POLITECNICO MILANO 1863

Assessment on WAste and REsources

mater
materia & energia da rifiuti
materials & energy from refuse

EVALUATING THE CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT SYSTEM IMPLEMENTED IN LOMBARDY REGION (ITALY) THROUGH LIFE CYCLE ASSESSMENT

***Lucia Rigamonti[1,2]**, Sara Pantini[1,2], Giulia Borghi[1]*

[1] Politecnico di Milano - Department of Civil and Environmental Engineering (Italy)

[2] MatER Research Center c/o LEAP, Piacenza (Italy)

OBJECTIVES OF THE RESEARCH PROJECT

- Quantifying construction and demolition waste (CDW) amount and flows within the management system of Lombardy Region
- Investigating types, amount and quality of "secondary products" obtained from CDW recovery plants and their actual use (highlighting the limiting factors for their market)
- Assessing the environmental performance of the current regional management system through the application of the Life Cycle Assessment (LCA) methodology
- Identifying benefits and critical aspects of the CDW management system
- Defining possible improving actions based on the state-of-the-art recovery technology and the LCA results of the current management scenario, to be compared and evaluated from a life cycle perspective

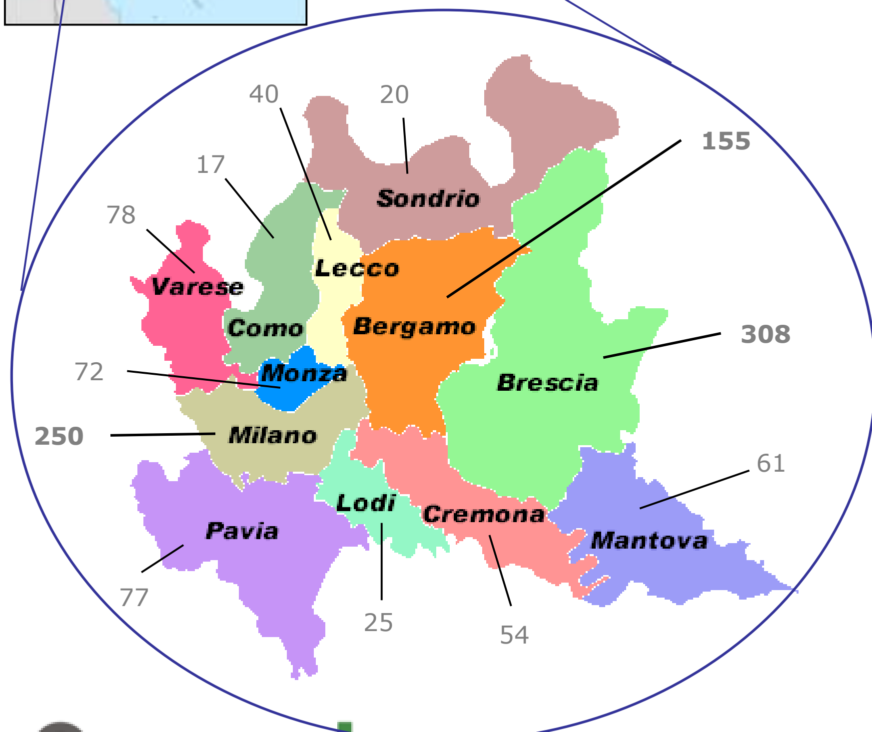
LOMBARDY REGION - ITALY

AREA: 23.844 km^2

POPULATION: 10 MILLION (1/6 ITALIAN POPULATION)

GROSS DOMESTIC PRODUCT (GDP): 22% ITALY'S GDP

ADMINISTRATIVE DIVISIONS: 12 PROVINCES, 1530 MUNICIPALITIES



Non hazardous CDW generation in Lombardy (2014): 11.9 Mt

(Italy: 50.2 Mt) (source: ISPRA2017)

CDW MANAGEMENT SYSTEM

1157 PLANTS IN OPERATION IN 2016 (LANDFILLS: 39; RECYCLING PLANTS + TRANSFER STATIONS: 1118)

SOURCE: CATASTO GEOREFERENZIATO DEI RIFIUTI REGIONE LOMBARDIA
http://www.cgrweb.servizirl.it/cgrweb/ricerca.do

NON-HAZARDOUS CDW INCLUDED IN THE STUDY:

EUROPEAN WASTE CODE (EWC) 17 XX XX:

- **17 01 concrete, bricks, tiles and ceramics**
  - CONCRETE (17 01 01)
  - BRICKS (17 01 02)
  - TILES AND CERAMICS (17 01 03)
  - CONCRETE, BRICKS, TILES AND CERAMICS IN MIXTURES, CONTAINING NON HAZARDOUS SUBSTANCES (17 01 07)
- **17 02 wood, glass and plastic** (17 02 01, 17 02 02, 17 02 03)
- **17 03 bituminous mixtures, coal tar and tarred products** (17 03 02)
- **17 04 metals (including their alloys)** (17 04 01, 17 04 02, 17 04 03, 17 04 04, 17 04 05, 17 04 06, 17 04 07, 17 04 11)
- **17 08 gypsum-based construction material** (17 08 02)
- **17 09 other construction and demolition waste**
  - MIXED CONSTRUCTION AND DEMOLITION WASTES (17 09 04)

