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Assessment of alternative strategies for the management of waste from the construction industry

G. Banias, Ch. Achillas, C. Vlachokostas, N. Moussiopoulos, P. Roidi, **C. Karkanias**

INTERNATIONAL HELLENIC UNIVERSITY

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Scope

- An enormous increase of the produced Construction and Demolition Waste (CDW) quantities globally.
- The **CDW stream** constitutes the **largest stream** within the EU.
- Alternative CDW management strategies are compared using Life Cycle Assessment tool, taking into account environmental criteria such as:
  - Energy consumption,
  - Global warming,
  - Depletion of abiotic resources and
  - Dispersion of dangerous substances.

Introduction

- Uncontrolled disposal of CDW has as a consequence long-term pollution costs, resource overuse and wasted energy.
- The most common practice in the field of CDW management was to discard all waste materials and debris to landfills, frequently in the same landfills that were used for the disposal of MSW.
- Disposal of CDW is located at the base of the pyramid of the hierarchy of alternative waste management practices
  - Is the least preferred management option of end of life materials, following the avoidance, reduction, reuse and recycling

Materials and methods

Methodology

- The LCA methodology has been adopted for the detailed environmental evaluation of various CDW management practices
  - generated by the demolition of a five-storey building located in Thessaloniki, Greece
- LCA comprises of four major stages:
  - (i) Goal and Scope Definition,
  - (ii) Life Cycle Inventory (LCI),
  - (iii) Life Cycle Impact Assessment (LCIA) and
  - (iv) Visualisation of the results (PRe Consultants, 2010a)

Methodology

Table 1: Environmental Indicators of CML method (PRe Consultants, 2010c).

CED:	Cumulative Energy Demand	Indicator relevant to the total energy resource consumption according to Boustead
GWP:	Global Warming Potential	Indicator relevant to the GH effect according to IPCC
ODP:	Ozone Depletion Potential	Indicator relevant to the stratospheric ozone depletion phenomenon;
AP:	Acidification Potential	Indicator relevant to the acid rain phenomenon
EP:	Eutrophication Potential	Indicator relevant to surface water eutrophication
POCP:	Photochemical Ozone Creation Potential	Indicator of photo-smog creation
HTTP:	Human Toxicity Potential	Indicator of consequences of toxic substances
ADF:	Abiotic Depletion Factor	Indicator of fossil fuel extraction

Materials and methods

Functional unit and system boundaries

- Demolition of an old five-storey building located in the city of Thessaloniki, Greece (functional unit).

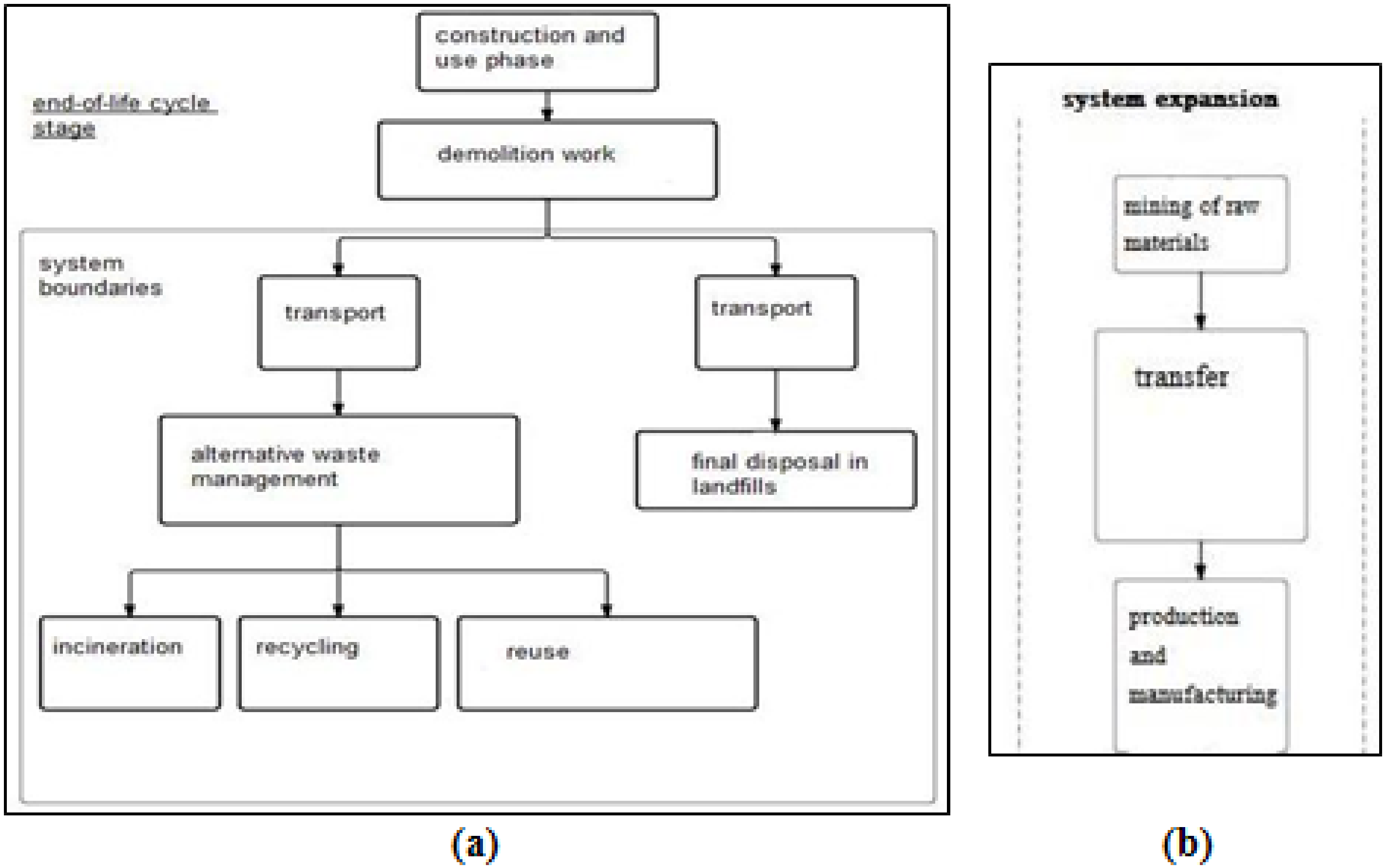
Table 2: Building's characteristics.

