Smart Water Fund

Creation of an Environmental Sustainability Assessment Tool (ESAT)

ESAT Manual

Version 1.3

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1. Aims and benefits

The ESAT tool aims to help the Melbourne metropolitan water service providers with the task of comparing alternative water and sewage servicing options. Built on the common Microsoft Excel platform, ESAT represents a simple but flexible tool which allows for rapid characterisation of alternative water servicing options. ESAT will perform quantitative life cycle assessment (LCA) and life cycle costing (LCC). Results for 5 environmental and the economic assessment category are consolidated by means of interactive multicriteria analysis (MCA) to show a final result for the preferred option.

The expected benefits of ESAT are a consequence of making sustainability assessment quicker and easier for water service providers:

- Accelerated delivery of sustainability assessments
- Support of 'sustainability thinking'
- Increased capacity to identify key variables that inform the sustainability of infrastructure solutions
- Increased capacity to innovate on the basis of insights into the relative sustainability of water and sewerage options

2. Introduction

ESAT is substantially self-explanatory. To understand how to choose options for different scenarios, to fill in the input fields accordingly and to obtain the results, please refer to chapter 3 of this document or the worksheet "Instructions" which is contained in ESAT. Chapter 4 of this manual provides a tutorial in the form of frequently asked questions (FAQ) to further support the user with typical input scenarios for different water servicing options. This user manual also provides some background information to help interpret the detailed database for each option and the methodology, conceptual framework, algorithms and assumptions used to develop the ESAT tool. All additional explanatory information with regards to the database which was previously outlined in the Milestone 2 report, is contained in this document. For a detailed view of the data for all water servicing options included in ESAT, please refer to the milestone 2 Excel spreadsheet '080901_Raw Data for ESAT_Alpha v1.0'.

In order to strike the intended balance between specificity and simplicity, ESAT contains a large amount of very detailed information about each water servicing option. At the same time it is designed to be operated by a wide variety of users so we have attempted to minimise the amount of data the user is required to enter, allowing the rapid generation of results. Consequently, numerous spreadsheets with detailed data and calculation procedures are hidden in the background. We estimate that the current version of ESAT will produce sensible results for at least approximately 3 years. After that a data update is considered a sensible measure.

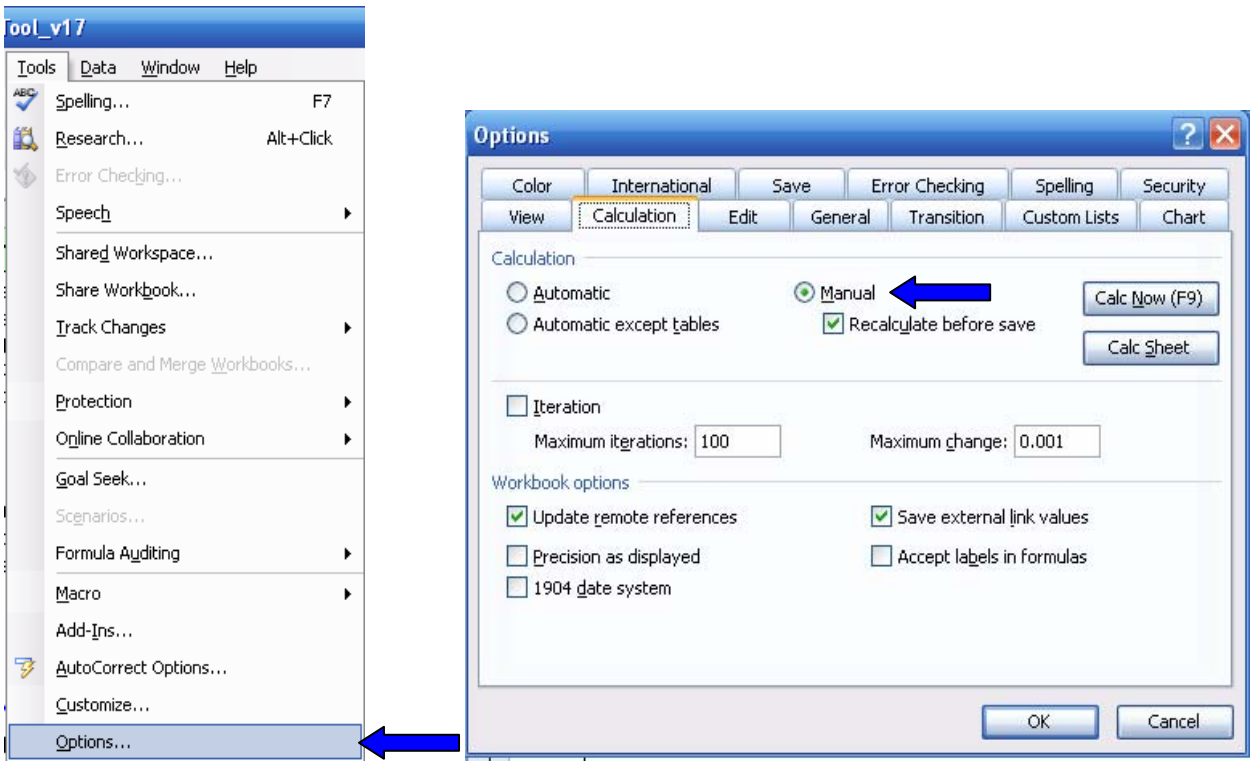
3. Quick ESAT user guide

This chapter is a guide for the ESAT-user to assist in filling in the required fields on the inputs page. Similar information can also be obtained by reading the worksheet 'Instructions' in the tool itself.

3.1 Before you start

Note 1:

When you first open ESAT, please change MS Excel's cell calculation mode to "manual". To do so, select Tools → Options → Calculation, then under Calculation, tick "Manual" and click "OK".



Note 2:

Since the automatic calculation is now switched off, ESAT needs to be told when input variables have changed. To update any changed inputs and to initiate ESAT to re-calculate the results, please hit "Enter" and then the UPDATE button, which is located at the left border of the worksheet 'Input'.

Note 3:

Please enter your input parameters into white cells only (please do not modify the Inventory or Costs tables). Also, not all parameters are relevant to all water servicing options. The model has therefore been configured to shade (grey) any parameters which, as determined by earlier inputs for each option, are not required.

3.2 User Inputs

The first step is to enter the input parameters for the water servicing options you wish to compare. In the following, the main input variables as presented on the worksheet 'Input' are explained:

3.2.1 Household / building water balance

Number of households / buildings: Insert the total number of households / buildings in the development.

Number of people per household / building: Insert the average number of people per household / building. The suggested default value for a residential household is 2.53.

Non-household (i.e.: municipal, commercial) water demand: Insert an expected amount of water needed for the irrigation area used in the development area under consideration, e.g. for sporting fields, or for any other water demands, e.g. industry water use.

Change compared to ESAT_Alpha v1.0
Water saving appliances: For the water saving appliances, the expected water efficiency labelling standards (0 stars to 6 stars) for the following devices can be entered.

- shower head
- dual flush toilet
- washing machine
- dishwasher

Development region: Select an area of Greater Melbourne for the location of the development. Click on 'View map to select development region', then please click on the respective region.

Flowrate for municipal irrigation periods: Insert a pump flowrate required for municipal irrigation.

3.2.2 Potable Supply

Potable supply: Specify the potable supply for the development. The options are given in the message box of the input field - please insert the respective number.

Electricity demand for potable reticulation: Specify the expected electricity demand for the potable supply transfer.

3.2.3 Rainwater

Rainwater tank: Select whether a rainwater tank will be installed for each household / building.

Tank size per household / building: Defines the size of the rainwater tanks. The options are given in the message box of the input field.

Tank material: Defines the material of the rainwater tank. The options are given in the message box of the input field - please insert the respective number.

Connected roof area per household / building: Defines the roof area connected to the rainwater tank.

Rainwater use: Select between five different uses for the rainwater. The options are given in the message box of the input field - please insert the appropriate number.

Nominal pipe diameter: Select the nominal diameter of pipes used to connect the rainwater tank (outside and in the house).

Length of pipe: Insert the total length of pipeline necessary to connect one household / building.

Pipe material: Select between two different pipe materials. The options are given in the message box of the input field - please insert the appropriate number.

3.2.4 Stormwater

A) Stormwater treatment system

Stormwater treatment system: Select whether a stormwater treatment system will be installed.

Stormwater system type: Define the stormwater system. The options are given in the message box of the input field - please insert the respective number. Click on 'View stormwater system design features' to obtain additional information.

Stormwater use: Select whether the treated stormwater will be reused for irrigation or discharged into the natural environment - please insert the respective number.

Height difference between stormwater source and stormwater use (if wetland): Please insert the height difference to determine pump power requirements.

Nominal pipe diameter (only if wetland): Select the nominal diameter of pipes used to connect the stormwater system.

Length of pipe (only if wetland → to connect development): Insert the total length of pipeline necessary to connect the development for irrigation purposes.

Pipe material (only if wetland): Select between two different pipe materials. The options are given in the message box of the input field - please insert the appropriate number.

B) Stormwater reuse system

Stormwater reuse system: Select whether a stormwater reuse system will be installed.

Impervious area connected to stormwater reuse system (per household / building): Defines the stormwater catchment area connected to an underground stormwater storage tank.

Stormwater use: Select between two different uses for the stormwater. The options are given in the message box of the input field - please insert the appropriate number.

Stormwater storage tank size per household / building: Defines the size of the underground storage tanks. The options are given in the message box of the input field.

Nominal pipe diameter: Select the nominal diameter of pipes used to connect the underground storage tank.

Length of pipe: Insert the total length of pipeline necessary to connect one household / building.

Pipe material: Select between two different pipe materials. The options are given in the message box of the input field - please insert the appropriate number.

3.2.5 Decentralised wastewater treatment

Greywater treatment system: Select whether a greywater treatment system will be installed.

Treated greywater use: Select between four different uses for the treated greywater. The options are given in the message box of the input field - please insert the respective number.

Blackwater treatment system: Select whether a household (hh) or neighbourhood (nbh) scale blackwater treatment system will be installed.

Type of treatment system: Define the blackwater treatment system. The options are given in the message box of the input field - please insert the respective number.

Recycled water use: Depending on the reclaimed water uses determined by the blackwater treatment system, select between the different uses for treated blackwater. The options are given in the message box of the input field - please insert the respective number.

3.2.6 Industrial / commercial wastewater input

Industrial / commercial wastewater input: Define the amount of additional wastewater inputs associated with non-residential landuse in the development.

3.2.7 Conventional STP

There is no input required in this section. ESAT determines based on the assumptions outlined in chapter 4.7 whether a connection to a conventional STP is necessary or not.

3.2.8 Water Recycling Plant (WRP)

WRP: Select whether the development is connected to a water recycling plant.

Recycled water use: Select between the different uses for water from the recycling plant. The options are given in the message box of the input field - please insert the respective number.

3.2.9 Reticulation

Reticulation system: Select between the different reticulation systems. The three generic options (conventional gravity system, low pressure sewage system and vacuum system) are given in the message box in the input field - please insert the respective number.

