Laymans report

Lo2x project

Supercritical water co-oxidation (SCWcO) of urban sewage sludges and wastes

Project cofinanced by European Union through LIFE programme.

LIFE12 ENV/ES/000477

Framework: environmental needs

Water quality remains an issue across Europe, with implications for public and environmental heath and biodiversity. According to the European Innovation Partnership (EIP) on water **in 2020, Europe must have safe, available and affordable water supply and wastewater treatment for all water in place**, based on **sustainable management of the water resources** and most **innovative, competitive and cost effective solutions**.

Increasing sludge production from wastewater treatment

The implementation of the Directive 91/271/CEE along the last 25 years has forced the EU to improve its wastewater network and treatment installations.
Sludge management has become **one of the most critical issues for the wastewater industry** worldwide, due to the very fast increase in sludge production resulting from increasing numbers of new wastewater treatment plants (WWTPs), more inhabitants connected to existing sewerage systems and upgrading of existing facilities to meet stricter discharge criteria.
This fact led to an increase on the sludge production in Europe up to 50% from 1992 to 2005, being constant from then on. Among the EU members, **Spain, Germany, United Kingdom, Italy and France** contribute to the **80% of the total European production**. Particularly, according to the Spanish Register of Sludge, Spain generated more than 1 M tons of sludge in 2006, being the Valencian Region one of the main generators.

Sludge produced in urban wastewater treatment plant (WWTP)

Sludge pollutants

- Organic micro-pollutants
- Heavy metals
- Micro-plastics
- Nano-particles
- Pathogens

Sludge management and treatment, an important challenge

The Spanish National Plan for Waste (2008-2012) indicated that current sludge treatments are not satisfactory regarding environmental and economic matters and that there was a **need** to develop **innovative and sustainable technologies** in this field avoiding long distance transportation of sludge for land application. This also matches the needs set in the baseline scenario resulting from the assessments on sewage sludge management carried out by the DG Environment of the European Commission in the process engaged for the revision of Directive 86/278/CEE, on application of sewage sludge in agriculture.

Sludge management is an important problem for Europe that requires the collaboration of all the stakeholders to solve it with **cost-effective solutions** without lowering environmental or public health standards. These new treatments should overcome the difficulties sludge treatment entails, mainly its heterogeneous composition.

Sludge treatment may generate a wide diversity of dissolved and suspended materials such as micro-plastics, nano-particles, micro-contaminants, heavy metals or pathogens, that must be eliminated to avoid their concentration in the final solid residue. It also applies for pesticides, associated to massive agricultural activities and, despite the existing regulatory framework, still found in big amounts in environmental media (in particular soil, air and water).

Framework: basis for Lo2x solution

The scope of Lo2x project involves a new alternative based on a treatment that excels all the treatment steps carried out at a WWTP and the external treatments up to final disposal as a whole and allows for the treatment of other organic wastes in the same infrastructure.

The innovative nature of the Lo2x project may be considered under different points of view:

Innovative model

The system changes the concept of the wastewater treatment plant towards a resource recovery plant, in line with one of the strategic objectives (turning waste into resources) in the Roadmap to a Resource Efficient Europe (COM(2011) 571). By 2020 waste should be managed as a resource and land filling of organics should virtually be eliminated.

Technological innovation

The technologic background relies upon Supercritical Water Oxidation of organic material. This technology is up to this date unavailable in Europe at commercial scale for the environmental application considered in this project. A tailor-made prototype was designed and constructed to demonstrate that the system works, considering previous work done by partners in this field.

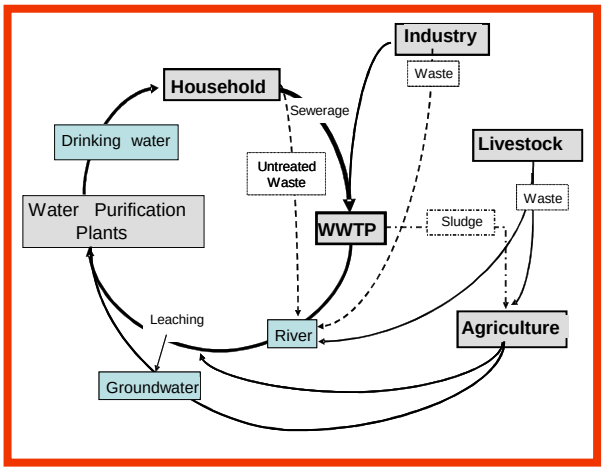
Innovative process

Process limitations already identified have been tackled by introducing the synergistic effect of co-oxidation of different selected wastes. Such wastes separately could be hardly processed in a cost-effective way but proper mixing procedures can do the work.

