

2024-01-25

Quality assessment of life cycle inventory data for composites

Summerscales, J

<https://pearl.plymouth.ac.uk/handle/10026.1/21970>

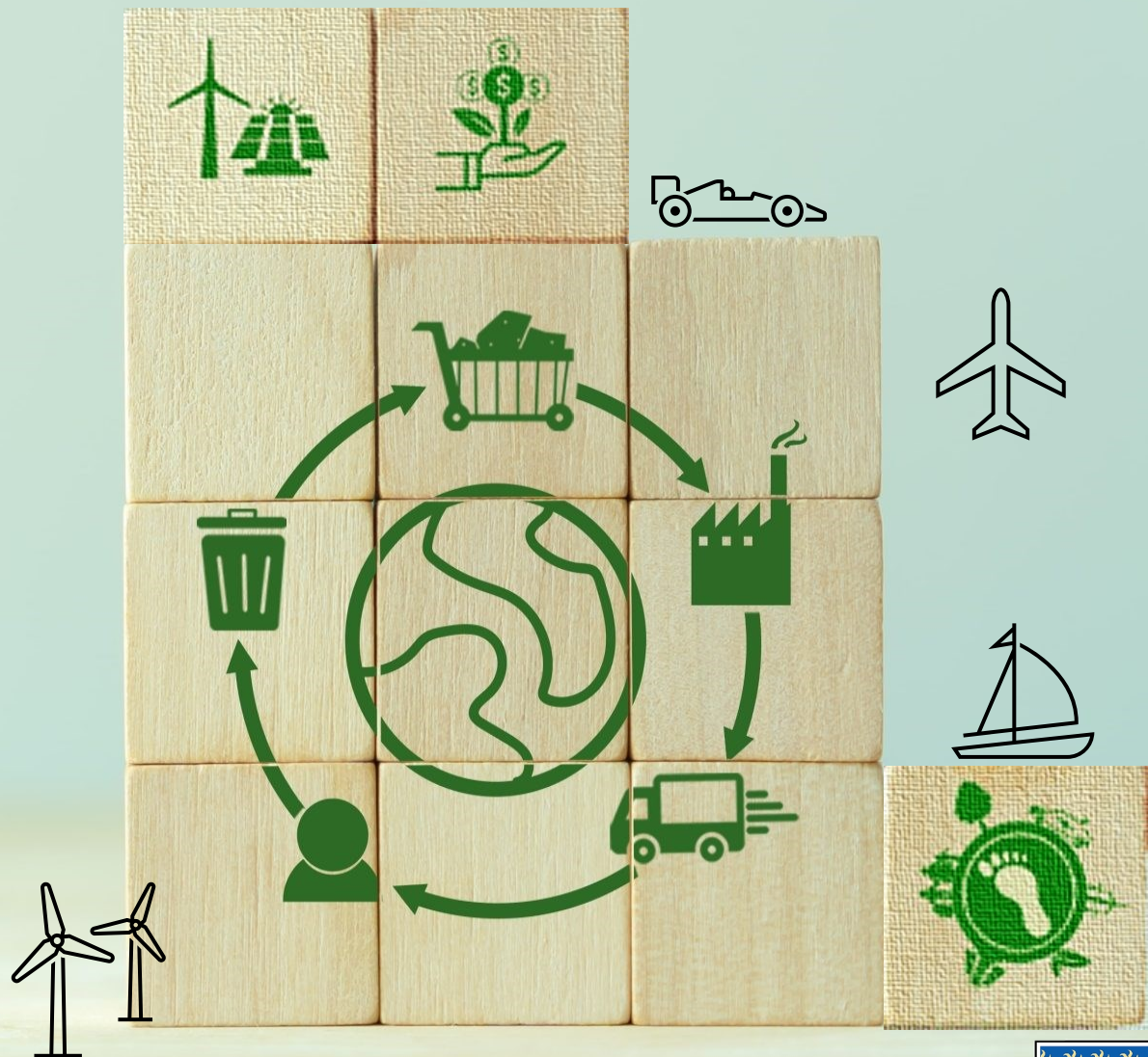
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Quality assessment of life cycle inventory data for Composites

Chair: Prof. John Summerscales

Presenter: Badr Moutik

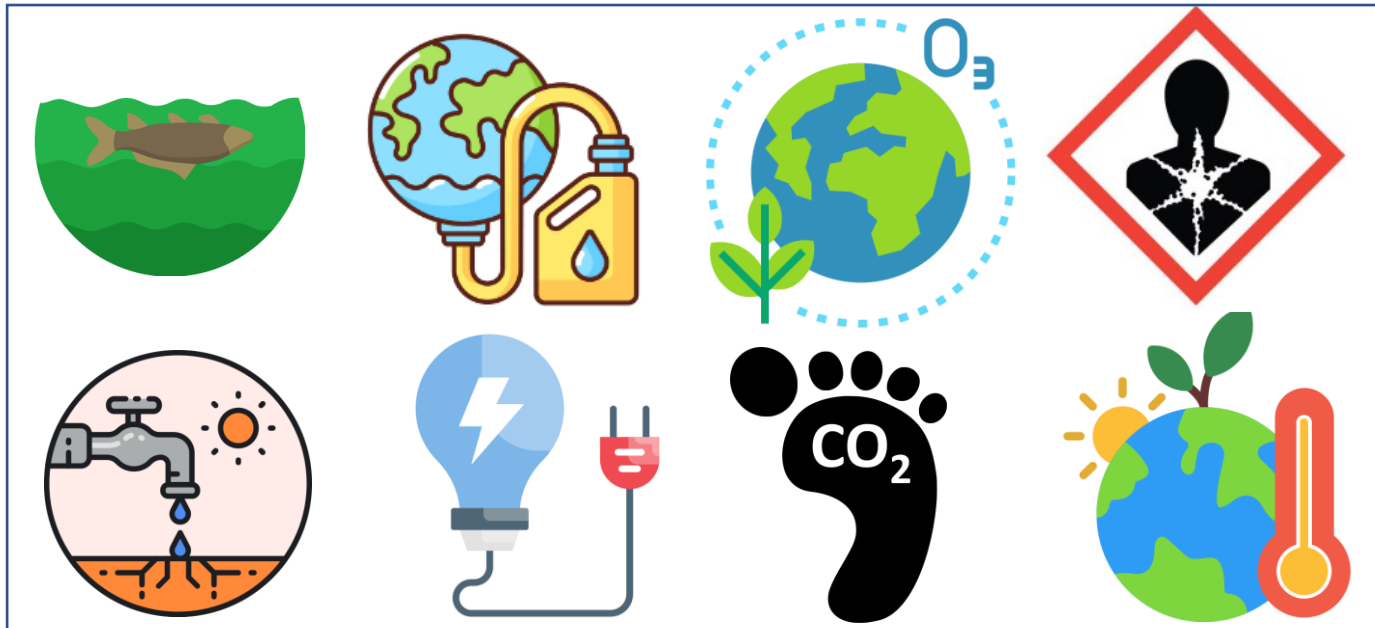
Jasper Graham-Jones, and Richard Pemberton



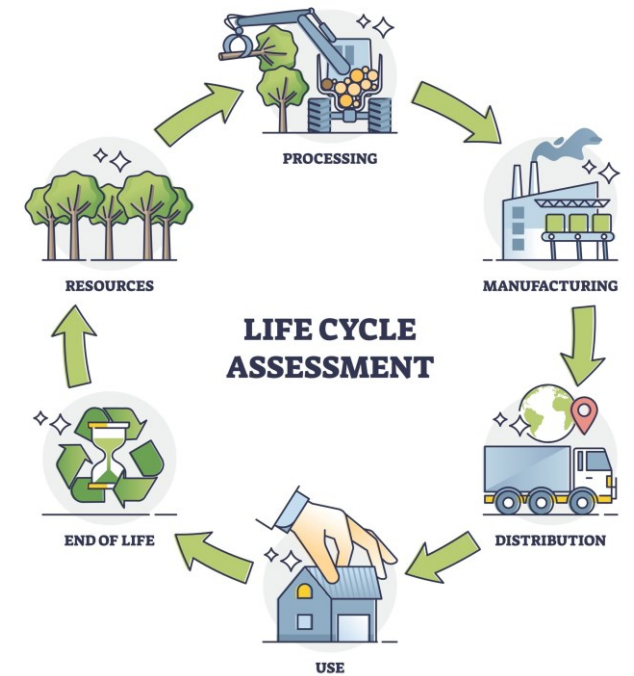
WHAT IS LIFE CYCLE ASSESSMENT (LCA)?

LCA is the “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO,2006)

Environmental impacts

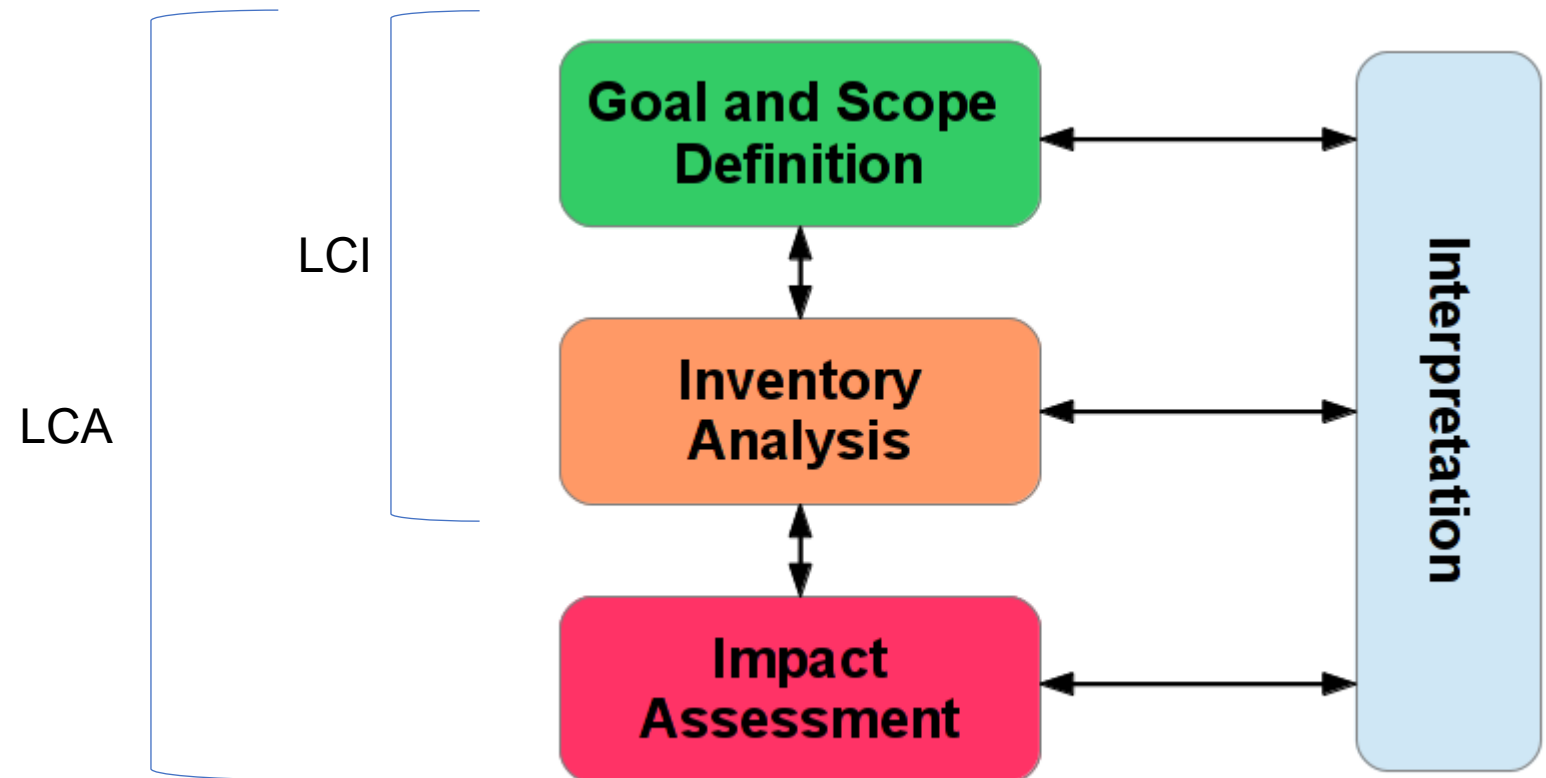


Product Life Cycle

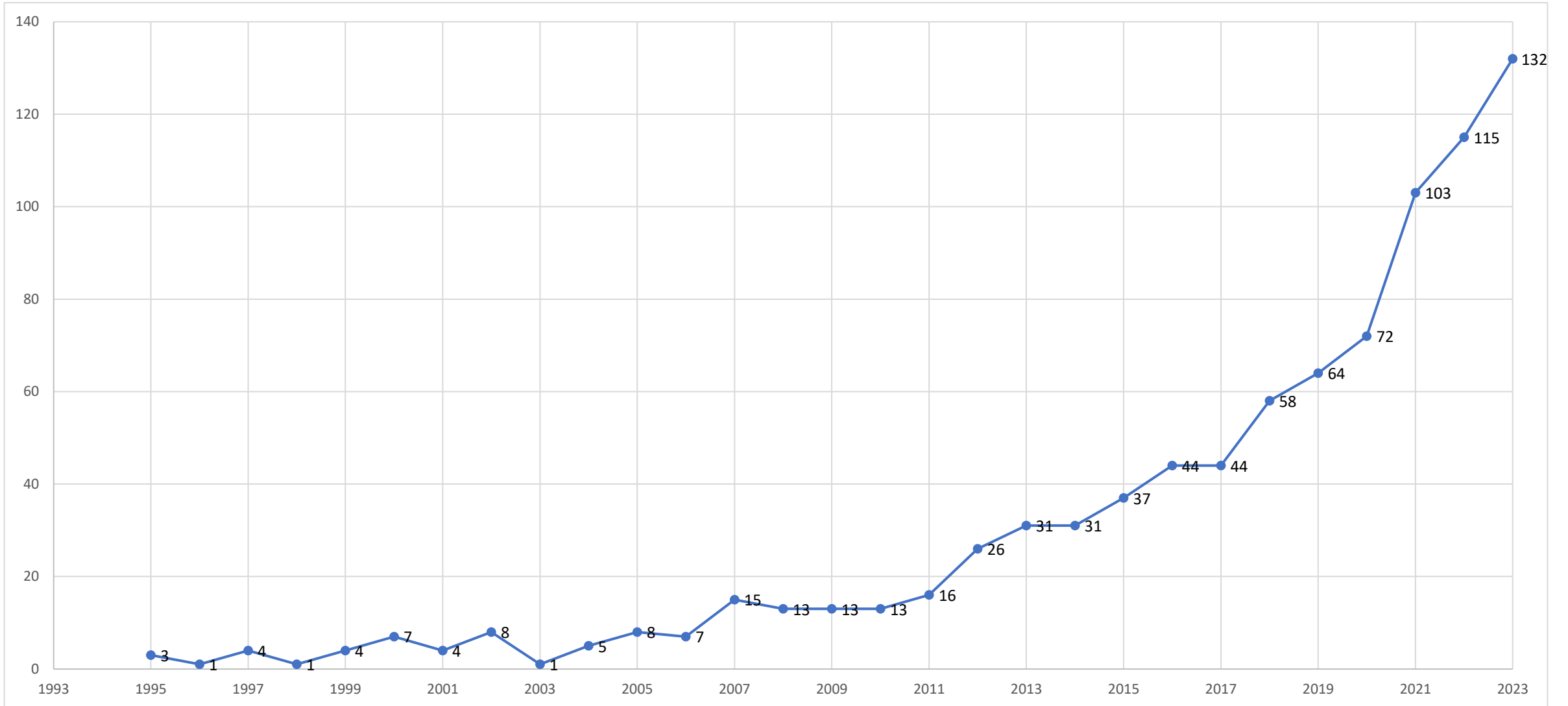


LIFE CYCLE INVENTORY ANALYSIS (LCI)

