FUNDACIÓ ent

ETSEIB, 15th March 2017

Lecture of: 820732/MJ2418 Sustainable Energy and Environment

Life Cycle Costing

Applied to waste management

CONTENT

- **Waste Management Systems**
  - Circular Economy
  - Evolution of Waste Management
  - Waste Hierarchy
- **LCA of Waste Systems**
  - Zero burden approach
  - System boundaries
- **LCC as a complement to LCA**
- **LCC Methodology**
  - LCC types
  - Cost types

---- (10-15 min BREAK) ----

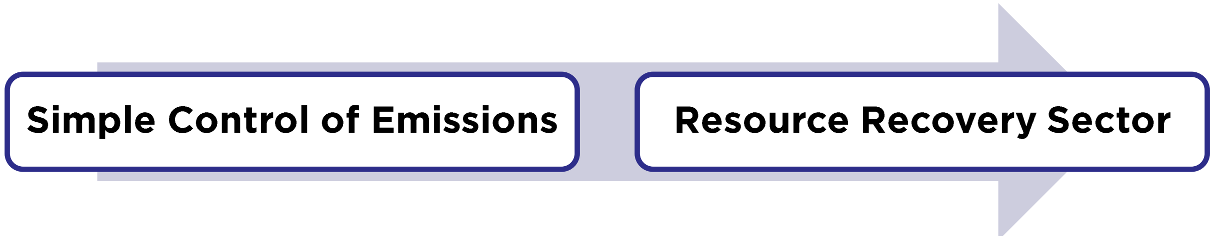
- **Case Study I**
- **Case Study II**
- **Conclusions**

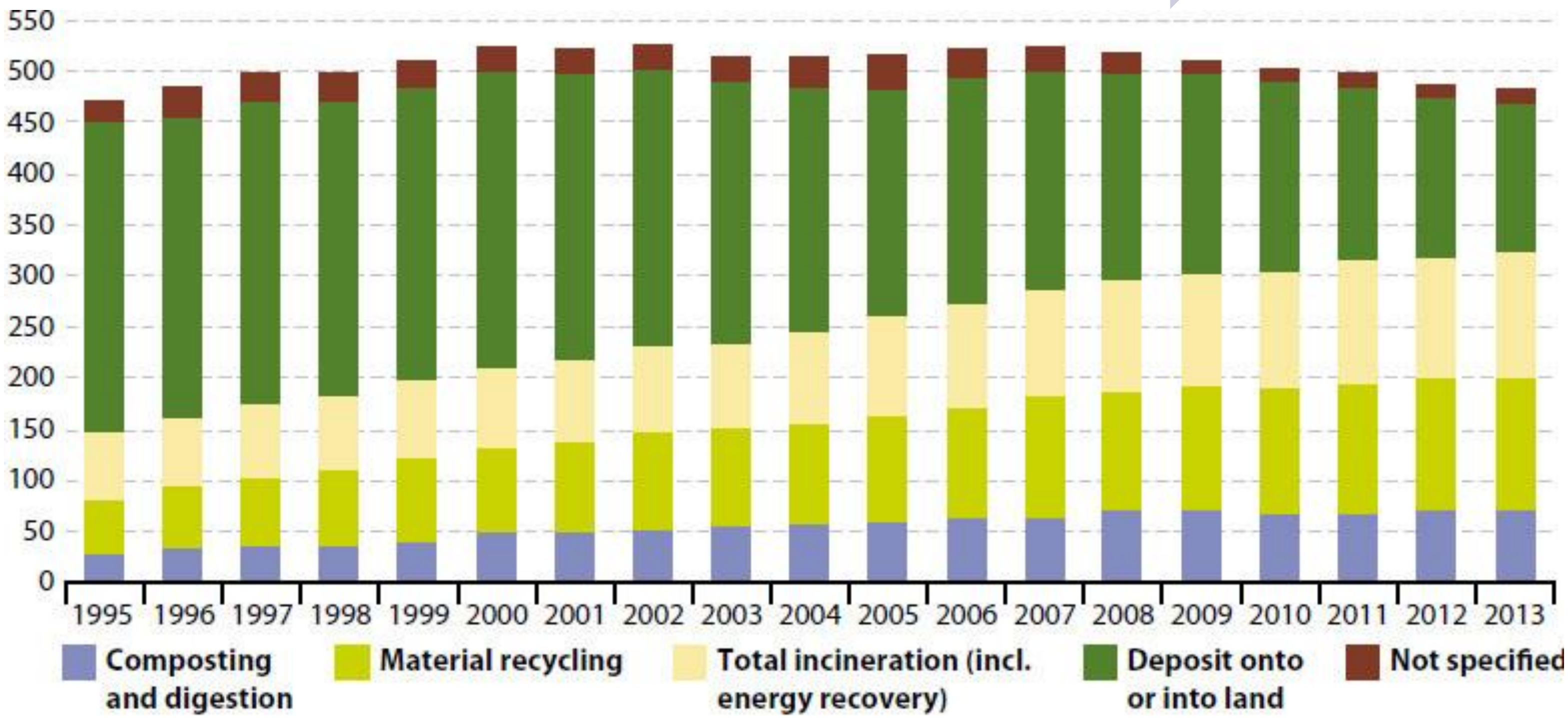
Learning Objectives

I. Key aspects of WMS
II. Key aspects of LCA of WMS
III. Types of LCCs
IV. Key aspects of LCC of waste systems

CIRCULAR ECONOMY

WASTE MANAGEMENT OVER TIME





SOURCE: http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tsdpc240&plugin=1

WASTE HIERARCHY

1. REDUCE
2. REUSE
3. RECYCLE
4. RECOVER
5. DISPOSE

To target resource efficiency:

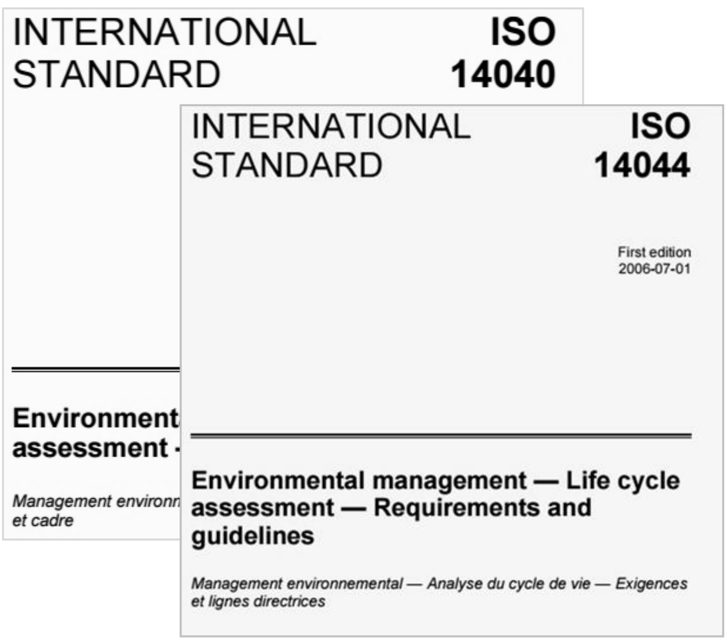
- Local consideration
- Break even points

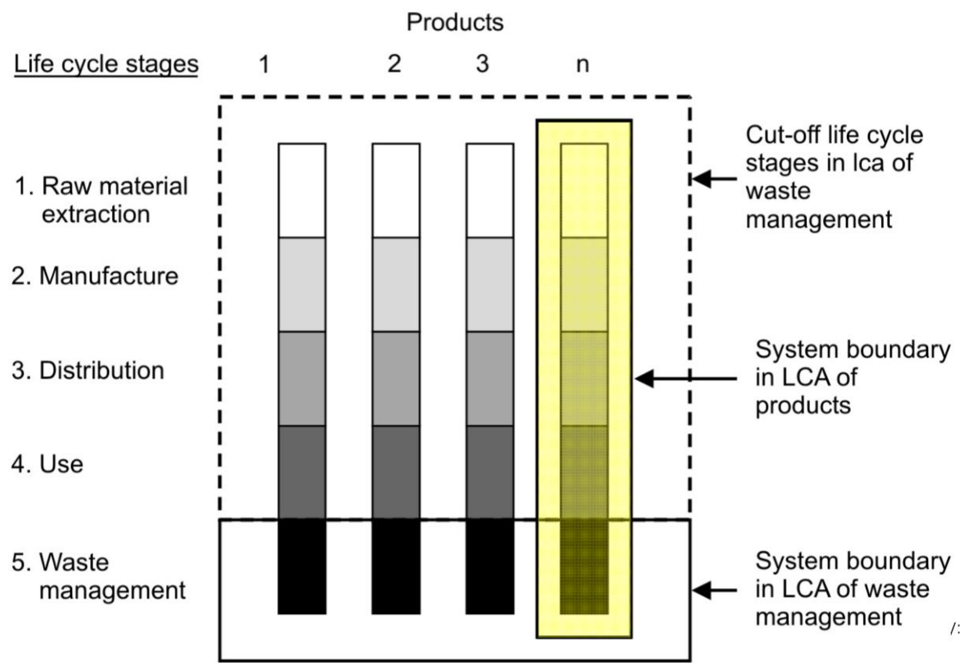
Environmental impact assessment can be used for that.

