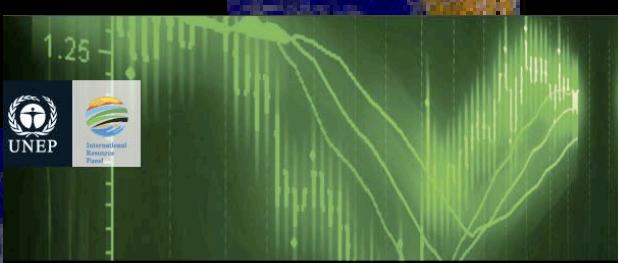
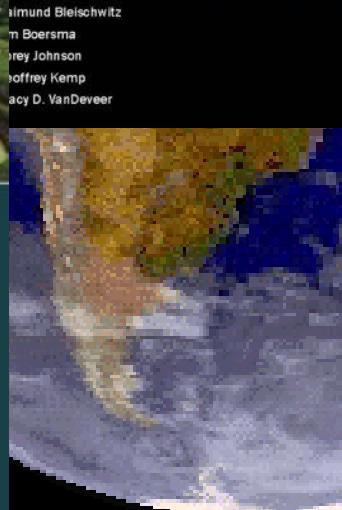
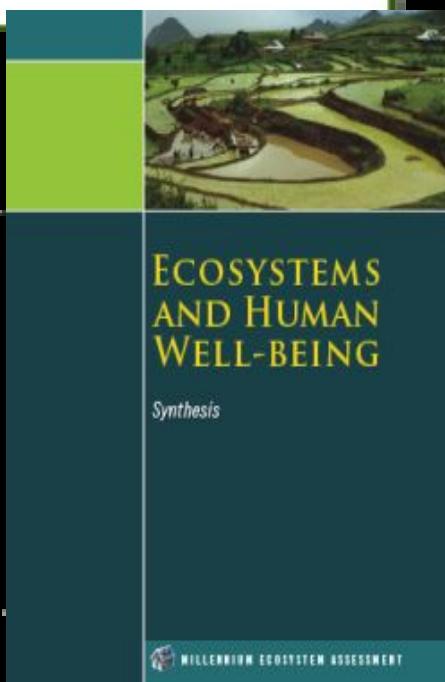
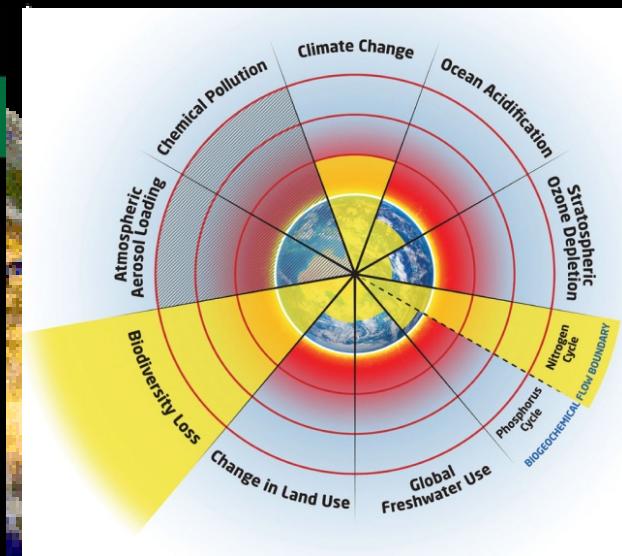
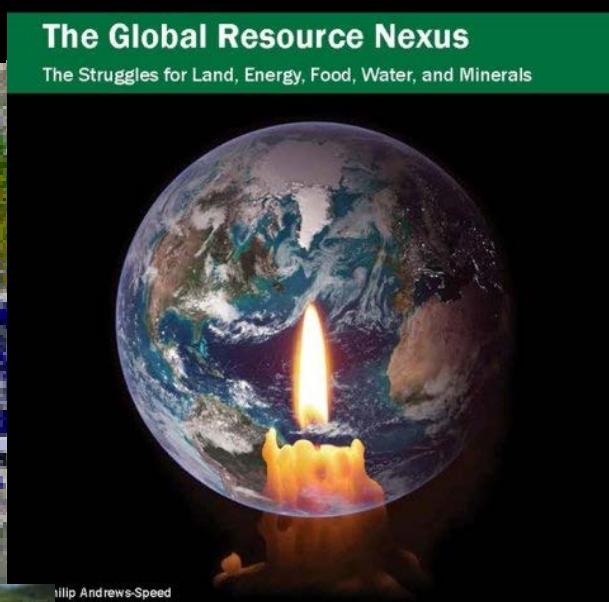
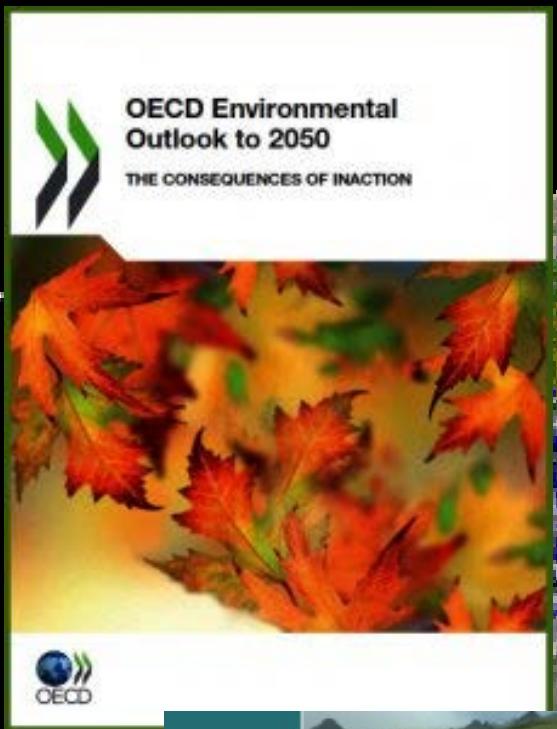


RISING TO GLOBAL CHALLENGES

25 Years of Industrial Ecology





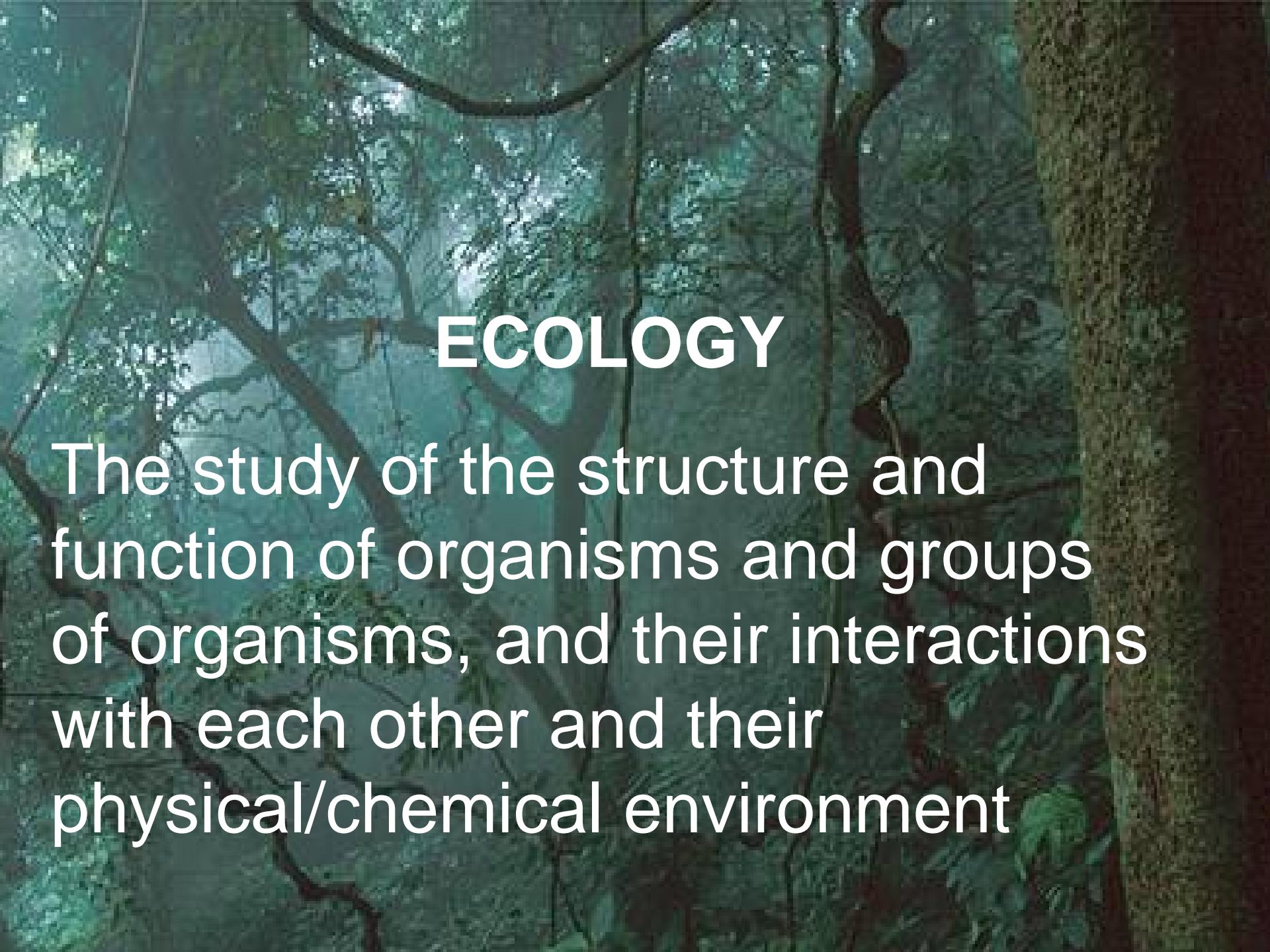
DECOUPLING
natural resource use and
environmental impacts
from economic growth