CDW FLOWS

REFERENCE YEAR: 2014

Imported CDW:
EWC 1701: 47,075 t;
EWC 170302: 174,389 t;
EWC 170802: 4,419 t;
EWC 170904: 382,931 t

EXPORT (plants)

EWC 17 01:	**9,189 t**
EWC 17 03 02:	**1,665 t**
EWC 17 08 02:	**4,870 t**
EWC 17 09 04:	**38,149 t**

CDW GENERATION IN LOMBARDY REGION(2014):

EWC 17 01:	**>= 804,625 t**
EWC 17 03 02:	**>= 1,018,580 t**
EWC 17 08 02:	**>= 31,405 t**
EWC 17 09 04:	**>= 5,851,639 t**

WASTE DELIVERY

WASTE MANAGEMENT SYSTEM

CDW PRODUCED AND TREATED IN LOMBARDY

EWC 17 01:	**763,950 t**
EWC 17 03 02:	**971,656 t**
EWC 17 08 02:	**20,988 t**
EWC 17 09 04:	**5,625,978 t**

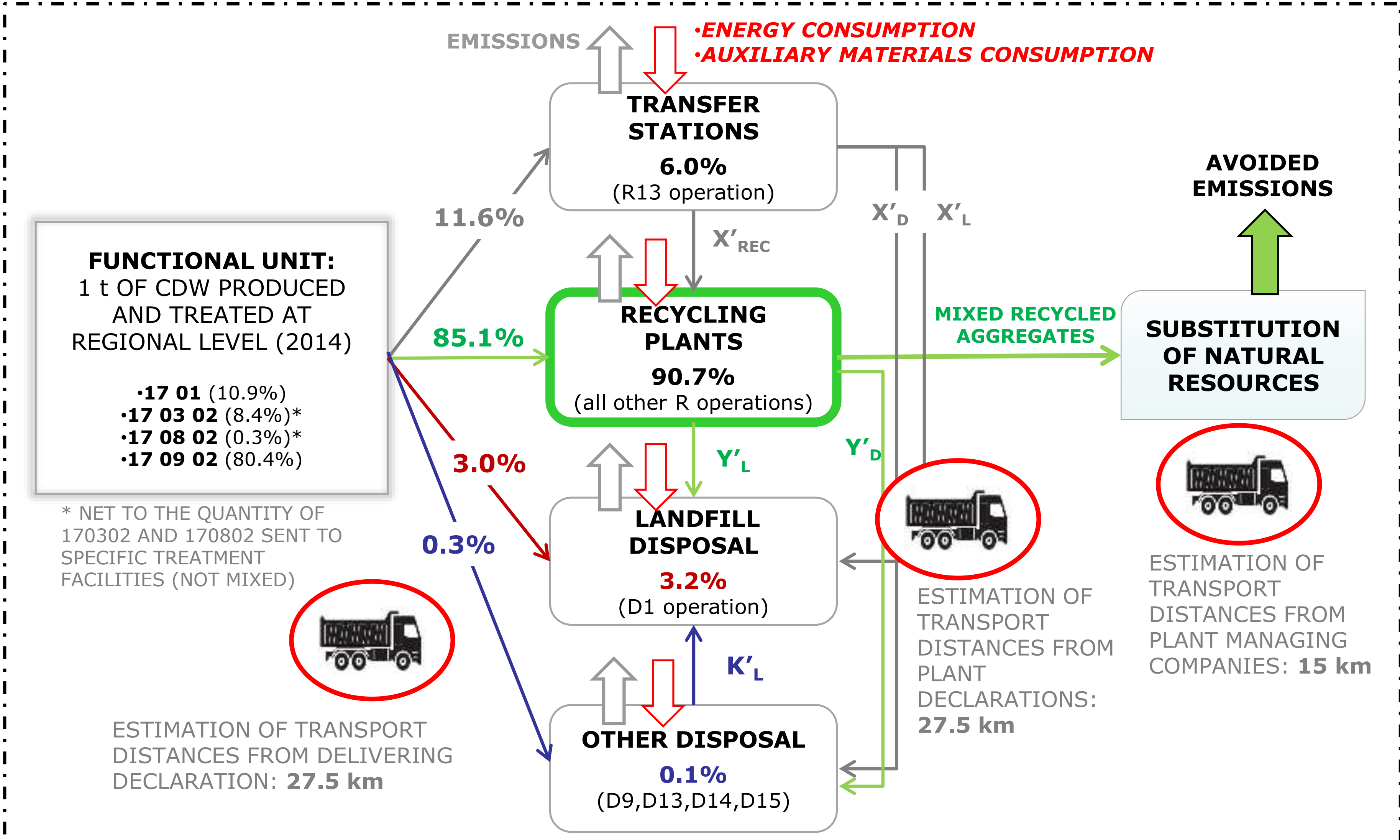
PRODUCED AND TREATED IN LOMBARDY
EWC 1701, 170302 and 170904: 95%
EWC 170802: 67%

