Get started with Life Cycle Assessment (LCA)

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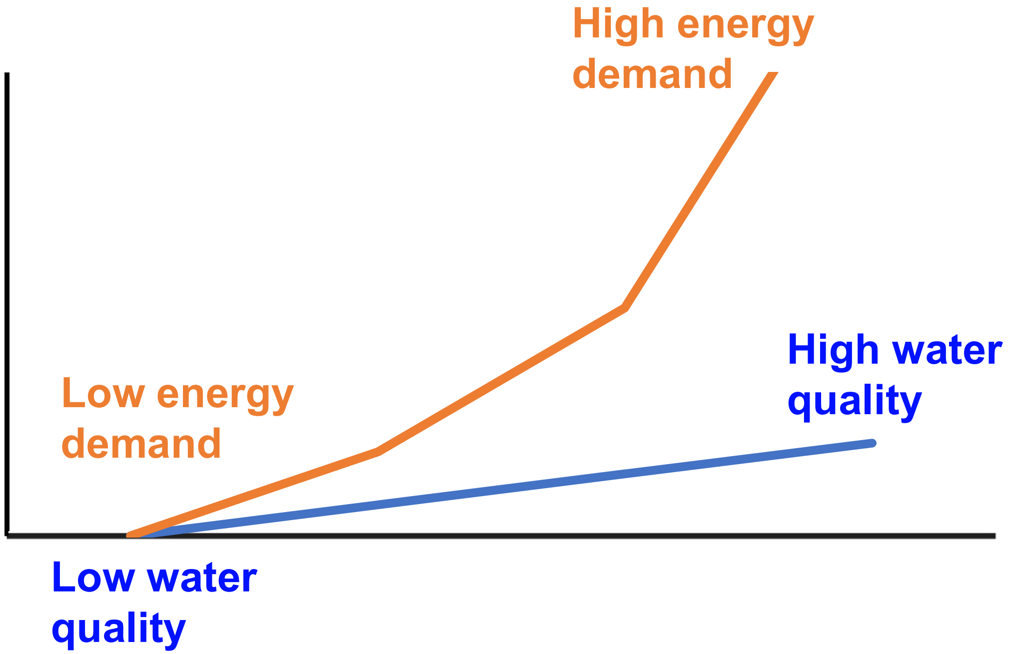
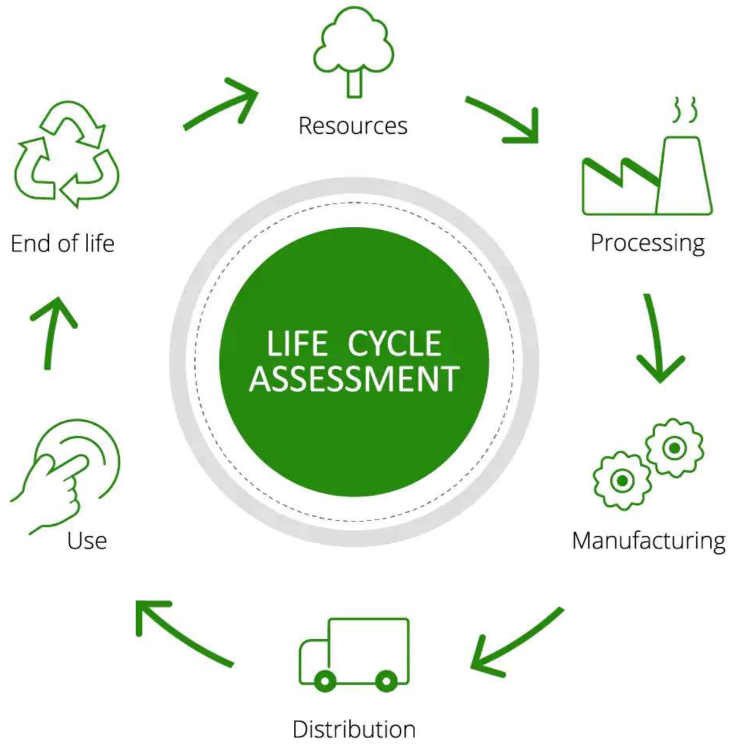
Is water reuse always green?

- Technically you can provide every kind of water quality (even drinking water quality as in US)
- BUT the higher the water quality, the higher correlation between technical effort and environmental impacts



Life Cycle Assessment (LCA)

- Standardized method defined in ISO 14040/44
- Products / processes / services
- Includes all parts of the life-cycle:
  - Direct emissions (= on-site)
  - Indirect emissions + resource use (electricity, chemicals, waste, …)
  - Credits for products



Source: Consulting Deloitte

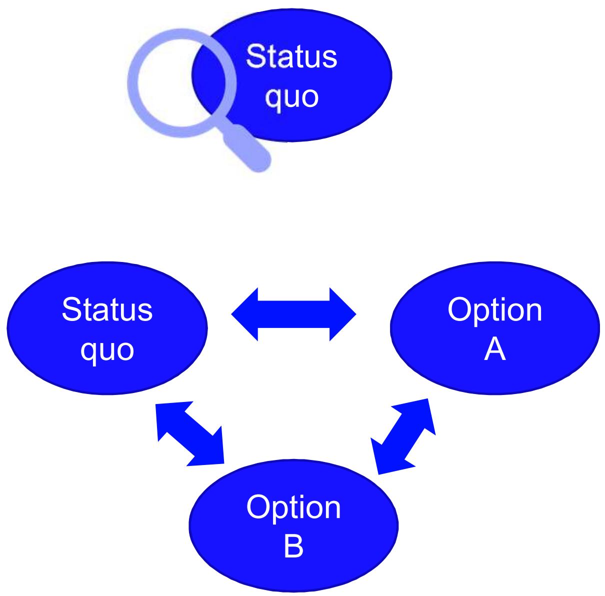
Why Life Cycle Assessment?

Life Cycle Assessment (LCA) provides insights on

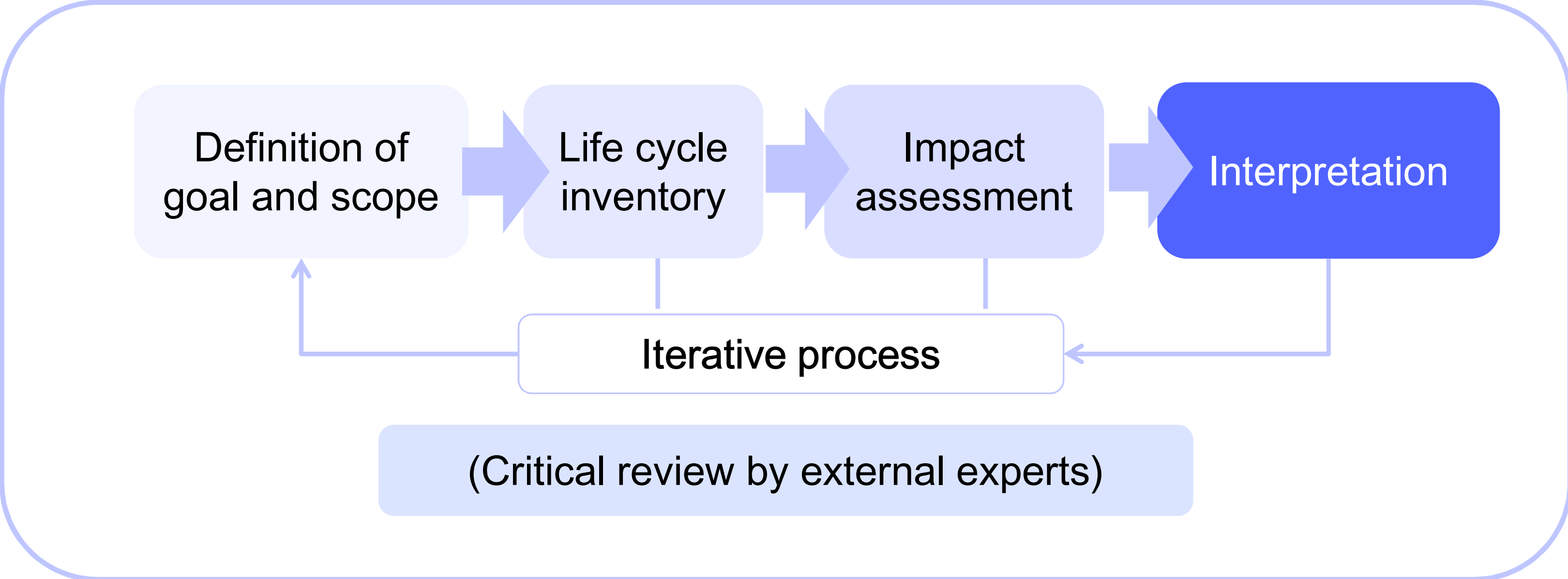
- Environmental benefits and impacts (e.g. reclaimed water vs. energy consumption)
- Hidden environmental burdens
- Comparison of CO2-emissions of status-quo and new technologies (groundwater pumping vs. energy demand of water purification)

→ Benefits and disadvantages of water treatment

LCA focuses on a global and long-term perspective!

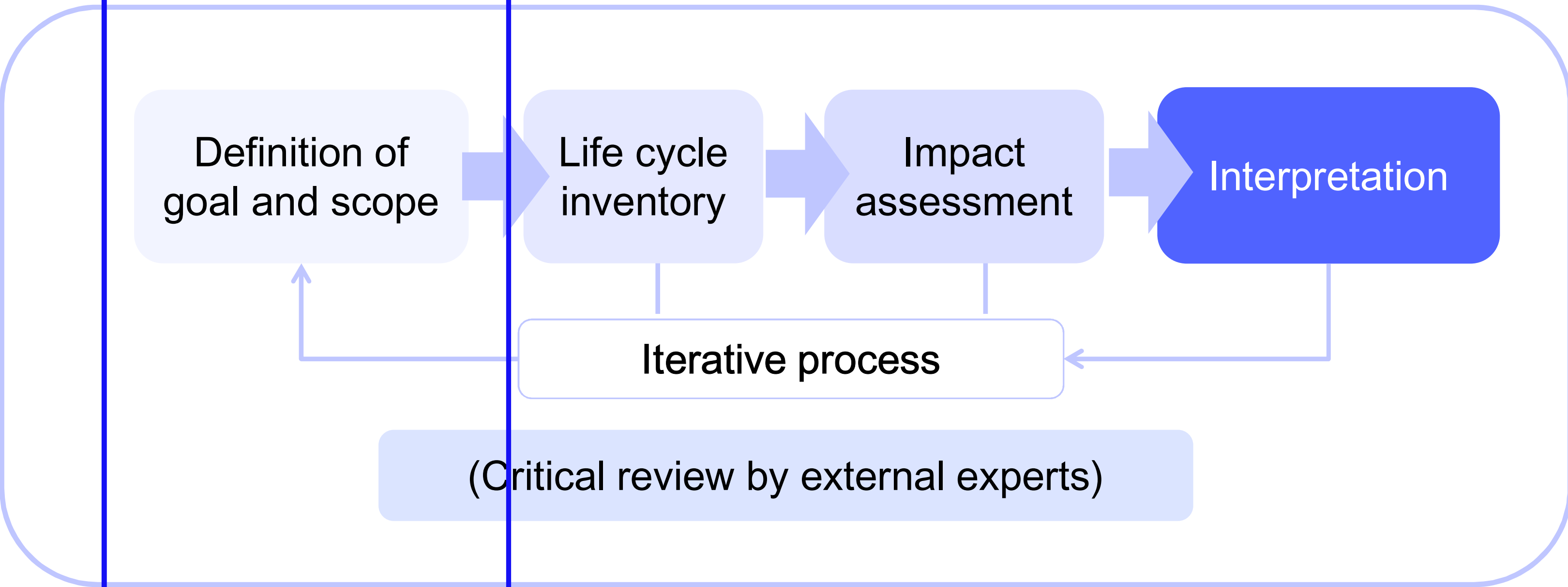


Framework of LCA (ISO 14040/44)



Framework of LCA (ISO 14040/44)

1. Step



-Goal
-Research objective
-System boundaries
-Functional unit

Goal and research objective definition

A declaration made by the organisation commissioning the LCA

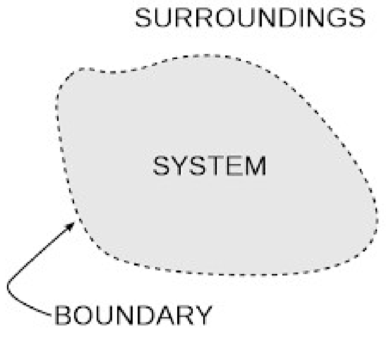
- Research object → What is considered?
- Interest of realisation → Why is the LCA conducted?
- Target groups → For whom is it conducted?
- Publication → Is it accessible for the public?

