Green Chemistry & Engineering 101 Workshop

Integrating Green Chemistry into the Sustainability Tool Box

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MICHIGAN GREEN CHEMISTRY CLEARINGHOUSE

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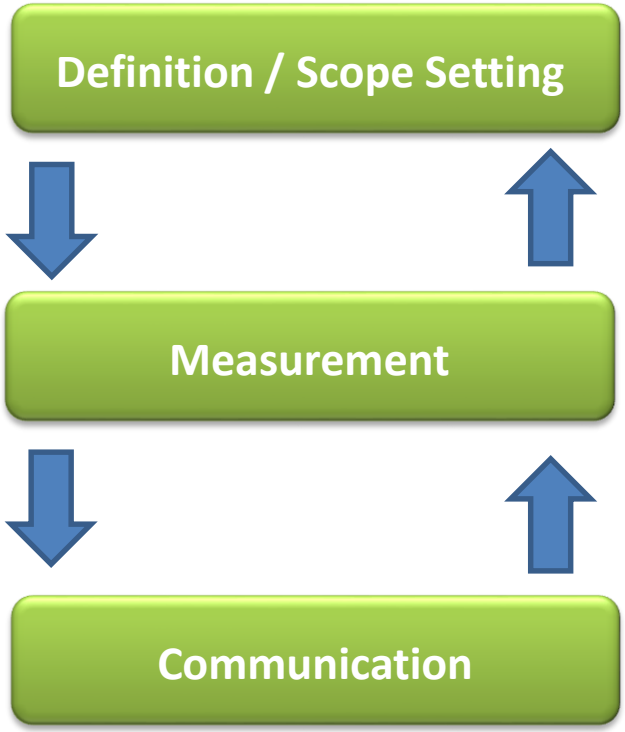
Creating the Toolbox



*What is **measured and communicated** should be consistent with how green is **defined***

*What is **communicated** should be consistent with what is **measured***

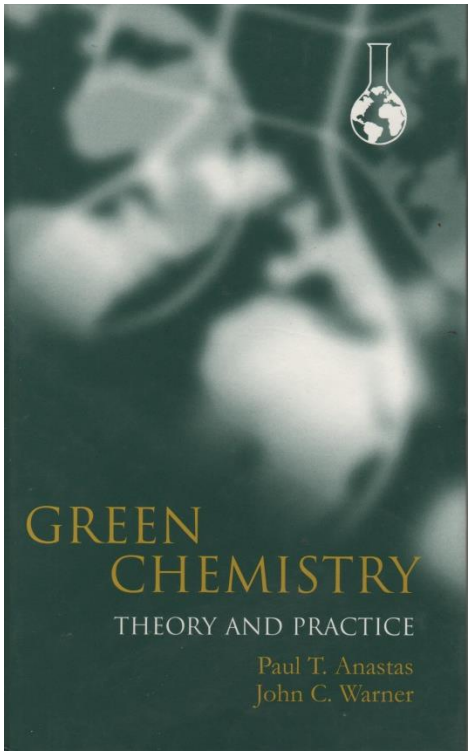
- **Databases**
- **Modelling software**
- **Monitoring & tracking**
- **Assessment protocols**

- **Substances of Concern Lists**
- **Reporting formats**
- **Guidance documents**
- **Standards**

Definition

- **What is Green Chemistry?**

Green Chemistry is the utilization of a set of **principles** that reduces or eliminates the use or generation of **hazardous substances** in the **design**, **manufacture** and **applications** of **chemical products**.[1]



1: Anastas, Paul T., and Warner, John C. Green Chemistry Theory and Practice, Oxford University Press, New York, 1998.

❑ Definition of Hazard / Hazardous

- Hazard is the inherent potential for a chemical, substance or waste to:
  (1) be toxic
  (2) be corrosive, ignitable, explosive, or chemically reactive ,or
  (3) adversely impact humans and the environment.

- Such chemicals, substances and wastes are defined as being "hazardous".