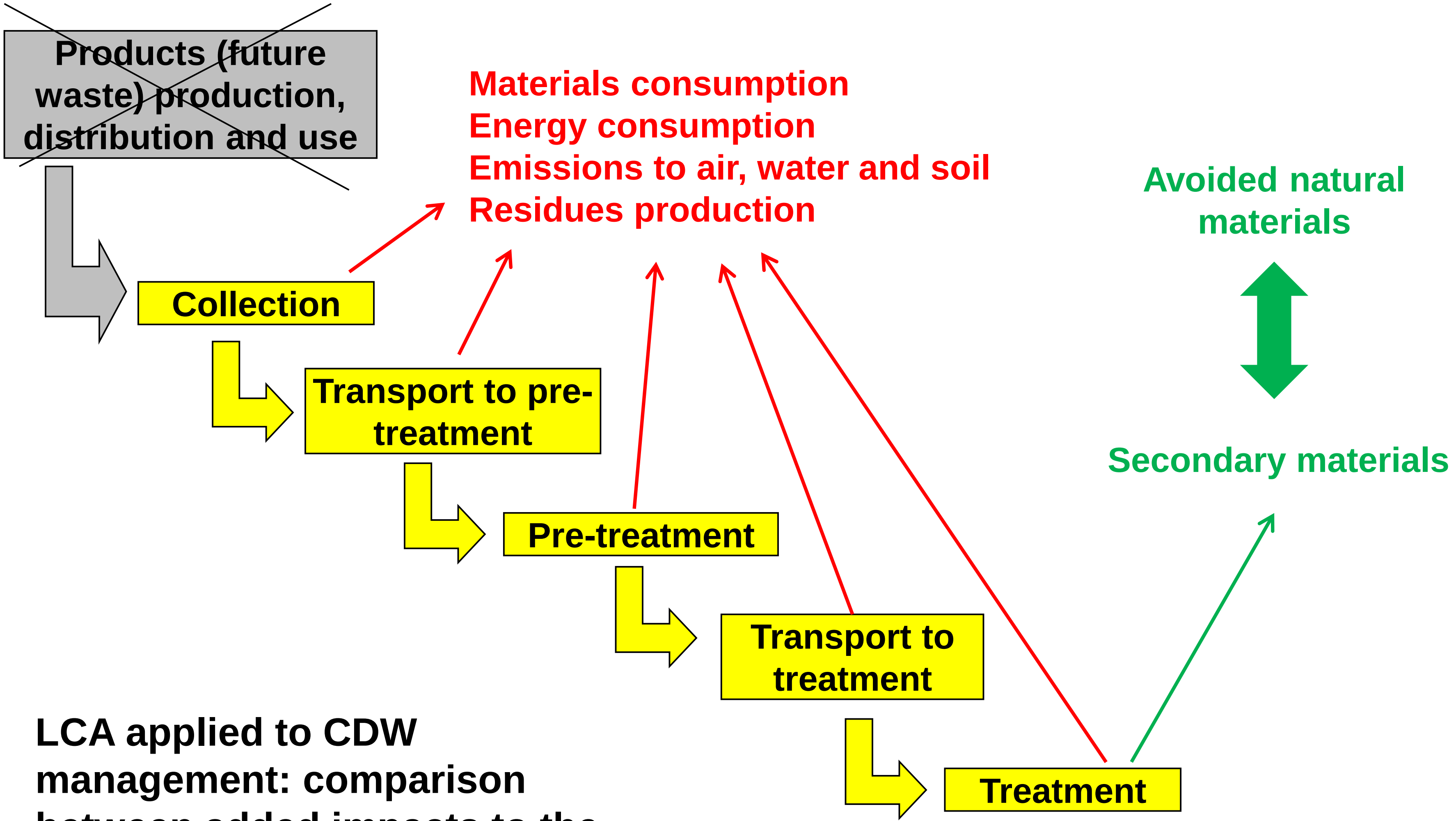
*DIRECTLY EXPORTED WASTE**

EWC 17 01:	**> = 31,487 t**
EWC 17 03 02	**> = 45,259 t**
EWC 17 08 02	**> = 5,547 t**
EWC 17 09 04:	**> = 187,512 t**

* >= because it doesn't include the CDW quantity from those producers not obliged to fill in the yearly waste declaration

LCA OF THE CDW MANAGEMENT SYSTEM IMPLEMENTED IN LOMBARDY REGION → 6,999,986 t in 2014





LCA applied to CDW management: comparison between added impacts to the environment (+) and avoided impacts (-) in each scenario

RECYCLING PLANTS

RECEIVED WASTE

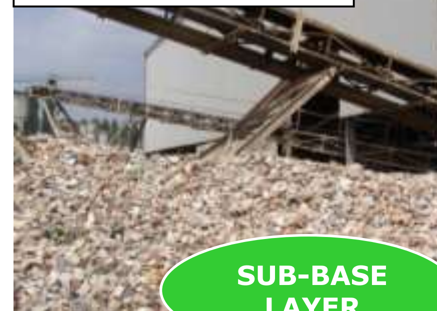
MIXED CDW
(EWC 170904)

FIXED PLANTS (TYPE A)

MOBILE PLANTS (TYPE B)

RECYCLED AGGREGATES (RA)

RA 25/63



SUB-BASE LAYER

RA 63/125

DRAINAGE LAYERS

RA 0/63

RECLAMATION /FILLINGS

LCA RECYCLING SYSTEM

FUNCTIONAL UNIT:
1 t OF MIXED CDW

- 1701 (10.9%)
- 170302 (8.4%)
- 170802 (0.3%)
- 170904 (80.4%)

