

Standards for Sustainable Manufacturing

Part 1 Background and Terminology

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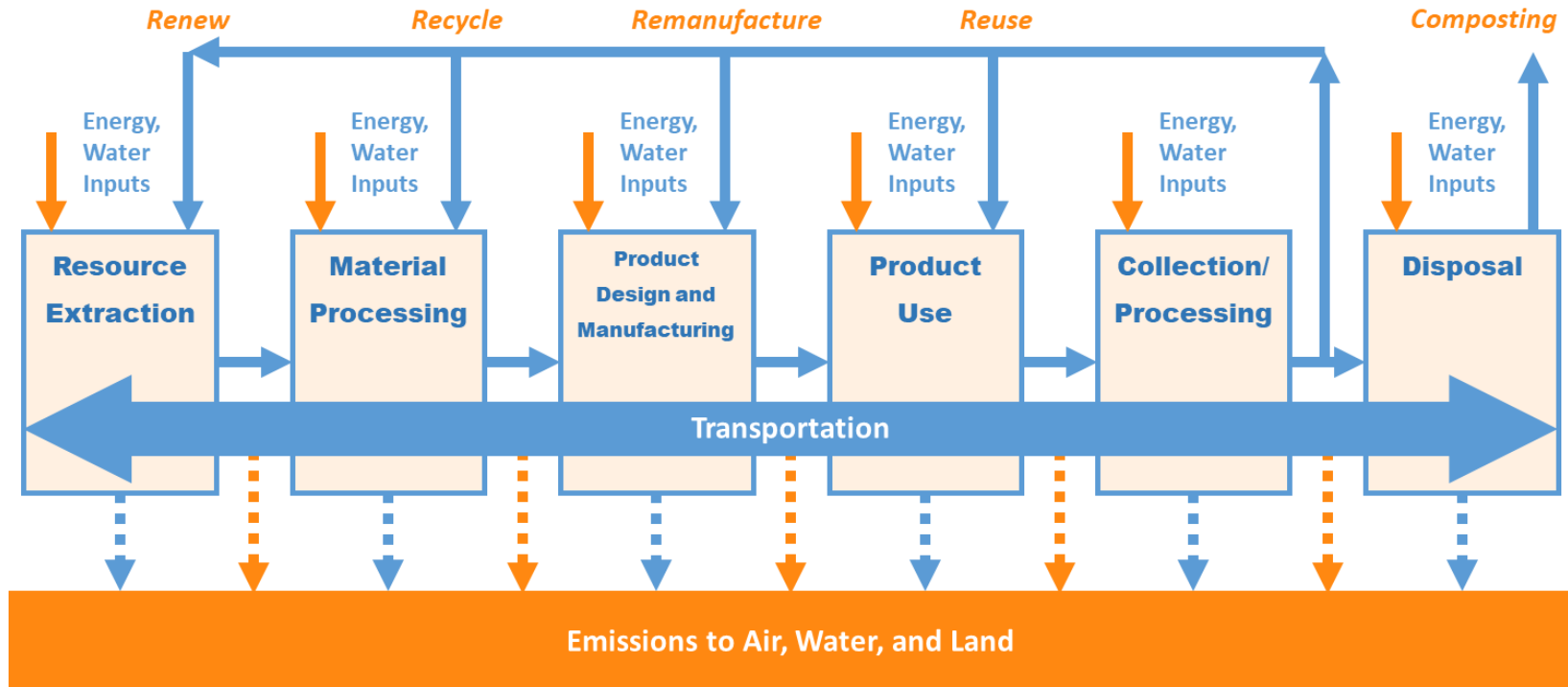
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Green Buildings and Sustainable Materials Project

