GreenDelta

sustainability consulting + software

Adapting LCA software to LCI databases and vice versa

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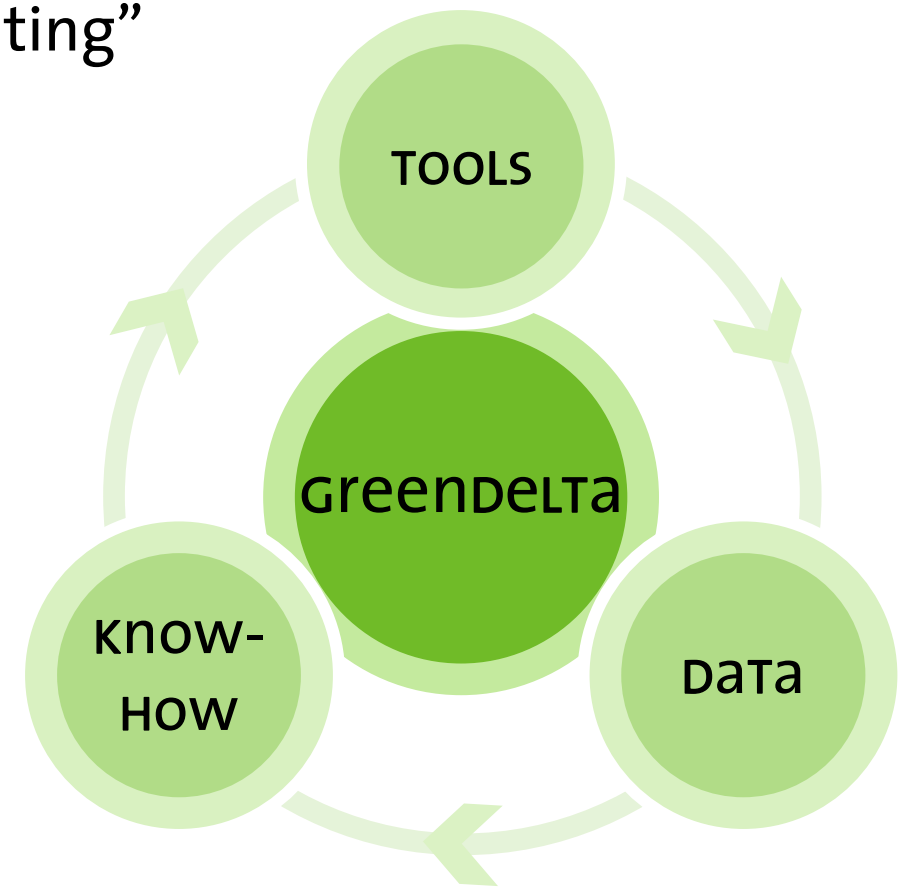
GreenDelta, what we do

"The art of sustainability consulting"

- sustainability research
- life cycle assessments
- databases
- software for LCA and sustainability



openLCA framework

- openLCA
- openLCA Nexus
- openLCA format converter
- Other tools based on openLCA core:
  - PROSUITE Decision Support Tool
  - Waste Reduction Model (WARM) Tool
  - Sustainable Materials Management (SMM) Tool
  - BASF-BEST

Agenda

- Adapting LCA software and databases

Examples: ecoinvent v.3, ELCD, PSILCA

→ Focus on openLCA

- The issue of the elementary flows and LCIA methods in different software

Databases used in examples

ecoinvent is the most famous LCA database worldwide used by around 4,500 users in more than 40 countries. The database contains international industrial life cycle inventory data on multiple sectors.

European reference Life Cycle Database comprises LCI data from EU-level business associations and other sources for key materials, energy carriers, transport, and waste management

PSILCA is a new database for social LCA developed by GreenDelta. It contains comprehensive generic inventory information for almost 15,000 industry sectors and commodities, for calculating and assessing social impacts of products along their life cycles

Adapting LCA software and databases

Formats

e.g. **ILCD in ELCD**

ecoSpold2 in ecoinvent v.3

openLCA → Implementation of ILCD and ecoSpold2 interfaces (for import and export)

- API created to import and export ILCD and ecoSpold2
- olca-io created to map the format to the database

Modelling

Products with multiple providers

e.g. **ecoinvent v.3**

Same product, multiple possible providers

(activityLinkId = Default provider)

SimaPro → Not possible (Products are always unique)

Status	Name
None	Electricity, low voltage {CA-NS}| market for | Alloc Def, U
None	Electricity, low voltage {CA-NT}| market for | Alloc Def, U
None	Electricity, low voltage {CA-NU}| market for | Alloc Def, U

GaBi → Possible, but only LCI datasets included

Modelling

Products with multiple providers

e.g. **ecoinvent v.3**

openLCA 1.4 → Possible, but a product could not be used several times in the same process with different providers (typical in ecoinvent 3)

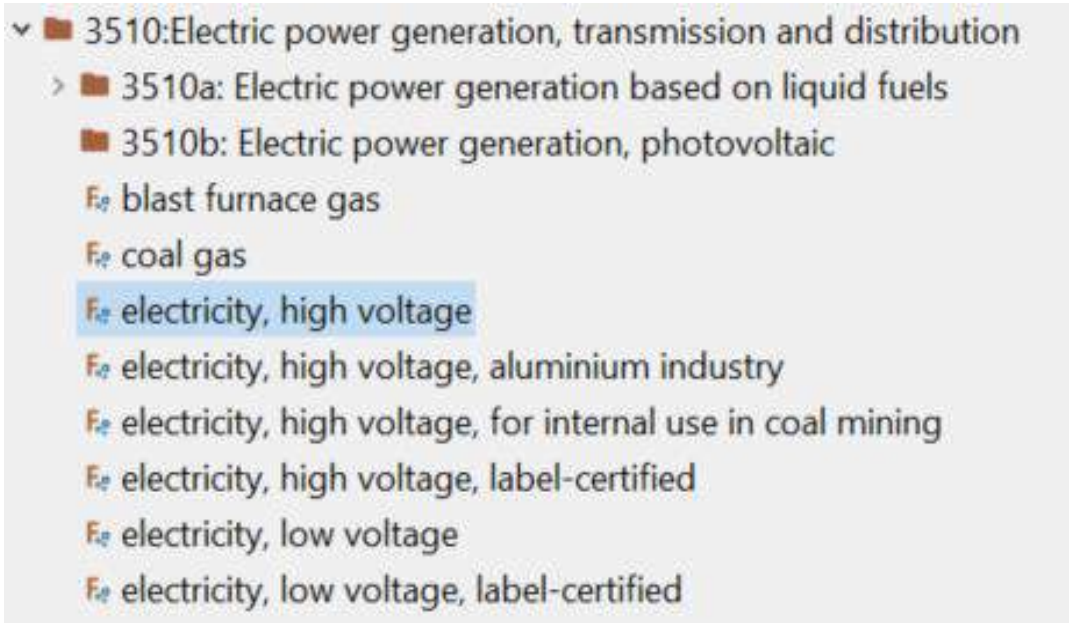
- electricity, high voltage | electricity production, nuclear, pressure water reactor - WECC, US only
- electricity, high voltage | electricity production, nuclear, pressure water reactor - ZA
- electricity, high voltage | electricity production, peat - EE
- electricity, high voltage | electricity production, peat - FI
- electricity, high voltage | electricity production, peat - IE
- electricity, high voltage | electricity production, peat - RoW
- electricity, high voltage | electricity production, peat - RU
- electricity, high voltage | electricity production, peat - SE
- electricity, high voltage | electricity production, wind, <1MW turbine, onshore - ASCC
- electricity, high voltage | electricity production, wind, <1MW turbine, onshore - AT

Modelling

Products with multiple providers

e.g. **ecoinvent v.3**

openLCA 1.5 → Possible to use a product with different providers in the same process



Modelling

Products with multiple providers

e.g. **ecoinvent v.3**

openLCA 1.5 → Possible to use a product with different providers in the same process

Inputs

Flow	Category	Amount	Unit	Costs	Uncertainty	Provider
electricity, high voltage	351:Electric power g...	1.00000	MJ		none	market for electricity, high ...
rice	011:Growing of non...	1.00000	kg		none	rice production - CN

- market for rice - GLO
- rice production - CN
- rice production - IN
- rice production - RoW
- rice production - US

Modelling

Products without provider

e.g. **ELCD**

SimaPro → Not possible (product = process)

Known inputs from technosphere (electricity/heat)
Name
Dummy secondary fuel
Dummy secondary fuel renewable
(Insert line he

Status	Name
Finished	Dummy BF Gas Sludge
Finished	Dummy BF Shop Dust
Finished	Dummy BF Slag
Finished	Dummy BOF Gas Dust
Finished	Dummy BOF Slag
Finished	Dummy CaF2 (low radioactice)
Finished	Dummy carbonyl sulphide

Modelling

Products without provider

e.g. **ELCD**

GaBi, openLCA → Possible (product flow will be listed in the inventory results)

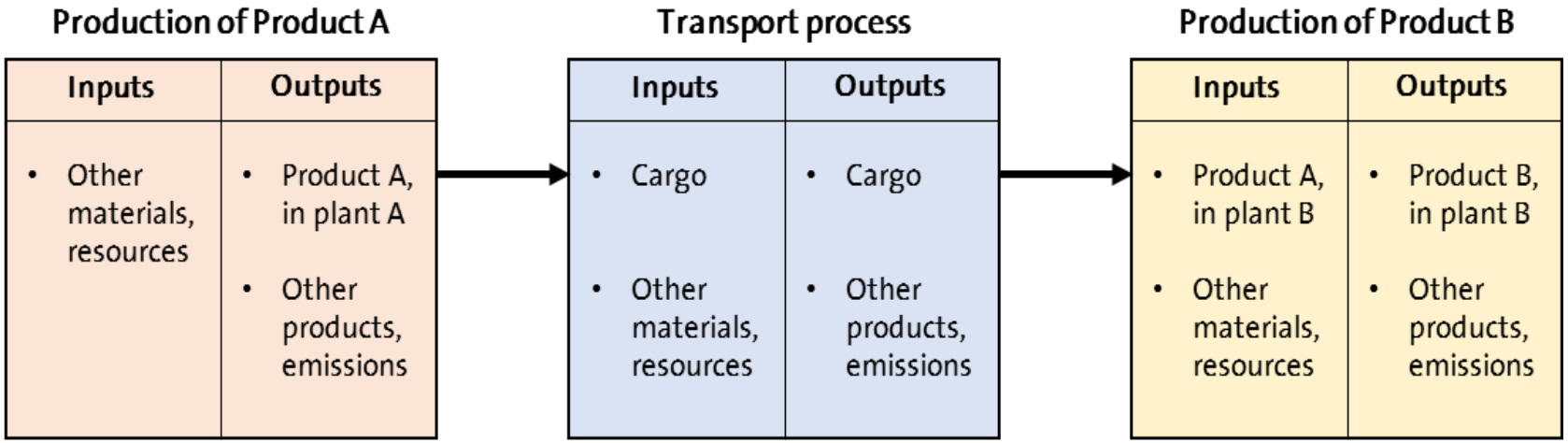
In openLCA, in order to simplify the creation of the product system to the user, dummy processes are set as default providers

Modelling

Connections between different products

e.g. **ELCD (transport modelling: cargo)**

GaBi → Possible (only manual creation of product systems [plans])



Modelling

Connections between different products

e.g. **ELCD (transport modelling: cargo)**

SimaPro → Not possible (unique products (ecoinvent transport modelling): automatic creation of product systems)

Known outputs to technosphere. Products and co-products

Name	Amount	U
Plane, technology mix, cargo, 68 t payload GLO	1	
(Insert line here)		

Known inputs from technosphere (materials/fuels)

Name	Amount
Dummy cargo	1
Kerosene, from crude oil, consumption mix, at refinery, 700 ppm sulphur EU-15 S	1*Spec_Consum = 2,68

