Life Cycle Assessment (LCA) and Recycle as the tools for Sustainable PVC

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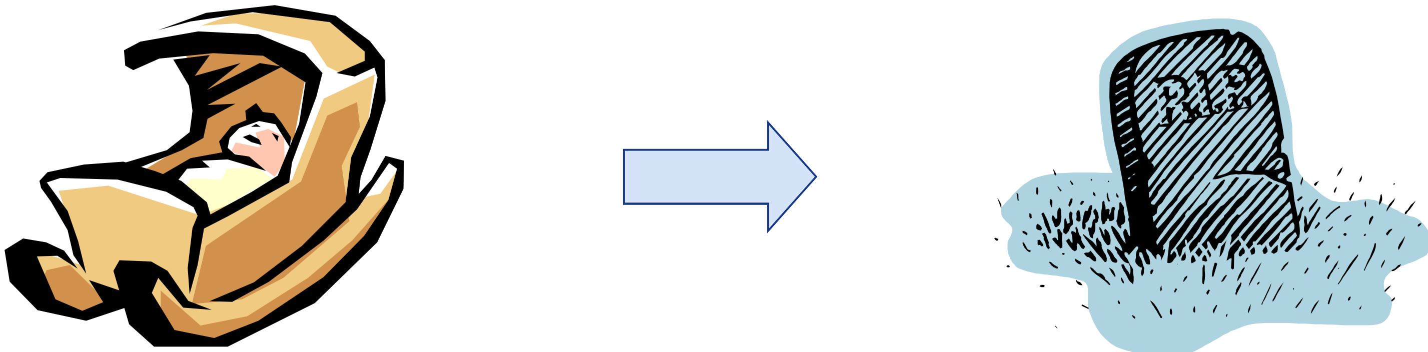
Presentation Outline

- Life Cycle Assessment (LCA)
  - LCA Concept
  - Methodology
  - Utilization of LCA
  - Status of LCA in Thailand and Global Situation
  - Benefits of LCA on Plastic Products
- Examples of LCA Studies on Plastic Recycling
- LCA of Pipe and Fitting
- Current Status of PVC Recycling in Thailand

LCA Concept

What is LCA ?

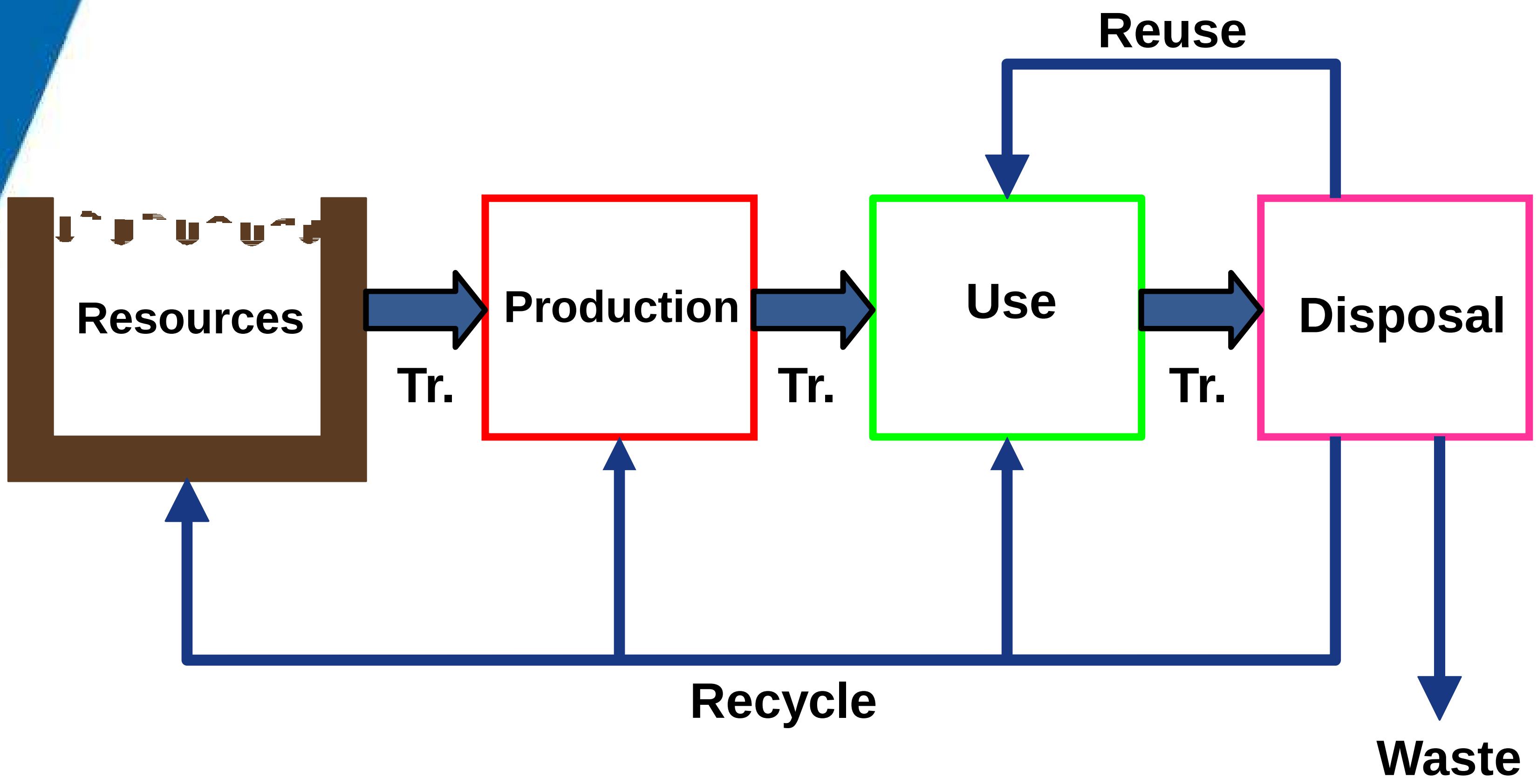
CRADLE TO GRAVE



Quantitative Environmental Impact Assessment

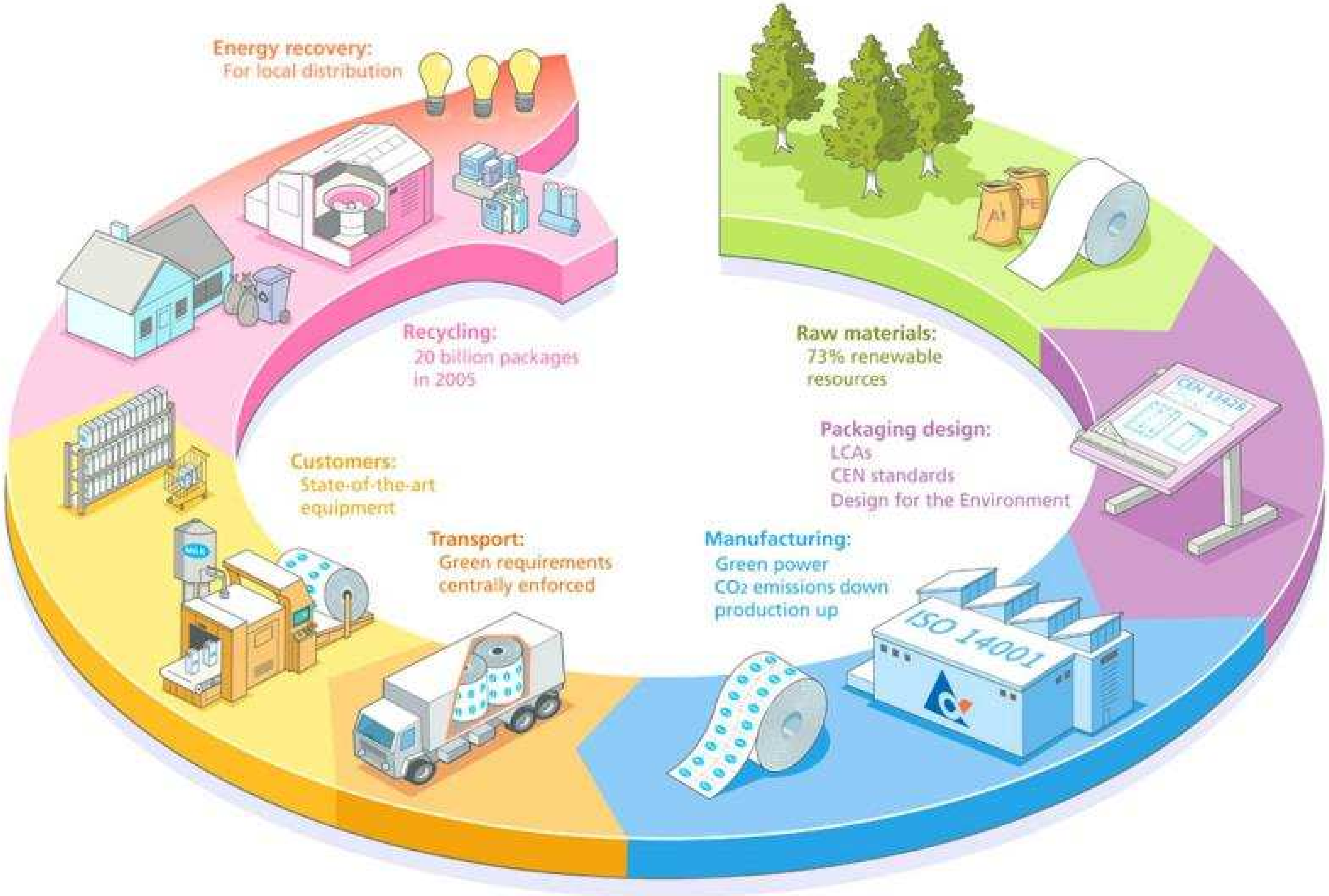
LCA is a tool to assess the potential environmental impacts of product systems or services at all stages in their life cycle – from extraction of resources, through the production and using the product to reuse, recycling or final disposal.

Product Life Cycle



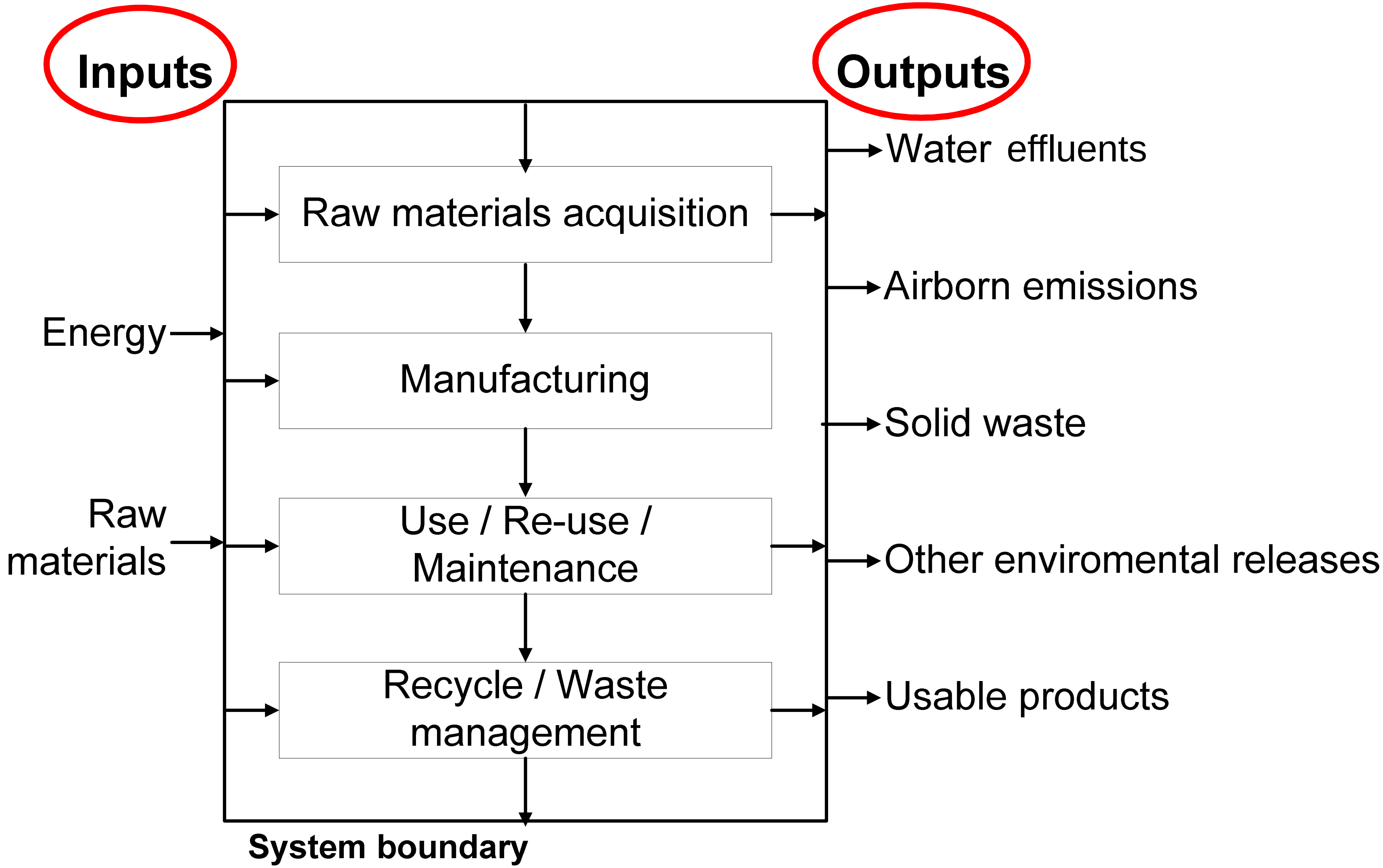
Tr. = Transportation

Product Life Cycle



Source: TetraPak

Life Cycle Stages and Boundary



(**Source:** *EPA, 1993*)

Category	Items
Energy	• Electricity (from coal, natural gas, ..) • Fuel (diesel, LPG, etc.)
Raw materials	• Iron, aluminium, etc. • Plastic resins
Chemicals	• HCl, NaOH, etc. • Fertilizer, herbicides, etc.
Air Emissions	• CO_2, CO, particulates, etc. • HCs, SO_x, NO_x, CFC, etc.
Wastewater	• COD, BOD • Toxic substances
Wastes	• Solid waste • Heavy metals, etc.

Emissions

CO_2
CH_4
CO
CFC

NO_x
SO_x

PAHs

Pb
Cd

PO_4
N

Environmental Impact Categories

Inventory	Impact category	Data item
CO_2		
CH_4	Global warming	
N_2O	Ozone layer depletion	
SO_2		
Total N	Acidification	
NMVOC	Eutrophication	
COD		
CFC-11	Photo. Oxidant creation	
NO_2	Human Toxicity	Heavy metals, PAHs, carcinogens

Environmental Impact Categories

Global Warming Potential (GWP)

(CO2 equiv. kg)	
CO_2	1
CH_4	21
N_2O	310
HFC-23	11700
HFC-41	150
HFC-134a	1300
SF6	23900

Ref: IPCC (Intergovernmental Panel on Climate Changes)

Ozone Layer Depletion (ODP)

	(CFC equiv. kg)
CFC-11	1
HALON-1201	1.4
HCFC-123	0.02
HCFC-141b	0.11
HCFC-22	0.055

Acidification Potential (AP)

	(SO_2 equiv. kg)
NH_3	1.88
HCl	0.88
HF	1.6
NO	1.07
NO_2	0.7
SO_2	1

Road Map - ISO 14000

Evaluation & Auditing Tools

Environmental Performance Evaluation (EPE)

ISO 14031 guidelines

Environmental Auditing (EA)

14010 general principles

14011-1 audit procedures

14012 qualification criteria for environmental auditors

Management Systems

ISO 14004 (EMS)

general guidelines on principles, systems & supporting techniques

ISO 14001 (EMS)

specification with guidance for use

Product-Oriented Support Tools

Life Cycle Assessment (LCA)

14041 general principles & practices
14042 life cycle inventory analysis
14043 life cycle impact assessment
14044 life cycle improvement assessment

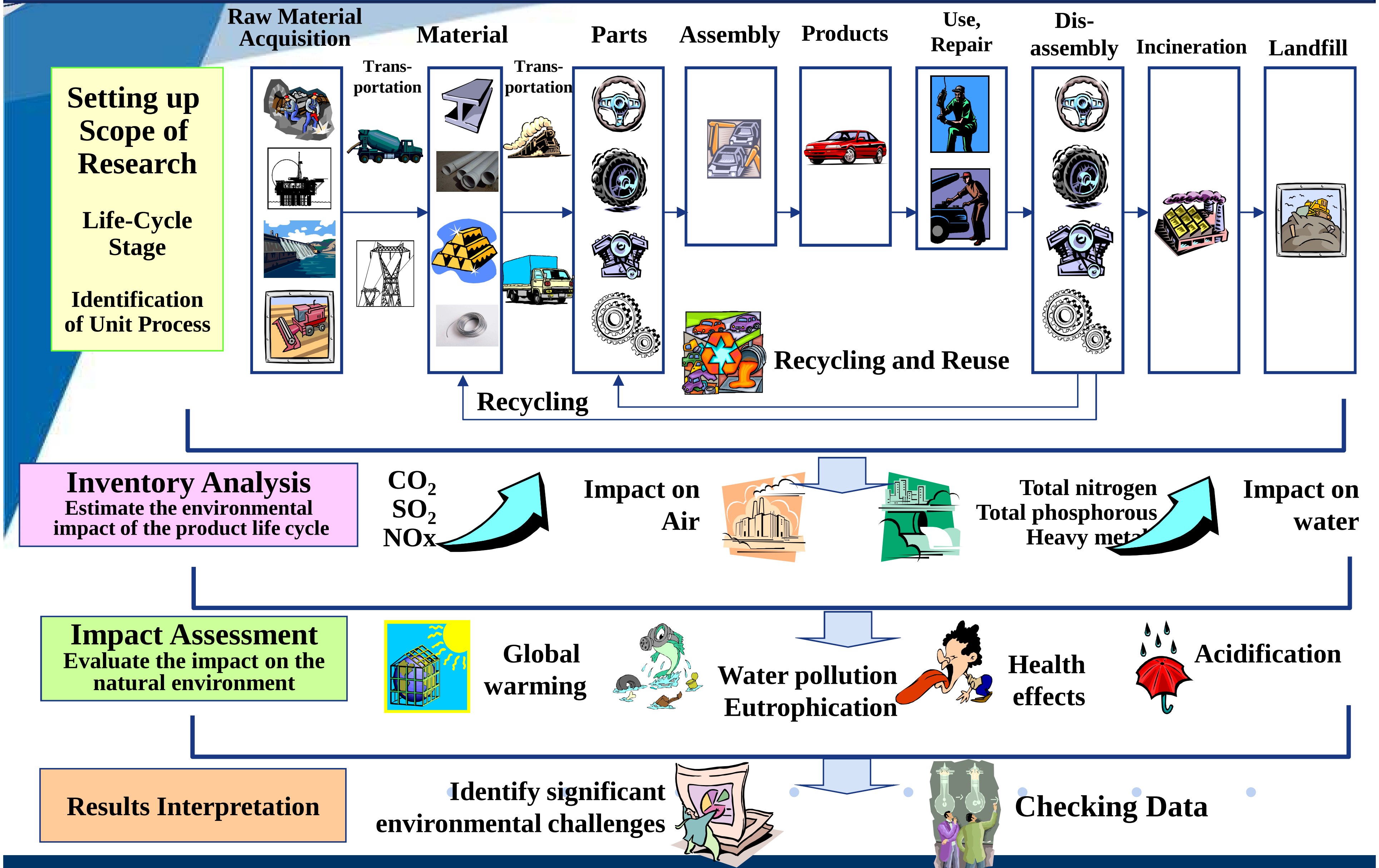
Environmental Labelling (EL)