Credit: Wikimedia Commons

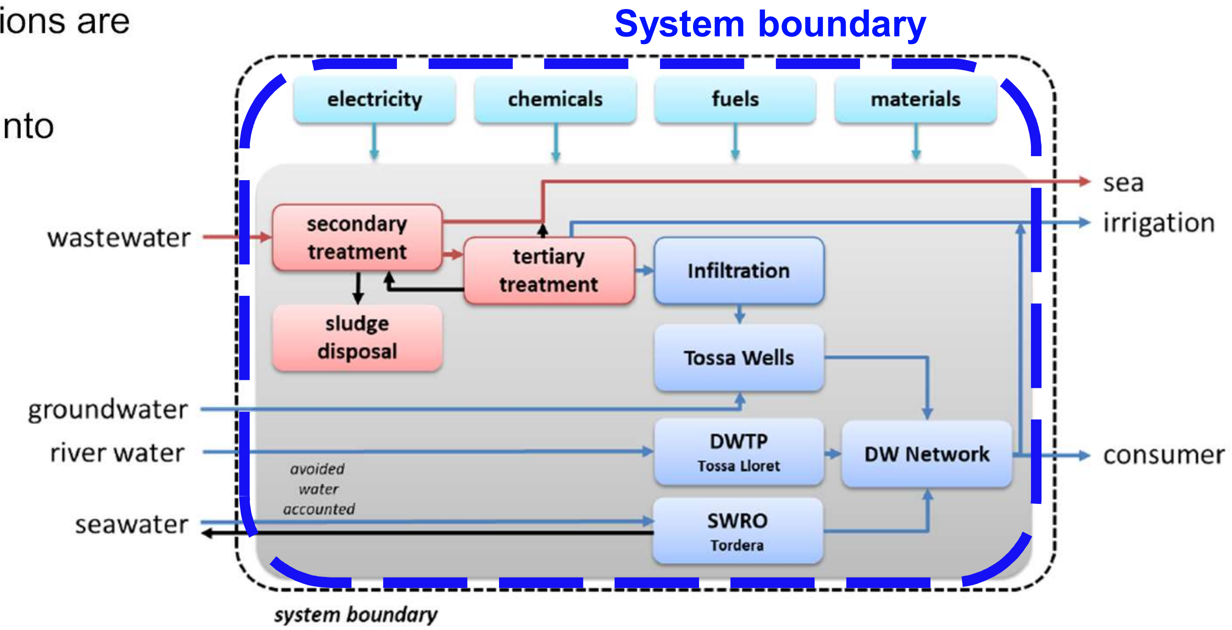
System boundaries

System description

- Best described in a flow chart
- Unit processes and their interrelations are usually represented by boxes
- All in- and outputs must be taken into consideration



Credit: Wikimedia Commons



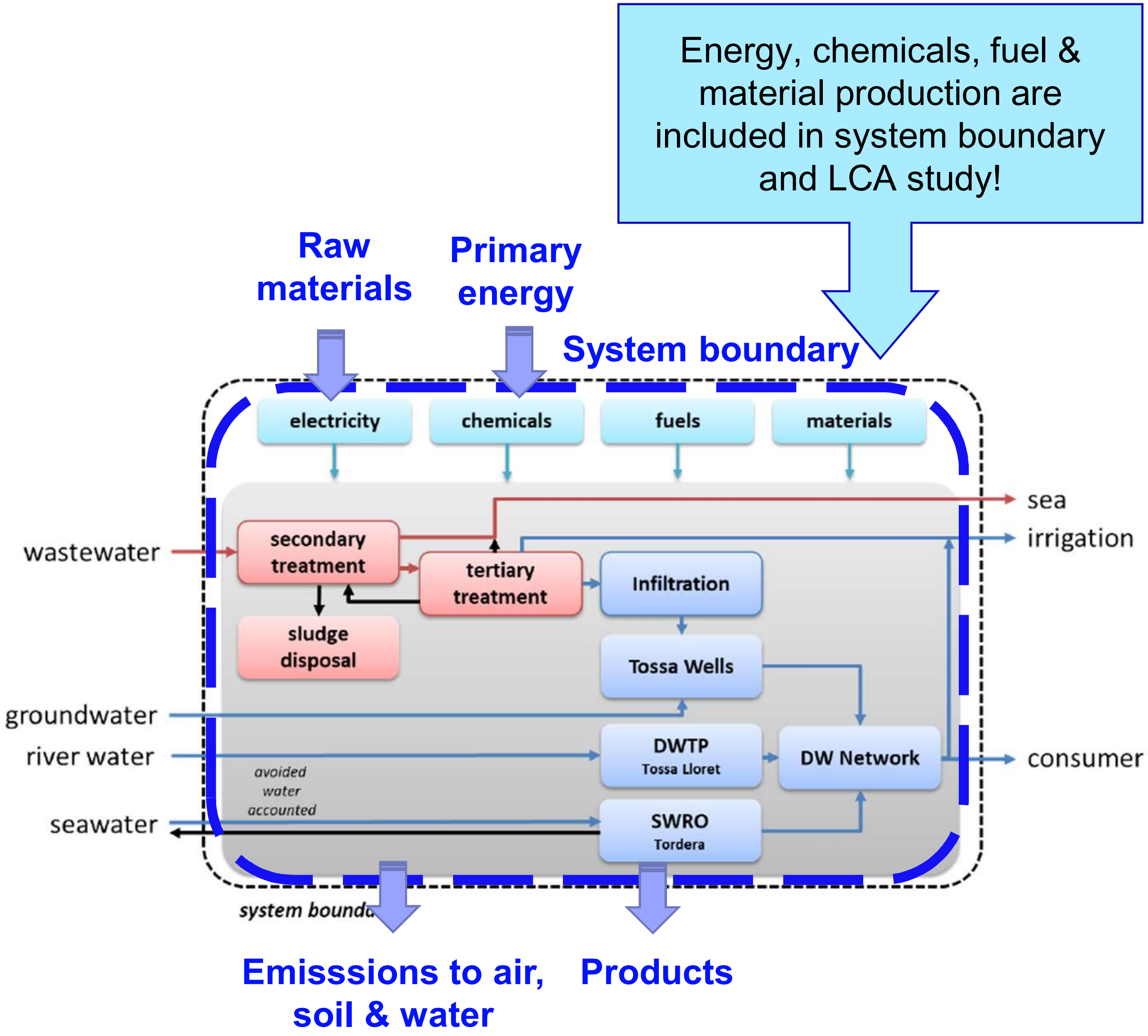
System boundaries

Inputs

- Elementary flows (raw materials, primary energy, air…)
- All processes necessary for the extraction of raw materials & to produce the energy are considered

Outputs

- Products
- Emissions to air, water and soil, waste …



Functional unit

- Starting point for building a model of the product system
- All inputs and outputs have to be referend to the functional unit
- The functional unit has to be equal for each product/system under consideration
- Example 1: „Environmental impact of a bulb of 10,000 lumen with a lifetime of 10,000 hours“of daylight“

Incandescent

LED

Halogen

Credits: Wikimedia Commons

? What may be a functional unit for water reuse?

Functional unit

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- All inputs and outputs have to be referend to the functional unit
- The functional unit has to be equal for each product/system under consideration
- Example 1: „Environmental impact of a bulb of 10,000 lumen with a lifetime of 10,000 hours“of daylight“

Incandescent

LED

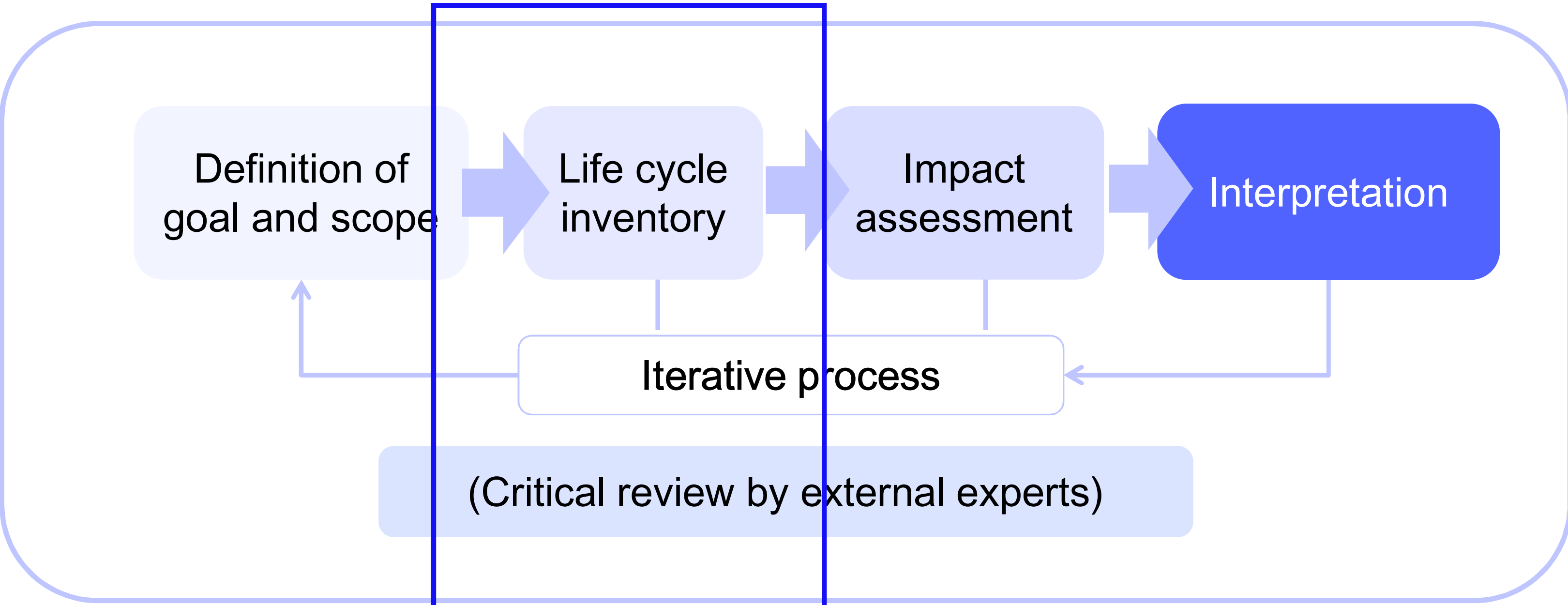
Halogen

Credits: Wikimedia Commons

- Example 2: “Environmental impact of 1 m^3 reclaimed water”

Framework of LCA (ISO 14040/44)

2. Step



-Data aggregation
-Data quality and origin

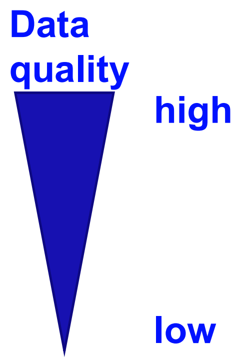
Life cycle inventory

Description of the system:

- Which **materials** in which quantities related to the functional unit are to be considered in the product system?
- Which mass flows with regard to **disposal or recycling and waste treatment** after use of the product exist?
- Which **transportations** have to be considered?

