BLUE RESPONSIBILITY AWARD

“Manufacturing for a Sustainable Terra Preta Sanitation System”

Project

Terra Preta Packaging System. A new “blue” waste management.

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ABSTRACT

UBTPPS COMPANY, The Terra Preta Packaging System

UBTPPS is a private company, responsible for a new "blue" waste management. The innovative system is called Terra Preta Packaging System (TPPS). It creates a loop system among food, excrement and soil closing a "blue" non-polluting cycle and creating value by selling Biochar.

The keys of the TPPS are:

- The Packaging Toilet System (PTS),
- The Handling Service (HS),
- The Green Pyrolysis Area (GPA),
- The Biochar.

The TPPS is based on the use of a PTS that can collect human excrements in compostable single use bags. The Handling Service takes excrements from single users thanks to Bag Containers, which are brought to a Green Pyrolysis Area. In this area an innovative pyrolysis of human excrement produces Biochar and syngas.

The loop is suited to work in both urban areas, with the existing urban sewerage system, and in emerging countries, with different PTS, HS and GPA, adapted to the local technologies, cultures and primary requirement.

The PTS is a diverting toilet that creates compostable single use bags of excrements, sealed and non-odour, moved down through the waste stack to the Bag Container located in the building basement.

The HS provides a daily picking of Bag Containers from single users to the GPA. In industrialized countries the service exploits natural gas vehicles, powered with syngas, consequence of the pyrolysis. In emerging countries this service needs participation of users to collect compostable single bags.

The GPA produces Biochar and syngas. GPA includes an area of compostable single use bags collection, a dryer, a pyrolysis reactor, an engine for the production of electricity and an area of Biochar stock.

An aggressive marketing campaign about the advantages of Biochar and a local team of agents in contact with farmers ensure the sale. The profit will be guaranteed thanks to the optimal chemical and physical properties of this type of innovative Biochar.

The Terra Preta Packaging System main strengths are:

- 100% waterless toilet system, eliminating flushing waste of water;
- Adaptability to a wide range of context including urban areas with a pre-existing urban sewerage system and emerging countries with different technical infrastructures;
- Very low impact for users on traditional habits and high level of sanitation (increase of sanitation in emergent countries);
- Creation of Biochar characterized by excellent chemical and physical properties, obtained by a pyrolysis process (first-time adoption);
- A green Handling Service, by vehicles in industrialized countries fed with self-produced natural gas or on foot in emerging countries;
- Creation of job opportunities (manufacturing of the toilets, handling service, maintenance of pyrolysis reactors) and value for the whole "blue" system that is completely auto-sufficient;

The following report describes the whole system and supports the sustainability of the proposal. It includes the Business Model and cost estimation analysis of the whole Terra Preta Packaging System managed by UBTPPS, a Technical Description of the elements and a detailed description of the Packaging Toilet System with the related Bill of Material.

MAIN PART

BUSINESS MODEL

UBTPPS (The Company)

The aim of the project is to realize a new type of waste management called Terra Preta Packaging System (TPPS), which should create a "blue loop", closer to the "Blue Economy" concept than the actual one (legislation on Appendix D).

UBTPPS is a private company, responsible for the integrated management of the whole TPPS.
The new system is based on the installation of a packaging toilet system, an innovative waterless toilet that can collect human excrements in compostable single use bags. A handling service takes excrements from the single users by means of Bag Containers, brought to a Green Pyrolysis Area.
In this area an innovative pyrolysis of human excrement produces Biochar and Syngas. The sale of Biochar ensures revenues to the company, while Syngas is employed to power the vehicles of the handling service.
All the activities are entirely managed by the company, except for the following parts of the system:

- Manufacturing of the Packaging Toilet Systems (PTS);
- Design and Manufacturing of compostable single use bags;
- Manufacturing of Pyrolysis reactors.

PTS is outsourced in the form of a subcontracting. UBTPPS designs the waterless toilet system (deeply detailed in the Technical Description) and deliver its implementation to an external company.
For the compostable single use bags, UBTPPS needs to invest in a partnership to co-design them, while the Pyrolysis reactors could be purchased on spot market.

The core business of the company is represented by the sale of an innovative product for agriculture, Biochar. Farming carries out many purposes for our society, first of all food production, but it also affects strongly the environment, human health, economy and social structures. European agricultural policies focus the attention on granting to the ever-growing population diversity and safety in nutrition, never forgetting the environment protection and safeguard of rural communities.
Biochar is the best answer to these challenges. The efficiency increase, due to the joint use of Biochar and N-fertilizers, is considerable. Thanks to this practice it would be possible to decrease the emission of greenhouse gases, for which fertilizers are accountable by the part 5%. Biochar makes also cultivation more resistant to disease, furthermore improving the agrarian system. In Europe, landslide costs 4.9 billion euro/year. Within 2050, landslide episode frequency will increase of 50% and costs will arise up to 500% due to the climatic change. Moreover, in Europe there are 3 billion of polluted sites. Soil remediation between 2005 and 2013 cost 2,250 billion euros. Apart from economical loss another important fact is that pollution has a dramatic consequence on the wellness and health of people.
Thanks to its chemical, biological and physical properties Biochar is a valuable help in protecting and healing the soil. It improves the physical-chemical feature of the land and absorbs most of the pollution, organic and non-organic, the last ones responsible for the corruption of the soil, of cultivations and of the aquifer, pollution as heavy metals, dioxin, pesticide and much more.
The use of Biochar is an effective weapon against the climate change and greenhouse gases emission, for at least three reasons:

- Carbon sequestration;
- Restraint of emissions due to the alternative use of the biomass that bears to Biochar;
- Use of the gas and bio-oil produced by the pyrolysis as alternative fuel.