14020 basic principles for all environmental labelling
14021 terms & definitions
14022 symbols
14023 testing & verification
14024 guiding principles, practices & criteria for certification programs

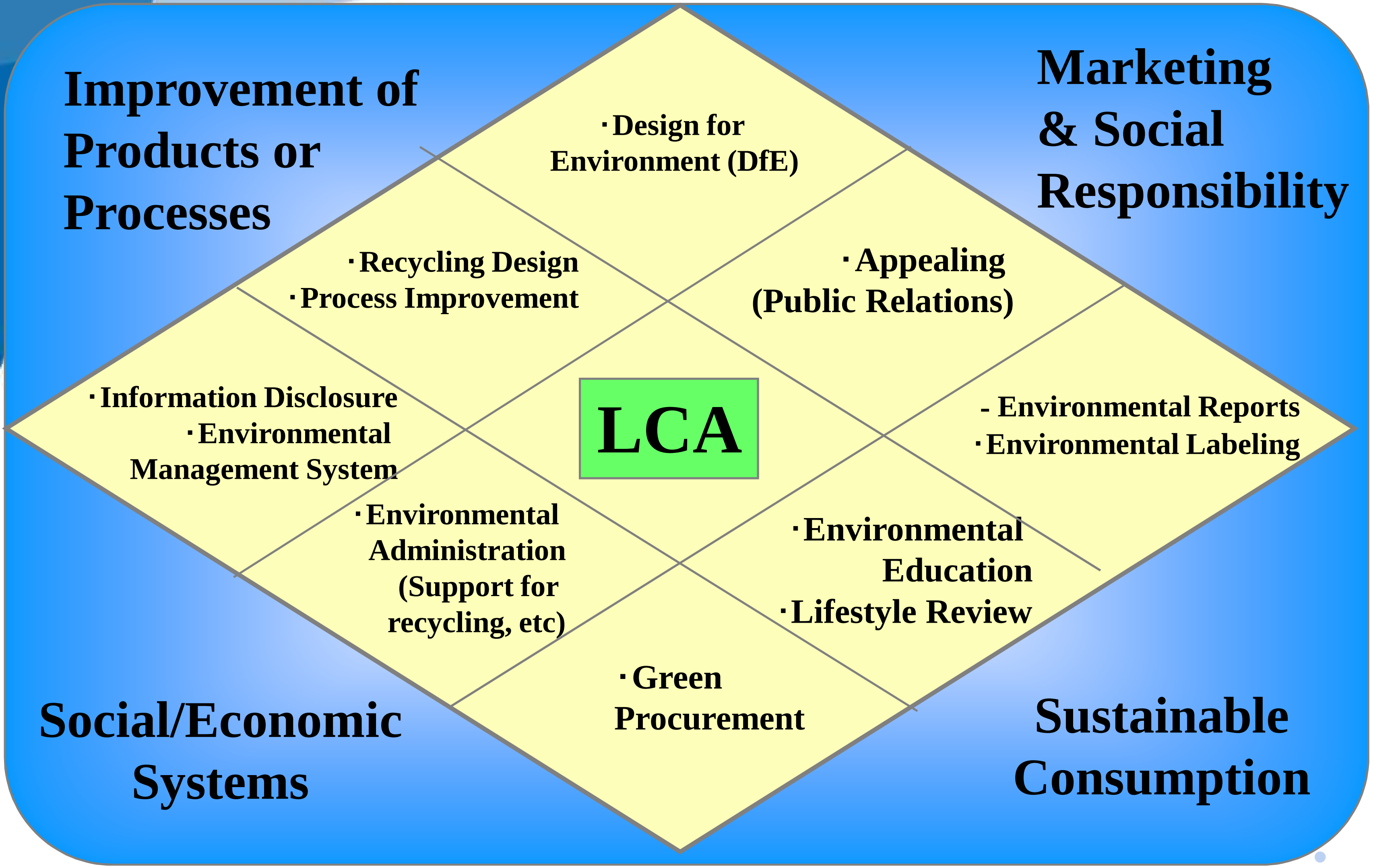
ISO 14067 Carbon Footprint of products

+ CSR (ISO 26000) 2011

LCA Methodology Based on ISO 14040 Series



Utilization of LCA



Adapted from: Ishizaka, Nagano prefecture

Design for Environment/Improvement

HITACHI

New Vacuum Insulator

For Refrigerator

Eco Products Fair, Tokyo, Japan


プラスチックを
探してみよう
プラスチック
リサイクル率
70%
株式会社グリーンサイクルシステムズ
プラスチック高度選別
PP
PS
ABS
PS
ABS
X線分析選別
湿式比重選別
ウォシュレットのリサイクル
(一部エリア・店舗にて限定回収)
START
洗浄
解体
サーマル
リサイクル
オリジナルのリサイクル文具
ノベルティーとして活用
ペレット化
チップ化
破砕
再生樹脂パレットとして
グループ内にて活用

植物由来高機能軟質ポリフタルアミド - リルサン HT
Rilsan HT
www.arkema.com
ARKEMA

ここにも！エコリーフ
身近な生活のワンシーンにも、エコリーフによる環境情報は"見える化"されています。
Product Environmental Aspects Declaration
ECO LEAF

CO_2排出量を大幅に削減
脱石油資源率99%以上

LCA (Life Cycle Assessment)
ライフサイクルアセスメント
航空機のLCA比較

Eco-Labels/Green Labels

RÓTULO ECOLÓGICO
ABNT - QUALIDADE AMBIENTAL
Brazil

EU, UK

Australia

USA

Republic of China

Czech Republic

New Zealand

Canada

Sweden (SSNC)

Croatia

Eco-Product

Germany

Korea

Hong Kong

Singapore

Philippines

Thailand

Spain

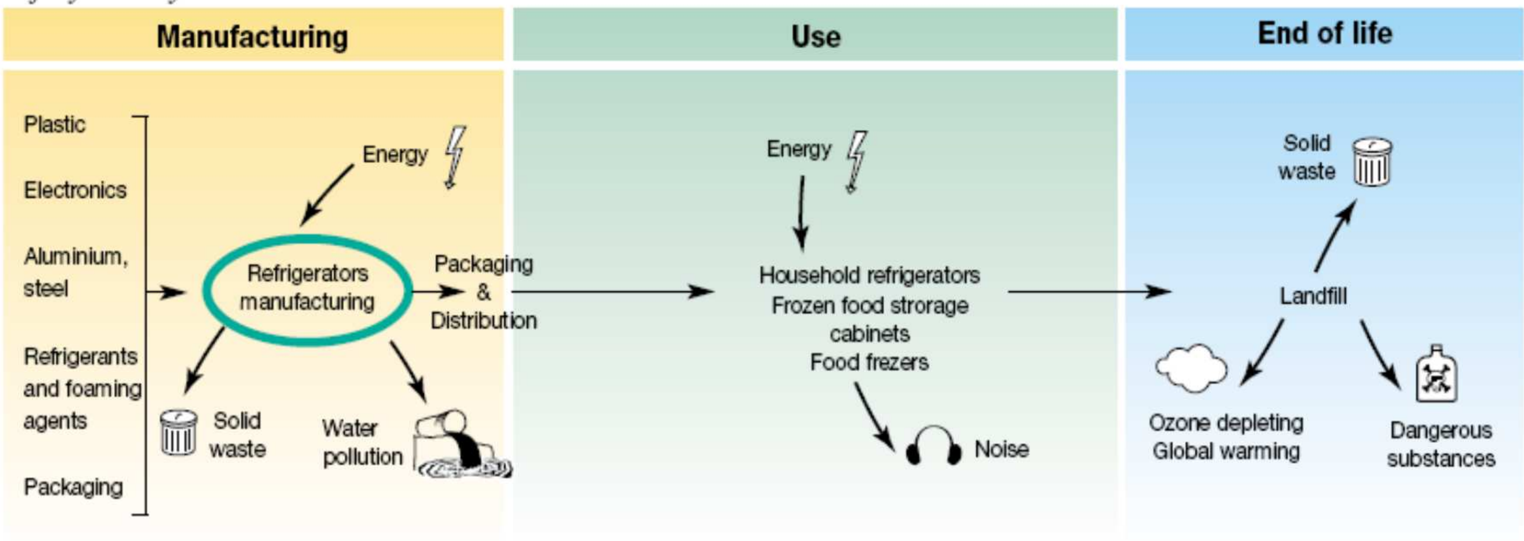
Japan

The European ecological label for refrigerators

Commission Decision 2000/40/EC of 16 December 1999.
O.J. n° L 13 of 19.1.00

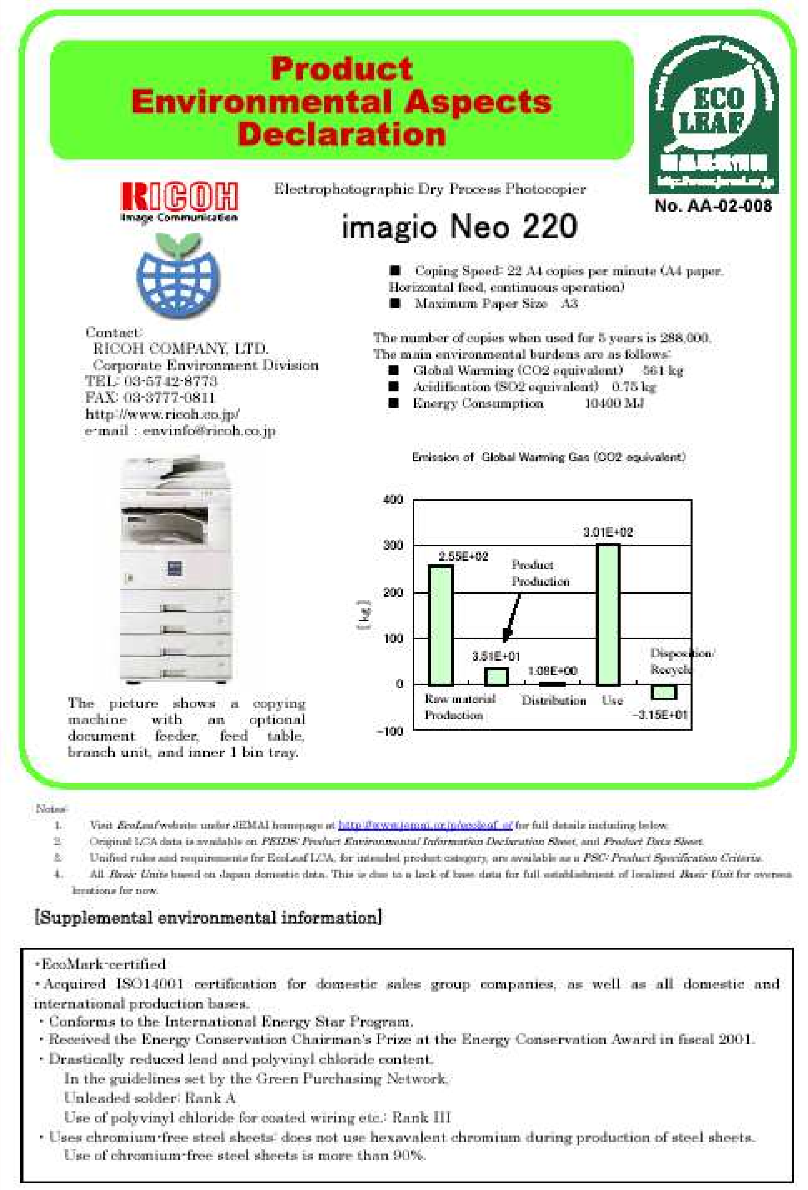
To receive the EU Eco-Label, refrigerators must meet the following ecological and durability criteria

Life cycle analysis



ECOLOGICAL CRITERIA

Eco-labeling Type III



Product Environmental Aspects Declaration

ECO LEAF

RICOH Image Communication

Electrophotographic Dry Process Photocopier

imagio Neo 220

No. AA-02-008

■ Copying Speed: 22 A4 copies per minute (A4 paper, Horizontal feed, continuous operation)
■ Maximum Paper Size A3

The number of copies when used for 5 years is 288,000.
The main environmental burdens are as follows:
■ Global Warming (CO2 equivalent) 561 kg
■ Acidification (SO2 equivalent) 0.75 kg
■ Energy Consumption 10400 MJ

Contact:
RICOH COMPANY, LTD.
Corporate Environment Division
TEL: 03-5742-8773
FAX: 03-3777-0811
http://www.ricoh.co.jp/
e-mail : envinfo@ricoh.co.jp

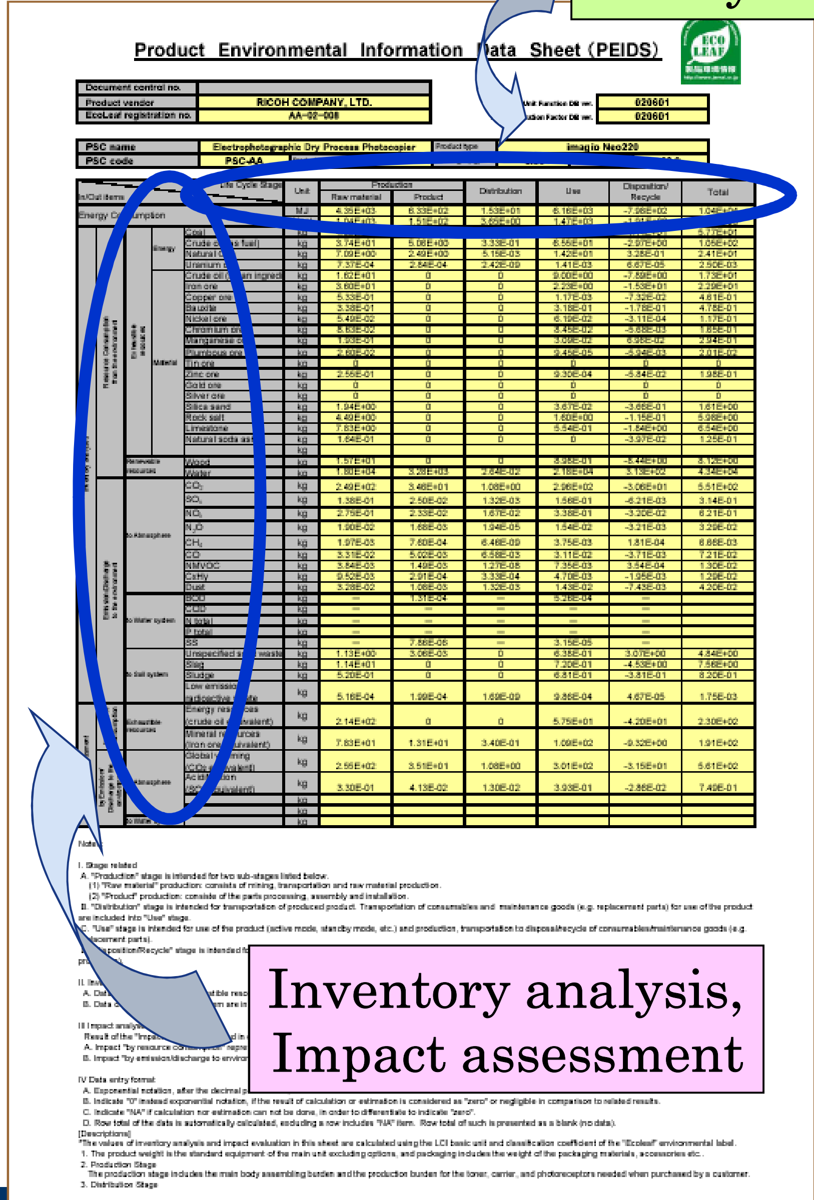
Emission of Global Warming Gas (CO2 equivalent)

The picture shows a copying machine with an optional document feeder, feed table, branch unit, and inner 1 bin tray.

Notes:
1. Visit EcoLeaf website under JEMAI homepage at http://www.jemai.or.jp/ecoleaf_e/ for full details including below.
2. Original LCA data is available on PEIDS: Product Environmental Information Declaration Sheet, and Product Data Sheet.
3. Unified rules and requirements for EcoLeaf LCA, for intended product category, are available as a PSC: Product Specification Criteria.
4. All Basic Units based on Japan domestic data. This is due to a lack of base data for full establishment of localized Basic Unit for overseas locations for now.

[Supplemental environmental information]

・EcoMark-certified
・Acquired ISO14001 certification for domestic sales group companies, as well as all domestic and international production bases.
・Conforms to the International Energy Star Program.
・Received the Energy Conservation Chairman's Prize at the Energy Conservation Award in fiscal 2001.
・Drastically reduced lead and polyvinyl chloride content.
In the guidelines set by the Green Purchasing Network,
Unleaded solder: Rank A
Use of polyvinyl chloride for coated wiring etc.: Rank III
・Uses chromium-free steel sheets: does not use hexavalent chromium during production of steel sheets.
Use of chromium-free steel sheets is more than 90%.



