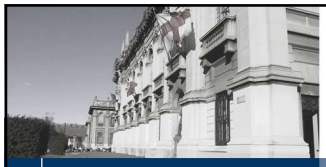

POLITECNICO DI MILANO





"AWARE" & LCT

Lucia Rigamonti & AWARE Research Group

Department of Civil and Environmental Engineering
Environmental section

Assessment on WAste and REsources

"AWARE" AND LCT

- LCA APPLIED TO WASTE TREATMENT / MANAGEMENT
- LCA APPLIED TO OTHER SERVICES AND TO PRODUCTS
- LCC APPLIED TO WASTE TREATMENT / MANAGEMENT
- METHODOLOGICAL DEVELOPMENTS / IMPROVEMENTS

"AWARE" AND LCT

LCA APPLIED TO WASTE TREATMENT/MANAGEMENT

LCA & MSW:

- Treatment of the residual waste
- Recycling activities
- Treatment of the organic fraction

Evaluation of integrated waste management systems

LCA applied to other specific categories of waste:

- Treatment of car fluff
- WEEE management
- C&D waste management

Primary data: field visits

"AWARE" AND LCT

LCA APPLIED TO WASTE TREATMENT/MANAGEMENT

LCA & waste prevention activities:

- Evaluation of each activity (use of tap water / water from public fountains / refillable bottles instead of one-way bottled water; loose distribution of liquid detergents and food products instead of the traditional distribution, farm delivery)
- Evaluation of an integrated waste management system when one or more prevention activities are implemented

LCA and re-use:

- Re-use of steel barrels for chemical and petrochemical products
- Re-use of Intermediate Bulk Containers (IBCs)
- Re-use of collapsible crates & mini-bins for fruit and vegetables

LCA and landfill mining

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"AWARE" AND LCT

LCA APPLIED TO OTHER SERVICES / TO PRODUCTS

- EPD®s of cartonboards entirely or mostly produced from recovered fibres
- Potentially sustainable consumption choices (disposable vs rechargeable household batteries, salad production by organic cultivation and distribution modes aimed at reducing packaging and the chain between producer and consumer)
- CO_2 submarine storage in glass capsules
- Greenrail: innovative railways sleepers
- FReSMe: synthesis of methanol from CO_2 Blast Furnace Gases to be used as ship transportation fuel
- IMAP: integration of a microalgal culturing unit within a conventional wastewater treatment plant

LCC APPLIED TO WASTE TREATMENT/MANAGEMENT

- Italian packaging waste management system from a local authority's perspective
- Energy from the residual waste according to different scenarios of treatment

"AWARE" AND LCT

METHODOLOGICAL DEVELOPMENTS / IMPROVEMENTS

- Approaches for the evaluation of MSW management systems which include waste prevention activities
  - Influence of different characterisation models and factors on the LCA results (toxicity-related and resource-related impact categories)
- Definition and quantification of replacement coefficients for the calculation of the amount of primary material that can be replaced by one unit of waste-derived (secondary) material
- Methods to include in LCA studies the benefits associated with the use of compost
  - Framework to evaluate the environmental convenience of packaging solutions for food waste prevention (trade-off situations)
  - Development of the Product Environmental Footprint Category Rules (PEFCR) for intermediate paper products (Environmental Footprint Pilot Phase by EC)
  - Methodology to calculate the ratios Qsin/Qp and Qsout/Qp, i.e. the terms in the Circular Footprint Formula that reflect the quality of both the ingoing and the outgoing recycled materials compared to that of virgin ones, for some food and beverage packaging materials

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"AWARE" AND LCT

4 focuses:

- LCA AND WASTE PREVENTION ACTIVITIES
- LCA AND RE-USE
- LCA AND C&D WASTE MANAGEMENT
- LCA AND COMPOSTING

"AWARE" AND LCT: LCA & WASTE PREVENTION ACTIVITIES

LCA & waste prevention activities
LCA to support sustainable consumption choices by citizens

- ✓ To verify if (and when) a reduction in waste generation implies also a reduction in the overall environmental impacts
- ✓ To evaluate the environmental convenience of some waste prevention activities included in the National Waste Prevention Programme
- ✓ To evaluate whether the examined waste prevention activities are actually capable of improving, and to which extent, the overall environmental performance of municipal waste management at the regional level

Nessi S., Rigamonti L., Grosso M. (2012). *"LCA of waste prevention activities: a case study for drinking water in Italy"*. Journal of Environmental Management, 108, 73-83.

