
Evaluation of the introduction of separate collection systems for organic waste and cardboard in Tulkarem

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“EVALUATION OF THE INTRODUCTION OF SEPARATE COLLECTION SYSTEMS FOR ORGANIC WASTE AND CARDBOARD IN TULKAREM” – OCTOBER 2017

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Executive summary

The main goal of the “Green Tulkarem Project” (AID 010147/CESVI/TOC) was the improvement of life quality and hygienic conditions in the Governorate of Tulkarem through the empowerment of the local institutions responsible for waste management, the promotion of campaigns to raise people’s and scholars’ environmental awareness and the rehabilitation of two illegal landfills.

In particular, “Green Tulkarem Project” introduced separate management of organic waste and cardboard, with different collection methods: big producers of vegetable waste were identified and provided with containers of different sizes; cardboard collection was carried out through street containers (steel cages). A population of 90,000 people (PCBS, 2016) lives in the area involved, considering the city of Tulkarem, Nur Shams Camp and the villages of Deir Al Ghousun and Anabta.

Results of this study, performed in February – March 2017, are summarized as follows:

- **Environmental impacts:** Daily amounts of fractions separated account for 1.41 t/d of organic waste and 3.35 t/d of cardboard (almost 50% of organic and cardboard produced in the target area). Separate collection accounts for 5% of MSW collected in the Governorate. The engagement of collection workers and merchants leads to a high quality of the separated organic fraction (less than 1% of contaminants). In terms of climate change and greenhouse gases emissions, the environmental impact of separate collection and treatment of cardboard (0.06 tCO₂^{eq}/t) and organic waste (0.27 tCO₂^{eq}/t) is considerably smaller than final disposal to the landfill (3.9 tCO₂^{eq}/t).
- **Economical impacts:** Waste management costs for cardboard (218 NIS/t) and organic waste (321 NIS/t) are higher than MSW management costs (186 NIS/t). The costs related to the collection of the organic waste are higher because the compactor truck covers a higher distance to collect less waste if compared with MSW and cardboard routes. Collection costs for cardboard are covered almost entirely by the enterprise performing the collection, with savings for the JSC ranging from 57 NIS/t to 174 NIS/t.
- **Social impacts:** High levels of awareness and engagement have been reached within the project. The project resulted in higher standards of hygiene and comfort for final users (merchants, public workers, citizens) and reduced costs for the Municipality. The prosecution of the project is expected.

Recommendations

An interruption of the separate collection service, with reference to both organic waste and cardboard, could affect seriously the feasibility of future similar projects, leading to a reduced faith in institutions promoting these initiatives. In order to avoid consequences, criticalities affecting the future development of the project should be tackled.

- **Municipalities should work with JSC to establish a new tariff system** in order to cover MSW management costs; proportion between the amount of produced waste and tariffs will guarantee more equity.
- **JSC can reduce costs of organic waste collection through the choice of a smaller collection vehicle**, as the compactor truck is not appropriate for long distances and small amounts of waste.
- **A decentralized management of organic waste appropriate for the rural context of Tulkarem could be evaluated** to reduce both the amount of waste reaching the landfill and the need for collection and transfer
 - e.g. identifying one area for Alsha’rawiya and one area for Wadi Alshæer for decentralized composting
 - decentralized composting can be operated by local communities or Municipalities
- **A clear balance sheet should be done**, including incomes and expenses from all partners involved in the project (JSC, Municipalities, and private companies), to evaluate the actual distribution of service costs and pursue a better relationship between waste management system actors and users
- **JSC should improve its data management system** in order to perform faster analysis
 - e.g. the technician can work together with an IT expert for a short period in order to rectify technical concerns of the database (incoherent structure, presence of duplicated items) and introduce analysis tools
- **JSC should organize trainings for collection workers about job safety and sanitary and environmental aspects**, as they appear scarcely concerned about potential risks.
- **A campaign oriented to manufacturing companies on appropriate waste management and disposal** will contribute reaching better levels of separation, and also create the basis for the separate collection of other fractions, such as plastic or metal.

1 Introduction

“Green Tulkarem Project” (AID 010147/CESVI/TOC) had as its main goal the improvement of life quality and hygienic condition in the Governorate of Tulkarem. This goal was pursued through the empowerment of the local institutions responsible for waste management, the promotion of campaigns to raise people’s and scholars’ environmental awareness and the rehabilitation of two illegal landfills.

Occupied Palestinian Territories are similar to low-income countries regarding the economic difficulties in providing basic services, but suffer also limitations on people movements, supply of goods and land control due to the political situation.

Waste management is critical as it deals with both land availability, health protection and the safeguard of environmental resources and landscapes.

2 Study site

The project involved the Municipality of Tulkarem, in the north of Occupied Palestinian Territories, and ten neighbouring villages (‘Attil, Deir Al Ghousun, Qaffin, ‘Illar, Al Sharquiywa, Iktaba, Anabta, Kafr al Labad, Beit Lid and Bal’a). This area has a population of 152539 inhabitants (PCBS, 2016) and is characterized by an agricultural vocation.

The "National Strategy for Solid Waste Management in the Palestinian Territory 2010-2014", promoted by the National Palestinian Authority, is the reference framework for waste management. Waste management services are currently guaranteed on the 60% of the Palestinian territory, also thanks to the international support. However, problems like the low quality of services, illegal transfers and final disposal, uncontrolled dumping or “open burning” are still common.

The improvement of waste management through both a more effective collection and virtuous practices such as reuse and recycling is a strategic goal, and it has to cope with gaps in financial and technical expertise and the lack of awareness among the population.

2.1 SWM System in Tulkarem

Formal Solid waste management (SWM) system in West Bank involves two main actors: Joint Service Councils for Solid Waste Management (JSCs-SWM) and Municipalities. JSCs are semi-governmental authorities designated for waste management; waste collection and transfer can be provided by both JSCs and Municipalities while the final disposal is always guaranteed by JSCs.

In the Governorate of Tulkarem waste is disposed to the landfill of Zahret Al-Finjan, with an overall capacity of 2.9 millions square meters. JSC Wadi Shaer (hereafter indicated as JSC) provides waste transfer from the Transfer Station (TS) of Wadi Shaer to Zahret Al-Finjan.