The carbon sequester made by pyrolysis allows Biochar to become a stable long-term carbon sink, delaying the time of decomposition and the return of carbon to the soil or to the atmosphere.
Compared to chemical fertilizer and N-fertilizer in particular, Biochar increases crop productivity, without polluting (up to 100%), increases N-fertilizers use efficiency and thus decreases their need (N recovery up to 18%). Biochar is a solution for aquifer and soil pollution caused by chemical fertilizers and it's cheap.
Compared to peat, Biochar is:

- Renewable (because made from biomass) and able to reduce greenhouse gases emissions, because of carbon sequestration.

Compared to sewage sludge, Biochar avoids:

- Leaching;
- Mobility in soil and availability for plant uptake of heavy metals, even if they are in some quantity into the Biochar itself.

The crucial role of Biochar for the planet and for the UBTPPS company leads to the importance of the location chosen for the production centres that is not random; the objective of the handling function is the path optimization, which results in the assignment of a customer to a specific GPA (Green Pyrolysis Area, deeply detailed in the Technical Description).
Another real challenge for the company is to relieve the client from any economic effort in acquiring the new toilet. PTS will be offered free of charge to users. The advantages in terms of the environmental and social impact will be immediate. The economic benefits for customers will be encountered also, in terms of lower costs for water users and with the zeroing of the taxes relative to the connection to the sewer.
A fundamental aspect of the technical solutions offered by UBTPSS is its portability: with little changes in the type of the TPS installed to users and simplifying the collection and handling process this system can be implemented in industrialized countries as well as in developing countries.
With the necessary adjustments, in fact, it is possible to provide a low-cost system implementation whose positive effects are proportionally incomparable with those of industrialized countries.

A business model analyses a number of key parameters that provide the basis for the value proposition of the company both for industrialized and emerging countries.

CUSTOMER SEGMENTS

The sale of Biochar is directed to different market segments:

1. Agricultural businesses;
2. Small farmers with a passion for organic local products;
3. Lovers of gardening.

In developing countries, the GPA equally produces Biochar, but the production of Syngas is converted into electrical energy, distributed for locally requirements since it is assumed that the movement takes place without the support of motorized vehicles.

CHANNELS

It is necessary to exploit an extensive distribution network of both TPS, in order to increase the quantity of material processed and Biochar, in order to reach the different market segments
UBTPPS introduces several distribution channels for the sale of Biochar.
The retail store on the place of production is able to serve small size users that do not require large amounts of product (business to consumer). For large size users, purchasing is through selling agent or via e-commerce (business to business).
A prerequisite to sale is marketing which is a key lever for the company. The innovation introduced by Biochar must be supported by a strong campaign to raise consumer awareness of the product characteristics and advantages. Marketing is the activity on which UBTPPS invests mostly (40% of revenues, with detailed costs in “Cost Estimation”). The marketing function has to instill the value of Biochar and effectively manage the image of the product. The company has to highlight the "green" and “blue” aspects, and UBTPPS will have to specify the best conditions of quality and yield compared to chemical fertilizers.
In developing countries the aim is to collaborate with the State and possibly with local NPO (Non-profit organization) that promote the use of the UBTPPS system in order to increase sanitation needs and to obtain electricity for primary requirements.

CUSTOMER RELATIONSHIPS

The goal is to create a bond with each market segment served. The agents in the area and sales agents have the task to promote Biochar use and to sensitize the user It is necessary to emphasize the social impact of the solution offered by UBTPPS; the environmental implications are far-reaching. The duty of the company is to convey the value of the Blue Responsibility, to instruct and educate users. Some countries already benefit from a full awareness of the environmental problems; other countries totally disregard the entity of these issues. It is a duty of the company to fill this void.
UBTPSS is not a NPO, therefore its ultimate purpose is to generate profit, but in this case this goes hand in hand with the objective of protecting the environment, public health and the consumer, wherever he is living.

KEY PARTNERS

The business idea requires a strong coordination between different business areas.
In addition to the internal management, it is also necessary to coordinate with the external partner companies of UBTPPS. It is essential to build partnership relationships marked by trust and long term.
The design of the TPS is internally developed according to the technical specifications and the aesthetic and functional needs of consumers, emerging thanks to an appropriate market analysis; instead, the production is outsourced. In addition, UBTPSS has to identify a supplier of second level for compostable single use bags, necessary for packaging. This company has to ensure optimal service levels in return for guaranteed production volumes.
The choice to outsource these activities derives from a classic problem of make or buy. The goal of the company is to offer an integrated service and to efficiently oversee the entire system; with the internalizing of these activities this is not possible. For this and other reasons such as: access to specialized suppliers, focus on core competencies, search of cost advantages, risk diversification, UBTPPS has chosen to exploit an outsourcing strategy.

