Meso-level eco-efficiency indicators to assess technologies and their uptake in water use sectors

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Finalized Systemic Environmental Analysis Tool – SEAT

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Abstract

The SEAT (Systemic Environmental Analysis Tool) is a flexible modelling environment for the simulation of water use systems, along with their components, processes & interactions, as well as the evaluation and visualization of material and energy flows. The finalized version of the SEAT was released in Month 25 (November 2013). The tool can be downloaded by all registered users from the EcoWater Toolbox web site:

http://environ.chemeng.ntua.gr/EWToolbox/Toolbox/Resources.aspx

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1 Introduction

SEAT is the core model building tool of the EcoWater project and supports the assessment of the environmental impacts of alternative technological configurations of a meso-level water use system. It provides the flows of the materials (water, resources, products, etc.) that can be used for estimating the environmental components of the eco-efficiency indicators.

SEAT allows the development of a model representation of the corresponding supply chain, its components, processes & interactions. The supply chain is the physical representation of the various processes that are involved in producing goods (and services), starting with raw materials and ending with the delivered product. In the current concept, the water supply chain consists of various processes which modify the quality and/or the quantity of the water flow. It follows the actual flow of the water resource and can be described using physical quantities (i.e. kg, m^3).

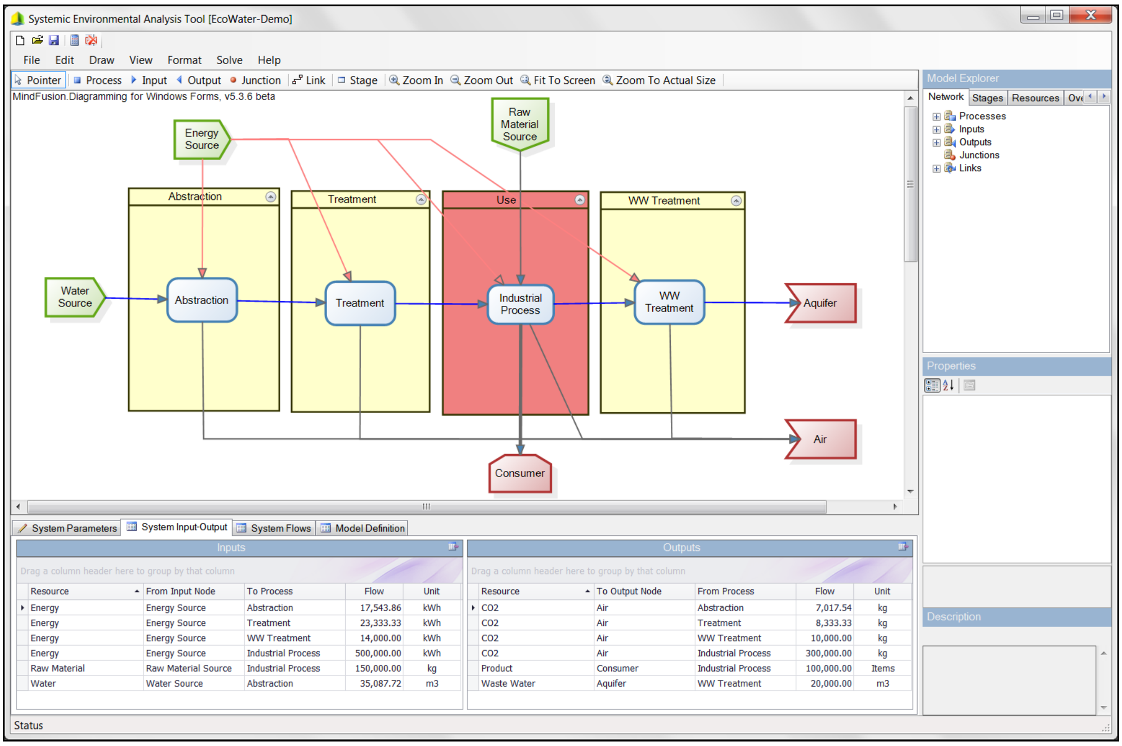

Figure 1. The SEAT modeling environment

1.1 Functionalities

The main functionalities provided by SEAT are:

- Design of a model representation of the analysed physical system.

