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Sustainable Solid Waste Management

Sustainable vacuum waste collection systems in areas of difficult access

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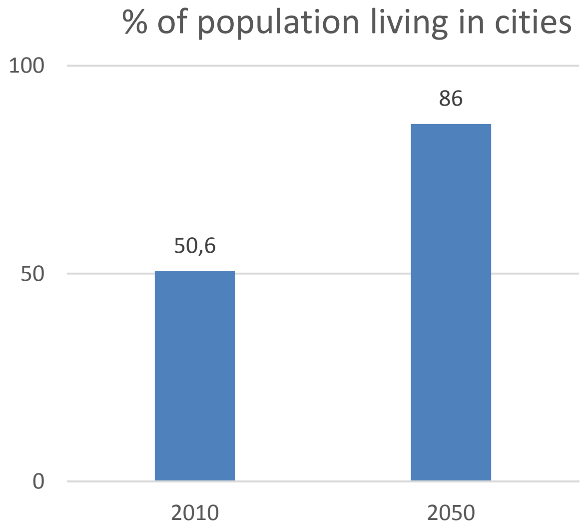
Work carried out in the frame of the PAVEtheWAySTE project

- Project funded by EC into LIFE + Program (LIFE14 ENV/GR/000722).
- Aim:
  - To establish an integrated and replicable system for source separation and treatment of municipal waste (MW) in remote areas.
  - The project includes:
    - The design and construction of 9 innovative prototype units for the treatment (fine sorting and compression) of 500 kg MW/day.unit.
    - Raising awareness of more tan 2,000 residents and tourist.
    - Recovery of more than 1,600 t of high quality materials.

Introduction

Urbanisation

- Urbanisation is an irreversible phenomenon that creates the need to expand existing residential areas.
- This trend collides head-on with the model of sustainable development that the new EU policies aim to implement.



- In these circumstances, the subsoil arises as a practically unexploited resource with the potential to alleviate the problems associated with the lack of free areas in modern cities.

Use of subsoil

- The use of subsoil has several potential advantages apart from the release of space on the surface:
  - the development of new green fields and residential areas;
  - better traffic mobility;
  - the preservation of "sensitive" areas, such as historical city centres and archaeological sites;
  - the reduction of travel distances, as well as considerable energy and time savings;
  - or the reduction of environmental impacts of some activities (noise, odours, risk threats).

Urban waste management

- Waste management is one of the major issues in urban engineering.
- The annual generation of municipal waste in the EU-27 reached 477 kg per person in 2015.
- The daily waste production per capita ranges from 0.48 to 2.16 kg, with people in highly developed countries producing more waste.
- In the coming years, both the increase of global population and the growth in developing countries is expected to create a boost in the municipal waste production.
- Only for the case of urban food waste its production is expected to increase by around 45% until 2025.

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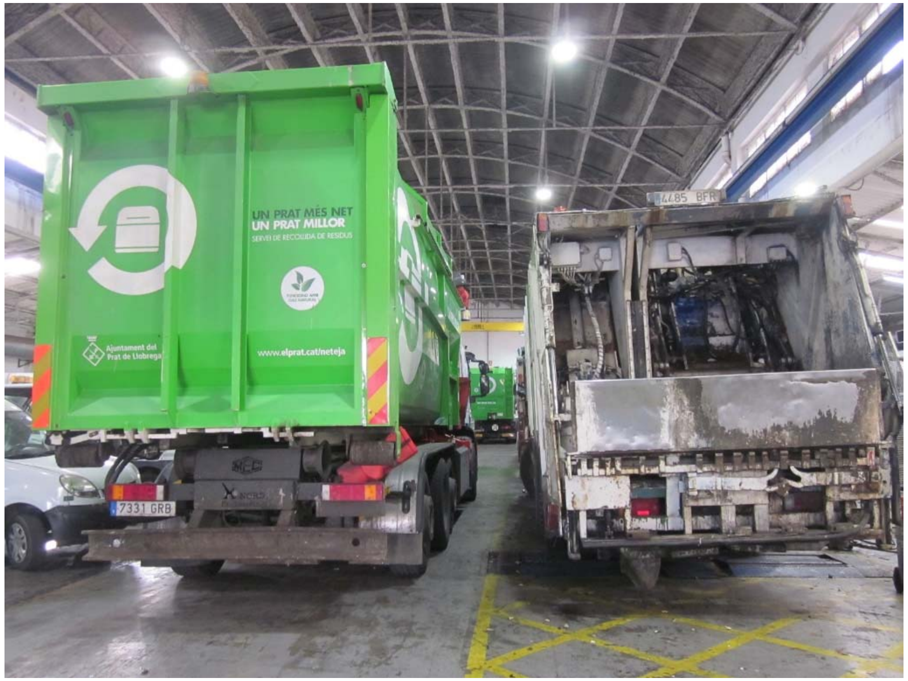
Cities will be facing new challenges in the following years to efficiently address the management of solid waste.

