Environmental and Climate Technologies
2024, vol. 28, no. 1, pp. 84–93
https://doi.org/10.2478/rtuect-2024-0008
https://content.sciendo.com

MSW Management in Two Italian Mountainous Areas

Marco RAGAZZI[1*], Fabio CONTI[2], Vincenzo TORRETTA[3], Francesco ROMAGNOLI[4], Claudio ZATELLI[5], Giorgio GHIRINGHELLI[6], Elena Simina LAKATOS[7], Elena Cristina RADA[8]

[1]*Civil Environmental and Mechanical Engineering Department – DICAM, University of Trento, 38122, Trento, Italy*
[2,3,8]*Department of Theoretical and Applied Sciences – DiSTA, Insubria University, 2100, Varese, Italy*
[4]*Institute of Energy Systems and Environment, Riga Technical University, Āzenes iela 12/1, Riga, Latvia*
[5]*Autonomous Province of Trento, 38122, Trento, Italy*
[6]*ARS Ambiente srl, 21013, Gallarate, Varese, Italy*
[7]*Institute for Research in Circular Economy and Environment Ernest Lupan, 400609 Cluj-Napoca, Romania*
[7]*Faculty of Industrial Engineering, Robotics and Product Management, Technical University of Cluj-Napoca, 400641 Cluj-Napoca, Romania*

Received 20.04.2023; accepted 07.12.2024

***Abstract* – Two case studies are reported in the present work. They regard municipal solid waste (MSW) management trends in the last decades in two Italian provinces selected to analyse some issues of waste management in mountainous areas. The first case study refers to a selective collection (SC) rate expected to reach 80 % soon. This scenario assumes SC mainly in kerbside mode. The scenario is based on specific local conditions: the absence of a thermo-chemical plant in the territory (but with a part of the residual MSW burnt in a neighbour province), the presence of local plant of anaerobic, and a sanitary landfill for pre-treated residual MSW. The adopted tariff helped increasing the SC rate: indeed, since 2013, a tariff calculated at user level, depending on the behaviour of each user, has been adopted. This is called punctual tariff. The second case study concerns an area where SC reached about 75 %. The punctual tariff has been recently introduced. In this scenario, an incineration plant and a Solid Recovered Fuel (SRF) plant allow implementing an industrial symbiosis solution in conjunction with a cement factory. The work demonstrates that SC can be the core of a correct MSW management and that kerbside collection is fully compatible with mountainous area. However, other issues remain to be optimized yet: the low density of mountain areas makes difficult to implement enhanced solutions of SC (e.g. for diapers) and increases costs for light packaging collection; moreover, the presence of tourist fluxes can significantly affect SC efficiency.**

***Keywords* – Circular economy; guidelines; management; mountain; municipal solid waste.**

Nomenclature	
CE	Circular Economy
MSW	Municipal Solid Waste
rMSW	residual Municipal Solid Waste

* Corresponding author.
E-mail address: marco.ragazzi@unitn.it

SC	Selective Collection
SRF	Solid Recovered Fuel

1. INTRODUCTION

The waste management sector has improved considerably in the last decades in many territories, thanks to the introduction of concepts of corporate social responsibility [1] and Circular Economy (CE) [2]. How society should deal with household waste has become a significant policy issue. Legislation and policy schemes have become wider, including specific targets and interests among households and those focusing on an economy-wide effort to minimize waste. Several awareness and knowledge mechanisms have been implemented worldwide. For example, in the United States and Canada, individual localities have introduced initiatives such as kerbside collection charges for household waste to reduce its amount [3]. Moreover, reuse or composting are examples of efforts to reduce household waste well established at European level. Of course, the final environmental impact of waste depends not only on the amount of waste after consumption but also on its fate. The trend evolved from a wide use of sanitary landfill to a scenario where recovery and reuse are priorities. The concept of the 3Rs (reduce, reuse and recycle) moved to 5Rs (reduce, reprocess, reuse, recycle and recovery), increasing citizen's awareness and involvement and responsibility not only in emerging countries but also in most evolved ones [4]–[6]. Nowadays, waste management demands first to prevent and minimise waste production also changing the design of the goods. The second indication is the tight connection to reuse in order to give a second life to the produced waste. For achieving these goals, it is necessary to have a good knowledge on the Municipal Solid Waste (MSW) composition, production and final use taking into account also the interaction between production, selective collection (SC) and potential final thermal treatments [7]–[9]. The main purpose in the MSW management in the last decade concerns the intelligent and extended use of the products to comply with the CE requirements [10]–[12]. The scientific literature in general refers to studies on industrial products and not with generated MSW [13], [14]. A key factor in this evolution was the introduction of the concept of "the polluter pays": pollution can be clearly linked to rMSW generation.