Content

- Industrial Ecology
- Historical Development
- Addressing Global Challenges
- More on the ISIE
- Teaching IE
- Impacts / Accomplishments

A photograph of a dense forest. Sunlight filters through the thick canopy of green leaves, creating bright highlights and deep shadows. The forest floor is visible at the bottom, showing more greenery and some fallen branches.

ECOLOGY

The study of the structure and function of organisms and groups of organisms, and their interactions with each other and their physical/chemical environment

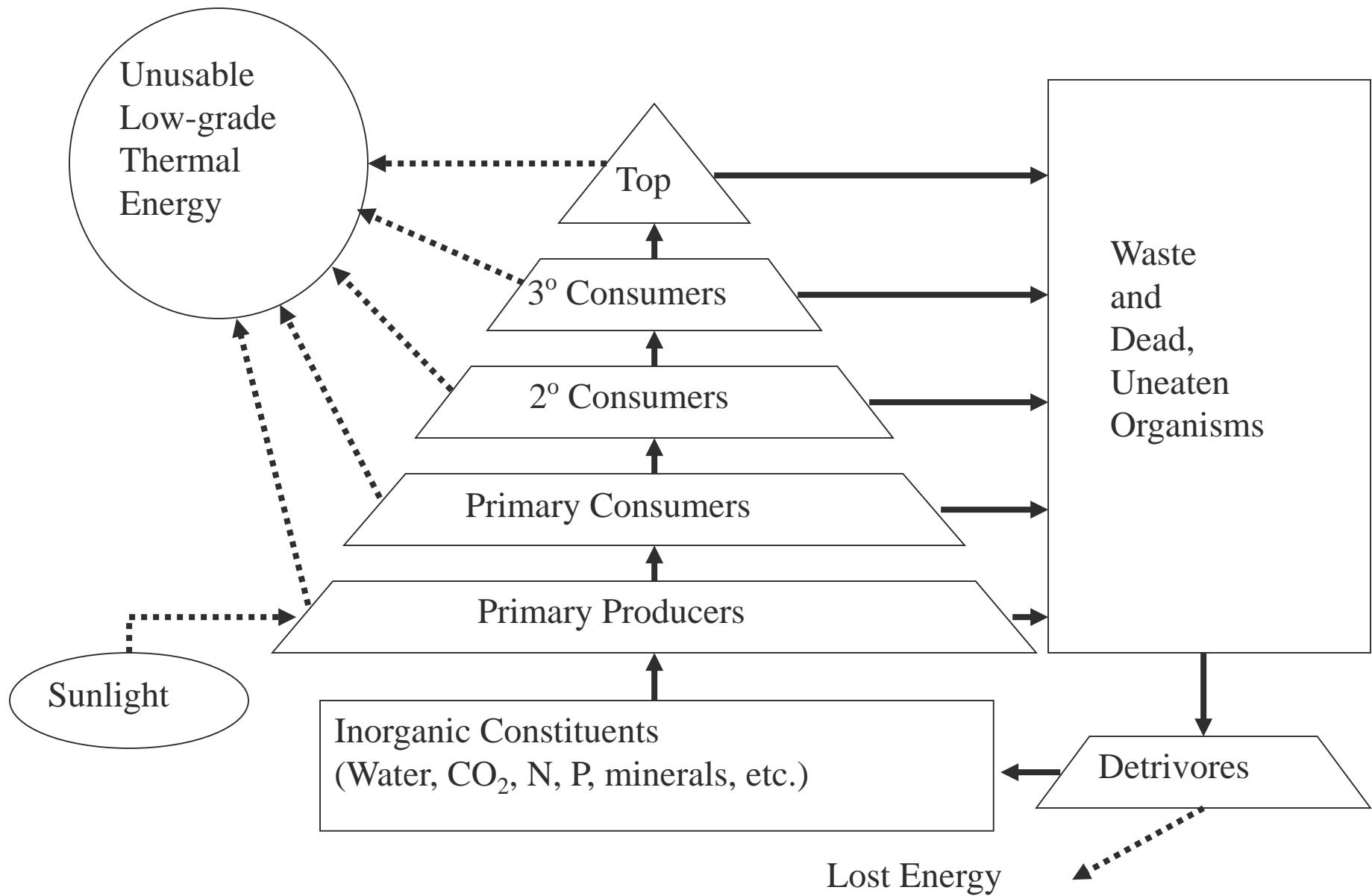


Why are big fierce animals rare?



trophic structure = the structure of energy transfer and loss between populations in the ecosystem