LCI is a phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle (*ISO,2006*)



BACKGROUND: EVOLUTIONARY TREND OF LCA RESEARCH PUBLICATIONS IN COMPOSITE



BACKGROUND: REGULATORY CONTEXT: THE FRAMEWORKS SHAPING SUSTAINABILITY



Brussels, 22.3.2023
COM(2023) 166 final
2023/0085 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
on substantiation and communication of explicit environmental claims (Green Claims Directive)



Green Claims Code - get

BACKGROUND: ENVIRONMENTAL PRODUCT DECLARATIONS AND REPORTS



ENVIRONMENTAL PRODUCT DECLARATION

TURKEY EPD®
ENVIRONMENTAL PRODUCT DECLARATIONS
EPD®
THE INTERNATIONAL EPD® SYSTEM

In accordance with ISO 14025 and EN 15804:2012+A2:2019 for
GFRP Composite Poles
from
MİTAŞ Composites

ENVIRONMENTAL PRODUCT DECLARATION
as per ISO 14025 and EN 15804+A2

Owner of the Declaration	DBC, EFCC, FEICA, IVK
Programme holder	Institut Bauen und Umwelt e.V. (IBU)
Publisher	Institut Bauen und Umwelt e.V. (IBU)
Declaration number	EPD-DBC-20220174-IBF1-EN
Issue date	29.08.2022
Valid to	28.08.2027

Products based on epoxy-resin, group 1

DBC - Deutsche Bauchemie e.V.
EFCC - European Federation for Construction Chemicals
FEICA - Association of the European Adhesive and Sealant Industry
IVK - Industrieverband Klebstoffe e.V.

www.ibu-epd.com | <https://epd-online.com>

Eco Report

Product: Dura Composites Moulded Product
Date: 9/27/2021



General Information

Functional unit
This Eco Report gives insights into the environmental impact of 1 Dura Composites Moulded Product of 1 kg.

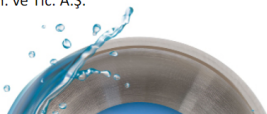
Content declaration
The LCA that has resulted in this Eco Report entails a cradle-to-gate analysis. Listed are



ENVIRONMENTAL PRODUCT DECLARATION



In accordance with ISO 14025 and EN 15804:2012+A2:2019 for
Glassfiber Reinforced Plastic (GRP) Pipes
from Subor Boru San. ve Tic. A.Ş.



ENVIRONMENTAL PRODUCT DECLARATION
as per ISO 14025 and EN 15804+A1

Owner of the Declaration	Vitrulan Technical Textiles GmbH
Programme holder	Institut Bauen und Umwelt e.V. (IBU)
Publisher	Institut Bauen und Umwelt e.V. (IBU)
Declaration number	EPD-VT-20220104-IAC1-EN
Issue date	13.04.2022
Valid to	12.04.2027

Glasarmierungsgitter
Vitrulan Technical Textiles GmbH

www.ibu-epd.com | <https://epd-online.com>

Eco Report

Product: UD Plank
Date: 6/24/2021

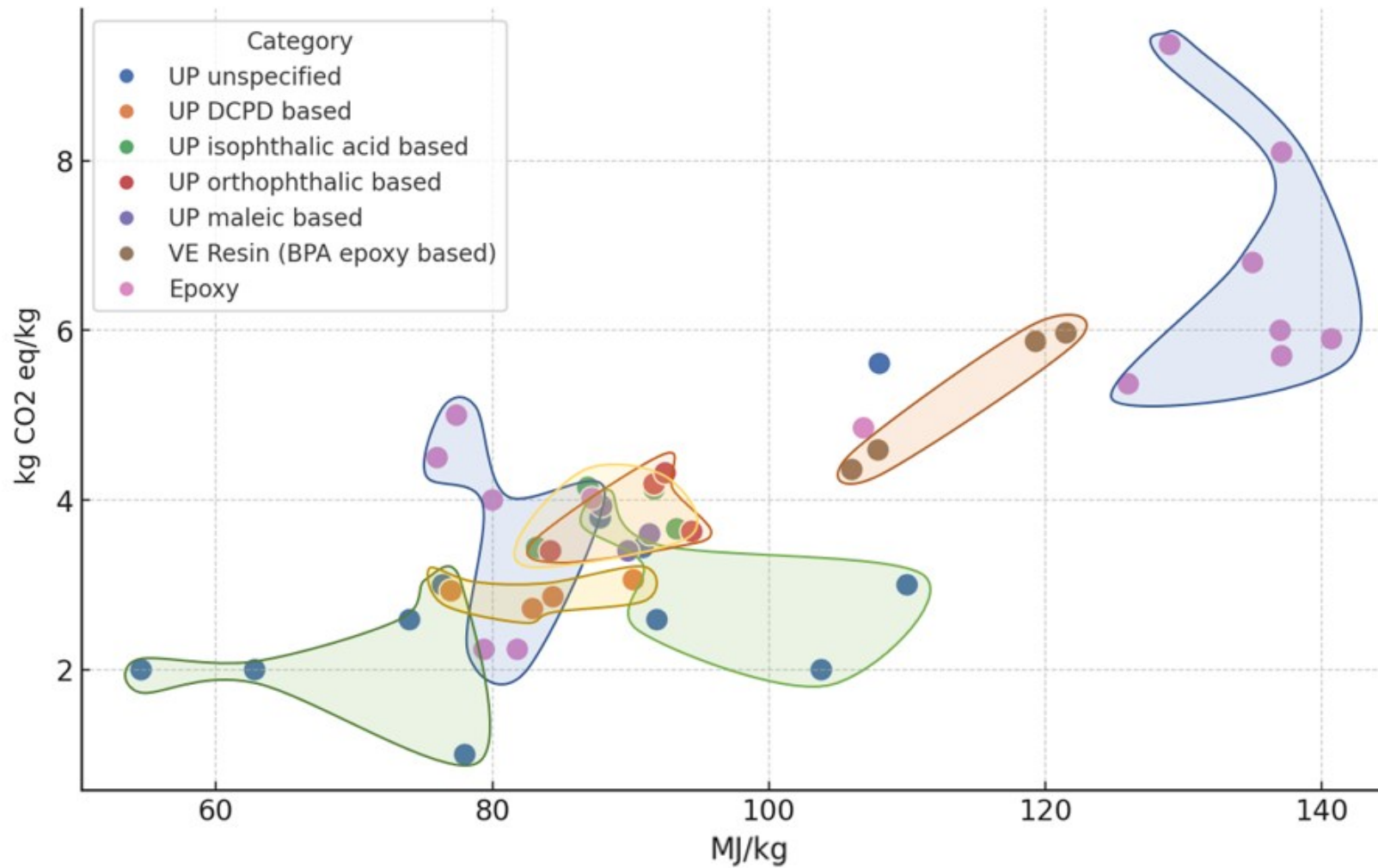


General Information

Functional unit
This Eco Report gives insights into the environmental impact of 1 UD Plank of 12.9 kg.

Content declaration
The LCA that has resulted in this Eco Report entails a cradle-to-gate analysis. Listed are materials representing more than 1% mass of the product. This factsheet is valid for the year 2021. For a full report about the used materials, please visit

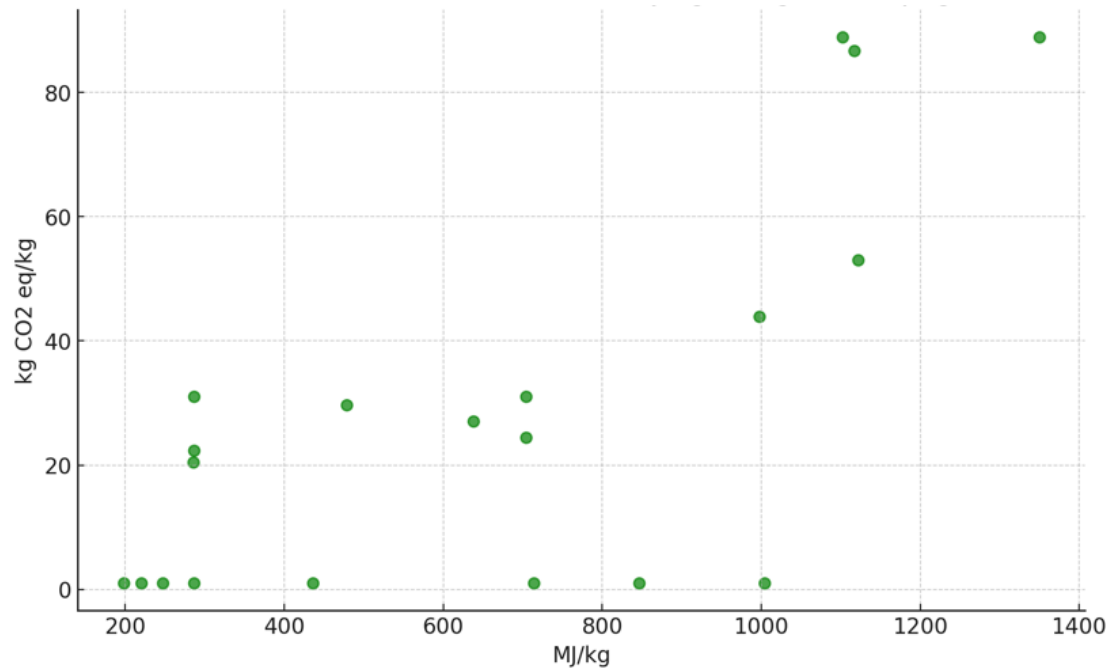
BACKGROUND: LIFE CYCLE GHG EMISSIONS AND CUMULATIVE ENERGY DEMAND VALUES: RESINS