In this frame, in spite inhabited mountain regions are clearly sensible to human activities, the literature on MSW management in mountain areas is scarce: a few articles in the Scopus database until early 2023, showing interest for particular regions (e.g. Hymalaya) [15]–[17]. In the present paper, two case studies are reported regarding the MSW management trend in two Italian mountainous areas complying with the targets of EU in terms of waste management, in order to contribute to the set up of guidelines that can be useful in similar areas of EU or EU-like countries, according to the CE concept. The present work reports an overview of the MSW management before the beginning of the COVID-19 pandemic as in Italy still the year 2022 included a period of national emergency that affected people behaviour and thus waste production and typology.

2. MATERIALS AND METHODS

In order to contribute to the development of guidelines for a MSW management in mountainous areas in line with the CE requirements, two case-studies at provincial level from the Northern areas of Italy were selected as characterised by high efficiencies of selective

collection (SC) in spite of their complex morphology [18]. A documentary analysis was performed.

The first case study refers to a collecting system with a good SC rate, i.e. 78 %, reached before the pandemic, following two decades of intensive strategies, and after four Waste Management Plans starting from 1993. In the analysed system within the Trento's Province, 14 communities, composed by variable numbers of municipalities, who live in 6200 km^2 have been considered.

The area has been subject of SC optimisation activities since the last decade [19] also as a tourism strategy [20], [21].

SC is made mainly door-to-door (i.e. kerbside). Some communities also have closed bins along the streets accessible only from pre-selected users. The proposed technical system is integrated with zonal collection centres for the treatment of specific fractions of waste and transfer stations.

In the analysed territory, a thermal waste plant is absent due to a partial co-management of the input into a nearby province thermal plant. The rest of the unsorted MSW, also named residual MSW (rMSW), in 2019 was sent mostly to a bio-mechanical pre-treatment before landfilling.

In the analysed system the management of light packaging, collected through source separation, is supported by a local separation plant dividing the input into plastics, cans, and composite materials. The material valorisation of these separated flows is performed in plants out of the Province.

A specific strategy was developed in the last decade to support citizens in understanding MSW management from the economic, social, ethical and environmental points of view (from production to final disposal). Particular attention was put to green procurements and to the environmental campaign "respect the territory – respect yourself". Within this inclusive approach eco-volunteers explain to the community the MSW management and the good waste practices (e.g. reuse days) [22].

The waste payment (a tariff in place of a tax) helped to increase the SC rate. Since 2013 a tariff calibrated at user level (punctual tariff) is used. It is constituted with a fixed part, that covers fixed costs independently on the quantity of waste produced, and a variable part, intended to cover variable costs related to the amount of waste produced. In this way, all the waste management service costs are covered by a tariff, including the administrative ones, the street sweeping costs and the amortisation costs. In addition, a Radio Frequency Identification (RFID) system was adopted for solid waste bins [23], [24].

The second case study (Varese Province) is addressed to a territory with 138 municipalities, in which SC reached about 72 % in 2019. In this context, intensive actions for increasing the SC rate began in 2001, while the first Waste Management Plan was issued in 1997 and the last in 2010 [25]. In 2000, the punctual tariff was used for the first time in a case study with prepaid bags. Since 2013, a RFID system was used for waste collection for bins and bags. Differently respect to the first case study, in the territory considered in the second scenario local energy related plants are available for rMSW: an incineration plant and a Solid Recovered Fuel (SRF) plant that send the final outputs to a cement factory and a sanitary landfill. In the province there is not a treatment plant for energy valorisation of food waste.

From the analysis of the selected case studies, the authors pointed out criteria useful for guidelines applicable for waste management in mountainous areas.

