



International
Resource
Panel

Session 3:

Technology for a Resource-efficient Circular Economy Technology for a Consumer-empowered Circular Economy

Anthony SF Chiu

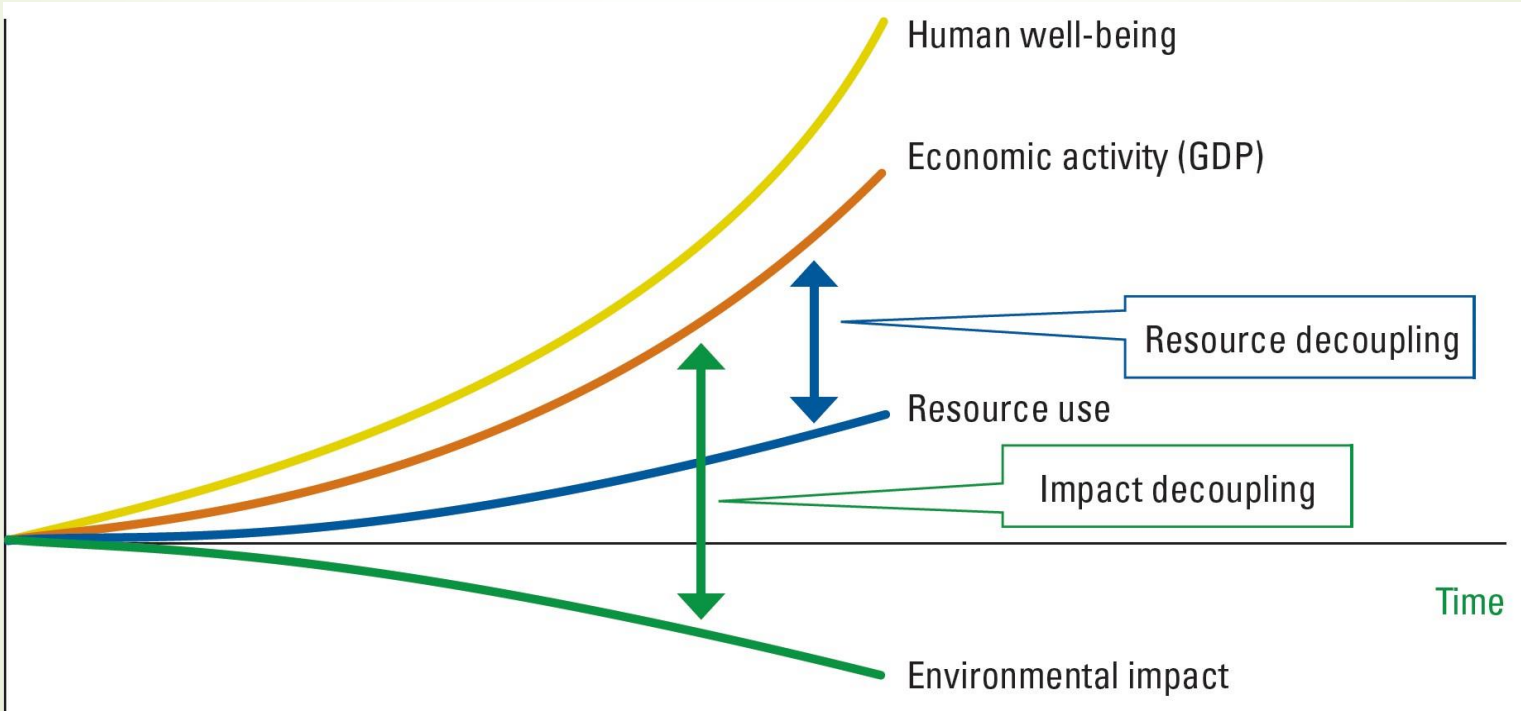
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Past President, Asia Pacific Roundtable for SCP

Member, International Resource Panel

Delegation to Rio+20, Republic of the Philippines

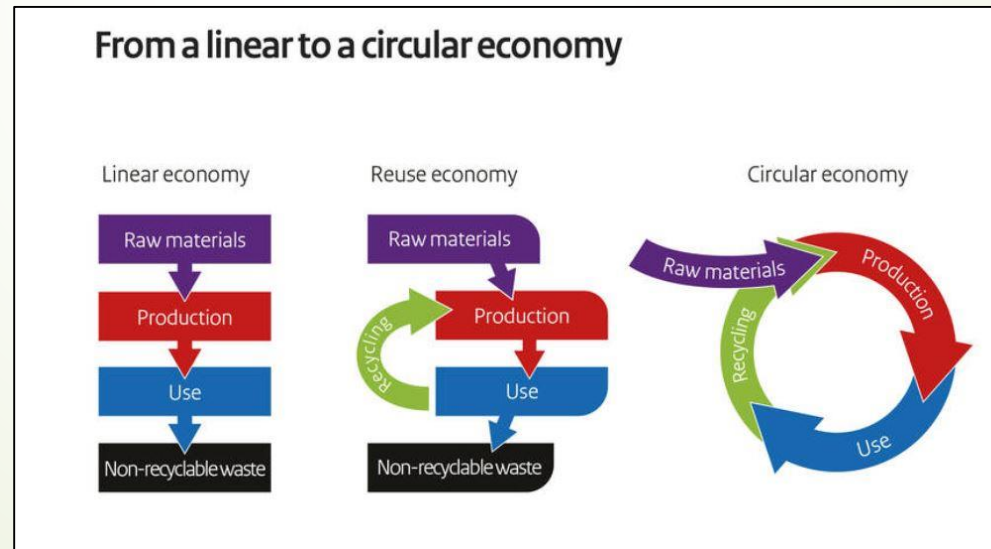
DECOUPLING IS THE IMPERATIVE OF MODERN ENVIRONMENTAL AND ECONOMIC POLICY



Eco-civilization, Sufficiency Economy, De-growth

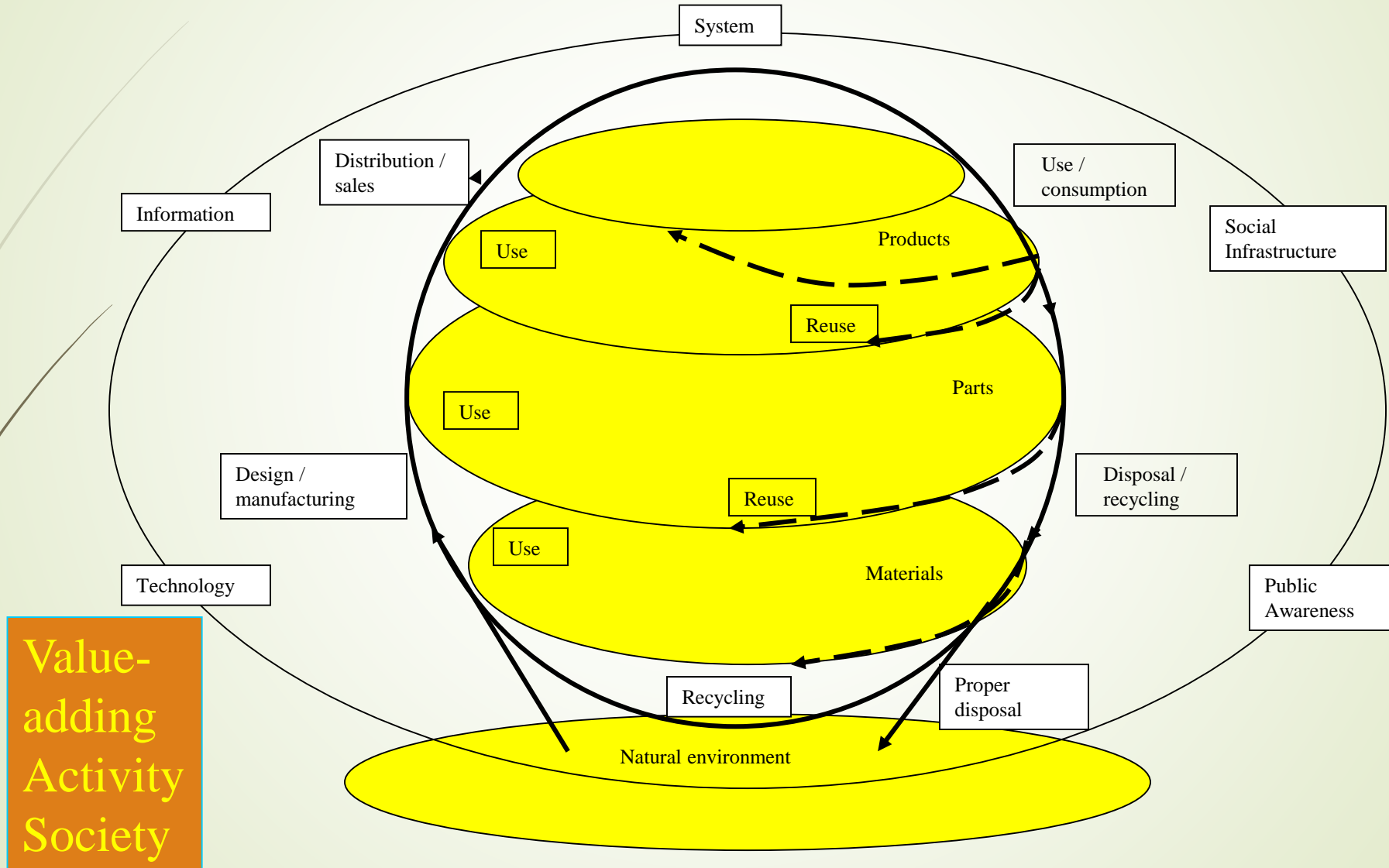
Difference between Conventional and Innovative Solutions

- **Conventional Solution** refers to the **traditional linear economy** of take – make and dispose. This means that raw materials are used to make a product, and after that the waste is thrown away.
- **Innovative Solution** refers to the **transition from linear economy to a circular economy**. Circular economy was enacted into Law in China during 2000s and revisited / defined by Ellen MacArthur as “an industrial economy that is restorative and regenerative by design and intention”.



Source: <https://www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy>

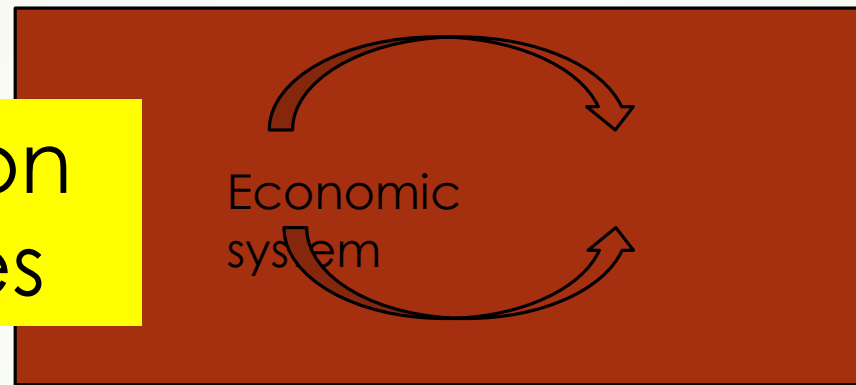
Recycling-Oriented Economic Society: A Knowledge-based Society





Technology for a Resource-efficient Circular Economy

Conservation of Resources



Human well-being and social equity
Environmental risks and ecological scarcities

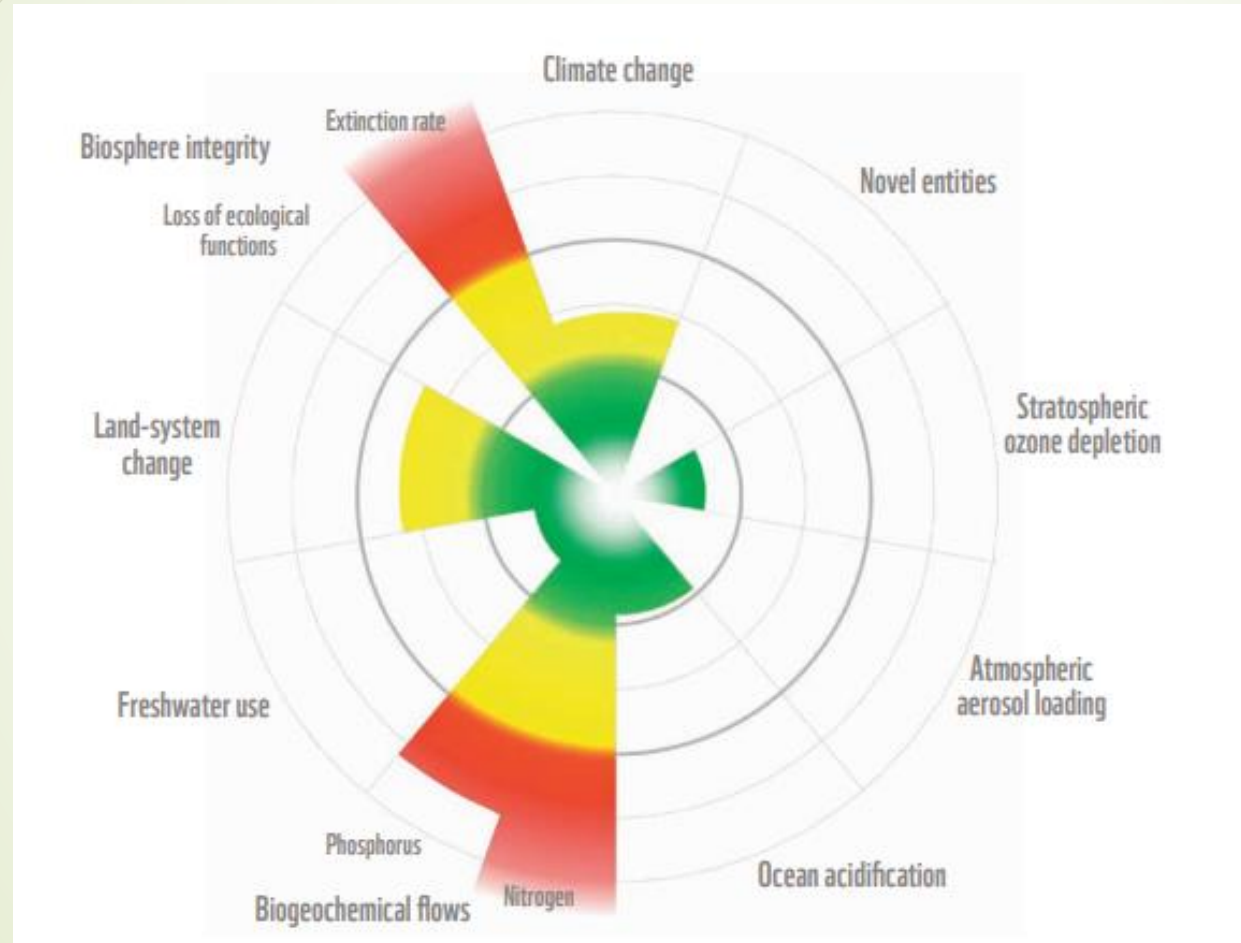
Products & Services

By-products



Objectives:
to MAXimize output with MINimum input, and operating within the carrying capacity of the eco-system

Planetary Boundaries



Key

- Beyond zone of uncertainty (high risk)
- In zone of uncertainty (increasing risk)
- Below boundary (safe)

GLOBAL MATERIAL USE HAS ACCELERATED

- Annual global extraction of materials grew from **22 billion tonnes in 1970** to around **70 billion tonnes in 2010**
- **Non-metallic minerals used in construction** was the **fastest growing group of materials**

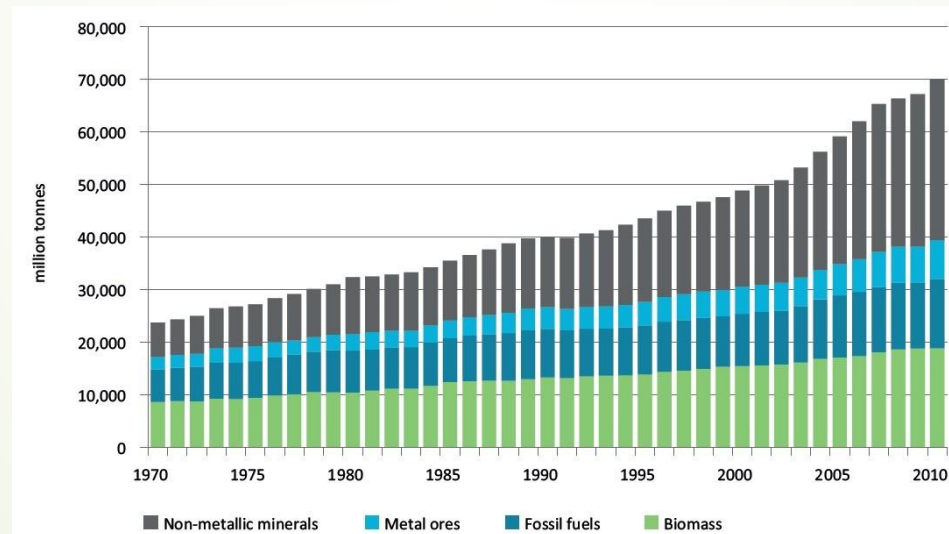


Figure 1. Global material extraction (DE) by four material categories, 1970-2010, million tonnes

MATERIAL EXTRACTION GREW UNEVENLY IN THE GLOBAL ECONOMY

- *Asia and the Pacific* had the **largest growth**, especially China and Southeast Asia
- Growth in Asia and the Pacific reverberated in *Latin America and Africa* who supplied materials to Asia



