Recovery of Tungsten, Niobium and Tantalum occurring as by-products in mining and processing waste streams

TARANTULA CLUSTERING EVENT

Social License to Operate (SLO) in mining sector and LCA methodologies for (re)processing of low-grade primary and secondary resources 19th April 2023

The TARANTULA project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No 821159 - https://h2020-tarantula.eu/

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The TARANTULA project

The TARANTULA project

Challenge: exploit potential of W, Nb, and Ta entrapped in complex low-grade resources within EU territory.

TARANTULA

"Recovery of Tungsten, Niobium and Tantalum occurring as by-products in mining and processing waste streams"

Grant agreement ID: 821159

Coordinator: TECNALIA (Spain)

Ongoing

1 June 2019 – 31 Nov 2023 (54 M)

6.9 MEUR

The TARANTULA consortium

16 European consortium partners (companies, industry associations, research institutions and universities) **covering the full value chain**.

FUNDACIÓN TECNALIA RESEARCH & INNOVATION, Spain

KATHOLIEKE UNIVERSITEIT LEUVEN, Belgium

SINTEF AS, Norway

CHALMERS TEKNISKA HOEGSKOLA AB, Sweden

TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER (T.I.C.), Belgium

SALORO S.L.U., Spain

VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V., Belgium

UNIVERSITE DE LIEGE, Belgium

OPTIMIZACION ORIENTADA A LA SOSTENIBILIDAD SL, Spain

STRATEGIC MINERALS SPAIN SL, Spain

CRONIMET Holding GmbH, Germany

SIDENOR INVESTIGACION Y DESARROLLO S.A., Spain

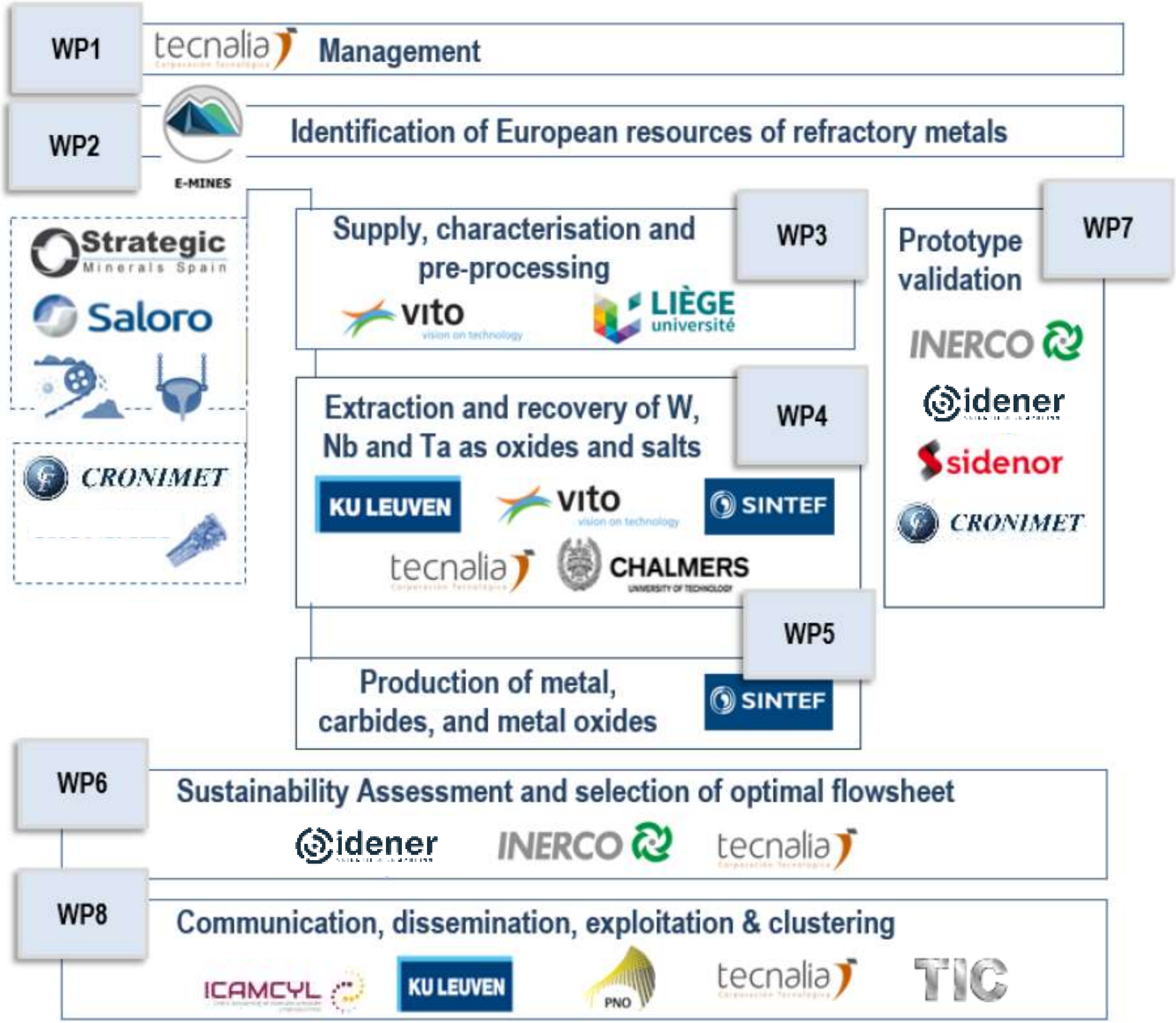
E-MINES, France

INERCO INGENIERIA, TECNOLOGIA Y CONSULTORIA S.A., Spain

PNO INNOVATION, Belgium

FUNDACION ICAMCYL, Spain

TARANTULA work plan



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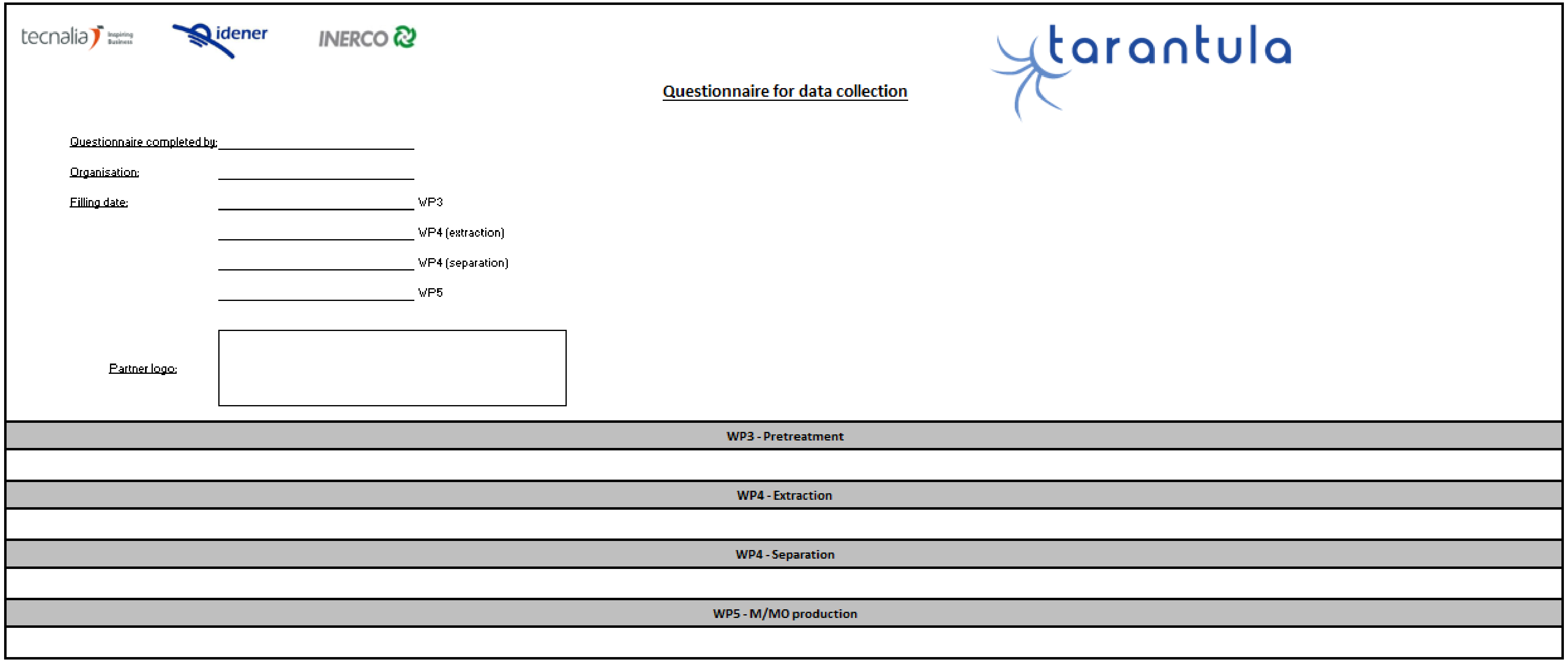
LCA of individual technologies