3. Results and Discussions

In the frame of the first case study, in 2019 the contribution of the Bozen incinerator (out of the province of Trento) could account for 15–20 ktons per year (the real amount was lower as effect of technical calibration). The rest of rMSW was pre-treated in a local plant before landfilling or directly landfilled. Export of rMSW was (and still is) allowed to Bozen because the area of waste generation belongs to the Trentino – South Tyrol Region. This Region is considered an optimal territorial context for an integrated rMSW management system. Moreover, in Italy the Environmental Ministry fosters the use of the rate of the waste-to-energy plants' capacity not yet exploited also through rMSW import from nearby regions. This strategy is subjected to a quick evolution depending on the contracts in force (the amount of waste accepted at the Bozen plant from Trentino can vary year by year). This situation is an example of optimisation of the exploitation of existing plants; however, that does not solve the overall problem of rMSW management in Trentino. The ongoing technical-scientific discussion concerns the final step of the waste management: waste to energy or landfilling? The discussion is particularly interesting because presently the amount of rMSW to be managed could be lower than the one suitable for an economically sustainable conventional solution. The final decision cannot be known in time for being part of this paper.

The Province of Trento has 130 waste collection centres (suitable for all recyclable materials), 15 zonal collection integrated centres and 9 transfer stations. These last ones allow for economic optimisation of the waste transportation thanks to an increase in the dimensions of the trucks involved [26]. The collection of rMSW is made kerbside in half of the communities. In the other ones it is done with closed (locked) street bins except one (that adopts an open street bin). The results obtained thanks to the introduction of the punctual tariff can be seen in Fig. 1 in terms of a SC increasing from 12 % to around 77 % in only two decades; meantime, from Fig. 1 it is possible to depict a rMSW decreasing to less than 100 kg inh^{-1} y^{-1}. This trend shows a consistent improvement of the management system (i.e. a significant reduction of rMSW).

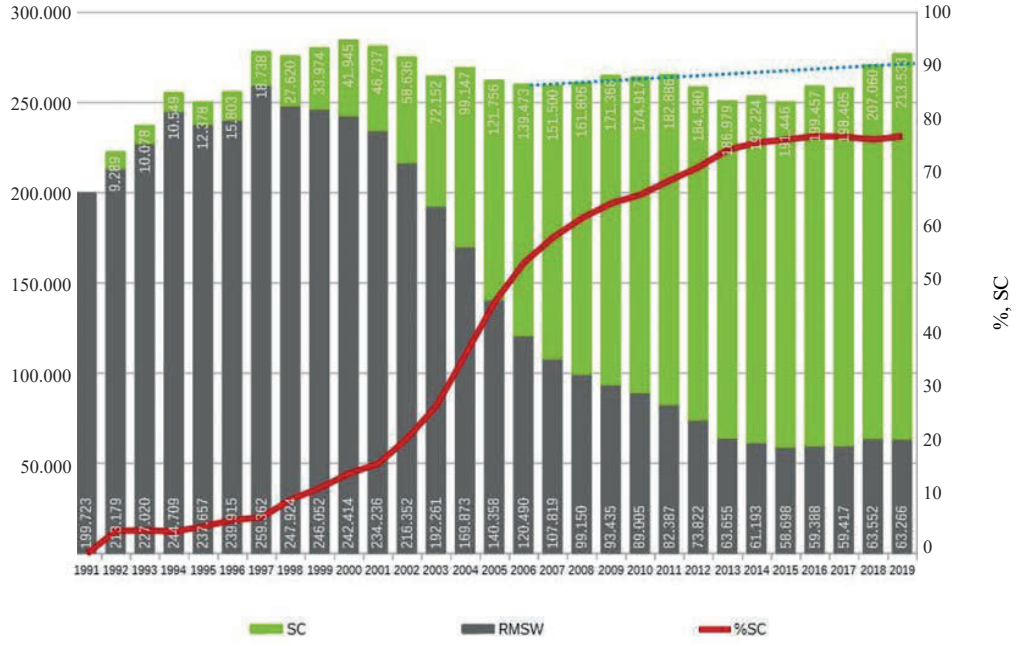

Fig. 1. rMSW production and SC trend in the last 3 decades in the Province of Trento (before pandemic).

The collected streams' quality control is systematically coupled with a manual approach. This required specific attention to both SC streams and rMSW composition, emphasizing the criticalities towards SC streams of food waste and light packaging.