JSC performed waste collection on the behalf of Municipalities with some relevant exceptions: in some cases municipalities collect and transfer waste directly to Zahret Al-Finjan (Attil, Illar, Baqa Al Sharquiywa and Qaffin); in other cases, they collect the waste by their own (Bal’a) or in collaboration with JSC (Tulkarem and Anabta), but the waste goes through the TS before reaching Zahret Al-Finjan.

Several trucks are available for collection and final transport of waste. Collection is organized through street containers ranging from small (0.04 m³ - 0.4 m³) to big (1.1m³ – 7m³) size. In 2014 the installed capacity was 2612.68 m³ (Filippini, 2014). Collection frequencies are different in Tulkarem (7-12 daily trips on different routes, partially overlapped) and within the villages (daily or weekly collection).

2.1.1 Solid waste collection in the Governorate of Tulkarem

Data on collected waste going through the TS are available since 2014, thanks to the weighbridge installed at the TS. Data for Attil, Illar, Baqa Al Sharquiyya and Qaffin result as an estimation based on available information (Filippini, 2014) (Tab. 1).

MSW collected in the Governorate of Tulkarem (t/year) : 2014-2017

Year	2014	2015	2016	2017
MSW managed by JSC through the Transfer Station (1)	41,400	42,553	43,969	5,531
* MSW destined for disposal in landfill (collected by the JSC)	13,634	13,179	12,680	2,116
* MSW destined for disposal in landfill (collected by Municipalities)	27,766	29,285	30,937	3,232
* Separate collection of organic	0	89	306	45
* Separate collection of cardboard	0	0	46	138
MSW managed by other actors	9,360	11,552	12,760	1,575
* Villages in the project (Attil, Illar, Baqa Al Sharquiyya, Qaffin) (2)	9,360	11,552	12,760	1575
* Other villages	N.A.	N.A.	N.A.	N.A.
Total	50,760	54,104	56,729	7,106
* Rate of separate collection of organic on MSW Collected	-	0.16%	0.54%	0.63%
* Rate of separate collection of cardboard on MSW Collected	-	-	0.08%	1.94%
* Rate of separate collection on MSW Collected	-	0.16%	0.62%	2.58%

(1) Database JSC-SWM

(2) Estimation on 2014 values (Filippini, 2014; Villa, 2017)

Tab. 1: MSW collected in the Governorate of Tulkarem (t/year): 2014-2017

Any assumption on the amount of waste generated in the Governorate based on the collected amount is risky (UN-HABITAT, 2010) due to the lack of data on informal collection and improper disposal. In this case the best choice is to refer to the collected waste amounts rather than those generated.

2.1.2 MSW characteristics

Considering an amount of 139 t collected daily in the whole Governorate of Tulkarem, the amount of organic waste is estimated in 64 t/d (46%), while cardboard and paper account for 20.8 t/d (15%). “Green Tulkarem” project was supposed to address big producers, which were mapped in 2014. The survey performed on 320 out of 491 production spots (markets, shops, universities and schools, plants, farms, nurseries) leads to an estimated recoverable-recyclable potential of 4.74 t/d of organic waste and 3.5 t/d of cardboard. Data are summarized in Tab. 2.

Project baseline for Green Tulkarem project

Project baseline for Green Tulkarem project						
Daily collected MSW in the Governorate of Tulkarem (2014) (1)				139.07	t/d	
Daily collected MSW in the Municipality of Tulkarem (2014) (1)				64.11	t/d	
Fraction	MSW composition in the Governorate of Tulkarem (Hamadah, 2011)	Estimated daily production for each fraction (t/d)				
		MSW (2)		Waste from big producers (2014) (3)	Cardboard collection in the Municipality of Tulkarem (4)	
		Governorate of Tulkarem	Municipality of Tulkarem			
Organic	46.00%	63.97	29.49	4.74	-	
Plastic	11.70%	16.27	7.50			
Cardboard	11.00%	15.30	7.05	3.5	3.55	
Paper	4.00%	5.56	2.56			
Wood	4.40%	6.12	2.82			
Glass	4.30%	5.98	2.76			
Metal	5.50%	7.65	3.53			
Tissue	9.00%	12.52	5.77			

(1) Estimate (Database JSC-SWM, 2017; Filippini, 2014)
 (2) Estimate based on MSW composition (Hamadah, 2011)
 (3) “Green Tulkarem” project survey on big producers in the Governorate of Tulkarem (Vitali, 2014)
 (4) Interview to the informal cardboard collector (Zambetti F., 2015)

Tab. 2: Project baseline for Green Tulkarem project

2.2 “Green Tulkarem” project

Solid waste management in Tulkarem is performed by JSC and Municipalities. Until 2014, SWM involved only general waste collection and transfer to Zahret Al-Finjan landfill, with very high costs.

“Green Tulkarem” project introduced separate management for organic waste and cardboard, with different collection methods. Concerning organic waste, big producers of vegetable waste, such as markets and greengrocers, were identified and provided with containers of different sizes, while cardboard collection was carried out through street containers (steel cages) located in defined collection points. A population of 90,000 people (PCBS, 2016) lives in the area involved in “Green Tulkarem”, considering the city of Tulkarem, Nur Shams Camp and the villages of Deir Al Ghousun and Anabta.

“Green Tulkarem” project provided equipments (such as cardboard and organic waste containers, 13 m³ compactor trucks, a shredding machine and a cardboard compactor machine), support to local managers and technicians from JSC and Thinnabeh cooperative, an awareness campaign about environmental issues addressing the whole community. At the same time, also the rehabilitation of two landfills was done.

2.2.1 Organic waste separate collection

At the initial stage, production centres for organic waste (such as markets and vegetables shops) located in Tulkarem and villages were mapped.

After this stage, “Green Tulkarem” project was expected to follow a five steps set-up, through the choice of significant areas for each urban typology (central urban areas, suburban areas, agricultural areas, refugee camps, villages). For each area a pilot was expected, in order to choose the most appropriate waste collection system. After testing the first two areas, which required more time than expected, collection was extended to the whole Municipality of Tulkarem (November 2015) and to villages (February 2016). Agricultural areas and refugee camps were excluded, as agricultural waste is autonomously managed by producers and camps are managed by UNRWA.

The final set-up of the project was defined after one year, covering Tulkarem, Deir Al Ghousun and Anabta; farthest villages were excluded due to economical considerations (the waste amount did not justify the covered distance).