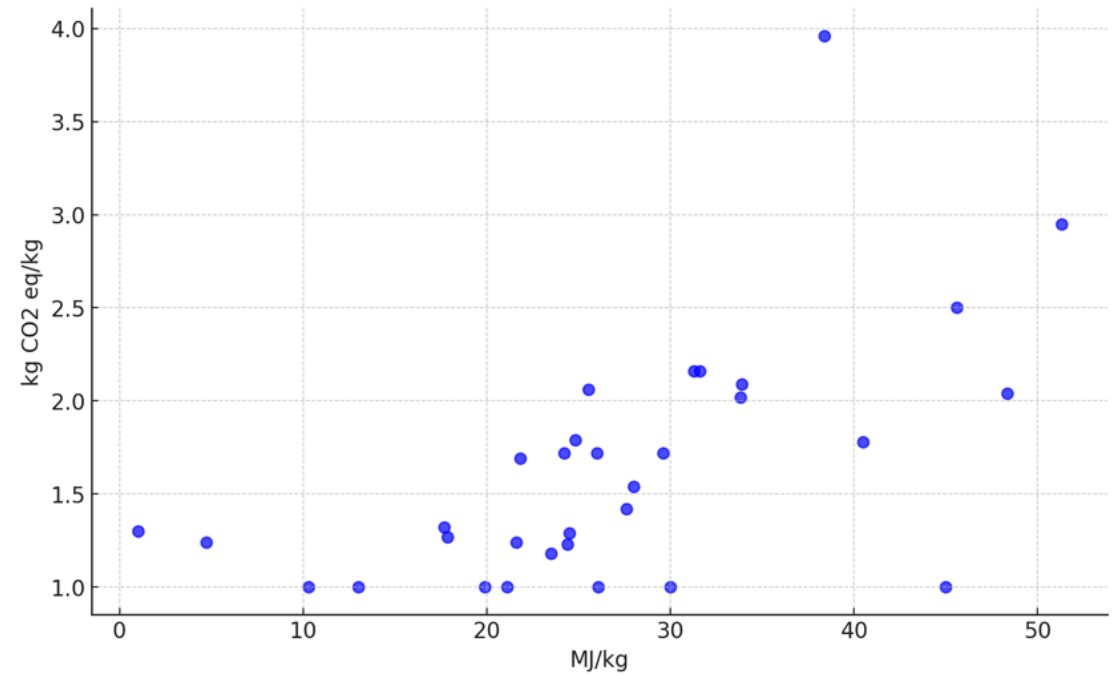
* GHG: Greenhouse gases emissions

BACKGROUND: LIFE CYCLE GHG EMISSIONS AND CUMULATIVE ENERGY DEMAND: CARBON FIBER AND GLASS FIBER

Carbon Fiber



Glass Fiber



Kg CO2 eq: One kg of CO2 equivalent – Global Warming Potential

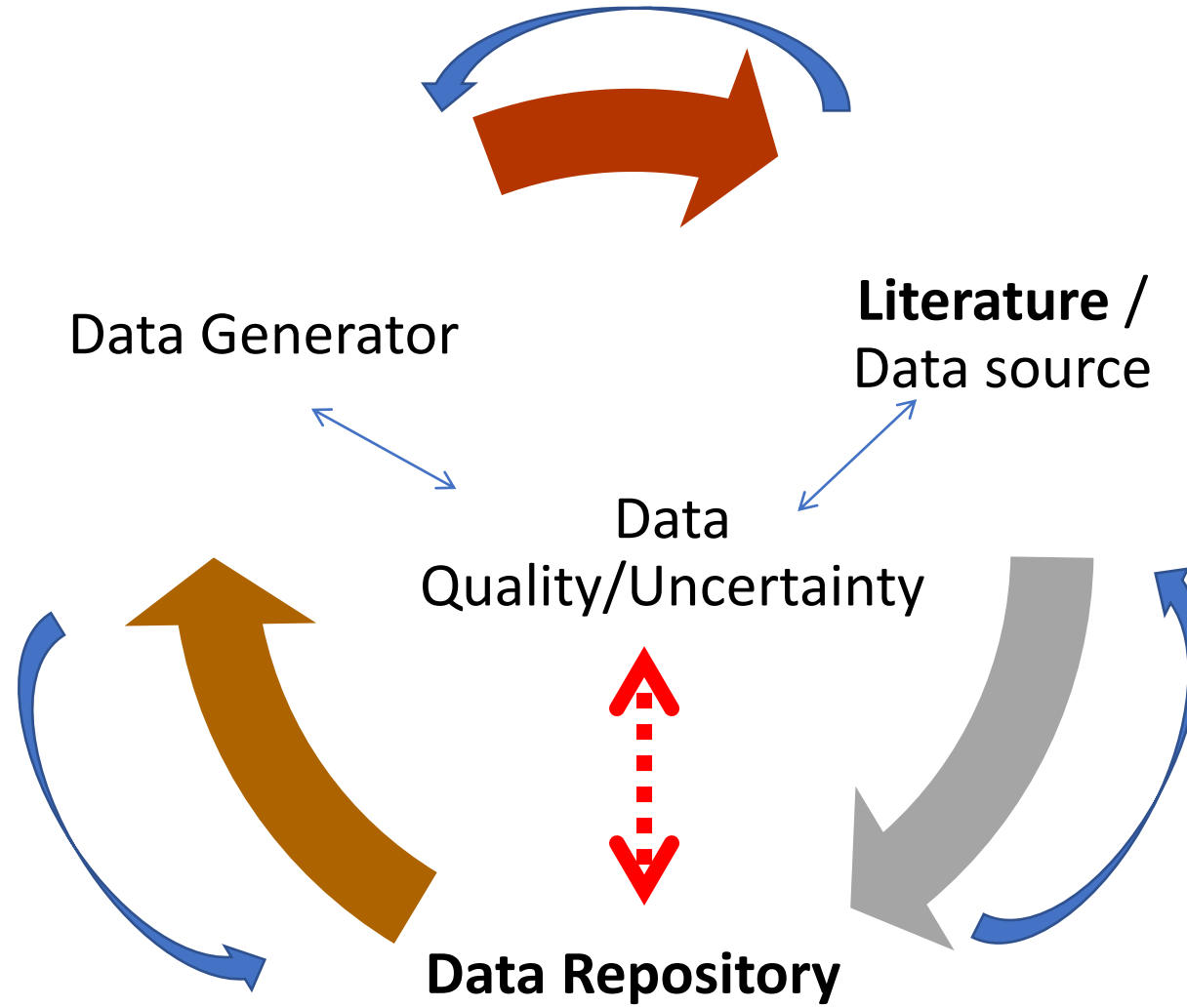
MJ: Megajoules – Cumulative Energy Demand

* The LCA data presented in this graph includes all moduli of glass-reinforced plastic (GRP) and carbon-reinforced plastic (CF) combined

DATA QUALITY ASSESSMENT

“You can’t manage what you can’t measure.”

LCA DATA LIFECYCLE



Major LCI data sources

softwares

SimaPro

openLca



thinkstep
GaBi

databases

ei ecoinvent

 **JRC**
EUROPEAN COMMISSION

FEDERAL
LOA
COMMONS

 **sphera**[®]

sector platforms


Eco Impact
Calculator
By EuCIA

MARINESHIFT360

literature

Scopus[®]



ELSEVIER

 Springer

 *literature*



ISO 14040/44:2006

- “The characteristics of data that relate to their ability to satisfy **stated requirements**”
- “**Data Quality requirements** shall be specified to enable the **goal** and **scope** of the LCA to be **met**”

LCA DATA QUALITY REQUIREMENTS

“where a study is intended to be used in comparative assertions intended to be disclosed to the public, the [following] data quality requirements” shall be addressed, (ISO,2006)

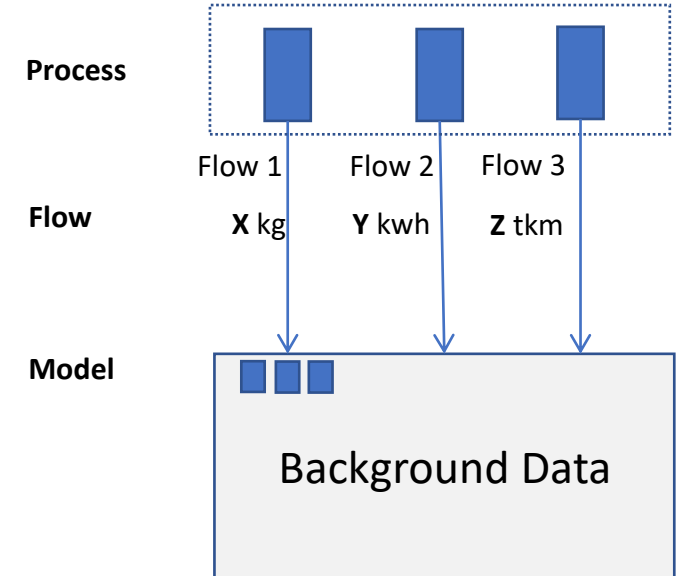


DATA QUALITY IN LCA



ISO 14040/44:2006

- Flexibility in determining the approach for addressing DQA-specific areas
- It does not specify to which component, or level, data quality analysis should be applied



METHODOLOGIES FOR LCI DATA QUALITY ASSESSMENT (DQA)

ILCD handbook
International Reference Life Cycle Data System



General guide for Life Cycle Assessment
- Detailed guidance



First editor



PEF/OEF

Product/Organisation Environmental Footprint

Pedigree Matrix

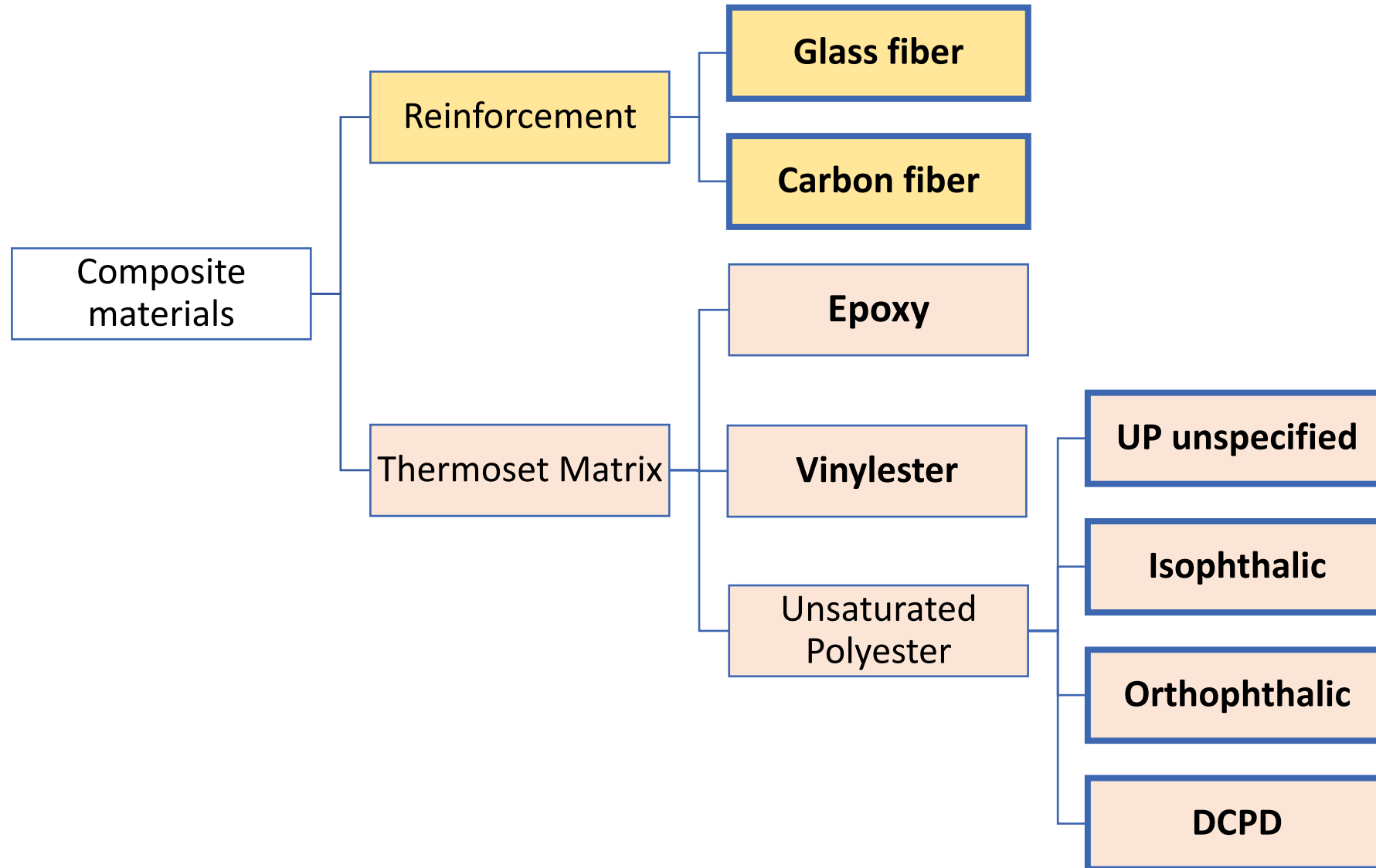
Indicator score	1	2	3	4	5 (default)
Reliability	Verified ³ data based on measurements ⁴	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on qualified estimates	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate
Completeness	Representative data from all sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from >50% of the sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from only some sites (<<50%) relevant for the market considered or >50% of sites but from shorter periods	Representative data from only one site relevant for the market considered or some sites but from shorter periods	Representativeness unknown or data from a small number of sites and from shorter periods
Temporal correlation	Less than 3 years of difference to the time period of the dataset	Less than 6 years of difference to the time period of the dataset	Less than 10 years of difference to the time period of the dataset	Less than 15 years of difference to the time period of the dataset	Age of data unknown or more than 15 years of difference to the time period of the dataset
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown or distinctly different area (North America instead of Middle East, OECD-Europe instead of Russia)
Further technological correlation	Data from enterprises, processes and materials under study	Data from processes and materials under study (i.e. identical technology) but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials	Data on related processes on laboratory scale or from different technology

U.S Life Cycle Inventory Database



Fiber Reinforced Composite Materials

FIBER REINFORCED COMPOSITE MATERIALS



UNSATURATED POLYESTER RESIN INPUT PROCESS DATA SET

Source UP unspecified	EI	USL CI	SP	Eu Cia
Input from Technosphere: Materials Resources				
Acetic anhydride	■			
Adipic acid	■			
Butadiene				■
ethylene glycol	■	■		■
ethylene at plant		■		
Maleic anhydride		■	■	■
Neo pentyl glycol		■		
Phthalic anhydride	■	■	■	■
Polyethylene terephthalate		■		
Purified terephthalic acid		■		■
Propylene glycol, liquid	■	■	■	■
Terephthalic acid		■		
Di ethylene glycol				■
Ethylene		■		
Tetrabromophthalic acid		■		
Styrene		■	■	■
Catalyst			■	
Nitrogen			■	■
chemical factory, organics	■			■

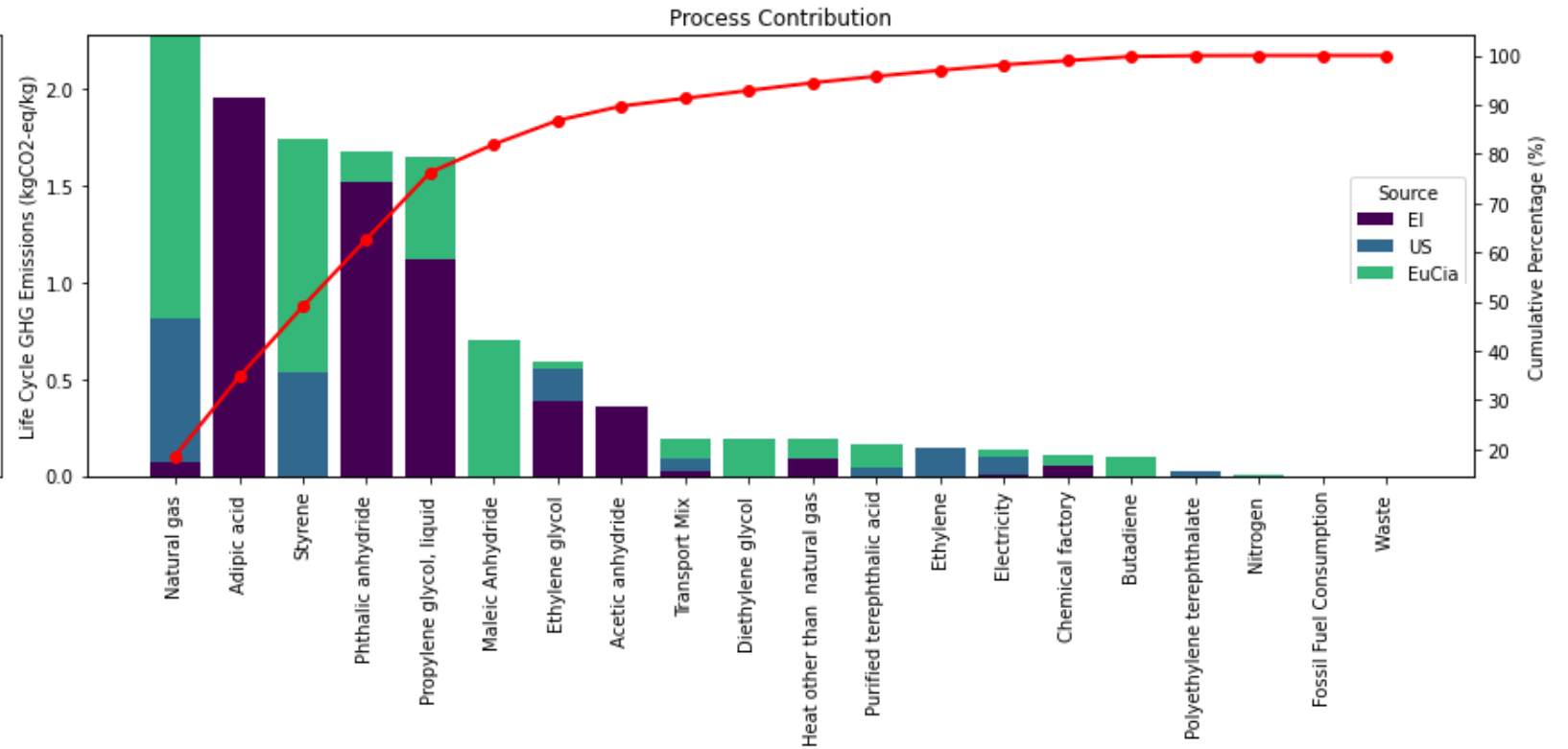
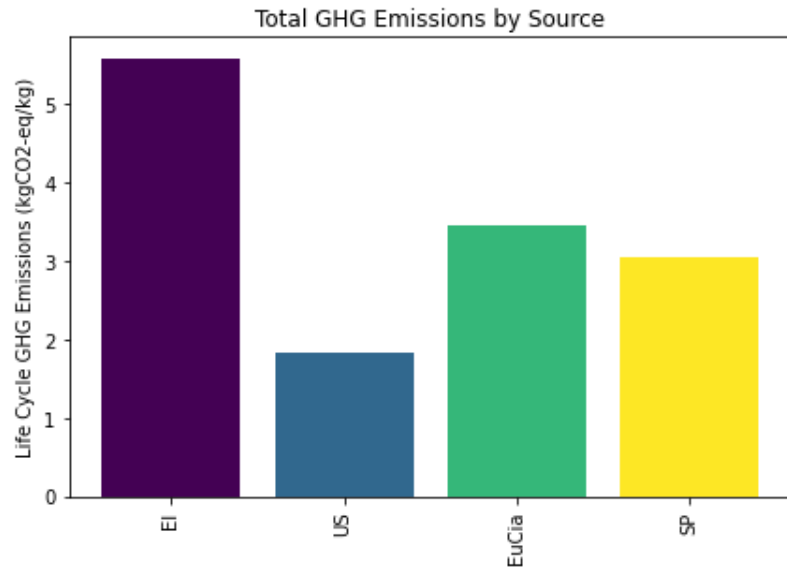
Input from environment				
Water for cooling	■			
Water	■	■		
Input from Technosphere: Energy				
electricity, medium voltage	■	■	■	■
heat natural gas	■	■	■	■
Heat Fuel	■			
Heat Diesel		■		
Steam				■
Input from technosphere: Transport				
Transport combined		■		■
Transport , Train, Diesel Powered		■		

