BIOGAS AND DIGESTATE WITH CONTROLLED AMMONIA CONTENT BY A VIRTUOUS BIOWASTE CYCLE WITH INTEGRATED BIO&CHEMICAL PROCESSES

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> "Before burning everything up, consider saving what is valuable: municipal biowaste contains valuable organic matter and the real waste is dismissing to landfills or burning it"

BIOWASTE

The estimated European production of **municipal biowaste** ranges around **100 million tons** per year. The two major streams of this waste are:
- park & garden
- kitchen waste

WATER

Municipal organic waste contains **50-80% of water**. This water, due to the destination of this type of waste and the treatments currently in use, is mostly dissipated.

LANDFILL

The most common destination for municipal biowaste is **landfilling** or, alternatively, **incineration**, due to the limitations of current treatment technologies.

SUSTAINABLE

With the LIFECAB process it is possible to **reduce** the production of **ammoniaca** (-100%) and **CO2** (-20%), **recover water**, **eliminate** the **inceneration** or **landfill** of **municipal biowaste**.

BUSINESS

Municipal organic waste can be used to produce **new bio-products** capable of stimulating the development of a **green economy**, in accordance with the paradigm of the **circular economy**.

POLICY

LIFECAB aims to stimulate communities, municipalities and private investors to **implement** specific **environmental EU policies** and to **update legislation** in this field.

CURRENT CONTEXT

LIFECAB is realised by Hysytech, Acea Pinerolese industriale, Agricultural university of Athens, Cyprus University of Technology, Organohumiki Thrakis, POOL.ITI, Sewerage Board of Limassol – Amathus, Università degli Studi di Torino, with the contribution of the LIFE Programme of the European Union.

LIFECAB Project

Biogas and digestate with controlled ammonia content by a virtuous bio-waste cycle with integrated bio and chemical processes

Summary

Introduction

The increasing in the production of municipal bio-wastes increased the need to find solution for their recycling.

Previous researches made by ACEA Pinerolese Industriale and University of Torino were finalized to upgrade biomasses as source for different kind of bio-based products.

These researches validated the initial idea of converting municipal bio-wastes to products with added value for different uses, both at laboratory and plant scale, with an increased monetary value (1-100 $/kg) considering a processing costs averagely of 0.1-0.5 $/kg, depending on the purity.

According to these researches, an increase in the biogas and methane production can be achieved by adding, to the feed of the biogas production reactor, soluble bio-organics, moreover, the ammonia content digestate can also be reduced with a process called controlled ammonia biogas production technology.

Such new technologies generate products which are still not known in the market requiring, then, both market assessment and legislative acceptance.

This solution presents advantages not only from the environmental point of view but also regarding costs since both operation and capital costs of the new controlled ammonia biogas technology are lower than traditional technologies for the same purpose justifying the integration of the proposed technology to facilities producing soluble bio-organics from compost for in-house as additive in anaerobic digestion reactor making the process independent to the allocation of soluble bio-organics external market.

The excess of soluble bio-organics, due to the new facility, represent the first step in the mutation of a waste treatment plant into a biorefinery to produce bio-based chemical products with added value and ecofriendly biofuel with a minimum financial risk.

The validation of the presented controlled-ammonia biogas production technology is one of the main aims of LIFECAB project, both at real operational environment (at the ACEA waste treatment plant) and at pilot level (in the three partner countries located in Greece and Cyprus), intended to sensitize both private investors and administrations to this new and environmental-friendly approach in urban waste recycling.

The partnership composition is a large-scale cooperation among public institutions and private companies demonstrating innovative process and products in the field of municipal bio-waste and can be a proper solution for the pilot activity in validating the technology proposed both in Italy and in other European countries. LIFECAB is also aimed to encourage investors at European level to make a biorefinery fed with municipal bio-waste a real option disseminating worldwide and validating the ideas proposed in the project thanks to the participant of a pool made up thanks to the European approach. In this way, the institutional activities and the industrial participants will impact many other countries demonstrating the feasibility to recycle bio-based waste into chemical and consumer's market with consequent advantages for environment, society and industry such as lower CO_2 emission, lower fossils consumption and lower concern for disposal practices of industrial wastes, low production cost, high product added value and lower consumption of synthetic chemicals

Project objectives

1. Validate the process at larger scale in the closest way possible to real operational condition
2. Prove that capital expenditure and operating expense of soluble bio-organics production unit are reduced if compared with the conventional digestate secondary treatment.
3. Prove that bio-waste can yield bio-based products, which in turn can be used to improve the fermentation process of the sourcing bio-waste and its environmental impact.
4. Demonstrate a new business model allowing the valorization of bio-waste through integrated biochemical and chemical processes in real operational environment with reduced entrepreneurial risk