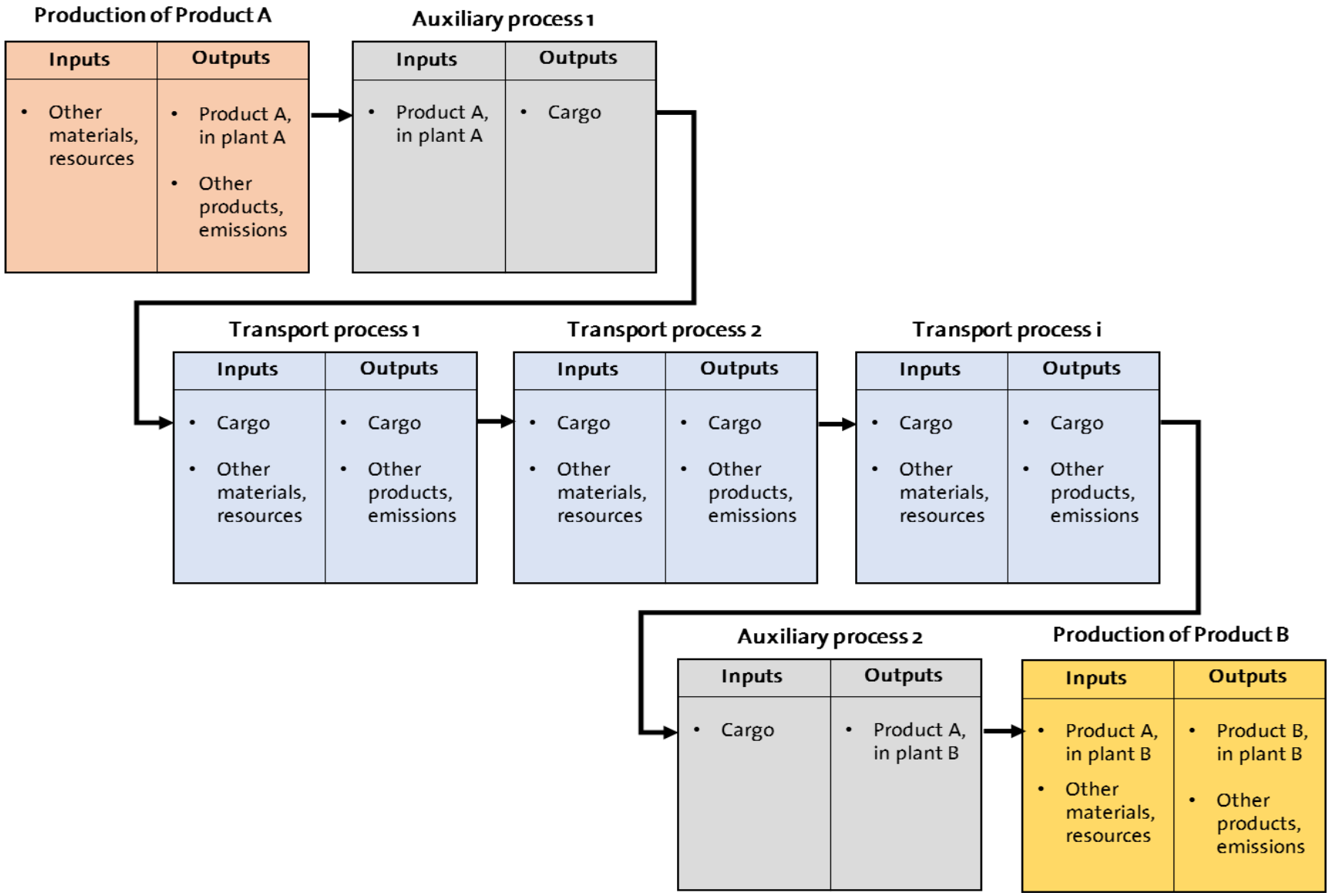
Modelling

Connections between different products

e.g. **ELCD (transport modelling: cargo)**

openLCA → Not possible, but intermediate processes can be created (or ecoinvent transport modelling)

Modelling


Production of Product A
Inputs
Other materials, resources
Outputs
Product A, in plant A
Other products, emissions
Auxiliary process 1
Inputs
Product A, in plant A
Outputs
Cargo
Transport process 1
Inputs
Cargo
Other materials, resources
Outputs
Cargo
Other products, emissions
Transport process 2
Inputs
Cargo
Other materials, resources
Outputs
Cargo
Other products, emissions
Transport process i
Inputs
Cargo
Other materials, resources
Outputs
Cargo
Other products, emissions
Auxiliary process 2
Inputs
Cargo
Outputs
Product A, in plant B
Production of Product B
Inputs
Product A, in plant B
Other materials, resources
Outputs
Product B, in plant B
Other products, emissions

Modelling

Loops due to self-referencing activities

e.g. **ecoinvent v.3**

Process: market for electricity, low voltage | electricity, low voltage | APOS, U

Inputs

Flow	Unit	Provider
electricity, low voltage	kWh	P electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel,
electricity, low voltage	kWh	P market for electricity, low voltage | electricity, low voltage | APOS, U - AU
sulfur hexafluoride, liquid	kg	P market for sulfur hexafluoride, liquid | sulfur hexafluoride, liquid | APOS, U - GLO
electricity, low voltage	kWh	P electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, r
distribution network, elect...	km	P market for distribution network, electricity, low voltage | distribution network, electri
electricity, low voltage	kWh	P electricity voltage transformation from medium to low voltage | electricity, low volta
electricity, low voltage	kWh	P electricity production, photovoltaic, 570kWp open ground installation, multi-Si | elec

Outputs

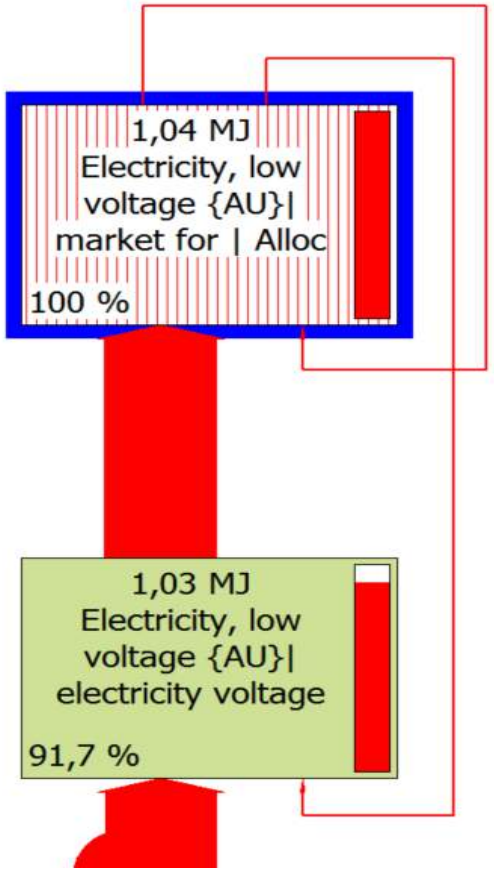
Flow	Category	Amount	Unit	Costs/Rev...	Uncertainty	Avoided p...	Ped
electricity, low voltage	351:Electric power g...	1.00000	kWh	0.10700 E...	none		

Modelling

Loops due to self-referencing activities

e.g. **ecoinvent v.3**

SimaPro → it can calculate self-loops



Modelling

Loops due to self-referencing activities

openLCA → Exchanges are merged during the import

Process: market for electricity, low voltage | electricity, low voltage | APOS, U

Inputs

Flow	Unit	Provider
electricity, low voltage	kWh	P electricity production, photovoltaic, 570kWp open ground installation, multi-Si | electricity, low
electricity, low voltage	kWh	P electricity voltage transformation from medium to low voltage | electricity, low voltage | APOS,
electricity, low voltage	kWh	P electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel, mounted |
distribution network, elect...	km	P market for distribution network, electricity, low voltage | distribution network, electricity, low vol
sulfur hexafluoride, liquid	kg	P market for sulfur hexafluoride, liquid | sulfur hexafluoride, liquid | APOS, U - GLO
electricity, low voltage	kWh	P electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted | e

Outputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided
electricity, low voltage	351:Electric power generation, transm...	0.97910	kWh	0.10700 EUR	none	

Modelling

ActivityLinkId specified in the ecoSpold2 files refers to an activity where the product flow is an input

e.g. **ecoinvent v.3**

"residual wood, dry" consumed by "market for residual wood, dry - GLO"
Provider: "shavings, hardwood, measured as dry mass to generic market for residual wood, dry - GLO" where "residual wood, dry" is a positive input provided by "market for residual wood, dry - GLO“

"venting of nitrogen, liquid" consumed by "market for venting of nitrogen, liquid - GLO"
Provider: "venting of nitrogen, liquid - RER" where "venting of nitrogen, liquid" is a positive input provided by "market for venting of nitrogen, liquid - GLO"

Modelling

ActivityLinkId specified in the ecoSpold2 files refers to an activity where the product flow is an input

e.g. **ecoinvent v.3**

Recommendation from ecoinvent: delete those exchanges in the database

Process: market for residual wood, dry

Inputs

Flow	Category	Unit	Uncertainty	Provider
residual wood, dry	162:Manufacture o...	m3	none	
transport, freight, lorry, u...	492:Other land tra...	t*km	lognorma...	P market for transport, freight, lorry, unspecified - GLO

Outputs

Flow	Category	Amount	Unit	Costs/Revenues	Uncertainty	Avoided p...	Pedigree u...
residual wood, dry	162:Manufacture o...	1.00000	m3	26.90000 EUR	none		

Modelling

Inputs as reference flows + Downstream connections

e.g. **ELCD (waste modelling)**

GaBi → any flow can be the reference (even no reference flow needed) and downstream connections possible

SimaPro → specific type of exchange “waste to treatment” and process type “Waste treatment”

(In e.g. **ecoinvent v.3** waste amounts are modified from negative to positive)

Modelling

Inputs as reference flows + Downstream connections

e.g. **ELCD (waste modelling)**

openLCA → Reference flow must exist and be an output product. Connections downstream of the reference process not possible

ecoinvent v.3 approach implemented:

- Wastes moved to the input side with negative amount in process producing them
- Wastes moved to the output side with negative amount in the waste treatment

Modelling

Inputs as reference flows + Downstream connections

e.g. **ELCD (waste modelling)**

In future openLCA versions → linking and calculation algorithms modified to allow this kind of modelling

Database content

Content that requires changes in the software's database schema and UI

e.g. **PSILCA (social aspects and indicators**)

openLCA → New element "Social indicator" added to the database, and new tab "Social aspects" in the process editor

Database content

Social indicator: Children in employment, total

General information

Name	Children in employment, total
Description	Explanation of unit of measurement: Percentage of all children ages 7-14
Category	Workers > Child labour
Version	01.00.000
UUID	041068c0-4553-40ba-88de-70e2d9a2239a
Last change	2016-02-23T11:09:35+0100

Additional information

Unit of measurement	% of children
Evaluation scheme	0% = no risk; 0%-<2,5% = very low risk; 2,5%-<5% = low risk; 5%-<10% = medium risk; 10%-<20% = high risk; >=20% = very high risk; n.a. = no data

Activity variable

Name	Working hours
Quantity	Duration
Unit	h

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Database content

Name	Raw value	Risk level	Activity variable	Data qua...	Comment	Source
Workers						
Child labour						
Freedom of association and collective bargaining						
Trade union density	26.0705910031997 [%]	High risk	0.00882159891...	(2;3;5;1;4)	Data from: 1998; La...	ILOstat 2014: Trade union membership
Right of Collective bargaining	3.0 [Score]	No risk	0.00882159891...	(2;3;4;1;4)	Data from: 2011; La...	ICTWSS 2013
Right to Strike	3.0 [Score]	No risk	0.00882159891...	(2;3;4;1;4)	Data from: 2011; La...	ICTWSS 2013
Right of Association	3.0 [Score]	No risk	0.00882159891...	(2;3;4;1;4)	Data from: 2011; La...	ICTWSS 2013
Fair Salary						
Sector average wage, per month	2301.725743952193 [USD]	Medium risk	0.00882159891...	(2;2;5;1;1)	Risk level referring t...	ILOstat 2014
Minimum wage, per month	1400.0 [USD]	Very low risk	0.00882159891...	(2;3;1;1;2)	Data scope: country...	WageIndicator 2014: Minimum wage
Living wage, per month	883.9134859535415 [USD]	High risk	0.00882159891...	(2;2;4;2;n.a.)	Mean over different...	WageIndicator 2014: Living wage
Working time						
Weekly hours of work per employee	29.885 [h]	High risk	0.00882159891...	(2;1;2;1;3)	Data from: 2013; La...	ILOstat 2014
Health and Safety (Workers)						
Workers affected by natural disasters	0.007852687440725469 [%]	Very low risk	0.00882159891...	(2;1;2;1;4)	Data from: 2014; La...	EM-DAT 2015: Natural disasters
Presence of sufficient safety measures		No data	0.00882159891...			
Rate of non-fatal accidents at workplace	2738.0 [#/yr and 100k empl.]	High risk	0.00882159891...	(2;3;4;1;3)	Data from: 2010; La...	ILOstat 2014: Fatal accidents
DALYs due to indoor and outdoor air and wate	0.768970284461878 [DALY rate]	Very low risk	0.00882159891...	(2;1;5;1;4)	Data from: 2004; La...	WHO 2009: DALYs
Rate of fatal accidents at workplace	1.77 [#/yr and 100k empl.]	Very low risk	0.00882159891...	(2;3;4;1;3)	Data from: 2010; La...	ILOstat 2014: Non-fatal accidents
Social benefits, legal issues						
Social security expenditures	18.575 [% of GDP]	Low risk	0.00882159891...	(2;1;4;1;4)	Mean value over av...	ILO 2015: Social Security
Evidence of violations of laws and employmen	13.275600375197483 [# per 1k empl.]	High risk	0.00882159891...	(2;1;1;5;2)	Data from: 2015; La...	USDOL 2015: Violations of employment r...
Discrimination						
Gender wage gap	16.8316831683168 [%]	Medium risk	0.00882159891...	(3;1;5;1;1)	Data from 2008	ILOstat 2014
Forced Labour						
Goods produced by forced labour		No data	0.00882159891...			
Trafficking in persons	1.0 [Tier]	Very low risk	0.00882159891...	(2;1;1;1;4)	Data from: 2014; La...	U.S. Department of State 2014: Traffickin...
Frequency of forced labour	1.5 [‰]	Very low risk	0.00882159891...	(2;4;3;3;n.a.)	Data from: 2012; La...	ILO 2012: Forced Labour
Value Chain Actors						
Corruption						
Active involvement of enterprises in corruption	1.0 [%]	Very low risk	0.00882159891...	(2;2;2;2;3)	Data from: 2014; La...	OECD 2014: Bribery
Public sector corruption	79.0 [Score]	Low risk	0.00882159891...	(2;1;3;1;n.a.)	Data from: 2012; La...	Transparency International 2012: Corrupti...