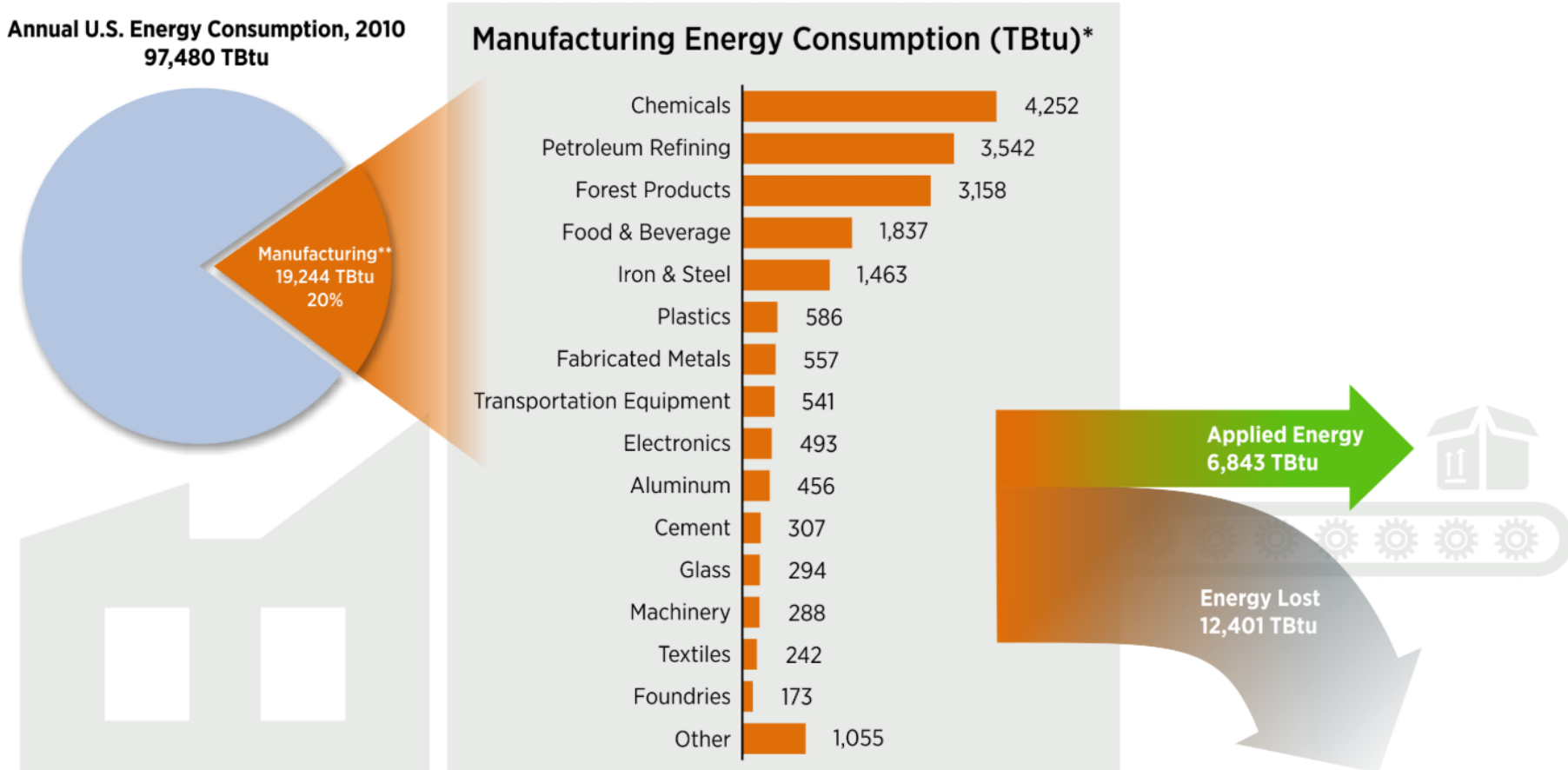
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Manufacturing and Materials' Life Cycle