Data collection for the LCI

The objective of the GA is to evaluate the environmental and economic impact of the different technologies developed in the project.

For this purpose, a questionnaire was developed by WP6 partners.



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Questionnaire for data collection

Questionnaire completed by: ____________________

Organisation: ____________________

Filling date: ____________________ WP3

____________________ WP4 (extraction)

____________________ WP4 (separation)

____________________ WP5

Partner logo:

WP3 - Pretreatment
WP4 - Extraction
WP4 - Separation
WP5 - M/MO production

Information about TARANTULA processes: energy consumption, materials needed, waste generated, personnel costs, emissions and equipment.

Scope of the study

Review of feedstock availability in the EU to define a new reference unit for data collection to better calculate the environmental and economic impact of TARANTULA technologies. The functional unit was used to represent the final results of each technology.

	Reference unit	Functional unit
Pre-concentration technologies (WP3)	5.000 ton/year of tailings as output	1 kg of concentrates produced
Extraction technologies (WP4)	5.000 ton/year of tailings as input	1 kg of metal extracted
Separation technologies (WP4)	5.000 ton/year of tailings as input	1 kg of metal oxide produced
Metal production technologies (WP5)	1 kg of metal production	Production/deposition of 1 kg of metal

Modelling framework: attributional modelling.

System boundaries: cradle to gate (from raw materials acquisition to final product production. Distribution, use and EOL management phases of Tungsten, Tantalum and Niobium metal have been excluded.

Allocation rules: whenever subdivision of unit processes was not possible, mass allocation was used for assigning the environmental and economic impacts when several metals were recovered together.

Data quality: data accuracy, geographical representativeness, temporal representativeness and dataset representativeness were the parameters evaluated in the study, using a score from 1 to 3 (1 means highest quality).

Software and databases: SimaPro v9 and Ecoinvent v3.7.