Database content

Content that requires changes in the software's database schema and UI

e.g. **PSILCA (social aspects and indicators**)

SimaPro → No new element added in the database or UI. Information of each social indicator repeated in all the elementary flows of that indicator. e.g.:

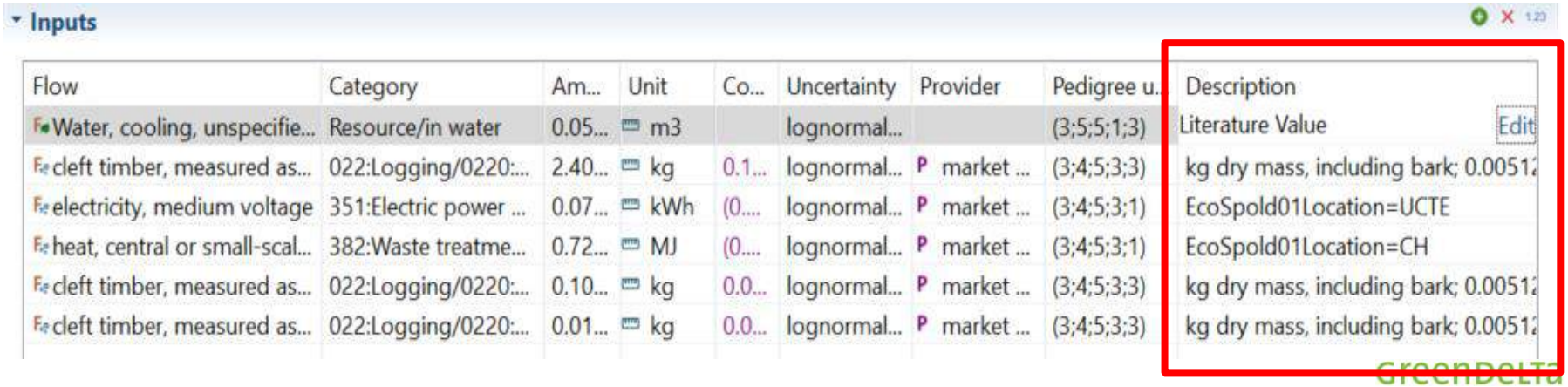
Social indicator:	Risk of child labor
Elementary flows:	Risk of child labor, no risk
	Risk of child labor, low risk
	etc.

Database content

Content that requires changes in the software's database schema and UI

e.g. **ecoinvent v.3.3 (exchanges descriptions)**

openLCA → New field "description" added in the database and in the Inputs/Outputs tab of the process editor



Inputs

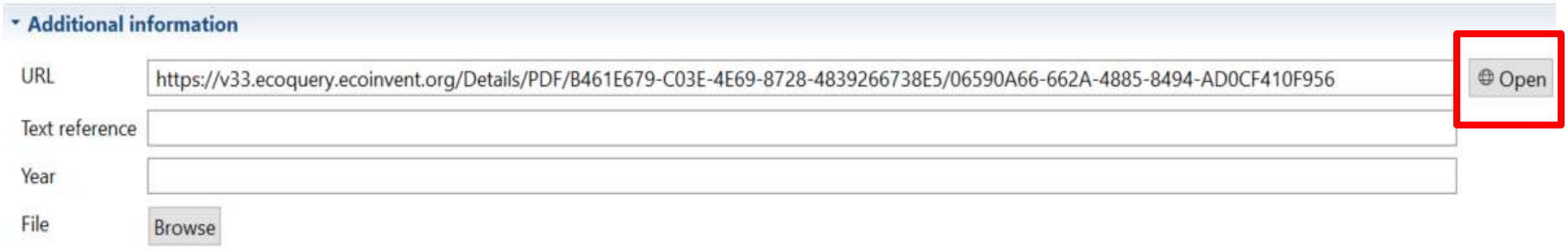
Flow	Category	Am...	Unit	Co...	Uncertainty	Provider	Pedigree u...	Description
Water, cooling, unspecifie...	Resource/in water	0.05...	m3		lognormal...		(3;5;5;1;3)	Literature Value Edit
cleft timber, measured as...	022:Logging/0220:...	2.40...	kg	0.1...	lognormal...	P market ...	(3;4;5;3;3)	kg dry mass, including bark; 0.0051
electricity, medium voltage	351:Electric power ...	0.07...	kWh	(0....	lognormal...	P market ...	(3;4;5;3;1)	EcoSpold01Location=UCTE
heat, central or small-scal...	382:Waste treatme...	0.72...	MJ	(0....	lognormal...	P market ...	(3;4;5;3;1)	EcoSpold01Location=CH
cleft timber, measured as...	022:Logging/0220:...	0.10...	kg	0.0...	lognormal...	P market ...	(3;4;5;3;3)	kg dry mass, including bark; 0.0051
cleft timber, measured as...	022:Logging/0220:...	0.01...	kg	0.0...	lognormal...	P market ...	(3;4;5;3;3)	kg dry mass, including bark; 0.0051

Database content

Content that requires changes in the software's database schema and UI

e.g. **ecoinvent v.3.3 (PDF and weblinks per process)**

openLCA → New function to open links directly from the source editor



Database content

Content that requires changes in the software's database schema and UI

e.g. **ecoinvent v.3.3 (flow properties per exchange)**

Flow properties (water content etc.): in ecoinvent linked to an exchange, in openLCA and ILCD linked to a flow

openLCA → Not implemented. Data lost during the import

Database content

Content that requires changes in the import function only applicable to a specific database

e.g. **ecoinvent v.3 (parameters)**

- Mathematical formulas from reference products refer to the undefined system
- Livelinks used in the mathematical formulas
- Formulas > 2000 characters (limit in openLCA), etc.

```
        <comment xml:lang="en">calculated from mass balance</comment>
      </uncertainty>
      <property propertyId="335fb25a-49eb-4a6c-8c28-9a19d16c9456" variableName="amount_ash_calc_prop_kg"
amount="0.00748" isDefiningValue="false" mathematicalRelation="LiveLink('C:\Documents and Settings\treyer_k\My
Documents\ecoinvent\EcoEditor\LiveLinks\electricity_production_hard_coal_LiveLinks.xls','Sheet1','C19','',
'Automatic')" isCalculatedAmount="true" unitId="487df68b-4994-4027-8fdc-a4dc298257b7" sourceId="6ad10bdb-
b629-4991-94a9-478b752cde90" sourceYear="2007" sourceFirstAuthor="Röder, A.">
        <name xml:lang="en">calculation property, kg</name>
```

Database content

Content that requires changes in the import function only applicable to a specific database

e.g. **ecoinvent v.3 (parameters)**

openLCA, SimaPro → Mathematical formulas not imported

Memory & Calculation

e.g. **ecoinvent v.3**

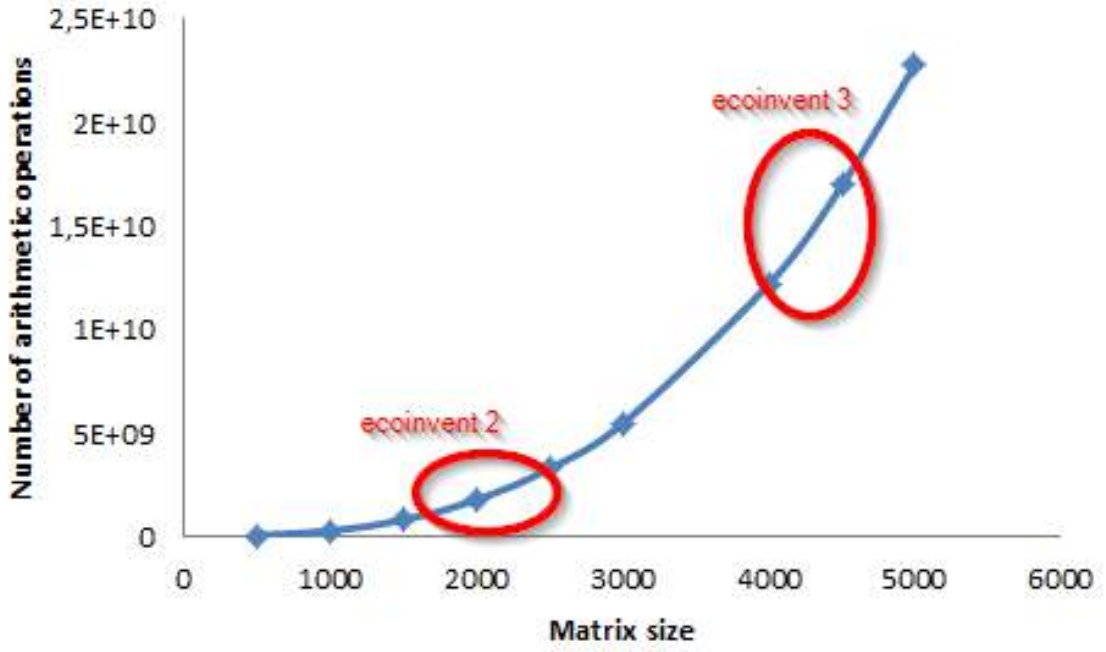
New types of process data sets, for markets, that typically link one process with another

→ a drastically increased in number of data sets in one typical product system (with the same number of LCA process data sets).

Memory & Calculation

e.g. **ecoinvent v.3**

Issue: Memory space requirements in a matrix calculation → cubic increase with the number of data sets



Memory & Calculation

e.g. **ecoinvent v.3**

Tasks:

- Reduction of memory space requirements
- Faster loading of product systems
- Faster calculation

Memory & Calculation

e.g. **ecoinvent v.3**

Performance improvements due to

- Improved data structures
- Improved queries (batching)
- Improved memory usage (caching)
- Improved algorithms and a faster numerical library

Memory & Calculation

Memory space requirements (ecoinvent 2.2)

openLCA 1.3:

Product system open:

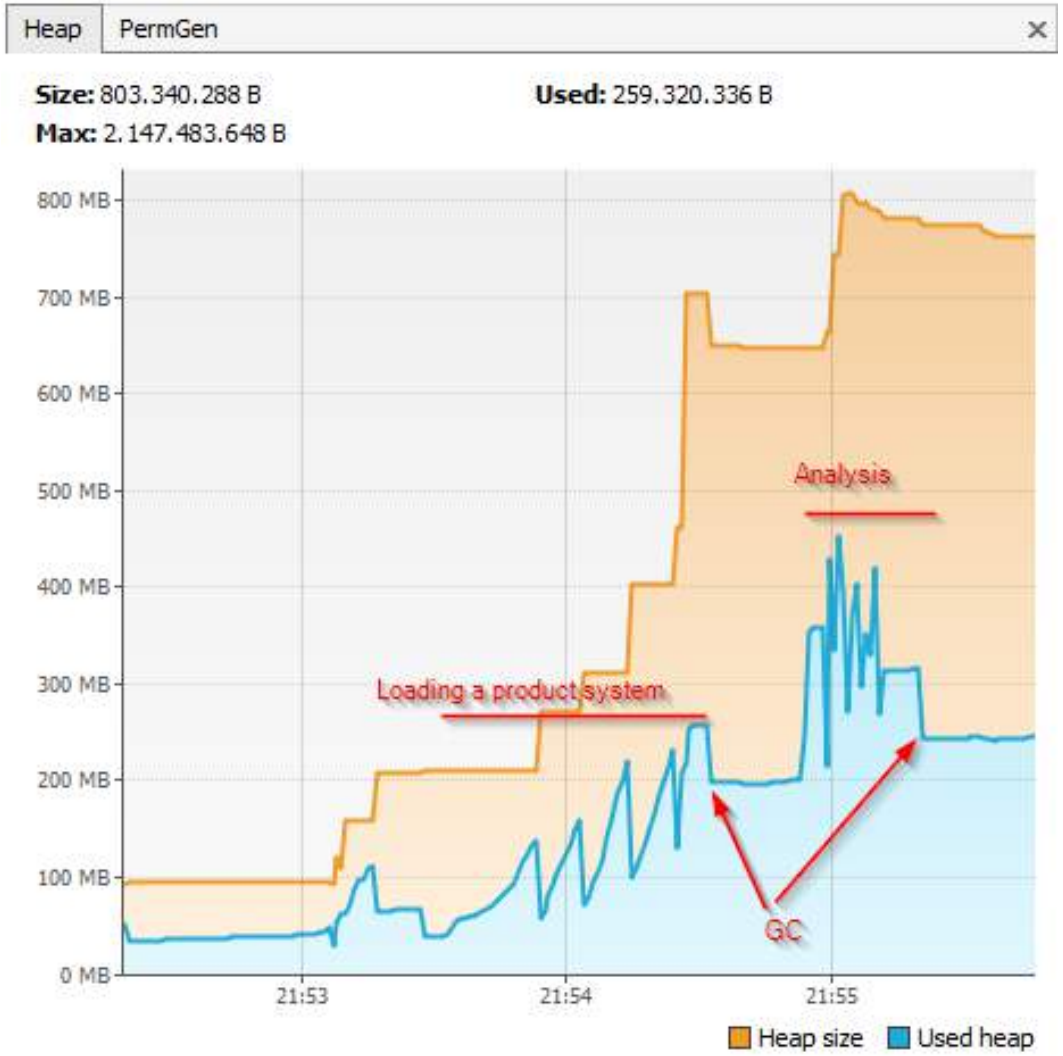
200 MB

Analysis peak:

450 MB

Product system & result open:

250 MB



Memory & Calculation

Memory space requirements (ecoinvent 2.2)

openLCA 1.4:

Product system open:

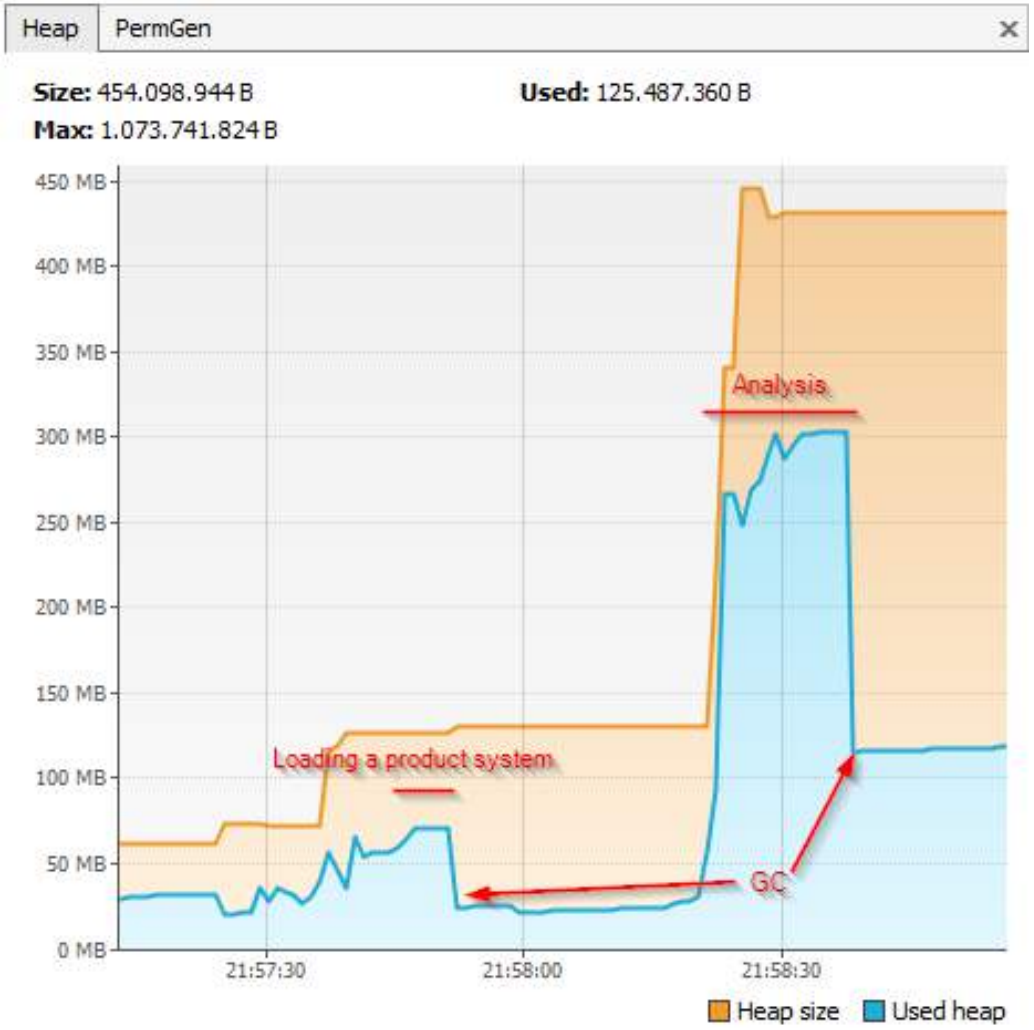
25 MB

Analysis peak:

300 MB

Product system & result open:

125 MB



Memory & Calculation

Memory space requirements (ecoinvent 3.01)

openLCA 1.4:

Product system open:

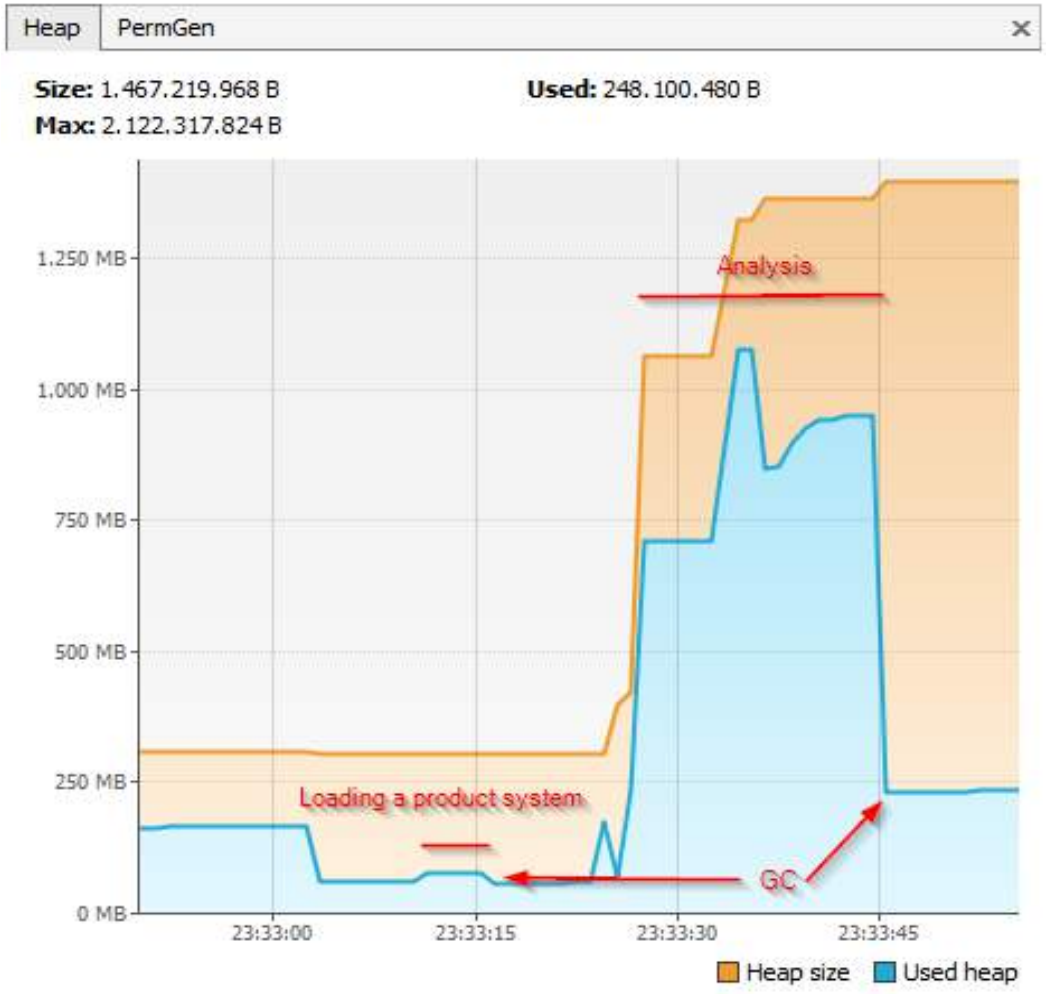
25 MB

Analysis peak:

1100 MB

Product system & result open:

125 MB



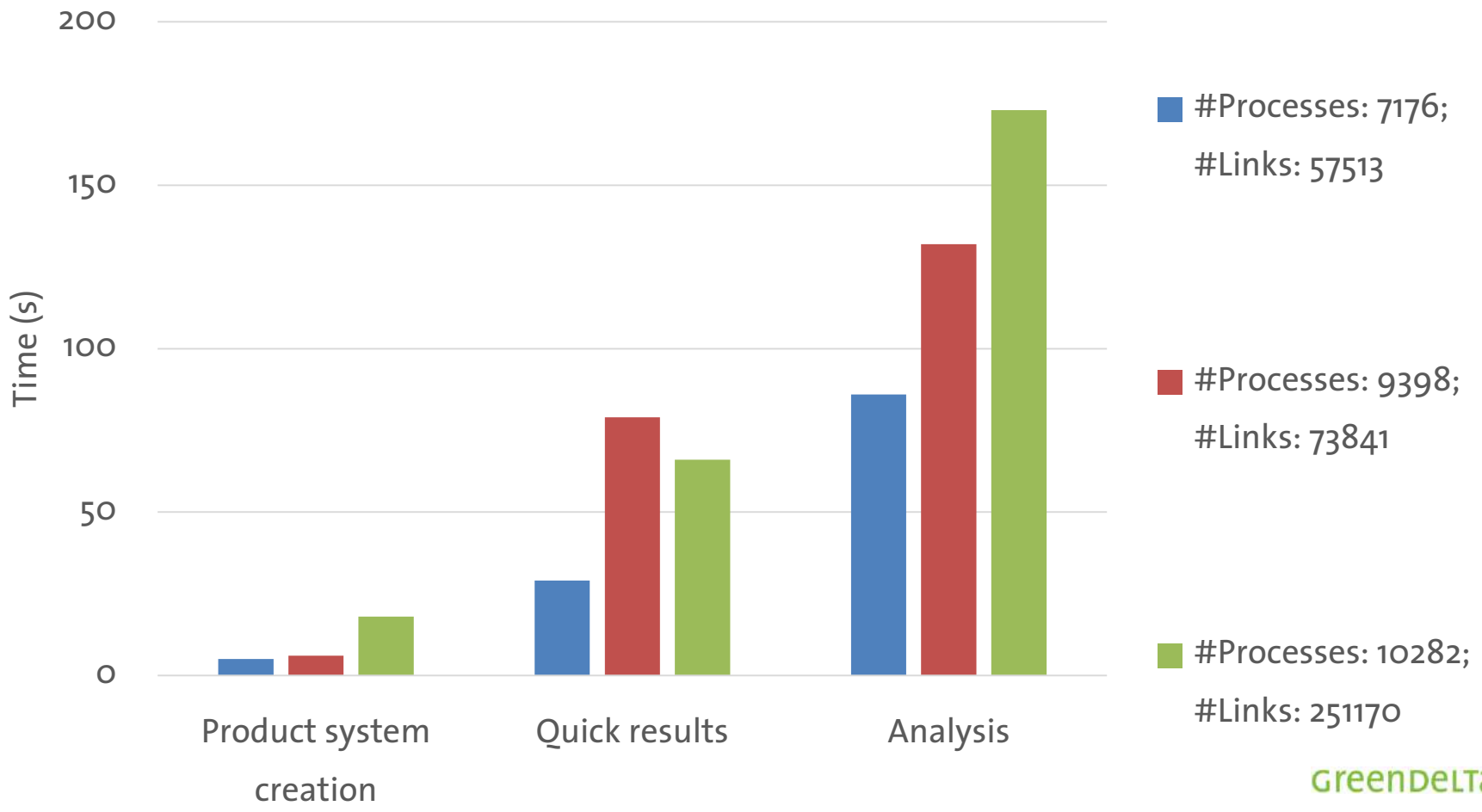
Memory & Calculation

Performance (openLCA 1.3 vs. 1.4)