Life cycle stage

Inventory analysis, Impact assessment

Carbon Footprint/Carbon Label

Japan

working with the Carbon Trust
100g
CO2

UK

CARBON counted.com

Canada

Korea

*HARICOT VERT EXTRA FIN 440GR
0.440 KG 2.84 €/KG
08/11/07
0,13 kg eq CO_2
3017800048221
1 € 25

INDICE CARBONE
450g de CO_2

FRANCE

CLIMATE CONSCIOUS
PLATINUM

USA

Thailand

Carbon reduction label

Carbon footprint label


0.5kg
CO2
イオン基準管理栽培
ピーマン
【宮崎県産】

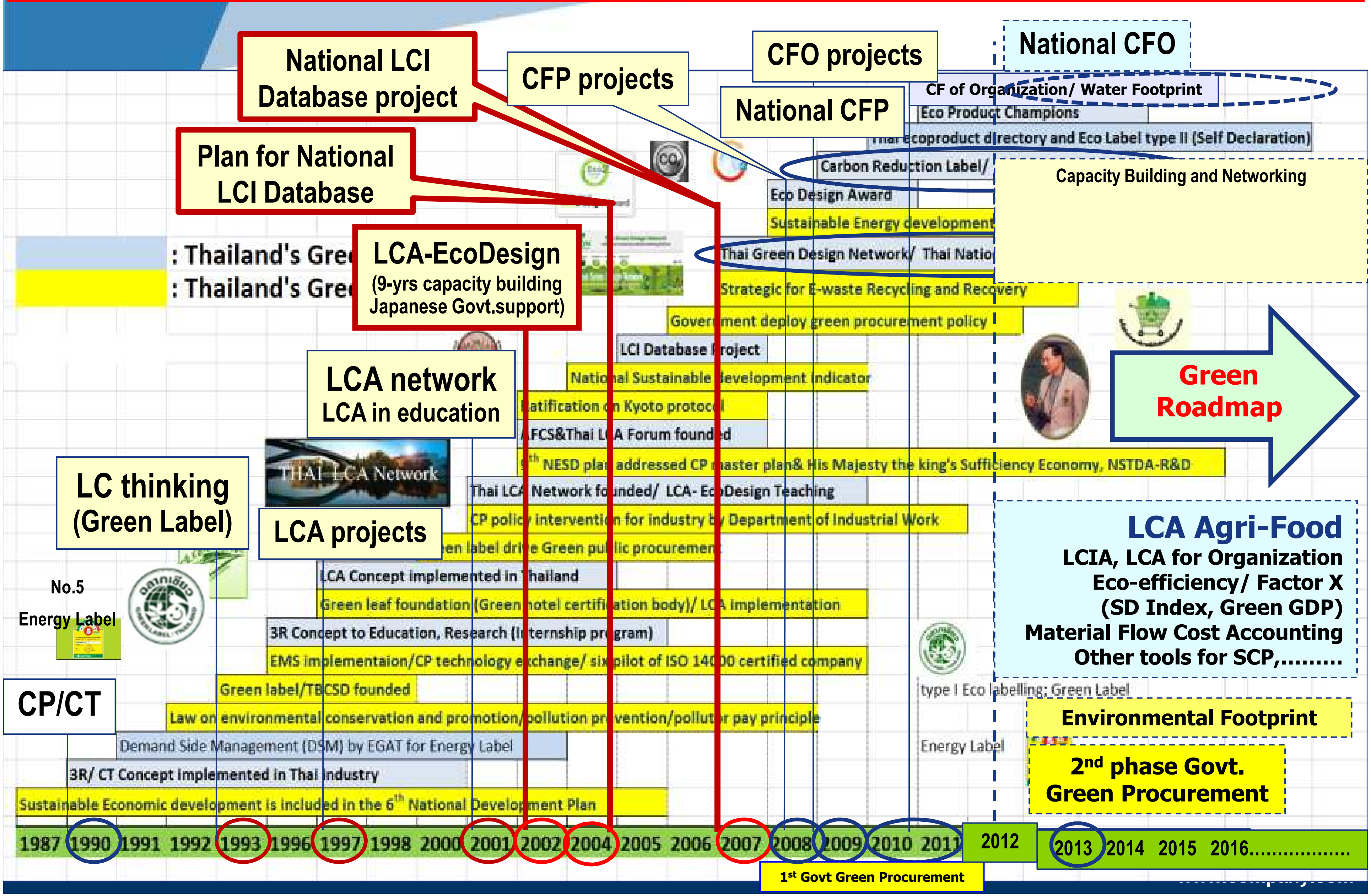

酵素の力で
汚れスッキリ
衣料用洗剤
スーパークリーン
SUPER CLEAN
ホワイト
6.3kg
CO2


特別栽培米
コシヒカリ
無洗米
4kg
CO2


CO2


ポリッピー
しお味
宗谷の塩
183g
CO2
ワンタン
CO2

Thai LCA-related SCP/Green Roadmap



Thai National LCI Database (Master Plan as of Dec. 2004)

Infrastructure

Energy, Utilities and Transportation

Coal, Natural Gas
Petroleum (gasoline, diesel, jet fuel, gas oil)
Biofuels
Electricity grid
Transportation system
Water supply (surface / ground)

Recycle and Waste Management

Recycle
Landfill
Anaerobic digestion
Incineration

Basic Materials

Industrial Materials

Plastics (PS, PE, PP, etc.)
Non-ferrous metals
Ferrous metals
Aluminum, Copper
Fibers
Synthetic rubber (SBR, BR)
Pulp & Paper
Petrochemicals (7)

Agriculture

Cassava
Rice
Sugar cane
Corn
Cotton
Natural rubber
Vegetable oil
livestock
Animal feed

Commodity Chemicals

NaOH
H2SO4
HCl
Cl2
Lime
Na2CO3
Sulfur
Fertilizer/ Pesticide

Building and Construction Materials

Steel
Gypsum
Cement
Glass
Wood
Tiles
etc.

Thailand National LCI Database

5 Organizations signed MOU to drive the Thai National LCI Database Project

The Federation of Thai Industries

Ministry of Industry by Department of Industrial Works

MTEC
a member of NSTDA

National Metal and Materials Technology Center NSTDA, Ministry of Science and Technology

สถาบันสิ่งแวดล้อมไทย
Thailand Environment Institute

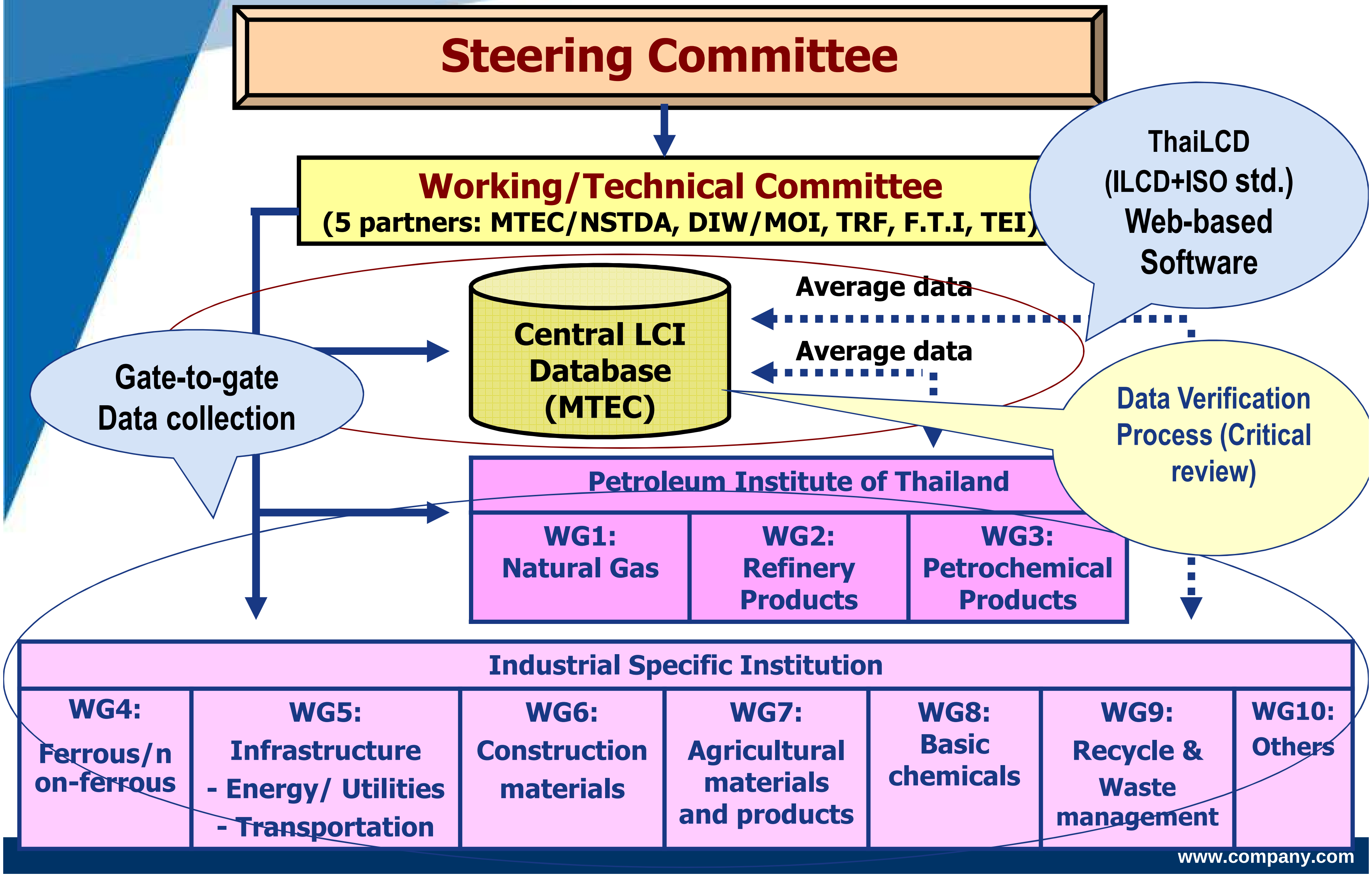
Thailand Environment Institute

สกว
T R F

Thailand Research Fund

(5 org. signed MOU on 30 Mar. 2007) (MOU with JRC/EU 22 Aug. 2007) (join UNEP/SETAC life cycle initiative)
(Technical Support by Japanese Government 2003-2010) (Financial Support by Thai Government)

Thai LCI Database Operation Structure



National LCI Database → for GHG emission factor + others

WG1: Natural Gas	6
WG2: Refinery	8
WG3: Petrochemicals	19
WG4: Ferrous & Non-ferrous	
Ferrous	9
Non-ferrous	5
WG5: Infrastructure/Transportation	
Electric Grid Mix	1
Water	6
Road Transportation: Truck	188
Transportation: Ship & Rail	21+22
WG6: Construction Materials	
Ceramics	7
Glass & Mirror	7
Alternative Materials for Wood	3
Construction Materials	8
WG7: Agriculture/Agro-products	
Feed mill	15
Livestock & Products Agriculture Machinery	19 33
Rubber	7

WG7: Agriculture/Agro-products (Cont)	
Rice	17
P[illegible]	9
[illegible]	17
[illegible]	2+13
L[illegible]	4+43
Pi[illegible]	1+10
P[illegible]	80
O[illegible]	24
Others (UHT coconut milk/ Curry paste)	3
WG8: Basic chemicals	
Paints + Industrial gases	6+3
Basic chemicals + Chemical products	14+2
Fertilizers and Herbicides	47
WG9: Recycle/Waste Management	
Incinerations	8
Landfills + Recycle	8+12
Wastewater Treatment	9
WG10: Others (Textile 30, EE Parts 80, Automotive Parts 3, Vanish oil 3)	116
TOTAL	**846**

C1-C4, Benzene, Toluene, p-Xylene, propylene, ethylene, PE, PP, PS, PU, PVC, SAN, VCM, Caprolactam, mixed C4

(by MTEC 711, Cradle to Gate Data 552)

Website of Thai National LCI Database

MTEC a member of NSTDA

สถาบันสิ่งแวดล้อมไทย
Thailand Environment Institute

NATIONAL LCI DATABASE

WEBSITE

Thai LCA Software

Thai LCI Data for Research

LCI Databases exchange with other Countries

http://www.thaiLCIdatabase.net

Global Situation of LCA

- **Kyoto Protocol**
- **EU, USA, Japan, Asia, Africa**
- **National LCI Databases**
  - **Ecoinvent (EU), JEMAI (Japan), USA, Thailand, Malaysia**
- **Commercial LCA softwares**
  - **SimaPro (Pre’), GaBi, Umberto, etc.**
- **LCA Centers/Institutes**
- **Companies**
  - **Benz, Coke, Sony, LG, BASF, NatureWorks, PTT, SCG, etc.**
- **Governments:**
  - **SCP/Green GDP/Green City**
- **Product Environmental Footprint (PEF, EU 2014…)**

Benefits of LCA on Plastic Products

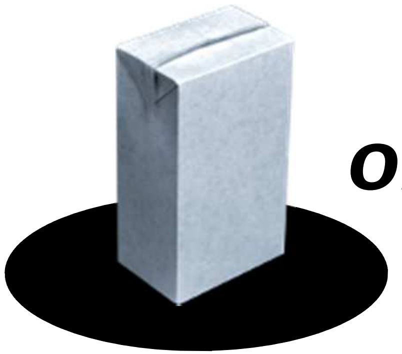
- **Comparison**
  - **Between products (selection/evaluation)**
  - **Between processes/method/management**
- **Product Development/Improvement**
  - **Green design/Eco-design**
  - **Green products/more environmental friendly**
  - **Better eco-efficiency (economic & ecology)**
- **Communication**
  - **Reports**
  - **Environmental declaration**
  - **Labels**
- **Policy**
  - **Decision making**
  - **Management policy**
  - **Environmental tax/subsidization/investment**

Comparison between Products

Which one would you choose?

or

or



or

or

Grocery bags

Plastic

- Use 70% less energy to produce than paper bags
- Generate 80% less waste
- Take 91% less energy to recycle per weight (lb)
- Generate 79% less greenhouse gas emissions

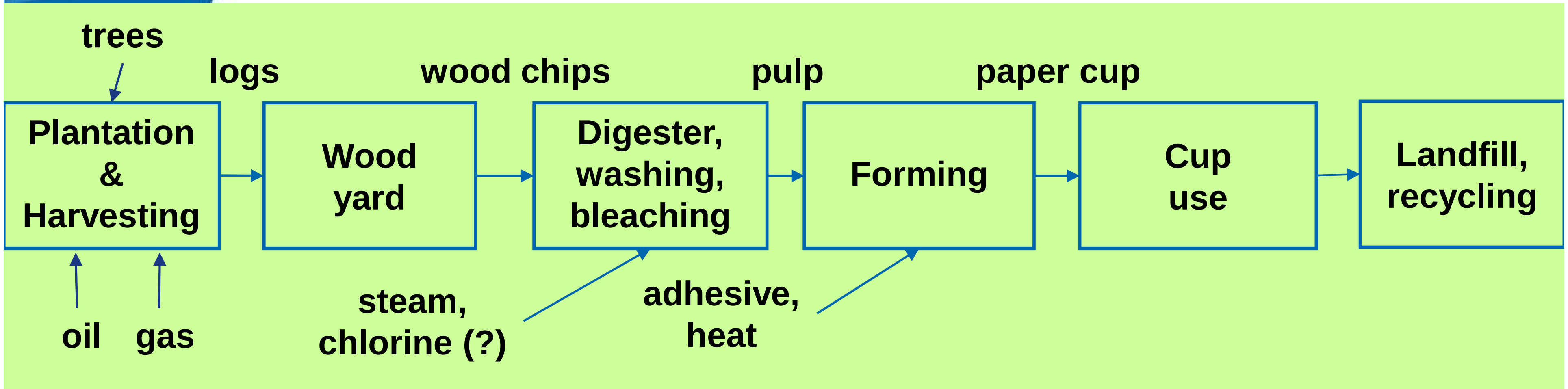
Winner!!!!