The design of the system has been achieved through interviews and inspections. Thanks to this approach, users and collection workers needs have been recognized, leading to an increase of the installed volume and the creation of a waste separation area in each market. The existing use of vegetable waste for animal feeding was identified as a virtuous behaviour. Some issues, such as the lack of attention from both users and collection workers (which resulted in containers damaging and improper waste disposal), were targeted.

Once tested different options the final system of waste collection is described as follows.

The collection is carried out once per day, in the evening (17-21), with a 13 m³ compactor truck run by a driver and two collection workers.

Different operative procedures have been applied. Small shops keepers have a 75L container which has to be located outside the shop following a planned timetable to be emptied by the JSC (kerbside collection). Shops located within markets have also their own small container, which is emptied by a municipal worker in bigger containers (240L) located in the external waste separation area, accessible to JSC collection workers (Fig. 1).



Fig. 1 Waste containers in the Main market: (a) single user bin, 75 L (b) big containers outside the market, 240 L

Organic waste is then transferred to Thinnabeh cooperative to be treated and composted. The shredding machine can treat organic waste with a maximum diameter of 8 mm and is composed by two conveyor belts (run by two engines of 5.3 kW each) and the shredder itself (22kW). The shredding machine has a load capacity of 2.5 t/h, but it works with an average load of 1 t/h of organic waste. Operative interruptions occur due to an irregular power supply. Whilst adverse weather conditions (rain and wind) during the winter can obstacle operations, from March till December waste is treated every two days.

2.2.2 Cardboard separate collection

Before the project started, cardboard collection was performed by an informal family-based enterprise, which runs also a small treatment station. Cardboard was sold to an Israeli company through a middle-man living in a settlement.

In the frame of “Green Tulkarem” project, an attempt to include the informal actor in the collection system run by JSC was undertaken, but it failed abruptly due to a fire which destroyed the treatment station. Subsequently, the public call for the cardboard collection service was won by a formal company, which covers the collection costs (driver and collection worker salaries, fuel) and is still selling cardboard to the Israeli company.

The compactor truck collects cardboard every day, following two different routes: Tulkarem and Deir Al Ghousun; Tulkarem, Kafr Al Labad and Anabta. After the collection, cardboard is transferred to the Transfer Station and treated with a compactor machine, which produces cardboard bales of approximately 500 kg. The load capacity of the machine is 1600 kg m³/h, with an installed power of 1.2 kW.



Fig. 2 Emptying of a cardboard steel box performed by a collection worker

3 Methods

Results of “Green Tulkarem” project and changes introduced in the existing waste management system have been analyzed from environmental, economical and social points of view.

In order to perform a coherent comparison it has been important to identify the different management procedures for each stream:

- **MSW** is collected by the Municipality or the JSC, go through Wadi Shaer TS and are transferred and finally disposed at Zahret Al-Finjan landfill.
- **Organic waste** is collected by the JSC (with a 13 m³ compactor truck), weighted in the TS, moved to Thinnabeh cooperative, treated with the shredder and composted.
- **Cardboard** is collected by the JSC (with a 13 m³ compactor truck), stored in the TS, where it receive a first treatment with a pulper and a compactor. No information is available about following stages.

3.1 Environmental analysis

3.1.1 *Quality of separate collection*

The quality of collected organic fraction has been studied through the characterization of organic fraction, performed in Thinnabeh cooperative the day following the collection. The influence of weather conditions has been taken into account in the agenda setting.

Following categories has been used:

- Organic fraction: vegetable waste from markets, greengrocers and vegetable plants.
- Contaminants: glass, metal, tissue, cardboard, paper, aluminium, plastic, waste of animal origin, WEEE, liquids, wood, construction and demolition waste, health care waste, others.

A visual assessment of the quality of collected cardboard has been done during the inspection tour on the compactor truck.

3.1.2 *Separate collection and quantitative impact on MSW streams*

An evaluation of the quantitative impact of separate collection on MSW streams is needed in order to understand the amount of waste successfully diverted from landfill disposal to recycling and

composting. Several levels have been taken into account: the amount of waste collected in the whole Governorate, the amount of waste collected in the project area and the estimate production of organic waste and cardboard by markets, shops and commercial activities addressed by the project. The project area changed from the beginning of the project, so results have been compared with variable amounts.

3.1.3 Collection routes

Different routes have been identified for organic waste and cardboard collection. Each route has been followed and tracked within an inspection tour, and collection points have been mapped with the GPS.

3.1.4 Installed capacity for separate collection

Plastic containers for organic waste and steel boxes for cardboard collection have been located in Tulkarem and in several villages within the project. Installed capacity for organic waste has been assessed using a bulk density of 338 kg/m³ (WRAP, 2009; Chandrappa and Das, 2012). Bulk density of MSW is assumed to be 234 kg/m³ (Al-Khatib, 2010).

3.1.5 Greenhouse gases emissions

A comparison between MSW, organic waste and cardboard management procedures, concerning greenhouse gases emission, has been done. Greenhouse gases emission in terms of carbon dioxide equivalent (CO₂^{eq}) considering a time span of 100 years has been calculated using simplified mass balances, resumed as follows:

- **Fuel consumption.** Collection and transfer to the landfill implicate fuel consumption for operating trucks. Fuel consumption (diesel, with a density of 0.832 kg/L) for collecting and transferring one tonnes of waste has been calculated for each stream (MSW, organic waste, cardboard). The following stoichiometric equation has been used for combustion: $4 C_{12}H_{23} + 71 O_2 \rightarrow 48 CO_2 + 46 H_2O + \text{energy}$
- **Power consumption for electromechanical equipments.** Shredding machine and compactor machine consume electricity. Nominal power for each of equipments is known. Operating hours have been calculated considering the load capacity of each of equipments. CO₂^{eq} emissions for electric kWh depend on the energy mix: for the Middle East this value is assumed to be 205.76 gCO₂/kWh (IEA, 2017).
- **Composting.** CH₄ and N₂O emissions from the biological treatment of 1 kg of waste are assumed to be 4 g CH₄/kg and 0.24 g N₂O/kg (IPCC, 2006). GWP₁₀₀ (Global Warming Potential over 100 years) used for the conversion to CO₂^{eq} emissions is 25 for methane and 298 for nitrous oxide.
- **Landfill disposal.** Waste disposed in a landfill provokes biogas emissions, which have been calculated using literature values (Sirini et al., 2010). In Zahret Al-Finjan the biogas is not treated and goes entirely to the atmosphere. For following calculations biogas is assumed to be composed by 50% CH₄ (with a density of 0.72 kg/m³) and 50% CO₂ (with a density of 1.98 kg/m³) (De Feo et al., 2012).