"not harmful to human health and the environment"

Human Health and Ecosystem Impacts

Life Cycle Impact Categories

- Resource depletion
- Land Use
- Global warming
- Stratospheric ozone depletion
- Acidification
- Eutrophication
- Smog formation
- Ecotoxicity
- Human health

Ecotoxicity

- Persistence
- Bioaccumulation
- Fugacity
- Toxicity

Human Health

- Carcinogenicity
- Mutagenicity
- Reproductive toxicity
- Developmental toxicity
- Teratogenicity
- Endocrine disruption
- Respiratory sensitization
- Asthmagens
- Neurotoxicity
- Hepatoxicity
- Systemic toxicity
- Skin irritation

Physical Hazard (Safety)

- Flammability
- Radioactivity
- Oxidizer
- Water-reactive
- Corrosive
- Explosivity

NSF /GCI /ANSI 355: *Greener Chemicals and Processes Information: Gate-to-gate information on chemical products and their manufacturing processes*

- Standardizes data elements, data quality objectives and **business-to-business reporting format** for specific categories pertaining to "greenness" within a gate-to-gate boundary:
- Does not offer a standardized, normative definition of "green" or "greener" or related term; however, under "Purpose" states:

"…greener refers to the relative measure of ecosystem and human health impacts of a chemical and its process when compared to the same or similar chemical and its process"

Primary Categories:

Product-Level	Process-Level	Facility-Level
Chemical Characteristics	**Chemical Processes**	**Social Responsibility**
Tier 1 ○ Human Health Effects (16) ○ Ecological Effects (22) ○ Physical Safety Properties (9)	Materials & Waste ○ Process Mass Efficiency ○ Recycled/Reused inputs ○ Waste generation	Human Rights ○ Child Labor ○ Forced Labor ○ Compliance
Tier 2 ○ Endocrine Disruption	Water ○ Use ○ Consumption ○ Discharge	Society Performance Indicators [OPTIONAL]
	Energy & GHG	
	Process Safety	
	Bio-Based Carbon Content	
	Innovation	

