

國立臺北大學自然資源與環境管理研究所

112 學年度第二學期『清潔生產與工業生態學』

課程進度(06)：工業生態學－為環境與永續性而設計

Introduction to Industrial Ecology: Design for Environment and Sustainability

● REVISITING THE “MASTER EQUATION” OF INDUSTRIAL ECOLOGY

- The Master Equation (G&A, p.28)

Environmental Impact

$$= \text{Population} \times [\text{GDP/person}] \times [(\text{Environmental Impact})/(\text{Unit of GDP})]$$

⇒ The IPAT Equation: I=Impact; P=Population; A=Affluence, T=Technology

⇒ The Kaya's identity: a mathematical expression for energy-related carbon emission

$$C = (P) \times (GDP/P) \times (E/GDP) \times (C/E)$$

where the total energy-related carbon emissions C is expressed as a product of Population P, GDP per capita, energy intensity E/GDP and carbon intensity of energy use C/E.

⇒ The IPAMDH Equation: $I = P \times A \times M \times D \times H$ (Kapur and Graedel, 2004)

M is the materials intensity, D the dissipation factor, and H the hazard factor, which depends on the chemical form of the material lost and the susceptibility of the receiving ecosystem.

Environmental Impact

$$= \text{Population} \times [\text{GDP/person}] \times [(\text{Units of Material})/\text{GDP}] \times [(\text{Units of Pollution})/(\text{Unit of Material})] \times [\text{Impact}/(\text{Unit of Pollution})]$$

- From Equations to Indicators

⇒ [Handbook on Constructing Composite Indicators: Methodology and User Guide](#)

⇒ [The Human Development Index and related indices](#)

⇒ [國發會-景氣指標查詢系統-景氣對策信號\(ndc.gov.tw\)](#)

⇒ [Environmental Performance Index \(yale.edu\)](#)

⇒ 許明華碩士論文：我國飲用水水質適飲性指標化評估之研究--2.1 環境指標系統

● HUMANITY AND TECHNOLOGY

- The Tragedy of the Commons (G&A, pp.2-4; <http://zh.wikipedia.org/zh-tw/公地悲劇>)

⇒ The Maximum Sustainable Yield; Free Riders and Externality

- The ‘Past Goods’ and the ‘New Bads’ (G&A, p.31)

- Decoupling of ‘Economic Goods’ and ‘Environmental Bads’

⇒ The Environmental Kuznets Curve ([Kuznets curve - Wikipedia](#))

- *Metabolic* “Dissipativeness” of Materials vs. *Anthropic* “Concentration” of Pollutants

- Final Sink of Materials: Consumption vs. Production

● TECHNOLOGICAL PRODUCT DEVELOPMENT

- Product Development Challenge (G&A, Chp.9, pp.115-117)

- Conceptual Tools for Product Designer (G&A, Chp.9, pp.117-118)

⇒ The Pugh Selection Matrix

⇒ The House of Quality

- Design for X (G&A, Chp.9, pp.118-121)

⇒ $X = A / C / D / ES / M / MC / R / SL / S / T$

- Product Design Teams (G&A, Chp.9, pp.121-122)

- Product Realization Process (G&A, Chp.9, pp.122-124)

- **DESIGN FOR ENVIRONMENT & SUSTAINABILITY: CUSTOMER PRODUCTS**
 - Choosing Materials (G&A, Chp.10, pp.126-129)
 - Combining Materials (G&A, Chp.10, pp.129-131)
 - Product Delivery (G&A, Chp.10, pp.131-134)
 - ⇒General Packaging Considerations: “Paper or Plastic” => the Packaging Materials
 - ⇒On-Site Recycling and “Take-Back” of Packaging Materials
 - The Product Use Phase (G&A, Chp.10, pp.134-135)
 - ⇒Dissipative Products
 - Design for Reuse and Recycling (G&A, Chp.10, pp.135-143)
 - ⇒The Comet Diagram => The Butterfly Diagram of Circular Economy
 - ⇒Closed-loop and Open-loop Recycling of Materials
 - ⇒Reverse Logistics and Remanufacturing
 - ⇒Dissipative Products
 - Guideline for DfES (G&A, Chp.10, pp.143-144)
 - ⇒Fiksel, J. (2009) [Design for Environment: A Guide to Sustainable Product Development](#)
 - ⇒[A Compilation of Design for Environment Guidelines \(researchgate.net\)](#)

