SPIonWeb

Advanced Sustainable Process Index calculation software

Manual and software structure

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1   Introduction

SPIonWeb is the successor software of SPIonExcel 2.07 (spionexcel.tugraz.at) running on a different platform and including methodological innovations as well as operational improvements. Changing the software platform from a Microsoft Excel macro to a web based tool offers many improved options compared to the previous version (e.g. centralized database, collaborative working, fast and intuitive SPI calculation).

This manual is intended for users having already gone through the "Step by step Instructions" (also provided on this webpage) and looking for in-depth information. Program features, methodology and calculation background are explained in this manual.

Users who did not study the Step-by-step guide are reminded at this point that we strongly recommend having some basic handling practice of SPIonWeb before using into this advanced manual.

It is advisable to have already an account registered in order to use SPIonWeb. If you don't have an account yet, please register yourself according the instruction in the step-by-step guide.

2   Sustainable Process Index (SPI)

This chapter introduces some basic knowledge about the Sustainable Process Index[1]. This is required to understand the calculation results and diagrams.

The Ecological Footprint is a method to quantify environmental impacts of goods and services. If the life cycle chain of products is followed, impacts from material and energy exchange between the process chain providing the product or service and the environment may be made visible. The SPI calculates the impact of these flows on the environment. **Note that the SPI only evaluates the environmental impacts resulting from the material and energy metabolism of the life cycle**. In order to estimate the whole environmental pressure of the life cycle, additional assessment methods for the structural impacts (e.g. loss of bio-diversity, impacts on landscapes, etc.) have to be employed. **The SPI does not evaluate the social and economic dimension of sustainability of the life cycle in question**.

The results from the SPI calculation can be used either for an ecological impact assessment of specific products or for comparison of different processes or design options.

2.1   Normative base of the SPI

For the quantification of ecological impacts to the environment a variety of tools is available. Users must choose their preferred assessment method, dependent on their needs as well as the

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[1] *Krotscheck, C., M. Narodoslawsky (1996). The Sustainable Process Index - A new Dimension in Ecological Evaluation. Ecological Engineering 6/4 (1996) pp. 241-258*

congruence of the normative fundament of the evaluation system with their personal/institutional value set about sustainable development. **Mind that all evaluation methods are value based and that therefore an analysis of the value base of the used method is compulsory to arrive at meaningful support for decisions**.

Ecological Footprints based on the Sustainable Process Index methodology are based on a strict sustainability concept:

- Human society may only live on the natural income that is constantly replenished (mainly solar radiation and geo-thermal energy).
- The preservation of the ability of natural systems to receive that income and transfer it into useful resources for human society must therefore not be put in jeopardy.

Note that this definition does not rule out the utilization of non-renewable resources (fossil or mineral). It limits their use however to the requirement to keep natural systems (represented in the SPI concept by the environmental compartments atmosphere, water and soil) in a state to receive and transform natural income into societal services that is at least not below its capacity at present (using the precautionary principle as a guideline). It also limits the use of natural resources (direct harvesting of solar radiation via PV and thermal solar energy, biomass, …) to their sustainable yields (expressed as harvest of the resource per area unit and year).

The SPI transforms this strict sustainability concept into an Ecological Footprint representing ecological impacts in area units. This reflects the fundamental role of the surface area of our planet in converting the main natural income (solar radiation) into social services: without area to receive solar radiation, no bio-resources, no global material cycles of water (driving the generation of renewable resources like biomass, hydro-power as well as supplying life on earth with water), air (providing wind power) and essential resources like nitrogen, oxygen and many others.

The SPI evaluates ecological pressures of anthropogenic activities by comparing the metabolic material exchange they induce with natural flows that can easily be referred to a unit area. By doing so it only refers to natural qualities and processes on the part of the environment and on material-, energy flows and emissions from the life cycle under evaluation. In order to convert the metabolic flows a life cycle exchanges with the environment into areas (and hence ecological footprints), the following two principles are employed:

Principle I:

Human activities must not alter long term storage compartments of global material cycles in quality as well as in quantity. If this principle is not adhered to resources will be depleted and substances accumulated in ecosphere, overstraining the natural cycles.

Principle II:

Flows to ecosphere have to be kept within the qualitative and quantitative range of natural variations in local environmental compartments. If such flows exceed the amount a

compartment can integrate sustainably the accumulating substances will alter the quality of the compartment. This alteration put the capability of the natural compartment to sustain flora and fauna in jeopardy and is therefore to be avoided following the precautionary principle.

2.2   Representation of the Ecological Footprint by SPIonWeb

SPIonWeb strives to provide the user with relevant information supporting his/her decisions. Therefore the ecological footprint (SPI value) in the results of SPIonWeb consists of seven values (partial footprints) representing different aspects of the ecological impact of the metabolism linking the life cycle under evaluation and the environment. Within the program they are identified by a color code:

- Footprint for direct area use and installations
- Footprint for non-renewable resources use
- Footprint for renewable resources use
- Footprint for fossil carbon use
- Footprint for emissions to water
- Footprint for emissions to soil
- Footprint for emissions to air

A high footprint is equal to a high environmental impact!

These partial footprints are defined in more detail below.

Footprint for direct area use and installations

This partial footprint accounts for the ecological impact through equipment, infrastructure and the direct use of area (e.g. the area required for buildings). The footprint for infrastructure/equipment summarizes the material and energy flows required to construct the infrastructure/equipment as well as the emissions caused by the life cycle of the infrastructure/equipment. The impact is linearly discounted using the expected life span of the equipment/infrastructure to reach the impact per year.

Footprint for non-renewable (mineral) resources use

Axiom II states that material consumption has to be related to a global natural reference cycle. Non-renewable materials (e.g. metal ores and minerals) are however used in a dissipative way, that means that they are extracted from a source and after they leave the life cycle as waste they are dissipated to the ecosystem. This dissipative character is covered by the three partial footprints handling emissions into air, water and soil, following principle II. The footprint under this heading summarizes the ecological pressures exerted by extracting the non-renewable resources, processing them and transporting them to the point where they enter the life cycle under evaluation.

Footprint for renewable resources use

This footprint summarizes the ecological pressures associated with the generation of renewable (bio-) materials (e.g. wood, grass). They all need area to be grown. Based on average yields (most data are for Austria), agriculture or forestry area to grow these resources is taken into account in this footprint for renewable resources. This direct area is required to close the global cycles for the material embodied in the bio-resources, as plants take this material from the environmental compartments as they grow, following principle I.

All other impacts incurred by providing these resources will be summarized under the appropriate partial footprint (e.g. the impact caused by tractor fuel for tending fields and harvesting will be added in the fossil carbon footprint, see below).

Footprint for fossil carbon use

Fossil resources fall under principle I. This requires comparing the use of fossil carbon by man with the rate at which carbon is taken out of the global carbon cycle and put in a long-term storage. The most important process doing this is precipitation of carbon to ocean beds (the process that eventually leads to the formation of crude oil and natural gas if the conditions are favorable). Approximately 500 m² of sea ground is needed per year to put 1 kg of carbon into the long term (fossil) storage of the sea bed.

Footprint for emissions to water

The rational for converting emission flows to the water compartment is based on the general assumption of a replenishment rate of the compartment and a natural concentration of the emitted substance in this compartment. The replenishment rate of the water compartment is based on the precipitation rate in a specific geographic region. From this rate the part that is evapo-transpirated back into the atmosphere is subtracted, giving the seepage rate. The remainder is seen as pure water that is replenishing the water compartment of the area on which it is precipitated. This pure water can take up emissions until it reaches the quality of the natural compartment water. In the SPI concept the concentrations found in ground water are the reference for this natural compartment. The footprint of a given emission flow is therefore the area that is necessary to provide so much pure water via the seepage rate that may dilute the emission to the reference concentration of the emitted substance in ground water. This approach fulfills principle II. As both seepage rate and natural concentrations of substances in ground water may vary geographically, the same emission to water can result in different footprints for emission to water in different geographical contexts.

Footprint for emissions to soil

Similar to footprint for emissions to water, this partial footprint is calculated based on the regeneration rate of the compartment soil and the natural concentrations of the emitted substances

in top soil. As process of replenishment of the compartment soil composting is used. Green biomass is used as the substrate of this composting process. The area to grow as much green biomass as is necessary to generate the amount of compost that will dilute the emission in question to the concentration of the substance in natural top soil is the footprint for emissions to soil. All arguments brought forward in the section on emissions in water apply correspondingly.

