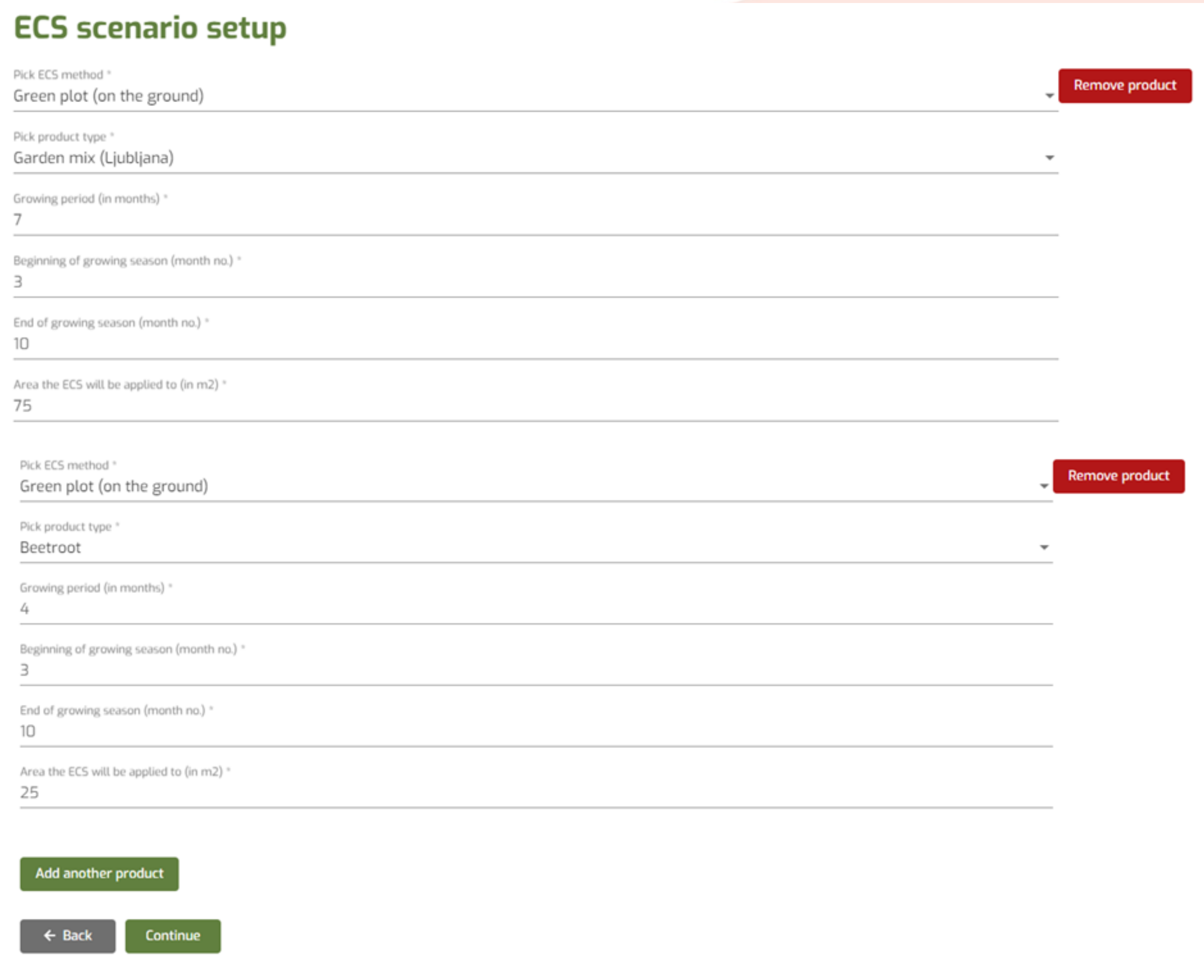


Figure 3: ESC scenario set up

3.3 ECS scenario results

3.3.1 Yields

Under **Yields** (Fig. 4), the user can view the information on optimal/expected annual yields, energy value (both in kJ and kcal), and nutritional value of the produced food (i.e., carbohydrates, fats, and protein content, all in kg), which were based on analytical report Roe M., 2007. In case of garden mixes, given the percentages in the last column of Tables 1-3, weighted averages of yield (in kg/m2), energy value (either in kJ/100 g or kcal/100 g), and the macronutrient content (g/100 g) were calculated for the particular garden mixes.

Yields | Resources demand | Irrigation | Fertilization

Product	ECS method	Annual yield (kg)	Energy value (kJ)	Energy value (kcal)	Carbohydrates (kg)	Fats (kg)	Proteins (kg)
Beetroot	Green plot (on the ground)	125	244,925	58,537.5	12.89	0.04	1.44
Garden mix (Ljubljana)	Green plot (on the ground)	416.25	644,479.88	154,054.13	33.22	0.58	6.62
Totals		541.25	889,404.88	212,591.63	46.11	0.62	8.06

Figure 4: ESC scenario results - Yields

Annual yield (kg) is calculated by multiplying product-specific yield (in kg/m^2) with the area of the fore-seen/existing ECS (in m^2) and a possible number of plantings per season. The energy value is calculated by multiplying the product-specific energy value (either in kJ/100 g or kcal/100 g) with the expected annual yield. Similarly, the nutritional value is calculated by multiplying product-specific macronutrient content (i.e., carbohydrates, fats and proteins, in g/100 g) with the expected annual yield.

3.3.2 Resources demand

Under **Resources demand** (Fig. 5), there is information on how much resources (i.e., nutrient, water and energy) are needed to achieve optimal yields.