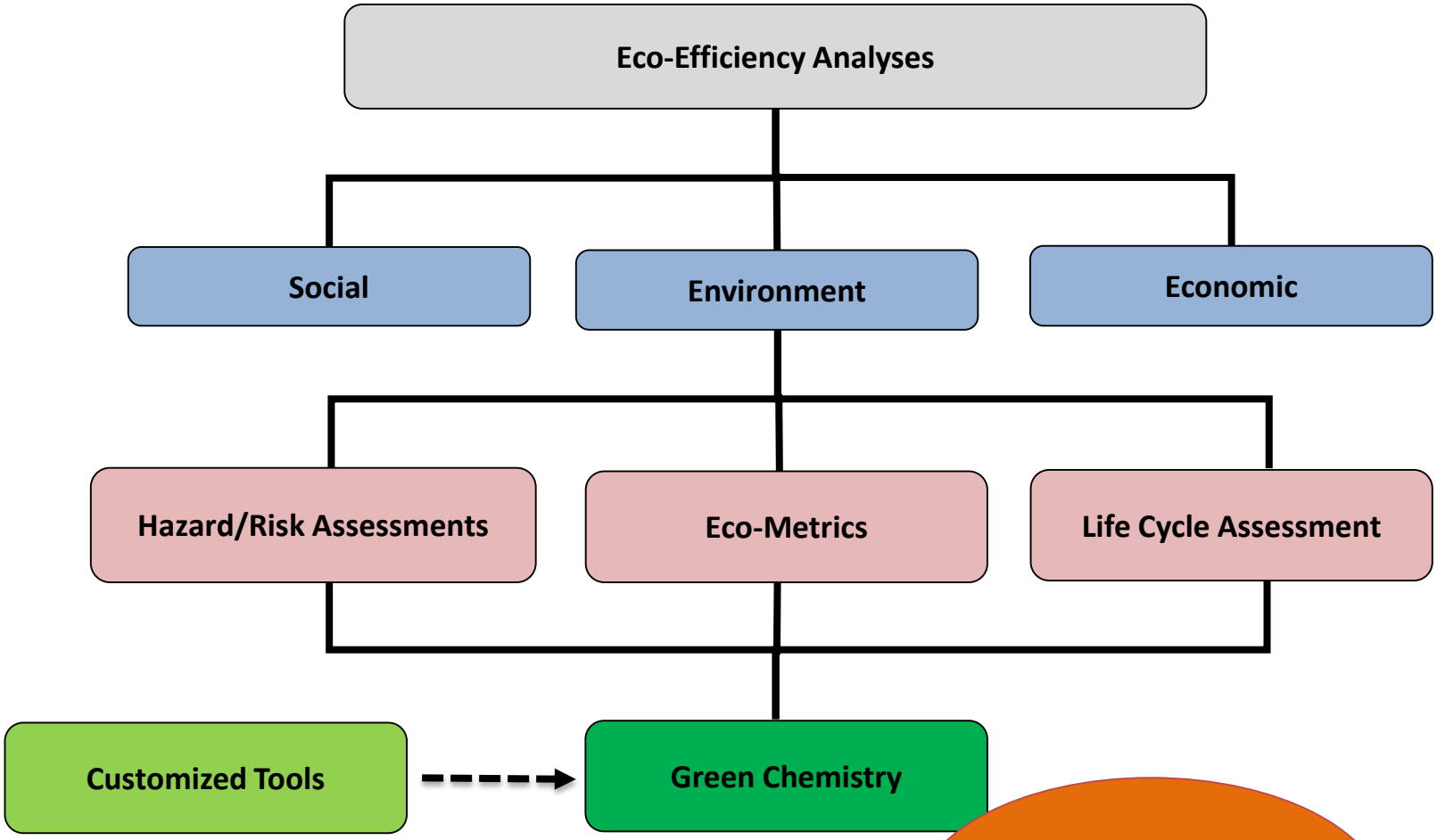
Scope and Boundaries

- *Establish scope and boundaries in deliberate and transparent manner*
- *Comparison of alternatives requires the same scope and boundary conditions*

- How does it fit with existing sustainability programs?
  - **Corporate Sustainability Policy**
  - **Key Performance Indicators**
  - **Sustainability metrics**
- Internal versus external drivers (regulatory, standards etc.)
- Single attribute vs. multi-attribute
- Life cycle Approach:
  - Life Cycle Stages
  - Life Cycle Impact Categories
  - Scale: Local, Regional, Global
- Product, process, service, packaging
- Relevance and significance

Measurement

Populating the Toolbox: Selecting the Tools



- **Point of Application: Design**
- **Conceptual approach**

iSustain™ Green Chemistry Index v2.0
specifically developed around the 12 Principles

Some factors to consider in selecting right tool for the job

- Internally developed vs. externally vetted
  - Does it comply to a standardized or procedure?
- Relevance and significance:
  - Measure “green” according to the scope and boundaries of the assessment
  - Measure the significant environmental aspect(s)
- Empirical considerations:
  - Qualitative, Semi-quantitative, quantitative
  - Measured, calculated, predicted (modelled)
  - Physical consumption vs. impact assessment
    - Physical consumption: consumption of water, energy, materials etc. in physical units
    - Impact assessment: life cycle impact categories
  - Numeric score(s)
    - Individual impacts
    - Cumulative impacts
    - Absolute or normalized
  - Data quality objectivities
  - Uncertainties and sensitivities
  - Multi-attribute analysis

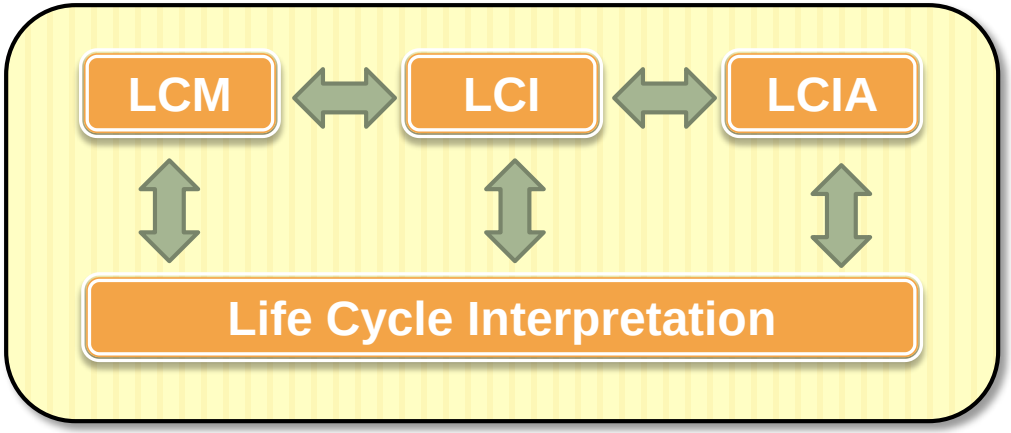
Life Cycle Assessment (LCA)

"Compilation and evaluation of inputs into and outputs and the potential environmental impacts of a product system throughout its life cycle." - ISO 14040

- Tool for the systematic (methodological) evaluation and ***quantification*** of the environmental aspects of a product or service system for all stages of its life cycle and life cycle impact categories.