<u>Footprint for emissions to air</u>

Air does not have a natural replenishment rate as the other compartments. The calculation of the footprint for emissions to air therefore draws on the general approach to compare anthropogenic with natural flows. In this case the natural emissions of gaseous substances by forests are taken as a reference. The footprint for emissions to air is calculated as the area of forest that emits the same amount than the emission in question.

3   Program structure

SPIonWeb is an ecological evaluation tool capable of evaluating life cycles of products and services. Results expressed in **ecological footprint (=area) per service unit [m²a/unit]** according the SPI methodology. The program needs as input the material and energy balances of the process life cycle to be evaluated. The program however provides the user with a comprehensive data bank of processes that allows evaluation of life cycles often if detailed balances are available for a central production process within the life cycle. Provision of many resources, transport as well as most processes providing process energy can then be taken from the data bank to estimate full life cycle impacts.

In terms of system requirements to use SPIonWeb, a computer with web browser is needed. It is recommended to use at least Firefox 18, Internet Explorer 9, Safari 5 or Chrome 21.

3.1   SPIonWeb Nomenclature

The following paragraphs define the basic elements of the nomenclature used in the program that are necessary to understand the argument in this manual. All other terms will be explained at the appropriate location in this manual.

3.1.1   Impacts

According the SPI methodology, mass flows that are directly exchanged between a human process and the environment cause the **ecological impact** of the process in question. These flows may be either resources (e.g. fossil oil, iron ore or wheat) exploited by or materials   (e.g. nitrogen oxides from combustion, heavy metals in waste flows) emitted from the process. These flows have to be transformed to ecological footprints that measure these ecological impacts by the program according to the principles

described in the previous chapter. In the nomenclature of SPIonWeb the footprints associated with flows directly exchanged with the environment are called **Impacts**.

3.1.2   Processes

A *process* in the nomenclature of SPIonWeb is a technical conversion of an input of material and energy flows to an output of products and emissions. The input can consist of flows directly exchanged with the environment (e.g. fossil oil, iron ore or wheat) whose **impacts** are added to the overall ecological footprint of the process in question. It may however also consist of intermediate products that are produced by other **processes**. In this case the ecological footprint of these up-stream processes (and the whole life cycle with all material flows exchanged with the environment) will be integrated in the evaluation.

3.1.3   CORE and USER

The prefix CORE will always be used for elements in the general data bank of the program that are available to all users. These elements can only be edited with administrator rights. A change in the CORE elements by the administrators will automatically change all results where this element is integrated.

USER will denote elements defined by users and restricted in their availability according to their will. **No USER data can be accessed or utilized by other users or the program administrator without consent by the author!**

Users are however free to copy CORE elements and re-name them. The copied elements are then USER elements and may be altered at will.

The following sub chapters are describing several levels of the program architecture of SPIonWeb: process grouping and collaborative working features (User level and Tags level), transforming mass flows to an Ecological Footprint or SPI value (Impact level) and description of the processes (Process level).
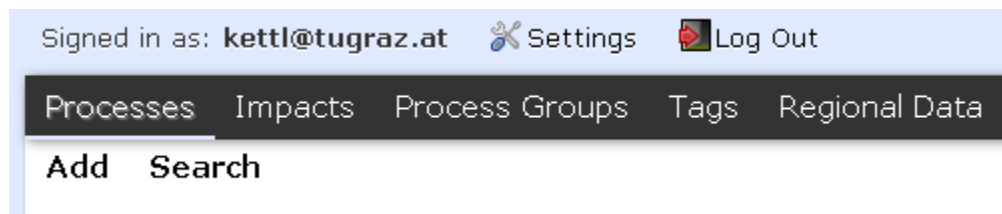

Figure 1: Main navigation bar

Main features of SPIonWeb can be accessed by the navigation bar on the top of the webpage. Elements described within the following chapter can be found through this navigation bar.

3.2 User level

The *User Level* defines data access and co-operation features within SPIonWeb. Each user may define for processes he/she created the possibility to share them with other users by grouping them in *process groups.* These process groups as well as access to them are defined on the User level accessible via the User function on the navigation bar.

Process groups are unique names where under which individual processes are grouped. Grouping offers several possibilities and advantages:

- Personal organization of processes (especially important if a user creates a large number of processes)
- Separation of private and collaborative processes
- Collaborative working on process groups through sharing option to multiple users

Figure 2 describes the macro structure of co-operation within SPIonWeb. Each USER process can be part of **one** process group, due to technical restrictions. Users are however able to share more than one process group.
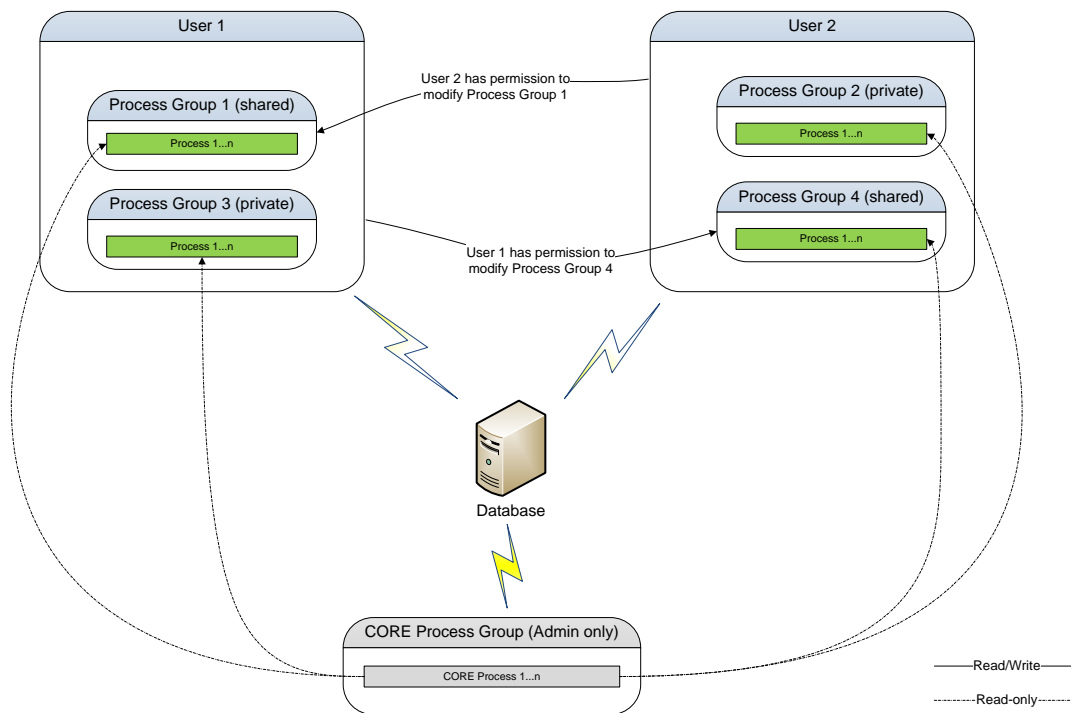
Figure 2: Process data sharing structure of SPIonWeb

CORE processes are part of process group as well, but are restricted to administrator users. Because CORE processes may be included in many USER processes from different users and other CORE processes, a change influences every connected consecutive process and leads to different SPI results. Therefore changes to existing CORE processes will only be made when the base of these processes

changes due to external developments (e.g. the change in the technology mix for providing electricity in a particular country). **Users will be warned about such changes by the administrators!**

A process group can be established by using the *Add* button on the Process Groups Screen. Whenever a process is assigned to that particular process group (see section Process Level), the statistics in this process group will be automatically up-dated (see Figure 3).

Process groups are differentiated between personal (*My Process Groups*) and shared process groups. Personal groups are invisible to other users and data is kept private. A process group can be shared to invite other people to work together on processes or to give users the possibility to copy processes to their account. This can be done by a click on *Edit* of the process group to be shared (opening the Process Group Administration Screen, Figure 4) and then to *Add* the account (e-mail) of the user that is allowed to share this process group. The process group will then be transferred to the table *Shared Process Groups* in Figure 3. Using the Process Group Administration Screen (Figure 4) *Add* button on Processes or Impacts will directly lead to the definition screens for processes resp. impacts explained below.