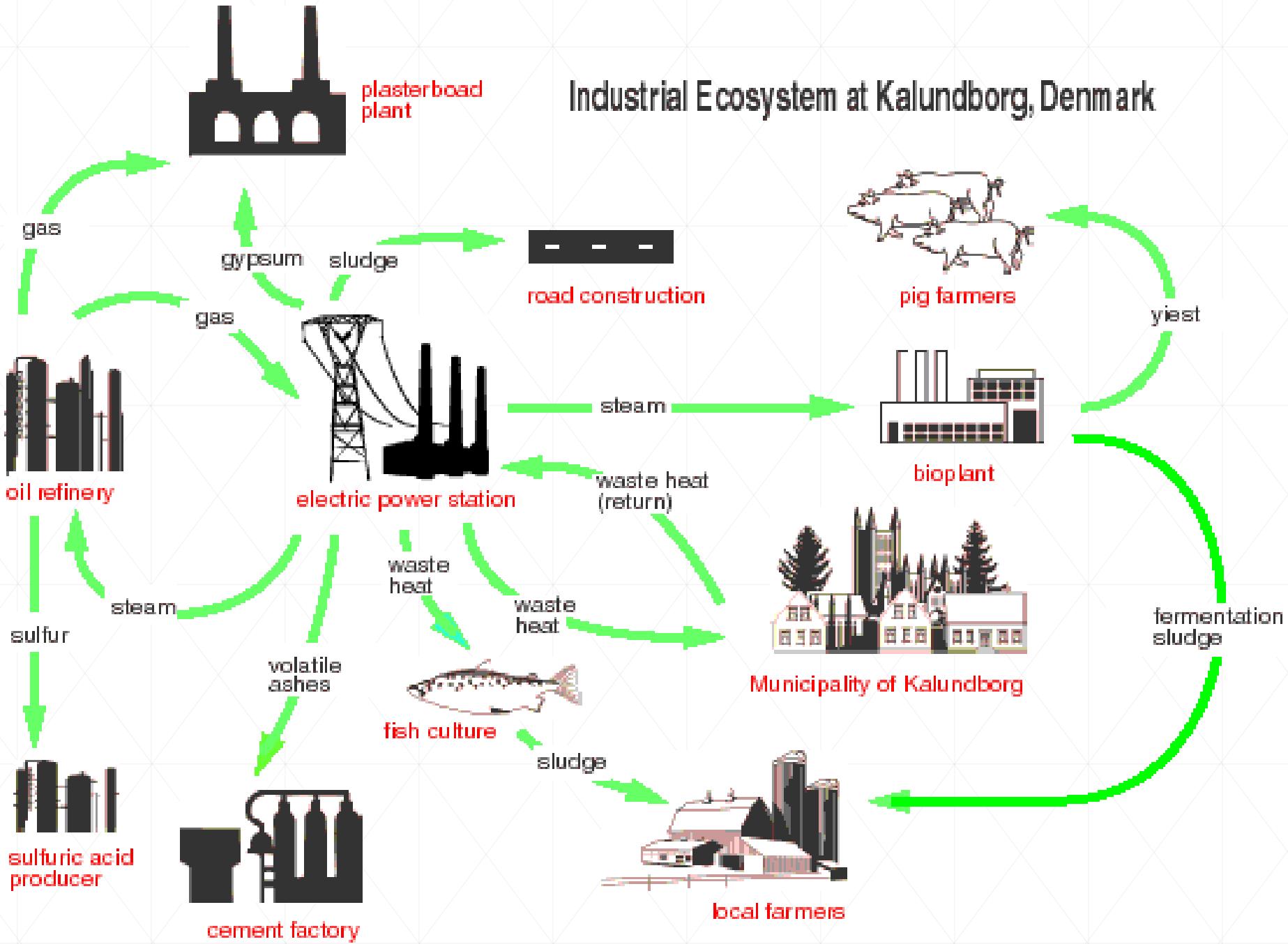
Ecosystems



INDUSTRIAL ECOLOGY

The study of energy and material flows – and their environmental impacts - in industrial–societal systems

Industrial Ecosystem at Kalundborg, Denmark



ECOSYSTEME BRUXELLES (16.178 ha)

PLANTES

$1500 \cdot 10^3$ t frais
 $750 \cdot 10^3$ t sec

HOMMES (1075000)

$59 \cdot 10^3$ t frais
 $19 \cdot 10^3$ t sec

ENERGIE DE SUPPLEMENT IMPORTATION (10^{12} kcal)

| | |
|-------------|----|
| Aliments | 2 |
| Electricité | 4 |
| Charbon | 3 |
| Pétrole + | 14 |
| Essence | 9 |
| Gaz | 26 |
| | 32 |

113

45+4

5900

CO₂

6350

O₂

60

138

100

330

0,4

94

PN₁

Φ

0,1

31

0,6

Exp.

0,5

ENERGIE NATURELLE

Bilan 58

27

390

435

ENERGIE TOTALE

EXPORTATION (10^{12} kcal)

89

Emissions (10^3 t)

| | |
|-----------------|-----|
| CO | 200 |
| SO ₂ | 30 |
| NO _x | 20 |
| Hydrocar. | 45 |
| Particules | 2 |
| Pb | 0,2 |

(M.S.)

Importation (10^3 t)

450

5900

CO₂

125

68

Ruisseaulement

60

57

Eaux usées

BILAN D'EAU

(10^6 t)

Immondices : 237

Egouts : 40

Déchets : 277

Exportations (10^3 t)

Imm. fines 75

Incin. 41

Gaz 11

30

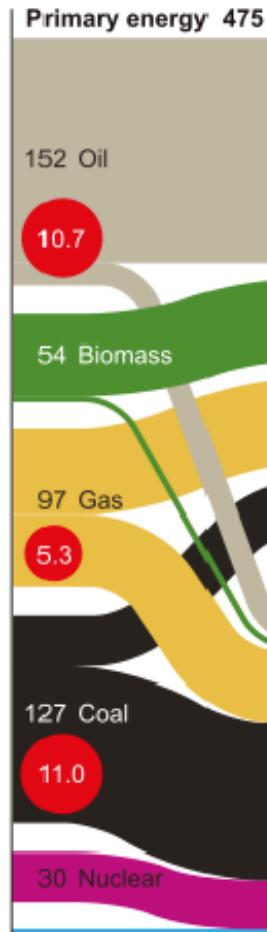
196

226

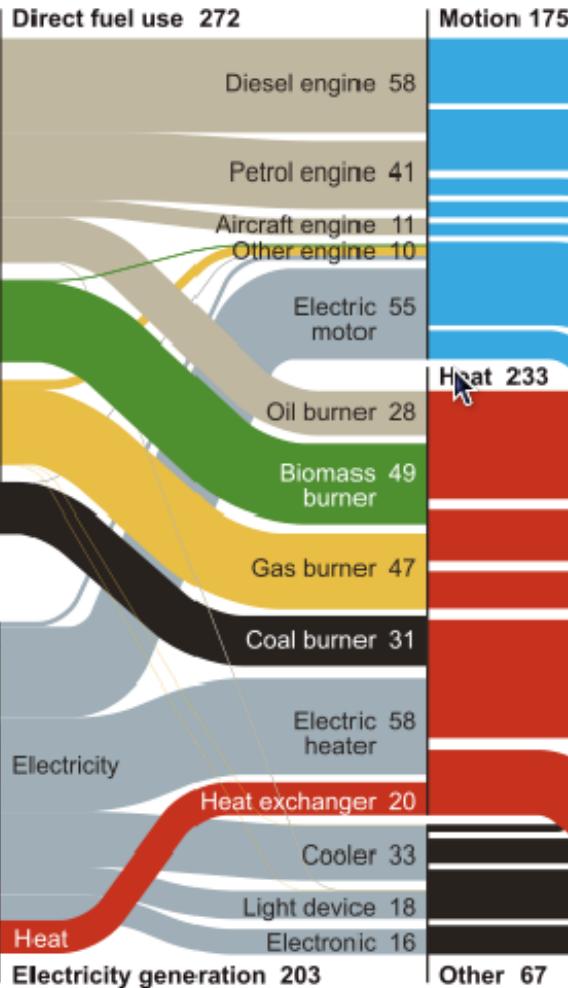
Déchets solides

Produits manufaturés ?

Energy sources



Conversion devices



Passive systems



Final services

Passenger transport
 23×10^{12} passenger-km

Freight transport
 46×10^{12} tonne-km

Structure
 $15 \times 10^9 \text{ MPa}^{2/3} \text{ m}^3$

Sustenance
 28×10^{18} J (food)