Food waste impurities decreased down to few percentage points. This reduction most probably reflects the effect of communication strategy to the citizens concerning the importance of the quality of source separation. Moreover, users know that the staff involved in kerbside collection can easily check the quality of source separation of this and other waste streams randomly. Concerning rMSW, the collection system is based on the use of a plastic bucket with a lid, available for each user involved (i.e. household): thus the mistakes made in separation can be easily detected, recorded an sanctioned in the tariff; indeed, after a certain number of reiterated mistakes, a fine can be applied.

A controversial situation emerged when a strategic substitution of plastic bags, vessels, and cutleries with biodegradable products was implemented to avoid non-biodegradable packaging. The problem emerged when the facility manager of the local composting plants, including schemes of anaerobic digestion and post-composting, verified that the lasting of the biodegradation process at the industrial plant was shorter than the lasting of the lab tests used for classifying the products as biodegradable. In other words, biodegradable products might not be degraded in time if the optimization of the real scale process allows for highly reduced time. There is here a need to re-calibrate the approach acting on the lab test requirements and on modifications of some stages of the process at the facilities.

About 33 % of light packaging is discarded after treatment before recycling processes that separate valuable and mixed streams (these ones often sent to energy recovery). From a technical point of view, the separation of high value packaging (e.g., PET, HDPE, aluminium cans, etc.) can be performed efficiently. Moreover, the use of a user-linked bar code on the plastic bags adopted to handle this stream limits the mistakes (as bags are transparent for control purposes and the bar code allows finding who makes a mistake). Thus, the main issue relates to the presence of low-value plastic packaging and its fate.

The rMSW characterization, before the COVID-19 pandemic, has been made seasonally for each community in the Trento's Province, allowing to quantify the presence of recyclable materials in this stream that should be dedicated to non-recyclable materials only. Italy was one the most affected EU countries by COVID-19. During the first pandemic year some specific indications were set connected with MSW management from their collection to their treatment/disposal taking into account also the people involved in all the process [27]. The main problems were related to the management of the protective masks that were intensively adopted for a long period since early 2020 and the amount of packaging in domestic waste caused by the increase of online purchases. In practice, the composition of MSW changed, specifically during the periods of lockdown. A consequence of the risks for workers during the pandemic was the suspension of the rMSW characterization studies that were developed by looking into 33 fractions of materials of interest to understand if and how much recyclable materials still can be found in rMSW (including seasonal changes). However, this approach based on intensive rMSW characterisation should be adopted everywhere to calibrate CE strategies. In this case study, this approach allowed to point out a surprising high percentage of diapers in the rMSW.

In Fig. 2 the municipalities that belong to the second case-study are reported. The collected rMSW is sent to three thermal plants in the provinces of Varese, Milan and Bergamo (40 %), to the Varese landfill, the Varese transfer station, and pre-treatment plants.

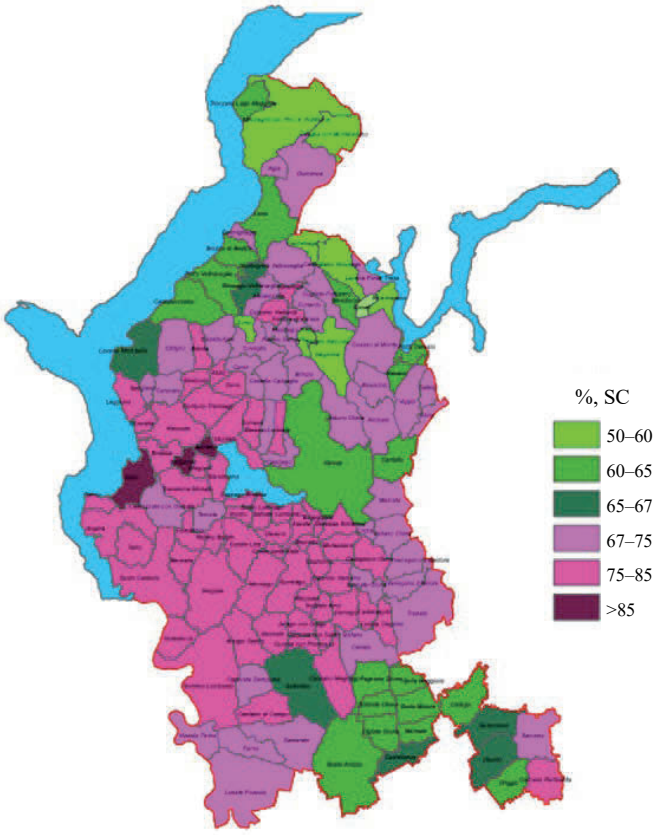

Fig. 2. Municipalities in the Province of Varese and SC in 2018.