STORAGE 0%

RECYCLING 96.7%

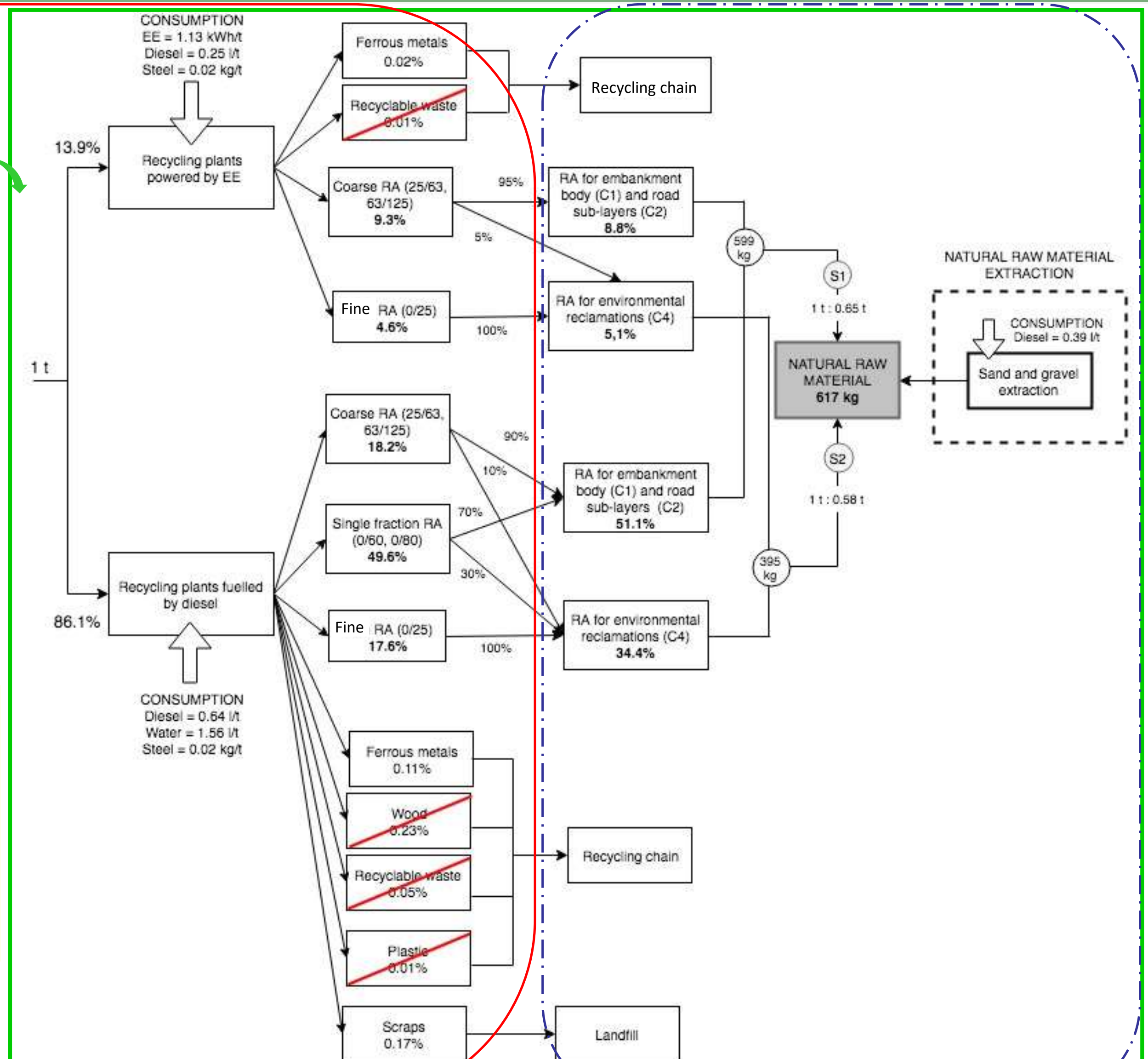
LANDFILL 3.3%

ASSUMPTIONS:

- Allocation of CDW storage to recycling and disposal
- Landfill includes CDW treated in "other disposal"
- Destination of recyclable waste, wood and plastic not modelled in the LCA analysis

TECHNICAL VISITS DATA-SET:

- 13.9% CDW sent to facilities powered by electricity (EE) (Type A) and 86.1% in facilities fuelled by diesel (Type B+C)
- Treatment efficiency: 99.8% in Type A; 99.3% in Type B+C



