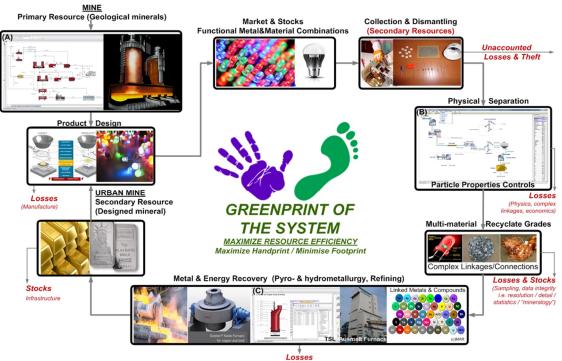
49. Environmental Impacts

HSC Sim includes an option for assessing the environmental impacts of the underlying process using openLCA and GaBi life cycle assessment (LCA) softwares¹. HSC provides a mass and energy balance for LCA software and thus allows a technology-based environmental assessment of a system.

The aim of an LCA is to study a given system and understand its resource efficiency, as shown in the following figure.



(Thermodynamics, system, technology, economics, metal price, feed morphology/analysis/complexity, dilution of alloying metals etc.)

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49.1. Introduction to Life Cycle Assessment (LCA)

The concept of LCA is portrayed as the compilation and evaluation of the **inputs**, **outputs**, **and potential environmental impacts** of a product system (product/service) throughout its life cycle (ISO 14040).

This means that each life cycle stage, including resource extraction, production, transportation, use/consumption, end-of-life activities (collection, sorting, recycling, waste disposal) should be acknowledged and included in an LCA. The product system is followed from its cradle, where raw materials are extracted from natural resources, through production and use to its grave, i.e., the end-of-life processes. Alternatively, products can be followed from cradle-to-gate (raw materials, production), from gate-to-gate (only production), or from cradle-to-cradle (entire life cycle including recycling).

The aim is to quantify the environmental impacts of a product from each process. Some more common usages of LCA methodology include the carbon footprint (ISO 14044), which is an LCA for only one environmental impact category (global warming potential). The comprehensive scope of LCA is useful in order to avoid problem shifting between life cycle phases, regions, or environmental problems.

An LCA consists of four main phases, presented in Fig. 1.

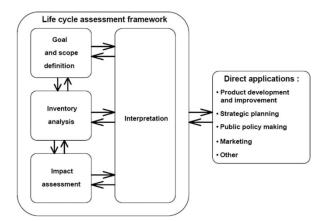


Fig. 1. Steps of Life Cycle Assessment¹⁻⁴.

- 1. Goal and scope definition
- a) Definition of what we want to accomplish with the study. For instance, finding hotspots within the life cycle for further product development, informing the customer about the equipment's/process's environmental impacts, strategic planning, marketing, comparing two alternatives.
- b) Definition of functional unit (proportioned to the unit for which we wish to estimate the results, for example, one tonne of copper, one piece of equipment, one consumer product). It is very common to use either the produced tonne of concentrate/metal as the functional unit OR one piece of production equipment. This will define which life cycle we are interested in.
- c) Definition of system boundaries. Which unit processes will be included in the LCA?
 - Cradle-to-Grave (Full Life Cycle Assessment)
 - Cradle-to-Gate (Raw materials extraction and production, excluding transportation to customer)

- Gate-to-Gate (One process in the production chain)
- 2. Life cycle inventory (LCI)

This phase is usually the most time-consuming phase, where the input and output data of the system are studied and collected. The LCI answers the question: How much of everything flows where?

Usually input and output can be classified into the following main fields:

- energy inputs, raw material inputs, ancillary inputs, other physical inputs
- products, co-products, and waste
- emissions into air, water, and soil
- other environmental aspects

All calculating procedures should be explicitly documented and all assumptions should be explained carefully. It is good to check the data validity during the LCA process. A production flow definition should be made using the real production distribution. For example, in the case of electricity, details such as fuel combustion, mix, conversion, etc. should be included.

When using LCA software, the LCI can be speeded up dramatically, since there are ready-made assumption datasets, e.g., for intermediary products, energy mixes, modes of transport.

However, the ready-made datasets rely heavily on the assumptions of the dataset provider. A trade-off between the accuracy and speed of the analysis may occur. If using datasets from a dataset provider, the process documentation attached to the process is important. For example, you can find steel in the database, but there are certain assumptions about locations, energy mixes, production technologies used, etc., which the user has to be aware of. A full-scale analysis requires that the supplier of the steel plate is known and the environmental profile of that particular supplier's steel is collected and used.

3. Life cycle impact assessment (LCIA)

LCIA identifies and evaluates the amounts and significance of the potential environmental impacts of the product system. LCIA answers the question: What are the resulting impacts? Calculating is usually done using four steps, where the first two are mandatory. **Fig. 2** describes the steps with example values.

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	IMPACT		Industrial		GWP for 100-ye	ar time horizon
LCI	CATEGORIES	FACTORS LCIA	designation or common name	Chemical formula	Second assessment report (SAR)	4 th assessment report (AR4)
Emissi	ions to air	1.21-00 *1	Carbon dioxide	CO2	1	1
	1.3kg GWP	1.3 kg CO ₂ * 1 3 kg CO * 3 — 160.3 kg CO ₂ Eq	Methane	CH ₄	21	25
CO2	and the	6 kg CH ₄ * 25	Nitrous oxide	N ₂ O	310	298
CO	3 kg	6 kg CH ₄ 25	Substances controlle	ed by the Montreal Proto	col	
CH_4	6 kg		CFC-11	CCI ₀ F	3,800	4,750
SO ₂	0.001 kg	0.001 kg SO ₂ * 1	CFC-12	CCI ₂ F ₂	8,100	10,900
NOx	0.08 kg	0.08 kg NO,* 0.7 - 0.849 kg SO ₂ Eg	CFC-13	CCIF ₃		14,400
HCI	0.9 kg AP	0.9 kg HCI * 0.88	CFC-113	CCI2FCCIF2	4,800	6,130
		515 Ng 1161 5165	CFC-114	CCIF ₂ CCIF ₂		10,000
Emissi	ons to water		CFC-115	CCIF ₂ CF ₃		7,370
PO4	2 kg	0.08 kg NO, * 0.13	Halon-1301	CBrF ₃	5,400	7,140
NH ₃	0.1 kg EP	2kg PO4 * 1 - 2.043 kg PO4Eq	Halon-1211	CBrCIF ₂		1,890
		0.1 kg NH ₃ * 0.33	Halon-2402	CBrF ₂ CBrF ₂		1,640
			Carbon tetrachloride	CCI4	1,400	1,400
			Methyl bromide	CH ₃ Br		5
	CLASSIFICATION	CHARACTERISATION	Methyl chloroform	CH3CCI3	100	146

Fig. 2. Life Cycle Impact Analysis and a few impact factors for CO₂ Eq.

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- <u>Classification</u>: All emissions are linked to one or more impact category, for example CH₄ belongs to the Global Warming Potential (GWP) category. Mandatory.
- <u>Characterization</u>: Converts the reference substance of the category by multiplying the quantities by the characterization factor, which means that the result unit is changed to the reference unit of the category where the quantity belongs. For example, CH₄ has a factor of 25, which means that CH₄ contributes 25 times more than CO₂ to the global warming potential. The most common factor developers are the Institute of Environmental Science (CML) in Europe and TRAICI in the United States³⁻⁴. Mandatory.
- <u>Normalization</u>: Converts and possibly aggregates the indicator results across impact categories using numerical factors based on value choices. The aim is to understand the relative magnitude for each indicator result. Not mandatory.
- <u>Grouping:</u> Sorting/ranking the characterization results, e.g. global/regional/local impacts, high/medium/low priority impacts, emissions to air/water. Not mandatory.
- <u>Weighting</u>: Different value choices are given to impact categories to generate a single score. The relative importance of an environmental impact is weighted against all the others. Predominantly based on social sciences. Not mandatory or even recommended.
- Interpretation phase. The results of the LCI or LCA or both, are summarized. The main aim here is to identify significant issues based on the LCI and LCIA phases of an LCA.

Not all these phases are always mandatory. Sometimes sufficient information is already assimilated by carrying out only the LCI and LCIA phases. This is usually referred to as an LCI study.



49.2. LCA in HSC Sim

The HSC Sim LCA tool covers the LCI phase. The subsequent LCIA can be performed by 3rd party LCA software, e.g., GaBi or OpenLCA. When the LCI has been completed with HSC Sim, the process is exported to a separate file. The file can be imported into GaBi (EcoSpold v1.0 file format) or OpenLCA (JSON-LD file format) LCA software. In these 3rd party LCA software programs, other relevant processes (e.g., auxiliaries, transportation) are added. Please consult <u>www.thinkstep.com</u> for more information, and details about GaBi at <u>http://www.gabi-software.com/</u> and for OpenLCA <u>https://www.openlca.org/</u>.

The HSC Sim LCA tool can also be used to capture, in a black box summary of the process, how much of a compound is released into the environment, without the use of LCA software. However, LCA software provides mid- and end-point analyses of the impacts of these flows, materials, compounds etc., providing a detailed impact analysis of the flows.

HSC Sim LCA analysis is always based on a complete HSC Sim process model, where the input and output streams represent the data for the LCI phase. In LCA, the substances of interest are only the input and output streams to the environment (see blue and red streams in **Fig. 1**). Internal streams (black) are not taken into account because they are not relevant when analyzing the process as one black box. As LCA does not generally base its analysis of complete systems on closed mass and energy balances, it is always advisable to create a detailed process model to make the LCA results more accurate⁶⁻⁷.

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49.3. Using LCA Evaluation in HSC Sim

In this example we use a TSL smelter as an example process model (see Fig. 1).

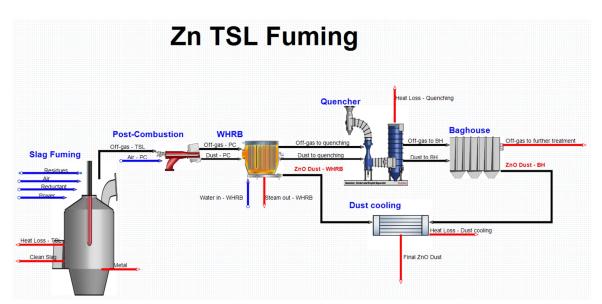


Fig. 3. TSL Furnace process model.

When the process simulation model is ready, the LCA tool is started by selecting $\underline{\text{Tools}} \rightarrow \underline{\text{LCA Evaluation}}$ from the main menu, as shown in **Fig. 4**.

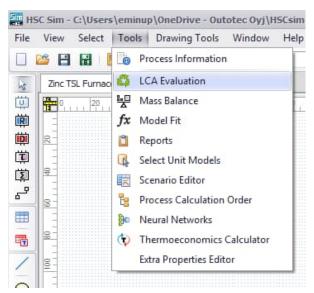


Fig. 4. Starting the LCA tool from the main menu.

49.3.1. Choosing the active database

HSC Sim LCA tool supports two dataset providers: GaBi and OpenLCA. The active database (dataset) can be chosen from the database section in the top menu, see **Fig. 5**.

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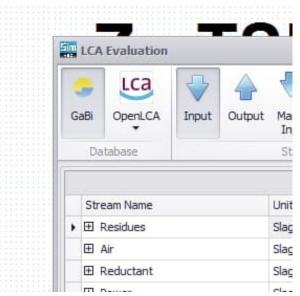


Fig. 5. Choosing the active LCA mode.

By default, the Gabi database is selected. The Gabi database is built into HSC and does not need any additional steps to be downloaded. OpenLCA, however, supports multiple different databases. These databases can be downloaded from https://nexus.openlca.org/ to OpenLCA. Please refer to the OpenLCA manual (https://nexus.openlca.org/ to OpenLCA. Please refer to the OpenLCA manual (https://nexus.openlca.org/ to OpenLCA. Please refer to the OpenLCA manual (https://nexus.openlca.org/ to OpenLCA. Please refer to the OpenLCA manual (https://nexus.openlca.org/ for more detailed guidelines on how to import the downloaded database to the OpenLCA tool.

OpenLCA supports database export to JSON-LD (.zip) file format, which can be imported to the HSC Sim LCA tool. Start the export by activating the desired database. When the correct database is active, the database name is bolded, then right-click and select "Export...", see **Fig. 6**.

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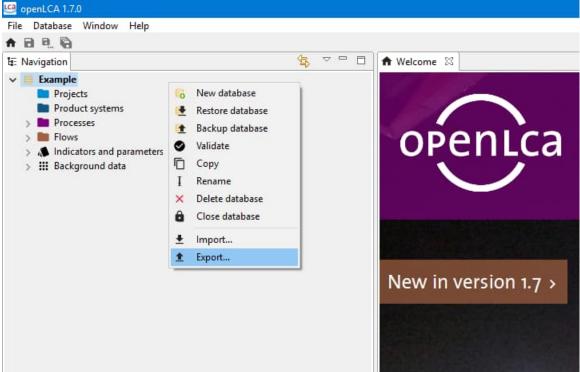


Fig. 6. Right-click when the correct database is active (bolded) and choose "Export..."

This opens a window from where JSON-LD should be selected, see **Fig. 7**. After selection, exported datasets should be defined. For HSC Sim purposes, only the flows are needed.

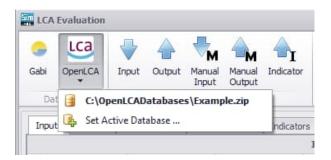
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43 Export	- 🗆 X	🧐 Export data sets —	□ ×
Select	±	Select data sets Please specify an output directory and select the data sets you want to export	
Select an export destination: type filter text		To file C:\OpenLCADatabases\Example.zip Projects Product systems Processes M Flows A Indicators and parameters Till Background data	Browse
< Back Next > Finish	Cancel	< Back Next > Finish	Cancel

Fig. 7. Select JSON-LD and then click "Next >". Select "Flows".

Now the created file can be imported to HSC Sim. This is done in the HSC Sim LCA Evaluation tool. If there is no previously defined OpenLCA database, the program will request it when the OpenLCA is first activated. The active database is visible in the dropdown menu under the OpenLCA button. From there, the active database can also be changed, see **Fig. 8**.



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Fig. 8. Active Database is shown in the dropdown menu. Active database can be changed with "Set Active Database..."