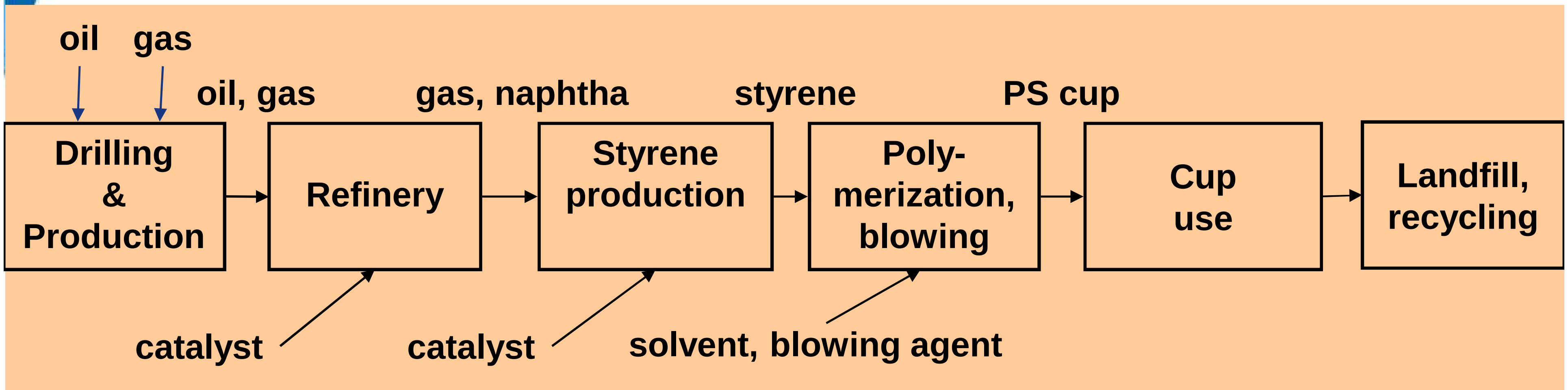
- ***Energy efficient production***
- ***High product-to-package ratio***
- ***Less Greenhouse gas emissions***

LCA Studies Around the World Comparing Plastic and Other Materials

- Carrefour Group
  - LCA study by Price-Waterhouse-Coopers (Feb, 2004) : Compare environmental impact of four types of bags: HDPE, paper, biodegradable plastic (50% corn starch and 50% polycaprolactone compostable plastic), and reusable plastic (flexible PE)
- Swiss Agency for the Environment
  - Life Cycle Inventories for packagings: paper, plastics, glass, aluminium and steel (1998)
- Eco-Profiles of the European Plastic Industry (2005)
- Boustead Consulting Associate Ltd.
  - LCA for three types of grocery bags – Recyclable plastic; Compostable, biodegradable plastic; and Recycled, Recyclable paper (2007)
- Chulalongkorn University, Kasetsart University

Life Cycle of Paper Cup & PS Cup





Data Acquisition

Cups

Paper vs. Plastic Cups

		Hocking 1991	Lave et al. (EIO-LCA) 1995
Plastic (100,000 cups)	Electricity (kWh)	20-30	2630
	Air emissions (kg)	7-8	10
Paper (100,000 cups)	Electricity (kWh)	980	5150
	Air emissions (kg)	18-28	19

♥ **Plastic**

Data Acquisition

Bags/Sacks

Paper vs. Plastic Grocery Sacks

		Allen & Bakshani	Graedel & Allenby	Ciambrone
PE (60,790 sacks)	Energy (M BTU)	40	40	34
	Air pollution (lb)	73	76	59
Paper (30,395 sacks)	Energy (M BTU)	50	49	39
	Air pollution (lb)	195	198	49

Plastic ♥

Comparison of Environmental Impacts of 3 Types of Bags (Paper/PE/Compostable)

(Equivalent to 1,000 Paper Bags)

	Paper Bag (30% Recycled Fiber)	Traditional Polyethylene Bag	Compostable Plastic Bag
Total Energy Usage (MJ)	2622	763	2070
Fossil Fuel Use (kg)	23.2	14.9	41.5
Municipal solid Waste (kg)	33.9	7.0	19.2
GHG (CO2 Equiv. Tons)	0.08	0.04	0.18
SOx (kg)	0.579	0.0758	0.413
NOx (kg)	0.264	0.0681	0.456
Fresh Water Usage (Gal)	1004	58	1017

Boustead Consulting & Associates Ltd. (2007)

9 Packaging Materials for Drink Containers were compared using LCA

Huang & Ma (2004) Journal of Science of the Total Environment

Basis of Comparison : 1 liter

Table 1
Average function units of nine packaging materials

Packaging materials/containers	Average function units of bottles (g/l)		Average function units of bottle tops (g/l)	
PET containers	PET	89.02	PP	5.12
HDPE containers	HDPE	59.57	PP	12.77
PP containers	PP	82.33	PP	7.17
PS containers	PS	57.00	Aluminum foil	2.00
Steel cans	Tin plate	156.27	None	
Aluminum cans	Aluminum ingots	46.20	None	
Glass containers	Glass (brown)	1015.63	Aluminum ingots	8.13
Cardboard boxes	Cardboard liquid	37.76	PP	1.12
	PE	6.66		
Liquid paperboards	Cardboard liquid	29.46	None	
	PE	8.42		
	Aluminum foil	2.21		

LCA Results – Total Environmental Impact Points

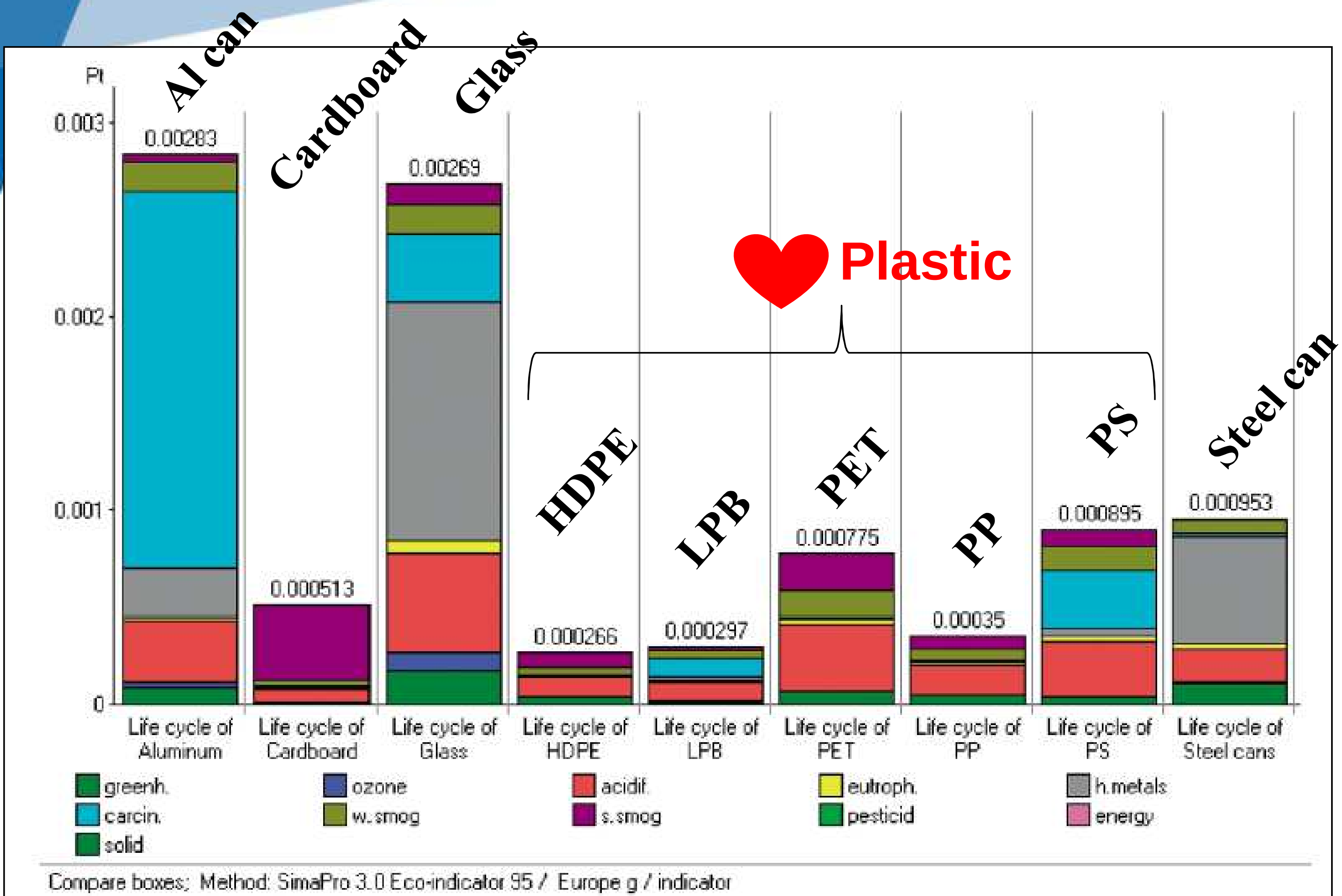


Fig. 4. LCA result of materials (all life cycle, unit: point, Pt).

Plastic Pouch & Glass Bottle for Milk Packaging (per 1 million liters)

Source: Carnegie Mellon University, USA

	Glass		Plastic pouch	
Material required (MTon)	45.4		0.4	
	Energy (GJ)	Water (m3)	Energy (GJ)	Water (m3)
Phase I: Production of raw materials	671.92	1,608.0	32.22	25.6
Phase II: Production of bottles/pouches	530.27		4.56	
Total	1,202.19	1,608.0	36.78	25.6
Phase III: Filling & distribution	Fuel (liter)	Energy (GJ) Single [Return]	Fuel (liter)	Energy (GJ) Single [Return]
	2,049	114.75 [213.43]	1,120	62.73 [106.64]

Emissions During Phase I & Phase II

per 1,000,000 liters of milk

		Glass	Plastic Pouch
Air emissions			
CO	kg	54.3	0.6
CO_2 *(GHG)*	kg	6,610.2	760.0
SO_x	kg	134.8	5.2
NO_x	kg	68.1	4.8
CH_4 *(GHG)*	kg	39.5	3.2
HCl	kg	5.3	0.0
Dust	kg	67.6	1.4
Water emission			
Suspended solids	kg	352.3	0.2
Chloride	kg	4,535.5	0.1

Comparison of Environmental Performance between Retort Pouch and Steel Can for Tuna Meat

Source: Ratanawan Mungkung et al. (2007) – Kasetsart University

Steel can	Retort Pouch
• Tin-free steel • 2 pieces/coated • 85 gm filling • 11,765 cans per ton tuna meat • ~70% Recycled	• PET/Al foil/Nylon/PP • Laminated • 100 gm filling • 10,000 pouches per ton tuna meat • ~10/20/70% Re/Inc/LF

Product Life Cycle

Resources → **Manufacture** → **Can/Pouch** → **Filling** → **Sterilization** → **Packing** → **Distribution** → **Use** → **Waste Management**

Life Cycle Comparison between Steel Can and Retort Pouch for 1 Ton of Tuna Meat

		Steel Can	Retort Pouch
Resources Used			
Coal	**kg**	550.80	36.03
Natural Gas	**m3**	58.0	29.13
Petroleum	**kg**	69.59	50.6
Environment/Emission			
Global Warming	**CO_2 kg**	3,100	1,150
Acidification	**SOx kg**	25.8	8.66
Energy Utilization			
Filling & Packing	**kWh**	317.29	259.19
Total	**Points**	82,200	42,800

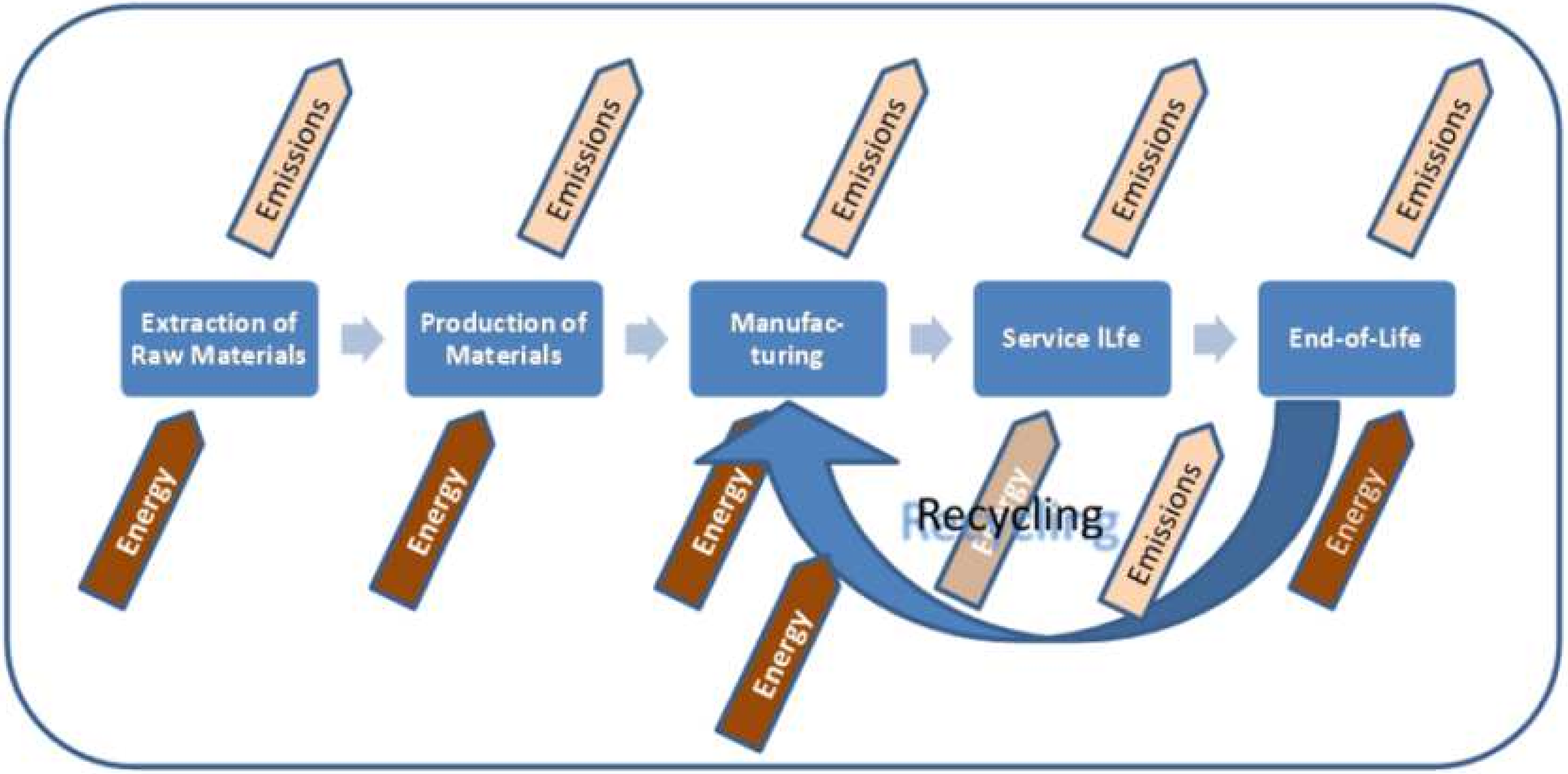
- ***Transportation load for 1 ton steel can tuna ~1.5 times retort pouch.***
- ***Cardboard weight for 1 ton steel can tuna ~1.7 times retort pouch.***
- ***It needs to recycle steel can 5 times to get the same environmental load as the retort pouch.***

Examples of Use of LCA for the Sustainable Management of Plastics with a Focus on Recycling

The Netherlands
PET bottle recycling

Modelling of Recycling in LCA

Tom N. Ligthart and Toon (A.)M.M. Ansems
TNO, Utrecht, Netherlands



Reduction in Non-Renewable Energy Use (NREU) Resulted from Recycling PET Bottle

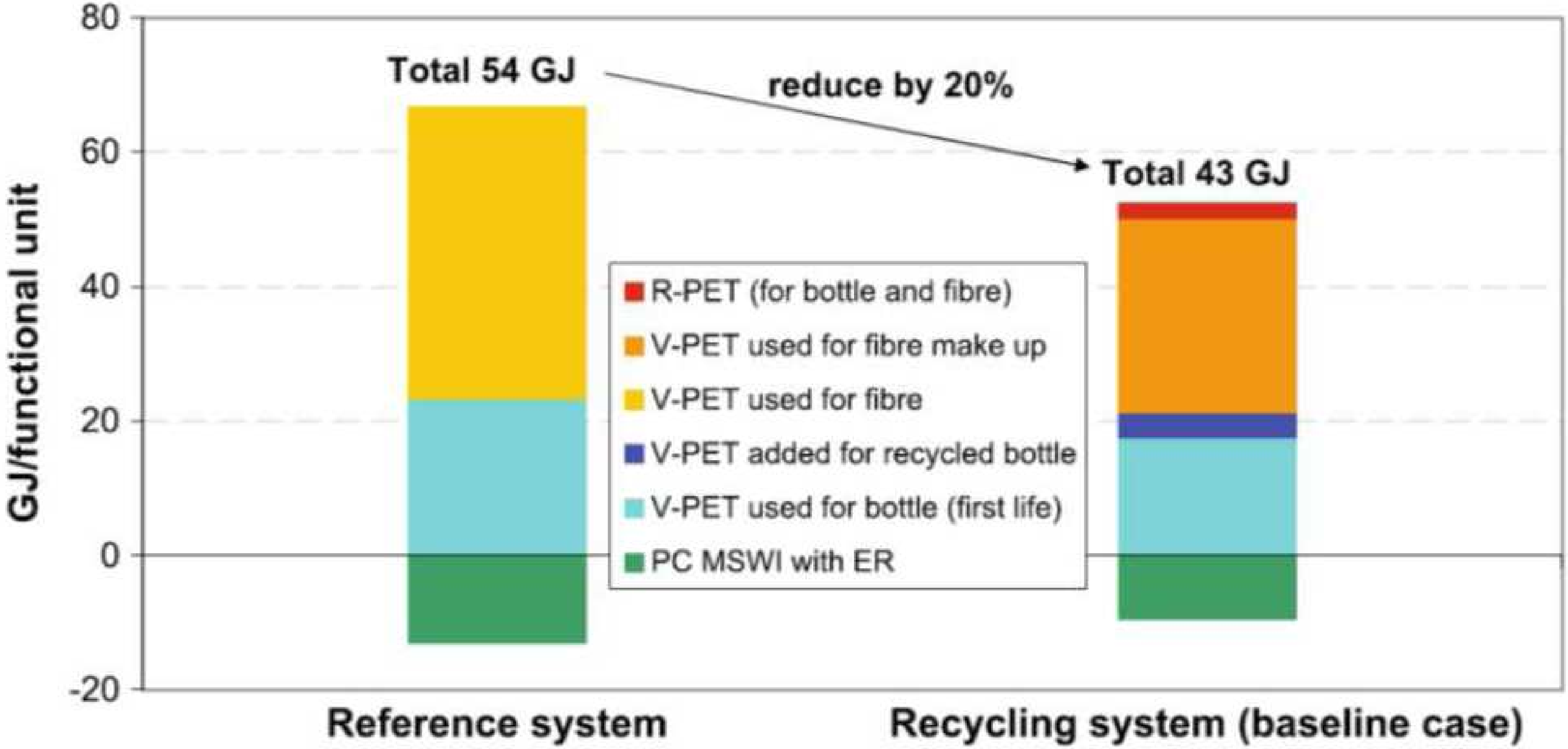
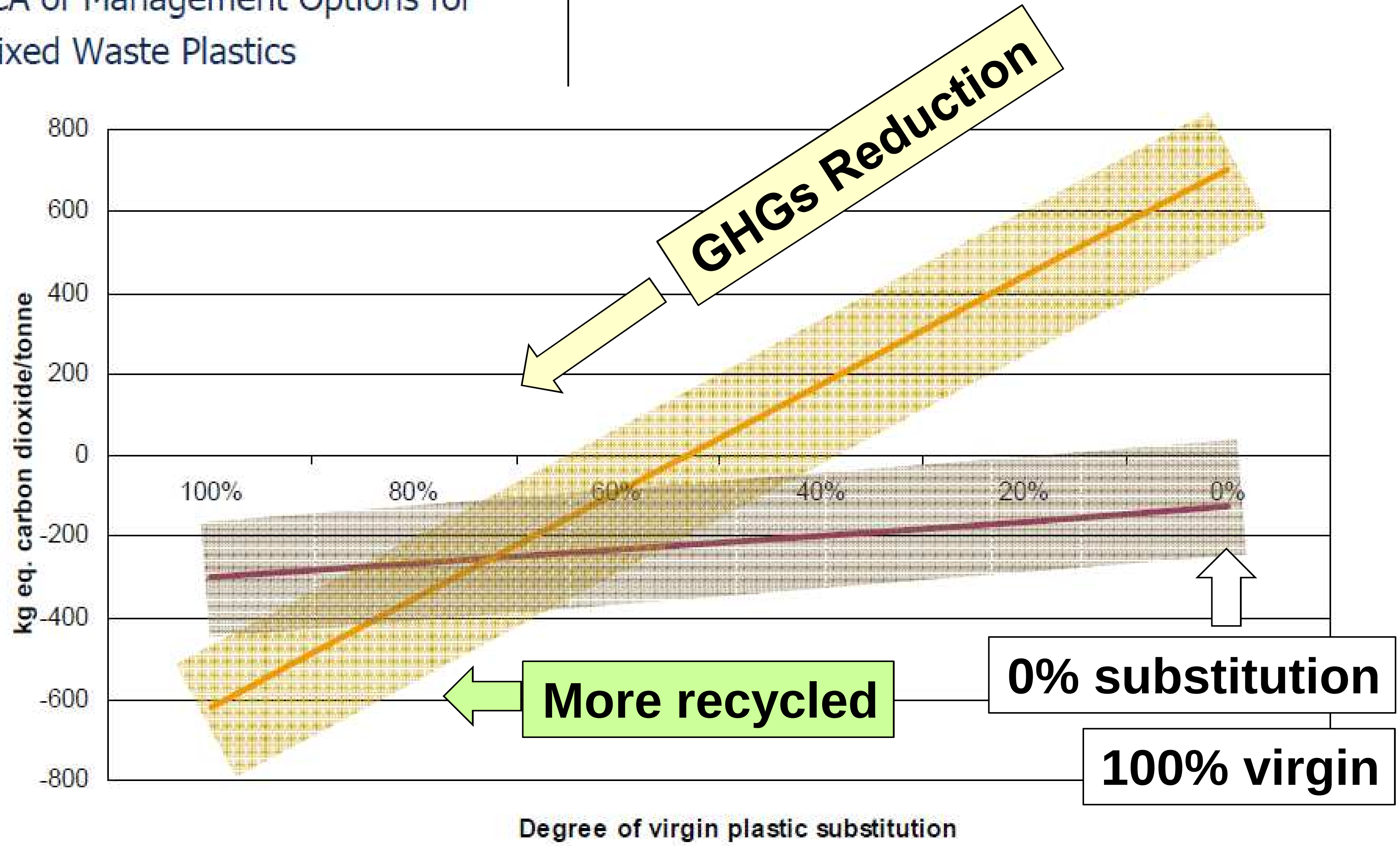


