Airbus Amber

LCA SiC/AlSi study

Comparing alternative materials for optical instrument structural parts

DEFENCE AND SPACE

Ariane Bouilly (ADS) – Nicolas Mazollier (Capgemini consulting – ex Altran)

ESA Clean Space Industrial Days

23 September 2021

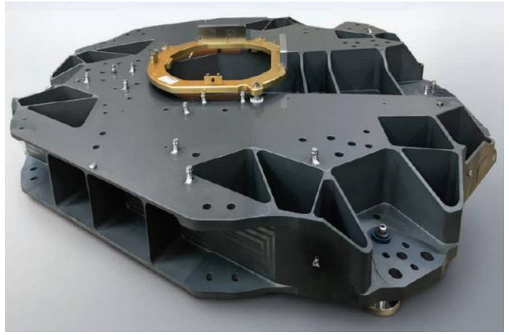
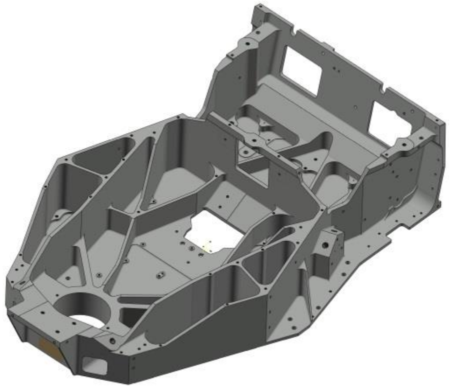
altran Part of Capgemini

AIRBUS

Studied Product and study setup

Comparison of SiC / AlSi structural part of satellite optical instruments

COMPARED PRODUCTS

Techno Name	SiC (Silicon Carbide)	AlSi (Aluminum Silicon)
		
Example of project	LSTM (ESA)	Trishna (CNES)

CRITERIA OF CHOICE

- Good study case for a comparison → interchangeable technologies for similar use cases
- Possibility to reuse study results for customers projects → LSTM for ESA with a full satellite LCA

Project Team, Timeline

PROJECT TEAM

• Altran	LCA engineer	Performed the "core" LCA
• TEXD	LCA technical interface	Coordinating the LCA, Ensuring consolidation
• TESMT	LCA product technical PoCs	Gathering the technical inputs, activity data needed for the LCA
• Suppliers		Providers of data for supplied parts

TIMELINE (small study)

• Kick off	November 2020
• Study Final Presentation	March 2021
• Validated Deliverables	April 2021

Quick reminder on LCA Methodology

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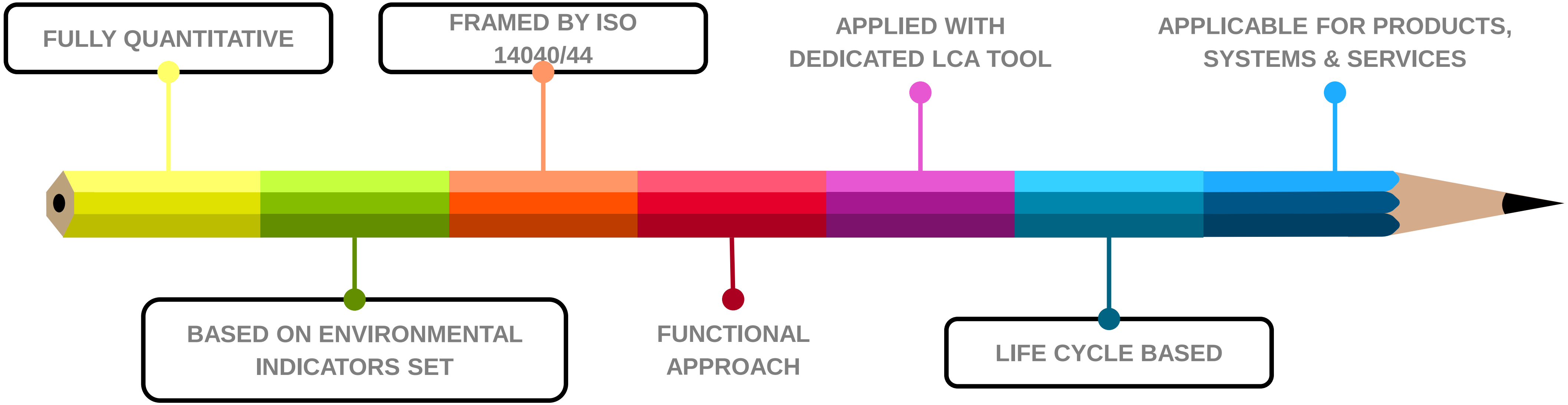
Life cycle assessment

What is a Life Cycle Assessment (LCA)?

Life cycle assessment is a methodology that aims to **identify and quantify environmental impacts** of a product, a system or a service along its full life cycle (cradle to grave).

What are LCA main characteristics ?



Life cycle assessment

How to conduct an LCA ? (according to ISO 14040):

1. GOAL & SCOPE DEFINITION

- Definition of the objective of the study and the functional unit
- Description of the product and its life cycle, system boundaries establishment

2. INVENTORY ANALYSIS (LCI)

- Data collection of inputs and outputs associated to the product studied
- Example of data to collect: bill of processes, bill of materials, air emissions…

3. IMPACT ASSESSMENT (LCIA)

- Assessment of the life cycle inventory results (LCI)
- Usage of LCA expert tool

4. INTERPRETATION OF RESULTS

- Interpretation of the results coming from LCI or LCIA (or both)
- Conclusion with recommendation and decision making

LCA Study Implementation

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1 – Goal and Scope definition

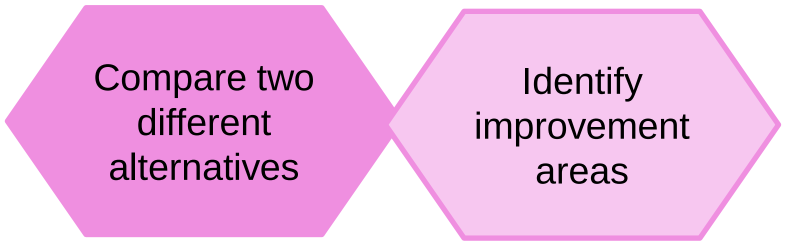
1. GOAL & SCOPE DEFINITION

- Definition of the objective of the study and the functional unit
- Description of the product and its life cycle, system boundaries establishment