A Typical Life-Cycle of Materials

Energy Consumption of the Manufacturing Industry

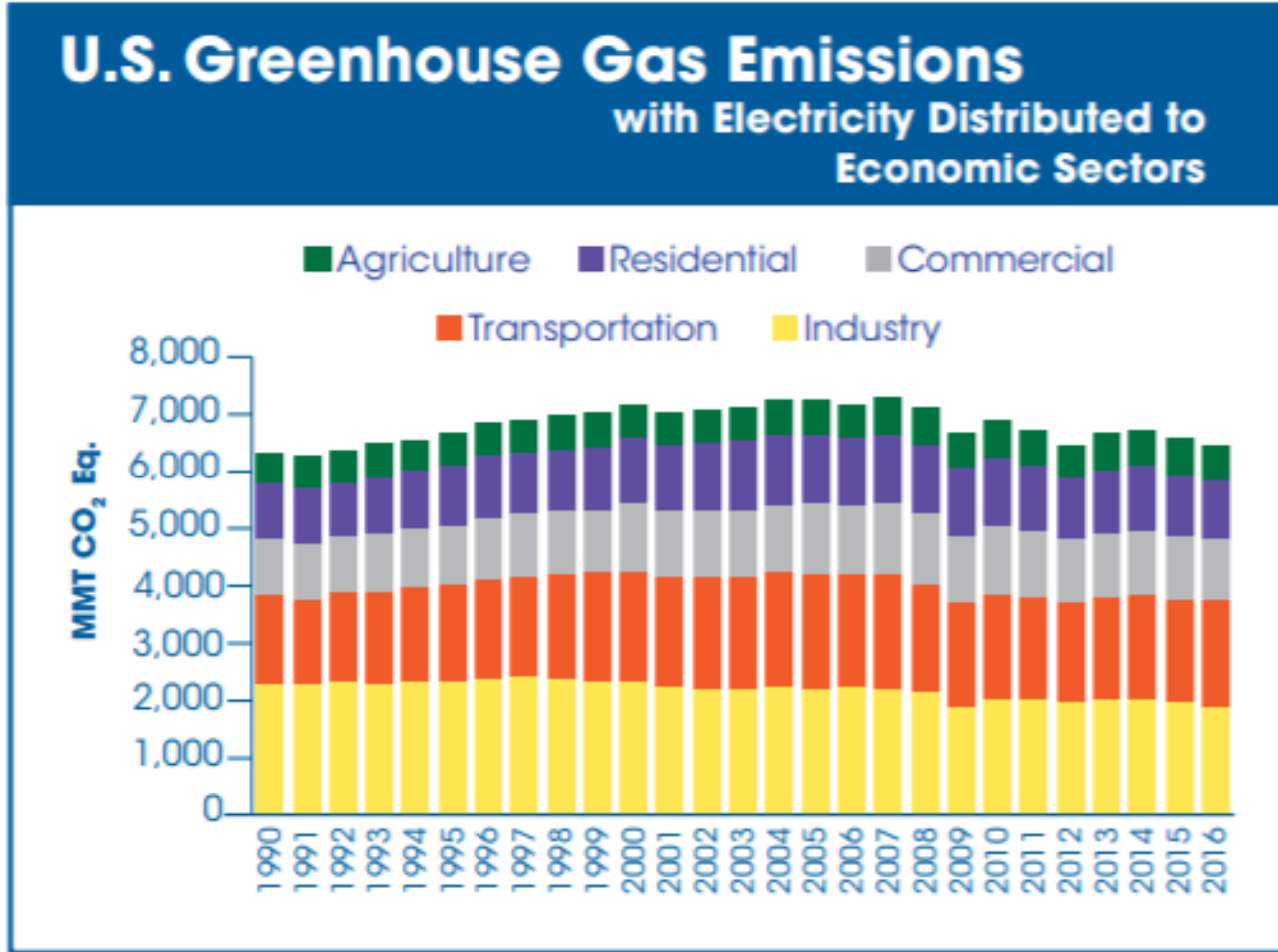


* Values include offsite energy losses but exclude the energy value of fuels used as raw materials, known as feedstocks (e.g., petroleum processed into plastic).

** The primary energy value shown here (19,244 TBtu) is about 7 TBtu greater than the input value in the flow diagram (19,237 TBtu); this is attributed to the non-combusted renewable electricity generated onsite, primarily in the Forest Products (about 6 TBtu) and Food & Beverage (about 1 TBtu) subsectors.

Energy Consumption of U.S. Manufacturing Industries

GHG Emissions of the Manufacturing Industry



Note: Does not include U.S. territories.

Sustainable Manufacturing

- **ASTM E2987 / E2987M** Standard Terminology for Sustainable Manufacturing
- **ASTM E3096** Standard Guide for Definition, Selection, and Organization of Key Performance Indicators for Environmental Aspects of Manufacturing Processes
- **ASTM E2986** Standard Guide for Evaluation of Environmental Aspects of Sustainability of Manufacturing Processes
- **ASTM E2979** Standard Classification for Discarded Materials from Manufacturing Facilities and Associated Support Facilities
- **ASTM E3012** Standard Guide for Characterizing Environmental Aspects of Manufacturing Processes



ASTM is a not-for-profit organization that provides a forum for the development and publication of international voluntary consensus standards for materials, products, systems and services.