WASTE FLOWS AND TREATMENT

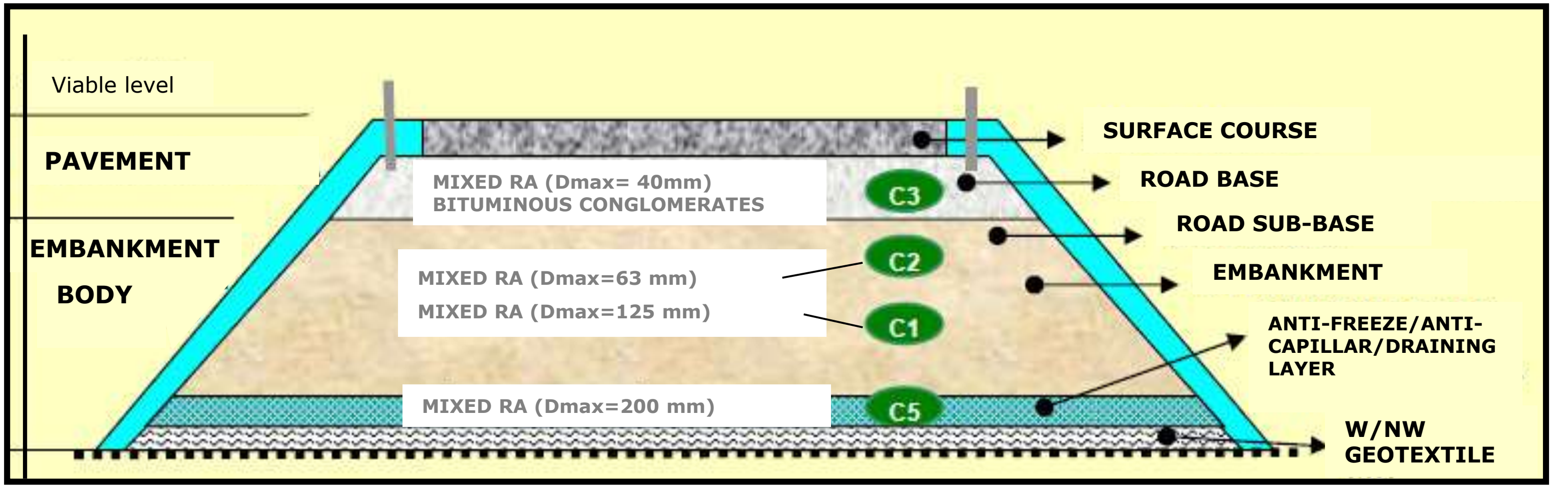
NATURAL RESOURCES SUBSTITUTION

REQUIREMENTS AND SUITABILITY FOR RECYCLED AGGREGATES USE: CIRCULAR n. 5205/2005 + EC MARKING (UNI 13242)

	% on total recycled aggregates	Use of recycled aggregates: Embankment body/sub-base layer (C1/C2)	Use of recycled aggregates: Environmental reclamations (C4)	Replaced natural resource
Coarse aggregates * (25/63; 63/125)	24.8%	90%	10%	MIXED NATURAL RAW MATERIAL
Fine aggregates (0/25)	21.6%	0%	100%	
All-in aggregates (0/60; 0/80)	53.5%	70%	30%	

* COARSE AGGREGATES CAN BE USED ALSO IN THE CONSTRUCTION OF DRAINAGE LAYERS (C5) IN SUBSTITUTION OF ROUND/CRUSHED GRAVEL. IN THE ACTUAL LCA SCENARIO THIS APPLICATION HAS BEEN NEGLECTED.

AVOIDED IMPACTS: ONLY EXTRACTION



DATA SOURCES

INFORMATION OBTAINED

Modelling the natural aggregates production in Lombardy region

Data sources	Information obtained
Local quarries plans	- Authorized volumes in 10 years (283,074,399 t) - Extractive activities distribution on the territory (Milano, Brescia, Bergamo) - Authorized volume for dry (40%), wet (44%) and terrace extraction (16%)
Local authorities statistics	Quantities of extracted material every year, energy consumption and destination of natural aggregates produced
Quarries technical visits	Characteristics associated with the various types of quarry cultivation

Dry pit quarry

Wet pit quarry

Terrace quarry

THE MARKET FOR RECYCLED AGGREGATES

- **The recycled aggregates market in Lombardy region is unstable** and strictly connected to the realization of great works (e.g. EXPO 2015, high speed rail lines, ..)
- The **low cost (4-5 €/t) of natural aggregates and their wide availability** (low taxes associated to the extraction activity and lack of restrictions in Lombardy) represent the main factors that limit the development of the recycled aggregates market, making them less competitive than natural virgin materials
- **Lack of knowledge** in designers and **diffidence by end-users** in the technical characteristics of recycled aggregates (because of their "waste origin")
- **Not updated technical instruments to the European standards** (in call of tenders no equivalence between recycled and natural aggregates)
- **Lack of specific "end of waste" criteria** for CDW, that limits the recycled aggregates use in the construction sector

LCA SHOULD CONSIDER NOT ONLY THE TECHNICAL CHARACTERISTICS OF RECYCLED AGGREGATES, BUT ALSO THE AVAILABILITY OF A MARKET

REPLACEMENT COEFFICIENT (R) BETWEEN RA AND NA CALCULATION

METHOD 1:

$$R = Q * M$$

Q = quality and performance, associated to the specific application of the RA:

$$Q = Q_1 \cdot Q_2$$

Q_1 → RA quality (i.e. soil) ⇒ $Q_1=0.97$

Q_2 → technical characteristics for the specific RA end-use ⇒ Q_2 (C1/C2) = 1; Q_2 (C4) = 0.89

M = market factor for RA:

M=1 → RA totally sold
M=0 → RA totally unsold
⇒ M=0.67

Application for mixed recycled aggregates	**R value**	*Range*
Embankment (C1) and sub-layers (C2)	**0.65**	0-0.97
Environmental reclamations (C4)	**0.58**	0-0.86

METHOD 2:

$$R = \frac{Price\ (RA)}{Price\ (NA)}$$

Price (RA) = average selling price for recycled aggregates: 0-4.2 €/t ⇒ P(RA)=1.95