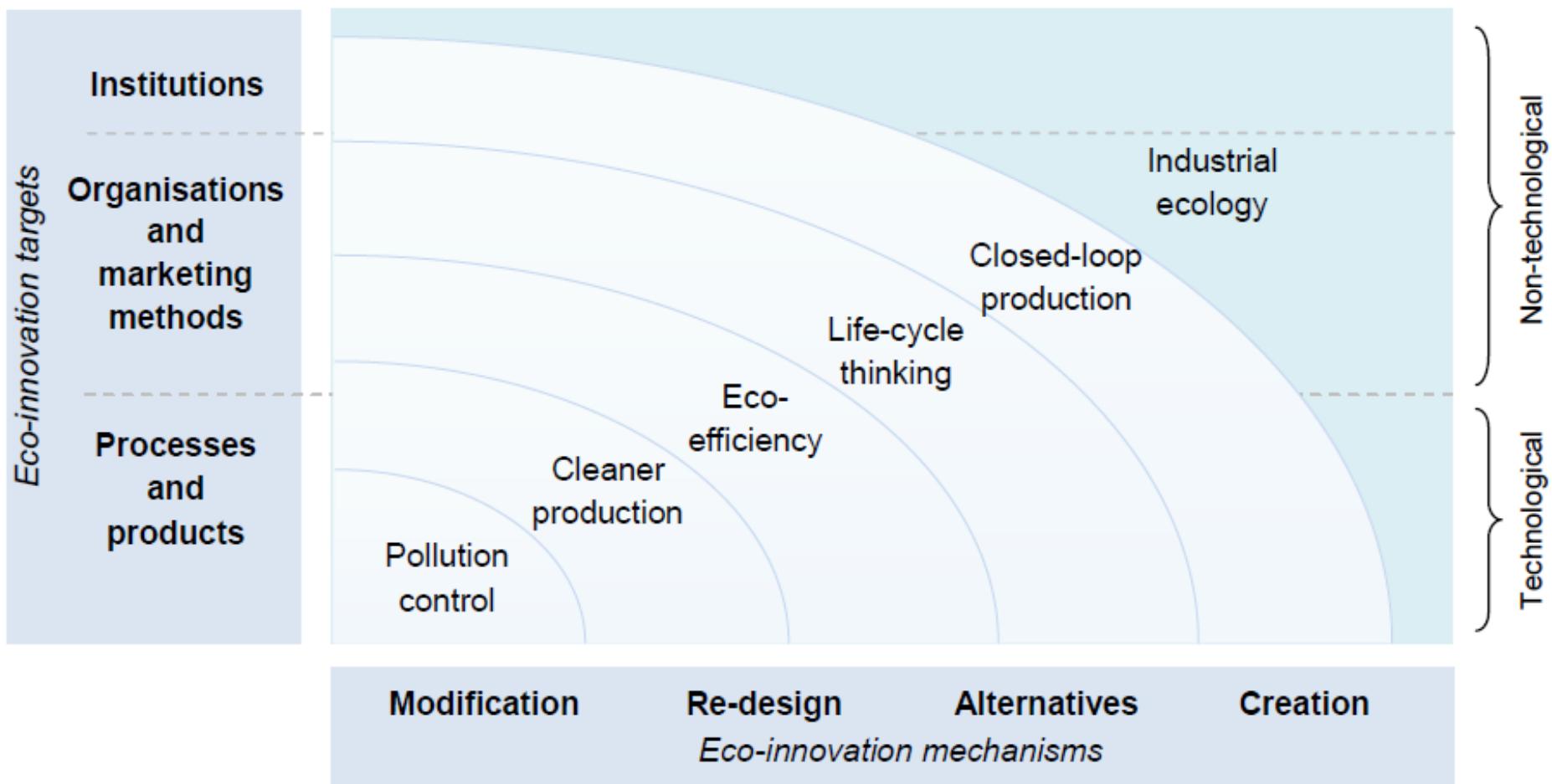
Hygiene
 $1.5 \times 10^{12} \text{ m}^3\text{K}$ (hot water)
 $2.8 \times 10^{18} \text{ Nm}$ (work)

Thermal comfort
 $30 \times 10^{15} \text{ m}^3\text{K}$ (air)

Communication
 280×10^{18} bytes
Illumination
 $480 \times 10^{18} \text{ lm s}$

Annual global flow of energy
in 2005, EJ [10^{18} joules]

Annual global direct carbon emissions
in 2005, Gt CO₂ [10^9 tonnes of CO₂]



Conceptual relationships between sustainable manufacturing and eco-innovation (OECD 2009)



Historical Development of IE

Frosch & Gallopolous,
Strategies for Manufacturing.
Scientific American, 261 (3),
144–152 (1989).





Frosch & Gallopolous:

"why would not our industrial system behave like an ecosystem, where the wastes of a species may be resource to another species? Why would not the outputs of an industry be the inputs of another, thus reducing use of raw materials, pollution, and saving on waste treatment?"

Industrial ecology: an historical view

S. Erkman

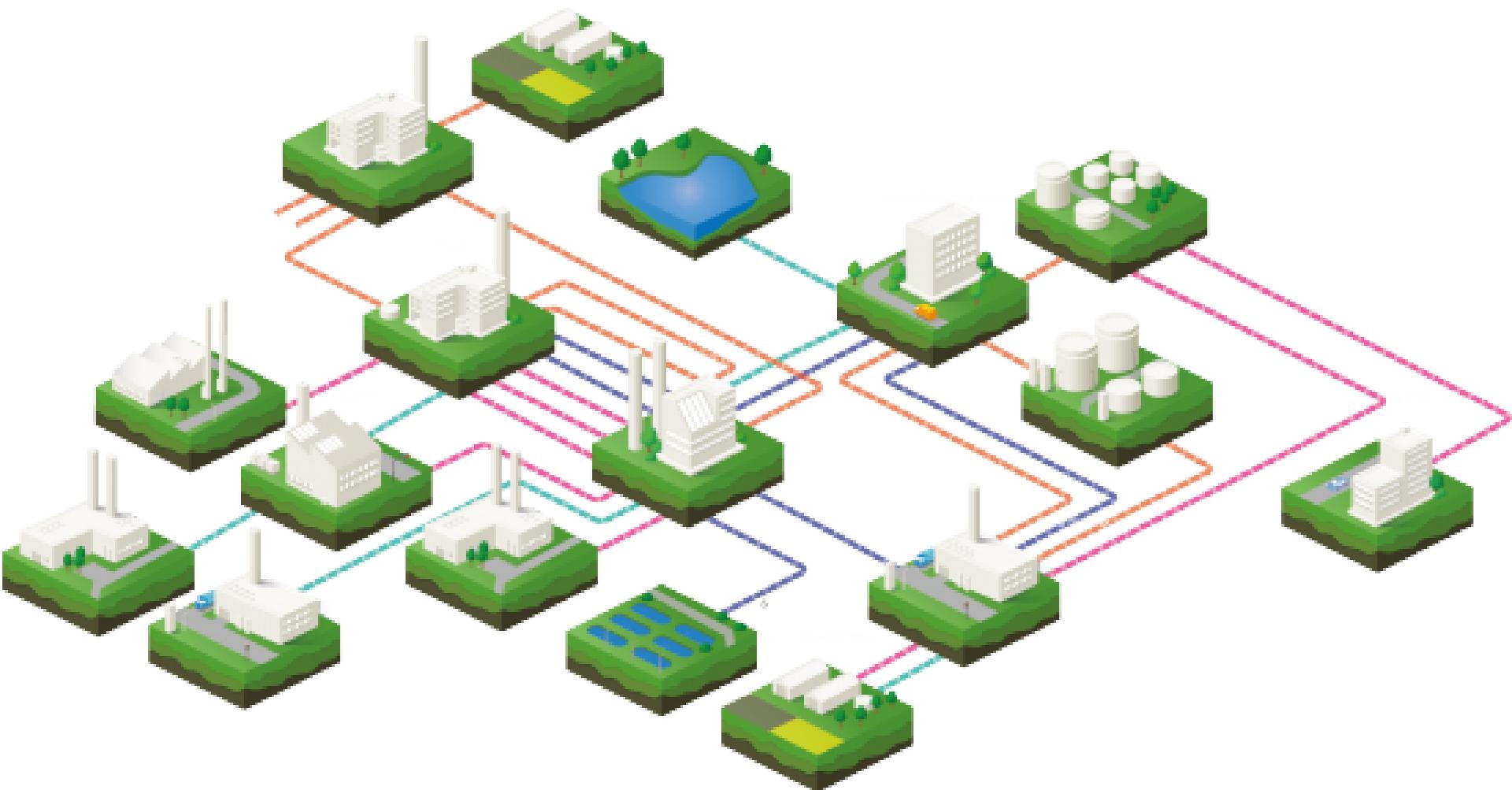
Early IE focussed on

- Eco-industrial parks
- Dematerialization of the service sector



ISIE Sections

- Eco-industrial Development
- Socio-Economic Metabolism
- Sustainable Urban Systems
- Organizing Sustainable Consumption & Production
- Environmental Extended Input Output
- Life Cycle Sustainability Assessment



ECO-INDUSTRIAL DEVELOPMENT

Quantitative Assessment of Urban and Industrial Symbiosis in Kawasaki, Japan

RENE VAN BERKEL,[†]
TSUYOSHI FUJITA,^{†,‡}
SHIZUKA HASHIMOTO,^{*,†} AND
MINORU FUJII[†]