Add

Process Groups

My Process Groups

Name		# Impacts	# Processes	# Tags	# Regions	# Users		
Desmet Ballestra		0	0	0	0	1		Edit ✖ Delete
ELAS		0	268	3	0	4		Edit ✖ Delete
FB-Vision		0	2	1	0	2		Edit ✖ Delete
M2Lab		0	23	3	0	1		Edit ✖ Delete
Testprozesse		0	11	0	0	2		Edit ✖ Delete

Shared Process Groups

Name	# Impacts	# Processes	# Tags	# Regions	# Users	Owner	
Vitikult	0	56	11	0	4	stephan.maier@tugraz.at	Edit
Grapos	0	6	3	0	3	stephan.maier@tugraz.at	Edit

Figure 3: Process groups screen

Figure 4: Process group administration screen

Processes, Impacts, Tags and Regions of this process group and last activities are presented to the user on the Process Group Administration Screen (accessible by *Edit* in the respective process group on the Process Group Screen). Users which are already in the process group are shown on the bottom right part. New users can be added to the group and the owner can be changed to transfer a whole group to another person.

Creating process with no process group is also possible if no further collaborative possibilities are intended. **The assignment to a process group must be made when the process is initially defined, it cannot be changed later**, due to technical restrictions.

3.3   Tags level

Tags may be defined by the user for better distinguishing within process groups, using the **Tags** function on the navigation bar. Within the process groups, this supports sorting and filtering functions, to handle huge amount of data. Tags may be defined by the *Add* button in the Tags Screen (Figure 5) and must be assigned to a process group. The user will be provided with a selection of his process groups in the pull-down menu opening in the editing window.

Figure 5: Tags Screen

3.4 Impact level

Many *impacts* for processes providing important intermittent materials, services, transport and energy for industrial processes are predefined as **CORE impacts** and available for every user (e.g. Figure 6). They may only be edited with administration rights.

Users may create customized **USER impacts** if flows not available in the data base are exchanged with the environment or if a different valuation (of existing) impacts are required. Any new USER impact can be assigned to an already existing process group. This allows sharing USER impacts with other users. If a process group is shared, the impacts are shared as well. Impact name, description/comments and Reference can be used to document the USER impact. A SPI category has to be chosen to define in which SPI category the impact has to be converted. For example, an emission of Mercury into water would need the SPI category "water". **The same emission in another compartment (e.g. "soil") would need a separate entry.** In terms of nomenclature it is recommended to name Impacts for emission to air, water and soil in the following style:

Hg (air); Hg (water) and/or Hg (soil)

This naming convention makes it easier to include those impacts into processes.

Radioactive has to be ticked for emissions of radioactive substances because these impacts are handled slightly different than normal emissions to the three compartments. Because radioactive substances are not diluted over time through regeneration of compartments (like water and soil emissions), they have a fixed pre-calculated SPI value per kBq of emission.

For most of the SPI partial footprints a conversion factor between mass flow and impact area (y_{spec}) is given with the exception of emissions to water and soil. Those emissions need an additional calculation step, which is dependent on regional data, to obtain a y_{spec} value (see chapter 5.1.2).

GWP - Factor (IPCC) allows defining the CO_2 equivalent, if the emission in question has a global warming potential.

Name		SPI	y_{spec} [m²·a/Unit]	Unit	c_{nat} [mg Substr/kg Comp]	GWP - Factor (IPCC)	Unit	Group	
1,1,1-Trichloro ethane	2 ☰	Water			0.02			Core Processes	✎ Edit ✖ Delete
1,1-Dichloro ethene		Water			0.0003			Core Processes	✎ Edit ✖ Delete
1,2-Dichloro ethane		Water			0.009999992			Core Processes	✎ Edit ✖ Delete
1,2-Dichloro ethene		Water			0.009999992			Core Processes	✎ Edit ✖ Delete
2,3,4,6-Tetrachloro phenol		Water			0.0999992			Core Processes	✎ Edit ✖ Delete
2,4,5-Trichloro phenol		Water			0.009999992			Core Processes	✎ Edit ✖ Delete
2,4,6-Trichloro phenol		Water			0.0999992			Core Processes	✎ Edit ✖ Delete
2,5-Dichloro phenol		Water			0.003			Core Processes	✎ Edit ✖ Delete
2.6-Dichloro phenol		Water			0.003			Core Processes	✎ Edit ✖ Delete
3-Chloro phenol		Water			0.0499996			Core Processes	✎ Edit ✖ Delete
4-Chloro phenol		Water			0.029999868			Core Processes	✎ Edit ✖ Delete
Acenaphthenes	1 ☰	Water			0.029999868			Core Processes	✎ Edit ✖ Delete
Acenaphthylenes	3 ☰	Water			0.029999868			Core Processes	✎ Edit ✖ Delete
Acetone	29 ☰	Air	154.0	kg				Core Processes	✎ Edit ✖ Delete
Acrolein (air)	43 ☰	Air	154.0	kg				Core Processes	✎ Edit ✖ Delete
Acrolein (water)		Water			0.007			Core Processes	✎ Edit ✖ Delete

Figure 6: CORE Impacts (admin only)

New Impact

Process Group	[▼]
Name	[ ]
Description	[ ]
Reference	[ ]
SPI Category	[▼]
Radioactive?	☐
Yspec	[ ] [m²·a/ ▼]
GWP - Factor (IPCC)	[ ] [▼] [CO₂ Equivalents]

Figure 7: Create custom impacts

3.5 Regional data

Emission impacts as well as impacts relating to the generation of renewable resources (e.g. solar energy per m²a or yields of crops per m²a) are dependent on the geographical context. Therefore each process can also have different regional context with data reflecting the particular situation in this region. This affects in particular impacts to water and soil according the SPI methodology. For every

needed geographic location, the basic parameters to calculate these impacts can be pre-defined and used in processes. The information needed to define a new regional data entry are:

- related to *Area for emissions to water*
    - y_w = Annual amount of precipitation [mm/a]
    - r = Average seeping ratio [1]
- related to *Area for emissions to soil*
    - y_s = Annual amount of fresh biomass yield [kg/m²a]
    - l = Average biomass-to-compost loss ratio [1]

Using these data region specific SPI values per unit of inventory are calculated. Figure 8 shows the Regional Data Screen. With the Add button data for a specific relevant region may be defined and the process in question may be related to this region. Mind that a life cycle may comprise processes in different regional settings (e.g. provision of crops in America, transport to Europe and processing of crops in Europe).

Regional Data

Process Group Core Processes

Region		y_w	r	y_s	l	Group	
Austria	✏	1200.000	0.300	0.750	0.560	Core Processes	✖ Delete
Europe	✏	983.000	0.300	0.750	0.560	Core Processes	✖ Delete

Figure 8: Regional Data Screen

3.6   Process definition

3.6.1   Process level definition

SPIonWeb provides the interface to define processes and link them to each other to form comprehensive life cycles (

Figure 9 SPIonWeb represents life cycles in *process levels*. Process levels are automatically defined by the program, depending on the structure of the life cycle. The rule here is that higher level processes provide intermediates as input to lower level processes. These *process levels* are relevant for the presentation of results discussed in chapter 4.

In order to support the user to evaluate comprehensive life cycles SPIonWeb provides life cycle impacts on a large number of processes providing frequently used intermediate materials or energy. These *CORE processes* can only be edited with administration rights (see definition of CORE). The user may integrate these *CORE processes* as well as any other process he/she has already defined in SPIonWeb into a life cycle. Whenever a process is added to the life cycle all impacts from processes in higher levels (providing this particular process with resources and energies) will automatically be added,

so that the user is assured that his results actually reflect the whole ecological life cycle impact. The necessary steps to generate the input to define a process will be given below.
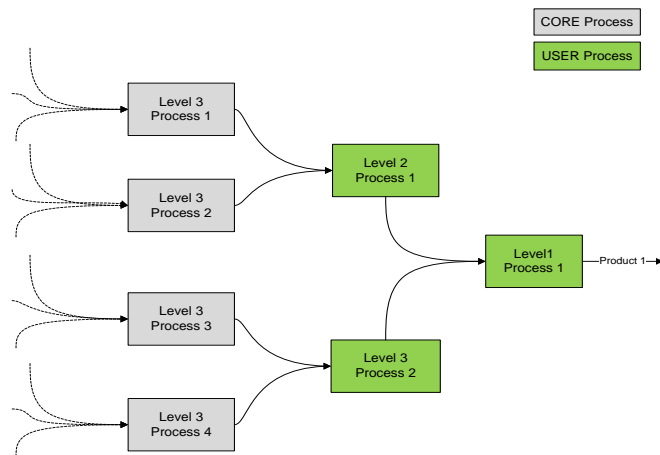
Figure 9: Process level approach

3.6.2 Generating a USER process

3.6.2.1 Preparation of data

Before starting to evaluate a process the user must prepare existing data in accordance with the program requirements. This applies to the *inventory* (mass and energy balances) of the process as well as to necessary auxiliary data (e.g. for allocation of environmental impacts to different products).