Nessi S., Rigamonti L., Grosso M. (2014). *"Waste prevention in liquid detergent distribution: a comparison based on life cycle assessment"*. Science of the Total Environment, 499, 373-383.

Nessi S., Rigamonti L., Grosso M. (2015). *"Packaging waste prevention activities: A life cycle assessment of the effects on a regional waste management system"*. Waste Management & Research, 33(9), 833-849.

Dolci G., Tua C., Grosso M., Rigamonti L. (2016). *"Life Cycle Assessment of consumption choices: a comparison between disposable and rechargeable household batteries"*. International Journal of Life Cycle Assessment, 21, 1691-1705.

"AWARE" AND LCT: LCA & WASTE PREVENTION ACTIVITIES

LCA & waste prevention activities: conclusions

- ✓ Preventing the production of waste does not automatically imply a better overall performance (e.g. water from public fountains if car is used)
- ✓ Burden shifting may play a role (e.g. impacts of the tank used in the loose distribution of detergents)
- ✓ Compared to traditional waste management and treatment, the effectiveness of waste prevention activities is strongly dependent on the behaviour of citizens/consumers
- ✓ Prevention activities have different potential to reduce waste and environmental impacts of the overall system

An **LCA-based guidance** is needed to support local authorities wishing to implement waste prevention practices, as well as for citizens to make such practices really effective

"AWARE" AND LCT: LCA & RE-USE

Project: Re-use of packaging in Italy (financially supported by the National Packaging Consortium – CONAI)

Intermediate Bulk Containers

Collapsible crates & mini-bins for fruit and vegetables

Barrels for chemical and petrochemical products

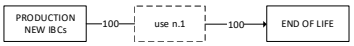
Rigamonti L., Biganzoli L., Grosso M. (2016). *"Re-use of packaging in Italy"*. SUM2016 3rd Symposium on urban mining and circular economy, Bergamo, 23-25 May 2016. Paper n. 16, pp. 1-6.

Rigamonti L., Biganzoli L., Dolci G., Tua C., Grosso M. (2016). *"Packaging re-use in Italy"*. SIDISA2016 X International Symposium on Sanitary and Environmental Engineering, Rome, 19-23 June 2016. Symposium proceedings ISBN 978-88-496-391-1: E05-1, pp. 1-7.

"AWARE" AND LCT: LCA & RE-USE OF INTERMEDIATE BULK CONTAINERS (IBCs)

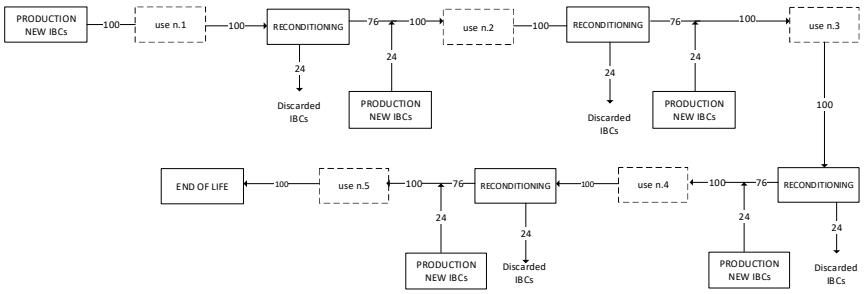
IBCs after use can be sent to recycling:

n=1



or can be reconditioned:

2 ≤ n ≤5



"AWARE" AND LCT: LCA & RE-USE OF INTERMEDIATE BULK CONTAINERS (IBCs)