LCA of Waste Systems

ZERO BURDEN APPROAH

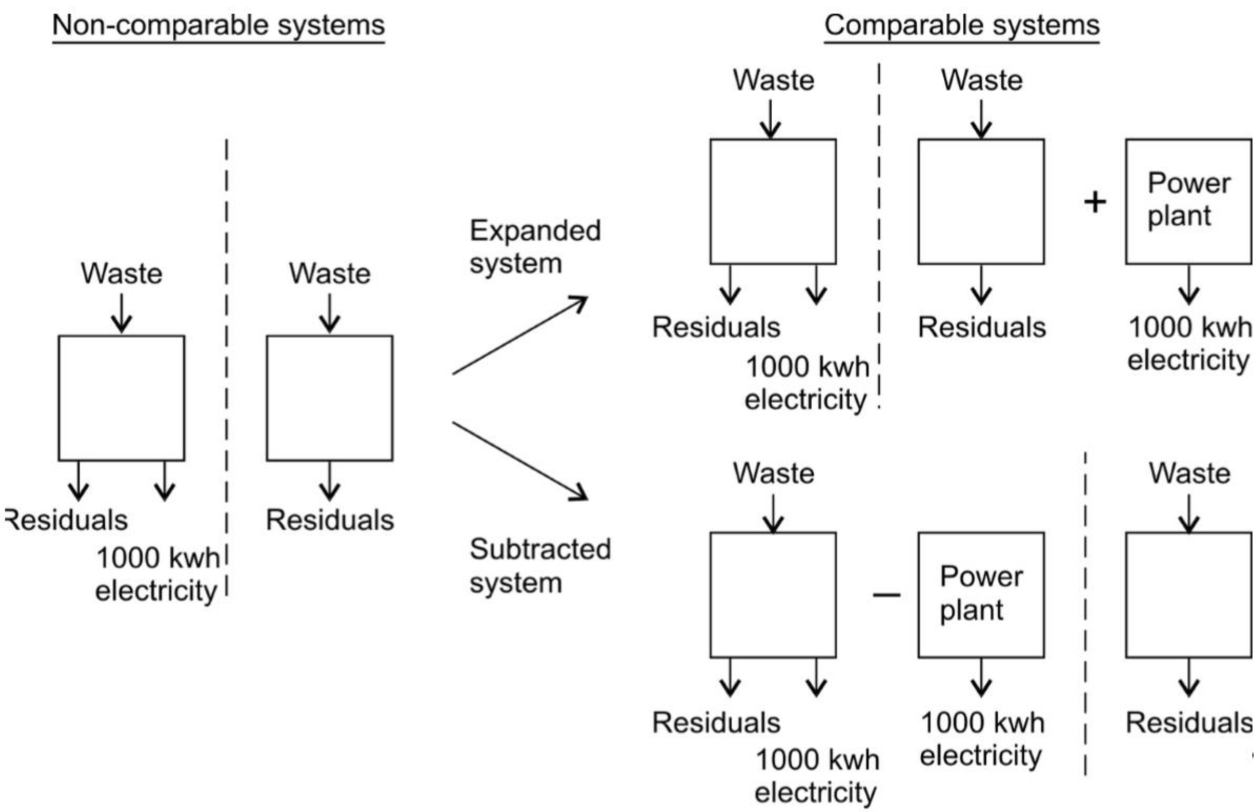
Life Cycle Assessment (LCA) is a broadly accepted DECISION SUPPORT TOOL for ENVIRONMENTAL assessment



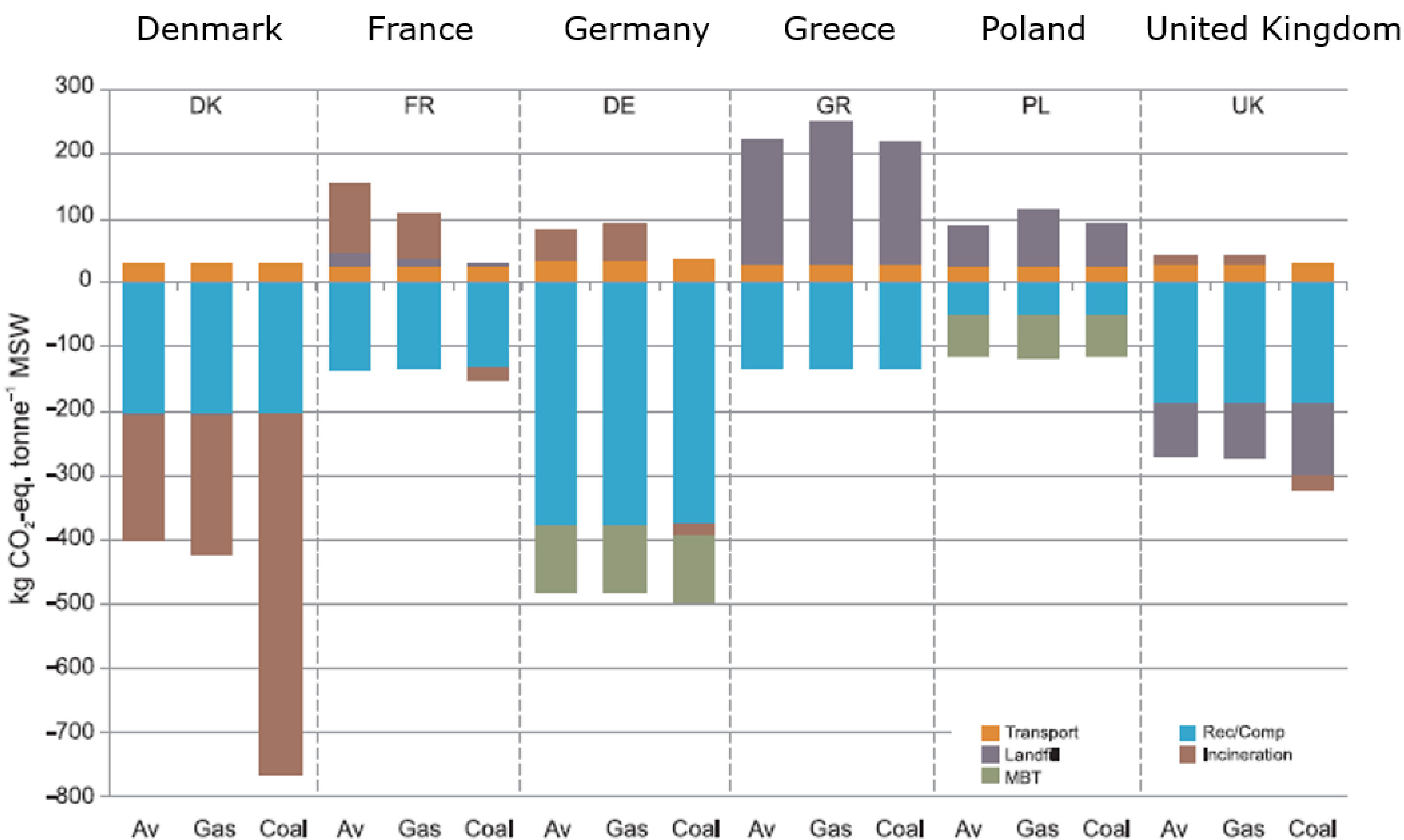


Zero Burden Approach is commonly used in waste LCA.