Data quality and origin:

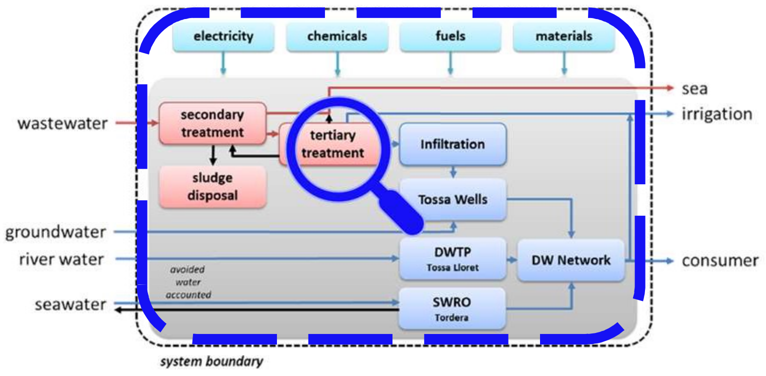
- Primary data from a full-scale operation plant (often from industry, operators)
- Generic data - averages or representative single values (often expert estimations, literature data)
- Estimations (if other data is not available)

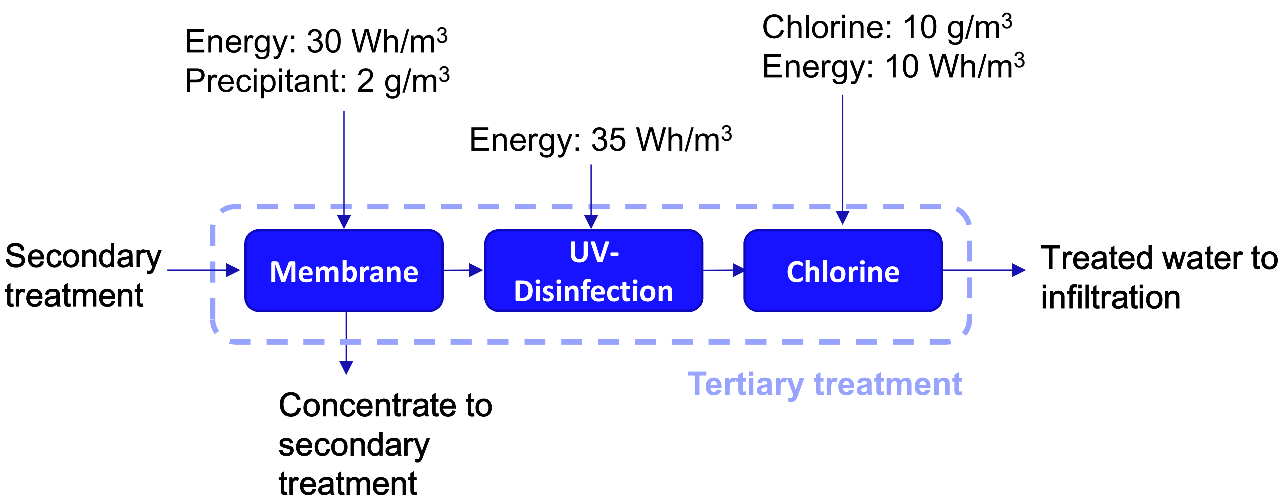


Life cycle inventory

Quantification of all inputs to and outputs within the system boundaries:

- Substance flows per unit process (smallest element in the life cycle inventory analysis for which input and output data are quantified)
- Example:





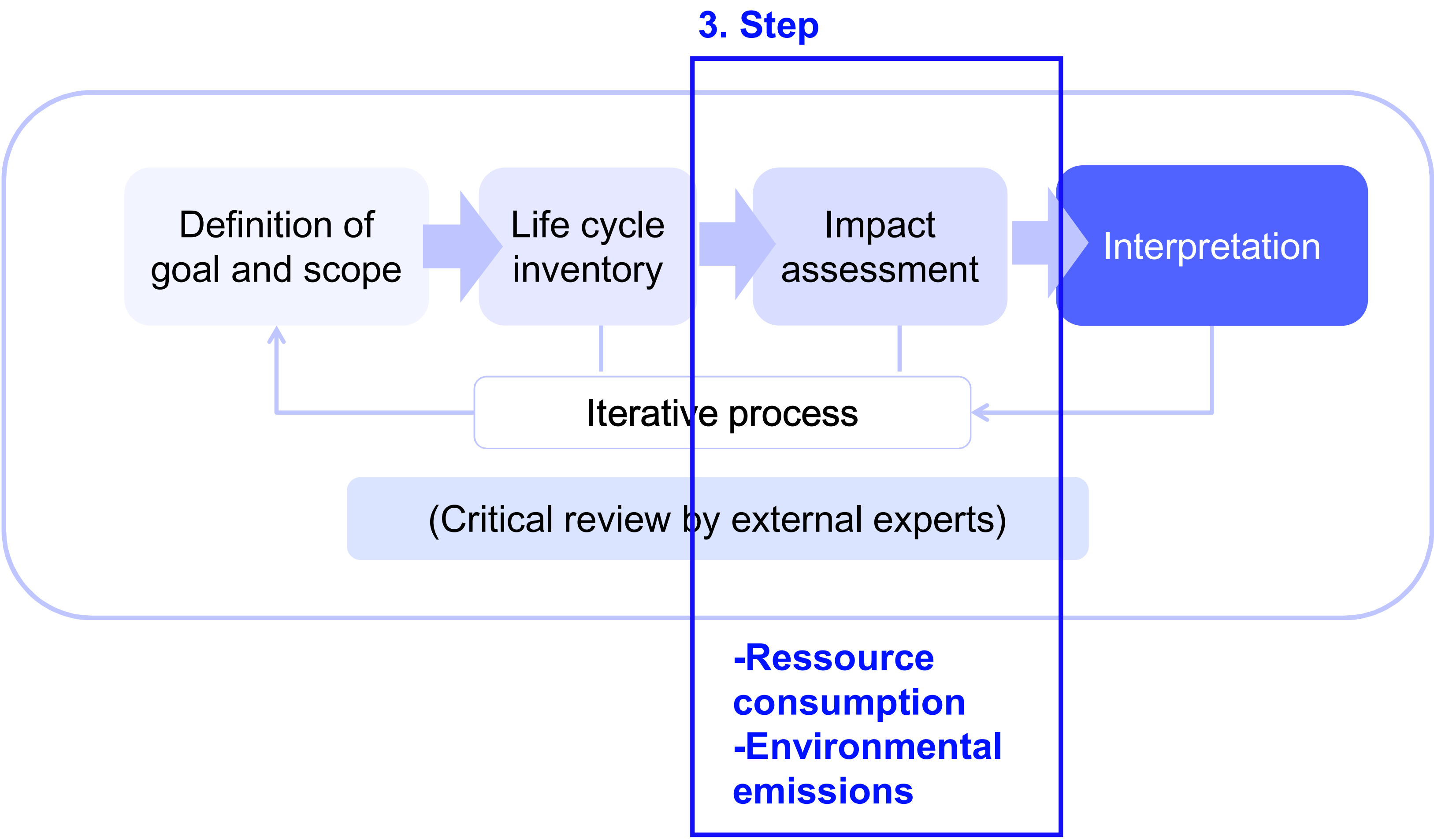
Life cycle inventory

Further step for ISO 14040/44…

Allocation:

- stands for the allocation of emission and energy contributions to the "actual source“
- More details in a following LCA workshop…

Framework of LCA (ISO 14040/44)



Impact assessment or LCA results

- Evaluation of the potential environmental impacts by converting the inventory results into specific impact categories
- For every study the most relevant impact categories are selected individually!
- Impact categories:
  - Non-renewable cumulative energy demand in MJ
  - CO_2-footprint or global warming potential in kg CO_2-Eq

    Most relevant for water reuse technology comparisons

  - Freshwater eutrophication potential in kg P-Eq
  - Marine eutrophication potential in kg N-Eq