Action	Ecoinvent v.2.2		Ecoinvent v.3.01
	openLCA 1.3	openLCA 1.4	openLCA 1.4
Creating a new product system	72 s	3 s	13 s
Opening an existing product system	8 s	< 1 s	<1 s
Calculation and Analysis	10 s	4 s	17 s

Memory & Calculation

Performance (openLCA 1.4.2, ecoinvent v.3.2)



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Memory & Calculation

e.g. **PSILCA**

Number of processes

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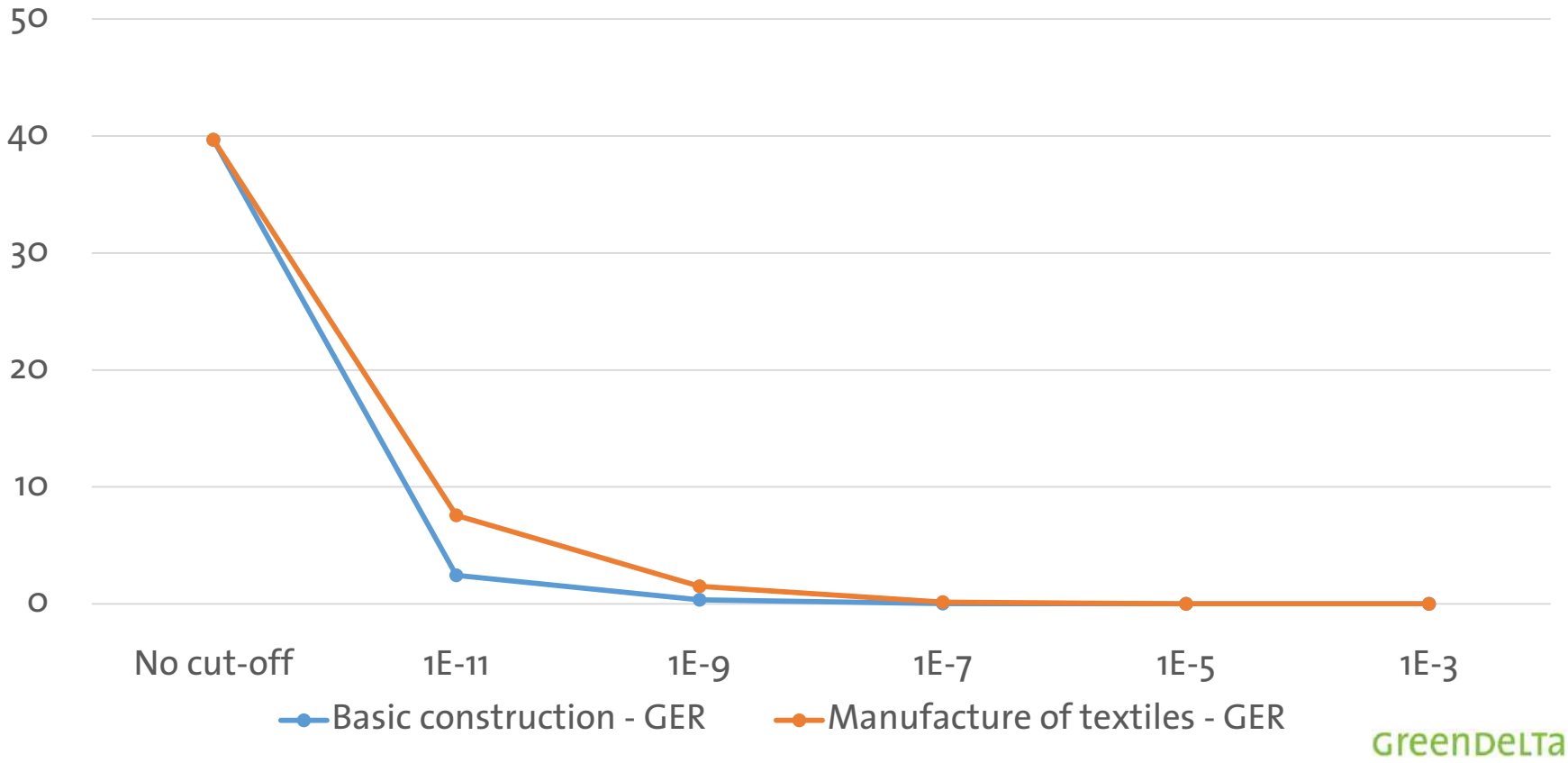
Memory & Calculation

e.g. **PSILCA**

Number of process links (in millions)



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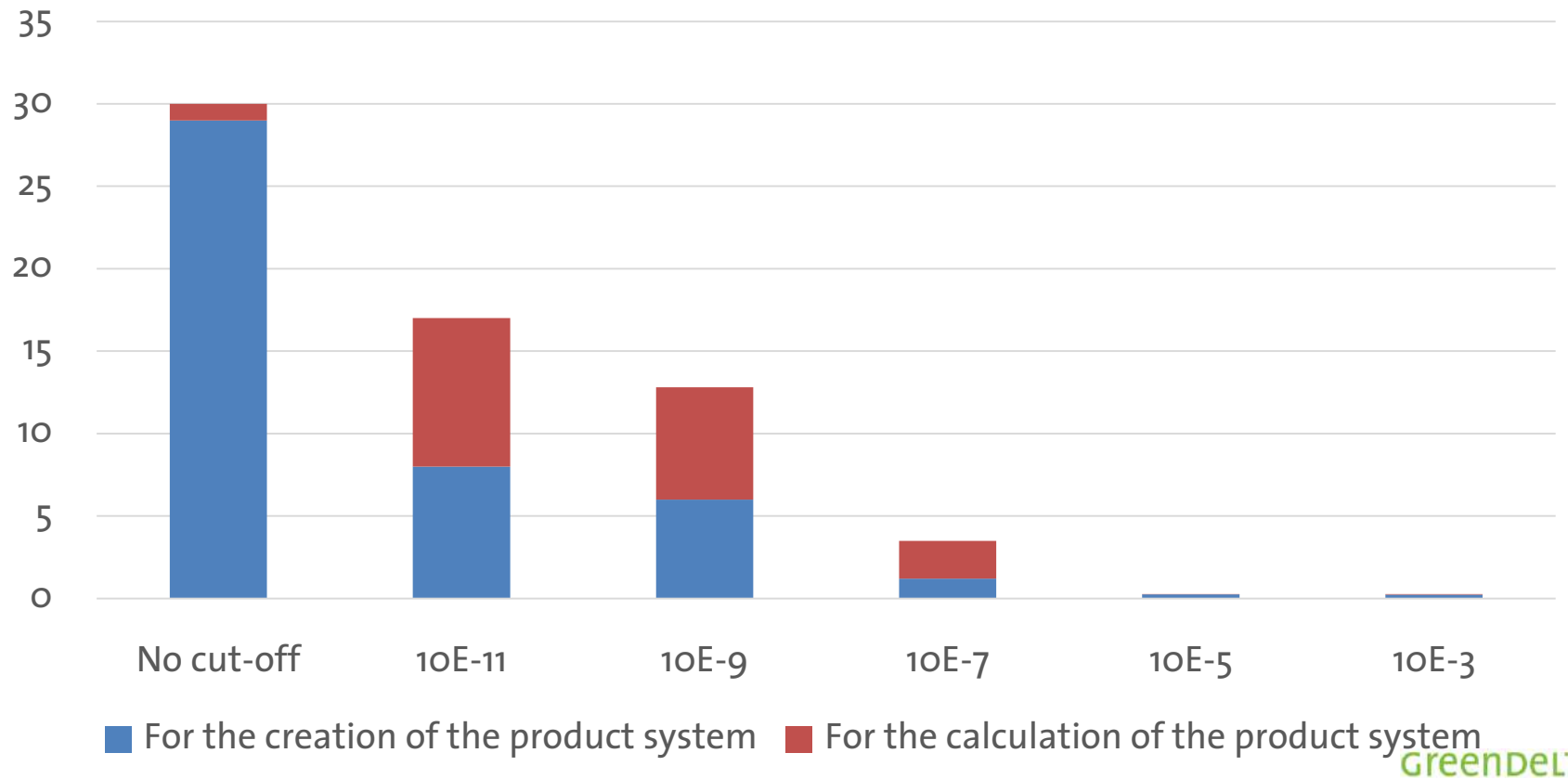
Memory & Calculation

e.g. **PSILCA**

Required RAM (GB)



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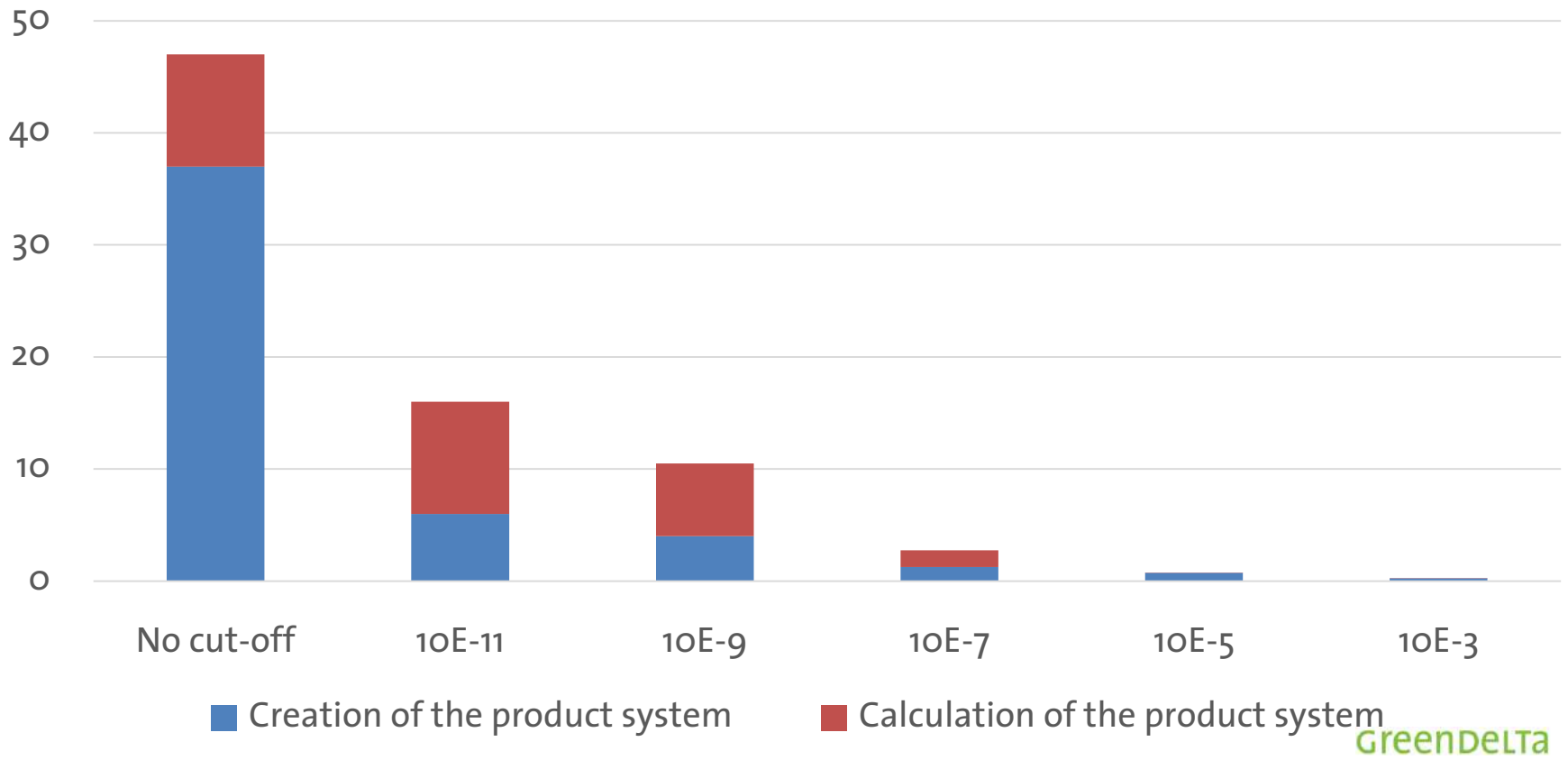
Memory & Calculation

e.g. **PSILCA**

Time (min)



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Memory & Calculation

e.g. **PSILCA**

Cut-offs in available databases

Database	openLCA	SimaPro
PSILCA Developer	No cut-off	Not Available
PSILCA Professional	1E-7	Not Available
PSILCA Starter	1E-5	Not Available
PSILCA Starter (SimaPro)	Not Available	1E-4

Memory & Calculation

e.g. **PSILCA**

Future modification of the software:

- Store pre-calculated matrices of background systems as libraries to reduce significantly the time of calculation and memory requirements

The issue of the elementary flows and LCIA methods

“Old” issue still unresolved

The issue

The same dataset characterized with the same LCIA method can yield very different results in different LCA software

The cause

Different elementary flows used in the software, LCI databases and LCIA methods

→Different mappings applied

→Different intrepretation of LCIA methods

Publications: Herrmann and Moltesen, 2015; Speck et al., 2015

Lack of harmonization in elementary flows

- Different flow nomenclature
- Lack of clarifiers (e.g. synonyms, CAS numbers, formulas, etc.)
- Different definition of context (i.e. compartment, subcompartment information)
- Misspelling, capitalization differences, etc.