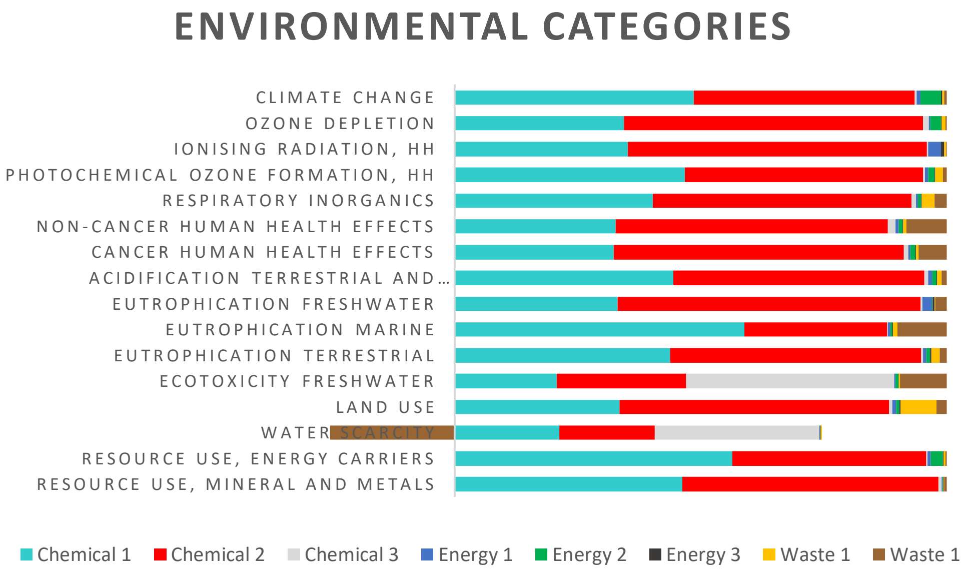
Impact and cost categories

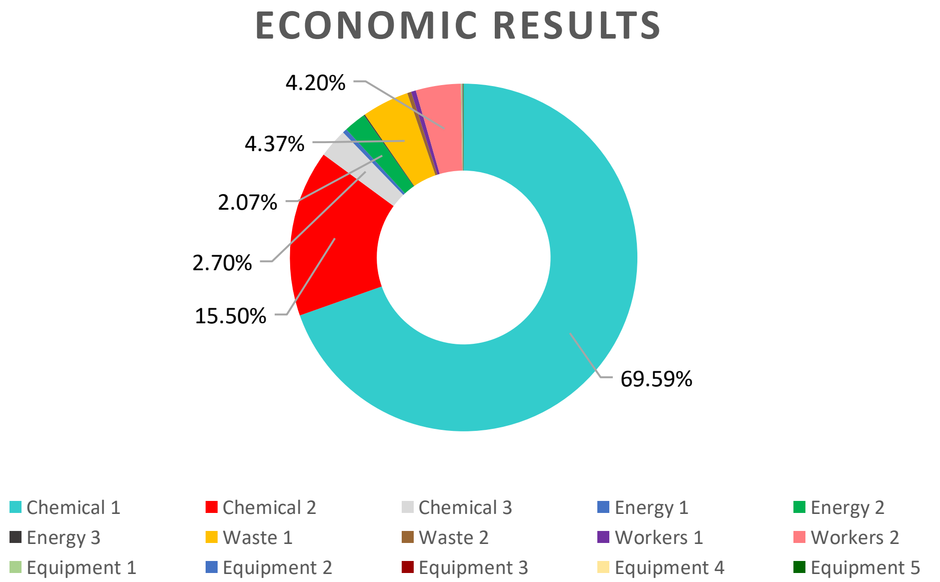
The environmental impact categories included in the document "Suggestions for updating the Product Environmental Footprint (PEF) method" (Zampori and Pant, 2019) were used.

ENVIRONMENTAL CATEGORIES					
Climate change	CC	kg CO2 eq	Eutrophication freshwater	EF	kg P eq
Ozone depletion	ODP	kg CFC-11 eq	Eutrophication marine	EM	kg N eq
Ionising radiation, HH	IR	kBq U-235 eq	Eutrophication terrestrial	ET	mol N eq
Photochemical ozone formation, HH	POF	Kg NMVOC eq	Ecotoxicity freshwater	ECF	CTUe
Respiratory inorganics	RI	disease inc.	Land use	LU	Pt
Non-cancer human health effects	NCHH	CTUh	Water scarcity	WS	m3 depriv.
Cancer human health effects	CHH	CTUh	Resource use, energy carriers	RUEC	MJ
Acidification terrestrial and freshwater	ATF	mol H+ eq	Resource use, minerals and metals	RUMM	kg Sb eq

ECONOMIC INDICATORS			
Materials cost	€	Labour costs	€
Energy costs	€	End of life costs	€

Impact assessment and interpretation





Results given for every metal that is extracted in the process:

- Results for the 16 environmental impact categories included in the study.
- Aggregated results using PEF normalization and weighting factors.
- Aggregated results for the economic assessment.

