A data quality assessment method for life cycle inventories in LCA

Work in progress

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Universiteit Leiden
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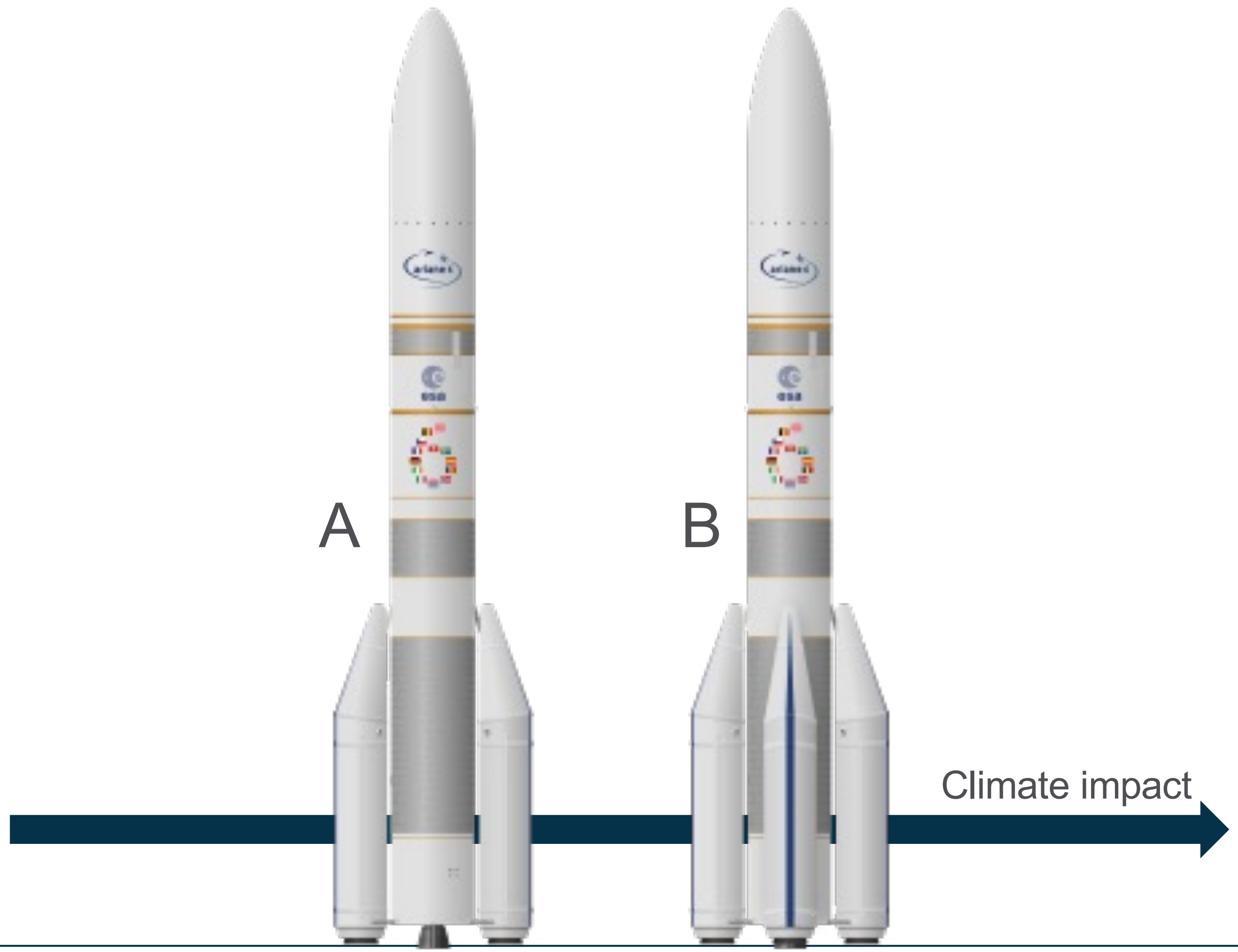
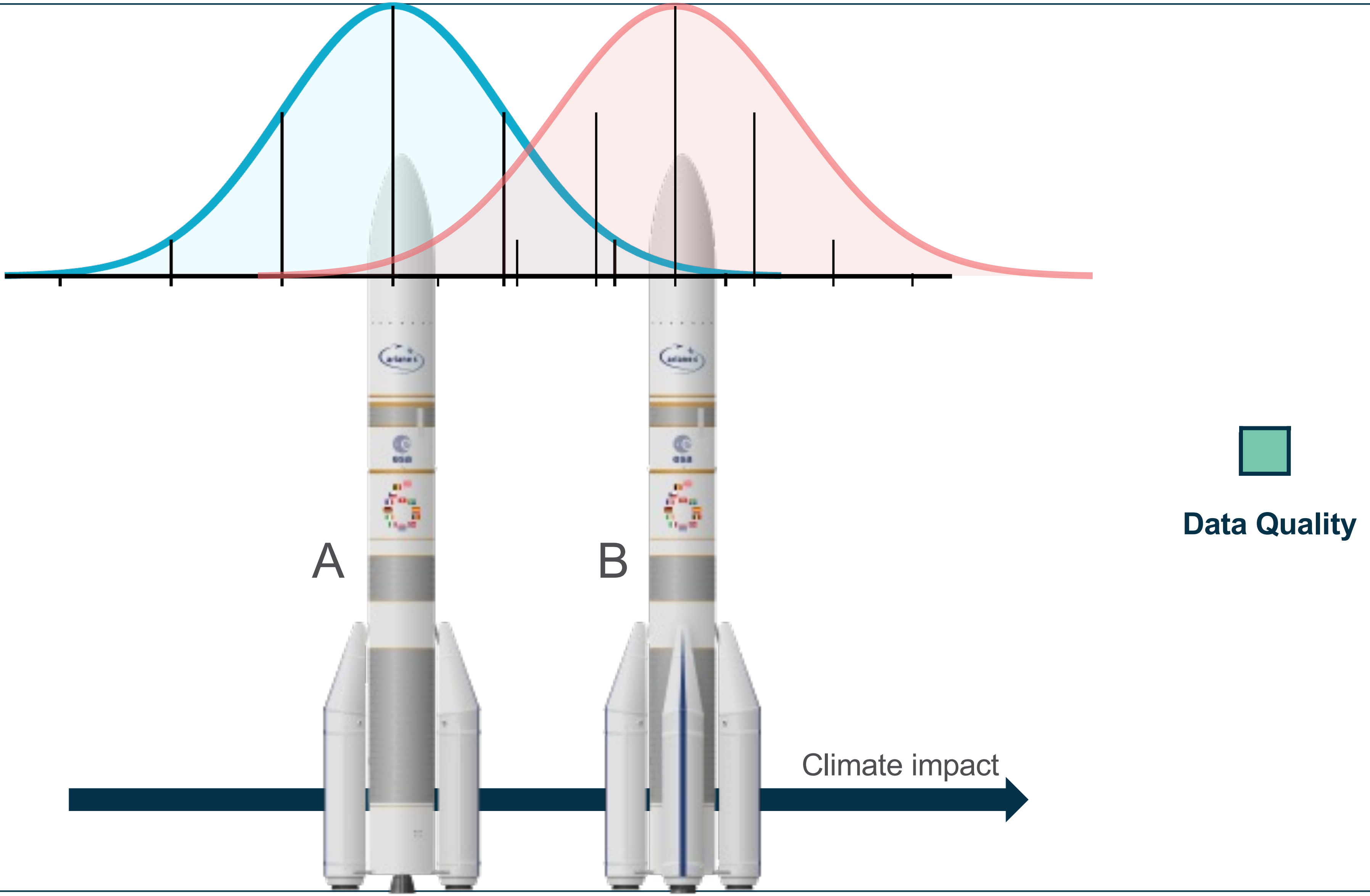
Context Relevance: Data quality in LCA



Context Relevance: Data quality in LCA



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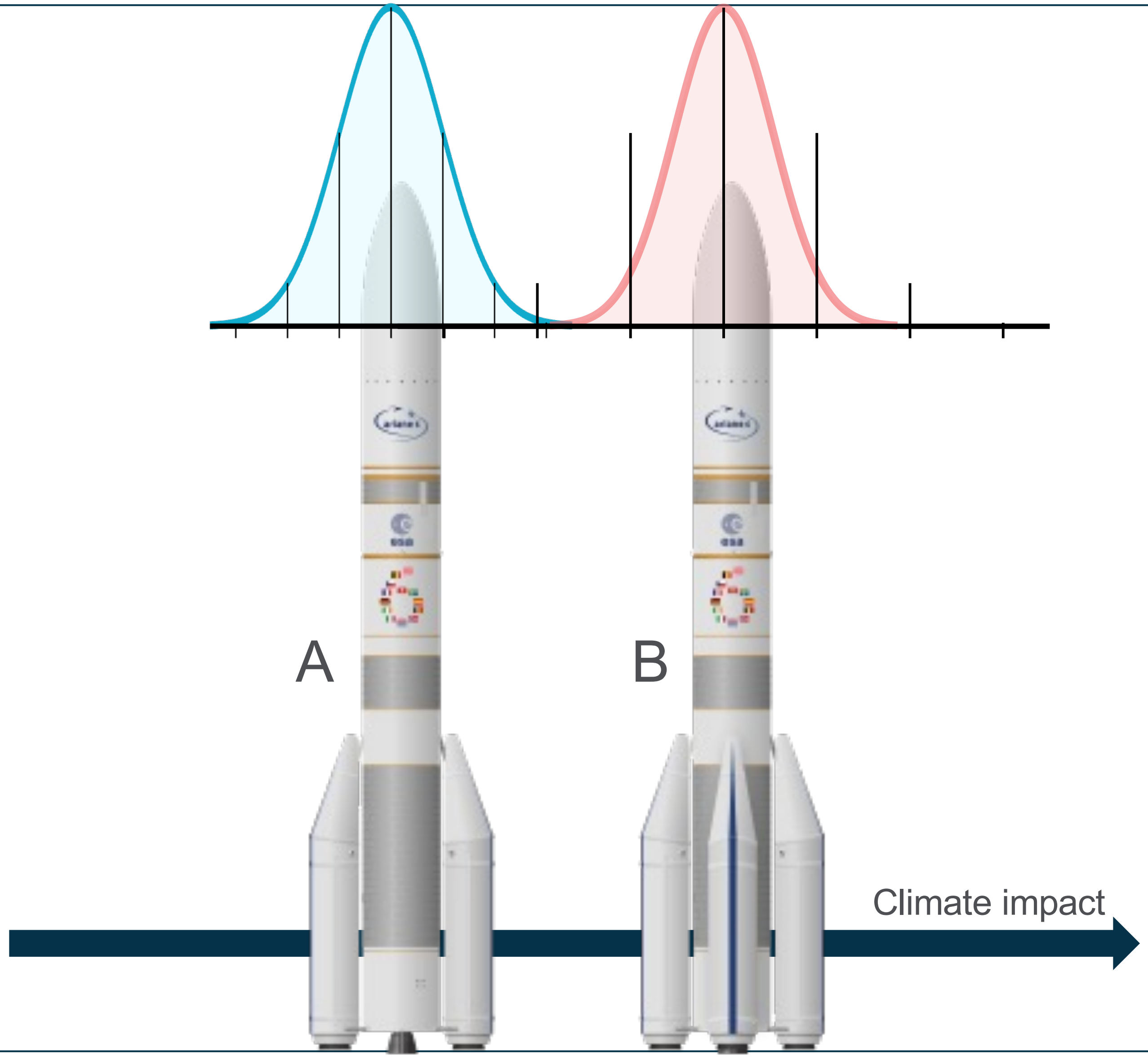