3.2 Economical analysis

Items of income and expense have been identified for each management procedure. Fuel consumptions have been estimated using daily logs provided by the JSC and interviews. Personnel costs have been estimated on data provided by the JSC and attributed to the amount of collected waste. Energy consumption costs for the shredding machine have been estimated in 80 NIS/month

(considering 25.5 t of organic waste treated each month in 2016); no data were available about the operation of the compactor machine for cardboard. Maintenance and administration costs have been deduced on the basis of JSC balance for 2015: maintenance costs are 18.4 NIS/t and administration account for 7.4% of total collection costs.

Tariff system for the Governorate of Tulkarem has been analyzed. Municipalities ask 204 NIS/year to households and 260-630 NIS/year to non-domestic consumers to cover collection expenses. JSC receives a quota from the Municipalities depending on the service provided: 71 NIS for each tonne of waste transferred to Zahret Al-Finjan and between 135 and 170 NIS for each tonne of collected and transferred waste. For each tonne disposed to Zahret Al-Finjan, the JSC pays a fee to the JSC Jenin (33 NIS/t).

Finally, market values for secondary raw materials have been assessed: 348 NIS/t for compost, 420 NIS/t for paper and 360 NIS/t for cardboard. Values for cardboard and paper must be decreased of a 25% due to water added during treatment phases.

3.3 Social analysis

“Green Tulkarem” project is having a social impact on awareness and behaviours of the community.

The effectiveness of waste management actions is strongly influenced by stakeholders’ and people’s engagement, which has to be investigated.

Thirteen interviews have been done to subjects directly involved in the project, such as JSC’s workers and managers, Municipality’s officials and operators, workers of Thinnabeh composting station, shop keepers. Interviews have been qualitative and semi-structured, with open-ended questions, trying not to provide answer options. Following aspects has been questioned: role and level of the engagement, degree of satisfaction, needs and suggestions, future perspectives. English and Arabic languages have been used, with the local technical officer of the project acting as interpreter.

4 Results

4.1 Environmental analysis

4.1.1 *Quality of separate collection*

The characterization of the organic fraction has been repeated four times on the whole amount of collected organic waste, resulting in a percentage of contaminants smaller than 1%. This result has been reached thanks to the awareness activities addressing shop keepers and merchants, and the engagement of collection workers, which actively contribute to a good collection picking up nylon and other contaminants from the waste.

4.1.2 *Separate collection and quantitative impact on MSW streams*

“Green Tulkarem” project introduced separate collection of organic waste in 2015, while data on cardboard separate collection are available since September 2016.

The project went through three phases involving only Tulkarem in a first moment (hereafter called “Tulkarem area”), Tulkarem and planned villages (“design area”) in a second phase and only Tulkarem, Anabta, Deir Al Ghousun and Attil (“final set-up area”) at the end of the project. Consequently, results of the project can be described taking into account the amount of MSW collected in areas actually involved in the project, on a monthly basis, as shown in Fig. 3.

Collected organic waste during the project has been stationary around an average value of 24

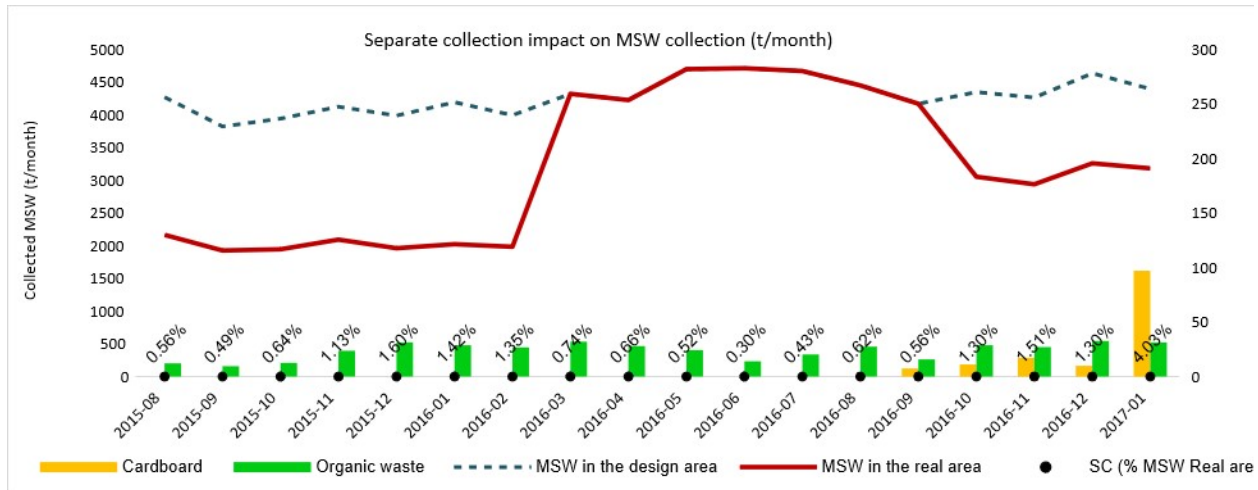


Fig. 3 Separate collection (SC) impact on MSW collection (t/month)

t/month. In the period when the design area was covered, the average value was 23 t/month, while in the final set-up a result of 30 t/month was reached. This result justifies the decision to resize the collection area following economical considerations which will be discussed in the following section.

On a daily basis, results for organic waste are shown in Tab. 3.

Organic waste collected daily		
	Average (t/d)	Variation (%)
2015	0.72	-
2016	1.08	50.77%
2017	1.41	30.16%
August 2015 - February 2016	0.84	-
August 2016 - February 2017	1.24	48.35%

Tab. 3: Daily amount of collected organic waste and variation in the effectiveness of the collection

Organic waste production is not only influenced by the collection area, but also by seasonal variability and progressive increase of the effectiveness of the project. Comparing similar periods (August-February) in consecutive years allows focusing on the increment of effectiveness (48%).

Considering cardboard, the JSC started cardboard collection in September 2016, reaching 97.2 t/month in January 2017. Similar results were reached by the informal collector (Zambetti, 2015). In September, an average of 1.86 t/d were collected, while in January a daily amount of 3.35 t/d was reached, with an increment of 80% in 5 months.