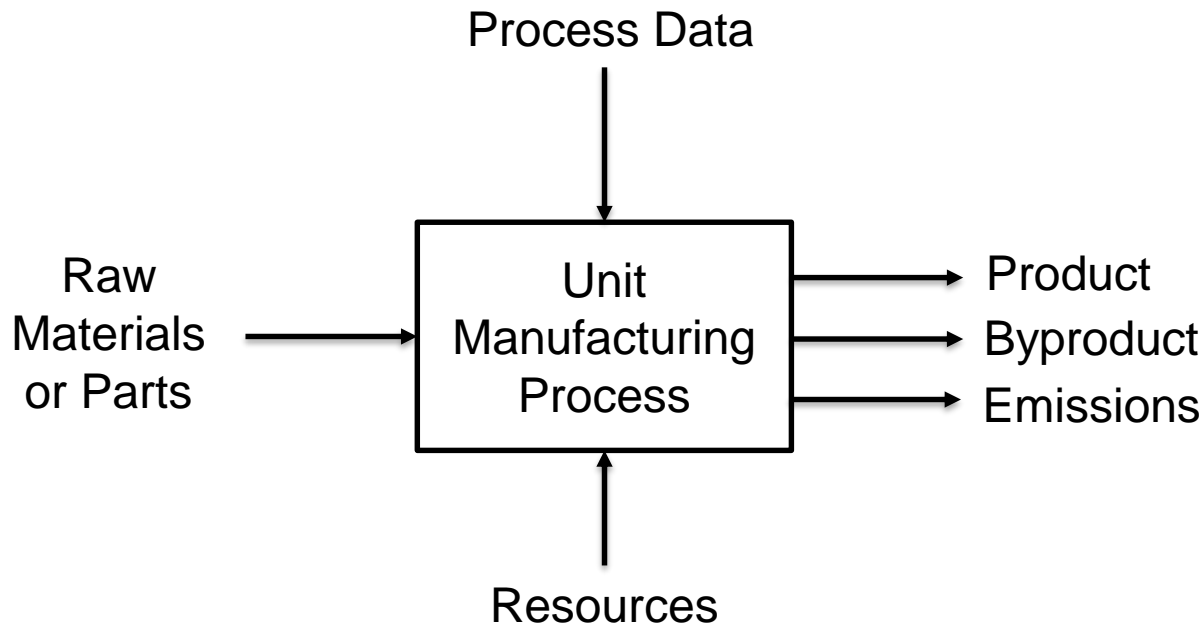
Source: <https://www.astm.org/ABOUT/faqs.html>

Terminology

ASTM E2987 / E2987M Standard Terminology for Sustainable Manufacturing

Unit Manufacturing Process

“The individual operation or subset of operations necessary to convert, modify, or add value from a defined initial state to a defined end state”.



Examples:

- Casting
- Machining
- Mixing
- Surface treatment
- Preparation for shipping

Process Data Unit

“Smallest element of a unit manufacturing process for which discrete data are collected”.

Indicator

ASTM E2987 / E2987M Standard Terminology for Sustainable Manufacturing

“Quantitative value or qualitative information derived from a set of parameters that provides information about the state of a phenomenon”.

“An indicator can be used as a reference for decision- making”.

Question – What are common indicators you know related to sustainability?

Examples:

- GHG emissions in metric ton of CO₂ equivalent
- Total energy consumption in MJ
- Total raw material consumption in metric ton
- Costs in \$
- Total number of jobs created locally

Key Performance Indicator (KPI)

ASTM E2987 / E2987M Standard Terminology for Sustainable Manufacturing

“A quantifiable attribute that a company or industry uses to gauge or compare performance for meeting operational and strategic goals”.

ASTM E3096 Standard Guide for Definition, Selection, and Organization of Key Performance Indicators for Environmental Aspects of Manufacturing Processes

“Provide standard approaches for systematically identifying, defining, selecting, and organizing KPIs for determining the impact of manufacturing process on the environment.”

Definition, Selection, and Organization of KPI

Step 1 Establish Environmental KPI Objectives

“A KPI objective is a threshold of achievement to improve certain environmental aspects of manufacturing processes.”

Example:

Reduce total energy consumption 40% within 5 years in a concrete production process.

Question – Can you think of other environmental KPI objectives?

Step 2 Identify Candidate KPIs

Example:

Environmental Objective:

Reduce total energy consumption 40% within 5 years in a concrete production process.

Candidate KPI:

Total energy consumption in MJ. This KPI can be directly measured or estimated through physics-based equations.