VALUE PROPOSITIONS

The value propositions are: environmental benefits, water retention, enrichment of nutrients, better stability of soils and agronomic benefits for the industrialized countries and increase of sanitation and primary requirements as electricity for the emerging countries.
The social aspect of the project has a direct impact on the value offered, which is not purely economic. The strength of this business idea is in its entirety, in the vision that starts with the habits of the individual in an everyday action such as going to the bathroom at the time when a glowing flame burning waste in absence of oxygen, producing a highly coal nourishing the ground that sooner or later will generate food to feed the mankind. UBTPPS wants to present itself to the market as the means by which the human waste acquires value and thus can be reused by the community, generating a virtuous circle.
The objective of the TPPS is to reduce waste of water and nutrients, which occur in almost all the human ecosystems and close a "blue" loop; being able to assist in this proposition a solid business opportunity, in line with the increasingly popular concept of organic and regenerative farming representing a great opportunity in Europe. In fact, today all agronomic techniques are aimed at obtaining healthy food, high quality and low costs. This is not possible without a rethinking of the fertilizers that enrich soils.

KEY ACTIVITIES

The key activity of the company is the engineering process operated by the technical office of the PTS (Packaging Toilet System). The technical solution offered by the company and supported by the partner meets the needs of the market, responding to requirements such as: no change in user habits, easy to use, easy to clean, with simple maintenance and suitable design. The technological collaboration with the manufacturing company is fundamental in order to permit a correct flow of know-how between the technical office of UBTPPS and the operation function of the partner company. This collaboration allows creating an object corresponding to both the domestic needs of the customer and to the new specifications of the waterless toilet.
In addition, UBTPPS consider as key activities the distribution channels, the customer relationship and the services offered to the client.

KEY RESOURCES

The key resource of the organization is the intellectual capital. In particular, the skills possessed by the technical office, which led to the creation of what was, at first glance, an utopian idea; the procedures and best practices established in the process of transformation, that will allow skilled workers to operate properly in the Green Pyrolysis Areas; the social skills of commercial agents.

REVENUE STREAMS

Tab.1 Revenues

INCOME STATEMENT (20,000 inhabitants)		YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
REVENUES							
Biochar sale		€ -	€ 2,190,000.00	€ 2,233,800.00	€ 2,278,476.00	€ 2,324,045.52	€ 2,370,526.43
TOTALE REVENUES		**€ -**	**€ 2,190,000.00**	**€ 2,233,800.00**	**€ 2,278,476.00**	**€ 2,324,045.52**	**€ 2,370,526.43**

The only activity that allows UBTPPS to get the revenue (Tab.1) is the sale of Biochar, which before the end of the fourth year permits the company to reach the breakeven point and later on generate wealth. UBTPPS does use neither public nor private subsidies in industrialized countries. The PTS is delivered and installed for free, as well as the service of material handling. The compostable single use bags are at the expense of the user, who buys them from the partner company. It is possible that the activity of production of the bags will be internalized in future, but actually the revenues depend entirely from the sale of Biochar, which is the reason why the investments in marketing are so elevated (40% of revenues with a decrease of 5% per year after the first Year.

COST ESTIMATION

It is necessary to distinguish the different cost centres as shown on Tab.2:

- Purchase costs of the toilets (PTS) at the supplier company;
- GPA costs, including all its elements;
- Cost of Maintenance of the GPA;
- Insurance costs of the pyrolysis reactor;
- Marketing costs,
- Sales agents costs;
- System of material handling costs

Tab.2 Costs

	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
COSTS						
Toilet Cost	€ 1,265,333.33	€ -	€ -	€ -	€ -	€ -
Toilet Depreciation	€ -	€ 253,066.67	€ 253,066.67	€ 253,066.67	€ 253,066.67	€ 253,066.67
Pyrolyzer Cost (150 kW)	€ 375,000.00	€ -	€ -	€ -	€ -	€ -
Pyrolyzer Depreciation	€ -	€ 34,090.91	€ 34,090.91	€ 34,090.91	€ 34,090.91	€ 34,090.91
Maintenance Operator Cost	€ -	€ 100,000.00	€ 102,000.00	€ 104,040.00	€ 106,120.80	€ 108,243.22
Marketing Cost	€ -	€ 876,000.00	€ 832,200.00	€ 790,590.00	€ 751,060.50	€ 713,507.48
Sale Agent Cost	€ -	€ 60,000.00	€ 61,200.00	€ 62,424.00	€ 63,672.48	€ 64,945.93
Pyrolyzer Insurance	€ -	€ 37,500.00	€ 38,250.00	€ 39,015.00	€ 39,795.30	€ 40,591.21
Handling Cost	0	€ 90,315.35	€ 92,121.66	€ 93,964.09	€ 95,843.37	€ 97,760.24
Vehicle Cost	€ 40,000.00	€ -	€ -	€ -	€ -	€ -
Vehicle Depreciation	€ -	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00
TOTAL COSTS	**€ 1,680,333.33**	**€ 1,455,972.93**	**€ 1,417,929.23**	**€ 1,382,190.67**	**€ 1,348,650.03**	**€ 1,317,205.64**

The whole cost estimation (Appendix A) refers to an industrialized country. Regarding an emerging country, the estimation has to consider greater information about shipments and installing costs of the PTS, and related costs of the transport of the Biochar to the industrialized countries.
The costs of the toilets are estimated according to some real quotations by some Chinese producers. GPA costs are estimated basing on local pyrolysis reactor. Insurance, material handling and sales agents costs reflect real hypothesis according to local cost models.