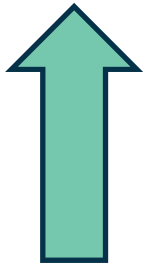

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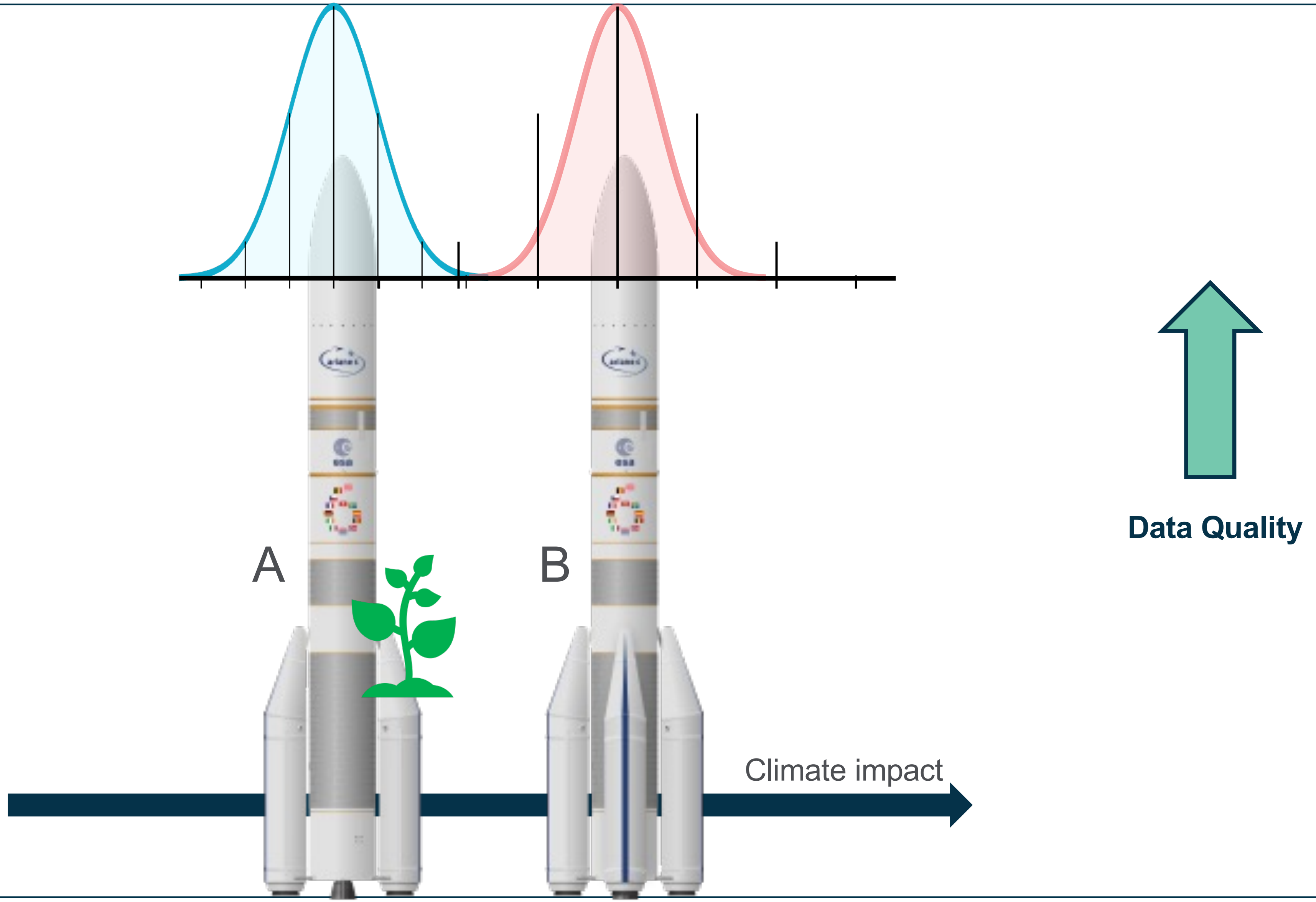
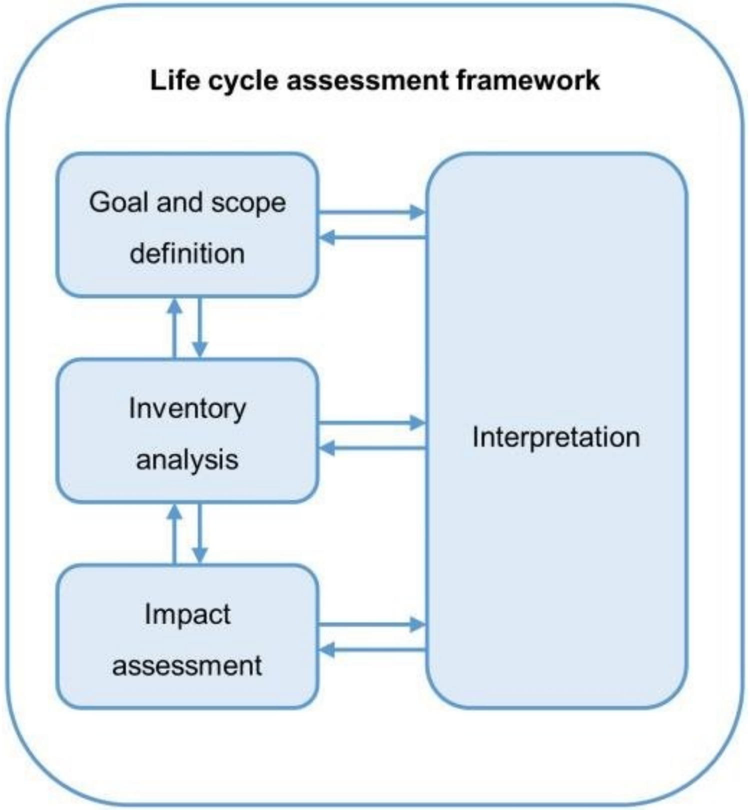


Context Terminology

A data quality assessment method for life cycle inventories

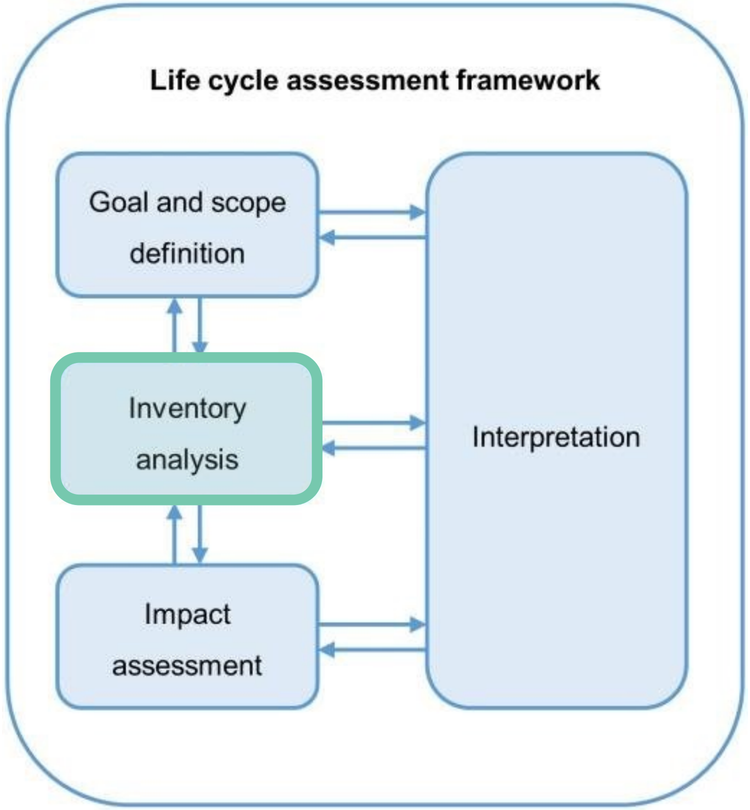
LCA



Context Terminology: LCI

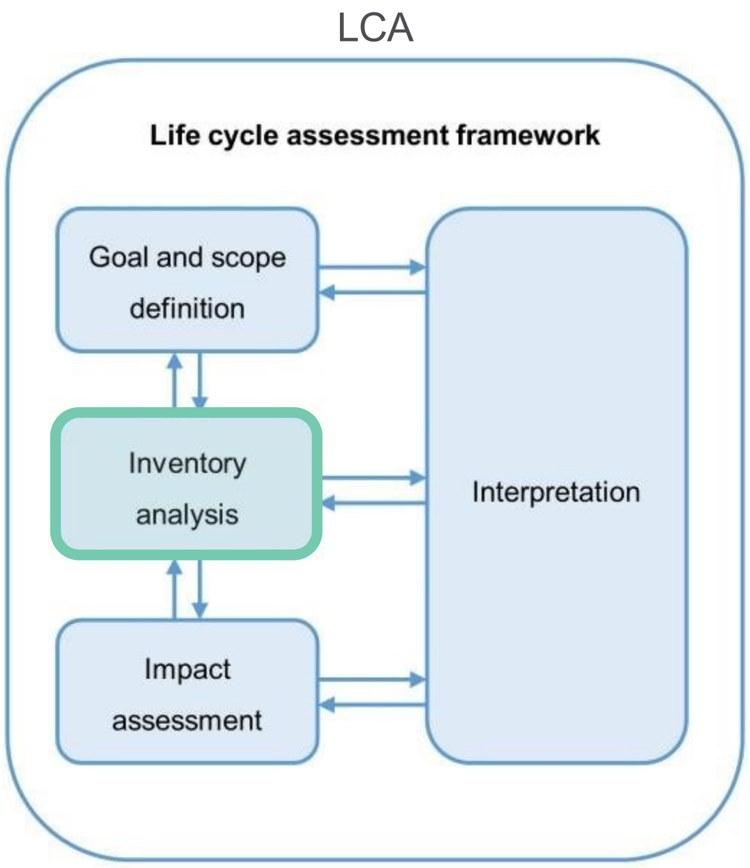
A data quality assessment method for life cycle inventories

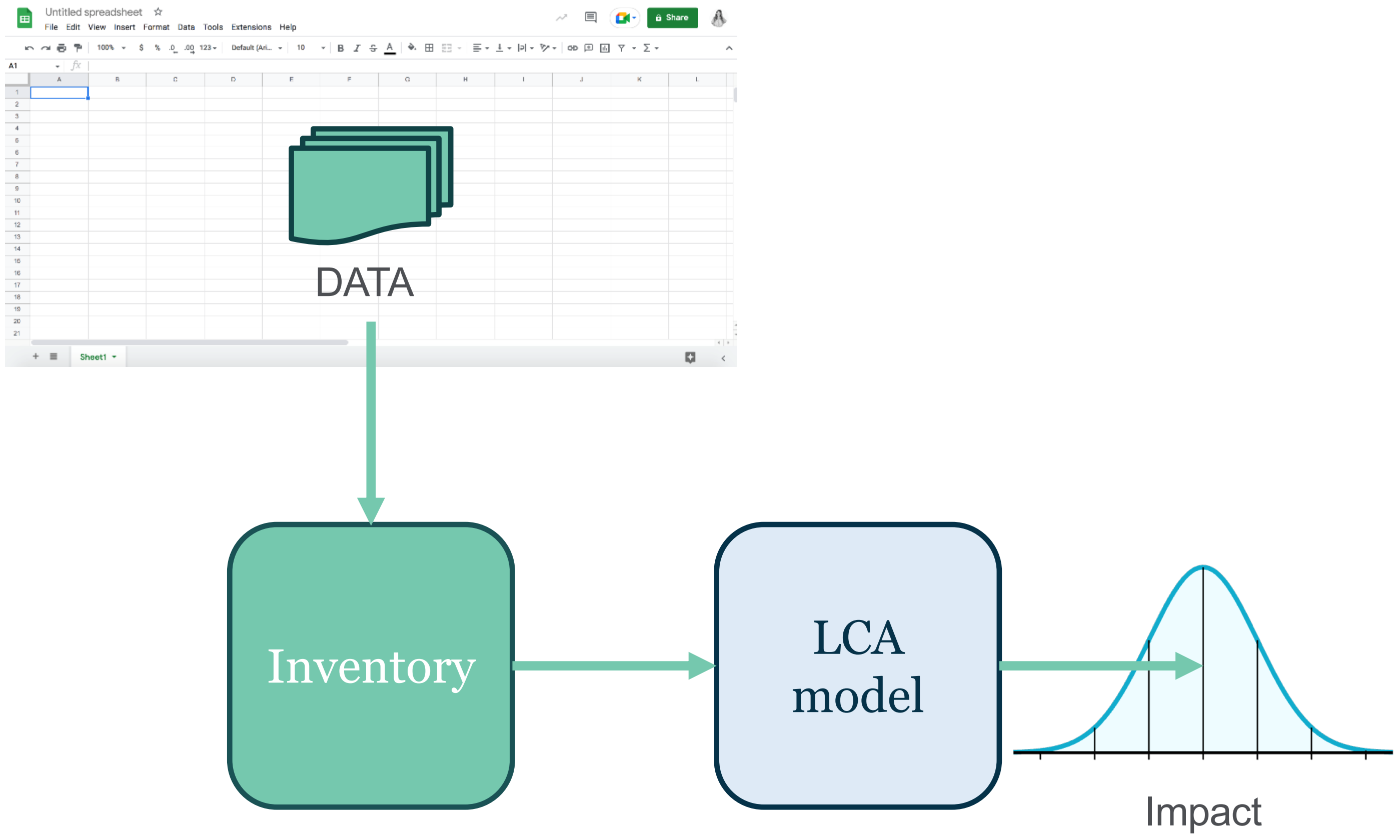
LCA



Context Terminology: LCI

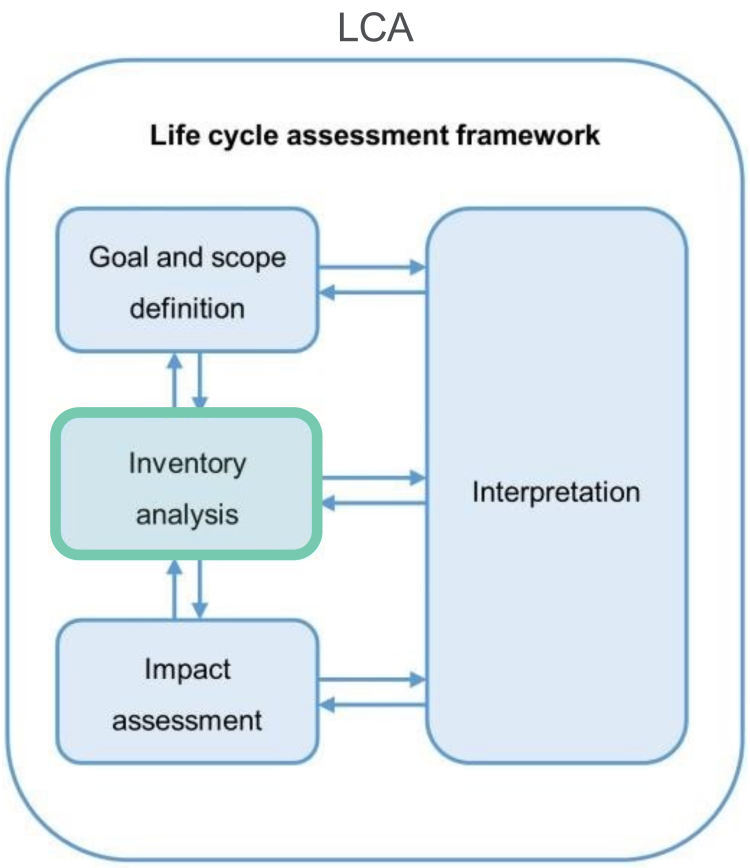
A data quality assessment method for life cycle inventories