- Standardization:

  ISO 14040:2006 "Environmental management -- Life cycle assessment -- Principles and framework" and Series



Life Cycle Management (LCM)

- ❑ Goals and Scope
- ❑ Define ***functional unit***
- ❑ Setting boundaries:
  - ▪ Life Cycle Stages
  - ▪ Life Cycle Impacts

Life Cycle Inventory (LCI)

- ❑ Identify and quantify flows for:
  - ▪ Material inputs
  - ▪ Energy inputs
  - ▪ Wastes & emissions
- ➢ Physical quantities (standard units of measure)

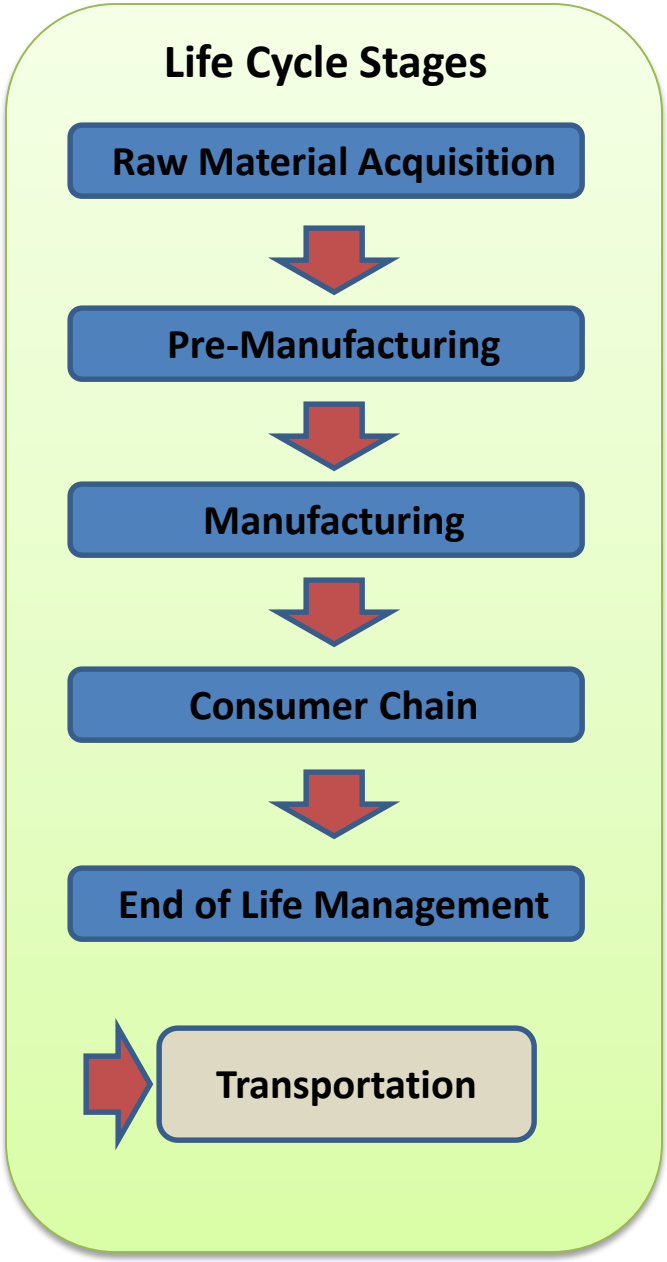
Life Cycle Impact Assessment (LCIA)

- ❑ Impact categories:
  - ▪ Selection
  - ▪ Classification
  - ▪ Characterization Factors
- ❑ Multiple-attribute analysis:
  - ▪ Normalization
  - ▪ Grouping
  - ▪ Weighting