IBCs can be reconditioned after use or sent to recycling

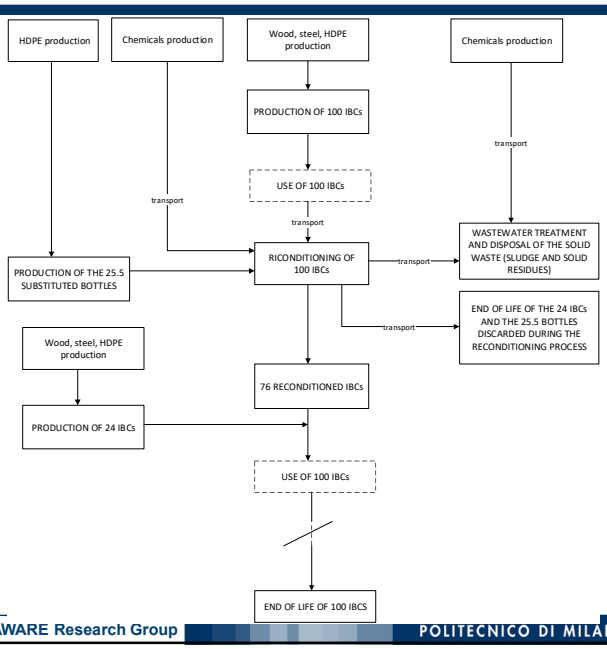
AIM OF THE STUDY: evaluation of the environmental impacts associated with the life cycle of IBCs as the number of rotations changes, by using an LCA approach

The analyzed system includes:

- the IBCs production
- the reconditioning process: first selection (24% of the IBCs is discarded because too damaged); cleaning; second selection (25.5% of the bottles are discarded because cannot be properly cleaned and are substituted with new ones); recycling/disposal of the discarded IBCs and bottles; wastewater treatment
- recycling/disposal of the IBCs at their end of life

"AWARE" AND LCT: LCA & RE-USE OF INTERMEDIATE BULK CONTAINERS (IBCs)

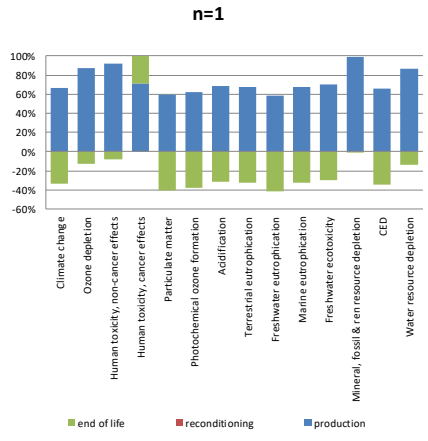
SYSTEM BOUNDARIES

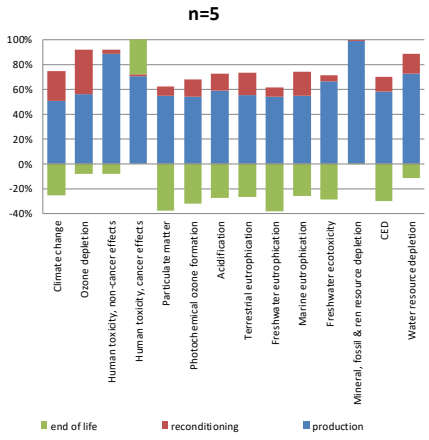


FUNCTIONAL UNIT: 100 IBCs (1 m^3 bottle with pallet in wood, steel or plastic) ready to be used n times, with n included between 1 and 5

"AWARE" AND LCT: LCA & RE-USE OF INTERMEDIATE BULK CONTAINERS (IBCs)