SYSTEM BOUNDARIES



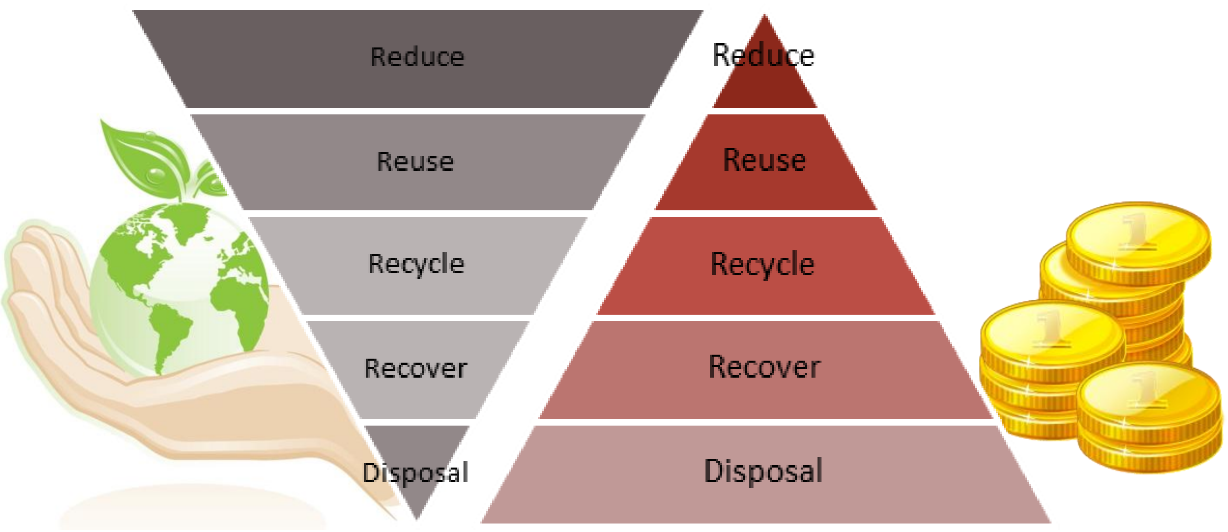
ENERGY IMPORTANCE



LCC to support LCA

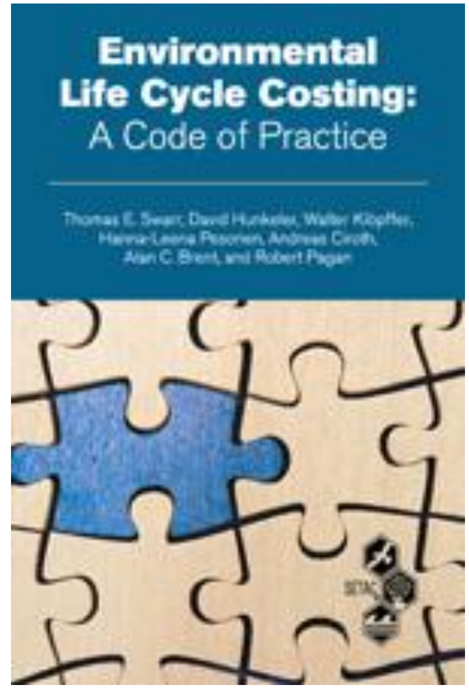
LCC to support LCA I

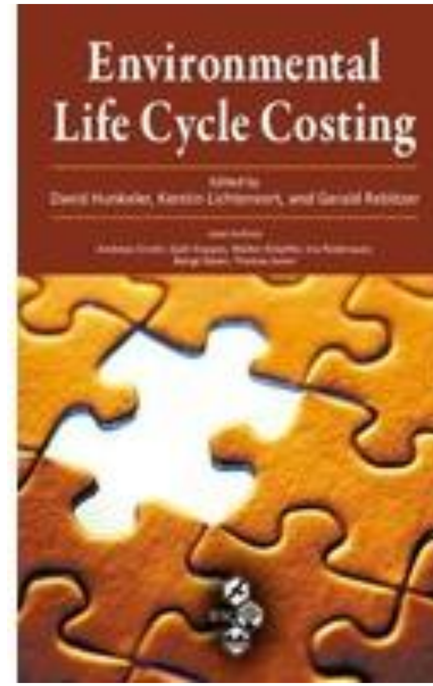
- Waste decision-markers are interested in ENVIRONMENT and BUDGET constraints.
- Independent assessments often based on different assumptions
- Lack of integrated assessment limits the value of both assessment tools.



Generic LCC methodology

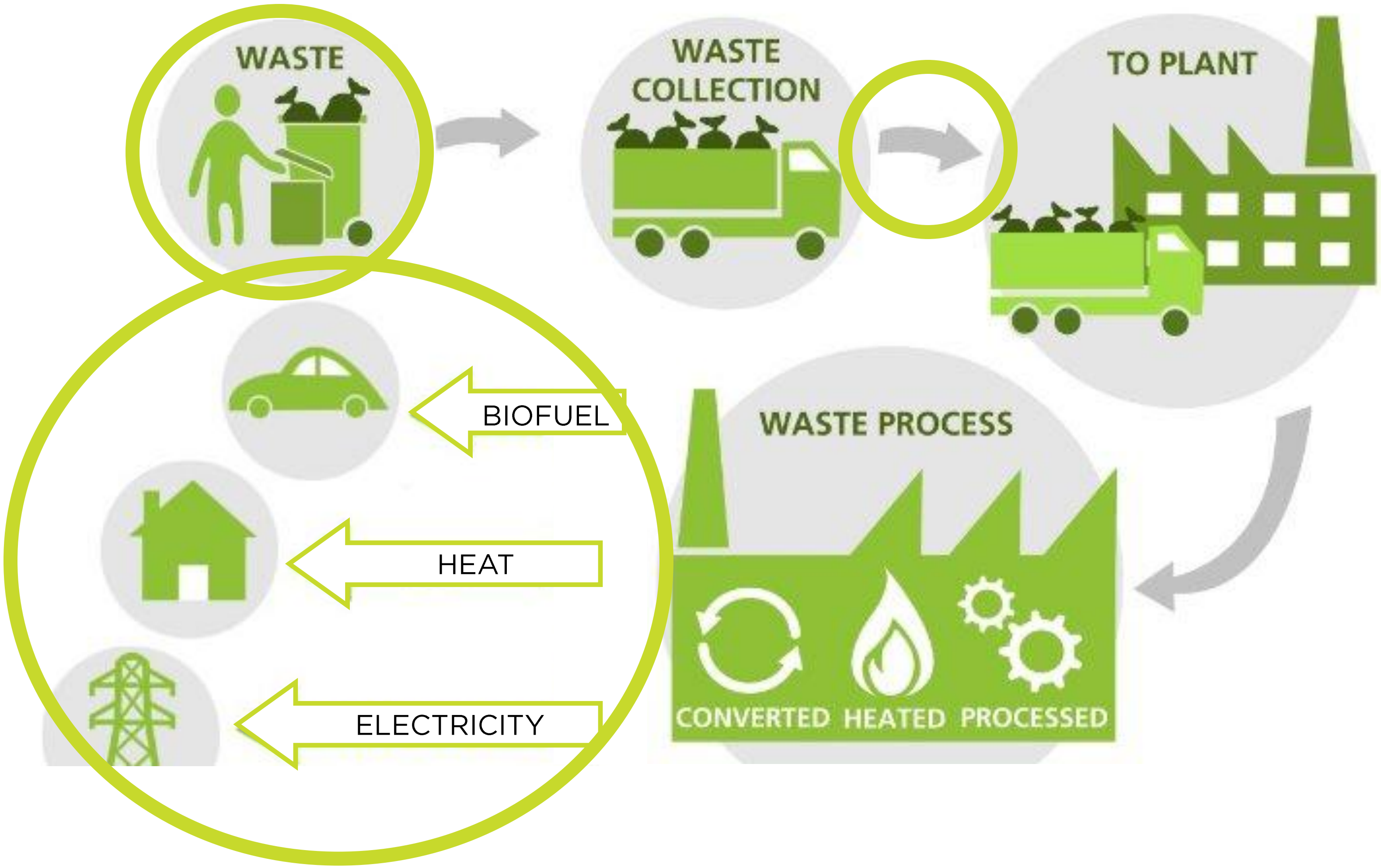
- Life Cycle Assessment (LCA) is a broadly accepted tool for Environmental assessment





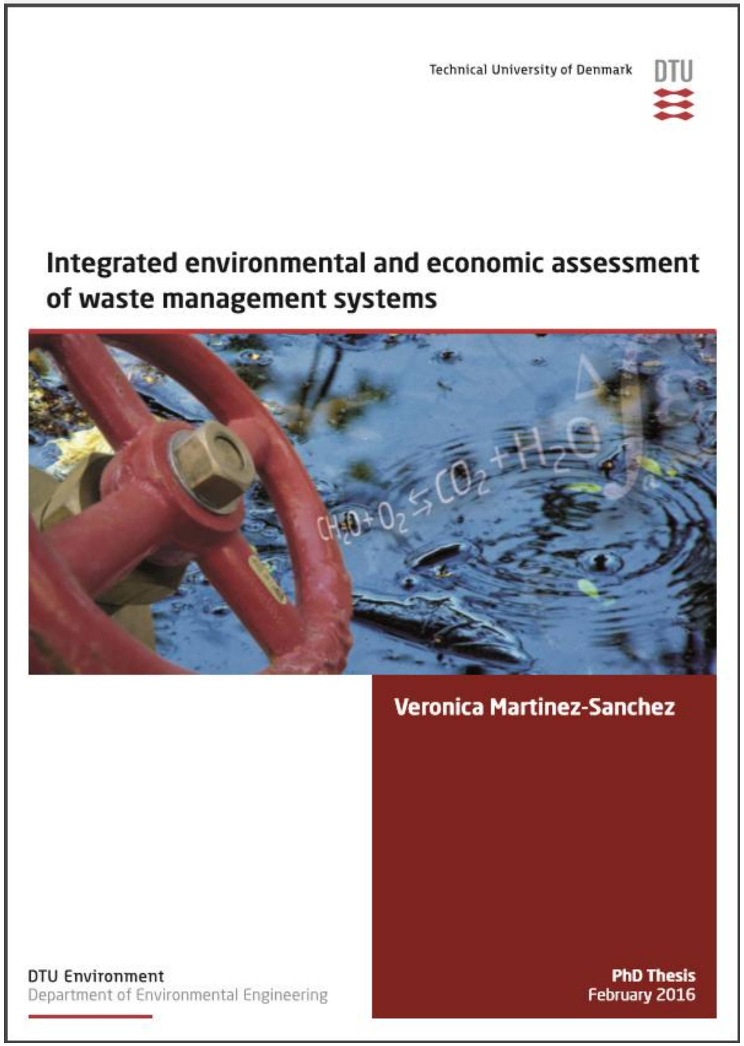
- Hunkeler and Swar suggested Life Cycle Costing as consistent framework with LCA.
- Generic guidelines for common product and services.