As a first step the user must define the products of the process and **assign unique names to them**. The name of the product should also refer to the process producing it so that later inclusion of this process in other life cycles is supported (e.g. biodiesel_from_tallow).

As a second step one of the products should be defined as *main product*. **All inventory data (as well as the flows of other products!) have to be referred to one unit of this *main product***.

In a third step inventory data must be prepared. This comprises all **input flows of intermediary products** (e.g. raw materials, process energy) as well as **direct flows to and from the process exchanged with the environment** (e.g. emissions). **Mind that all input data have to be related to one unit of main product**.

Finally a method for allocating the ecological impact to the products of the process in question has to be selected. SPIonWeb provides three possible methods:

- *Main product*: all ecological impact is allocated to the main product, by-products do not have an ecological pressure (e.g. because they are wastes and cannot be used in any other life cycle);

- *Output*: this will allocate ecological impacts according to their respective flows from the process (this is only viable if products are either only materials or only energies);
- *Value*: in this case ecological impact is allocated according to the relative weight assigned by the user. This may be their selling price on the market. **In this case the user must supply the value of one unit for every product leaving the process**.

Mind that the method of allocation may significantly influence the ecological impact allocated to any product!

3.6.2.2   Defining a USER process

SPIonWeb allows an estimated life cycle analysis already on the base of limited engineering data, a situation frequently encountered in the design phase of an industrial process. The first step is to activate the Process Level on the navigation bar. Activating the *Add* function allows the definition of a *new process* (see Figure 10).

Figure 10: New Process Screen

In this screen the user must assign a **unique nam**e to the process. The user may also assign the process to a *process group* (via choosing from a pull-down menu showing all process groups the user has access to) and a *tag* for better identifying the process later. Finally the user must chose a *region* the process is located in.

Optionally the user may use a free text field for *Description* of the process, helping in documentation as well as a *Reference* that identifies the data source. For further documentation of the background to the process the user may upload *Files*.

3.6.2.3   Input for evaluation of a process

When a process is defined the user can provide/alter the necessary input to evaluate a process. This will be activated by clicking on the process in the *process tab*le on the *Process Screen.* This will open the Process Details Screen (see Figure 11).

Here the user must provide the inventory for the process, starting with defining the allocation method, followed by providing the flows of products. Clicking on *+Add new product* will open a line to define the

product using the data prepared in advance. The user may choose the appropriate dimension of the flow in the pull-down menu and give the flow rate (always related to one unit of main product). The *main product* must be indicated by clicking on the selection button and must have a flow of one in the appropriate unit. When the *value* allocation type is used, the user must supply the unit value of the product in question.

As the next step the user provides the inventory of intermediate (raw) materials. For this the user clicks the *+Add Sub process* button and a line for defining the up-stream process generating the intermediate material will appear. Using the *Search* field the user may search for a process using a free text search for the product or service required as input to the process. This search extends over all processes available to the user (accessible *process groups* as well as CORE processes). Clicking on the appropriate sub-process in the emerging menu and clicking, entering the appropriate flow rate and clicking *Save* will integrate the sub-process to the life cycle of the process to be evaluated. The footprints associated with this sub-process will be according to the chosen flow rate and the allocation method defined in the chosen sub process.
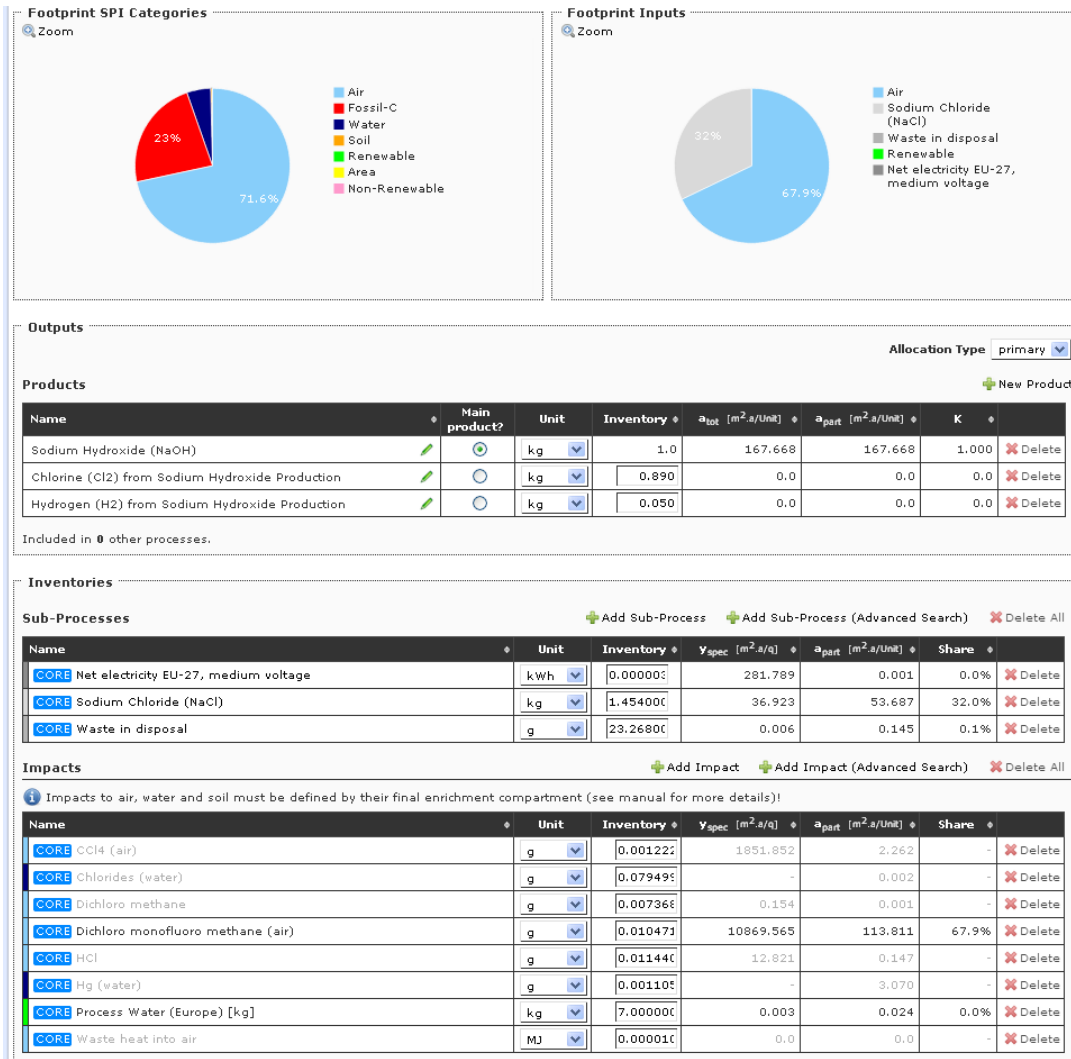

Footprint SPI Categories
🔍 Zoom

- Air
- Fossil-C
- Water
- Soil
- Renewable
- Area
- Non-Renewable

23% / 71.6%

Footprint Inputs
🔍 Zoom

- Air
- Sodium Chloride (NaCl)
- Waste in disposal
- Renewable
- Net electricity EU-27, medium voltage

32% / 67.9%

Outputs

Allocation Type [primary ▼]

Products   ➕ New Product

Name		Main product?	Unit		Inventory	a_{tot} [m².a/Unit]	a_{part} [m².a/Unit]	K	
Sodium Hydroxide (NaOH)	✏	◉	kg	▼	1.0	167.668	167.668	1.000	✖ Delete
Chlorine (Cl2) from Sodium Hydroxide Production	✏	○	kg	▼	0.890	0.0	0.0	0.0	✖ Delete
Hydrogen (H2) from Sodium Hydroxide Production	✏	○	kg	▼	0.050	0.0	0.0	0.0	✖ Delete

Included in **0** other processes.