The production of MSW for the reported case-study was 475 kg inh^{-1} y^{-1} in 2019; this amount refers to the last pre-pandemic year as the COVID-19 crisis altered the generation of waste in Italy. From the total MSW production, only a very limited percentage is landfilled, as requested from the EU priorities.

Additionally, it must be underlined that the strategy of bottom ash treatment for material recovery from incineration is increasingly adopted in Italy [28], [29] with a consequent decrease of landfill volumes.

Looking at the municipalities close to the main lake of the province of Varese (Fig. 2) it seems that SC in the tourist areas suffers from the arrival of people not used to the local MSW collection system. As a result, SC is often lower than most of the municipalities in the province. It is important to underline that SC exceeds 85 % in three municipalities. That means basically that only non-recyclable materials could/should remain in the rMSW.

However, the minimisation of impurities in SC streams is an issue that cannot be forgotten and is considered a priority in Italy.

Looking at the overall good results of the SC, the local experience demonstrates that incineration is not in conflict with SC. However, incineration remains a controversial point of discussion because often considered a disincentive for households to make a more effective separation.

Fig. 3 shows a slight trend to lower costs of MSW management in the municipalities where SC is higher, but the main parameters that affect the costs are the proximity to the treatment plants and the morphology of the territory (as expected in a mountain area).

From an integrated analysis of the information collected for the two case studies, some useful considerations can be put forward in order to provide guidelines applicable to other similar contexts of MSW and rMSW.

Mountainous areas are more sensible to the presence of treatment plants also for the impact on landscape; adapting this evidence to the analysed contexts, specific guidelines could be drafted:

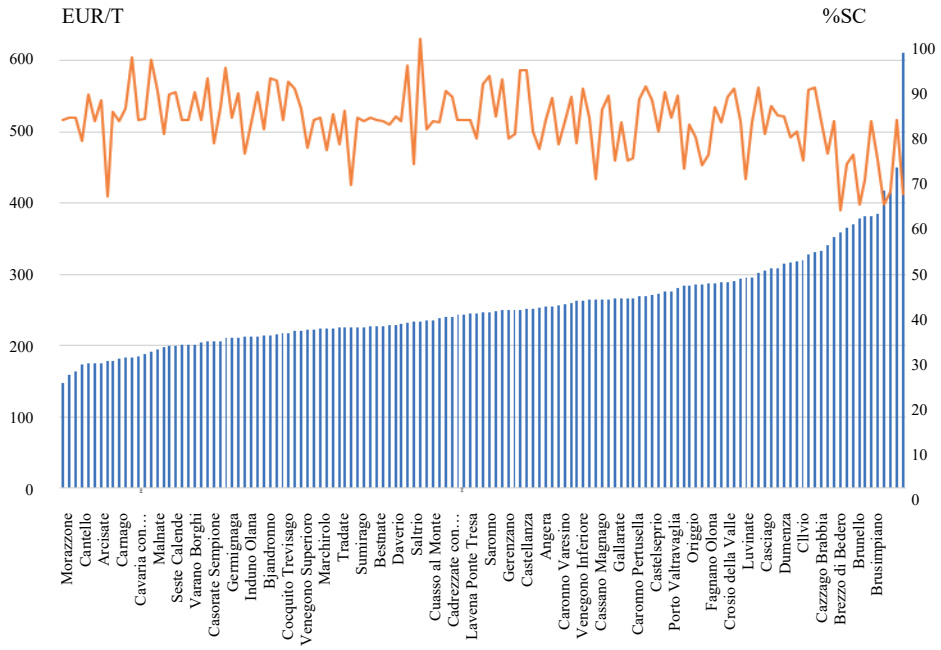

Fig. 3. Specific costs for MSW management at the municipality level and SC efficiency.

- Medium size thermal plants for rMSW (and special waste) can be constructed with a medium height stack;
- Anaerobic digestion plant for source separated food waste (with post treatment of green waste) could have an impact due to the height of the digesters, thus horizontally designed digestor can be a solution;
- Transfer stations are useful in the case of areas with low density of generation of MSW.