Yields | Resources demand | Irrigation | Fertilization

Nutrients (kg/year)

Product	ECS method	N	P2O5	K2O
Beetroot	Green plot (on the ground)	0.38	0.13	0.49
Garden mix (Ljubljana)	Green plot (on the ground)	1.87	0.52	2.2

Water (m3/month)

Product	Start of vegetation period (month no.)	Duration of vegetation period (in months)	End of vegetation period (month no.)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Beetroot	3	4	10			1.2	1.875	2.725	3						
Garden mix (Ljubljana)	3	7	10			3.6	5.625	8.175	9	10.05	8.475	5.1			

Energy

Product	Energy demand
Beetroot	low
Garden mix (Ljubljana)	low

Figure 5: ESC scenario results – Resources demand

Nutrients (kg/year)

Nutrient demand (kg), considering optimal soil nutrient conditions, is calculated separately for nitrogen (N), phosphorus pentoxide (P_2O_5), and potassium oxide (K_2O) by multiplying product-specific nutrient demand (in g/kg product) with the annual yield (kg). If soil nutrient content is not optimal, which can be determined by soil measurements, amount for fertilization may vary, i.e., either additional or no fertilization may be needed. For more information, please refer to Mihelič et al., 2010.

Water (m3/month)

To calculate water demand (in m3/month), we considered crop evapotranspiration under standard conditions (ETc) to be the same as the reference evapotranspiration (ET0). The reference surface considers a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m-1 and an albedo of 0.23, which closely resembles an extensive surface of green grass of uniform height, actively growing, completely shading the ground and with adequate water. On the other hand, the standard conditions of ETc refer to crops grown in large fields under excellent agronomic and soil water conditions. Thus, ETc differs distinctly from the ET0, as the ground cover, canopy properties, and crop aerodynamic resistance are different from grass. The effects of characteristics that distinguish field crops from grass are integrated into the crop coefficient (Kc), while crop evapotranspiration is calculated by multiplying ET0 by Kc. For simplification purposes, we used the Kc value of 1 (Allen et al., 1998).

Thus, monthly values of water demand (m^3) were simplified and calculated as the product of location specific ET_0 (in mm) and the specific ECS area (in m^2).

The water demand data is presented for each crop from the beginning of the growing season till the end of product's growing period. If more plantings are possible per season (due to shorter growing periods), water demand information is extended accordingly.

Energy

Energy demand is given only in a descriptive way (i.e., high in the case of hydroponics and low in case other ECS methods are selected).

3.3.3 Irrigation

Under **Irrigation** (Fig. 6), the user can review options for covering a water demand. The tool offers three options:

A) Rainwater harvesting
B) Irrigation using tap water
C) Waste water reuse

Only artificial irrigation by rainwater harvesting, tap water, or treated wastewater was foreseen to cover total water demand. Contribution of direct rainfall on crops is neglected as it is too event-specific. Namely, the distribution of rainfall during the month can vary and not all rain water can be absorbed by the plant. The efficiency of different types of irrigation systems was also not considered, although it may vary from 5 to 40 % (Pintar, 2006).

Enter additional information for calculation of irrigation options

At first, the user can fill in the information under *Enter additional data for calculation of irrigation options*:

- **Impervious area for rainwater collection (m^2):** For example, rainwater could be collected from the rooftops in the vicinity of the ECS.
- **Suggested reservoir volume (m^3):** Initial reservoir volume is determined to cover 14 days of total water demand in July (given the reservoir is full at the beginning of the month). This value can be changed by the user.
- **Cost of tap water (EUR/m^3):** This information is location specific. The default value is 2 EUR/m^3 but can be changed by the user.

Yields | Resources demand | Irrigation | Fertilization

Enter additional data for calculation of irrigation options

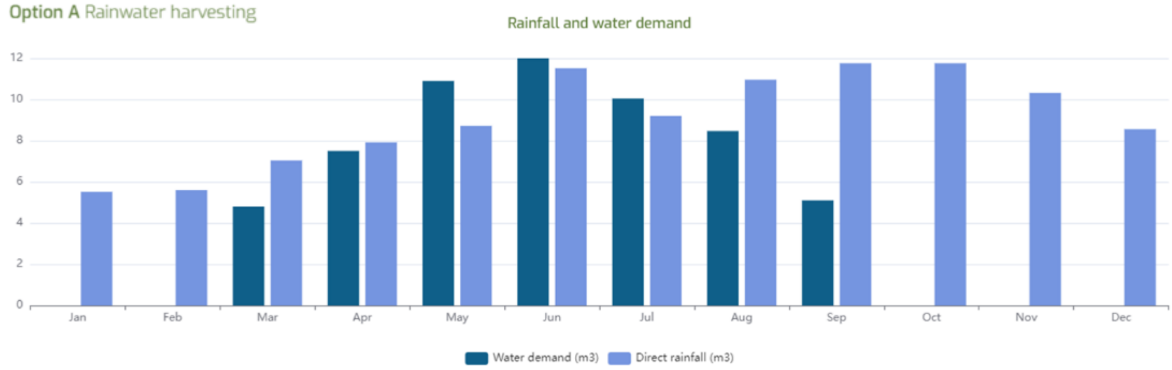
Impervious area (m2) *
150

Suggested storage volume (m3) *
5.46

Cost of tap water (EUR/m3) *
2

Number of inhabitants *
4

Option A Rainwater harvesting



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
water demand (m3)	0	0	4.8	7.5	10.9	12	10.05	8.47	5.1	0	0	0	58.83
direct rainfall (m3)	5.52	5.6	7.04	7.92	8.72	11.52	9.2	10.96	11.76	11.76	10.32	8.56	108.88
irigation demand (m3)	0	0	0	0	2.18	0.48	0.85	0	0	0	0	0	3.51
available rainwater from impervious area (m3)	10.35	10.5	13.2	14.85	16.35	21.6	17.25	20.55	22.05	22.05	19.35	16.05	204.15
amount of water in the reservoir (m3)	5.46	5.46	5.46	5.46	5.46	5.46	5.46	5.46	5.46	5.46	5.46	5.46	65.52
amount of water needed from other sources (m3)	0	0	0	0	0	0	0	0	0	0	0	0	0