Depending on the type of system selected for reticulation and treatment, the user will be required to enter some preliminary design information regarding the reticulation system. For simplicity, the reticulation system is divided into three sections, a), b) and c). In turn, these may be described in terms of three subsections with different diameters and other characteristics.

a) Pipework from household / building to decentralised treatment system or pumping station: Please insert the total length of pipe for each diameter to connect all households / buildings.

b) Pipework from pumping station to STP: Please insert the total length of pipe/rising main for each diameter.

Connect to existing sewer network: Select whether the development will be connected to an existing sewer network.

Electricity demand of existing network: Specify the expected electricity demand for the sewerage transfer.

c) Pipework from WRP or decentralised treatment system back to households / buildings: Please insert the total length of pipe/rising main for each diameter.

Nominal pipe diameter: Define the diameter of pipes used.

Length of pipe: Define the length of pipes used.

Pipe material: Select between two different pipe materials. The options are given in the message box of the input field - please insert the appropriate number.

Maintenance holes: Indicate the number of maintenance holes required.

Gravitational head @ pumping station: Indicate the height difference between pumping station base and highest point.

Proportion of flow through pumping station: Indicate the proportion of flow (based on total flow to sewer) which is pumped by the particular pumping station.

3.3 Additional inputs

The advanced ESAT-user may choose to adjust additional input fields which are listed on the sheet '2nd input'. For each of the presented variables, references are given that indicate the origin of each value. Further explanations on each of the items are given in

the respective sections of this document. The 2nd input variables consist of the following parts:

- Lifespans for infrastructure items
- Electricity demands for water servicing options

Change compared to ESAT v1.1

Considering the significant environmental impact of electricity consumption, the advanced user may also enter different electricity demands for all water servicing options. References for the default values are given under "2nd input".

- Cost variables (see section 6.6)

Change compared to ESAT_Alpha v1.2

Due to the normally high contribution of reticulation to the total capital expenditure and LCC of an LCA, the ESAT-user is able to calculate a total construction cost function for uPVC and DICL pipes. The total construction cost function can be generated by entering the cost data per m of pipe for different pipe diameters. Once the data is entered, ESAT calculates a linear function from which the slope and the y-intercept value can be entered under '2nd input'.

- Rainwater tank modelling variables (see section 4.3)
- Stormwater treatment system storage size (see section 4.4)
- Stormwater reuse modelling variables (see section 4.4)
- Recycling rates (see section 5.2)
- Temporary footprint value (see section 6.5)
- Inflow / Infiltration rate (see section 4.9)

3.4 Water Balance and life cycle inventory data

After entering all your inputs and updating the model, the ESAT-user can start to view the results. On the Input page, two result tables are shown immediately on the right side of the screen. They show the water balance as well as physical inputs and outputs such as electricity, materials and money. This inventory is shown after it has been divided by the lifespan of the chosen water servicing system which is why the units are given per annum. In LCC, the Net Present Value (NPV) is calculated for a time period of 30 years.

3.5 Numeric results - the impact table

The 'Inventory' tables on the Input page tell the ESAT-user about basic input and output flows. In order to know what the potential impact of the overall system is, this program converts the inventory into impacts in the following categories: energy, water use, greenhouse gas emissions, nutrients, footprint and life cycle cost. Potential environmental impacts in the categories greenhouse gas emissions and nutrients are expressed in terms of their equivalence to a well-recognised contributor to each impact category. For example, many emissions contribute to greenhouse gas but their impacts differ in severity. To account for this and make them comparable, all of the emission types are equated to

the mass of carbon dioxide that would have the same greenhouse gas effect (CO_2-equivalent).

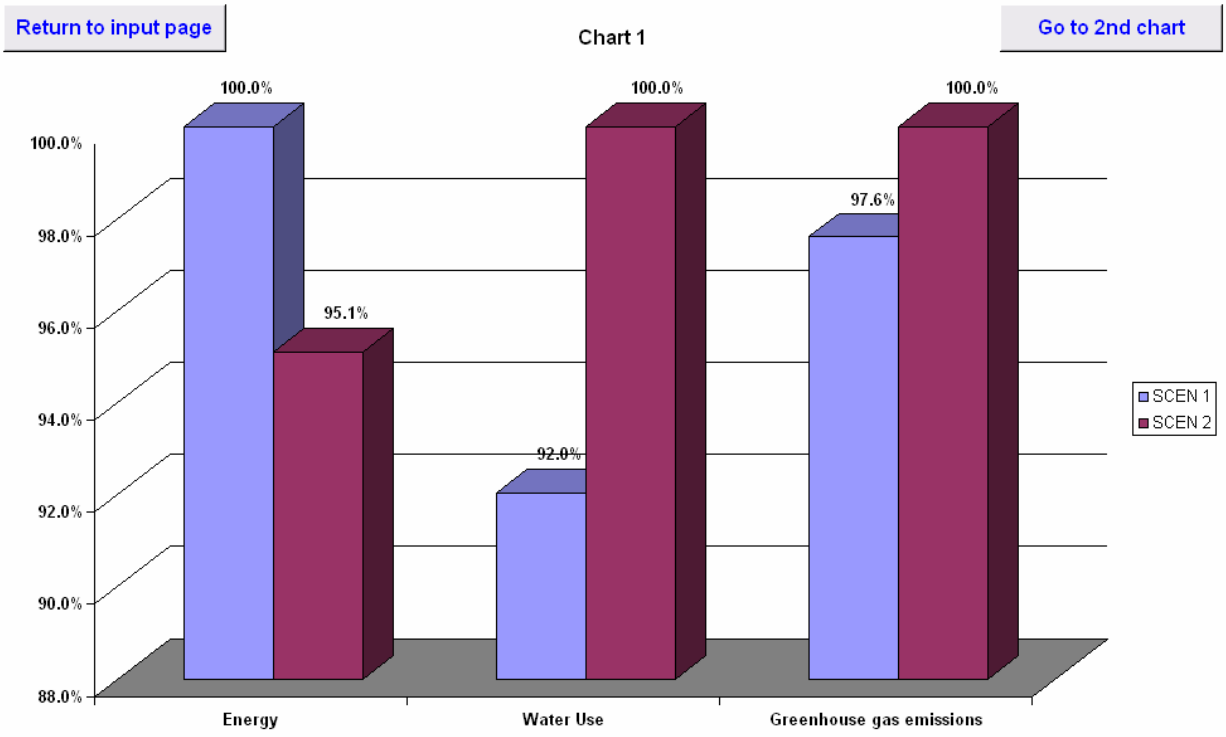
Click on the "Show impact table" button to see a detailed breakdown of the impacts of each scenario.

3.6 Graphic results – the impact graphs

Click on the "Show first chart" button to see graphs illustrating the potential environmental impacts of your specified water service scenario, expressed in relative terms as a percentage of the highest impact (=100%) in each impact category. The categories are the same as those in the impact table.

In the example shown below SCEN 1 has a larger impact on energy use, but SCEN 2 has a larger impact on water use.

Note that the graphs are intended for use in comparing the different systems, since they are expressed in relative terms.



For viewing the impacts in the remaining three impact categories, click on "Go to 2nd chart".

3.7 Aggregated result – Multicriteria Analysis (MCA)

Click on the "Show final results" button to see the result from the multicriteria analysis (MCA).

Based on the weighting factors entered for each impact category, a final result indicating the most favourable scenario will be presented.

In the example shown below SCEN 2 represents the preferred water servicing option.

Note that any rating scale can be used to weigh the different impact categories, as long as the values are positive.

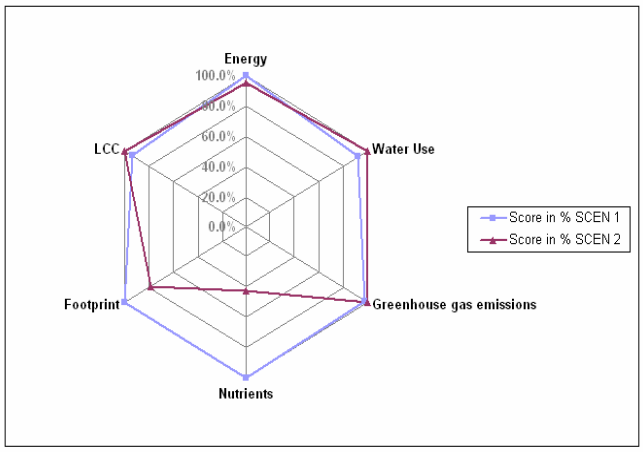
Multicriteria Analysis	Energy	Water Use	Greenhouse gas emissions	Nutrients	Footprint	LCC	
==> Weighting Factor (need to be a positive scale)	2.0	1.0	4.0	1.0	0.5	5.0	
Score in % SCEN 1	100.0%	92.0%	97.6%	100.0%	100.0%	93.6%	100.0%
Score in % SCEN 2	95.1%	100.0%	100.0%	42.2%	78.8%	100.0%	97.8%

Return to input page

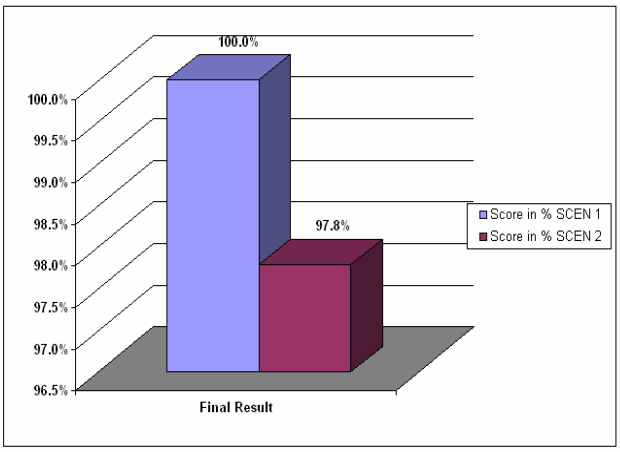
Go to absolute results per household / building and person

UPDATE

Individual Results SCEN 1 vs. SCEN 2



Result after MCA



Based on the weighting factors chosen, Scenario 2 represents the preferred water servicing option.

Please also note that the absolute results for each impact category are available in tabular and graphical form on a per household / building and per person basis. To view these results click on 'Go to absolute results per household / building and person'.

4. Frequently asked questions (FAQ)

The purpose of this chapter is to provide a quick reference guide explaining the main modelling principles for each of the input sections of ESAT. It is also intended to help the user get familiar with how to use ESAT, pointing out useful features such as graphs and figures and highlighting the tool's capabilities. Furthermore, it provides references to more detailed explanations about the assumptions for each water servicing option which can be found in the following chapters in this manual.

