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EXPERTS IN SUSTAINABILITY

AIGMF

All India Glass Manufacturer‘s Federation

All India Glass Manufacturer’s Federation New Delhi India

LCA of Container Glass and comparison with PET, Tetra and Pouch Critical Review by Panel of Experts

Rajesh Singh and Ritesh Agrawal
PE Sustainability Solutions Pvt Ltd, India
A subsidiary of PE International AG, Germany

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1. **Overview on LCA**
2. **Technical details of the project**
    1. Goal & Scope discussion
    2. LCI data collection
3. **Timelines, Visits and Deliverables of member companies**
4. **GaBi I Report**
5. **Introduction to PE International**

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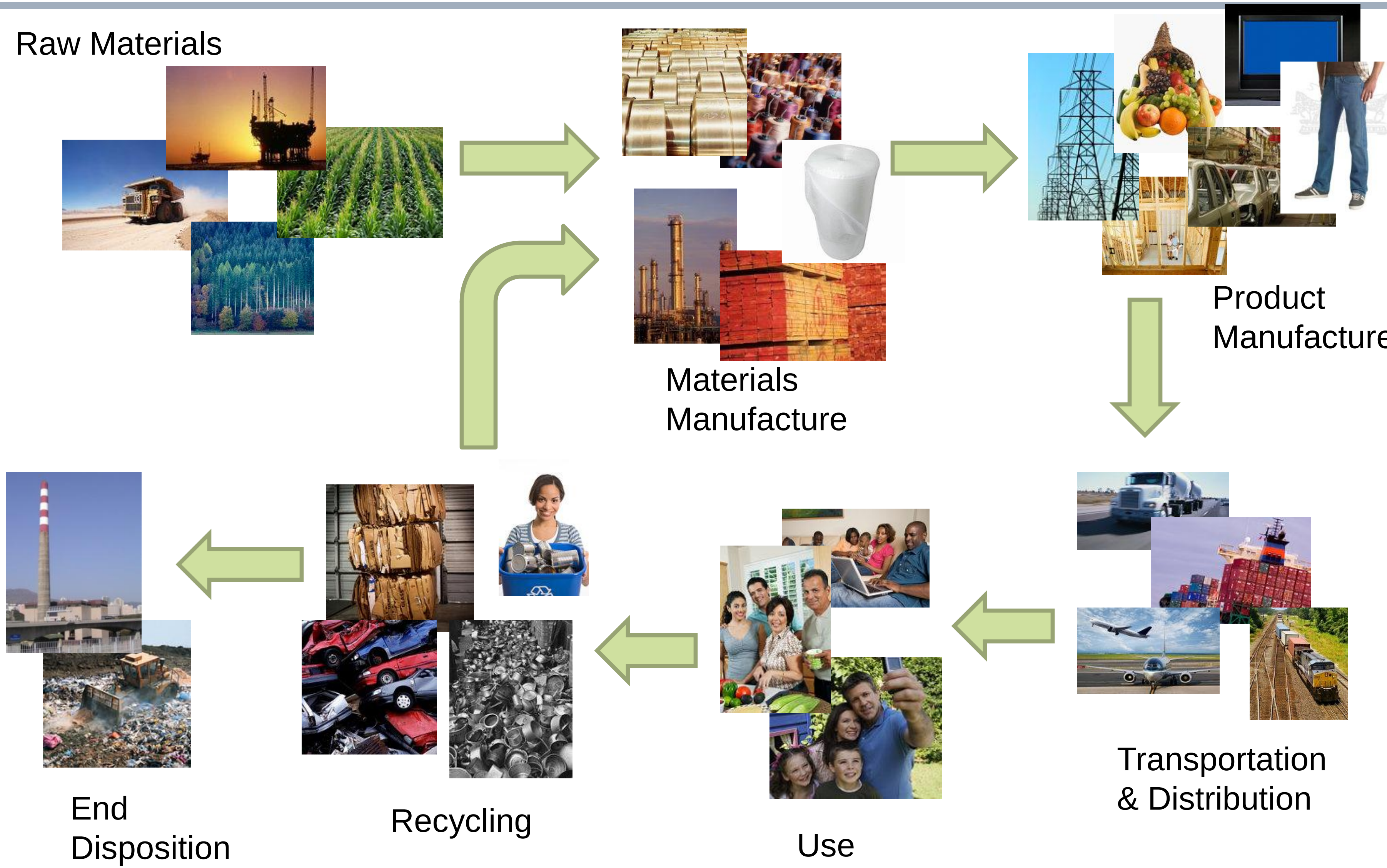
LCA

Definition of Life Cycle Assessment from ISO 14040 / ISO 14044:

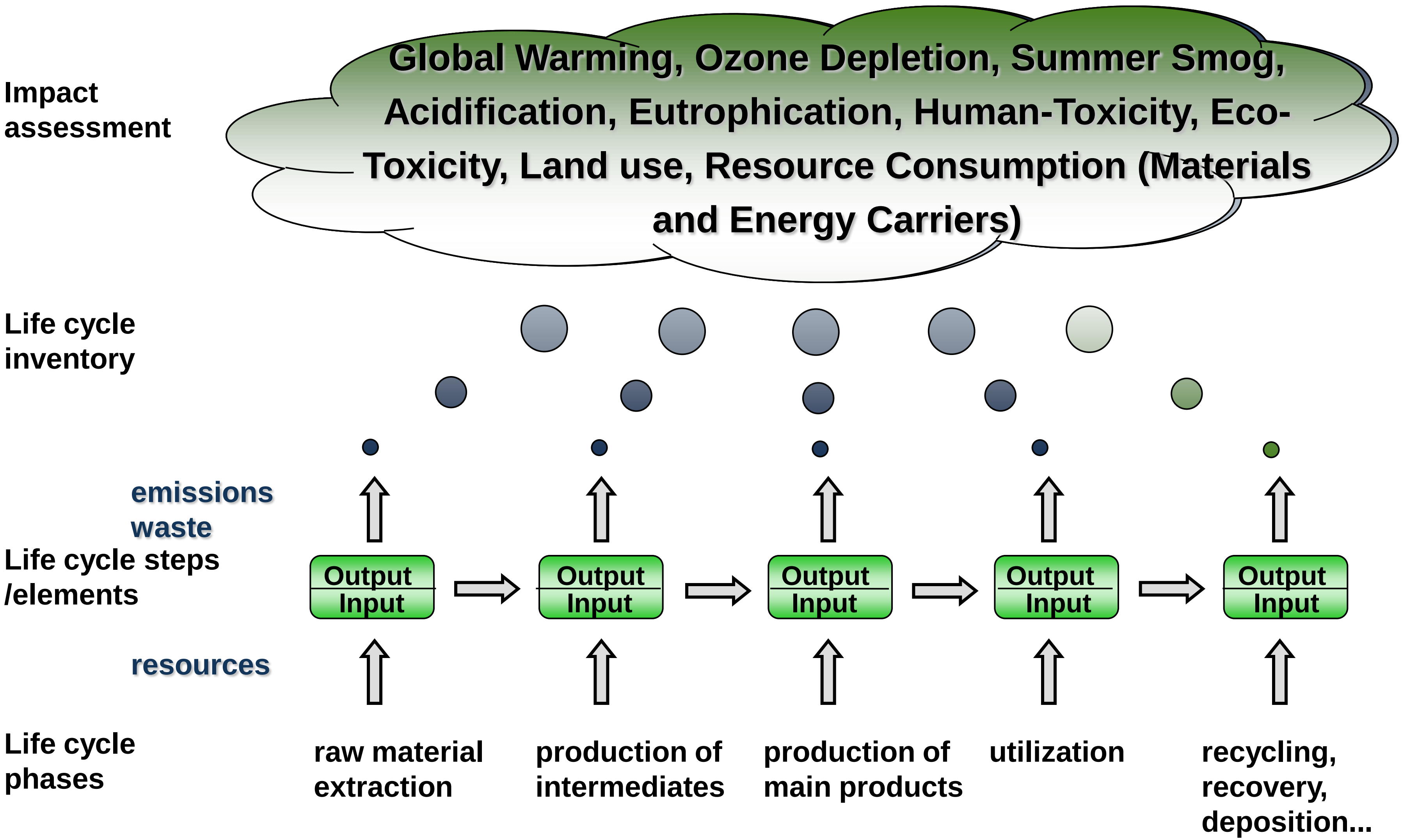
Life Cycle Assessment is the compiling and evaluation of the input and outputs and the potential environmental impacts of a product system during its lifetime.