UNSATURATED POLYESTER RESIN OUTPUT PROCESS DATA SET

Output	EI	US	SP	Eu Cia
Source UP unspecified				
1-Butanol				
Carbon dioxide, fossil				
Carbon monoxide				
Dicyclopentadiene				
Ethylene glycol				
Heat, waste				
Hydrocarbons, unspecified				
Maleic anhydride				
Methane				
Methyl methacrylate				
Nitrogen oxides				
Hydrocarbons, unspecified				
Particulates, > 2.5 um, and < 10um				
Particulates, < 2.5 um				
Particulates, unspecified				
O-phthalic acid				
Styrene				
Sulfur oxides				
Toluene, vinyl				
NMVOC, non-methane volatile organic compounds				
Xylene				
Emissions to water				

Aluminium				
BOD5 (Biological Oxygen Demand)				
Cadmium				
Chromium				
COD (Chemical Oxygen Demand)				
Cyanide				
Suspended solids, unspecified				
Lead				
Nickel				
Oils, unspecified				
Suspended solids, unspecified				
DOC, Dissolved Organic Carbon				
TOC, Total Organic Carbon				
Water, RER				
Zinc				
Unsaturated Polyester resin scrap				
Outputs to technosphere: Waste				
Disposal solid waste to municipal incineration				
Disposal solid waste to waste energy				
Disposal solid waste to sanitary landfill				
Hazardous waste incineration				
Wastewater				

LIFE CYCLE GHG EMISSIONS: CONTRIBUTION ANALYSIS

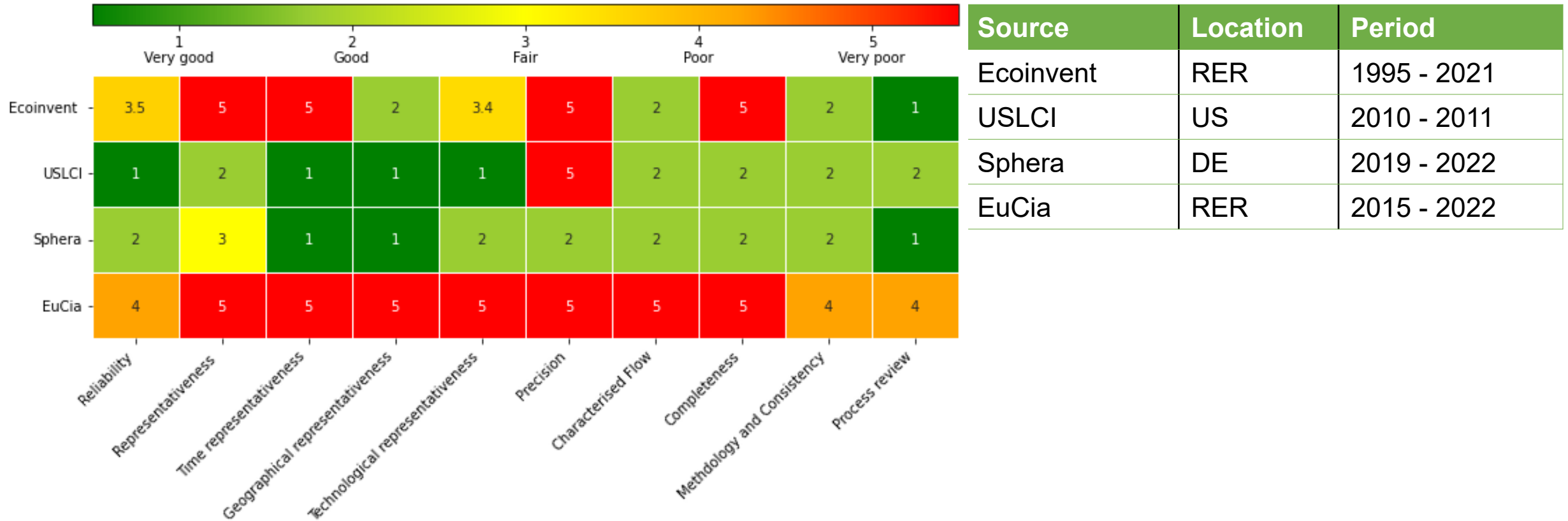


DATA QUALITY ASSESSMENT @ FLOW LEVEL: UNSATURATED POLYESTER RESIN

	1 Very good	2 Good	3 Fair	4 Poor	5 Very poor		
I: acetic anhydride	3	5	5	1	3		
adipic acid	3	5	5	1	3		
chemical factory	4	5	5	3	5		
electricity	3	5	5	1	3		
ethylene glycol	3	5	5	1	3		
heat, natural gas	3	5	5	1	3		
phthalic anhydride	3	5	5	1	3		
propylene glycol, liquid	3	5	5	1	3		
Water	5	5	5	1	4		
O: BOD5, Biological Oxygen Demand	3	5	5	1	3		
COD, Chemical Oxygen Demand	3	5	5	1	3		
DOC, Dissolved Organic Carbon	4	5	5	3	5		
TOC, Total Organic Carbon	3	5	5	1	3		
Water	2	2	5	1	1		
	Reliability	Representativeness	Time representativeness	Geographical representativeness	Technological representativeness	Precision	Fit for Purpose

- Ecoinvent
- Polyester resin production, unsaturated – RER (Europe)
- Period : 1995-01-01 to 2021-12-31

DATA QUALITY ASSESSMENT @ PROCESS LEVEL: UNSATURATED POLYESTER RESIN



Source	Location	Period
Ecoinvent	RER	1995 - 2021
USLCI	US	2010 - 2011
Sphera	DE	2019 - 2022
EuCia	RER	2015 - 2022

UNSATURATED POLYESTER RESINS INPUT PROCESS DATA SET

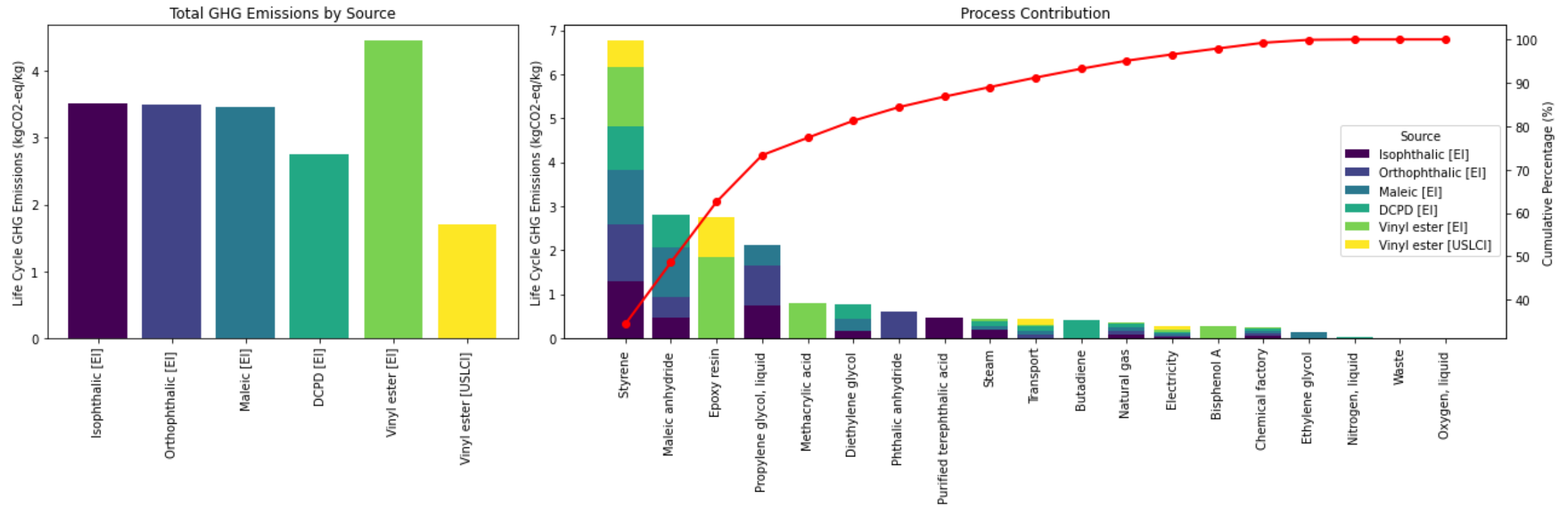
Source	ISO	Ortho	DCPD	Vinyl	Vinyl US
Input from technosphere: Materials Resources					
Bisphenol A, powder					
Acrylic acid					
Epoxy					
Diethylene glycol					
Maleic anhydride					
Methacrylic acid					
Butadiene					
Propylene glycol					
Purified terephthalic acid					
Styrene					
Oxygen, liquid					
Nitrogen, liquid					
Chemical factory					

Phthalic anhydride					
Silica Sand					
Electricity, low voltage					
Electricity, renewable energy					
Heat					
Steam, in chemical industry					
Input from technosphere: Transport					
Transport combined truck					
Transport , Train, Diesel Powered					
Transport ocean freighter					
Input from environment					
Water					

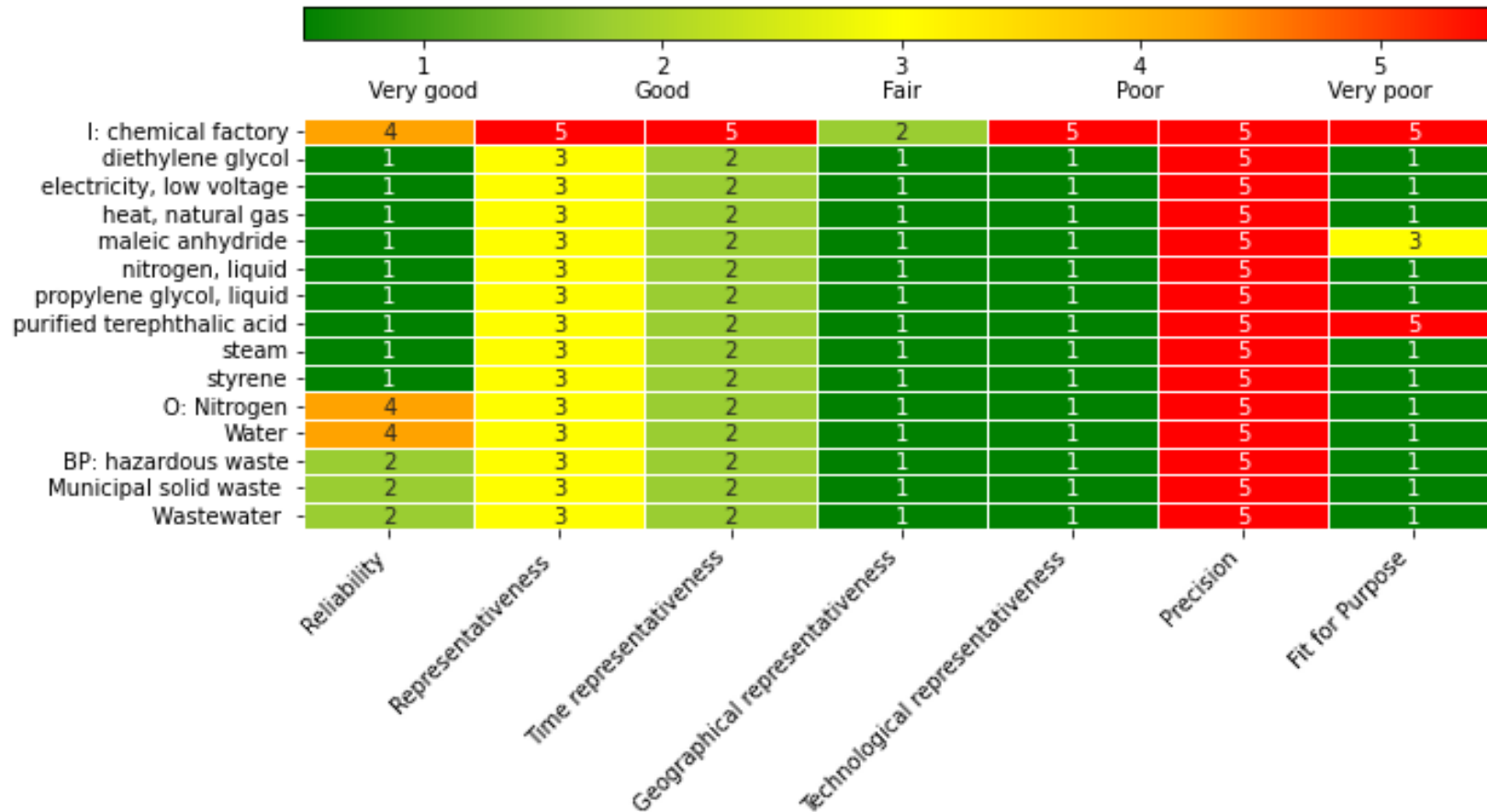
UNSATURATED POLYESTER RESINS OUTPUT PROCESS DATA SET