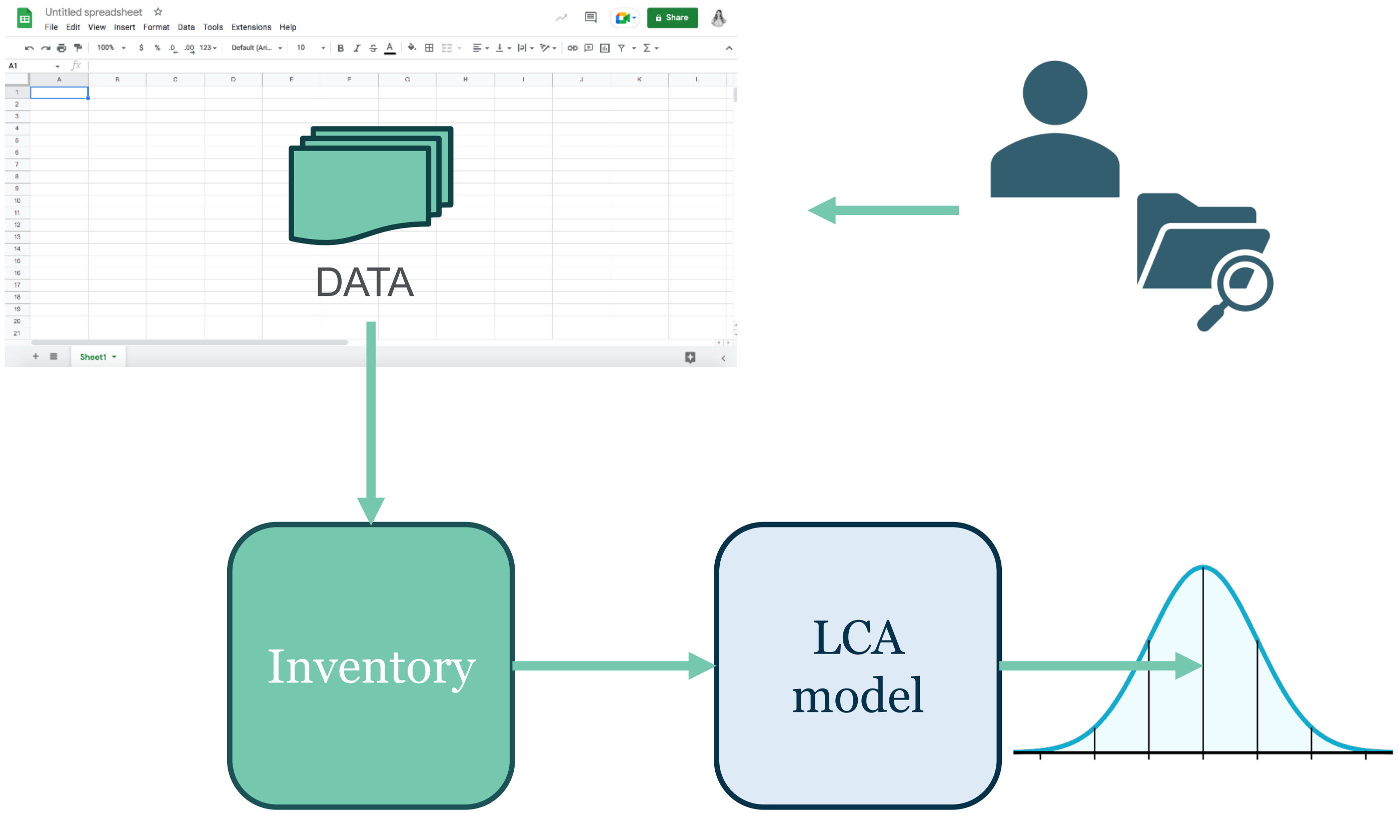




Context Terminology: LCI

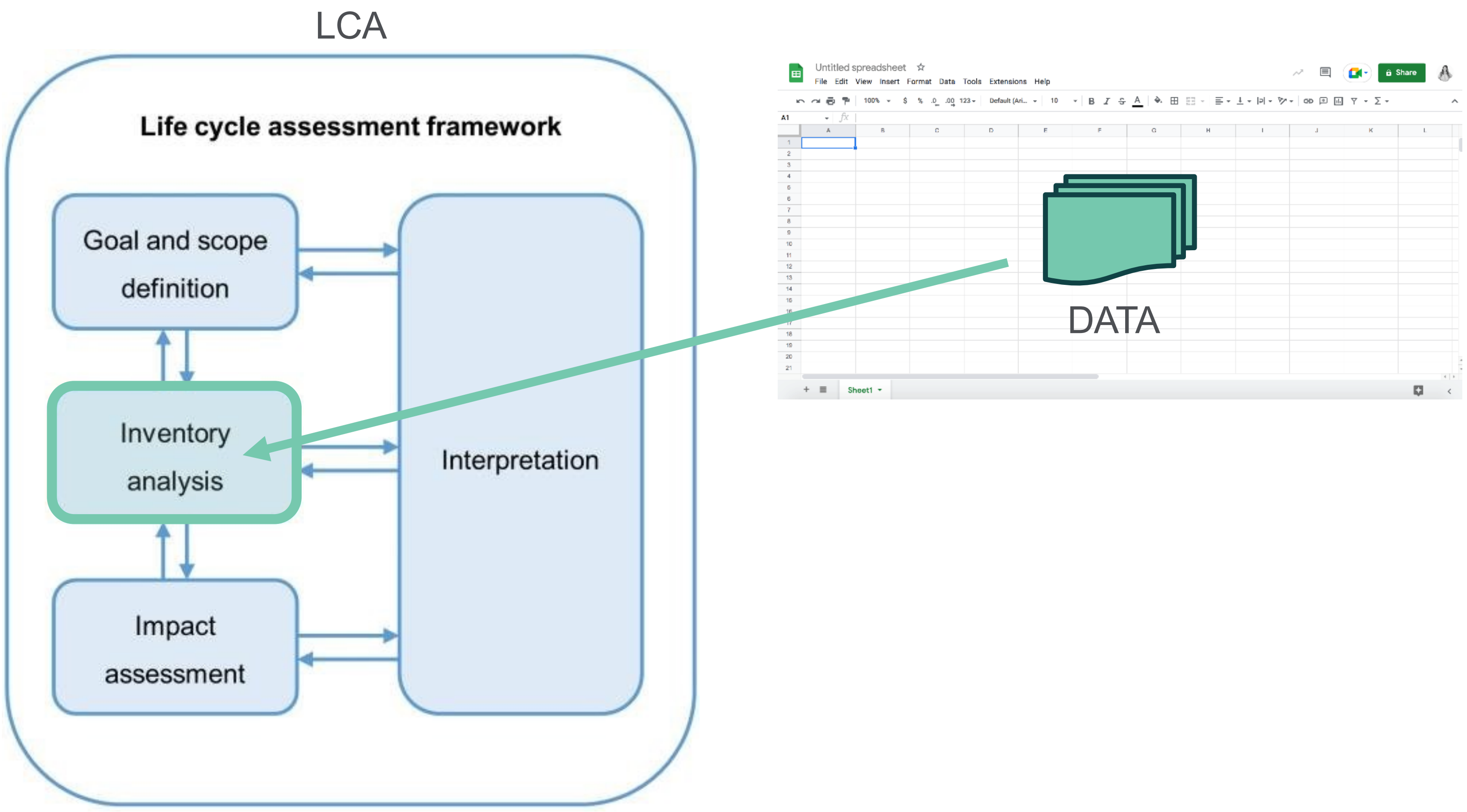
A data quality assessment method for <u>life cycle inventories</u>





Context Terminology: DQA

A data quality assessment method for life cycle inventories



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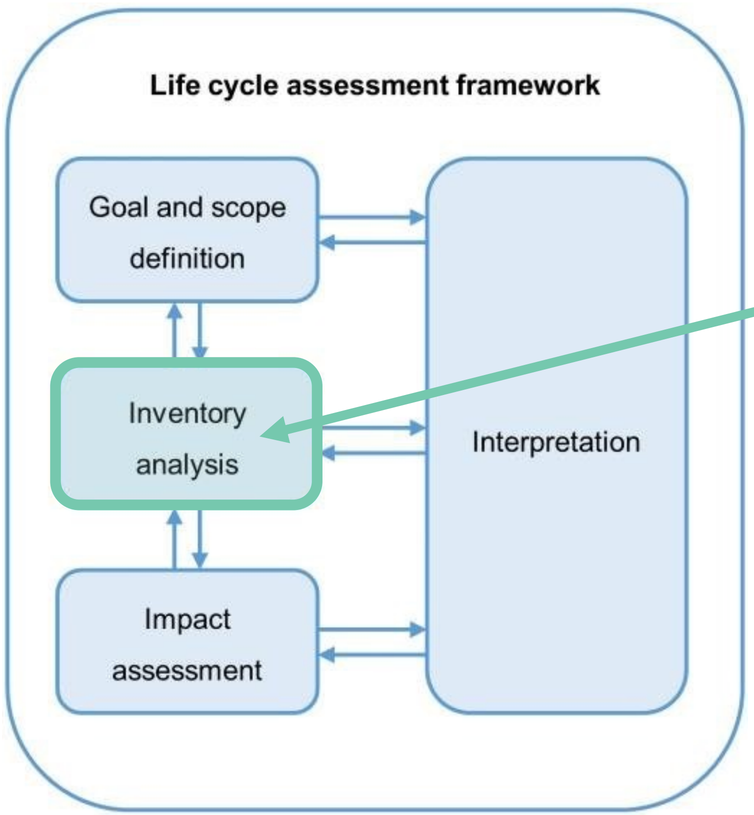
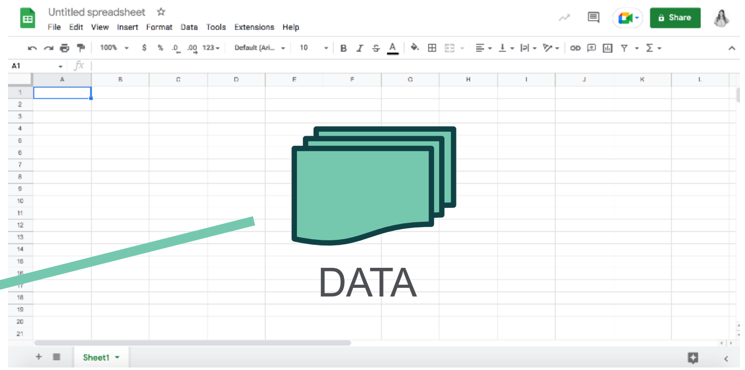


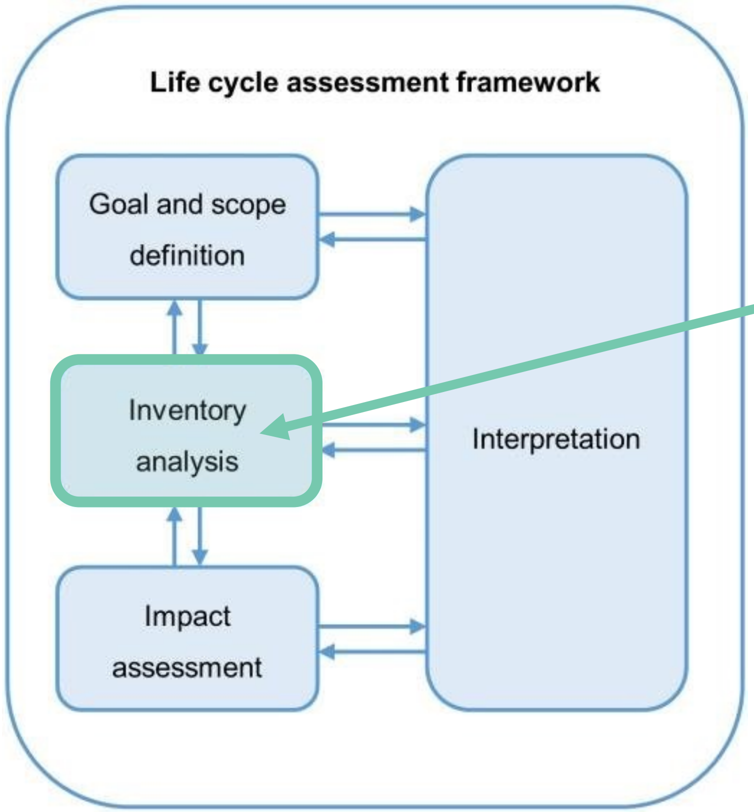


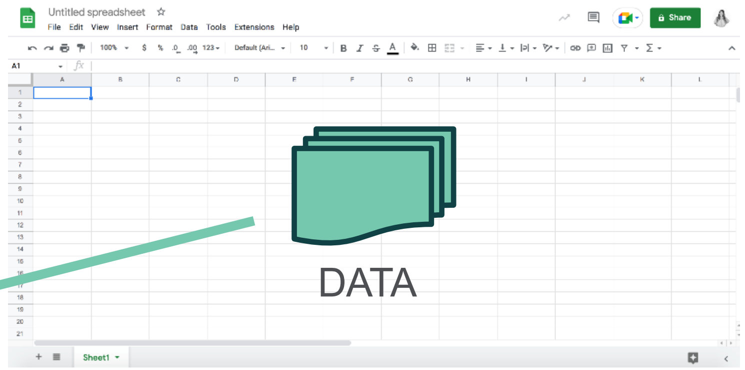
How well does the data plugged into the model *represent the true data?*

Context Terminology: DQA

A data quality assessment method for life cycle inventories

LCA





How well does the data plugged into the model *represent the true data?*

- Representativeness (time, location, technology)
- Sample size
- Source of data
- Completeness
- Consistent use of calculations methods
- Measurement errors
- …

Context Terminology: DQA

A data quality assessment method for life cycle inventories

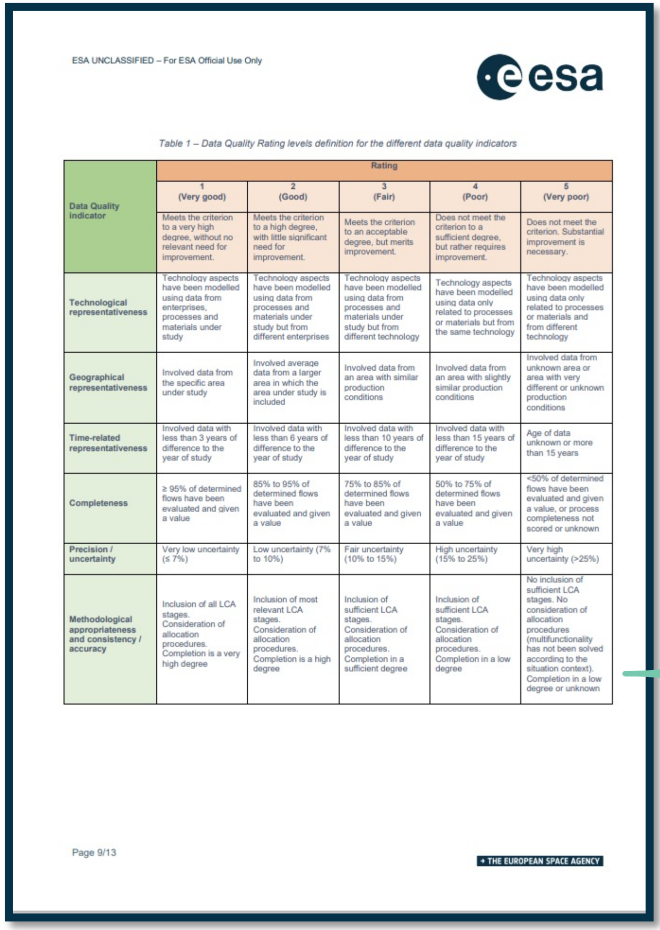


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Table 1 – Data Quality Rating levels definition for the different data quality indicators