Option B Irrigation water cost estimation

	Totals
demand (m3/year)	3.51
water price (EUR/m3)	2
yearly cost (EUR/m3)	7.02

Option C Waste water reuse

	Totals
no. of inhabitants	4
waste water production (m3/inhab./year)	54.75
gray water production (m3/inhab./year)	31.03
black water production (m3/inhab./year)	9.13
amount of waste water produced (m3/year)	219
amount of gray water produced (m3/year)	124.12
amount of black water produced (m3/year)	36.52

Figure 6: ESC scenario results – Irrigation

- **Number of inhabitants:** Needed in case the user wants to test the water-reuse option. This information refers to a building representing a source of wastewater, which could be treated and used for irrigation.

Option A) Rainwater harvesting

Total water demand (m^3) is calculated as the sum of water demands for all the crops within the observed ECS.

Available rainwater from the impervious area (m^3) is calculated by multiplying the impervious area (m2) by monthly precipitation (mm).

Generated storage/shortage (m^3): This information refers to the amount of water in the reservoir. We start a year with a full reservoir (i.e., in January, generated storage/shortage corresponds to the suggested reservoir volume). In each following month, generated storage/shortage is calculated by adding the rainwater from the impervious area to the amount of water in the reservoir stored in the previous month and reducing the amount by the total water demand. However, there are two restraints: 1) generated storage cannot exceed reservoir volume, and 2) if shortage (negative value) is calculated in the previous month, the amount of water in the reservoir stored in the previous month is considered to be zero. Calculated shortages that reservoir cannot cover should be provided from other sources (e.g., tap water).

Option B) Irrigation using tap water

Annual water demand (m^3) is calculated as the sum of monthly values of total water demand.

Annual cost of tap water irrigation (EUR): yearly water demand (m^3) multiplied by the cost of tap water (EUR/m^3).

Option C) Waste water reuse

Here, the user can find information on how much wastewater, which could be treated and used for irrigation, can be produced in a selected building (e.g., a single-family home), ideally located in the vicinity of the ECS. Annual amounts of the produced mixed, grey- and blackwater are presented.

Greywater refers to domestic wastewater generated in households or office buildings containing lower levels of contamination. Sources of greywater include sinks, showers, bathtubs, washing machines, and dishwashers. It can be treated and reused onsite for toilet flushing, landscape or crop irrigation, and other non-potable uses, as long as no harmful chemicals are present. Blackwater is the wastewater from toilets and pissoirs that contains faecal matter and urine.

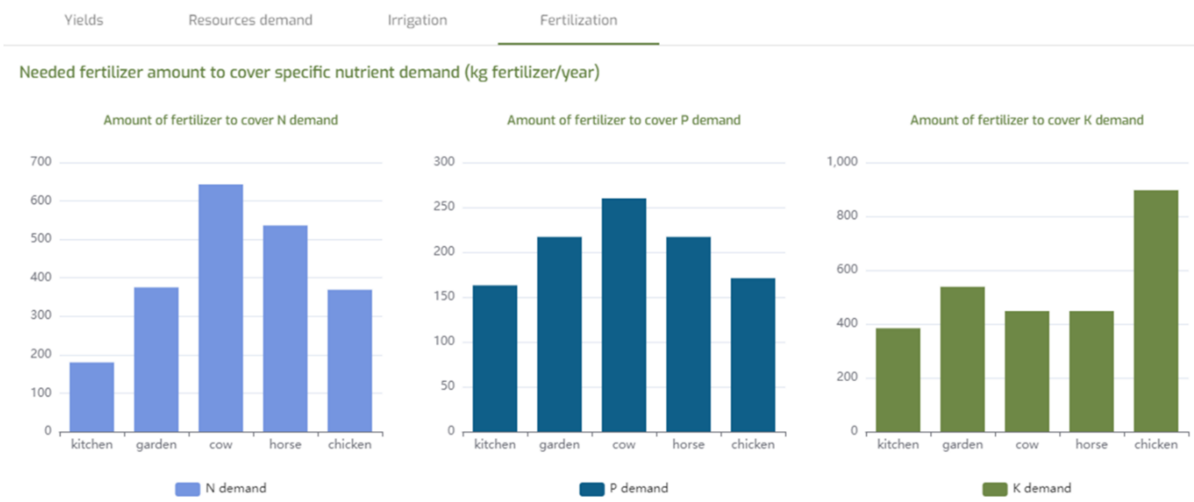
The annual amount of produced mixed, grey- and blackwater (m3) is calculated as the product of the number of inhabitants and the average mixed, grey- and blackwater production (see Table 4).

Table 4: Wastewater production data

	mixed wastewater			**grey water**			**black water**		
	min	**max**	**avg**	**min**	**max**	**avg**	**min**	**max**	**avg**
Production (l day^{-1} per capita)	120	180	150	50	120	85	20	30	25

3.3.4 Fertilization

Under **Fertilization** (Fig. 7), the user can review options for covering total nutrient demand using alternative nutrient sources (Mihelič et al., 2010).