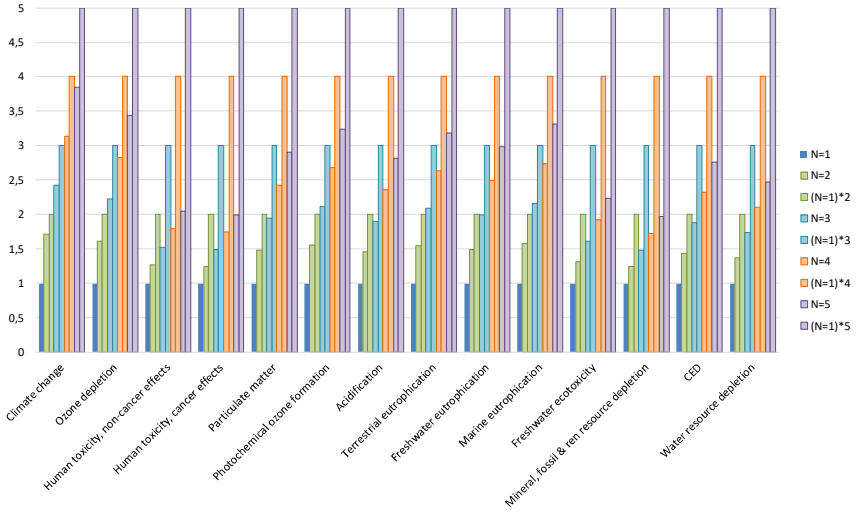
RESULTS: percentage contribution of the life stages "production", "reconditioning", and "end of life" for 100 IBCs with wood pallet:





"AWARE" AND LCT: LCA & RE-USE OF INTERMEDIATE BULK CONTAINERS (IBCs)

RESULTS: re-use (N=2, N=3, N=4, N=5) vs. single-use ((N=1)*2, (N=1)*3, (N=1)*4, (N=1)*5)



"AWARE" AND LCT: LCA & C&D WASTE MANAGEMENT

Project: LCA of the construction and demolition waste management system implemented in Lombardy region (financially supported by Regione Lombardia)

Regione Lombardia

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 limiting factors for the market of recycled materials)
- Assessing the environmental performance of the current regional system through the application of the LCA methodology
- Identifying benefits and critical aspects of the CDW recycling chain
- Defining possible improving scenarios, to be compared and evaluated from a life cycle perspective

"AWARE" AND LCT: LCA & C&D WASTE MANAGEMENT

Non hazardous CDW → Lombardy: 11.9 Mt; Italy: 50.2 Mt (2014; source: ISPRA 2017)
MSW → Lombardy: 4.5 Mt; Italy: 29.6 Mt (2014; source: ISPRA 2016)

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

REFERENCE YEAR: 2014

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 GENERATED 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

GENERATED 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

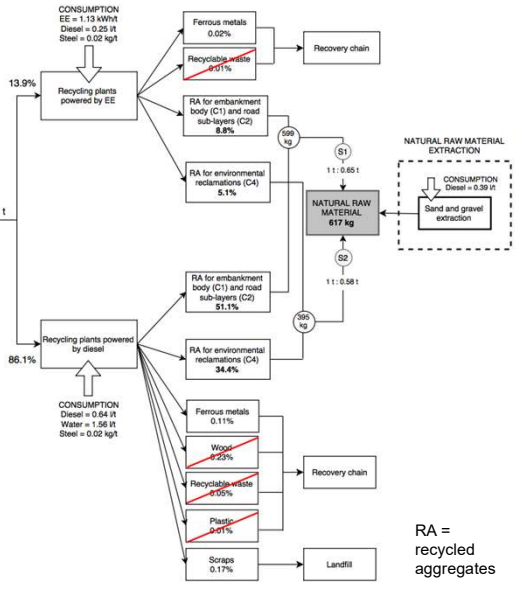
* >= because it doesn't include the CDW quantity from those producers not obliged to fill in the yearly waste declaration

"AWARE" AND LCT: LCA & C&D WASTE MANAGEMENT

LCA of the mixed CDW management:

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:
- 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

RA = recycled aggregates

"AWARE" AND LCT: LCA & C&D WASTE MANAGEMENT

RECEIVED WASTE

MIXED CDW (code 170904)