LCA is a tool to measure, assess and manage the environmental performance of a product from raw materials through production, use, and end-of-life phases

LCA Overview



LCA Overview



Goal & Scope Definition

Determination of scope and system boundaries

Life Cycle Inventory

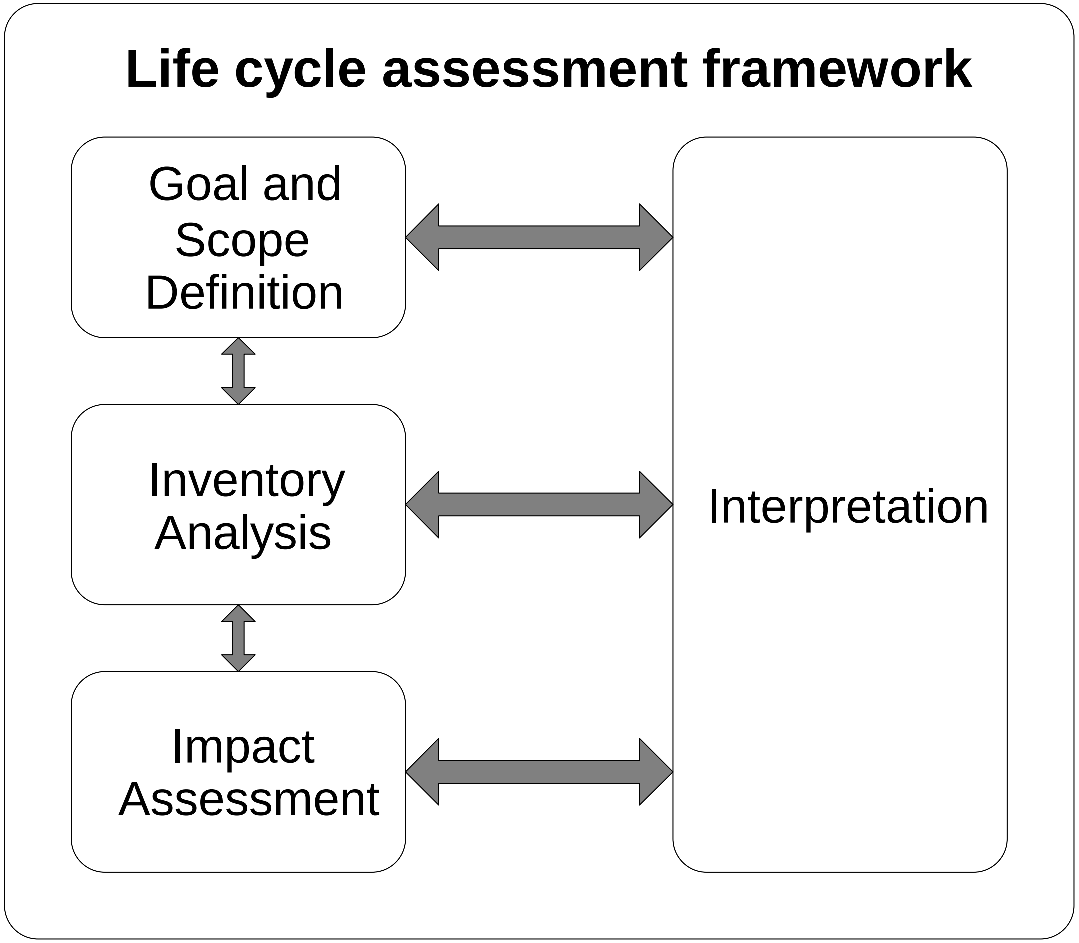
Data collection, modeling & analysis

Impact Assessment

Analysis of inputs and outputs using indicators

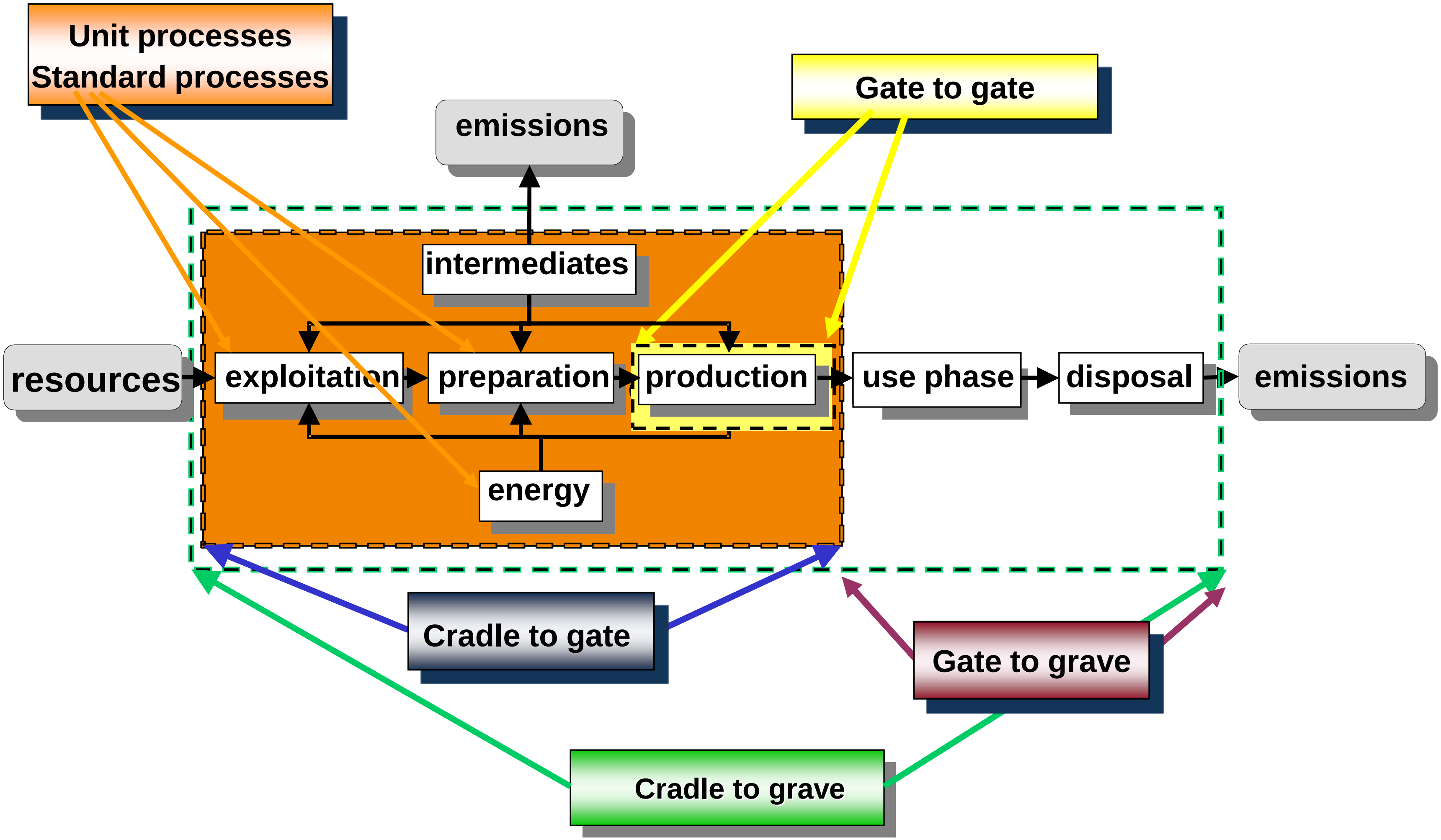
Interpretation

Sensitivity analysis, dominance analysis, etc.



Scope of the study

Definition of System Boundaries



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Proposal Presentation

- Glass is by far the most recycled packaging material
- Can be recycled indefinitely without loss of quality or performance.
- Glass recycling is a closed loop system, creating no additional waste or by-products.
- Returning glass to the glassmaking process makes a great deal of sense in **environmental terms**, since it saves energy and primary mineral resources, as well as reducing waste and pollution emissions.
- Recycling glass reduces consumption of raw materials, extends the life of plant equipment, such as furnaces, and saves energy.

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Objective

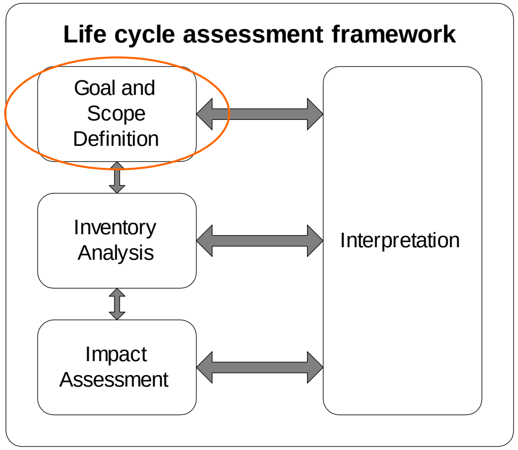
- To evaluate the environmental profile of glass, determine improvement opportunities, comparison with alternative packaging materials such as PET, Tetra , pouch and external communication of product environmental attributes for enhancing the green brand of glass product.
- Provide the foundation for meaningful use of LCA results and help member companies of AIGMF to project the green image of the product amongst consumers and other stakeholders.
- Critical Review by Panel of International Experts

Coverage of study

Scope, functional unit, reference flow, time frame, geographical boundary, data requirements

Who will be audience

Internal, external



Who is doing what?