49.3.2. Automatic Import of All Input and Output Streams

The LCA tool creates up to five sheets, named <u>Input</u>, <u>Output</u>, <u>Manual Input</u>, <u>Manual</u> <u>Output</u>, and <u>Indicator</u>, as shown in **Fig. 9**. The Input and Output Streams info sheets contain all the process input and output streams in HSC Sim format for the process or complete flowsheet. In these sheets, stream detail content is available and imported directly from the simulation model.

NOTE! No internal streams are captured through this, as only streams that can interact with the environment and flow out from the system into the environment are used in the assessment.

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LCA	Evaluation															
G aBi	LCa OpenLCA	Input	Output	Manual Input	Manual Output	I Indicator	Mapping	Normalize	Process Info	To EcoSpold v1.0 (GaBi)	To JSON-LD (OpenLCA) ▼	To Exce	I Help			
Da	tabase			Stream	15			Tools			Export		Info			
									Input St	reams						
Stre	am Name		Unit Name		Amount		Unit	Use Exergy	LCA Eq	uivalent			LCA Group		Main Product	
	esidues		Slag Fumin	g		100000,00	kg kg		Lead - i	Zinc srap			From Technosphere			
									Input	Streams						
	9. Name						Value				1	Jnit				
	Mass Flow	N					100					:/h				
	Temperat	ture					25					2				
	Pressure						1					bar				
	Enthalpy	Flow					-22623	8,48090039	2			W				
	Exergy Flow						30074	1333647939				W				
	Total Volume						25,075	680851037				Vm3				
	Total Soli	ds Flow					100				:/h					
	Total Gas	Flow					0				/h					
	Total Liqu						0				/h					
	FeO						50					:/h				
	SiO2						35					:/h				
	CaO						5					:/h				
	ZnO						10					:/h				
	FeO						50					:/h				
	SiO2						35					h				
⊞ A	ir.		Slag Fumin	g		1,29	9 kg		Air				From Nature	Ψ.		
ΞF	eductant		Slag Fumin	g		4397,4	9 kg		Metallu	rgical coal			Materials/Fuels	-		
₽	ower		Slag Fumin	g		63020,50	kWh		Electric	ty			Electricity/Heat			
± ۸	ir - PC		Post-Comb	ustion		34590,7	4 kg		Air				From Nature			
E V	Vater in - WH	RB	WHRB			39957,7	5 kg		Water				From Nature	~		

Fig. 9. "Input" streams info sheet extracted from flowsheet showing details of "Residues".

The LCA streams sheets contain the HSC Sim stream names (as defined by the design engineer) and amounts, which must be mapped to the LCA software equivalents on the active database. The default is "No Mapping" which, unless changed, will exclude that stream from the evaluation. **Fig. 9** shows the details of the Residues input stream while **Fig. 10** shows the output and more specifically the final ZnO dust stream. Please note that the exergy value is also given, which is very useful additional information for analyzing technology, reactors, plants, and systems. The exergy value can also be used as the amount for the stream and this is done by checking the "Use Exergy" box.

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GaBi C	LCA DpenLCA	Input	Output		Manual Output	Indicator	Mapping		Process Info	To EcoSpold v1.0 (GaBi)	To JSON+LD (OpenLCA) •	To Exce	I Help				
Datab	base			Streams	1			Tools			Export		Info				
								0	utput St	reams							
Stream	n Name			Unit N	Amount		Unit	Use Exergy	LCA Eq	uivalent			LCA Group	Main Product			
E Met	tal			Slag F		15784,66	kg		Iron				Reference Product (To technosph	-			
E Cle	an Slag			Slag F		71601,55	kg		Slag				To Nature				
⊞ Hea	at Loss - TS	5L		Slag F		6302,05	kWh		Waste	heat			To Nature	-			
🗄 Ste	am out - W	HRB		WHRB		39957,75	kg		Steam	(hp)			Allocated by product	-			
🕀 Hea	at Loss - Qu	uenching		Quenc		3327,22	kWh		Waste	heat			To Nature	-			
⊞ Off	f-gas to fur	ther treat	ment	Bagho		43353,35	kg		Exhaus	it.			To Nature	-			
E Fina	al ZnO Dust	t		Dust c		8012,99	kg		Zinc ox	ide			Reference Product (To technosph	-			
٩	۹ Name				Amou	nt				Unit							
•	Mass Flow	N					8,012	99287024603	1		t/h						
	Temperat	ture					25				C						
	Pressure						1				bar						
1	Enthalpy	Flow					-9525	,8013253581	6		kW						
	Exergy Fl	low					779,7	92177940232	1		kW						
	Total Volu	ume					1,429	36012669391			Nm3						
	Total Soli						0				t/h						
	Total Gas	Flow					0				t/h						
	Total Liqu	uid Flow					0					t/h					
	ZnO						8,012	99287024603				t/h					
	ZnO							99287024603				t/h					
	at Loss - Du	ust cooling		Dust c		441,09	kWh		Waste	heat			To Nature	-			

Fig. 10. LCA Streams sheet for "Output," also marking the main product relative to which every flow is normalized.

49.3.3. Adding Manual Streams not Defined in the Process Simulation Model

Sometimes, during LCI compilation in HSC Sim, some missing streams may be identified. The best and recommended way is to add missing streams directly to the process simulation model. This typically would include all fugitive emissions, additional power, leakages from the system, etc. In some cases, it is also appropriate to add streams for LCA purposes only. Adding these is done via the "Manual Streams" sheet, as depicted in **Fig. 11**.

For example, if general ancillary process electricity usage is not defined with its own stream in the process simulation model, then it can be defined via the Manual Streams dialog sheet. This can also be done for the output side. As shown in **Fig. 11**, the stream can be added (click on "Add new input stream" button at the bottom of the window), adding a name as well as the units and the amount for the flow that matches the data in the flowsheet as it is being simulated.

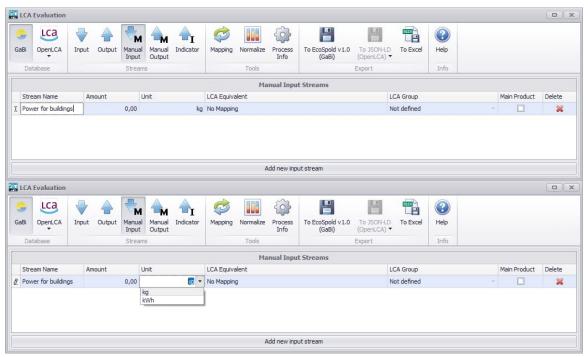


Fig. 11. LCA Manual Input Streams sheet for defining additional flows that do not appear in the simulation.

49.3.4. Adding key indicators in the Process Simulation Model

The Key Indicator sheet offers the possibility to examine how much of the compounds are released into the environment (Nature). The output streams that "LCA Group" in the mapping has selected "To Nature" are those that are counted to indicators. Indicators are a valuable part of the evaluation as a transparent analysis can be made of all the compounds that flow into the environment. **Fig. 12** shows all the indicator values and adds them together once they have been mapped as entering the environment. You can use the "*" wildcard (**Table 1**) to capture more than a single compound, e.g. CO* will collect all CO and CO₂ etc. species, as defined in the model.

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Table 1. Possible wildcard for compound definition

Wildcard	Description
*	Zero or more characters
?	Any single character
#	Any single digit (0-9)

You can type any compound in the sheet after having clicked on the <u>Add new indicator</u> <u>stream</u> bar at the bottom of the window. Some defaults are given. The compound definition may contain wildcards, as presented in **Table 1**. The LCA tool will automatically check if there are double counts of elements/compounds/species. A message box will inform the user of double counting and will not add the compound to the list.

All the <u>indicators</u> that contain some amount will be automatically added to the <u>Manual</u> <u>Output</u> streams list. If these emissions are to be excluded from the LCA, the streams can be deleted manually by clicking the red cross.

GaBi	LCa OpenLCA	Input	Output	Manual Input	Manual Output	Indicator	Mapping	Normalize P	rocess T Info	Fo EcoSpold v1.0 (GaBi)	To JSON-LD (OpenLCA) •	To Excel	() Help		
Da	atabase			Stream	s		Tools Export Info								
								Ind	icator Str	eams					
Str	eam Name		Mea	sured Pro	perty	An	ount		Unit		LCA Equiv	alent		LCA Group	Delete
Ŧ	E CO(g) CO(g)							0,00) kg		Not defined			No Mapping	×
CO2(g)							15951,35	i kg		To Nature		-4	Carbon dioxide	×	
Stream Name					Amount				Unit			Co	unted		
	► 🗄 Off-ga	as to furth	er treatme	ent				15951	,35218412	5218412 Kg				\checkmark	
Ŧ	H2O(g)		H2O	(g)				0,00) kg		Not defined			No Mapping	×
Ŧ	SO*		SO*					0,00	kg		Not defined			No Mapping	*
Đ	NO*		NO*					0,00	kg		Not define	d		No Mapping	*
								Add n	ew indicator	r stream					

Fig. 12. Key Indicator sheet.

49.3.5. Mapping of Process Simulation Flows with LCA software Flow Definitions

In order to perform LCA calculations, all HSC streams have to be mapped to LCA software equivalents. It is recommended to map all streams, but those which are left without mapping will be discarded and reported to the user in the normalization and export phases.

The mapping dialog is started by clicking the mapping button on the button menu. On the left side of the dialog window, all the HSC Sim process streams are shown and the search tool for the active database is on the right side. Stream mapping and selection are done by drag-and-drop from the database side to the HSC stream side (see Fig. 13 and Fig. 14).

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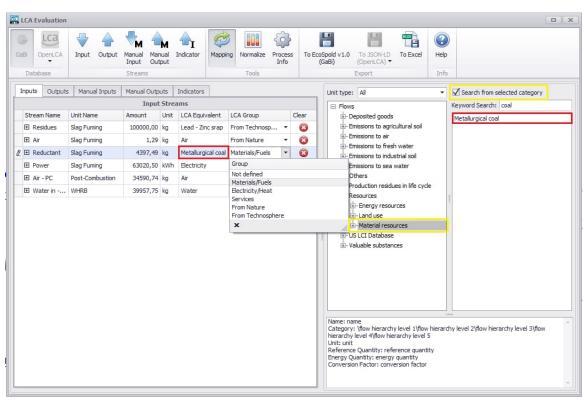


Fig. 13. Selecting a stream for mapping by drag-and-drop from the right into the LCA Equivalent box as shown in red. Please note that here you also need to select where this stream comes from, using the dropdown menu.

GaBi OperLCA Database	Input Output	Manual Mar Input Out Streams	M nual tput	Indicator	Mappin		Process Info	To Ec	oSpold v 1.0 (GaBi)	To JSON-LD 1 (OpenLCA) ▼	To Excel	(3) Help	
Inputs Outputs	s Manual Inputs	Manual Outp	uts	Indicators	1				Unit type:	Mass		•	Search from selected category
		Input	Strea	ams					Flow type:	Elementary		•	Keyword Search: coal
Stream Name	Unit Name	Amount	Unit	LCA Equiv	alent	LCA Group	1	Clear	E Flows				Coal, 18 MJ per kg, in ground
⊞ Residues	Slag Fuming	100000,00	kg	No Mappin	ng	Not defined	•	8	ė- Ele	ementary flows			Coal, 26.4 M3 per kg, in ground
🖽 Air	Slag Fuming	1,29	kg	No Mappin	ng	Not defined	•	8	÷	- air			Coal, 29.3 MJ per kg, in ground
2 🗄 Reductant	Slag Fuming	4397,49	kg	metallurgi	cal coal	Not defined	•	0	ė	- resource			Coal, bituminous, 24.8 MJ per kg, in
Power	Slag Fuming	63020,50	kWh	No Mappin	na	Group		-	····	+- biotic			Coal, brown, 10 MJ per kg, in ground
E Air - PC	Post-Combustion	34590,74	ka	No Mappin	-	Not defined				in air in ground			Coal, brown, 8 MJ per kg, in ground
E Water in		39957,75		No Mappin	-	Materials/Fue Electricity/Hea				- in water			Coal, brown, in ground
E water In	WIND	39937,73	Ng	no mappi	iy i	Services	11			⊕-land			Coal, feedstock, 26.4 MJ per kg, in g Coal, hard, 30.7 MJ per kg, in ground
						From Nature							Coal, hard, unspecified, in ground
						From Technos	phere		1	- soil			Gas, mine, off-gas, process, coal mini
						x				water			metallurgical coal
						_	_	_		ementary flows/U		1	Coal, 18 MJ per kg, in ground
									T	organic emissions aterial resources	to air		Coal, 26.4 MJ per kg, in ground
									1	-			Coal 20 3 Milliper ka in around

Fig. 14. In OpenLCA mode, flows can be filtered according to their unit and/or type as shown in yellow. Keyword search and drag-and-drop works the same as with the GaBi mode as shown in red.

Selection of the flow "LCA Group" is always a very important step. The flow group defines the nature of the stream, i.e., where it comes and where it flows to. There are specific group types for input flows and output flows. The flow group is selected from the dropdown menu as shown **Fig. 13** and **Fig. 14.** NB! The "To Nature" selection only has meaning in the case of OpenLCA because indicators will be calculated based on this selection.



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There are two ways of searching for the LCA equivalent of each stream in GaBi mode. A keyword search is one option, during which the hits are listed below the search word (**Fig. 13** and **Fig. 14**) and the second option is a tree view for manual searching. In both cases, double click on the stream name to select. With the keyword search, it is possible to limit the search by selecting some tree view node before the search, so that the search is performed under the selected node. All hits below this node will be presented. In OpenLCA mode, possible streams can also be filtered by unit and type, see **Fig. 14**. Filtering applies to visible nodes and hence filters the keyword search as well. Also shown is the pulldown menu for the LCA Group (**Fig. 13** and **Fig. 14**) and the possible places it can flow to, as selected.

The stream description field is shown when clicking a stream. In OpenLCA mode, the description can show the stream name, category, reference quantity, flow type, CAS number, and formula. With Gabi the properties are the stream name, category, unit, reference quantity, energy quantity, and conversion factor, see **Fig. 15**.



Fig. 15. On the left is the stream description with OpenLCA, and on the right with GaBi.

If changes are required, simply drag and drop a new LCA software equivalent or if something is to be omitted select <u>Not defined</u> from the pulldown menu or click on the cross at the end of the row. When navigating away from the page you will be prompted to apply the changes, as shown in **Fig. 16**. All changes must always be saved to be effective.