FINAL COMMENTS – Business Model, Cost Estimation

Examining realistic revenues and costs, a cash flow statement describes a real cost estimation for 20,000 inhabitants (Tab.4). Revenues are estimated based on the annual production of Biochar with a 2%/year increase. To be consistent, all costs are considered with the same increase.
A NPV (Net Present Value on Tab.5) on forecasts a positive profit at the end of the fifth year, proved that break-even point is reached during fourth year. UBTPPS creates value for populations and finds better ways to solve problems. This means that not only an emerging country is to be considered as a target of the project. Requirements are different and results of the new waste management reflect these needs.

Tab.4: Income

	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
INCOME BEFORE TAXES	**-€ 1,680,333.33**	**€ 734,027.07**	**€ 815,870.77**	**€ 896,285.33**	**€ 975,395.49**	**€ 1,053,320.79**
Taxes (40%)	€ -	€ 293,610.83	€ 326,348.31	€ 358,514.13	€ 390,158.20	€ 421,328.31
NET INCOME	€ -	**€ 440,416.24**	**€ 489,522.46**	**€ 537,771.20**	**€ 585,237.29**	**€ 631,992.47**

Tab.5: Net Present Value

NPV	**YEAR 0**	**YEAR 1**	**YEAR 2**	**YEAR 3**	**YEAR 4**	**YEAR 5**
	-€ 1,680,333.33	**€ 141,498.88**	**€ 698,412.73**	**€ 706,632.26**	**€ 711,837.56**	**€ 1,219,394.27**
SUM OF ACTUALIZED CASH FLOW	**€ 1,797,442.37**	**>**	**0**			

TECHNICAL DESCRIPTION

THE TPPS LOOP

The TPPS circular loop (Fig. 1) is based on three fundamental nodes: the Packaging Toilet System, the Handling Service and the Pyrolysis Reactor.

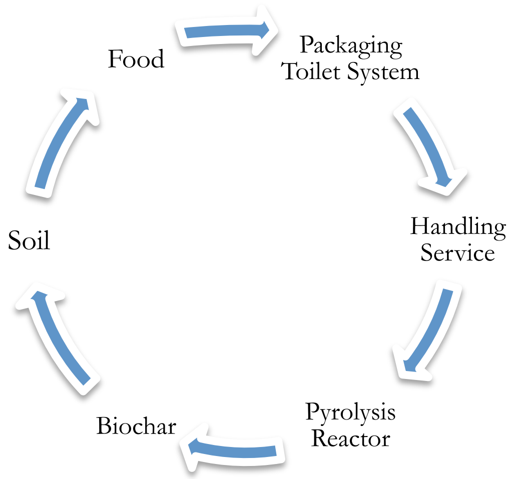

Fig. 1: The TPPS circular loop.

The proposal points out a new waterless toilet that would collect the excrements out of the place where the toilet would be installed, in order to avoid the following problems:

- Hygienic problem and behaviour issue: a composting tank needs to works at a certain temperature (40-65°C) for a certain period of time in such a way to reduce and kill the pathogens content. This means that the owner of the toilet should pay attention to the process during the composting period to guarantee the effectiveness of the safety issues: this could be acceptable in a developing country but it is not suitable for a developed country, where people are used to "forget" about the toilet all day long
- Handling issue: after the compost has "matured", it should be ready to be moved to the soil. In a developed country a toilet that obliges users to do a heavy work to empty smelly tank, is difficult to accept. Moreover, a modern citizen has neither a place where to put a large amount of compost nor someone who can take it from his place.
- Odour problem: the largest part of the composting toilets already available has a vent fan, which should remove odours. According to the technical part of the team, this solution is not sufficient to guarantee a complete odour block.

Adaptability to urban areas

TPPS suits urban areas, using part of the existing pipelines. In particular, PTS would be able to fully integrate in the context of a modern city and it would be repeatable in a smaller and simpler reality (e.g. in some emerging country the excrements tank could be placed directly under the toilet seat instead of in the basement, without the complexity of the waste stack). A feature of TPPS is the willing of implementing and integrating the system into the pre-existing pipelines system, without constructing new infrastructures. In every case it would be necessary to study the map of each building to get the best available solution with the minimum impact on the structure.

Adaptability to a wide range of geographies and cultures

This issue can be summarized in two points:

- A modern country has a scarce necessity of a new kind of waterless toilet, because its infrastructure is based on the wastewater treatment system that avoids disease problems but implies a huge consumption of water. On the other hand a modern country has a high level of standards systems, which would stop any tentative to adapt a toilet engineered for a developing country.
- An emerging country necessitates urgently the developing of a waterless toilet solution to reduce problems caused by lack of sanitation (for example, people who has no possibility to wash their hands) and to save water, which is the most precious good in the world.

THE PACKAGING TOILET SYSTEM

Thanks to an anonymous form questionnaire (Appendix B) 177 people assessed their behaviours about sanitation, environment and sustainability, identifying the most important features of a new type of a waterless toilet.