TABLE 7. Classification of Physical Exchanges in Kawasaki^a

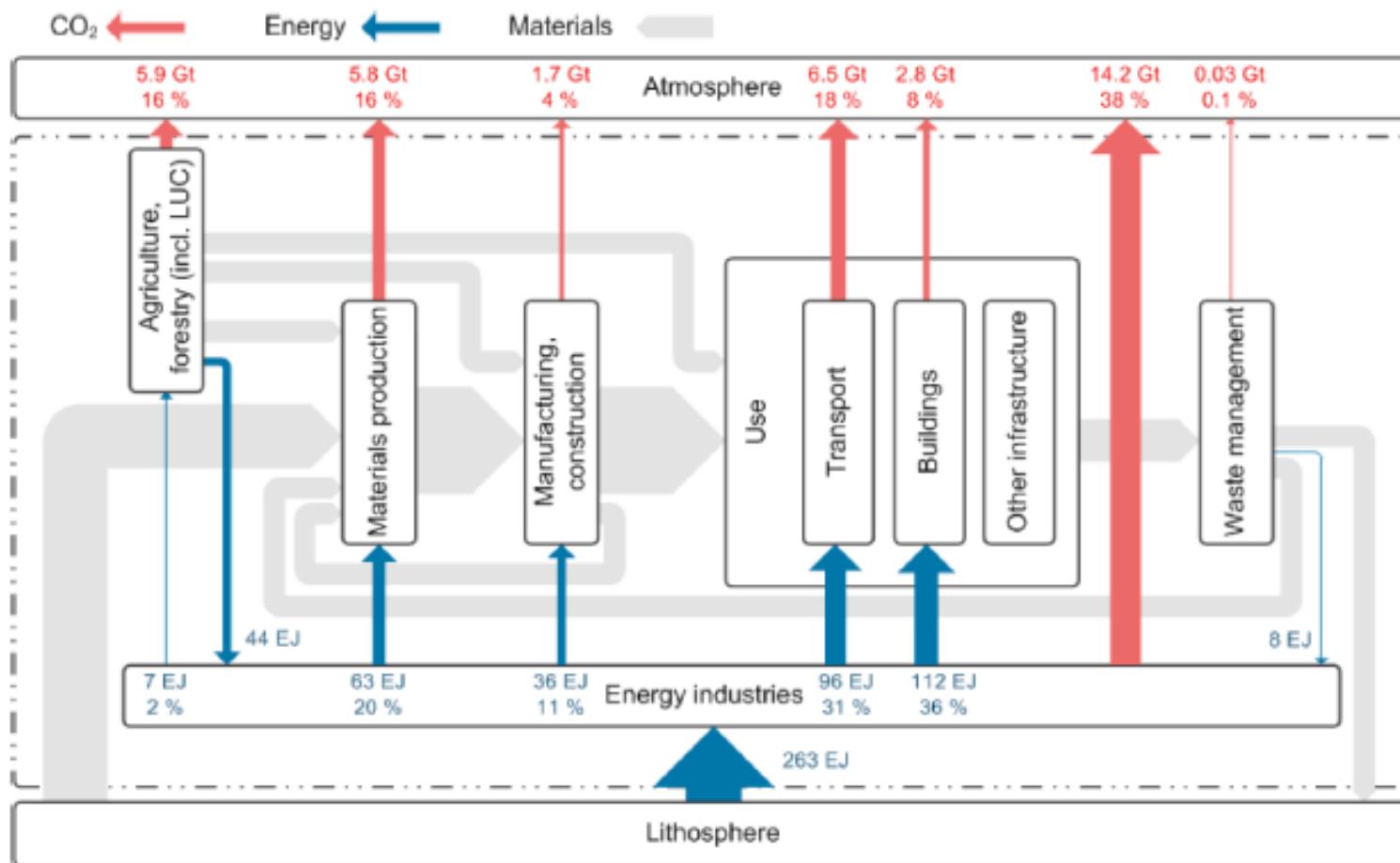
| purpose for application | industrial origin | urban origin | physical transfer |
|-------------------------------------|--|---|-------------------|
| 1. byproduct exchanges | <ul style="list-style-type: none">• alternative cement fuel• alternative cement raw materials• substitute cement clinker | <ul style="list-style-type: none">• alternative BF reductant• synthesis gas (ammonia production) | |
| 2. utility synergies | <ul style="list-style-type: none">• power from BF gas | <ul style="list-style-type: none">• industrial water reuse | |
| 3. new recycling industries | <ul style="list-style-type: none">• mixed paper recycling• plastics reuse in form-boards | <ul style="list-style-type: none">• chemical recovery of PET• home appliances dismantling | |
| 4. traditional recycling operations | <ul style="list-style-type: none">• scrap recycling (steel production)• scrap recycling (stainless steel production) | | |
| total | 8 | 5 | 1 |



SOCIO ECONOMIC METABOLISM

Carbon Emissions of Infrastructure Development

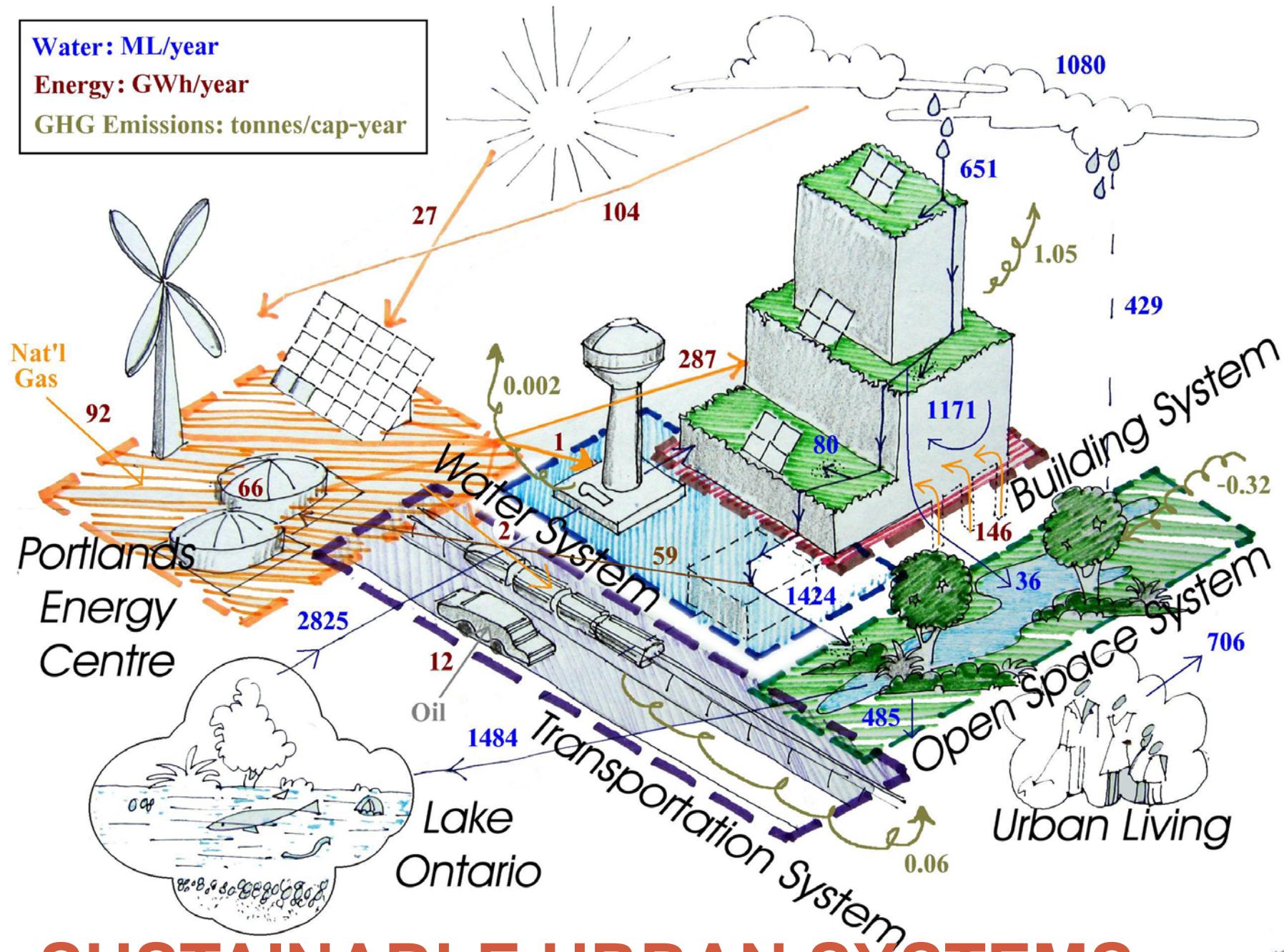
Daniel B. Müller,^{†,*} Gang Liu,[†] Amund N. Løvik,[†] Roja Modaresi,[†] Stefan Pauliuk,[†] Franciska S. Steinhoff,[†] and Helge Brattebo[†]