Input Out Streams Manual Inputs Manual Outp Input Unit Name Amount Slag Fuming 100000,00	Output Indicators Dutputs Indicators Dutputs LacA Equivale Unit LCA Equivale Unit LCA Equivale Unit LCA Equivale Quite A Arr A B A A A A A A A A A A A A A A A A A A	Info Tools ent LCA Group Clea grap From Technosp • C From Nature • C (coal Materials/Fuels • C	Emissions to agricultural soil Emissions to air Emissions to fresh water	
Manual Inputs Manual Outp Input Input Unit Name Amount Slag Fuming 100000,00 Slag Fuming 1,29 Slag Fuming 4397,49 Slag Fuming 63020,50 Post-Combustion 34590,74	Utiput Streams Utiput Streams Utiput CA Equivale Utiput CA Equi	ent LCA Group Clea rap From Technosp • 6 From Nature • 6 Lcoal Materials/Fuels • 6	Unit type: All	Search from selected category Keyword Search: coal
Input Unit Name Amount Slag Fuming 100000,00 Slag Fuming 1,29 Slag Fuming 4397,49 Slag Fuming 63020,50 Post-Combustion 34590,74	Unit LCA Equivale Unit LCA Equivale Loo kg Lead - Zinc sr L29 kg Air 7,49 kg Metallurgical 0,50 kWh Electricity	rap From Technosp • C From Nature • C I coal Materials/Fuels • C	r → Piows → Deposited goods → Emissions to agricultural soil → Emissions to air → Emissions to firsh water	Keyword Search: coal
Unit Name Amount Slag Fuming 100000,00 Slag Fuming 1,29 Slag Fuming 4397,49 Slag Fuming 63020,50 Post-Combustion 34590,74	Unit LCA Equivale 0,00 kg Lead - Zinc sr 1,29 kg Air 7,49 kg Metallurgical 0,50 kWh Electricity	rap From Technosp • C From Nature • C I coal Materials/Fuels • C	ar ⊕-Deposited goods ⊕-Emissions to agricultural soil ⊕-Emissions to air ⊕-Emissions to fresh water	
Slag Fuming 100000,00 Slag Fuming 1,29 Slag Fuming 4397,49 Slag Fuming 63020,50 Post-Combustion 34590,74	0,00 kg Lead - Zinc sr 1,29 kg Air 7,49 kg Metallurgical 0,50 kWh Electricity	rap From Technosp • C From Nature • C I coal Materials/Fuels • C	Emissions to agricultural soil Emissions to air Emissions to fresh water	Metallurgical coal
Slag Fuming 1,29 Slag Fuming 4397,49 Slag Fuming 63020,50 Post-Combustion 34590,74	1,29 kg Air 7,49 kg Metallurgical 0,50 kWh Electricity	From Nature From Nature Katerials/Fuels Katerials/Fue	Emissions to air Emissions to fresh water	
Slag Fuming 4397,49 Slag Fuming 63020,50 Post-Combustion 34590,74	7,49 kg Metallurgical 0,50 kWh Electricity	coal Materials/Fuels 🔹 🕻	⊕- Emissions to fresh water	
Slag Fuming 63020,50 Post-Combustion 34590,74	0,50 kWh Electricity	0.0.00	Emissions to industrial soil	
		Electricity/Heat 🔻 🔞	En ciliasions to industria soli	
WHRB 39957,75),74 kg Air	Fro Question	Others	
	7,75 kg Water	Fro Apply mappi	Production residues in life cycle Resources	
		Yes	hierarchy level 4\flow hierarchy level 5 Unit: unit	chy level 2\flow hierarchy level 3\flow
				Category: (flow hierarchy level 1\flow hierarchy level 1\flow hierarchy level 5

Fig. 16. When navigating away from the "Mappings" sheet, you will be asked to apply mapping changes.

49.3.6. Main Product Selection and Normalization of Data

Selection of the <u>Main Product</u> is needed in order for normalization of the data to be performed. There can only be one main product. The main product is selected by checking the box as shown in **Fig. 12**. The main product can be from either the Input or Output side.

<u>Normalize</u> calculates how much of each flow is needed to obtain 1 kg of the main product. The <u>Normalize</u> button in the button menu executes normalization and the results are written in a new <u>LCA normalized data</u> sheet, which appears after the calculation, as shown in **Fig. 17**. The normalization sheet summarizes all the process LCA data and in addition provides a good opportunity to check the data validity. All the same mappings are combined in one stream and unmapped streams are not included in the summary. If, for example, more than one stream is mapped with the same LCA software data "Air", all Air LCA Equivalents will be added to create one stream.

This normalization sheet (**Fig. 17**) also provides a complete overview of all the flows, which thus provides an excellent black box summary of the complete simulation, producing a complete and consistent mass and energy balance. As only mapped inputs and outputs are considered and there are no internal flows, the black box does not reveal any proprietary process detail, making it ideal for benchmarking processes, inclusion in environmental databases, etc.

9	LCa	\checkmark	\bigcirc	M	A				2	H				2			
GaBi	OpenLCA	Input	Output	Manual Input	Manual Output	Indicat	or Mapping	g Normalize	e Process Info	To EcoSpolo (GaBi)		To JSON-LD (OpenLCA) ▼	To Exce	el Help			
Da	tabase			Stream	ş			Tools				Export		Info			
								No	rmalized Fl	DWS							
Dire	ection	F	low Name		Group	Name	Category		Sub Catego	ry	Amour	nt	Norn	malized Amour	nt	Unit	
• 🖽 1	nput	Le	ead - Zinc	srap			Waste for re	covery				100000	,00		12,48	kg	
ΞI	nput Air			Material reso	urces	Renewable	resources		34592	2,03		4,32	kg				
ΞI	Input Metallurgical coal			Material reso	urces	Non renewa	able resour		4397	7,49		0,55	kg				
ΞI	input	E	lectricity				Energy carrie	er.	Electric pow	/er		63020	,50		7,86	kWh	
ΞI	input	V	/ater				Materials		Operating n	naterials		39957	7,75		4,99	kg	
⊕ (Dutput	Ir	on				Material resources		Non renewa	able elements		15784	1,66	5 1 ,97		kg	
①	Dutput	S	lag				Waste for re	covery				71601	,55		8,94	kg	
⊞ (Dutput	W	/aste heat	t			Other emission	ons to air				10070	,36		1,26	kWh	
 (Dutput	S	team (hp)				Energy carrie	er	Thermal en	ergy		39957	7,75		4 <mark>,</mark> 99	kg	
⊞ (Dutput	E	xhaust				Other emissio	ons to air				43353	3,35		5,41	kg	
 (Dutput	Z	inc oxide				Materials		Intermediat	e products		8012	2,99		1,00	kg	
Ð (Dutput	C	arbon dio:	kide			Inorganic em	issions to				15951	,35		1,99	kg	

Fig. 17. A complete normalized data set defining the complete process, flowsheet, or system as a black box.

49.3.7. Exporting LCI Data

To Gabi

The <u>To EcoSpold v1.0 (GaBi)</u> exporting menu button writes an EcoSpold version 1.0 XML file. The exported file contains metadata, which provides general process information as required by the LCA methodology. Metadata information is entered in the <u>Process Information</u> window and needs to be completed before exporting (**Fig. 18**). The process information window can be opened from the menu with the <u>Process Information</u> button. Stream details are taken from the normalization sheet.

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Process Informat	ion		X
Process			
Process Name:	TSL Furnace		
Technology:	Pyro		
General Comment:	Zn Fuming		
HSC Ver. (Last save)	9.6.1		
Location			
Location:	Finland		•
Location Comment:	Pori		
Developer			
Author:	Markus Reuter		
Date:	3.9.2018		•
Version Number:	1.0		
OK		Cancel	

Fig. 18. Process Info dialog for entering process detail.

It is not mandatory to complete all the process information fields, but it is worth filling them well. After completion of the process information, save it by clicking. Process info can also be used without the LCA tool to describe the process well, hence providing a good summary for use in process design.

Exporting buttons are found on the right of the button menu. If normalization has not been done, the LCA tool will automatically ask you to perform normalization first. Exporting opens a file search dialog where the location and name of the exported file is defined/entered. A popup window will inform the user if the export was successful and in what format, as shown in **Fig. 19**.

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Lca									
	input Output Manua Input	al Manual Indicator	Mapping		Process Info	To EcoSpold v1.0 (GaBi) (OpenLCA) ▼	To Excel Help		
Database	Strea	ms		Tools		Export	Info		
				1	input Str	eams			
Stream Name	Unit Name 🔺	Amount	Unit	Use Exergy	LCA Equ	iivalent	LCA Group		Main Produc
🖽 Air - PC	Post-Combust	. 34590,74	ł kg		Air		From Nature		
	Slag Fuming	100000,00) kg		Lead - Z	linc srap	From Technosphere	10	
🗄 Air	Slag Fuming	1,29	kg		Air		From Nature	7	
⊞ Reductant	Slag Fuming	4397,49	kg		Metallur	gical coal	Materials/Fuels	7	
Power	Slag Fuming	63020,50			Electricit	ty	Electricity/Heat	1.7	
	WHRB	39957,75		xport	Mator	x	From Nature	+	

Fig. 19. Popup to inform the user of successful export.

To OpenLCA

The <u>To JSON-LD (OpenLCA)</u> exporting menu button writes a JSON-LD compressed file. The exported file contains metadata, which provides general process information as required by the LCA methodology. Metadata information is entered in the <u>Process</u> <u>Information</u> window and needs to be completed before exporting (**Fig. 19**). The process information window can be opened from the menu with the <u>Process Information</u> button. Stream details are taken from the normalization sheet.

It is not mandatory to complete all the process information fields, but it is worth filling them well in order to export the process in a form that is the most usable in OpenLCA. After completion of the process information, save it by clicking. Process info can also be used without the LCA tool to describe the process well, hence providing a good summary for use in process design.

Exporting buttons are found on the right of the button menu. With OpenLCA, there are two export options, as shown in **Fig. 20.** <u>To Active Database</u> exports the process to the active database (database which is active in HSC Sim LCA Tool). <u>To Empty File</u> opens a file window where the user can specify the file where the process is exported. To ensure compatibility in the OpenLCA software, it is recommended to export to the same database as that used in the HSC Sim tool.

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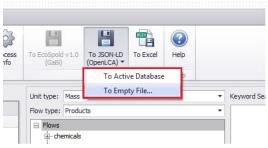


Fig. 20. OpenLCA export options.

If normalization has not been done, the LCA tool will automatically ask you to perform normalization first. A popup window will inform the user if the export was successful and in what format, as shown in **Fig. 21**.

	i±i⊷ glass
Export	× mater
JSON-	LD export succeeded! mmy p
[OK picasca

Fig. 21. Popup to inform the user of successful export.

To Excel

Metso

There is also an option to export the information to Excel, which can be used as an input for other applications, reports, publications etc., as shown in **Fig. 22**.

1	A B	C D	E	F G	н	1	J		L	M	N	0	P	
1		- 10	1. C	I	put Streams									
2 :	Stream Nam	ne t Na Amount	Un	t Use Exergy	LCA Equivalent		LCA Group	0	Main Product					
3 /	Air - PC	Pos 34	590,74 kg	Unchecked	Air	From Nature	2	L	Unchecked					
4		Name		Val	ue		Unit							
5	Mass Fl	ow	34,	5907 44 6892004		t/h								
5	Temper	ature	25			с								
7	Pressur	e	1			bar								
в	Enthalp	y Flow	0			kW								
9	Exergy	Flow	450	,447145912722		kW								
0	Total Vo	olume	268	73,7217976676		Nm3								
1	Total So	olids Flow	0			t/h								
2	Total Ga	as Flow	34,	5907 <mark>44</mark> 6892004		t/h								
3	Total Lie	quid Flow	Ó			t/h								
4	N2(g)		26,	5339545167274		t/h								
5	O2(g)		8,0	5679017247305		t/h								
6	N2(g)		26,	5339545167274		t/h								
7	O2(g)		8,0	5679017247305		t/h								
8 F	Residues	Slag 1000	000,00 kg	Unchecked	Lead - Zinc srap	From Techn	osphere	L	Unchecked					
9		Name		Val	ue		Unit							
20	Mass Fl	ow	100			t/h								

Fig. 22. Excel export of all information for further use by other software.

49.3.8. Importing a Process to GaBi and Further Analysis

GaBi software is 3rd party LCA software and not part of HSC Chemistry software (http://tutorials.gabi-software.com/). Extending the GaBi process database is possible by selecting Edit→Import→Ecospold V1 (see **Fig. 23**), which produces functional GaBi processes.

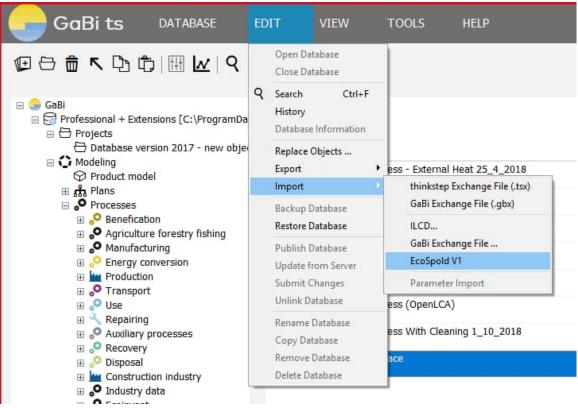


Fig. 23. Importing a new process to the GaBi database from the directory into which the XML file was exported.

A file search window opens for the exported HSC Sim file search. The file selection function first opens the process summary, where the user is also informed of the process export path in the GaBi process tree. **Fig. 24** lists all the flows and amounts and if this summary is OK, the final import can be started by clicking the green play button. At the end of this import, a log file popup appears in GaBi that informs the user whether the import was successful or not. The log file can be closed without saving in GaBi.