Parts composing the questionnaire: are

- SECTION I: OVERWIEV - information about age, gender and current job of the interviewed.
- SECTION II: ENVIROMENTAL SUSTAINABILITY - responsiveness about environment sustainability and knowledge of wasteful habits
- SECTION III: TOILET FACILITIES - relevance of the characteristics of a new waterless toilet

The analysis states that people require a waterless system that does not affect traditional habits. Moreover, the new waterless system has to be easy to be used and easy to be cleaned, with a simple maintenance and a suitable design.

The Packaging Toilet System, heart of the loop, has been developed according to these main criteria.

The PTS is the assembly of two components: the Packaging Toilet Unit and the Tank Unit. The PTS is the core of the TPPS collecting system: it allows to collect the excrements and to transfer them into the tank, which is usually located in the building basement, by the waste stack.

Hereafter, the Packaging Toilet Unit will be described in details.

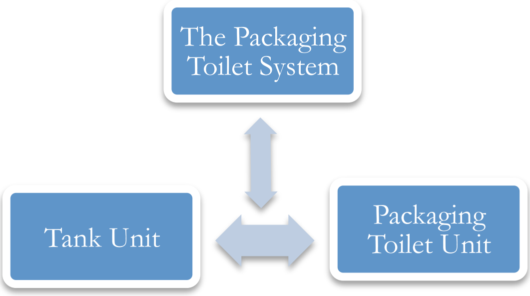

Fig. 2: Components - Packaging System

The Packaging Toilet Unit (PTU)

The Packaging Toilet is a waterless toilet which separates the urine from the faeces, thanks to an urine separator: the urine is canalized in a pipeline and guided to the urine tank, located in the basement next to the excrements tank, while the excrements are collected at first into a single use bag which is sealed immediately and sent to the tank.

The tanks are took away before they are completely filled up and substituted with new ones.

The Packaging Toilet Unit (Fig. 3) can be divided into five sub assemblies:

- The Mechanism Box
- The Toilet Shell
- The Recharge Column Group
- The Rear Guide
- The Base Cabinet

The first three assemblies are the most important ones. The PTU is composed by 60 elements (49 without the Base Cabinet).

Appendix C.1 includes the BoM (Tab C.1-1), the drawings (Fig C.1-1, Fig C.1-2, Fig C.1-3, Fig C.1-4, Fig C.1-5, Fig C.1-6, Fig C.1-7) and the final cost of the toilet (Tab C.1-2).

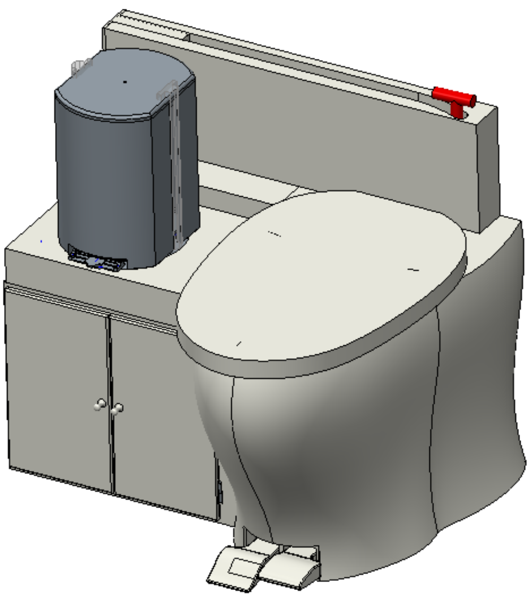

Fig. 3: The Packaging Toilet Unit.

The Mechanism Box

The Mechanism Box (Fig. 4) is the inner part of the assembly; it is located inside the Toilet Shell and supports the Recharge Column Group. It includes the Sealing mechanism and the Ramp Mechanism: the Sealing Mechanism, activated by a dedicated pedal, aims to seal the single use bag, which already contains a certain amount of excreta, by means of two Sealers. The Sealers have two stainless steel blades that can be heated to an established temperature, thanks to an electric circuit, in order to obtain the heat-sealing of the bag. The Ramp Mechanism, activated by another dedicated pedal, is designed to help the bag to leave the toilet in the waste stack direction: when the pedal is pushed the Ramp rotates, in such a way to create a 35/40° angle with the floor, and at the same time the Shutter, which is the part designated to block the odours, opens up to let the bag pass. After that, the system will return to its resting position, thanks to the action of some torsional springs. The Mechanism Box has two lateral Windows, useful for maintenance operations.

The outer case and all the other components, except the sealers blades, are made of PVC, an economic fully recyclable that, because of its durability, guarantees a long lasting useful life, with a very low necessity of maintenance services.

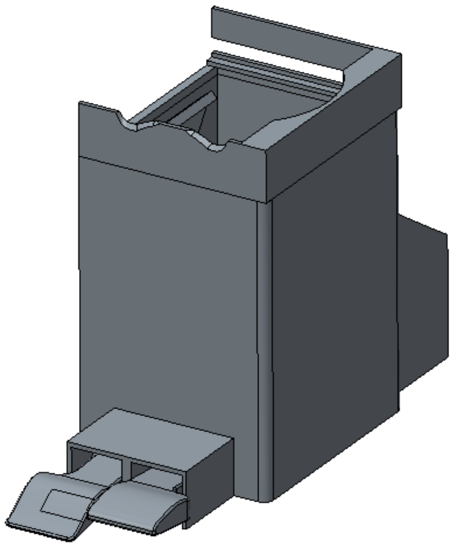

Fig. 4: The Mechanism Box.