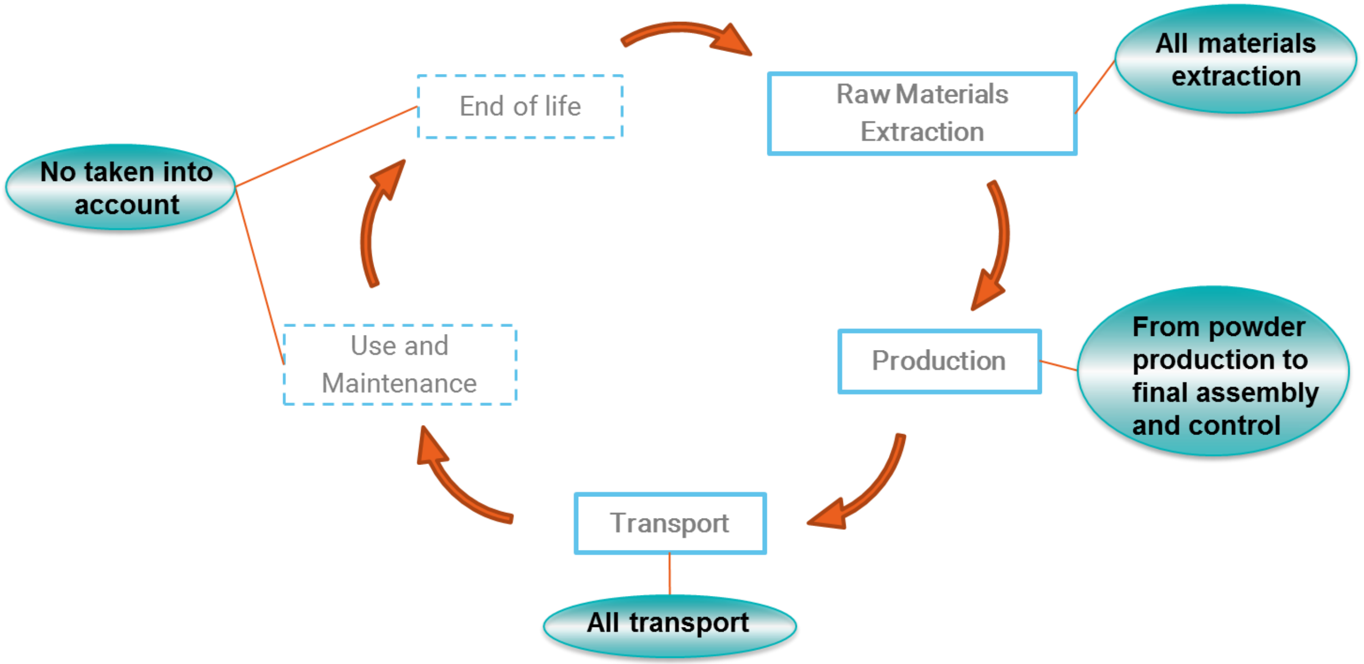
FUNCTIONNAL UNIT

« Production of an optical satellite's instrument structural plate »

OBJECTIVE



SYSTEM BOUNDARIES



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2 – Inventory analysis – An iterative process

Get a first overview of the **production process**

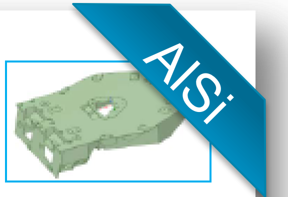
SIC vs AlSi

SIC

- Powder production
- Isostatic pressing
- Blank Machining
- Sintering (Hight temp)
- Final Machining (Grinding)

MERSEN

AlSi



- Powder or Flake (Melt spinning) production
- Can manufacturing
- Hot Isostatic Pressure
- Rought Machining
- Temperature stabilisation
- Final Machining
- Protection treatment

Powder Light Metals
Hochleistungs-Aluminium

RSP TECHNOLOGY

2 – Inventory analysis – An iterative process

Dependant on support from product technical PoCs

Get a first overview of the production process

Start collecting "easy" data, identify inputs/outputs, and evaluate which data will be possible to retrieve or not

Main characteristcis

Hypotheses Baseplate pour Trade-off Eco-Design							
	L	W	H	Volume	Surface	Masse	Commentaires
	[mm]	[mm]	[mm]	[m3]	[m2]	[Kg]	
Dimensions finies	928	620	195	0.009	2.18	24.2	
Dimensions Brut AlSi	970	660	235	0.150	-	382.1	brut optimisable
Dimensions Brut SIC	1164	792	282	0.260	-	779.9	+20%
Donnees AlSi40%							
Densité	2540	[Kg/m3]					
RSP		site	http://www.rsp-technology.com/				
		Adresse	RSP Technology Metaalpark 2 9936 BV Delfzijl The Netherlands				

Suppliers names and locations

SiC

Step	Data known	Questions	Retrievable data (Y/N) ?	Answ...
1. Powder production	1.1 Silicium	Amount ?	N	
		location ?	N	
	1.2 carbon	Amount ?	N	
		location ?	N	
	1.3 heating	Energy ?	N	
		temperature ?	Y	
		location ?	Y	[illegible]
	1.4 crushing by granulometrie	Energy ?	N	
		Materials needed ?	N	
		location ?	Y	[illegible]
	1.5 sifting	Energy ?	Y	
		location ?	Y	[illegible]
	1.6 Additive mix	type of additive	Y	
		amount ?	Y	
		location ?	Y	[illegible]
	1.7 atomisation	energy?	Y	
		other?	Y	
		location ?	Y	[illegible]
2. Isostatic pressing	Powder pressing	Energy ?	Y	
		type of machine used ?	Y	Isostatic pressing
		location ?	Y	[illegible]
3.cutting		Energy ?	N	
		type of machine used ?	Y	
		location ?	Y	[illegible]

Energy, material, consumables, waste

2 – Inventory analysis – An iterative process

Dependent on suppliers contribution

Get a first overview of the production process and related inputs/outputs

Start collecting “easy” data, identify inputs/outputs, and evaluate which data will be possible to retrieve or not

Ensure as many “activity data” as possible are collected, and extrapolate unavailable data (using public literature, similar process, …)

MERSEN BOOSTEC

Step	Data known	Questions	Retrievable data (Y/N) ?	Ans
production	1.5 grain size selection	Energy ?	N	
		location ?	Y	[illegible]
	1.6 Additive mix	type of additive	Y	[illegible]
		energy?	Y	xxxx kWh
		amount ?	Y	xxxx kg
		location ?	Y	[illegible]
	1.7 spray-drying	energy?	Y	xxxx kWh
		other?	N	
		location ?	Y	[illegible]
2. Isostatic pressing	Powder pressing	Energy ?	Y	xxxx kWh
		type of machine used ?	Y	[illegible]
		location ?	Y	[illegible]
3.cutting		Energy ?	Y	xxxx kWh
		type of machine used ?	Y	[illegible]
		location ?	Y	[illegible]
4. blank machining	Machining	Energy	Y	xxxx kWh
		Materials needed ?	Y	[illegible]
		location ?	Y	[illegible]
5.Sintering	Sintering	Energy	Y	xxxx kWh
		Materials needed ?	N	
		location ?	Y	[illegible]
6. final machining	Diamond grinding	Energy	Y	xxxx kWh
		Materials needed ?	Y	[illegible]
		location ?	Y	[illegible]
7. Dye penetrant inspection		Energy	Y	Manual spray
		Materials needed ?	Y	Dye penetrant (0.2 l)
		location ?	Y	[illegible]
8. Cleaning Bath		Energy	Y	[illegible]
		Materials needed ?	Y	[illegible]
		location ?	Y	[illegible]

SiC

Activity data from production steps at suppliers facilities

2 – Inventory analysis – An iterative process

SiC

LIFE CYCLE ASSESSMENT – SIC VS ALSI

INVENTORY : SIC INFORMATION

- 61.3%Si + 38.7%C (by mass)
- Buy to Fly ratio : 780 to 24.2 kg
- 2/3 from recycled SiC : only 260 kg of SiC primary produced
- 9 steps :
  - European supplier : Powder Production (1)
  - Boostec Lannemezan : Powder Production (2)
  - European subcontractor : Isostatic Pressing
  - Boostec Bazet: Cutting, Blank Machining, Sintering, Final Machining, Control and Cleaning