Life Cycle Interpretation

- ❑ Evaluation: Sensitivity & Uncertainty Analysis
- ❑ Documentation and communication (in transparent manner)

Life Cycle Stages



Life Cycle Impact Categories

- ❑ Resource depletion
- ❑ Land Use
- ❑ Global warming
- ❑ Stratospheric ozone depletion
- ❑ Acidification
- ❑ Eutrophication
- ❑ Smog formation
- ❑ Ecotoxicity
  - ▪ Terrestrial toxicity
  - ▪ Aquatic toxicity
- ❑ Human health

Life Cycle-Based Tools

- Full LCA
- Streamline LCA:

  - Focus on specific life cycle stages: e.g.
    - Cradle-to-Gate
    - Gate-to-Gate
  - Focus on specific impact categories: e.g.
    - Global warming potential for carbon foot-printing (carbon label rules)
    - Life Cycle Energy Analysis (LCEA)

- Combination of primary consumption data and impact potential characterization

- Integrate with other **sustainability metrics**:
  - Economic input–output life cycle assessment
  - Environmental Value Chain Analysis
  - Life Cycle Costing
  - Social / Socio-Economic LCA
  - Eco-Efficiency Analyses

Characterization Factors

Conversion of LCI data (in physical units) to a measure of impact potential (equivalency units)

$$\text{Impact Metric} = \Sigma\,(Y_i \times M_i)$$

where,
Y_i = impact potential of material *i* (characterization factor)
M_i = quantity of material *i* (mass or moles)

- Each life cycle impact category has its specific set of characterization factors:
  - Confidence in the characterization factors can vary significantly
  - Characterization factors may not yet be developed for specific chemicals, materials etc.
  - Conversion based on characterization factors works better for some impact categories (e.g. those were the LCI data are standard physical units for quantity)

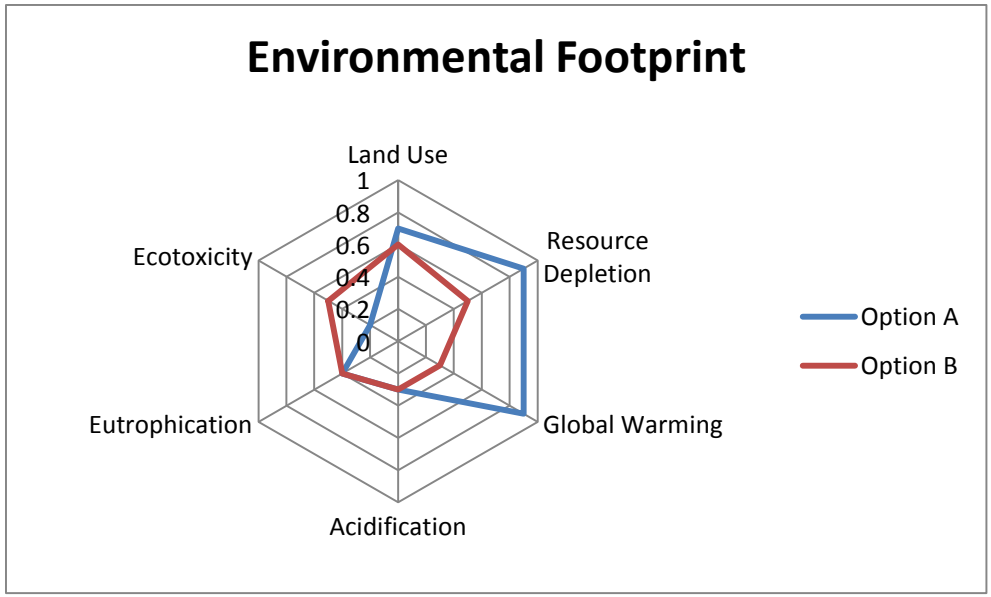
- Process:
  - Normalization
  - Grouping
  - Weighting (valuation)