The Toilet Shell

Inspired by the classic flushing toilet design, the Toilet Shell (Fig. 5) is shaped in such a way to transmit an idea of comfort and cleanliness: the classical shape aims to instil in the user a sort of self confidence feeling, trying to reduce the gap between the attractiveness of a flushing toilet and the attractiveness of a waterless one. The Toilet Shell encloses the Mechanism Box and a part of the Recharge Column Group.

It is composed by three main parts:

- Ceramic Body
- Urine Separator
- Seat/Lid Group

The Ceramic Body is the outer coat of the toilet, it can be made of ceramics, in the version for the developed countries, or cement, for the developing countries: this latter choice implies the use of a more economic material which permits both to lower the total cost of the product and to create a sort of local manufacturing system. The Body presents a side opening in such a way that it permits to reach the two lateral Windows of the Mechanism Box without the necessity of disassemble the entire toilet.

The Urine Separator is the part dedicated to the separation of the excreta and it is placed upon the Ceramic Body. The Urine Separator is extractable to allow an easy access to the Mechanism Box and to provide a deeper cleaning of the parts. It is made of stainless steel, which guarantees safety, hygiene and durability for every kind of use.

The Seat/Lid Group includes the Toilet Seat and the Toilet Lid: both are realized of Polypropylene, a recyclable polymer that guarantees robustness and respect of the hygienic standards.

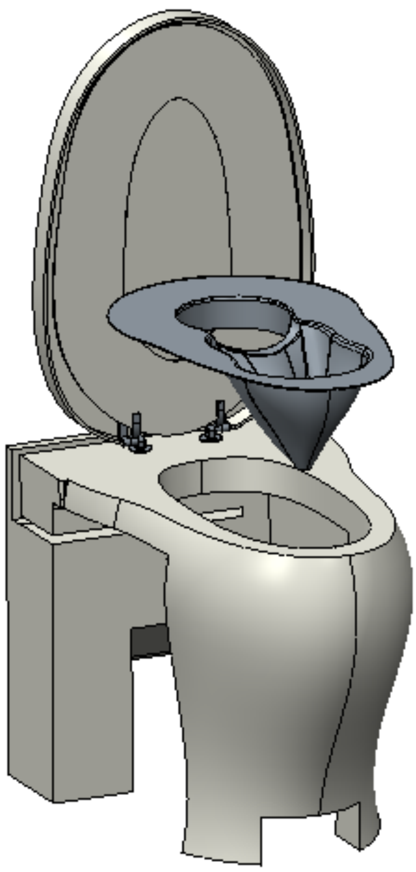

Fig. 5: The Toilet Shell.

The Recharge Column Group

The Recharge Column Group (Fig. 6) is the most important sub assembly of the toilet, together with the Mechanism Box. It is composed by 23 parts and can be divided into four main sub groups:

- Track Group
- Bag Positioning Mechanism
- Column Assembly
- Bag Holder Group

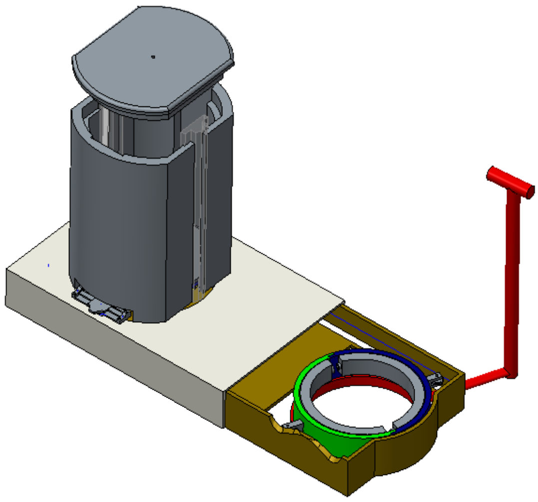

Fig. 6: The Recharge Column Group.

The Track Group's support structure is a two parts assembly (the lower part, the Track, and the outer part, the Track Case) that has two functions: it has to ensure that the Bag Holder Group can slide without any problem and it has to support the Bag Positioning Mechanism.
The Bag Positioning Mechanism moves the new Bag from inside the column to the Bag Holder Group to provide a refill for the system: the Bag Positioning Mechanism is activated by the Bag Holder Group that pushes against the Slider.
The Column Assembly contains a pre-set number of Bags: the number of contained Bags depends on the height of the column. A standard column is 300 mm high and contains 100 Bags. The Column has two lateral windows, so the user is able to check when the recharge of bags is needed. The Bag Holder Group is free to move along the track: at first, it is recharged with a new bag (Refill Position, right under the Column Assembly) and later on it is placed right under the Toilet Seat, in order to collect excrements (Operative Position): in this latter position the two Inner Holders push against the two External Holders, to block the thicker edge of the Bag and to guarantee its correct positioning. When the collection of the excreta is completed, the Bag Holder Group can be rotated to let the border of the bags free: that's because of the action of the two Castor Wheels. The two Castor Wheels are connected to the Inner Holders: when the Bag Holder Group rotates, the Castor Wheels follow the wall of the Track so the Inner Holders are pushed to the inside leaving a clearance between them and the External Holders. After that, the Sealing Mechanism can be activated. The Bag Holder Group is hand operated and is guided by the Rear Guide. The Bags are made of PLA, Polylactic Acid, a bio-polyester obtained by the monomers of the Lactic Acid. It has a clean life cycle, because of its origin from the corn-starch. The mix of two kind of co-polymer (90%D, 10%L) allows obtaining a flexible film with good mechanical properties. Its low glass temperature (around 60°C) permits to lower the thermal energy needed by the Sealers. The properties of the PLA can be modified by the change of the percentage of the two co-polymers or by the stretching process ("Studio e Sperimentazione per la Saldatura Laser di Film realizzati con Biopolimero", Master thesis by Stefano Tommaso Polidori).