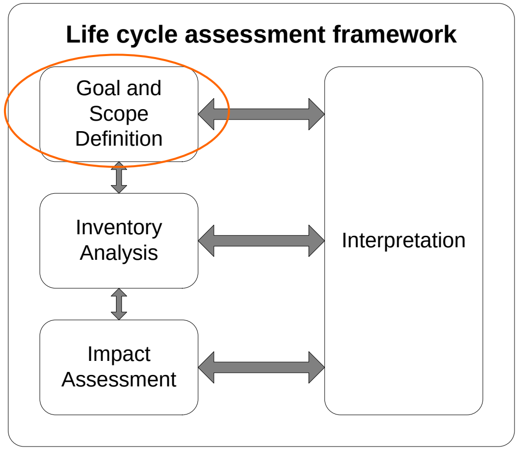
• Project management:	PE International
• Data collection:	Member Companies/AIGMF/PE
• Modeling and QA:	PE International
• Report writing:	PE International / inputs from AIGMF
• i-report template:	PE International
• Meetings:	all

Functional unit

Colour (amber, flint, green) or Products comparative to all the packaging mediums i.e. glass, tetra, PET and Pouch respectively

Time coverage

2009-10 or 2010-11



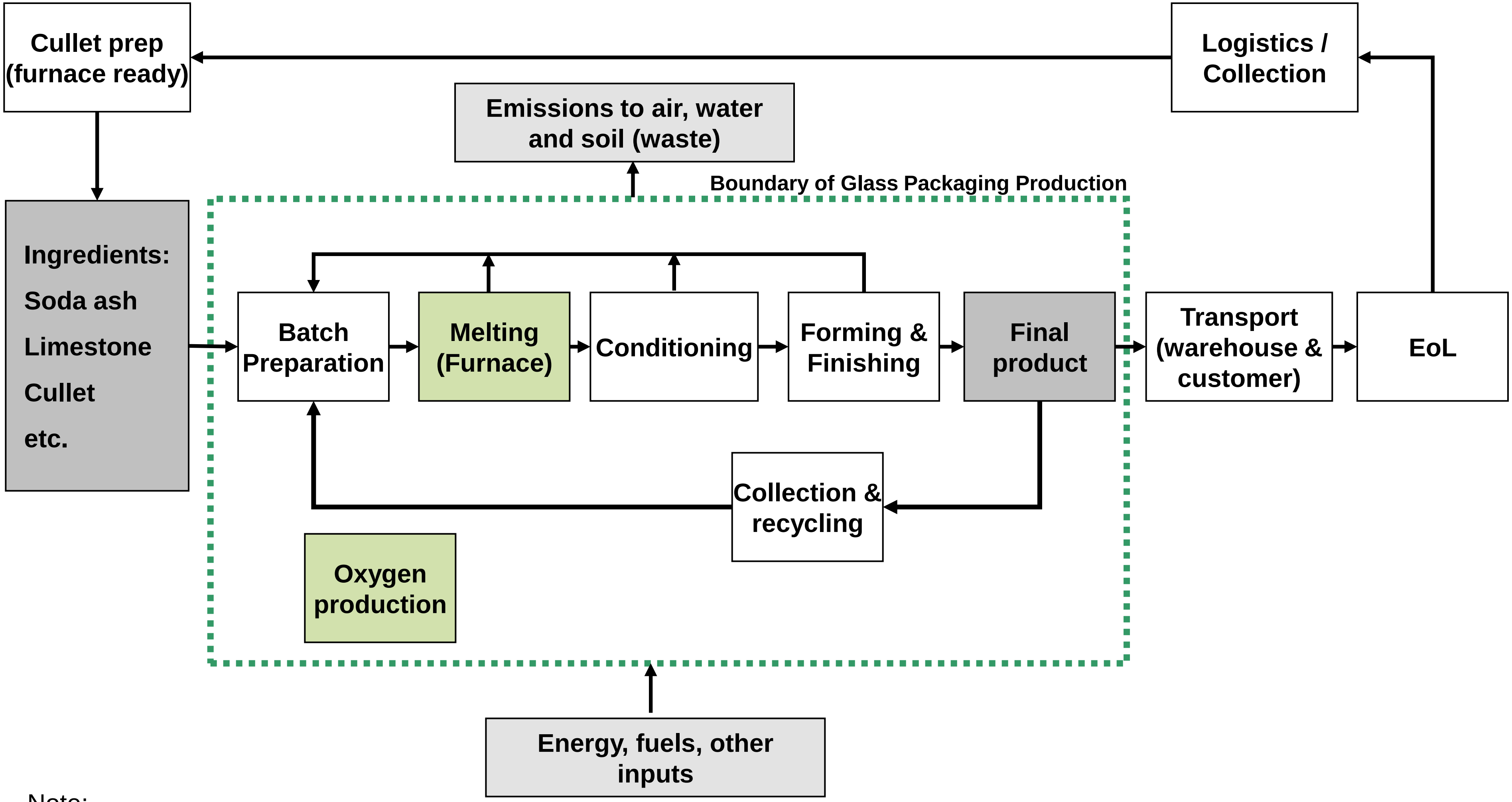
Geographical coverage (production)

70-80% of Indian production mix (48 furnaces; 7596 tpd)

Background data (raw materials, fuels and energy)

Fuels, energies, construction and auxiliary materials are taken from the ELCD / GaBi 4 LCI database or other sources if appropriate

System boundary overview



Note:

If information on internal energy production (e.g. thermal energy) is available, this can be modeled specific (to each company)

System boundary details

Batch Preparation → Melting (Furnace) → Conditioning → Forming & Finishing → Final Product (no filling) → Packaging →

Batch Preparation
- Input materials (e.g. sand, cullet, etc.)

Melting (Furnace)
- Regenerative
- Recuperative
- Oxy-fuel
- Electric

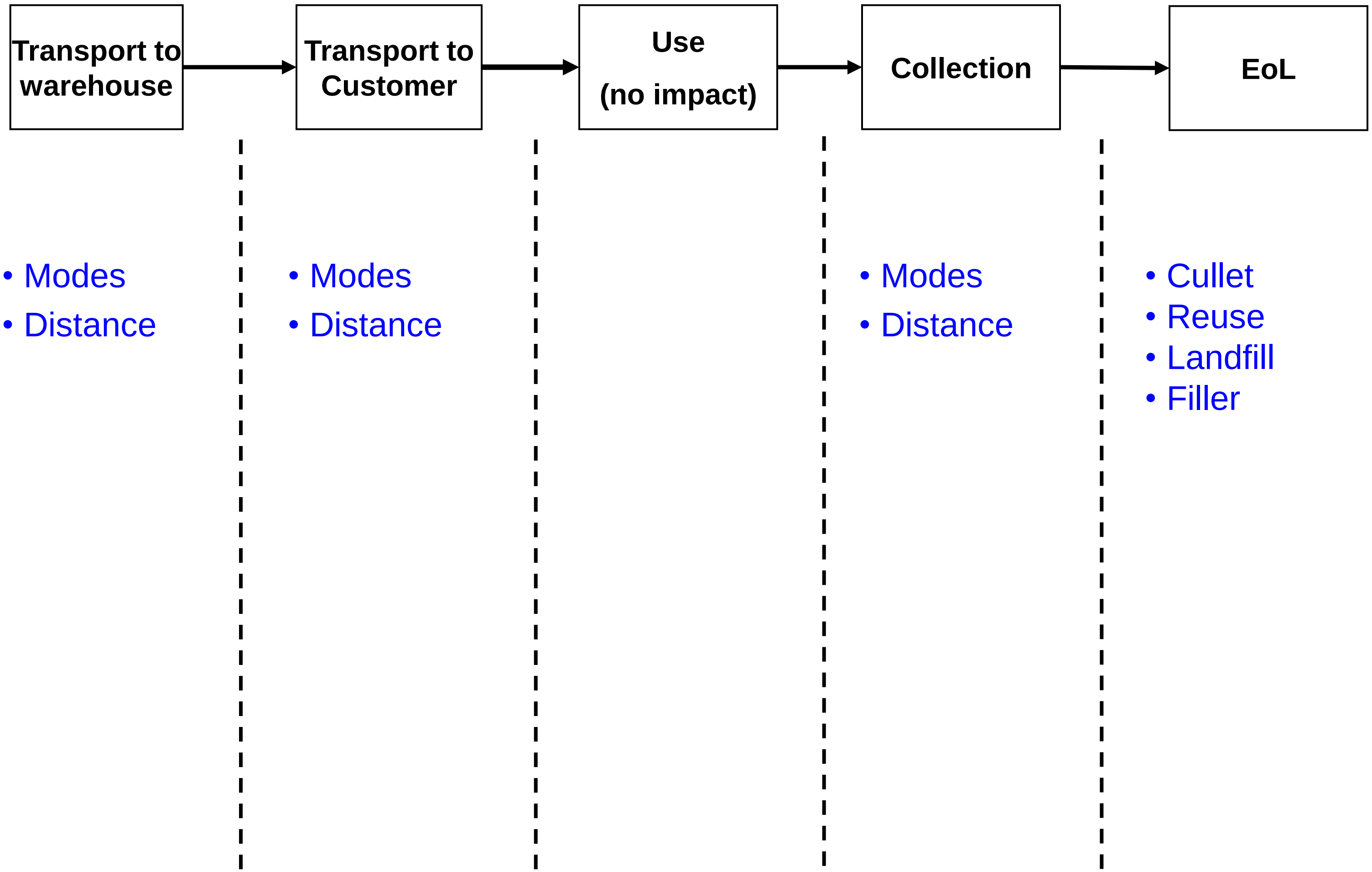
Conditioning

Forming & Finishing
- Blow & blow
- Press & blow
- Narrow neck press & blow

Final Product (no filling)

Packaging

System boundary details



Transport to warehouse:
- Modes
- Distance

Transport to Customer:
- Modes
- Distance

Collection:
- Modes
- Distance

EoL:
- Cullet
- Reuse
- Landfill
- Filler

What is in and what is out!