  The user specifies the stages and the processes of the water use system by actually drawing the elements of the model.

- Mapping of the stages and the production processes in the supply chain.

  The user specifies the flow of resources to and from processes, as well as the relationship between input and output flows.

- Calculation of the resource flows per stage and process.

  All flows of the resources are calculated by using the input-output relation defined in the previous step, when at least one flow is manually defined.
- Presentation and reporting of the results.

  The software supports the tabular representation of the calculated flows per link, process and stage, and for the entire system.

The following sections briefly introduce the main methodological concepts of SEAT and present its main functionalities. More information is available in the tutorials (presentation and video) at the EcoWater Toolbox web site:

http://environ.chemeng.ntua.gr/EWToolbox/Toolbox/Help.aspx

1.2 System Requirements

SEAT is a Windows Applications developed with the Visual Basic .NET programming language. The software requirements are:

a. Microsoft® Windows XP Service Pack 2 (32bit or 64bit), Microsoft® Windows Vista (32bit or 64bit) or Microsoft Windows 7 (32bit or 64bit) and
b. NET framework 4.0.

2 Concepts

SEAT is based on the principles of Material Flow Networks (MFN), which model material and energy flows in production chains. This analysis of MFNs can provide information on the resources used and the corresponding emissions, which can lead to environmental assessment of the analyzed system as well as the economic value estimations.

In each system described by a SEAT model, generic materials (water, raw materials, energy, etc.) are processed and transformed into other materials, while releasing emissions external to the system (air, land, water). The state of the system is characterized by the flows of these generic materials (inventory of elementary flows), consisting of:

- Water service related materials (e.g. fresh water, groundwater, waste water).
- Supplementary resources used in the processes (e.g. energy, raw materials, chemicals, etc.).
- Emissions generated from the processes.
- Products/services or by-products produced by the processes.

The main elements of a SEAT model are two different types of vertices called processes and places. They are connected with links and can be grouped into stages.

Processes represent an activity or task, which is entered by all the required materials (input) and, as a result, generates new or modified materials (output). In this way, processes link material consumption to production. Process specifications can summarize underlying activities in terms of simple relations between input and output flows or algorithms for whose computation programs are used.

Places may be interpreted as stores for resources within the network. They are distinguished as:

- Input Nodes: The initial sources of resources flowing towards processes.
- Output Nodes: The target sinks of resources flowing from processes.
- Junctions: They connect processes, acting as an output node for one process and input node for the other process.

Links represent a mean by which material can flow from a place (input node or junction) to a process or from a process to a place (output node or junction)

Stages serve as containers for grouping multiple model elements. They can be used in cases where part of a model can be aggregated as an individual unit.

3 User Interface Elements

The main SEAT user interface elements (Figure 2) are the following:

(a) Menu Toolbar

It provides access to the most important functions of the program and consists of seven sub-menus:

- File menu: Provides the option for creating, opening, saving and managing model, as well giving access to printing and exporting operations of both the model diagram and the model definition report.
- Edit menu: Allows the user to search for manually defined flows.
- Draw menu: Gives access to model editing operations (inserting new process, input/output node, link, junction or stage).
- View menu: Allows altering the model diagram area, by toggling the grid, enlarging and decreasing the size of the diagram and setting the background color.
- Format menu: Allows editing the appearance of the model elements, by resizing and aligning them.
- Solve menu. Provides access to the model solution algorithm of the tool.
- Help menu: Provides access to the SEAT help system.