4.1 How do I model multi-storey apartment blocks in ESAT?

Think of a multi-storey apartment block as a house with lots of people living in it. For example, if you wanted to model a development with eight 5-storey apartment blocks and 5 units per storey, you would input the following numbers in ESAT (assuming that there will be 2.53 people living in each unit):

1. Household / building water balance				
Number of households / buildings	8	8	*number*	5 storeys 5 units per storey 2.53 people per unit --> 5 x 5 x 2.53 = 63
Number of people per household / building	63	63	*number*	

4.2 Why do I get a negative IWD reduction due to water saving appliances?

If the standards for water saving appliances which you entered was lower than the Melbourne average, the water balance in ESAT may show negative values, see below.

Water saving appliances		
- shower head	3 stars	3 stars
- dual flush toilet	0 stars	3 stars
- washing machine	1 star	3 stars
- dishwasher	1 star	3 stars

WATER BALANCE	SCEN 1	SCEN 2	*Units*
IWD reduction due to water saving appliances	-1,931	3,822	*kL/a*

The reason for this is that the current average individual water demand of 207 L/p/d is based on a certain level of water saving standards which was recorded for 2007.

If, as in the example above, a “0 star”-rated toilet was selected and the standards of the other appliances was comparatively low as well, the final water demand (FWD) would be higher than the initial water demand (IWD) resulting in a negative IWD reduction due to water saving appliances installed. For more information, please refer to chapter 5.1.

Change compared to ESAT_Alpha v1.0

Please note: The Water Efficient Labelling Standard (WELS) Scheme has replaced the voluntary National Water Conservation Rating and Labelling Scheme (the 'AAAAA' Scheme). Consequently, the input fields were changed to the “star-rating”.

4.3 What if I don't know the electricity demand for potable reticulation or for an existing sewer network?

YVW uses energy maps which show different electricity consumption for potable supply and sewerage transfer figures for different locations. Based on these figures, you should be able to determine or at least estimate an appropriate electricity demand for locations covered by those maps. Hallmann et al. (2003) offer a default value of 100 kWh/ML for all water transport in Australia. If you are uncertain about the accuracy of the kWh/ML entered, you could vary the figures to see if they have a significant impact on the final results.

4.4 Which rainwater input variables influence the rainwater yield and how can I see the results?

The main input fields responsible for influencing the rainwater yield are the tank size and the connected roof area, see below.

3. Rainwater

Tank size per household / building	20	10	*kL*
Connected roof area per household / building	200	200	*m2*

There are additional input fields under the tab '2nd input' which can be adapted. For more information on these input fields please refer to chapter 5.3.

3 Rainwater tank modelling variables

Item	Value
Dead tank volume (in % of tank volume)	5%
Initial tank volume (in % of tank volume)	50%
Potable top-up level (in % of tank volume)	20%
Coefficient of runoff	85%
First flush depth (in mm)	2

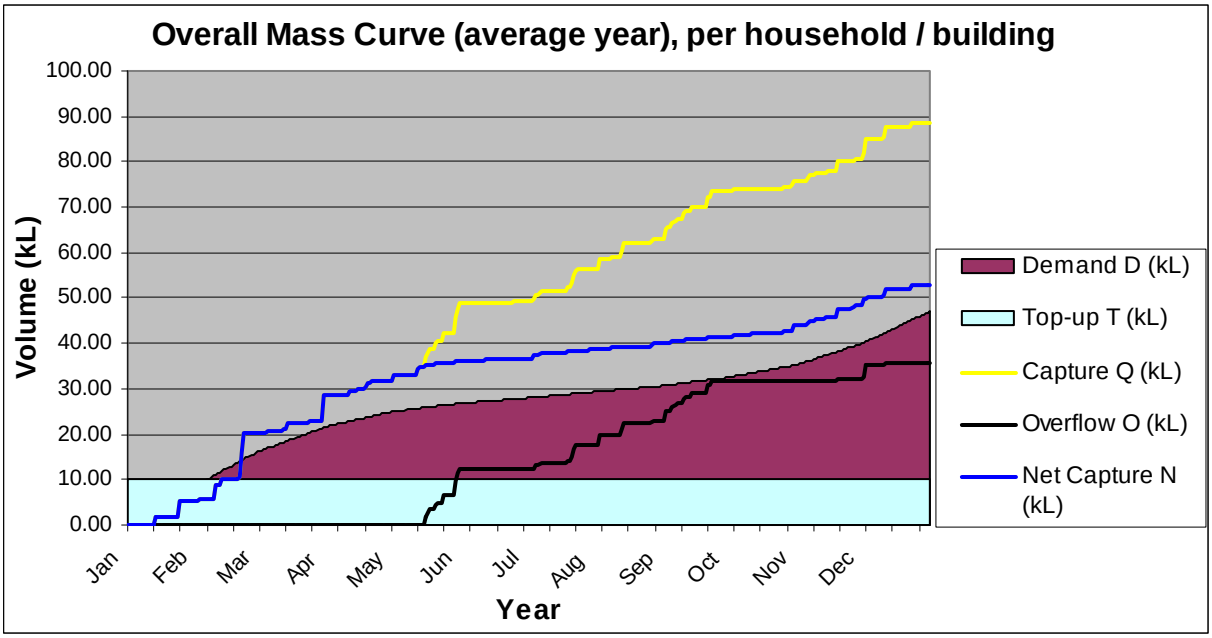
Also, the different amounts of annual rainfall in each development region may influence the results.

Development region	4	4	View map to select development region

To see how much water is available for reuse you can either refer to the respective section in the water balance, see below,

WATER BALANCE	SCEN 1	SCEN 2	Units
Used rainwater	4,702	0	kL/a

or click on View annual rainwater capture (graphs) to get to a more detailed view, see below.



4.5 What's the difference between a stormwater treatment and a stormwater reuse option?

In the input section 4.A), you have the option to select one of two stormwater treatment systems, a raingarden or a surface wetland. The raingarden is a household scale whereas the surface wetland is development scale stormwater treatment system. If a surface wetland is chosen, the treated and collected stormwater can be reused for municipal irrigation. If you click on See stormwater system design features you can see additional information on both stormwater systems.

In the input section 4.B) a stormwater reuse option can be defined. This option is characterised by the collection of stormwater running off from impervious surfaces around the house and can be reused for either outdoor irrigation purposes or toilet flushing. Further details are outlined in chapter 5.4 of this manual.

4.6 What combinations of wastewater treatment can be modelled in ESAT?

In input section 5, you may select either a household scale greywater (SCEN 1) or a decentralised blackwater system (SCEN 2), see below.

User Inputs	SCEN 1	SCEN 2	Units	
5. Decentralised wastewater treatment			*number of systems*	
Greywater treatment system	y	n	*100*	*0*
Greywater use	4	4		
Blackwater treatment systems	n	y	*0*	*1*
Type of treatment system	6	5		
Recycled water use	2	1		

The blue numbers on the right indicate how many systems will be needed. Based on the system provider's information, each system comes with their specific recycled water use options. When you select a greywater system, ESAT will automatically connect the development to a conventional STP, if a blackwater treatment system is selected, a connection to a conventional STP is not necessary since all excess wastewater will be treated and discharged into a river/creek. Please see below the resulting inputs for the conventional STP based on the input decisions above.

7. Conventional STP		
Conventional STP	y	n

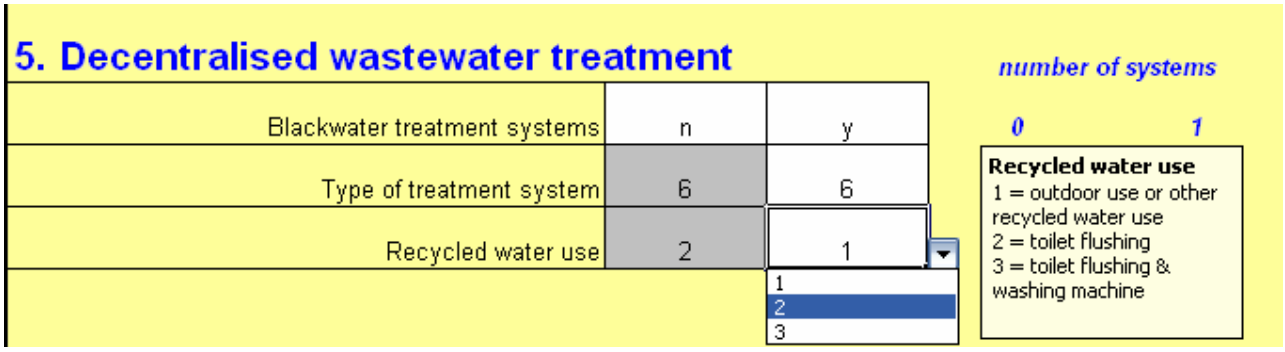
The only exception is a sewer mine. With this blackwater treatment system selected, only the recycled water is extracted and the excess water continues to the conventional STP. For more detailed information, please refer to chapter 5.5 in the manual.

4.7 How do I incorporate an industrial / commercial wastewater stream in ESAT and how do I model wastewater reuse options?

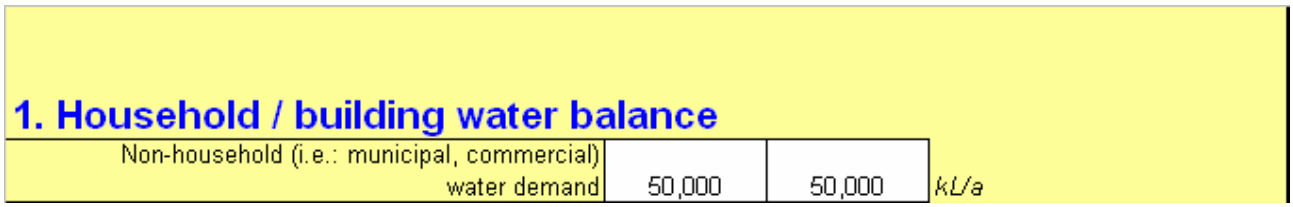
ESAT provides an input field for industrial / commercial wastewater, see below.