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🕞 Import: EcoSpold file			10-01		×
✓ FI: TSL Furnace [HSC] [Pyro]	én				
No mapping scheme loaded.					
Preview IOs Object list Mapping scheme					
Inputs	a a transmission and a same				
Flow	Amount Unit		(EStandard	de\Com	nent, u
Lead - Zinc srap [Waste for recovery]	12,4797315583kg	Х			
Air [Material resources] [Renewable resources]	4,31699271521kg				
Metallurgical coal [Material resources] [Non renewable resources]	0,54879493039kg	х			
Electricity [Energy carrier] [Electric power]	7,86478961206 kWh	x			
	4 9866 1999 771 kg				
Water [Materials] [Operating materials]	4,9866 1999271 kg				
Water [Materials] [Operating materials]	4,9866 1999271 kg				
Water [Materials] [Operating materials]	4,9866 1999271 kg				\$
	4,9866 1999271 kg				3
Water [Materials] [Operating materials]	Amount Unit	Trad	≪Standard	de Comm	anent, un
Water [Materials] [Operating materials] Vater [Materials] [Operating materials] Dutputs Flow Iron [Material resources] [Non renewable elements]	Amount Unit 1,96988373445kg	Trad	∝Standard	de'Comr	aent, un
Water [Materials] [Operating materials] Upututs Flow Iron [Material resources] [Non renewable elements] Slag [Waste for recovery]	Amount Unit		«Standard	de [,] Comm) nent, un
Water [Materials] [Operating materials] Uutputs Flow Iron [Material resources] [Non renewable elements] Slag [Waste for recovery] Waste heat [Other emissions to air]	Amount Unit 1,96988373443kg	x	αStandard	de [,] Comr	anent, un
Water [Materials] [Operating materials] Water [Materials] [Operating materials] Qutputs Flow Iron [Material resources] [Non renewable elements] Slag [Waste for recovery] Waste heat [Other emissions to air] Steam (hp) [Energy carrier] [Thermal energy]	Amount Unit 1,96988373443kg 8,93568084385kg		αStandard	de [,] Comm	nent, ur
Water [Materials] [Operating materials] Water [Materials] [Operating materials] Uputputs Flow Iron [Material resources] [Non renewable elements] Slag [Waste for recovery] Waste heat [Other emissions to air] Steam (hp) [Energy carrier] [Thermal energy] Exhaust [Other emissions to air]	Amount Unit 1,96988373445kg 8,93568084385kg 1,2567540903CkWh	x x	αStandard	de [.] Comm	anent, un
Water [Materials] [Operating materials] Water [Materials] [Operating materials] Value Va	Amount Unit 1,96988373443kg 8,93568084385kg 1,2567540903CkWh 4,98661999271kg 5,41038193351kg 1 kg	x	∝Standard	de Comm	anent, un
Water [Materials] [Operating materials] Water [Materials] [Operating materials] Uputputs Flow Iron [Material resources] [Non renewable elements] Slag [Waste for recovery] Waste heat [Other emissions to air] Steam (hp) [Energy carrier] [Thermal energy] Exhaust [Other emissions to air]	Amount Unit 1,96988373443kg 8,93568084385kg 1,2567540903CkWh 4,98661999271kg 5,41038193351kg	x x	«Standard	de'Comm	nent, ur
Water [Materials] [Operating materials] Water [Materials] [Operating materials] Value Va	Amount Unit 1,96988373443kg 8,93568084385kg 1,2567540903CkWh 4,98661999271kg 5,41038193351kg 1 kg	x x	∝Standard	de Comm	› nent, un

Fig. 24. Process summary presented during import as a check before clicking on the play button to complete the import.

The new process is available in GaBi processes under the HSC folder. This HSC Sim generated process can now be used in the new LCA plans together with all the other GaBi processes. By double clicking the process you can see the process details (see **Fig. 25**).

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bject Edit	View Help								
🖻 🛄 .	¥ D 🛱 🛱 🗠) 🗗 🔶 🖥	· •		?				
Name	FI V TSL Furnace								Source
arameter									
Parameter	Formula		10	Value	Μ	linimum Mi	aximur Standar Comr	ner	
Parameter									
0.00		D							
P LCA 🕥	LCC: 9,83 EUR 🤣 LCWE	Documentation							
Completeness	No statement	\sim							
Inputs									
Flow		Quantity	Amount	Unit	Tr	a Standar	Origin	Comment	
	ity [Electric power]	: Energy (net ca	28,3	MJ	X	0%	(No statement)		
≓Lead - 2	Zinc srap [Waste for reco	Mass	12,5	kg	x	0%	(No statement)		
≓ Metallu	irgical coal [Non renewab	Mass	0,549	kg	х	0%	(No statement)		
≓ Air [Ren	ewable resources]	Mass	4,32	kg		0 %	(No statement)		
₩ater [0	Operating materials]	Mass	4,99	kg		0 %	(No statement)		
Flow									
<									
<u>O</u> utputs									
Flow		Quantity	Amount	Unit	Tr	a Standar	Origin	Comment	
≓ Iron [N	on renewable elements]		1,97	kg	х	0%	(No statement)		
≓ Steam	(hp) [Thermal energy]	Mass	4,99	kg	X	0%	(No statement)		
the state of the second se	ide [Intermediate produc		1	kg	x	0%	(No statement)		
Carbon o	dioxide [Inorganic emissions to	Mass	1,99	kg		0 %	(No statement)		
≓ Exhaust	[Other emissions to air]		5,41	kg		0 %	(No statement)		
	aste for recovery]	Mass	8,94	kg		0 %	(No statement)		
₩aste h	eat [Other emissions to air]	Energy (net calor	4,52	MJ		0 %	(No statement)		

Fig. 25. New process information after import.

In Gabi, the system where processes can be connected to each other is called "Plan". **Fig. 26** presents a plan where electricity and the TSL furnace are connected. Right click on the Plan and select "Calculate Results" to calculate the LCIA results.

The results sheet contains multiple tabs; one tab for each impact method. All common impact categories are presented in the bar charts (see **Fig. 27**). Numerical values are available in the results tab.

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TSL Furna	ce <lc> [Manu</lc>	al Example]	DB Plan *									×	\$
Object Edit	View Help												
V 🗖 🖉	X D Ö	100%	<u> </u>	P			3 9	¢	?	Search		(۹
Name	Natior \lor TSL	Furnace				Source		\sim	Life cyd	e		\sim	
TSL Fur Process plansRefe The names of the		e shown.						Sel	ection: 1	SL Furnace		۲	^
	Fl: Electrici ts	ty grid mix 🗲	Electri 28,3 MJ	city —	FI: TSL	Furnace	°						
×												>	Ŷ
System: Changed	ł.	La	ast change: S	ystem 1	. 10.2018 16	6.16.01		GUID:	{D71FD9	66-DDB8-4870	BFA1-E2	305698	8

Fig. 26. The imported process can now be linked to other GaBi processes, e.g., energy.

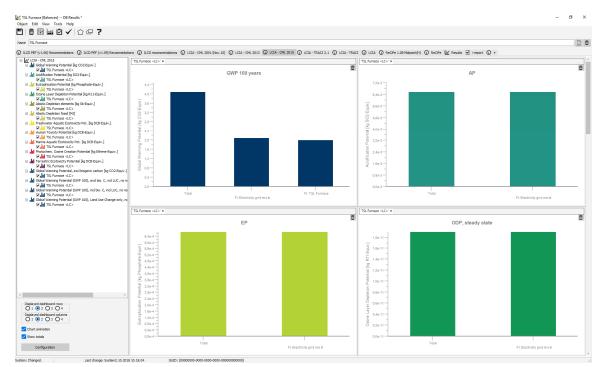


Fig. 27. Example of calculated environmental impacts.

49.3.9. Importing a Process to OpenLCA and Further Analysis

OpenLCA software is 3rd party LCA software and not part of HSC Chemistry software (<u>http://www.openlca.org/learning/</u>). Extending the OpenLCA process database is possible by right clicking on the active database and selecting import (see **Fig. 28**). Make sure that the database contains the flows used in HSC Sim when the export is done. NB! The safest way is to import exactly the same database that is used in HSC Sim.

		ecoinvent_34_cu	toff_lci_20180314	
~		ecoinvent ?*		
	>	Project:	New database	
	>		Restore database	
	>	🖿 Process 😭	Backup database	
	~	Flows 🥑	Validate	
		> 📥 A:A	Сору	
		> 🖿 air 💾	17	
		> 🖿 B:M I	Rename	
		> 🖿 C:M 🗙	Delete database	
		> 🖿 D:El 🔒	Close database	ng s
		> E:W	h	en
		> 🖿 Eler 🛨	Import	
		> 🖿 End 🟦	Export	
		> 🖿 F:Constru	iction	

Fig. 28. Importing a new process to the OpenLCA database.

Import opens a file type selection dialog (see **Fig. 29**). After type selection, the actual file search window will open for the exported HSC Sim file (JSON file) search.

LC3 Import		×
Select		∎
		-
Select an import source:		
type filter text		
✓ ➡ File Import		
XML EcoSpold 1		
XML EcoSpold 2		
Excel		
🕷 ILCD		
SimaPro CSV		
ILCD Network Import		
ILCD Network Import		
V 🗖 Other		
×ML EcoSpold2 geographies		
🐸 Import entire database		
XML KML geographies		
Linked Data (JSON-LD)		
Repository Import		
	-	
< Back Next > Finish	Canc	el

Fig. 29. Import file type selection.



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The new process is available in "Processes" under the HSC folder. This HSC Sim generated process can now be used in the new "Product Systems" together with all the other processes. To create a new Product System, double-click the process and select "Create product system" (see **Fig. 30Error! Reference source not found.**). A new p roduct system creation dialog will open where the provider adding method is selected. "Prefer default providers" will automatically add processes which generate a product needed by our processes. In other cases, processes should be added manually.

General inform	ation
General informa	
Name	TSL Furnace OpenLCA 21.11.2018
Description	Zn Fuming
Category	HSC
Version	00.00.000 🔿 🛞
UUID	9da29677-9e04-45ee-9be4-99a141125bb9
Last change	
Infrastructure pro	cess

Fig. 30. New "Product System" creation.

The product system just created can be opened by double-clicking the product system from the left panel product system section. A product system model graph is available in the "Model Graph" tab (see **Fig. 31**). This is the place where the process system boundaries are defined. Which processes are included in our impact analysis?

Fig. 31. Product system model graph where electricity production is linked to TSL furnace.

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Calculations are performed on the created product system "General information" tab by clicking the calculate button (see **Fig. 32**). The allocation method, impact assessment method, and calculation type are defined on the Calculation properties sheet. "Analysis" calculation type gives a more detailed view of the impacts than quick results.

🗄 General i	information: T	SL Furnace OpenLCA	
▼ General inf	ormation		
Name	TSL Furnace Open	LCA	
Description	First created: 2018 Linking approach		– 🗆 X
		Calculation properties	
		Please select the properties for the	e calculation
Version	00.00.004	Allocation method	As defined in processes
UUID	28b5dde6-79c1-41	Impact assessment method	🐏 CML 2001
Last change	2018-11-22T11:44:4	Normalization and weighting set	· · · · · · · · · · · · · · · · · · ·
	 Calculate 	Calculation type	Quick results Analysis Regionalized LCIA Monte Carlo Simulation
			Include cost calculation
▼ Reference			Assess data quality
Process	P TSL Furnace		
Product	F.º zinc oxide		
Flow property	y 🕸 Mass		
Unit	📟 kg		< Back Next > Finish Cancel
Target amou	nt 1.0		

Fig. 32. Calculation properties need to be selected before calculation.

Analysis results contain general information about the top emission contributors (see **Fig. 33**). On that page we can make process level investigations for each flow and impact category. On that page results are described in bar charts. On that tab, the results can also be saved in Excel format for further analysis.

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Fig. 33. Example of calculated environmental impacts.

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The impact analysis tab offers detailed information about the impacts. For each impact category the contributor processes and process flows (see **Fig. 34**) are presented. The figures for the stream inventory result, impact factor, and impact result are clearly presented for each stream.

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E Impact analysis: TSL Furnace OpenLCA

▼ Impact analysis

Subgroup by processes 🗹 Cut-off 🛛 🔹 %

Name	Category	Inventory result	Impact factor	Impact result	Unit
> 📃 acidification potential - average European				0.00597	kg SO2-Eg
> acidification potential - generic					kg SO2-Eg
climate change - GWP 100a					kg CO2-Eg
 P electricity, high voltage, production mix electricity, high voltage Cutof 	DiElectricity gas steam and air conditioning		-		kg CO2-Eq
F Carbon dioxide, fossil	Emission to air / low population density	1.65443 kg	1.00000 kg CO2-Eg/kg		kg CO2-Eq
F Carbon dioxide, fossil	Emission to air / high population density	0.05658 kg	1.00000 kg CO2-Eq/kg		kg CO2-Eq
F Carbon dioxide, fossil	Emission to air / unspecified	0.02261 kg	1.00000 kg CO2-Eq/kg		kg CO2-Eq
F Methane, fossil	Emission to air / low population density	0.00563 kg	25.00000 kg CO2-Eq/kg		kg CO2-Eq
 P TSL Furnace OpenLCA 	HSC	0.00003 Kg	23.00000 kg CO2-Eq/kg		kg CO2-Eq
F Carbon dioxide, fossil	Emission to air / high population density	1.59821 kg	1.00000 kg CO2-Eq/kg		kg CO2-Eq
E climate change - GWP 20a	Emission to an 7 high population density	1.55021 Kg	1.00000 kg CO2-Eq/ kg =		kg CO2-Eq
E climate change - GWP 500a					kg CO2-Eq
climate change - lower limit of net GWP					kg CO2-Eq
climate change - upper limit of net GWP					kg CO2-Eq
> eutrophication potential - average European					kg NOx-Eq
> eutrophication potential - generic					kg PO4-Eq
> E freshwater aquatic ecotoxicity - FAETP 100a					kg 1,4-DCB-Eq
Freshwater aquatic ecotoxicity - FAETP 20a					kg 1,4-DCB-Eq
> E freshwater aquatic ecotoxicity - FAETP 500a					kg 1,4-DCB-Eq
Freshwater aquatic ecotoxicity - FAETP infinite					kg 1,4-DCB-Eq
Freshwater sediment ecotoxicity - FSETP 100a					kg 1,4-DCB-Eq
Freshwater sediment ecotoxicity - FSETP 20a					kg 1,4-DCB-Eq
Freshwater sediment ecotoxicity - FSETP 500a					kg 1,4-DCB-Eq
Freshwater sediment ecotoxicity - FSETP infinite					kg 1,4-DCB-Eq
> 🗄 human toxicity - HTP 100a				0.41543	kg 1,4-DCB-Eq
> 📘 human toxicity - HTP 20a					kg 1,4-DCB-Eq
> 📘 human toxicity - HTP 500a				0.41765	kg 1,4-DCB-Eq
> 📘 human toxicity - HTP infinite					kg 1,4-DCB-Eq
ionising radiation - ionising radiation				6.51003E-8	DALYs
> 🗄 land use - competition				0.00911	m2a
> 🚦 malodours air - malodours air				3.11306E4	m3 air
> 📃 marine aquatic ecotoxicity - MAETP 100a				1.26556	kg 1,4-DCB-Eq
> 🚦 marine aquatic ecotoxicity - MAETP 20a				0.19060	kg 1,4-DCB-Eq
> 🗄 marine aquatic ecotoxicity - MAETP 500a				6.72769	kg 1,4-DCB-Eq
> 📳 marine aquatic ecotoxicity - MAETP infinite				1997.18657	kg 1,4-DCB-Eq
> 🚦 marine sediment ecotoxicity - MSETP 100a				1.31996	kg 1,4-DCB-Eq
> 📳 marine sediment ecotoxicity - MSETP 20a				0.31411	kg 1,4-DCB-Eq
> 🗄 marine sediment ecotoxicity - MSETP 500a				5.83619	kg 1,4-DCB-Eq
> 🗄 marine sediment ecotoxicity - MSETP infinite				845.67165	kg 1,4-DCB-Eq
> EBIR				0.00013	kg formed ozone
> 📘 photochemical oxidation (summer smog) - high NOx POCP				0.00025	kg ethylene-Eq
> 📘 photochemical oxidation (summer smog) - Iow NOx POCP				0.00011	kg ethylene-Eq
photochemical oxidation (summer smog) - MIR					kg formed ozone
photochemical oxidation (summer smog) - MOIR					kg formed ozone
resources - depletion of abiotic resources					kg antimony-Eg
stratospheric ozone depletion - ODP 10a					kg CFC-11-Eg
Figure Statespheric ozone depletion - ODP 15a					kg CFC-11-Fg

Fig. 34. Impact analysis results.