Data Quality indicator	Rating				
	1 (Very good)	2 (Good)	3 (Fair)	4 (Poor)	5 (Very poor)
	Meets the criterion to a very high degree, without no relevant need for improvement.	Meets the criterion to a high degree, with little significant need for improvement.	Meets the criterion to an acceptable degree, but merits improvement.	Does not meet the criterion to a sufficient degree, but rather requires improvement.	Does not meet the criterion. Substantial improvement is necessary.
Technological representativeness	Technology aspects have been modelled using data from enterprises, processes and materials under study	Technology aspects have been modelled using data from processes and materials under study but from different enterprises	Technology aspects have been modelled using data from processes and materials under study but from different technology	Technology aspects have been modelled using data only related to processes or materials but from the same technology	Technology aspects have been modelled using data only related to processes or materials and from different technology
Geographical representativeness	Involved data from the specific area under study	Involved average data from a larger area in which the area under study is included	Involved data from an area with similar production conditions	Involved data from an area with slightly similar production conditions	Involved data from unknown area or area with very different or unknown production conditions
Time-related representativeness	Involved data with less than 3 years of difference to the year of study	Involved data with less than 6 years of difference to the year of study	Involved data with less than 10 years of difference to the year of study	Involved data with less than 15 years of difference to the year of study	Age of data unknown or more than 15 years
Completeness	≥ 95% of determined flows have been evaluated and given a value	85% to 95% of determined flows have been evaluated and given a value	75% to 85% of determined flows have been evaluated and given a value	50% to 75% of determined flows have been evaluated and given a value	<50% of determined flows have been evaluated and given a value, or process completeness not scored or unknown
Precision / uncertainty	Very low uncertainty (≤ 7%)	Low uncertainty (7% to 10%)	Fair uncertainty (10% to 15%)	High uncertainty (15% to 25%)	Very high uncertainty (>25%)
Methodological appropriateness and consistency / accuracy	Inclusion of all LCA stages. Consideration of allocation procedures. Completion is a very high degree	Inclusion of most relevant LCA stages. Consideration of allocation procedures. Completion is a high degree	Inclusion of sufficient LCA stages. Consideration of allocation procedures. Completion in a sufficient degree	Inclusion of sufficient LCA stages. Consideration of allocation procedures. Completion in a low degree	No inclusion of sufficient LCA stages. No consideration of allocation procedures (multifunctionality has not been solved according to the situation context). Completion in a low degree or unknown

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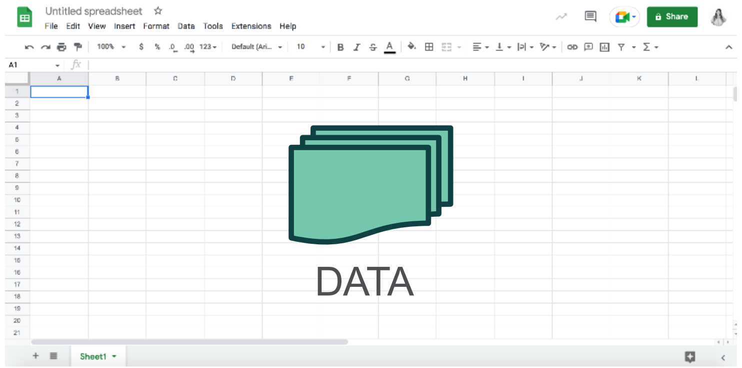

How well does the data plugged into the model *represent the true data?*

- Representativeness (time, location, technology)
- Sample size
- Source of data
- Completeness
- Consistent use of calculations methods
- Measurement errors
- …

Context Terminology: Pedigree matrix

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Context Terminology: DQA Method

A data quality assessment method for life cycle inventories

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2.3. Pedigree matrix

The previously mentioned DQI are mapped over five different score, the result is shown below in Table 1. This table is defined to be, and in this document referred to as the 'pedigree matrix'.

Table 1. Pedigree matrix used for applying scores to determine the data quality

				(Very good)	(Good)	(Fair)	(Poor)	(Very poor)
				1	2	3	4	5
Static	Flow	**Inherent uncertainty/ Spread**	Primary data	sample size of n > 8 as based on expert measurement and externally verified and adequate sample size	sample size 8< n < 1 as based on expert measurements or verified computational models	n = 1 Expert elicitation 4 step procedure; BoM, factory data calculations	n = 1 Expert elicitation point-value, reasonability checked	n = 1 Non-expert estimate not based on literature
Static	Flow	**Inherent uncertainty/ Spread**	Secondary data		sample size of n > 8 Extensive data available in literature and adequate sample size	sample size 8< n < 1 Partial data available in literature	n = 1 Data found in literature, reasonability checked	n = 1 Data estimate based on literature, I/O aggregate
Dynamic	Flow	**Temporal representativeness**		Data obtained within 1 year and TRL 9	Data obtained within 3 years or more recent and TRL 9	5 years or more recent and TRL 9	10 years or more recent or TRL 5, 6, 7 or 8	10 years or older/ unknown or TRL 1, 2, 3 or 4
Dynamic	Flow	**Technological representativeness**		1 point score	2-point score	3-point score	4-point score or 'market' process	5-point score
Dynamic	Flow	**Geographical Representativeness**		1 point score	2-point score	3-point score	4-point score or	5-point score
Static	Process	**Completeness**		BoM is used and a mass balance and external process expert feedback (with 5 years of experience) and energy balance/site-visit	BoM is used and a mass balance and validated by an external process expert feedback (with 5 years of experience)	BoM/patent is used and a mass balance and an internal validation	Input-output scheme of plant is used with allocation	Literature and comparable processes are used
Dynamic	Model	**Methodological appropriateness**		All life cycle stages included. 90% cut-off criteria are shared. System is subject to external review and mass balance of foreground processes system.	All life cycle stages included. 90% cut-off criteria of processes in the system are shared. System is subject to external review.	All life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. System is subject to external review.	Not all life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. No external review for completeness of system.	Unkown if all life cycle stages included. Unknown amount of cut-off criteria of processes in the system are shared. No external review for completeness of system.

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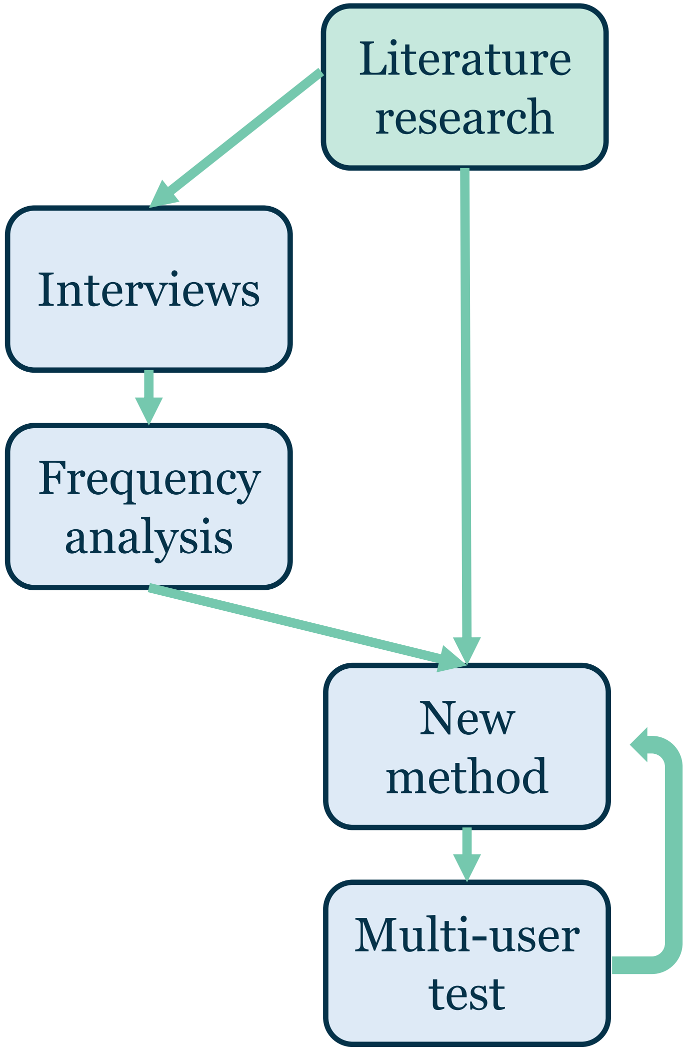
Method: Research questions

How can data quality be assessed and improved for the Life Cycle Inventory (LCI) of space missions?

1. Overview of current DQA methods?
2. Status of current DQA methods?
3. Strengths, Weaknesses and Points of improvement DQA methods?
4. How should data quality for the LCI of space missions be assessed?



Method: Interviews

2 Interview groups:

Group 1

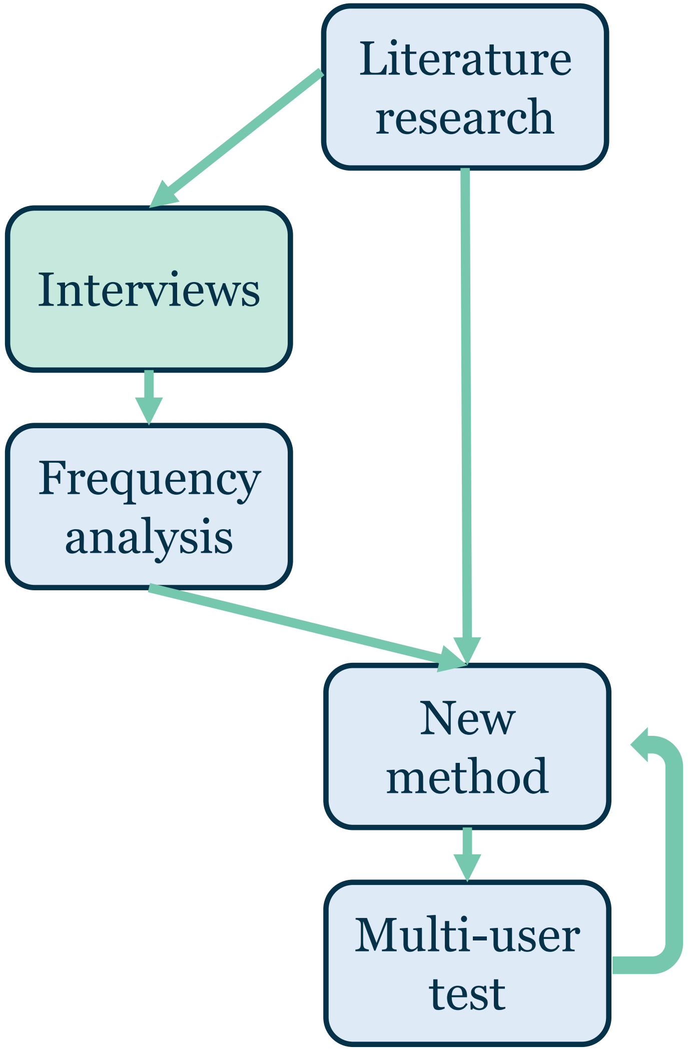
LCA Experts that have applied LCA to space systems

8

Group 2

LCA Experts that have not applied LCA to space systems

11



Method: Frequency analysis

2 Interview groups:

Group 1

LCA Experts that have applied LCA to space systems

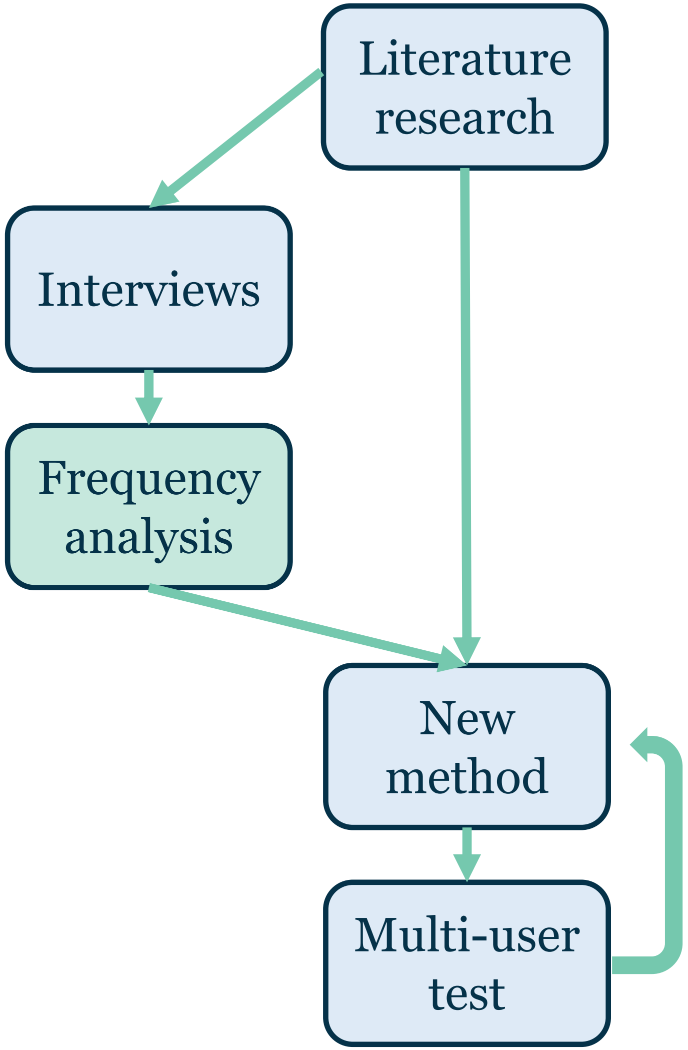
8

Group 2

LCA Experts that have not applied LCA to space systems

11

1. Transcribing all the interviews
2. Label each new piece of information
3. How many times was this piece if information mentioned?