Waste collection

- Collection is the most important and costly aspect of the urban waste cycle.
- This activity accounts for 80% of all costs associated with waste disposal.
- The amount of carbon emissions created by heavily polluting waste collection vehicles causes severe local pollution.



Waste collection in remote areas

- Remoteness of centralised municipal treatment systems.
- Difficult access when climatic conditions are adverse.
- The restrictive characteristics of remote areas greatly impede the execution of works related to waste collection, transportation, storage, treatment and disposal activities and entail high management costs, due to the need to transfer waste, in the case of islands, to the continent.

Underground vacuum waste collection systems

Underground vacuum waste collection

- Alternative to traditional waste management systems.
- No need of trucks inside cities.
- Permanent infrastructures.
- Powered on electricity.

Underground waste collection: pros and cons

UWC PROS	UWC CONS
☺ Release space in the surface and improve aesthetics.	☹ Pipe blockages can occur.
☺ Reduced operation and maintenance costs leading to cost savings in the long run.	☹ High investment cost required in the initial phase.
☺ Ability to properly collect the main waste streams.	☹ Unsuitable for the management of large items and liquid waste. Difficulties when handling cardboard and glass waste.
☺ Able to manage high volumes of waste. Ideal for high populated areas.	☹ Not recommended for low populated areas due to economic reasons.
☺ High adaptability to varying topography, including slopes, climatic conditions and space limitations.	☹ Modifications after installation are costly.
☺ Avoid the usage of garbage trucks in the collection area.	☹ Truck usage is still needed for transportation after the collection station.
☺ Better working conditions.	☹ Qualified workforce is required.
☺ Noise, odour and hygienic problems are minimised.	
☺ Superior protection against vandalisms.	
☺ Adaptation to Smart Cities.	

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Underground waste collection: costs analysis

- The UVWC systems suppose, in general, reduced operating costs for waste handling compared to traditional systems.
- Although a greater initial investment is required, the more economical operation of the system can actually compensate this disadvantage in the long term.
- An important part of the economic benefits of UVWC structures are latent and are associated with social and environmental externalities as:
  - urban revival,
  - time savings,
  - limited disturbance in the city,
  - environmental protection.

Underground waste collection: costs analysis

- Costs comparative over 30 years among traditional and underground waste collection systems for a development of 10,000 dwellings in 2017. Source: ENVAC.

Capital Expenditure (CAPEX)	Underground system	Traditional system (EUROBIN)	Comments
Capital costs	13,600,000 €[1]	3,060,000 €[2]	[1]Design, piping, inlets deployment, equipment in collection station [2]Trucks replaced every 15 years, 1,700 bins x 300 €/bin replaced every 5 years
Waste housing cost	620,000 €[1]	12,750,000 €[2]	[1]Building to host 1,700 bins x 2.5 m^2/bin x 3,000 €/m^2 [2]Building for collection station
Excavation works	1,360,000 €	0 €	Trenching
Total CAPEX	15,580,000 €	15,810,000 €	
CAPEX per dwelling	1,558 €	1,581 €	
CAPEX per dwelling and year	**52 €**	**52.7 €**	
Operational Expenditure (OPEX)	**Underground system**	**Traditional system (EUROBIN)**	**Comments**
Maintenance	115,300 €	36,000 €	Replacements and cleaning
Energy	12,900 €	0 €	
Personnel collection costs	0 €	160,000 €[2]	[2]1,700 bins require 8 full time staff , salary 20,000 €/y
Waste collection costs (fee)	100,000 €[1]	500,000 €[2]	[1]10 €/dwelling/year [2]50 €/dwelling/year
Total OPEX per year	228,200 €	696,000 €	
OPEX per dwelling and year	**22,8 €**	**69,6 €**	

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Underground waste collection in remote areas

- The application of UVWC systems will depend mainly on the existing population density:
- Rural area with a high dispersion of the population:
  - UVWC systems are not unsuitable due not only to logistic (e.g. long walking distance to the nearest collection point), but also economic (e.g. high return on investment period).
- Rural area or island highly populated due, for example, to touristic reasons:
  - UVWC system can solve many of the problems associated with waste management in remote areas, as seasonality or low levels of selective collection, among others.