Process Boostec

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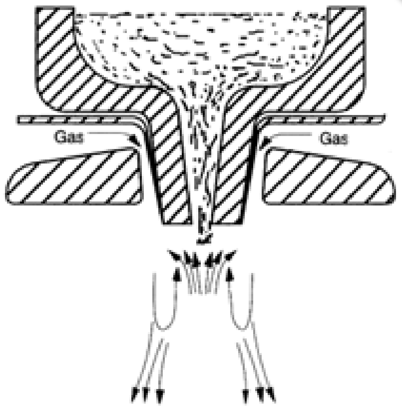
2 – Inventory analysis – An iterative process

LIFE CYCLE ASSESSMENT – SIC VS ALSI

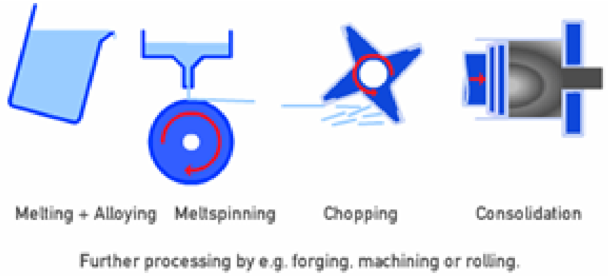
INVENTORY : ALSI INFORMATION

AlSi

- 60%Al + 40%Si
- Buy to fly ratio : 380 to 24.2 kg
- 9 steps :
  - ECKA (Germany) or RSP (Netherlands) : Raw materials production
  - PLM (Germany) or RSP (Netherlands) : Can Manufacturing, Hot Isostatic Pressing , Can Removing
  - Machinist in Toulouse : Rough and Final Machining
  - Bodycote (Paris) : Temperature Stabilisation
  - Testia (Toulouse) : Dye Penetrant Inspection
  - Modertech (St Etienne) : Surface Treatment



Spray-Drying (ECKA)



Meltspinning (RSP)

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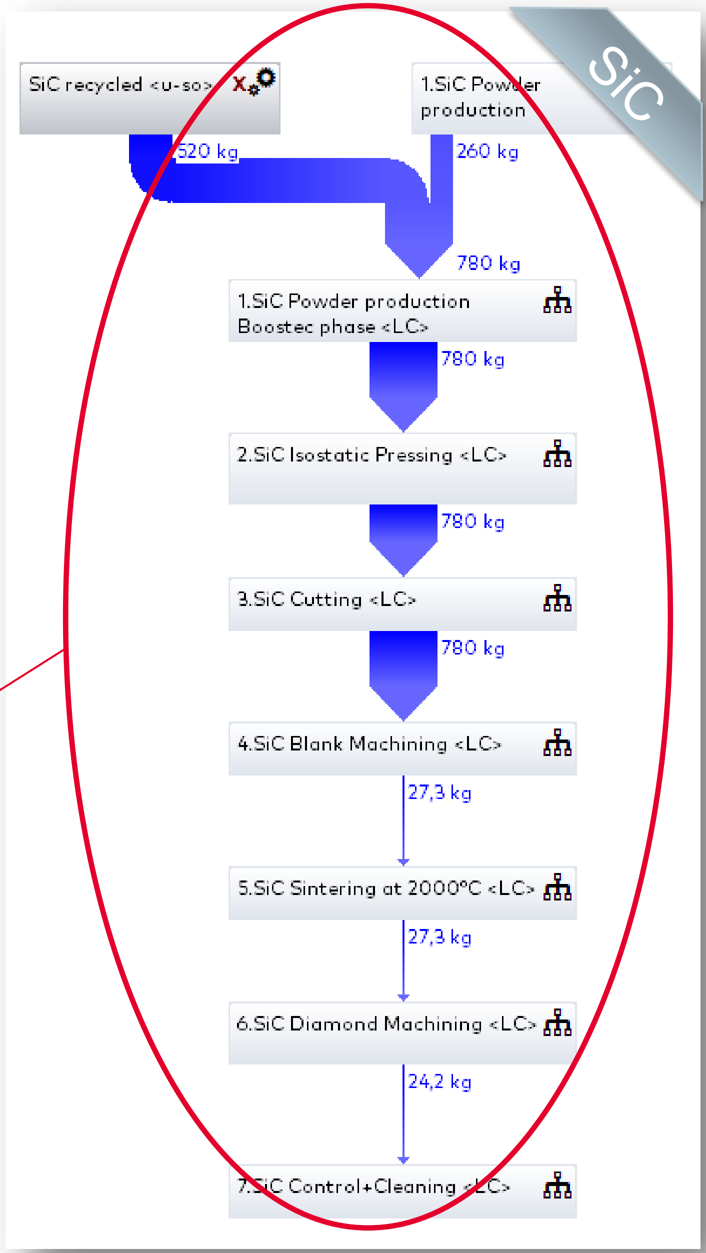
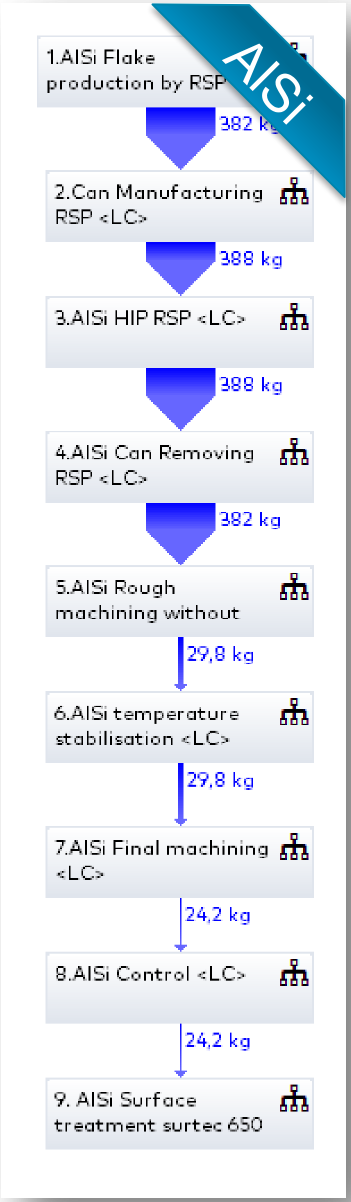
3 – Impact Assessment