Expected results

Several results concerning this project are expected. These results cover several aspects of environmental, social and economic interest.
From the environmental and social point of view:

- Availability of HP yielding soluble bio-organics by hydrolysis of compost of municipal bio-waste from different EU locations.
- Producing 50 t soluble bio-organics for use as additive in anaerobic digestion tests performed in real operational environment or at pilot scale in the project.
- Validating and replicating, in real operational environment or at pilot scale in partner countries, previously published laboratory data on new municipal bio-waste anaerobic fermentation process assisted by added soluble bio-organics for producing digestate with low NH_3 content.
- Calculating EU environmental benefits of the new process, i.e. 15 % (55 Mt/ yr.) CO_2 and 100 % (450,000 t/yr.) NH_3 lower emission.
- Stimulating landfill practices dismissal in EU countries by the attracting benefits of the project new municipal bio-waste technology.
- Assessing feasibility of technology transfer of the new project hydrolysis and fermentation processes and perspectives of improved waste treatment education in EU Member States that are less active in municipal bio-waste management practices.

- Contributing new technology for fermenting other bio-waste, such as manure or sewage sludge, that does not require secondary digestate treatment for soil spreading.
- Improving water quality for reuse in the new chemical and biochemical LIFECAB addressed processes.
- Improving digestate quality for use as soil fertilizer.

From the economical point of view:

- Demonstrating new business model at low entrepreneurial risk for the valorization of municipal bio-waste as source of soluble bio-organics for in-house use and market allocation for other uses;
- Expected yearly outputs based on model municipal bio-waste treatment plant treating 105 municipal bio-waste t/yr.:
- 8.6 Mm^3 biogas, 6000 t digestate, 5400 t compost (from 18000 t gardening wastes and digestate mixed in 2/1 w/w ratio to yield compost after 70 % mass reduction), 1000 soluble bio-organics t from compost hydrolysis, 100 soluble bio-organics t/yr. for in house use, 900 t/ yr. sold in external market.
- Calculating EU economic benefits of the new fermentation process not requiring secondary digestate treatment for abating NH_3 compared to conventional technology: i.e. 30 M€/yr. savings from fermentation of 100 Mt/ yr. EU produced municipal bio-waste.

Actions and means involved

As mentioned before, thanks to an hydrolyzation process, composted municipal bio wastes can be turned into soluble bio-based products that, in turn, can be used to improve both anaerobic fermentation of the raw municipal bio-waste and the quality of the process digestate by reducing its NH_3 content.
The first objective of LIFECAB is to prove that the bio-waste cycle described above, including biochemical and chemical processes is both replicable and transferrable to the industry. This is exploited through the following:

- Collection of raw and composted municipal bio-waste
- Design and construction of prototypes:
    - 1 composted municipal bio-waste hydrolysis prototype (HP) to produce soluble bio-organics;
    - 2 anaerobic digestion and 2 composting prototypes.
- Production of soluble bio-organics from composted municipal bio-waste supplied by each partner.
- Carrying out anaerobic fermentation runs processing local raw municipal bio-waste.
- Life cycle assessment. Calculation and optimization of the new process economic and environmental impact as a function of the municipal bio-waste nature at the different partners locations, in order to assess results replicability and process transferability.

Climate relations

Even though LIFECAB is related to waste treatment, the environmental benefits brought by the innovations proposed will impact on the climate too.

Starting from the first step of the project, the municipal bio-waste will be recycled reducing the environmental impact (gas emission into the atmosphere and leachate released into soils) with positive consequences also on the greenhouse effect. Moreover, the more ecofriendly digestate produced, characterized by reduced ammonia content, can be used as soil natural fertilizer instead of using traditional chemical products

Allowing, at reduced entrepreneurial risk, the market assessment related soluble bio-organic products in several sectors such as chemical industry, animal husbandry and agriculture, the construction of bio-waste fed refinery, the project will achieve higher climate related values

Soluble bio-organics can be used as diet supplements of animal feed creating manure with lower green gas emission and inorganic N leachate.

A further climate advantage is represented by replacing traditional fossil sourced commercial products with soluble bio-organics currently used for the manufacture of chemical and agricultural finished formulations

To quantify the environmental benefits, LCA will be assessed in order to compare, in a quantitative and measurable way, the innovative protocol with the conventional treatment technologies for municipal bio-waste treatment.

Environmental problems targeted

Two sectors of human activities will be impacted by LIFECAB project: municipal bio-waste management (from collection to landfilling) and agriculture. Municipal bio-waste is biodegradable and the estimated production ranges around 76.5-102 Mt.