Building features	
Number of floors:	5
Number of flats:	15
Total building area:	1020 m^2
Construction year:	2005
Location:	Municipality of Kalamaria, Thessaloniki

Materials and methods

Functional unit and system boundaries

- Only the **last phase of building's life cycle** (end-of-life phase) has been included in the LCA model.



1. System boundaries (a) and expansion (b).

Materials and methods

Functional unit and system boundaries

- Wastes produced by demolition include

Table 3: CDW quantities.

Material	Quantity (t)	Material	Quantity (t)
Concrete	1778,8	Plastic (pipes)	0,3
Bricks	90,3	Aluminum	8,6
Ceramic tiles	15,8	Iron and steel (heating coil)	1,1
Sanitary ware	1,4	Iron and steel (boiler)	0,3
Marbles	8,4	Iron and steel (pipes)	1,5
Wood	4,1	Cables	0,2
Glass	`2,5	Insulation materials	1,5

Materials and methods

Inventory analysis

- **Towards optimal CDW management**, **nine practices** have been considered.
- Each CDW management practice has **different environmental**, **economic**, and **social consequences**
- It should be highlighted that all CDW management practices are realistic and technically possible.
- The philosophy of the proposed CDW management practices is focused towards reuse, recycling, energy recovery and final disposal in landfills

Materials and methods

Inventory analysis

- **Practice 1 (P1):** In this practice, the five-storey building is demolished without sorting of the different materials. The wastes of this demolition are dumped to landfills.

- **Practice 2 (P2):** The five-storey building is also demolished without sorting of different constituents, but after demolition, the wastes go to a sorting platform for construction and demolition waste. After sorting of the different fractions of wastes, metals are recycled while all other categories of waste go to a landfill.

- **Practice 3 (P3):** In this practice, the five-storey building is also demolished without sorting and wastes go to the sorting platform. After sorting, metals are recycled and inert wastes are recovered in road engineering.

Materials and methods

Inventory analysis

- **Practice 4 (P4):** The first step of this practice is the selective deconstruction of the five-storey building, i.e., all non-hazardous and hazardous components are removed before demolition of the building structures. Each waste type, except metals and glass, which are recycled, go to sanitary landfills.

- **Practice 5 (P5):** The first step is the selective deconstruction of the five-storey building before demolition. Inert wastes are recovered in road engineering. Metals, glass and insulation are recycled. Wood wastes are used as fuel for district heating, and other non-dangerous wastes go to a landfill.

- **Practice 6 (P6):** The difference between this practice and Practice 5 is that inert wastes are used to produce new concrete blocks as raw material.