    Show nutrient emissions from WWTP effluent to water bodies

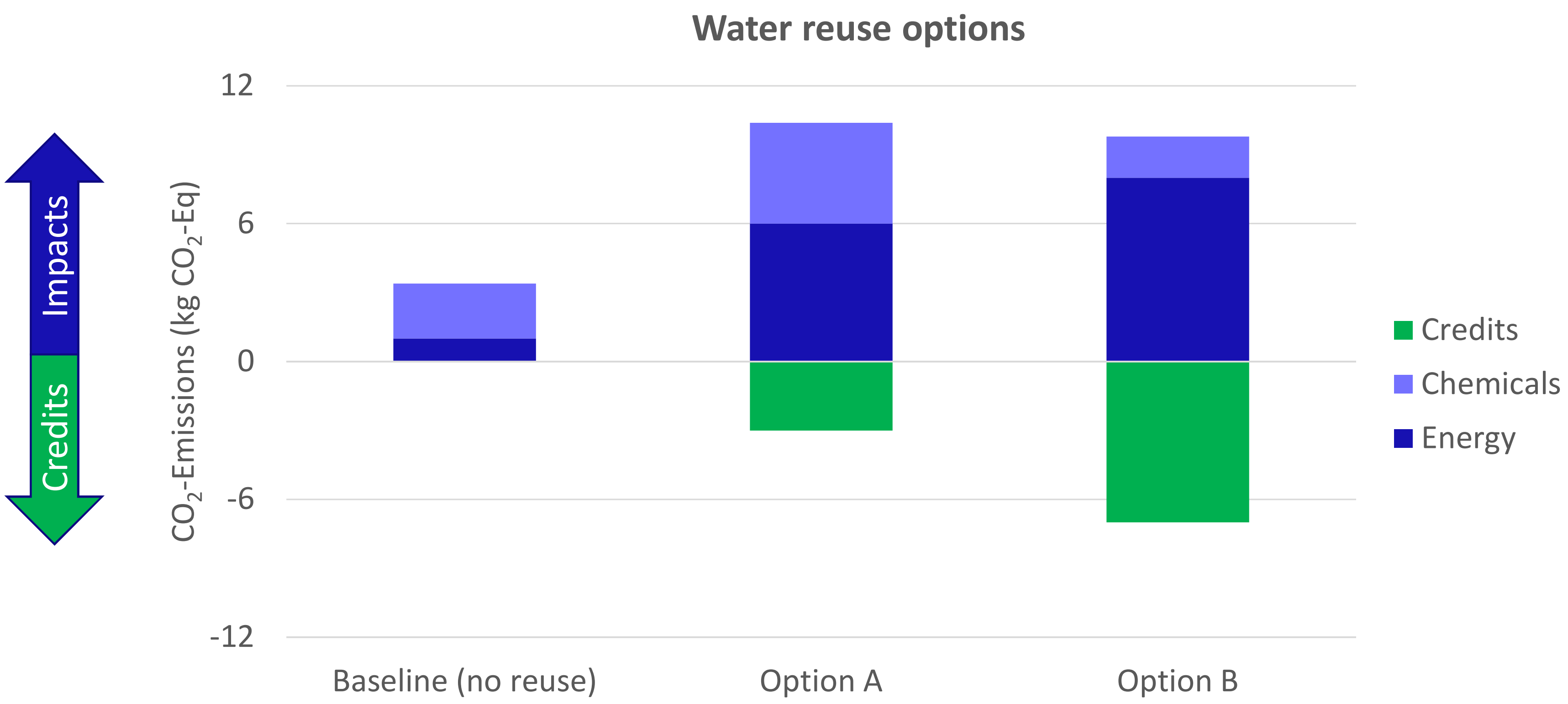
  - Human toxicity or eco toxicity potential

    -Mainly consider heavy metals, not so much trace elements
    - No acute toxic exposure represented
    → risk assessments

  - Many more
  - No impact category for microbial contamination

Results CO_2-footprint

How results could look like….



Interpretation

- Identification of significant issues based on the results
- Conclusions → What are the main results/ crux of the LCA?
- Limitations → Which statements can the LCA make and which not?
- Recommendations → What needs to be developed further? What are the strengths and weaknesses of the technology?

Limitations of LCA in Water Reuse

- LCA is not the best tool to asses water quality
  - The benefit of energy intensive technologies, which are able to provide a higher water quality, is „poorly“ addressed in LCA
  - Other assessment methods (e.g. QMRA, QCRA) are better suited here

- “Avoided ground water consumption” is hard to include in LCA
  - It can be included by e.g. crediting “avoided electricity consumption of groundwater pumping” or “avoided electricity for seawater desalination” → the origin of the water determines the amount of the given credits

- Different water footprint methods exist, however, it is difficult to take local conditions into account
  - Example: One m^3 groundwater consumption has less impact in Sweden than in Iran
  - Used method must be carefully examined!

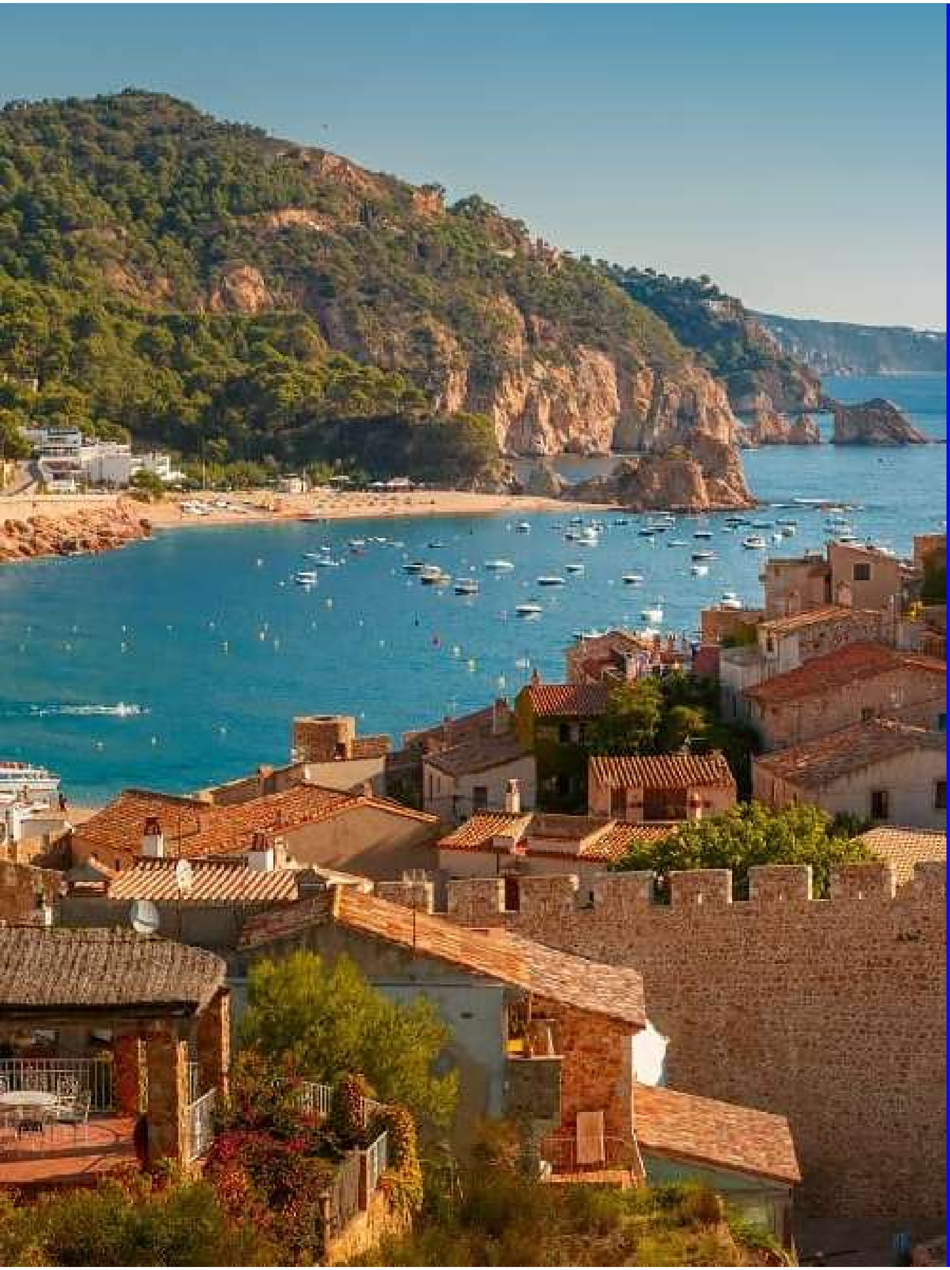
What do you need for an LCA?

1. **Knowledge** about the assessed technology and the LCA method
2. Good stakeholder **cooperation** (manufacturer, operator, WWTP operator, authorities …)
3. **Software & Database:**

- Well-known commercial LCA software:
    - Umberto (iPoint) → what we use at KWB with the ecoinvent database
    - GaBi (Sphare) → own sphere database which can be combined with ecoinvent
    - SimaPro → only suitable for product LCA (PRé Sustainability B.V.)
    - 2000-3000 €/year licence fees
- OpenLCA → free and open source software, however, most data sets must be purchased

Software	**Database**
umberto know the flow.	ecoinvent
sphera	sphera ecoinvent
SimaPro	ecoinvent
openLCA	Free datasets (incomplete)

WWTP: wastewater treatment plant



Experience with LCA in water reuse

Lea Conzelmann (KWB)

Tossa de Mar - Spain

Winter: 12,000 residents

Summer: 60,000 residents

Example: Tossa de Mar in Spain

- Tossa de Mar: town in the south of Costa Brava, Spain
- Seasonal water stress due to high touristic activity
- Import drinking water from Tordera drinking water plant & the Tordera seawater desalination plant

➢ Competition on available drinking water resources with other touristic areas

➢ Is water reclamation of the Tossa WWTP effluent an environmental friendly option?

Tordera desalination plant

Tordera drinking water plant

Groundwater

Drinking water production in Tossa de Mar

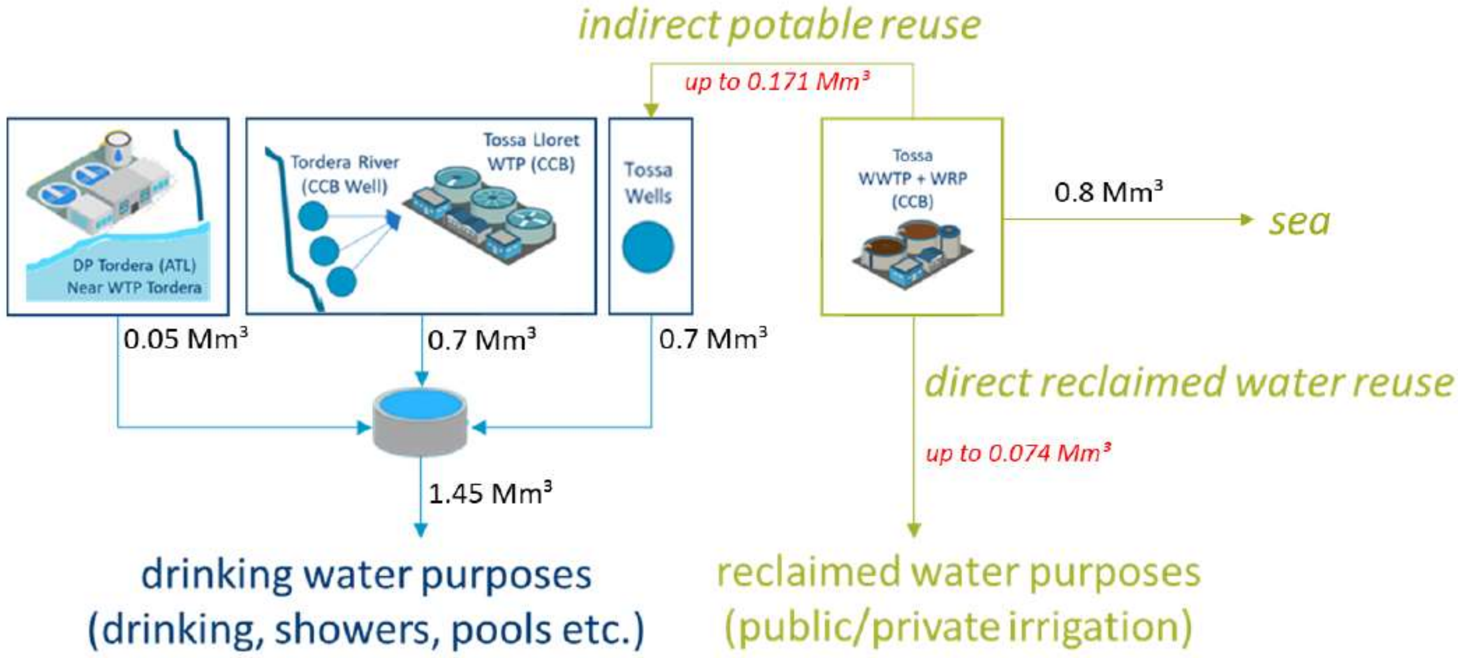
Water reclamation in Tossa de Mar

Status quo

Water reclamation in Tossa de Mar

Baseline:

- Existing secondary treatment
- No water reclamation

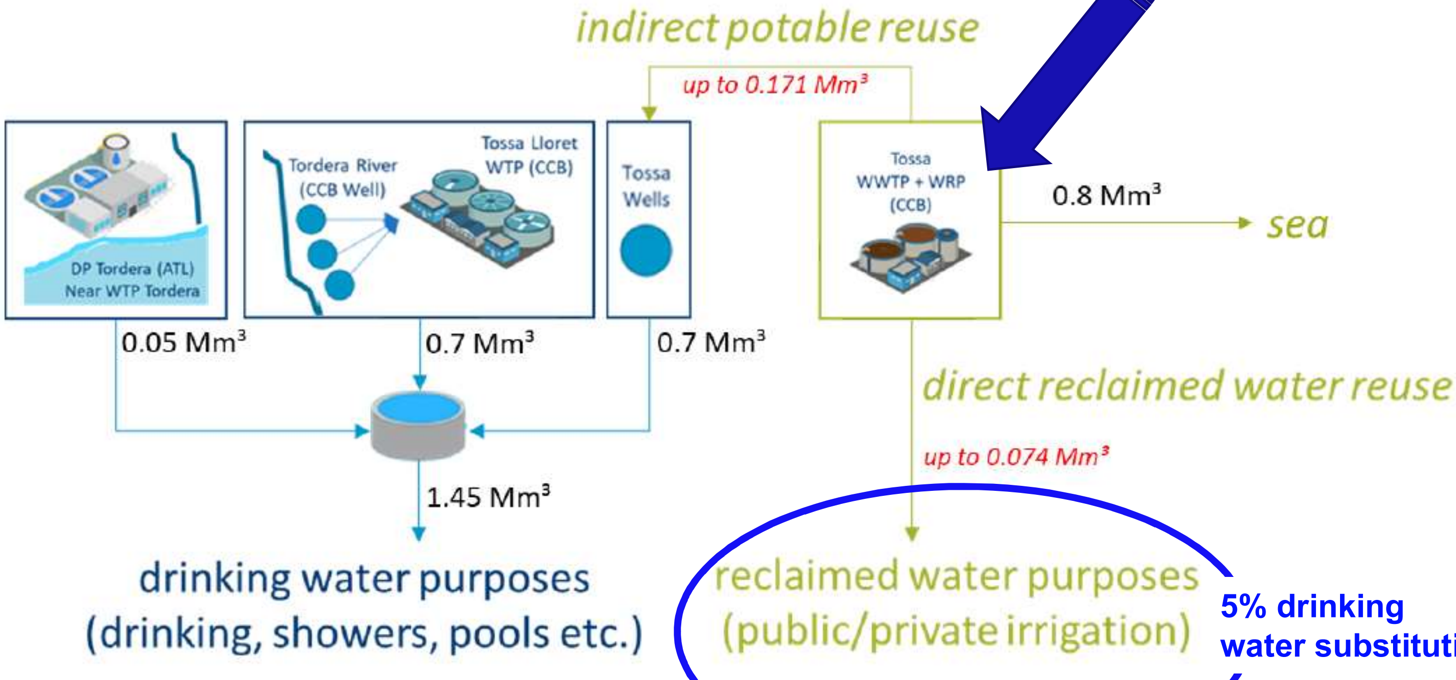


Water reclamation in Tossa de Mar

Option 1 “5% drinking water substitution”:

- Existing secondary treatment
- Tertiary treatment (membrane treatment + UV-disinfection + chlorine)
- Reclaimed water is used for irrigation in summer (74,000 m^3/year) → 5% annual drinking water substitution

WWTP + Membrane treatment + UV-disinfection + chlorine



5% drinking water substitution

WWTP: wastewater treatment plant

Water reclamation in Tossa de Mar

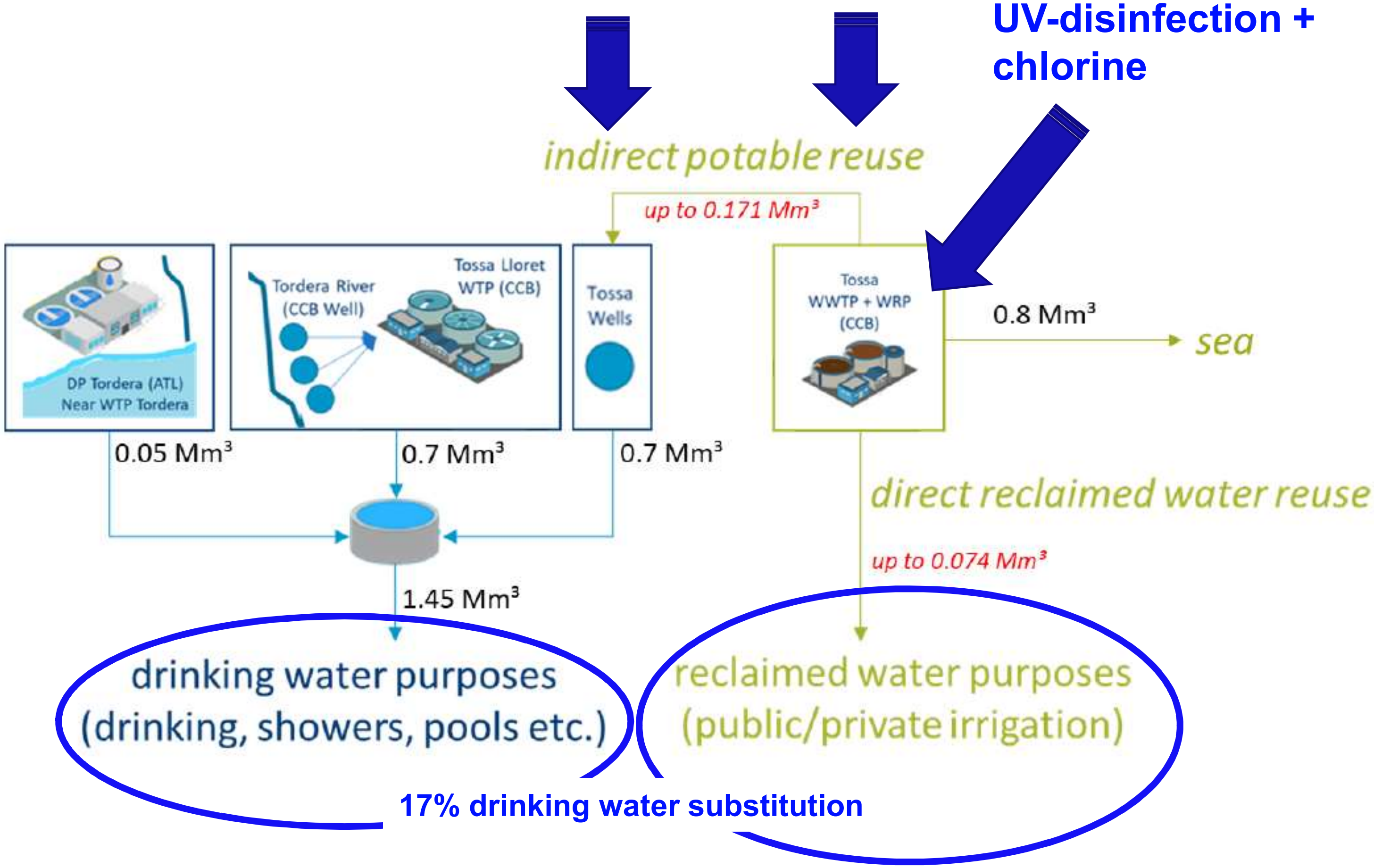
Option 2 “17% drinking water substitution”:

- Upgraded secondary treatment (higher capacity for a year-round removal of ammonium, which is a pre-condition for extending water reuse to water infiltration)
- Tertiary treatment (membrane treatment + UV-disinfection + chlorine)
- Reclaimed water is used for irrigation in summer and for Tossa Wells infiltration (245,000 m^3/year) → 17% annual drinking water substitution