Performances of separate collection are shown in Fig. 4. Impact of separate collection on MSW streams is evaluated on daily basis.

In 2017, the daily average value of MSW collected in the Governorate of Tulkarem was 162 t/d, while daily amounts for separate fractions account for 1.41 t/d of organic waste and 3.35 t/d of cardboard. The resulting impact of separate collection on the whole SWM system of Tulkarem is a

reduction of 3% of waste disposed to Zahret Al-Finjan landfill. In the final set-up area the amount of collected MSW was 104 t/d, so the impact of separate collection reached the 5%.

The actual impact of separate collection should be calculated taking into account the real boundaries of the collection system. Cardboard collection has been organized as a street collection. A term of reference can be the amount of cardboard and paper (15%) inside MSW collected in the final set-up area (17 t/d estimated), so the project is currently intercepting the 23% of the potential production. The target value of the project (3.5 t/d) has been almost reached.

While the overall production of organic waste was calculated in 48 t/d (46% of MSW collected in the final set-up area), the target value was estimated in 4.74 t/d, considering only markets and shops. The value of 4.74 t/d included also organic waste from animal sources (such as bones, skins, etc.), which cannot be treated by Thinnabeh cooperative for safety reasons, and vegetable waste which is currently given to farmers for animal feeding. The reference value has been consequently reduced to 2.9 t/d, which is currently intercepted by the project at 49%.

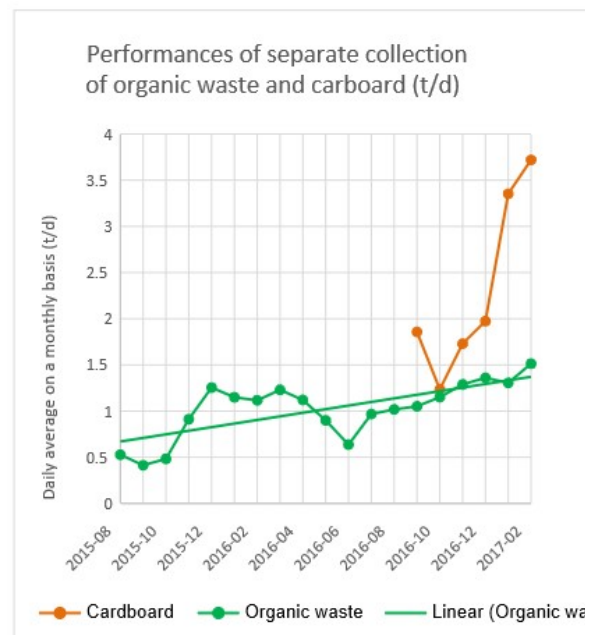


Fig. 4 Performances of separate collection

4.1.3 Collection routes

The truck performing the organic waste collection follows a single route (Anabta, Deir Al Ghousun, Attil, Tulkarem) which include also the weighting in the Transfer Station, before reaching the Thinnabeh cooperative (with a total length of 50 km) (Tab. 4, **Errore. L'origine riferimento non è stata trovata.**). Collection points are few (30) and collection operation requires little time (less than 3 hours). Cardboard is collected following two different routes (Deir Al Ghousun and Tulkarem; Anabta, Kafr Al Labad and Deir Al Ghousun) with almost the same length (37 km). Cardboard collection requires more time (almost 7 hours). This is due to the high number of collection points (95), but also to the complexity of collection operation (each box has to be manually emptied, cardboard can be spread around or has to be selected from general waste containers). This time include also a break of half an hour for workers' rests.

	Organic and cardboard collection routes		
	Organic	Cardboard	
		Tulkarem + Deir Al Ghousun	Anabta + Kafr Al Labad
Distance	49.9 km	36.9 km	15.8 km
Trip duration	2:48 hours	7:12 hours	2:37 hours
Running time	1:58 hours	2:36 hours	0:56 hours
Dwell time	0:50 hours	4:36 hours	1:41 hours
Collection points	30	95	

Tab. 4: Organic and cardboard collection routes: distances, trip durations, running times, dwell times and number of collection points for each route

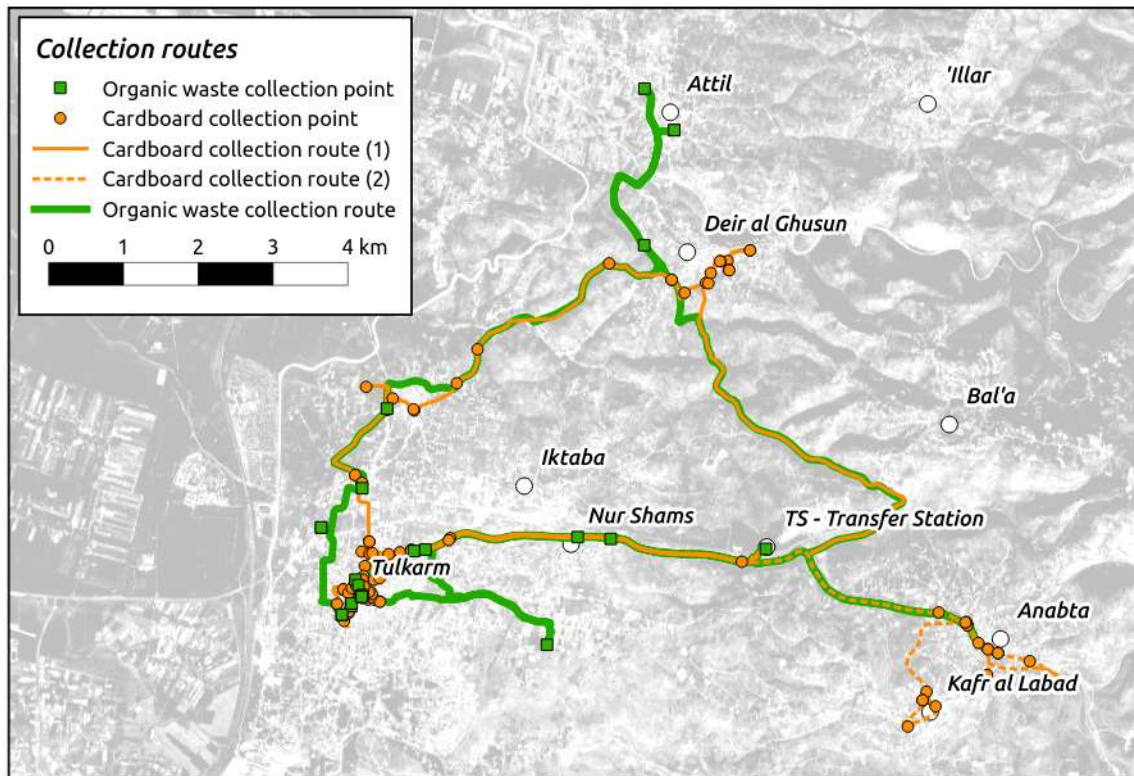


Fig. 5 Collection routes and collection points for the organic waste and cardboard