6. Industrial / commercial wastewater input			
Industrial / commercial wastewater input	70,000	70,000	kL/a

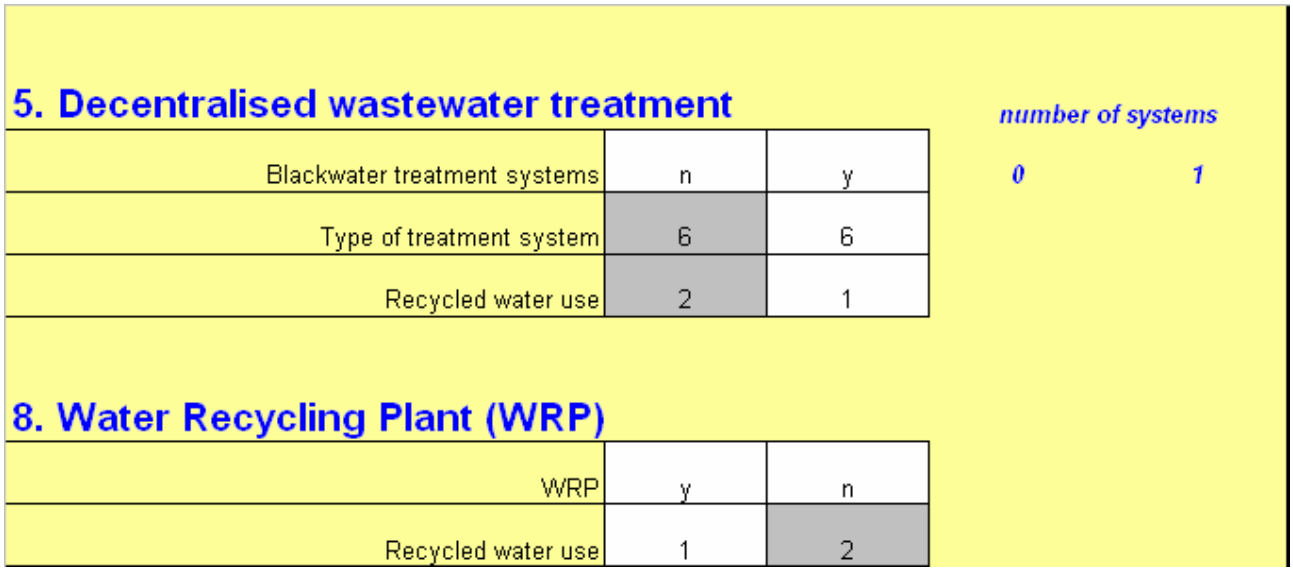
ESAT also caters for modelling the reuse of treated wastewater. Each wastewater system has specific wastewater reuse options, see the example below.



You also have the option to enter additional non-household water demands under section 1 of the input sheet. For example, if industry had a demand for 50,000 kL of recycled water per year, you could enter the amount here:

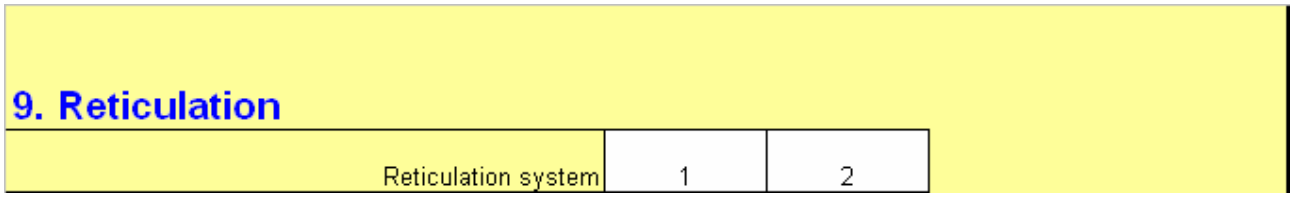


In order to provide recycled water from industrial / commercial wastewater, a neighbourhood-scale decentralised treatment system or a conventional STP coupled with a WRP has to be selected. In the example below, a connection to a WRP is selected for scenario 1 and a decentralised neighbourhood scale wastewater system is selected for scenario 2. Please note, that in order to reuse the treated wastewater for industrial purposes you have to select option 1 = outdoor use or other recycled water use.



4.8 How do I fill out the 3 different reticulation sections in ESAT?

First of all, you can choose between a conventional gravity, a low pressure or a vacuum reticulation system.



The three different reticulation sections cover three sections of the total reticulation network. When you click on View reticulation diagrams you are directed to diagrams illustrating each section.

In section (a) you may specify up to three different pipe sizes with its respective lengths and materials.

You are only asked to enter reticulation details for section (b), if the development is connected to a conventional STP. In this section, you have the option to connect to an existing sewer network and can enter the corresponding electricity demand for the sewerage transfer. In addition or if there is no existing sewer network, you can enter a total of three different pumping station and rising main combinations as well as two downstream gravity mains. For each pumping station you can determine the amount of wastewater as a proportion in % of the total flow which is handled by the pumping station. In the example below the development in SCEN 1 is not connected to an existing sewer. Only one pumping station is required to handle the total sewerage flow (gravitational head = 30 m), so the flows through optional pumping stations 2b and 3b are set to 0%. The diameter, length and material of the rising main connected to pumping station 1b are entered as specified. In this example another pipeline is required (1b) to connect to the conventional STP, using the inputs given below. Finally, three maintenance holes are required for this pipeline section.

b) Pipework from pumping station to STP			
Total flow to sewer	*96,855*	*0*	*kL/a*
Connect to existing sewer network	n	y	
Electricity demand of existing network	800	800	*kWh/ML*
Gravitational head @ pumping station 1b	30	5	*m*
Proportion of flow through pumping station 1b	100%	100%	%
Nominal rising main diameter (pumping station 1b)	250	150	*mm*
Length of rising main (pumping station 1b)	300	500	*m*
Rising main material (pumping station 1b)	1	1	
Gravitational head @ pumping station 2b	20	20	*m*
Proportion of flow through pumping station 2b	0%	0%	%
Nominal rising main diameter (pumping station 2b)	150	150	*mm*
Length of rising main (pumping station 2b)	0	500	*m*
Rising main material (pumping station 2b)	1	1	
Gravitational head @ pumping station 3b	20	20	*m*
Proportion of flow through pumping station 3b	0%	0%	%
Nominal rising main diameter (pumping station 3b)	150	150	*mm*
Length of rising main (pumping station 3b)	0	0	*m*
Rising main material (pumping station 3b)	1	1	
Nominal pipe diameter - pipe 1b	250	150	*mm*
Length of pipe 1b	1000	200	*m*
Pipe material - pipe 1b	1	1	
Nominal pipe diameter - pipe 2b			*mm*
Length of pipe 2b			*m*
Pipe material - pipe 2b			
Maintenance holes b)	3	3	*number*

Please note that greyed-out input fields do not require any attention since the values are not relevant for any calculations.

In reticulation section (c) you can specify additional pipes which may be necessary to transport recycled water from the WRP or a decentralised treatment system back to the households / buildings. Please note that a household scale grey- or blackwater treatment system comes with a pump to provide recycled water to the households / buildings. In this case you should set the proportion of flow through pumping station (1c) to 0%.

For further details on the reticulation section, please refer to chapter 5.9.

4.9 How do I analyse the results of chosen scenarios?

Once you entered all relevant information in the input fields, you should hit 'UPDATE' on the left side of the input screen. The effects of the scenarios chosen on the water balance and the life cycle inventory are shown on the right side of the input screen. To view the results in the environmental impact categories and the life cycle cost you can click on **Show first chart** at the bottom right corner of the input screen. The results are expressed in relative terms as a percentage of the highest impact (=100%) in each impact category. In order to view the absolute results for each impact category and to analyse which unit processes contribute significantly or little to individual impact categories, you can switch to the impact table by clicking on **Show impact table**. The absolute results for each impact category are also presented in tables and charts on a per household / building and a per person basis. You can access these results by clicking on **Go to absolute results per household / building and person**. Finally, to obtain the final result for the most sustainable water servicing scenario, you can click on **Show final result**. You can enter a weighting factor for each impact category representing its relative importance. Based on the weighting factors chosen and using multicriteria analysis as a decision support tool ESAT calculates a final result.

For further details please refer to chapter 3.4 following and chapter 7.

5. Explanatory information on water servicing options

5.1 Household / building water balance

In order to determine the water demand and wastewater generation for a particular development, the ESAT-user will specify the number of households / buildings in the development and the number of people per household / building. ESAT assumes an initial individual water demand of 207 litres/ person/ day (L/p/d) which represent the consolidated Melbourne residential water consumption (WSAA, 2006). Depending on whether there is an additional water demand for non-household use (i.e. municipal irrigation or industrial / commercial use), ESAT will calculate the Initial Water Demand (IWD) for the development.

When ESAT is used for modelling a residential development, 2.53 people per household is the suggested default value and was obtained from WSAA facts 05/06.

Next, the ESAT-user will indicate the expected water ratings for different pieces of equipment installed (e.g.: washing machine). Depending on the planned selection of water efficiency standards for the different appliances, the Initial Water Demand (IWD) decreases or increases and a Final Water Demand (FWD) is calculated.

With regards to the water saving appliances, the default value of 207 L/p/d reflects the mix of the different Water Efficiency Standards that were representative in 2007, as obtained from the ABS for 2007. The water demand for appliances with the respective rating were obtained from the Water Efficiency Labelling Scheme (WELS) report (Wilkenfeld et al. 2003). Please note that the split of standards for water saving appliances is a prediction

for 2007, based on real numbers from 2002 or 2003. Due to the above, when entering data in ESAT a situation can occur where the selection of relatively water inefficient appliances lead to a higher FWD than the IWD. In this case, the IWD reduction figure will appear as a negative number.

Change compared to ESAT_Alpha v1.0

Please note: The Water Efficient Labelling Standard (WELS) Scheme has replaced the voluntary National Water Conservation Rating and Labelling Scheme (the 'AAAAA' Scheme).

In order to reflect the level of water saving standards for different appliances which can be associated with the water consumption obtained from the Enduse Model (CWW, 2007), the following assumptions have been made:

Water appliance	Water consumption by appliance		Additional variables to calculate the unit as per WELS-Scheme	Unit as per WELS-Scheme	Corresponding WELS-category
	(%)	(L/p/d; total = 207 L/p/d)			
			Shower length in min/p/d	*L/min*	
Shower head	30.5%	63.1	5.5	11.5	★ - ★★
			Average number of flushes per person per day	*Average litres**	
Toilet	12.7%	26.3	6.9	3.8	★★ - ★★★
			Distribution top loaders vs. front loaders and respective water consumption in L/kg load	*L/kg load*	
Washing machine	18.0%	37.3	79% top loaders -> 20 L/kg load 21% front loaders -> 10 L/kg load	17.9	★★ - ★★★
			Projected water efficiency rating dishwashers in L/place setting	*L/place setting*	
Dishwasher	1.5%	3.1		1.3	★★★★ - ★★★★★

*average litres are based on the weighted average of 4 half and 1 full flush.

Note that the second and third columns of this table reflect both the average use of water in these devices when installed and the prevalence of these devices in typical Melbourne households. The data for the fields highlighted in dark grey are taken from Wilkenfels et al. (2003), partly based on projected data for 2007.

The table below shows the water consumption for each water appliance for the different star-ratings.

	showerhead	toilet	washing mashine	dishwasher
Unit	*L/min*	*avg. litres*	*L/kg load*	*L/place*
no stars	16	11	40	3.5
★	14	5	30	2.5
★★	10.5	4.25	21	2.06
★★★	8.25	3.75	14.7	1.7
★★★★	6.75	3.25	10.3	1.4
★★★★★	5.25	2.75	7.2	1.16
★★★★★★	4.5	2.5	5	0.96

Average values for each category according to the Water Efficient Labelling Standard (WELS) Scheme

The split of the typical residential water consumption by water device was obtained from the Enduse Model 2007. The following water devices and their respective water consumptions in % of the total residential water consumption have been distinguished:

cold taps	hot taps	toilet	household irrigation	cold washing machine	hot washing machine	cold shower	hot shower	cold dish-washer	hot dish-washer	TOTAL
3.2%	9.5%	12.7%	24.6%	14.4%	3.6%	9.2%	21.4%	1.2%	0.3%	**100%**

Depending on the user's subsequent choices of water servicing options and the selected water reuse options, ESAT calculates the water balance for the development indicating the remaining potable demand after consideration of the different reuse options.