Waste Specifications



PhD Goal

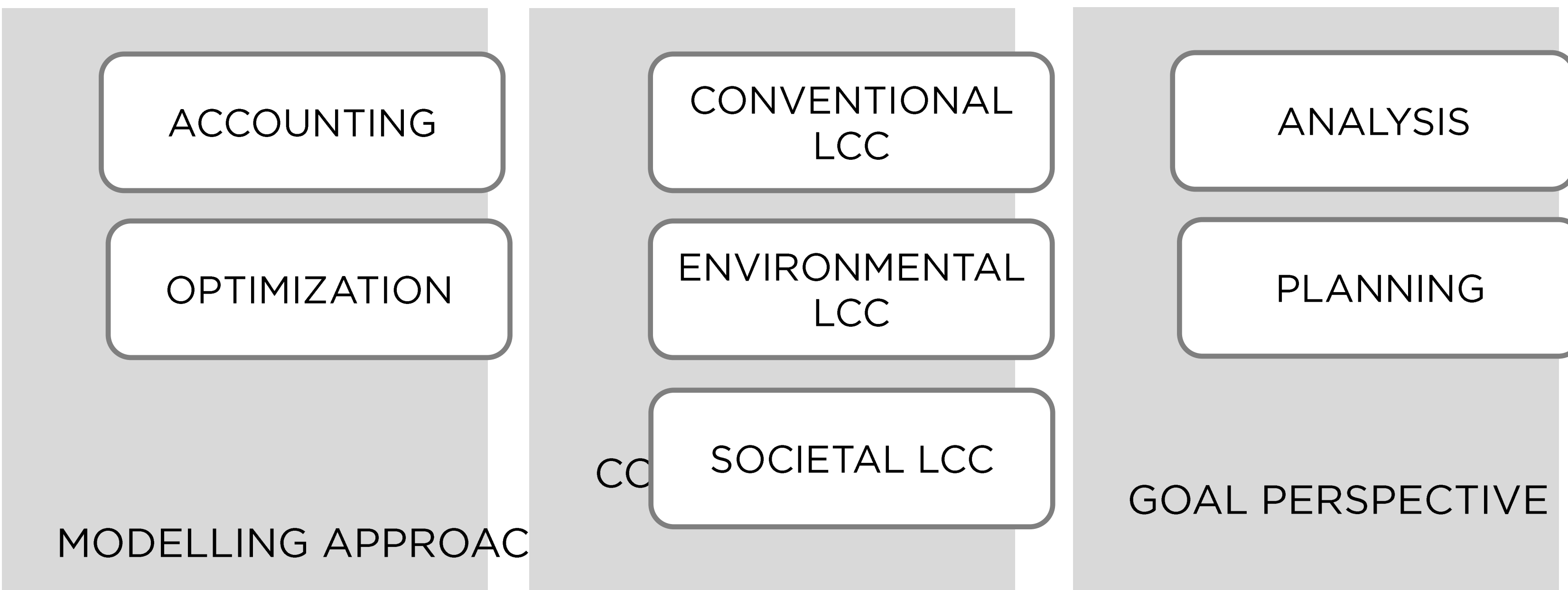
To provide a framework for performing **economic assessment** of **Solid Waste Management** systems with different levels of LCA integration



LCC Methodology

LCC types

LCC Method Umbrella



LCC - Modelling Approach

Technology pathways decided beforehand

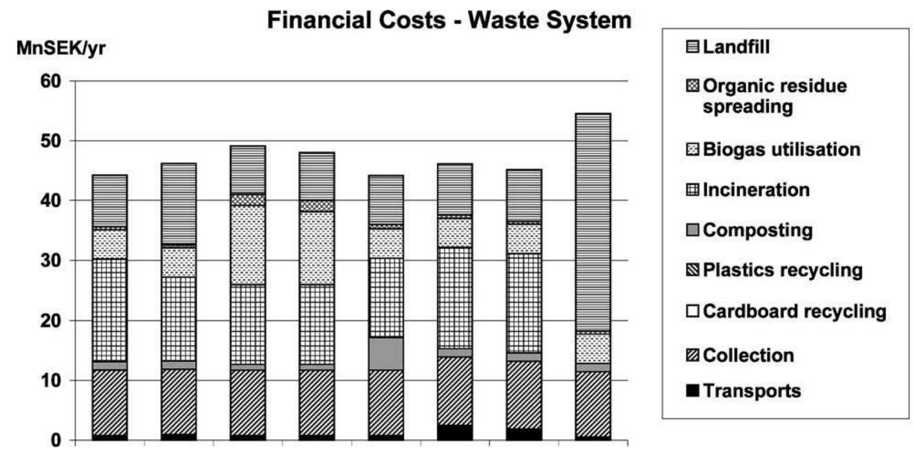
ACCOUNTING

OPTIMIZATION

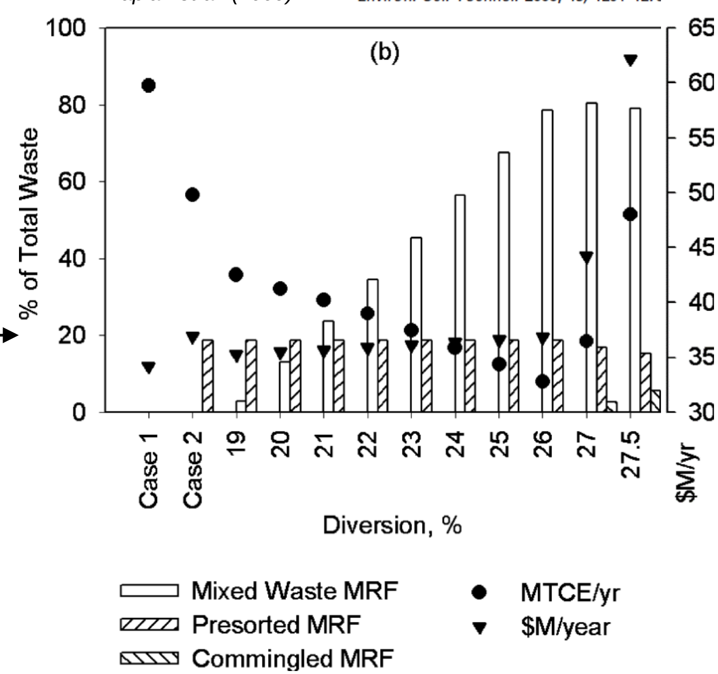
MODELLING APPROACH

Scenarios are the results of the optimization

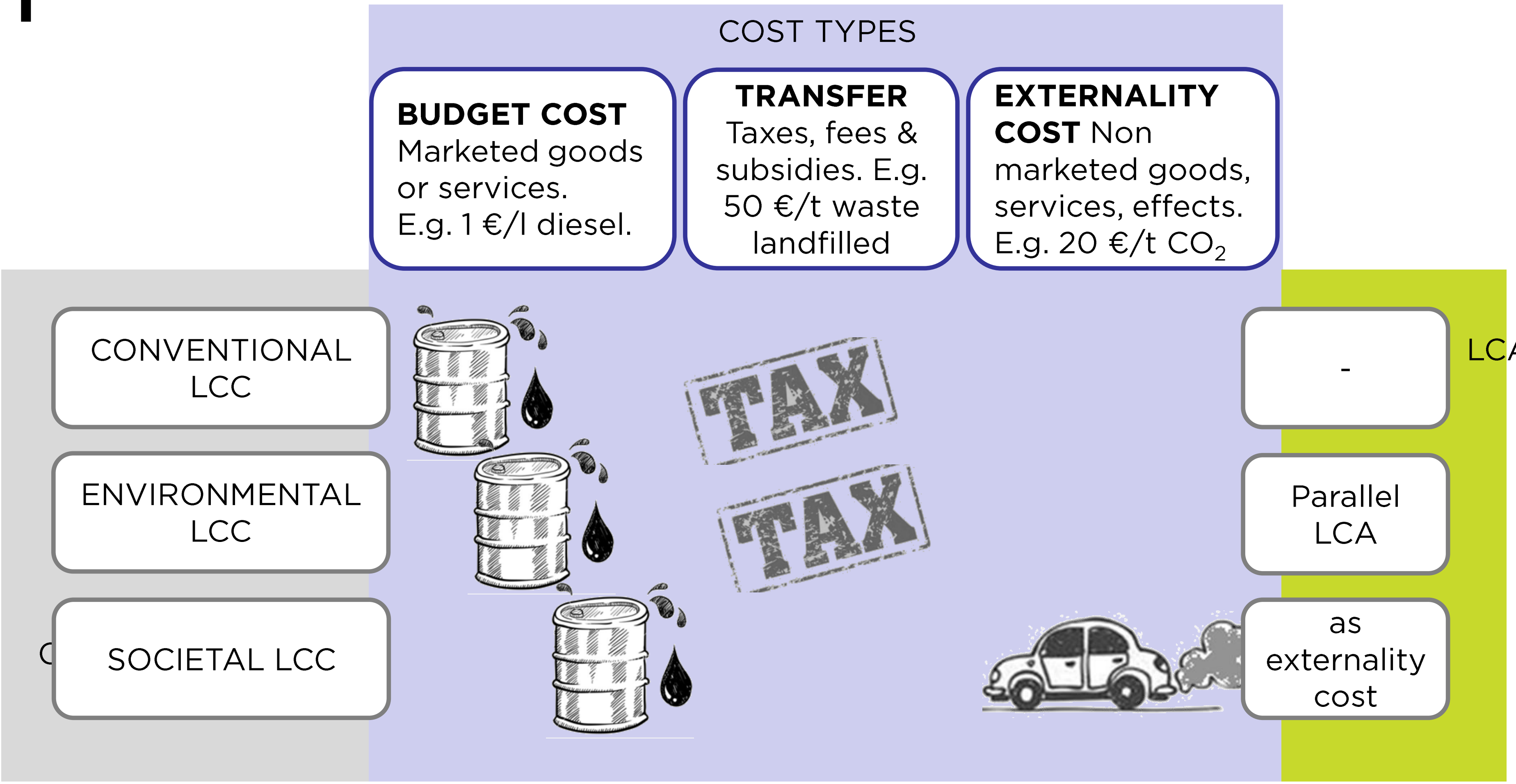
M. Carlsson Reich / Journal of Cleaner Production 13 (2005) 253 263