The Rear Guide

The Rear Guide is not a structural element: its aim is to guide the Bag Holder Group. It is situated in the rear part of the toilet and it is made of PVC.

The Base Cabinet

The Base Cabinet is placed right under the Column Assembly. It has two functions: it helps to support the Recharge Column Group and contains the new refill of the Bags. It is also made of PVC, except the Hinges made of Stainless Steel. The Base Cabinet can be replaced with another kind of support or may be missed for the most economic versions.

The Production Process

In order to satisfy the necessity of a large-scale production (around 7,000 toilets) for an urban area of 20,000 inhabitants, a mass production manufacturing system has been chosen. The system can be divided in two main departments: the first is dedicated to the production of the Plastic Based Components (Injection Molding), in the latter the Ceramic Body is fabricated (basing on the present White Wear production systems). The Stainless Steel components are standardized (except the Urine Separator), so they can be bought from an external supplier.

Final Comments – The Packaging Toilet System

The Sealing System introduced with the Packaging Toilet represents an important step forward to solve the hygienic issue of waterless toilets. It allows both to deploy the excrements treatment outside the dwelling and to enormously simplify the excreta handling. This because the Sealed Bag creates a strong barrier between the excreta and the rest of the system: in such a way it is possible to move the filled bag from the PT to the Excreta Tank, with the excreta that are unable to flow out.

To improve the cleanliness of the Toilet Seat and of the Urine Separator a Foam Nozzle can be included in the system.

The showed system is hand operated: that's because the necessity of keeping a low price, especially for the users of emerging countries. An automatic dumping system can be included for the high-priced markets.

A Life Cycle Assessment, LCA, analysis should be carried out to evaluate the product involving the productive process.

THE PYROLYSIS REACTOR

The excrements are processed in the GPAs with Pyrolysis Reactors (Appendix C.2), to produce Biochar.

Handling service provide excrements to the GPA in which biomasses are stocked, dried and processed.

The GPA has a surface area of about 50 square meters and includes: area of waste collection, drying, pyrolysis, engine for the production of electricity supplied to Syngas and the final area of stocking of finished products.

The compostable single use bags, once arrived in the GPA, are stored in the warehouse at the first entry to the dryer. Here the bags are placed on a conveyor belt that runs through the dryer, the area where heat is supplied to the biomass in order to reduce relative humidity from 70-85% to 45%.

This step is strictly necessary, assuming that the input material must possess homogeneity and relative humidity content to the maximum of 45%.

At the exit of the dryer, a typical biomass is obtained as input material for pyrolysis.

This process, not yet used for this type of material, is already used for other wastes of animal origin (droppings, cow and pig dung).

In the Pyrolysis Reactor, the atmosphere is controlled: there is no presence of oxygen and the process takes place in vacuum. In order to ensure a high quality of Biochar, the operating temperature must be kept around 350 °C with a rotation speed of 1-8 revolutions/min and a residence time of about 5 minutes. The possible presence of catalysts can reduce the residence time.

In this way, assuming to use a 150 kW Pyrolysis Reactor that works 7,000 hours/year with 1,575 tons/year of biomass in input to the dryer, the outcome is 315 tons/year of Biochar, 315 tons/year of Syngas and 270 tons/year of fuel oil.

The Syngas guarantees production of electrical energy in order to allow the full autonomy of the plant and a surplus of about 20 % of Syngas can be used for handling vehicles.

To determine the installation costs it is necessary to define the power required from the Pyrolysis Reactor to accomplish the needs of users. The standard sizes, available on the market, are 25-50-100-150 kW.

It is assumed an installation cost of 3,000 euro/kW for Pyrolysis Reactor with size of less than 100 kW, and for greater sizes a cost of 2,500 euro/kW (used in cost estimation).

The advantage of this type of system is its ductility. It can be installed both in a industrialized country and in a developing one: in this latter case, the work temperature needs to be raised in order to guarantee a lower production of Biochar in favour of a larger production of Syngas that can be used as an energy source, in favour of populations requirements. In fact, using a temperature higher than 500 °C the fractions of Syngas and fuel oils are larger (around the 10%) while the production of Biochar is lower and the product has a worse quality.