LARGE BLOCKS (code 170904)

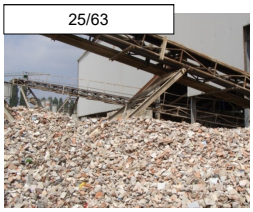
PLANTS

FIXED

MOBILE

RECYCLED PRODUCTS

25/63



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"AWARE" AND LCT: LCA & C&D WASTE MANAGEMENT

REPLACEMENT COEFFICIENT (R) BETWEEN RECYCLED AND NATURAL AGGREGATES

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

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) and sub-layers (C2)	**0.65**	0-0.97
Environmental reclamations (C4)	**0.58**	0-0.86

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

RA = recycled aggregates
NA = natural aggregates

SENSITIVITY ANALYSES

"AWARE" AND LCT: LCA & C&D WASTE MANAGEMENT

Results for 1 t of mixed CDW	BASELINE SCENARIO	LANDFILL SCENARIO	BEST-CASE SCENARIO
Climate change (kg CO_2 eq)	3.40	11.44	-1.78
Cumulative Energy Demand (MJ)	65.0	304.5	-24.1
Natural resource consumption (kg sand and gravel)	-611.4	175.3	-1025.4
Saved volume of landfill (m^3)	0.69	-	0.69

BEST-CASE SCENARIO:

- 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

"AWARE" AND LCT: LCA & C&D WASTE MANAGEMENT

Conclusions:

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

Recommendations:

- Promote the market of the recycled aggregates
- Produce better-quality recycled aggregates
- Optimise the management system

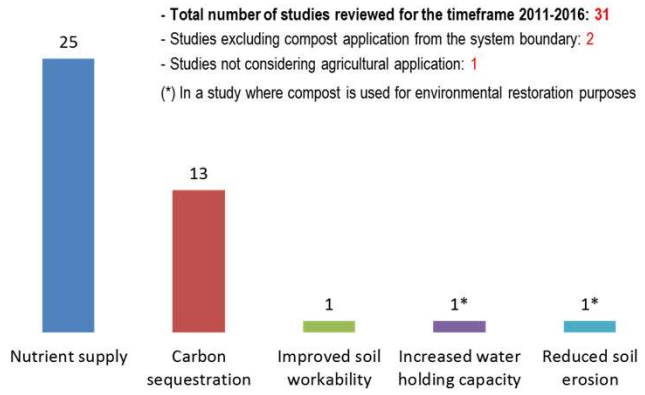
Pantini S., Rigamonti L. (2016). *"Evaluation of the mass balance of the construction and demolition waste management system in Lombardy Region, Italy"*. 5th International Conference on Industrial & Hazardous Waste Management, Chania (Crete, Greece), 27-30 September 2016. Proceedings Crete 2016, n. 44, 1-9. ISBN: 978-960-8475-24-3; ISSN: 2241-3138.

Borghi G., Pantini S., Rigamonti L. (2017). *"Analisi LCA a supporto della pianificazione della gestione dei rifiuti da costruzione e demolizione non pericolosi in Lombardia"*. Accettato per Ingegneria dell'Ambiente.

"AWARE" AND LCT: LCA & COMPOSTING

AGRONOMIC BENEFITS OF COMPOST IN PUBLISHED (ORGANIC) WASTE LCA

- Most studies only include traditionally acknowledged benefits, although modelling is not uniform…
- Few studies attempt to extend the range of considered benefits (but without transparency or by relying on site-specific values not related to agricultural application)



- Lack of shared approaches and data for the modelling of the benefits related to the improvement of soil properties from compost application

"AWARE" AND LCT: LCA & COMPOSTING

AGRONOMIC BENEFITS OF COMPOST: state of knowledge

Based on the review by Martínez-Blanco et al. (2013) and most recent literature surveys by AWARE (for some benefits)