In relation to the first proposed aspect, the stack's height affects the dispersion of the off-gas. The lower stack could be compensated by high off-gas velocity and favorable temperature of release.

The second aspect allows for a resulting volume of the plant that gives the impression of a facility not related to the waste sector. A remark could be that food waste treatment plants can have as main problem not so much the skyline but an odorous impact. In reality, the adoption of an anaerobic stage before composting changes the paradigm because such a solution allows for an enhanced control of the odorous substances. This is very important for the acceptability of plants to be located in a mountainous area. Again, the case of the anaerobic digestion plant in Trentino demonstrated it.

The third point could be effective in mountainous areas, where large cities could be unusual (in a few regions). The concept of a transfer station is simple: SC and rMSW collection are organised through the adoption of medium size trucks to allow a penetration of the territory adequate to reach whatever user. When the distance from the zone of collection to the location of the related treatment plant is higher than around 50 km, the minimisation of the transport costs must take into account the option of moving the waste into larger trucks. Transport on train is not viable for complex territories like a mountainous area. A limitation is surely the reduced railways network, but also the limited distances to travel in case of treatment in proximity takes out the train among the viable options.

Concerning incineration in the first case scenario, the delay in the decision provided extended time for scientific studies within territorial universities and research bodies. The related studies [30], [31] demonstrate that a modern combustion plant based on Best Available Techniques, built in a strategically selected site, designed to the local needs, can have a negligible impact also thanks to the possibility of decreasing the authorised values of the pollutants emitted at the stack compared to the regulatory ones.

Another aspect that emerged from the analysis of waste management in the mountainous areas concerns the role of domestic composting. Through this approach, the availability of a composter to be located in the household's garden avoids the kerbside collection of food waste, with a direct benefit on the tariff. From the point of view of SC, the amount of food waste that is used as input of domestic composters is counted as a stream in the overall efficiency. Mountainous areas are more suitable to this option thanks to a lower verticality in the buildings in residential areas.

The analysed scenarios have shown that it is typical to find villages not easily reachable in mountainous areas when kerbside bins must be emptied. To face this criticality, community composting is proposed at the commercial level. However, the critical aspect of very small composting plants is compost quality (conventional approaches can count on continuous, direct control of the process).

Finally, the rural characteristic of some mountainous areas could favour the local use of compost in a sort of zero-km strategy. This is coherent both with the principles of CE and with the limitation of CO_2 emissions from transport.

Summing up, analysis of the two case studies pointed out some strategies that could support the creation of guidelines in EU territories to optimise MSW management in mountainous contexts. Particular attention should be devoted to:

- the treatment capacity of incineration with energy recovery, where correctly designed, does not affect SC efficiency;
- sanitary landfill can be minimized where SC and incineration are well integrated and bottom ash is recycled;
- SRF generation can give flexibility to MSW management (if a market of SRF exists);
- incineration can integrate the treatment of waste from different territories;
- MSW composition and impurities analyses are strategic;
- food waste, when source separated, can be a source for renewable energy generation and not only an input for compost production;
- CE and anaerobic digestion are linked by composting;
- the adoption of the punctual tariff helps in the optimization of the system;
- dissemination of environmental concepts among the population is strategic.

Concerning the specificity of mountainous areas:

- The preservation of landscape can foster lower impacting structures in the waste management plants;

- Transfer stations are strategic in valleys to decrease the cost of waste transport thanks to the change of the typology of trucks;
- Specific studies demonstrate that a modern incineration can be compatible with mountainous areas (when design, authorization pathway and operation are optimized);
- The rural characteristic of some mountainous areas can foster the local use of compost (if high quality is guaranteed);
- The urbanization characteristics in mountainous areas can open to a more extensive adoption of domestic composting.
- In mountainous areas, kerbside collection, compared to conventional street collecton, can allow high SC rates as users are not affected by the territory slopes when they deliver their waste.