Kaplan et al. (2009) Environ. Sci. Technol. 2009, 43, 1264–1270

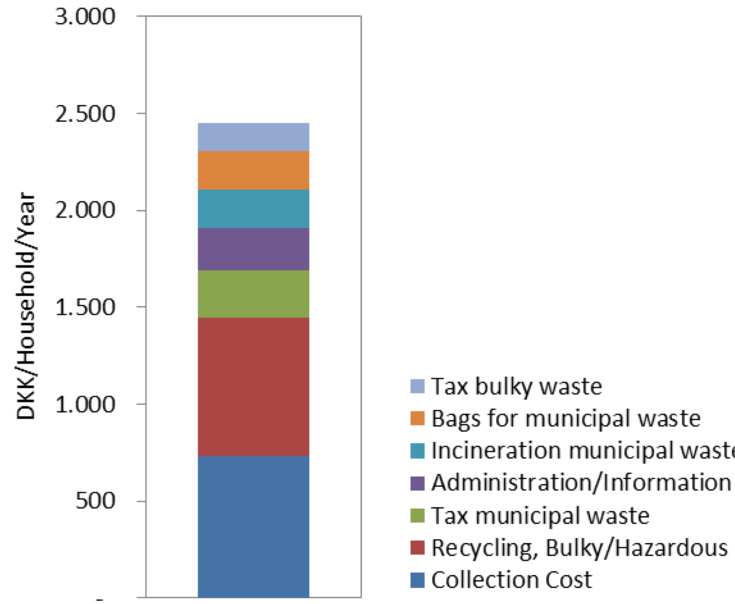


LCC - Cost Approach



LCC - Goal Perspective

Static analysis
Current status of a system
(E.g. Household waste fee estimation.)



ANALYSIS

PLANNING

GOAL PERSPECTIVE

Dynamic analysis
Effects of a system change.
(E.g. Is the introduction of organic waste separation beneficial for society?)

10-15 MIN BREAK

CASE STUDY - I

INTRODUCTION

Waste Management 50 (2016) 364–375

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Estimation of marginal costs at existing waste treatment facilities

Veronica Martinez-Sanchez [a,*], Tore Hulgaard [b], Claus Hindsgaul [b], Christian Riber [b], Bettina Kamuk [b], Thomas F. Astrup [a]

[a] Technical University of Denmark, Department of Environmental Engineering, Miljoevej, Building 113, 2800 Kgs. Lyngby, Denmark
[b] Ramboll Group A/S, Hannemanns Allé 53, 2300 Copenhagen S, Denmark

ARTICLE INFO

Article history:
Received 18 December 2015
Revised 12 February 2016
Accepted 23 February 2016

Keywords:
Cost
Waste-to-energy
Incineration
Diversion
Economy
Solid waste management

ABSTRACT

This investigation aims at providing an improved basis for assessing economic consequences of alternative Solid Waste Management (SWM) strategies for existing waste facilities. A bottom-up methodology was developed to determine marginal costs in existing facilities due to changes in the SWM system, based on the determination of average costs in such waste facilities as function of key facility and waste compositional parameters. The applicability of the method was demonstrated through a case study including two existing Waste-to-Energy (WtE) facilities, one with co-generation of heat and power (CHP) and another with only power generation (Power), affected by diversion strategies of five waste fractions (fibres, plastic, metals, organics and glass), named "target fractions". The study assumed three possible responses to waste diversion in the WtE facilities: (i) biomass was added to maintain a constant thermal load, (ii) Refused-Derived-Fuel (RDF) was included to maintain a constant thermal load, or (iii) no reaction occurred resulting in a reduced waste throughput without full utilization of the facility capacity. Results demonstrated that marginal costs of diversion from WtE were up to eleven times larger than average costs and dependent on the response in the WtE plant. Marginal cost of diversion were between 39 and 287 € Mg^{-1} target fraction when biomass was added in a CHP (from 34 to 303 € Mg^{-1} target fraction in the only Power case), between −2 and 300 € Mg^{-1} target fraction when RDF was added in a CHP (from −2 to 294 € Mg^{-1} target fraction in the only Power case) and between 40 and 303 € Mg^{-1} target fraction when no reaction happened in a CHP (from 35 to 296 € Mg^{-1} target fraction in the only Power case). Although average costs at WtE facilities were highly influenced by energy selling prices, marginal costs were not (provided a response was initiated at the WtE to keep constant the utilized thermal capacity). Failing to systematically address and include costs in existing waste facilities in decision-making may unintendedly lead to higher overall costs at societal level. To avoid misleading conclusions, economic assessment of alternative SWM solutions should not only consider potential costs associated with alternative treatment but also include marginal costs associated with existing facilities.

Research Question: Effects of new waste strategies in existing facilities?
Scenarios: WtE facility affected by diversion strategies.

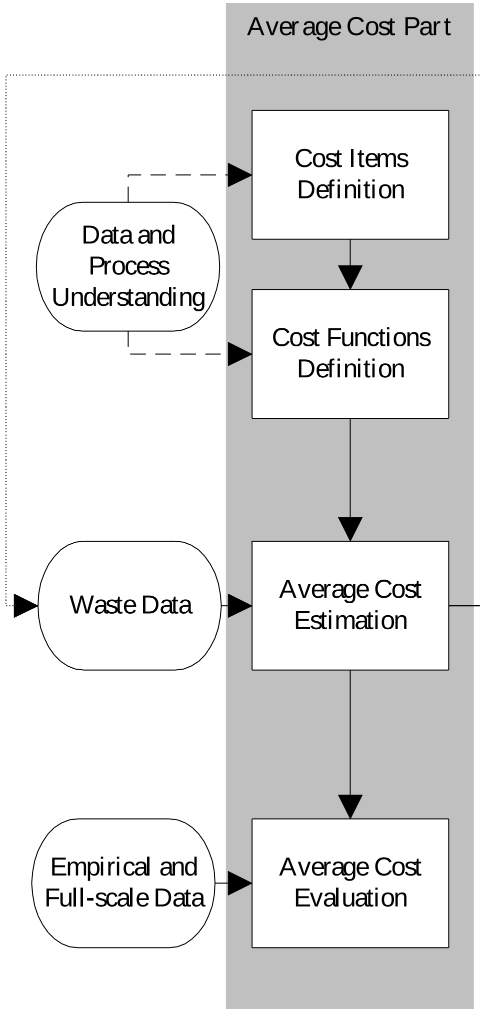
The novelty of the study was the **method developed** to estimate **marginal costs** of new waste strategies for existing facilites.

METHOD

1st Step: Estimation of average costs.

2nd Step: Average Cost Validation

CHP 115 MW (€/Mg)	
Our Gross Average Cost	98
ENEA (2007)	67-143
Massaruto (2015)	100-130



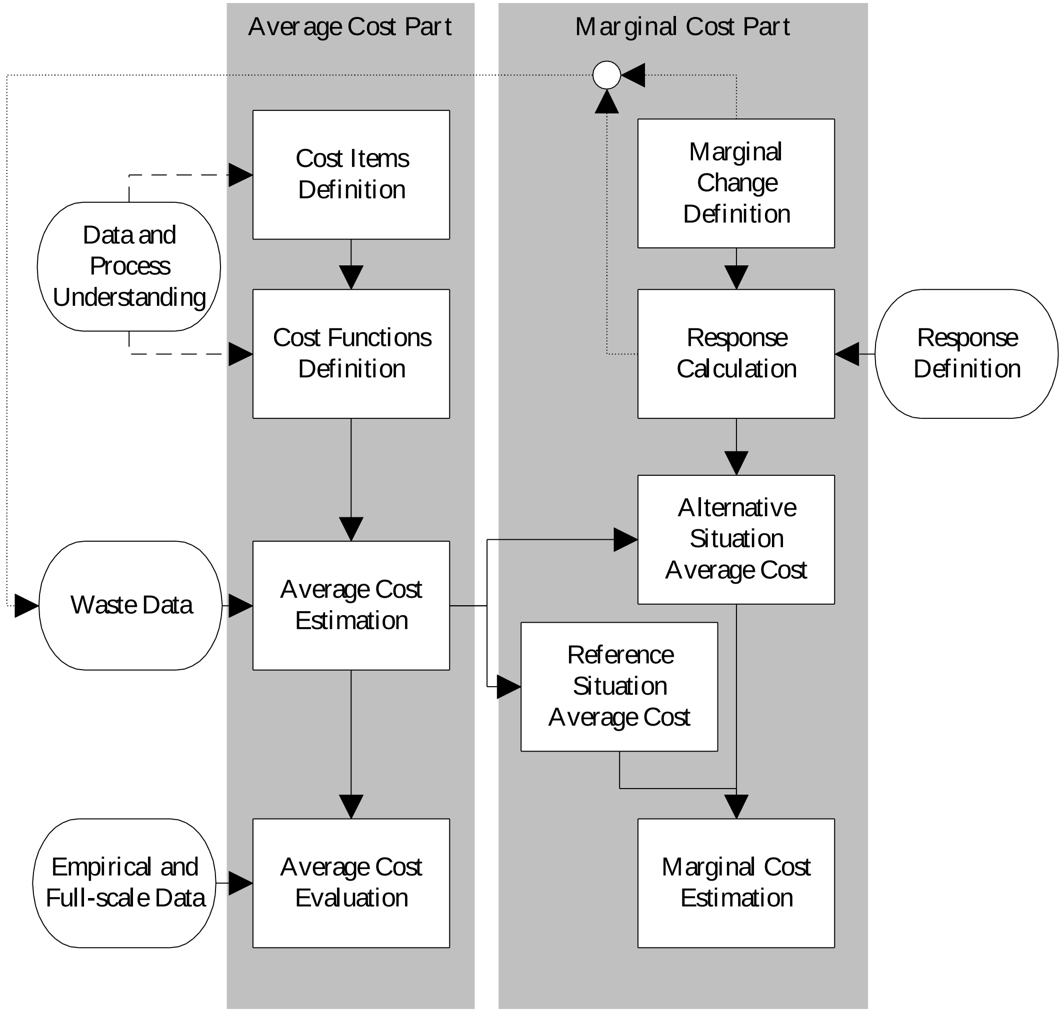
CHP (€/Mg)	
Energy Recovery System	-72
Power Consumption	3
Ash Disposal	4
Flue Gas Cleaning	4
Fixed Cost	87
Average Cost	**26**