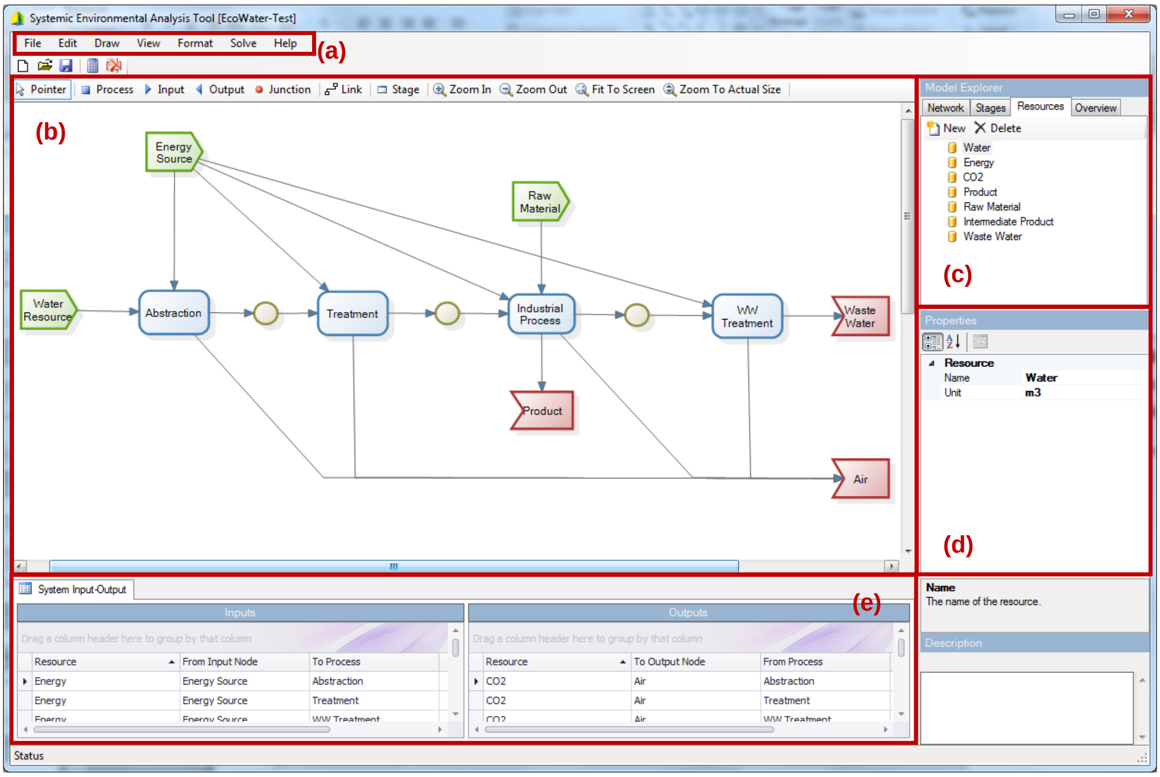

Figure 2. User Interface Elements

(b) Graphical Model Editor

It is the main screen of SEAT and allows the user to create, edit and remove model elements. The Graphical Model Editor toolbar provides access to all the model editing operations (inserting new process, input/output node, link, junction or stage). At any given time, the active state of the cursor is highlighted at the toolbar. The “Pointer” state is the default state of the cursor.

(c) Model Explorer

It is located in the upper right corner of SEAT. The model explorer area is an active window which basically gathers all the model information. It contains four individual tabs, each serving a distinct purpose:

- The “Network” tab, presenting the existing elements of the model, categorized by their type.
- The “Stages” tab, presenting the processes and the input/ output nodes of the model, categorized by stage.
- The “Resources” tab, presenting all the resources in the model.
- The “Overview” tab, showing an overview of the system model.

(d) Properties Editor

It presents all the properties of the model element that is selected either in the graphical model editor or in the model explorer

(e) Model Specification Area

It includes three different categories of tabs:

- “Model Specification” tabs
- “Results” tabs and
- “Model Definition” tab.

4 Model Design

4.1 Creating Model Elements

Creating a model element (process or place) is performed by clicking on the respective button in the toolbar of the graphical model editor, and then clicking and dragging the mouse to draw the element. After the creation of the new element, the draw state reverts to the default "*Pointer*" state.