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Included

- Raw materials
- Processing of materials
- Energy production
- Operation of primary production equipment
- Transport of raw materials and finished products
- Packaging of products
- Furnace rebuild

Excluded

- Construction of capital equipment
- Maintenance and operation of support equipment
- Manufacture and transport of packaging materials not associated to final product

- Moulds
- Internal transportation of materials
- Overhead (heating, lighting) of manufacturing facilities

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The following data is necessary:

1. **Raw materials needed for glass production:** e.g. sand, cullet, soda ash, limestone, dolomite, borax, boric acid, feldspar, zinc oxide, alumina, iron oxide, sodium sulphate etc.
2. **Melting furnace:**
   - Energy consumption (electricity/ natural gas) → specific to technology (electric, oxygen, end-/ cross fired)
   - Quantities specific to raw materials input
   - Direct emissions (e.g. CO_2, NO_x, SO_2, H_2S, dust, chlorides, fluorides, metals) and waste
   - Mass of “glass” leaving melting furnace
3. **Packaging design production:**
   - Mass of “glass” needed for production and final weight of product
   - Energies needed for production of glass packaging design
   - Direct emissions associated with production of packaging design
   - Information on top of packaging design (materials and weights)
4. **Logistics:** average transportation distance and mode of raw materials as well as final product
5. **End of Life: each EoL scenario which should be analyzed**
   - Materials/ chemicals, energies needed and direct emissions
   - Logistics/ transportation/ take back system

Material and energy inputs to container glass production

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Glass forming materials

- Silica sand, process cullet, post consumer cullet

Intermediate and modifying materials

- Soda ash (Na_2CO_3), limestone ($CaCO_3$), dolomite ($CaCO_3.MgCO_3$), feldspar, nepheline syenite, potassium
- carbonate, fluorspar, alumina, zinc oxide, lead oxide, barium carbonate, basalt, anhydrous sodium sulphate,
- calcium sulphate and gypsum, barium sulphate, sodium nitrate, potassium nitrate, boron containing
- materials (e.g. borax, colemanite, boric acid), antimony oxide, arsenic trioxide, blast furnace slag (mixed
- Calcium, aluminum, magnesium silicate and iron sulphide)

Coloring/ Decoloring agents

- Iron chromite ($Fe_2O_3.Cr_2O_3$), iron oxide (Fe_2O_3), cobalt oxide, selenium/zinc selenite

Energy: Electricity, fuels (e.g. natural gas, fuel oil, ….)

- Data Collection Excel

Transport & EoL Data Collection

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Proposal Presentation

Timelines, Visits and Deliverables of member companies

- East- Rishra (HNG) : November 23
- West- Jambusar (Piramal) : November 25/26
- South- Hyderabad (AGI) : Nov 28
- North- Bahadurgarh (HNG) : Dec 5
- Firozabad (Farukhi) : Dec 7/8

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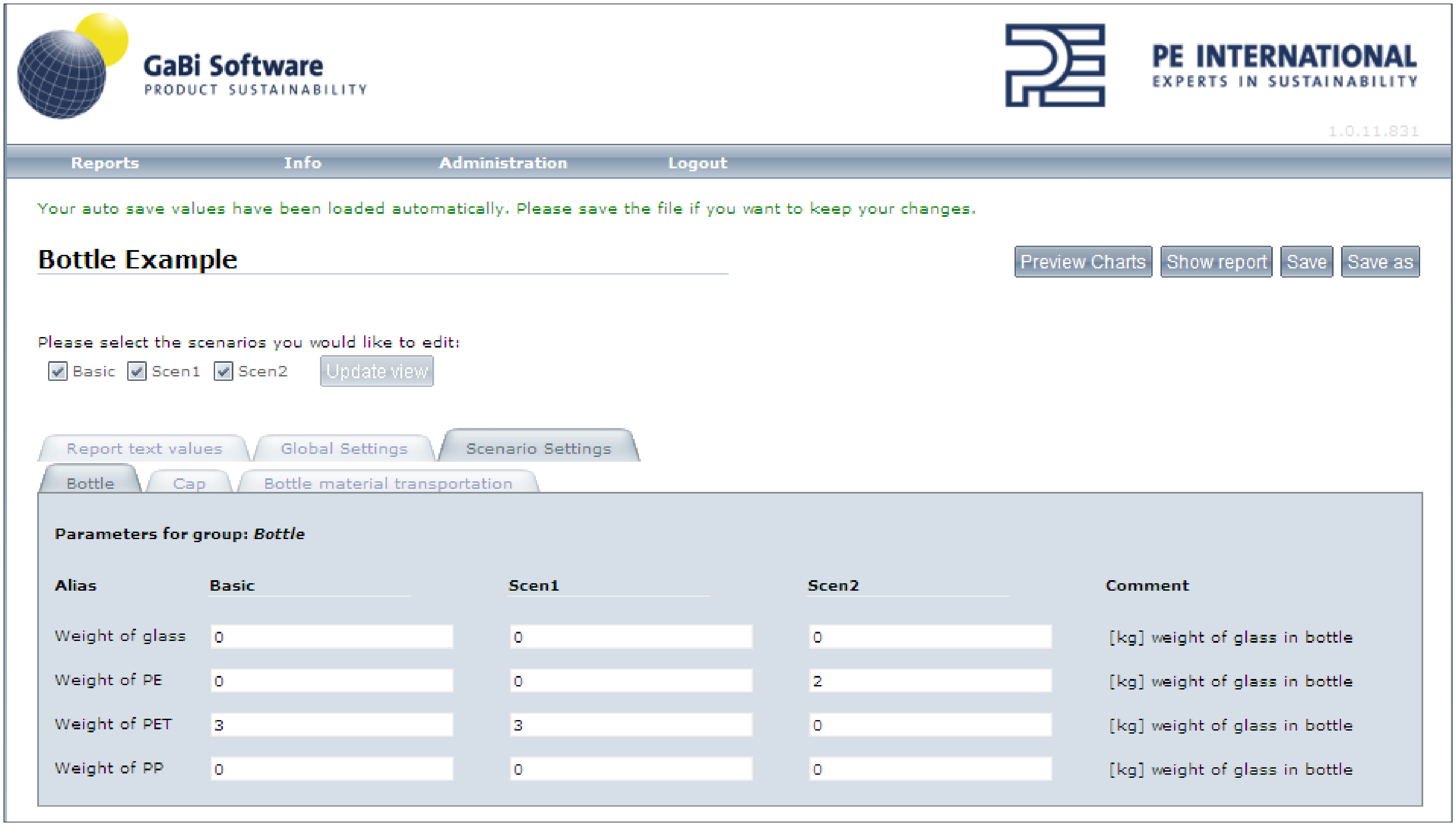
GaBi I-report

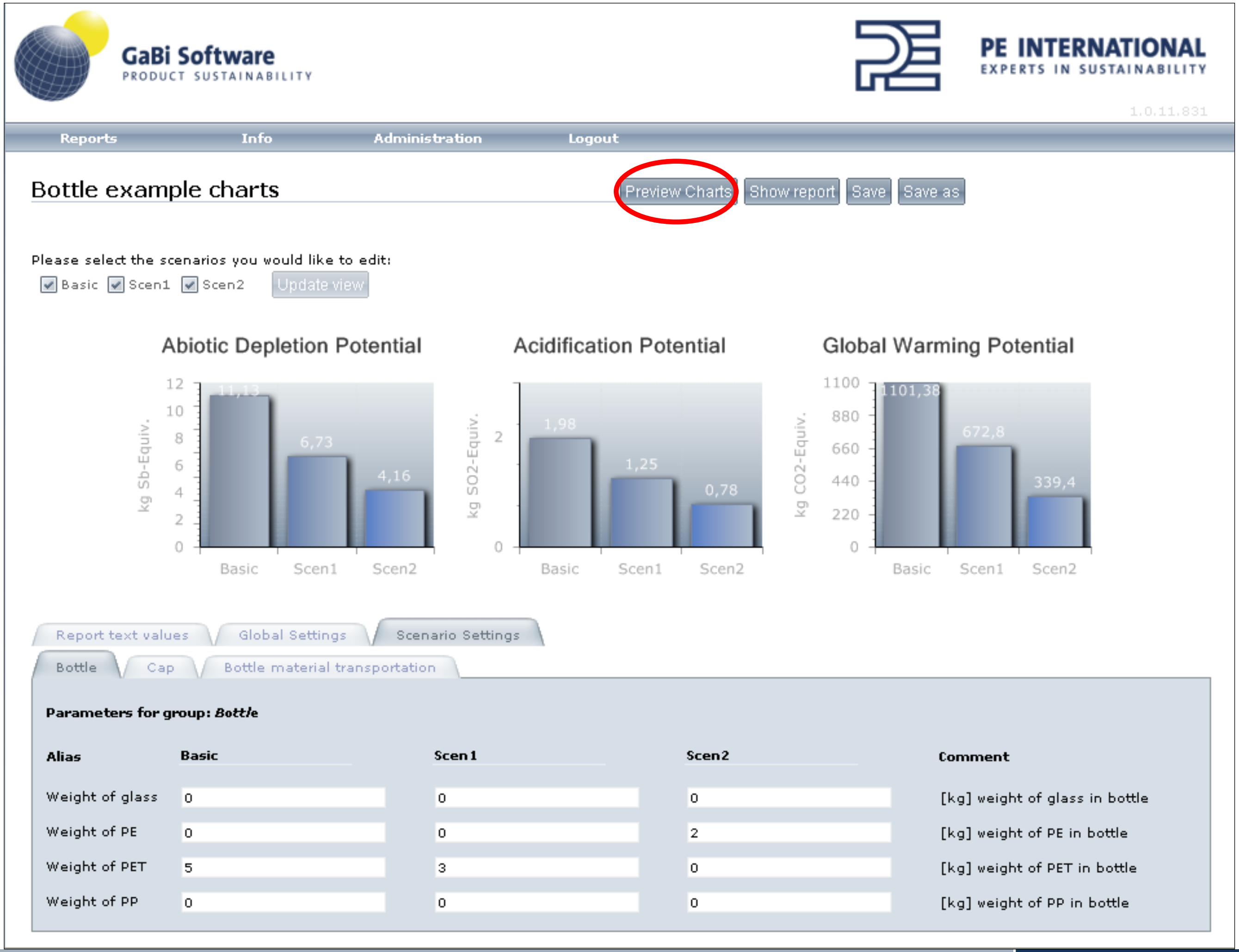
i-report

- The parameter section in the web is dynamically created from your GaBi model file



i-report

- Preview Charts give an quick overview of results



Which variables should be parameters?