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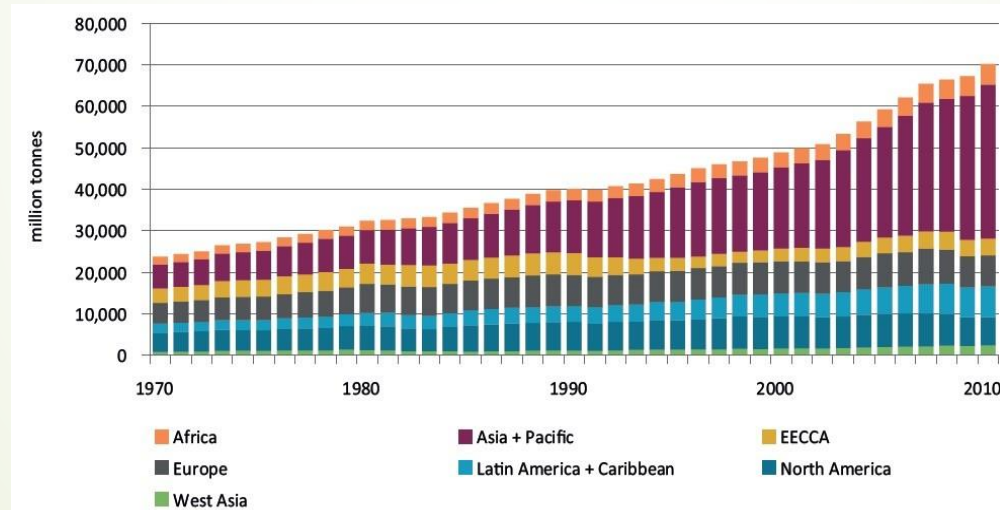
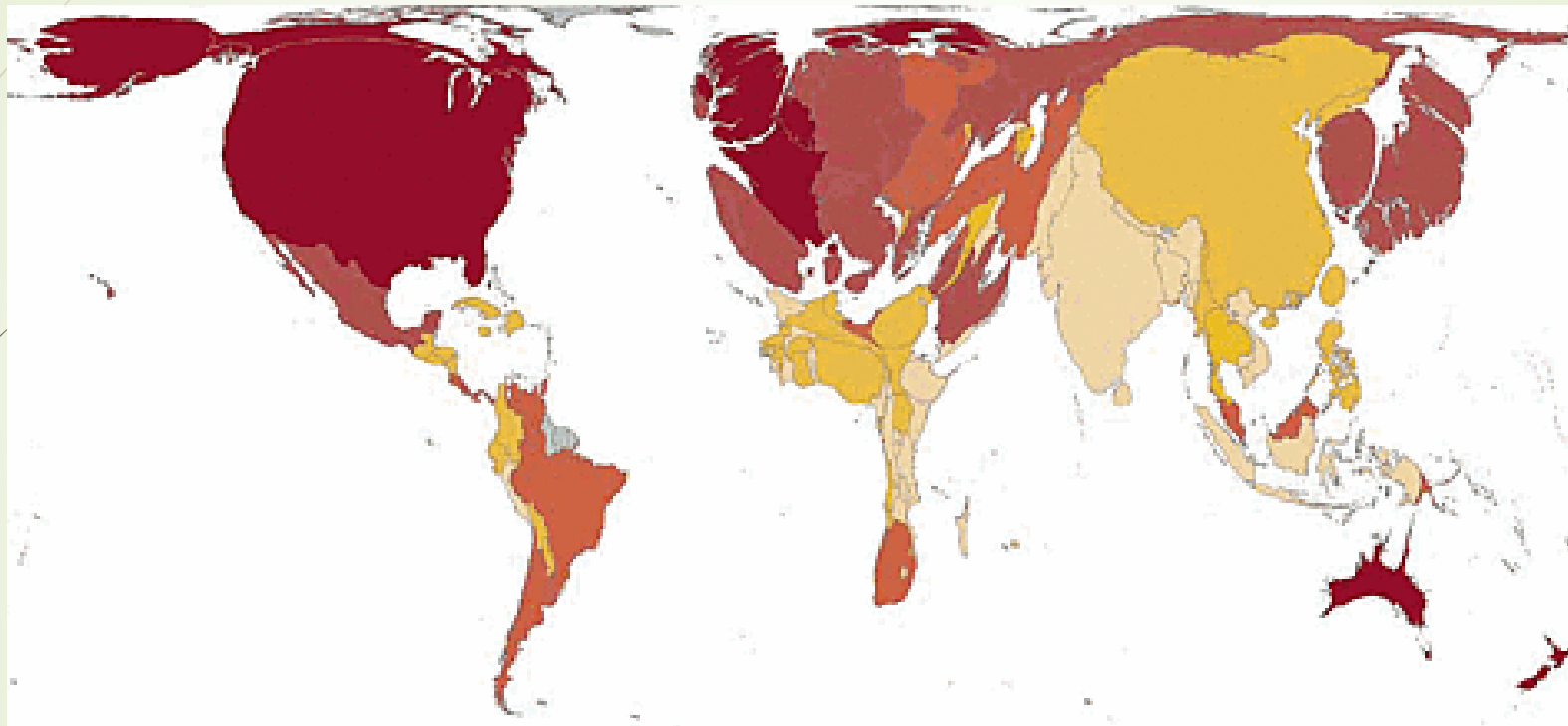


Figure 2. Domestic extraction (DE) by seven subregions, 1970-2010, million tonnes

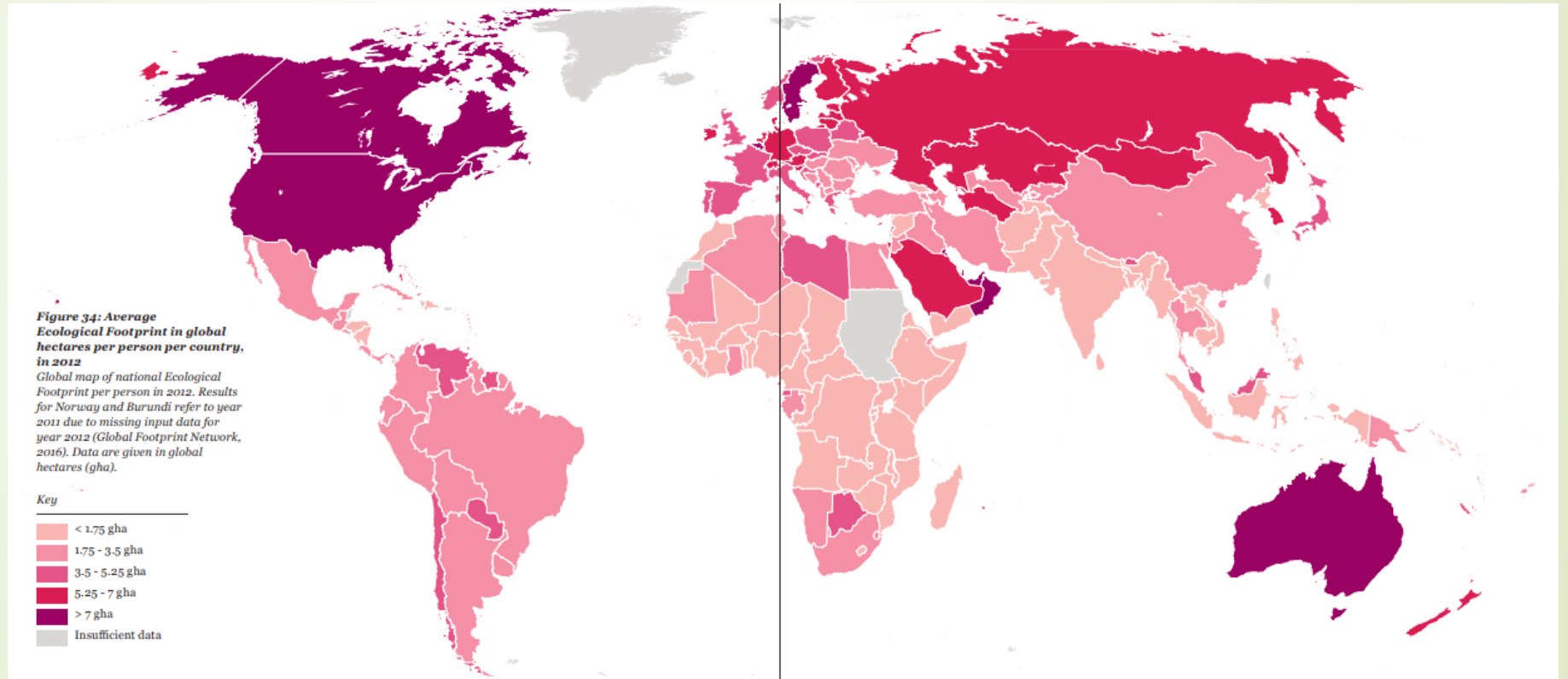
UN
environment

Eco Footprint 2006

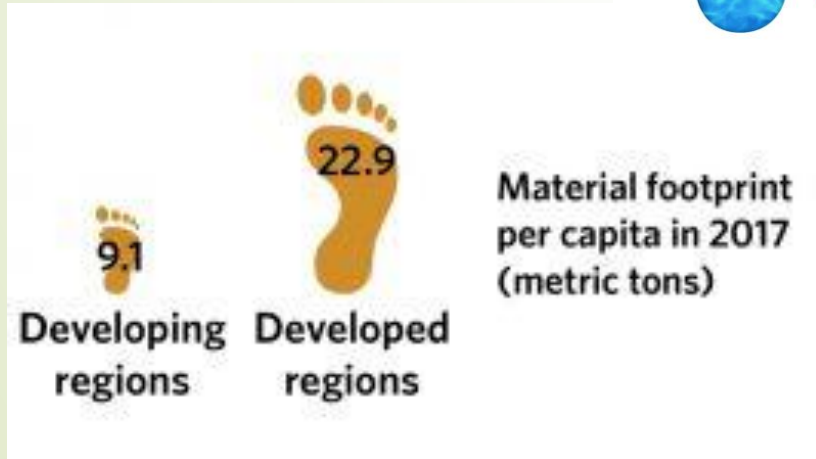
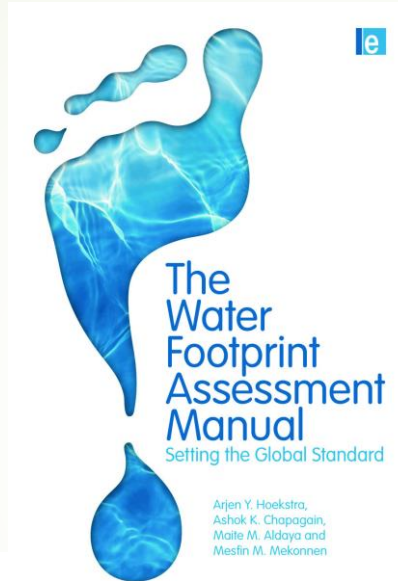


- More than 5.4 global hectares per person
- 3.6–5.4 global hectares per person
- 1.8–3.6 global hectares per person
- 0.9–1.8 global hectares per person
- Less than 0.9 global hectares per person
- Insufficient data

2016 Eco-footprint



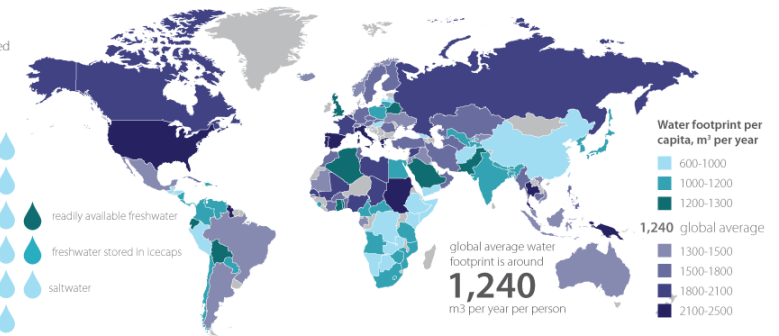
More scrutinies



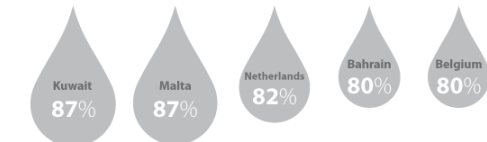
the global water footprint

The 'water footprint' of a country is defined as the volume of water needed for the production of goods and services consumed by the inhabitants of the country.

amount of freshwater available

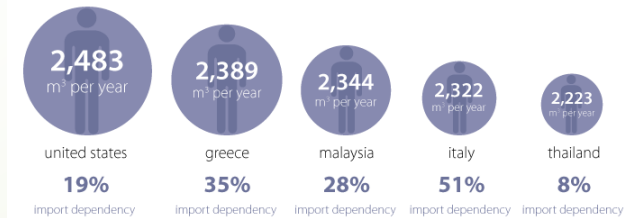


countries most dependent on water imports

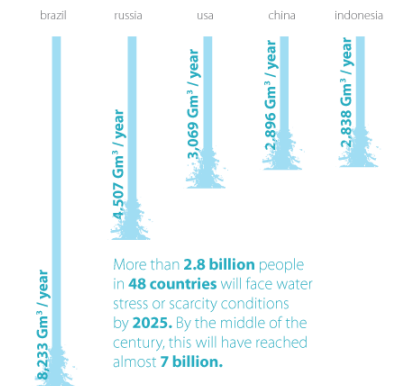


70% of existing freshwater is withdrawn for irrigation in agriculture

the highest water footprints per capita



highest renewable water resources



water footprint of different foods



Source: WaterFootprint.org and WWF

RICHEST COUNTRIES CONSUME ON AVERAGE 10 TIMES THE MATERIALS AS POOREST COUNTRIES

- Average material footprint of medium HDI countries has grown slowly over past two decades, reaching 5 tonnes per capita, while **material footprint in low HDI countries has been stagnant** for the past two decades at 2.5 tonnes per capita

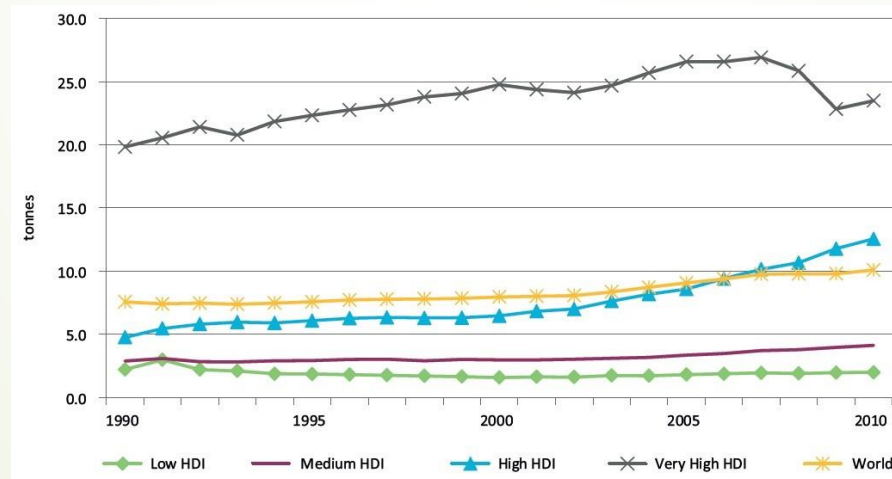


Figure 8. Per capita material footprint (MF) by HDI level, 1990-2010 (the HDI is a compound index on life expectancy, literacy and income)

CONSUMPTION IS DRIVING GLOBAL MATERIAL USE

- *Growth in per capita income and consumption have been the strongest driver of growth in material use, even more important than population growth in recent decades*



Figure 5. Drivers of material footprint, 2010–2015 (percentages) (adapted from IRP, 2017).

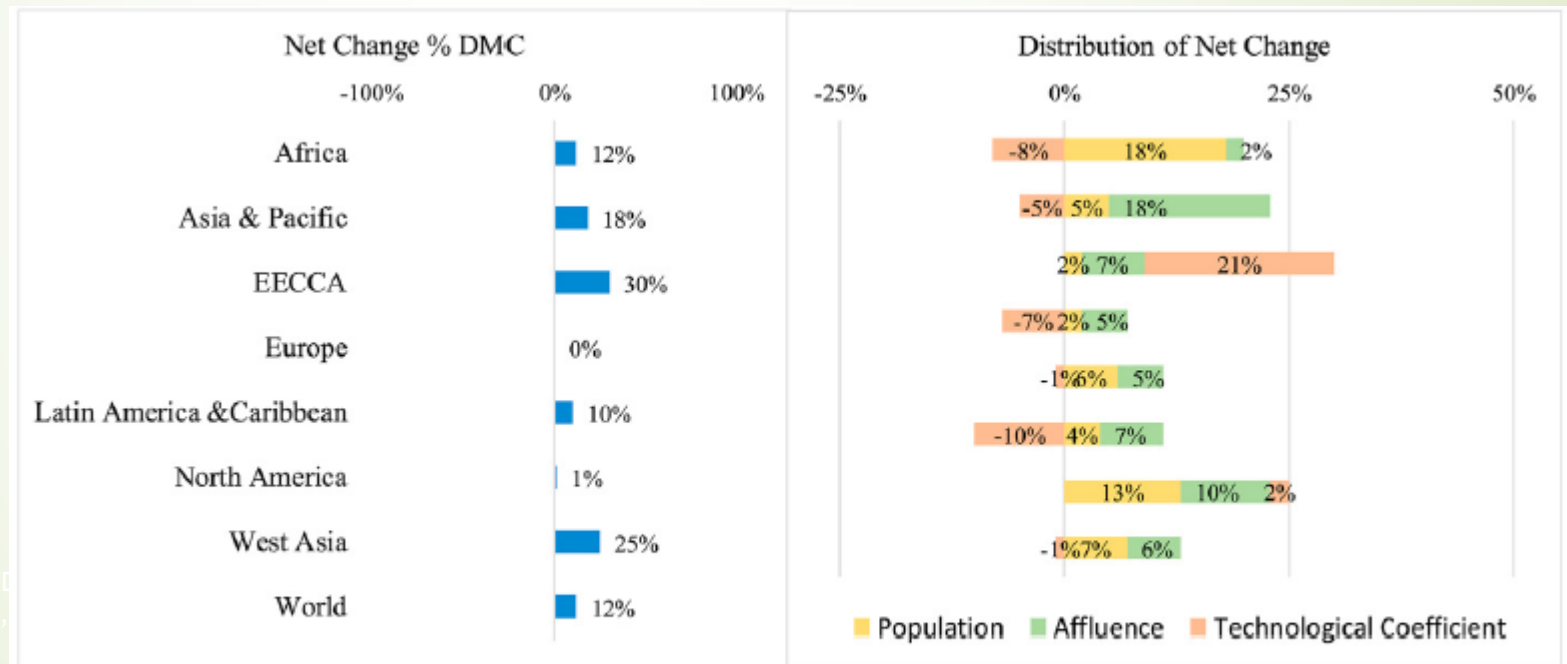
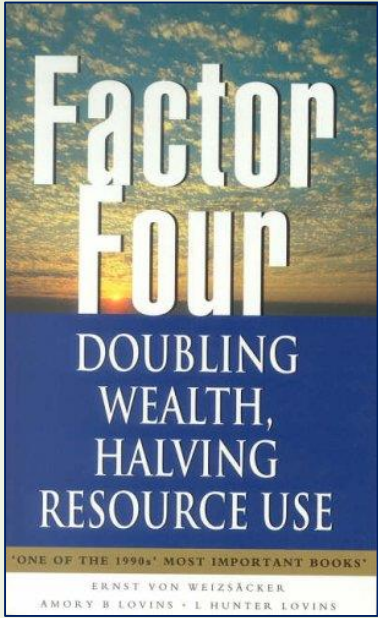
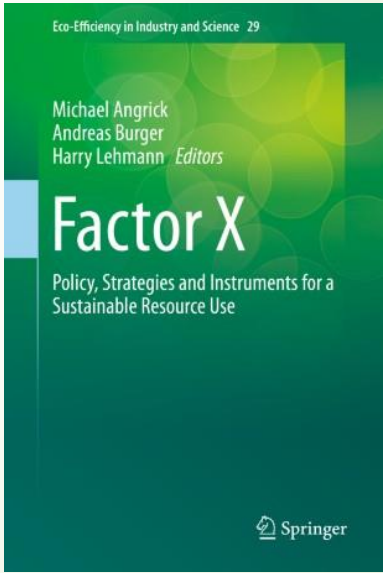
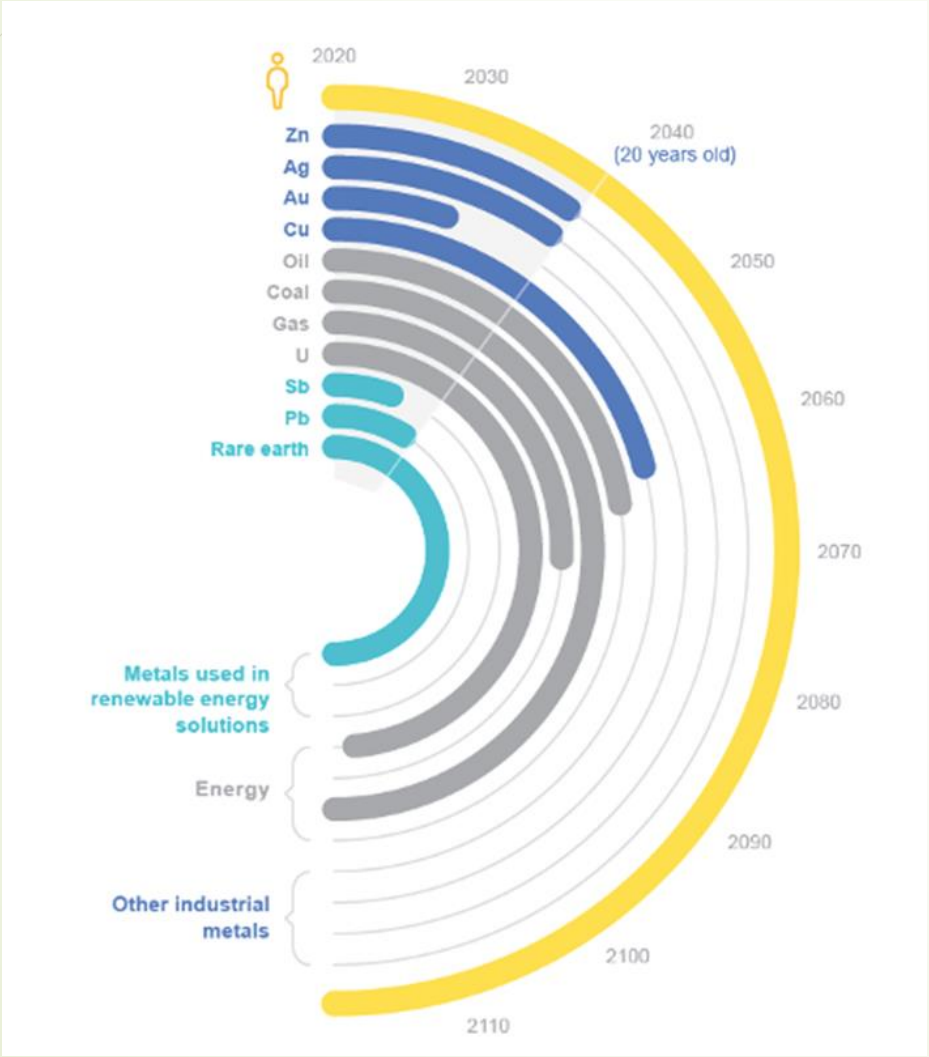