4. CONCLUSIONS

The present work demonstrates that SC is the core of a correct MSW management and that kerbside collection is fully compatible with mountainous area. In spite of the complexity of the territory that can be found in mountainous areas, the effiviency reached in the two case studies show that the rMSW stream can be reduced even to one fifth of the amount of MSW generated. Moreover, the administrative fractionation of a territory does not seem to be an obstacle towards a good waste managemen: the above mentioned results concern two provinces with a high number of municipalities. In this frame, the introduction of a punctual tariff of MSW management seems to be strategic as it involves directly the responsibility of the users when performing SC activities. However, other issues remain to be optimized yet even in areas with a developed organization of the sector of waste management:

- In EU, when SC is high, a visible percentage of rMSW is represented by diapers and similar sanitary products; thus, a specific SC could be organized to send this stream to recycling. In reality, problems still remain in terms of SC solutions related to the privacy of the users in case of kerbside collection and the availability of reliable recycling technologies for adopting a CE approach;
- The light packaging stream is only partially managed under the principles of CE because around 33 % of the collected material is discarded during the valorisation treatments and sent to energy recovery; alternatives for switching towards material recovery are expected in the short term as more attention is made today to the sustainable design of the products and to their packaging strategies.
- The presence of tourist fluxes can significantly affect SC efficiency. Thus an additional effort in terms of communication must be made in these cases.

REFERENCES

[1] Rajesh P. Solid waste management- sustainability towards a better future, role of CSR – a review. *Social Responsibility Journal* 2019:15(6):762–771. https://doi.org/10.1108/SRJ-11-2018-0286

[2] Cobo S., Dominguez-Ramos A., Irabien, A. From linear to circular integrated waste management systems: a review of methodological approaches. *Resources, Conservation and Recycling* 2018:135:279–295. https://doi.org/10.1016/j.resconrec.2017.08.003

[3] Choe C., Fraser I. An economic analysis of household waste management. *Journal of Environmental Economics and Management* 1999:38(2):234–246. https://doi.org/10.1006/jeem.1998.1079

[4] Drimili E., *et al.* Public views and attitudes about municipal waste management: Empirical evidence from Athens, Greece. *Waste Management and Research* 2020:38(6):614–625. https://doi.org/10.1177/0734242X20911708

[5] Savastano M., Belcastro M., Dentale F. The role of waste collection centers in a circular economy scenario: An empirical study on the citizens' perception. *Environmental Engineering and Management* 2019:18(10):2181–2192.