- **Production**
  - **Raw Materials (cullet, sand, etc.)**
  - **Energy (electricity, natural gas, etc.)**
  - **Transportation (truck, rail, etc.)**
  - **Furnace type (regenerative, recuperative, etc.)**
  - **Packaging designs**
  - **Forming (press & blow, blow & blow)**
- **Use**
  - **Transportation (truck, rail, etc.)**
- **End of Life**

Default settings for industry or technology average and each company

Critical Review Process

- The critical review process involves the selection of the review panel.
- According to ISO at least 3 panel members are required.
- The recommendation is to cover within the review panel the LCA expertise as well as the technical expertise on glass and/ or packaging.
- A panel of three eminent experts would be selected through the mutual agreement from AIGMF.
- The panel would have one international Glass expert, one international LCA expert and one Indian LCA expert to do the peer review of the LCA of Glass Container along with the Comparative LCA of Glass vs PET, Tetra and Pouch.

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6. **Critical Review**
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Critical Review Process

- A Comparative Study on Food & Beverage Packaging Systems - PET, Tetra and Pouch
- Selection of variable parameters to analyze the main influencing parameters along the life cycle of all considered packaging options (EoL scenarios, logistics, recyclable content, etc.)
- Highlighting “green” aspects of container glass in comparison with competitive packaging systems

Technical Approach

- The following aspects of PET, Tetra and pouch will be analyzed:
  - cradle-to-cradle
  - EoL scenario
  - EoL pathway
  - Recovery rate
- Country specific conditions
- Material production data (gate-to-gate)
- Data quality / source

  The LCA model of PET, Tetra and pouch would not be based on the primary data collection but on an average calculation as per Indian specific condition.

Stages of Critical Review Process

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- **Stage 1: Report submission to the panel to understand the Study Purpose, Boundaries, and Data Categories**
  - Step 1:Convene brief teleconference of reviewers to make introductions and determine a Chairperson of Review Committee (who will be the primary communication point)
  - Step 2: Presentation of LCI results and comparative LCA results to reviewers
- **Stage 2: Review of LCA of Glass Containers**
  - Step 3: Panel reviews the LCI model
  - Step 4: Panel discusses potential revisions/adjustments to LCI model and communicates feedback.
  - Step 5: Incorporate feedback into revised LCI model
- **Stage 3: Review of the Comparative LCA of Glass vs. PET , Tetra, Pouch**
  - Step 7:Panel reviews the comparative LCA of Glass vs. PET, Tetra and pouch
  - Step 8:Panel discusses potential revisions/adjustments to the comparative study and communicates feedback
  - Step 9: Incorporate feedback into revised study

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PE INTERNATIONAL

Our business model is sustainability - since 20 years

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We assist our clients in:

Defining and Developing sustainable strategies

Analysing, assessing and managing the challenges and opportunities of sustainability:

- at the **company** level
- at the **product** level

Designing, developing and implementing Sustainability Solutions:

- Consulting
- Software
- Data bases

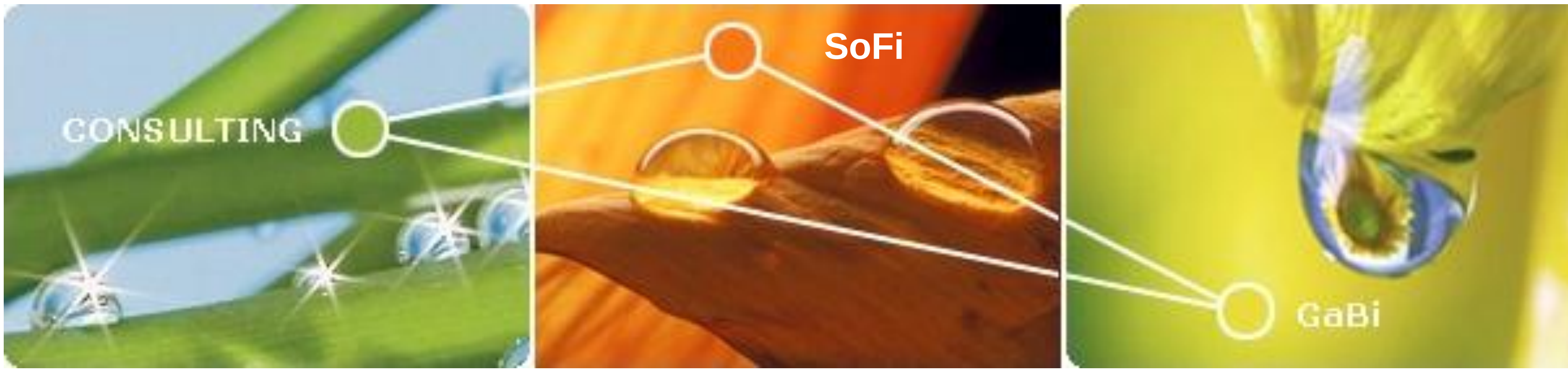
by using a unique set **of tools, services, expertise** and **people**, that enables them to leverage their innovative power and busines Value.

Our Vision:

We will be **market leaders** in dedicated sustainability markets.

We want to provide the **highest quality**, the **best service** and have a most exclusive **image**

Sustainability is a long-term issue – and has been a business model for PE INTERNATIONAL for 20 years.



Consulting

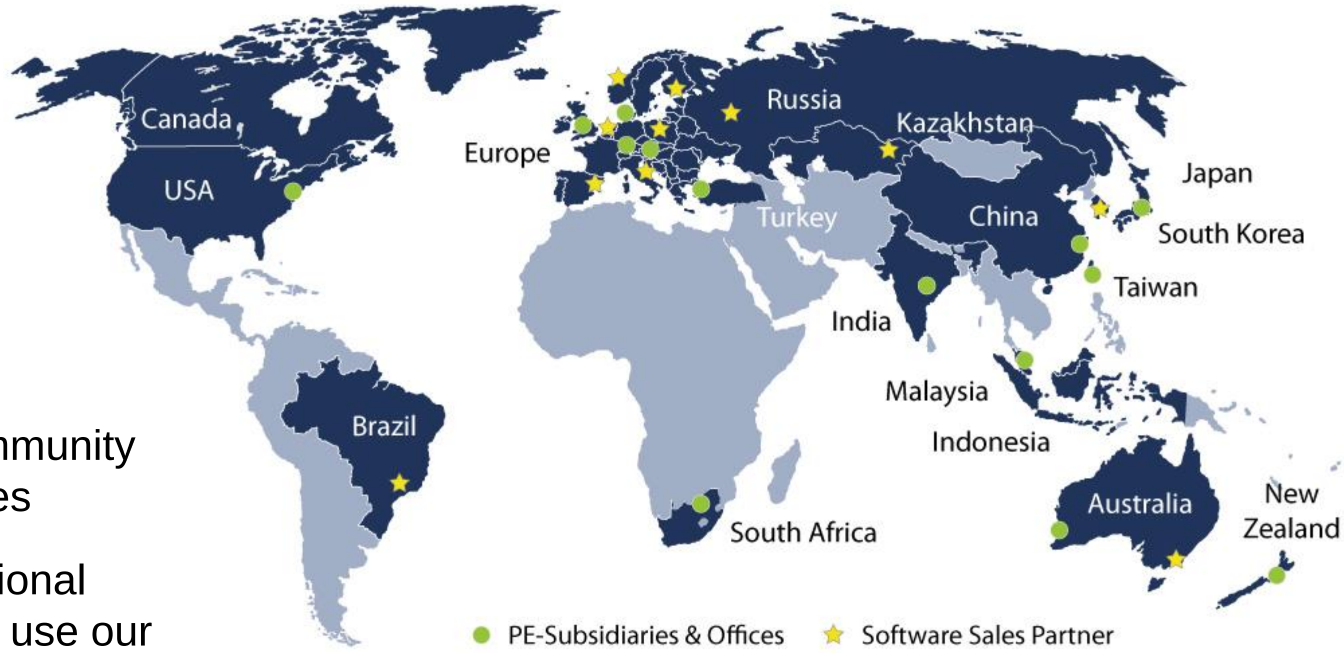
- Life Cycle Assessment (LCA)
- Energy efficiency studies
- Monitoring and Reporting Systems
- Carbon Footprints / Offset
- Compliance and risk management
- Management Systems
- Communication

Solutions for Corporate Sustainability

- Sustainability information management and reporting (e.g., GRI, ISO 14001, OHSAS 18000)
- Key Performance Indicator (KPI) systems
- Corporate Carbon Footprint
- Supply Chain Management

Solutions for Product Sustainability

- Life Cycle Assessment
- Design for Environment, Recycling, Disassembly
- Product Carbon Footprint



- In business since almost 20 years
- Wide variety of industries
- Satisfied user community in over 70 countries
- Over 500 Multinational companies (DJSI) use our solutions
- Setting standards through projects with international clients and standardization bodies worldwide
- Today, PE INTERNATIONAL employ approx. 140+ people worldwide representing 20 different nationalities in 10 companies, operating offices in 14 countries. Headquarters are in Stuttgart, Germany

Our Involvement

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•We participate in the development of the new Product Life Cycle Accounting and Reporting Standard and the Scope 3 (Corporate Value Chain) Accounting and Reporting Standard. We provide our **GaBi** and **SoFi** software to 60 global corporations for road testing of the new GHG Protocol standards .