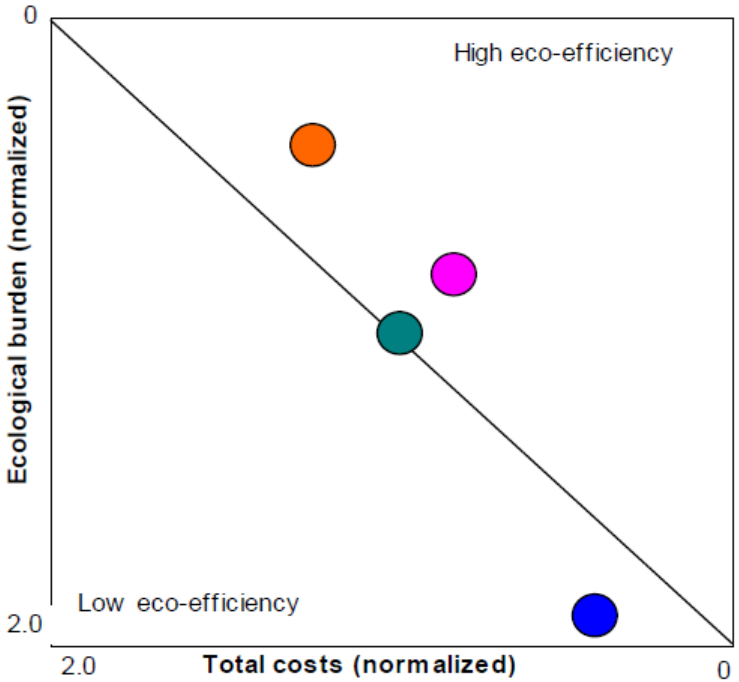
"weighting, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public".
(ISO 14044:2006)

- Internal comparative analysis of:
  - Changes to a specific process
  - Different products (with equivalent functional unit)
- External comparative analysis of competitive products?

Multi-Attribute Analysis

Considering that impact categories have no numeric relationship, how can the life cycle-based tools be used to allow comparative analyses of overall (cumulative) environmental impact





Source: NSF Protocol 355 *Validation and Verification of Eco-efficiency Analyses*

Communication

*What is **communicated** should be consistent with the **definition**, **scope**, **measurement** of green*

Recognizing:

- Limitations of tools:
  - Results are **model-dependent** and interpretation should be made with full access to the model (boundary conditions, assumptions weighting etc.)
  - Tool may not be intended for comparative purposes
  - Complexity:
    - May lead to misunderstanding or misrepresentation
    - Significance of specific environmental impacts may be lost (tool may not be appropriate)

- What is the intended purpose and who is the intended audience?

- Internal decision making

- External communications:
  - Business-to-Business
  - Business –to-Consumer

Standardization of Environmental Marketing Claims

- **Federal Trade Commission (FTC) *Green Guides***[1]

- "It is deceptive to misrepresent, directly or by implication, that a product, package, or service offers a **general environmental benefit**" (emphasis added)
- Examples cited:
  - Eco-friendly
  - Greener

Guiding Principles for General and Specific Claims

- **Qualifications and disclosures** – clear, prominent, and easily understood language (transparency); avoid ambiguity
- **Distinction between benefits of product, package and service** – does the claim refer to the product, packaging, or service, and to the components in part or full? Language must be encompassing
- **Overstatement of environmental attribute** – avoid express or implicit overstatements of the significance of an attribute; includes claims without qualification
- **Comparative claims** – clearly state basis for comparison, and substantiate claim, especially over time

- **Transparency**
- **Specificity**
- **Qualification**
- **Substantiation**

1: 16 C.F.R. Part 260 – Guides For The Use of Environmental Marketing Claims (Revised 2012)

❑ International Organization of Standardization (ISO)[1]

ISO 14020 "Environmental labels and declarations -- General principles"[1]

- **Type I**

  Performance against standards established and verified by an independent third-party organization; A mark or logo ("eco-label") is awarded for fulfillment of criteria.

- **Type II**

  Self-declaration made by company using criteria established by company themselves (i.e. first-party); may not undergo an independent third-party review.