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49.4. Using LCA Evaluation (beta) in HSC Sim

In this example we use Iron Process as an example process model (Fig 1).

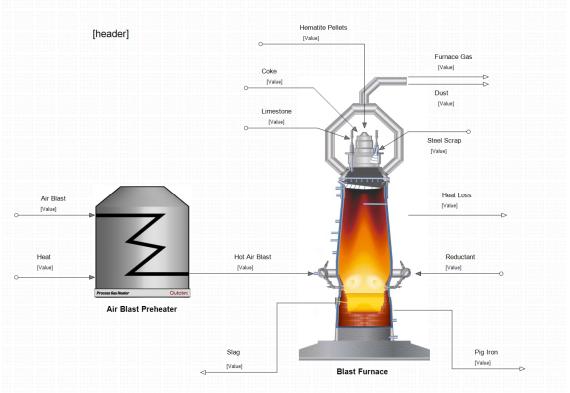


Fig 1. Iron Process

NOTE! As this tool is beta version, all might not work as expected! Before using the tool, please take back-ups from important models and in case of problems please email <u>hsc@metso.com</u>

49.4.1. Downloading and initializing openLCA

First, to be able to use the LCA Evaluation tool, unstable build of the openLCA needs to be downloaded. This can be done downloading the openLCA 2.0.0 zip file from <u>Files</u> - <u>ownCloud (greendelta.com)</u>. Please read README file before going any further.

"Note: This is **not a stable openLCA version** and should not be used in production. Existing databases can be used with this version but when opening a database with it **an update may be executed which is not reversible**. Thus, it is highly recommended to **backup a database before opening it** with this version. Also, there is no database compatibility guaranteed between different development versions. When you used a database with one experimental version it may not work with another. Thus, the best way to test a development version is to take a fresh database from a stable release and upgrade it (but please make a backup first)."

After downloading the zip file, extract the contents into a folder, and start openLCA.exe by double-clicking it. If there are no databases in the software yet, restore them by clicking <u>Database</u> \rightarrow <u>Restore database</u> (**Fig 2**). After that select the correct file(s). All openLCA free and purchasable databases can be downloaded from openLCA Nexus webpage <u>openLCA Nexus: The source for LCA data sets</u>.

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Next, open the correct database by double clicking the name or right clicking the name and selecting <u>Open database</u> (**Fig 3**).



Fig 3. Select and open the database from openLCA.

NOTE! If you are using ecoinvent databases, select the system process database, i.e., it will have the abbreviation "LCI" in its name. The tool has not yet been validated with the use of unit process databases.

Next, IPC Server is started from the main menu: $\underline{\text{Tools}} \rightarrow \underline{\text{Developer tools}} \rightarrow \underline{\text{IPC}}$ <u>Server</u> (**Fig 4**). By checking the <u>gRPC service (experimental)</u> and then pressing the green run button the gRPC service will be started (**Fig 5**).

File Database Too	s <u>H</u> elp				
	Show views	>	1		
Navigation fx	Parameters		1	Welcome ×	
Aecoinve	Developer tools	>	sqL	SQL	The second second software for such in hills
Project	Bulk-replace	>	Ð	Console	The open source software for sustainability
> Proces	Flow mapping (experimental)	>	Py	Python	For modeling the life cycle of things.
> 🖿 Flows > 📣 Indicat	Formula interpreter		-	IPC Server DLCa	Licenced under the Mozilla Public Licence 2
> III Background				IPC Server	Created and maintained since 2006 by Gre

Fig 4. Select IPC Server from the main menu.

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You can make the calculation in	openLCA faster. <u>Learn more.</u>	
	3 Start an IPC Server	– 🗆 X
What is new in openLCA >	Port 8000 Start as gRPC service (experimental) Click on the 'run' button to start the IPC server.	
Getting started >		
		Close
Manuals, case studies and data		and the second

Fig 5. Start as IPC Server.

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After enabling the gRPC services, the openLCA software will work on the background while all rest of the work will be done in HSC Sim.

49.4.2. Downloading flow and impact method data to HSC Sim

In HSC Sim, the first thing to do is to download the flow and impact method data to the tool. Open the LCA Evaluation (beta) by selecting $\underline{\text{Tools}} \rightarrow \underline{\text{LCA Evaluation}}$ from the menu (**Fig 6**).

🗳 🗄 🔛	0	Process Information		🖻 • 📇 🖷 🗄	E H • 🛍 👉 🙆	• 20 C Arial - 8 -	B I Al 🗆 -
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*	-	LCA Evaluation	80 , 100 , 1	20 140 160	180 , 200 , 220 , 3	240 280 220 300 320 340 380 320 400 420 440 460 680 500 520 54	Process KPI Page
8.	0.4	Mass Balance				^	Project
		Reports					Project Name
			ler]		Hematte Pelies		Project Path
¥-	4	Select Unit Models	cij	o <u> </u>	(/siud)		Process
		Scenario Editor				Furnace Gas	Name
0	1	Process Calculation Order		Coke		para para para para para para para para	Technology
	De	Neural Networks		0		Dist	Sub Technology Plant Type
3						Deed	Products
10-1		Thermoeconomics Calculator		Limestore (Velue)			More Information
-		Model Optimization		0		Stael Scrap	Comment
100		Internal: Vex_IO Editor				biau Scrap owwei	Simulation Model
1		Extra Properties Editor					Mass Balance
8		Internal: IrisMQ variable mapping report			¥		HSC Ver. (Last save)
					and the second s	HeatLoss	Last Save
1	. 🔳	Model Species		Cleaned Furnace Gas		Heat Loss	Last Modified Online
140		Test: Save a snapshot		(recei			Last Modified Online
		Test: Restore the latest snapshot					Name
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					T I		
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200	9	LCA Evaluation (beta)	Blast Preheater		100-00		Unit Icons
802		Global Sieve Series Editor (beta)					Process Tr Log View
			4	Slag		Pg los	2 III Units by Type

Fig 6. Start LCA Evaluation (beta) from the main menu.

Next, press the openLCA button and select either Unit or LCI (system) database (**Fig 7**). If the connection is successful, it will start downloading the flows and impact method data. This might take several minutes. In case of errors, message window will pop up and indicate the reason for the error. If the reason is "Connecting", it is enough to repress the openLCA button or wait for couple of minutes of the connection to be formed between HSC Sim and openLCA.

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• and Markal Stream • Context	LCA													-		X
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7 N2(g) 186,14 8 O2(g) 56,52 9 10 Energy 11 Heat 81500,48 kW 12 Energy 13 Heat 81500,48 kW 14 Benentary Flow 15 Energy 16 Hematic Pellets 200,00 t/h 18 Fe2O3 183,00 19 SiO2 13,00 20 MnO2 2,30 21 P2O5 0,20 22 Al2O3 0,50	5 A				Elementary Flow	1										
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25	25		25.37													-1
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Fig 7. Start openLCA.

The flows and impact methods will be displayed in the <u>Flows and Methods</u> view on the right side of the tool. Successful connection will be indicated by the very first tree list node which name is *Flows (loading database)* and for methods *Methods (loading database)*. After the downloading is complete, the node names will change to include the name of the database. By pressing the plus sign next to the first node, the tree lists will be expanded. Downloading the flows for the Iron Process example is shown in **Fig 8**.

Flows and Methods #	Flows and Methods
Hows × Impact Methods and Categories	Flows × Impact Methods and Categories
Enter text to search Find Clear Enter text to search Find Clear	Clear Enter text to search Find Clear
Flows (loading database) Image: Contract of the second s	 Flows (pTesting_ecoinvent_3_8_LCt) AAgriculture, forestry and fishing BAming and quarrying DElectricity, gas, steam and air conditioning supply EWater supply; sewerage, waste management and remedi FiConstruction GiWholesale and retail trade; repair of motor vehicles and HiTransportation and food service activities Diardiffersional, scientific and technical activities Ni:Administrative and support service activities S:Other service activities S:Other service activities Bienentary flows

Fig 8. Downloading and showing the flows of the database in the tree list view.

49.4.3. Automatic import of all input and output streams

The LCA tool creates three sheets, named <u>Inputs</u>, <u>Outputs</u>, and <u>Results</u>. The Inputs and Outputs sheet show all the input and output streams for the process flowsheet. This includes stream names, amounts, units, stream species contents and their phases. **Fig** shows the Inputs sheet for the Iron Process.

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LCA												
	🚯 Add Manua		Hide Stream Content	onvert Stream to Indicators	Add Custom S	m Sheet om Sheet	Import External Sheet Export to Excel	 Add Mapping Delete Mapping 	 Add Impact Ca Delete Impact 	Category	Hide Result Content	(3) Help
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	В	С	D E	F	G		н		1 2	Flows	s 🗶 Impact Methods and Categories	
1 2 Stre 3					Flow Mapping				ocation		nter text to search	ar
4 5 Air			242,66 t/h	Elementary Flow		1				¢	lows (pTesting_ecoinvent_3_8_LCI) } A:Agriculture, forestry and fishing } B:Mining and quarrying	
6 Pyre 7	o Phase	N2(g)	242,66 186.14								C:Manufacturing	
8		O2(g)	56,52								D:Electricity, gas, steam and air conditioning supply E:Water supply; sewerage, waste management and re	
9		(6/									F: Construction	emed
10 11 Hea	at		81500,48 kW	Elementary Flow						ŧ	G:Wholesale and retail trade; repair of motor vehicles H:Transportation and storage	and .
12 Ene 13 14	ergy	Heat	81500,48								 I:Accommodation and food service activities J:Information and communication M:Professional, scientific and technical activities 	
15	matite Pellets		200.00 t/h	Elementary Flow		-				Ē	 N:Administrative and support service activities S:Other service activities 	
and the second	ro Phase		200,00 t/n	Elementary How	·						Elementary flows	
18		Fe2O3	183,00									
19		SIO2	13,00									
20		MnO2	2,30									
21		P2O5	0,20									
22		Al2O3 CaO	0,50 0.50									
23		MgO	0,50									
25		IN BO	0,50									
										1		

Fig 9. Input streams and their contents for the Iron Process.

The stream content can be hidden by pressing the <u>Hide Stream Content</u> button from the toolbar. The button will hide/show the stream contents both from the Inputs and Outputs sheets at the same time. If the stream content is hidden, then only the stream name row is displayed (**Fig 10**).

LCA									
LCA penLCA	Add Manual Stream Delete Manual Stream	Show Stream Content	Convert Stream to Indicators	Rename C	stom Sheet ustom Sheet	Import External Sheet Export to Excel	 Add Mapping Delete Mapping 	 Add Impact Cate Delete Impact C 	Category Hide Result Save Results to Custom sheet Help
Modes	1	Streams		Custom	Sheets	External Sheet	Mapping	Calculation Meth	
22	~				-				Flows and Methods
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1 2 Stre 3	eam	Amount U	nits LCA Flowtype	Flow Mappi	ng Provide	er	Lo	ocation	Enter text to search Find Clear Flows (pTesting_ecoinvent_3.8.LCt)
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.0 .1 Hea	at	81500,48 k	W Elementary Flow	~					C:Manufacturing D:Electricity, gas, steam and air conditioning supply
5 6 Hen	natite Pellets	200,00 t/	'h Elementary Flow	~					E:Water supply; sewerage, waste management and remedi.
6 7 Cok	æ	50,00 t/	'h Elementary Flow	~					G:Wholesale and retail trade; repair of motor vehicles and H:Transportation and storage
4 5 Lime	iestone	30,42 t/	'h Elementary Flow	~					 I:Accommodation and food service activities I:Information and communication
) 1 Stee	el Scrap	1,87 t/	h Elementary Flow	~					M:Professional, scientific and technical activities N:Administrative and support service activities S:Other service activities
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3									
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0	H Inputs / Outputs / Resu				<			×	

Fig 10. Input stream contents hidden.

NOTE! No intermediate streams are shown in the sheets, as only streams that can interact with the environment are used in LCA calculations.

49.4.4. Adding manual streams

Sometimes, during LCI compilation in HSC Sim, some missing streams may be identified. The best and recommended way is to add missing streams directly to the process simulation model. This typically would include all fugitive emissions, additional power, leakages from the system, etc. In some cases, it is also appropriate to add



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streams for LCA purposes only. Adding these is done by pressing the <u>Add Manual</u> <u>Stream</u> from the toolbar, which will create new manual stream on bottom of the automatic streams either on the Inputs or Outputs sheet, depending which one is open. **Fig 11** shows adding manual streams to the Inputs sheets.