In accordance with each water reuse option available to choose from in ESAT, the following demand profiles have been determined and incorporated into ESAT:

a) Outdoor use:

Based on a study by Zhou et al (2002), a seasonal variation of residential water consumption can be observed for Melbourne. In this study the suburban area of Chelsea with a population of 35,000 people was investigated and hourly water consumption data from 1989 to 1995 was analysed. The authors found out that seasonal variations in residential water use arise from changing irrigation demands. The following monthly irrigation demands (in % of the annual irrigation demand) could be derived from the study and are incorporated in ESAT:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	TOTAL
2.9%	2.9%	3.9%	5.8%	10.1%	15%	17.9%	16.4%	11.6%	7.2%	3.9%	2.4%	100%

ESAT uses the average daily irrigation demand for each month.

b) Toilet flushing:

A constant daily water demand is assumed.

c) Washing machine

The average household washes approximately 5 washing machine loads per week (ABS 2002). Based on this figure, we assume that a load is washed every workday.

d) Hot water system

A constant daily water demand is assumed.

In ESAT, water losses due to leaks in the water supply network are considered to be a function of pressure and pipeline length, which are assumed to be constant for different options and therefore not accounted for. Equally, consumptive losses are neglected. However, an inflow / infiltration rate for the sewerage system is incorporated into ESAT and set to 12%. This default value can be adapted on '2nd input'.

In order to calculate aspects of stormwater management and rainwater supply, the ESAT-user will specify a greater Melbourne region reflecting the approximate location of the development.

In order to calculate the energy requirements for a pump used for municipal irrigation, the ESAT-user will specify a flowrate in kL/h during irrigation periods.

5.2 Potable Supply

The following three water supply options will be available to choose from in ESAT:

1 = Conventional water supply (dam → WFP)

2 = Desalination plant (seawater reverse osmosis)

3 = Groundwater harvesting

Depending on the calculated FWD, the amount of potable water and the respective LCI data will be accounted for in ESAT. For data details on the potable supply options, please refer to '080901_Raw Data for ESAT_Alpha v1.0'.

It is worth noting that the potable water demand may be reduced significantly by selecting from the multitude of different water servicing and reuse options. A reduced potable water demand will also affect the electricity demand necessary to transfer potable water to the development. However, ESAT assumes that the potable reticulation network dimensions are dependent on fire fighting requirements and/or not sufficiently variable in terms of cost or environmental burden.

5.3 Rainwater

For the location of the development region the ESAT-user will choose from 5 areas in Greater Melbourne. ESAT will use this information to allocate the respective rainfall record which in turn determines rainwater and stormwater yields.

The following representative daily rainfall records have been included in ESAT for the different areas. For each rainfall record a total of 29 years was analysed in order to determine a year with median rainfall. The omission of some years for the rainfall stations of Little River and Scoresby result from gaps in measurements due to e.g. equipment failure, interruption of measurement, etc.

Development region	Rainfall Station	Rainfall records included	Median year	Rainfall for median year in mm
1	Little River	1977 - 92, 1994 - 97, 1999 - 07	2001	508
2	Melbourne Airport	1979 - 07	2001	538
3	Melbourne Regional Office	1979 - 07	1999	610
4	Dandenong	1967 - 95	1969	734
5	Scoresby	1948 - 59, 1975 - 86, 2001 - 02, 2004 - 06	2004	847

If a rainwater tank is chosen, it is assumed that every household / building in the development will have a rainwater tank of the same size and of the same material. Furthermore, it is assumed that all households / buildings have the same connected roof area and use the rainwater for the same purposes.

The experienced ESAT-user will be able to choose from additional rainwater modelling parameters which can be found under '2nd input'. The additional parameters are:

Dead tank volume (low level at which potable top-up cuts in): default value = 5% of tank volume

Initial tank volume (volume at start of modelling period): default value = 50% of tank volume

Potable top-up level (high level at which potable top-up cuts out): default value = 20% of tank volume

Coefficient of run off (accounts for issues like splash losses, gutter overflows, etc.): default value = 85% (Gould and Nissen-Petersen,1999)

First flush depth (the volume of roof run off diverted): default value = 2 mm (Gould and Nissen-Petersen,1999)

The options available for rainwater use are the following:

1 = outdoor use only

2 = toilet flushing

3 = outdoor use and toilet flushing

4 = toilet flushing and washing machine

5 = hot water system

Cost data for different domestic-scale rainwater tanks (2, 5, 10, 20 kL) were collected distinguishing three different materials: steel, concrete and polymer. Additionally, data for a typical household rainwater pump are presented in '080901_Raw Data for ESAT_Alpha v1.0'. It is assumed that a pump is installed with each rainwater tank.

All rainwater tanks are assumed to be installed above the ground. As a result, no excavation work is required.

Mainly depending on the rainwater use option chosen, the ESAT-user is asked to enter the pipework details (i.e. pipe diameter, length of pipe, pipe material) to connect one rainwater tank to one household / building.

5.4 Stormwater:

The stormwater section in ESAT is divided into two parts – A and B.

Part A: The ESAT-user may choose between two different stormwater treatment options: a raingarden or a surface wetland. Further details are provided below.

Part B: In addition, it is possible to select a separate stormwater reuse option. This option is characterised by the collection of stormwater running off from impervious surfaces around the house. The water is filtered to remove oil and particles and then stored in an underground tank. It can then be used either for outdoor irrigation purposes or for toilet flushing. In the latter case, the water is chlorinated (5 g/kL). The ESAT-user may choose to add the connected roof area per household / building to the impervious area connected to the stormwater reuse system. By doing so, rain- and stormwater are collected at the same time in the stormwater tank. The following additional assumptions have been made for the stormwater reuse option:

- Stormwater storage tank sizes available: 2, 5, 10 or 20 kL
- Tank material for stormwater storage underground tanks: reinforced concrete
- Excavation volume calculated for stormwater storage underground tank and connections: tank volume x 2
- Each household / building is supplied with a typical household pump to provide for garden irrigation or toilet flushing.
- Cost data for stormwater storage underground tanks, plumbing and pumps are the same as for the rainwater tank installation and maintenance and included in ESAT. Additional excavation costs (640 $/household / building) are considered.
- Similar to the rainwater modelling parameters, also the stormwater reuse system is based on the following additional parameters which can be adapted on '2nd input'.

- ***Dead tank volume*** (low level at which potable top-up cuts in): default value = 5% of tank volume
- ***Initial tank volume*** (volume at start of modelling period): default value = 50% of tank volume
- ***Potable top-up level*** (high level at which potable top-up cuts out): default value = 20% of tank volume
- ***Coefficient of run off*** (accounts for issues like splash losses, gutter overflows, etc.): default value = 85% (Gould and Nissen-Petersen,1999)
- ***First flush depth*** (the volume of roof run off diverted): default value = 1 mm

With regards to the stormwater treatment options, the following two will be available to choose from in ESAT:

1 = raingardens

2 = surface wetland

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Software was utilised to estimate treatment performance in terms of the key water quality parameters of interest (TSS, TN, TP) and the capital and operating expenditures for different sizes of both stormwater treatment systems.

Depending on the chosen development region, the reflecting regions for the purpose of stormwater modelling are used in ESAT to calculate the treatment performance:

Development region	Stormwater modelling region	Mean annual rainfall in mm	Mean annual evapotranspiration in mm	Annual stormwater flow in ML/ha/year
1,2 and 3	West Melbourne	609	1201	2.88
4 and 5	East Melbourne	756	1201	3.43

In both regions, 6 minute interval rainwater data for the years 1970 – 79 was used.

The ESAT-user will further specify whether a household scale stormwater treatment system (= raingarden) or a development scale treatment system (= surface wetland) shall be constructed.

If the raingarden is selected, it is assumed that every household / building in the development will have this type of stormwater treatment system.

If a wetland is selected, it is assumed that it is big enough to treat the entire amount of stormwater of the development to the minimum standard treatment level (specified below).

If a surface wetland is chosen, the treated and collected stormwater can be reused for municipal irrigation. Raingardens only provide the stormwater treatment benefits, but no reuse option.

In order to model the above scenarios in MUSIC, the following assumptions had to be made:

- 14.29 lots per ha (based on average lot size of 700 m^2, (Department of Sustainability & Environment 2006)
- Impervious area = 45% (assumed by UNSW with reference to Francey 2004)
- For the following rainfall-runoff parameters, MUSIC default values were selected except for two parameters for which Melbourne-specific averages were available as shown:

Impervious area properties:

- Rainfall threshold (mm/day) = 1

Pervious area properties:

- Soil storage capacity (mm) = 30 (Melbourne specific data)
- Initial storage (% of capacity) = 30
- Field capacity (mm) = 20 (Melbourne specific data)
- Infiltration capacity coefficient "a" = 200
- Infiltration capacity exponent "b" = 1

Groundwater properties:

- Initial depth (mm) = 10
- Daily recharge rate (%) = 25
- Daily baseflow rate (%) = 5
- Daily deep seepage rate (%) = 0

Regarding concentrations of TSS, TN and TP, both for base flow and storm flow, the following MUSIC default concentrations for the characteristics of an urban development were assumed (all average log mg/L figures):

Total Suspended Solids (TSS)		**Total Phosporous (TP)**		**Total Nitrogen (TN)**	
Stormflow concentration	Baseflow concentration	Stormflow concentration	Baseflow concentration	Stormflow concentration	Baseflow concentration
2.2	1.1	-0.45	-0.82	0.42	0.32

For the **surface wetland** stormwater treatment option, the following assumptions have been made based on MUSIC default values (if not indicated in brackets otherwise):

Inlet properties:

- Low flow bypass (m^3/s) = 0
- High flow bypass (m^3/s) = 0.015 (Werribee), 0.019 (Dandenong) To determine the one year maximum flow rate for sizing the high flow bypass for the

wetland we identified a one in one year rainfall event and the peak rainfall rate on the basis of 6 minute data. Conservatively assuming that the ground was completely water-logged, we calculated the run-off rate for 1 ha as 15 L/s and 19 L/s for Werribee, and Dandenong respectively.