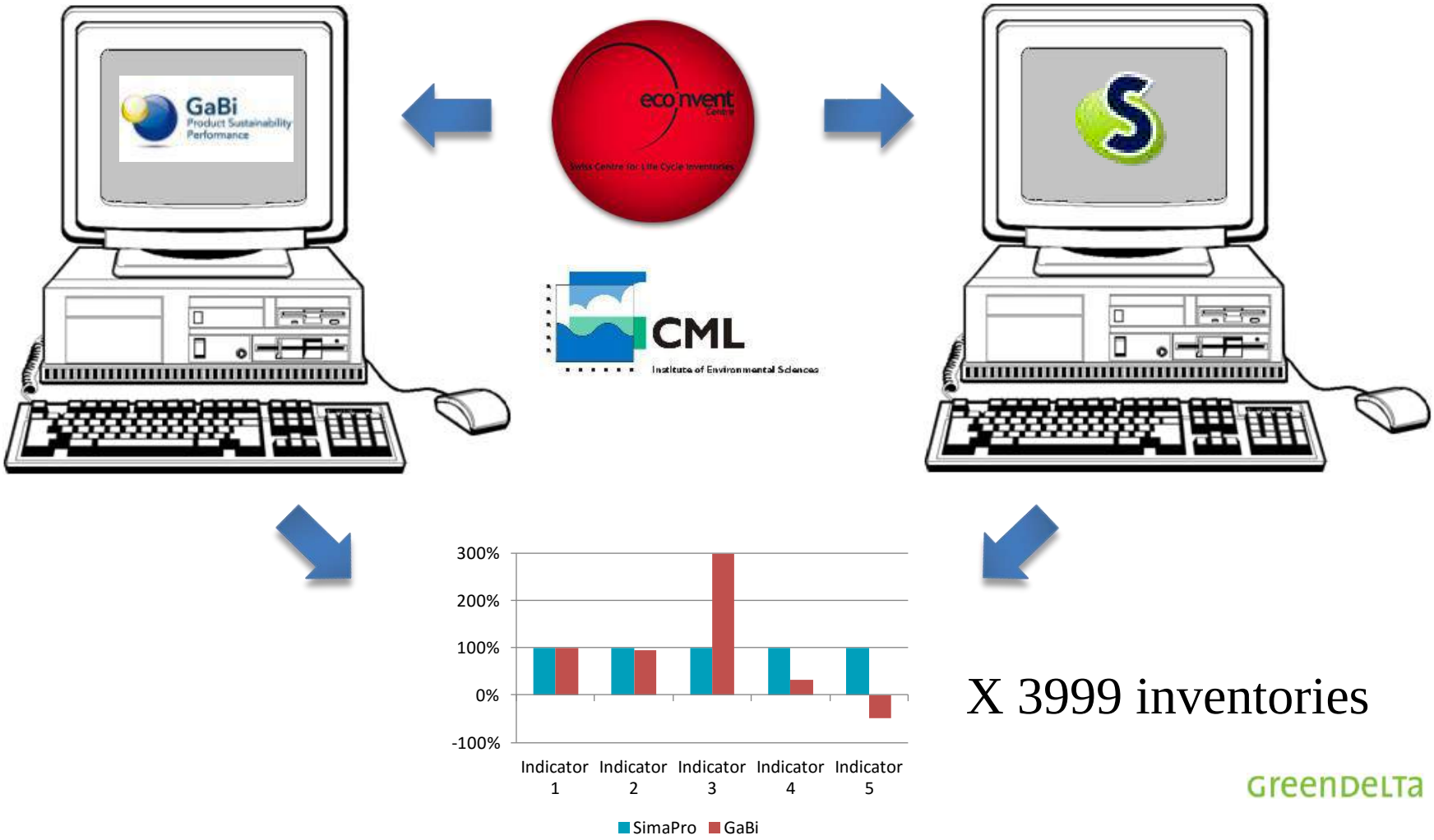
→ **All makes more difficult the creation of mappings**

Lack of harmonization in elementary flows

Source	Flow name	CAS	Flow context
ecoinvent v.3.2	Butylcarbamate, iodopropynyl	55406-53-6	Air - non-urban air or from high stacks
openLCA	3-Iodo-2-propynyl butylcarbamate	055406-53-6	Air – low population density
SimaPro	Butylcarbamate, iodopropynyl	-	Emissions to air – low. pop.
GaBi	Butylcarbamate, iodopropynyl		Emissions to air – Organic emissions to air (group VOC) – Group NMVOC to air
ILCD	3-iodo-2-propynyl butylcarbamate	055406-53-6	Emissions – Emissions to air – Emissions to non-urban air or from high stacks

Impact in LCIA results

CIRAIG analysis (2014, Pascal Lesage)



X 3999 inventories

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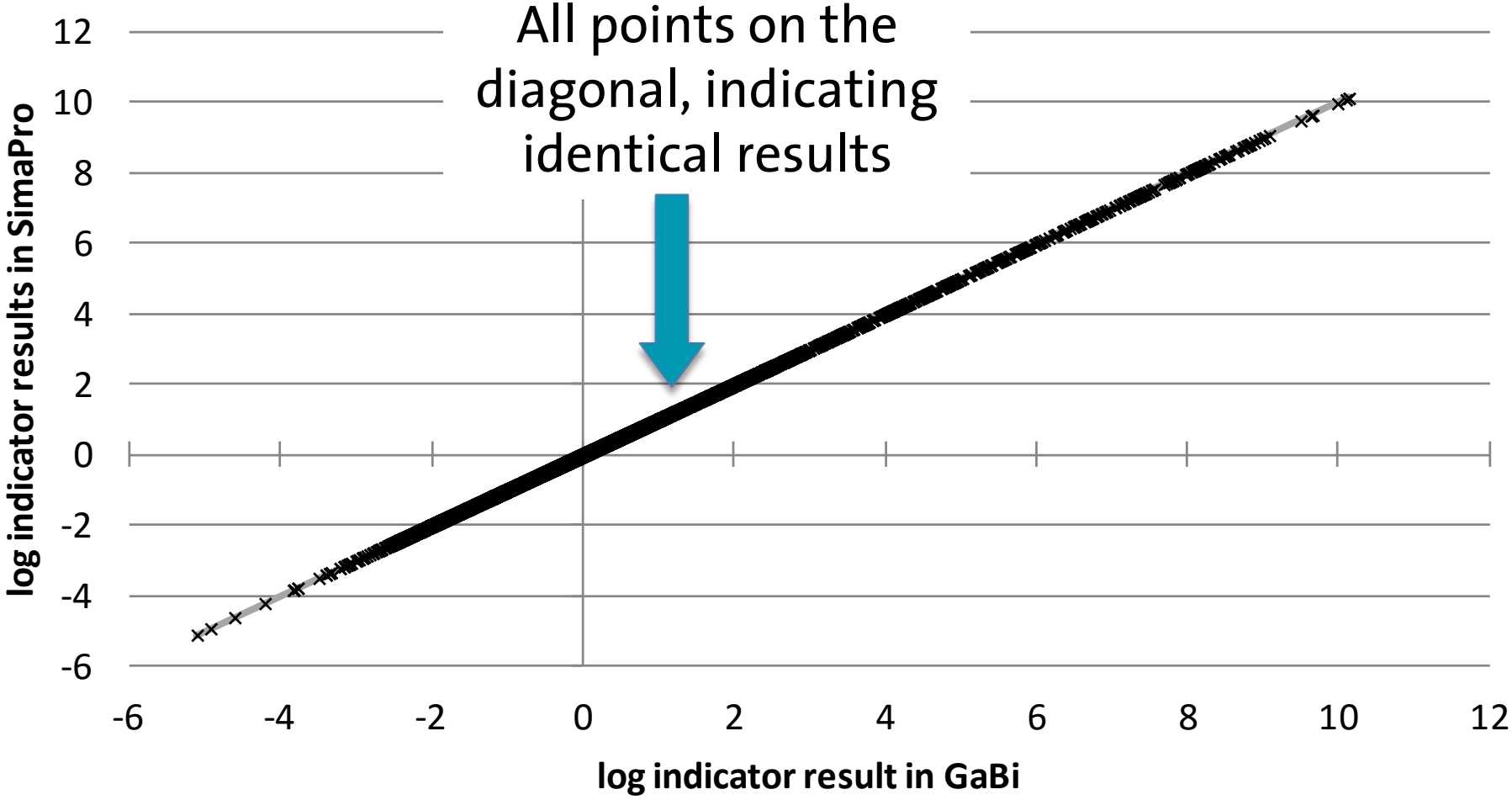
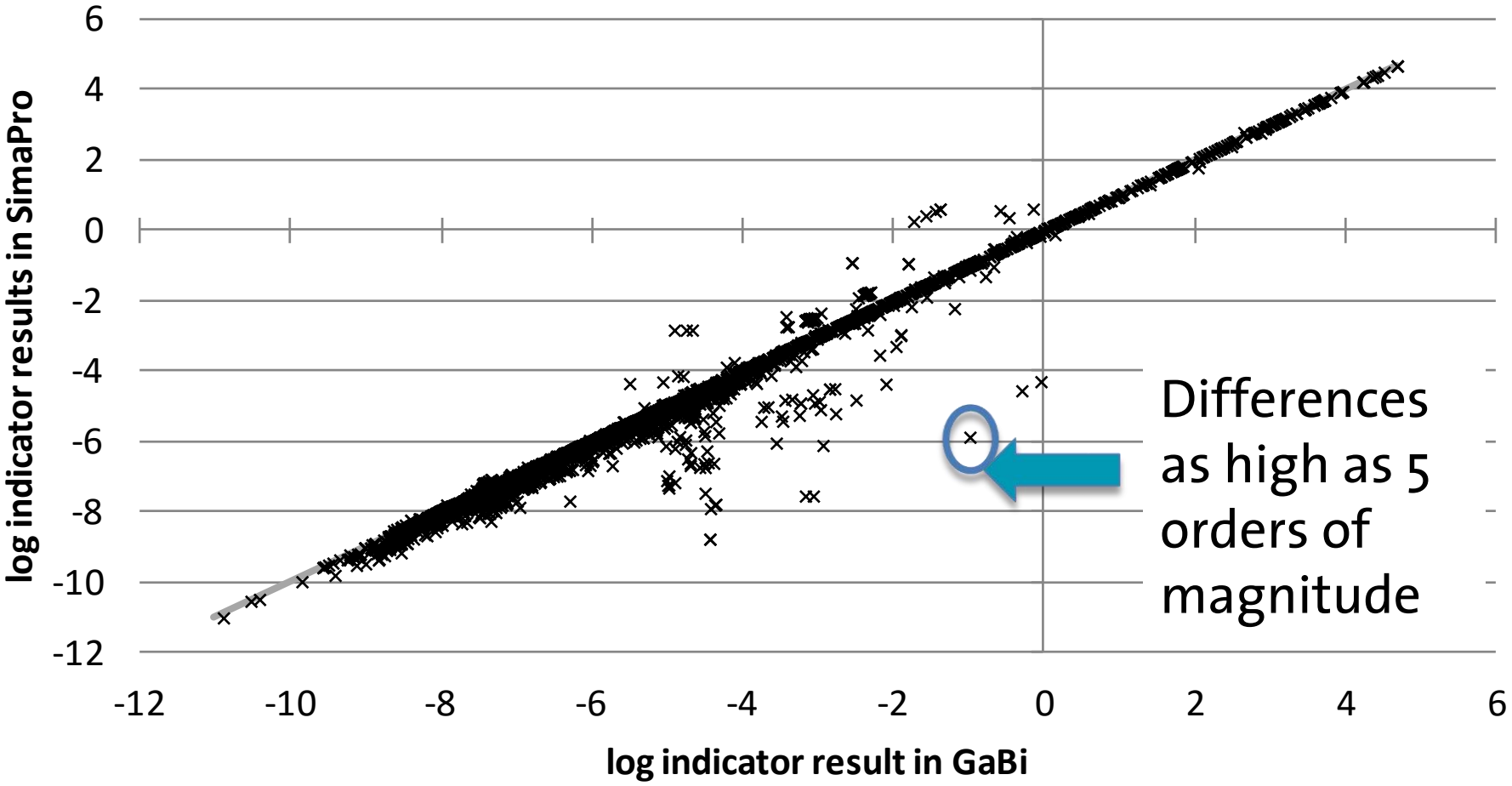
Impact in LCIA results: Global Warming