LCa penLCA	Add Manual Stream Delete Manual Stream	Show Stre			tream to Indicators ndicators back to Stream	Add Custom Sheet	Import External Sheet Export to Excel	Add Mapping Delete Mapping	Add Impact Cat Delete Impact (2.2	Mide Result	Calculate Results	et Helo
•	Uelete Mariual Stream	Conten		sivert t	nuicators back to Stream	Rename Custom Sheet		-	-	-	Content	-	
Modes	h	5	Streams			Custom Sheets	External Sheet	Mapping	Calculation Met	hods		Results	Info
54	Add Manual Stream										nd Methods		
	В	С	D	E	F	G	н	6	1 ^	Flows	× Impact N	Methods and Categories	
L 2 Stre						Flow Mapping			Location	Ente	er text to searc	th • Find	Clear
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	Blast		242.66	5 t/h	Elementary Flow	~						forestry and fishing	
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Hea	t		81500,48	8 kW	Elementary Flow	~				Ē	D:Electricity, ga	as, steam and air conditioning sup	
i Her	natite Pellets		200.00	a t/h	Elementary Flow	~					E:Water supply E:Construction	y; sewerage, waste management a	and remed
5 THEI	latite Pellets		200,00	, (J.I.								nd retail trade; repair of motor vel	ides and
7 Cok	e		50,00) t/h	Elementary Flow	~						on and storage	
1 5 Lim												ion and food service activities and communication	
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	el Scrap		1,87	/ t/h	Elementary Flow	~					N:Administrativ S:Other service	ve and support service activities	
B											Elementary flow		
9 Red	uctant		16,00) t/h	Elementary Flow	~							
	anual Input Stream>				Elementary Flow	~							
5													
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7 8													
9													
0									J				

Fig 11. Adding manual streams to the Inputs sheet.

The manually inserted stream can be deleted on the <u>Delete Manual Stream</u> button. To be able to delete specific stream, the manual stream row needs to be selected (

LCA													-	a x
openLCA Modes	Add Manual Stream Delete Manual Stream	Show Str Conte	eam 🔟 d		ream to Indicators dicators back to Stream	Add Custo Delete Cu Rename C Custom	stom Sheet Custom Sheet	Import External Sheet	Add Mapping Delete Mapping Mapping	Add Impact Cate Delete Impact Ca Calculation Meth	stegory H	ide Result Content Results to Cust Results	om sheet	Help Info
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4 5 Air 10	Blast		242,6	i6 t/h	Elementary Flow	~					A:A	(pTesting_ecoinvent_3_8_LCI) Igriculture, forestry and fishing lining and quarrying		
11 He	at		81500,4	18 kW	Elementary Flow	~						fanufacturing fectricity, gas, steam and air conditioni	na supoly	
15 16 He	matite Pellets		200,0	10 t/h	Elementary Flow	~					E:W	Vater supply; sewerage, waste manage ionstruction		emedi
26 27 Col	æ		50,0	10 t/h	Elementary Flow	~					H:Tr	Vholesale and retail trade; repair of mo ransportation and storage commodation and food service activiti		and
_	iestone		30,4	2 t/h	Elementary Flow	~					j:In	ccommodation and food service activitie nformation and communication Professional, scientific and technical act		
	el Scrap		1,8	17 t/h	Elementary Flow	~					N:A	idministrative and support service activ ther service activities		
48 49 Re d	luctant		16,0	10 t/h	Elementary Flow	~						mentary flows		
53 54 <m< th=""><td>anual Input Stream></td><td></td><td>_</td><td>1</td><td>Elementary Flow</td><td>~</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></m<>	anual Input Stream>		_	1	Elementary Flow	~								
55 56 <m< th=""><th>anual Input Stream></th><th></th><th></th><th></th><th>Elementary Flow</th><th>~</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></m<>	anual Input Stream>				Elementary Flow	~								
57 58 59 60					-									
64	Inputs Outputs Resu	lts /					<			> ×				

Fig 12). If manual stream name row is not selected, window with error message "Manual stream is not selected" will pop up.

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LCA													(_ 0
LCa penLCA Modes	Add Manual Stream Delete Manual Stream	Show Si Conti	tream		ream to Indicators dicators back to Stream	Add Custor	tom Sheet istom Sheet	import External Sheet	Add Mapping Delete Mapping Mapping	Add Impact Cat Delete Impact C Calculation Meth	Category	Hide Result Content	Calculate Results	eet Help
54	Delete Manual Stream	1									Flows an	nd Methods		
	В	с	D	E	F		G	н	1	1 ^	Flows	× Impact N	fethods and Categories	
Stre					LCA Flowtype	Flow	Mapping I			Location	Ente	er text to searc	h • Find	Clear
Air I	Blast		242,0	56 t/h	Elementary Flow	~						A:Agriculture, f B:Mining and qu		
Hea	t		81500,4	18 kW	Elementary Flow	~						C:Manufacturin D:Electricity, ga	ng as, steam and air conditioning su	pply
Hen	natite Pellets		200,0	00 t/h	Elementary Flow	~						E:Water supply E:Construction	; sewerage, waste management	and remedi.
i 7 Cok	e		50,0	00 t/h	Elementary Flow	~					(e) I	I:Transportatio	nd retail trade; repair of motor ve on and storage	ehides and
Lim	estone		30,4	12 t/h	Elementary Flow	~					ē.	I:Information a	on and food service activities and communication , scientific and technical activities	
Stee	el Scrap		1,8	37 t/h	Elementary Flow	~					ē,		e and support service activities	
B Red	uctant		16,0	00 t/h	Elementary Flow	~						Sother service Elementary flow		
<ma< td=""><td>anual Input Stream></td><td></td><td></td><td>1</td><td>Elementary Flow</td><td>~</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></ma<>	anual Input Stream>			1	Elementary Flow	~								
	anual Input Stream>				Elementary Flow	Ý								
0	Inputs / Outputs / Resu	ilts /					<			~				

Fig 12. Deleting manual stream.

To be able to utilize the manual streams in the evaluation, amounts and units need to be added to the stream. Manual streams can also be named, and this is highly recommended as the interpretation of results can get complicated if there are several manual streams with same name. Adding the name, amounts, and units is easy – just write it on the cells. The current possible units to be used are t/h for mass and kW or MJ for energy. Examples of ready set manual stream is shown in Fig 13. It is also possible to use cell references in the manual streams.

Extra electricity 10000,00 kW Elementary Flow	Extra electricity 10000,00 kW	Elementary Flow	

Fig 13. Manual stream with name, amount and unit inserted.

49.4.5. Converting streams to indicators

By converting streams to indicators, it is possible to examine how much of the single stream species affect the LCA results. This is especially useful if no LCA equivalent is found in the database for the stream, but for the species is. For an example, **Fig 14** shows Furnace Gas in the output sheet with complex composition in the Iron Process. It is impossible to find LCA equivalent for this kind of stream in the databases, but it is possible to find for the equivalents for CO(g) CO2(g), H2O(g) etc. species.

1			CONTRACTOR OF THE		
2	Stream	Amount Unit	s LCA Flowtype	Flow Mapping Provider	Location
3					
4				the second s	
5	Furnace Gas	367,11 t/h	Elementary Flow		
6	Pyro Phase	367,11			
7	CO(g)	64,50			
8	CO2(g)	101,34			
9	H2(g)	1,66			
10	H2O(g)	9,92			
11	SO2(g)	0,16			
12	N2(g)	186,14			
12 13	O2(g)	3,38			
14					

Fig 14. Furnace Gas stream in Iron Process.

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Converting streams to indicators happen by selecting the stream row and then pressing the <u>Convert Stream to Indicators</u> button (**Fig 15**). The button will be disabled if something else than the stream row is selected (e.g., manual stream row – they cannot be converted to indicators).

LCA															-	
openLC/	A 😑 Del	i Manual St	Stream Hid	Stream ontent	Convert Stream to Indicators back		Add Custom She Delete Custom S Rename Custom Custom Sheet	Sheet Sheet Sheet	Add Mapping Delete Mapping Mapping	Add Impact Cate Delete Impact C Calculation Meth	Category	Hide Resu Content	it 🕞 Save F	Results to Custom	n sheet	Help
G5		~			Convert Stream to Indic	ators					Flows	and Metho	ds			
	В	с	D	E	F		G	н		Τ ^	Flow	s 🛪 Impa	ct Methods and	d Categories		
1 2 5t 3	tream		Amount	Units	LCA Flowtype	Flow	Mapping Provide	r	Location	,		nter text to s	sarch g ecoinvent 3	 Find 8 LCI) 	Ck	lear
5 FL	urnace Ga	5	367,11		Elementary Flow	~					G		e, forestry and			
6 P) 7	yro Phase	CO(g)	367,11 64,50									C:Manufac		nd air conditionin	a sunaly	
8		CO2(g) H2(g)	101,34								6	E:Water su	oply; sewerage	, waste manager		remedi
10		H2(g) H2O(g)									G		e and retail tra	de; repair of mot	or vehicle:	s and
11 12		SO2(g) N2(g)	0,10 186,14										tation and store	age d service activitie:	s	
13		O2(g)	3,38										on and commun	nication nd technical activ	rities	
14				_		_								ort service activit		

Fig 15. Converting stream to indicators.

Indicators can be converted back to normal streams by selecting the indicator row and pressing the <u>Converting Indicators back to Stream</u> (**Fig 16**). Again, the button will be disabled if correct row is not selected.

LCA														_] [
openLCA Modes	-	i Manual Str	tream Hide	Stream ontent Strea	Convert Stream to Ir		Add Custom Sheet Custom Sheet Custom Sheet Custom Sheets Custom Sheets	Import External Sheet Export to Excel External Sheet	Add Mapping Delete Mapping Mapping	Add Impact Ca Delete Impact Calculation Me	Category	Mide Result Content	Calculate Results	t F	() Help
G7		~			Convert Indicators b	ack to Stream					Flows	and Method	5		1
	В	С	D	E	F		G	н		I Т /	Flows	× Impac	t Methods and Categories		
3 4	ream		Amount 367,11		LCA Flowtype	Flow N	Napping Provider		Location	1	🖃 Fl		ecoinvent_3_8_LCI) , forestry and fishing	Clear	
-	ro Phase		367,11									B:Mining and			
7		CO(g)	64,50	i	Elementary Flow	~					1 7	C:Manufactu	ring gas, steam and air conditioning sup;	N	
8		CO2(g)	101,34	l,	Elementary Flow	~							oly; sewerage, waste management a		medi
9		H2(g)	1,66		Elementary Flow	~					¢	F:Constructio	n		
LO		H2O(g)	9,92	5	Elementary Flow	~					¢	G:Wholesale	and retail trade; repair of motor veh	ides ar	ind
1		SO2(g)	0,16		Elementary Flow	\sim							tion and storage		
.2		N2(g)	186,14	le l	Elementary Flow	~							ation and food service activities		
13		O2(g)	3,38		Elementary Flow	~					4		and communication		
14													al, scientific and technical activities		

Fig 16. Converting indicators back to normal stream.

If the stream or indicator has already flow mapping, then when trying to convert it, error message will pop up and indicate that flow mapping will be lost if conversion is done.

49.4.6. Adding and deleting custom sheets

It is possible to add custom sheets to the tool. This can be beneficial if some additional calculations are needed to be performed, for an example, to calculate manual stream amounts from other streams.

Adding custom sheets happens by pressing the <u>Add Custom Sheet</u> button (**Fig 17**). The created sheet can be deleted by opening the sheet and then pressing the <u>Delete Custom</u> <u>Sheet</u> button (**Fig 18**). If there are some data on the sheet, all of it will be deleted.

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Sim LCA													
openLCA	🚯 Add Mani	ual Stream anual Stream	Content	Co	nvert Stream to Indicators nvert Indicators back to Stream	Add Custom Sheet Custom Sheet Rename Custom Sheet	 Import External Sheet Export to Excel 	Add Mapping Delete Mapping	Add Impact Cate Delete Impact Cate	itegory	Mide Result Content	Calculate Results	() Help
Modes			Stream	ms		Custom Sheets	External Sheet	Mapping	Calculation Meth			Results	Info
G30	~					Add Custom Sheet					d Methods		.0
	В	С	D	E	F	G		н	^	Flows 3	x Impact!	Nethods and Categories	
1 2 Stre 3	am		Amount	Units	LCA Flowtype	Flow Mapping	Provider		Locatio		text to sear	coinvent 3.8_LCI)	lear
4							4					forestry and fishing	
5 Air I	Blast o Phase		242,66		Elementary Flow					🕑 B:	Mining and q	uarrying	
7	o Phuse	N2(g)	186.14								Manufacturin		
8		O2(g)	56,52									as, steam and air conditioning supply /; sewerage, waste management and	
9											Construction		reneu
10									2			nd retail trade; repair of motor vehicle	es and
11 Hea			81500,48	kW	Elementary Flow V							on and storage	
12 Ener	rgy	12204										on and food service activities and communication	
13 14		Heat	81500,48									, scientific and technical activities	
14												e and support service activities	
	natite Pellet	s	200,00	t/h	Elementary Flow						Other service ementary flor		
17 Pyro	o Phase		200,00								ementary no	15	
18		Fe2O3	183,00										
19		SiO2	13,00										
20		MnO2	2,30										
21 22		P2O5 Al2O3	0,20 0,50										
22		CaO	0,50										
24		MgO	0,50										
25			-/										
	Inputs /0	utnute /Recu	lts /			<			, ×				

Fig 17. Adding custom sheet.