Lo2x model: WWTP as a kidney removing pollutants from water cycle and source of valuable substances

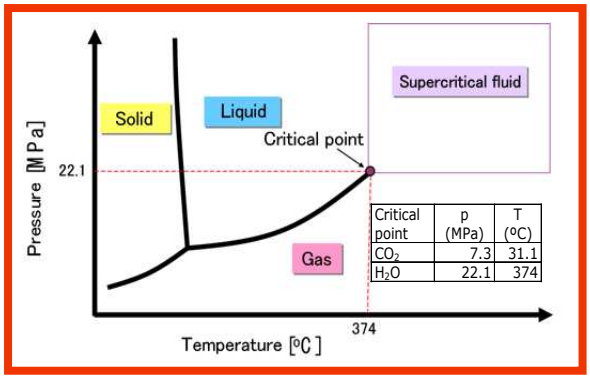
If appropriately conceived, WWTP is the unit responsible of **water cleaning and purification**, acting like a kidney eliminating pollutants from water cycle. Lo2x approach matches this concept, so that the treatment process makes the WWTP able to **eliminate pollutant and harmful compounds**, as well as concentration of toxic substances such as heavy metals in small effluent fractions.

On the other hand, the Lo2x process makes possible the **recovery of valuable substances** such as **phosphorous**.



WWTP role in the water cycle as a purification unit

Lo2x technological basement: Supercritical Water



Water exhibits **special properties** under temperature and pressure conditions **beyond its critical point** (p>221 bar; T>374 ºC): its density, viscosity, solvent power capacity, miscibility with gases such as oxygen, etc. change extensively compared to those of the liquid water. In such conditions, a single dense phase reaction medium is formed and organic compounds may be oxidized in a quite short period of time to smaller molecules such as CO_2, N_2, H_2O… with a 100% efficiency without generating others linked to environmental problems such as NO_x. Additionally, it is possible to use the heat produced by the exothermic reactions, favouring the energy balance.

Thus, the supercritical water oxidation technology can be an interesting alternative to treat some wastes, since organic pollutants may be eliminated without requiring further inertization treatment and facilitating final disposal of a small inert fraction.

General objective

To demonstrate the environmental and socio-economic benefits of a synergic co-treatment of sewage sludge and other wastes by *supercritical water co-oxidation (SCWcO).*

WWTP as a resource recovery factory

Sewage sludge Other waste streams

- *Pesticides*
- *Food wastes*
- *Manure*
- *Leachates*
- *Others*

Project objectives:

The objectives set to demonstrate the technology performance:

O1 **Design and construction of a prototype for SCWcO of mixtures of urban sewage sludge and other wastes.**
The demonstration plant was designed to treat real sewage sludge and other substances. Main matrix (sludge) contained phosphorus and organic carbon and was mixed with other wastes for synergistic enhanced performance like: manure (for organic matter ellimination and nutrient recovery), food wastes (for extra carbon), concentration of toxic substances in solid phase residue and elimination of pesticides.

Once the demonstrative prototype developed and ready,

O2 **Determination of operating conditions for SCWcO treatment.**
Operating conditions were found for best process yield and energy balance, linking water/energy and contributing the achievement of climate neutral waste water systems and a 20% energy improvement in wastewater treatment for 2020.

O3 **Determination of operating conditions to optimise P recovery from wastes.**
Operating conditions to optimise phosphorus recovery from wastes were found, contributing to the objectives of the Resource Efficiency Roadmap (Wastewater Treatment Plants WWTP as resource factories).

O4 **Determination of reduction of waste generated in a WWTP and better quality for safe disposal.**
A reduction of the final amount of waste generated in a WWTP and a better quality of the materials to be disposed contributes to the objectives of the Waste Directive and the phasing out of land filling of organic wastes.

O5 **Determination of economic balance linking environment, innovation & socio-economic growth:**
- Reduction of costs of sludge management versus current sludge management scheme.
- Cost of the treatment compared to current treatment/disposal pathways.
- Economic balance of energy.
- Dissemination effectiveness and social awareness assessment.

Demonstrative prototype: Lo2x vs baseline

The project has involved the construction and operation of a prototype that is able to treat a significant fraction of the raw sludge generated in a representative medium size urban WWTP and wastes collected from the surrounding area.