The environmental and economic impacts of the treatments depend on local conditions such as population density, infrastructure and climate, as well as on markets for associated products.

LIFECAB proposes an innovative approach based on a virtuous material cycle involving anaerobic digestion and composting, coupled to chemical hydrolysis.

Agronomic benefits (improvement of soil structure, moisture infiltration, water-holding capacity, soil microorganisms and nutrients) can be obtained by the use of compost and digestate as fertilizer.

The environmental impact of composting is mainly due to limited greenhouse gas emissions and volatile organic compounds, moreover it is influenced by the quantity of NH_3 produced due to organic N mineralization (Ammonia inhibits methanogenic bacteria, especially sensitive to this compound).

Nitrate Directive (91/676/EEC) restricts, in Europe, the input of mineral N on farmland, to protect the ground and surface water from pollution.

Benefits are expected at two stages:

- in the short term, from the application in real operational environment of the new municipal bio-waste anaerobic digestion process;
- in the longer term, from promoting biorefinery construction for soluble bio-organics production at reduced entrepreneurial risk.

The economic benefits may encourage communities to dismiss landfills and reduce incineration practices in the perspective of more economically rewarding and ecofriendly technology.

The proposed LIFECAB technology is very simple and can be applied in bioreactors of any size. Small farms can purchase the soluble bio-organics, once it becomes a marketed product, and add it in small amounts to the local biogas reactor. This would allow producing locally an environmentally friendly digestate with

controlled amount of ammonia, with an estimated cost of 0.2-1 €/N kg, without purchasing and operating secondary treatments facilities.
Considering that, the total EU manure production is one order of magnitude higher the food loss and waste, that manure is spread over a myriad of small farms, whereas food wastes are concentrated in urban areas collection facilities, and the impossibility of adapting current conventional technologies at small farm scale, the proposed LIFECAB technology applied to manure has potential to achieve additional high beneficial environmental impact throughout EU countries.
In agriculture, in the long-term period, the use of soluble bio-organics at lower dosed than compost is expected to enhance plant growth and productivity, while reducing the environmental problems connected to the use of compost. The use of soluble bio-organics as feed supplement for animal husbandry is expected to reduce GHC emission, and ammonia and nitrate leachates from manure, moreover, in place of synthetic chemical products for diversified uses would contribute to decrease the depletion of fossil sources and the consequent CO_2 emission.
The ultimate benefits from recycling are a more sustainable economy and the possibility of reducing chemical fertilizers. The more ecofriendly LIFECAB digestate and/or soluble bio-organics are expected to generate the same benefits, while reducing the environmental impact of the traditional current composts and digestates outlined above.
According to Italian DL 29th April 2010, n. 75, based on chemical composition the soluble bio-organics fall well into the category of fertilizers.

Socio Economic effect

“Before burning everything up, consider saving what is valuable; municipal bio-waste contains valuable organic matter and the real waste is dismissing to landfills or burning it” can be consider the best socio-economic message of LIFECAB.
LIFECAB will assess two new technological and socio-economic concepts:

- municipal bio-waste treatment plant may be turned into a biorefinery for the production of fuel and valuable bio-based products with beneficial environmental impact
- municipal bio-waste may be a source revenue, and not merely a burden for society.

The appealing economic benefits of the integrated municipal bio-waste plant producing biogas and soluble bio-organics might be an important socio-economic driver for diverting waste from landfill or from incinerating valuable organic matter. In densely populated areas the integrated municipal bio-waste plant producing biogas and soluble bio-organics might become a real viable option to reduce landfills and incineration.
Thus, LIFECAB will allow achieving to integrate environmental sustainability with economic growth and welfare by decoupling environmental degradation from economic growth and doing more with less, a key EU objective stated in the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan.

LIFECAB proposes a new business innovation model with reduced entrepreneurial risk. This starts with a virtuous in-house bio-waste cycle and develops stepwise toward the production of marketable processes and products. The model has potential to develop public-private partnership ventures dealing with sustainable municipal bio-waste management through selected case-studies at different scales and within

different regulatory frames, based on accepted economic indicators. New value chains will be created involving different sectors.

The economic and environmental benefits stemming from the project actions are likely to induce participation in this framework by countries that are poorly active in waste management. The project will develop business models that integrate economic actors along the value chain from waste to biorefinery plants to consumers of bio-based materials, by creating new cross-sector connections and supporting cross-industry partnership; it will demonstrate cost and performance improvements to levels that are competitive with fossil-based alternatives.