Fig. 2. Drivers of material footprint, 2010–2015 (percentages) (adapted from IRP, 2017).

Factor 4 or Factor X ?





Systems Thinking

Conservation
of Resources

Resource
Efficiency



Human well-being and social equity
Environmental risks and ecological scarcities



Products & Services



By-products



Objectives:
to MAXimize output with MINimum input, and operating within the carrying capacity of the eco-system

OVERALL DECLINE IN MATERIAL EFFICIENCY

- Global economy now needs **more materials per unit of GDP** than it did at the turn of the century
- This has been caused by large **shift of economic activity from very material-efficient economies** such as Japan, the Republic of Korea and Europe **to the much less material-efficient economies** of Asia and the Pacific

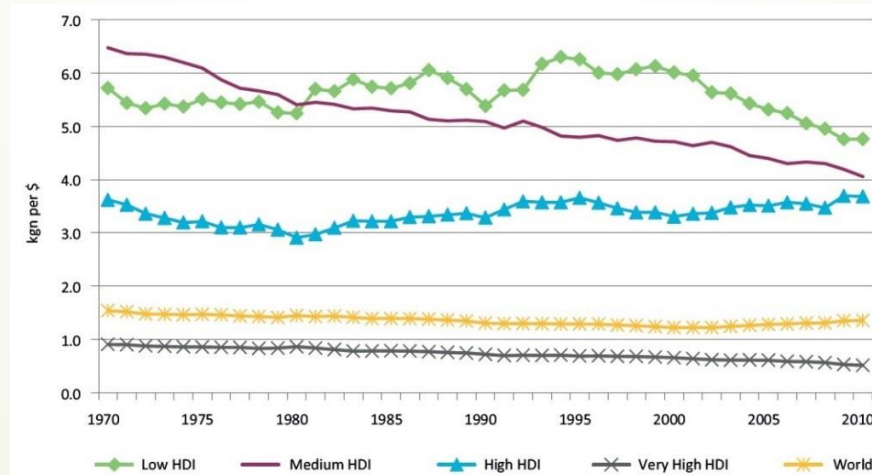
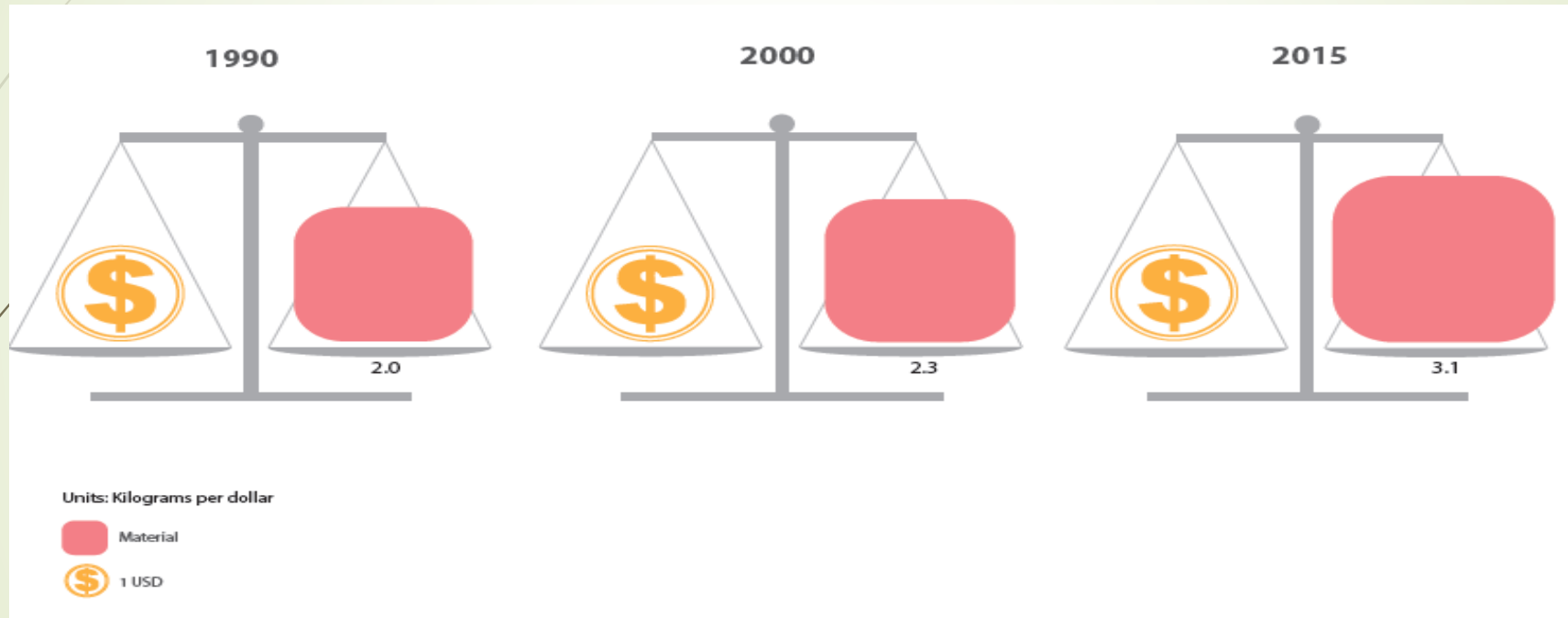


Figure 7. Material intensity by development status and global material intensity, 1970-2010

Increasing intensity of resource use in Asia Pacific



THE LEVEL OF WELL-BEING ACHIEVED IN WEALTHY INDUSTRIAL COUNTRIES CANNOT BE GENERALIZED GLOBALLY BASED ON THE SAME SYSTEM OF PRODUCTION AND CONSUMPTION

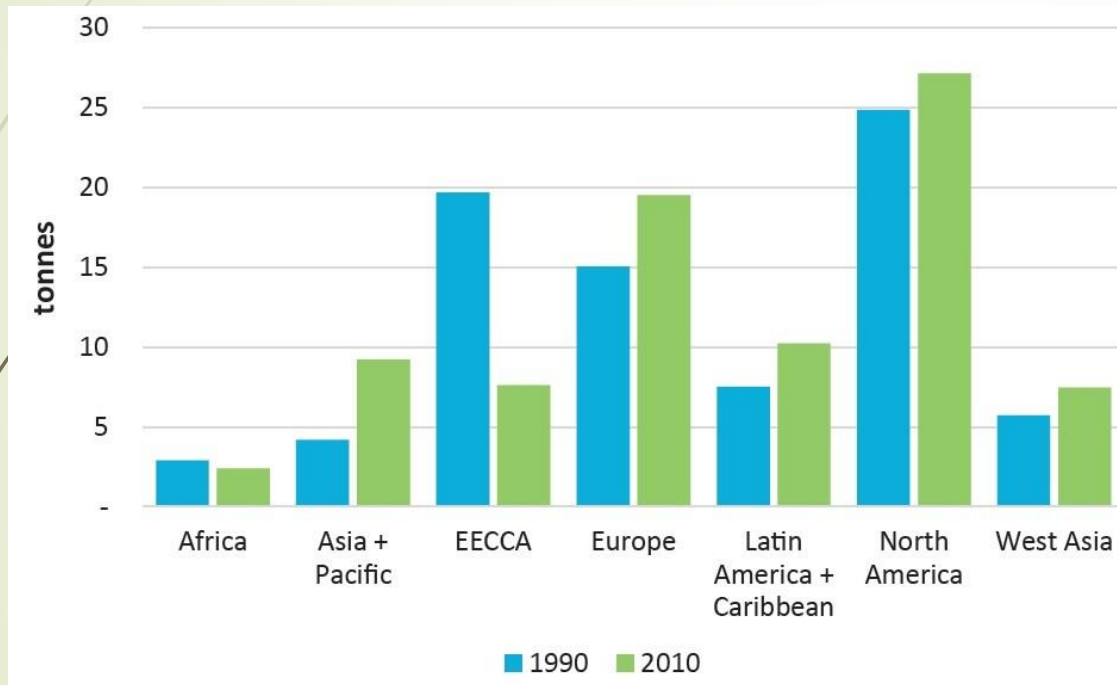
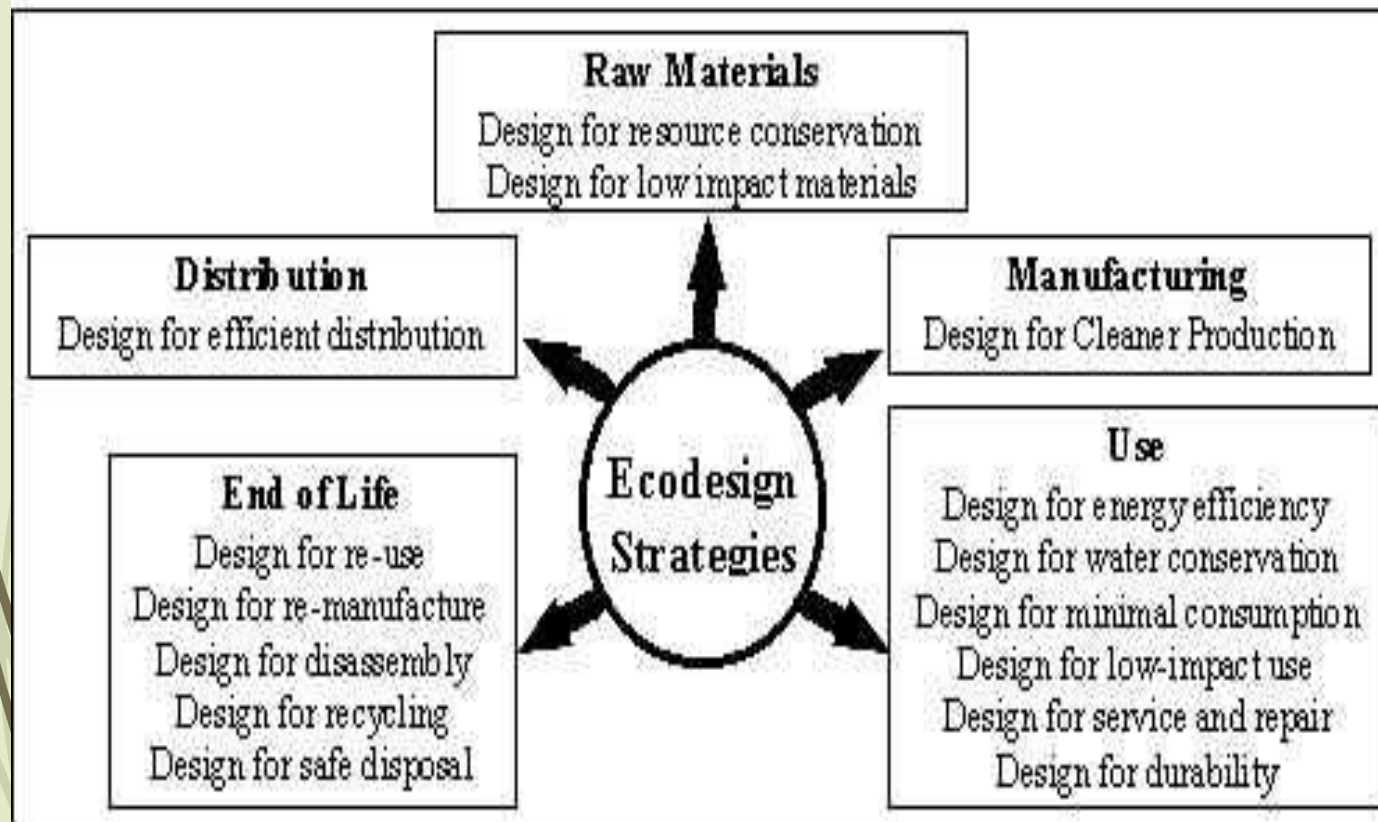


Figure 6. Per-capita material footprint (MF) by seven world regions, 1990 and 2010, tonnes

*If current systems of production and provision for major services will not be changed, nine billion people would require about **180 billion tonnes** of materials annually **by 2050**, almost **three times today's amounts***

Sustainable Product Innovation (SPIN)



Design principles

Design to **create value**

Design approaches

- Design to integrate value
- Design for quality

Design to **preserve value**

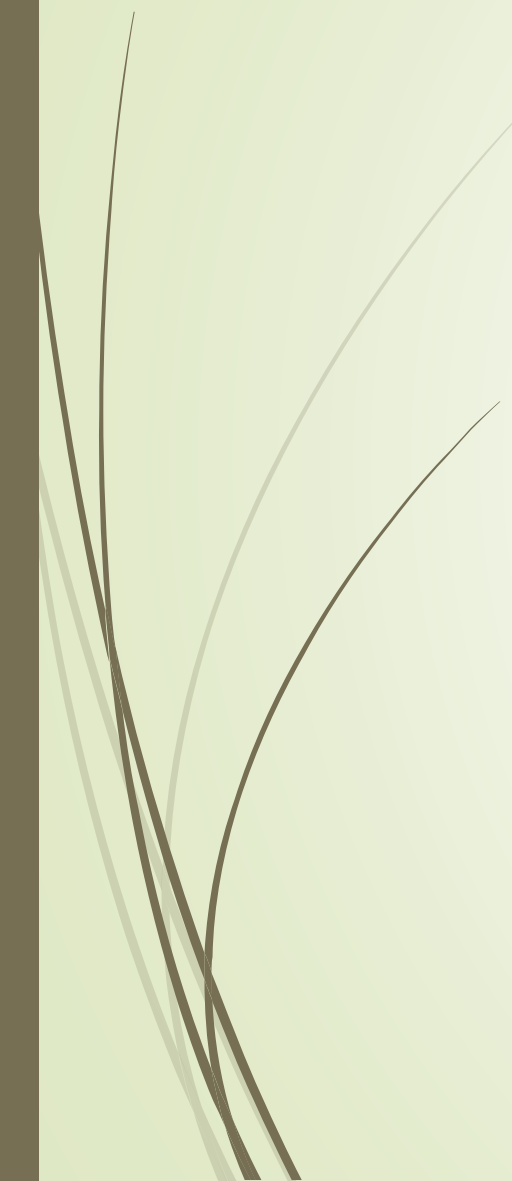
- Design for durability
- Design for viability
- Design for serviceability

Design to **recover value**

- Design for disassembly / separability
- Design for assessability
- Design for restorability



Circular Design Strategies (also see Circular Design Guide)

- Dematerialization
 - Product-as-a-Service
 - Design for extended product life
 - Circular material choice
 - Modular design
- 