4.1.4 Installed capacity for separate collection

The total installed capacity for organic waste was 13.9 m³, of which the 68% was located in Tulkarem and the 10% was located in Anabta, Deir Al Ghousun and Attil. Collection area was resized due to economical reasons, with a remaining final capacity of 10.95 m³ (3.7 t). Containers placed inside markets reach a total capacity of 3.1 t, but collection workers collect waste directly from external containers, which account for 2.3 t. This means a residual capacity which can be still exploited, for example locating more containers in the waste separation area.

4.1.5 Greenhouse gases emissions

Greenhouse gases emissions in terms of carbon dioxide equivalent (CO₂^{eq}) are different for each waste stream procedure and account for 3905554 gCO₂^{eq}/t for MSW, 270699 gCO₂^{eq}/t for organic waste, 60735 gCO₂^{eq}/t for cardboard. Concerning cardboard, the lack of information related to treatment and transport stages leads to an underestimate.

4.2 Economical analysis

Average costs for managing one tonne of MSW (collected and transferred to Zahret Al-Finjan – CT; simply transferred - T), organic waste or cardboard have been calculated.

Concerning only the collection phase, daily logs provided by the JSC and measured lengths of cardboard and organic waste collection routes consent to calculate the average distance, cost and fuel consumption referred the collection of one single tonne of waste. Results are resumed in Tab. 5.

Collection details for each stream of waste				
	km/trip	km/t	L/t	NIS/t
MSW	77.9	15.2	7.20	40.04
Organic	49.9	48.3	36.52	202.98
Cardboard	36.9	20.5	22.46	124.83

Tab. 5: Collection: lengths of collection trips and average distances, costs and fuels for one tonne of waste.

Management costs (Tab. 6) covered by the JSC and its partners (Thinnabeh and the official enterprise charged with cardboard collection) are included in the calculation, while collection costs covered by Municipalities (MSW-T) are unknown.

Waste management costs (NIS/t) covered by the JSC and other partners

	Organic waste (NIS/t)	Cardboard (NIS/t)	MSW-CT (NIS/t)	MSW-T (NIS/t)
Management costs, of which	321	219	186	69
- covered by the JSC	318	12	186	69
- covered by other partners	3	207	-	-
<i>Collection</i>	294.63	191.63	108.34	ND
* Personnel (drivers, workers)	73.25 (1)	48.40 (1)	49.90 (1)	ND
* Fuel	202.98 (2)	124.83 (2)	40.04 (2)	ND
* Maintenance	18.40 (1)	18.40 (1)	18.40 (1)	ND
<i>Administrative expenses</i>	23.57	15.33	8.67 (1)	ND
<i>Storage in the Transfer Station (cardboard, MSW)</i>	-	12 (1)	12 (1)	12 (1)
<i>Treatment (organic waste, cardboard)</i>	3.14	ND	-	-
* Energy consumption (shredding machine for organic waste)	3.14 (1)	-	-	-
* Energy consumption (pulper for cardboard)	-	ND	-	-
* Energy consumption (compactor for cardboard)	-	ND	-	-
* Management costs for Thinnabeh (organic waste)	ND	-	-	-
<i>Transfer to Zahret Al-Finjan (MSW)</i>	-	-	57.00	57.00
* Fuel (MSW)	-	-	14.56 (3)	14.56 (3)
* Truck maintenance and driver (MSW)	-	-	9.44 (1)	9.44 (1)
* Disposal fee (MSW)	-	-	33.00 (1)	33.00 (1)

(1) Based on interview results

(2) Based on daily logs provided by JSC (average fuel price : 5.50 NIS/L)

(3) Based on daily logs provided by JSC (average fuel price : 5.64 NIS/L)

Tab. 6: Waste management costs (NIS/t) covered by the JSC and other partners

Waste management costs for cardboard (218 NIS/t) and organic waste (321 NIS/t) are higher than MSW management costs (186 NIS/t).

Collection is the most expensive phase, and its costs are influenced by collection duration, distance covered by trucks and waste collected amount.

The costs related to the collection of the organic waste are higher because the compactor truck covers a higher distance to collect less waste if compared with MSW and cardboard routes. Possible solutions to minimize organic waste collection costs can include the selection of a smaller and more efficient truck, the increment of collection users in the same area, a further resizing of the collection area.

Collection costs for cardboard are covered almost entirely by the official enterprise performing the collection, with savings for the JSC ranging from 57 NIS/t (MSW-T) to 174 NIS/t (MSW-CT).

Treatment costs have a little influence on total costs. Transfer and disposal costs are subjected to little variations. As they affect only MSW management, these costs can be considered as “avoided costs” for both organic waste and cardboard. Total costs for waste management calculated on the amount of waste managed by the JSC each year are resumed in Tab. 7.

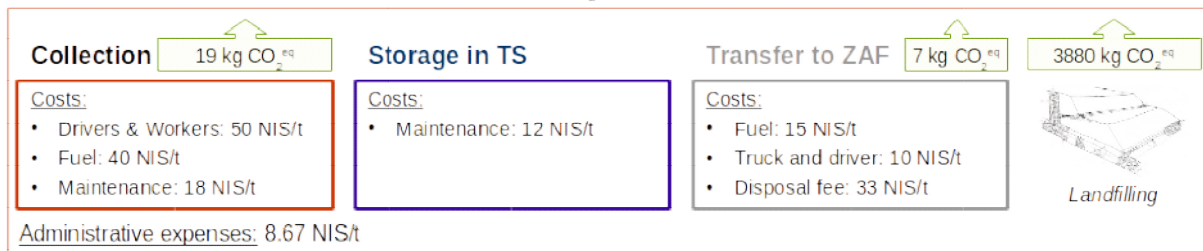
Total costs for waste management (NIS/year)				
	2014	2015	2016	2017
<i>Collection and transfer (MSW-CT)</i>	2,535,925	2,451,269	2,358,599	393,668
• Private sector	38,019	96,293	244,827	46,841
• Public sector	2,497,906	2,354,975	2,113,772	346,827
<i>Transfer (MSW-T)</i>	1,915,866	2,020,657	2,134,640	223,002
• Private sector	16,878	29,101	66,419	5,639
• Public sector	1,898,988	1,991,556	2,068,221	217,362
<i>Organic waste</i>	0	28,686	98,303	14,441
<i>Cardboard</i>	0	0	10,011	30,241
Total	4,451,791	4,500,612	4,601,553 (1)	661,352

(1) Total costs for 2016 should be higher as organic waste was disposed to Zahret Al-Finjan.