Interpretation of the results in order to identify the main environmental and economic hotspots:

- For most processes, chemical consumption is the main environmental and economic aspect.
- For some processes, energy is the main environmental aspect.
- For some processes, waste treatment is the main environmental aspect.

Solid-liquid factor is a critical factor for WP4 technologies, as this implies that more chemicals are needed and more waste will be generated.

User-friendly tool

Inputs and outputs selection:

- Energy
- Materials
- Transport
- Emissions
- Wastes
- Personnel
- Product

Type of experimental data needed:

- kWh of energy consumed
- kg of chemicals needed
- Quantity of wastes generated
- Etc.

Methodological approach:

- Hotspots assessment (quantitative results are provided though).
- Mass allocation to separate impacts between the different co-products.
- No equipment included, E-LCC focused on operational costs.

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Life Cycle Inventory

Category	Input/output	Unit	Value	Cost per unit	Reusability	Comments
Energy consumption	Electricity (RER)	kWh	2,50E+05	0,10 €		
Energy consumption	Heat, from diesel	MJ	1,20E+04	0,30 €		
Energy consumption		#N/D				
Energy consumption		#N/D				
Energy consumption		#N/D				
Material use	Acetic acid	kg	3,80E+05	5,00 €		
Material use	Calcium chloride	kg	5,00E+03	1,50 €		
Material use	Ethylene glycol	kg	8,90E+03	3,00 €		
Material use	Nitric acid	kg	2,00E+05	1,00 €		
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Material use		#N/D				
Transport	Lorry	tkm	1,14E+05			
Transport		#N/D				
Transport		#N/D				
Transport		#N/D				
Transport		#N/D				
Emissions to air	CO2 (air emissions)	kg	4,00E+03			
Emissions to air	N2 (air emissions)	kg	5,00E+02			
Emissions to air		#N/D				
Emissions to air		#N/D				
Emissions to air		#N/D				
Waste generation	Solid waste (inert)	kg	6,00E+03	0,02 €		
Waste generation	Liquid aqueous waste	m3	1,50E+02	10,00 €		
Waste generation	Liquid organic waste	kg	9,00E+04	0,14 €		
Waste generation		#N/D				
Waste generation		#N/D				
Waste generation		#N/D				
Waste generation		#N/D				
Waste generation		#N/D				
Waste generation		#N/D				
Labour hours	Person A	hours	1,80E+03	50,00 €		
Labour hours	Person B	hours	3,60E+03	25,00 €		
Labour hours	Person C	hours				
Labour hours	Person D	hours				
Products	Nb recovered	kg				
Products	Ta recovered	kg				
Products	W recovered	kg	3,00E+02			

Calculate results for Nb

Calculate results for Ta

Calculate results for W

Delete LCI sheet

User-friendly tool

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Results and interpretation

1. Characterization
for 1 kg of W

	GWP	ODP	IR
	kg CO2 eq	kg CFC11 eq	kBq U-235 eq
TOTAL RESULTS	**4,95E+03**	**6,85E-04**	**7,35E+02**
Energy consumption	3,79E+02	2,97E-05	2,11E+02
Material use	3,89E+03	6,27E-04	5,15E+02
Transport	6,21E+01	1,43E-05	4,61E+00
Emissions to air	1,33E+01	0,00E+00	0,00E+00
Waste generation	6,06E+02	1,46E-05	4,15E+00
Labour hours	0,00E+00	0,00E+00	0,00E+00

2. Normalization
for 1 kg of W

	GWP	ODP	IR
TOTAL RESULTS	**6,38E-01**	**2,94E-02**	**1,74E-01**
Energy consumption	4,88E-02	1,27E-03	5,01E-02
Material use	5,02E-01	2,68E-02	1,22E-01
Transport	8,01E-03	6,11E-04	1,09E-03
Emissions to air	1,72E-03	0,00E+00	0,00E+00
Waste generation	7,81E-02	6,26E-04	9,83E-04
Labour hours	0,00E+00	0,00E+00	0,00E+00