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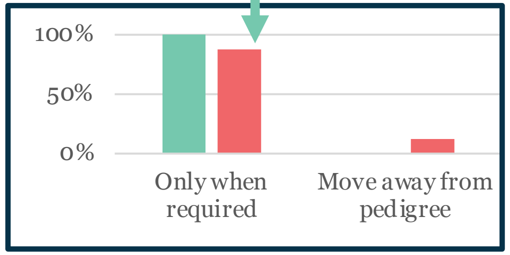
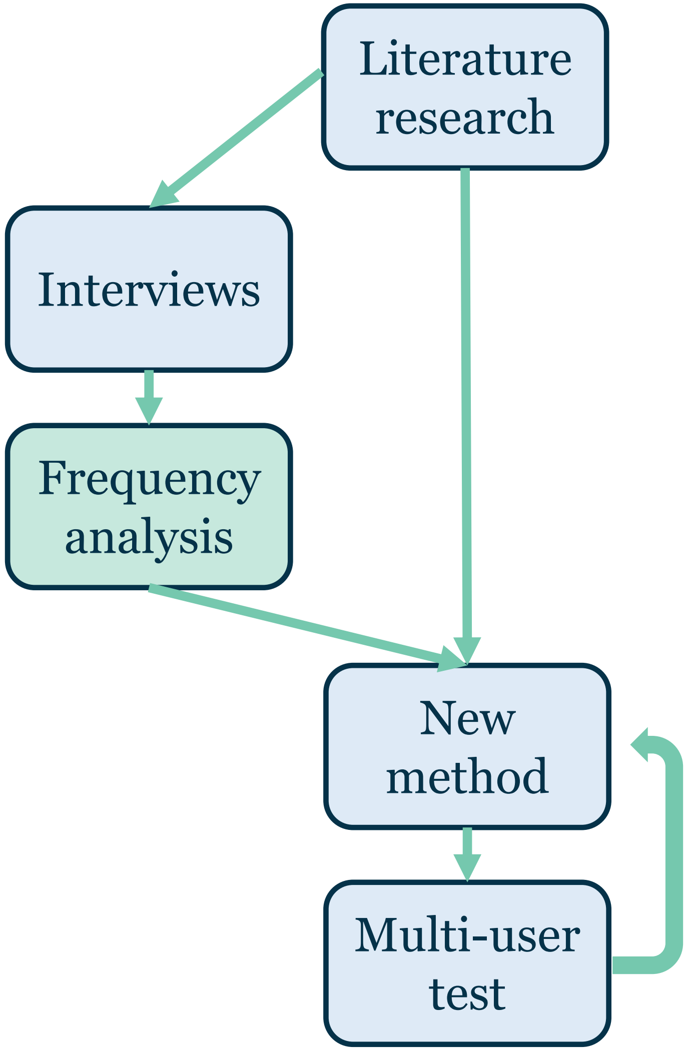




Method: New method

2 Interview groups:

Group 1

LCA Experts that have applied LCA to space systems

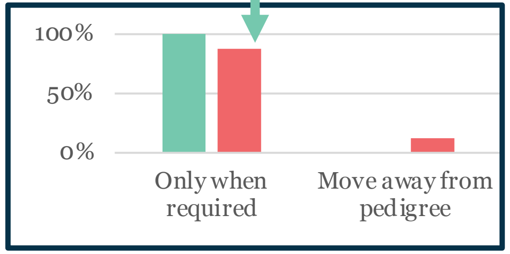
8

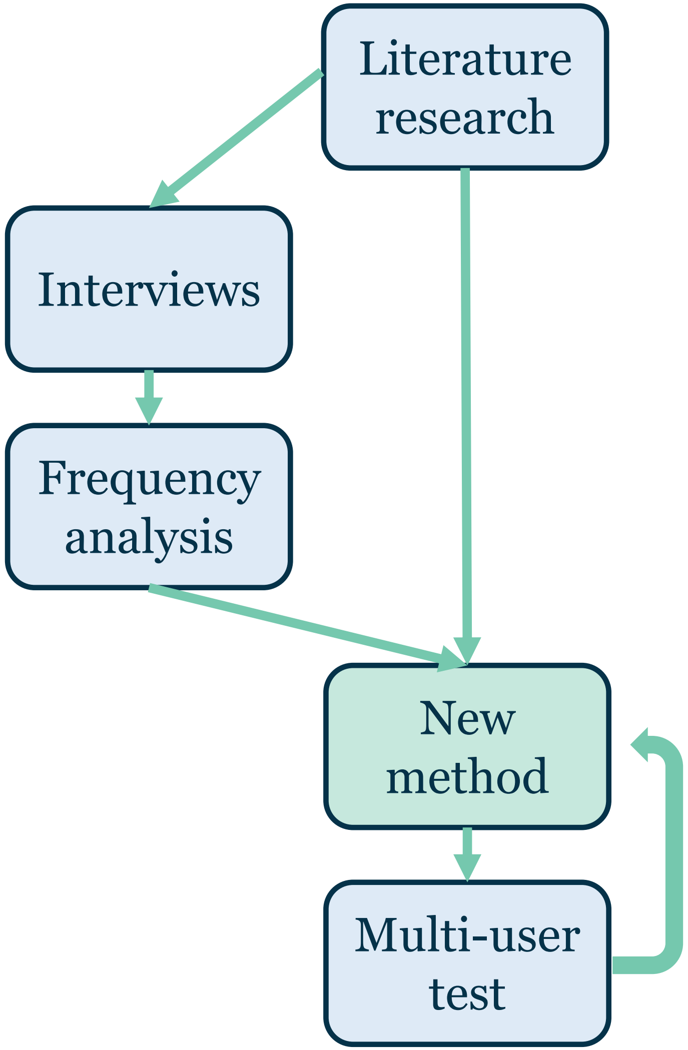
Group 2

LCA Experts that have <u>not</u> applied LCA to space systems

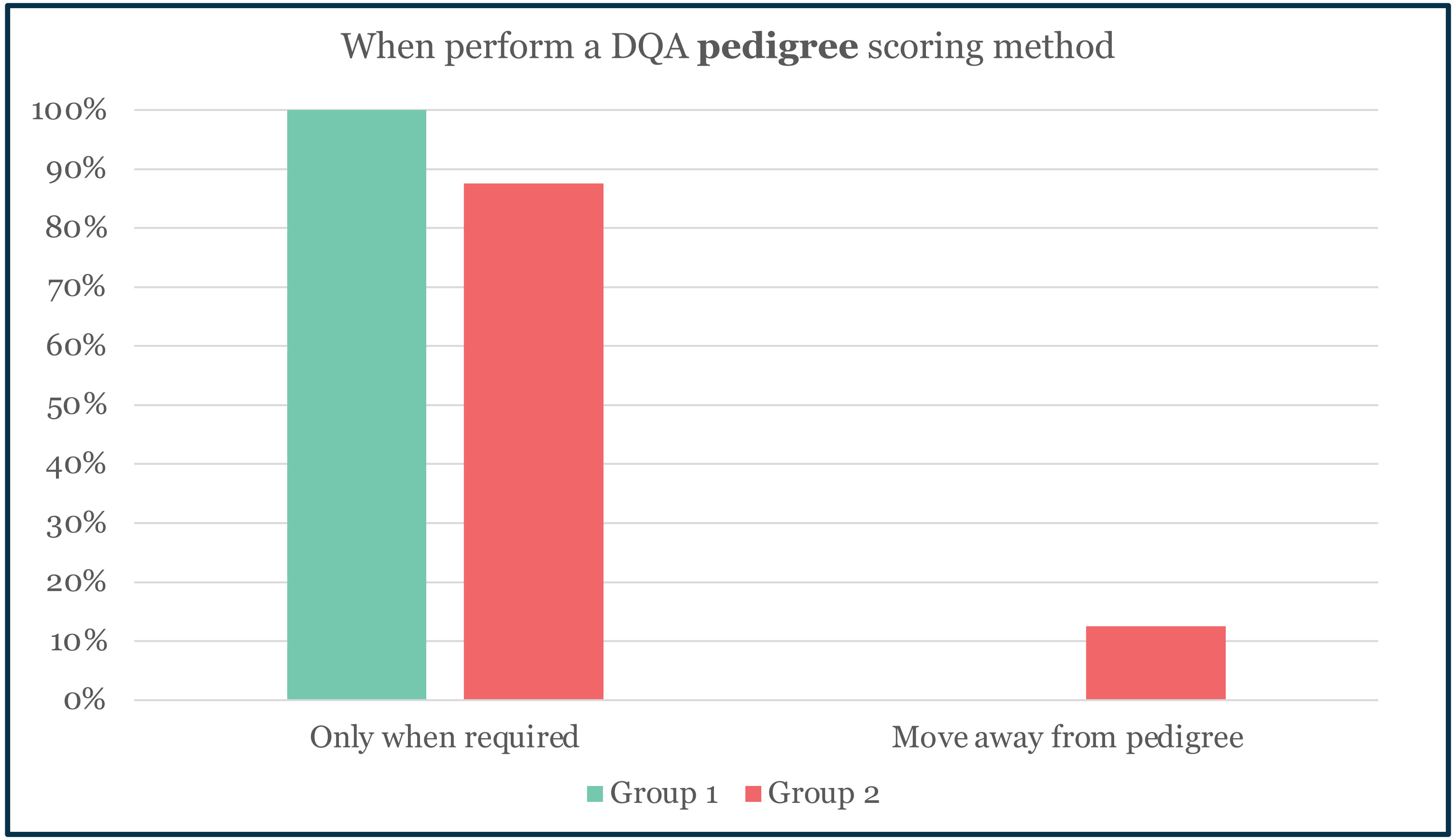
11

1. Transcribing all the interviews
2. Label each new piece of information
3. How many times was this piece if information mentioned?





Results: Frequency analysis

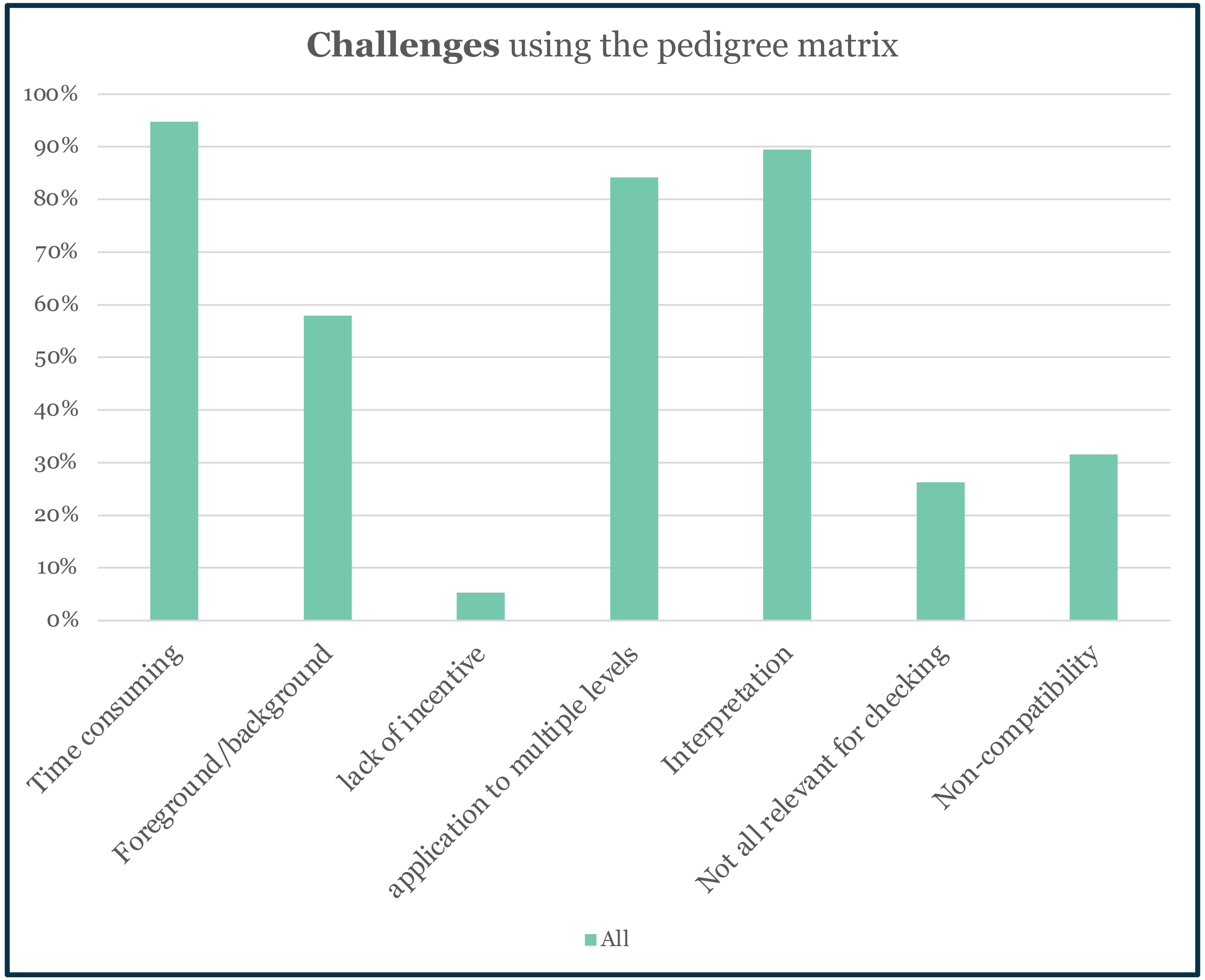


Using a formalised DQA method is very unpopular

- Omitted when possible
- Only used when a Monte Carlo Analysis is required by customer

Results: Frequency analysis

- **Interpretation** required for pedigree this makes
  - The DQA results non-reproducible
  - The DQA method very time-intensive
- It is challenging to apply the pedigree to a **database** (background datasets)
- No DQA score propagation method
- **No clear use** for DQA results
- **Not all relevant DQ characteristics** of LCI data are assessed
- Very **constrained** by expertise of data suppliers
- DQA results not usable for **Monte Carlo**