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Underground waste collection in Smart Cities

- Inlets of the pneumatic waste collection systems are prepared to integrate all types of sensors.
- Households can be encouraged to source separate their waste fractions, for example by using individual electronic ID cards to open these inlets and following policies of "produce less, pay less".

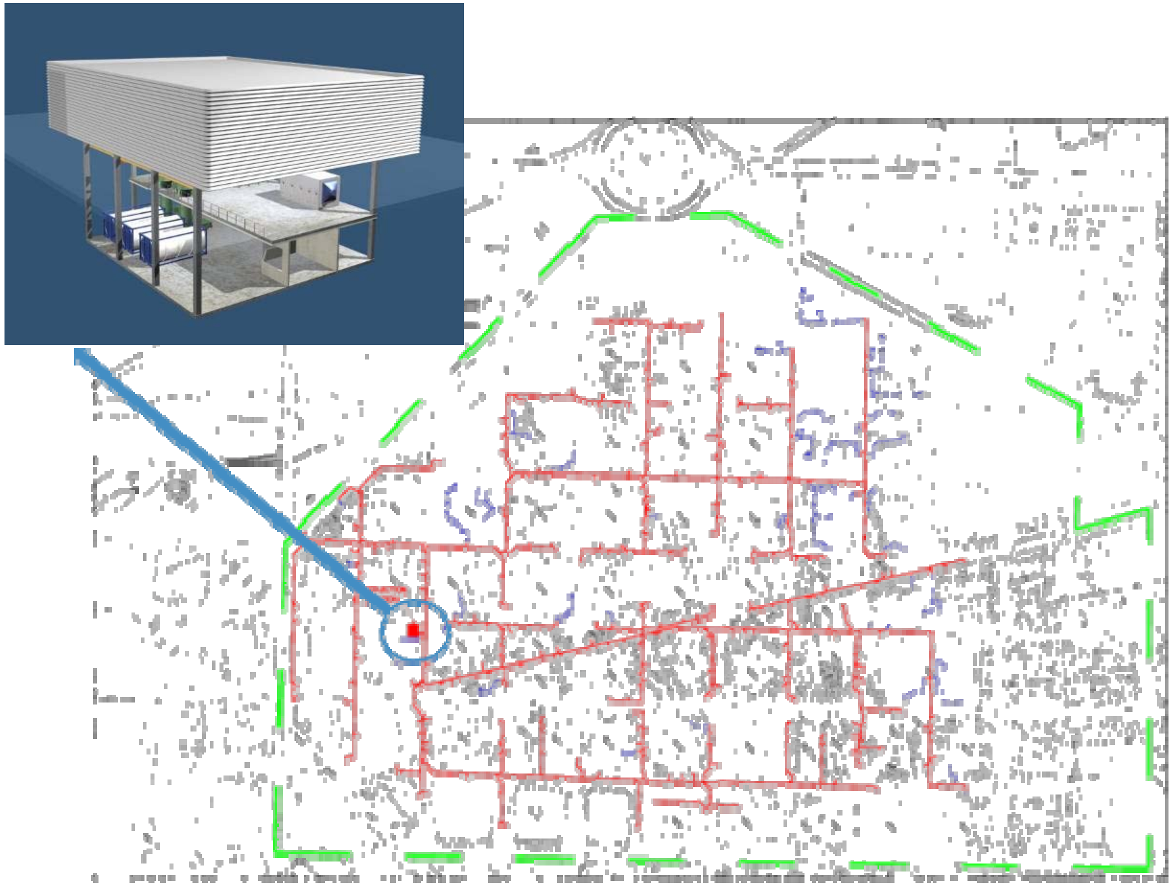
- Sensorization in UVWC collection systems can provide reliable and timely information for the requirements defined by the Smart Cities.
- Gathered data (e.g. number of openings by user, volume and weight deposited in each opening, quality of the separation, etc.) would allow to know the social behaviour to establish and plan, in a simple and operative way, the collection processes and information policies.

Case studies

Case study 1: Barcelona (Spain)

- Barcelona is the forefront of pneumatic waste collections systems utilization aiming at a complete integration of such systems in the city.
- The city has 8 system running plus 2 mobile, serving or collecting the waste of 141.000 inhabitants.
- The Municipality is taking advantage that they are revamping some areas or districts to introduce novel waste collection technologies on them.
- An example is the area @22 comprising 12,6 Mm^2 with 12,600 dwellings and 4,225 inhabitants.
- A 3 fractions system was designed: 1,300 t/year of rest and 1,381 t/year of recyclable (organic to be collected from the dwellings and paper and cardboard from the offices).
- After the change, an environmental study was implemented.