CIRAIG analysis (2014, Pascal Lesage)



Impact in LCIA results: Abiotic depletion (elements)

CIRAIG analysis (2014, Pascal Lesage)



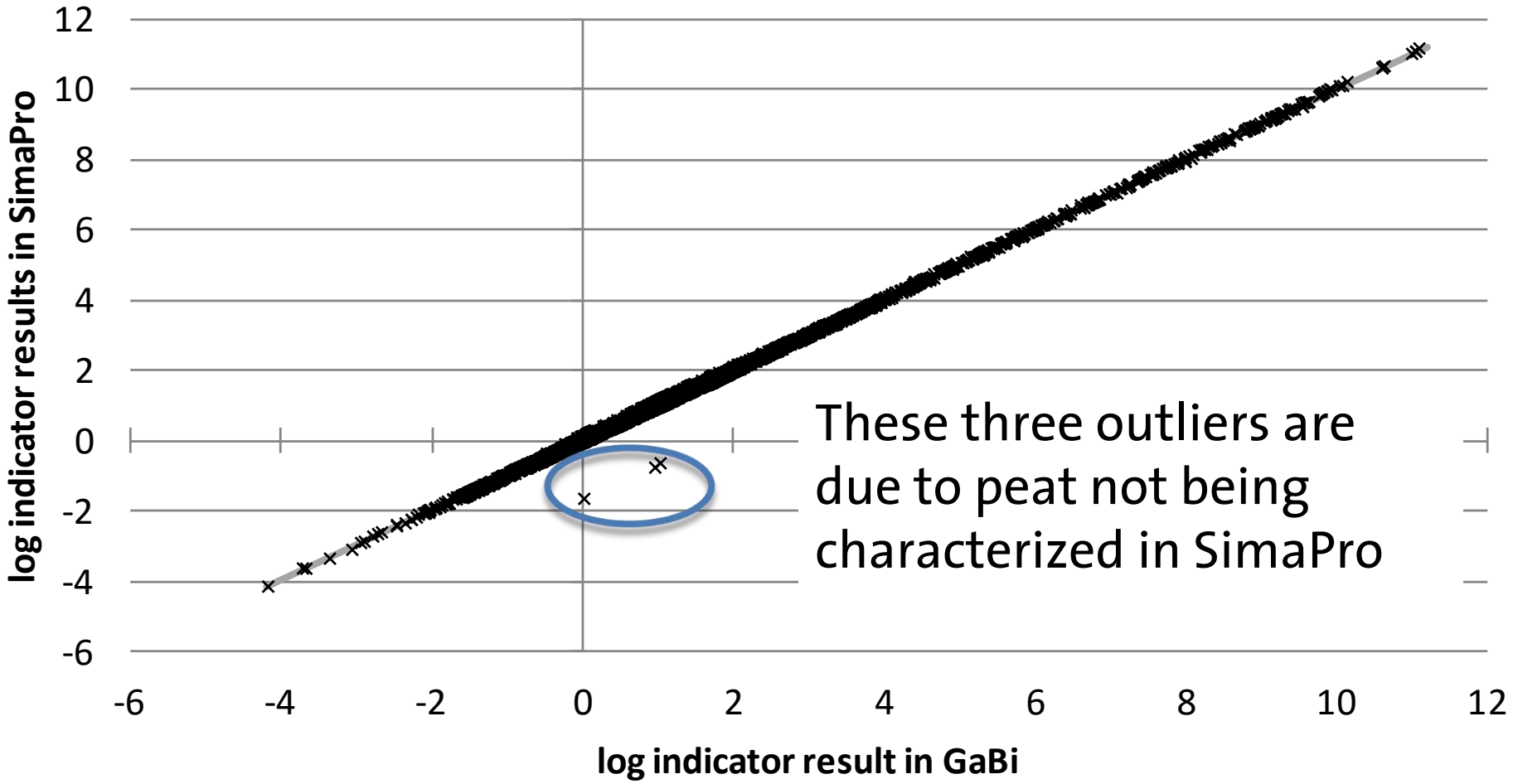
Impact in LCIA results: Abiotic depletion (elements)

CIRAIG analysis (2014, Pascal Lesage)

- GaBi includes so-called “obsolete” characterization factors (CFs): Barium sulphate, Cinnabar, Colamanite ore, Borax, Gypsum, Antimonite, Sodium chloride, Sodium sulphate, Spodumen
- GaBi CF 100x lower for cadmium
- Mismatch in GaBi nomenclature for Uranium

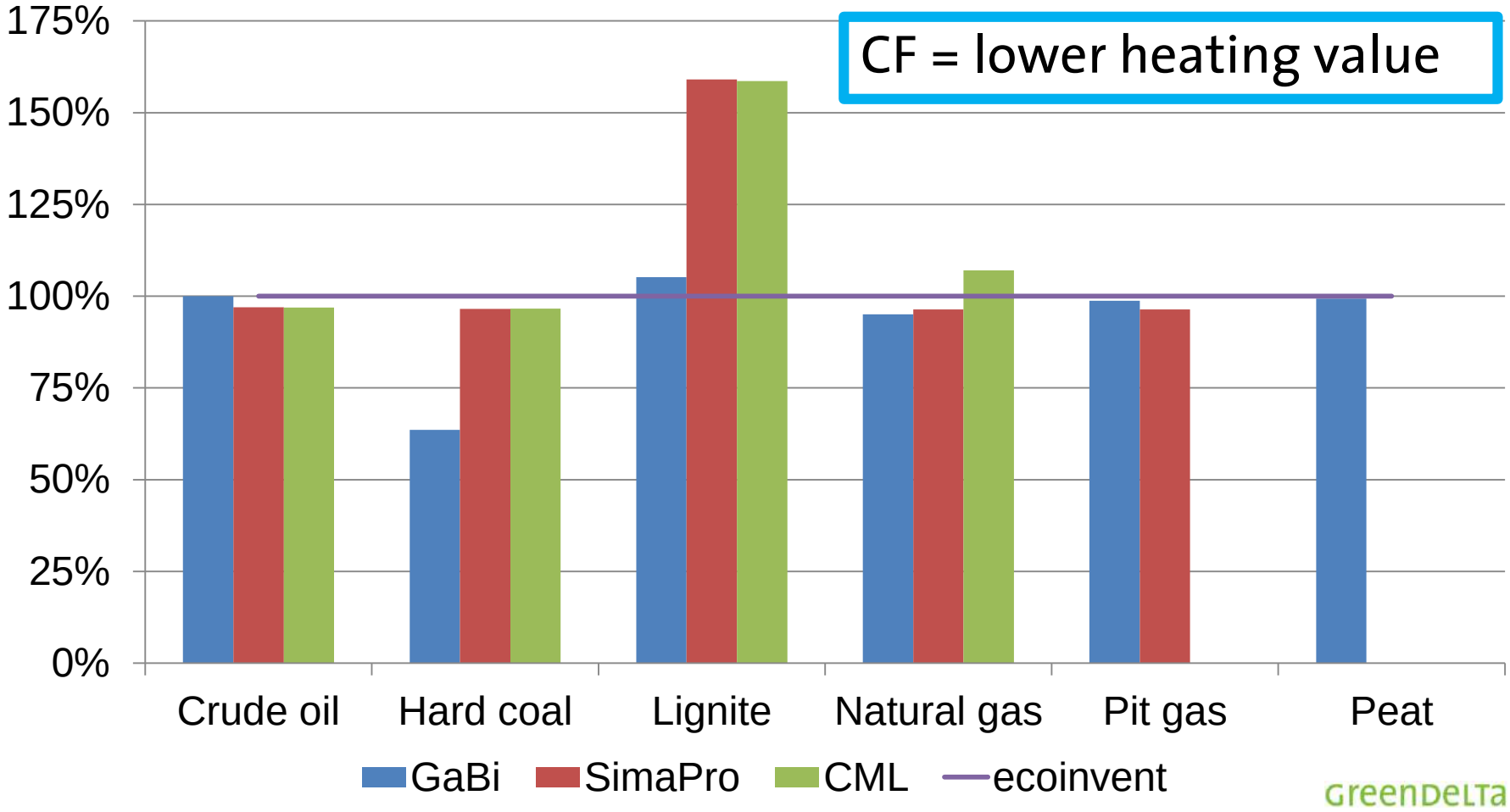
Impact in LCIA results: Abiotic depletion (fossil fuels)

CIRAIG analysis (2014, Pascal Lesage)



Impact in LCIA results: Abiotic depletion (fossil fuels)

CIRAIG analysis (2014, Pascal Lesage)