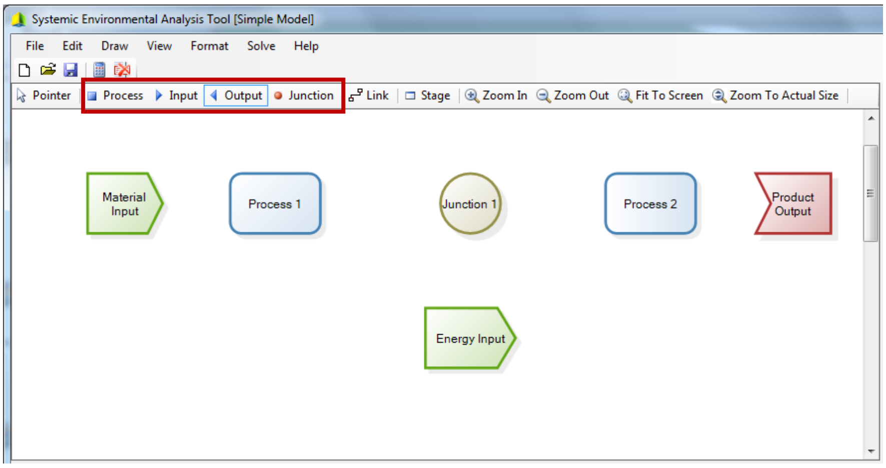

Figure 3. Creating model elements

Multiple components of the same type can be inserted by double-clicking the appropriate button in the component toolbar. Exiting the multiple insertion mode is done by either pressing the *Escape Key* or clicking on the pointer button to return to *Pointer* state mode.

4.2 Connecting Model Elements

The connection of two elements of the model is performed by clicking the "Link" button in the graphical model editor toolbar, selecting the source node, holding the mouse button and finally releasing the mouse on the target node.

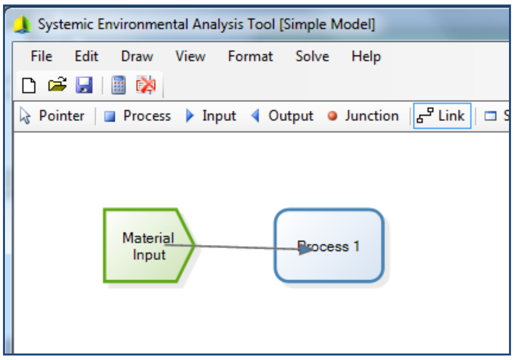

Figure 4. Connecting two model elements

4.3 Editing Model Elements

Editing a model element involves the selection of the element, either in the Graphical Model Editor or in the Network Tab of the Model Explorer, navigating to the Properties Editor and changing the properties.

5 Process Mapping

5.1 Managing Resources

The creation of a new resource is achieved by navigating to the Resource Manager and pressing the “New” Button. Editing a resource involves the navigation to the Properties Editor and changing its name and its unit.

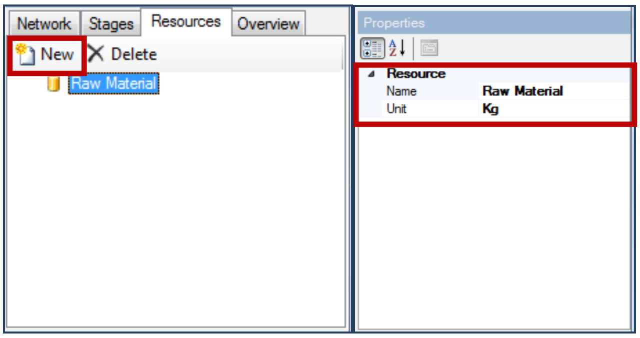

Figure 5. Creating and editing a resource

5.2 Specifying processes

In order to fully specify a process, all the input and output flows must be defined and then the relationship between them must be determined.

The simplest way of specifying a process is by using the so-called production factors, which define linear relationships between a process’ inputs and outputs. Figure 6 illustrates the procedure used in SEAT to define the production factors.