Groundwater infiltration

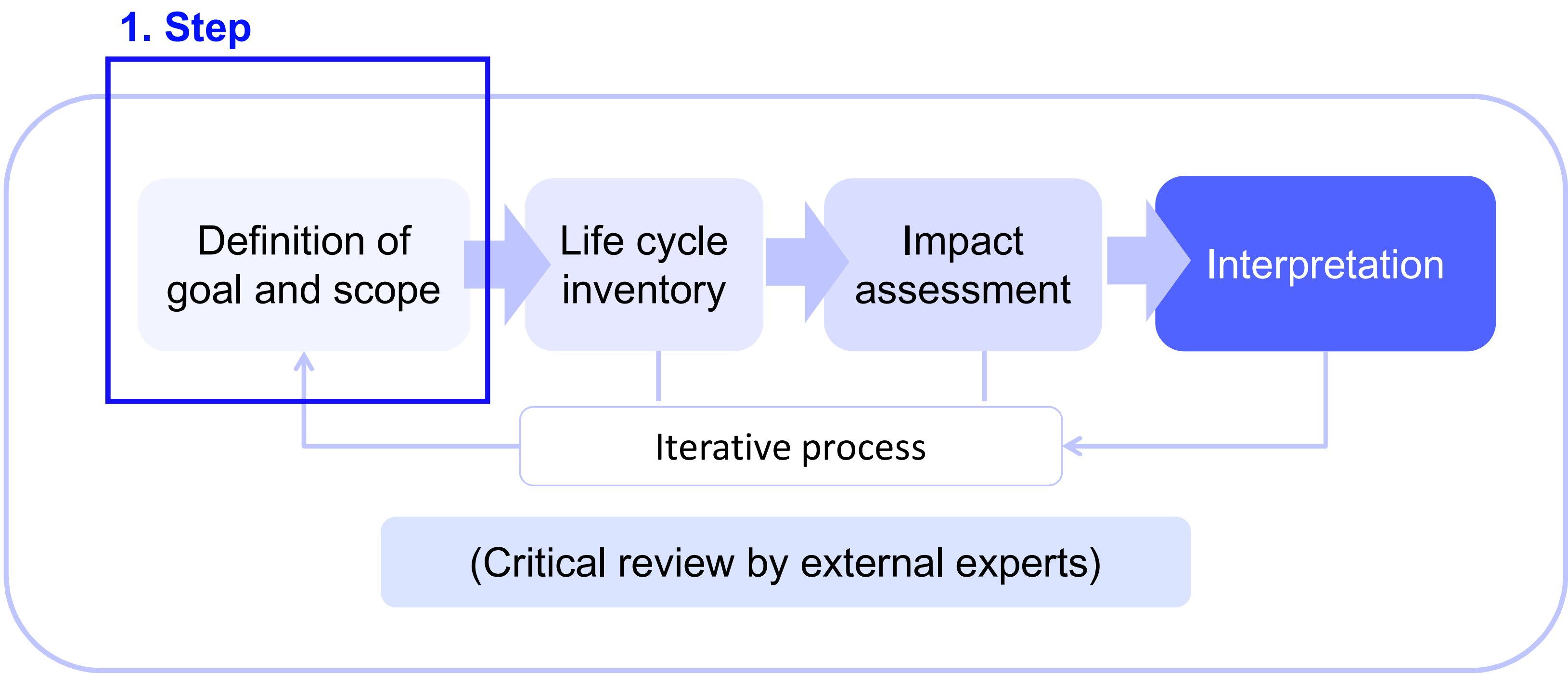
Upgrade WWTP

WWTP + Membrane treatment + UV-disinfection + chlorine



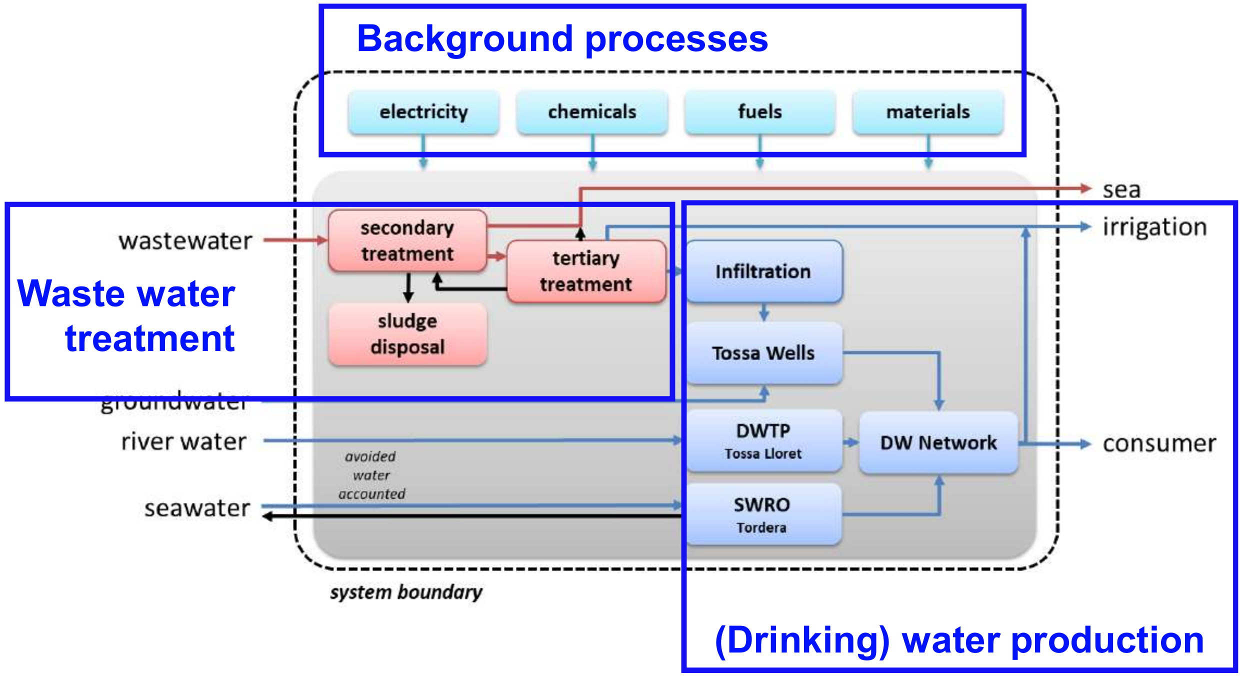
WWTP: wastewater treatment plant

Framework of LCA (ISO 14040/44)



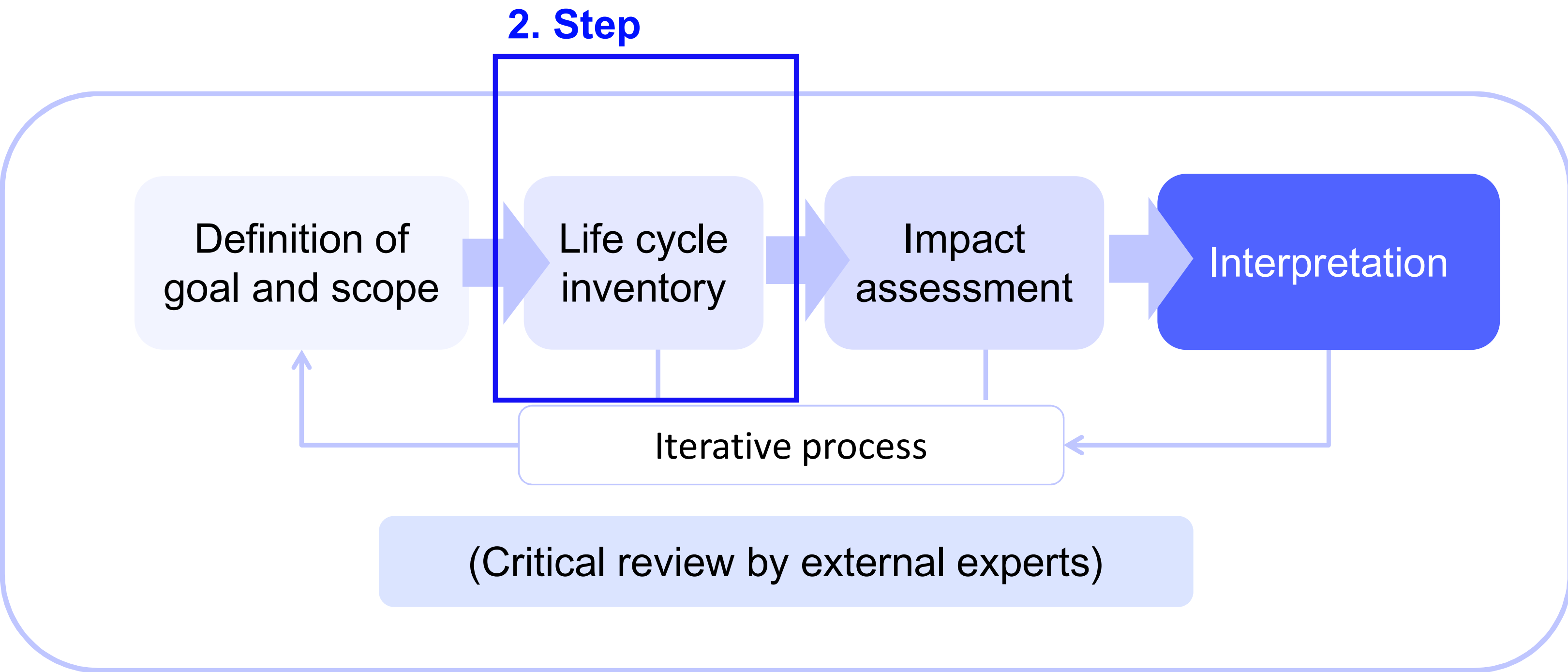
Definition of goal and scope

- Functional unit: “environmental impact per m^3 reclaimed water” or “environmental impact per person*year”
- System boundaries
- Methodological choices
  - Region: Spain
  - Database: ecoinvent
  - Standard: ISO 14040/44



System boundaries of water reclamation in Tossa de Mar (Spain)

Framework of LCA (ISO 14040/44)



Quantification of all inputs to and outputs from the processes within the system boundaries

Inventory

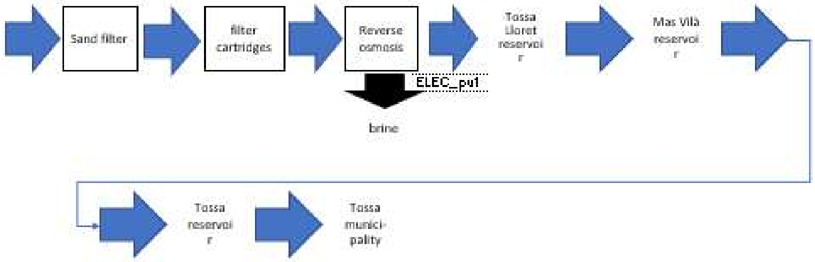
LCA data demand

Quantification of all inputs to and outputs from the processes within the system boundaries

- Flow chart
- Substance flows per unit process
- Demand of electricity, heat, chemicals (with concentrations), …
- Waste composition and disposal route
- Products
- Infrastructure (material demand)

NextGen LCA/ LCC Questionaire on data inventory

Case Study: **Tossa de Mar/ Comparison of freshwater resources**



Volumes supplied

parameter	abbr.	unit	value	type of sampling	period of sampling	remarks
volume flow	Q_a	m³/year	10.602.319			total
volume flow	Q_a	m³/year	440.096			volume for ET.
volume flow	Q_a	m³/year	1.750.000			volume for ET.
volume flow	Q_a	m³/year	3.209.150			volume for ET.
volume flow	Q_a	m³/year	5.203.073			volume for Ca

operational parameters treatment

parameter	abbr.	unit	value	type of sampling	period of sampling	remarks
electricity DP	ELEC_dp	kWh/year	#######			entire treatmer
Ferric chloride	FeCl3	kg/year	3.400			40%
sodium hydroxide	NaOH	kg/year	146.000			30%
Carbon dioxide	CO2	kg/year	440.000			98%
Calcium hydroxide	CaOH2	kg/year	374.433			92%
Antiscalant		kg/year	14.060			-
Sodium Metabisulphite		kg/year	113.200			98%

recovery rates

parameter	abbr.	unit	value	type of sampling	period of sampling	remarks
RO	RO_ef	%	43,7			brine to sea

operational parameters pumping

parameter	abbr.	unit	value	type of sampling	period of sampling	remarks
electricity pumping	ELEC_pu1	kWh/m³	0,043			pumping to To

Inventory

LCA data demand

Important notes:

- Up-scaling required for pilot data because pilot-plants are not optimized;
  - E.g. specific electricity demand (kWh/m^3 water) of a pilot plant > full-scale plant
  - Data from „full-scale“ plants in operation needed
- Water quality and chemical demand can often be applied from pilot data
- Calculation of annual average consumptions!