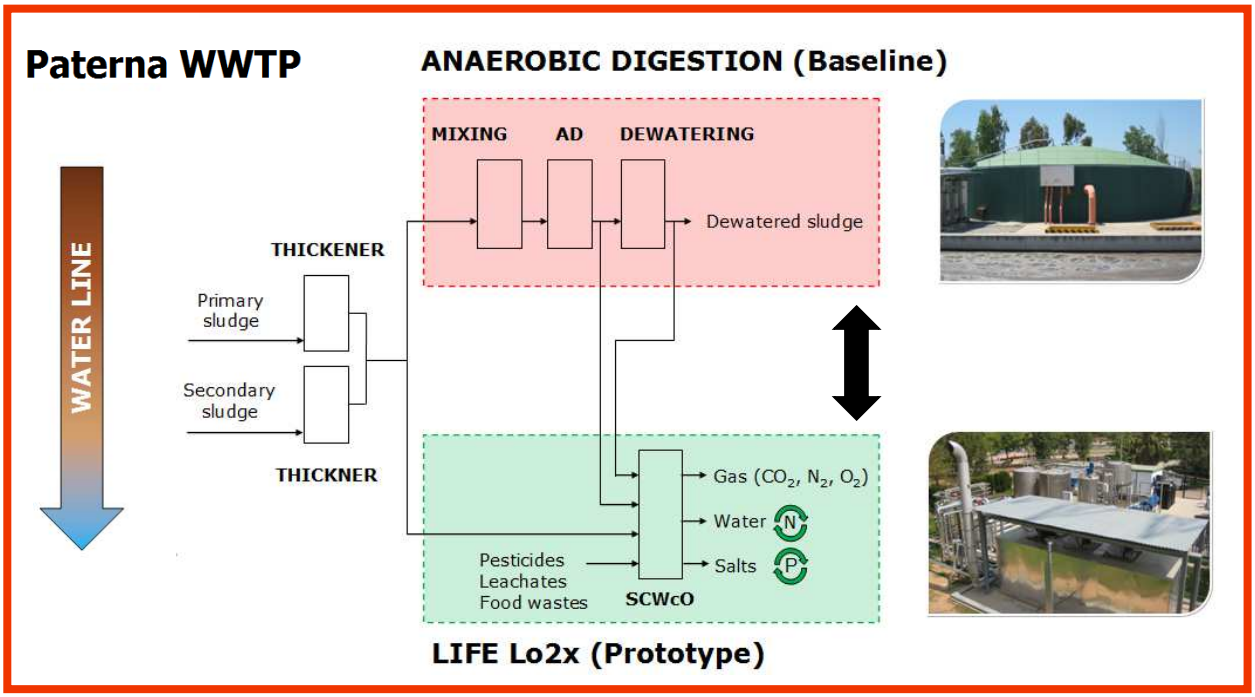
Paterna-Fuente del Jarro wastewater treatment plant in Valencia (Spain).

The demonstrative SCWcO plant was built in a WWTP in the East Coast of Spain, in Valencia Metropolitan area.

Water is a limited resource in Spain, specially in this mentioned area, where different water quality stresses occur: high sludge production and strong nutrient pollution due to an intensive agriculture activity with pesticides overuse. The streams treated in the project (sludge and other wastes) were collected in this surrounding area.