LCa penLCA Modes	Add Mar Delete N	anual Stream Hi	12	Convert Strea	m to Indicators ators back to Stri	eam	Add Custom Sh Delete Custom Rename Custon Custom Shee	Sheet n Sheet	Export to E	Excel	Add Mappin Delete Map Mapping		Add Impact Delete Impa Calculation	act Cate	egory Hide Res Conter	all Calculate Results	neet H	(3) Help
1	~						Delete Custom	sheet						E	lows and Meth	ods		
I I 2 3 4 5 5 6 7 8 9 10 11 12 13 13 15 15 16 17 18 19 20 21 22 22 23 24 24 25		B C		E	F	G				κ		M	N		Finter text to Flows (pTesti A:Agricult BMMining a C:Marufa D:Electrid E:Water s F:Constru G:Wholes H:Transpt I:Accomm J:Informa M:Profess N:Adminis	ng, accivent, 3, 2, L(1) , are, forestry and fairing ind quarrying turing turing turing turing turing and air conditioning group turing and air conditioning turing and air conditioning dation and food service activities for and technical activities that the conditioning and technical activities traities and technical activities traities and technical activities traities and technical activities traities activities activities traities activities activities traities activities activities	nt and rem vehicles ar	medi

Fig 18. Deleting custom sheet.

The custom sheets can be renamed. First the sheet is opened and then pressing the <u>Rename Custom Sheet</u> button is pressed (**Fig 19**). Next, the desired name is written and OK pressed. There cannot be identical sheet names, and the sheet's name cannot start with 'Saved', 'Norm', or 'Ext'.

														Rename Sheet		
ual Stream	ø			m to Indicators		Add Custon		Import E		-	id Mapping		Add Impa	New Sheet Name		
anual Stream	Hide Stream Content	Co	invert Indica	ators back to St	eam [🦻 Rename Cu	stom Sheet	Export to	Excel	i Del	elete Mapping		elete Im			
	Strei	ams				Custom S	neets	Externa	al Sheet	N	lapping	0	alculatio	Example		
						Rename Cust	om Sheet								ОК	Cancel
B	C D)	E	F	G	н	1	J	К	L		M	N			

Fig 19. Renaming custom sheet.

49.4.7. Importing and exporting Excel sheets

It is possible to import and export Excel workbook sheets to/from the LCA Evaluation tool. This feature is intended for the comparison of results from different flowsheets.



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However, the feature can be used for other cases also, for an example, it might be beneficial to do further analysis in Excel with the exported LCA result sheets.

Importing the external sheets happens by pressing the <u>Import External Sheet</u> button (**Fig 20**). Next, the correct file is selected. To be able to import the file, it needs to start with 'LCA_exports' name. Next, the sheets inside the workbook file are selected from the list and the green <u>Apply and close</u> button is pressed. After this the imported sheets need to be renamed.

						Flow	sheetT	ables		X
licators	👍 Add Custom Sheet	Import External Sheet	Add Mapping	Add Impact Category	ø	0	0		Columns	1 🗘
ck to Stream	Delete Custom Sheet	Export to Excel	Delete Mapping	Delete Impact Category	Hide Res Conter	- 11-	Apply a	and close iheet Name		
	Custom Sheets	External Sheet	Mapping	Calculation Methods				Outputs		
		Import External Sheet					\checkmark	Results		
		Import External Sheet		Flows	and Meth			Result Comparison		
	G		н	 Flows 	X Imp	-				
					- Longer					

Fig 20. Importing external sheets.

All the imported sheets will have the 'Ext' in beginning of their name. Deleting (as well as renaming) the imported sheets works the same way as in deleting the custom sheets.

Exporting the sheets to Excel workbook happens by pressing the <u>Export to Excel</u> button (**Fig 21**). Then the file can be saved to desired location. The file name is automatically 'LCA_exports.xlsx'. This will export all the sheets inside the LCA Evaluation tool.

Sin LCA														
	 Add Manual S Delete Manual 		VIII Hide St	~		onvert Stream to Indicators	Add Custom Sheet	Import External Sheet Export to Excel	🚯 Add Mapping	🚯 Add Impact			Mide Re Conter	Sult 🕞 Save Resu
Modes				Strea	ams		Custom Sheets	External Sheet	Mapping	Calculation M	letho	ods		Results
G30	~							Export to Excel				Flows	and Meth	ods
	В	С		D	E	F	G		н		^	Flows	× Imp	pact Methods and Ca
1														

Fig 21. Exporting the sheets to Excel workbook.

49.4.8. Mapping streams to LCA flow equivalents

All the streams to be included in the LCA evaluation must be mapped to the LCA equivalents found in the *Flows* treelist. For default *Flow Mapping* cell in the stream/indicator row is empty, meaning that the stream/indicator will be excluded from the evaluation.

To be able to do the mapping, the stream and LCA equivalent need to be of the same LCA Flowtype. The different types are elementary, product, waste, or reference flows. These types describe the origin or destination of the stream from the process. The origin/destination can either be from/to the nature (elementary flow) or from/to the technosphere, i.e., from/to other processes (product/waste flow). The reference flow is the main product of the process, the results are calculated based on this.

The type for the stream is selected from the drop-down menu (**Fig 22**). At default the type is elementary. The flowtypes differ by Product and Waste Flow for the input and output streams.

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Stream		Amount Units	LCA Flowtype	Flow Mapping	Stream	<u>, с</u> ,	Amount	Units	LCA Flowtype	Flow Mapping
Air Blast		242,66 t/h	Elementary Flow 🗸		Furnace Gas		367,11			
Pyro Phase	N2(g) O2(g)	105.14	Elementary Flow Product Flow Reference Flow(s) (Product)		Pyro Phase	CO(g) CO2(g) H2(g) H2O(g)	367,11 64,50 101,34 1,66 9,92		Elementary Flow Elementary Flow Waste Flow Reference Flow(s) (Product) Elementary Flow	

Fig 22. Different LCA flowtypes for input and output streams.

The flowtype for the LCA Equivalent is shown with initial before the name of the flow in the *Flows* tree list data (**Fig 23**).

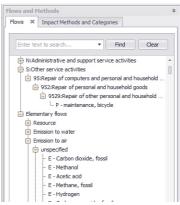


Fig 23. P for product flow, E for elementary flow.

The different flowtypes are summarized in Table 2.

	Elementary Flow	Elementary Flow	Product Flow	Waste Flow	Reference Flow (Product)	Reference Flow (Product)
Stream	Input	Output	Input	Output	Input	Output
Origin / Destinatio n Initial in	From the nature	To the nature F	From another process P	To another process W		_
Flows	-	-	•	•••		
Note					Results calcu on this. Can only be process	llated based

Table 2. LCA flowtypes summarized.

The flow mapping starts by selecting the correct flowtype for the stream (**Fig 22**). Next, the correct LCA Equivalent with the same flowtype is chosen from the *Flows*. The LCA Equivalent can be selected either by expanding the different nodes and looking for the correct flow under the categories, or directly searching with possible name in the search box and pressing enter or Find (**Fig 24**). After searching, the nodes need to be expanded.

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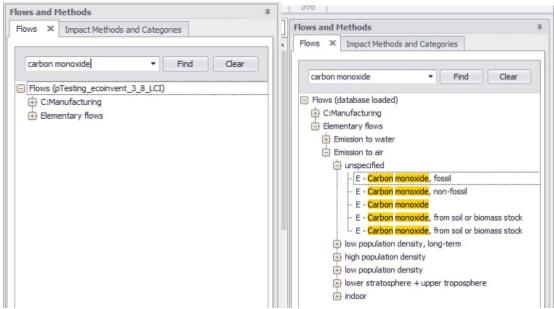


Fig 24. Search specific flow by writing name or part of into the search box.

After finding suitable LCA equivalent, mapping is done by selecting the stream/indicator row and then double-clicking the node or clicking the flow node and then pressing the <u>Add Mapping</u> (**Fig 25**).

dd Manual Stre elete Manual S	- <i>\P</i>	 Convert Stream to I Convert Indicators I 		Add Custom	om Sheet	Import External Sheet Export to Excel	Add Mapping Delete Mapping	Add Impact Ca Delete Impact		Hide Result Content Gave Results to Custom s	sheet	() +
	St	reams		Custom Sh	eets	External Sheet	Mapping	Calculation Me	thods	Results		.1
~							Add Mapping		Flows	and Methods		
С	D E	F		G		н		I T ^	Flows	Impact Methods and Categories		
		s LCA Flowtype	Flow	Mapping Provi	ider		Locatio	n	E FI	arbon monoxide Find Flows (pTesting_ecoinvent_3_8_LCI) C:Manufacturing	Clea	tar
5	367,11 t/h 367,11								Ē	Elementary flows		
CO(g)	64,50	Elementary Flow	~							Emission to soil		
CO2(g)	101,34	Elementary Flow	~	i						Emission to water Emission to air		
H2(g)	1,66	Elementary Flow	~							indoor		
H2O(g)	9,92	Elementary Flow	~							high population density		
SO2(g)	0,16	Elementary Flow	~							inspecified		
N2(g)	186,14	Elementary Flow	~							E - Carbon monoxide, fossi		
O2(g)	3,38	Elementary Flow	~							- E - Carbon monoxide, non-fossi		
		N								 E - Carbon monoxide, land transform E - Carbon monoxide, biogenic 	nation	
										E - Carbon monoxide		
	2,05 t/h	Elementary Flow	~							E - Carbon monoxide, from soil or b	iomass str	too
	2,05									low population density		
CaO	0,17									lower stratosphere + upper troposphe	re	
SiO2	0,16									🗄 low population density, long-term		
Al2O3	0,02											

Fig 25. Adding new flow mapping.

Metso

Besides the LCA flowtypes, the unit of the stream/indicator must be the same as for the LCA equivalent. Now only **kW**, **MJ**, and **t/h** are supported for the streams. If the units are different error message will pop-up.

For elementary flow mapping it is just enough to add new mapping. However, for the product and waste flows, providers and locations need to be selected also. This happens by selecting the correct provider from the drop-down menu next to the flow mapping (**Fig 26**). The selection can also be done based on the location. Changing the location/provider will change the other one automatically. Most of the locations are in two letter abbreviations, however; depending on the original database, there might be some additional abbreviations.

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13		Heat	81500,48				Þ
14							0
15							
16	Hematite Pellets		200,00 t/h	Product Flow	 iron ore, beneficiated, 6 	55% Fe No provider V No locatic V	
17	Pyro Phase		200,00			No provider	
18		Fe2O3	183,00			iron ore beneficiation to 65% Fe iron ore, beneficiated, 65% Fe iron mine operation and iron ore beneficiation to 65% Fe iron ore	(⊕ 08:
19		SIO2	13,00			market for iron ore, beneficiated, 65% Fe iron ore, beneficiated,	÷ 09:1
20		MnO2	2,30				C:Man
21		P2O5	0,20				D:Elect
22		AI203	0,50				E:Wate
23		CaO	0.50				F:Cons

Fig 26. Selecting provider for the flow based on the provider's name.

If there are more than 15 providers, then the location needs to be selected first. In this case, the provider drop-down menu will only show the providers in that location (**Fig 27**).

53								
54	Extra electricity	10000,00 kW	Product Flow	 electricity, high v 	oltage		No location V	
55							No location	^
56							AE	
57							AM	
58							AO	
59							AT	
60							AU	
61								
49 49	Reductant	16,00 t/h	Elementary Flow	~				
53	Neutrant	10,00 (/11	Dementary now	•				
	Extra electricity	10000,00 kW	Product Flow	 electricity, high voltage 	No provider	~ AE	~	
55					No provider			
56					market for electricity, high voltage electricity, high voltage, production mix			
57					electricity, high voltage, production mix electricity, high voltage, import from SA			
58					electricity, high voltage, import from OM			
59								

Fig 27. If there are more than 15 providers, location needs to be selected first.

The flow mapping can be deleted by selecting the stream name row and then pressing the <u>Delete Mapping</u> (**Fig 28**).

LC	4									
LC2 openL			Show Stream Content		onvert Stream to Indicators onvert Indicators back to Stream	Add Custom Sheet Custom Sheet Rename Custom Sheet	Import External Sheet	Add Mapping Delete Mapping	 Add Impact Category Delete Impact Category 	Hide Result Content
Mode	25		Strea	ms		Custom Sheets	External Sheet	Mapping	Calculation Methods	
G54	~ ele	ctricity, hig	h voltage					Delete Mapping		
	В	С	D	E	F	G		н	1	T
48										
49	Reductant 16,00		t/h	Elementary Flow 🗸						
53										
54	Extra electricity		10000,00	kW	Product Flow 🗸	electricity, high voltage	market for electricity, high vo	Itage	✓ AE	
55					.					

Fig 28. Deleting flow mapping.

For every process the main product i.e., Reference Flow (Product) needs to be selected. Main product is not mapped.

49.4.9. Selecting impact methods and categories for calculation

The third sheet, <u>Results</u>, which is inherently empty (**Fig 29**), will eventually show the LCA results. Before calculating the results, the impact method and categories need to be selected. The results will be calculated based on the selected method. All the methods available in the database for calculation are in the *Methods* tree list. By expanding the different nodes in the tree list the methods and categories under these can be seen. Searching methods/categories works the same way as searching for the flows.

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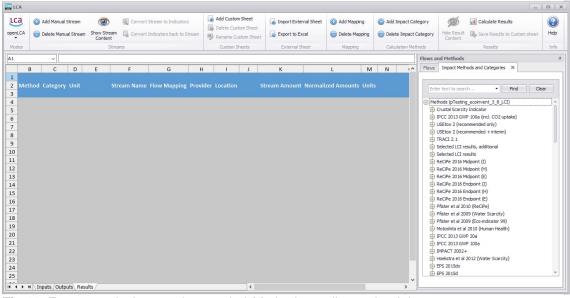


Fig 29. Empty result sheet and expanded Methods tree list on the right.

Selecting the impact methods and categories happens similarly as for the selecting the flows, i.e., selecting the correct node and then pressing the <u>Add impact category</u> button as (**Fig 30**) or double-clicking the node. It is possible only select categories inside the same impact method.

n Show Stream Gontent	Convert Stream to Indicators	Rename Custom Sheet	Import External Sheet Export to Excel	Add Mapping Delete Mapping	Add Impact Category Delete Impact Category	Content *	Hel
Streams		Custom Sheets	External Sheet	Mapping	Calculation Methods Add Impact Category	Results	Inf
C	DE	F G	н	J K	A Flow		
Category		tream Name Flow Mappi	ng Provider Location	Stream Ame	ount Normali.	nter text to search	ar
						} ei - ReCiPe Midpoint (I) } ei - ReCiPe Midpoint (I) V1.13	

Fig 30. Selecting impact category.

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If too many impact categories are added to the sheet, extra ones can be deleted by selecting the impact category name row and pressing <u>Delete impact category</u> button (**Fig 31**).