METHOD

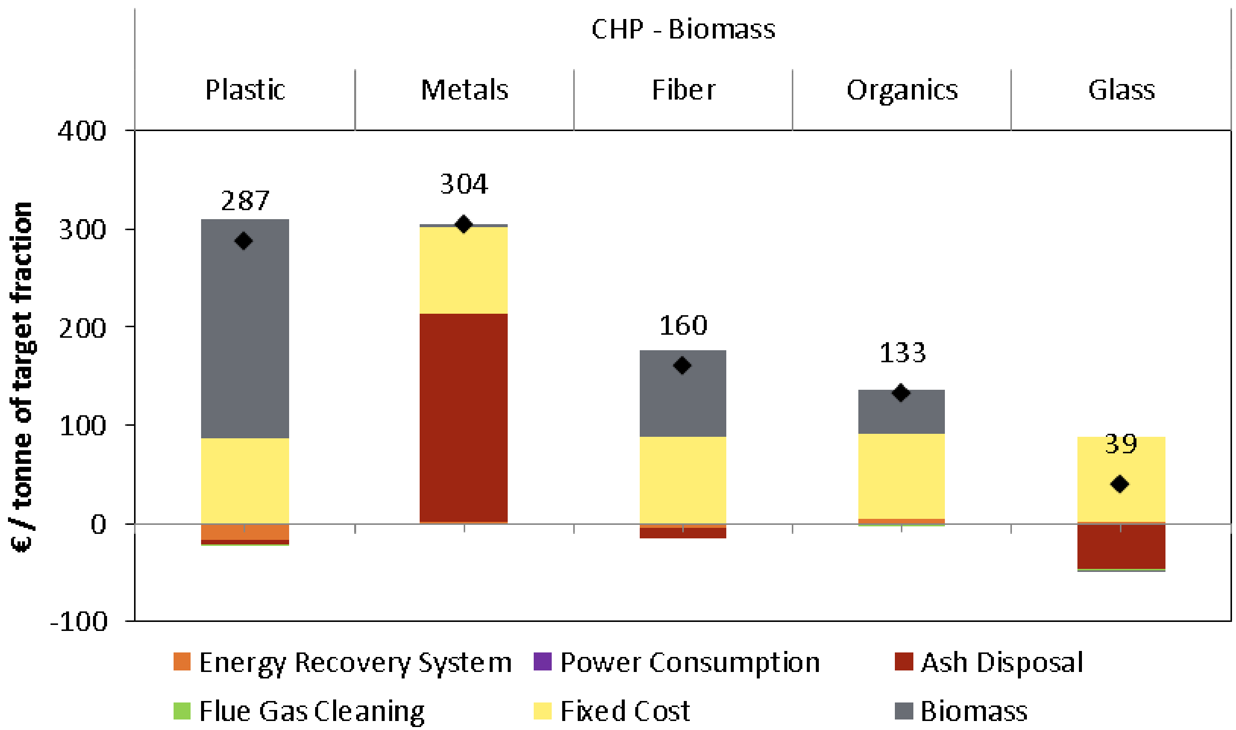
1st Step: Estimation of average costs.

2nd Step: Average Cost Validation

3rd Step: Estimation of marginal cost.



RESULTS



Main contributions

- Fixed Cost
- Biomass consumption
- Ash disposal for metals and glass

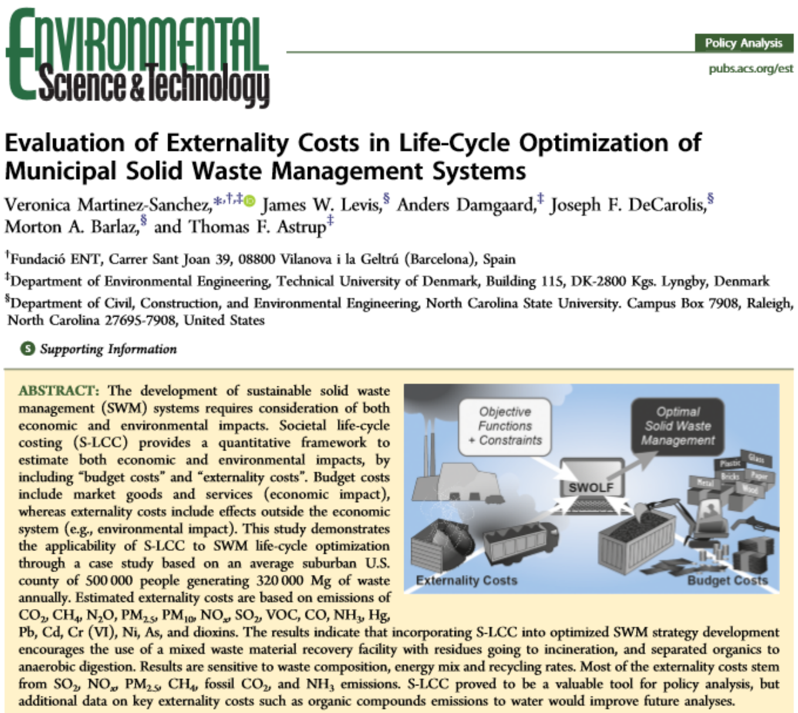
Marginal Cost in WtE facilities

- Much larger than average cost
- Depends on the reaction fraction price

Diversion strategies have **large marginal cost** associated in existing WtE facilities complety dependent on the **response** initiated in the facility

CASE STUDY - II

INTRODUCTION



Environmental Science & Technology

Policy Analysis

pubs.acs.org/est

Evaluation of Externality Costs in Life-Cycle Optimization of Municipal Solid Waste Management Systems

Veronica Martinez-Sanchez,[*,†,‡] James W. Levis,[§] Anders Damgaard,[‡] Joseph F. DeCarolis,[§] Morton A. Barlaz,[§] and Thomas F. Astrup[‡]

[†]Fundació ENT, Carrer Sant Joan 39, 08800 Vilanova i la Geltrú (Barcelona), Spain

[‡]Department of Environmental Engineering, Technical University of Denmark, Building 115, DK-2800 Kgs. Lyngby, Denmark

[§]Department of Civil, Construction, and Environmental Engineering, North Carolina State University. Campus Box 7908, Raleigh, North Carolina 27695-7908, United States

Supporting Information

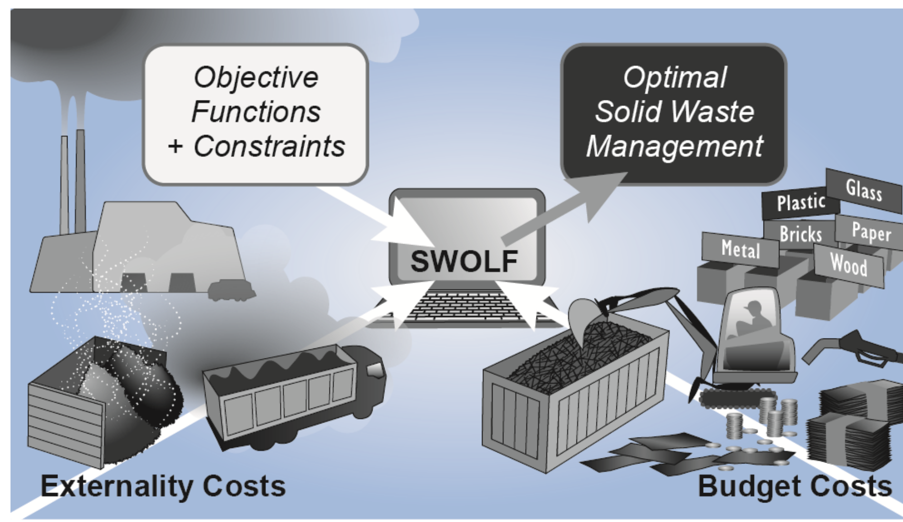
ABSTRACT: The development of sustainable solid waste management (SWM) systems requires consideration of both economic and environmental impacts. Societal life-cycle costing (S-LCC) provides a quantitative framework to estimate both economic and environmental impacts, by including "budget costs" and "externality costs". Budget costs include market goods and services (economic impact), whereas externality costs include effects outside the economic system (e.g., environmental impact). This study demonstrates the applicability of S-LCC to SWM life-cycle optimization through a case study based on an average suburban U.S. county of 500 000 people generating 320 000 Mg of waste annually. Estimated externality costs are based on emissions of CO_2, CH_4, N_2O, $PM_{2.5}$, PM_{10}, NO_x, SO_2, VOC, CO, NH_3, Hg, Pb, Cd, Cr (VI), Ni, As, and dioxins. The results indicate that incorporating S-LCC into optimized SWM strategy development encourages the use of a mixed waste material recovery facility with residues going to incineration, and separated organics to anaerobic digestion. Results are sensitive to waste composition, energy mix and recycling rates. Most of the externality costs stem from SO_2, NO_x, $PM_{2.5}$, CH_4, fossil CO_2, and NH_3 emissions. S-LCC proved to be a valuable tool for policy analysis, but additional data on key externality costs such as organic compounds emissions to water would improve future analyses.