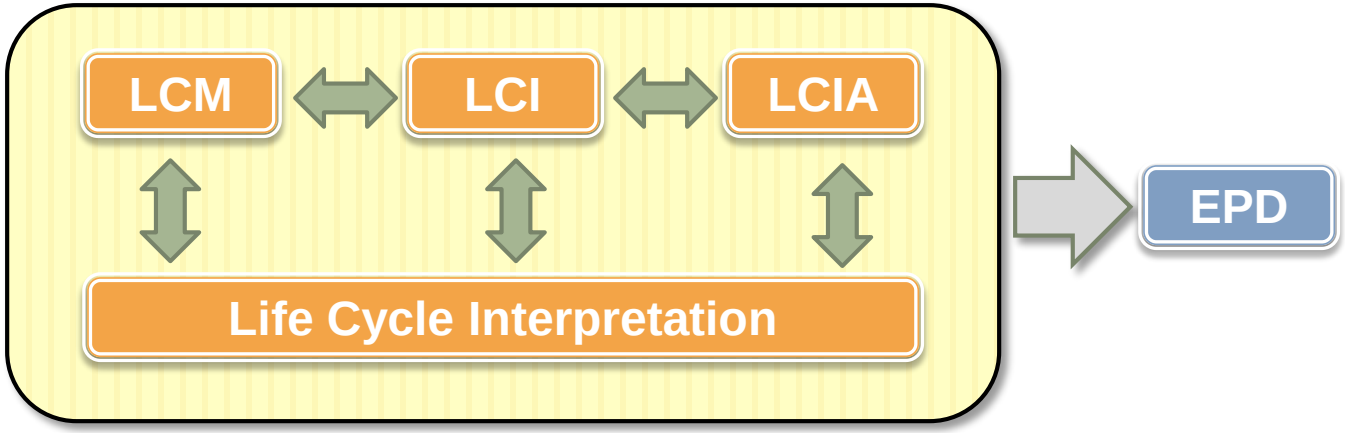
- **Type III**: Environmental Product Declarations (EPD)

> "Quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information." - ISO 14025

1: ISO 14020 series includes: ISO 14021:1999 (Type II); ISO 14024:1999 (Type I); ISO 14025:2006 (Type III)

Environmental Product Declaration (EPD)

❑ A label that discloses the environmental performance of a product over its life cycle (environmental marketing claim)



❑ Standardization

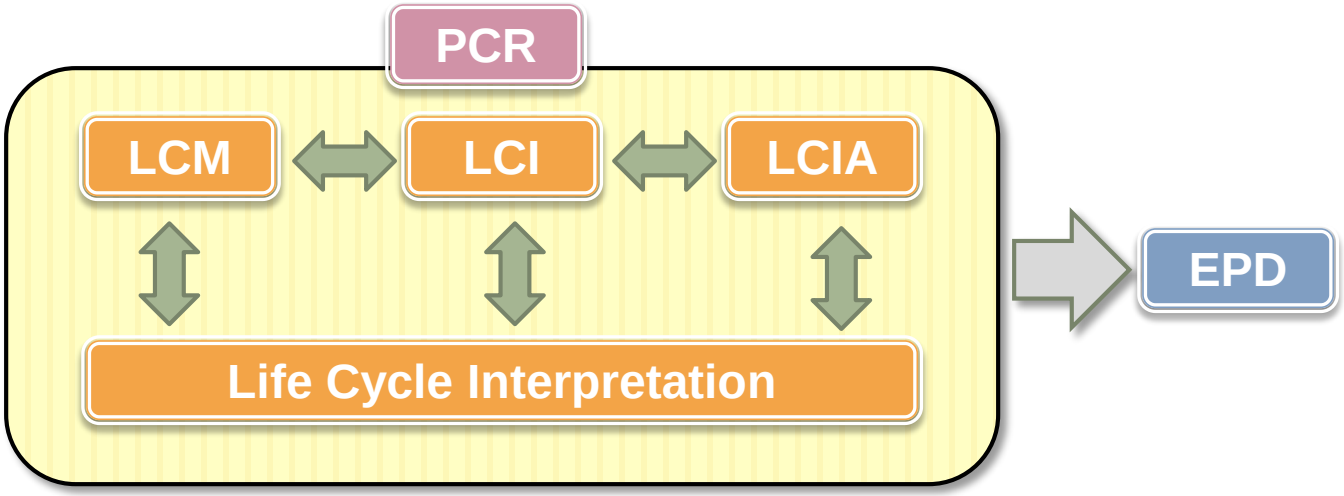
- ❖ Must be based on Life Cycle Assessment (LCA) in accordance with:
  - ISO 14040: 2006
  - Product Category Rules (PCR)
- ❖ Compliant with ISO 14025: 2006
  - Independent third-party verified

- Primarily intended for Business-to-Business communication, but their use for Business-to-Consumer is not precluded.