Modelisation of the global processes in GABI

Dependent on LCA engineer & LCA Software + databases

Level 1 model

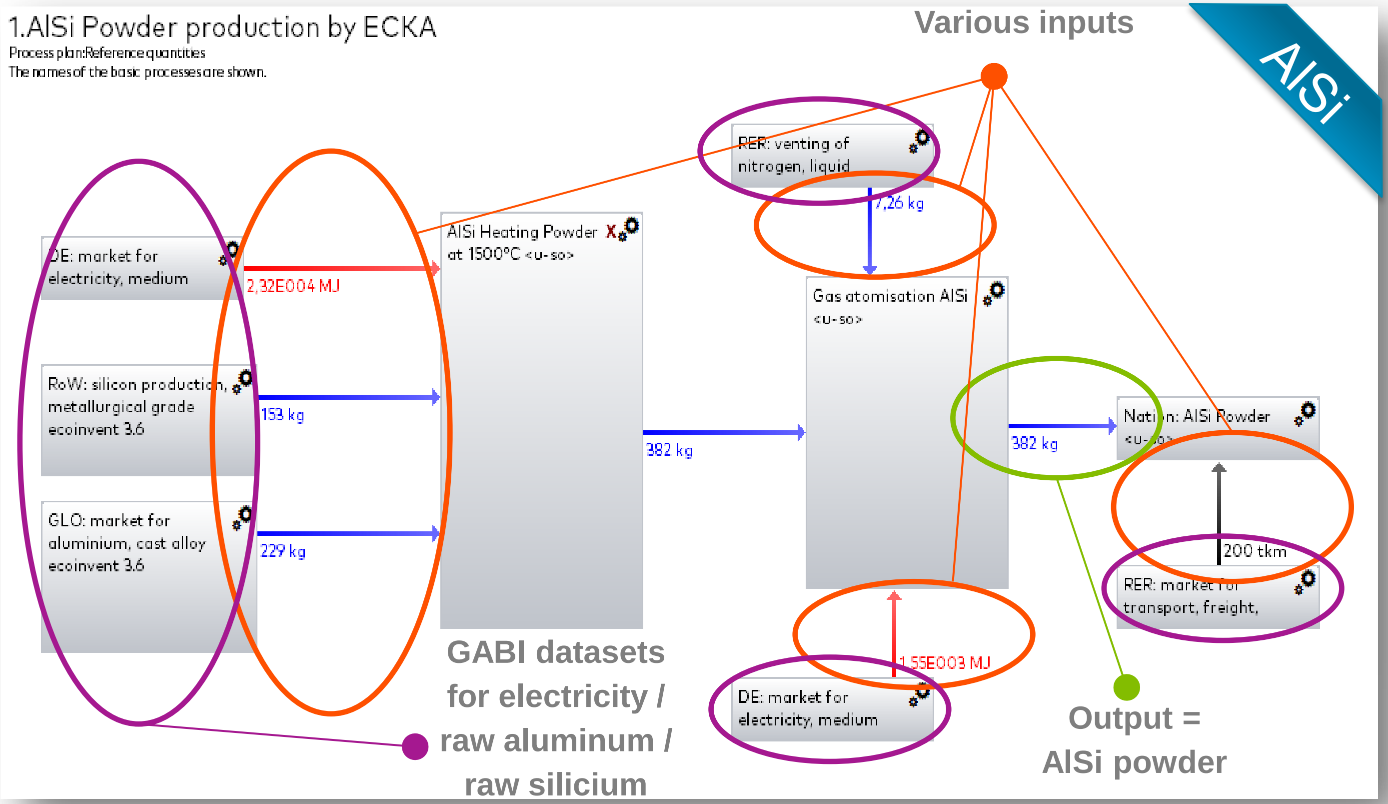


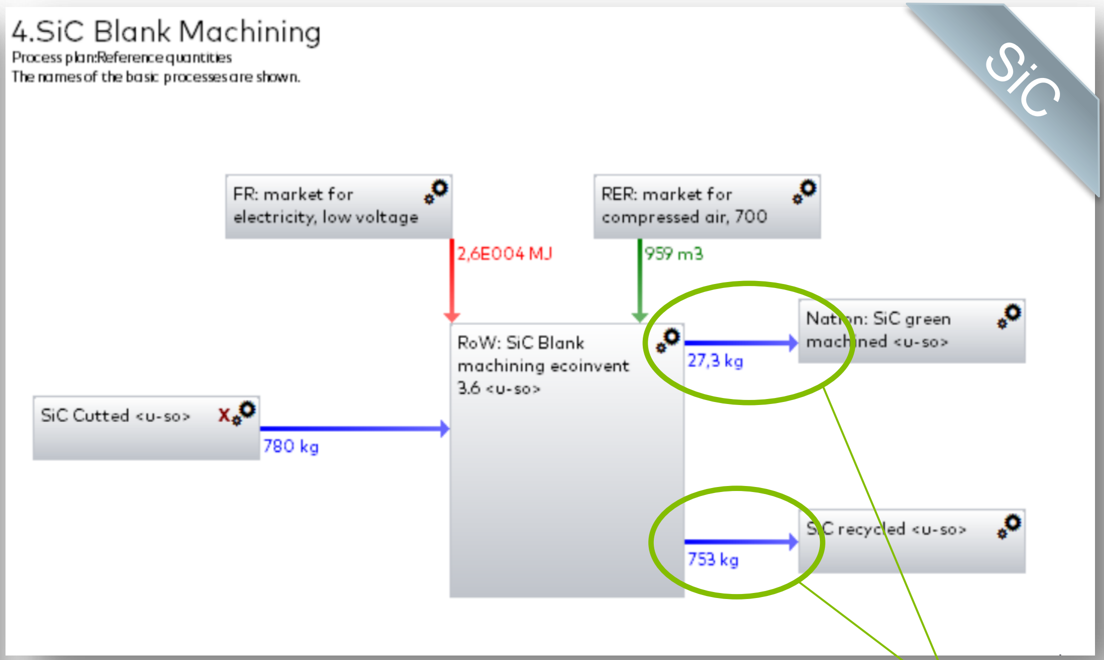


3 – Impact Assessment

Modelisation of the global processes in GABI

Modelisation of each process including its inputs + outputs + combination with the relevant data sets of GABI database





Output = SiC Part + SiC scraps

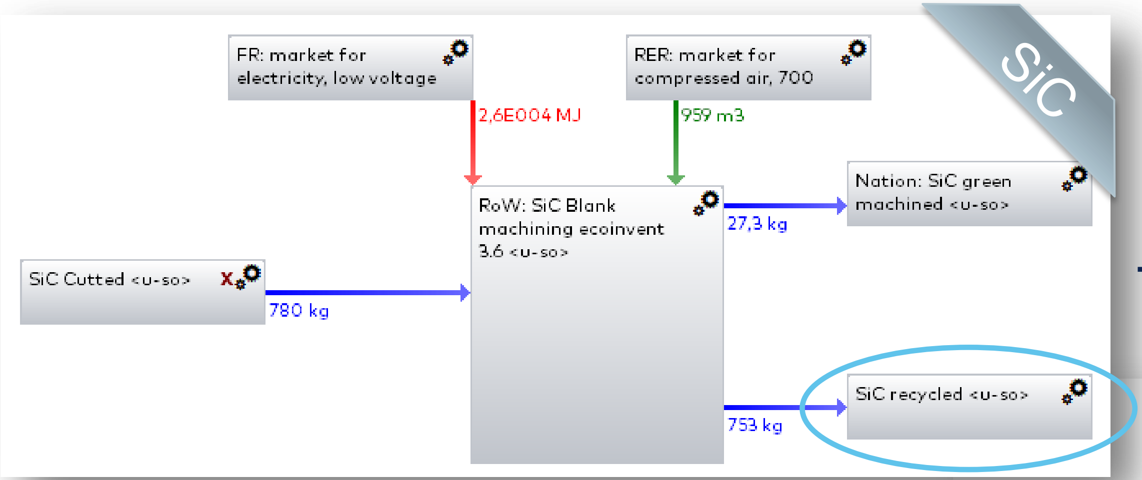
More details on GABI dataset

3 – Impact Assessment

Modelisation of the global processes in GABI

Modelisation of each process including its inputs + outputs in GABI + combination with the relevant data sets of GABI database