Water: ML/year

Energy: GWh/year

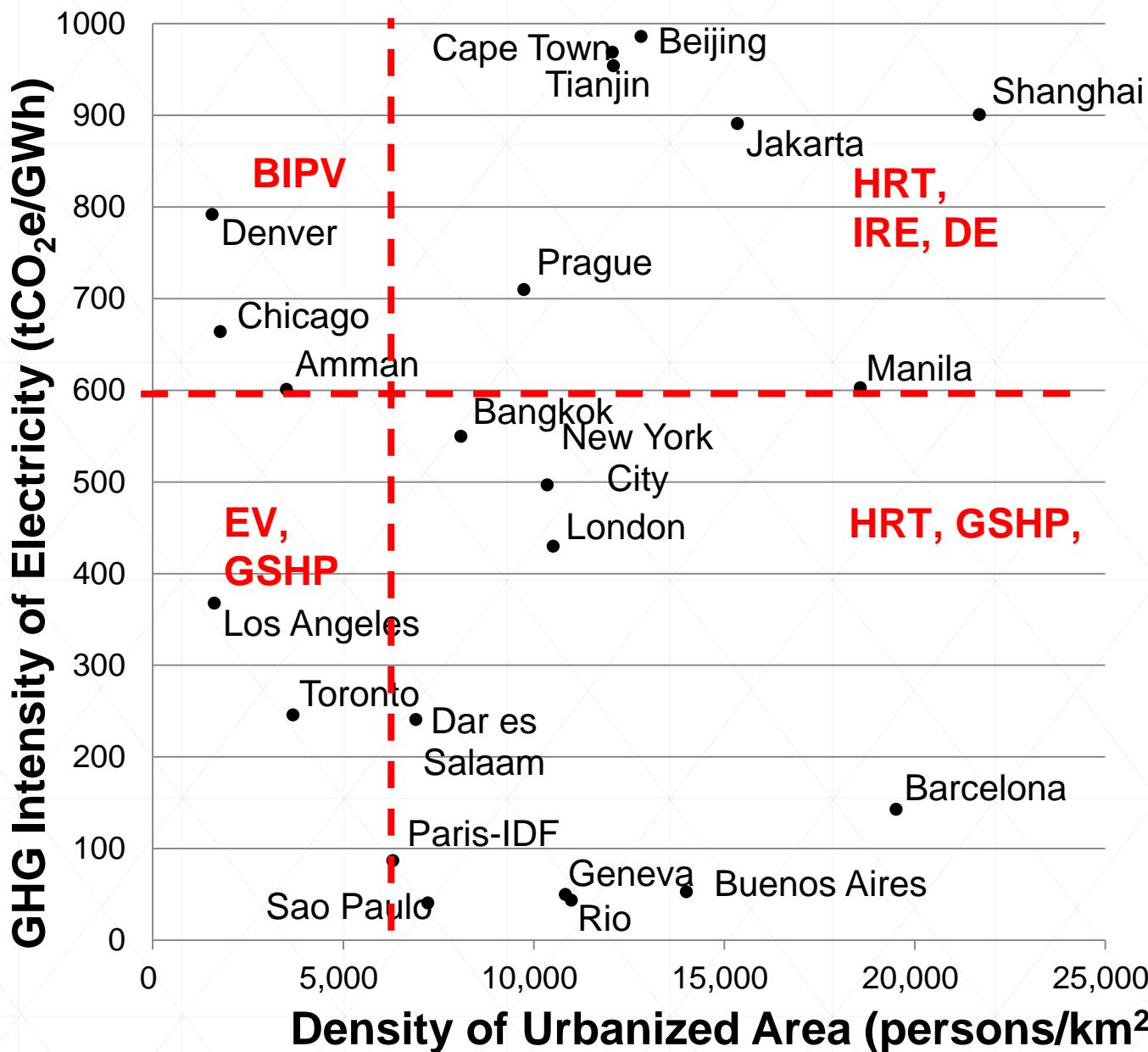
GHG Emissions: tonnes/cap-year



SUSTAINABLE URBAN SYSTEMS

Low Carbon Infrastructure Strategies for Cities

(Kennedy et al 2014)