Inventories

Sub-Processes   ➕ Add Sub-Process ➕ Add Sub-Process (Advanced Search)   ✖ Delete All

Name		Unit		Inventory	y_{spec} [m².a/q]	a_{part} [m².a/Unit]	Share	
CORE Net electricity EU-27, medium voltage		kWh	▼	0.000003	281.789	0.001	0.0%	✖ Delete
CORE Sodium Chloride (NaCl)		kg	▼	1.454000	36.923	53.687	32.0%	✖ Delete
CORE Waste in disposal		g	▼	23.26800	0.006	0.145	0.1%	✖ Delete

Impacts   ➕ Add Impact ➕ Add Impact (Advanced Search)   ✖ Delete All

ℹ Impacts to air, water and soil must be defined by their final enrichment compartment (see manual for more details)!

Name		Unit		Inventory	y_{spec} [m².a/q]	a_{part} [m².a/Unit]	Share	
CORE CCl4 (air)		g	▼	0.001222	1851.852	2.262	-	✖ Delete
CORE Chlorides (water)		g	▼	0.079499	-	0.002	-	✖ Delete
CORE Dichloro methane		g	▼	0.007368	0.154	0.001	-	✖ Delete
CORE Dichloro monofluoro methane (air)		g	▼	0.010471	10869.565	113.811	67.9%	✖ Delete
CORE HCl		g	▼	0.011440	12.821	0.147	-	✖ Delete
CORE Hg (water)		g	▼	0.001105	-	3.070	-	✖ Delete
CORE Process Water (Europe) [kg]		kg	▼	7.000000	0.003	0.024	0.0%	✖ Delete
CORE Waste heat into air		MJ	▼	0.000010	0.0	0.0	-	✖ Delete

Figure 11: Process Details Screen

Using the +Add Sub process (advanced search) button will open a screen for advanced search features (
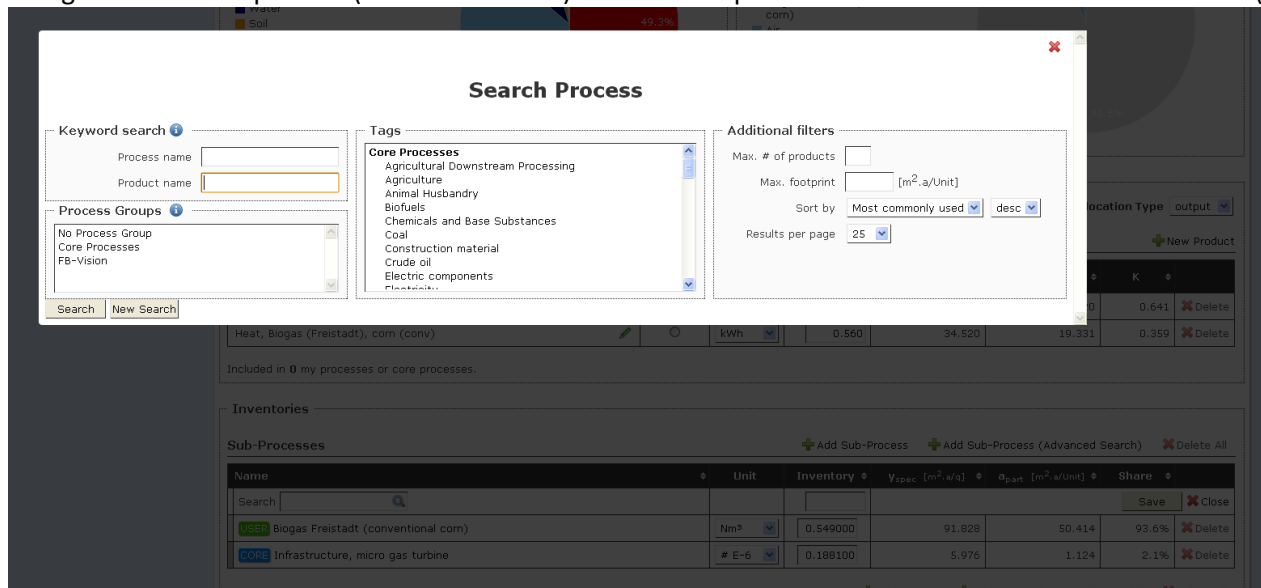

Figure **12**). This allows the user to search for processes, products as well as along tags and provide additional restrictions (e.g. max. footprint) to the search.
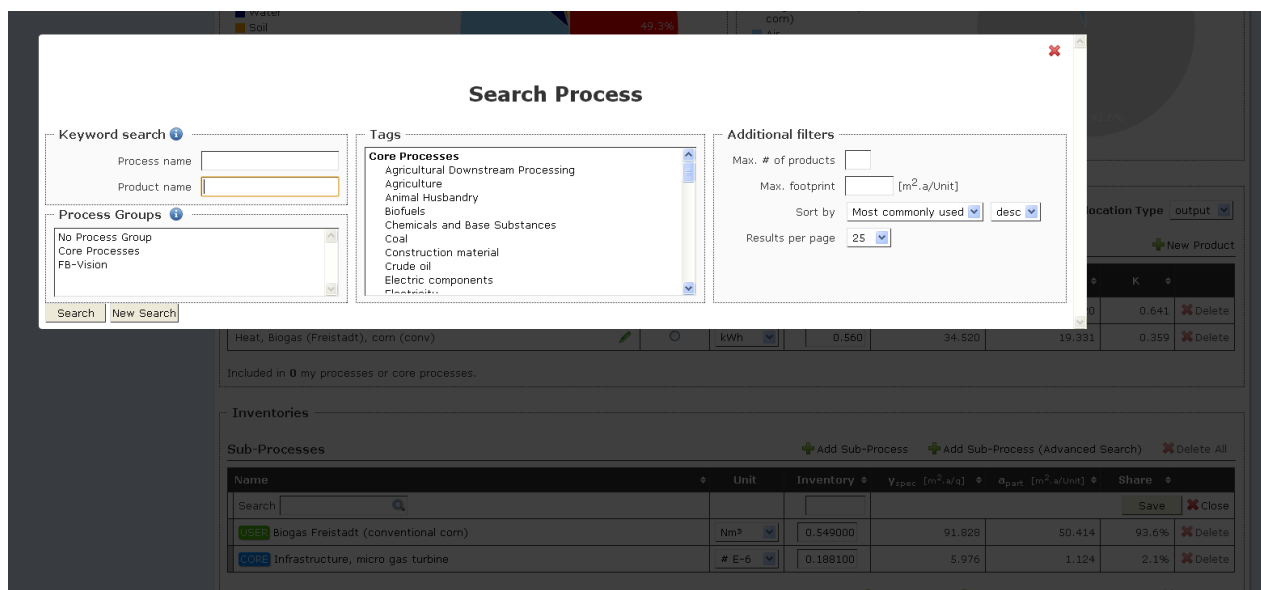

Figure 12: Advanced Search features

When all input flows to the process are defined the user may add *impacts* (emissions) generated by the process, using the *+Add impact* (or *+Add Impact (advanced search)*) button. The same rules as provided with the sub-processes are valid here. **Mind that only impacts generated by the process in question have to be added, as the impacts from sub-processes in the life cycle are automatically integrated in the evaluation**.

3.6.3 Following the calculation during input

SPIonWeb dynamically calculates the SPI Footprints during input. Whenever the user clicks the *Save* button for an entry, the evaluation for the process is automatically up-dated. This refers on the one hand to the representation in the *sub-process* or *impact* tables. They will show the contribution to the overall SPI Footprint in absolute numbers and as a fraction of the total ecological impact of any entry. It also applies to the *product* table, showing the footprint for every product based on the given input so far.

The graphs above these tables (that are also automatically up-dated with every input) depict the distribution of the SPI footprint according to the SPI categories over the whole life cycle (left graph) and the contribution of the process itself (via its *impacts*) and the sub-processes on the second process level (right graph). This allows the user to constantly follow the evaluation and identify ecological "hot spots" already in the input stage.

3.7 Operating with processes and within life cycles

3.7.1 Process options

For all process some options for handling/altering them are available at the bar on topof the Process Details Screen. *Back* brings the user to the Process Overview Screen. *Copy* enables users to copy processes. Reasons for copying processes may be:

Figure 13: Process options

- Copy CORE process to USER for customization of CORE processes
  The user may copy a core process in order to change the inventory according to his/her requirements. The process then is treated as a USER process.
- Copy USER proceses between proces groups, to allow different user groups to access different user processes
- Easy and quick creation of process case studies with only minor changes in the life cycle.