Fig. 20. Cradle-to-grave non-renewable energy use (NREU) recycling system and the reference system in which no recycling takes place (Schen et al., 2011).

UK

Final Report

LCA of Management Options for Mixed Waste Plastics



United States

LCA and recycling policy — a case study in plastic

Brandon Kuczenski and Roland Geyer

Life Cycle Assessment IX
Boston, MA

October 1, 2009

CALIFORNIA CONSERVATION

RECYCLING

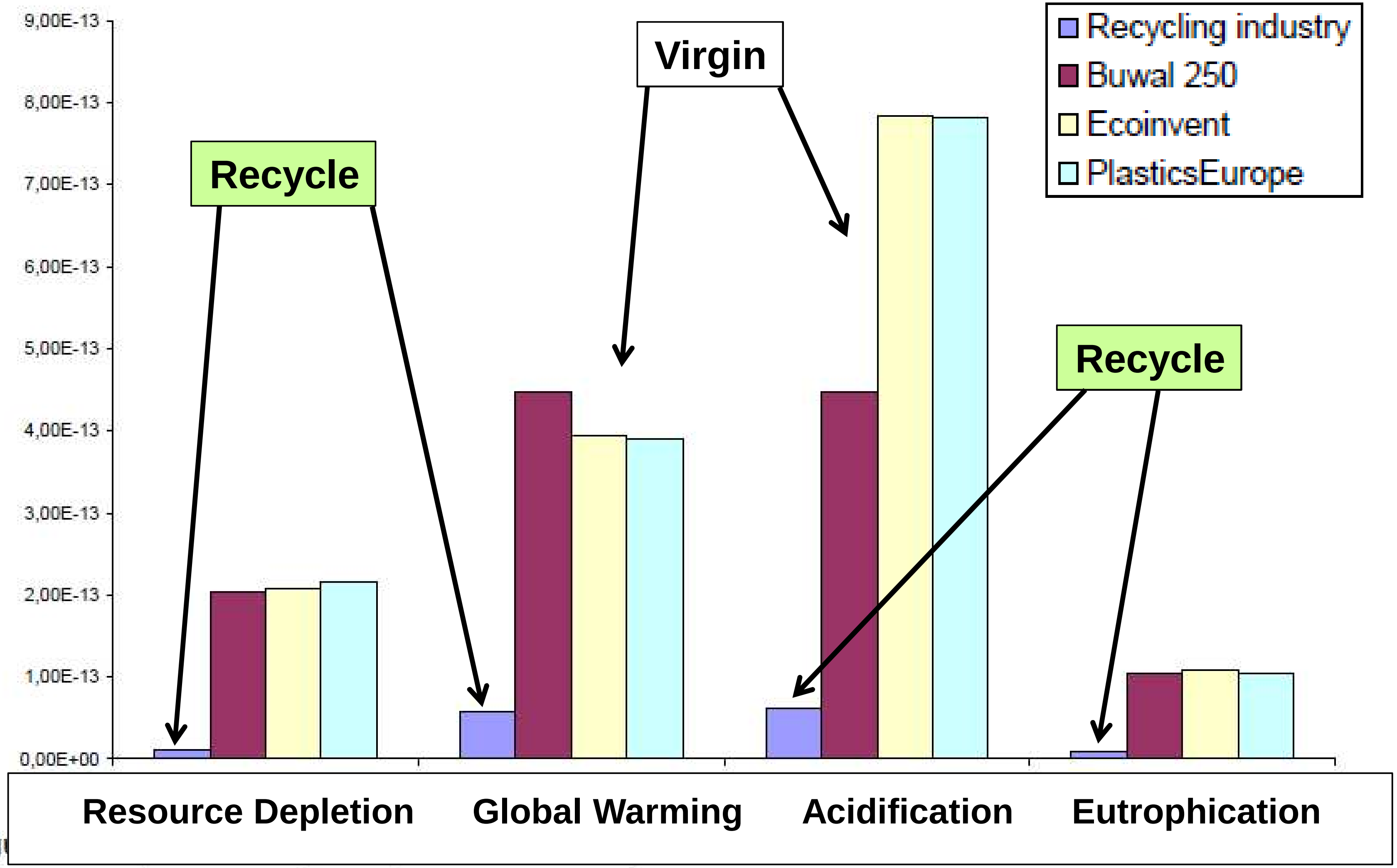
DONALD BREN SCHOOL OF
ENVIRONMENTAL SCIENCE & MANAGEMENT
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

- Each kg of PET recycled help us avoid 1 kg disposal and 0.78 primary production

- PET bottle recycling saves 54% of the primary energy demand associated with consumption (mostly feedstock), but avoids only 23% of GHG production.

Spain — Technological Institute of Plastics, Valencia

Environmental Comparison between Recycled vs. Virgin HDPE



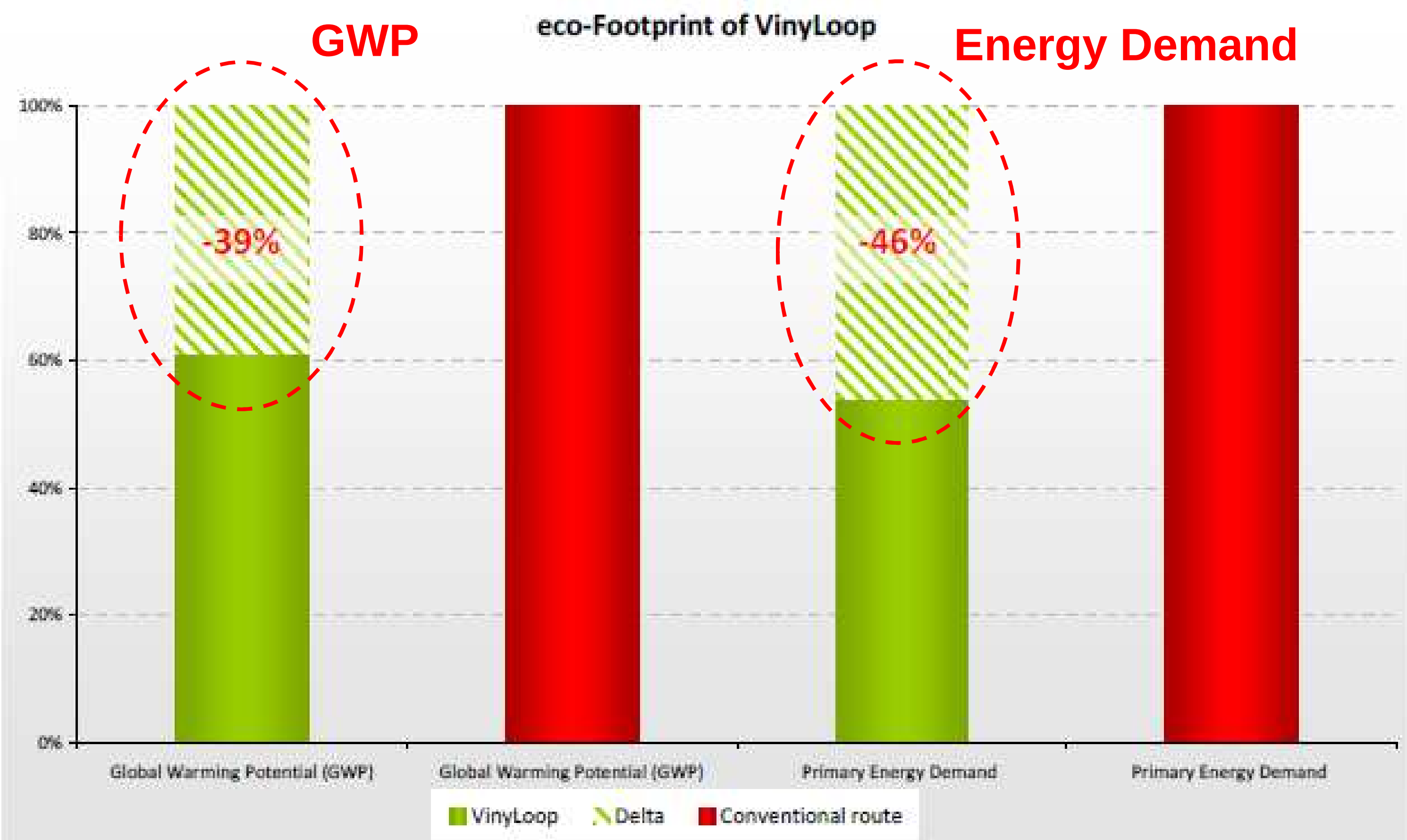
Fig

The VinyLoop® Eco-Footprint

Benchmarking of the environmental impact of PVC compound recycled in the VinyLoop® process with PVC compound produced in conventional route (virgin PVC compound and incineration)

February 2012

The VinyLoop Recycled PVC from cable waste reduces the environmental footprint. For each kilogram of PVC compound (functional unit) recovered through the VinyLoop process, the production of 1kg of PVC compound and the incineration of the corresponding amount of PVC waste are avoided.



Impact Category	Unit	VinyLoop®	PVC conventional route	Delta
Global Warming (GWP 100a – IPCC 2007)	kg CO2-Eq	61%	100%	-39%
Primary Energy Demand	MJ	54%	100%	-46%

Life Cycle Assessment Study of PVC Pipe and Fitting in Thailand

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The Petroleum and Petrochemical College
Chulalongkorn University

Dr.Manit Nithithanakul
Mr.Sompit Petchprayoon
Mr.Seksan Papong

Target Products

Pipe

-Diameter: 18 mm. and 55 mm.

-Length: 4 m.

-Class: 8.5

-Grade: Standard

-Service period ≥ 50 years*

Fitting

-Elbow 90 º

-Class 13.5

-Grade: Standard

-Service period ≥ 50 years*

Functional units: 1 piece or set (pipe & fitting) and 1 kg of product (pipe & fitting)

*Same as the service life used in other LCA studies of PVC pipes, including TEPPFA.

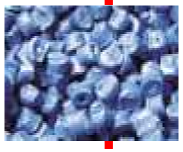
System Boundary

Cradle to Grave

Cradle to Gate

Gate to Gate

Resin Production → **Pipes and Fittings Production** → **Use** → **End of Life (Disposal)**



- TPC

- VNT

❖ Advanced Pipe

❖ Nawaplastic

❖ Thai Pipe

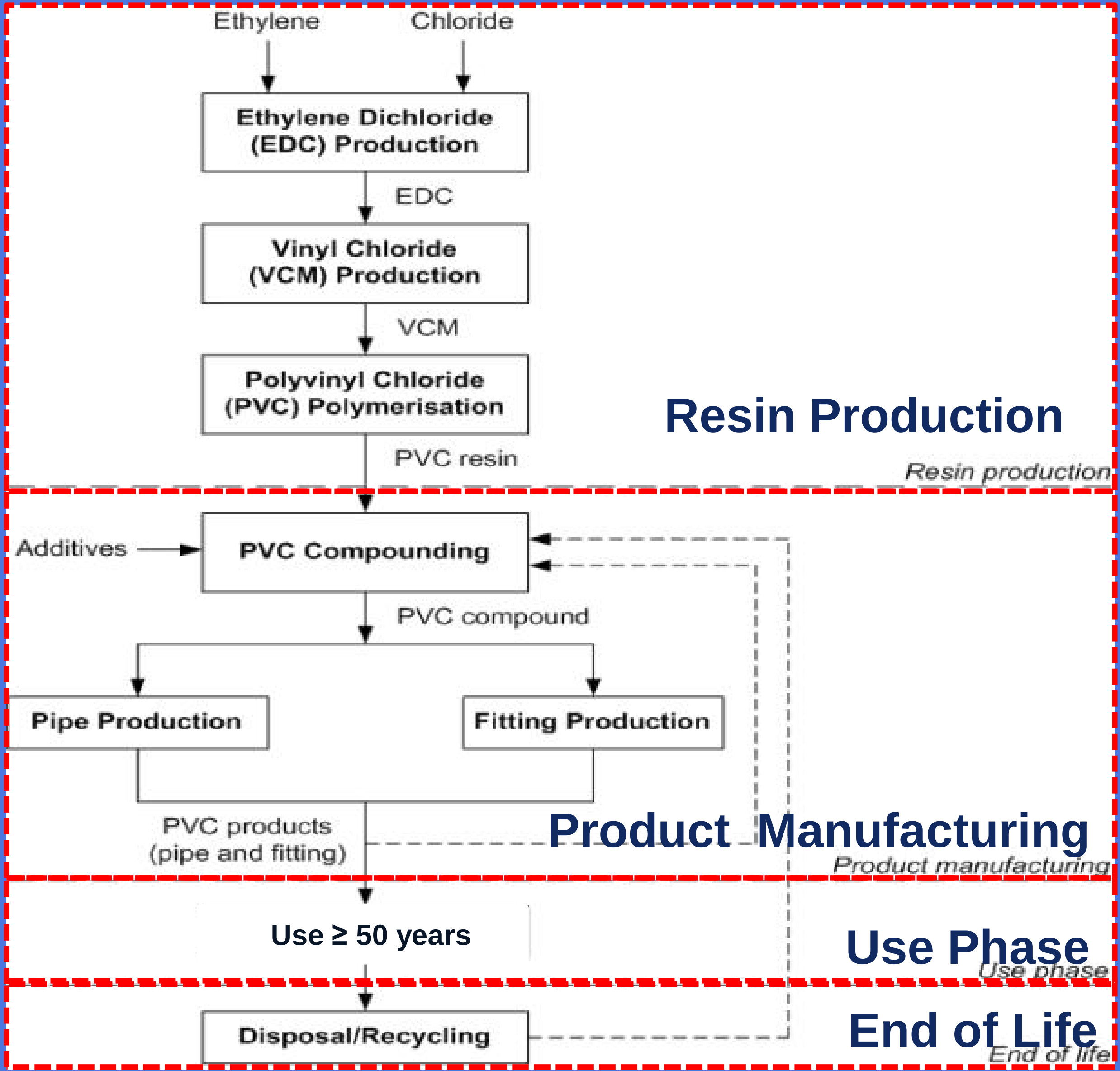
Literatures

Scenarios
- Landfill
- Incineration
- Recycle
- Combination

Including:
- Recycle 0%
- Recycle 30%
- Recycle 50%
- Recycle 75%
- Recycle 90%

Secrecy agreements were signed with companies providing data

Processed Involved in the System



Research Methodology

Sources of Data for LCA Analysis

Life Cycle Stage of Pipe & Fitting Production

National LCI Database 2006

VCM production → PVC-S Production → Pipe & Fitting Production → Use

- 1° Nawaplastic Industries Co., Ltd.
- 1° Advanced Pipe Co., Ltd.
- 1° Thai Pipe Industry Co., Ltd.