- Inlet pond volume (m^3) = 10% of surface area wetland x 1.5 m depth

Storage properties:

- Extended detention depth (m) = 0.45 m
  This value is based on the maximum allowed by the Melbourne Water guidelines (Melbourne Water, 2002, p.7) which would minimise opportunity costs faced by the land developer.
- Permanent pool volume (m^3) = surface area wetland x 1 m depth
- Vegetation cover (% of surface area) = 50
- Seepage loss (mm/hr) = 36 (average value for soil type sandy clay to sandy loam – mid range)
- Evaporative loss (% of potential evapotranspiration (PET) = 125

Outlet properties:

- Equivalent pipe diameter (mm) = diameter chosen so that a notional detention time of 72 hours can be achieved
- Overflow weir width (m) = 10% of the perimeter of inlet pond

For the **raingarden** as the other stormwater treatment option, the following assumptions have been made based on MUSIC default values (if not indicated otherwise):

Inlet properties:

- Low flow bypass (m^3/s) = 0
- High flow bypass (m^3/s) = 0.015 (Werribee), 0.019 (Dandenong)
  To determine the one year maximum flow rate for sizing the high flow bypass for the wetland we identified a one in one year rainfall event and the peak rainfall rate on the basis of 6 minute data. Conservatively assuming that the ground was completely water-logged, we calculated the run-off rate for 1 ha as 15 L/s and 19 L/s for Werribee, and Dandenong respectively.

Storage properties:

- Extended detention depth (m) = 0.2 m (assumed by UNSW)
- Seepage loss (mm/hr) = 36 (average value for soil type sandy clay to sandy loam – mid-range)

Infiltration properties:

- Filter area (m^2) = surface area
- Filter depth (m) = 1
- Filter median particle diameter (mm) = 5
- Saturated hydraulic conductivity (mm/hr) = 100

- Depth below underdrain pipe (% of filter depth) = 10

Outlet properties:

- Overflow weir width (m) = 10% of the perimeter of surface area
- Overall cost data was obtained from MUSIC assuming the mid-range ("expected") values for acquisition, maintenance, renewal and decommissioning costs and the following default settings:
- Life cycle = 30 years
- Renewal adaptation period = 20 years

The different scenarios were modelled so that in the ideal case the minimum reduction for TSS, TP and TP required by the Melbourne Water guidelines (Melbourne Water, 2002, p. 3) could be achieved, namely:

- TSS: 80% reduction
- TP: 45% reduction
- TN: 45% reduction

The ESAT-user can also decide to have a stormwater treatment system but omit the reuse option. In this case the treated stormwater is discharged into a creek/river.

Since the treatment performance of the two stormwater systems were calculated with 6 min interval rainfall data from the years 1970 -1979, the same 10 year timeframe was used to obtain the available outflow (=overflow) from the stormwater systems. After the exclusion of the year with the highest outflow, the median year was taken to calculate the reusable amount of stormwater.

The outflow and the design parameters of the stormwater treatment system are scaled based on the system design parameters calculated for a development of 1ha (= 14.29 lots per ha).

If a surface wetland is the preferred stormwater treatment option and the user elects to use stormwater as a water source, ESAT assumes that the outflowing stormwater is collected in a "storage". This storage can be thought of as a tank, however, in practice this is likely to be provided by increasing the variable depth of the stormwater detention device, so no tank material is accounted for in the life cycle inventory data. The size of this storage is assumed to be 50% of the wetland storage surface area x extended detention depth. This default value is flexible and can be changed on '2nd input'.

Regarding the outlet pipe diameter of the stormwater treatment system, an additional assumption had to be made. The outlet pipe diameter depends on the designed detention time for which the stormwater should remain in the treatment system in order to fulfill the required treatment performance. The detention time necessary is 72 hours and the pipe diameter is entered in MUSIC accordingly (eWater CRC 2005). The various scenarios modelled in MUSIC showed a correlation between the width of the overflow weir and the diameter of the outlet pipe: width of overflow weir in m x 10 = outlet pipe diameter in mm. This correlation is assumed for this part of the stormwater system design.

Excavation volumes for the 2 stormwater systems have been calculated as follows:

Raingarden: Surface area x filter depth (1m)

Surface Wetland: Surface area x extended detention depth + inlet pond volume

For the pipes used for irrigation purposes and connected to the stormwater system (only applies for surface wetland), an excavation volume was calculated as follows: diameter pipe x length of pipe x 1 m x 2.

The same as for all other excavation work, a John Deere small hydraulic excavator with a 6 m^3/min. excavator efficiency and a diesel consumption of 44.25 litres/hour was assumed (John Deere 2008).

In case a surface wetland is chosen and the treated stormwater is used for irrigation, the ESAT-user is asked to enter the pipework details (i.e. pipe diameter, length of pipe, pipe material) to connect the treated stormwater to the municipal irrigation facility. In this case, also a pumping station will be required. In order to determine the pumping capacity, the ESAT-user is asked to enter the height difference between stormwater source and stormwater use.

5.5 Decentralised wastewater treatment

5.5.1 Greywater treatment system

If a greywater system is chosen, it is assumed that every household / building in the development will have this type of treatment system. However, as soon as the capacity needed exceeds the domestic greywater system's recommended peak flow (i.e. 1.08 kL/d), the system's material requirements are scaled up by a factor based on supplier data or, in its absence, standard industry scale up factors.

The ESAT-user may choose either a household / building greywater treatment system or a decentralised blackwater treatment system but selecting both is considered infeasible. If neither of these options are chosen, ESAT will automatically default to a conventional STP.

The available treated greywater use options are the following:

1 = outdoor use only

2 = toilet flushing

3 = outdoor use and toilet flushing

4 = toilet flushing and washing machine

Excess greywater is discharged into the sewer untreated.

Cost, energy and material data for a household scale greywater treatment system was collected, please refer to '080901_Raw Data for ESAT_Alpha v1.0' for details. The Excel table also specifies the treatment performance considering the reduction in BOD_5, SS, TN and TP.

5.5.2 Blackwater treatment systems

The following blackwater treatment systems and their respective reclaimed water uses will be available in ESAT to choose from. Detailed data is presented in the Excel spreadsheet '080901_Raw Data for ESAT_Alpha v1.0' which is based on significant suppliers of the particular technology:

Ident. Number in ESAT	Household / Neighbourhood scale	Treatment technology	Reclaimed water use
1	Household	- Septic tank system (BioSeptic)	- Outdoor irrigation
2	Household	- Fixed film system (Biolytix)	- Outdoor irrigation - Toilet flushing - Washing machine
3	Household	- Membrane bioreactor (EcoNova)	- Outdoor irrigation - Toilet flushing - Washing machine
4	Neighbourhood	- Septic tank primary treatment - Sand media filter (Orenco)	- Outdoor irrigation
5	Neighbourhood	- Suspended growth system (COPA Water HBNR)	- Outdoor irrigation
6	Neighbourhood	- Fixed film system (Biolytix)	- Outdoor irrigation - Toilet flushing - Washing machine
7	Neighbourhood	- Membrane bioreactor (Aquatec Maxcon MBR)	- Outdoor irrigation - Toilet flushing - Washing machine
8	Neighbourhood	- Sewer Mine (Aquacell S)	- Outdoor irrigation

ESAT allows blackwater treated at the household scale to be used for several purposes in households / buildings. If the user wants to irrigate a suburban sporting field or reuse recycled water for commercial / industry purposes, a neighbourhood scale blackwater treatment system should be selected. These systems can also supply household / building recycled water needs.

If a decentralised blackwater system is selected, all wastewater will be treated and all excess treated wastewater will be discharged into a local river/creek, it is not connected to a sewer. Although this practice may not be consistent with current regulations, the alternative of a connection and discharge to a conventional STP bypassing the decentralised wastewater treatment system would be cost prohibitive if compared to an exclusive connection to a conventional STP. The only exception is a sewer mine. If a sewer mine is selected, only the recycled water is extracted, the excess water continues on to a conventional STP.

As previously mentioned, it is possible to choose either a greywater or a blackwater treatment system but not both. If neither of these options are chosen, ESAT will automatically default to a connection to a conventional STP. Furthermore, the possibility of choosing to treat blackwater and suburban scale has been prevented in the model.

Sharing blackwater treatment systems between several properties is feasible. Depending on the blackwater supply and the capacity of the system selected, a minimum number of household blackwater systems is calculated in ESAT. All materials including the number of pumps, the physical footprint, energy and costs are based on this number.

For all neighbourhood scale wastewater treatment systems, the LCI data is scaled linearly depending on the data obtained from the system providers and the amount of wastewater in the development.

If the ESAT-user opts for a neighbourhood scale sand media filter wastewater treatment system, the tool assumes the installation of septic tanks as a household scale primary treatment device. Depending on the blackwater supply and taking the treatment capacity of the septic tanks into account (2.5 kL/d), a minimum number of septic tanks are calculated in ESAT. Based on an Orenco case study, it is further assumed that 1/3 of the onsite septic systems convey effluent by gravity and 2/3 by pump (Orenco 2001). For further data, please refer to the Excel spreadsheet '080901_Raw Data for ESAT_Alpha v1.0'.

5.6 Industrial / commercial wastewater input

The ESAT-user has the option to include industrial / commercial wastewater inputs. This option becomes viable if the planned development includes businesses or industries which produce wastewater or if nearby existing businesses want to connect to the wastewater treatment system of the development. In such a case the user will either have to choose one of the neighbourhood scale wastewater treatment systems or a connection to the conventional STP since only they have the capacity to handle the additional inputs. ESAT also caters for modelling the reuse of treated wastewater. The user has the option to enter additional water demands under section 1 of the input sheet (household / building water balance). In order to provide recycled water from industrial / commercial wastewater, a neighbourhood-scale decentralised treatment system or a conventional STP coupled with a WRP has to be selected.

5.7 Conventional STP

Operating cost and energy data for Melbourne's main conventional STPs (Eastern and Western STP) was collected. Data for typical chemical use was obtained from an earlier Sydney Water LCA. We were unable to find cost data on the incremental capital cost of augmentation of Melbourne's sewage treatment plants. If our research partners are able to obtain this we would like to insert it.

ESAT will determine automatically whether the development needs to be connected to a conventional STP or whether the chosen decentralised wastewater treatment systems will treat all wastewater from the development. The following cases are possible:

1. If the ESAT-user has chosen to install greywater treatment systems for the development, all households will have to be connected to a conventional STP.
2. If the ESAT-user has chosen any of the available decentralised blackwater treatment systems, the development will not be connected to a conventional STP. In this case, the unclaimed treated wastewater will be discharged into a creek/river.
3. If the ESAT user has neither chosen a decentralised grey- or blackwater system, the development will be connected to a conventional STP.

Whenever the use of a conventional STP is indicated, the wastewater either goes to the Western or the Eastern Sewage Treatment Plant in Melbourne. This depends on whether the development region is in the west (regions 1-3) or in the east (regions 4 and 5). Specific data for the Western STP or the Eastern STP is used accordingly.

5.8 Water Recycling Plant (WRP)

Connection to a WRP is only possible if the development is connected to a conventional STP. It is assumed that a possible WRP is located at the STP site, so the connecting pipework is insignificant.

With regards to the supply of recycled water from a WRP, in ESAT it is assumed that the demand of the development can always be satisfied.

For data details on the WRP, please refer to '080901_Raw Data for ESAT_Alpha v1.0'.

5.9 Reticulation

The following three reticulation systems are available to choose from in ESAT:

1 = Conventional Gravity System (CGS)

2 = Low Pressure Sewage System (LPSS)

3 = Vacuum System (VS)

On account of the manufacturer's description of how the VS operates, if a household scale greywater or blackwater system is chosen, only the CGS or the LPSS are available to choose from.