Source	ISO	Orht ho	DCP D	Vinyl	Vinyl US
Nitrogen, atmospheric					
NMVOC, non-methane volatile organic compounds					
Methyl methacrylate					
Particulate matter					
Emissions to water					
Water/m3					
Hazardous waste, for incineration					
Municipal solid waste					
Wastewater					
Municipal solid waste to landfill					
Solid waste to incineration with energy recovery					
Solid waste to incineration without energy recovery					
Recycling Solid waste					

LIFE CYCLE GHG EMISSIONS: UNSATURATED POLYESTER RESINS

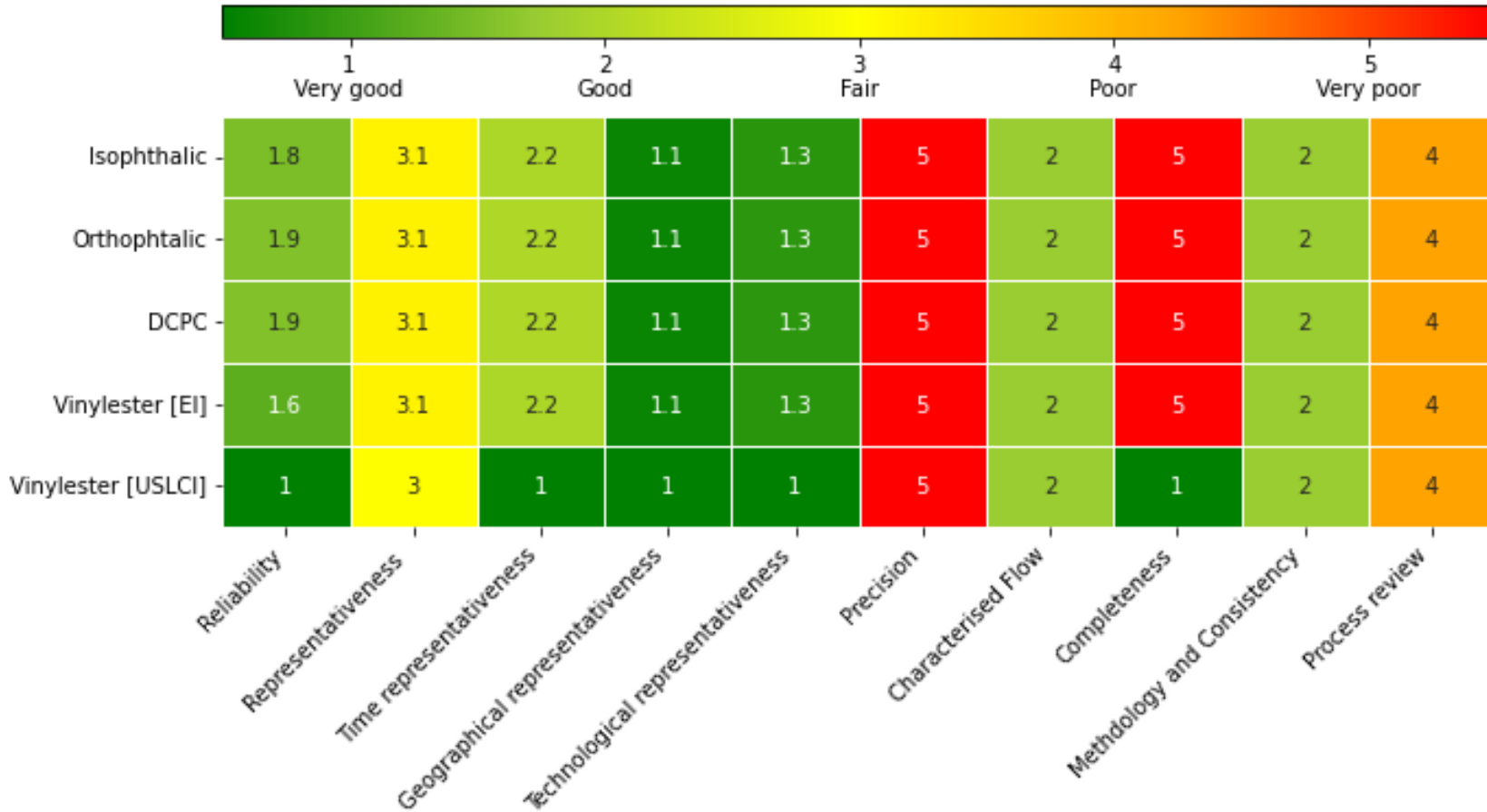


DATA QUALITY ASSESSMENT @ FLOW LEVEL: ISOPHTHALIC UNSATURATED POLYESTER RESIN



- Ecoinvent/EuCia
- isophthalic acid based unsaturated polyester resin production – RER
- Period : 2013 to 2022

DATA QUALITY ASSESSMENT @ PROCESS LEVEL: UNSATURATED POLYESTER RESINS



Source	Location	Period
Ecoinvent	RER	2013 - 2022
USLCI	US	2021 - 2022

EPOXY INPUT PROCESS DATA SET

Source Epoxy	EI	PE	US	Sph era
Bisphenol A, powder				
Epichlorohydrin				
Nitrogen				
Sodium hydroxide, without water				
Isopropanol				
Hydraulic Acid				
Catalyst				
Styrene				
Oxygen, liquid				
Nitrogen, liquid				
Chemical factory				
Crude oil				
Electricity, low voltage				
Heat				
Steam, in chemical industry				
Electricity Mix				
Water, cooling, unspecified natural origin				
Water, river				
Water, well, in ground				
Deonised Water				

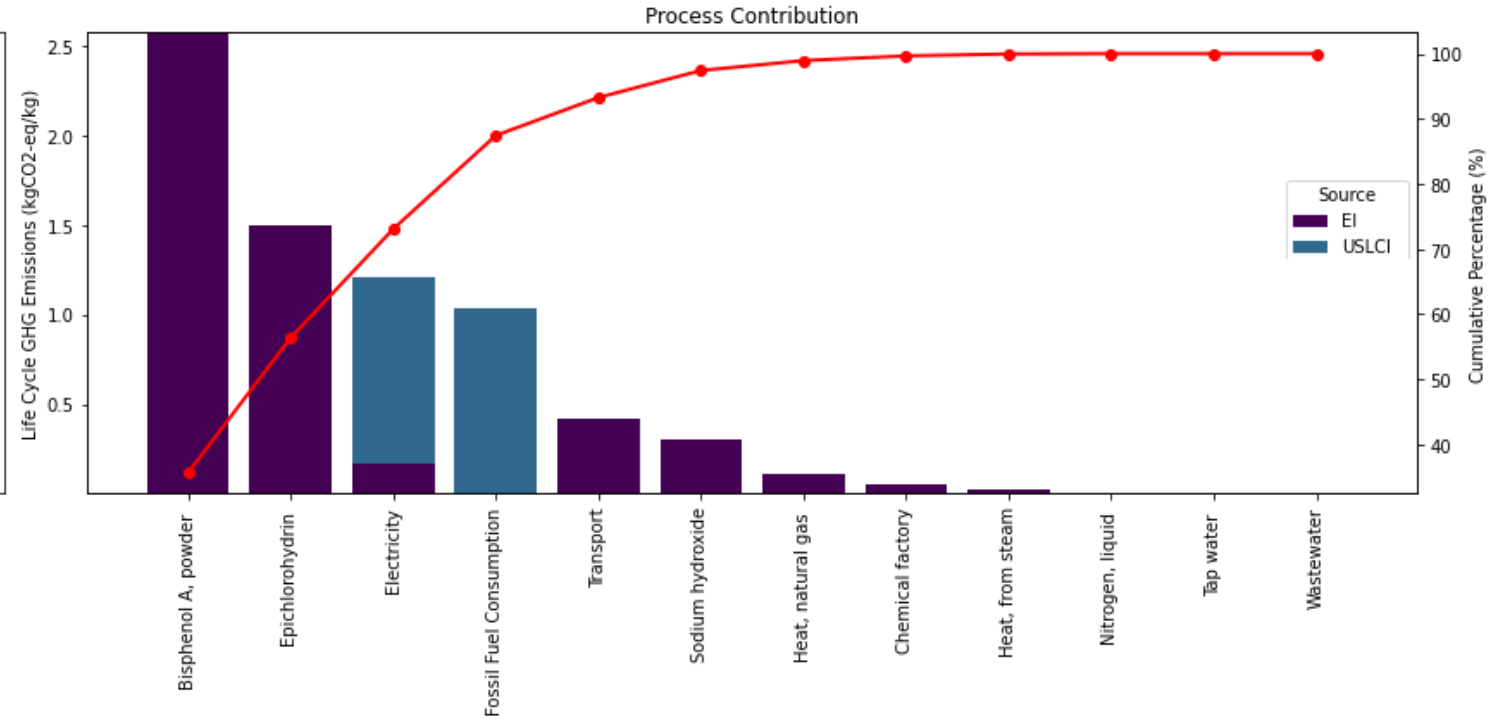
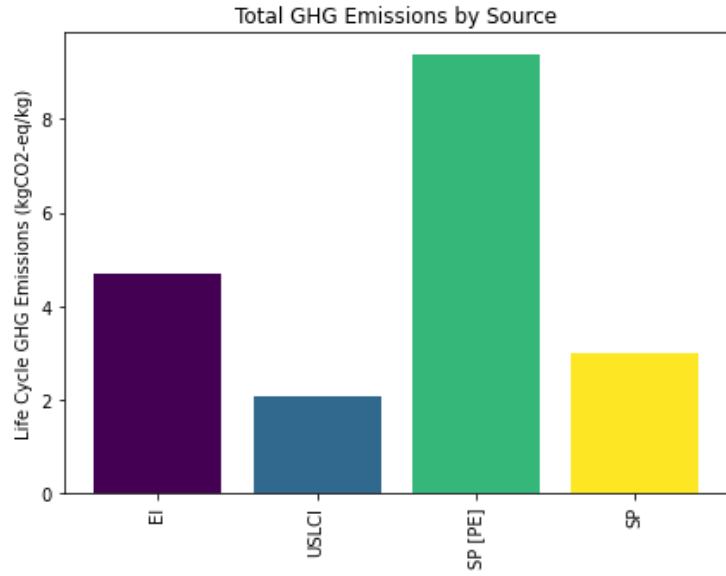
Deionised water				
Quartz sand				
Packaging				
Electricity, medium voltage				
Heat, district or industrial, natural gas				
Propane				
Light fuel oil				
Heavy fuel oil				
Oxygen				
Input from Technosphere: Transport				
Transport				
River transport				
Rail transport				
Road transport				

EPOXY OUTPUT PROCESS DATA SET

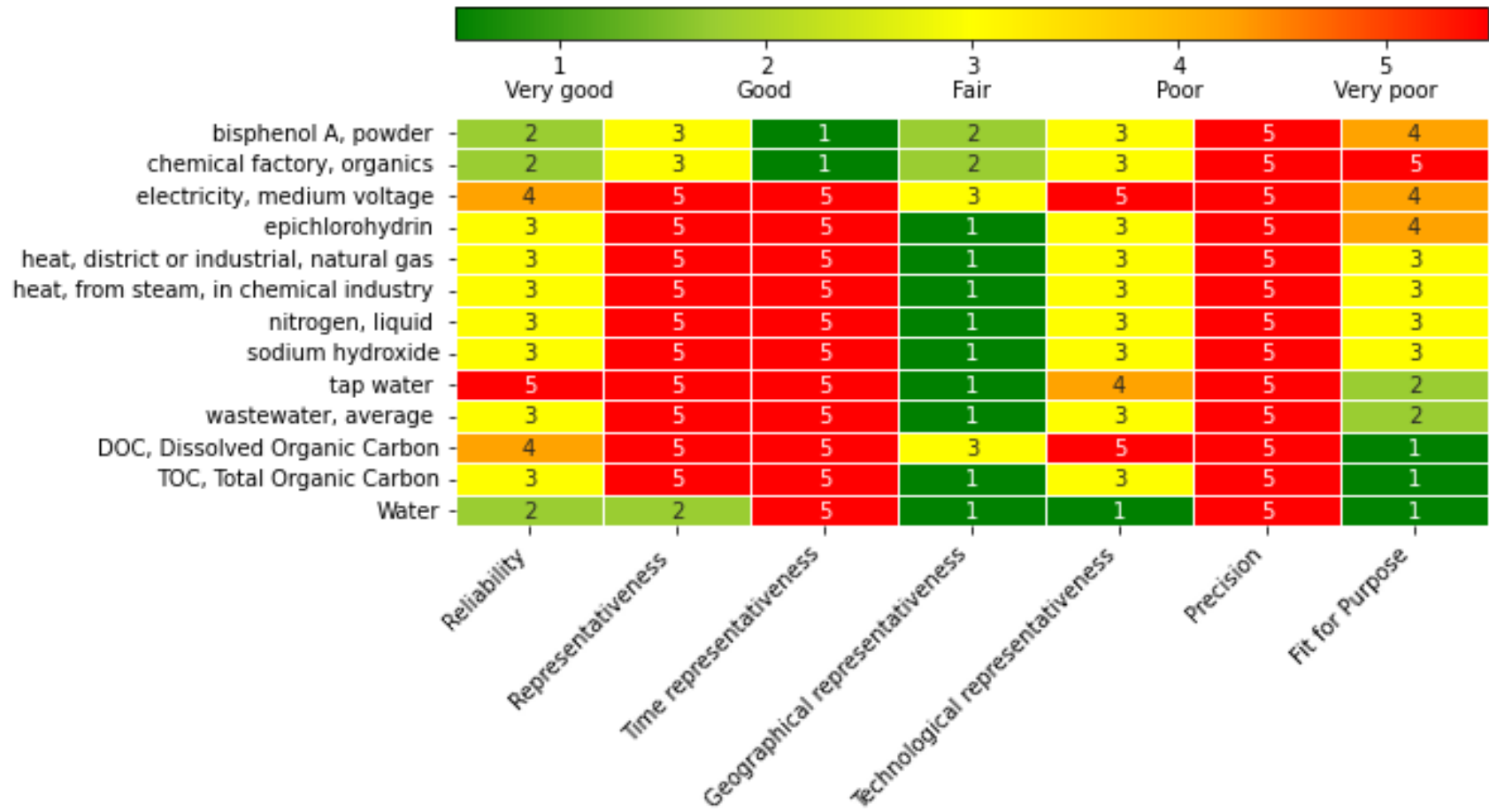
Output: Emission to Air				
Antimony				
Arsenic				
Cadmium				
Carbon dioxide, fossil				
Hydrogen chloride				
Hydrogen fluoride				
Nitrogen oxides				
NMVOC, non-methane volatile organic compounds				
Particulates, < 2.5 um				
Particulates, > 10 um				
Particulates, > 2.5 um, and < 10um				
Sulfur dioxide				
Emissions to Water				
Water/m3				
Water, RER				