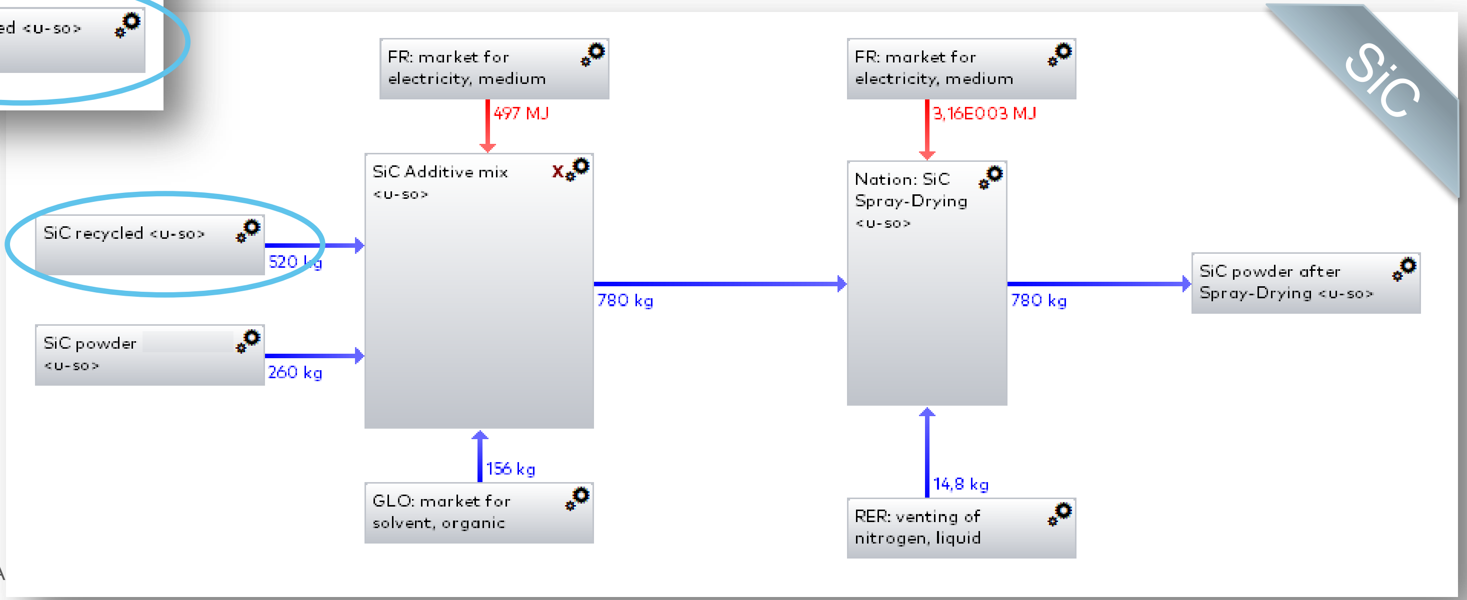
FOCUS: Integration of all specificities susceptible to modify the environental impact: recycling loop



→ Recycling loop of SiC from blank machining step :

Directly reused for powder production →

(1/3 virgin material – 2/3 recycled)



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LCA IS BASED ON ENVIRONMENTAL INDICATORS SET

4 – Results interpretation – the indicators

Selection of the method and indicators to consider

Recipe Midpoint H 2016 with 19 Impact categories :

Impact category	Unit
Climate change, default, excl biogenic carbon	[kg CO2 eq.]
Climate change, incl biogenic carbon	[kg CO2 eq.]
Fine Particulate Matter Formation	[kg PM2.5 eq.]
Fossil depletion	[kg oil eq.]
Freshwater Consumption	[m3]
Freshwater ecotoxicity	[kg 1,4 DB eq.]
Freshwater Eutrophication	[kg P eq.]
Human toxicity, cancer	[kg 1,4-DB eq.]
Human toxicity, non-cancer	[kg 1,4-DB eq.]
Ionizing Radiation	[kBq Co-60 eq. to air]
Land use	[Annual crop eq.·y]
Marine ecotoxicity	[kg 1,4-DB eq.]
Marine Eutrophication	[kg N eq.]
Metal depletion	[kg Cu eq.]
Photochemical Ozone Formation, Ecosystems	[kg NOx eq.]
Photochemical Ozone Formation, Human Health	[kg NOx eq.]
Stratospheric Ozone Depletion	[kg CFC-11 eq.]
Terrestrial Acidification	[kg SO2 eq.]
Terrestrial ecotoxicity	[kg 1,4-DB eq.]

Indicators considered as priority indicators by ESA

Indicators focusing on **Ecosystem quality**

Indicators focusing on **Human Health**

Indicators focusing on **resources quality/quantity**

4 – Results interpretation – the raw data

Impact category	Unit	total	Powder european [illegible]	Powder Boostec [illegible]	Pressing	Cutting	Blank Machining	Sintering	Diamond machining	[illegible]
Climate change, default, excl biogenic carbon	[kg CO2 eq.]	3.78E+03	[illegible]	[illegible]	6.43E+02	[illegible]	[illegible]	[illegible]	3.41E+02	2.32E-0[illegible]
Climate change, incl biogenic carbon	[kg CO2 eq.]	3.82E+03	3.59E+02	2.18E+02	6.63E+02	2.15E+00	7.53E+02	1.48E+03	3.45E+02	2.32E-01
Fine Particulate Matter Formation	[kg PM2.5 eq.]	4.83E+00	6.62E-01	3.82E-01	7.05E-01	3.04E-03	1.04E+00	1.57E+00	4.68E-01	4.36E-04
Fossil depletion	[kg oil eq.]	8.46E+03	3.23E+02	4.60E+02	2.37E+02	5.14E+00	2.01E+03	4.43E+03	9.94E+02	2.63E-01
Freshwater Consumption	[m3]	2.75E+02	1.71E+02	5.41E+00	2.25E+00	7.09E-02	2.66E+01	5.60E+01	1.28E+01	2.20E-03
Freshwater ecotoxicity	[kg 1,4 DB eq.]	5.34E+02	3.43E+01	1.32E+01	1.14E+01	6.45E-01	2.48E+02	1.06E+02	1.21E+02	1.16E-02
Freshwater Eutrophication	[kg P eq.]	1.52E+00	7.11E-02	5.74E-02	4.57E-01	1.16E-03	3.54E-01	4.37E-01	1.44E-01	7.76E-05
Human toxicity, cancer	[kg 1,4-DB eq.]	2.10E+02	1.67E+01	8.45E+00	2.91E+01	1.69E-01	5.94E+01	6.92E+01	2.73E+01	8.42E-03
Human toxicity, non-cancer	[kg 1,4-DB eq.]	6.69E+03	[illegible]	[illegible]	[illegible]	5.57E+00	2.03E+03	2.28E+03	9.62E+02	2.83E-01
Ionizing Radiation	[kBq Co-60 eq. to air]	1.65E+04	[illegible]	[illegible]	[illegible]	1.06E+01	4.23E+03	9.46E+03	2.11E+03	2.85E-02
Land use	[Annual crop eq.·y]	1.65E+02	2.07E+01	7.41E+00	2.01E+01	9.69E-02	3.49E+01	6.55E+01	1.63E+01	5.71E-03
Marine ecotoxicity	[kg 1,4-DB eq.]	6.58E+02	4.37E+01	1.66E+01	1.91E+01	7.80E-01	2.99E+02	1.32E+02	1.46E+02	1.49E-02
Marine Eutrophication	[kg N eq.]	4.11E-01	5.75E-03	1.48E-02	3.13E-02	2.71E-04	1.01E-01	2.09E-01	4.84E-02	6.07E-06
Metal depletion	[kg Cu eq.]	1.49E+01	1.84E+00	9.44E-01	1.57E+00	1.15E-02	4.33E+00	4.16E+00	2.07E+00	2.02E-03
Photochemical Ozone Formation, Ecosystems	[kg NOx eq.]	1.00E+01	1.56E+00	7.64E-01	2.72E+00	4.27E-03	1.51E+00	2.79E+00	6.94E-01	1.79E-03
Photochemical Ozone Formation, Human Health	[kg NOx eq.]	9.76E+00	1.52E+00	6.91E-01	2.68E+00	4.18E-03	1.48E+00	2.72E+00	6.77E-01	1.34E-03
Stratospheric Ozone Depletion	[kg CFC-11 eq.]	4.76E-03	6.47E-04	3.11E-04	3.39E-04	2.55E-06	9.64E-04	2.03E-03	4.66E-04	2.02E-07
Terrestrial Acidification	[kg SO2 eq.]	1.26E+01	1.74E+00	1.04E+00	1.82E+00	7.79E-03	2.67E+00	4.06E+00	1.21E+00	1.17E-03
Terrestrial ecotoxicity	[kg 1,4-DB eq.]	2.78E+04	3.54E+03	9.78E+02	7.40E+03	1.69E+01	6.43E+03	6.30E+03	3.12E+03	1.10E+00