Furthermore, the user can choose between two different pipe materials: DICL and uPVC.

Excavation volumes depend on the diameter, the length and the depth of the pipe. The following average depths have been assumed for each reticulation system:

- CGS: 2 m (US EPA 2001)
- LPSS: 0.36 m (US EPA 1999)
- VS: 0.9 m (DWC 2008)

The calculated pipe volume is multiplied with a factor of 2 to account for the actual volume of soil that needs to be excavated.

In ESAT an inflow/infiltration rate is assumed for the total sewerage reticulation system. Currently the default value is set to 12% but can be adjusted on '2nd input'.

The user may separately configure up to three sections of the total reticulation network:

a) Pipework from household / building to decentralised treatment system or pumping station

Within this section of the possible network, the user may specify up to three different pipe sizes in simultaneous use.

If a CGS is selected, it is assumed that all wastewater runs under gravity to the decentralised wastewater treatment system or to the pumping station if a conventional centralised STP is chosen. In this initial section, there are no pumping energy requirements.

If a LPSS is selected, grinder pumps are allocated in ESAT. The number of grinder pumps accounted for depends on the amount of wastewater coming from each household / building. A capacity of 2.5kL/d is assumed for each grinder pump and a minimum number of pumps is calculated accordingly. These pump the wastewater to the decentralised treatment system or pumping station.

If a VS is selected, ESAT accounts for a vacuum pumping station with all parts necessary and as described in '080901_Raw Data for ESAT_Alpha v1.0'.

b) Pipework from pumping station to STP

If a conventional STP is used, the ESAT-user has the option of describing another section of the network.

The ESAT-user may choose to connect to an existing sewer network. In this case the ESAT-user is asked to input an average electricity consumption figure for the sewerage transfer to the conventional STP.

In addition, a total of three different pumping stations and rising main combinations and two downstream gravity mains can be chosen. For each pumping station the ESAT-user can determine the amount of wastewater which is handled by the pumping station. The relevant amount can be entered as a proportion in % of the total flow to the STP. If for example only one pumping station is required, the ESAT-user would enter 100% in the field "Proportion of flow through pumping station 1b" and 0% in the corresponding fields for pumping station 2 and 3. If the user chooses to connect to an existing sewer network and has specified the electricity demand for sewerage transfer and none of the above described infrastructure items are necessary all input fields under 'b) pipework from pumping station to STP' should be set to zero.

ESAT calculates the energy requirements for pumping wastewater through the rising mains based on Coulson and Richardson (1985) assuming turbulent flow and:

Input constants:

- Density of fluids, rho = 1000 kg/m3

- Acceleration due to gravity, g = 9.81 m/s^2
- Pump efficiency, ef = 0.7
- Roughness; e = 0.0006 m (DICL pipe); e = 0.000003 (uPVC pipe)
- Rise or gravitational head
  (in case of delivery of water to household / building a pressure head of 15m was assumed, according to the drinking water supply pressure (Sydney Water Corporation 2005 – 2010).)

Input variables:

- Diameter pipe
- Flowrate
- Length of pipe

The following formulas lead to the calculation of the electrical power demand in kW for the pump:

1) massflow = flowrate * 1000 * rho / 3600 / 24 (in kg/s)

2) u = massflow / rho / (3.142 / 4 * diameter ^ 2) (in m/s)

3) phi = 1 / (3.2 - 2.5 * Log(e/diameter)) ^ 2

4) Hdynamic = 4 * phi * L / diameter * (u ^ 2) / g

5) Hstatic = rise

6) pump power = massflow * (Hstatic + Hdynamic) * g

7) Electrical power demand = pump power / ef / 1000 (in kW)

c) Pipework from WRP or decentralised treatment system back to households / buildings

If recycled water from a decentralised treatment system or a WRP is reused in households / buildings, the ESAT-user can specify two additional sets of pipes and a pumping station with rising main.

Since a household scale grey- or blackwater treatment system comes with a pump to provide recycled water to the households / buildings, the ESAT-user should set the proportion of flow through pumping station (1c) to 0%.

For any neighbourhood scale decentralised system or a WRP it is assumed that the recycled water for which there is a reuse demand is pumped to a reservoir (via a pumping station and rising main). The water is then supplied to the households / buildings via gravity. No material or footprint is considered for the reservoir itself.

If a pumping station is necessary, the same formula as described above is used to calculate the electrical power demand.

5.10 Sludge Treatment

If further sludge treatment is required, it is performed at a conventional STP. However, in these cases which produce sludge, ESAT will take into account the kilometres driven by a truck which collects the sludge and delivers it to the nearest STP and the energy required to treat the sludge.

Metcalf and Eddy (2003) estimate a concentration of 210 mg/L of solids in typical sewage. Digestions processes during treatment reduce this value to about 160 mg/L (Peters and Rowley 2008). The treatment and transportation of the biosolids for agricultural application demands about 0.052 kWh/kL of sewage.

If the ESAT-user chooses to treat the wastewater of the development in a conventional STP, the energy requirements are included in the overall system energy figure. Based on specific provider information for decentralised wastewater treatment systems the following desludging assumptions are made:

Treatment system	Additional energy requirements for desludging	Reference
Greywater system	No desludging required	Nubian 2008
Septic tank system	0.052 kWh/kL raw effluent	
Fixed film system (hh/nbh)	No desludging required	Biolytix 2008
MBR (hh)	No desludging required	Econova 2008
Sand media filter	0.052 kWh/kL raw effluent	
Suspended growth system	0.052 kWh/kL raw effluent	
MBR (nbh)	65% of 0.052 kWh/kL = 0.034 kWh/kL	Aquatec Maxcon 2008
Sewer mine	No desludging required	
WRP	No desludging required	

In addition to the sludge treatment energy requirements, truck transport (default 50 km) once a year is assumed to transport the “wet” biosolids to the nearest STP for treatment. To calculate the tonne-kilometres necessary to account for the trucking, the following logic is applied. 0.052 kWh are necessary to produce 0.16 kg dry biosolids out of 0.21 kg wet biosolids. In ESAT, based on the amount of wastewater treated, the energy demand is calculated. To then calculate how much wet sludge has to be transported, the following factor is applied: 0.21 kg/kL / 0.052 kWh/kL = 4.04 kg/kWh. This factor multiplied with the energy demand (in kWh) results in the amount of “wet” biosolids.

Since biosolids can be used as fertilisers in agriculture, their use leads to an avoided amount of N and P-fertiliser. To which amount biosolids from treated sludge can substitute conventional N- and P-fertiliser, please refer to section 4.2.

6. Additional comments on life cycle inventory data

In addition to considering the manufacture of infrastructure items and the operation and maintenance of the systems as outlined above, ESAT also accounts for environmental burdens in relation to transport distances and the footprint.

6.1 Transport:

Based on the location of the production sites for the materials covered in ESAT, the following transport distances have been assumed.

Item	Means of transport	Transport distance (one way)	Reference
Concrete/ cement	Truck	50 km	Assumed CWWT
Steel/ iron	Truck	50 km	Assumed CWWT
Diesel	Truck	50 km	Assumed CWWT
Chemicals	Truck	50 km	Assumed CWWT

Item	Means of transport	Transport distance (one way)	Reference
Membranes	Ship	3,801 nautical miles = 7,039 km	http://www.searates.com/reference/portdistance/?fcity1=12117&fcity2=27613&speed=14&ccode=4616
Membranes	Truck	50 km	Assumed CWWT
Tanks	Truck	50 km	Assumed CWWT
Pipes	Truck	50 km	Assumed CWWT
Pumps	Truck	50 km	Assumed CWWT
Excavated soil	Truck	10 km	On the basis of Andrew and Vesely, 2007
Filling material (sw system)	Truck	10 km	On the basis of Andrew and Vesely, 2007
Greywater system	Truck	889 km	Artarmon NSW to Melbourne, www.maps.google.com
Household fixed film system	Truck	1,692 km	Brisbane to Melbourne, www.maps.google.com
Household MBR	Truck	1,817 km	Nambour QLD to Melbourne, www.maps.google.com
Neighbourhood suspended growth system	Truck	897 km	Hornsby NSW to Melbourne, www.maps.google.com
Neighbourhood fixed film system	Truck	1,692 km	Brisbane to Melbourne, www.maps.google.com
Neighbourhood MBR	Truck	1,655 km	Ipswich QLD to Melbourne, www.maps.google.com
Sewer Mine	Truck	50 km	Assumed CWWT, Manufactuing site in Moorabbin VIC
Vacuum system	Truck	889 km	Artarmon NSW to Melbourne, www.maps.google.com
Sludge treatment	Truck	50 km	Assumed CWWT
Steel reprocessing	Truck	50 km	Assumed CWWT
PE reprocessing	Truck	50 km	Assumed CWWT

With regards to the decentralised wastewater treatment systems, specific data from individual providers was collected. In accordance to that data, respective transport distances were put in ESAT reflecting the system provider's manufacturing locations as a

default value. However, the ESAT-user is able to change these data on the 'LCI Transport' sheet.

6.2 Material reprocessing / Avoided products;

ESAT takes into account that some of the materials used for different water servicing options get recycled and reprocessed to produce new material. From an environmental point of view reprocessing presents a saving or an environmental credit.

The reprocessing of steel and polyethylene plastics (PE including HDPE and LDPE) are taken into account. The following assumptions are made for each material:

Steel:

Only the high quality (stainless) steel normally used for tanks and pumps is recycled and reprocessed into new stainless steel. A specific process was designed in GaBi to reflect the special recycling and reprocessing circumstances. The particular data set used represents an end of life scenario assuming closed loop recycling with a collection rate of 95% (flexible in ESAT) and average losses during recycling. It includes the "avoided burden" of the recycling product calculated by system expansion. This data set corresponds with the data set production of stainless steel sheet.

PE:

PE-type plastics are mainly used for different types of water storage tanks in ESAT. Based on the results of the latest National Plastics Recycling Survey, an average recycling rate of 21% can be assumed for the different types of PE plastics, HDPE and LDPE (PACIA 2006). In ESAT it is assumed that 100% of the recycled PE-material can be used to produce new materials. The amount of PE recycled and reprocessed represents an environmental credit and therefore reduces the original impact of virgin PE production.

For both materials a transport distance of 50 km from the development site to the reprocessing facitlity is assumed. The ESAT-user will be able to change these distances under 'LCI Transport'.

Concrete could also be considered a recyclable product. After its use phase it can be crushed, and the gravel can be used for road construction, for example. This is called open-loop recycling. However, from an environmental point of view, recycling and crushing concrete is considered equivalent in environmental impact to the production of the avoided product from virgin materials. Therefore, concrete recycling is not considered in ESAT.

All other materials used are considered insignificant or non-recyclable.