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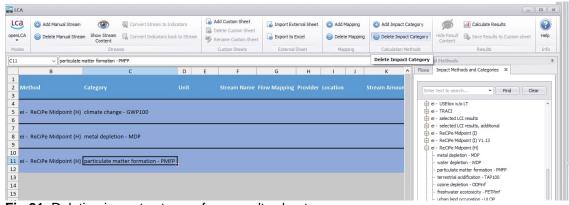


Fig 31. Deleting impact category from results sheet.

49.4.10. Calculating results

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In the result calculation all the stream information (amounts, units, flow types and mappings) will be inserted into the database in the openLCA as a process. Also, a product system is created from the process. Then, the results are calculated using either the product system or the process (depending on whether the database is unit or system). The results are calculated based on the impact method selected to the result sheet. Finally, the results are sent back to HSC Sim where they are displayed in the result sheet.

The calculation of results can be started by pressing the <u>Calculate Results</u> button in the toolbar (**Fig 32**). Error windows will pop-up if not all necessary steps for result calculation have been done. These are selecting providers for product and waste flows, choosing reference flow as well as selecting the impact methods and categories. The result calculation might take some time, depending on the size of the process and size of the database.

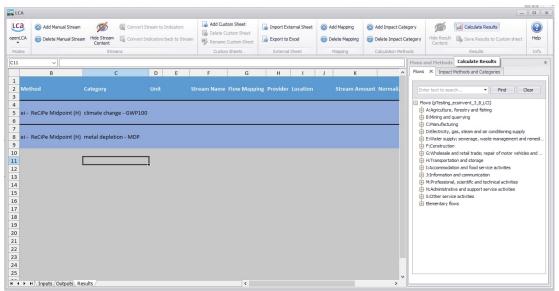


Fig 32. Calculating results.

Calculated results for the Iron Process example are shown in Fig 33 and Fig 34.

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LCA												-
	enLCA Convert Indicators back to Stream Content		Delete Custom Sheet			Add Impact C Delete Impac		~ -				
Modes		Stream	IS		Custom Sheets	External Sheet	Mapping	Calculation M	lethods		Results	Info
133	~								Flows and	Methods		
	с	D	E	F	G		н	1 ^	Flows 3	K Impact Me	thods and Categories	
1 2 Cate 3	egory	Unit		Stream Name	Flow Mapping	Provider		Locatic	100	text to search. (pTesting_eco		ar
	ate change - GWP100										estry and fishing	
6		Blast Furnace								Mining and qua Manufacturing	rrying	
7			Inputs								, steam and air conditioning supply	
8 9 10				Coke Steel Scrap Hematite Pellets Limestone	petroleum coke steel, low-alloyed pig iron lime, hydrated, loose weigl	market for petrole market for steel, le market for pig iror it lime production, h	ow-alloyed า	GLO GLO RoW ht RoW	€ F: € G: € H:	Construction Wholesale and Transportation		
12 13 14 15				CO(g) CO2(g) SO2(g) Pig Iron	Carbon monoxide, fossil Carbon dioxide, fossil Sulfur dioxide				9 3: 9 M 9 N 9 S 5	information and Professional, s Administrative Other service a		
17		Manual Strea		rig non					(€) Ek	mentary flows		
.8			Inputs	Extra electricity	electricity, high voltage	market group for	electricity, high volt	are GLO				
20				entra creetherty	cicculary, ingit voltage	market Broup for a	cicconterty, tilgit voit	APC OLD				
21												
22 met	al depletion - MDP											
23		Blast Furnace	Ě									
24			Inputs									
25				Coke	petroleum coke	market for petrole		GLO				
20	H Inputs Outputs Res			ai 1.a				~~~~				

Fig 33. Results displayed.

1									and the second
Unit		Stream Name	Flow Mapping	Provider	Location	Stream Amount Normaliz	ed Amounts Units	Norr	malized Results Units
								Total	16883,27 kg CO2-Eq per t/h of Pig Iron
Blast Furnace								Total	3419,04
	Inputs							Total	2685,82
		Coke	petroleum coke	market for petroleum coke	GLO	50,00	0,36 t/h		136,60
		Steel Scrap	steel, low-alloyed	market for steel, low-alloyed	GLO	1,87	0,01 t/h		25,57
		Hematite Pellets	pig iron	market for pig iron	RoW	200,00	1,45 t/h		2326,72
		Limestone	lime, hydrated, loose weight	lime production, hydrated, loose weight	RoW	30,42	0,22 t/h		196,93
	Output	5						Total	733,22
		CO(g)	Carbon monoxide, fossil			64,50	0,47 t/h		0,00
		CO2(g)	Carbon dioxide, fossil			101,34	0,73 t/h		733,22
		SO2(g)	Sulfur dioxide			0,16	0,00 t/h		0,00
		Pig Iron				138,22	1,00 t/h		
Manual Stream	5							Total	13464,22
	Inputs							Total	13464,22
		Extra electricity	electricity, high voltage	market group for electricity, high voltage	GLO	10000,00	72,35 kW		13464,22

Fig 34. Results for the climate change category.

As from the above figures can be seen, the result sheet shows the total contribution to the different categories, as well as the unit (as well as both inputs and outputs streams of that unit specified) specific contributions to that category. Also, the individual contributions of each stream to the specific category can be seen. All these results are normalized based on the reference flow. For that reason, the unit of the normalized results is defined by reference flow. In this example, the unit for the climate change is 'kg CO2-eq per t/h of Pig Iron'.

In addition to the normalized results, the result sheet shows the flow mappings and possible provider and location for the stream. The original stream amount as well as normalized stream amount is also shown. The normalized stream amount unit is defined also by the reference flow as in the results. However, for simplicity, this unit is not shown in the result sheet.

The results details can be hidden in the Result sheet, similarly as the stream content can be hidden. This happens by pressing the <u>Hide Result Content</u> from the toolbar. The details can be again shown by pressing the <u>Show Result Content</u> button. Hidden results for the Iron Process are shown in **Fig 35**.

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																-		
LCa	🚯 Add Manual Stream	TO	🖏 Convert Strea	m to Indicato	rs	10000	Custom Sheet		rt External Sheet	Add Mapping	Add Impact Category	0	all.	Calculate	Results	2		
openLCA	Delete Manual Stream	Hide Stream Content	Convert India	itors back to	Stream		te Custom Sheet ame Custom Shee		rt to Excel	Delete Mapping	Delete Impact Category	Show Resi Content		Save Res	ults to Custom sheet	Help		
Modes		Strea	ams				stom Sheets	Ext	ernal Sheet	Mapping	Calculation Methods			Results		Info		
к40	~																	
	В	(2	DE		F	G	н	T	J K	L	M	N	0	р		Q	V
1																		
			U	nit			e Flow Mapp	ing Provid	er Location	Stream Amo	ount Normalized Amount	s Units		N	ormalized Results	Units		
	thod (Category	U	nit	Stro	am Nam	e Flow Mapp	ing Provid	er Location	Stream Amo	ount Normalized Amount	s Units		N	ormalized Results	Units		
2 Me	ethod (Category	U	nit	Stro	am Nam	e Flow Mapp	ing Provid	er Location	Stream Amo	ount Normalized Amount	s Units		N	ormalized Results	Units		
2 Me 3 4	thod .			nit	Stre	am Nam	e Flow Mapp	ing Provid	er Location	Stream Amo	ount Normalized Amount	s Units		Ni Total			-Eq per t/h of Pig Irc	on
2 Mo 3 4				nit	Stre	am Nam	e Flow Mapp	ing Provid	er Location	Stream Amo	ount Normalized Amount	s Units					-Eq per t/h of Pig Irc	on

Fig 35. Hidden results for the Iron Process.

49.4.11. Automatic update of the result sheets

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The result sheet is updated automatically if the values of the streams (which have flow mappings i.e., are included in the result calculation) in the input or output sheets change. This makes it possible to calculate results at the same while running the simulations. At this point, the gRPC connection to the openLCA does not need to be open anymore.

However, if some other information is changed, for an example flow mapping for a stream or totally new stream is added, these are not added to the results automatically. In this case, the results need to be calculated again, otherwise there will be old process in the result sheet. Changing, adding, or deleting impact categories will delete all the old results.

49.4.12. Saving results to custom sheets

It is possible to save the snapshot of the results into a custom sheet. This can be useful if the original results are needed later or if the results will be compared later with other results. Saving results to custom sheets happens by pressing the <u>Save Results to</u> <u>Custom Sheet</u> button (**Fig 36**).

External Sheet Mapping Calculation Methods Results Info	
Save Results to Custom sheet	

Fig 36. Saving results to custom sheet.

All the saved results sheets will have the 'Saved' in beginning of their name. Deleting as well as renaming the saved result sheets happens similarly as with the custom sheets.

49.4.13. Further analysis in openLCA

After results have been calculated in HSC Sim, the process and product system created in openLCA can be used to further analyse the example.

First, whenever something is done in HSC Sim side, the database in openLCA needs to be refreshed. Refreshing happens by clicking the three dots in the left side of the navigation bar and the selecting the <u>Refresh</u> (**Fig 37**).

Emilia Nuppumäki, Matti Peltomäki, Markus Reuter, Susanna Horn September 5, 2023 File Database Tools Help Navigation Navigation Convent33, cut, cff, LCI Convent33, cut, cff, LQI Convent33, cut, cff, LQI Convent33, cut, cff, LQI Convent34, cut, cut, LQI Convent34, cut, cut, LQI Convent34, cut, cut, LQI Convent34, conseq, LQI Convent34, cutoff, LQI Convent34, cutoff, LQI Convent34, cutoff, LQI Convent35, LGI Convent33, Cutoff, LQI Convent34, CUtoff, LQI CONVENT344, CUtof 😫 🖇 🗁 🗖 🏦 Welcome 🗙 E Navigation 😩 Link with Editor The open source software for sustainability assessment. C Refresh For modeling the life cycle of things. opentca Licenced under the Mozilla Public Licence 2.0. Created and maintained since 2006 by GreenDelta, Berlin 2.0.0.alpha3 (Windows amd64) an make the calculation in openLCA faster. Learn mo Start an IPC Serve Port 8080 What is new in openLCA Start as gRPC service (experimental) The IPC server is running. Click on the 'stop' button or close this dialog to stop it. **Getting started** Close Manuals. case studies and data >

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Fig 37. Refreshing the database.

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For this example, under the *Product systems* and *Processes* three new processes (one for the main process and two for the unit processes) and one new product system have been added (**Fig 38**, **Fig 39**, **Fig 40**). The main process connects all the unit processes together. The unit processes are units of the HSC Sim flowsheet. Product system is created from the main process.

puts/Outputs: LCA Proc	ess 2022-03-28 14:15										
Inputs										C	× 1.2
Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided waste	Provider	Data quality ent	Location	Description	
F. Blast Furnace Reference Flow	new category	1.00000	📖 kg		none		P Blast Furna				
Re Manual Streams Reference Flow	v new category	1.00000	📟 kg		none		P Manual Stre				
Dutputs										C	×
Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided product	Provider	Data quality ent	Location	Description	
Fe Pig Iron	new category	1.38217E5	m kg		none						

Inputs/Outputs: Blast Furn	ace 2022-03-28 14:14						Inputs/Outputs: Manual St	reams 2022-03-28 14:15						
• Inputs							- Inputs							
Flow	Category	Amount Unit	Costs/Revenues	Uncertainty	Avoided warte	Provider C	 mputs 							
Ee lime, hydrated, loose weight	222Manufacture of non-metallic	1.0422464 📼 kg		0006		P Ime produce	Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided waste	Provider
Er petroleum coke	182Manufacture of refined petrol.	5.00000E4 📼 kg		none		P market for								
Er pig ison	241:Manufacture of basic iron an	2.00000E5 📼 kg		none		P market for	Fe electricity, high voltage	351:Electric power generation, tra	3.60000E4	- M)		none		P market g
Er steel, low-alloyed	241:Manufacture of basic iron an	1866.43383 📼 kg		note		P market for s								
• Outputs							* Outputs							
Bow	Category	Amount Unit	Cests/Revenues	Uncertainty	Avoided product	Provider E								
Ex Blast Farnace Reference Flow	new category	1.00000 == kg		none			Flow	Category	Amount	Unit	Costs/Revenues	Decetaiota	Avoided product	Brouider
Fe Carlson dioxide, fossil	Emission to ain/unspecified	1.01344E5 📼 kg		nose									Arcideo produce	Providen
Fe Carbon monoxide, fossil	Emission to air/unspecified	6.4500854 📼 kg		0006			Er Manual Streams Reference FL.	new category	1.00000	🚥 kg		none		
Fe Sulfur dioxide	Emission to air/unspecified	163.78198 📼 kg		nore										

Fig 39. The unit processes.

Emilia Nuppumäki, Matti Peltomäki, Markus Reuter, Susanna Horn September 5, 2023 P Blast Furnace 2022-03-28 14:... P Manual Streams 2022-03-28 14:... *LCA Process 2022-03-28 14:... × P LCA Process 2022-03-28 14:... P market for steel, low-alloved I ... P market for pig iron | pig iron | ... ۰ P market for petroleum coke | p... Blast Furnace 2022-03-28 14:14 P lime production, hydrated, loo... Ð LCA Process 2022-03-28 14:15 P market group for electricity, hi... Manual Streams 2022-03-28 1...

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Fig 40. Produt system based on the main process.

49.5. Bibliography

Metso

- 1. E. Worrell and M.A. Reuter (2014): Handbook of Recycling, Elsevier BV, Amsterdam, 595p. (ISBN 978-0-12-396459-5).
- 2. SFS-EN ISO 14044
- 3. SFS-EN ISO 14040
- 4. J. Gediga, Life-Cycle Assessment, pp. 555-562, In: E. Worrell and M.A. Reuter (2014): Handbook of Recycling, Elsevier BV, Amsterdam, 595p.
- 5. GaBi Paper Clip tutorial, Handbook for Lifecycle Assessment, Using the GaBi software, <u>http://tutorials.gabi-software.com/</u>
- 6. Markus A. Reuter, Antoinette van Schaik and Johannes Gediga, Int J Life Cycle Assess (2015) 20:671-693.
- 7. Thomas E. Graedel, Markus Reuter, "Metal Recycling: Opportunities, Limits, Infrastructure," United Nations Environmental Protection (UNEP), 2013.