NextGen LCA/ LCC Questionaire on data inventory

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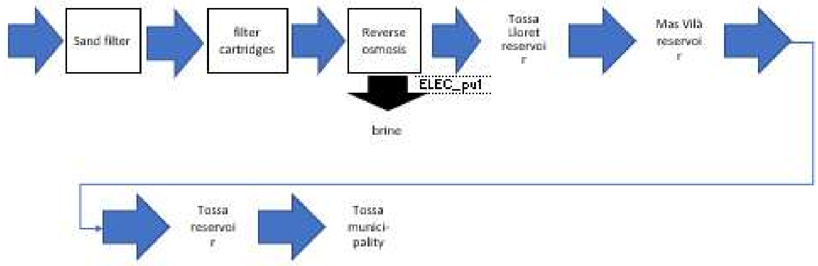

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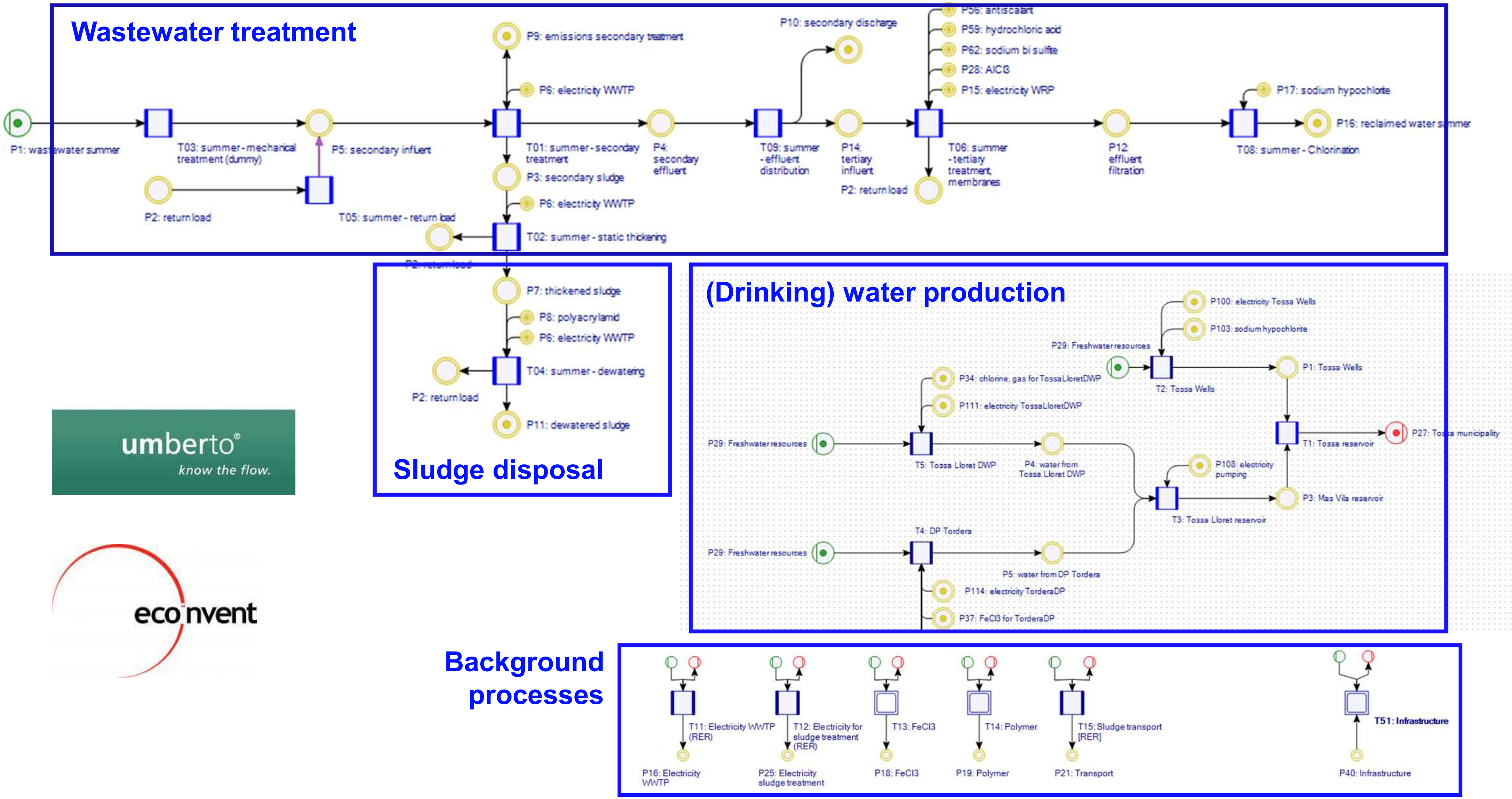
LCA software UMBERTO®



umberto®
know the flow.

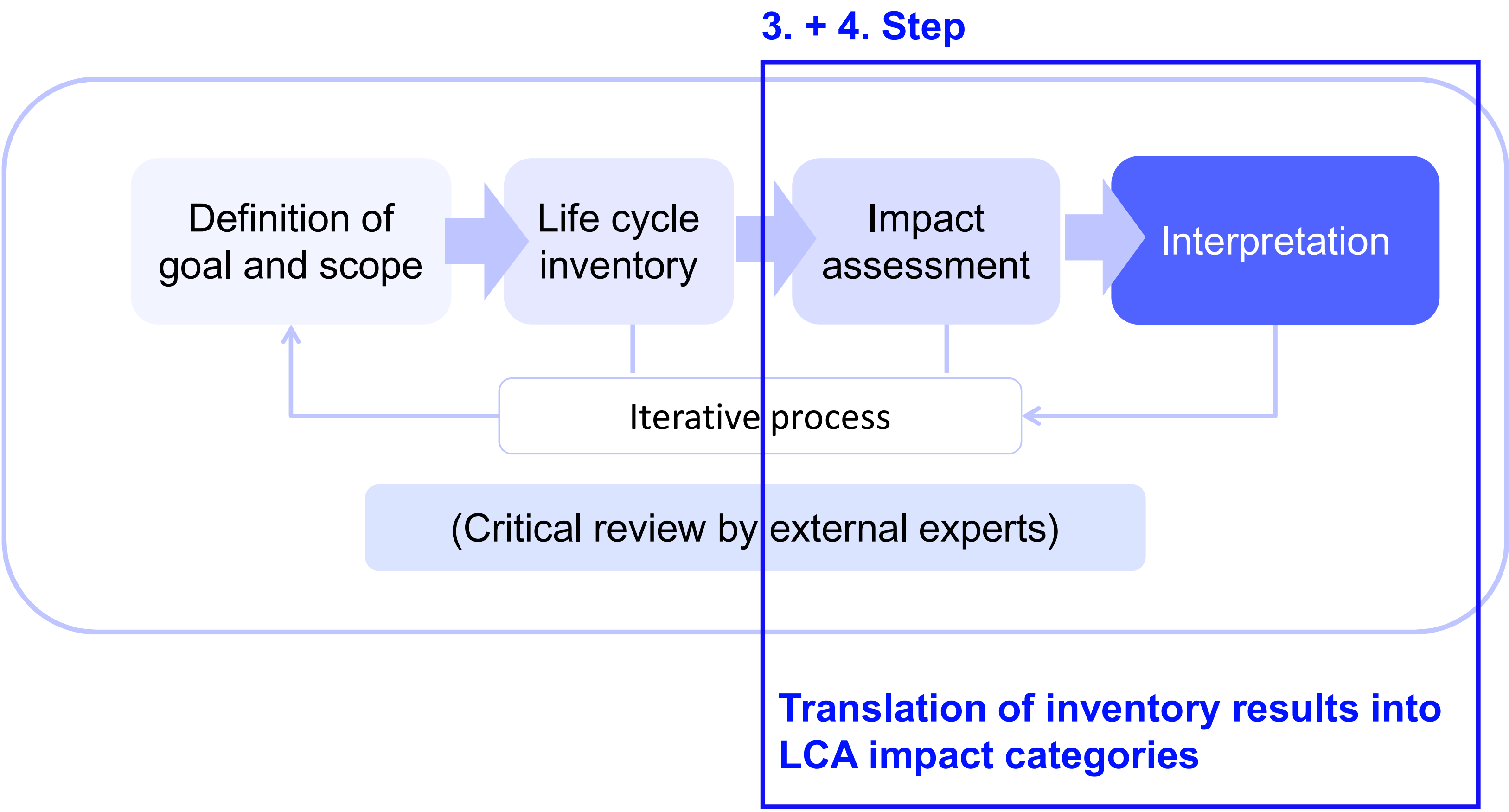
ecoinvent

Data source and quality

Parameters, data source and estimated data quality

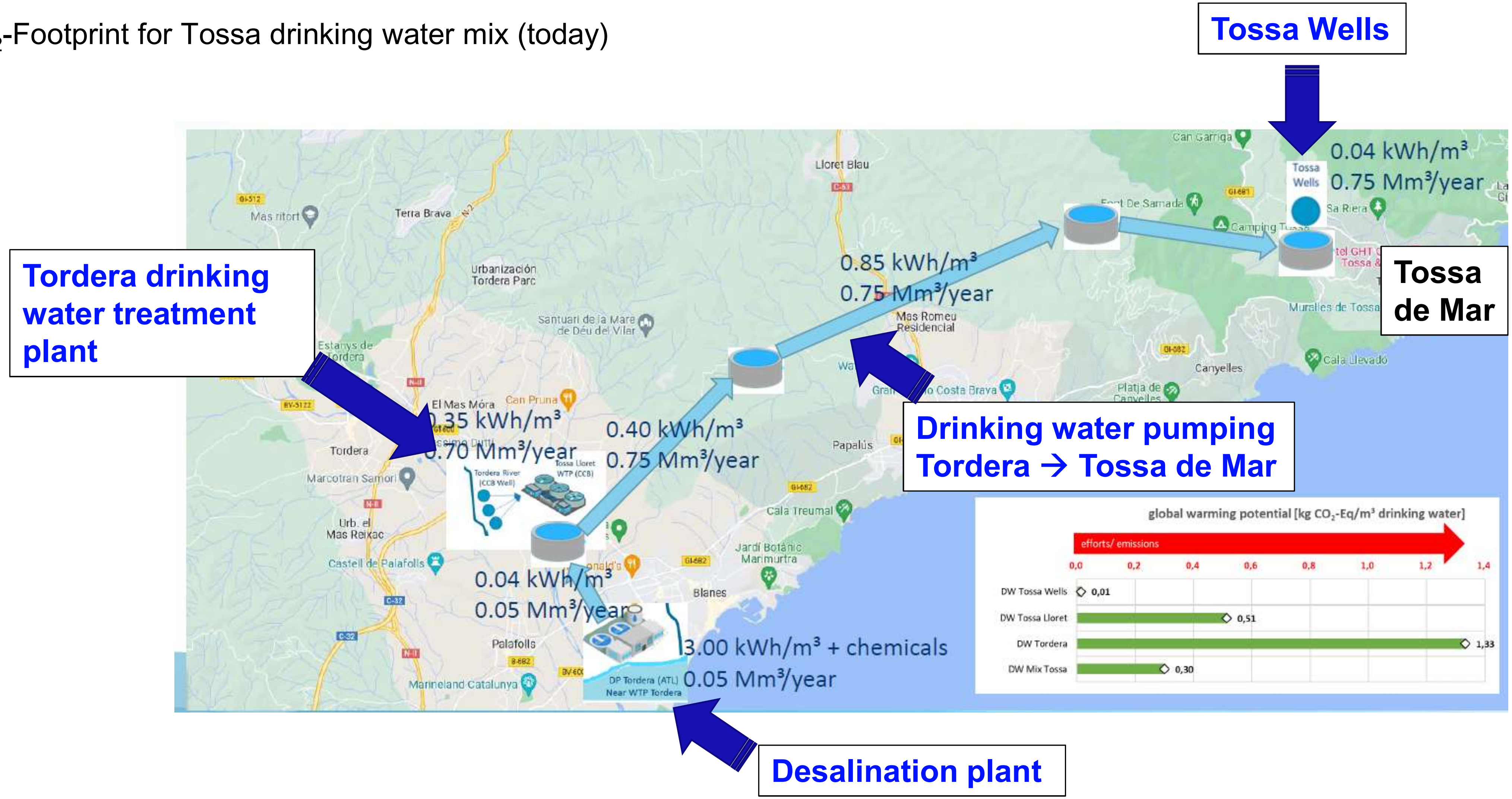
Parameter/ Process	Data source	Data quality
WWTP - Baseline		
Water quality and quantity	WWTP operator (CCB, 2019)	very good
Energy and chemical consumption	WWTP operator (CCB, 2019)	good
Gaseous emissions from WWTP	Literature (ATV, 2000; Parravicini et al., 2016)	Low-medium
Tertiary Treatment		
Energy and chemical consumption (Scenario 2./3.)	WWTP operator (CCB, 2019; Serra, 2021)	medium
Energy and chemical consumption (Scenario 4.)	Literature (Kraus et al., 2016; Van Houtte, 2016)	medium
Drinking Water Treatment		
Energy and chemical consumption	WWTP operator (CCB, 2019; Sala, 2022; Serra, 2021)	medium