SiC

Quantitative evaluation of the impact

But also for each lower level modelled

For each type of impact for the global production

More details on impact calculation

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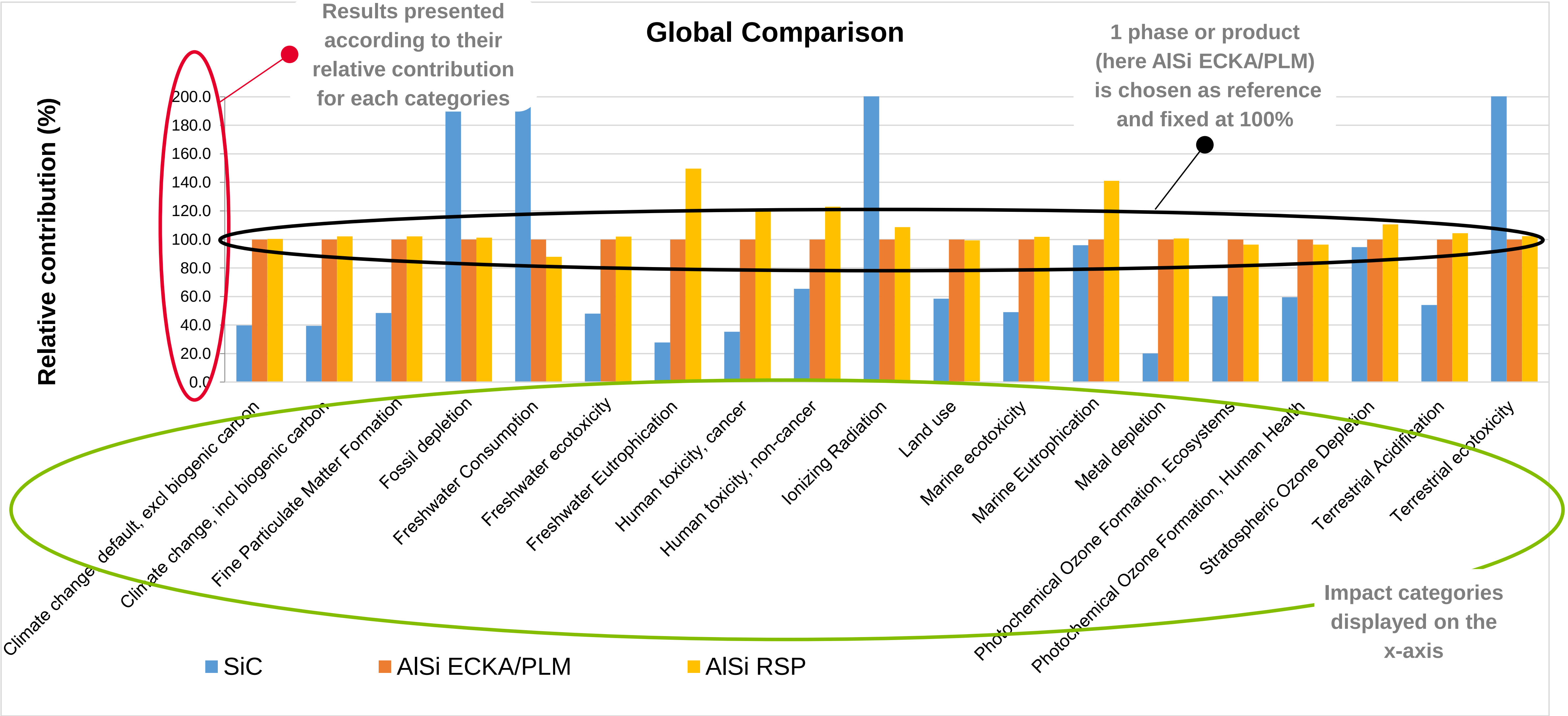
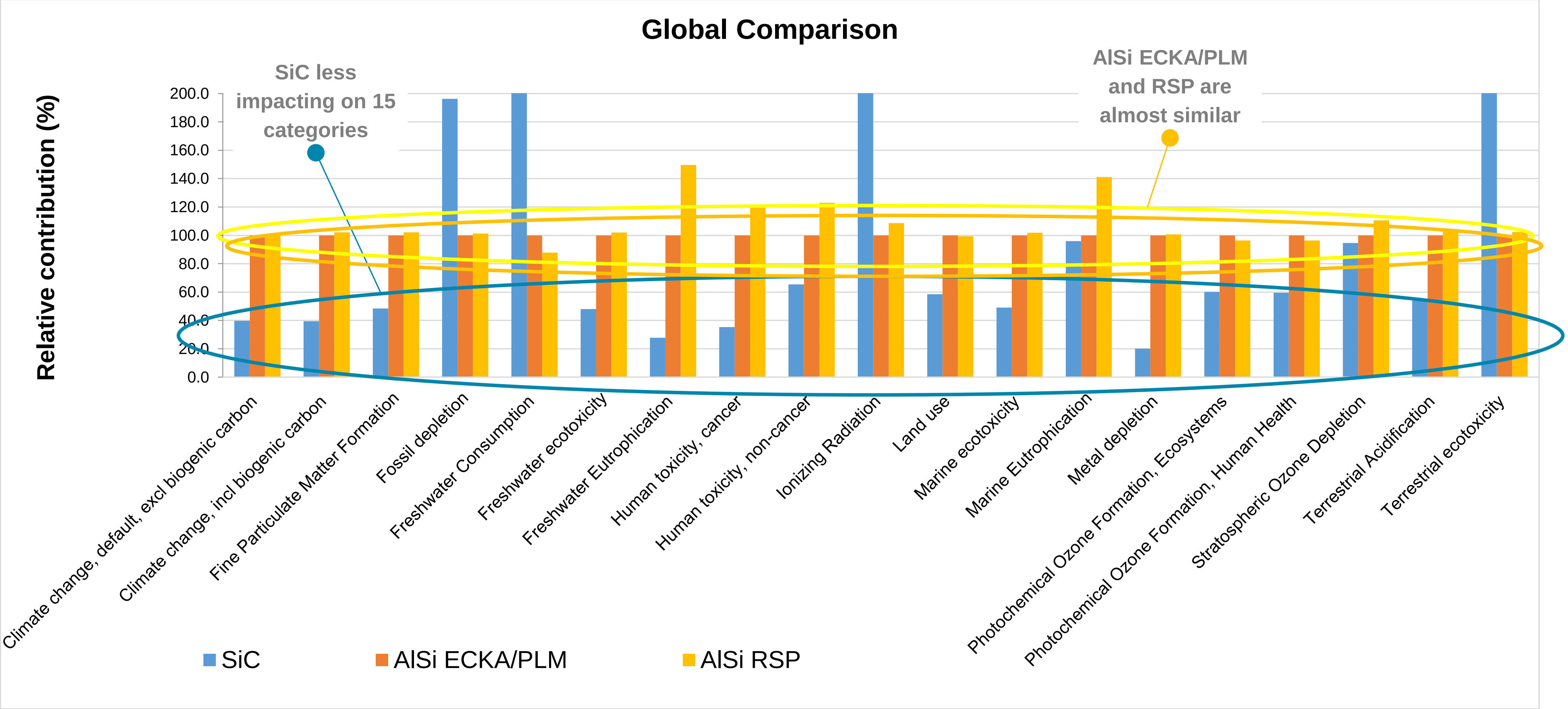
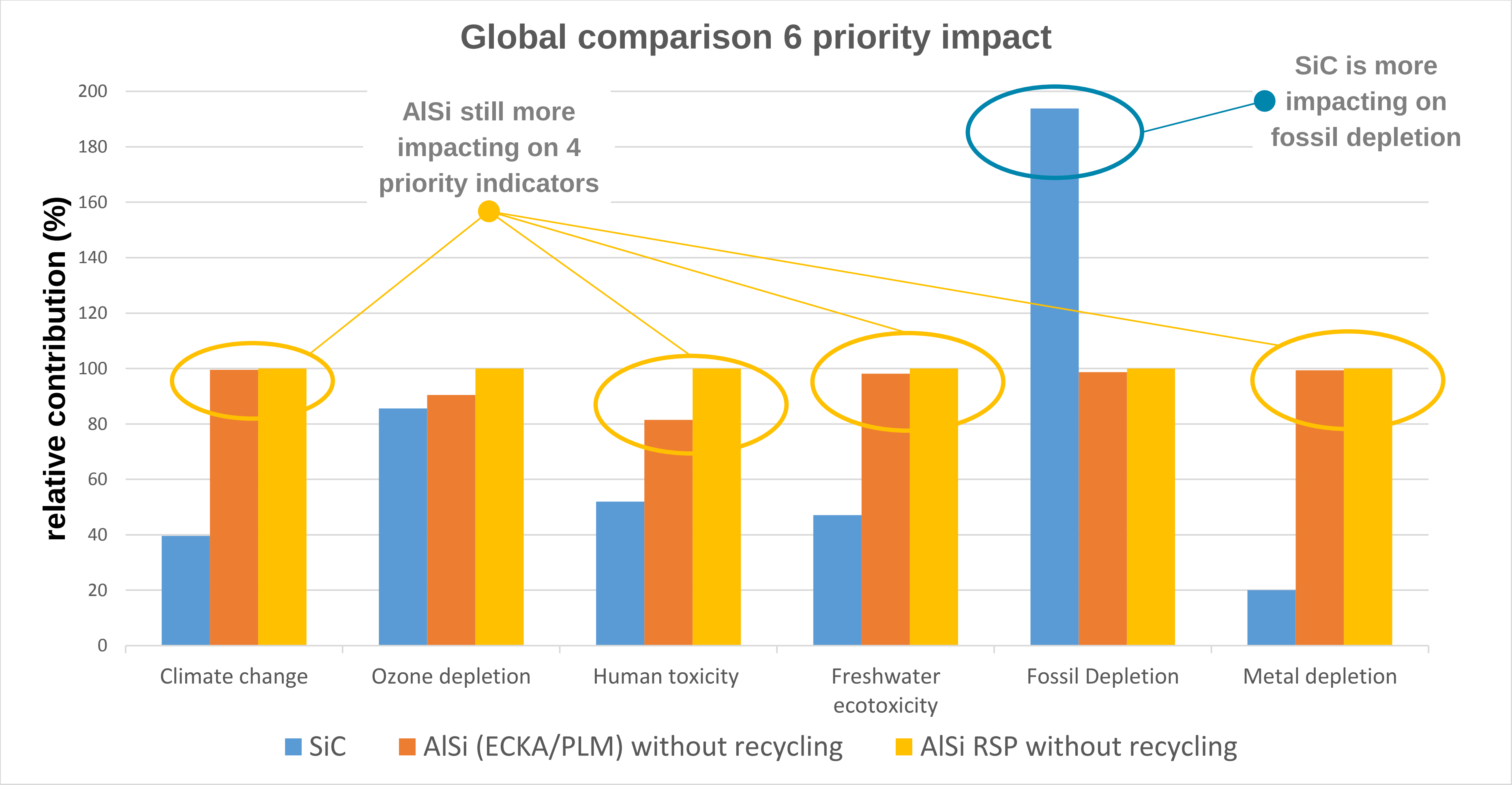
4 – Results interpretation – How to read the graphs