3. Weighting
for 1 kg of W

	Environmental impact	Economic impact	
	Pt	€	
TOTAL RESULTS	**4,13E-01**	**€**	**7.513,40**
Energy consumption	4,11E-02	€	95,33
Material use	3,43E-01	€	6.770,67
Transport	5,31E-03	€	-
Emissions to air	3,62E-04	€	-
Waste generation	2,30E-02	€	47,40
Labour hours	0,00E+00	€	600,00

4. Main hotspots

	GWP	ODP	IR
	kg CO2 eq	kg CFC11 eq	kBq U-235 eq
1	**Nitric acid**	**Acetic acid**	**Acetic acid**
2	Acetic acid	Nitric acid	Electricity (RER)
3	Liquid organic waste	Electricity (RER)	Nitric acid

	Pt	€
1	**Acetic acid**	**Acetic acid**
2	Nitric acid	Nitric acid
3	Electricity (RER)	Person A

Results given for every metal that is extracted in the process. Results for 16 environmental impact categories (including normalization and weighting) and 4 economic indicators.

The three main hotspots for every impact category and economic indicator are identified in order to allow the technical partners to optimise their process.

Transport costs are assumed to be included in the material use costs and externalities such as emissions have not be considered in the assessment.

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LCA of production routes

LCA of production routes

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The objective of the GA is to select the most promising flowsheet considering environmental and economic aspects.

The production routes in TARANTULA extract W, Ta and Nb from the different feedstocks and convert them into metals. The route must work for the different feedstock in the project.

Production route #1	KU LEUVEN: Solvoleaching (T4.1a) →	KU LEUVEN: Non-aqueous solvent extraction (T4.1c) →	SINTEF: Electrodeposition from MO (T5.1a)
Production route #2	tecnalia: DES leaching (T4.1b) →	tecnalia: Ionic liquid extraction (T4.1d) →	SINTEF: Electrodeposition from MO (T5.1a)
Production route #3	vito: MW-assisted fusion (T4.2a) →	vito: L/S extraction (T4.2b) →	SINTEF: Electrodeposition from MO (T5.1a)

EEA ranking

**Unit vector = normalized vector magnitude

$$|v| = \sqrt{x^2 + y^2}$$

LCA RESULTS		Process A	Process B	Process C
Abiotic depletion	kg Sb eq/kg	2,00E-05	1,65E-05	7,03E-06
Abiotic depletion (fossil fuels)	MJ/kg	8,06E+00	1,20E+01	4,91E+00
Global warming (GWP100a)	kg CO_2 eq/kg	5,88E-01	9,81E-01	1,20E-01
Ozone layer depletion (ODP)	kg CFC-11 eq/kg	3,95E-07	8,59E-08	1,12E-08
Photochemical oxidation	kg C_2H_4 eq/kg	1,80E-04	7,48E-05	3,84E-04
Acidification	kg SO_2 eq/kg	4,29E-03	5,31E-03	9,68E-03
Eutrophication	kg PO_4^{3-} eq/kg	1,63E-03	1,50E-03	2,39E-04

Process A	Process B	Process C
0,74	0,62	0,26
0,53	0,79	0,32
0,51	0,85	0,10
0,98	0,21	0,03
0,42	0,17	0,89
0,36	0,45	0,82
0,73	0,67	0,11

***Geometric aggregation:** is a mean or average, which indicates the central tendency or typical value of a set of numbers by using the product of their values

$$\left(\prod_{i=1}^{n} x_i\right)^{\frac{1}{n}} = \sqrt[n]{x_1 x_2 \cdots x_n}$$