CARBON DISCLOSURE PROJECT
ACCREDITED PROVIDER

•***"CDP is delighted to be working with PE INTERNATIONAL as a Carbon calculation Partner. SoFi has undergone testing by a third party to ensure it meets our criteria for performance and we are pleased to recommend this tool in the calculation of carbon emissions."***

•Paul Dickinson, CEO of the Carbon Disclosure Project

•We are a GRI Organisational Stakeholder since 2005 and were co-organizer of the launch conferences . We are involved in the OS feedback processes and applied for certification of our **SoFi** software.

•We participated in the standardization group that developed the **PAS 2050 -** Assessing the life cycle greenhouse gas emissions of goods and services.

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Selection of references

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- Automotive
- Automotive suppliers
- Aerospace
- Electronics
- Materials
- Chemical
- Construction

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Selection of references

- Heating
- Energy
- Finance
- Public bodies
- Food/Retail
- Asssociations

Key References

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- Name of client organization:
  European Container Glass Federation (FEVE), Brussels
- Type of Business:
  Industry Association
- Projects and Services provided:
- PE International worked with the European Container Glass Federation (FEVE) to develop the Life Cycle Inventory of container glass production in Europe. During the project, PE International worked closely with member companies to collect primary data from almost **two-hundred plants**, representing over **72% of the European market**. This critically reviewed LCA study, conducted in parallel with a study in North America, contains the first industry wide primary data available on the production of container glass used for packaging materials.
- In addition to development of LCI profiles, PE International developed an **interactive Life Cycle Assessment calculator**. This interactive report (i-Report) allows FEVE member companies to run simulations with varying packaging designs, efficiency, transportation, and end-of-life scenarios. PE International also supported FEVE in the communication of their environmental performance results with stakeholders.

Key References

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- Name of client organization:

  Glass Packaging Institute (GPI), United States
- Type of Business:

  Industry Association
- Projects and Services provided:

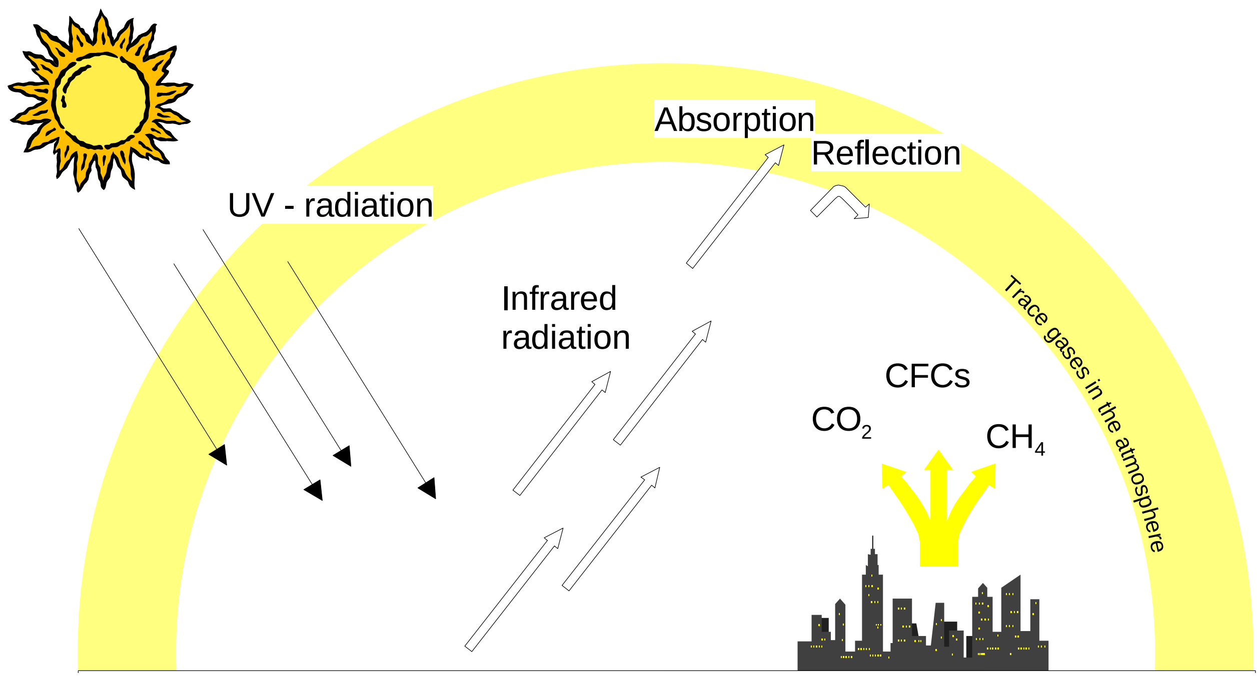
  PE worked with the Glass Packaging Institute (GPI) to develop the Life Cycle Inventory of container glass production in North America. During the project, PE Americas worked closely with member companies to collect primary data from **over one-hundred plants**, representing over **75% of the US market**. This critically reviewed LCA study, conducted in parallel with a study in Europe, contains the first industry wide primary data available on the production of container glass used for packaging materials.
- In addition to development of LCI profiles, PE developed an **interactive Life Cycle Assessment calculator**. This interactive report (i-Report) allows GPI member companies to run simulations with varying packaging designs, efficiency, transportation, and end-of-life scenarios. PE Americas also advised GPI on how to communicate their environmental performance results with stakeholders.

Effect: Increased warming of the troposphere due to anthropogenic greenhouse gases e.g. from the burning of fossil fuels.

Reference Substance: Carbon Dioxide (CO_2)

Reference Unit: kg CO_2-Equivalent

Source: IPCC (Intergovernmental Panel on Climatic Change)

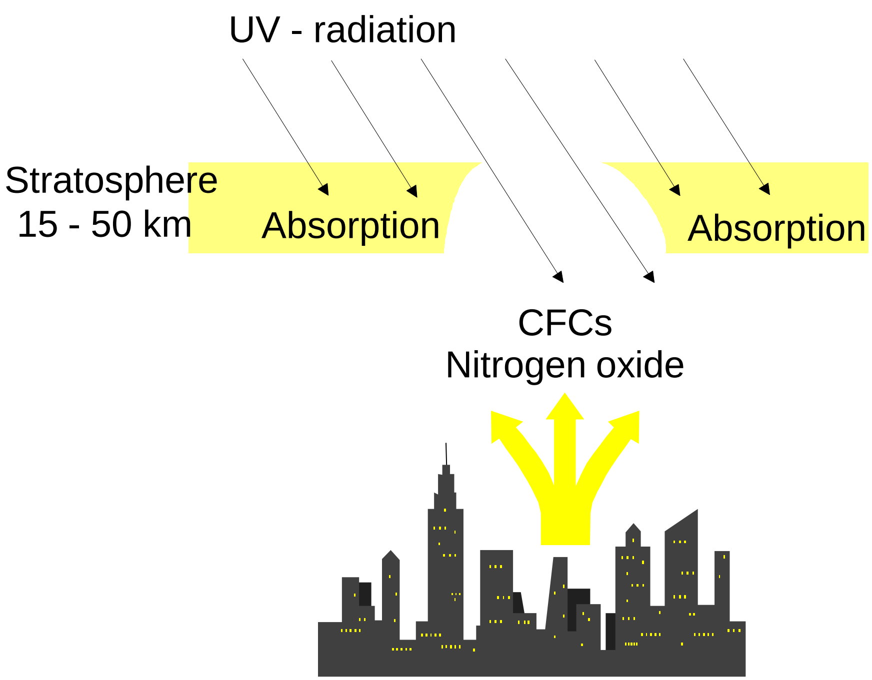


Effect: Reduction in the ozone concentration of the Stratosphere due to emissions such as Chloro-fluoro-carbons (CFCs)

Reference Substance: Tri-chloro-fluoro-methane (R11)