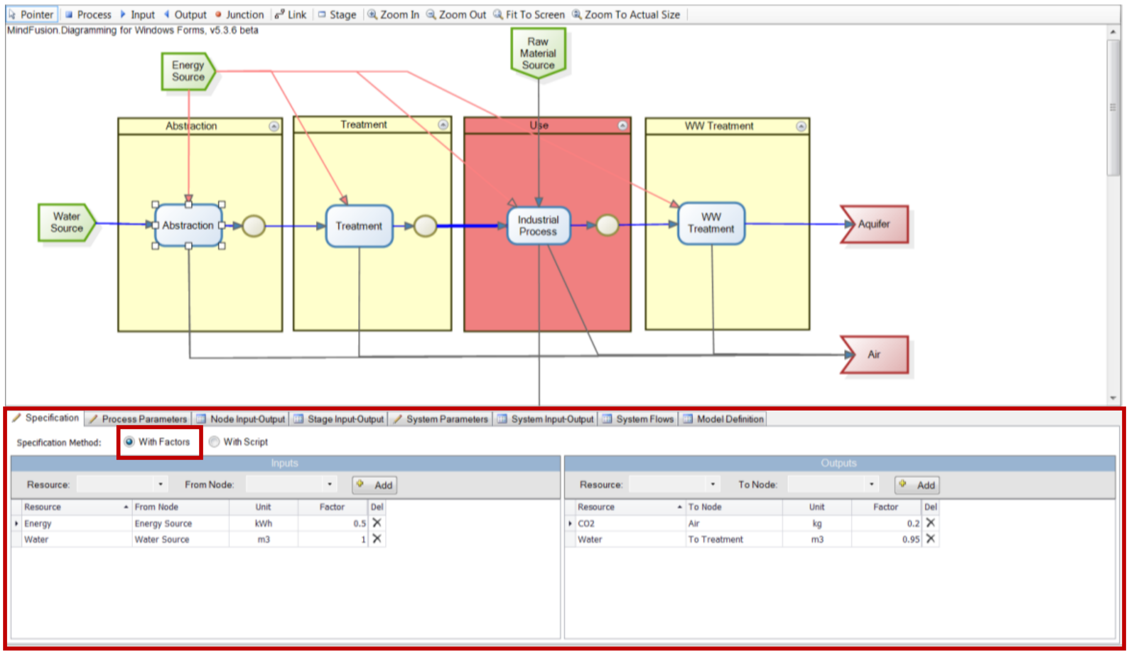

Figure 6. Process specification using production factors

In the above context, production factors (c_i) become scale coefficients, and knowing a single flow (f_{ref}) in the process immediate vicinity is sufficient to calculate the values of all other flows (f_i), according to the following equation:

$$f_i = f_{ref}\frac{c_i}{c_{ref}}, i = 1, \ldots, N \qquad (2)$$

where N is the total number of input and output flows.

A more complex but somewhat more flexible approach for process specification uses a set of expressions to describe relationships between input and output flows. This makes it possible to model non-linear dependencies. Using scripts to attach complex rules or models to a transition can extend SEAT further, without violating any of their theoretical foundations.