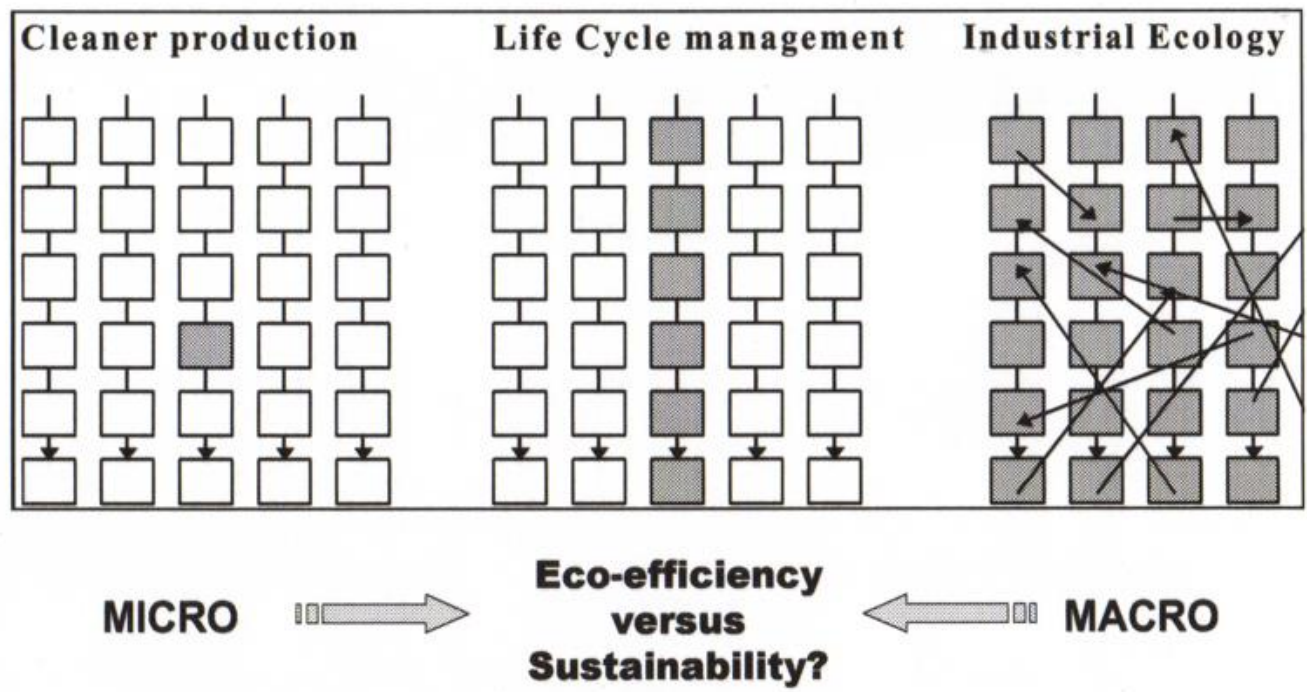


Material Innovation



- (1) New materials could improve resource efficiency by replacing conventional materials that have higher carbon footprints.**
- (2) New materials could be less harmful to the environment and human health.**

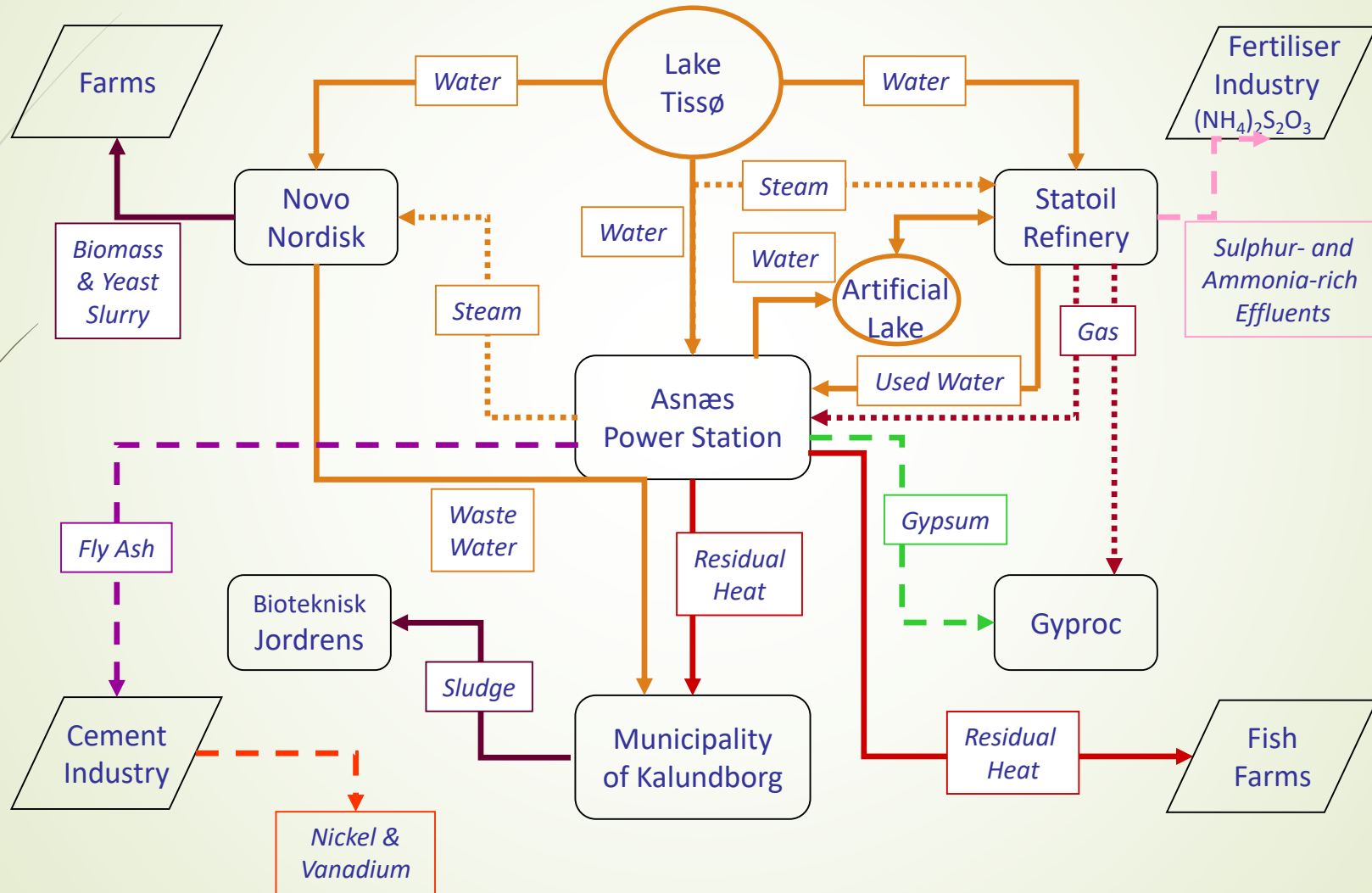
Extended Principles and Ideas



Zero Emission (or industrial symbiosis)

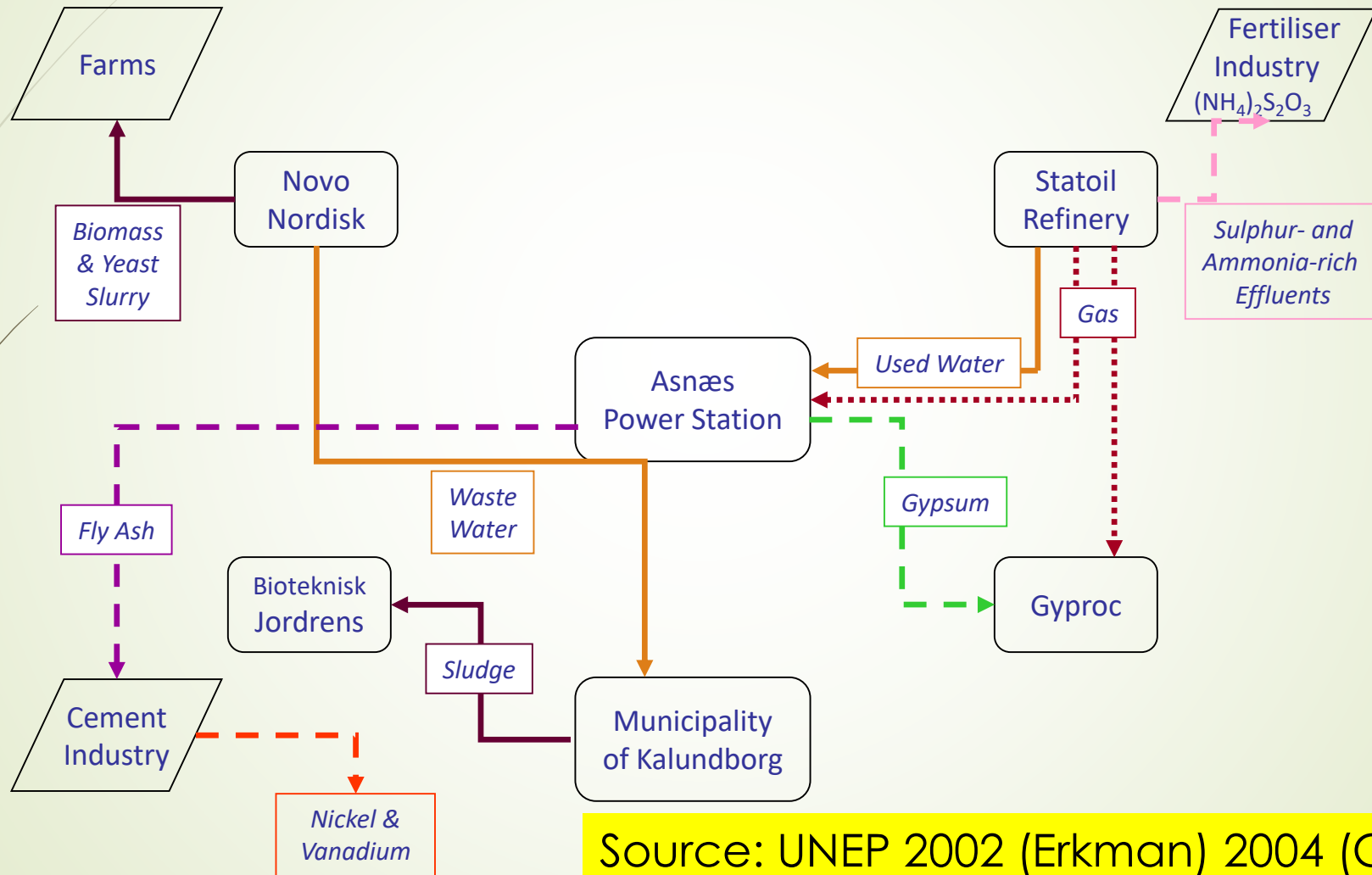
Zero-emission can be defined as a vehicle, engine or energy source that does not produce any dangerous gases that could pollute the environment. It is a key fundamental concept in Consumer Sustainability. It can be extended to an enlarged system, such as an industrial park, a city, or

Kalundborg Industrial Symbiosis

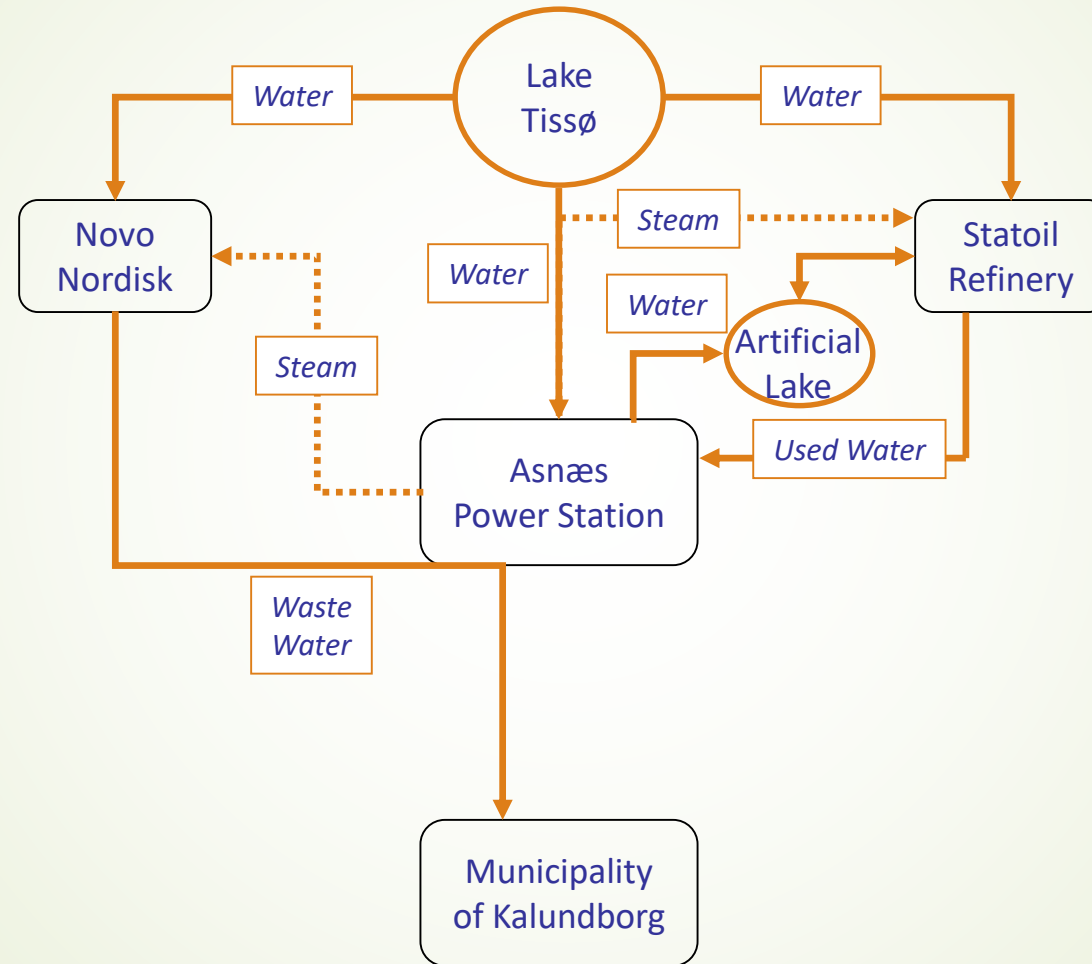


Source: UNEP 2002 (Erkman) 2004 (Chiu)

Kalundborg Industrial Symbiosis - Waste Flow

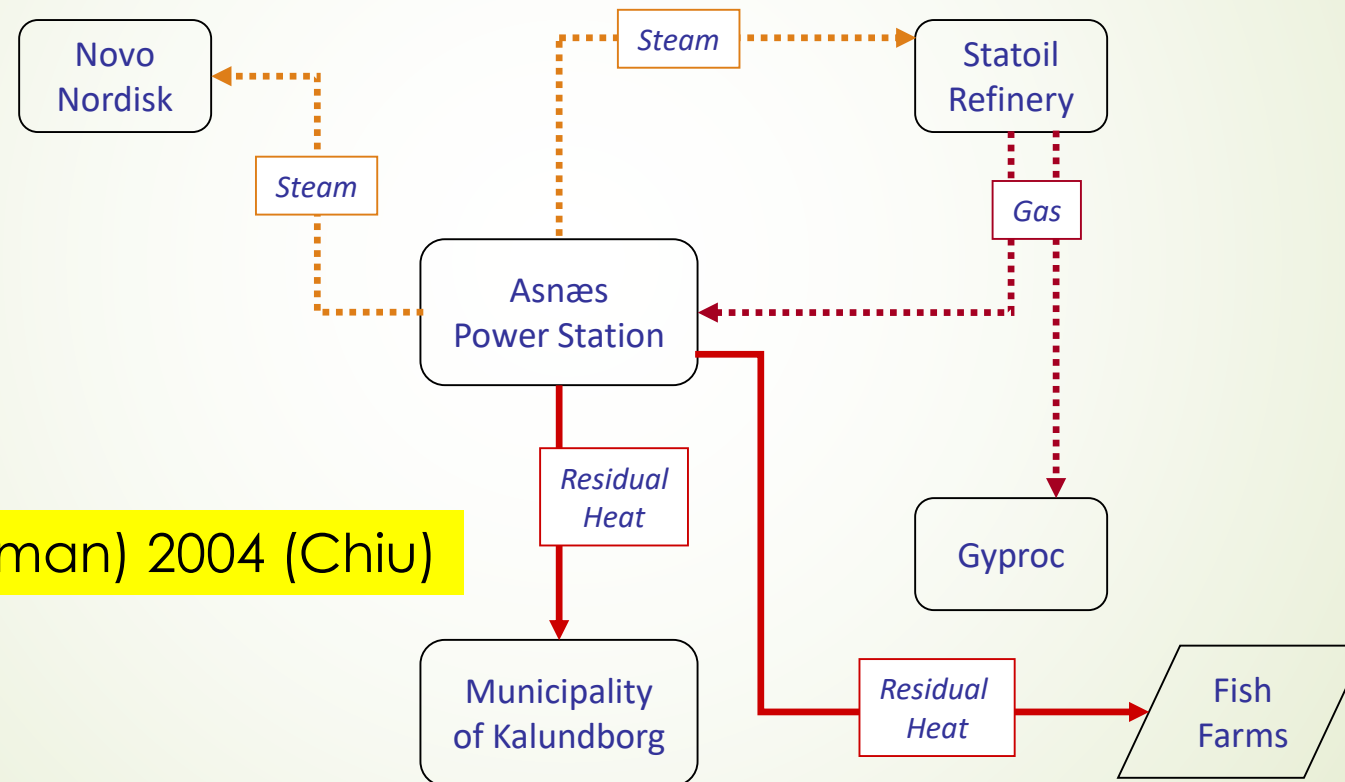


Kalundborg Industrial Symbiosis - Water Flow



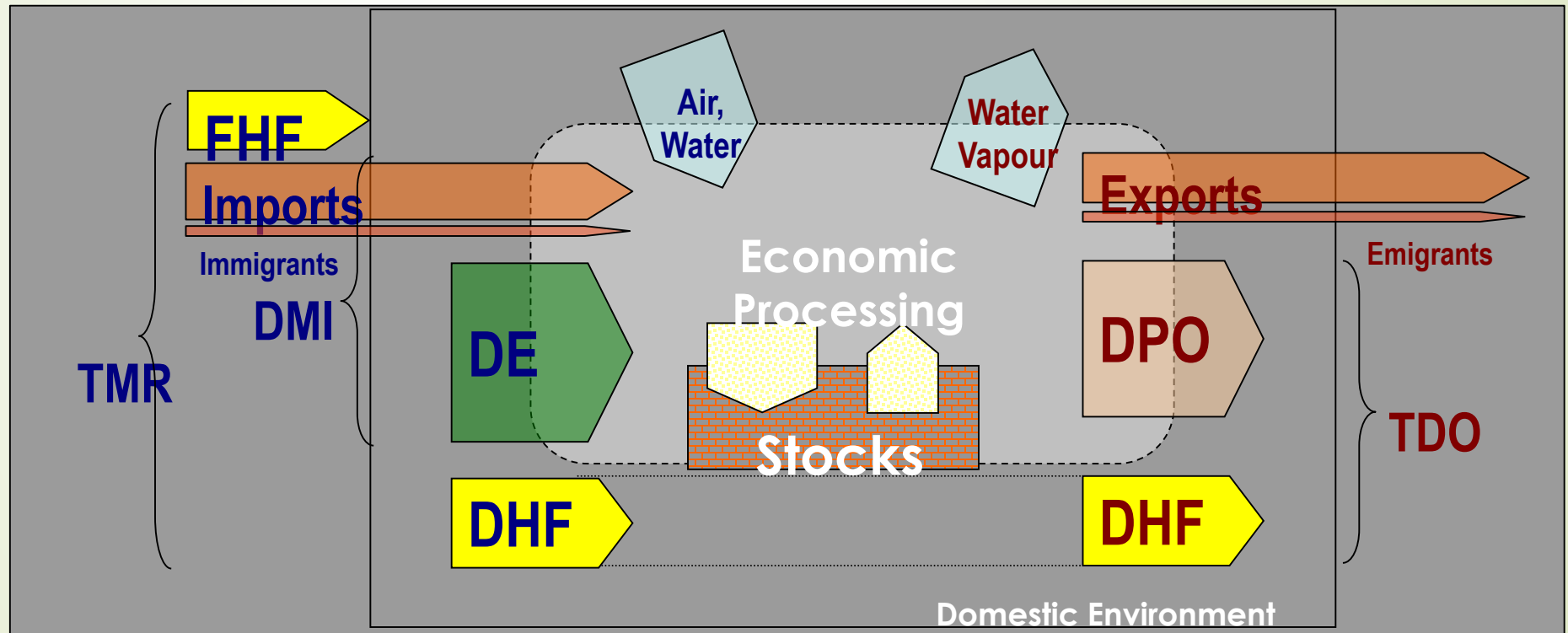
Source: UNEP 2002 (Erkman) 2004 (Chiu)