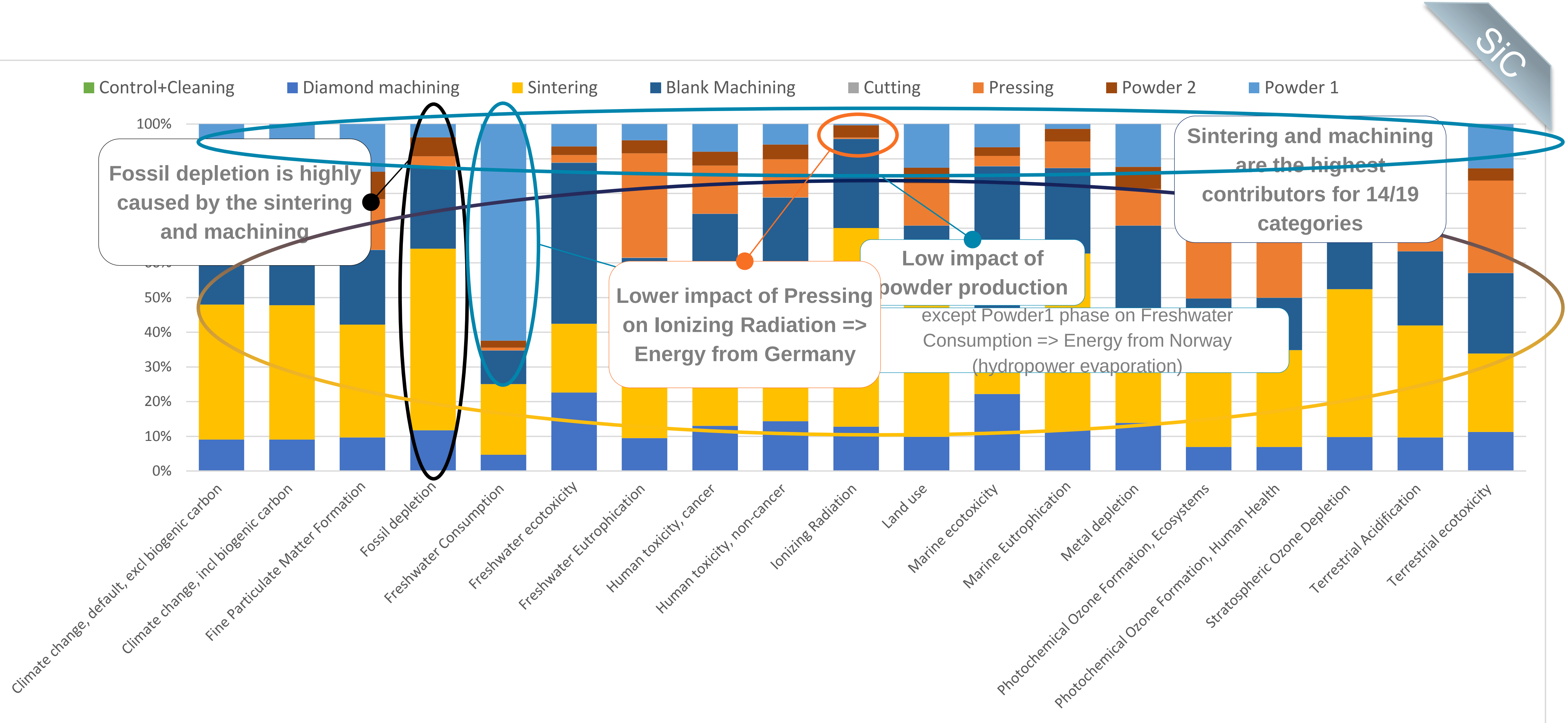
4 – Results interpretation – Global Comparison



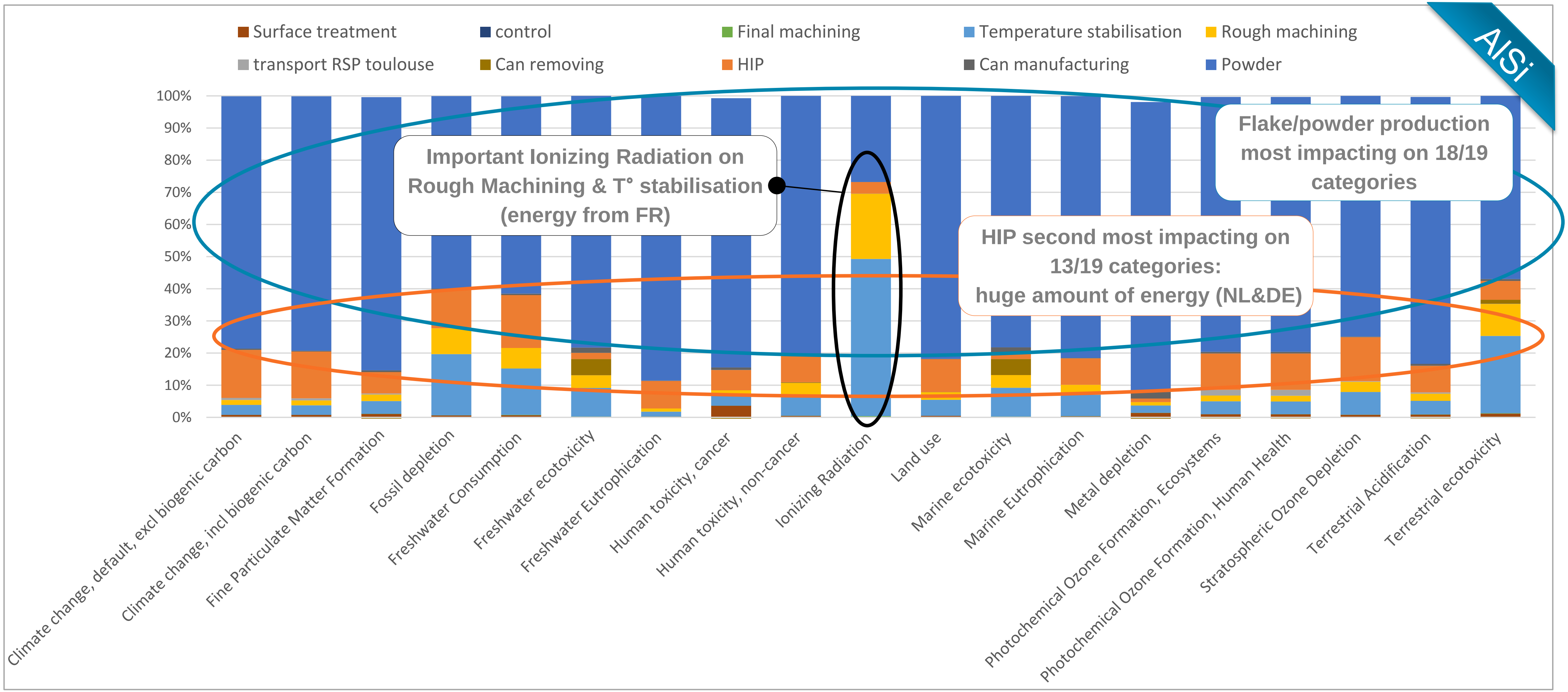
4 – Results interpretation – Global Comparison – ESA priority indicators



4 – Results interpretation – Global SiC Analysis



4 – Results interpretation – Global AlSi Analysis



4 – Results interpretation – conclusions and recommendation

Compare two different alternatives

- ❑ AlSi globally more impacting
- ❑ Lack of data for AlSi

Identify improvement areas

SiC

❑ Impacts of SiC :
- Blank Machining with important amount of materials machined
- Sintering at 2000°C
- Isostatic Pressing outside France (carbon intensive energetic mix)
- Final Machining with Diamond

❑ Potential improvement for SiC:
- Increase BtF ratio to reduce machining and quantity of material needed
- Switch to less impacting energy sources

AlSi

❑ Impacts of AlSi:
- Raw materials extraction with Silicon and Aluminium
- No recycled product used
- Additional steps of Can Manufacturing/Removing and Surface Treatment
- Process steps with electricity mix from Germany and Netherlands
- More transport steps

❑ Potential improvement for AlSi
- Manage Raw Material impact (e.g. specify and certify the use of recycled aluminum as raw material)

Questions - Discussions

THANK YOU

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BACK-UP SLIDES