Enter additional data for calculation of fertilization options

Composted household waste (%) *
50

Composted garden greens (%) *
20

Cow manure (%) *
0

Horse manure (%) *
30

Chicken manure (%) *
0

Nutrients covered by the selected fertilization scenario (%) *

	Fertilizer percentage	Fertilizer amount	N	P	K
total demand (kg/year)			2.25	0.65	2.69
total nutrients applied (kg/year)	100		3.61	1.49	2.69
kitchen waste, composted, applied (kg/year)	50	192.1	2.4	0.77	1.34
garden greens, composted, applied (kg/year)	20	107.6	0.65	0.32	0.54
cow manure applied (kg/year)	0	0	0	0	0
horse manure applied (kg/year)	30	134.5	0.56	0.4	0.81
chicken manure applied (kg/year)	0	0	0	0	0

* Data calculated based on needed amount of specific nutrient source type to cover K2O demand.

Figure 7: ESC scenario results – Fertilization

Needed fertilizer amount to cover N, P2O5 and K2O demand (kg fertilizer/year)

In this section, the user can learn about the amounts of a specific nutrient source type needed to cover total N, P2O5, and K2O demand based on our selected products and area applied. These amounts are calculated by dividing total nutrient demand (in kg/year) by average nutrient content in a particular nutrient source type (kg/t) (see Table 5). Note that different types of fertilizers are available for plants in different time frames. N from the finished compost is usually very slow to release. In the first year, 10-20 % is released, later even less. Therefore, this calculation is just an estimation of how much fertilizer is theoretically needed to cover selected crop demand.

Table 5: Average nutrient content of organic fertilisers (Mihelič et al., 2010)

	N	**P2O5**	**K2O**
	kg/t	**kg/t**	**kg/t**
Composted household waste	12.5	4	7
Composted garden greens	6	3	5
Cow manure (dairy cow, 20-25 % dry mass)	3.5	2,5	6
Composted cow manure (dairy cow, 25-30 % dry mass)	5.5	5	11
Horse manure (25-30 % dry mass)	4.2	3	6
Chicken manure (dryed manure from laying hens, 50 % dry mass)	15.4	24	14

Enter additional information for calculation of fertilization options

Based on local sources of fertilizers user can adjust percentage of different fertilizers used to cover crop demand. Data is calculated based on needed amount of specific nutrient source type to cover K2O demand. K2O was selected because it is the most limiting, i.e., when the potassium demand is met, the nitrogen and phosphorous demands are also covered. Nutrient source types available are composted material (either household waste or garden greens) and manure (either cow, horse, or chicken). For example, the user can choose to cover 50% of K2O demand by applying composted household waste, 20% by composted garden greens, and 30% by horse manure.

Nutrients covered by the selected fertilization scenario (%)

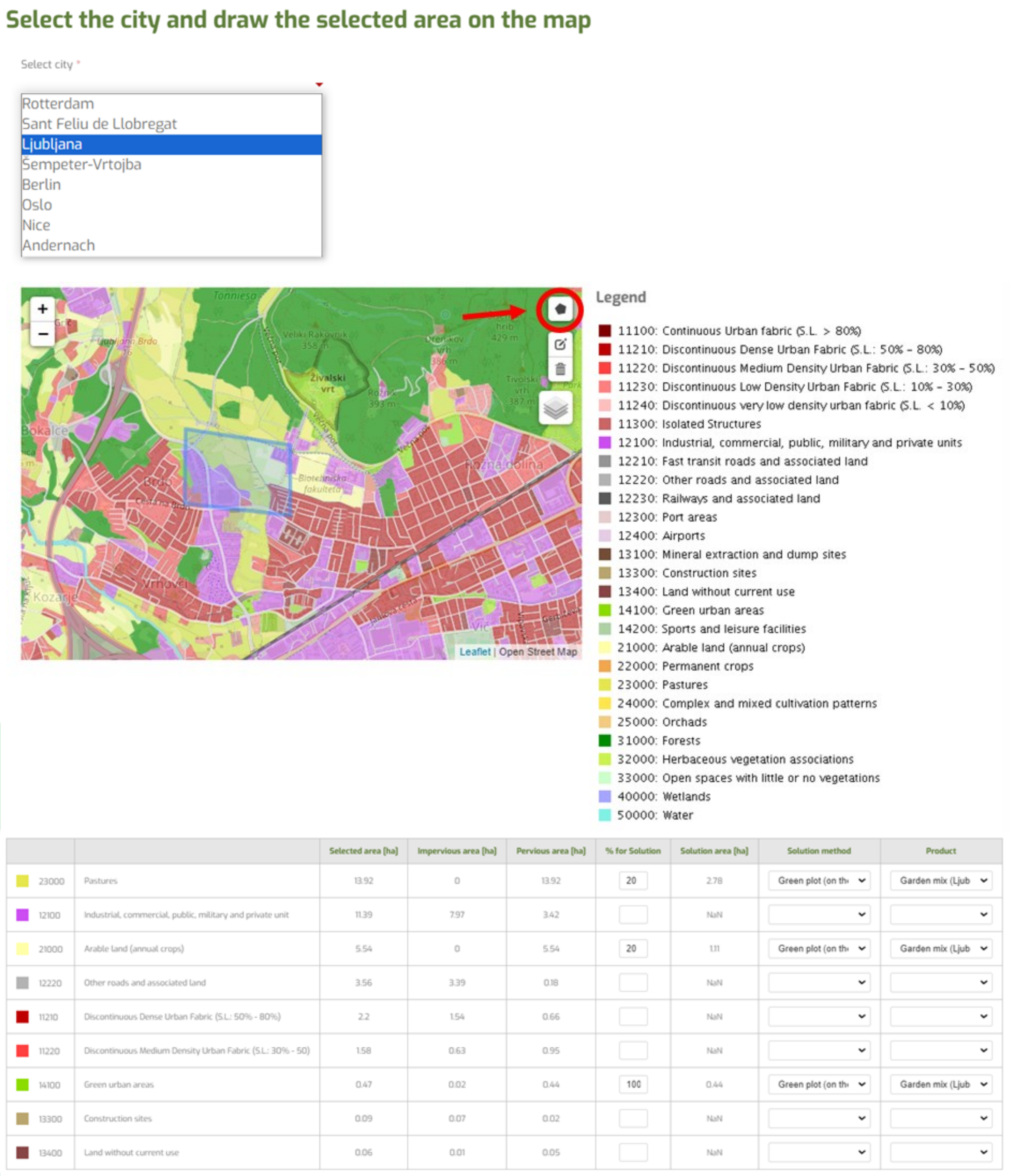
Here, the user can check the fertilization scenario results, namely the ones resulting from the applied percentages of total K2O demand to be covered by a particular nutrient source type. **Fertilizer amount (kg/year)** is calculated as a product of the needed fertilizer amount to cover K2O demand (kg/year) and the selected %. With covered K2O demand amount of N and P2O5 may exceed needed yearly amount. The covered nutrient demand (%) for K2O is the same as the selected percentages. Note that this calculation assumes optimal growth and soil nutrient content at the beginning of season. Different types of fertilisers have different level of nutrient availability for first and later years. So, this calculation can be used only for estimation of how much fertilisers are needed for optimal growth of selected crops.