Research Question

U.S. Societal Optimal SWM system?

Software

SWOLF – Solid Waste Optimization Life-cycle Framework, Software developed in North Carolina State University

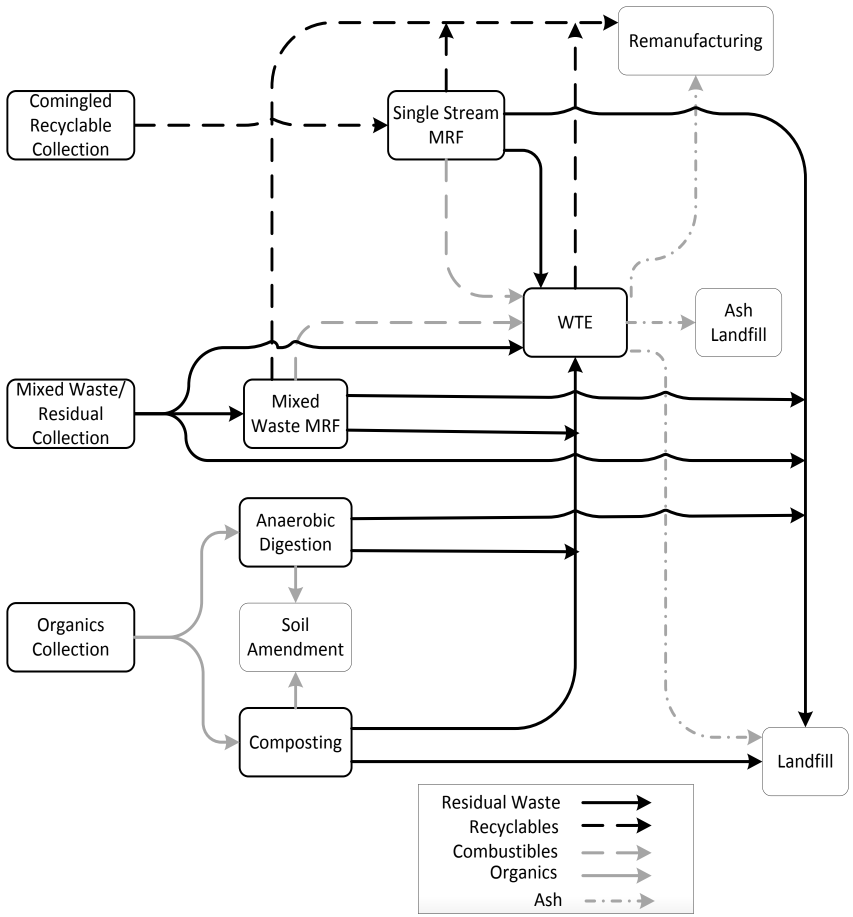


NEW

The novelty of the study was the optimization of SWM using Societal LCC.

METHOD

SWOLF Optimization model



Emission	Accounting Price ($\$ \cdot kg^{-1}$)
CO_2 (fossil)	0.04
CH_4	0.82
N_2O	11.62
CO	0.87
PM_{10}	2.95
NH_3	25.5
VOC	1.5
$PM_{2.5}$	341.8
SO_2	64.47
NO_x	40
Hg	87067
Pb	458
Cd	115
Cr	590
Ni	11
As	236
Dioxins	5.50E+08

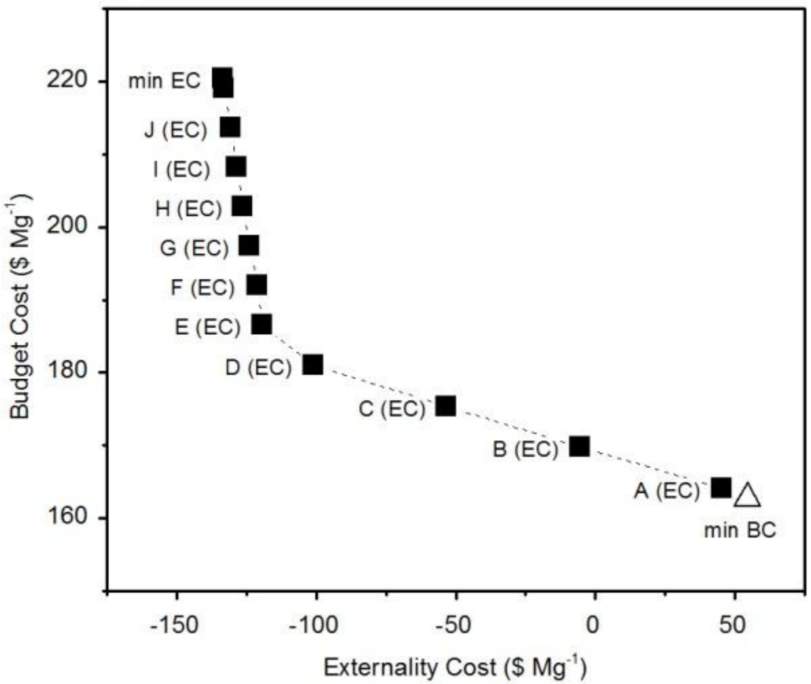
The optimization followed a standard "constraint method":

- Externality cost was the variable within the optimization function
- Budget cost was the constraint variable.

RESULTS

Social Cost = Externality Cost + Budget Cost

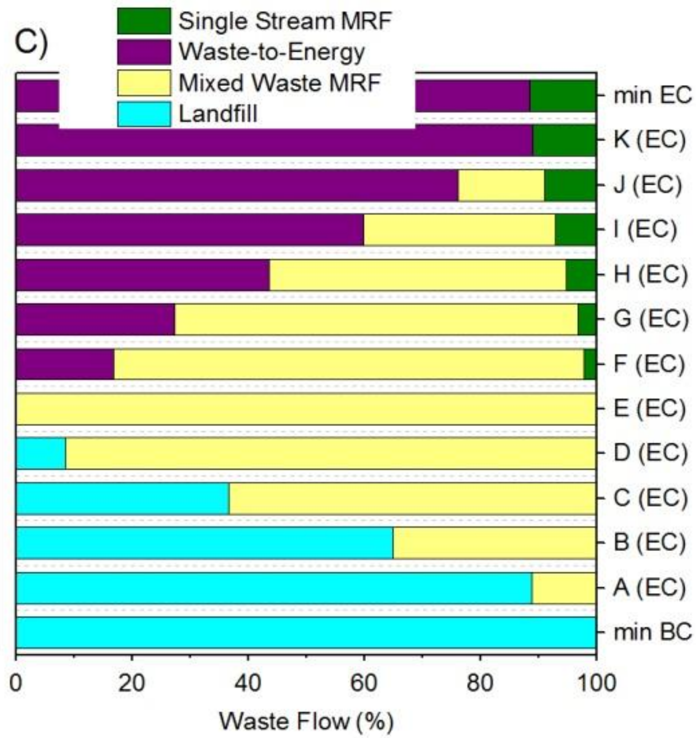
A)



B)

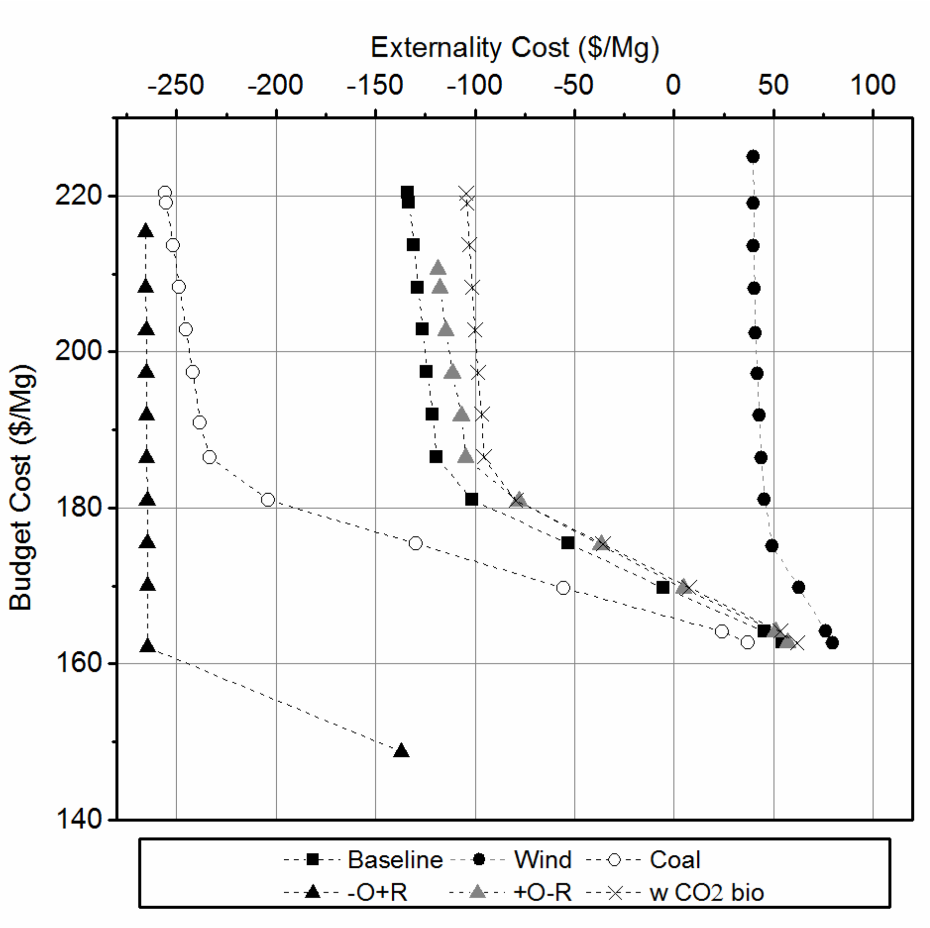
Social Cost ($/Mg)	
min EC	124
K (EC)	123
J (EC)	119
I (EC)	115
H (EC)	111
G (EC)	107
F (EC)	104
E (EC)	99
D (EC)	111
C (EC)	152
B (EC)	193
A (EC)	238
min BC	245