Biosolids can be applied in agriculture as a substitute for conventional N and P fertiliser. Results from a recent study on biosolids suggest that for each dry kg of biosolids put out on fields, 0.011 kg of N-fertiliser and 0.037 kg of P-fertiliser can be avoided (Peters and Rowley 2008). This environmental credit is incorporated into ESAT based on the biosolids production for each scenario.

7. Life cycle impact assessment

In this phase of the environmental and economic assessment, the inventory data presented for all phases is translated into contributions to relevant impact categories. The impact categories included in ESAT are presented in the following sections.

7.1 Energy use

To determine the energy use, the gross calorific value (= upper calorific value) for all processes included in ESAT was taken as defined in GaBi (GaBi).

7.2 Water use

Change compared to ESAT_Alpha v1.0

The impact category water use reflects both the water used during material production or electricity generation as well as the remaining potable water demand. For the first component of the water use, the characterisation method EDIP 97 has been used (Wenzel et al. 1997).

7.3 Greenhouse gas emissions

The baseline characterisation methods developed by Guinee et al. (CML 2001) have been applied.

7.4 Nutrients

The impact category called “Nutrients” in ESAT refers to eutrophication potential, a term regularly used in LCA literature. This impact category is defined in GaBi and based on CML 2001.

Depending on the availability of data, the following emissions contribute with specific characterisation factors to the Nutrients impact category, which is expressed in kg PO_4-equ.:

Emissions	BOD_5	COD_5	TN	TP	Nutrients in kg PO_4-equ.
Characterisation factor	**0.022**	**0.022**	**0.42**	**3.06**	**1**

In ESAT all water flows released into the environment (rainwater, treated stormwater, effluent from decentralised and conventional STPs) are taken into account with their specific water quality, depending on the chosen scenario and are expressed in the Nutrients impact category.

The following general assumptions are made:

- The size of the whole development is based on the assumption that there will be 14.29 lots per ha (based on average lot size of 700 m^2, (Department of Sustainability & Environment 2006)
- Impervious area = 45% (assumed by UNSW with reference to Francey et al. 2004)

- 45% of the total rainwater amount per development area would enter the stormwater system if selected by the ESAT-user (based on MUSIC modelling results). The remaining rainwater (minus the rainwater captured by any possible rainwater tanks) is discharged into the environment.
- If no stormwater system is selected all rainwater (minus the rainwater captured by any possible rainwater tanks) is discharged into the environment.

With regards to the types of discharged water in the development and their specific quality (affecting the Nutrients impact category) the following can be distinguished:

Emissions	BOD_5 in mg/L	TN in mg/L	TP in mg/L	Nutrients in kg PO_4-equ./L	Reference
Potable water used for irrigation	6.25	0.02	0.009	**1.7E-04**	- National Water Quality Management Strategy 2004 - City West Water 2007 - South East Water 2007 - Droste, R.L. 1997, - Xu, T., Birch, A. 2005
Rainwater run-off or rainwater used for irrigation		2.85	0.41	**2.5E-03**	- eWater CRC 2005, MUSIC manual
Treated stormwater (wetland west)		0.58	0.08	**4.9E-04**	- eWater CRC 2005, MUSIC manual
Treated stormwater (wetland east)		0.59	0.08	**4.9E-04**	- eWater CRC 2005, MUSIC manual
Treated stormwater (raingarden west)		0.8	0.1	**6.4E-04**	- eWater CRC 2005, MUSIC manual
Treated stormwater (raingarden east)		1.4	0.12	**9.6E-04**	- eWater CRC 2005, MUSIC manual
Stormwater runoff captured in underground storage tank and used for irrigation		2.85	0.41	**2.5E-03**	- same as rainwater run-off
Water discharged via Eastern STP	26	26	6.1	**3.0E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Water discharged via Western STP	2.6	11.1	8.8	**3.2E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Treated greywater used for irrigation or discharged into river/creek	4	10	3	**1.3E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Treated water from septic tank system used for irrigation or discharged into river/creek	5	5	0.03	**2.3E-03**	- see '080901_Raw Data for ESAT_Alpha v1.0' - Ecomax 2008
Treated water from fixed film system used for irrigation or discharged into river/creek	8.8	33	8	**3.9E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Treated water from MBR used for irrigation or discharged into river/creek	20	26	0.1	**1.2E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'

Emissions	BOD_5 in mg/L	TN in mg/L	TP in mg/L	Nutrients in kg PO_4-equ./L	Reference
Treated water from sand media filter used for irrigation or discharged into river/creek	6	15.5	12.4	**4.5E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Treated water from suspended growth system used for irrigation or discharged into river/creek	10	10	1	**7.5E-03**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Treated water from fixed film system used for irrigation or discharged into river/creek	8.8	33	8	**3.9E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Treated water from MBR used for irrigation or discharged into river/creek	10	15	3	**1.6E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Water extracted from Sewer Mine used for irrigation	5	10	9	**3.2E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0'
Water extracted from WRP used for irrigation	5	1.2	4	**1.3E-02**	- see '080901_Raw Data for ESAT_Alpha v1.0' - GHD 2008

7.5 Footprint

As agreed in the scoping dialogue report the footprint indicator in ESAT will take construction and land use effects into account. ESAT will distinguish between a temporary footprint, e.g. excavation to run a pipeline and a permanent footprint, e.g. area of a decentralised wastewater treatment system.

Both footprints are presented individually in the life cycle inventory data overview. When compiling into the final footprint impact category, both values are added, whereby the temporary footprint only accounts for 20% of the permanent footprint. This factor is flexible and can be adjusted by the ESAT-user in '2nd input'.

For WFPs as part of the conventional water supply, desalination plants and STPs, the physical footprint in m^2/ML is calculated by taking the area of the following plants divided by the respective flowrate. Per bulk supply option (conventional and desalination), an average is determined; for bulk treatment option, the specific footprint in m^2/ML was calculated for the Western and Eastern STP in Melbourne.

Bulk supply/ treatment option	Name of plant	Physical footprint in m^2	Flowrate in ML/a	Footprint in (m^2/ML)	Reference
WFP	Warragamba	12,035	1,344	8.95	Area estimation using maps.google.com and an area calculator (http://www.daftlogic.com/sandbox-google-maps-area-calculator-tool.htmhttp://www.daftlogic.com/sandbox-google-maps-area-calculator-tool.htm)
WFP	Woronora	25,924	18,914	1.37	
WFP	Macarthur	27,649	29,722	0.93	
WFP	North Richmond	31,507	6,920	4.55	
WFP	Prospect	168,710	461,503	0.37	
WFP	***Average***	***53,165***	***103,681***	***3.23***	
Desalination Plant	Kwinana, Perth	65,000	45,000	1.44	http://www.water-technology.net/projects/perth/specs.htm http://www.sese.uwa.edu.au/__data/page/96394/Seah_2005.pdf
Desalination Plant	Kurnell, Sydney	300,000	182,500	1.64	http://www.planning.nsw.gov.au/asp/pdf/05_0082_preferred_project_report_4_construction.pdf
Desalination Plant	Wonthaggi, Melbourne	350,000	150,000	2.33	http://www.dpi.vic.gov.au/CA256F310024B628/0/8B3D9564DA7D210ECA2573A30016CADD/$File/2007-24+Attachment+4+-+plant+layout.pdf http://www.dpi.vic.gov.au/CA256F310024B628/0/564978905F407668CA2573A30017B97E/$File/2007-24+Part+C_Project+Description.pdf
Desalination Plant	Tugun, Gold Coast	60,000	45,625	1.32	http://www.desalinfo.com.au/The_Project.asp
Desalination Plant	***Average***	***193,750***	***105,781***	***1.68***	
STP	Western STP	10,341,228	177,025	58.4	Area estimation using maps.google.com and an area calculator (http://www.daftlogic.com/sandbox-google-maps-area-calculator-tool.htmhttp://www.daftlogic.com/sandbox-google-maps-area-calculator-tool.htm)
STP	Eastern STP	4,675,483	135,050	34.6	

For a groundwater harvesting plant, no physical footprint is assumed.

All rainwater tanks are assumed to be installed above ground, the areas they take up are calculated according to '080901_Raw Data for ESAT_Alpha v1.0'.

For the stormwater treatment systems, the surface area (raingarden and surface wetland) and the size of the inlet pond (surface wetland) determines the physical footprint.

For all decentralised wastewater treatment options, the sizes as indicated in '080901_Raw Data for ESAT_Alpha v1.0' are chosen and scaled depending on the amount of wastewater they treat.

For a WRP, the same footprint in m^2/ML is assumed as for a desalination plant since dimensions are similar on a per kL basis. Only the proportion of the recycled water demanded by the development accounts for the WRP footprint.

Whereas all pipes are assumed to be underground and therefore only account for a temporary footprint, pumping stations are assumed to be above the ground and account for a permanent footprint. The temporary footprint for pipes is calculated as diameter of pipe x 2 x length of pipe.

7.6 Life cycle costing (LCC)

As part of the economic assessment of different water servicing option, ESAT compares the scenarios selected by the user on the basis of life-cycle costs expressed in the net present value (NPV). The NPV compares the value of a dollar today versus the value of that same dollar in the future (CML 2004). Both life spans of the various items and an adjusted discount rate (= expected market rate minus expected inflation rate) are taken into account to calculate the NPV according to the following formula (Huppes et al. 2004):

$$\mathrm{NPV} = C_0 + \sum_{t=1}^{N} \frac{C_t}{(1+r)^t}$$

With:

C_0 = initial investment

N = total time of the project (assumed 30 years)

t = time of the cash flow

C_t = net cash flow

r = adjusted discount rate

The specific cost data used is presented in '080901_Raw Data for ESAT_Alpha v1.0'.

The cost figures represent total resource costs which refer to all quantifiable costs regardless of who accrues them. Water pricing or other intra-system financial transfers are not considered in the LCC.

Change compared to ESAT_Alpha v1.2

The time span for the calculation of the NPV is 50 years. The expected discount rate is currently set to 7% but can be modified by the ESAT-user.

For different water servicing options, very often only a total operating expenditure (opex in $/kL) and one energy consumption (kWh/kL) figure was available. In order to calculate the split between energy related opex and other opex (e.g. maintenance, chemicals, etc.), a price of 10 cents per kWh was assumed. In ESAT the price for electricity can be adjusted and will have an effect on the energy related opex.

Change compared to ESAT_Alpha v1.2
Due to the normally high contribution of reticulation to the total capital expenditure and LCC of an LCA, the ESAT-user is able to calculate a total construction cost function for uPVC and DICL pipes. The total construction cost function can be generated by entering the cost data per m of pipe for different pipe diameters. Once the data is entered, ESAT calculates a linear function from which the slope and the y-intercept value can be entered under '2nd input'.

7.7 Multicriteria analysis (MCA):

By means of a simple Multicriteria Analysis (MCA) the ESAT-user is able to obtain an aggregated value result from the comparison of two modelled scenarios. For this purpose the user will have to enter a weighting factor for each impact category. Any weighting scale, providing the use of only positive values, will deliver a sensible result. Based on these weightings, ESAT will calculate a final result.

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