[6] De Feo G., De Gisi S. Domestic separation and collection of municipal solid waste: Opinion and awareness of citizens and workers. *Sustainability* 2010:2(5):1297–1326. https://doi.org/10.3390/su2051297
[7] Muri H. I. D. I., Hjelme D. R. Sensor Technology Options for Municipal Solid Waste Characterization for Optimal Operation of Waste-to-Energy Plants. *Energies* 2022:15(3):110. https://doi.org/10.3390/en15031105
[8] Khandelwal H., *et al.* Application of life cycle assessment in municipal solid waste management: A worldwide critical review. *Journal of Cleaner Production* 2019:209:630–654. https://doi.org/10.1016/j.jclepro.2018.10.233
[9] Rada E. C. Effects of MSW selective collection on waste-to-energy strategies. *WIT Transactions on Ecology and the Environment* 2013:176:215–223. https://doi.org/10.2495/ESUS130181
[10] Ignatyeva M., *et al.* How Far Away are World Economies from Circularity: Assessing the Capacity of Circular Economy Policy Packages in the Operation of Raw Materials and Industrial Wastes. *Sustainability* 2021:13(8):4394. https://doi.org/10.3390/su13084394
[11] Khatiwada D., *et al.* Circularity in the Management of Municipal Solid Waste - A Systematic Review. *Environmental and Climate Technologies* 2021:25(1):491–507. https://doi.org/10.2478/rtuect-2021-0036
[12] Fellner J., *et al.* Potential impacts of the eu circular economy package on the utilization of secondary resources. *Detritus* 2018:2:16–23. https://doi.org/10.31025/2611-4135/2018.13666
[13] Rossi J., Bianchini A., Guarnieri P. Circular economy model enhanced by intelligent assets from industry 4.0: The proposition of an innovative tool to analyze case studies. *Sustainability* 2020:12(17):7147. https://doi.org/10.3390/su12177147
[14] Liaskos C., Tsioliaridou A., Ioannidis S. Towards a Circular Economy via Intelligent Metamaterials. *Proceedings of the 23rd IEEE International Workshop on Computer Aided Modeling and Design of Communication Links and Networks, (CAMAD)* 2018:8514986. https://doi.org/10.1109/CAMAD.2018.8514986
[15] Pal M. S., Bhatia M. Challenges and proposed architecture of Municipal Solid Waste in Context of Hilly Terrain Shimla City, India. *Proceeding 2021 International Conference on Computing Sciences, ICCS* 2021:178–182. http://doi.org/10.1109/ICCS54944.2021.00043
[16] Mushtaq J., Dar A. Q., Ahsan N._Physio-chemical characterization of municipal solid waste and its management in high-altitude urban areas of North-Western Himalayas. *Waste Disposal and Sustainable Energy* 2020:2(2):151–160. http://doi.org/10.1007/s42768-020-00040-1
[17] Khaton A. Waste management – A case study in Nepal. *Solid Waste Policies and Strategies: Issues, Challenges and Case Studies* 2020:10:185–196. http://doi.org/10.1007/978-981-15-1543-9_17
[18] ISPRA. Rapporto rifiuti urbani 2022 (Report on municipal solid waste 2022). Rome: ISPRA, 2023. (in Italian)
[19] Ragazzi M., *et al.* Experiencing Urban Mining in an Italian Municipality towards a Circular Economy vision. *Energy Procedia* 2017:119:192-200. https://doi.org/10.1016/j.egypro.2017.07.068
[20] Rada E. C., Zatelli C., Mattolin P. Municipal solid waste selective collection and tourism. *WIT Transactions on Ecology and the Environment* 2014:180:187–197. https://doi.org/10.2495/WM140161
[21] Ranieri E., *et al.* Municipal solid waste management in Italian and Romanian tourist areas. *UPB Scientific Bulletin, Series D: Mechanical Engineering* 2014:76(2):277–288.
[22] Trento Municipality (TM). 2020. [Online]. [Accessed 15.03.2023]. Available: https://www.comune.trento.it/Aree-tematiche/Ambiente-e-territorio/Rifiuti-urbani/Gestione-integrata-rifiuti/Raccolta-differenziata (in Italian)
[23] Hannan M. A., *et al.* Radio Frequency Identification (RFID) and communication technologies for solid waste bin and truck monitoring system. *Waste Management* 2011:31(12):2406–2413. https://doi.org/10.1016/j.wasman.2011.07.022
[24] Rada E. C., *et al.* Web oriented technologies and equipments for MSW collection. *Proceedings of the International Conference on Risk Management, Assessment and Mitigation* 2010:150–153.
[25] Provincia di Varese. Piano Provinciale per la Gestione Integrata dei Rifiuti ai sensi della L.R. 26/03 (Integrated Waste Management Plan from 26/03). Varese: PV, 2010. (In Italian)
[26] APPA. 5° aggiornamento del Piano Provinciale per la gestione dei rifiuti urbani (5th updating of the Provincial Plan for municipal solid waste management). 2022 [Online]. [Accessed 15.03.2023]. Available: https://www.appa.provincia.tn.it/Documenti-e-dati/Documenti-tecnici-di-supporto/5-aggiornamento-del-Piano-provinciale-di-gestione-dei-rifiuti-rifiuti-urbani (in Italian)
[27] Ragazzi M., Rada E. C., Schiavon M. Municipal solid waste management during the SARS-COV-2 outbreak and lockdown ease: Lessons from Italy. *Science of the Total Environment* 2020:745:141159. https://doi.org/10.1016/j.scitotenv.2020.141159
[28] Stabile P., *et al.* Vitrification treatment of municipal solid waste bottom ash. *Waste Management* 2019:95:250–258. https://doi.org/10.1016/j.wasman.2019.06.021
[29] Iadarola M., Bareschino P., Pepe F. Management of Hazardous By-products of Urban Waste Incineration: Some Considerations on the Italian Situation. Environmental Geochemistry. 2nd Ed. Elsevier, 2018:363–376. https://doi.org/10.1016/B978-0-444-63763-5.00014-8
[30] Schiavon M., *et al.* Integrated methodology for the management of human exposure to air pollutants. *WIT Transactions on Ecology and the Environment* 2019:236:287–296. https://doi.org/10.2495/AIR190281
[31] Ragazzi M., *et al.* Potentials of the waste-to-energy sector for an unconventional district heating system. *International Journal of Energy Production and Management* 2019:4(2):115–123. https://doi.org/10.2495/EQ-V4-N2-115-123