Benefits	Experimentally proven	Notes
1. Nutrient supply	X	-
2. Carbon sequestration in soil	X	-
3. Weed, pest and disease suppression	X	Only for a restricted number of soil-borne fungal diseases
4. Increase in crop yield	-	Controversial evidence, frequently reporting non-significant effects from compost use
5. Reduction in soil erosion	X	-
6. Increase in soil water holding capacity	X	-
7. Improved soil workability	X	-
8. Improved soil biological properties and biodiversity	X	Limited to the effects on soil microbial community (evidence on aboveground species scarce and contrasting)
9. Improved crop nutritional properties	-	Lack of evidence for field crop. Positive effect proved only for specific substances in few crops

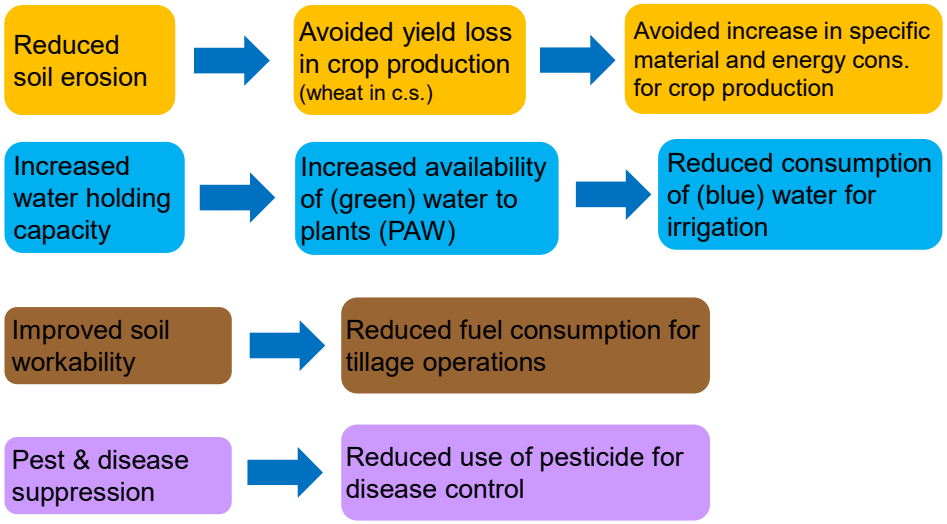
"AWARE" AND LCT: LCA & COMPOSTING

1. **PROPOSAL OF QUANTITATIVE APPROACHES FOR THE MODELLING OF:**
   - 5. Reduced soil erosion
   - 6. Increased water holding capacity (WHC)
   - 7. Improved soil workability
   - 3. (Pest and disease suppression)*
2. **DEVELOPMENT OF A DEMONSTRATIVE LCA CASE STUDY**
   - Comparison among the different benefits
   - Analysis of a management scenario for organic MSW including composting and subsequent land application of compost for agricultural purposes

(*) For specific situations of compost application in agriculture

"AWARE" AND LCT: LCA & COMPOSTING

AGRONOMIC BENEFITS OF COMPOST: possible modelling approaches



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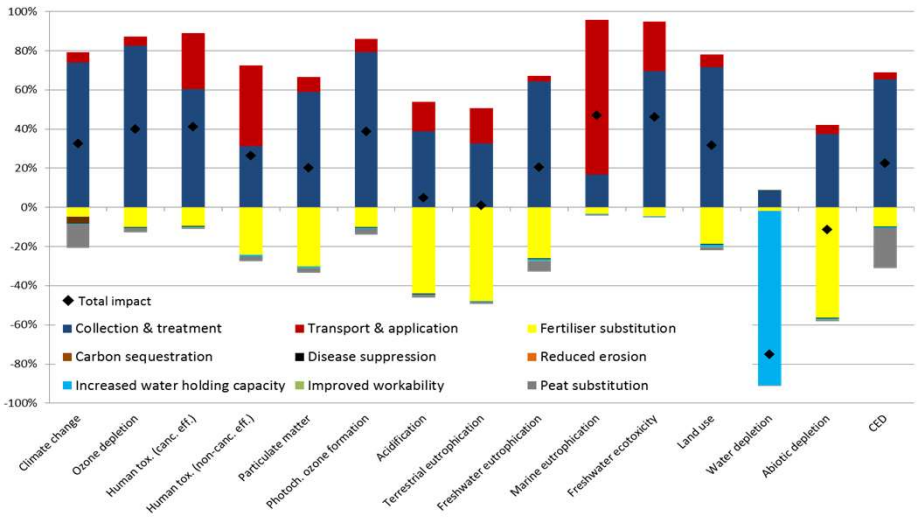
"AWARE" AND LCT: LCA & COMPOSTING