Materials and methods

Inventory analysis

- **Practice 7 (P7):** The first step of this practice is the selective deconstruction of each building before demolition of their structures. Inert wastes are recovered for use in aggregates for road engineering. Metals, wool, PVC and insulation are recycled. Wood wastes are used to make particle board.

- **Practice 8 (P8):** The only difference between this practice and Practice 7 is that inert wastes are used to produce new concrete blocks, as in the Practice 6.

- **Practice 9 (P9):** This practice is the same as Practice 7, except that wood wastes are used as fuel for district heating.

Results and Discussion

- A comparative analysis of the nine proposed practices was carried out with the use of:
  - SimaPro software package and
  - The Ecoinvent v.3 Life Cycle Inventory database.

Table 4: Numerical results of CDW practices' Environmental Impact.

CDW Management Practice	Environmental indicator						
	ADF Kg Sb eq	AP Kg SO_2 eq	NP Kg PO_4 eq	GWP_{100} Kg CO_2 eq	ODP Kg CFC-11eq	HTP Kg 1,4-DB eq	POCP Kg C_2H_4 eq
P_1	286	199	55,9	$3{,}98\cdot10^4$	0,006	$1{,}71\cdot10^4$	6,42
P_2	229	160	45,1	$3{,}2\cdot10^4$	0,005	$1{,}92\cdot10^4$	5,13
P_3	1,02	1,32	0,575	918	$2{,}93\cdot10^{-5}$	$3{,}03\cdot10^3$	0,02
P_4	258	179	50,5	$3{,}6\cdot10^4$	0,005	$1{,}81\cdot10^4$	5,77
P_5	-0,12	2,03	0,95	345	0,0001	$3{,}03\cdot10^3$	0,0039
P_6	1,92	2,54	0,845	461	0,0001	$1{,}64\cdot10^3$	0,04
P_7	-2,92	0,994	0,715	24,6	$8{,}61\cdot10^{-5}$	$2{,}95\cdot10^3$	-0,04
P_8	-0,47	1,64	0,622	161	$6{,}15\cdot10^{-5}$	$1{,}58\cdot10^3$	0,007
P_9	-0,63	1,45	0,58	137	$5{,}85\cdot10^{-5}$	$1{,}56\cdot10^3$	0,002