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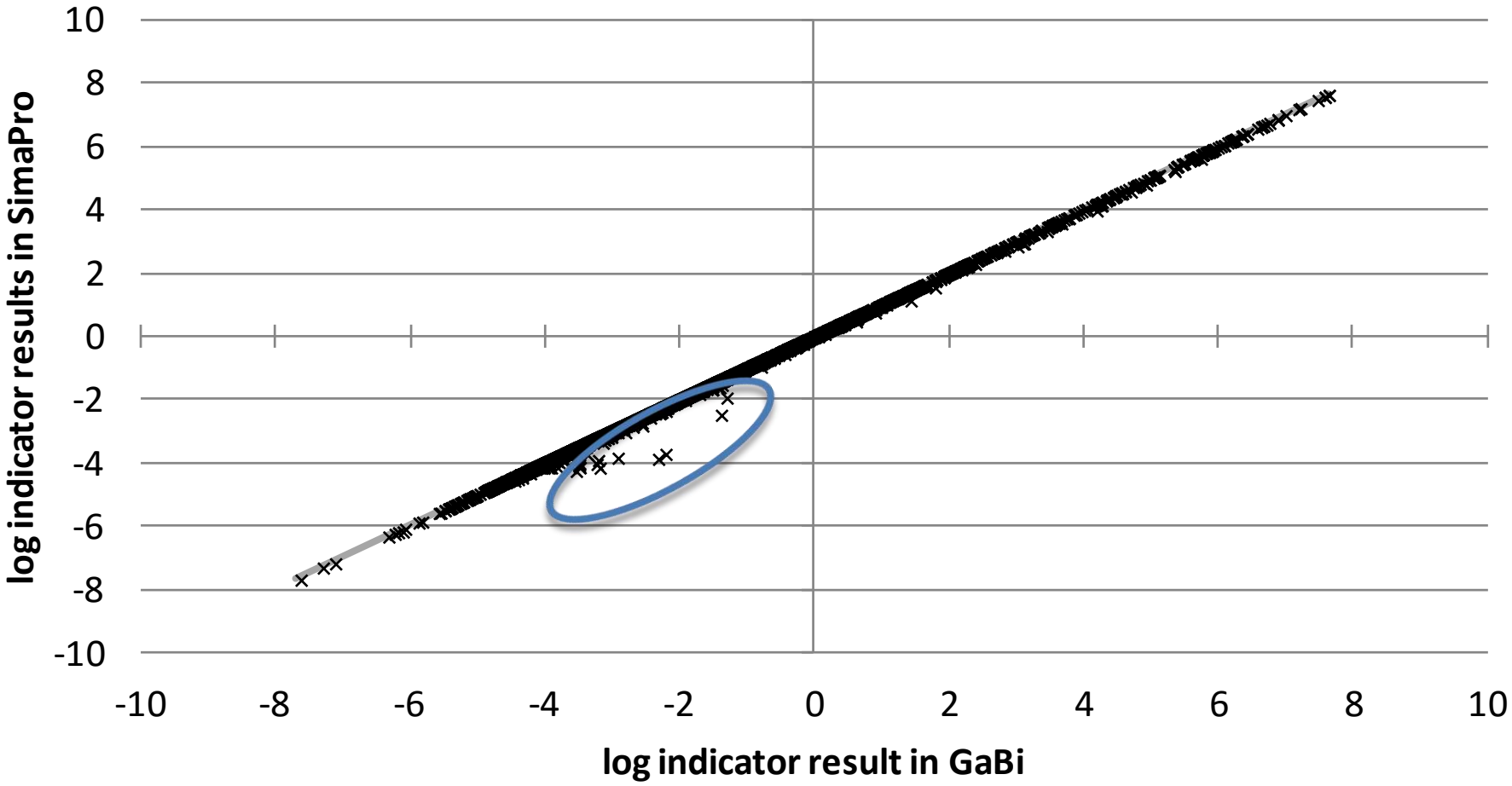
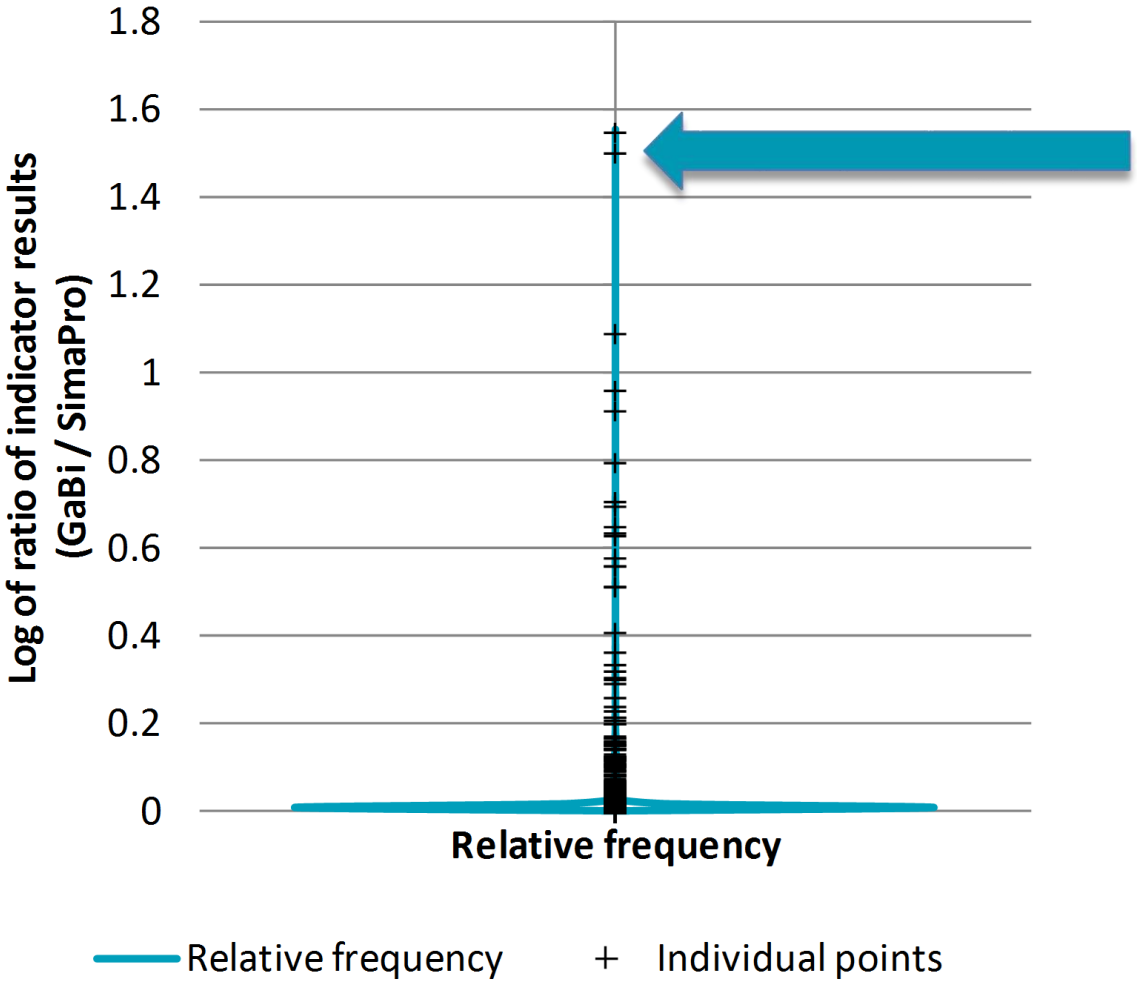
Impact in LCIA results: Acidification potential

CIRAIG analysis (2014, Pascal Lesage)



Impact in LCIA results: Acidification potential

CIRAIG analysis (2014, Pascal Lesage)



In GaBi can be as much as 35x higher

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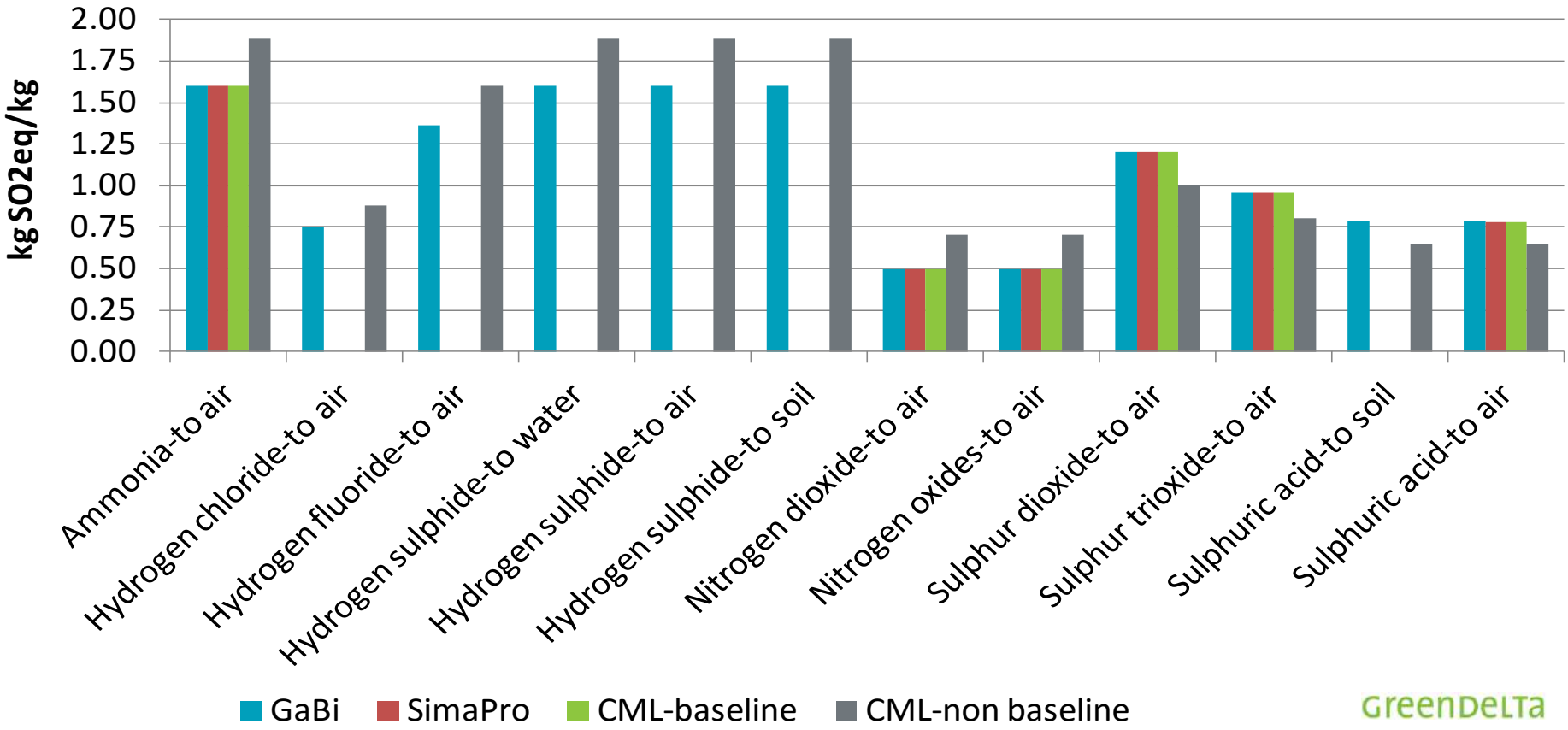
Impact in LCIA results: Acidification potential

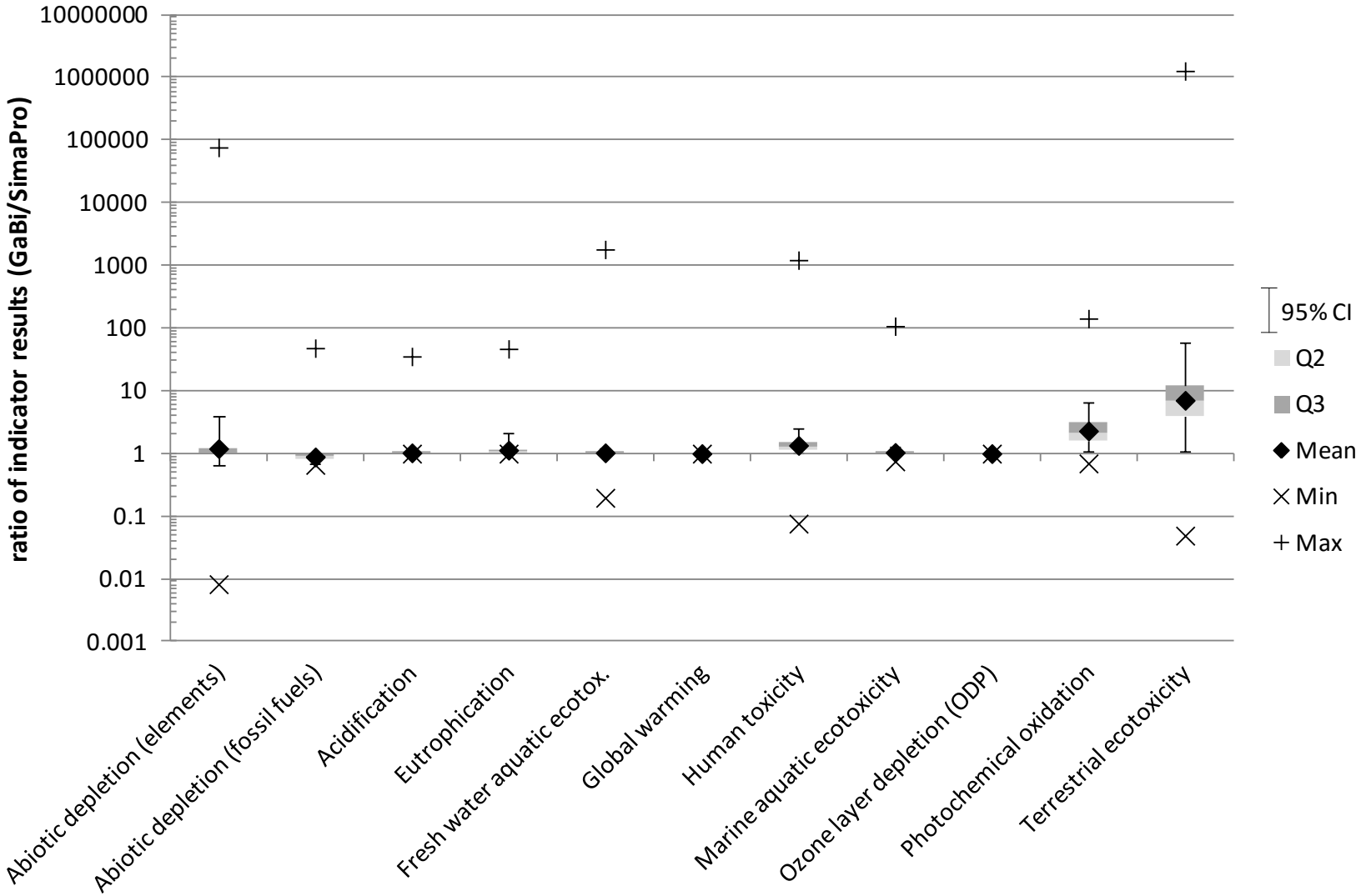
CIRAIG analysis (2014, Pascal Lesage)

Characterisation factors



Impact in LCIA results: CML results

CIRAIG analysis (2014, Pascal Lesage)



But there is hope…

Global LCA Data Access network (GLAD) – UNEP

Nomenclature Working Group, deliverables:

- Agreed mapping system
- Critical review of nomenclature systems
- Principles for maintenance and update of the flow list
- Principles for the harmonization of processes nomenclature and taxonomy

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sustainability consulting + software

Thank you!

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