Reference Unit: kg R11-Equivalent

Source: CML, (Heijungs, Centrum voor Milieukunde Leiden), 1992

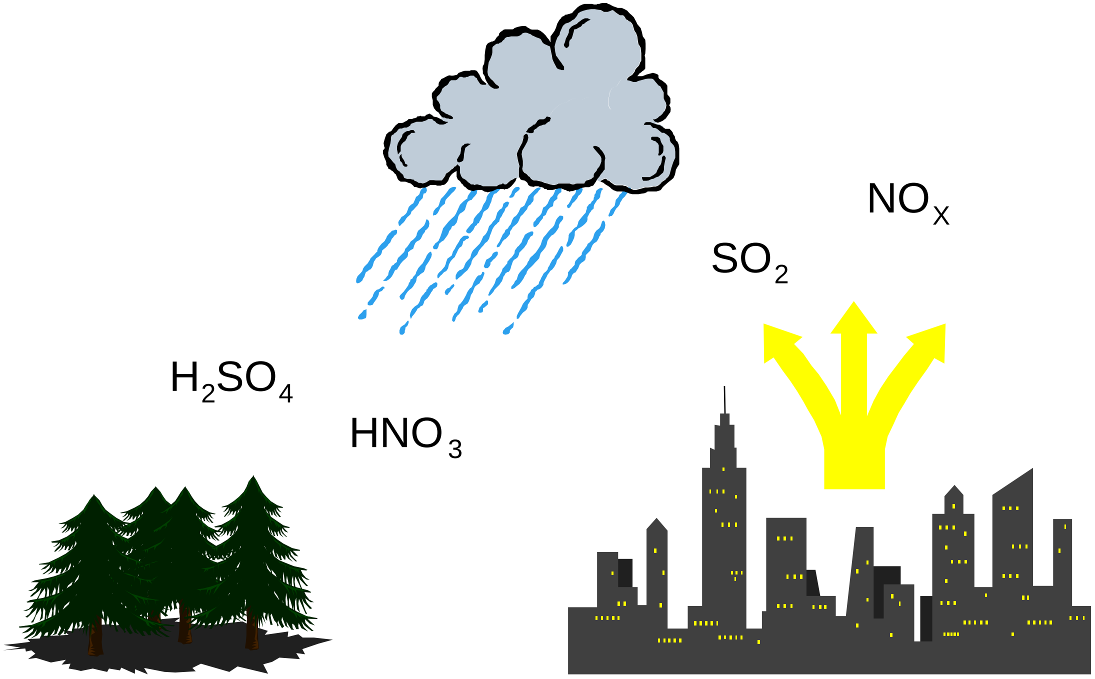


Effect: Increase in the pH-value of precipitation due to the wash-out of acidifying gases e.g. Sulphur dioxide (SO_2) and Nitrogen oxides (NO_x).

Reference Substance: Sulphur dioxide (SO_2)

Reference Unit: kg SO_2-Equivalent

Source: CML, (Heijungs, Centrum voor Milieukunde Leiden), 1992



Life Cycle Impact Assessment

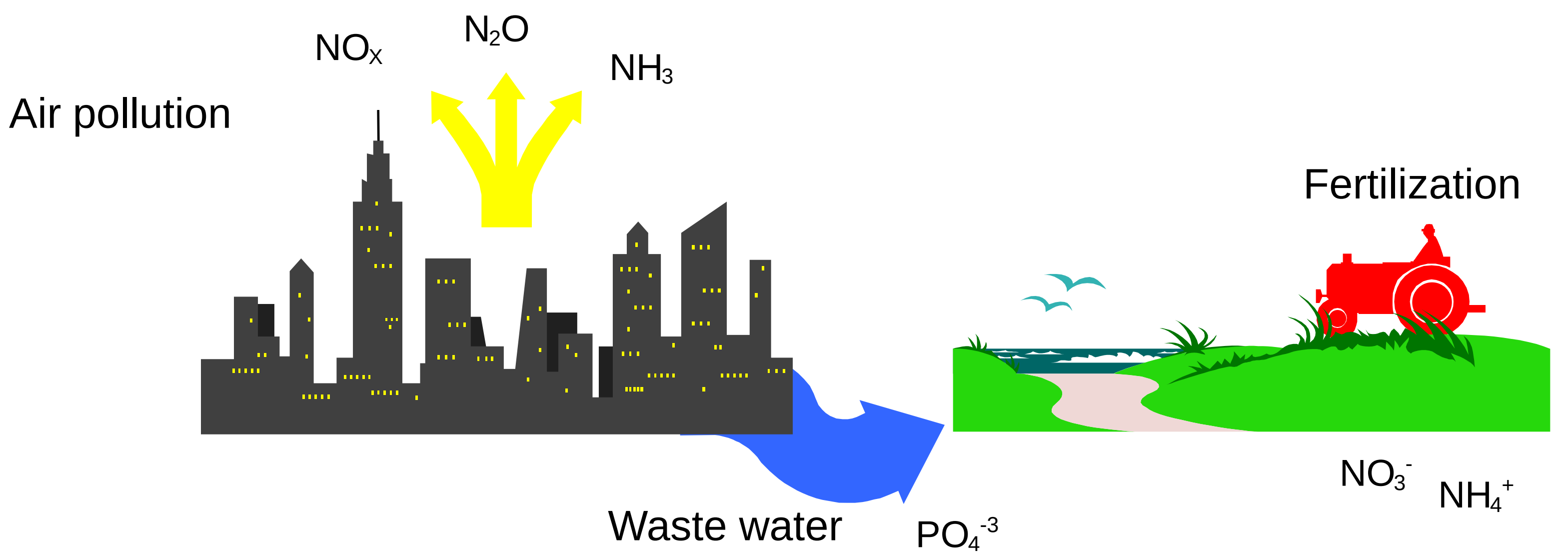
Eutrophication Potential (EP)

Effect: Excessive nutrient input into water and land from substances such as phosphorus and nitrogen from agriculture, combustion processes and effluents.

Reference Substance: Phosphate (PO_4-)

Reference Unit: kg PO_4- Equivalent

Source: CML, (Heijungs, Centrum voor Milieukunde Leiden), 1992

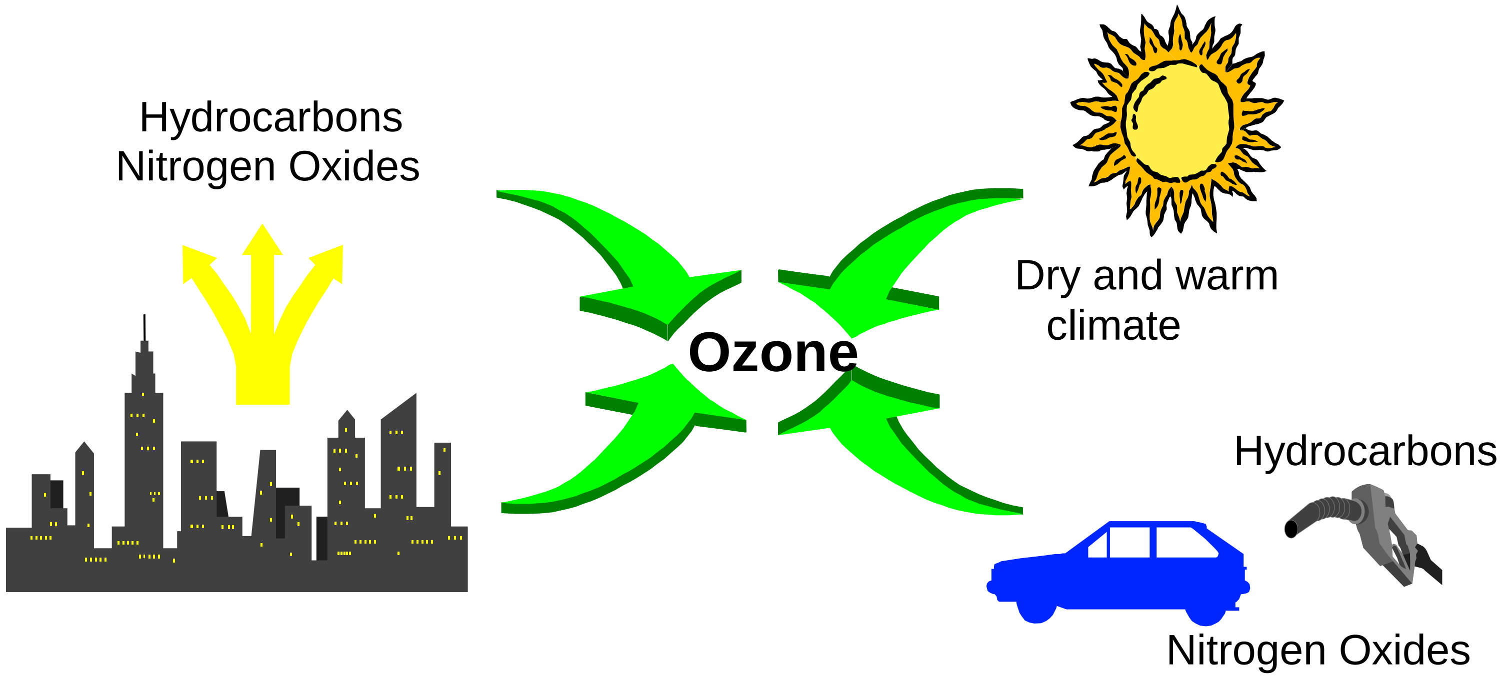


Effect: Formation of low level ozone by sunlight instigating the photochemical reaction of nitrogen oxides with hyrocarbons and volatile organic compounds (VOC)

Reference Substance: Ethylene (C_2H_4)

Reference Unit: kg C_2H_4 -Equivalent

Source: Udo de Haes et al., 1999



Human Toxicity Potential (HTP)