BIPV = building integrated photovoltaics,

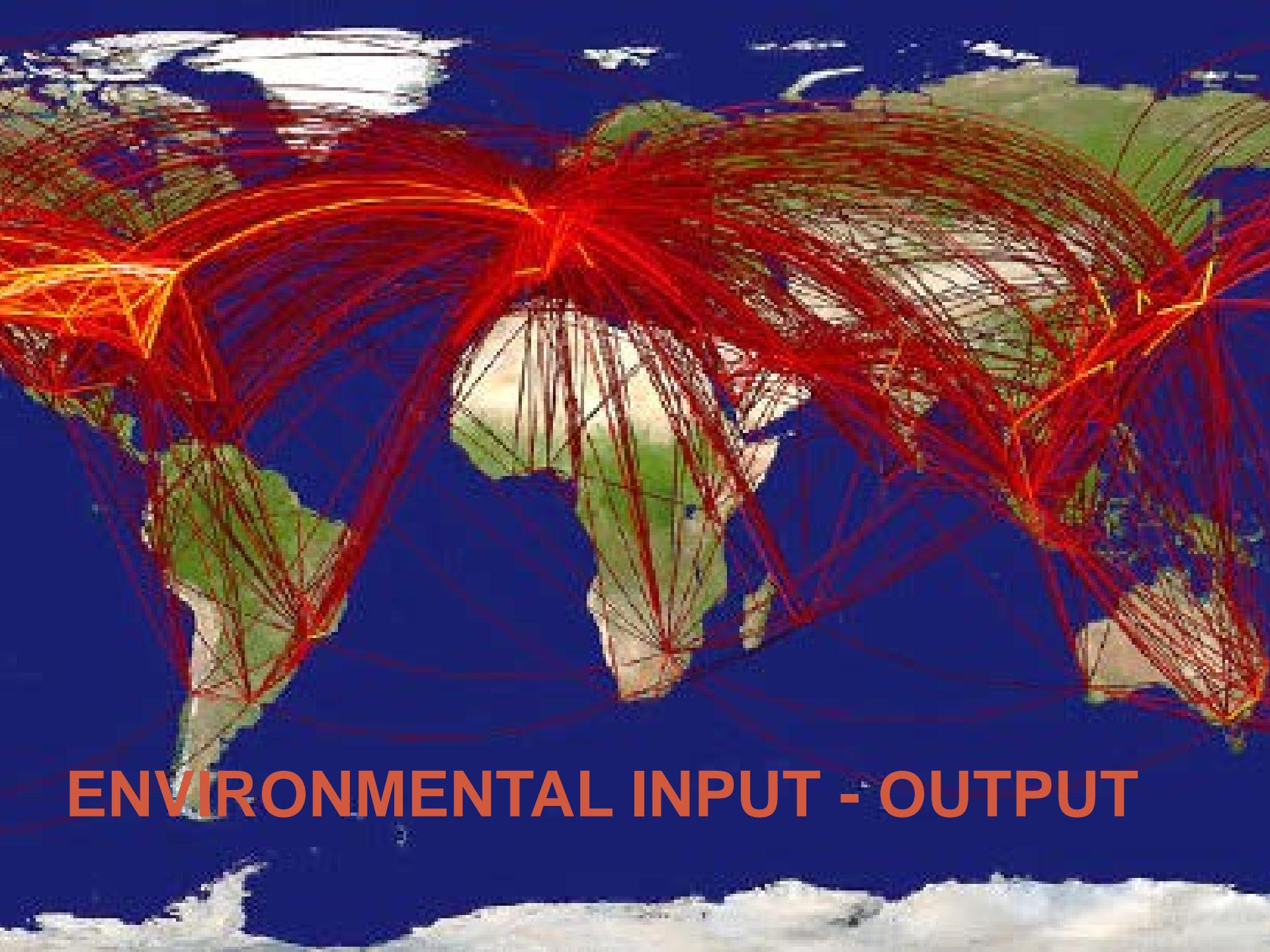
DE= district energy,

EV = electric vehicles,

GSHP= ground source heat pumps,

HRT=heavy rapid transit,

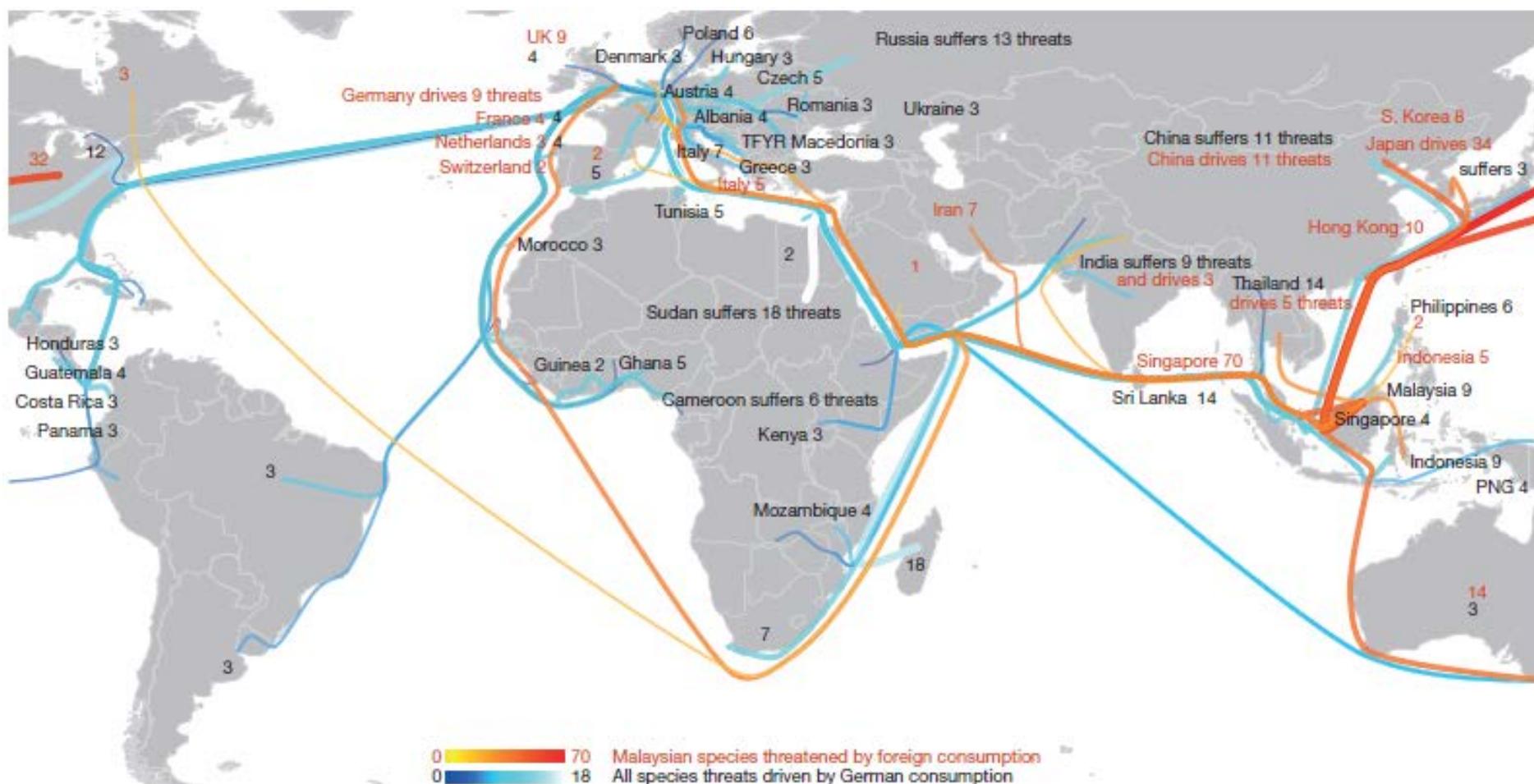
IRE=import renewable electricity

A 3D perspective map of the Earth's surface, colored in shades of blue, green, and white, representing terrain and land cover. Overlaid on this map are numerous thin, red, curved lines that form a complex network, suggesting air or water flow paths between various locations around the globe.

ENVIRONMENTAL INPUT - OUTPUT

International trade drives biodiversity threats in developing nations

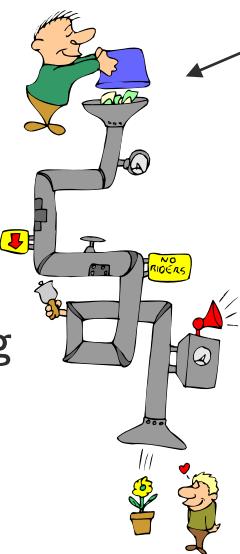
M. Lenzen¹, D. Moran¹, K. Kanemoto^{1,2}, B. Foran^{1,3}, L. Lobefaro^{1,4} & A. Geschke¹



Materials extraction

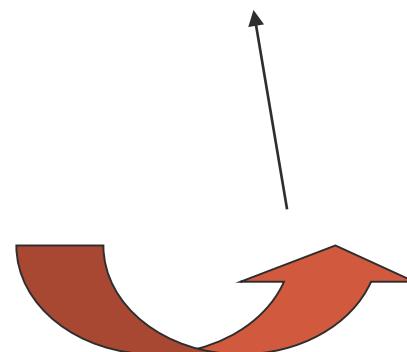


Materials processing



Manufacturing

Recycling



Use

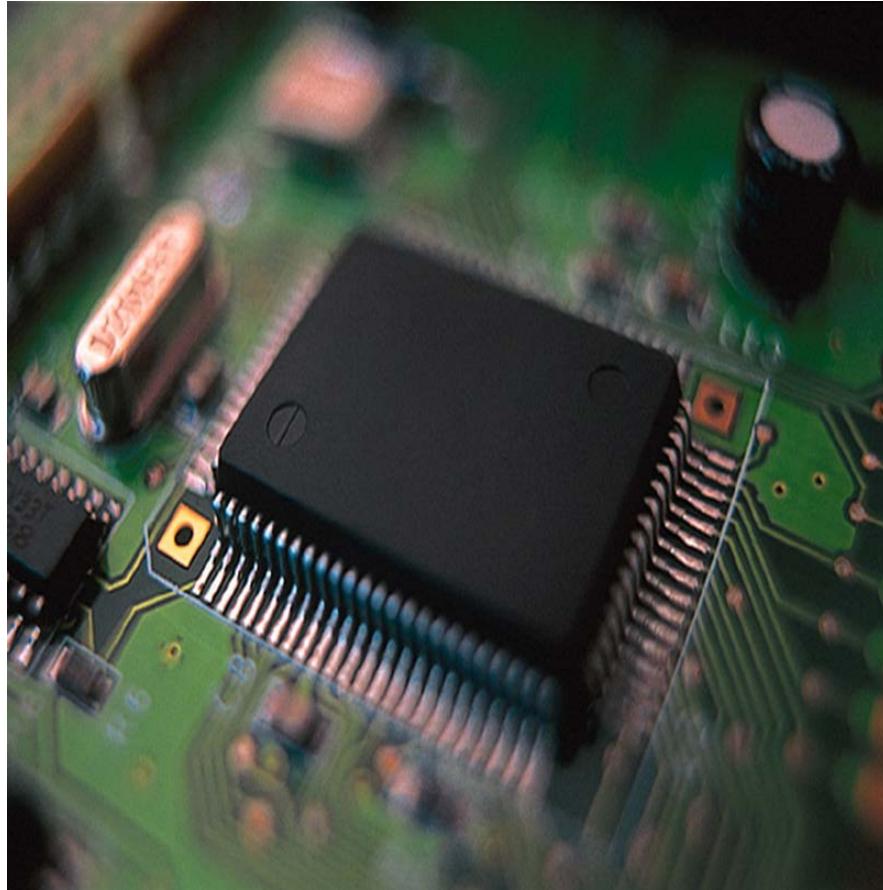
Disposal (end-of-life)



LIFE CYCLE SUSTAINABILITY ASSESSMENT

The 1.7 Kilogram Microchip: Energy and Material Use in the Production of Semiconductor Devices

Eric D. Williams ^{*†}, Robert U. Ayres [‡] and Miriam Heller [§]