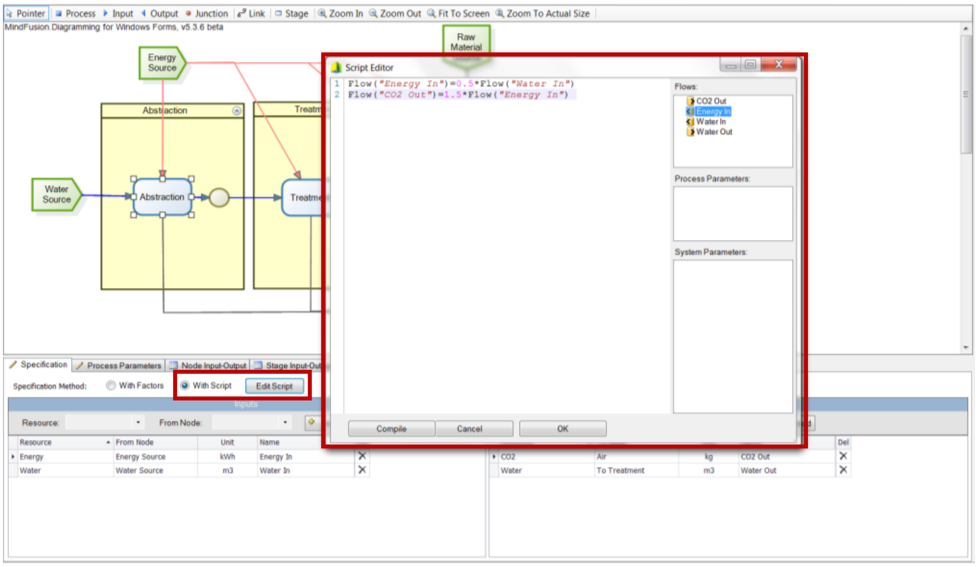

Figure 7. Process specification using script editor

5.3 Specifying input/output nodes

In each input or output node, the initial stock of the relevant resources should be specified.

5.4 Specifying links

For each link, the user should specify if the respective will be calculated of will be inserted manually. At least one manual flow should be specified in order to solve the model.

6 Results and Analysis

6.1 Running the Model

The overall network solution procedure is an iterative algorithm, based on the following steps:

- At least one reference flow must be specified (manual flow).
- Knowing some flows, the corresponding processes can be solved, calculating previously unknown flows.
- The known flows can be propagated through junctions, triggering the calculation of other processes.
- Hopefully, all data gaps (unknown flows) can be closed.

6.2 Results

The results tabs consist of various tables:

- System Input-Output Table (Figure 8). Presents all the input and the output flows which respectively enter and leave the system boundaries.
- System Flows Table (Figure 9). It is the inventory of all the elementary flows of the system.
- Stage Input Output Table. Presents all the input and the output flows which respectively enter and leave the selected stage.
- Node Input Output Table. Presents all the input and the output flows which respectively enter and leave the selected node.

All tables can be exported in a spreadsheet file, in a comma-separated value file or in a text file by clicking the button located in the upper right corner of the respective tab.

The contents of these tables can be grouped simply by dragging the header of the selected column to the top of the table.