4. City scale planning

4.1 ECS scenario setup

Select the city

The user can choose among the list of cities already included in the tool (i.e., Rotterdam, Sant Feliu de Llobregat, Ljubljana, Šempeter Vrtojba, Berlin, Oslo, Nice and Andernach). After making the selection, the city map appears, coloured according to the Urban Atlas nomenclature (Fig. 8).



		Selected area [ha]	Impervious area [ha]	Pervious area [ha]	% for Solution	Solution area [ha]	Solution method	Product
23000	Pastures	13.92	0	13.92	20	2.78	Green plot (on th	Garden mix (Ljub
12100	Industrial, commercial, public, military and private unit	11.39	7.97	3.42		NaN		
21000	Arable land (annual crops)	5.54	0	5.54	20	1.11	Green plot (on th	Garden mix (Ljub
12220	Other roads and associated land	3.56	3.39	0.18		NaN		
11210	Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)	2.2	1.54	0.66		NaN		
11220	Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50)	1.58	0.63	0.95		NaN		
14100	Green urban areas	0.47	0.02	0.44	100	0.44	Green plot (on th	Garden mix (Ljub
13300	Construction sites	0.09	0.07	0.02		NaN		
13400	Land without current use	0.06	0.01	0.05		NaN		

Figure 8: City selection and drawing of a polygon

The selection of the city is also important because of the climate data (i.e., precipitation and reference evapotranspiration) used to calculate water demand. For most cities, the mean monthly climate data were obtained from the AQUASTAT Climate Information Tool, displaying average monthly values of climate variables for the period 1961-1990, obtained by interpolating data from different climate stations. Thus, they can only indicate climatic conditions. For more accurate assessments, it is advisable to use locally measured data and long-term statistics.

Draw a polygon of the selected area

The user can select a particular area of the city to be analysed, corresponding to, e.g., a particular neighbourhood or a city district. To draw the polygon of the selected area, the user must click the **Draw a polygon** button (i.e., a black pentagon symbol). The polygon can be drawn by clicking on the map (see Fig. 8). To close the area, the user must click the first point of the polygon.

ECS scenario setup

After the polygon has been drawn, the **ECS scenario setup** table appears below the map, showing a summary of different land uses within the observed polygon, together with their areas (in hectares).

In the ECS scenario setup window (Fig. 8), the user must decide which particular land uses are to be converted into the ECS and to what extent. For each converted land use, a single ECS method can be applied, as well as a single product. The user must fill the following information:

- **% for Solution:** Percentage of a particular land use area to be converted into the ECS.
- **Solution method:** Current options are green plot (on the ground), greenhouse, hydroponics, or substrate-based. Based on the selected ECS method, the resources demand and irrigation options are being calculated.
- **Product:** Currently, the user can choose among different vegetable types, depending on the preferred ECS method. For example, in the case of a greenhouse, only eggplants (aubergines) and tomatoes can be selected, while in the case of a green plot (on the ground), the user can choose among more than 40 vegetable types and three typical garden mixes, obtained based on the results of the FoodMetres project funded by the European Union. Within the project, the researchers investigated urban food production in London, Milan, and Ljubljana. The project results revealed the ten most common vegetable types grown in a particular city and their yields (see Tables 1-3). Given the percentages in the last column of Tables 1-3, weighted averages of yield (in kg/m2), energy value (either in kJ/100 g or kcal/100 g), and the macronutrient content (g/100 g) were calculated for the particular garden mixes.

Other information is automatically filled in:

- **Selected area [ha]:** area of a single land use inside the drawn polygon.
- **Impervious area [ha]:** calculated for each single land use by applying pre-determined percentages of imperviousness (see Table 6).
- **Pervious area [ha]:** calculated by subtracting the impervious area from the total land use area.
- **Solution area [ha]:** calculated by multiplying the % for Solution and Selected area [ha].

To continue, the user must click the **Continue** button.

4.2 ECS scenario results

4.2.1 Yields

Under **Yields** (Fig. 9), the user can view the information on optimal/expected annual yields, energy value (both in kJ and kcal), and nutritional value of the produced food (i.e., carbohydrates, fats, and protein content, all in kg), which were based on analytical report Roe M., 2007. In case of garden mixes, given the percentages in the last column of Tables 1-3, weighted averages of yield (in kg/m2), energy value (either in kJ/100 g or kcal/100 g), and the macronutrient content (g/100 g) were calculated for the particular garden mixes.