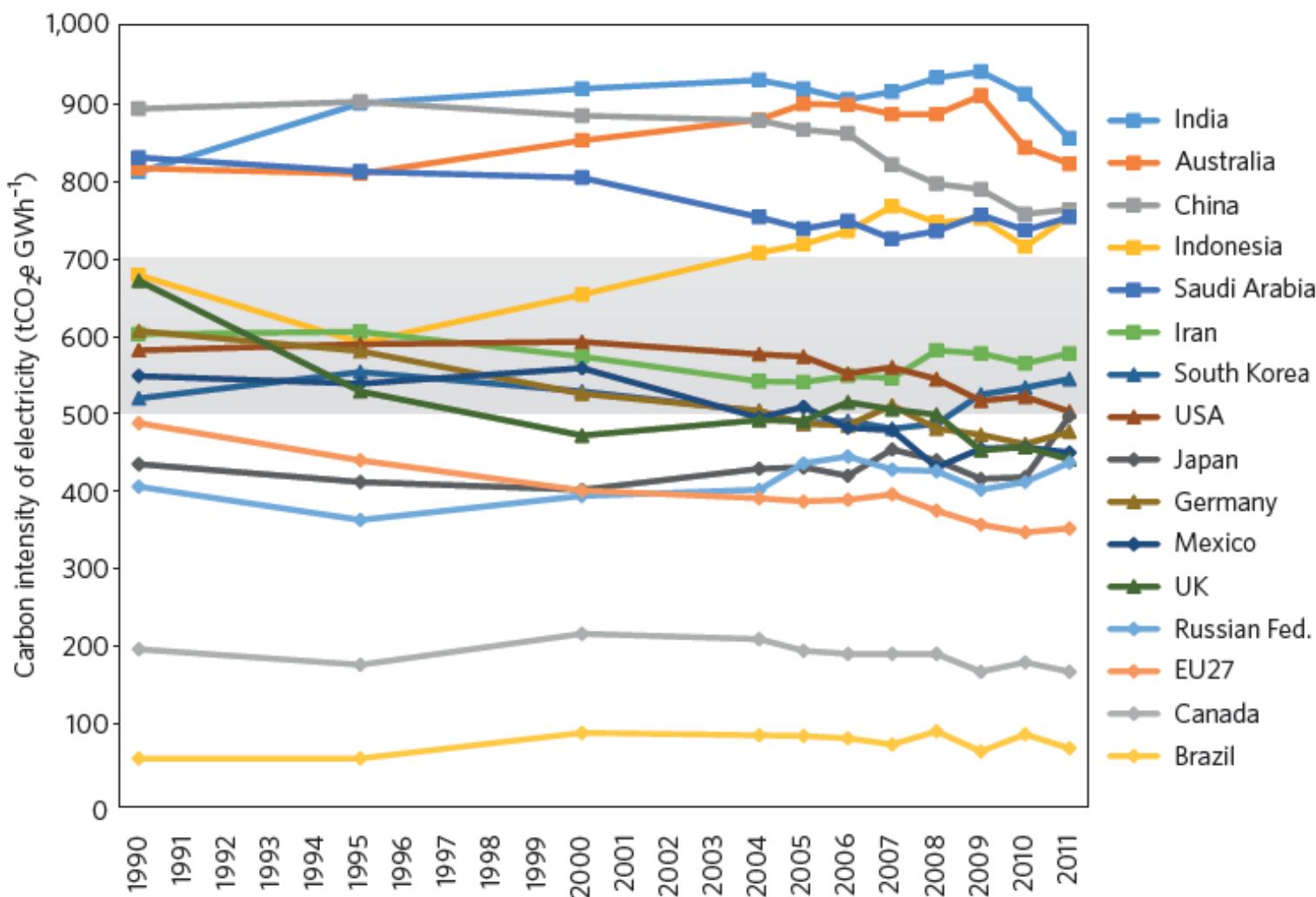
Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles

Troy R. Hawkins, Bhawna Singh, Guillaume Majeau-Bettez, and Anders Hammer Strømman



Key threshold for electricity emissions

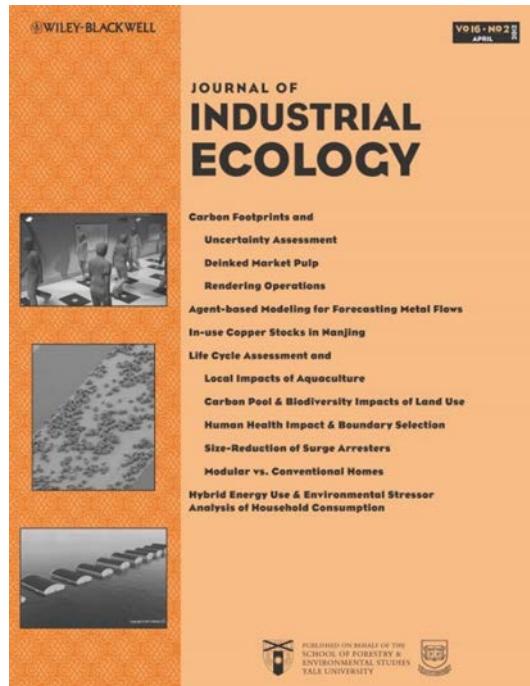
Christopher Kennedy





International Society
for Industrial Ecology

Journal of Industrial Ecology



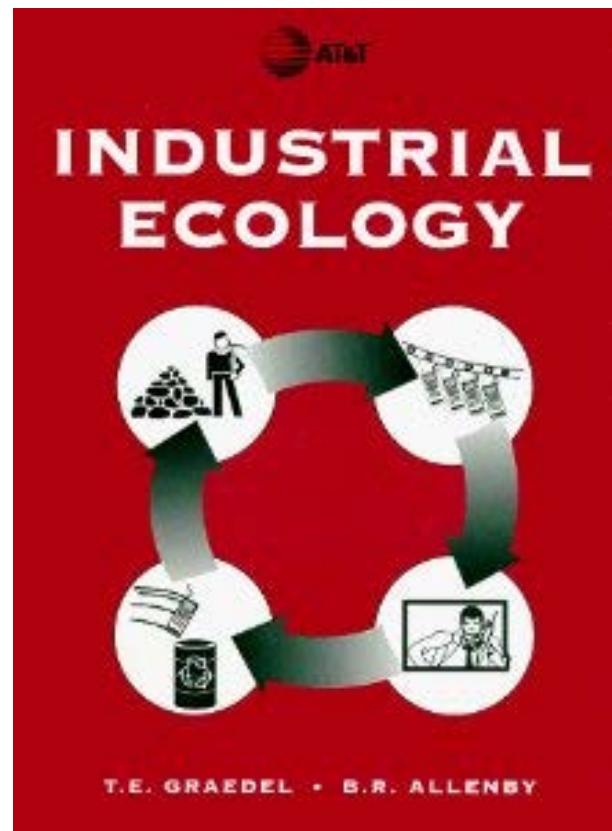
In its 19th year in 2015,
JIE has been rated as the top
journal devoted to industry and
the environment by North
American management
researchers (Cohen, 2005).

5-year impact factor: 3.15



Teaching IE

Over 400 courses in IE are taught in universities around the world.





Several universities have established programs or certificates in IE, e.g.:

Chalmers University

Erasmus Mundus

Leiden / Delft

NTNU

University of Michigan

Yale University

Shandong University

Northeast University

Beijing University of Science and Technology



Elements of Model IE Program

- Technology and Global Environmental Change
- Fundamentals of 3 metabolism (IM, SEM, UM)
- Methodological (LCA, MFA)
- Business-oriented (corporate env. management,...)
- Design for Environment
- Energy Systems
- Environmental Policy
- Foundational (economics, stats, systems analysis)



Elements of Model IE Program

Advanced courses (examples)

- Industrial Symbiosis
- EIO modelling
- Thermodynamics
- Waste management & recycling technologies
- Renewable energy technologies
- Environment & Resource economics
- Green finance



Achievements of IE

- Guidelines behind the ISO standards for LCA
- Furthered EIO models for economy-wide env. impacts.
- MFA in Environmental Accounts of OECD countries
- UN International Resource panel reports on resource decoupling, metals, biofuels, global land use change,...
- Led or contributed to chapters of the IPCC's 5th Assessment Report
- Standard approaches for inventorying GHGs for cities