Results: New Method (Pedigree)

				(Very good) 1	(Good) 2	(Fair) 3	(Poor) 4	(Very poor) 5
Static	Flow	Inherent uncertainty/ Spread	Primary data	sample size of n > 8 as based on expert measurement and externally verified and adequate sample size	sample size 8< n < 1 as based on expert measurements or verified computational models	n = 1 Expert elicitation 4 step procedure; BoM, factory data calculations	n = 1 Expert elicitation point-value, reasonability checked	n = 1 Non-expert estimate not based on literature
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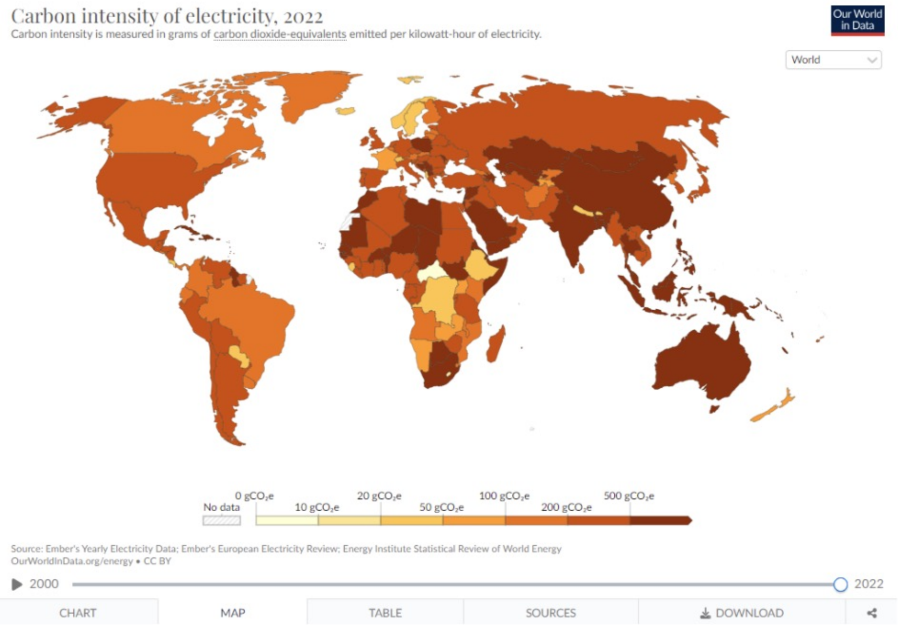
Results: New Method (Pedigree)

Geographical representativeness

Aspects to be scored:

- Granularity
  - Based on UN standard (local, country, UN subregion, UN region, global)
- Location
  - Carbon intensity of electricity grid (Publicly available data, annually updated)



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Results: New Method (Pedig

Geographical representativeness
Aspects to be scored:

- Granularity
  - Based on UN standard (local, country, UN subregion, UN region, global)
- Location
  - Carbon intensity of electricity grid Grouped in a, b, c, d (Publicly available data, annually updated)

Reference data

Assessment			a	b	c	d
		Local	Country	Country	Country	Country
	Local	1	2	3	4	5
a	Country	2	1	2	3	4
a	UN Subregion	3	2	3	4	5
a	UN region	4	3	4	5	5
*	Global	5	4	5	5	5

				(Very good) 1	(Good) 2	(Fair) 3	(Poor) 4	(Very poor) 5
Static	Flow	Inherent uncertainty/ Spread	Primary data	sample size of n > 8 as based on expert measurement and externally verified and adequate sample size	sample size 8< n < 1 as based on expert measurements or verified computational models	n = 1 Expert elicitation 4 step procedure; BoM, factory data calculations	n = 1 Expert elicitation point-value, reasonability checked	n = 1 Non-expert estimate not based on literature
Static	Flow	Inherent uncertainty/ Spread	Secondary data		sample size of n > 8 Extensive data available in literature and adequate sample size	sample size 8< n < 1 Partial data available in literature	n = 1 Data found in literature, reasonability checked	n = 1 Data estimate based on literature, I/O aggregate
Dynamic	Flow	Temporal representativeness		Data obtained within 1 year and TRL 9	Data obtained within 3 years or more recent and TRL 9	5 years or more recent and TRL 9	10 years or more recent or TRL 5, 6, 7 or 8	10 years or older/ unknown or TRL 1, 2, 3 or 4
Dynamic	Flow	Technological representativeness		1 point score	2 point score	3 point score	4 point score or 'market' process	5 point score
Dynamic	Flow	Geographical Representativeness		1 point score	2 point score	3 point score	4 point score or	5 point score
Static	Process	Completeness		BoM is used and a mass balance and external process expert feedback (with 5 years of experience) and energy balance/site-visit	BoM is used and a mass balance and validated by an external process expert feedback (with 5 years of experience)	BoM/patent is used and a mass balance and an internal validation	Input-output scheme of plant is used with allocation	Literature and comparable processes are used
Dynamic	Model	Methodological appropriateness		All life cycle stages included. 90% cut-off criteria are shared. System is subject to external review and mass balance of foreground processes system.	All life cycle stages included. 90% cut-off criteria of processes in the system are shared. System is subject to external review.	All life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. System is subject to external review.	Not all life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. No external review for completeness of system.	Unkown if all life cycle stages included. Unknown amount of cut-off criteria of processes in the system are shared. No external review for completeness of system.

Results: New Method (Pedig

(IS,TeR,GR,TiR,C,M)

				(Very good) 1	(Good) 2	(Fair) 3	(Poor) 4	(Very poor) 5
Static	Flow	Inherent uncertainty/ Spread	Primary data	sample size of n > 8 as based on expert measurement and externally verified and adequate sample size	sample size 8< n < 1 as based on expert measurements or verified computational models	n = 1 Expert elicitation 4 step procedure; BoM, factory data calculations	n = 1 Expert elicitation point-value, reasonability checked	n = 1 Non-expert estimate not based on literature
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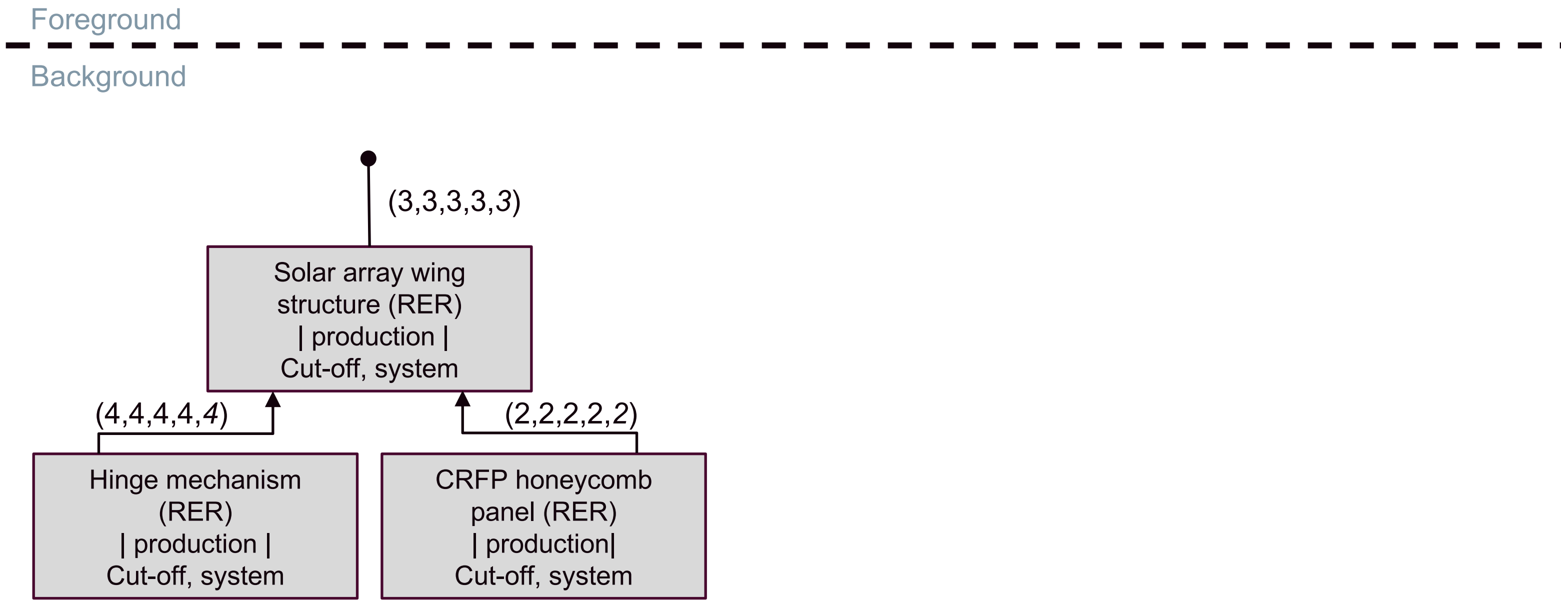
Dynamic	Model	Methodological appropriateness		All life cycle stages included. 90% cut-off criteria are shared. System is subject to external review and mass balance of foreground processes system.	All life cycle stages included. 90% cut-off criteria of processes in the system are shared. System is subject to external review.	All life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. System is subject to external review.	Not all life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. No external review for completeness of system.	Unkown if all life cycle stages included. Unknown amount of cut-off criteria of processes in the system are shared. No external review for completeness of system.

Results: New Method (Pedigree)

(IS,TeR,GR,TiR,C,M) DQI

DQA score propagation method

- Scores applied with pedigree
  - ➢ Vertical propagation via averaging



Results: New Method (Pedigree)

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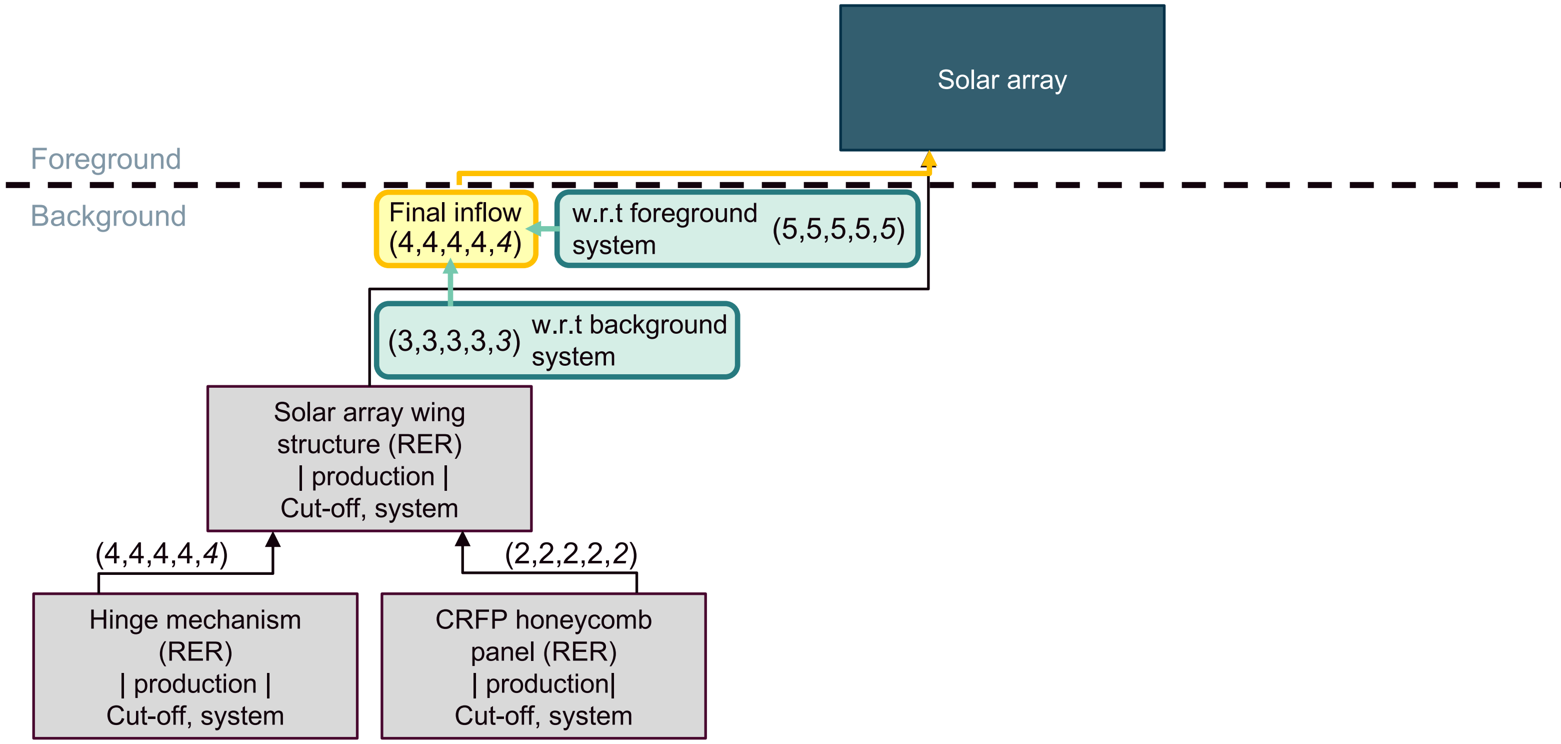
(IS,TeR,GR,TiR,C,M) DQI