Waste				
Waste mineral oil				
Waste mineral wool, for final disposal				
Waste mineral wool, for final disposal				
Waste paint				
Wastewater from glass production				

LIFE CYCLE GHG EMISSIONS: EPOXY RESIN

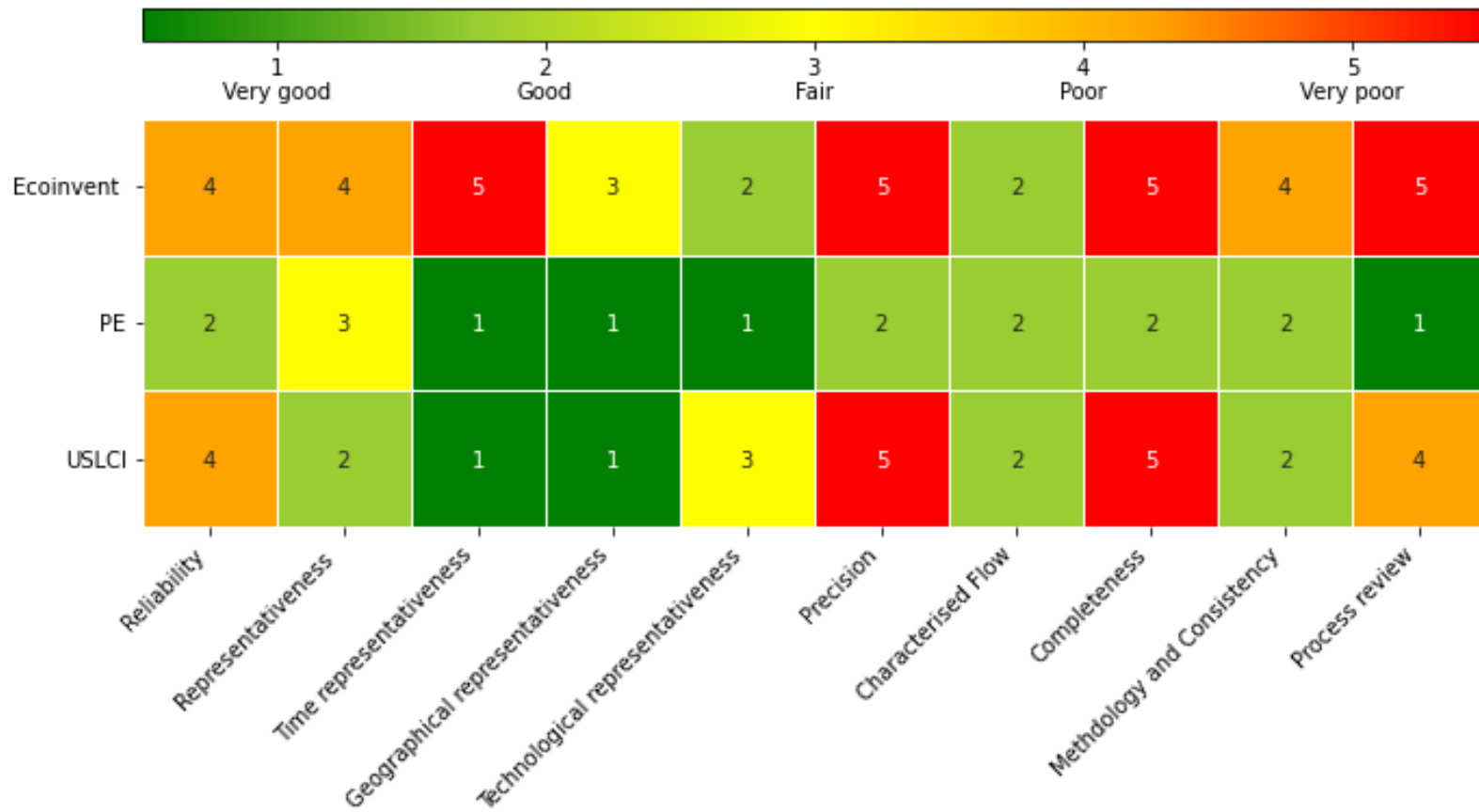


DATA QUALITY ASSESSMENT @ FLOW LEVEL: EPOXY RESIN



- Ecoinvent
- Epoxy resin production, liquid - RER
- Period : 2015 to 2021

DATA QUALITY ASSESSMENT @ PROCESS LEVEL: EPOXY RESIN



Source	Location	Period
Ecoinvent	RER	2015 - 2022
USLCI	US	2019
PE	RER	2005

CARBON FIBRE INPUT PROCESS DATA SET

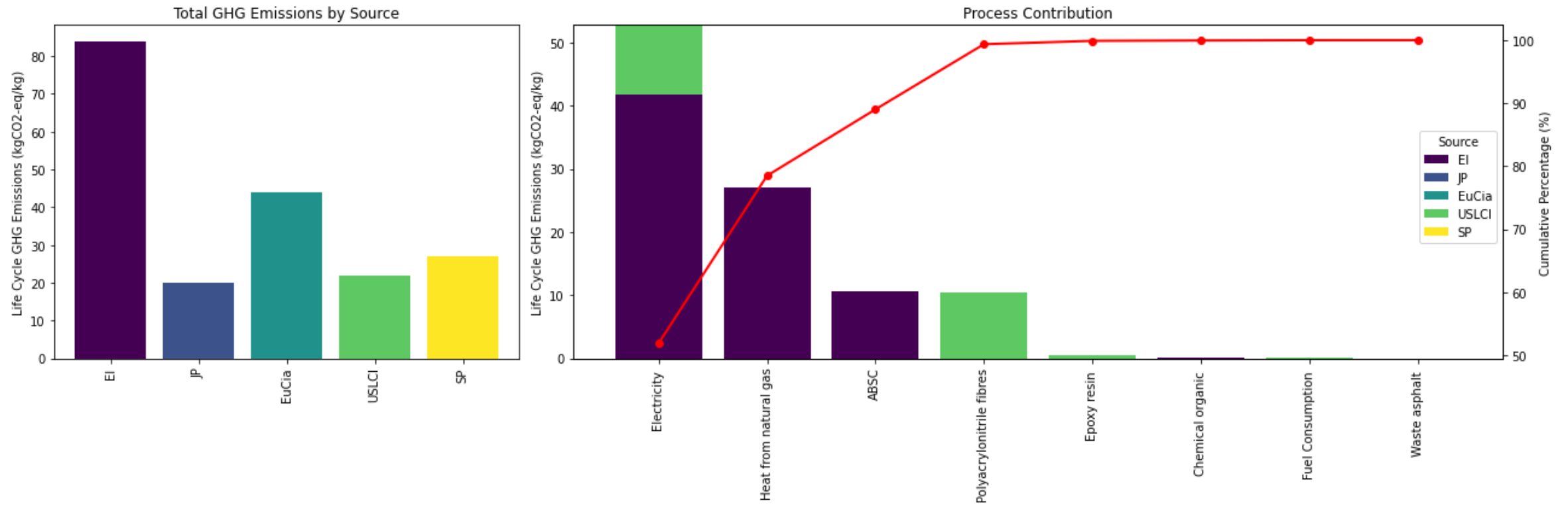
Source	SP	EI	EuC ia	US	JP
Inputs from technosphere					
Polyacrylonitrile fibres					
Acrylonitrile butadiene styrene copolymer					
Acrylonitrile					
Comonomer					
Polymerization catalyst					
Solvent					
PAN fiber oil					
Chemical organic					
Injection moulding					
Carbon fiber sizing agent					
Electrolyte (sulfuric acid)					
Outer packaging material					
Epoxy resin					
Hexamethylene diamine (HMDA) from acrylonitrile via adiponitrile					
Potassium permanganate					
ammonium bicarbonate					
Sulfuric Acid					
Polydimethylsiloxane					
Nitrogen (gaseous)					
Ammonia Hydrogen carbonate					

Energy/heat					
Electricity					
Heat from natural gas					
Carbonization HT primary gas					
Carbonization HT primary electricity					
Carbonization LT primary gas					
Carbonization LT primary electricity					
Washing primary electricity use					
Washing primary gas					
Drying-I primary electricity use					
Drying-I primary gas use					
Avivage primary electricity					
Avivage primary gas use					
Drying-II primary electricity					
Drying-II primary gas use					
Spooling primary electricity					
Spooling primary gas					
Steam Consumption					
Fuel Consumption					

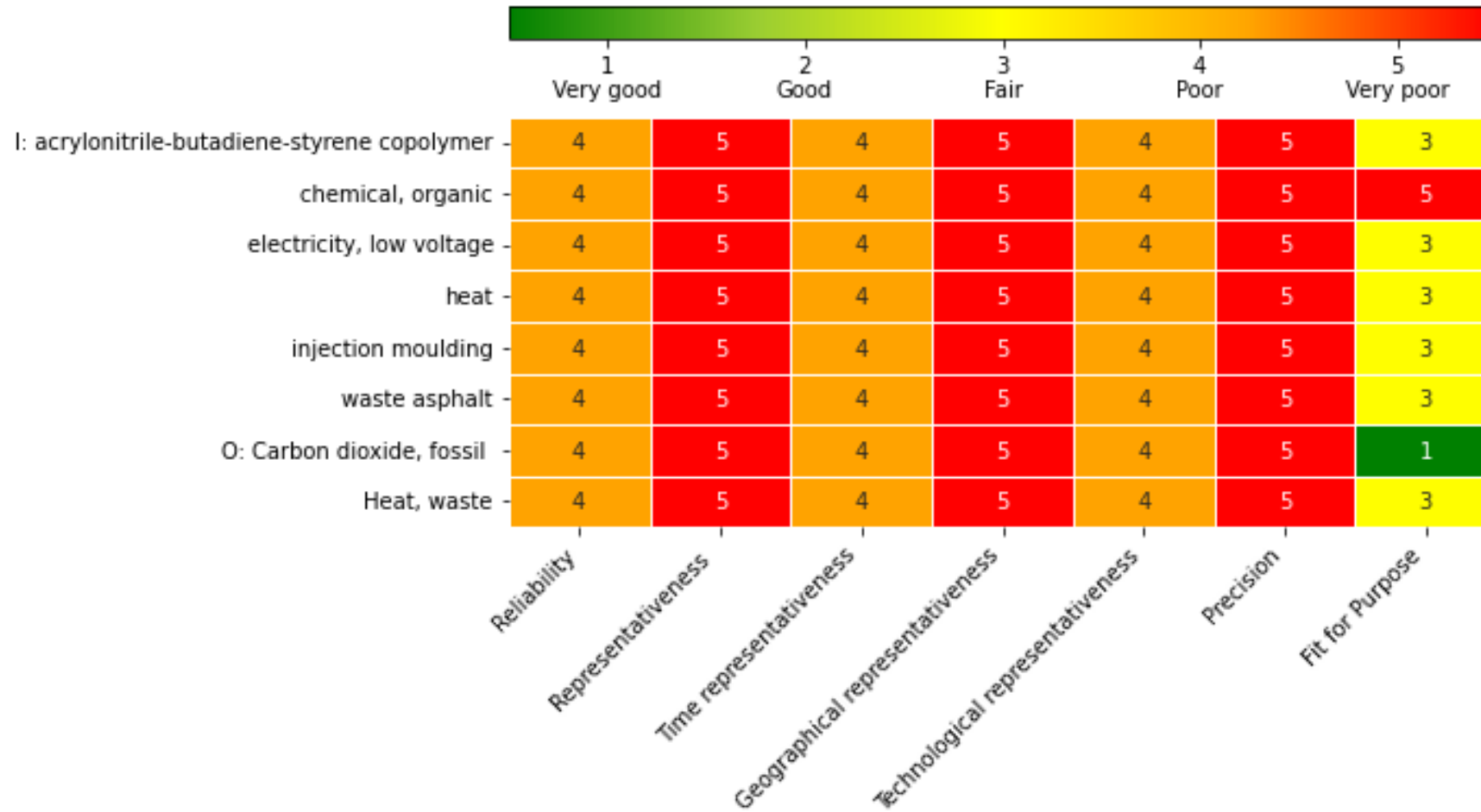
CARBON FIBRE OUTPUT PROCESS DATA SET

Source	SP	EI	EuC ia	US	JP
Carbon dioxide, fossil					
Heat, Waste					
Nitrogen oxide (NOx)					
Emissions to water					
Water					
Waste					
Waste asphalt					
Solid waste					
Exhaust gas treatment					
Elektrolysis					
Transport					
Transport Mix					