Kalundborg Industrial Symbiosis - Energy Flow



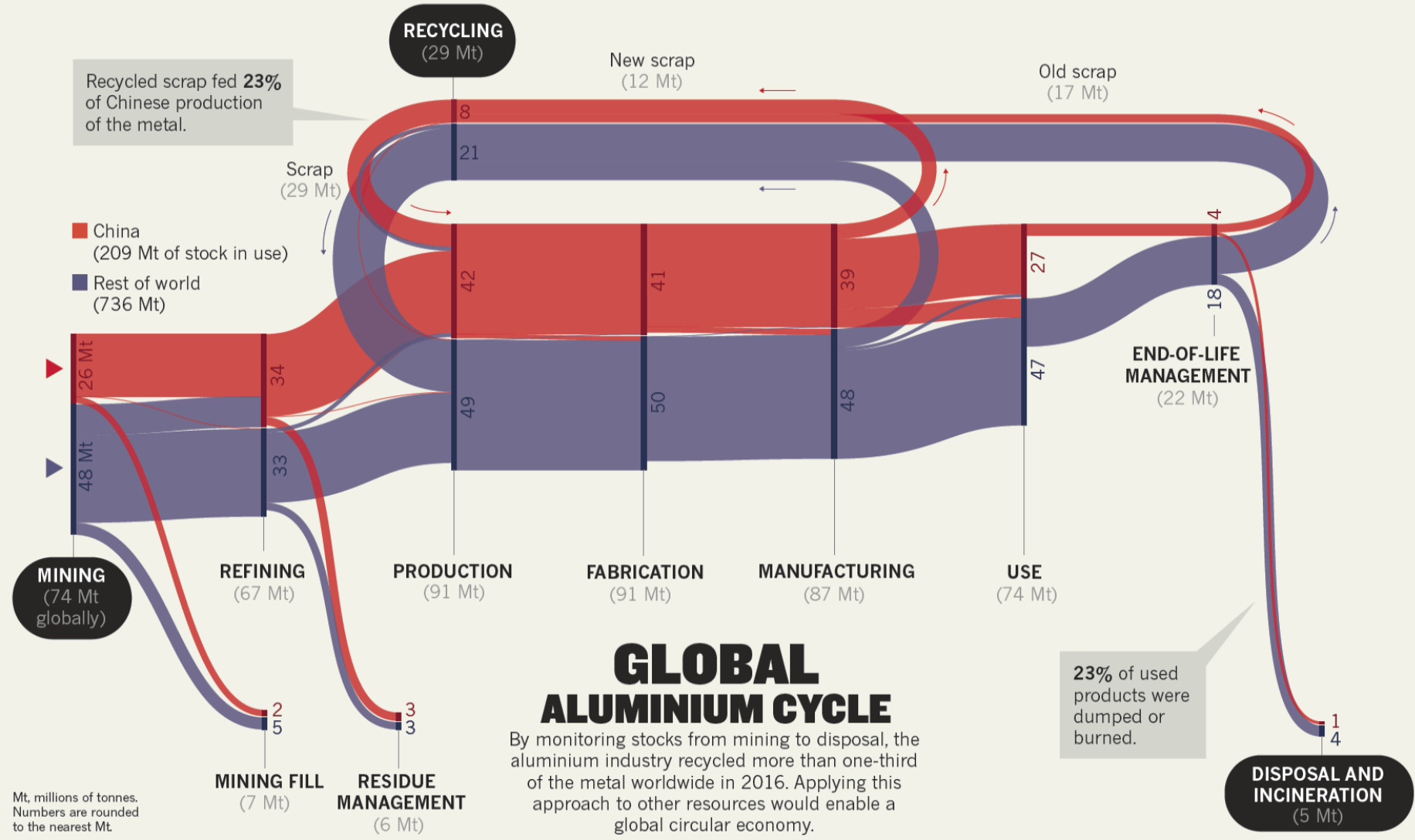
Source: UNEP 2002 (Erkman) 2004 (Chiu)

Technology for a consumer-empowered Circular Economy

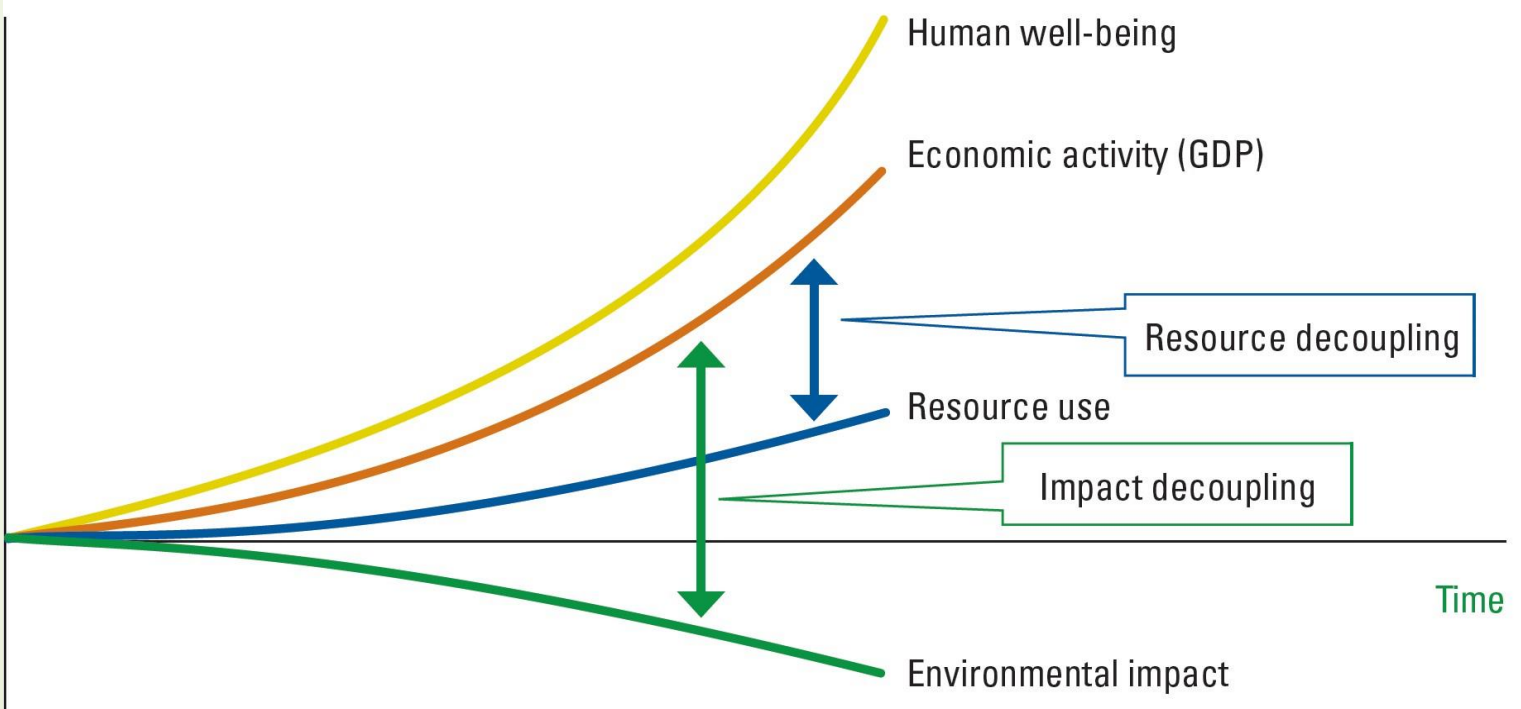


Source: WRI et al., 2000, 2016; Rapera, Chiu, et al.

Globalize the Circular Economy
(NATURE | VOL 565 | 10 JANUARY 2019)

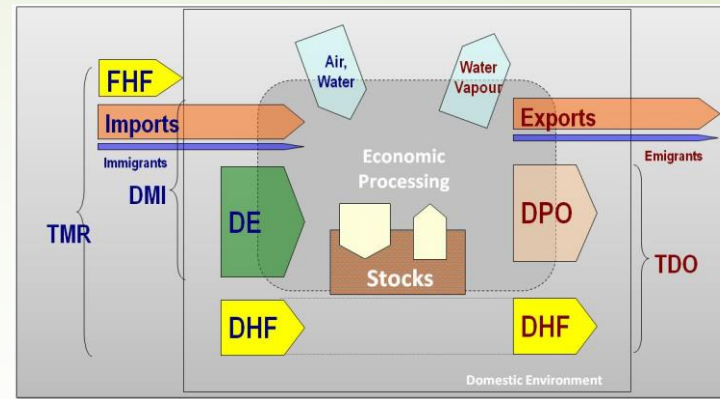


DECOUPLING IS THE IMPERATIVE OF MODERN ENVIRONMENTAL AND ECONOMIC POLICY



Eco-civilization, Sufficiency Economy, De-growth

INDICATORS



INPUT

Total Material Requirement (TMR)

Direct Material Input (DMI) = Domestic Extraction (DE) + imports

Domestic Hidden Flows (DHF)

Foreign Hidden Flows (FHF)

OUTPUT

Domestic Processed Output (DPO)

Total Domestic Output (TDO) = Domestic Processed Output (DPO) + DHF

Direct Material Output (DMO)

Total Material Output (TMO)

BALANCE

Net Addition to Stocks (NAS) = DMI + Air and Water – Exports – DPO – Water Vapour

Imports and Exports

Air, Water, Water Vapour

MFA Components

Domestic

- ▶ **Non - Renewable**
 - ✓ Energy Carriers
 - ▶ Metal Ores
 - ✓ Industrial Minerals
 - ✓ Construction Materials
 - ▶ Excavation
- ▶ **Renewable**
 - ✓ Plant Biomass
 - ✓ Animal Biomass
- ▶ **Soil Erosion**

Imports

- ▶ **Non - Renewable**
 - ✓ Energy Carriers
 - ▶ Metal Ores
 - ✓ Industrial Minerals
 - ✓ Construction Materials
 - ▶ Excavation
- ▶ **Renewable**
 - ✓ Plant Biomass
 - ✓ Animal Biomass
- ▶ **Semi-Manufactures**
- ▶ **Final Products**
- ▶ **Hidden Flows**
 - ▶ Imported Raw Materials
 - ▶ Imported Semi-Manufactures

Comparisons between China and Other Countries



Countries	US	Canada	Japan	Australia
SO ₂ emission(kg/1000US\$GDP)	2.3	3.7	0.3	4.7
NOx emission(kg/1000US\$GDP)	2.7	2.9	0.6	5.5
Countries	France	Germany	OECD	China
SO ₂ emission(kg/1000US\$GDP)	0.8	0.7	2.0	18.5
NOx emission(kg/1000US\$GDP)	1.4	1.0	2.1	16.6

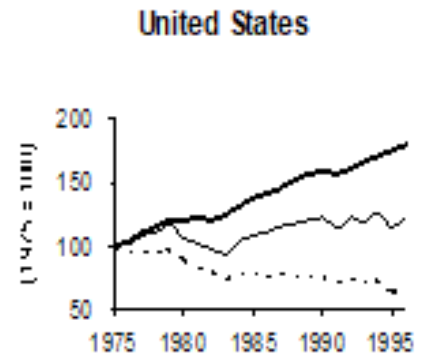
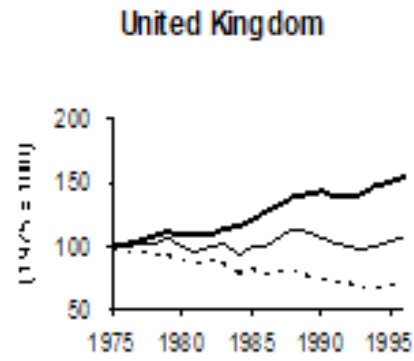
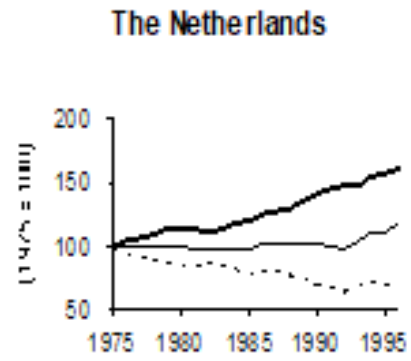
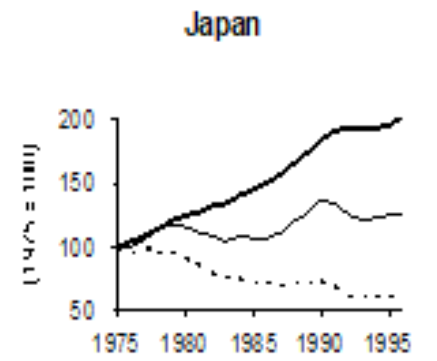
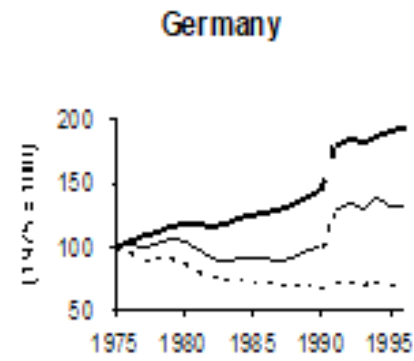
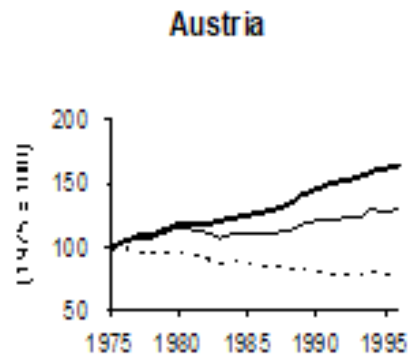
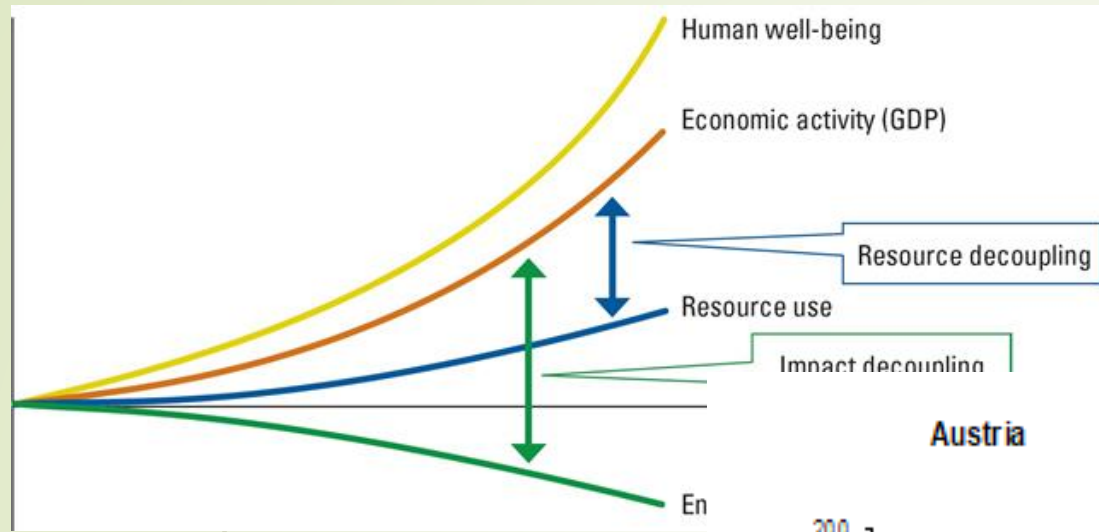
Geng, ISIE 2005

Energy Comparison

Geng, ISIE 2005



C O U N T R Y	J A P A N	I T A L y	F R A N C E	G E R M A N Y	U K	U S	C A N A D A	C H I N A
Energy Consump tion Per USD	1.00	1.33	1.50	1.50	2.17	2.67	3.50	11.5