- **DFES: BUILDINGS AND INFRASTRUCTURE**
 - The (Infra)structures of Society (G&A, Chp.11, pp.146-147)
 - ⇒Electric Power / Water / Transportation / Telecommunication Infrastructure (pp.148-151)
 - Green Buildings (G&A, Chp.11, pp.152-153)
 - ⇒The LEED System: U.S. Leadership in Energy and Environmental Design
 - ⇒BREEAM: U.K. Building Research Establishment Environmental Assessment Method
 - ⇒Taiwan’s EEWB System: Ecology-Energy Saving-Waste Reduction-Health
 - ⇒[SKA vs BREEAM vs LEED vs Fitwel vs WELL | Office Principles](#)
 - Infrastructure and Building Material Recycling (G&A, Chp.11, pp.153-157)
 - Green (Infrastructure) Design Guidelines (G&A, Chp.11, pp.157-158)

- **ECODESIGN AND SYSTEMS OF SUSTAINABLE CONSUMPTION AND PRODUCTION**
 - Ecological design or EcoDesign
 - ⇒An approach to designing products and services that gives special consideration to the environmental impacts of a product over its entire lifecycle.
 - EcoDesign symposium
 - ⇒Topics of EcoDesign 2023
 - Product Life Cycle Design and Management
 - Sustainability Assessment for EcoDesign
 - Sustainable Technology
 - Social Perspectives in EcoDesign
 - 永續性產品與產業管理研討會
 - ⇒研討會主旨：...永續資訊揭露、綠色消費、綠色設計、循環經濟、低碳與智慧生活未來的推動，建構橫跨經濟、社會及環境範疇之「永續性產品與產業管理」...
 - ⇒論文主題：永續治理、循環經濟-循環設計、永續績效-資訊揭露、安全衛生-防災、淨零減碳、自然為本解方、綠色供應鏈、綠色消費、生態創新設計
 - EU Ecodesign for Sustainable Products Regulation (ESPR)
 - ⇒[ESPR Guide – What is it & How to prepare \(2024 Update\) | Ecochain](#)

- **HOMEWORK ASSIGNMENT #5 (併入期中考試): Concept Map (Mind Map) of Design for X**

EcoDesign 2023

13th International Symposium on
Environmentally Conscious Design and Inverse Manufacturing
- EcoDesign with Art, Science and Technology -



TOPICS

Product Life Cycle Design and Management

► Environmentally Conscious Design of Products and Services

E. g., Life cycle design, Design for environment (DfE), Design for disassembly, Design for recycling, Design for remanufacturing, Design from waste, Zero waste design, Design for behavior, Product service system (PSS)

► Life Cycle Management

E. g., Maintenance, Smart life cycle management, Life cycle simulation (LCS), Product lifetime, Reliability analysis, Machine/System health monitoring, Waste valorization

► Sustainable Manufacturing

E. g., Industrial symbiosis, Industrial ecology, Zero-carbon factory, Cleaner production, Lean manufacturing, Smart materials, Additive manufacturing

► EoL Management and Process Technologies

E. g., Recycling, Disassembly, Remanufacturing, Refurbishment, Repair, Reuse, Urban mining, Critical raw materials (CRMs), Material recovery

► Green Supply Chain Management

E. g., Closed-loop supply chain management, Reverse logistics, Green Logistics

Sustainability Assessment for EcoDesign

► Life Cycle Evaluation

E. g., Life cycle assessment (LCA), Carbon footprint, Material footprint, Water footprint, Material flow analysis (MFA), Material flow cost accounting (MFCA), Economic impacts of environmental regulations, Input-output analysis, Environmental product declaration (EPD), Social life cycle assessment (S-LCA)

► Sustainability Indices

E. g., Resource efficiency, Energy efficiency, Material criticality, Total material requirement (TMR), Social indicators of emergent technologies, Social acceptance of technology, Social shaping of technology (SST)

Sustainable Technology

► Digital and AI Technologies for Sustainability

E. g., Digitalization in developing country, Cyber physical system (CPS), Telework, Internet of things (IoT), Digital twin, Digital transformation (DX), Automation technology, Business innovation, Big data analytics, AI for optimizing energy consumption, AI for sustainable waste management, Green transformation (GX)

► Sustainable Social Infrastructure

E. g., Carbon neutral (CN), Renewable energy, Energy security, Smart grid, Green transportation system, Autonomous car, Sustainable constructions, Water security, Food security, Smart city, Resilience, Mining industry

Social Perspectives in EcoDesign

► Sustainable Consumption and Production

E. g., Sharing economy, Behavioral science, Environmental consumer behavior, Social acceptance, Green marketing, Sufficiency, Locally oriented manufacturing, Behavior change in pandemic

► Policy, Legislation and Social Activities

E. g., Circular economy (CE), Digital product passport (DPP), Extended producer responsibility (EPR), Eco-label, International standard, Education for sustainable development (ESD), Corporate social responsibility (CSR), Ethical legal and social aspects research, Environmental justice, Environmental literacy

► Finance and Investment for Sustainability

E. g., Green procurement, Task force on climate-related financial disclosures (TCFD), Environmental social and governance (ESG)

In addition, organized sessions will be arranged on special themes.