Mind copied processes as well as their products must be re-named in order to avoid conflicting input. All processes using products from altered processes must be changed so that this process is now part of their life cycle. This is done by deleting the original process from the sub-process list and integrating the new copied process.

Delete helps so remove orphaned user processes which are not needed anymore. This is only possible if the process to delete is not included in any life cycle as sub-process. *Results* opens a new page with much more detailed calculation results based on this active process. This part is described in detail at chapter 4.

3.7.2 Inspecting/changing sub-processes in a life cycle

SPIonWeb allows the user to generate whole life cycles with the knowledge of the inventory of only the last process in the chain if sub-processes from the data bank (either CORE or accessible USER processes) are used. In many cases the user may wish to inspect the inventory of up-stream sub-processes in order to ensure that the data used there are in accordance with his/her knowledge. In this case the user may open a sub-process simply by clicking on the respective sub-process in the Process Detail Screen of the process to which it provides input. This will open the Process Detail Screen for this particular sub-process and allow inspection of the inventory used to evaluate this process.

If the user wants to alter this inventory and if the sub-process is a USER process, he may do so at any time. The calculation for the whole life cycle will automatically be up-dated. **Mind that changing a process will however change all other life cycles of which this particular process is part of**.

If the sub-process in question is a CORE process or if the user wants to avoid disturbing evaluations of other life cycles where this sub-process is embedded, the sub process may be copied (see above) and then altered **after re-naming the process and products**. **Mind that in this case all processes in the life cycle to which this sub-process provides intermediary materials or services must be altered to integrate the renamed products**.

3.7.3   Evaluating loop life cycles

In some cases it may be interesting to evaluate life cycles that contain recycle loops, e.g. when products or services provided by a process are utilized in an up-stream sub-process. An example for this is the evaluation of biodiesel production where biodiesel is used to power tractors in the agriculture providing the crops used to produce biodiesel.

In these cases the life cycle can be established as described above with the process on level 1 that produces the product to be recycled up-stream. Then the sub-processes where this product is recycled to the life cycle are altered to use the process from level 1 as a sub-process. This may either be realized by copying the original sub-processes (following the instructions in 3.7.1 and 3.7.2) or directly altered (if they are USER processes, mind that this will change all other results of life cycles they are part of). SPIonWeb will automatically iterate the recycle loop and provide evaluation results.

4   Results from SPIonWeb

4.1   Results obtained by loading processes

Results are expressed in SPIonWeb in varying detail on different screens. Simple and quick SPI results of process are presented to the user by creating or loading processes (see Figure 11) in the *processes* screen (see Figure 14) and filtering for the appropriate *process group*. This screen shows the name of processes, the products, the regional context, the method of allocation and the SPI value per unit of product.

Processes

Figure 14: Processes Screen

Further information can be taken from opening any *process* on the *Process Details* Screen (Figure 11), as described already in chapter 3.6.3. Information provided there is the share of SPI footprints distributed between the SPI categories as well as between the process in question and the sub-processes of the first level as well as absolute numbers for the SPI footprints for every sub-process and impact.

4.2 Results generated by the *results* option in the *Process Details* Screen

A more detailed process analysis an extended results page can be opened for every single process by activating the results button on the *Process Details* Screen (chapter 3.7). The process in which the *results* option has been activated will become the level 0 process and will head of the process chain. The Results Screen consists of different parts which are explained in detail below.

4.2.1 Process Graph

SPIonWeb generates a *process graph* (Figure 15) automatically depicting the links between different sub-processes within the process chain under investigation. The user may choose the number of *process levels* to be represented. (**Warning:** Drawing too many levels may cause long calculation times as well as a confusing diagram!). For first level sub-processes impact presentation is part of the *process graph* per default. If required by the user, impacts for further levels may be included to the *process graph* by ticking the option *Everything* in the box at the right of the *process graph*.
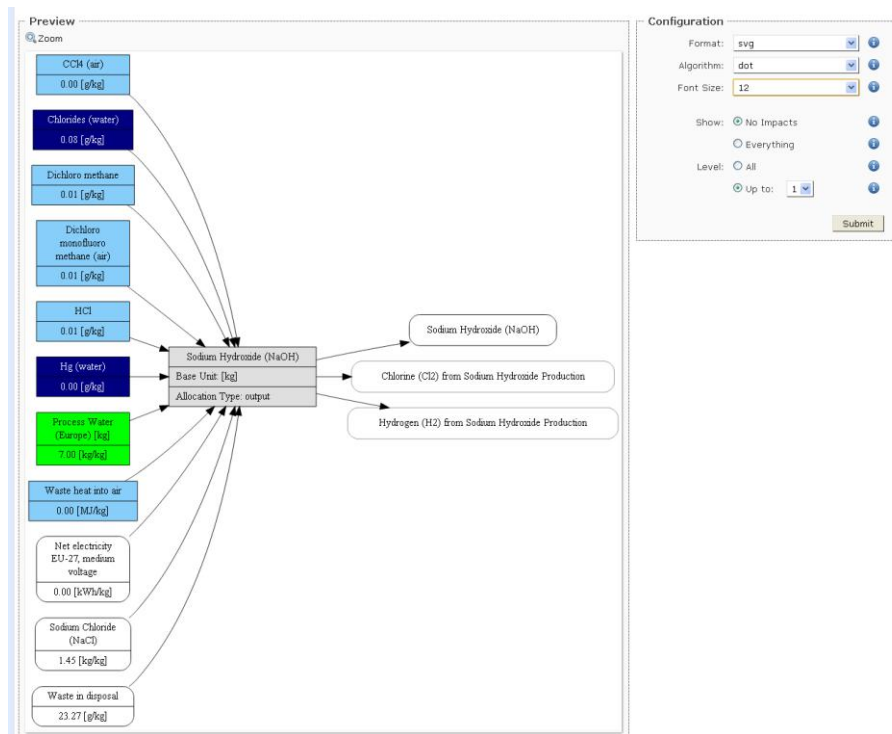
Figure 15: Process graph

Format allows choosing an output format for the graph. *Zoom* on the top left opens a new window with the graph in the chosen output format for further manipulation in other programs. *Algorithm* offers three different methods how to auto-generate a graph. Because process structures can be quite different (linear, star, pyramid,…) users may try which algorithm fit best for an optimal representation. Adjusting *font size* allows influences the size of the text within the boxes of the graph. After finishing changes to the configuration the *Submit* button has to be clicked to draw a new graph based on new settings.

4.2.2 SPI Overview – "Hot spot" graph

The *hot spot* graph (Figure 16) presents SPI footprints for processes on *process level* **1 and 2** of a of a process chain as bar diagram. Every bar consist all 7 partial SPI areas, allowing the user to identify the main contributor to the ecological pressure in terms of impact category as well as sub-process over the life cycle. Only processes which contribute more than 1% to the final SPI footprint are depicted as bars. The sum of SPI value of all level 2 process and impacts from level 1 comprise the final SPI footprint for level 1. *Zoom again* allows opening the graph in a separate window and saving it to a file for further external use.
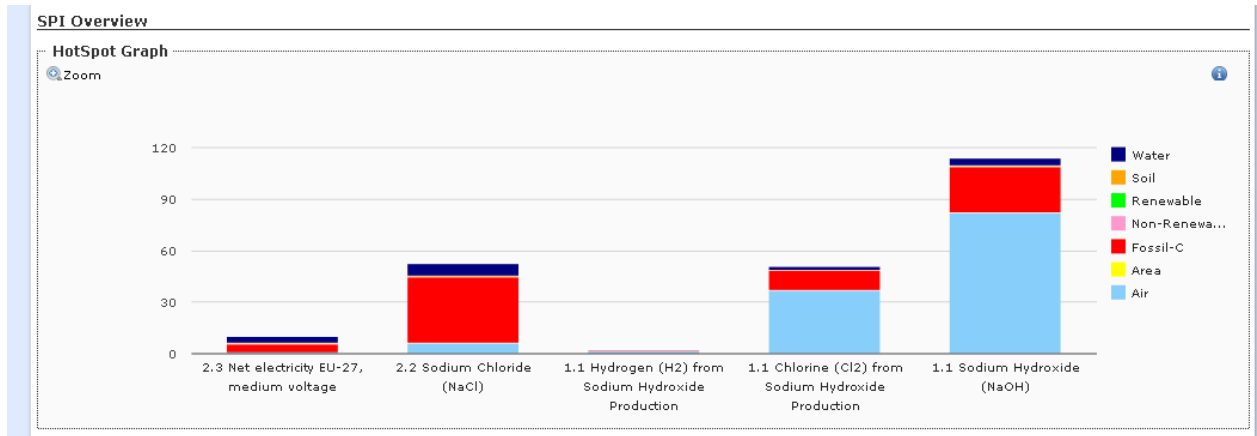
Figure 16: SPI hot-spot graph

A detailed view on the contribution to the ecological impact of flows along the whole the life cycle process levels are given in the Detailed SPI Overview table (Figure 17). The amount of the main product of level 1 process is per default set to 1 of the appropriate unit defined by the user. Every flow (inventory) is related to 1 unit of the main level 1 product.