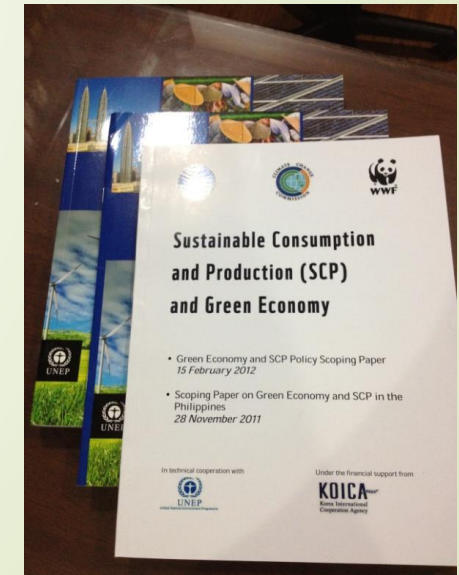
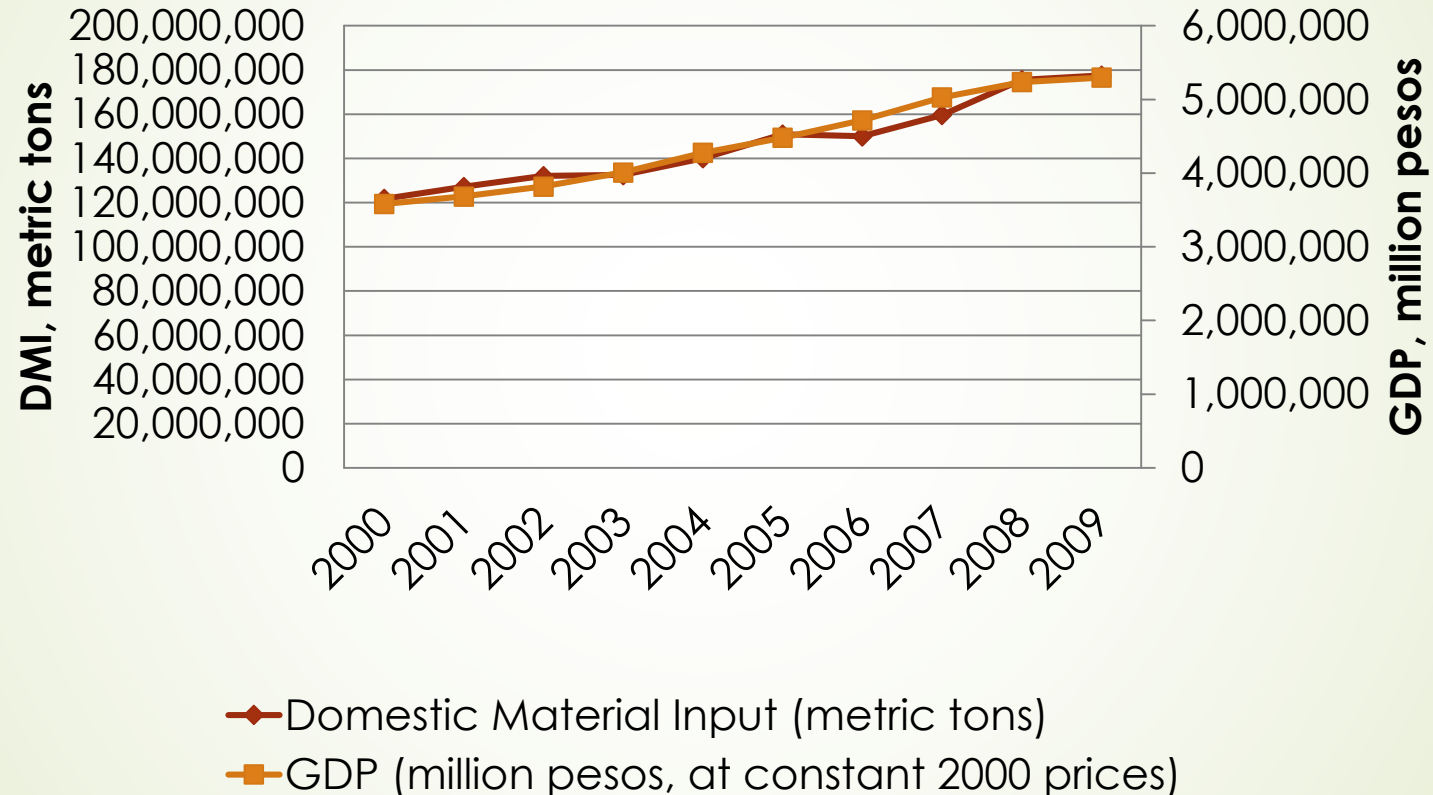
— GDP

- - - DMI

· · · DMI/GDP (1975 = 100)

Resource Utilization

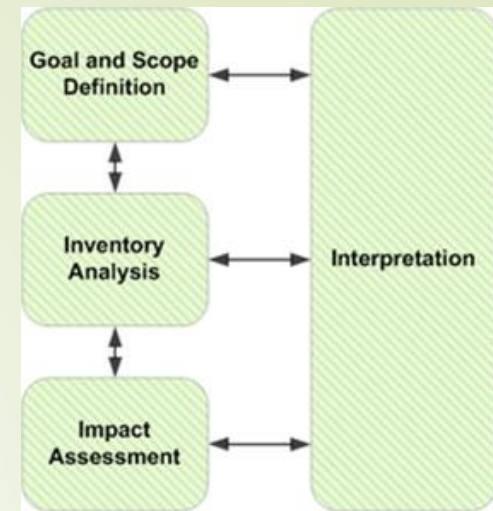
Philippine DMI and GDP



Life Cycle Assessment

There are generally four main stages in an LCA study:

- (a) Goal and Scope Definition, where the objective and boundaries of the study are decided;
- (b) Inventory Analysis, where a model of the life-cycle is made and data on environmental emissions and resource consumption from the different processes across the life-cycle are collected or calculated;
- (c) Impact Assessment, where the impact on the environment is assessed;
- (d) Interpretation, where significant issues are identified and conclusions are drawn. Sensitivity analyses, identification of significant data gaps and major uncertainties can also be included.



Environmental and health impact modelling

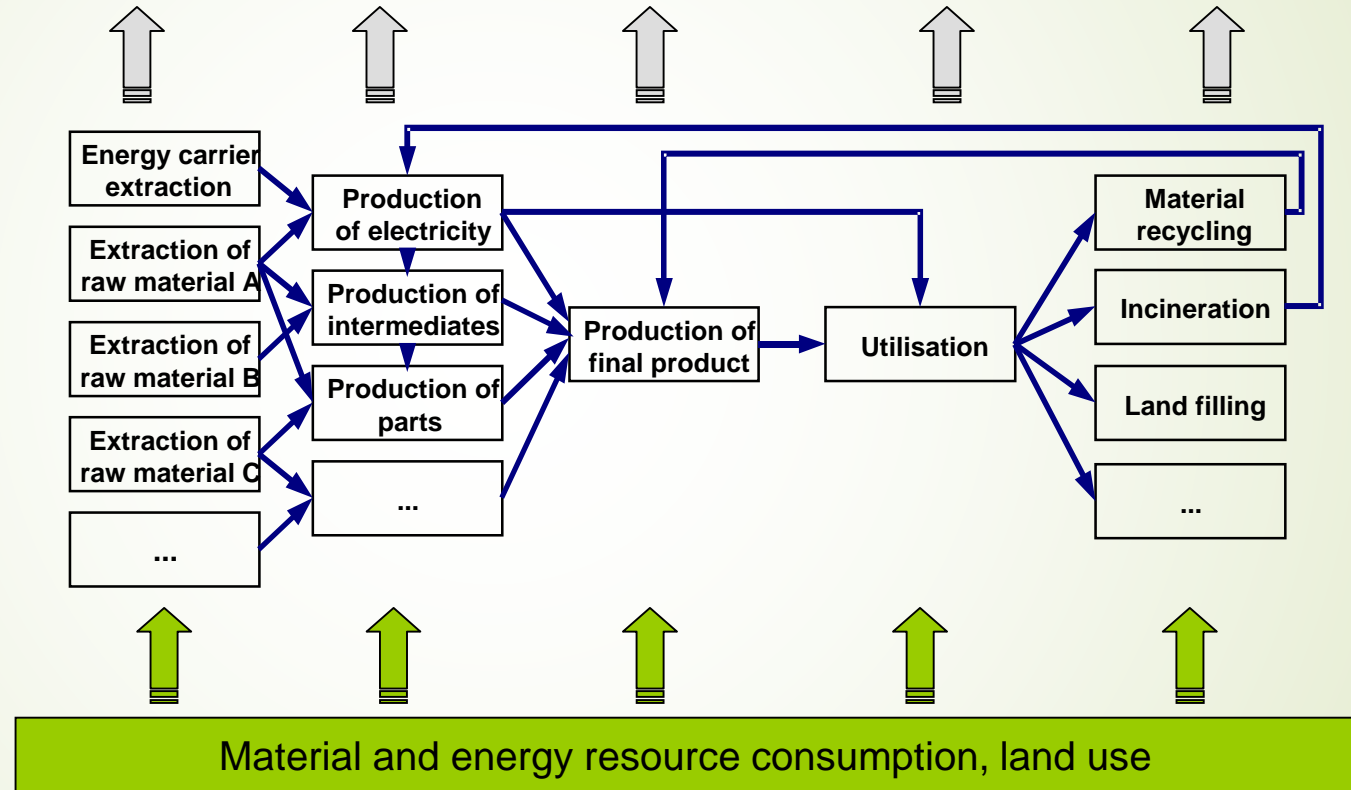
Climate change, Acidification, Summer smog, Human toxicity, Ecotoxicity, Eutrophication, Ozone layer depletion, Radioactive releases, ...

Emissions

Life Cycle Inventory

Resources

Resource depletion



Life Cycle Phases:

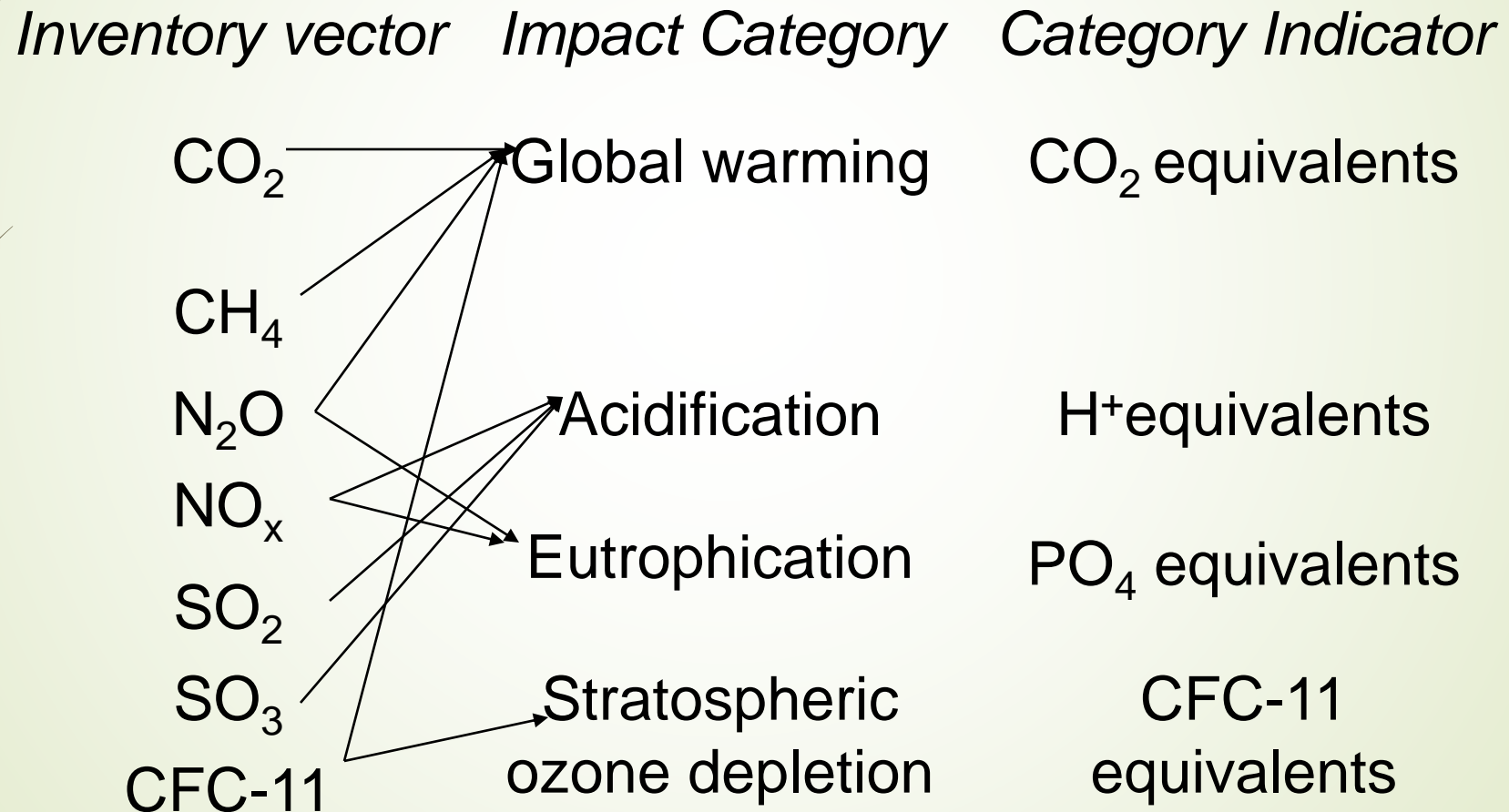
Production phase

Use phase

End-of-Life phase

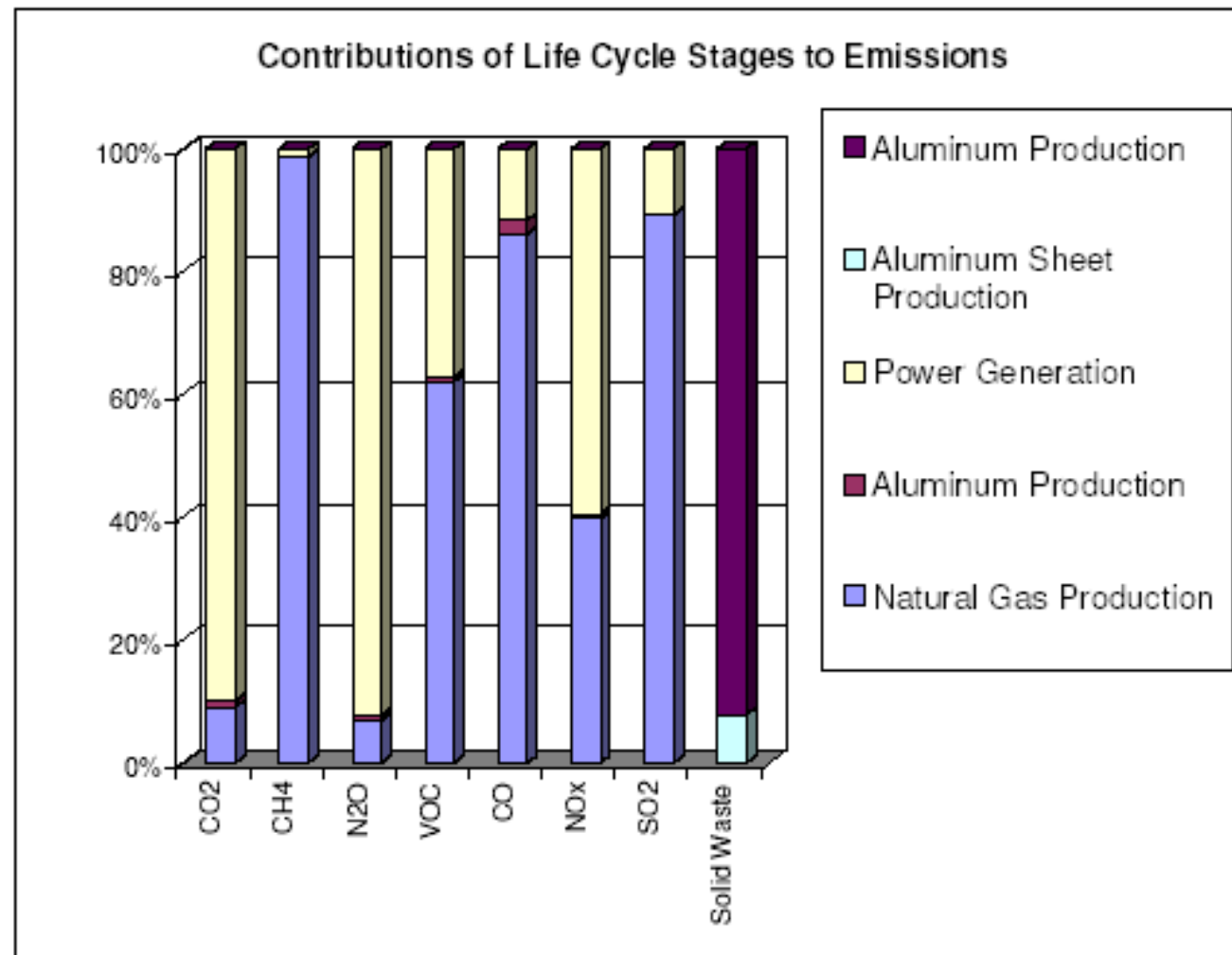
Scheme of Life Cycle Thinking and Assessment

Characterization



Contributions of Processes

39





Circular Supply Chain



It all starts with a tip

Consumers can directly tip their farmer, rewarding responsible and sustainable practices



That improves livelihoods

Producers, in-turn, gain additional direct income, driving more diverse consumer markets



Creates jobs

A new generation of producers emerges when economic benefits ease access to agriculture insurance and a financial credit history



Improves brand reputation

Processors, distributors, wholesalers and retailers can trace product provenance, creating market differentiation for sustainability and food security.



And mitigates environmental impact

Visibility into consumer demands enables effective inventory and harvest management, reducing enormous amounts of waste.