Table 6: Pre-determined percentages of imperviousness for different land uses

Code	Nomenclature	% impervious
11100	Continuous urban fabric	90
11210	Discontinuous dense urban fabric	70
11220	Discontinuous medium density urban fabric	40
11230	Discontinuous low-density urban fabric	20
11240	Discontinuous very low-density urban fabric	5
11300	Isolated structures	60
12100	Industrial, commercial, public, military and private units	70
12210	Fast transit roads and associated land	95
12220	Other roads and associated land	95
12230	Railways and associated land	90
12300	Port areas	100
12400	Airports	100
13100	Mineral extraction and dump sites	80
13300	Construction sites	80
13400	Land without current use	20
14100	Green urban areas	5
14200	Sports and leisure facilities	40
21000	Arable land (annual crops)	0
22000	Permanent crops	0
23000	Pastures	0
24000	Complex and mixed cultivation patterns	0
25000	Orchards	0
31000	Forests	0
32000	Herbaceous vegetation associations	0
33000	Open spaces with little or no vegetations	70
40000	Wetlands	0
50000	Water	0

Yields | Resources demand | Irrigation | Fertilization

Product	ECS method	Annual yield (kg)	Energy value (kJ)	Energy value (kcal)	Carbohydrates (kg)	Fats (kg)	Proteins (kg)
Garden mix (Ljubljana)	Green plot (on the ground)	962,520.2	1,490,270,025.66	356,228,726.02	76,809.11	1,347.53	15,304.07
Totals		962,520.2	1,490,270,025.66	356,228,726.02	76,809.11	1,347.53	15,304.07

Figure 9: ESC scenario results - Yields

Annual yield (kg) is calculated by multiplying product-specific yield (in kg/m^2) with the area of the fore-seen/existing ECS (in m^2) and a possible number of plantings per season. The energy value is calculated by multiplying the product-specific energy value (either in kJ/100 g or kcal/100 g) with the expected annual yield. Similarly, the nutritional value is calculated by multiplying product-specific macronutrient content (i.e., carbohydrates, fats and proteins, in g/100 g) with the expected annual yield.

4.2.2 Resources demand

Under **Resources demand** (Fig. 10), there is information on how much resources (i.e., nutrient, water and energy) are needed to achieve optimal yields.

Yields | Resources demand | Irrigation | Fertilization

Nutrients (kg/year)

Product	ECS method	N	P2O5	K2O
Garden mix (Ljubljana)	Green plot (on the ground)	4,331.32	1,203.12	5,082.12

Water (m3/month)

Product	Start of vegetation period (month no.)	Duration of vegetation period (in months)	End of vegetation period (month no.)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Garden mix (Ljubljana)	3	7	10			4,162.249	6,503.515	9,451.775	10,405.624	11,619.613	9,798.629	5,896.52			

Energy

Product	Energy demand
Garden mix (Ljubljana)	low

Figure 10: ESC scenario results – Resources demand

Nutrients (kg/year)

Nutrient demand (kg), considering optimal soil nutrient conditions, is calculated separately for nitrogen (N), phosphorus pentoxide (P_2O_5), and potassium oxide (K_2O) by multiplying product-specific nutrient demand (in g/kg product) with the annual yield (kg). If soil nutrient content is not optimal, which can be determined by soil measurements, amount for fertilization may vary, i.e., either additional or no fertilization may be needed. For more information, please refer to Mihelič et al., 2010.

Water (m3/month)

To calculate water demand (in m^3/month), we considered crop evapotranspiration under standard conditions (ET_c) to be the same as the reference evapotranspiration (ET_0). The reference surface considers a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m^{-1} and an albedo of 0.23, which closely resembles an extensive surface of green grass of uniform height, actively growing, completely shading the ground and with adequate water. On the other hand, the standard conditions of ET_c refer to crops grown in large fields under excellent agronomic and soil water conditions. Thus, ET_c differs distinctly from the ET_0, as the ground cover, canopy properties, and crop aerodynamic resistance are different from grass. The effects of characteristics that distinguish field crops from grass are integrated into the crop coefficient (K_c), while crop evapotranspiration is calculated by multiplying ET_0 by K_c. For simplification purposes, we used the K_c value of 1 (Allen et al., 1998).

Thus, monthly values of water demand (m^3) were simplified and calculated as the product of location specific ET_0 (in mm) and the specific ECS area (in m^2).

The water demand data is presented for each crop from the beginning of the growing season till the end of product's growing period. If more plantings are possible per season (due to shorter growing periods), water demand information is extended accordingly.

Energy

Energy demand is given only in a descriptive way (i.e., high in the case of hydroponics and low in case other ECS methods are selected).

4.2.3 Irrigation

Under **Irrigation** (Fig. 11), the user can review options for covering a water demand. The tool offers three options:

A) Rainwater harvesting
B) Irrigation using tap water
C) Waste water reuse

Only artificial irrigation by rainwater harvesting, tap water, or treated wastewater was foreseen to cover total water demand. Contribution of direct rainfall on crops is neglected as it is too event specific. Namely, the distribution of rainfall during the month can vary and not all rainwater can be absorbed by the plant. The efficiency of different types of irrigation systems was also not considered, although it may vary from 5 to 40 % (Pintar, 2006).