LIFE CYCLE GHG EMISSIONS: CARBON FIBRE

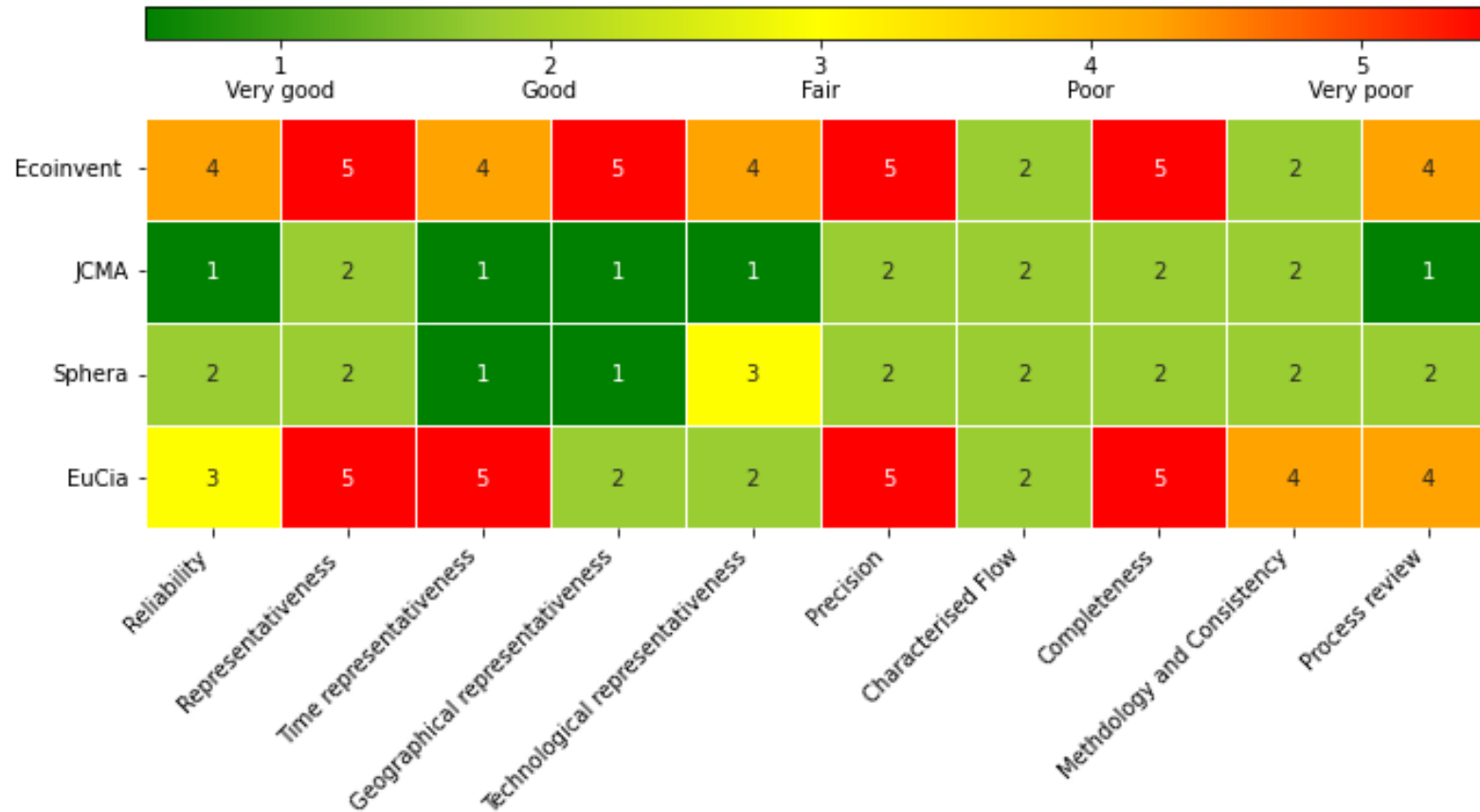


DATA QUALITY ASSESSMENT @ FLOW LEVEL: CARBON FIBRE



- Ecoinvent
- Carbon fibre reinforced plastic, injection moulded – GLO
- Period : 2016 to 2021

DATA QUALITY ASSESSMENT @ PROCESS LEVEL: CARBON FIBRE



Source	Location	Period
Ecoinvent	RER	1995 - 2021
JCMA	JP	2010 - 2011
Sphera	DE	2019 - 2022
EuCia	RER	2015 - 2022

GLASS REINFORCED PLASTIC (GRP) INPUT PROCESS DATA SET

Source	EI	PwC	SP	US
Input from Technosphere: Materials Resources				
Aluminium oxide, non-metallurgical				
Boric acid, anhydrous, powder				
Boric oxide				
Borax anhydrous				
Burnt dolomite				
Chemical, organic				
Calcium borat				
Colemanite				
Ethylene glycol				
Epoxy resin				
Feldspar				
Kaolin				
Clay				
Dolomite				
Gypsum				
Polyvinyl acetate				
Flat glass factory				
Filmformer				
Fluorspar, 97% purity				
Phenolic resin				
Lime				
Quicklime				
Limestone				
Magnesium oxide				
Hydrated Lime				
PH-modifier				
Lubricating oil				

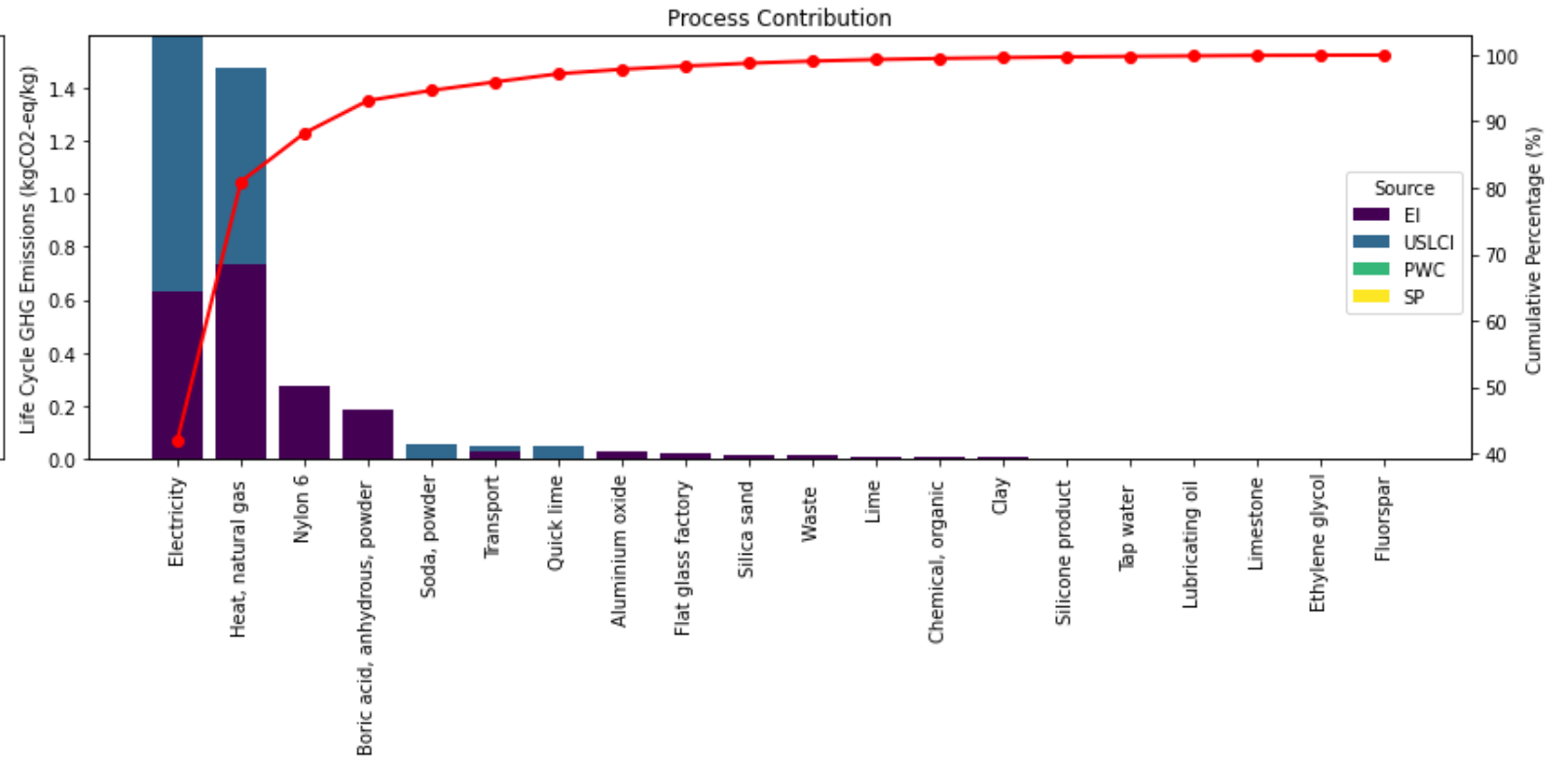
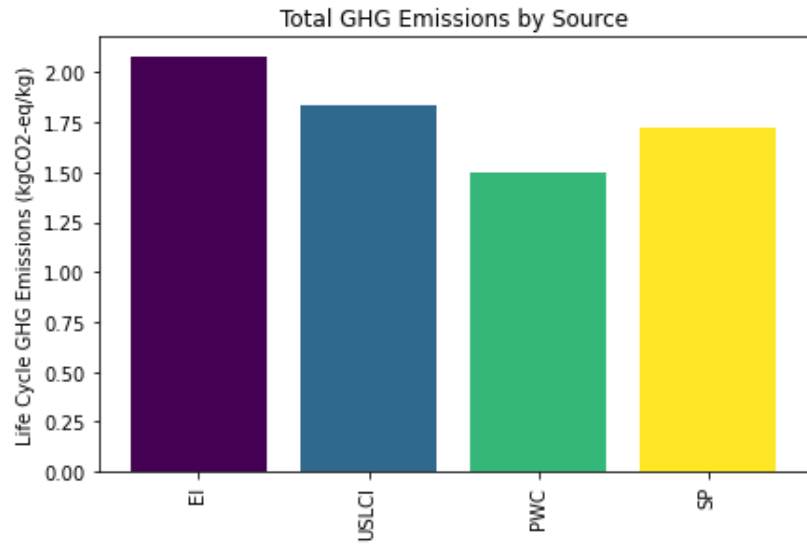
Phthalic anhydride					
Silica Sand					
Electricity, low voltage					
Electricity, renewable energy					
Heat					
Steam, in chemical industry					
Input from technosphere: Transport					
Transport combined truck					
Transport , Train, Diesel Powered					
Transport ocean freighter					
Input from environment					
Water					

GLASS REINFORCED PLASTIC (GRP) OUTPUT PROCESS DATA SET

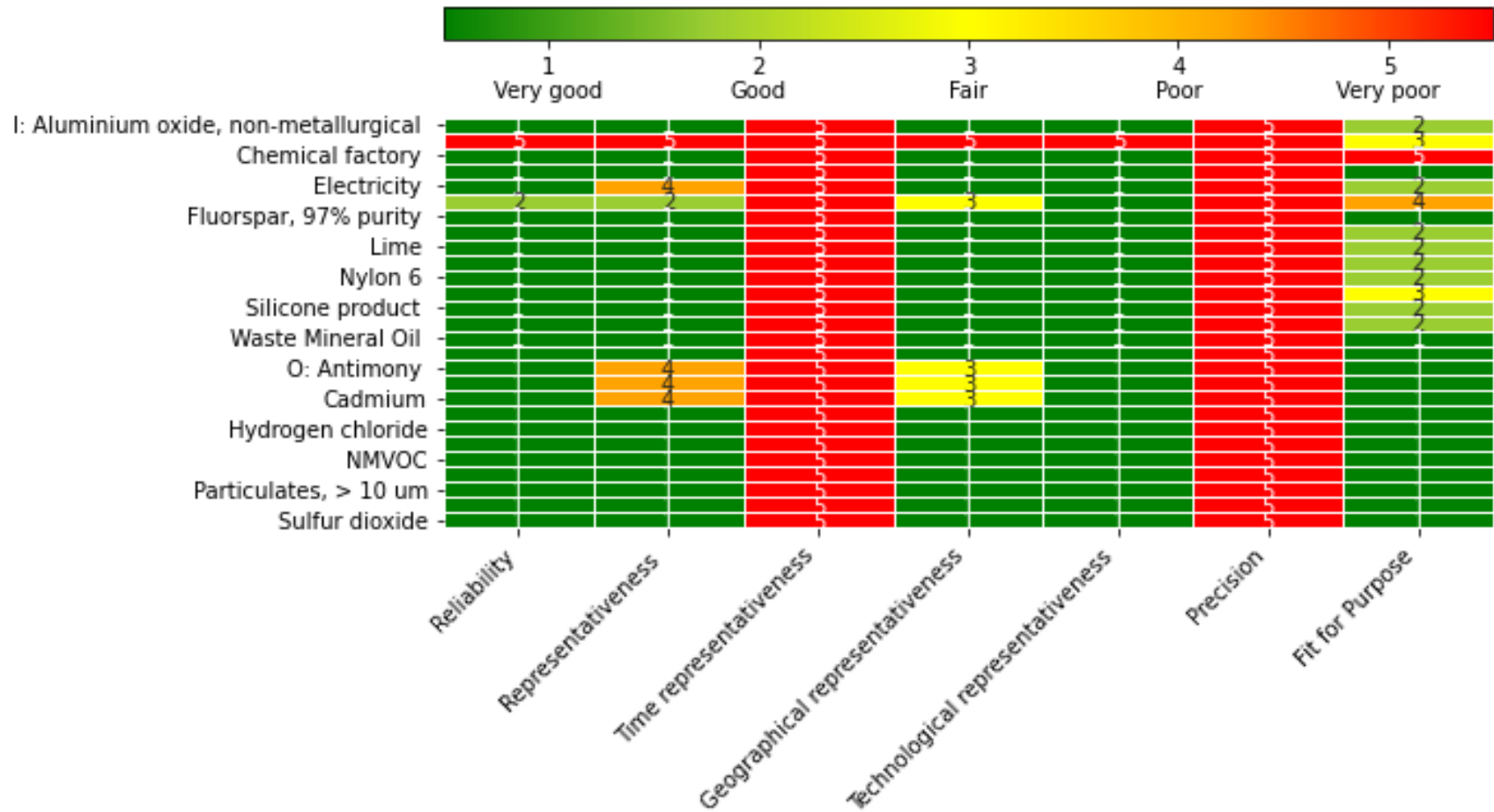
Source	EI	PwC	SP	US
Output: Emission to Air				
Antimony				
Arsenic				
Cadmium				
Carbon dioxide, fossil				
Hydrogen chloride				
Hydrofluoric acid				
Hydrogen fluoride				
Nitrogen oxides				
NMVOC, non-methane volatile organic compounds				
Volatile organic compounds				
Methanol				
Particulates, < 2.5 um				
Particulates, > 10 um				
Particulates, > 2.5 um, and < 10um				
Sulfur dioxide				
Xylene				
Styrene				

Emissions to Water				
Water/m3				
Water, RER				
Waste				
Waste mineral oil				
Waste mineral wool, for final disposal				
Waste paint				
Wastewater from glass production				

LIFE CYCLE GHG EMISSIONS: GLASS REINFORCED PLASTIC (GRP)