- Not intended for comparative claims

- Content:
  - Product description (including functional unit)
  - Material Declaration
  - EPD Declaration: LCA scope (boundaries - life cycle impact categories, stages) & results (material/energy flows, emissions, impacts etc.)
  - Other environmental information
  - Statement of conformance and verification (ISO Standards, PCR, independent review)

Product Category Rules (PCR)



- Set of specific rules, requirements and guidelines for developing an EPD for a given product, including predetermined parameters on how the LCA must be conducted, interpreted and reported.

- Product category: a group of products performing equivalent function(s); delineated by a common functional unit.

Health Product Declaration (HPD)

Name
Product ID
Website
Manufacturer
Address
Address Line 2
City, State, Code

MasterFormat

Contact Name
Title
Phone
Email

Health Product DECLARATION 1.0

Description

Release Date
Expiry Date
HPD URL

☐ Self-declared
☐ Second Party — Certifier
☐ Third Party — Certificate #

SUMMARY

The content of this product was assessed for health hazard warnings as required using

Residuals Disclosure

☐ Measured 100 ppm (ideal)
☐ Measured 1000 ppm
☐ As per MSDS (1,000 & 10,000 ppm)
☐ Predicted by process chemistry
☐ Not disclosed
☐ Other

Full Disclosure of Intentional Ingredients ☐ Yes ☒ No
Full Disclosure of Known Hazards ☐ Yes ☒ No

Disclosure Notes

Contents in Descending Order of Quantity (If the area below is full, refer to the following pages for additional listings)

Hazards

☐ PBT (Persistent and Bioaccumulative Toxic)
☐ Cancer
☐ Gene mutation
☐ Development
☐ Reproductive
☐ Endocrine
☐ Respiratory
☐ Neurotoxicity
☐ Mammal
☐ Skin or Eye
☐ Aquatic toxicity
☐ Land toxicity
☐ Physical hazard
☐ Global warming
☐ Ozone depletion
☐ Multiple
☐ Unknown

Total VOC Content

Material (g/l)
Regulatory (g/l)
Content Notes

Does the product contain exempt VOCs? ☐ N/A ☐ Yes ☐ No
Are there VOC-free tints available? ☐ N/A ☐ Yes ☐ No

Certifications and Compliance (If the area below is full, refer to the following pages for additional listings)

VOC Content
VOC Emissions

Nutritional Label

Environmental Facts	
Manufacturing:	
Product Mass	2573 g
Content Sustainability:	
Post-consumer Recycled input	12%
Recyclable from product	74%
Renewable	17%
Process Impact:	
Carbon Footprint (thru mfg)	393 kg
Energy Used	457 MJ
Recoverable	7%
Product Usage:	
Power Demand:	
Hibernation	0.01 w
Stand By	0.2 w
Normal	47 w
Max	63 w
Ingredients:	
Regulated:	
Lead (Pb), exempt applications	0.2 g
Bromine (Br), exempt applications	23.6 g
Chlorine (Cl)	0.04 g
Other Halogens	5.4 g
REACH Candidate SVHCs >0.1%: Dibutyl phthalate, Bis(2-ethylhexylphthalate) (DEHP)	
Other Ingredients >0.1%: iron, copper, ABS plastic, epoxy, nickel, tin, bioplastic, aluminum, silicon, tantalum, silver, titanium, chromium, boron, ruthenium, palladium, indium, berylium, calcium	
Other Ingredients <0.1%: mercury, hexavalent chromium, PBBs, PBDEs, cadmium (<0.01%)	

Source: Health Product Declaration Standard v1.0

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INTERACT | Spotlight on Michigan | Education | Public | Industry | Government | Toolbox | Funding & Incentives

Toolbox | Funding & Incentives

- Definition of Green Chemistry
- 12 Principles of Green Chemistry
- Green Engineering
- Chemical Assessment Tools
- Library
- Directory of Green Chemistry Organizations

Thank You!

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