The activities planned in LIFECAB are expected to become a driving force for the sustainable economic and social growth for the whole EU region, expanding an existing industrial sector towards commercial market. Furthermore, upon proving economically viable and technically efficient the LIFECAB proposed waste management approach, specialized scientific and technical personnel will be required for the operation of industrial units that employ this technology, thus increasing the employment opportunities in the region.

By the above after project end actions, LIFECAB will promote market acceptance of new value-added products and technologies. This will lead to increasing competitiveness of the EU bio based chemical industry based on municipal bio-waste exploitation, as measured in terms of market share, turnover, cost effectiveness, employment and intellectual property.

The spreading of results among the local authorities should bring to an increasing in the green conscience of the population, encouraging the environmentally friendly behaviors.

LIFECAB therefore well fits the EU social and economic policy and can contribute to achieving the objectives, and to updating and/or integrating the following EU policy documents:

- Decision 2010/707, 2013/208, 2014/322, COM/2009/0257
- Europe 2020
- EC new legislative proposal on strategy to transform Europe into a more competitive resource-efficient economy, addressing a range of economic sectors, waste and circular efficient economy compatible with jobs and growth.
- Circular Economy Communication and forthcoming review of the EU 2020 Strategy
- "Towards a circular economy: A zero waste program for Europe"
- Employment policies, as Green Employment Initiative
- The EC Communication "Green Action Plan (GAP)" for SMEs

In this fashion, the EU has set out quantitative targets to be achieved by the end of 2020. They concern the employment, research and development, climate and energy, education, social integration and poverty reduction, as well as more ambitious recycling targets to move to a circular economy with more jobs and sustainable growth. The achievement of the new targets on waste is expected to create 580.000 new jobs, making Europe more competitive and reducing the demand for scarce and costly resources. The project is expected to contribute significantly to the above EU new employment estimates

Project Pilot

Much effort is currently done to manage municipal bio-waste. The total EU municipal bio-waste production is estimated1 at 76.5-102 Mt/yr. Several processes are currently being operated to cope with the connected environmental impact. However, not all developed processes are necessarily clean (anaerobic fermentation of bio-waste to recover the heat value of contained organic matter as biomethane).

Unfortunately, the process requires a secondary treatment of the digestate containing the recalcitrant organic bio-waste fraction because the process produces also NH_3 which has important drawbacks since it inhibits methanogenic bacteria.

NH_3 emission and/or nitrate leaching can occur due to inappropriate handling, storage and application. In Europe, the Nitrate Directive (91/676/EEC) restricts the input of mineral N on farmland, aiming to protect the ground and surface water from pollution.

The NH_3 abatement through traditional technologies is quite expensive. Through LIFECAB technologies the NH_3 content in the digestate could be reduced by promoting its conversion to N_2 offering the perspective of new technology for ammonia removal from digestate which is achievable without digestate secondary treatment.

LIFECAB will validate the two following bio-wastes processes:

- hydrolysis of composted bio-wastes to produce soluble bio-organics;
- anaerobic digestion of municipal bio-waste organic humid fraction from separate source collection performed in the presence of added soluble bio-organics.

In more details LIFECAB will focus on the validation of both hydrolysis of composted municipal bio-waste and anaerobic digestion of as collected municipal bio-waste accounting for municipal bio-waste variability through different EU countries.

The LIFECAB hydrolysis process will produce enough soluble bio-organics to perform the biogas production trials in real operational environment using the two 2600 m^3 bioreactors currently operating in the Acea plant. For the pilot studies, one bioreactor will continue its routine fermentation (the control fermentation), while the other will perform the fermentation with the same routine feed but in the presence of added soluble bio-organics.

To validate the transnational applicability of the project technology, locally available municipal biowaste will be collected in Cyprus and Greece.

These will be composted locally by Organohumiki Thrakis and Sewerage Board of Limassol, and the composts will be shipped to the Acea plant to be processed in the hydrolysis process operating at this site. The soluble bio-organics obtained will be delivered by Acea for pilot validation studies in locally operating 1 m^3 capacity anaerobic digestion prototypes. The three case studies, in Italy, Cyprus and Greece, will therefore tackle the two principal stages of the current municipal bio-waste processing chain, i.e. anaerobic digestion and composting. However, the anaerobic digestion trials will be optimized at each partner site to account for the bio-wastes variability across the three different locations.

The Partnership

- Hysytech S.r.l., Italy
- ACEA Pinerolese Industriale S.p.A., Italy
- Agricultural University ofAthens, Greece
- Cyprus University of Technology, Republic of Cyprus
- Organohumiki Thrakis, Greece
- POOL.ITI S.r.l., Italy
- Sewerage Board of Limassol, Greece
- University of Torino, Italy

For more info, visit the project website: www.lifecab.eu