- No impact during use (50 years)
- Manual installation and removal

- 1° TPC
- 1° VNT

Update National LCI Database for PVC resin

Disposal Phase

2° Landfill | 1° Recycle | 2° Incineration

- 1° Amorn & Sanae Recyclers
- 2° Ecoinvent database

1° Data : Actual data are collected from real site
2° Data : Secondary data

End of Life Scenarios

Scenarios	End-of-life treatment (%)		
	Mechanical recycle	Landfill	Incineration
Base case*	**30**	**67**	**3**
1	100	0	0
2	0	100	0
3	0	0	100
4	50	50	0
5	70	30	0
6	75	25	0
7	80	20	0
8	90	10	0

*** Base Case recycle is based on previous study by MTEC**

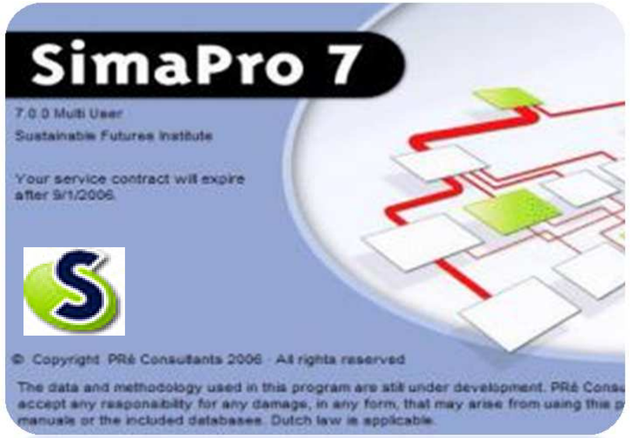
The total amount of general PVC post consumer products (wastes) was found to be about 30% of the total amount of PVC product production. The rest was assumed to be treated by current waste treatment system in Thailand based on PCD statistics (landfill and incineration).

Research Methodology

LCA Technique based on ISO14040 series framework

LCA Software: SimaPro 7.1

Licensed



LCIA Method	Environemental Impact categories
CML 2 baseline 2000 V2.03	• Global warming potential (CO_2eq) • Acidification (SO_2eq) • Eutrophication (PO_4eq) • Human toxicity (kg 1,4-DB eq)
Eco-indicator 95	• Energy resource (MJ)

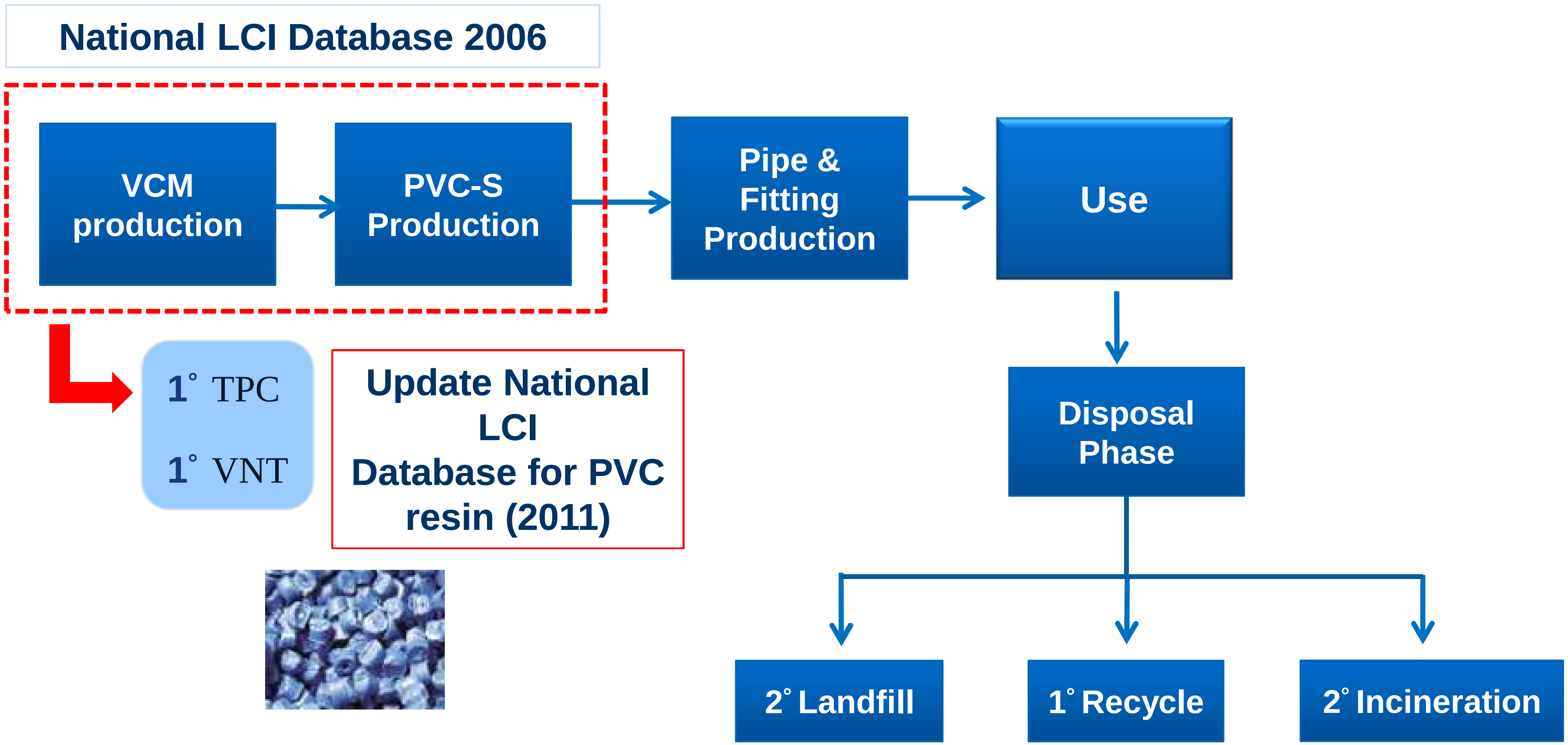
Description of Impact Categories

Impact Category	Impact on	Scale	Reference substance	Description
Global warming potential (GWP)	Ecosystem	Global	Carbon dioxide (CO_2eq)	Gaseous compounds adsorb infrared light and trap heat radiation.
Acidification potential (AP)	Ecosystem	Regional/ Local	Sulfur dioxide (SO_2eq)	Emission of acid can degrade some material.
Eutrophication potential (EP)	Ecosystem	Local	Phosphate (PO_4eq)	Chemical nutrients (nitrogen (N) and phosphorus (P)) in water bodies increase the rate of plant production and accumulation of organic matter that can degrade water and habitat quality.
Human toxicity potential (HTP)	Human health	Global/ regional / local	1,4 –dichloro-benzene (1,4-DB) eq	The degree to which a chemical substance elicits a deleterious or adverse effect upon the biological system of human exposed to the substance over a designated time period.
Energy Resource	Resource	Global/ regional / local	Energy (MJ)	Energy consumption in particular phase or throughout the life cycle of the product.

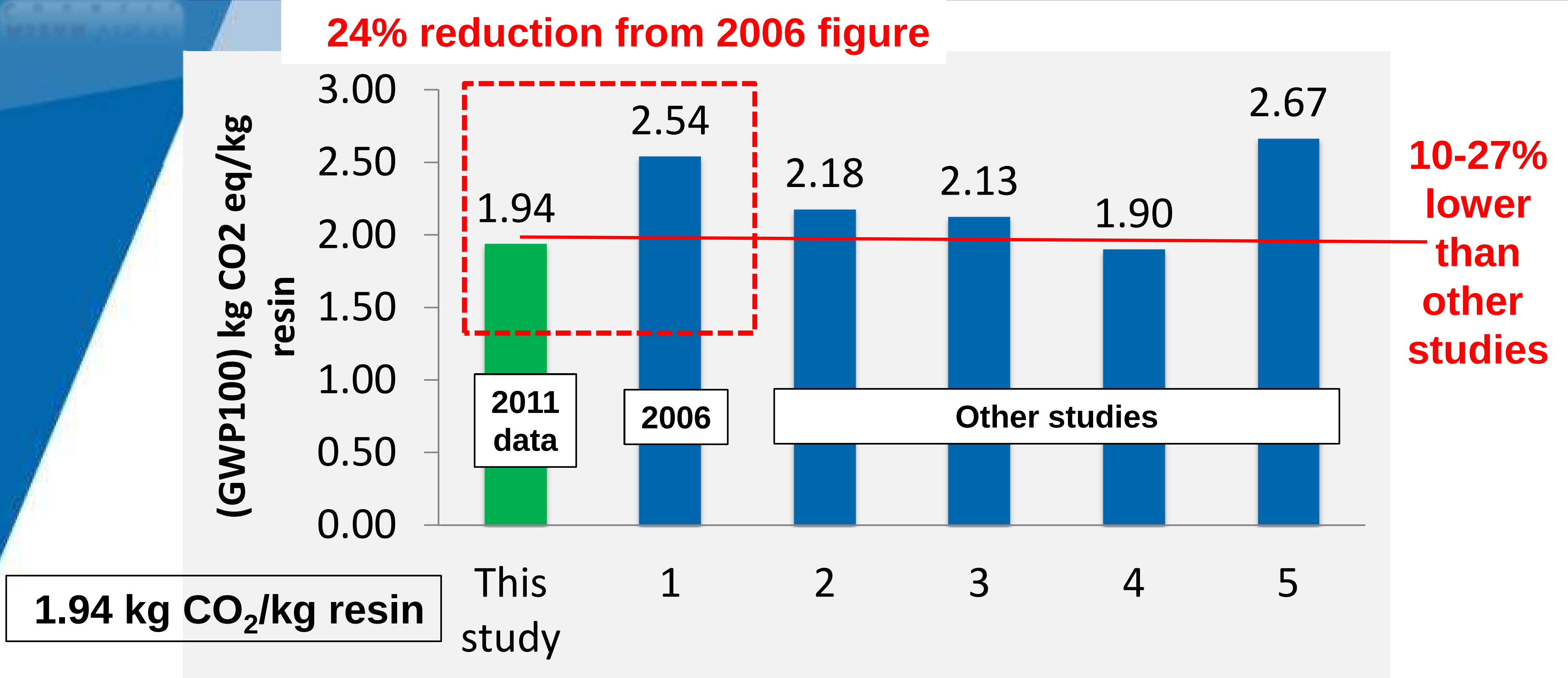
Results and Discussion

- Resin Phase (PVC Resin)
- Production Phase (PVC Pipe & Fitting)
- End of Life Phase (Disposal)
- Whole Life Cycle of PVC Pipe and Fitting

1. Resin Production Phase

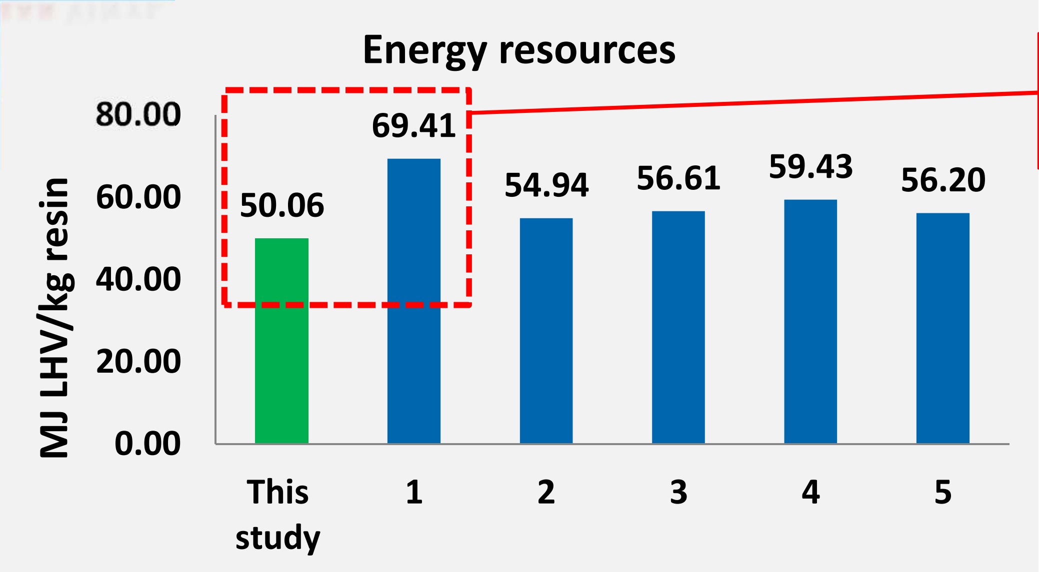


Global Warming Potential (GWP) of PVC Resin (kg CO_2 per kg resin)



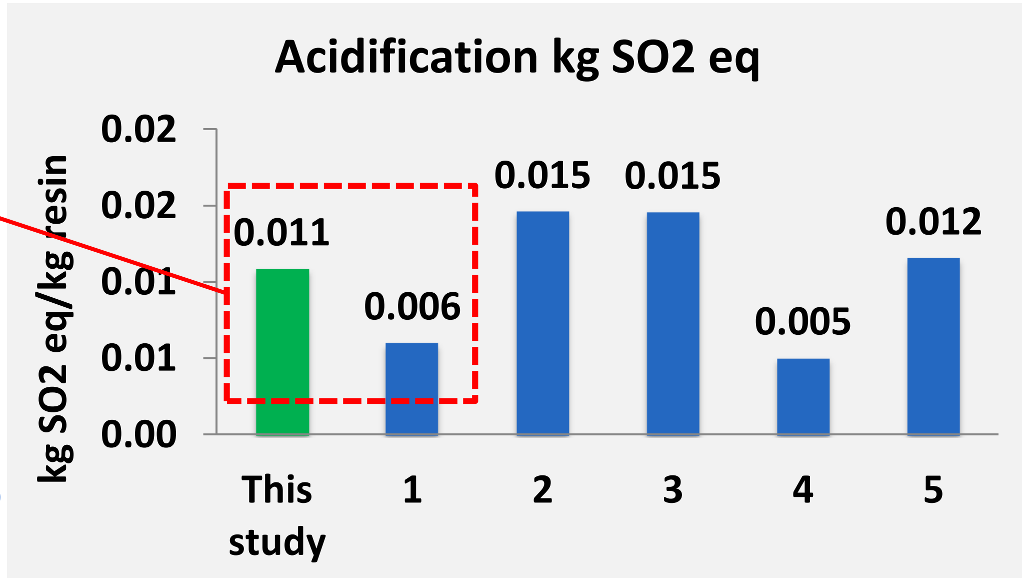
1	PVC-S National LCI Database Thailand (2006)
2	PVC (S) I (of project IDEMAT 2001) – Delft U. of Technology
3	PVC suspension A (of project Industry data)
4	Polyvinylchloride, suspension polymerised, at plant/RER U (of project Ecoinvent unit processes) – International Database
5	Polyvinylchloride resin (S-PVC), suspension polymerization, production mix, at plant RER (of project ELCD) – European Life Cycle Database

Energy Demand and Acidification Impact of PVC-S Resin (per kg resin)



28% reduction from 2006 figure

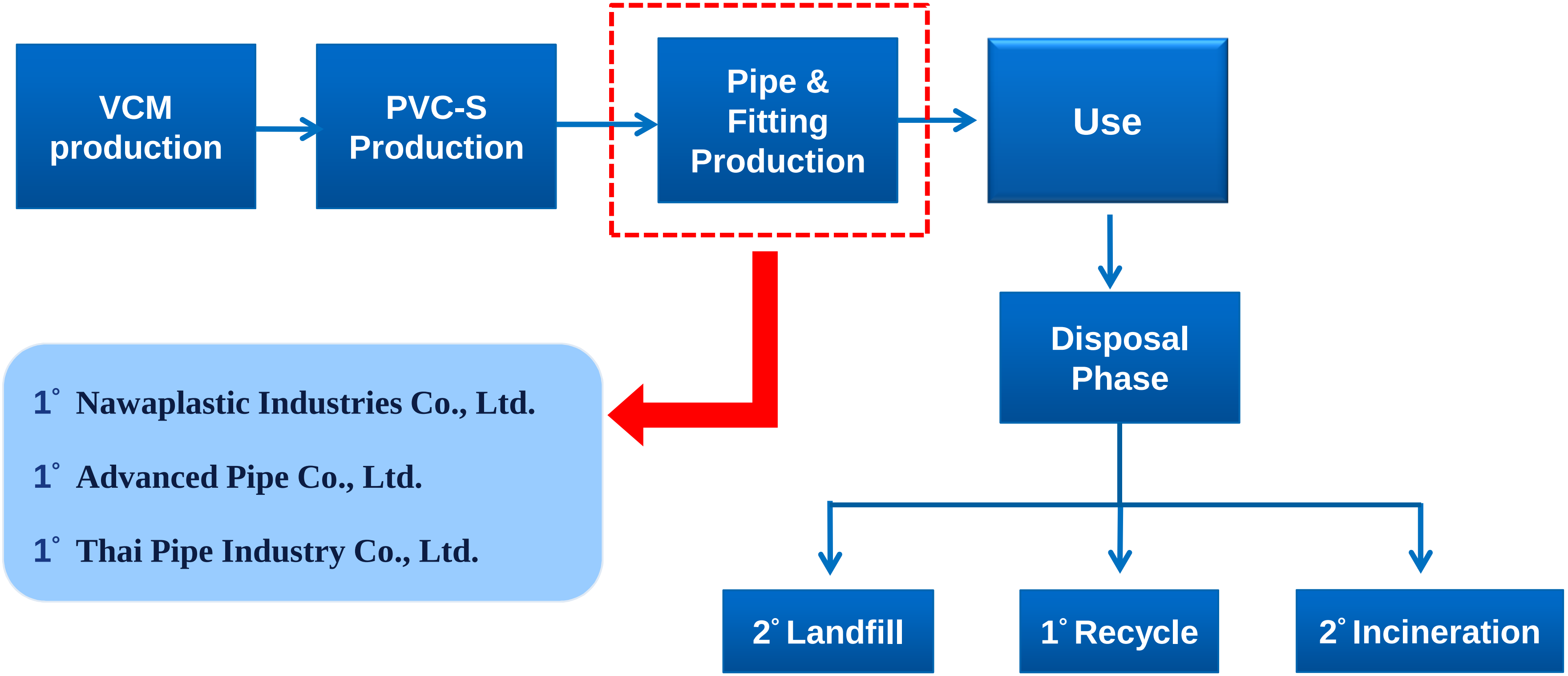
~50 MJ/kg resin



From ethylene, chlorine and EDC (2011 data are more detailed)