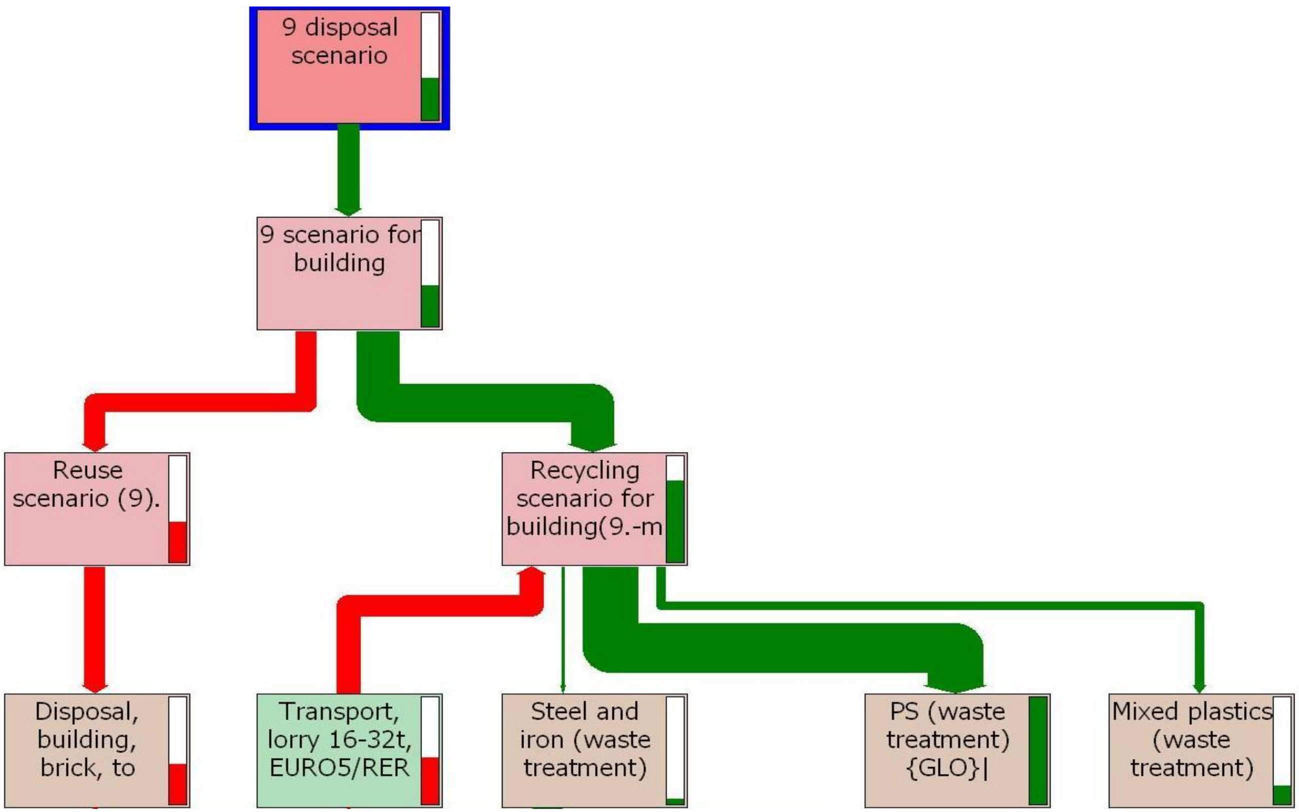
Results and Discussion

- CDW practices' Environmental Impact for the "Cumulative Energy Demand" indicator

CDW Management Practice	Environmental indicator						
	Average MJ	Nonrenewable-fossils MJ	Nonrenewable-nuclear MJ	Nonrenewable-biomass MJ	Renewable-biomass MJ	Renewable-wind, solar, geothermal MJ	Renewable-water MJ
P_1	$6{,}62 \cdot 10^5$	$6{,}29 \cdot 10^5$	$2{,}66 \cdot 10^4$	1,08	892	229	$4{,}79 \cdot 10^3$
P_2	$5{,}33 \cdot 10^5$	$5{,}07 \cdot 10^5$	$2{,}1 \cdot 10^4$	0,878	721	185	$3{,}88 \cdot 10^3$
P_3	$2{,}75 \cdot 10^3$	$2{,}98 \cdot 10^3$	-236	0,00448	3,38	-7,98	7,02
P_4	$5{,}99 \cdot 10^5$	$5{,}7 \cdot 10^5$	$2{,}39 \cdot 10^4$	0,986	809	207	$4{,}35 \cdot 10^3$
P_5	723	568	17,1	0,033	21,1	5,74	111
P_6	$4{,}94 \cdot 10^3$	$4{,}64 \cdot 10^3$	191	0,026	16,8	4,74	86,5
P_7	$-5{,}8 \cdot 10^3$	$-5{,}55 \cdot 10^3$	-341	0,02	13,2	3,78	66,9
P_8	-661	-585	-127	0,013	8,47	2,7	39,3
P_9	$-1 \cdot 10^3$	-935	-134	0,012	8,17	2,57	38,4

Results and Discussion

- SimaPro software has the ability to visualize the Environmental Impact through the “Network Process”.
- The “Network Process” depicts the environmental impact of CDW management practices graphically.



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Results and Discussion

Environmental indicator	Ranking								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Photochemical ozone creation	P_7	P_9	P_5	P_8	P_3	P_4	P_2	P_6	P_1
Human toxicity	P_9	P_8	P_6	P_7	P_5	P_3	P_1	P_4	P_2
Ozone depletion	P_3	P_9	P_8	P_7	P_6	P_5	P_2	P_4	P_1
Global warming	P_7	P_9	P_8	P_5	P_6	P_3	P_2	P_4	P_1
Eutrophication	P_9	P_3	P_8	P_7	P_6	P_5	P_2	P_4	P_1
Acidification	P_7	P_3	P_9	P_8	P_5	P_6	P_2	P_4	P_1
Abiotic depletion	P_7	P_9	P_8	P_5	P_3	P_6	P_2	P_4	P_1
Cumulative energy demand	P_7	P_9	P_8	P_5	P_3	P_6	P_2	P_4	P_1

Conclusions

- CDW can be considered as a top priority waste stream, with respect to the strategy for the waste management followed by the European Union (EU Waste Strategy).
- Measures that need to be considered towards emerging the principles of sustainable development in the construction industry:
  - The promotion of deconstruction (selective demolition),
  - the use of environmental friendly building materials,
  - the replacement of hazardous substances and materials,
  - the development of Construction Materials’ secondary market and
  - the adoption of stricter legislation framework
- A waste management strategy is not effective without a good sorting of different wastes.
- For inert wastes, recovery in aggregates for road engineering is a better solution than the use of these aggregates to produce concrete blocks.

Thank you for your attention!

For more details: gbanias@aix.meng.auth.gr