Price (NA) = average selling price for natural aggregates in Lombardy region: 4.0-9.2 €/t ⇒ P(NA)=5.3

Strongly variable and influenced by local factors

Application for mixed recycled aggregates	**R value**	*Range*
Embankment (C1), sub-layers (C2) and Environmental reclamations (C4)	**0.37**	0-0.8

SENSITIVITY ANALYSES

RA = recycled aggregates
NA = natural aggregates

LCA RECYCLING SYSTEM

FUNCTIONAL UNIT:
1 TON OF MIXED CDW

- 1701 (10.9%)
- 170302 (8.4%)
- 170802 (0.3%)
- 170904 (80.4%)

STORAGE 0%

RECYCLING 96.7%

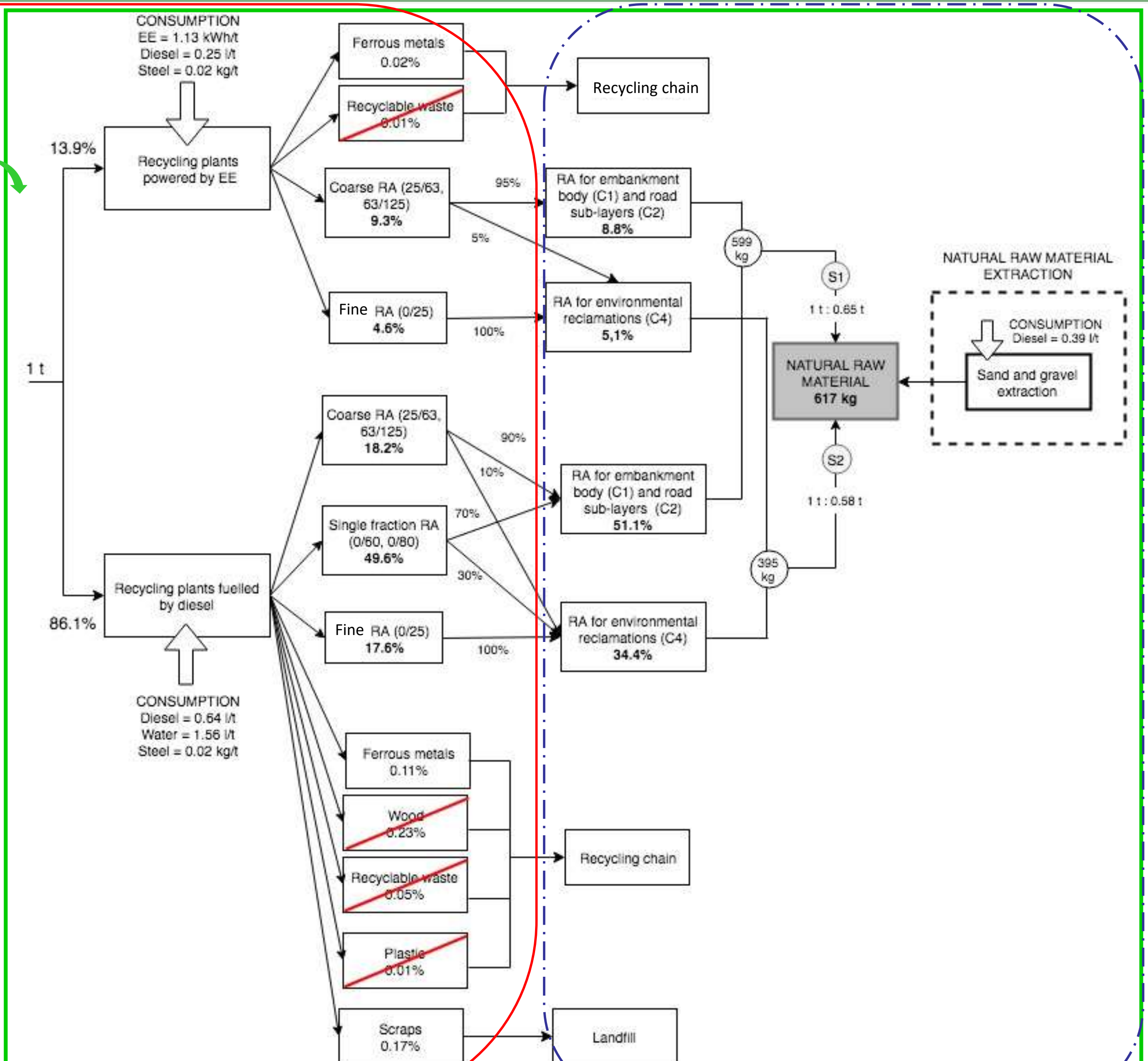
LANDFILL 3.3%

HYPOTHESES:

-Allocation of CDW storage to recycling and disposal
-Landfill includes CDW treated in "other disposal"
-Destination of recyclable waste, wood and plastic not modelled in the LCA analysis

TECHNICAL VISITS DATA-SET:

- 13.9% CDW sent to facilities powered by electricity (Type A) and 86.1% in facilities fuelled by diesel (Type B+C)
- Treatment efficiency: 99.8% in Type A; 99.3% in Type B+C