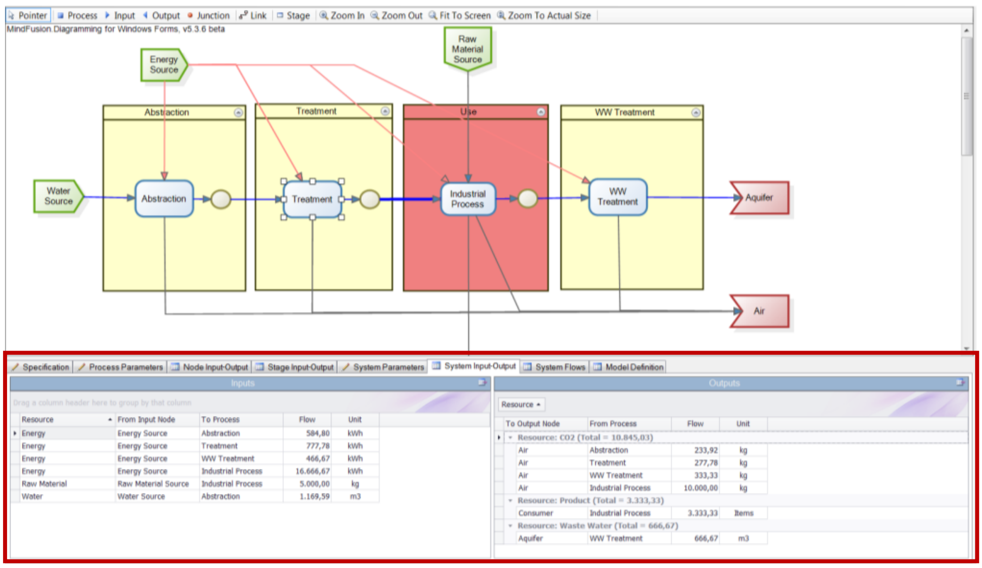

Figure 8. System Input-Output Table

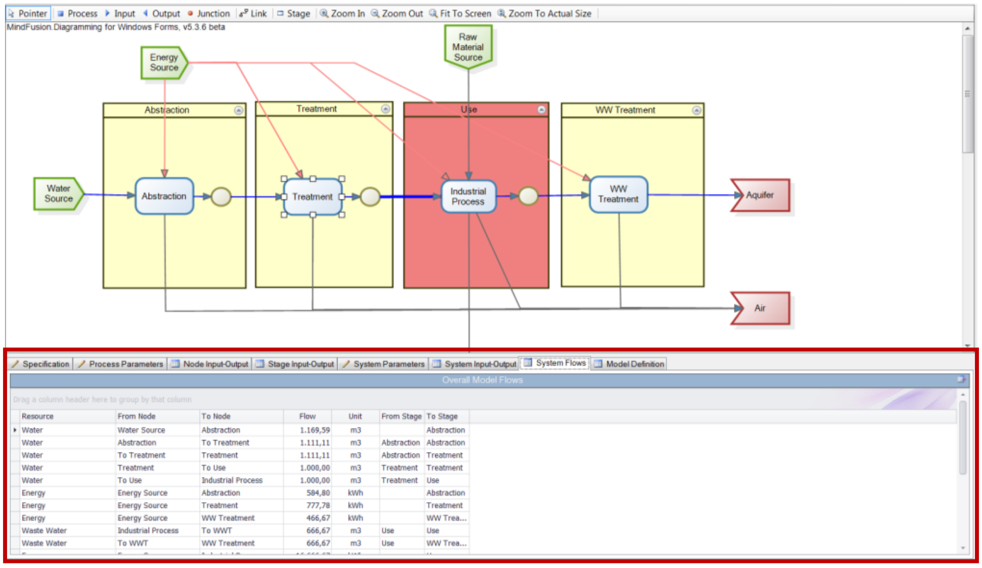

Figure 9. System Flows Table

6.3 Reporting

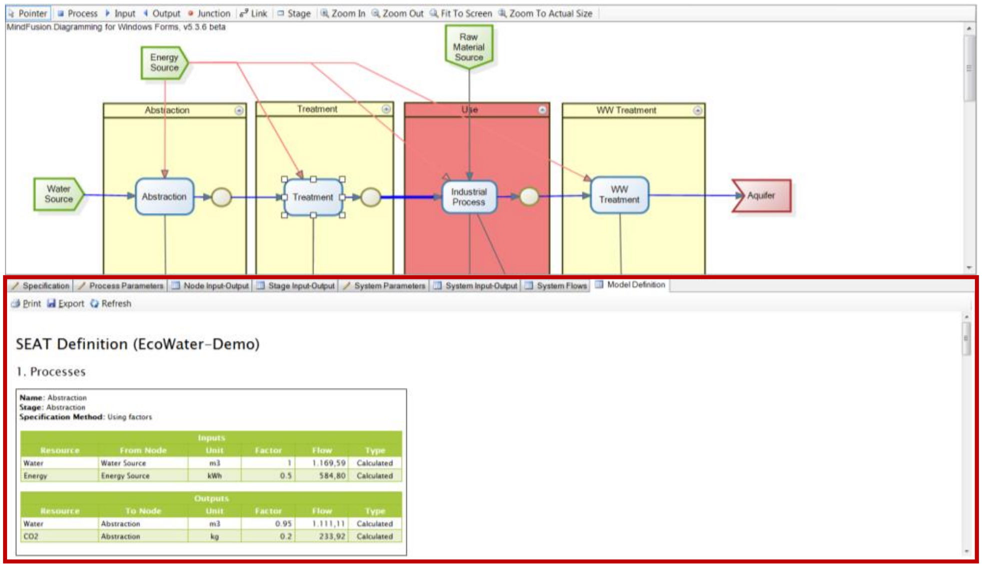

Figure 10. Model Definition Report