AGRONOMIC BENEFITS OF COMPOST: quantitative figures for the case study (application rate: 25 t/ha/y)

- Soil loss reduction 21.4%; 2.25 t/ha/y → Avoided yield loss 0.043%/ha/y; 0.0017%/t compost → Avoided increase in consumption for agric. production (wheat) 0.0017%/t compost
- Increase in PAW 11.4% → Reduced irrigation need 11.4% → Avoided water use for irrigation 350 m^3/ha/y; 14 m^3/t compost
- Reduction in fuel consumption 12.8% → Avoided fuel use 1.3 kg/ha/y; 0.0514 kg/t compost
- Effective suppression of *fusariosis* in wheat → Avoided pesticide application (Tebuconazole & Prothioconazole) 125 g/ha/y; 5 g/t compost

"AWARE" AND LCT: LCA & COMPOSTING

AGRONOMIC BENEFITS OF COMPOST: case study results



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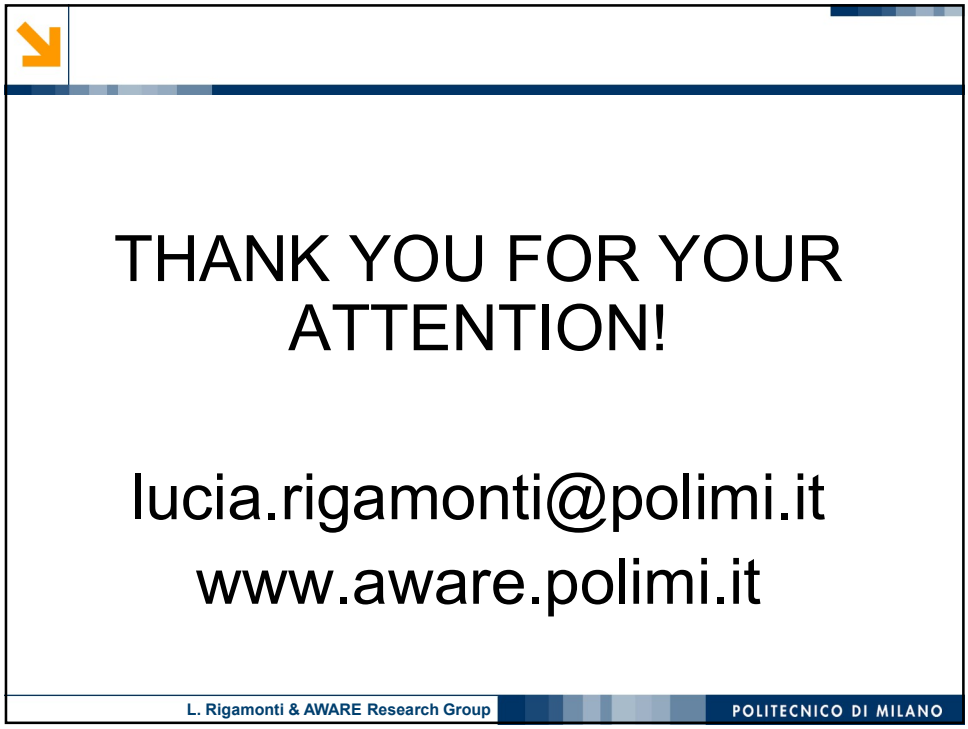
THANK YOU FOR YOUR ATTENTION!
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