~0.01 kg SO_2/kg resin

2. Pipe & Fitting Production Phase



Data Collection Sites

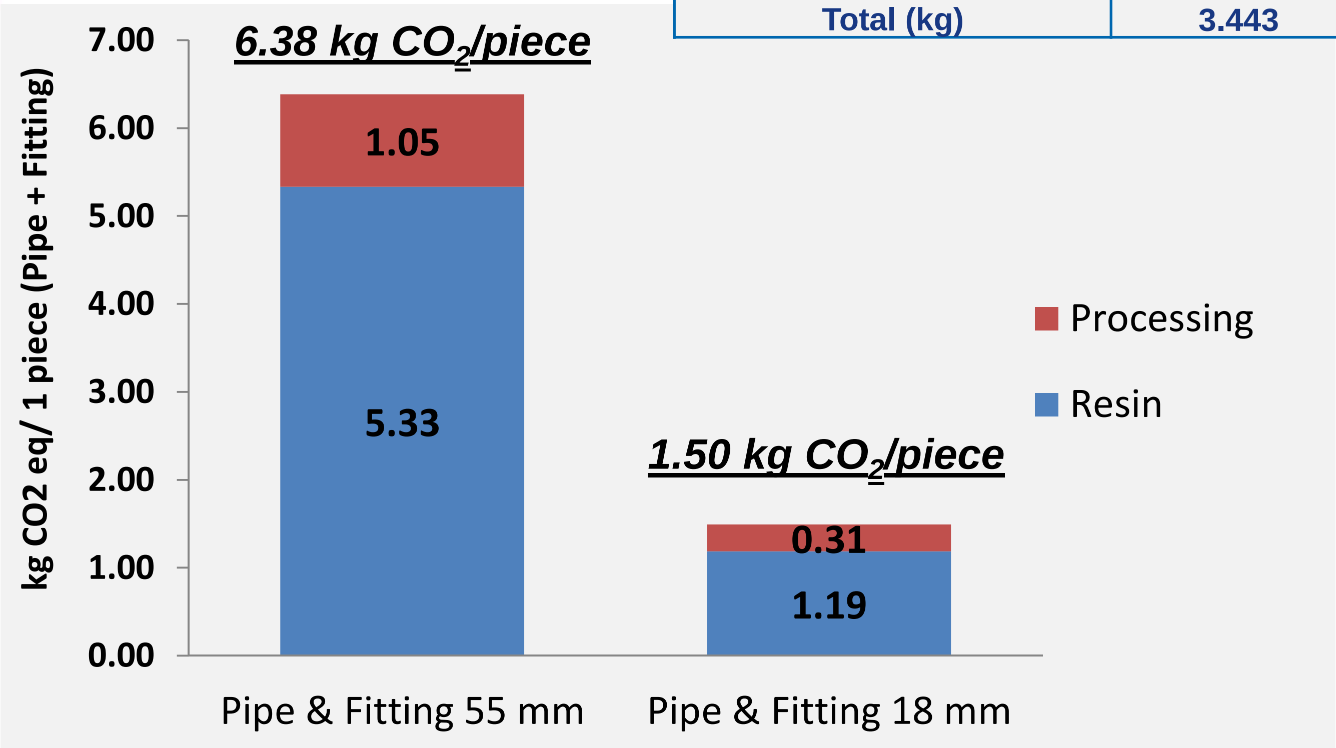
Advanced Pipe Co., Ltd.

Data Collection Sites

Nawaplastic Industries Co., Ltd.

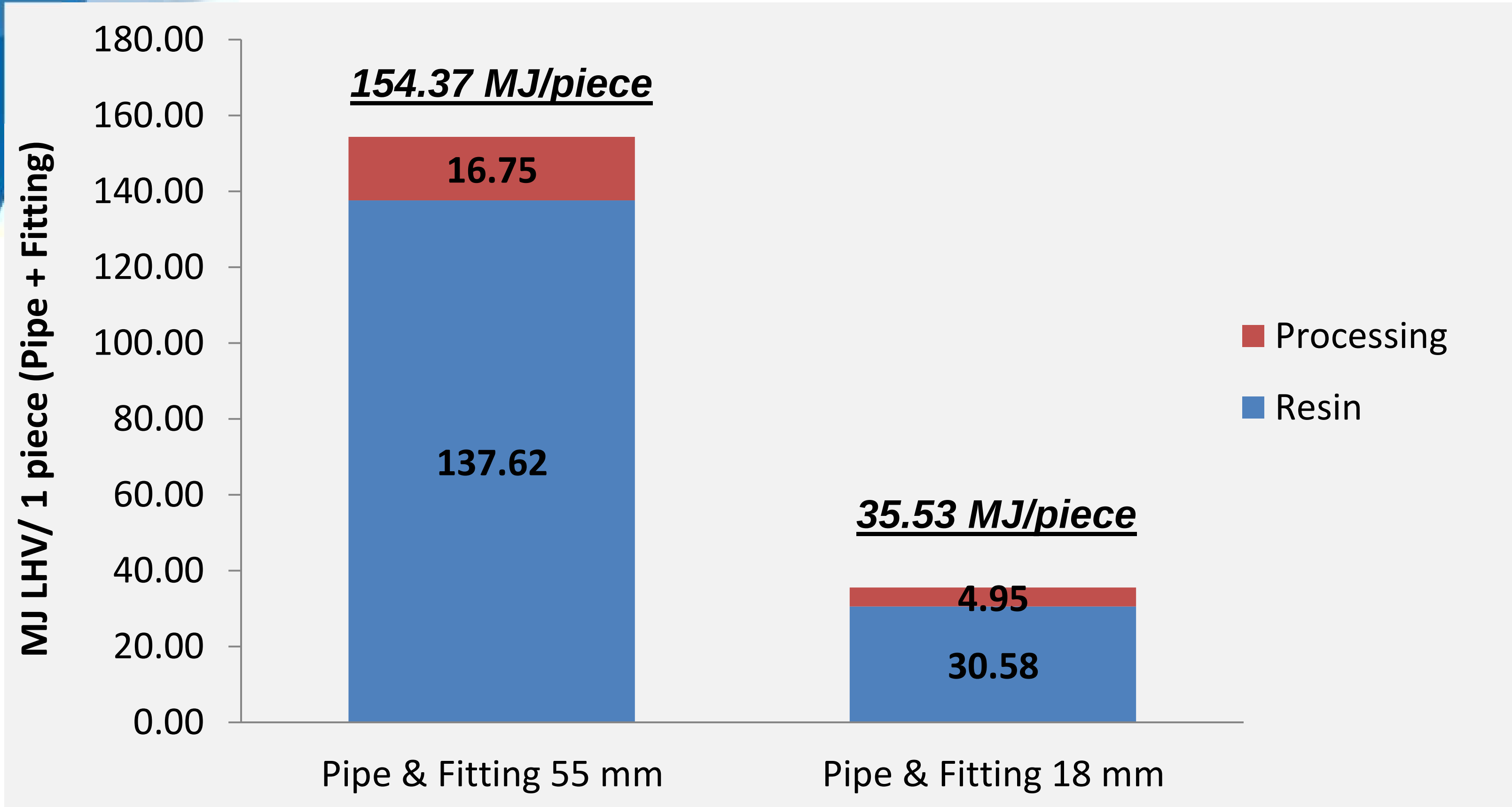
Global Warming Potential (GWP) of PVC Pipe and Fitting (Cradle-to-Gate)

Weight per piece	55 mm	18 mm
Pipe	3.152	0.750
Fitting	0.291	0.033
Total (kg)	**3.443**	**0.784**



- **Total GWP of pipe & fitting for both 55 mm and 18 mm is <u>1.85-1.91 kg CO_2 eq per kg of pipe & fitting</u>.**
- **Resin itself contributes <u>~80%</u> while processing contributes about 20%.**

Energy Use of PVC Pipe and Fitting (Cradle-to-Gate)



- **Energy resources for producing 1 piece (pipe + fitting) of 55 and 18 mm are 44-45 MJ per kg (of pipe & fitting together) .**
- **Approx. 85% of energy use is from resin phase.**

3. End of Life Phase (Disposal)

Minimal impact during use*
(Negligible)

VCM production → PVC-S Production → Pipe & Fitting Production → Use

Use → Disposal Phase

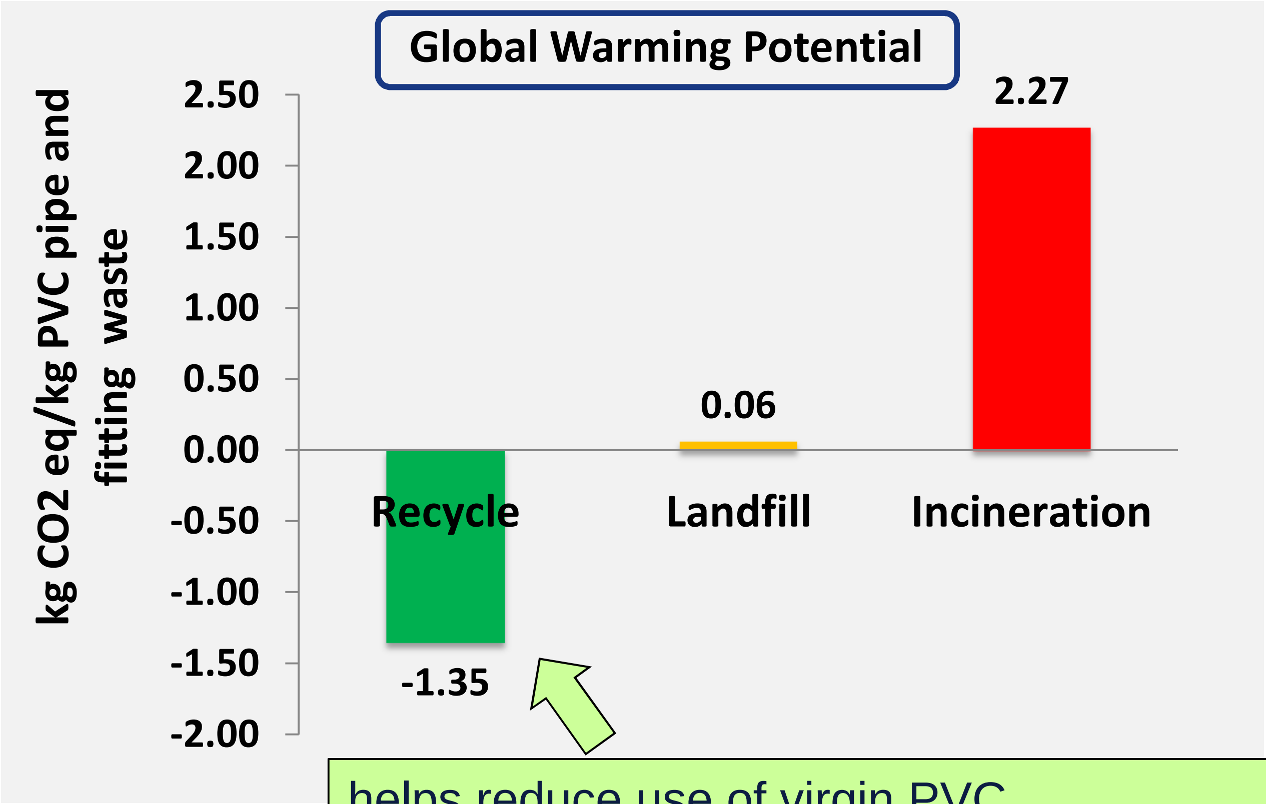
Disposal Phase → 2° Landfill / 1° Recycle / 2° Incineration

Comparison between three disposal technologies
100% Recycle / 100% Landfill / 100% Incineration

Basis: treatment of 1 kg PVC waste

3. End of Life Phase (Disposal)

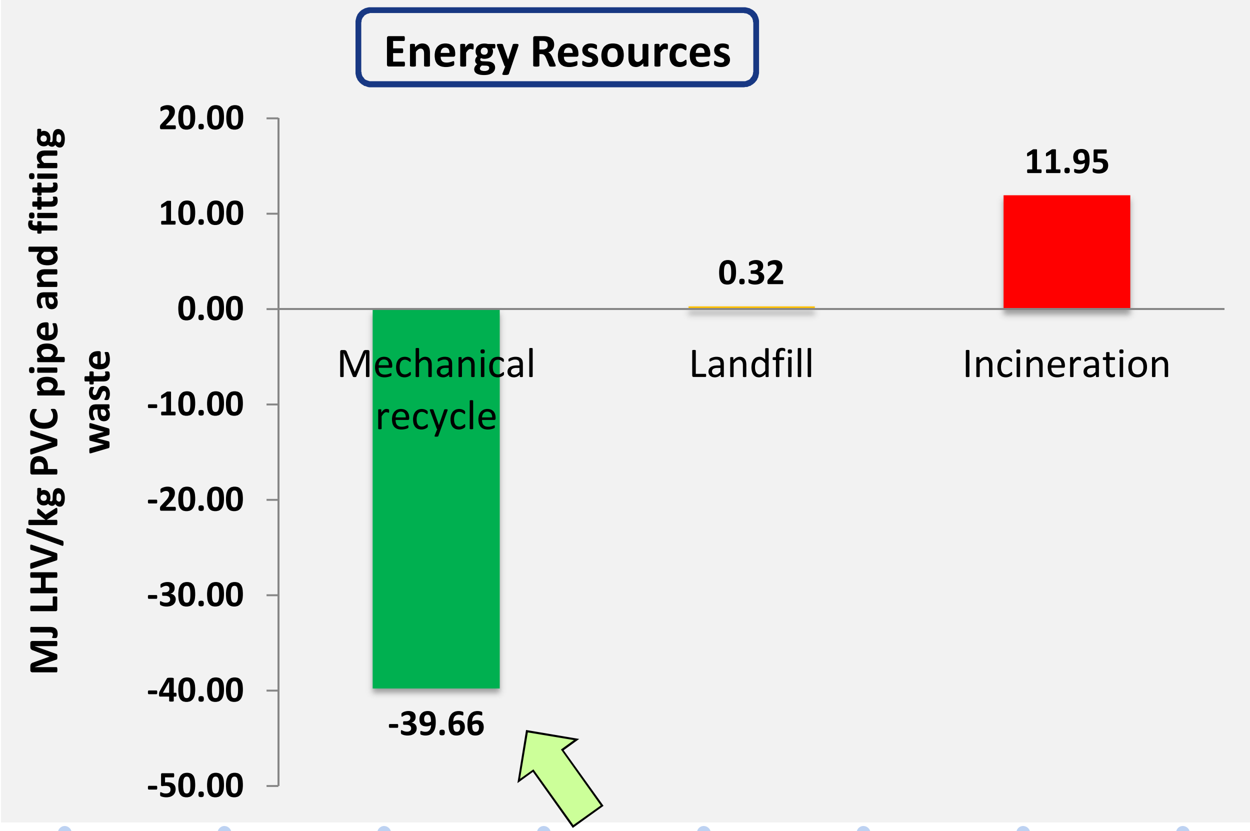
Comparison between three disposal technologies 100% Mechanical Recycle / 100% Landfill / 100% Incineration (per 1 kg of PVC waste)



helps reduce use of virgin PVC
= credits → benefits → negative environmental impact

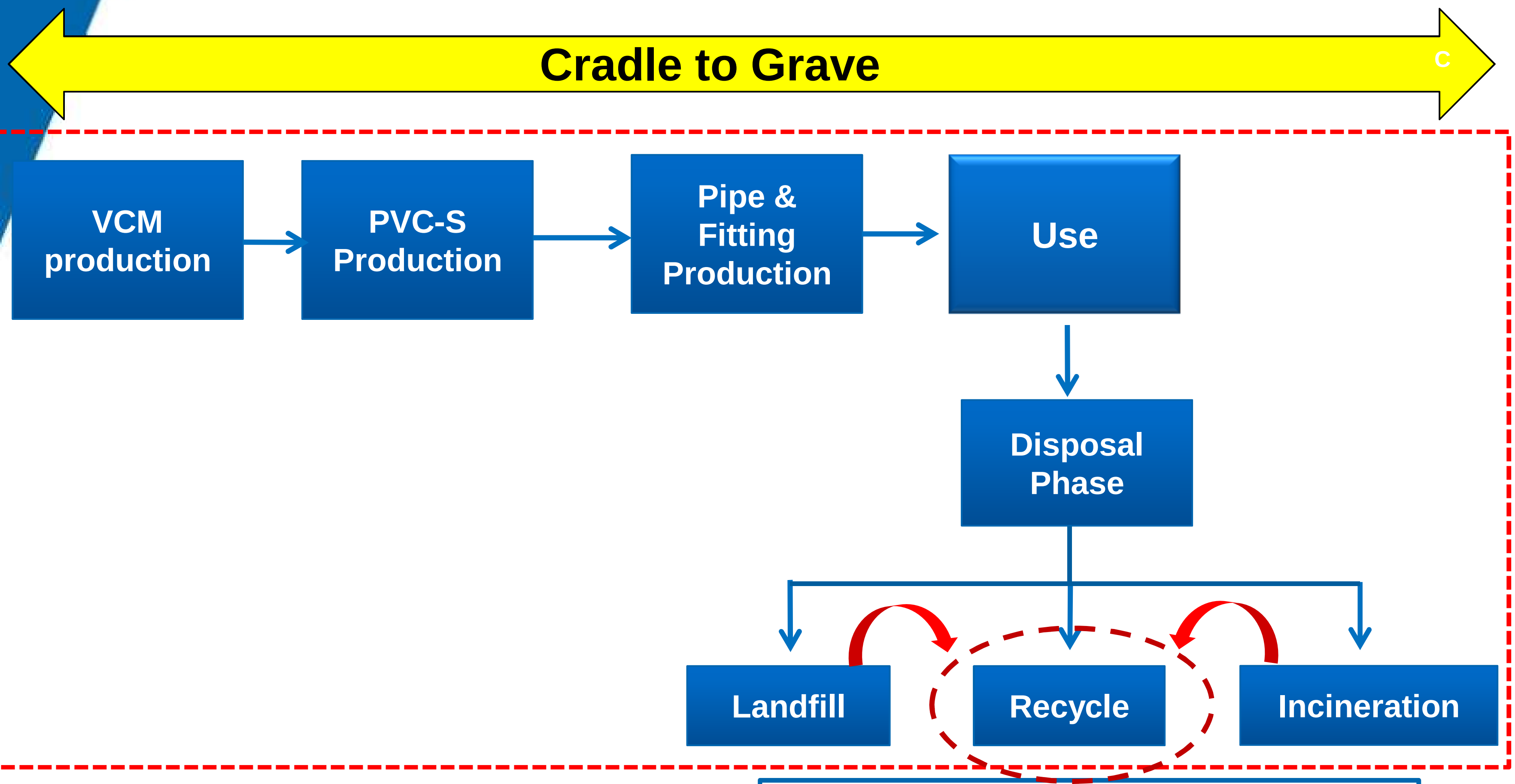
3. End of Life Phase (Disposal)