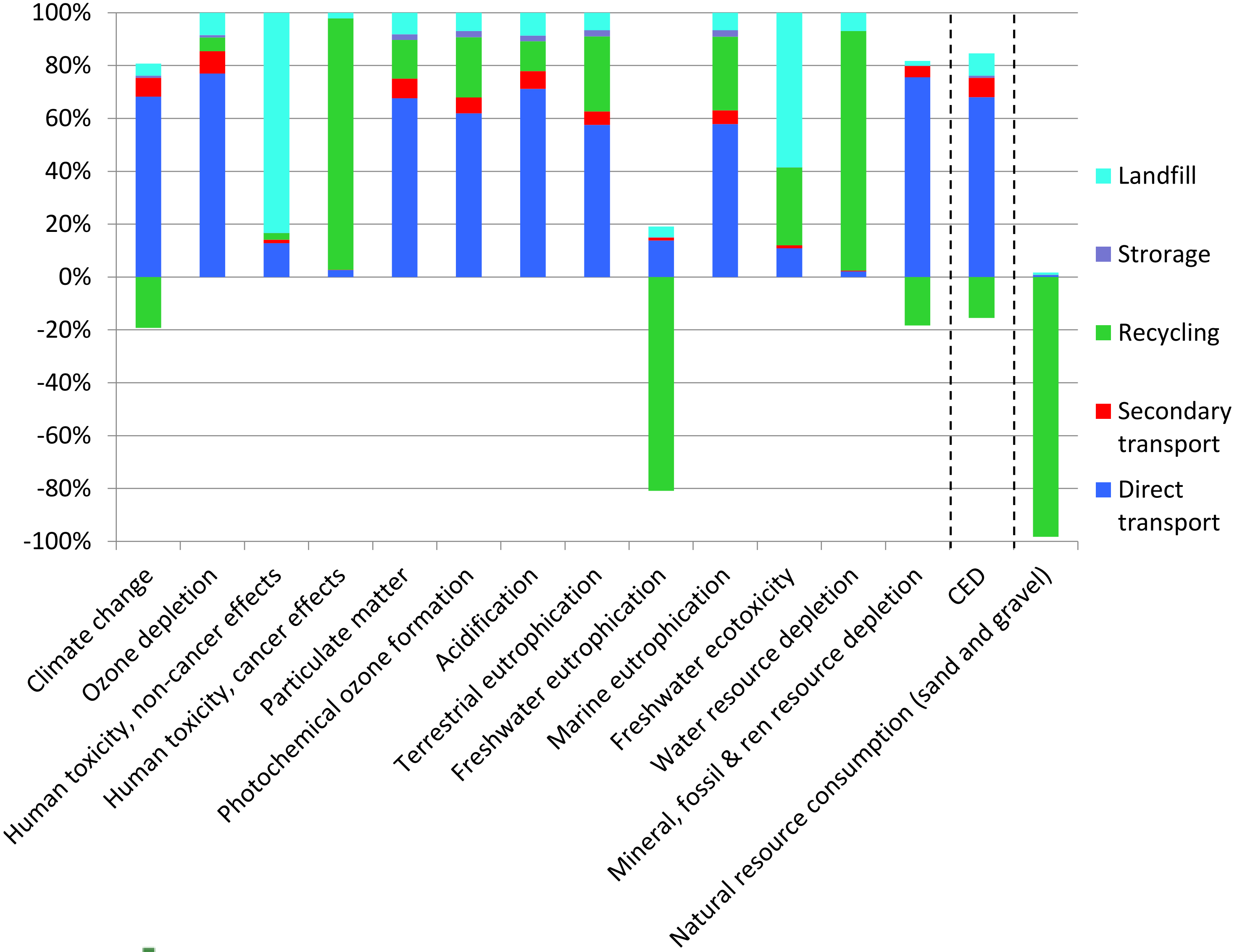
WASTE FLOWS AND TREATMENT

NATURAL RESOURCES SUBSTITUTION

LCA OF BASELINE SCENARIO, IN COMPARISON WITH A LANDFILL SCENARIO FOR 1 t OF MIXED CDW

Impact category	**Unit of measure**	**BASELINE SCENARIO**	**LANDFILL SCENARIO**
ILCD impact categories:			
Climate change	kg CO_2 eq	3.40	11.44
Ozone depletion	kg CFC-11 eq	9.27E-07	3.09E-06
Human toxicity (non-cancer effects)	CTUh	7.32E-06	1.86E-04
Human toxicity (cancer effect)	CTUh	5.00E-06	3.43E-06
Particulate matter	kg PM2.5 eq	2.93E-03	9.21E-03
Photochemical ozone formation	kg NMVOC eq	0.03	0.08
Acidification	mol H+ eq	0.02	0.08
Terrestrial eutrophication	mol N eq	0.10	0.27
Freshwater eutrophication	kg P eq	-1.38E-03	3.06E-03
Marine eutrophication	kg N eq	0.01	2.45E-02
Freshwater ecotoxicity	CTUe	226.1	4031.7
Water resource depletion	m^3 water eq	0.02	0.04
Mineral, fossil & renewable resource depletion	kg Sb eq	2.81E-04	5.81E-04
Cumulative Energy Demand (CED)	MJ	65.0	304.5
Natural resource consumption (sand and gravel)	kg sand&gravel	-611.4	175.3
Saved volume of landfill	m^3	0.69	-