THE HANDLING SERVICE

The main handling problem is to determine the optimal number of Pyrolysis Reactor to be installed in a district of 20,000 inhabitants, with the objective of minimizing the total cost, given by the sum between the total handling cost and the installation costs. The optimal solution is given by the trade-off between the handling cost, inversely related to the number of Pyrolysis Reactor, and the installation costs, which are directly proportional to the number of Pyrolysis Reactor.
In order to find the optimal solution a multi scenario analysis is implemented, with the purpose of comparing three different hypotheses:

- HIGH: one Pyrolysis Reactor serving the target district;
- MEDIUM: two Pyrolysis Reactors serving the target district;
- LOW: four Pyrolysis Reactors serving the target district;

These scenarios are emerged facing realistic assumptions concerning the average ability of the Pyrolysis Reactor and about the target users.

Installation Cost of Pyrolysis Reactor

Basing on the previous hypotheses the installation cost is showed in the following Tab. 6.

Tab. 6: Pyro reactor installation cost

		Power of each pyrolysis reactor to install (kW/pyro reactor)				
Scenario	Number of pyrolysis reactor n	n1	n2	n3	n4	Total Cost of installation
HIGH	1	150				€ 375,000.00
MEDIUM	2	100	50			€ 400,000.00
LOW	4	50	50	25	25	€ 450,000.00

Handling Cost

The solid waste collection concerns the service of a group of customers by a set of vehicles, which are located in one or more depots (GPA) and move through an appropriate road network. In particular, the Vehicle Routing Problem (VRP) minimizes the total distance driven by vehicles for visited CP, creating a set of routes that starts and ends at its own depot. The model boundary conditions are: all the requirements of the customers must be fulfilled, all the operational constraints must be satisfied. The objective function must allow the minimisation of the global transportation cost.
The VRP model is deeply detailed in Appendix C.3.
In order to respond to the requirement of transferability of the model, it has been applied to a district of 20,000 inhabitants characterised by a reticular form, where the distance between the streets on the x-axis and on the y-axis are fixed, 100 m and 200 m respectively.
In addition, another hypothesis of the model is the existence of a collection point (CP) at each intersection of roads. These CPs are gathering places where the vehicles must stop to collect the waste. With these assumptions, the result obtained is a square neighbourhood with the side of 1,600 m, and a total number of CP equal to 153. The position of the Pyrolysis Reactor is assumed to be out of the residential area in order to be barely invasive for the inhabitants.
The next Tab.7 presents the results of the implementation of the model:

Tab. 7: VRP results

Scenario	Number of pyrolyzer n	Total distance to serve the neighbourhood (km/year)
HIGH	1	3,203
MEDIUM	2	2,884
LOW	4	2,482

Assuming that the vehicles are powered by the methane produced by the Pyrolysis Reactor and that the material handling service needs three operators which have each a cost of 30,000 €/year, to calculate the annual handling cost, it is adopt a cost per km of 0.10 €/km. In addition, it is considered a work time equal to 365 days per year, this in order to respond to the exigencies of the users, and a time interval between two stops at the same CP of 4 days. To obtain the total handling cost, the annual cost is actualised supposing a period time of 5 years and a discount rate of 4%.

Tab. 8: Total Handling Cost.

Scenario	Annual Handling Cost	Period Time (years)	Discount rate	Total Handling Cost
HIGH	€ 90,315.35	5	0.04	€ 402,067.90
MEDIUM	€ 90,283.91			€ 401,927.91
LOW	€ 90,244.38			€ 401,751.92

Total Costs

Tab. 9: Total Cost

Scenario	Total Installation Cost	Total Handling Cost	Total Cost	Saving in percent
HIGH	€ 375,000.00	€ 402,067.90	€ 777,067.90	9%
MEDIUM	€ 400,000.00	€ 401,927.91	€ 801,927.91	6%
LOW	€ 450,000.00	€ 401,751.92	€ 851,751.92	0%

The solution that minimizes the total cost (Tab. 9) corresponds to the HIGH scenario, which includes the installation of only one pyrolysis reactor per 20,000 inhabitants, even if the difference in saving among the three proposed scenario is only 9% on a period of 5 years.

ADDITIONAL QUESTIONS

PROPOSAL PHASE

The TPPS system is an innovative solution that is not applied yet but whose implementation is feasible. There are some problems to be faced.

- First problem: adaptation of the PTS to different situations. In urban areas, PTS uses part of the urban sewerage system to carry compostable single use bag to the Tank Unit, while in developing areas, the Tank Unit is placed directly under the toilet seat. In each case, the architecture of each building has to be considered to choose the best possible solution with the minimum impact on the structure, preventing a standard way for application of the PTS.
- Second problem: feasibility of the pyrolysis of human excrements to create Biochar. This topic has been the focus of a European Project, E2BEBIS (Environmental and Economic BEnefits from Biochar), which confirmed the practicability of this solution at the Medical and Veterinary Sciences Department (University of Bologna) also if nobody has already implemented it. E2BEBIS is an international projects implemented through the CENTRAL EUROPE Programme co-financed by the ERDF.

In conclusion, TPPS system is still in a concept phase but it has real possibilities to become a successful solution in the next future.

ADDITIONAL INFORMATIONS

- “UB TEAM Logo” and “Headings of the Submission” are in blue colour, to underline the “blue sensibility”
- “Garamond” font may reduce the paper used in case of print, compared to traditional fonts.

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