Definition, Selection, and Organization of KPI

Step 2 Identify Candidate KPIs

Resources:

- TRACI developed by US EPA.
- The IMPACT World +
- Intergovernmental Panel on Climate Change (IPCC)
- The U.S. Life Cycle Inventory Database
- The Dow Jones Sustainability Indexes
- The Environmental Performance Index
- The Global Reporting Initiative

Question – What if there are gaps between KPIs and environmental objectives?

Solution – Define new KPIs

- Identify Gaps in Currently Used KPIs
- Define New KPIs

Bottom-Up Approach

- Using existing metrics to develop new KPIs
- Example: $\text{Material Loss} = \text{Material Input} - \text{Output}$

Top-Down Approach

- Decompose the organizational objectives into environmental objectives
- Different from metrics currently used

Definition, Selection, and Organization of KPI

Step 3 Select Effective KPIs

“The criteria are determined *independently* from the KPIs themselves. *Stakeholders* such as line managers, supervisors, and shop floor workers make their proposals for selection criteria. This information is then aggregated. A final set of criteria is obtained after *additional review by the stakeholders*. “

Examples (see more in the standard):

- *Accessible/Usable*
- *Comparable*
- *Actionable*

***Question – Are all criteria
equally weighted/important?***

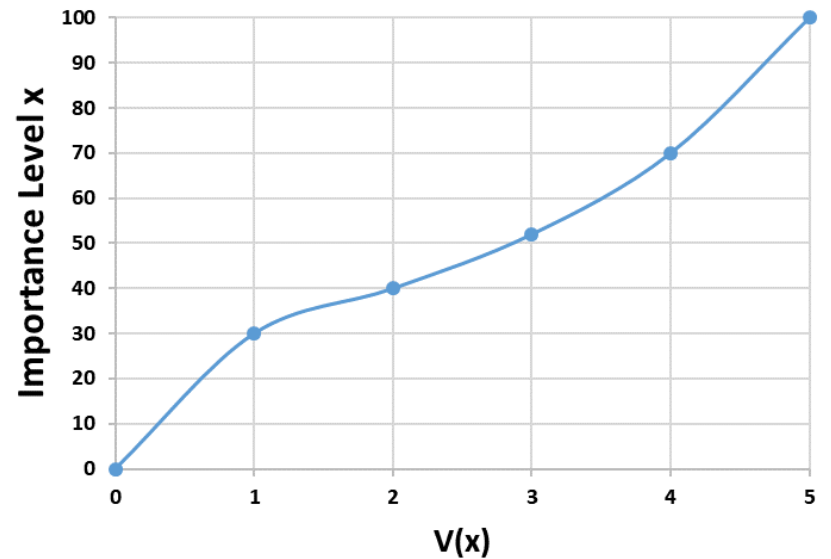
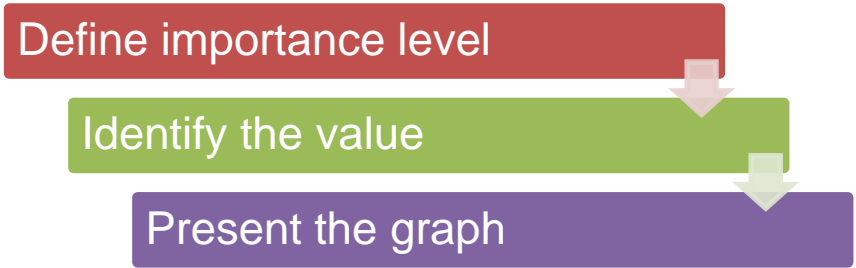
Definition, Selection, and Organization of KPI

Step 3 Select Effective KPIs

Question – Are all criteria equally weighted/important?

Solution – Value Function

Importance Level	Level x	V(x)
Not Important	0	0
Somewhat Important	1	30
Important	2	40
Fairly important	3	52
Very important	4	70
Extremely important	5	100



Definition, Selection, and Organization of KPI

Step 3 Select Effective KPIs

- *Value Function*
- *Rank KPIs*
- *Select KPIs based on the cut-off point determined by stakeholders*

“For each KPI in the candidate set, stakeholders independently assign an importance level for all the criteria.”

$$\text{Aggregated Value} = \sum_{i=1}^n v_i(x_i)$$

$v_i(x_i)$ – Average value function for criteria i from all stakeholders

Definition, Selection, and Organization of KPI

Step 4 Normalization and Weighting

Normalization – Equate measurements from different units relative to a norm

- Need for comparison and aggregation
- Not necessary when absolute scales of KPIs are needed

Example methods:

$$n_{ij} = \frac{X_{ij}}{\text{Max}(X_{ij})}$$

$$n_{ij} = \frac{X_{ij} - \text{Min}(X_{ij})}{\text{Max}(X_{ij}) - \text{Min}(X_{ij})}$$

$$n_{ij} = \frac{X_{ij}}{\sum_i X_{ij}}$$

Weighting – Assign relative importance based on a KPI's contribution to the environmental objective.