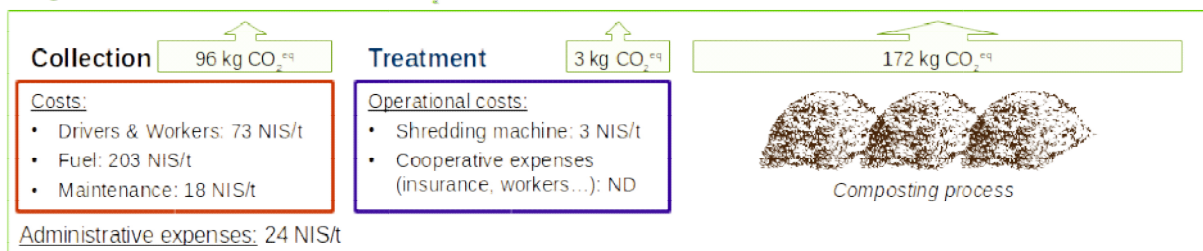
Tab. 7: Total costs for waste management (NIS/year)

The results of both environmental and economic analysis are resumed in Fig. 6. For each type of waste stream (MSW, organic waste or cardboard) every phase is described, with corresponding management costs in NIS/t and greenhouse gases emissions in kg CO₂^{eq}/t.

Municipal Solid Waste (MSW): 186 NIS/t – 3.9 t CO₂^{eq}/t



Organic waste: 321 NIS/t – 0.27 t CO₂^{eq}/t



Cardboard: 219 NIS/t – 0.06 t CO₂^{eq}/t

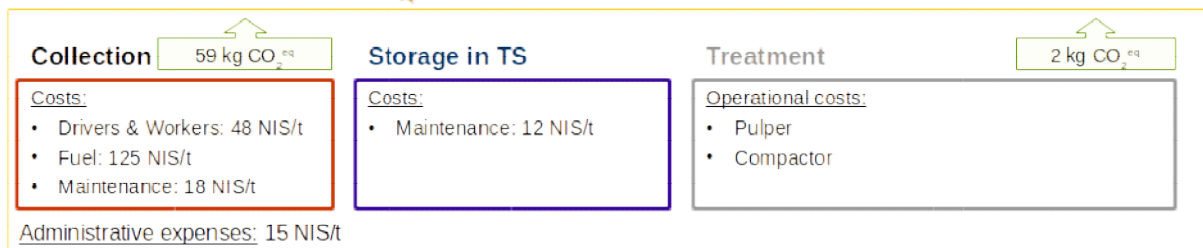


Fig. 6 Comparison between each waste stream (MSW, organic waste and cardboard) considering greenhouse gases emissions and management costs.

4.3 Social analysis

Social impacts of the project have been investigated through the analysis of questionnaires. Three main categories have been identified within interviewees: managers and technicians; collection and cleaning workers; merchants.

A high level of engagement is perceived by all groups, even by merchants which left the project due to logistical reasons. The project forced some changes in habits and behaviours leading to a more effective organisation of the system. Merchants appreciate the new level of comfort reached, as managing waste was more time-expensive before the project. An higher level of hygiene is seen as a main consequence of the project: shops, common spaces and waste collection areas are perceived as cleaner; work load of cleaning workers is diminished (while new job opportunities have been created); a smaller environmental impact is pointed out as a consequence of less burnt waste. Social value of collection workers has been recognized.

Concerning awareness, managers and technicians show background knowledge on waste management, and are satisfied with the opportunity for applying it. Merchants and collection workers, who didn't have a clear idea of waste composition before the project, now recognize the value of the compost and other recyclables.

Strength and weakness points have been highlighted by interviewees.

“Green Tulkarem” is seen as a potential case study, due to the success achieved in the cardboard collection and in reaching a high quality of collected organic matter. Moreover, the project leads to an increase of population awareness, and entails lower costs for the Municipality.

Criticalities have been divided by the interviewer where related to the project set-up or the local context.

Concerning the project set-up, in the opinion of interviewees external consultants have demonstrated a shallow knowledge of the Palestinian context and reticence to accept local technicians' suggestions. Other objections were about inaccurate initial estimates and the wrong dimensioning of the shredding machine.

The low economical sustainability of the separate collection, mainly due to the difficulty to reach farther villages, is related to the local context. While merchants are satisfied with the present collection service and wish its continuation, managers and technicians are particularly concerned about finding a sustainable way to manage organic waste.

With reference to the Palestinian context, the lack of space has been addressed as a strategic topic, not only related to a proper arrangement of containers among streets but also to the final disposal of waste. This enhances the need for waste reduction and valorisation through composting and production of energy, in order to avoid the construction of landfills and increasing the internal independence.

Concerning organic waste, technicians require a higher support by public authorities, including Municipalities, Ministry of Local Government and Environment Quality Authority, both related to rules (by insuring a stronger application of them) and to the financial aspect (by increasing collection and disposing tariffs). Further steps identified by interviewees concern the involvement of big producers and a solution for collection in farther villages.

Awareness campaigns addressing farmers and merchants have been suggested, concerning compost related topics such as quality and geographical provenance (enhancing the importance of a local production).

5 Conclusions

Performed analysis and data collection lead to a complete assessment of the implementation of a separate collection system promoted by the project “Green Tulkarem”.

Qualitative and quantitative results are good when compared with goals of the project. The chosen target of the organic waste separate collection have been big producers, which involvement has helped to reach a high rate of segregation, whilst cardboard has been collected through all the project area.