DQA score propagation method

- Scores applied with pedigree
  - ➢ Vertical propagation via averaging



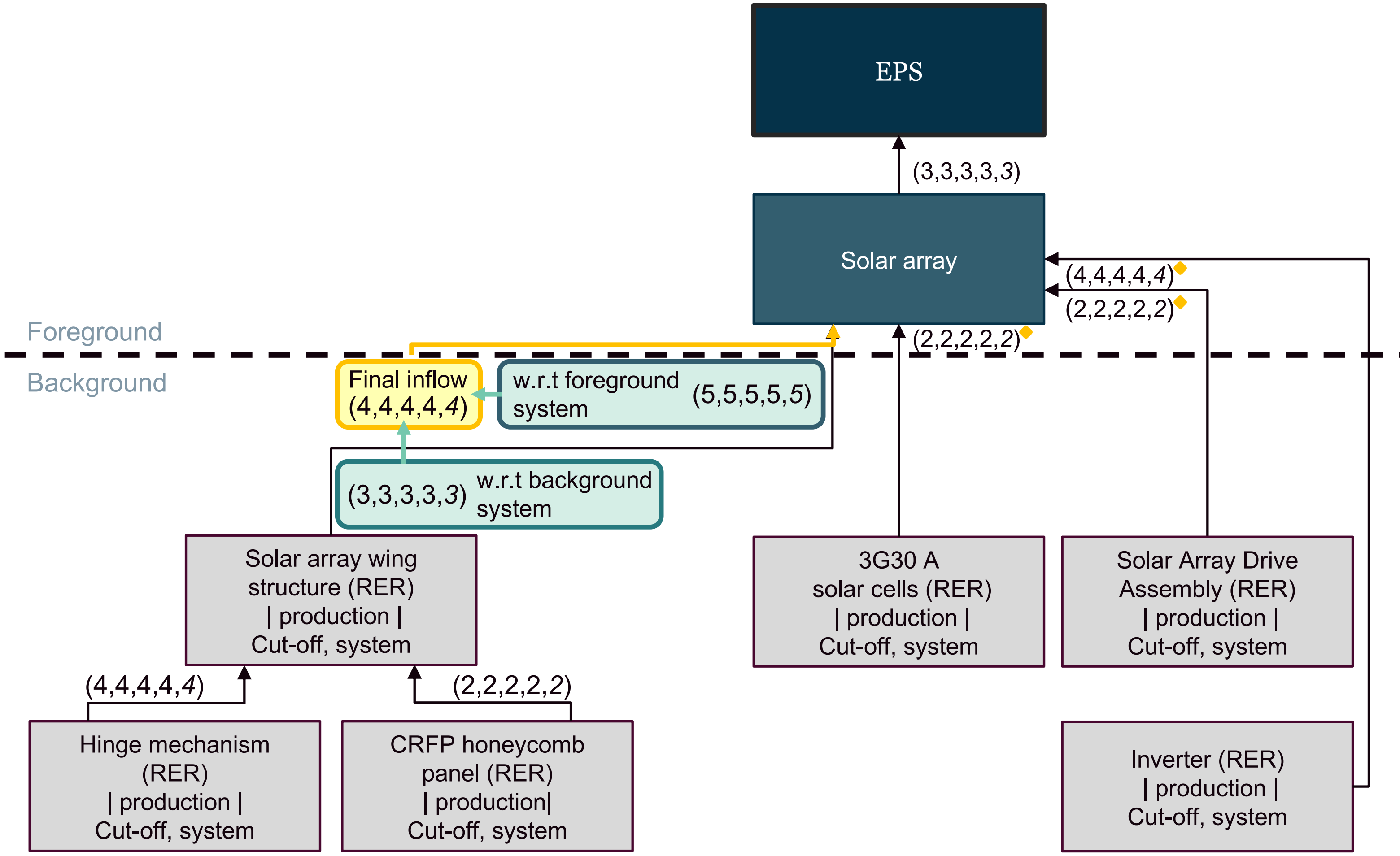
Results: New Method (Pedigree)

(IS,TeR,GR,TiR,C,M)

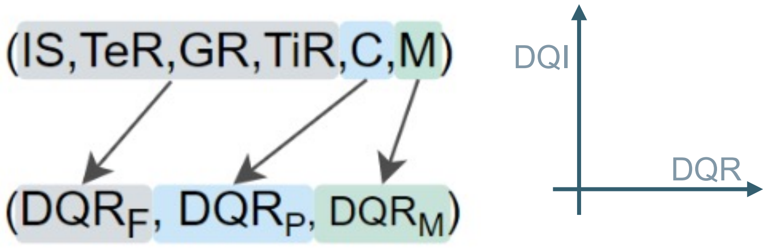
DQI

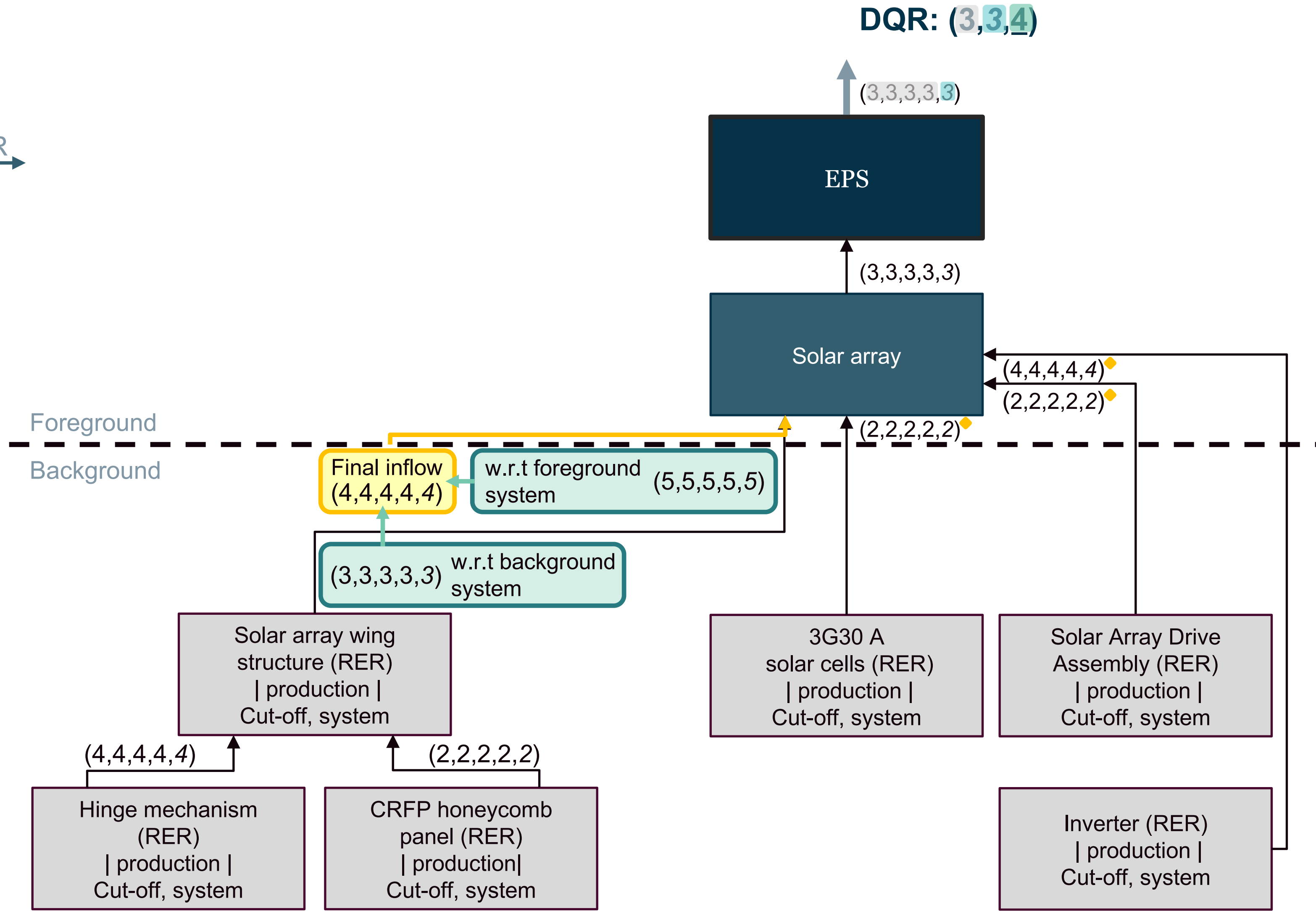
DQA score propagation method

- Scores applied with pedigree
  - ➢ Vertical propagation via averaging



Results: New Method (Pedigree)





DQA score propagation method

- Scores applied with pedigree
  - ➢ Vertical propagation via averaging

Calculation overall data quality

➢ Data Quality Rating **(DQR)**

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2.3. Pedigree matrix

The previously mentioned DQI are mapped over five different score, the result is shown below in Table 1. This table is defined to be, and in this document referred to as the 'pedigree matrix'.

Table 1. Pedigree matrix used for applying scores to determine the data quality

				(Very good) 1	(Good) 2	(Fair) 3	(Poor) 4	(Very poor) 5
Static	Flow	Inherent uncertainty/ Spread	Primary data	sample size of n > 8 as based on expert measurement and externally verified and adequate sample size	sample size 8< n < 1 as based on expert measurements or verified computational models	n = 1 Expert elicitation 4 step procedure; BoM, factory data calculations	n = 1 Expert elicitation point-value, reasonability checked	n = 1 Non-expert estimate not based on literature
			Secondary data		sample size of n > 8 Extensive data available in literature and adequate sample size	sample size 8< n < 1 Partial data available in literature	n = 1 Data found in literature, reasonability checked	n = 1 Data estimate based on literature, I/O aggregate
Dynamic		Temporal representativeness		Data obtained within 1 year and TRL 9	Data obtained within 3 years or more recent and TRL 9	5 years or more recent and TRL 9	10 years or more recent or TRL 5, 6, 7 or 8	10 years or older/ unknown or TRL 1, 2, 3 or 4
		Technological representativeness		1 point score	2-point score	3-point score	4-point score or 'market' process	5-point score
		Geographical Representativeness		1 point score	2-point score	3-point score	4-point score or	5-point score
Static	Process	Completeness		BoM is used and a mass balance and external process expert feedback (with 5 years of experience) and energy balance/site-visit	BoM is used and a mass balance and validated by an external process expert feedback (with 5 years of experience)	BoM/patent is used and a mass balance and an internal validation	Input-output scheme of plant is used with allocation	Literature and comparable processes are used
Dynamic	Model	Methodological appropriateness		All life cycle stages included. 90% cut-off criteria are shared. System is subject to external review and mass balance of foreground processes system.	All life cycle stages included. 90% cut-off criteria of processes in the system are shared. System is subject to external review.	All life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. System is subject to external review.	Not all life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. No external review for completeness of system.	Unkown if all life cycle stages included. Unknown amount of cut-off criteria of processes in the system are shared. No external review for completeness of system.

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- Renewed pedigree matrix
  - Reproducible
  - Operationalisable
- DQA propagation method
  - Foreground/background interface

Discussion

Next steps

- Perform multi-user test
- Operationalisation
- Further research regarding
  - Non-weighted averaging
    (to omit model and characterisation uncertainty)
  - DQA for each impact category (Current ESA method)

Limitations

- Only compares inventory data to true data
  - No model uncertainty
  - No characterisation uncertainty
- More data driven -> Slightly different scores than previous method

A data quality assessment method for life cycle inventories in LCA

Work in progress

Floor Bagchus (F.M.Bagchus@student.tudelft.nl)

17/10/2023

Opportunities for improvement

- **Interpretation** required for pedigree this makes
  - The DQA results non-reproducible
  - The DQA method very time-intensive
- It is impossible to apply the pedigree to a **database** (background datasets)
- No DQA score aggregation method
- **No clear use** for DQA results
- **Not all relevant DQ characteristics** of LCI data are assessed
- Very **constrained** by expertise of data suppliers
- DQA results not usable for **Monte Carlo**

- Clear **instructions** and **distinction** between flow, process, model level
- **Minimise time** required
  - ➢ **Operationalise DQA**
- Extract results usable for **Monte Carlo**
  - ➢ **Probability density & Range of values**
- **Operationalisation**
  - ➢ Minimise required user input
  - ➢ Use data already present in database information for scoring
  - ➢ Use modelling decision for scoring
- **Add** DQA score propagation method

… al whilst keeping in mind data availability constraints

Pedigree matrix (1/2)

Table 1. Pedigree matrix used for applying scores to determine the data quality

				(Very good)	(Good)	(Fair)	(Poor)	(Very poor)
				1	2	3	4	5
Static	Flow	**Inherent uncertainty/ Spread**	Primary data	sample size of n > 8 as based on expert measurement and externally verified and adequate sample size	sample size 8< n < 1 as based on expert measurements or verified computational models	n = 1 Expert elicitation 4 step procedure; BoM, factory data calculations	n = 1 Expert elicitation point-value, reasonability checked	n = 1 Non-expert estimate not based on literature
			Secondary data		sample size of n > 8 Extensive data available in literature and adequate sample size	sample size 8< n < 1 Partial data available in literature	n = 1 Data found in literature, reasonability checked	n = 1 Data estimate based on literature, I/O aggregate
Dynamic		**Temporal representativeness**		Data obtained within 1 year and TRL 9	Data obtained within 3 years or more recent and TRL 9	5 years or more recent and TRL 9	10 years or more recent or TRL 5, 6, 7 or 8	10 years or older/ unknown or TRL 1, 2, 3 or 4
		Technological representativeness		1 point score	2 point score	3 point score	4 point score or 'market' process	5 point score
		Geographical Representativeness		1 point score	2 point score	3 point score	4 point score or	5 point score

Pedigree matrix (2/2)

			(Very good)	(Good)	(Fair)	(Poor)	(Very poor)
			1	2	3	4	5
Static	Process	**Completeness**	BoM is used and a mass balance and external process expert feedback (with 5 years of experience) and energy balance/site-visit	BoM is used and a mass balance and validated by an external process expert feedback (with 5 years of experience)	BoM/patent is used and a mass balance and an internal validation	Input-output scheme of plant is used with allocation	Literature and comparable processes are used
Dynamic	Model	**Methodological appropriateness**	All life cycle stages included. 90% cut-off criteria are shared. System is subject to external review and mass balance of foreground processes system.	All life cycle stages included. 90% cut-off criteria of processes in the system are shared. System is subject to external review.	All life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. System is subject to external review.	Not all life cycle stages included. Below 90% cut-off criteria of processes in the system are shared. No external review for completeness of system.	Unkown if all life cycle stages included. Unknown amount of cut-off criteria of processes in the system are shared. No external review for completeness of system.