Comparison between three disposal technologies 100% Mechanical Recycle / 100% Landfill / 100% Incineration (per 1 kg of PVC waste)



4.Whole Life Cycle (Cradle to Grave)

Effect of Recycle on the Life Cycle Environmental Performance of PVC Pipe & Fitting



Using scenario analysis

Recycle shop Company A

- Collection
- Sorting
- Separating
- Cutting
- Cleaning
- Drying (air)

Recycle shop Company A


Cleaning


Cleaning


Drying


Packing


Ready to send out

Recycle shop Company B

- From A
- Grinding (course)
- Grinding (fine)

Scenarios with Increasing Recycle

Scenarios	End-of-life treatment (%)		
	Mechanical recycle	Landfill	Incineration
Base case*	30	67	3
1	100	0	0
2	0	100	0
3	0	0	100
4	50	50	0
5	70	30	0
6	75	25	0
7	80	20	0
8	90	10	0

Shown already (Base case, 1–3)

Increasing Recycle

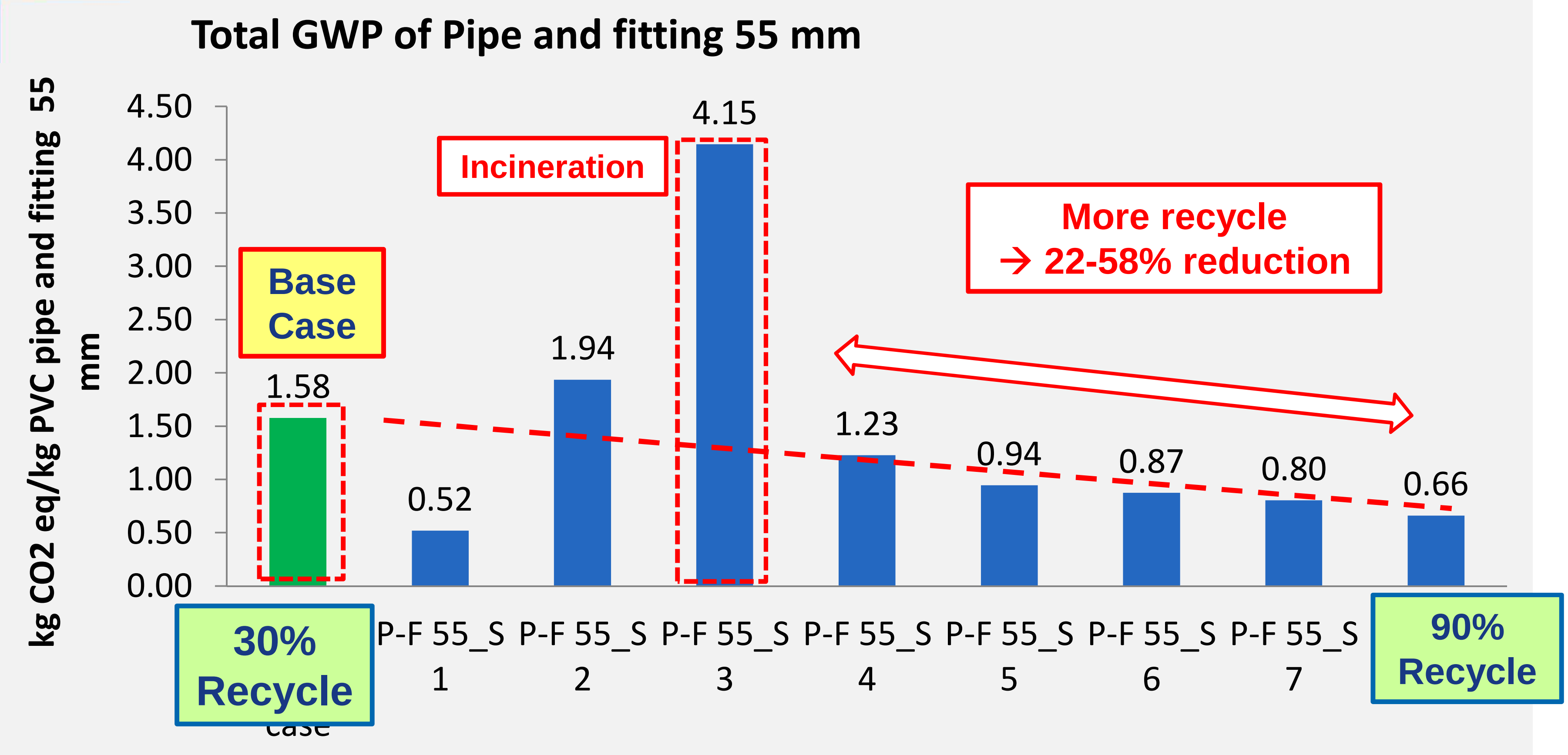
Minimizing Landfill

Zero incineration

* Base Case is considered as current situation (based on MTEC study)

Life Cycle Greenhouse Gases Emission

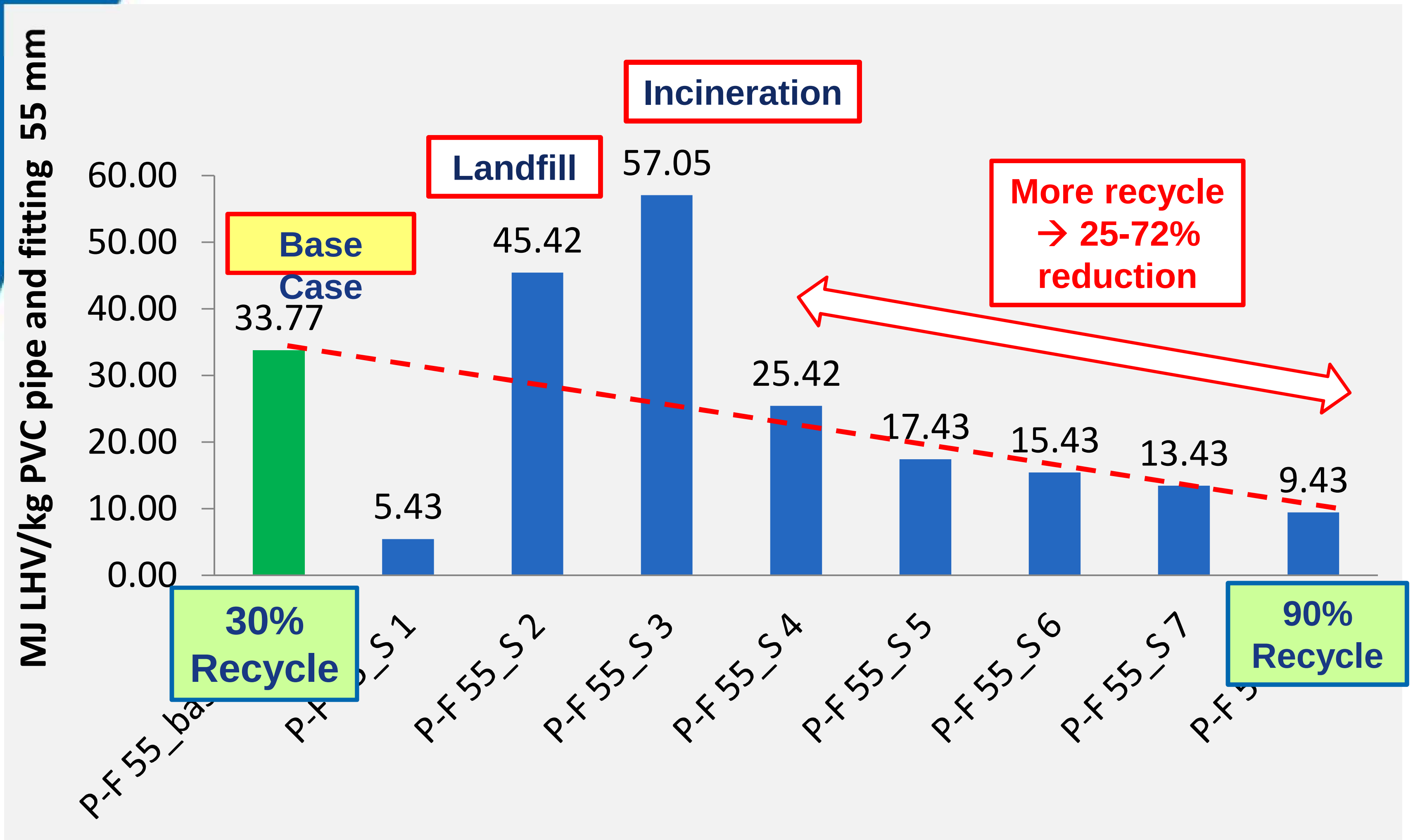
NET GWP (kg CO_2 eq/kg pipe and fitting set)



The more recycle, the better to the environment

Life Cycle Energy Use

NET Energy Used (MJ/kg pipe and fitting set)



Study of PVC Recycling in Thailand Using Material Flow Analysis (MFA)

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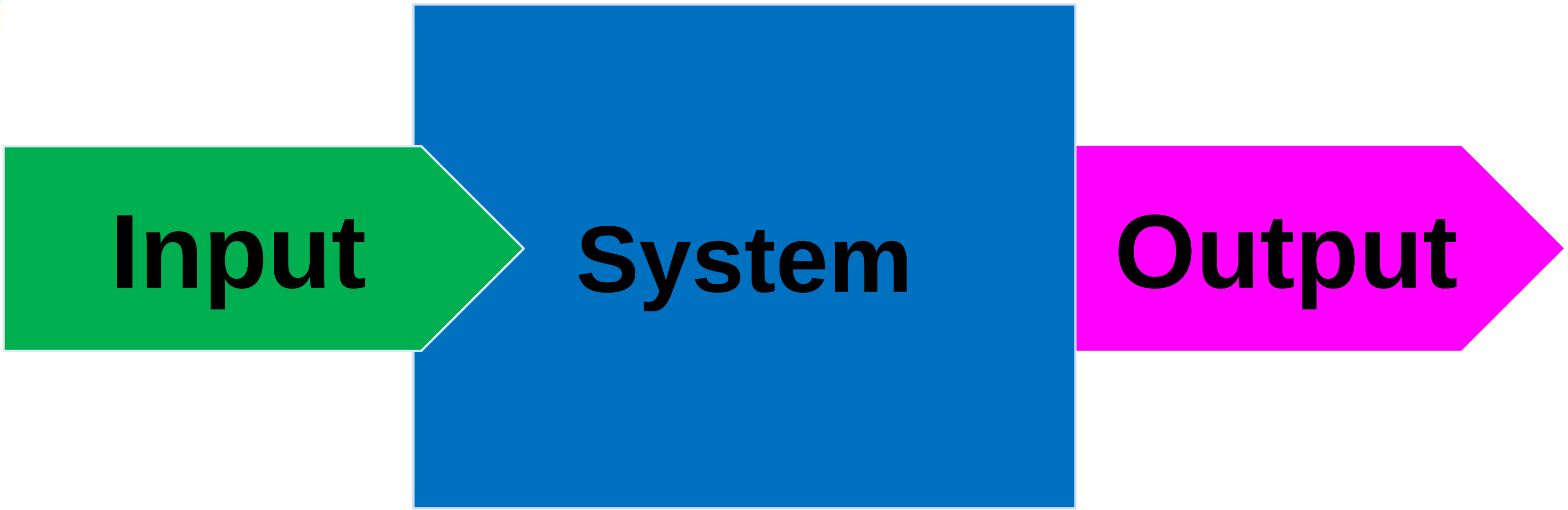
Dr.Ampira Charoensaeng (PPC-CU)

Mr. Seksan Papong (MTEC)

Mr. Thanakorn Rodcharoen, Mr. Suriyaphong Nakem, Ms.Wikanda Khomchu (M.S.

Concept of Material Flow Analysis (MFA)

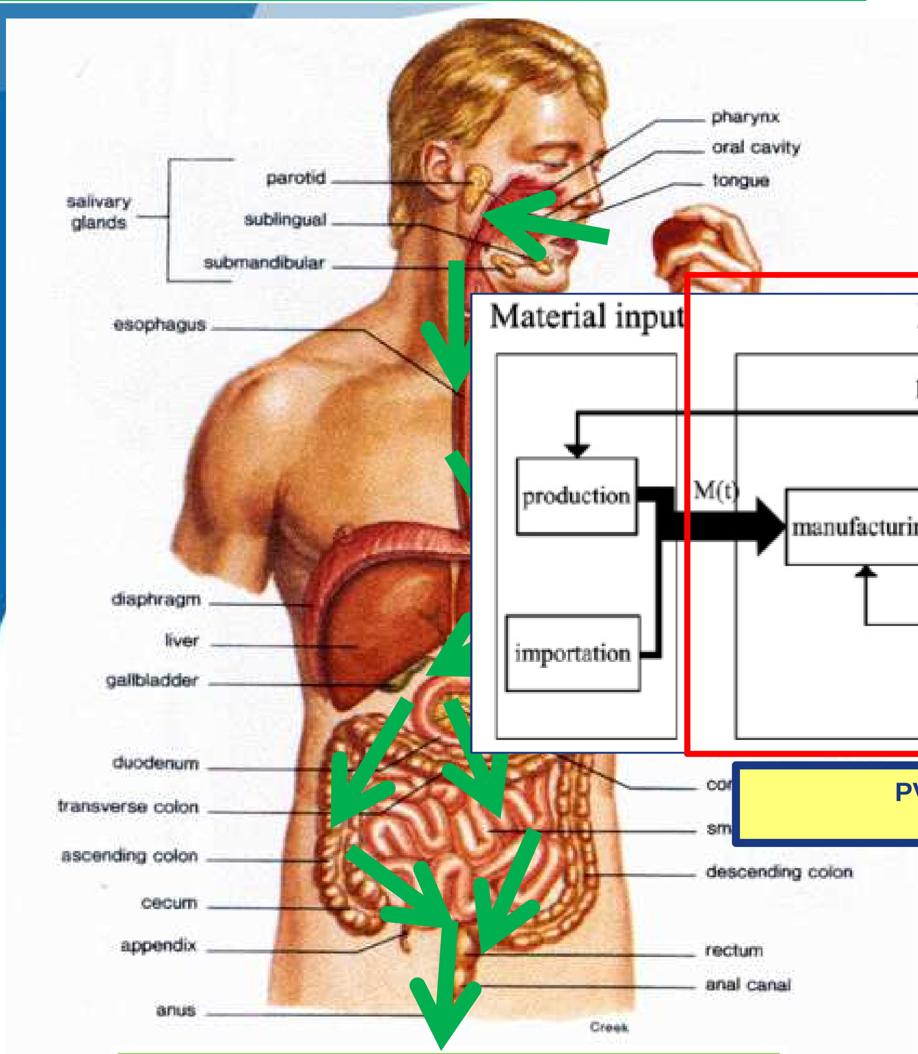
Material Flow Analysis (MFA) is a systematic assessment of flow and stock of materials within a specific system. This tool can be used to identify and analyze the flow of materials added in and removed out from the system.

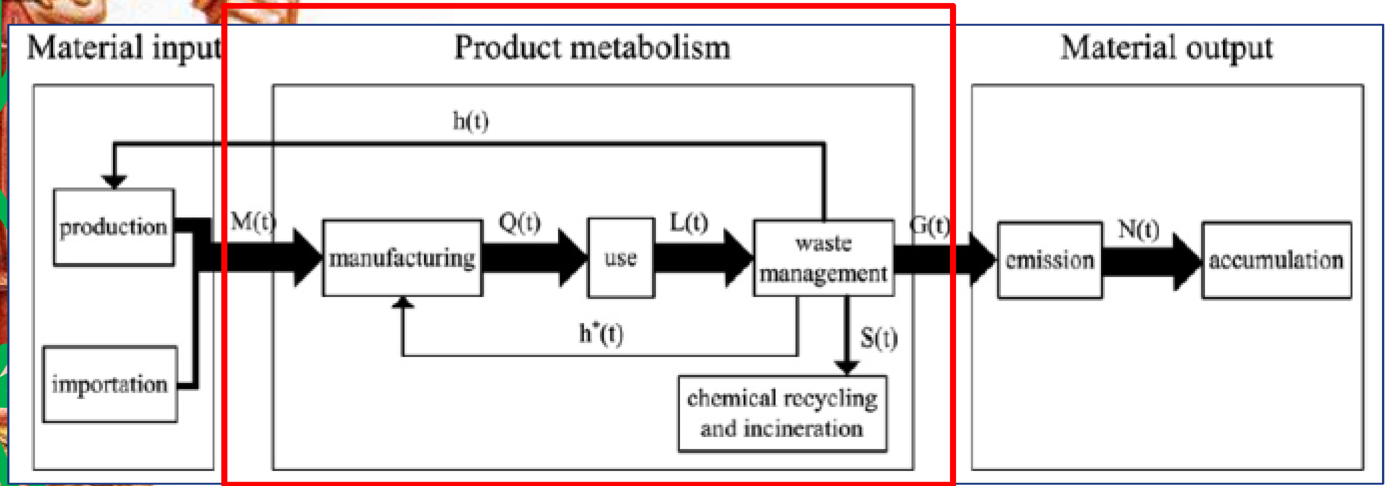


MFA sometimes referred to as "Product Metabolism"

Material Flow Analysis or Product Metabolism

Concept of Product Metabolism





PVC Product Metabolism

Metabolism in our body

Thank you for your kind attention

Dr.Pomthong Malakul Na Ayudhaya

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