Concerning greenhouse gases emissions, the comparison between different waste management procedures (organic waste, cardboard, MSW) consent to assert that separate collection entails less emission than the final disposal in the landfill. This is mainly due to anaerobic degradation processes which occur in the landfill, following the disposal. Concerning only the collection phase, the length of organic waste collection route, correlated with the amount of collected waste, lead to more emission. Even if the impact of this phase on the overall procedure is minimal, this topic needs to be addressed, looking for a more appropriate solution.

Increased public hygiene due to an improved cleanliness of collection point and markets’ areas has been an important consequence of the project. This aspect is worth to be taken into account (Wilson et al., 2015) and can undergo further investigations.

Population involvement is a basic need when dealing with waste management. Following awareness campaigns promoted under the project, advantages related to the separate collection of organic waste have become clear to merchants, which are now interested in the continuation of the service.

An interruption of the separate collection service could affect seriously the feasibility of future similar projects, leading to a reduced faith in institutions promoting these initiatives. In order to avoid consequences, criticalities affecting the future development of the project should be tackled.

The economic sustainability is the first issue, as municipal solid waste management has a fundamental role but is characterized by high costs. In a low-income context, the collection phase can reach the 70-80% of the budget of a Municipality (Coffey and Coad, 2010). In the present situation, tariffs established by Municipalities are not enough to cover MSW management costs, and this should be addressed within a combined effort of JSC and governance authorities. Besides, a proportion between the amount of produced waste and fees should be pursued, in order to guarantee equity in the distribution of service costs.

Dealing with both economic and environmental sustainability, the collection phase plays a crucial role, and it is necessary to find appropriate solutions. Besides the city of Tulkarem, this Governorate represents a rural context, in which distances between villages are high. A decentralized management of organic waste could help to diminish the load on the waste management system, reducing not only the amount of waste reaching the landfill but also the need for collection and transfer.

Considering the present set-up, the choice of a smaller collection vehicle could help to further reduce costs. The compactor truck used for organic waste collection would be more appropriate for fractions such as metals and plastic (De Feo, 2012), and biggest amounts of waste. The decision of purchasing a big compactor truck has been the result of an agreement with local partners, which preferred a solution characterized by a higher technological content with respect to other alternatives, even if the technology is known to only partially address waste management issues.

Concerning other technical issues, also the shredding machine appears to be oversized if compared with goals of the project. This would lead to new opportunities in future, which are nonetheless conditioned by the willingness of the Thinnabeh cooperative to collaborate.

In general, the “trial & error” approach used within the project has to be recognized as successful, as it permitted to adapt the whole management system to users’ needs.

On the financial and economic side, a higher level of transparency could help to address several issues. A clear balance sheet, which would include incomes and expenses from all partners involved in the project (JSC, Municipalities, and private companies), will lead to a fairer distribution of service costs and to a better relationship between waste management system actors and users. Besides, it will help also to perform more detailed costs analysis.

Transparency remains an issue also concerning data management, even if some results have been reached. JSC database has still some technical concerns (such as an incoherent structure and the presence of duplicated items), which need to be fixed in order to perform faster analysis. Also data access has been difficult, mostly due to incomprehension. Nonetheless, the positive role of CESVI in enhancing the importance of a systematic data collection has to be recognized.

Finally, concerning the social impact of the project, a good level of involvement has been reached through people directly involved in the project, from local partners to collection workers and merchants. Furthermore, other reasons for reflection come from the analysis carried out.

A process of formalization of the informal actor which was collecting cardboard and plastic had been started (De Nardo, 2015), but it ended up unsuccessfully due to an accident which destroyed his transfer station. In spite of this result, criticalities and potentialities of this process should be analyzed, in order to benefit from this experience.

Another point which requires further efforts is the training for collection workers about job safety and sanitary and environmental aspects, as they appear scarcely concerned about potential risks.

Besides awareness initiatives which have been already promoted by the project, a campaign oriented to manufacturing activities on appropriate waste management and disposal will contribute reaching better levels of separation, and also create the basis for the separate collection of other fractions, such as plastic or metal.

References

- Al-Khatib I. A. et al, 2010. Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district – Palestine, *Journal of Environmental Management* 91 (2010) 1131–1138
- Coffey M., Coad A., 2010. *Collection of Municipal Solid Waste in Developing Countries*, UNHABITAT.
- De Feo G., De Gisi S., Galasso M., 2012. *Rifiuti Solidi, Progettazione e gestione di impianti per il trattamento e lo smaltimento* (pp. 1-816). DARIO FLACCOVIO EDITORE.
- De Feo Giovanni, De Gisi Sabino, Galasso Maurizio, 2012. “Rifiuti solidi”, Dario Flaccovio Editore.
- Hamadah S.R., 2011. *Comparative Analysis of Separation Versus Direct Transport of Solid Waste from Tulkarem District to Zahret Al-Finjan*, An-Najah National University Faculty of Graduate Studies
- IEA International Energy Agency, 2017. (<http://www.iea.org/>) [accessed 15 March 2017]
- IPCC - Intergovernmental Panel on Climate Change, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan
- R. Chandrappa and D. B. Das, 2012. *Solid Waste Management, Environmental Science and Engineering*, DOI: 10.1007/978-3-642-28681-0_2, Springer-Verlag Berlin Heidelberg
- Sirini P., Tchobanoglous G., La Diega R. C. N., 2010. *Ingegneria dei rifiuti solidi*. McGraw-Hill.
- UN-HABITAT, 2010. “Collection of Municipal Solid Waste in Developing Countries”, Gutenberg Press, Malta.
- Wilson D.C., Rodic L., Cowing M.J et al., 2015. “Wasteaware” Benchmark Indicators for Integrated Sustainable Waste Management in Cities. *Waste Management*, 35. 329-342. ISSN 0956-053X
- World Bank, 2009. *Implementation completion and results report (TF-24696) on a credit in the amount of us\$ 9.42 million equivalent to the West Bank and Gaza for a Solid Waste and Environmental Management project*, Report No: ICR00001277
- WRAP, 2009, *Summary Report – Material Bulk Densities*, Report prepared by Resource Futures
- CESVI, Reports:
 - Filippini Gian Carlo, Final report of technical supervisor, October 2014
 - Vitali Francesco, Report, October 2014
 - De Nardo Federico, Report, December 2014
 - Zambetti Cristina, Report, August 2015
 - De Nardo Federico, Report of the consultant, December 2015