C)



The societal optimal SWM for a US context rely completely on mixed waste MRF in which organic residues are sent to anaerobic digestion and other residues to WtE.

RESULTS



The results are really sensitive to the electricity replaced.

The + fossil intensive is the replacement, the more WtE is proposed by the optimization model. More externality benefits from the WMS.

The – fossil intensive is the replaced energy, less WtE is suggested. Less externality benefits from WMS.

CONCLUSIONS

LEARNING OBJECTIVES

Learning Objectives

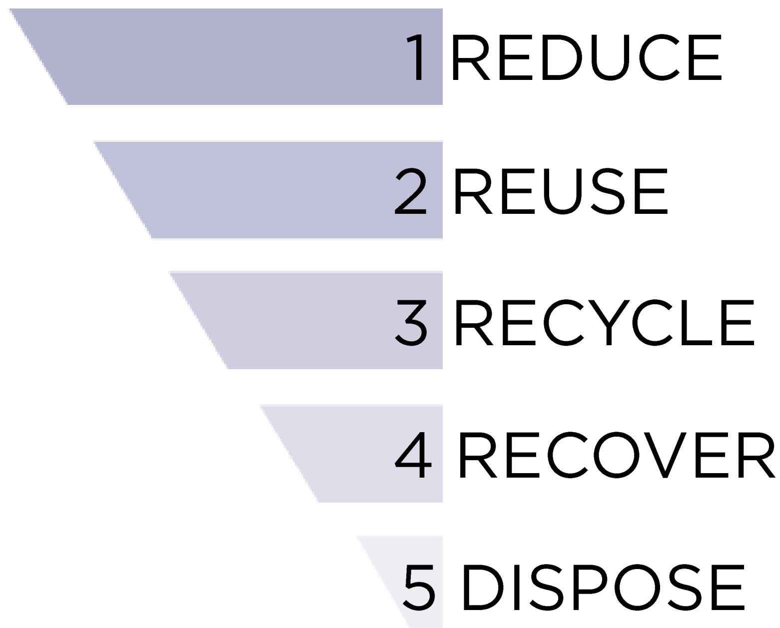
I. Key aspects of WMS
II. Key aspects of LCA of WMS
III. Types of LCCs
IV. Key aspects of LCC of waste systems

WASTE MANAGEMENT

Learning Objectives:

I. **Key aspects of waste management systems**
II. Key aspects of LCA of WMS
III. Types of LCCs
IV. Key aspects of LCC of waste systems

- ✓ Not only **Control of Emissions** but also a **Resource Recovery Sector**
- ✓ **Waste Hierarchy** as main principle

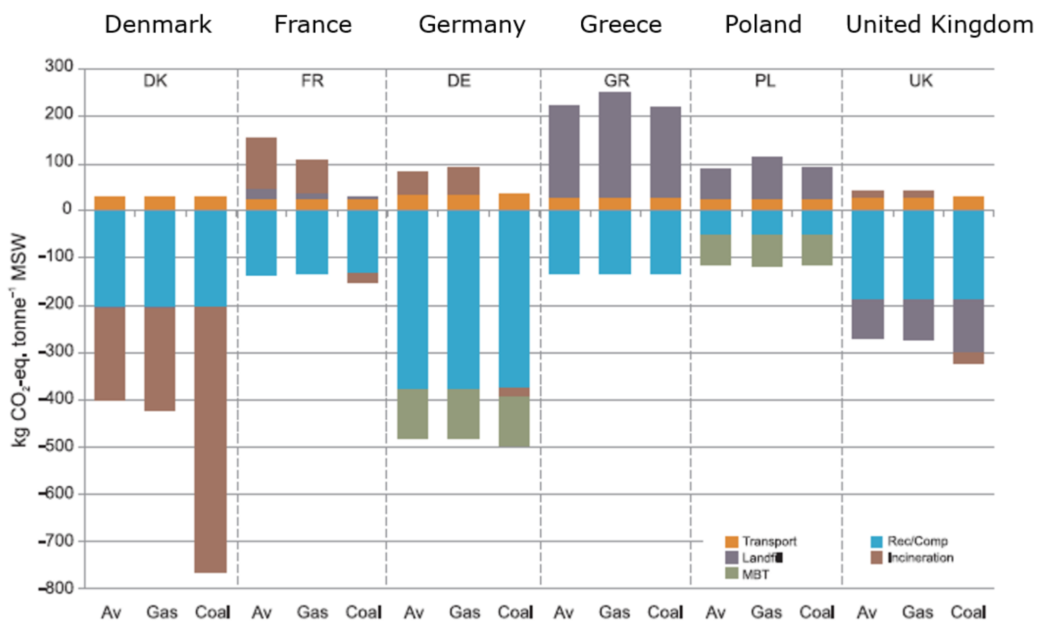


WASTE LCAs

Learning Objectives

I. Key aspects of WMS
II. Key aspects of LCA of WMS
III. Types of LCCs
IV. Key aspects of LCC of waste systems

- ✓ **Zero Burden approach**
- ✓ **System Expansion**
- ✓ Importance of the **Energy** Replaced

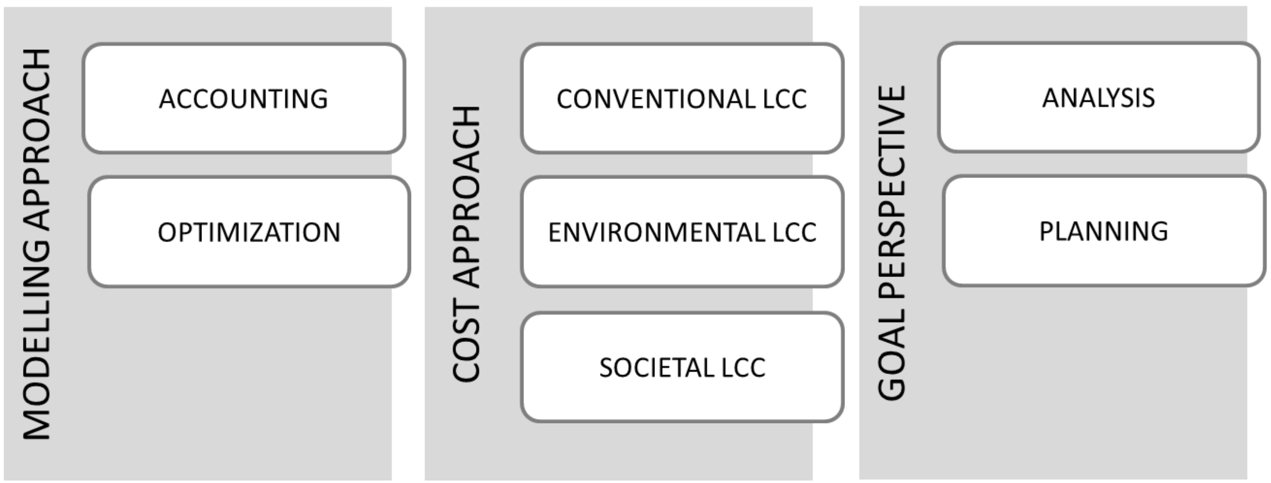


LCC TYPES

Learning Objectives

I. Key aspects of WMS
II. Key aspects of LCA of WMS
III. Types of LCCs
IV. Key aspects of LCC of waste systems

LCC METHOD UMBRELLA



WASTE LCCs

Learning Objectives

I. Key aspects of WMS
II. Key aspects of LCA of WMS
III. Types of LCCs
IV. Key aspects of LCC of waste systems

- ✓ Type of LCC
- ✓ Dynamics of SMW
- ✓ Importance of Rebound Effects

When options compared incurre different costs – savings will be used and the impacts of the new consumption have to be accounted for.

- Low-Energy consumption products
- Cheese prices reduction
- Prevention of food waste

Veronica Martinez Sanchez
vmartinezs@ent.cat
www.ent.cat

FUNDACIÓ ent

Thanks for your attention