Process A	Process B	Process C
0,75	**0,60**	**0,27**

****Unit vector =** normalized vector magnitude

$$|v| = \sqrt{x^2 + y^2}$$

Process A	Process B	Process C
0,71	**0,46**	**0,21**

LCC RESULTS		Process A	Process B	Process C
Economic benefit	€/kg	2	10	5

Process A	Process B	Process C
0,18	**0,88**	**0,44**

Values to calculate eco-efficiency

$$|v| = \sqrt{x^2 + y^2}$$

**Unit vector = normalized vector magnitude

EEA ranking

	Process A	Process B	Process C
Environmental impact	0,75	0,60	0,27
Economic benefit	0,18	0,88	0,44

(I)

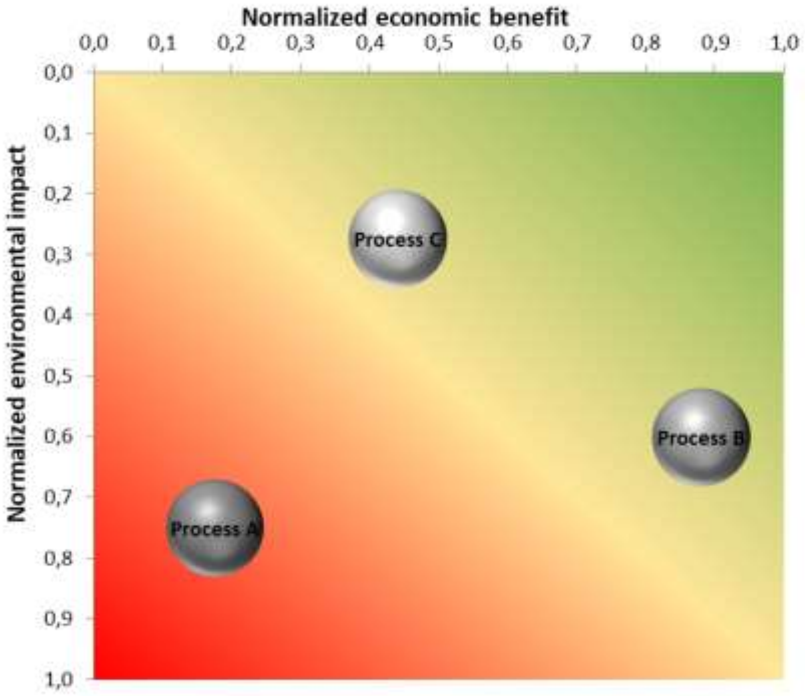
$$\textbf{Eco}-\textbf{efficiency} = \frac{\text{Economic benefit}}{\text{Environmental impact}}$$

	Process A	Process B	Process C
Eco-efficiency index	**0,23**	**1,46**	**1,60**

	Process A	Process B	Process C
**Eco-efficiency index	**0,11**	**0,67**	**0,73**

(II)

(I)



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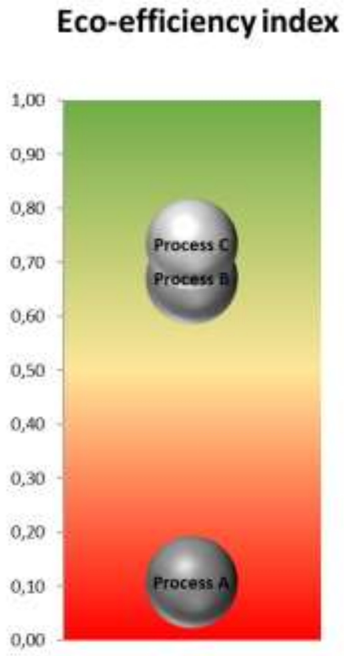