Framework of LCA (ISO 14040/44)



Impact Assessment

CO_2-Footprint for Tossa drinking water mix (today)



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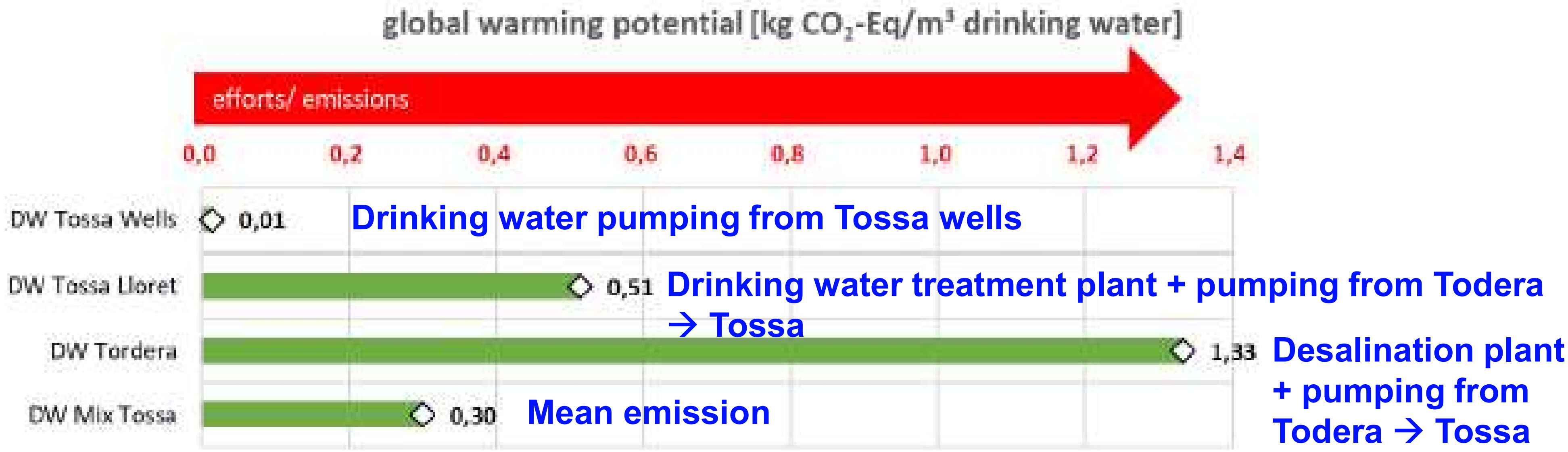
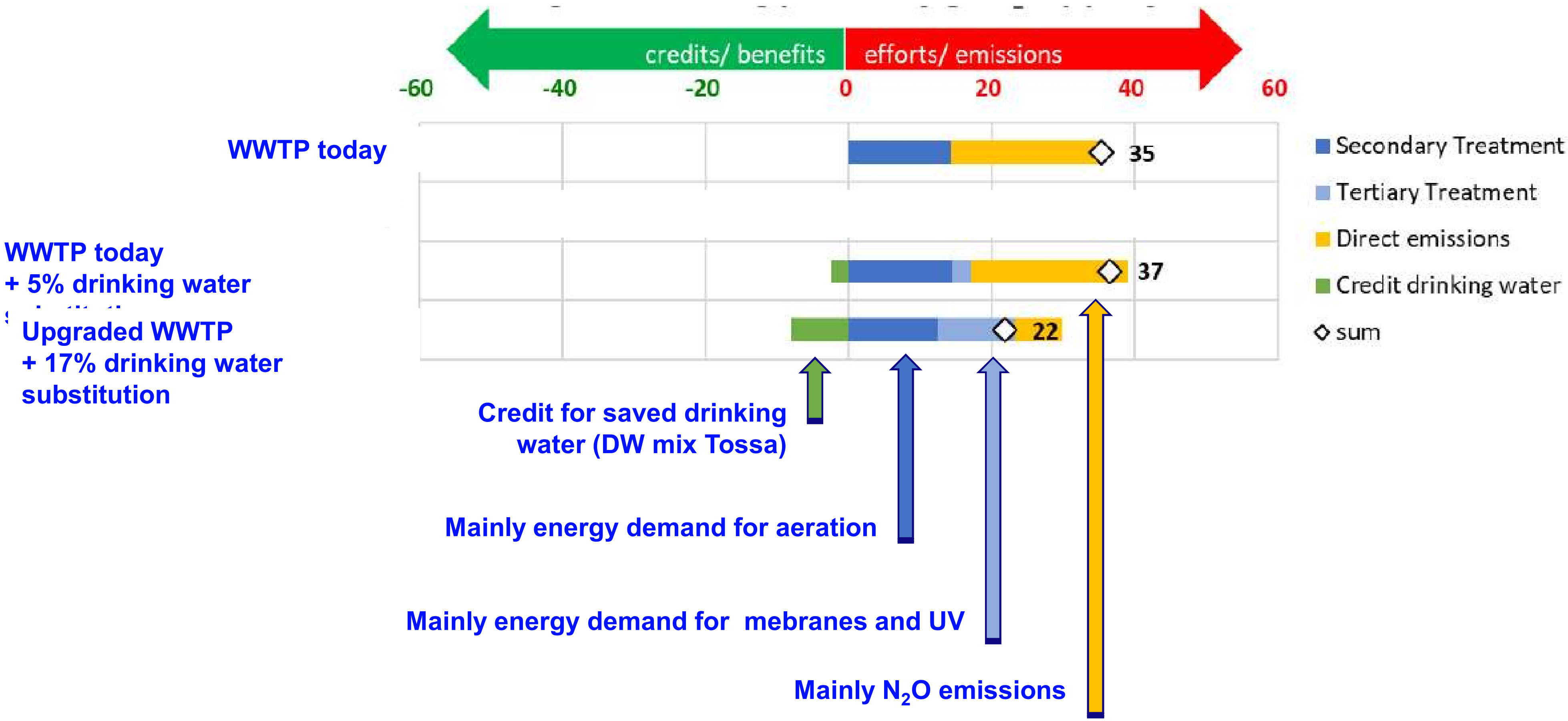


- Origin of drinking water is decisive for the CO_2-footprint
- Average drinking water (DW) mix Tossa: 0.3 kg CO_2-Eq/m^3

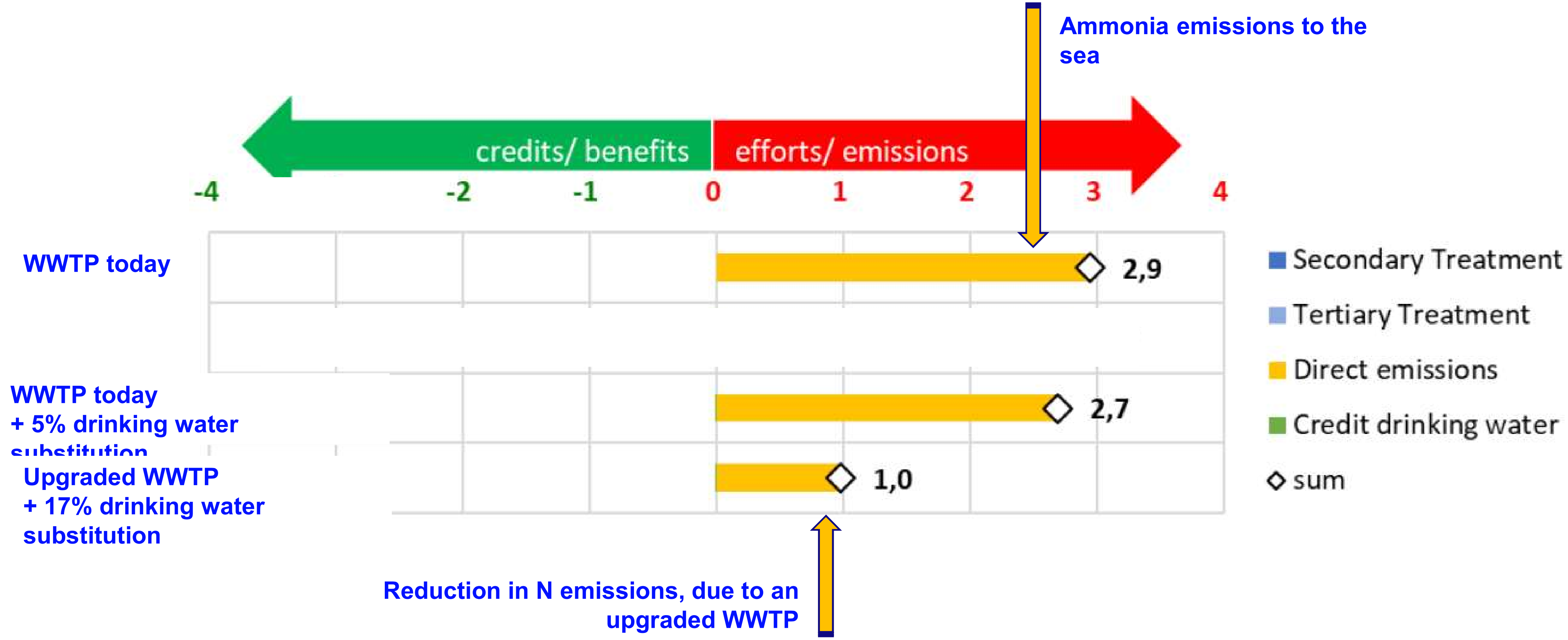
CO_2-Footprint in kg CO_2-Eq / (pe*a)

Comparison of Options



Marine eutrophication potential in kg N-Eq/(pe*a)

Comparison of Options



Key findings

LCA in water reuse

- The results of water reuse are **energy driven** → main part of impacts corresponds to electricity demand
- Electricity demand for membranes and UV is higher than for drinking water production (of the Tossa water mix)
- Water reclamation is able to reduce energy use and the CO_2-footprint, however, the existing Tossa WWTP has to be upgraded to face ammonia issues
- Results of the comparison depend on local alternatives of water production (groundwater pumping < water transportation/pumping <<sea water desalination)

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Do you want more insights into the Tossa de Mar LCA?

nextGen

nextGen report, deliverable 2.1:
https://nextgenwater.eu/wp-content/uploads/2023/03/D2.1-Environmental-Life-Cycle-Assessment-and-risk-analysis.pdf

KWB

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