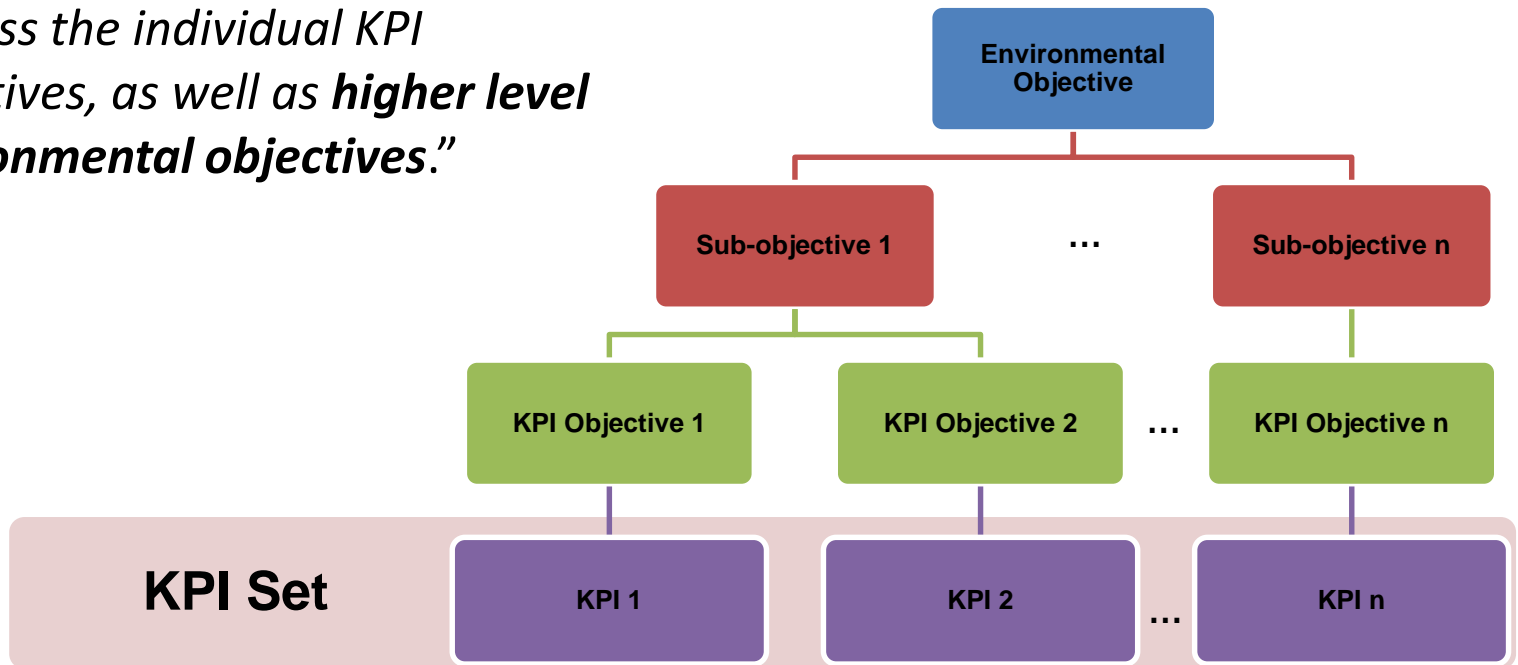
- Weights are dimensionless
- Weights can be derived based on the total value of the KPI in the previous step

Definition, Selection, and Organization of KPI

Step 5 KPIs and Organization

Organization – organize all KPIs into a set

“The selected KPI set should address the individual KPI objectives, as well as higher level environmental objectives.”



Visit Our Project Website

<https://faculty.cnr.ncsu.edu/yuanyao/green-buildings-and-sustainable-materials/>

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