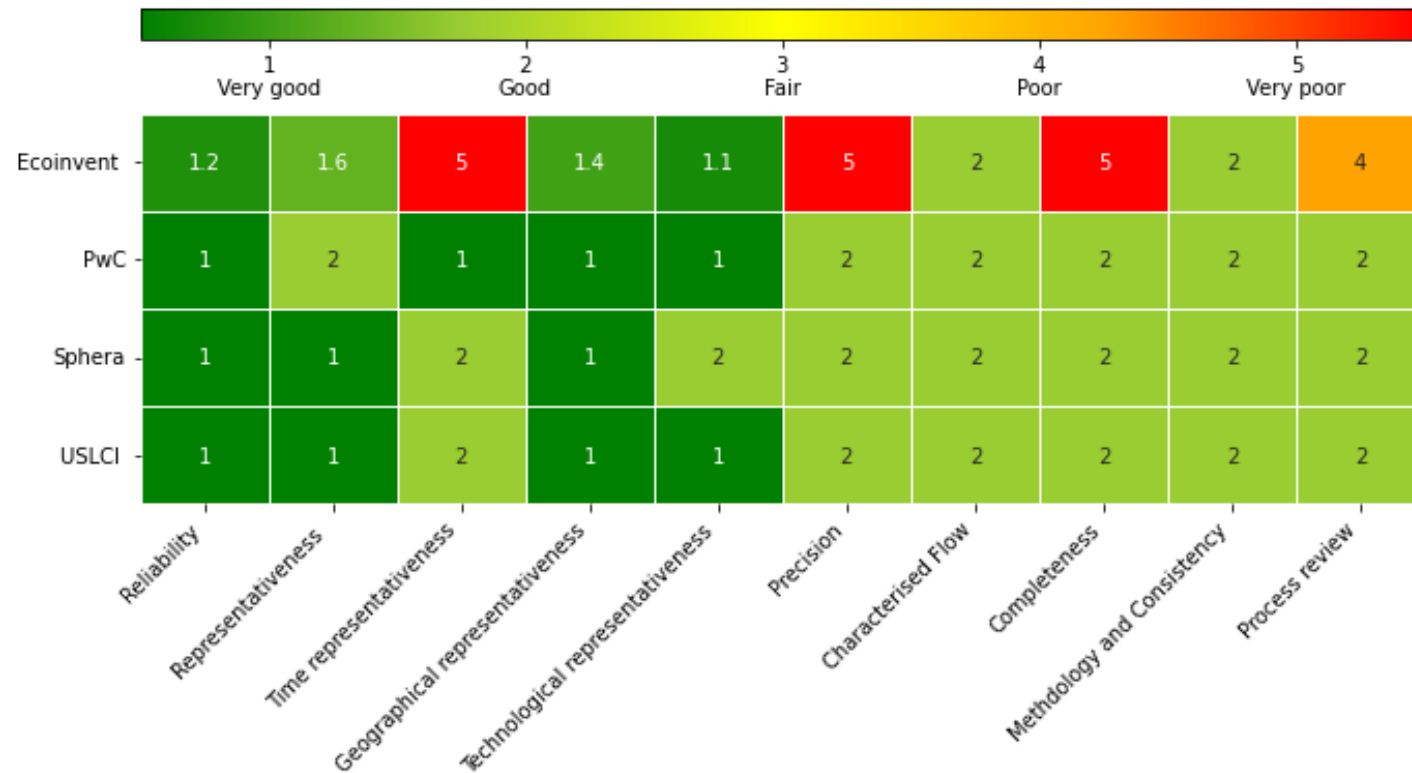


DATA QUALITY ASSESSMENT @ FLOW LEVEL: GLASS FIBRE



- Ecoinvent
- Glass fibre production RER
- Period : 2000 to 2021

DATA QUALITY ASSESSMENT @ PROCESS LEVEL: GLASS FIBRE



Source	location	Period
Ecoinvent	RER	2000 - 2021
PwC	RER	2022 - 2023
Sphera	DE	2019 - 2022
USLCI	US	2010 - 2011

ILLUSTRATIVE CASE STUDY

한국정밀공학학회지 제 36 권 제 9 호 pp. 875-881
J. Korean Soc. Precis. Eng., Vol. 36, No. 9, pp. 875-881

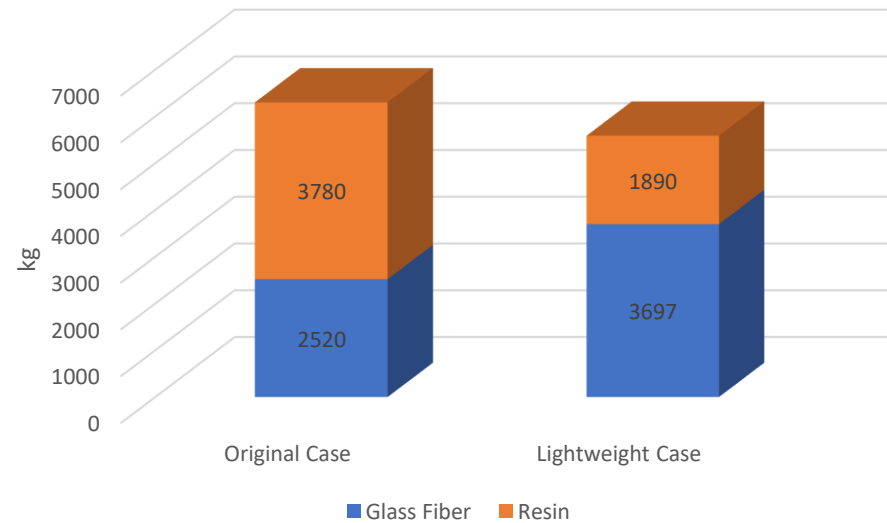
September 2019 / 875
<https://doi.org/10.7736/KSPE.2019.36.9.875>
ISSN 1225-9071 (Print) / 2287-8769 (Online)

Environmental Impact Evaluation on Lightweight Structure Design of a Composite Ship by LCA (Life Cycle Assessment)

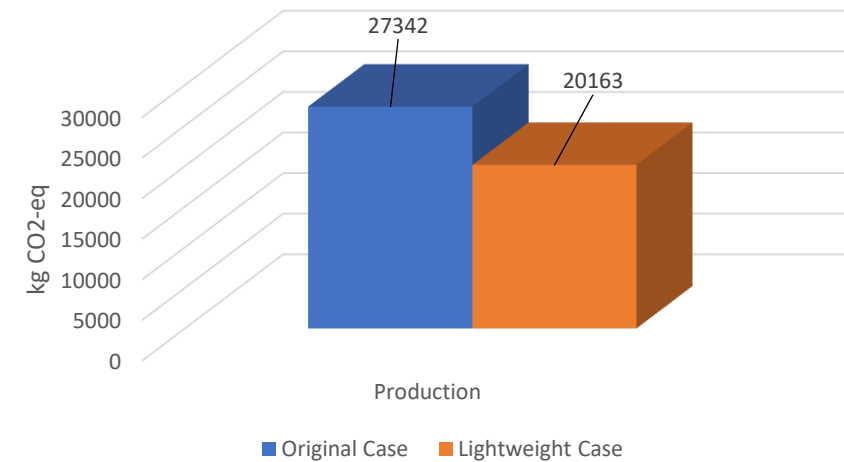
(Daekyun Oh *et al*, 2019)



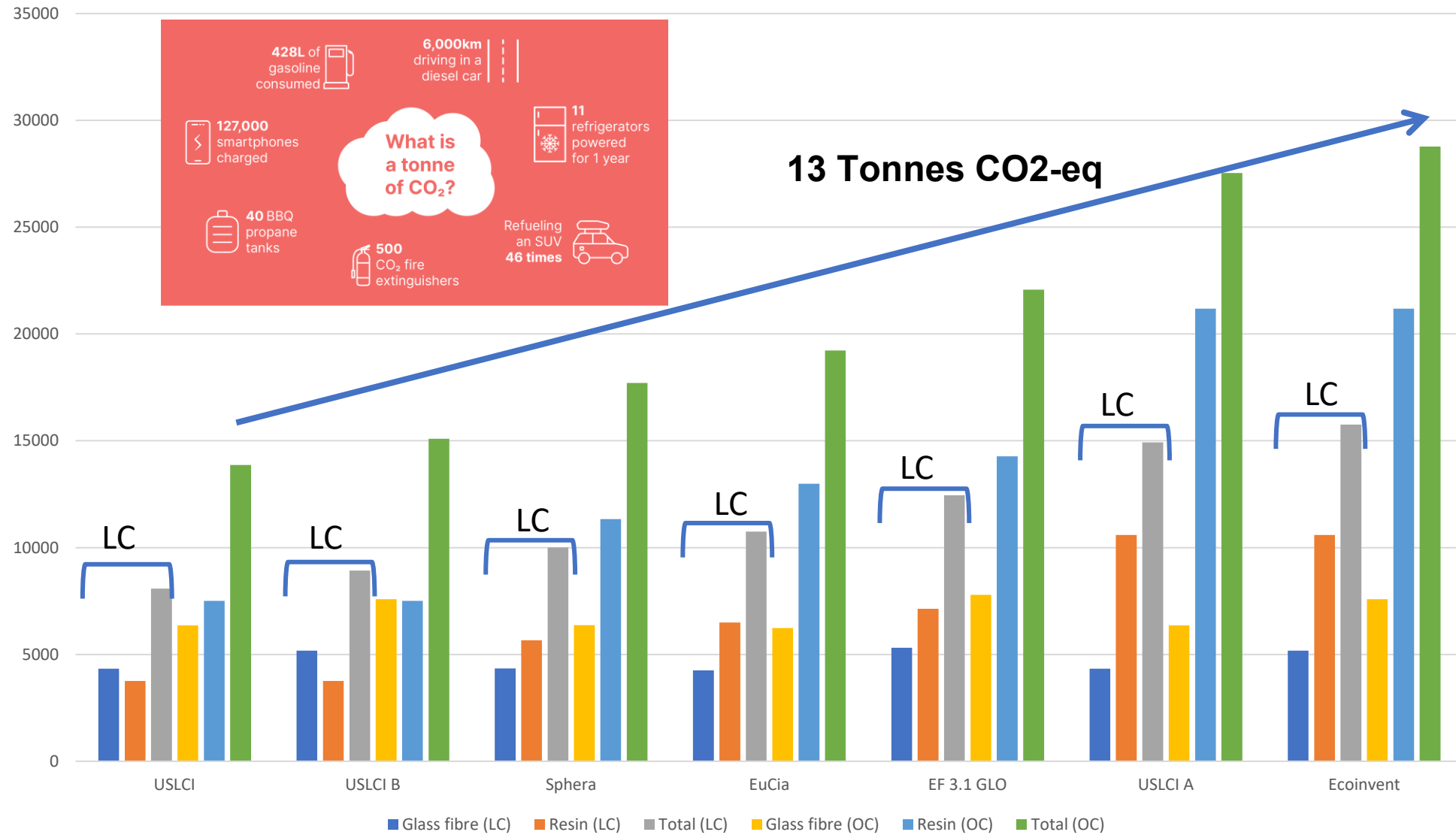
Weight variation composite materials lightweight design



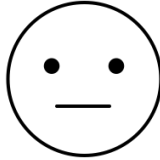
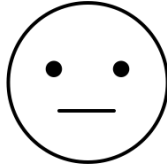
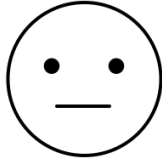



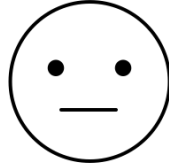

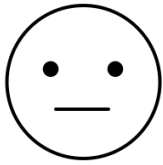



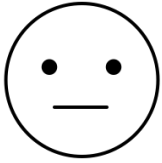
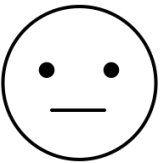


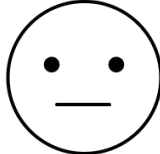






Variation for GWP indicator with lightweight for production phase



ILLUSTRATIVE CASE STUDY



	UP resin unspecified	Ortho/ISO/DCPD/ Vinyl ester	Epoxy resin	Glass fiber	Carbon fiber
					
					
					
					
The J apan C arbon Fiber M anufacturers A ssociation					

RECOMMENDATIONS

For LCA Practitioner:

Select proxy data and data sources carefully

Compare Data from different sources especially for high contributing process elements

Assess the data quality and uncertainty

Communicate the data quality and availability issues

Interpret the influence of data quality and data gaps on the LCA results

RECOMMENDATIONS

For Databases, Sector Platforms, Composite Industry:

Guidelines: Create industry-specific LCI data collection and analysis guidelines

Harmonisation: Standardise data quality assessment methods across the sector.

Criteria: Define acceptable data quality levels for composites LCI datasets.

Communication: Ensure transparency about data quality and availability.

Centralisation: Establish a central LCI database for composites.

Automation: Introduce an automated system for visualising data quality in relation to process contributions.

Focus Areas: Focus on data completeness, precision, and thorough process review.

MATERIALS SAFETY DATA SHEET (MSDS)

LIFE CYCLE INVENTORY DATA SHEET (LCIDS)

PRESENT

<p>Identifikatsiya:</p> <p>086 290</p>	<p>Niut opdoli: 89.1N</p> <p>monaxeasticite</p> <p>onopomnis</p> <p>ogtebicatte.</p> <p>chesnizator</p> <p>usteedcs radics</p> <p>off Sopujekieinecs</p> <p>ninescol et poatutiligy</p>
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<p>R.A:2E2</p> <p>B.A.CEB</p> <p>D.A6EA</p> <p>B.A6L8</p> <p>B.A6A2</p> <p>B.A6L8</p> <p>B.A6LS</p> <p>AJM</p>	<p>0H4</p> <p>1</p> <p>T</p> <p>1</p> <p>8.</p> <p>8.</p> <p>T.</p> <p></p>
<p>6008</p> <p>5888</p> <p>1300</p> <p>1058</p> <p>988</p> <p>888</p> <p>1038</p> <p>84.8</p>	<p>086 290</p>



208 ← ← FUTURE

<p>MSDS</p> <p></p> <p>Mehiid caffel</p> <p></p> <p>Lifee Invyauy Shet</p>	<p>LCIDS</p> <p></p> <p></p>
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<p>Emissions</p> <p></p> <p>2220</p> <p>100-00</p>	<p></p> <p></p> <p>226</p>
<p></p> <p>9826</p> <p>LMBC S</p>	<p></p> <p>289</p>