Case study 1: Barcelona (Spain)



Case study 1: Barcelona (Spain)

	Traditional waste collection	Vacuum collection
Collection points	230	644
Number of collections per week	7	12.6
Average waste amount per transport (t)	6.8	664
Energy housekeeping	Less electrical energy but more fossil vehicle fuel	More electrical energy but less fossil vehicle fuel
Material housekeeping in life cycle perspective	More plastic but less steel and aluminium	Less plastic but more steel and aluminium
Technical life spam for important components		
Buildings (y)	30	30
Storage bins (y)	7	-
Vehicles (y)	7	10
Inlets	-	10
Pipe system	-	30
Garbage trucks figures		
Operation (km/y)	23,560	117
Working time (h/y)	2,685	65
Fuel consumption (l)	38,800	76
CO_2 emissions (t)	109	0.2

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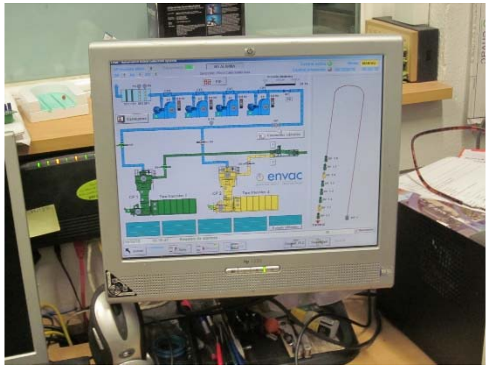
Case study 2: León (Spain)

- The city of León has installed a vacuum system for the historical part of the city where narrow streets made it difficult for conventional waste collection vehicles to access the area.





- In 2016, the system managed a total of 62 t of packaging and 819 t of rest fraction with a consumption of 225 kW per ton of waste collected.
- The estimation of the local CO_2 emissions saving is 98.4%. The total cost of the project amounted to 5.2 M€
- Maintenance costs are estimated to be today around 300,000 € per year.

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Case study 3: Balearic and Canary Islands (Spain)

- With one system installed in Tenerife and two in Palma de Mallorca, these territories were pioneer in the introduction of underground waste collection systems in remote areas.
- Complex network of pipes that run through narrow streets and inlet chutes strategically placed according to the existing historical elements in Palma de Mallorca.
- Tower N in Tenerife.

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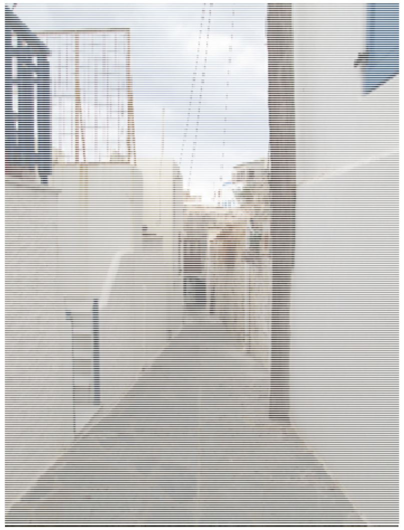
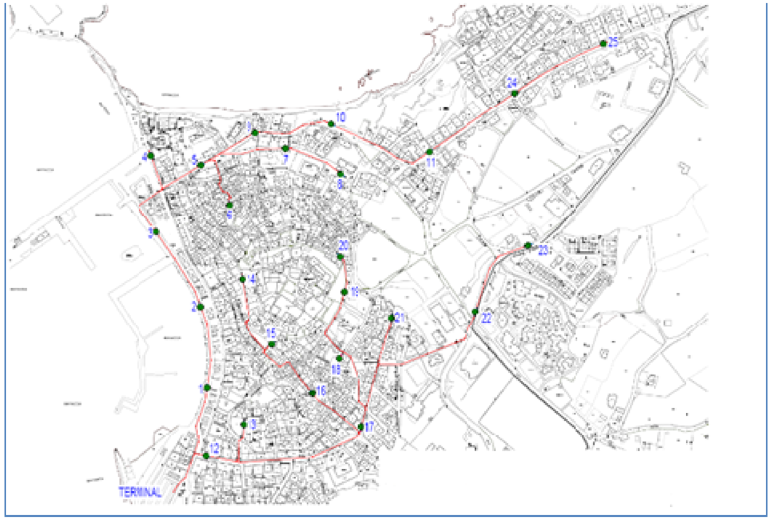
Case study 4: Naxos Island (Greece) - simulation