SCP Push-Pull Scenario

SUPPLY

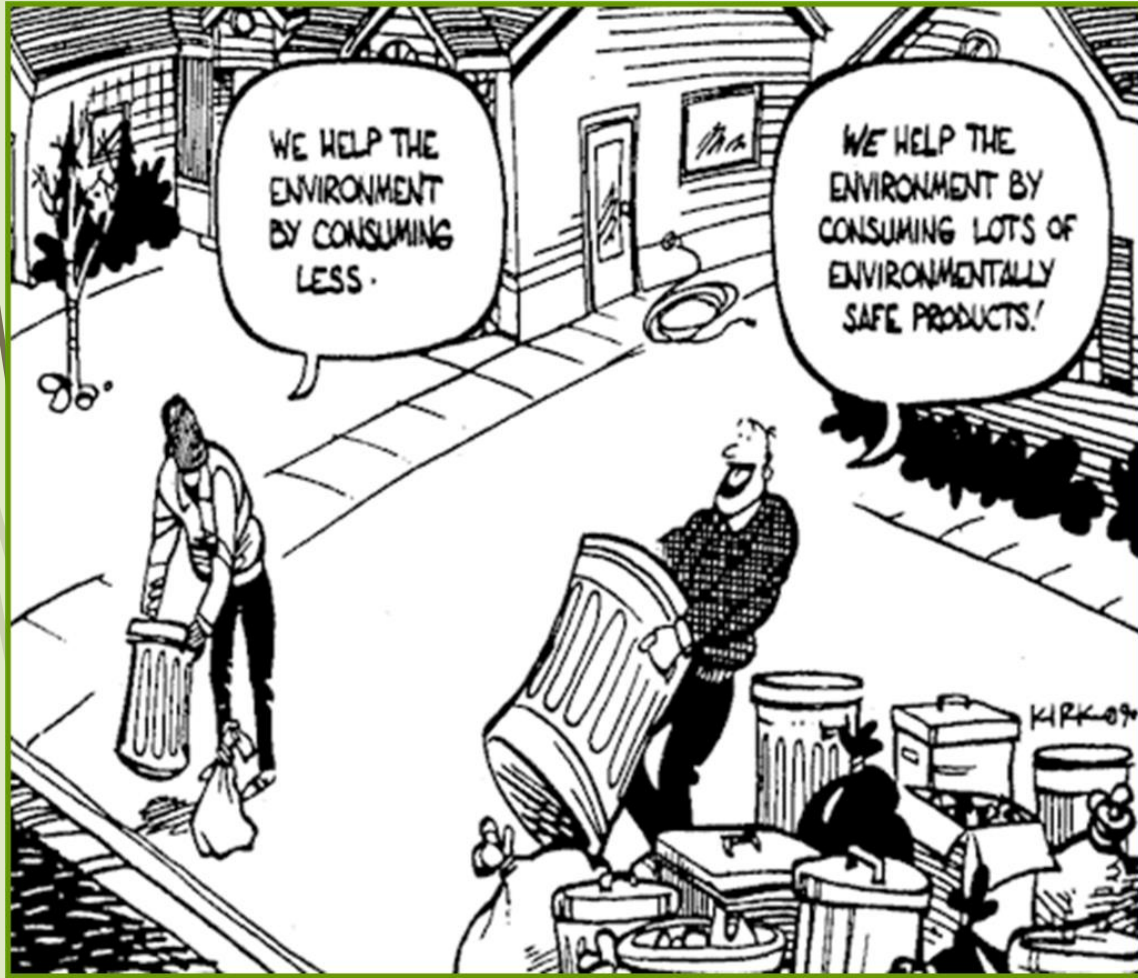
Eco-design
Green Procurement
Circular Economy
RECP
LCA
Technology Progress
Policy Options



DEMAND

Lifestyle
Marketing ads
'Mesolimbic
Dopaminergic
Reward System'
Human needs
Human wants
Human desires

Related Principles and Ideas

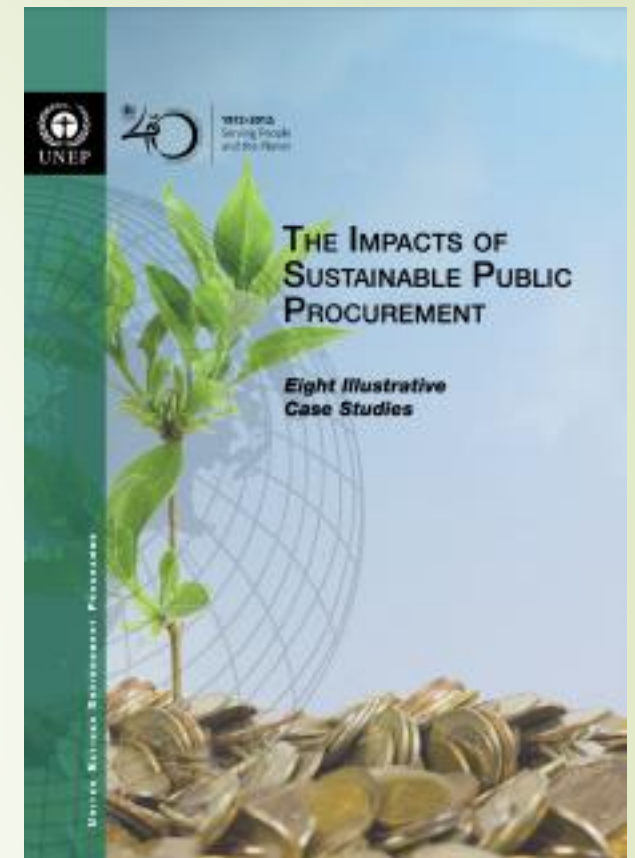


- Green / environmentally friendly consumption,
- ethical consumption,
- choice editing,
- lock-in pokayoke, and
- sustainable consumption

Related Principles and Ideas

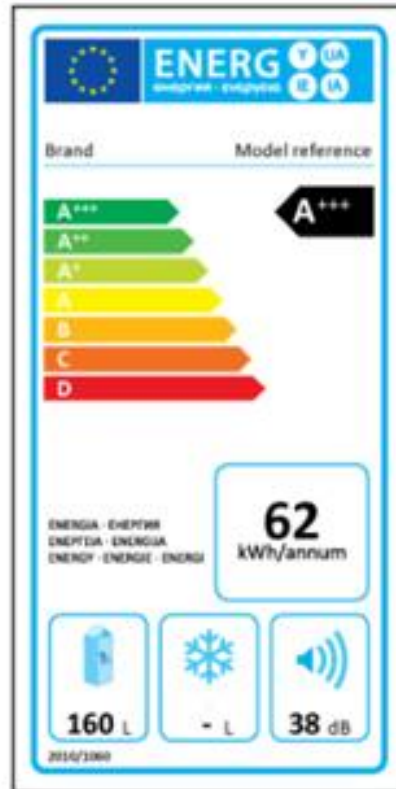
Ecolabel and Sustainable Public Procurement

Ecolabelling is defined by the International Organization for Standardization (ISO) as a voluntary method of environmental performance certification and labelling. It is practiced around the world. An ecolabel identifies products or services proven to be environmentally preferable within a specific category.

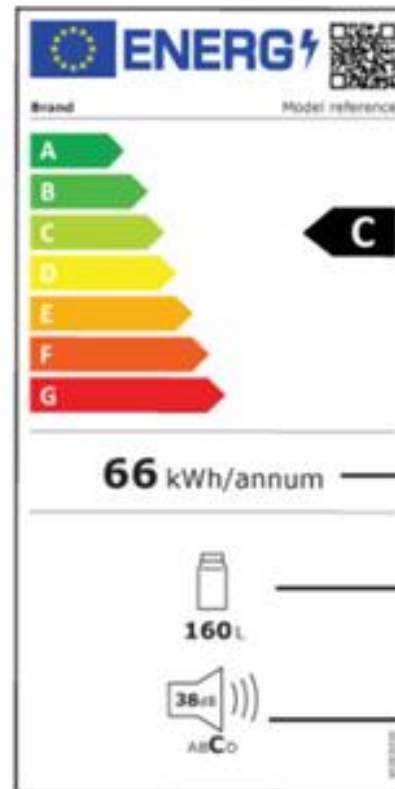


Shaping a Circular Lifestyle: A Consumer's Choice

Current energy label



New energy label



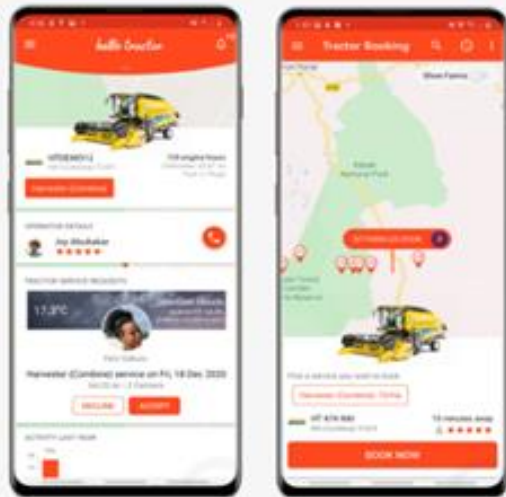
The **QR code** gives access to more information on the model

The **rescaled energy efficiency class** for this fridge, an A+++ in the previous label

The **annual energy consumption** of this fridge is calculated with refined methods

The **volume** of the fridge expressed in liters (L)

The **noise level** measured in decibels (dB) and using a four classes scale



Contractor App

Booking App

Improving Service Delivery



Selling a Solution



Financing More



Home

Air

Water

Carbon

Enterprise

Brands/Suppliers

Ecology

Pandemic

TESCO

adidas

Filter ^

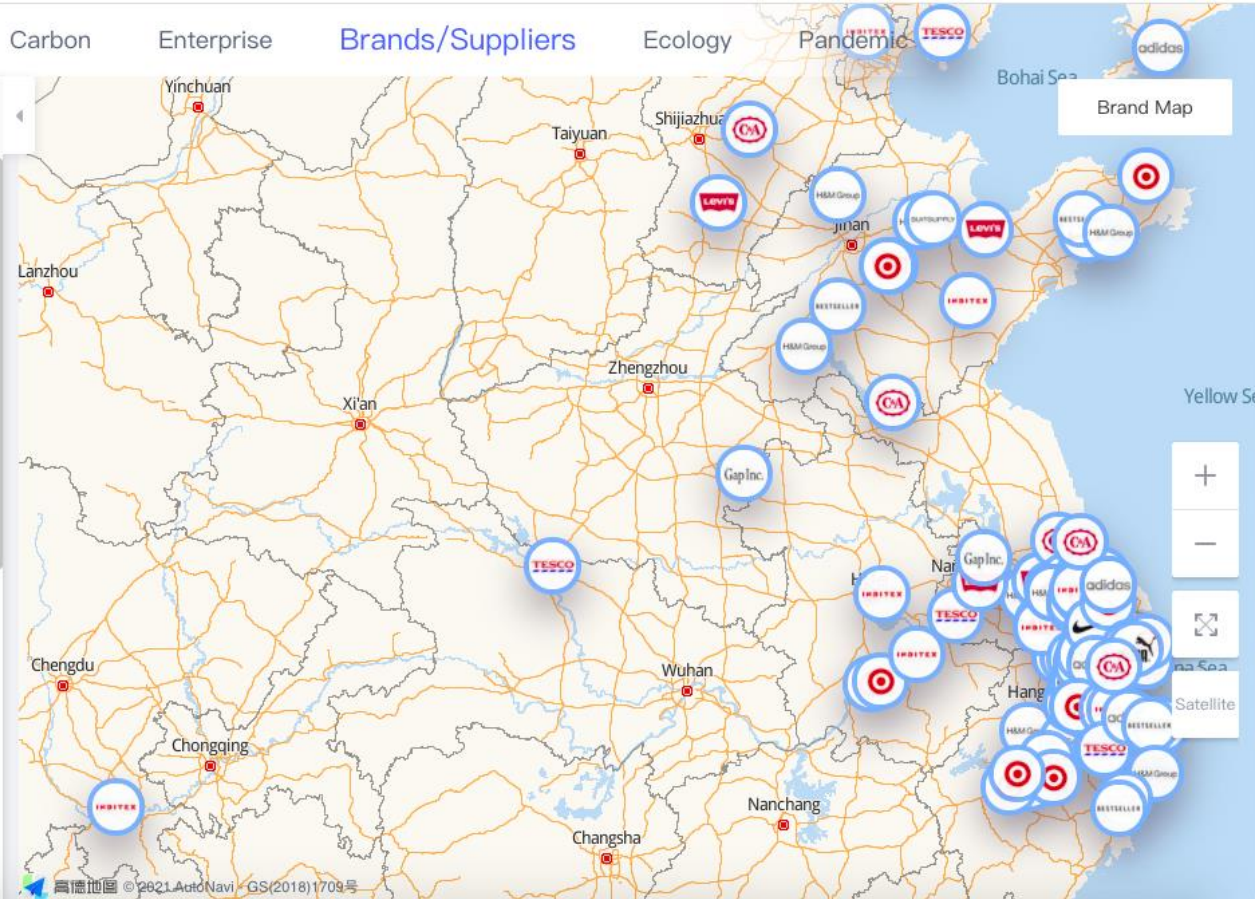
Map Explanation

Filter by whether enterprises discloses:

- Real-time online data
- Enterprise feedback
- Annual emissions data

Legend:

↑ Indicates emissions exceed standards



Innovative Technology





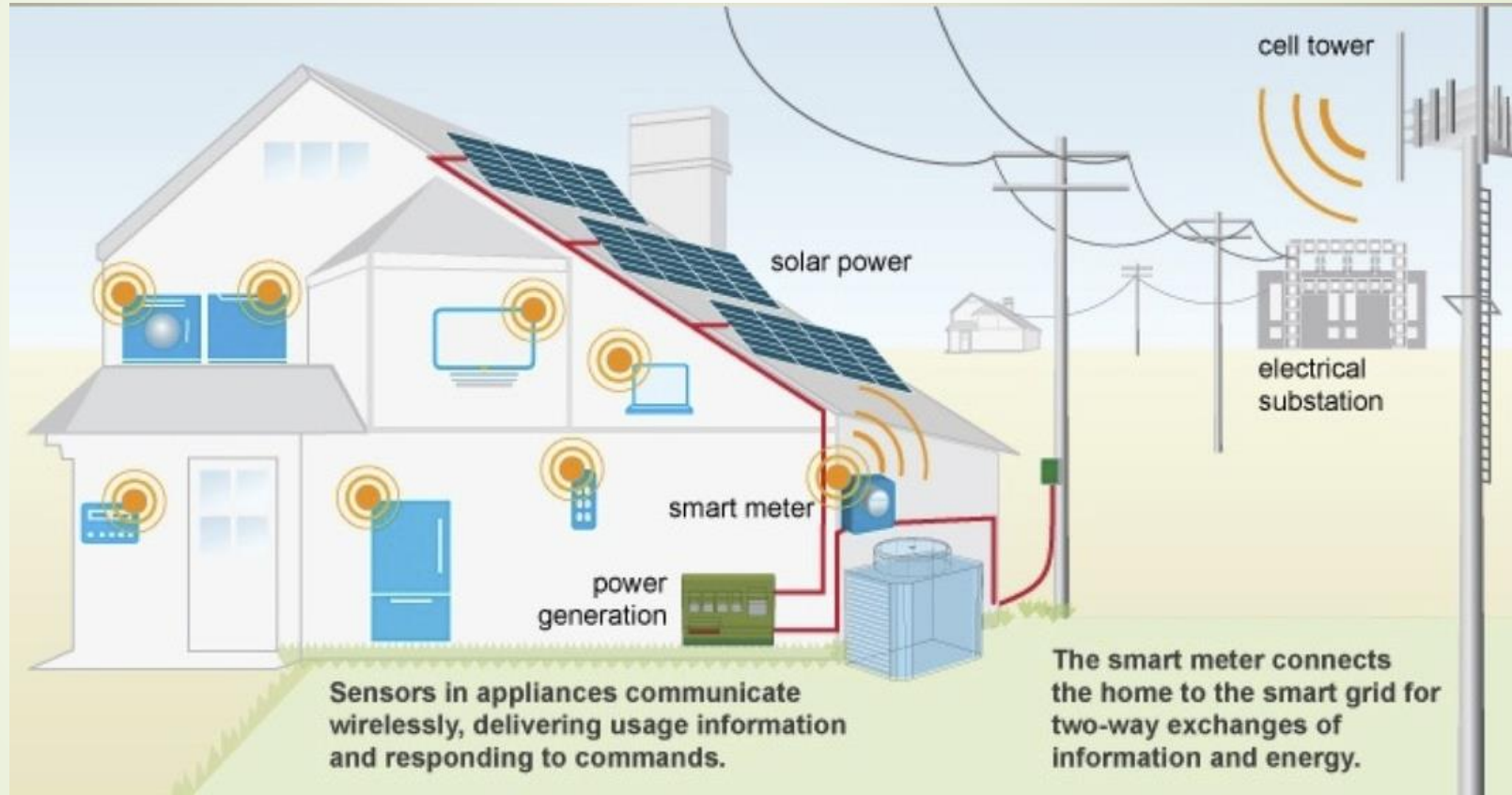
Innovative Technology

Some of the key technologies and trends expanding their influence on society are:

1. Internet of Things (IoT)
2. Blockchain
3. Big Data
4. Artificial Intelligence

These technologies are both disruptive and exponential. That is, they are set to replace well-established ways of doing things with new process and markets; and they become more **effective and cheaper extremely fast**—which will see their adoption skyrocket rapidly.

Smart Meters



Singapore's Jurong Lake District

- Aims to demonstrate how technology can enable a liveable and sustainable urban environment, and a key feature is IoT technology.... But Wifi bandwidth, stability, etc necessity
- Data from farecards and sensors throughout the district will give planners a clearer sense of the location, types, and frequency of transport services that are needed and cater to these needs more effectively.

Smart Singapore

Singapore is expanding its use of technology to entrench its position as a leading global city and improve Singaporeans' quality of life. Here are some upcoming initiatives:

Punggol pilot: The first "smart" housing project will be launched in Punggol next year, and will include energy-efficient measures like motion sensor lights in carparks.

One ring to pay them all: An embedded chip could turn a ring, a watch or your identity card into a payment device, eliminating the need for cash or credit cards.

Remember me: A new digital platform is being developed to bypass the need for citizens to provide their personal data repeatedly for government transactions.

Mapping the future: A new 3D map project called Virtual Singapore will integrate layers of data about Singapore's buildings, land and environment. Government agencies and other organisations can use it to solve problems such as identifying the most flood-prone areas, while the public can contribute information like traffic patterns or the locations of their favourite nasi lemak stores.

Phone home: Controlling household appliances from a smart phone may be possible once HDB determines the digital infrastructure needed for an automated home. Trials start next year.

Senior sensors: Sensors in the homes of the elderly will monitor their movements and send alerts to caregivers if irregular behaviour is detected.

Virtual therapy: A "tele-rehab" system being tested at community hospitals will allow patients to perform therapy exercises at home, while sensors attached to their limbs transmit data back to the hospitals.

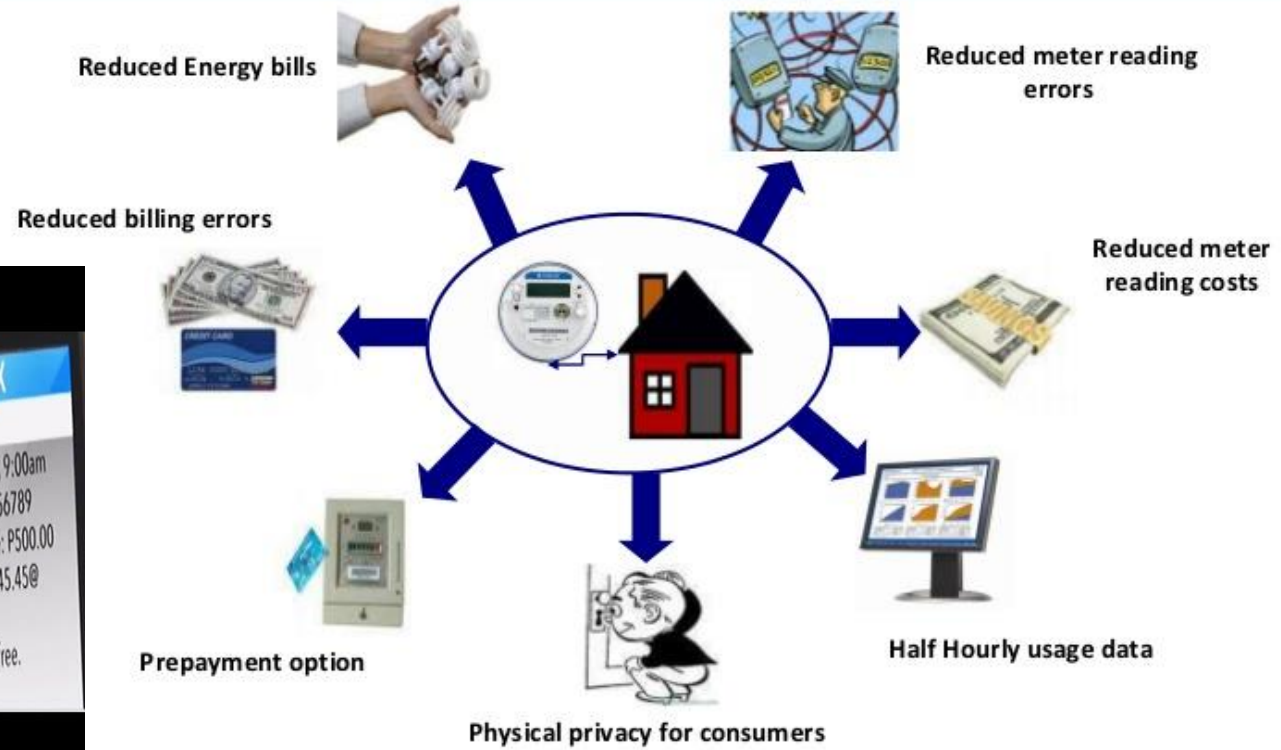
Where's my bus: By next March, commuters can use the MyTransport app to find out bus arrival times by the minute and how crowded each bus is.