Inherent uncertainty/Spread (Prim. data)

Required inputs	*Number of samples, type of data (primary/secondary), source of data*	
Score	Primary data	
5	Non-expert Non-literature n = 1	Estimate made by a non-expert, e.g. a person not directly familiar with the product. Most likely an estimate by the LCA practitioner not based on a literature study under time pressure.
4	Expert elicitation Reasonability check n = 1	The expert was supplied with the data questionnaire containing a 4 step expert elicitation procedure, however the expert only supplied a single value. This value is deemed to be the most likely value. This value is then subject to a reasonableness test by the LCA practitioner, e.g. by comparing the value to a value of a similar process or a valuableness check based on experience.
3	Expert elicitation Reasonability check n = 1 (Reasonability check is advised)	4 step expert elicitation procedure: a. Realistically, the value could be as low as … [unit] b. Realistically, the value could be as high as … [unit] c. My best guess of the mean is … [unit] d. For the interval I've created above, I think the chance that the mean observed in the study will fall in this interval is … % The modelling value is the 'best guess of the mean' and a beta distribution may be set up for a Monte Carlo analysis. This score can also be applied to values taken from a Bill of Materials (including ranges) or factory data calculations using primary data like production capacity.
2	Expert measurement	The data is obtained via averaging 1 to 8 measurements which are performed by an expert. E.g. a person that has operated the equipment under study for a prolonged amount of time.
	Verified computational models 8 < n < 1 (Reasonability check is advised)	Or data is obtained via verified computational models. This means that the model that has computed the data has been verified.
1	Expert measurement Externally verified Adequate sample size n > 8	The data is obtained via averaging more than 8 measurements which are performed by an expert. E.g. a person that has operated the equipment under study for a prolonged amount of time. The data and the method to gather the data has been verified by an expert external to the company that acquired the data. Furthermore, the sample size of the dataset should be adequate: $n_{sp} = g * t * c$ Where n_{sp} is the number of sub-populations, g is the number of countries in which the sites are located, t is the number of technologies, c is the number of classes of capacity/production of companies. Within this set op subpopulations, the required sample size (n_{ss}) is calculated: $n_{SS} = \sqrt{n_{SP}}$

Inherent uncertainty/Spread (Sec. data)

Required inputs		*Number of samples, type of data (primary/secondary), source of data*
		Secondary data
5	Non-expert Estimate based on literature or I/O result n = 1	Estimate based on literature or a value based on/taken from an Input-Output (I/O) aggregate or environmentally extended input–output analysis.
4	Data from literature Reasonability checked n =1	Data is found directly in literature and is subject to a reasonableness test by the LCA practitioner, e.g. by comparing the value to a value of a similar process or a valuableness check based on experience.
3	Partial data 8 < n < 1	1 to 8 partial data samples is found in literature and the mean value of this is taken. Partial data is defined as data of which some features or some labels are not perfectly defined or known, or data that is specified by a set of possible values rather than a single precise one.
2	Extensive data n > 8	Extensive data is found in literature and the average value is taken. Furthermore, the sample size of the dataset should be adequate: $n_{sp} = g * t * c$ Where n_{sp} is the number of sub-populations, g is the number of countries in which the sites are located, t is the number of technologies, c is the number of classes of capacity/production of companies. Within this set op subpopulations, the required sample size (n_{ss}) is calculated: $n_{SS} = \sqrt{n_{SP}}$

Temporal Representativeness (TiR)

A.2. Temporal Representativeness (TiR)

Table 3. Detailed description of TiR DQI scoring method

Required inputs	*Data of acquisition/representativity of data, TRL*	
Score		
5	Representative year TRL 1, 2, 3, 4	The data is acquired 10 or more years ago or The time representativity or acquisition of the data is unknown or The data is related to a technology that has a TRL of 1, 2, 3 or 4
4	Representative year TRL 5, 6, 7, 8	The data is acquired between 6 up to 10 years ago or The data is related to a technology that has a TRL of 5, 6, 7 or 8
3	Representative year TRL 9	The data is acquired between 4 up to 6 years ago and The data is related to a technology that has a TRL of 9*
2	Representative year TRL 9	The data is acquired between 1 up to 4 years ago and The data is related to a technology that has a TRL of 9*
1	Representative year TRL 9	The data is acquired within the timespan of 1 year and The data is related to a technology that has a TRL of 9*

** It may be assumed that all data present in commonly used background databases are related to a technology with TRL 9*

Technological Representativeness (TeR)

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Table 4. Detailed description of TeR scoring method

Required inputs	*Similarity between true flow and proxy, enterprise, modelling choice/primary data*		
TeR scoring system			
	Starting score = 6	*True*	*False*
Background flow	Same enterprise?	0	-1
Background flow	Non-similar flow or unknown similarity	-1	
Background flow	Scaled proxy of similar flow	-2	
Background flow	Scaled & specified* proxy of similar flow	-3	
Foreground flow	Primary data obtained of exact same true flow	-4	

** Specified by tweaking or adding small flows to more closely resemble the true flow*

Table 5. Detailed description of TeR 'Similarity' definitions

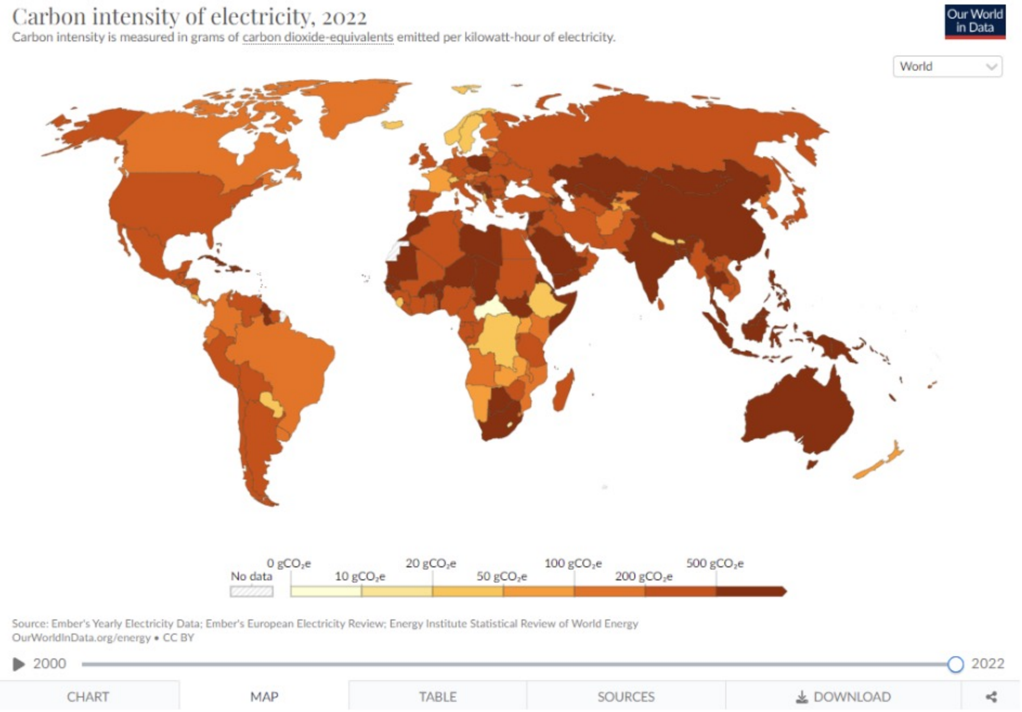
Transformation process	
Defined as similar if the true process can be found in the same category as the proxy	
Heat	Casting, forging, hot rolling, laser machining, laser machining, welding
Pressure	Contouring, (Deep) drawing, impact extrusion, rolling, turning, milling, drilling
Coating	Anodising, enamelling, powder coat, selective coat, plating
General	Degreasing, general metal working (+1 additional TeR point)
Material	
Non-similar	It is proposed to make a modelling choice on the basis of similar embodied energy
Similar	A similar material is defined to share 60% of the core material used in the proxy with the true material
Transportation	
Defined as similar if the true process can be found in the same category as the proxy.	
Road	
Railway	
Air	
Water	
Item/Equipment	
Non-similar	The proxy is not in the same Central Product Classification category as the true flow or it has the same function
Similar	The proxy is in the same Central Product Classification category as the true flow or it has the same function and means to execute that function

Geographical Representativeness (GeR)

Geographical representativeness

Aspects to be scored:

- Granularity
  - Based on UN standard
    (local, country, UN subregion, UN region, global)
- Location
  - Carbon intensity of electricity grid
    Grouped in a, b, c, d
    (Publicly available data, annually updated)

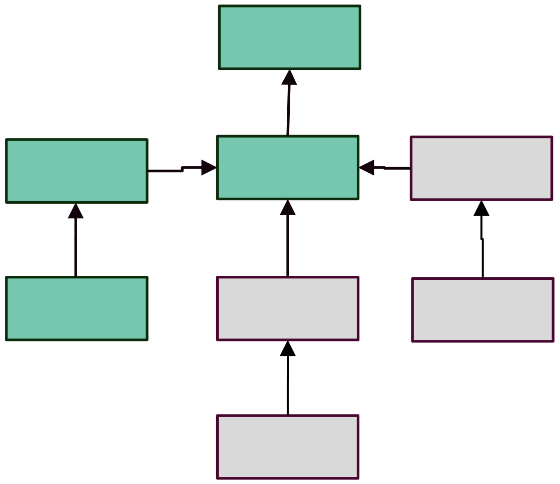


Reference data

Assessment			a	b	c	d
		Local	Country	Country	Country	Country
	Local	1	2	3	4	5
a	Country	2	1	2	3	4
a	UN Subregion	3	2	3	4	5
a	UN region	4	3	4	5	5
*	Global	5	4	5	5	5

Completeness (C)

			(Very good)	(Good)	(Fair)	(Poor)	(Very poor)
			1	2	3	4	5
Static	Process	**Completeness**	BoM is used and a mass balance and external process expert feedback (with 5 years of experience) and energy balance/site-visit	BoM is used and a mass balance and validated by an external process expert feedback (with 5 years of experience)	BoM/patent is used and a mass balance and an internal validation	Input-output scheme of plant is used with allocation	Literature and comparable processes are used



Methodological Appropriaties (M)

			(Very good)	(Good)	(Fair)	(Poor)	(Very poor)
			1	2	3	4	5
Static	Process	**Completeness**	BoM is used and a mass balance and external process expert feedback (with 5 years of experience) and energy balance/site-visit	BoM is used and a mass balance and validated by an external process expert feedback (with 5 years of experience)	BoM/patent is used and a mass balance and an internal validation	Input-output scheme of plant is used with allocation	Literature and comparable processes are used
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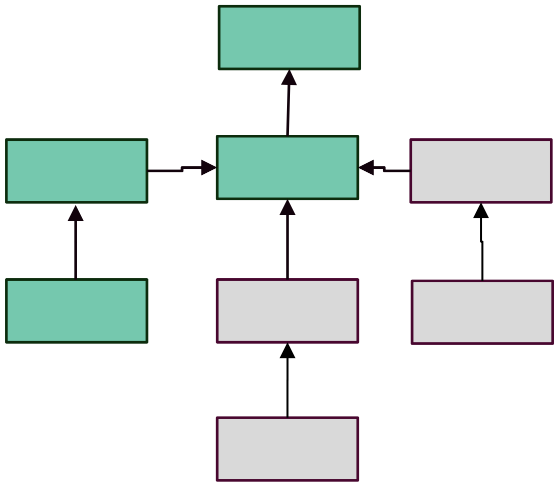

Glossary of Terms

Variability	Extent to which data points differ from each other (e.g. over time)
Inherent uncertainty	Uncertainties related to the inaccuracies of measurements or model for a single sample
Dispersion	Range around a variable resulting from inherent uncertainty, spread and unrepresentativeness. Dispersion is assessed with the pedigree matrix.
Spread	Variability resulting from the level of representativeness
Unrepresentativeness	Uncertainty as a consequence of the non-alikeness of modelled situation to the true situation

Indicators (1/3)

Inherent uncertainty/Spread (IS)	
The inherent uncertainty are uncertainties related to the inaccuracies of measurements or model at no level of horizontal averaging (averaging over samples like multiple sites or time points). The spread applies in case to a sample size of more than 1, and is the variability around an average resulting from horizontal averaging. This 'spread' is added on top of the inherent uncertainty related to inaccuracies of measurements or model.	
Flow level	*Static*
Assessed component	Parameter uncertainty/model uncertainty, spatial/temporal/source variability
Theoretical basis for indicator scores	Statistical methods, Expert elicitation

Technological representativeness (TeR)	
The extent to which the technology (process, material, equipment, transportation) related to the modelled flow reflects the true technology. Technological representativeness includes operating conditions of (transformation) processes, material composition, material finishing and cleaning, transportation methods and functionalities of items and equipment.	
Flow level	*Dynamic*
Assessed component	Modelling choices, attributes of technology and supply chain, primary/secondary data
Theoretical basis for indicator scores	Expert opinion and modelling choices

Indicators (2/3)

Time-related representativeness (TiR)	
The extent to which the time of data acquisition of the modelled flow reflects the true time defined in the scope and the likelihood of large changes related to the TRL.	
Flow level	*Dynamic*
Assessed component	Time of acquisition of data and TRL
Theoretical basis for indicator scores	Uncertainty connected to TRL, performance rate over time

Geographical representativeness (GR)	
The extent to which the geographical location of the modelled flow reflects the true geographical location and therefore upper-level basic production environment like electricity source and transportation distance.	
Flow level	*Dynamic*
Assessed component	Granularity on geographical level, average carbon intensity of the electricity grid
Theoretical basis for indicator scores	Production environment

Indicators (3/3)

Completeness (C)	
The extent to which the number and correctness of the present flows modelled for the unit-process match the real flows connected to the unit-process.	
Unit-process level	*Static*
Assessed component	The representativity and number of modelled flows compared to the true flows
Theoretical basis for indicator scores	Expert opinion on reviewing and data acquisition methods.

Methodological appropriateness (M)	
The degree to which the allocation methods and life cycle stages are consistently applied and used, and the degree to which the modelled system represents the true system in terms of present flows and unit-processes.	
Model level	*Dynamic*
Assessed component	Consistent application and use of allocation method and life cycle stages. Completeness of system in terms of unit-processes and flows present.
Theoretical basis for indicator scores	Expert opinion on reviewing data and allocation procedures.