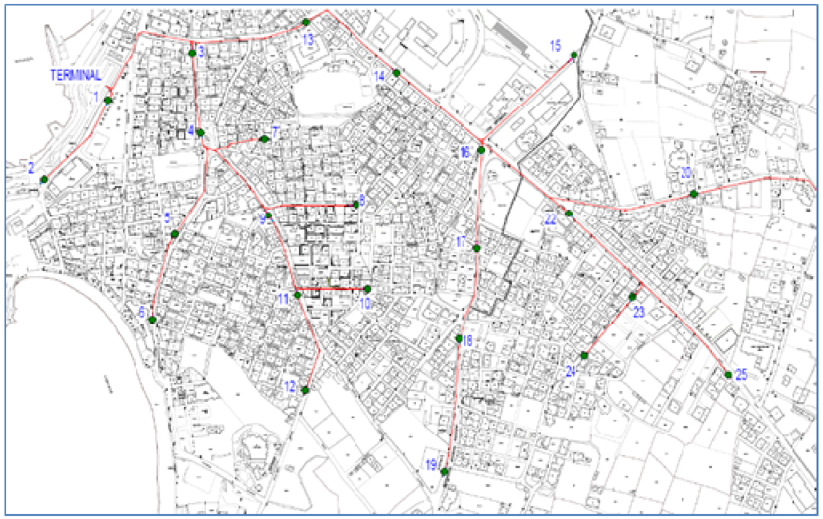
- The potential application of vacuum collection systems in Naxos Town (Chora), is being analysed.
- Narrow streets with steep slopes characterise the structure of this medieval and touristic city.
- Underground collection arises here as an interesting option considering its potential advantages.



Case study 4: Naxos Island (Greece) - simulation

- The proposed development of the UVWC system in Naxos Chora includes 2 terminals, 2 independent pipe networks and a total of 50 disposal point, each one composed by 4-6 inlet chutes (for selective collection).
- The system will serve to approx. 10,500 equivalent dwellings.





Case study 4: Naxos Island (Greece) - simulation

- Estimated capital expenditure for the UVWC in Naxos.

Concept	Cost (Million €)
Terminal T1	1.279
Outdoor inlets T1	2.524
Pipe network T1	1.372
Terminal T2	1.226
Outdoor inlets T2	2.542
Pipe network T2	1.318
Total	10.261

- The UVWC system is assumed to have a working life of about 30 years, so the annual amortisation of the system is 342,000 €, that is 32.6 € per dwelling and year.
- The capital expenditure for the conventional collection system already existing extended to 10,000 dwellings can be estimated around 115,000 €, this is 3 times less than the UVWC system.

Case study 4: Naxos Island (Greece) - simulation

- Estimated annual operational expenditure for the UVWC in Naxos.

Concept	Cost (€)	Comments
Personnel costs	162,000	5 full-time workers
Electricity costs	50,400	370,000 kWh
Maintenance costs	90,600	Preventive maintenance works and spare parts
Total	303,000	
Final cost/tonne	37,5	
Final cost/dwelling	30,3	

- The operational costs for a conventional system in Greece are around 75 € per ton of collected waste (*Nakou et al., 2014*), the double than the estimations for the UVWC system in Naxos (37,5 €/t).

Case study 4: Naxos Island (Greece) - simulation

- According to these figures, **the sum of investment and operational costs favours again the underground waste collection concept** over a traditional one for a hypothetic deployment in a remote area as it is Naxos island.
- Apart from the reduction in noise and the improvement of the aesthetics of the city, the pollutant emissions generated by the transport trucks would be prevented, with the consequent upgrade in the city´s air quality.
- Annual emissions potentially avoided in Naxos with the implementation of an UVWC system:

Pollutant	Emissions EURO 10 trucks (kg/ 1,000 km)	Total emissions avoided (kg)
SO_2	0.64	35
NOx	8.83	486
Particulates	0.18	9
CO	2.34	128
NMVOC	0.75	41
CO_2	1.054	57,943
CH_4	0,02	1
N_2O	0,01	0.5

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Future trends and conclusions

Future trends

- It is expected that UVWC will progressively increase both:
  - in densely populated areas with traditional waste systems already installed and,
  - in new urban projects where these infrastructures can be introduced from the beginning of the project.
- For remote areas, the implementation of underground collection schemes seems a sensible strategy in the case of touristic destinations.
- UVWC systems, with multi inlet configurations and smart openings of the inlets by using ID cards, can assist in achieving the targets for waste recycling:
  - implementation of novel policies, as the pay-as-you-throw concept,
  - or the source separation principle.

Further information:

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Thank you for your attention