"Public" transport: Self-driving cars will be tested on public roads for the first time come January next year, in One-North at Buona Vista.

GRAPHICS: MIKE M DIZON AND CHNG CHON HONG TEXT: RACHEL AU-YONG

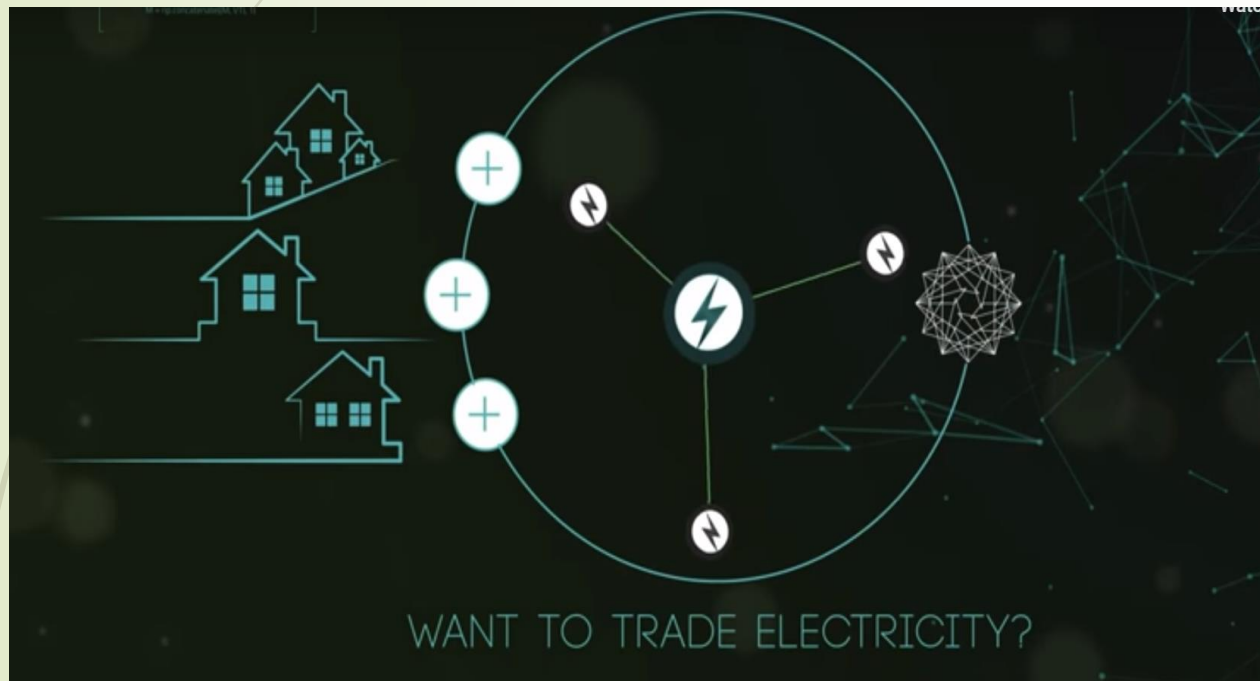
IoT Example 2: Manila Electric Co. (Meralco)

Advanced Metering Benefits



Applications of Blockchain:

Peer to peer clean energy sharing

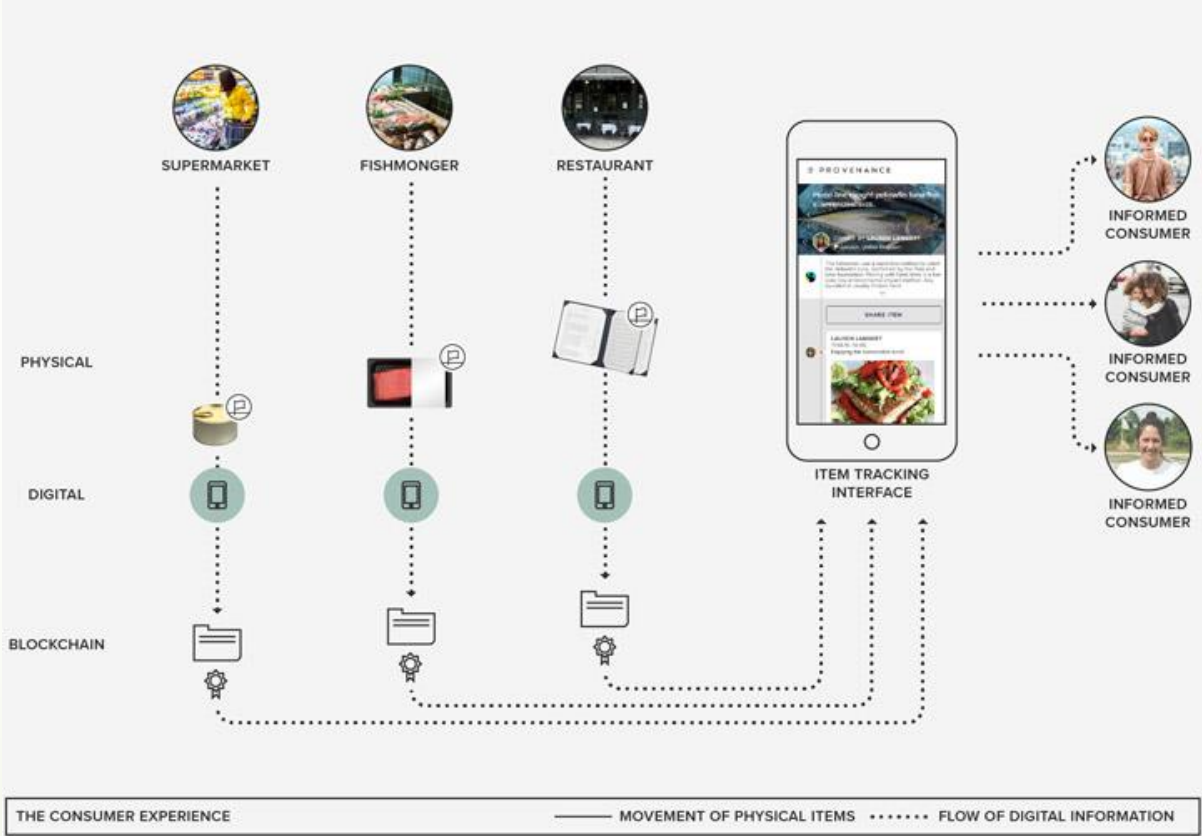


- Australian firm Power Ledger commenced a trial in Bangkok's Sukhumvit neighbourhood where an apartment complex, a school, a mall, and a dental hospital with solar panels trade clean energy with one another, and the city's electricity grid, over a blockchain marketplace.
- the system is one of the world's largest peer to peer renewable energy trading platforms using blockchain.

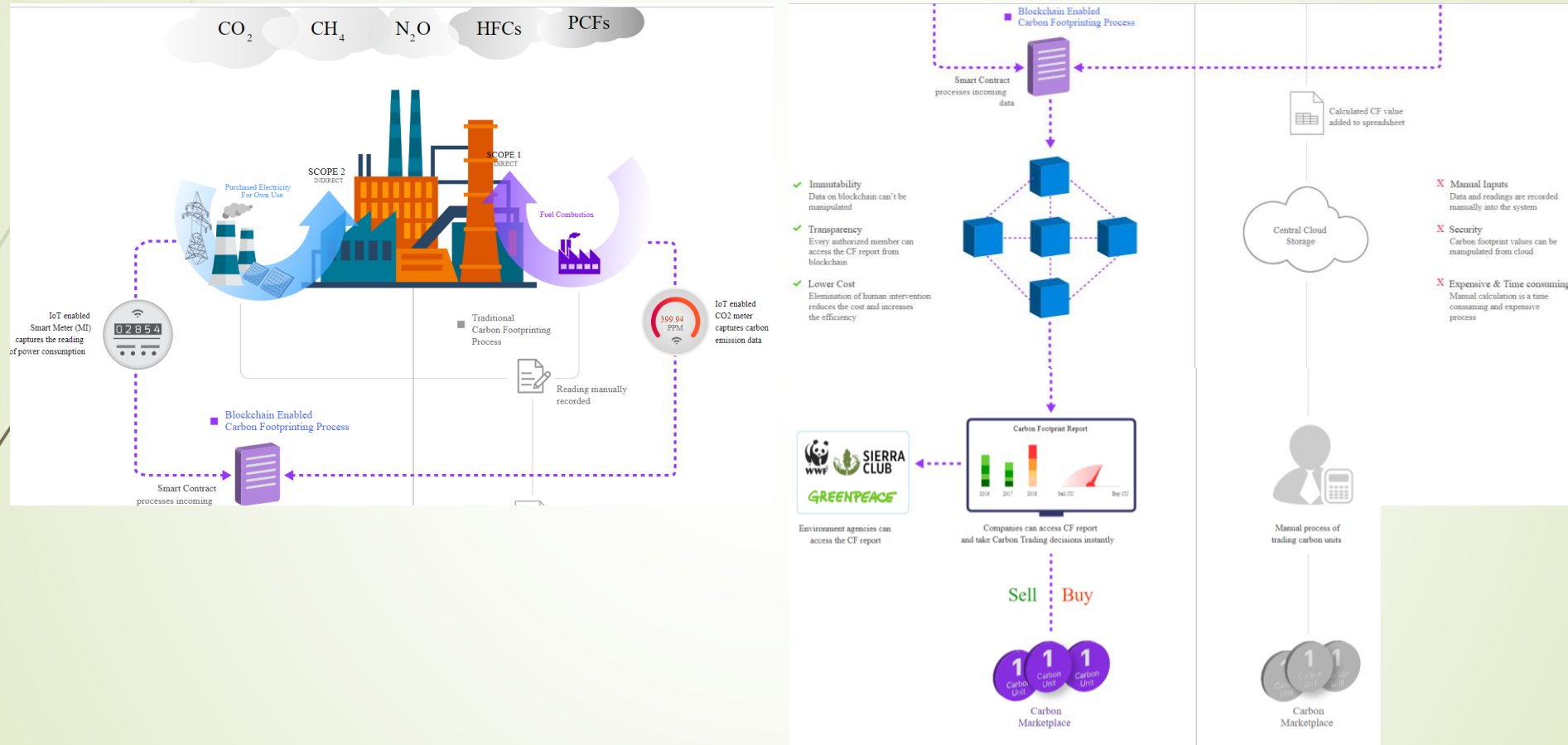
Innovative Technology

2. Blockchain

Provenance

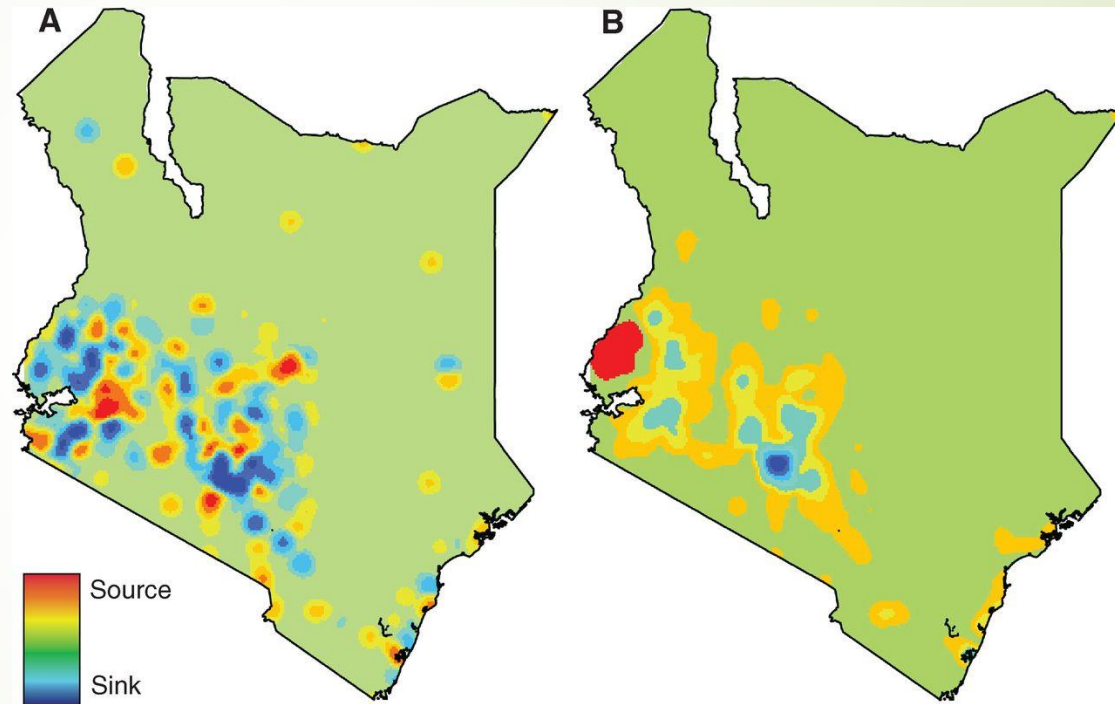


Applications of Blockchain: Carbon Footprinting



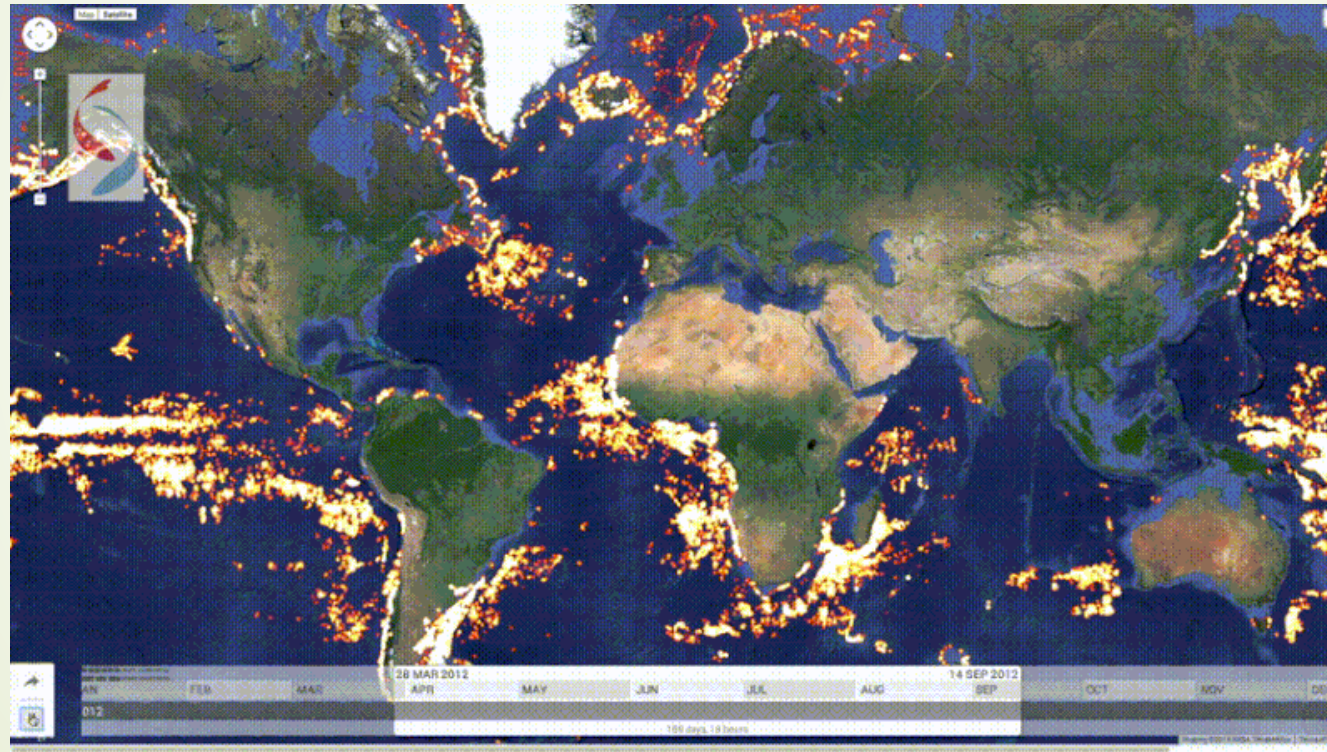
Big Data Applications

- Human travel patterns and malaria-** In Kenya, Caroline Buckee, a Harvard University researcher processed data from 15 million cell phones in 2012 to identify how human travel patterns contributed to the spread of malaria—this helped officials allocate resources to disease control efforts.



(A) Travel sources and sinks. (B) Parasite sources and sinks.

Global Fishing Watch - launched in 2016, the platform processes over 22 million position messages from more than 200,000 ships every day to detect patterns that signify which vessels are fishing, when and where. This allows anyone with an internet connection to see fishing activity anywhere in the ocean in near real-time, for free.



Innovative Technology

4. Artificial Intelligence

The Climate Corporation's Climate Fieldview software

CLIMATE FIELDVIEW

Climate FieldView provides all the tools necessary to ensure efficiency and informed decisions all year long

- Weather**
Real-time and future forecasted weather up to 3 hours
- Script Creator**
Create variable-rate planting scripts
- Data Visualization**
Real-time field data collection for future informed decision making
- Field Health Advisor**
Satellite imagery to detect crop issues
- Scouting**
Drop geo-located pins in your field to identify specific areas of interest
- Nitrogen Advisor**
Anticipate field level nitrogen supplies based on applications, crop stage and weather