Enter additional information for calculation of irrigation options

At first, the user can fill in the information under *Enter additional data for calculation of irrigation options*:

- **Impervious area for rainwater collection (m^2):** For example, rainwater could be collected from the rooftops in the vicinity of the ECS.
- **Suggested reservoir volume (m^3):** Initial reservoir volume is determined to cover 14 days of total water demand in July (given the reservoir is full at the beginning of the month). This value can be changed by the user.
- **Cost of tap water (EUR/m^3):** This information is location specific. The default value is 2 EUR/m^3 but can be changed by the user.
- **Number of inhabitants:** Needed in case the user wants to test the water-reuse option. This information refers to a building representing a source of wastewater, which could be treated and used for irrigation.
-

Option A) Rainwater harvesting

Total water demand (m^3) is calculated as the sum of water demands for all the crops within the observed ECS.

Available rainwater from the impervious area (m^3) is calculated by multiplying the impervious area (m2) by monthly precipitation (mm).

Generated storage/shortage (m^3): This information refers to the amount of water in the reservoir. We start a year with a full reservoir (i.e., in January, generated storage/shortage corresponds to the suggested reservoir volume). In each following month, generated storage/shortage is calculated by adding the rainwater from the impervious area to the amount of water in the reservoir stored in the previous month and reducing the amount by the total water demand. However, there are two restraints: 1) generated storage cannot exceed reservoir volume, and 2) if shortage (negative value) is calculated in the previous month, the amount of water in the reservoir stored in the previous month is considered to be zero. Calculated shortages that reservoir cannot cover should be provided from other sources (e.g., tap water).

Yields | Resources demand | Irrigation | Fertilization

Enter additional data for calculation of irrigation options

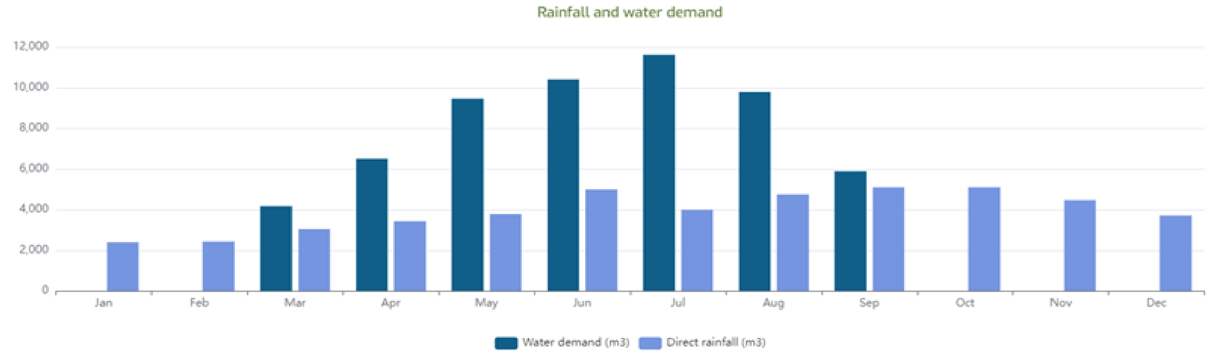
Impervious area (m2) *
150

Suggested storage volume (m3) *
5.46

Cost of tap water (EUR/m3) *
2

Number of inhabitants *
4

Option A Rainwater harvesting



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
water demand (m3)	0	0	4,162.25	6,503.51	9,451.77	10,405.62	11,619.61	9,798.63	5,896.52	0	0	0	57,837.92
direct rainfall (m3)	2,393.29	2,427.98	3,052.32	3,433.86	3,780.71	4,994.7	3,988.82	4,751.9	5,098.76	5,098.76	4,474.42	3,711.34	47,206.85
irigation demand (m3)	0	0	1,109.93	3,069.66	5,671.06	5,410.92	7,630.79	5,046.73	797.76	0	0	0	28,736.86
available rainwater from impervious area (m3)	10.35	10.5	13.2	14.85	16.35	21.6	17.25	20.55	22.05	22.05	19.35	16.05	204.15
amount of water in the reservoir (m3)	5.46	5.46	-1,091.27	-3,054.81	-5,654.71	-5,389.32	-7,613.54	-5,026.18	-775.71	5.46	5.46	5.46	-28,578.25
amount of water needed from other sources (m3)	0	0	1,091.27	3,054.81	5,654.71	5,389.32	7,613.54	5,026.18	775.71	0	0	0	28,605.55

Option B Irrigation water cost estimation

	Totals
demand (m3/year)	28,736.86
water price (EUR/m3)	2
yearly cost (EUR/m3)	57,473.72

Option C Waste water reuse

	Totals
no. of inhabitants	4
waste water production (m3/inhab./year)	54.75
gray water production (m3/inhab./year)	31.03
black water production (m3/inhab./year)	9.13
amount of waste water produced (m3/year)	219
amount of gray water produced (m3/year)	124.12
amount of black water produced (m3/year)	36.52

Figure 11: ESC scenario results – Irrigation

Option B) Irrigation using tap water

Annual water demand (m^3) is calculated as the sum of monthly values of total water demand.

Annual cost of tap water irrigation (EUR): yearly water demand (m^3) multiplied by the cost of tap water (EUR/m^3).

Option C) Waste water reuse

Here, the user can find information on how much wastewater, which could be treated and used for irrigation, can be produced in a selected building (e.g., a single-family home), ideally located in the vicinity of the ECS. Annual amounts of the produced mixed, grey- and blackwater are presented.

Greywater refers to domestic wastewater generated in households or office buildings containing lower levels of contamination. Sources of greywater include sinks, showers, bathtubs, washing machines, and dishwashers. It can be treated and reused onsite for toilet flushing, landscape or crop irrigation, and other non-potable uses, as long as no harmful chemicals are present. Blackwater is the wastewater from toilets and pissoirs that contains faecal matter and urine.