BASELINE SCENARIO: CONTRIBUTION ANALYSIS



LCA: ALTERNATIVE SCENARIOS

Analysed alternative scenarios

- **Calculation methodology**
  - R → Method 2 (R=0.37)
- **Management**
  - SG1 → No storage operations
  - SG2 → CDW totally landfilled
- **Recycling**
  - SR1 → CDW totally sent to recycling plants powered by EE (96.7% of the total CDW managed)
  - SR2 → CDW totally sent to recycling plants fuelled by diesel (96.7% of the total CDW managed)
- **Transport**
  - ST1 → CDW transport distances variation
    - $ST1_A$=20 km
    - $ST1_B$=35 km
  - ST2 → RA selling distances variation (10-30 km)
    - $ST2_A$=10 km
    - $ST2_B$=30 km
  - ST3 → NA selling distances variation (30-60 km)
    - $ST3_A$=30 km
    - $ST3_B$=60 km
- **Replacement coefficient**
  - SF1 → Market factor (M) variation (0-1)
    - $SF1_A$ → M=0
    - $SF1_B$ → M=1
  - SF2 → Method 2 replacement coefficient variation (0-0.8)
    - $SF2_A$ → R=0
    - $SF2_B$ → R=0.8
- **Alternative uses for recycled aggregates**
  - SA → Production of 100% high-quality RA (replacement coefficient between RA and sand and gravel aggregates 1:1)

Actual scenario (baseline):
R: 0.65 or 0.58
Storage: 11.6%
Landfill: 3.3% and Recycling: 96.7%
Electricity plants: 13.9%; diesel plants: 86.1%
CDW transport distance: 27.5 km
Recycled aggregates selling distance: 15 km
Natural aggregates selling distance: 40 km
Market factor: 0.67
High-quality recycled aggregates production: 0%

RA = recycled aggregates
NA = natural aggregates

LCA: BEST-CASE SCENARIO

ASSUMPTIONS:

- **No CDW storage**
- **No CDW sent to landfill**
- **100% electricity plants**
- **Minimum distance for CDW delivery**
- **Minimum distance for recycled aggregates selling**
- **Unchanged distance for natural aggregates selling**
- **Market factor =1**
- **90% high-quality recycled aggregates (10% low-quality used for environmental reclamation (fine fraction))**

***considering 6.999.986 t:**
23800 t CO_2 eq → -12500 t CO_2 eq

Impact category	Unit of measure	BEST-CASE SCENARIO
ILCD impact categories:		
Climate change	kg CO_{2eq}/t	-1.78*
Ozone depletion	kgCFC-11$_{eq}$/t	-5.1E-08
Human toxicity (non-cancer effects)	CTUh/t	1.0E-07
Human toxicity (cancer effect)	CTUh/t	4.6E-06
Particulate matter	kgPM2.5$_{eq}$/t	-0.0013
Photochemical ozone formation	kgNMVOC$_{eq}$/t	-0.010
Acidification	mol H+$_{eq}$/t	-0.0104
Terrestrial eutrophication	mol N$_{eq}$/t	-0.03
Freshwater eutrophication	kg P$_{eq}$/t	-0.0018
Marine eutrophication	kg N$_{eq}$/t	-0.0031
Freshwater ecotoxicity	CTUe/t	65.5
Water resource depletion	m^3 $_{water\ eq}$/t	0.013
Mineral, fossil & renewable resource depletion	kg Sb$_{eq}$/t	9.1E-05
Cumulative Energy Demand (CED)	MJ/t	-24.1
Natural resource consumption (sand and gravel)	kg/t	-1025.4

The actual (2014) CDW management system implemented in Lombardy region

- has better environmental performances than the landfill disposal
- can be improved so that the environmental benefits associated with the use of recycled aggregates in the civil sector are higher than the impacts induced by the waste management

PROMOTE THE MARKET OF THE RECYCLED AGGREGATES

Regulatory tools aimed at promoting the use of recycled aggregates	Green Public Procurement
Mining sector planning aimed at having a more sustainable use of natural resources	• Higher taxes for the extraction activities • More rational permission system, that considers recycled aggregates availability on the territory
Adapt the technical tools to the European standards	Special tender dossier, price list of construction works

PRODUCE BETTER-QUALITY RECYCLED AGGREGATES

Selective demolition on site to improve the CDW quality entering the recycling facilities	• Separation of undesired materials • Market creation for those materials that are now mixed together before the recycling treatment
Improve the plant technologies	• Encourage and promote the authorization of recycling facilities powered by electricity • Improve selection efficiencies; implement more advanced plant technologies

OPTIMISE THE MANAGEMENT SYSTEM

Minimize transport distances and temporary management phases	• Optimal facilities distribution • Updating recycling plants regional lists and maps • Promote the opening of facilities where it is needed
Reduce landfill disposal	• Increase disposal taxes • Ban on disposal for those fraction that can be recycled

ACKNOWLEDGMENTS

This research project was financially supported by the Lombardy region government. We thank ARPA Lombardia, ANPAR and ANCE for the technical support; local officers for having supplied quarries statistic data; all CDW plants and quarries managers for having supplied primary data for the LCA study and road companies for the information about recycled aggregates final use.

THANK YOU FOR YOUR ATTENTION

Contacts:

lucia.rigamonti@polimi.it

www.aware.polimi.it