MCDA ranking

Unit vector = normalized vector magnitude

$$|v| = \sqrt{x^2 + y^2}$$

LCA RESULTS		Process A	Process B	Process C	Process A	Process B	Process C	Weight
Abiotic depletion	kg Sb eq/kg	2,00E-05	1,65E-05	7,03E-06	0,74	0,62	0,26	10%
Abiotic depletion (fossil fuels)	MJ/kg	8,06E+00	1,20E+01	4,91E+00	0,53	0,79	0,32	15%
Global warming (GWP100a)	kg CO_2 eq/kg	5,88E-01	9,81E-01	1,20E-01	0,51	0,85	0,10	40%
Ozone layer depletion (ODP)	kg CFC-11 eq/kg	3,95E-07	8,59E-08	1,12E-08	0,98	0,21	0,03	5%
Photochemical oxidation	kg C_2H_4 eq/kg	1,80E-04	7,48E-05	3,84E-04	0,42	0,17	0,89	10%
Acidification	kg SO_2 eq/kg	4,29E-03	5,31E-03	9,68E-03	0,36	0,45	0,82	10%
Eutrophication	kg PO_4^{3-} eq/kg	1,63E-03	1,50E-03	2,39E-04	0,73	0,67	0,11	10%

Weight
50%

Weights can be changed to show different points of view

LCC RESULTS		Process A	Process B	Process C	Process A	Process B	Process C	Weight
Economic benefit	€/kg	2	10	5	**0,18**	**0,88**	**0,44**	50%

$$|v| = \sqrt{x^2 + y^2}$$

Unit vector = normalized vector magnitude

MCDA ranking

Identification of the best and worst option (min. and max. values)

LCA RESULTS		Process A	Process B	Process C
Abiotic depletion	kg Sb eq/kg	2,00E-05	1,65E-05	7,03E-06
Abiotic depletion (fossil fuels)	MJ/kg	8,06E+00	1,20E+01	4,91E+00
Global warming (GWP100a)	kg CO_2 eq/kg	5,88E-01	9,81E-01	1,20E-01
Ozone layer depletion (ODP)	kg CFC-11 eq/kg	3,95E-07	8,59E-08	1,12E-08
Photochemical oxidation	kg C_2H_4 eq/kg	1,80E-04	7,48E-05	3,84E-04
Acidification	kg SO_2 eq/kg	4,29E-03	5,31E-03	9,68E-03
Eutrophication	kg PO_4^{3-} eq/kg	1,63E-03	1,50E-03	2,39E-04

LCC RESULTS		Process A	Process B	Process C
Economic benefit	€/kg	2	10	5

The chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution:

Geometric distance to the best option

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (Q_{ij} - Q_j^+)^2}$$

Geometric distance to the worst option

$$S_i^- = \sqrt{\sum_{j=1}^{n} (Q_{ij} - Q_j^-)^2}$$

Total geometric distance

$$S_i^+ + S_i^-$$

	Process A	Process B	Process C
Si^+	0,10	0,39	0,14
Si^-	0,36	0,05	0,27
$Si^+ + Si^-$	0,46	0,43	0,41

$$Closeness\ coeficient\ (CC) = \frac{S_i^+}{(S_i^+ + S_i^-)}$$

	Process A	Process B	Process C
CC	**0,79**	**0,10**	**0,66**

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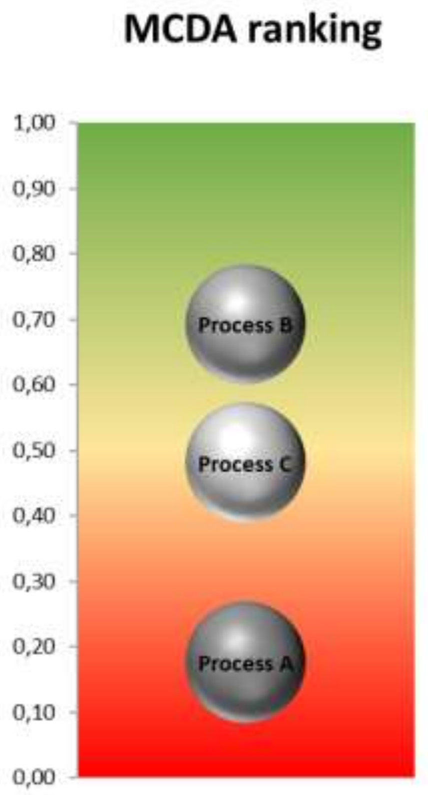

Contact us

https://h2020-tarantula.eu

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