The annual amount of produced mixed, grey- and blackwater (m3) is calculated as the product of the number of inhabitants and the average mixed, grey- and blackwater production (see Table 4).

4.2.4 Fertilization

Under **Fertilization** (Fig. 12), the user can review options for covering total nutrient demand using alternative nutrient sources (Mihelič et al., 2010).

Needed fertilizer amount to cover N, P2O5 and K2O demand (kg fertilizer/year)

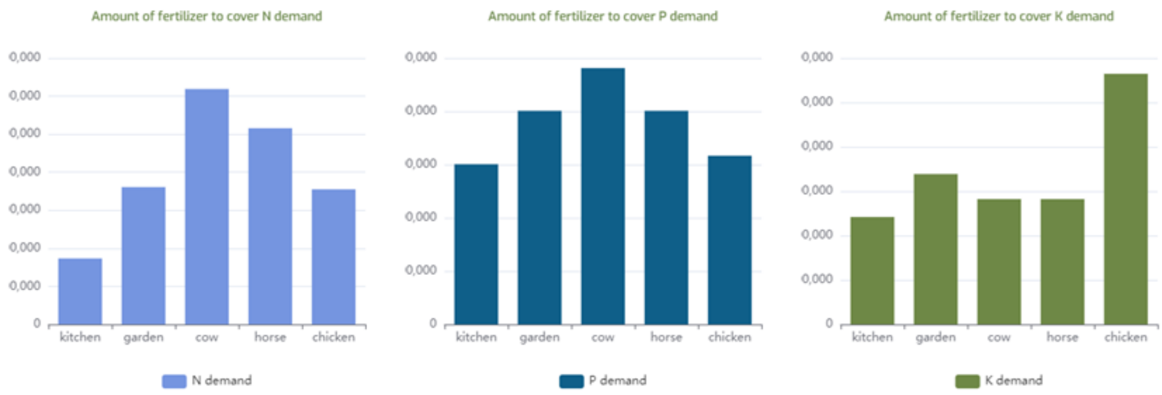
In this section, the user can learn about the amounts of a specific nutrient source type needed to cover total N, P2O5, and K2O demand based on our selected products and area applied. These amounts are calculated by dividing total nutrient demand (in kg/year) by average nutrient content in a particular nutrient source type (kg/t) (see Table 5). Note that different types of fertilizers are available for plants in different time frames. N from the finished compost is usually very slow to release. In the first year, 10-20 % is released, later even less. Therefore, this calculation is just an estimation of how much fertilizer is theoretically needed to cover selected crop demand.

Enter additional information for calculation of fertilization options

Based on local sources of fertilizers user can adjust percentage of different fertilizers used to cover crop demand. Data is calculated based on needed amount of specific nutrient source type to cover K2O demand. K2O was selected because it is the most limiting, i.e., when the potassium demand is met, the nitrogen and phosphorous demands are also covered. Nutrient source types available are composted material (either household waste or garden greens) and manure (either cow, horse, or chicken). For example, the user can choose to cover 50% of K2O demand by applying composted household waste, 20% by composted garden greens, and 30% by horse manure.

Yields Resources demand Irrigation Fertilization

Needed fertilizer amount to cover specific nutrient demand (kg fertilizer/year)



Enter additional data for calculation of fertilization options

Composted household waste (%) *
50

Composted garden greens (%) *
20

Cow manure (%) *
0

Horse manure (%) *
30

Chicken manure (%) *
0

Nutrients covered by the selected fertilization scenario (%) *

	Fertilizer percentage	Fertilizer amount	N	P	K
total demand (kg/year)			4,331.32	1,203.12	5,082.12
total nutrients applied (kg/year)	100		6,824.57	2,824.2	5,082.12
kitchen waste, composted, applied (kg/year)	50	363,008.6	4,537.61	1,452.03	2,541.06
garden greens, composted, applied (kg/year)	20	203,284.8	1,219.71	609.85	1,016.42
cow manure applied (kg/year)	0	0	0	0	0
horse manure applied (kg/year)	30	254,106	1,067.25	762.32	1,524.64
chicken manure applied (kg/year)	0	0	0	0	0

* Data calculated based on needed amount of specific nutrient source type to cover K2O demand.

Figure 12: ESC scenario results – Fertilization

Nutrients covered by the selected fertilization scenario (%)

Here, the user can check the fertilization scenario results, namely the ones resulting from the applied percentages of total K2O demand to be covered by a particular nutrient source type. **Fertilizer amount (kg/year)** is calculated as a product of the needed fertilizer amount to cover K2O demand (kg/year) and the selected %. With covered K2O demand amount of N and P2O5 may exceed needed yearly amount. The covered nutrient demand (%) for K2O is the same as the selected percentages. Note that this calculation assumes optimal growth and soil nutrient content at the beginning of season. Different types of fertilisers have different level of nutrient availability for first and later years. So, this calculation can be used only for estimation of how much fertilisers are needed for optimal growth of selected crops.

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About the EdiCitNet project

EdiCitNet is demonstrating innovative Nature-Based Solutions (NBS). **Edible City Solutions** are going one step further: We include the whole chain of urban food production, distribution and utilisation for **inclusive urban regeneration** and address societal challenges such as mass urbanisation, social inequality and climate change and resource protection in cities. The key components (1) **City Teams**, (2) **Living Labs**, (3) **Masterplans** and the (4) **Edible Cities Network** with *Toolbox* and *Marketplace* form the basic structure of EdiCitNet.

Thank you!

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Edible Cities Network

EdiCitNet has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 776665.

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