Level		Process	Unit	Inventory	CO_2 [kg]	GWP [kg]	a_{part} [m².a]
1	1.1	USER Sodium Hydroxide (NaOH)					
		Sodium Hydroxide (NaOH)	kg	1.0	0.1942	0.1963	114.0977
		Chlorine (Cl2) from Sodium Hydroxide Production	kg	1.0000	0.0971	0.0981	57.0488
		Hydrogen (H2) from Sodium Hydroxide Production	kg	1.0000	0.0583	0.0583	34.2293
		CCl4 (air)	g	0.0012	-	0.0017	2.2622
		Chlorides (water)	g	0.0795	-	0.0	0.0022
		Dichloro methane	g	0.0074	-	0.0	0.0011
		Dichloro monofluoro methane (air)	g	0.0105	-	0.0	113.8109
		HCl	g	0.0114	-	0.0	0.1467
		Hg (water)	g	0.0011	-	0.0	3.0701
		Process Water (Europe) [kg]	kg	7.0000	-	0.0	0.0237
		Waste heat into air	MJ	< 0.0001	-	0.0	0.0
2	2.1	CORE Waste in disposal					
		Waste in disposal	kg	0.0233	0.0006	0.0021	0.1448
	2.2	CORE Sodium chloride (NaCl)					
		Sodium Chloride (NaCl)	kg	1.4540	0.2829	0.2829	52.6025
		Process Water (Austria) [kg]	kg	3.1988	-	0.0	0.0089
		Rock salt	kg	1.4540	-	0.0	0.0
	2.3	CORE Net electricity EU-27, medium voltage					
		Net electricity EU-27, medium voltage	kWh	< 0.0001	< 0.0001	< 0.0001	0.0008

Figure 17: Detail SPI overview - table

The user may change the flow of the primary product of the life cycle at this point. This allows calculating life cycle inventory data based on any amount of primary product, e.g. to represent the ecological impact of an industrial site with a given production capacity.

The table is organized in sections for every sub-process, ordered according to *process levels*. In the first part the ecological impacts of the input flows to the sub-process are shown. The second part represents the emissions from the sub-process. Every line represents a particular flow to or from the process. The information contained in the line is the amount/inventory (related to the amount of primary level 1 product) and the unit for measuring the amount. CO_2 emission and GWP of the flow in question are given as well as the overall SPI footprint. A click on the symbol ☰ expands for every input flow a field showing all 7 partial SPI areas that constitute the total SPI footprint for the provision of this intermediary input. *Show all* reveals partial areas for all intermediaries as well as which sub-process provides input for which other processes.

Fields greyed out are impacts which are part of the life cycle but have no influence to the final SPI Footprint, due to the key emission area rule described in chapter 5.1.2.

4.2.3 Impacts Overview

Impacts over the whole life cycle are cumulated and presented as table and diagram (Figure 18). For a quick view how the share between different impacts are distributed for the life cycle, the diagram shows every partial SPI area as own bar.
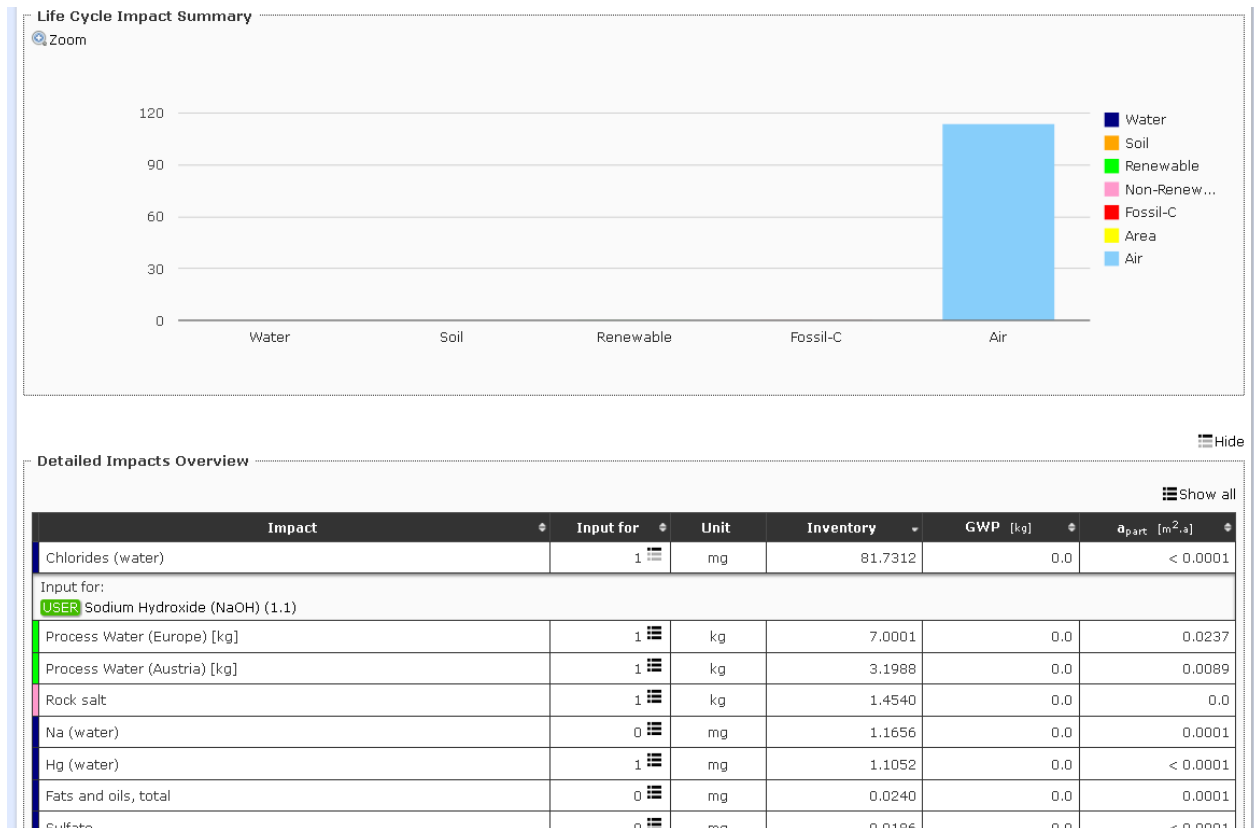
Figure 18: Life Cycle Impact summary

The table lists all impacts listed over the whole life cycle. *Input for* can be expanded for every entry to look for the sub-process of origin of the impact. Inventory, GWP and a_{part} (=SPI footprint) are listed and sorting functions on the headers allow to sort the list for the highest/lowest values.

4.2.4   Products Overview

The *Detailed Products Overview* table (Figure 19) shows a summary of the impact of all products generated by any sub-process in the life cycle. Inventory, unit of measurement, GWP and SPI Footprint are given for each product. Sorting functions allow searching for large contributions in any of those categories. The *input for* option reveals for which sub-processes the product in question serves as an input.