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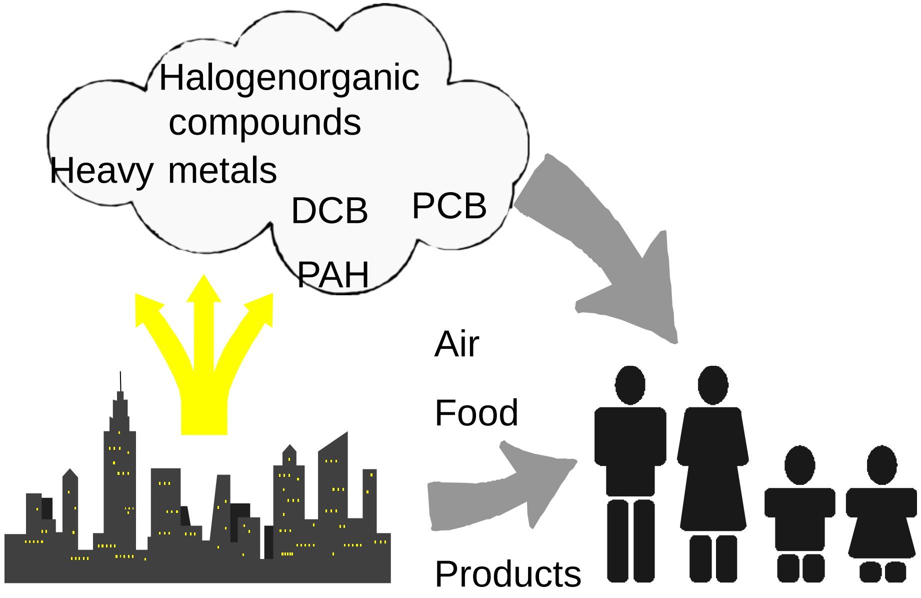
Effect: Continuous toxicological impact on humans (arbitrary estimation)

Reference Substance: 1,4-Di-chloro-benzene (DCB, $C_6H_4Cl_2$)

Reference Unit: kg DCB - Equivalent

Source: CML (Centrum voor Milieukunde Leiden); RIVM (National Institute of Public Health and Environmental Protection)

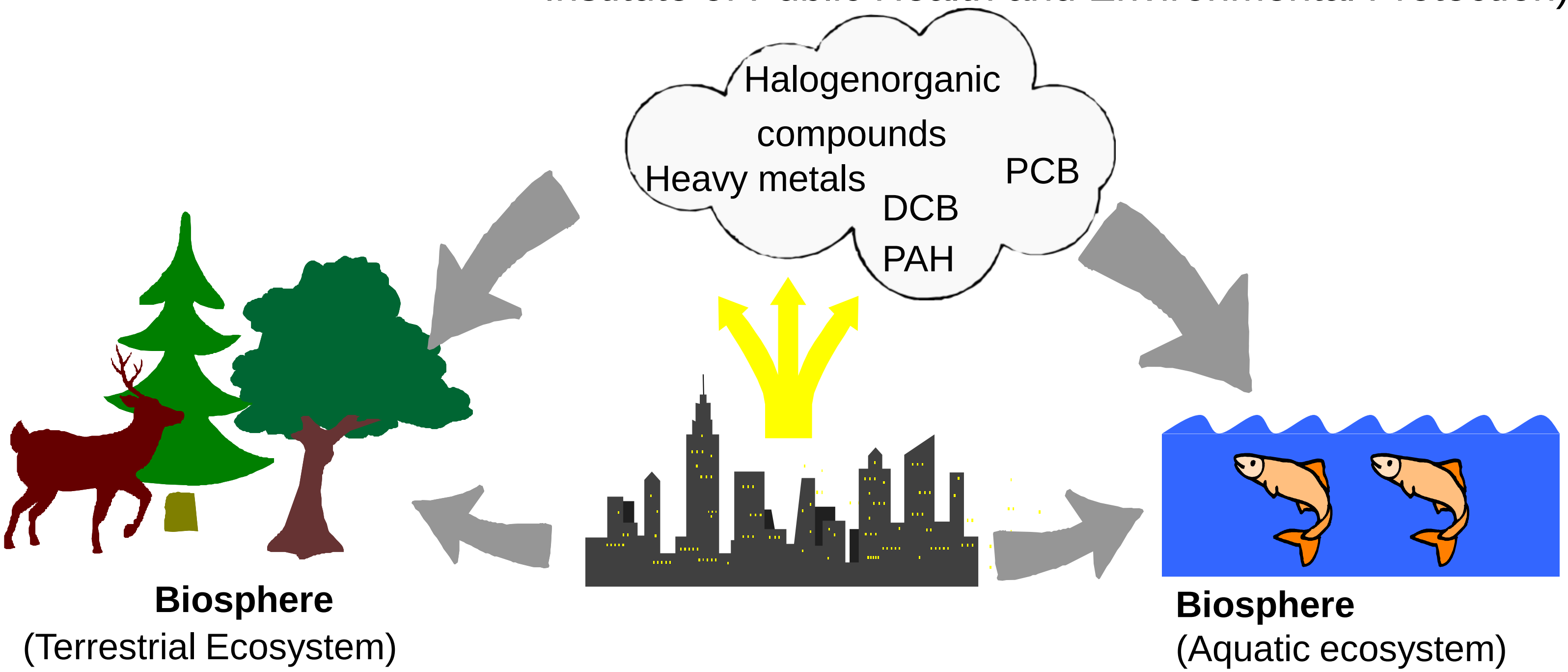


Effect: Continuous toxicological impact on aater and soils (arbitrary estimation)

Reference Substance: 1,4-Di-chloro-benzene (DCB, $C_6H_4Cl_2$)

Reference Unit: kg DCB - Equivalent

Source: CML (Centrum voor Milieukunde Leiden); RIVM (National Institute of Public Health and Environmental Protection)



Reminder: elements of life cycle impact assessment:

- **Classification:** Assignment of LCI results which are exclusive to one impact category and identification of LCI results which relate to more than one impact category.
- **Characterization:** Conversion of LCI results to common units and the aggregation of the converted results within the impact category.
- **Normalization:** Calculation of the magnitude of the category indicator results relative to reference value(s) → Comparison with the reference quantity.
- **Weighting:** Conversion and often aggregation of indicator results across categories using numerical factors based on value-choices

Inventory value	*	GWP Factor	=	Impact potential
25 kg CO_2	*	1	=	25 [kg CO_2-Equivalent]
2 kg CH_4	*	23	=	46 [kg CO_2-Equivalent]
...	*	...	=	...
			Total:	71 [kg CO_2-Equivalent]

1 kg CH_4 is equivalent to the impact of 23 kg CO_2

Inventory

Resources

.....

Emissions to air

CO_2
CO
CF_4
CH_4
N_2O
NO_x
SO_2
HCl
HF
.....

Emissions to water

Phosphate
NH_3
NH_4
.....

	GWP
CO_2	1
CO	3
CF_4	6300
CH_4	23
N_2O	270

$\sum GWP_i * Emission_i$ [kg] → $\sum$ **GWP**

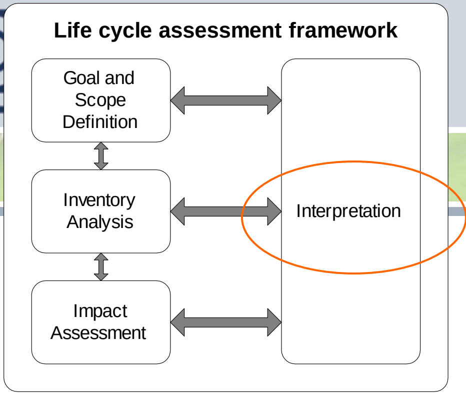
	AP
NO_x	0.7
SO_2	1
HCl	0.88
HF	1.6

$\sum AP_i * Emission_i$ [kg] → $\sum$ **AP**

	NP
NO_x	0.13
Phosphate	1
NH_3	0.33
NH_4	0.33

$\sum EP_i * Emission_i$ [kg] → $\sum$ **EP**

The final steps: Interpretation, Report and Critical Review



Interpretation:

On the basis of the inventory results and the impact assessment the analysis and interpretation of the study is performed. These are the fundamentals for further discussions or system optimization.

Report:

Prerequisites of performing a Life Cycle Assessment are the definition and the specification of a large number of system boundaries as well as the description of the system investigated. To guarantee the traceability of the results obtained, a defined way of reporting is necessary.

Critical Review:

For internal projects this step is an optional one. If a study compares competitive products and will be published, a critical review of the study is required.

GWP Example System	**Total**	**71**	**kg CO_2 Equivalent**
		/	
Normalization Factor		**4.94E+12**	**kg CO_2-Equivalent**
=		↓	
Normalized Global Warming Potential		**1.35E-11**	

In this step the impact potentials are put in relation to the total potential in a defined reference area i.e. United States.

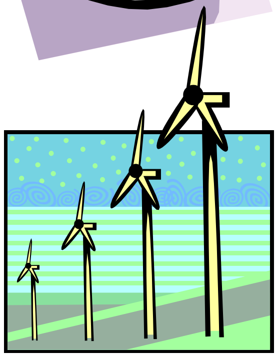
→ **Result:** **non-dimensional quantities, which allow comparison of impact potentials**

Life Cycle Impact Assessment

Categories - global, regional and local

Global Criteria

- Resource depletion
- Global Warming Potential (GWP)
- Ozone Depletion Potential (ODP)



Regional Criteria

- Acidification Potential (AP)
- Land use

Local Criteria

- Human- and Eco-Toxicity Potential (HTP, ETP)
- Eutrophication Potential (EP)
- Photochemical Oxidant Creation Potential (POCP)

Other Criteria

- Nuisance (noise, odor, landfill demand, ionizing radiation)