Product	Input for	Unit	Inventory	GWP [kg]	a_{part} [m²·a]
Infrastructure Distribution Natural Gas High pressure EU	0 ☰	MJ	0.4372	0.0010	0.1571
Natural gas High Pressure distributed EU	0 ☰	MJ	0.4372	0.0462	6.2103
Infrastructure Industrial heater	0 ☰	MJ	0.4343	0.0001	0.0130
Process energy, natural gas, industrial heater >100kW	1 ☰	MJ	0.3779	0.0512	6.8498
Input for: CORE Sodium chloride (NaCl) (1.1)					
Process energy, heavy fuel oil, industrial heater 1MW	1 ☰	MJ	0.2672	0.0565	7.6026
Infrastructure Industrial Heater Hard Coal	0 ☰	MJ	0.2566	0.0125	2.0088
Process energy, hard coal, industrial heater 1MW	1 ☰	MJ	0.2053	0.0881	10.6982
Input for: CORE Sodium chloride (NaCl) (1.1)					
Transport Truck 40t	1 ☰	tkm	0.0800	0.0453	4.1664
Infrastructure Vehicle Truck 40t	0 ☰	tkm	0.0800	0.0052	1.3610
Infrastructure Road Truck	0 ☰	tkm	0.0800	0.0065	0.8883
Water decarbonized	0 ☰	kg	0.0510	0.0005	0.1256
Transport Tankship overseas	0 ☰	tkm	0.0483	0.0011	0.1136
Infrastructure Tankship overseas	0 ☰	tkm	0.0483	0.0002	0.0261
Net electricity EU-27, production mix	0 ☰	kWh	0.0278	0.0343	6.9806
Net electricity EU-27, medium voltage	1 ☰	kWh	0.0274	0.0343	6.9806

Figure 19: Products Overview

5 Calculation details

This chapter aims to describe the internal algorithms of SPIonWeb. This applies in particular to the way impacts have to be converted to equivalent footprints as well as calculations expressing life-cycle-CO_2 emissions and GWP potentials.

5.1.1 Impact summation

Impacts are the ecological footprints that are associated with material flows directly exchanged between the life cycle and the environment. As explained in chapter 2, each product/service provided by a process will be assigned an SPI value, depending on the ecological footprint of inputs needed in the provision process (represented by *sub-processes* in the process chain leading up to the process under evaluation) and emissions from the process. Ecological footprints of products generated by any process A can be transferred to another process B in a higher process level by just multiplying the SPI value with the flow (*inventory*) necessary to supply this higher level process. The product of the lower level process A is then an input to the higher level process B, the ecological impact associated with the whole process chain supporting the product exchanged between A and B (using the allocation method applied to process A if there are more than one products) will then become part of the ecological impact of process B and hence all products generated by this process.

SPI values are a summary of seven partial ecological footprints as mentioned already in chapter 2. This helps to identify the quality of impacts, a very important feature for any highly aggregated ecological measure like the SPI Footprint. Along the process chain leading to a certain product/service,

the partial footprints are summarized within their categories, allowing the analysis of what particular ecological pressure exerted by the life cycle is contributing what share of the overall impact.

Following the process chain through all levels allows identifying what sub-process contributes the largest impact in a certain category and hence contributes prominently to the ecological impact of the life cycle.

5.1.2 Impact conversion

For most SPI categories, conversion from impact to area is straight forward:

a_{part_n} = Inventory i [unit]* y_{i_n}

In this equation a_{part_n} represents the partial ecological footprint in SPI category n for the flow of material i (represented by its *inventory i*) with the appropriate unit of measurement *[unit]*. y_{i_n} represents the specific flow rate per year of material i that requires a partial footprint in category n of 1 *[m²]*.

This specific flow rate y_{i_n} for non-renewable raw materials represent the amount of this material that requires a total ecological footprint of 1 m² for its provision at the gate of the refining plant producing this material.

The specific flow rate for material i to compartment n for the compartments soil and water may be calculated

$y_{i\_n} = c_{i\_n} * r_{R\_n}$

with c_{i_n} in [mg/kg] the natural concentration of material I in compartment n[2] and r_{R_n} is the replenishment rate for the compartment in [kg/m²a]. This rate is the seepage rate for water and the yield of compost from 1 m² of green biomass. These rates may vary for different regions, they are defined by the data provided in the *Regional Data* Screen if the user wants to use alternative data to those provided in the data bank.

For all other impacts y_{i_n} values represent natural flows per m² and year: For fossil carbon it represents the amount of carbon sedimented to the sea floor per year (0.002 kg/m²*a). **Mind that this impact also includes the emissions of CO_2 from fossil sources, as principle I is satisfied!**

For emissions to air the amount of material i exchanged per m² and year between forests and atmosphere.

In terms of emissions to environment, always the **final enrichment compartment of a specific emission has to be taken into account**. If a certain flow contains more components that have *impacts* to air, water and soil, only the largest area (**key emission area**) within these three partial SPI areas is contributing to the final SPI process Footprint.

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[2] Reference for c_{i_n} values: Reference class A values from Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (Ed.) (1988): Leidraad Bodensanering. (4th ed.) `s Gravenhage

5.1.2.1 Examples

Example: Input of 1 t crude oil

Inventory = 1 t (user input)

Impact = Crude oil; SPI category = fossil carbon; specific impact y_{spec} = 500 m²a/kg (database entry)

$$a_{part\_x} = Inventory\ X\ [unit]*\ Impact\_X;\ SPI\ category = fossilC\ [m²a/unit] = 500,000\ m²a$$

Example: Emission of 100 mg 1,1-Dichloro ethane into the compartment **water**:

R_w = y_w * r = 1200 [mm/a] * 0.3 [1] = 360 kg / m²a (Austrian average conditions; dependent on regional settings)

c_{nat} = 0.0003 mg Subst / kg (water)

$$y_{spec} = \frac{100}{0.0003*360} = 925.9\ m²a$$

One major exception in calculating emission to air partial areas is CO_2. CO_2 emissions have a SPI value of 0 m²a because CO_2 is the oxidized form of carbon. Carbon utilization is already part of Area for fossil carbon. To **avoid double counting, area for CO_2 emissions to air have been set to zero**.

5.1.3 CO_2 and GWP emissions

For detailed process results, which are described in chapter 4, life-cycle-CO_2 emissions and life-cycle-GWP (=global warming potential) are calculated. CO_2 emissions can be calculated from the partial area "Area for fossil carbon". Fossil carbon which has been extracted will be oxidized to CO_2 over the life cycle and finally end up as CO_2 emission to the atmosphere. This also applies to fossil carbon based materials (e.g. polymers) as at the end of their life cycle they are either de-composed or burned, in both cases releasing their carbon as CO_2.

The amount of fossil carbon can be identified by:

$$Fossil\ carbon\ [kg] = \frac{Area\ from\ fossil\ carbon\ [m^2a]}{500\ [\frac{m^2a}{kg}]} \qquad y_{spec}\ of\ fossil\ resources = 500\ m²a/kg$$

$$CO_2\ emission\ [kg] = Fossil\ carbon\ \ kg\ *\ \frac{molar\ mass\ CO2\ [\frac{g}{mol}]}{molar\ mass\ C\ [\frac{g}{mol}]}$$

GWP potentials are calculated on the base of GWP factors. Material flows GWP are calculated by multiplying the GWP factor of the components in the flow their respective inventory. The sum of CO_2 life-cycle-emissions and other GWP relevant impacts are the total GWP measured in kg CO_2 equivalent.

GWP emission [kg] = CO_2 emission $kg + \sum GWP$ Process 1....n

5.1.4   Allocation methods

Allocation of SPI results to products within a process is needed only if **more than one product** is defined. Regardless of the amount of defined products, the final SPI result for the whole process is the same, because it is a cumulative value of the inputs and emissions. This total environmental impact has however to be shared between the products. SPIonWeb offers three allocation methods how to share the SPI value. Be aware that **changing the allocation method within a process chain affects and changes every following process as well, where this process is included as sub-process**.

Allocation method 1:   Primary

The whole SPI footprint is assigned to the *main product* (see Figure 11). The primary product is indicated through the button in the column "*Main product?*. The *main product* can be changed at will. Other products (and sub-process and impact inventories) are then recalculated automatically because the primary product has to be 1 and every by-product in relation to the main product.

Allocation method 2:   Output

Choosing "output" as allocation method results in applying flow allocation. According the inventory data given by the user for each product, the SPI footprint is shared between every product based on the produced amount. **Mind that this is only possible if the product flows can be measured in the same unit (e.g. mass)**.

Allocation method 3:   Value

The option value as allocation method triggers an allocation according to values assigned to each unit of product. Depending on each products value [currency/unit], the SPI footprint is shared according the relation between value per product and overall value generated by this process. For defining values, a new column will show up (Figure 20).

Figure 20: Value/Price allocation