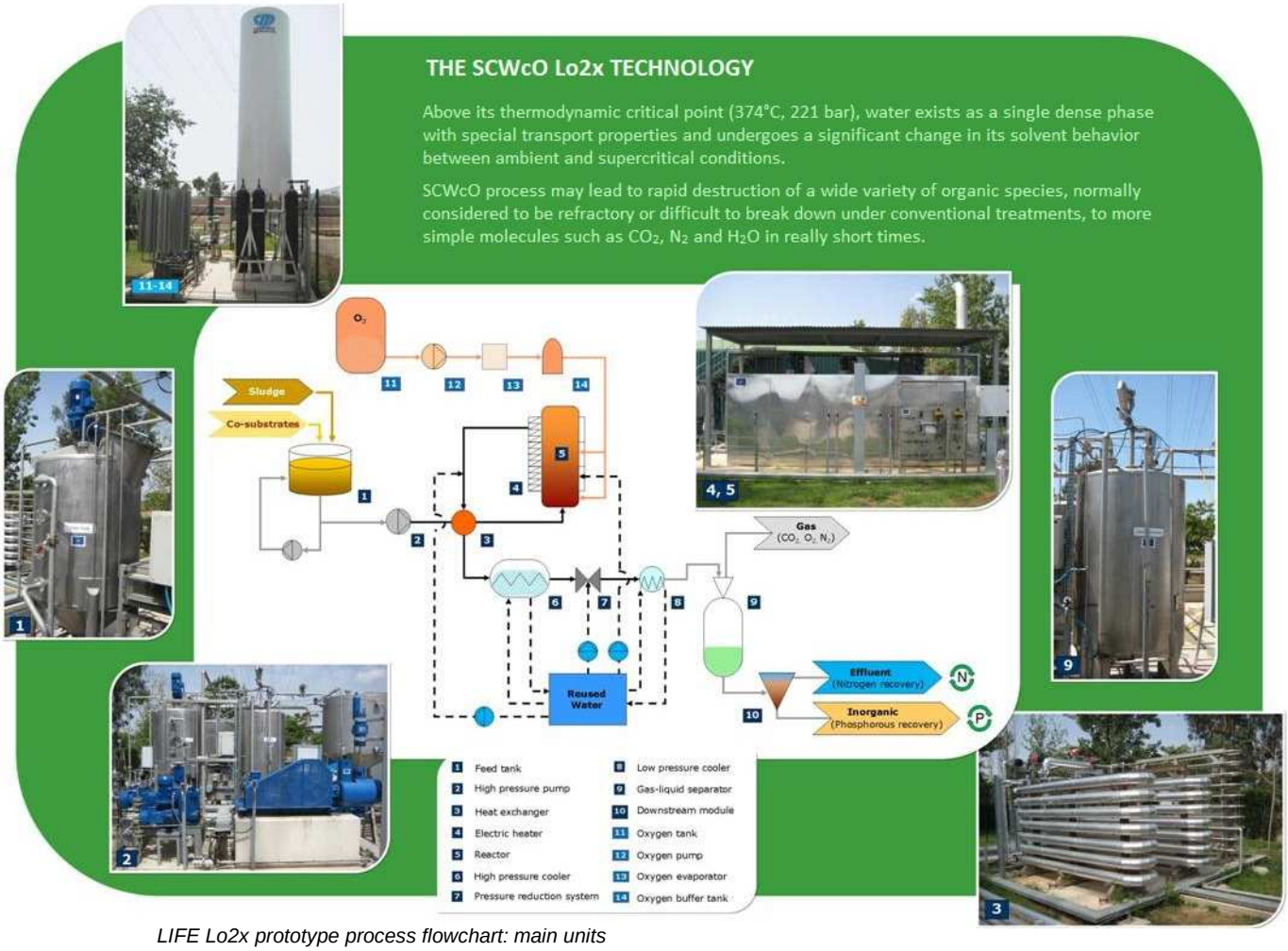
The LIFE Lo2x project has developed the first demonstrative plant in the EU with tubular reactor for valorising, through supercritical water co-oxidation, WWTP sludges not suitable for agriculture together with other wastes in the WWTP nearby area.

At first, it was planned to built a prototype able to treat 0.1 tons of dry sludge per day, that represents the 5% of the capacity of the WWTP. However, the development of the project led to the construction of a larger plant to reinforce its demonstrative purpose, so that it has been possible to carry out experiments entailing a capacity 3 or 4 times higher than the forecast, with the idea to collect sharp data to assess the LIFE Lo2x process alternative with respect to the baseline.



Comparative assessment between baseline and LIFE Lo2x

Lo2x prototype & process: SCWcO



LIFE Lo2x prototype process flowchart: main units

The **supercritical water co-oxidation (SCWcO) plant consists of the reactor,** that is the main unit of the system where the organic contaminants are transformed into non/low-toxic substances, **plus other elements**.

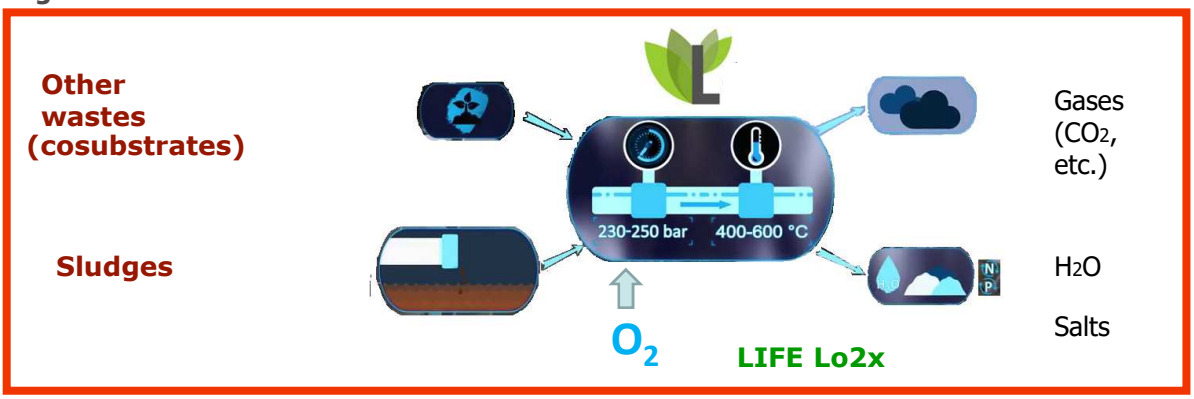
The demonstrative installation may be divided into **three different subsystems**:
- Low-pressure zone: units where the sludge and co-substrates are conditioned to be fed
- High-pressure zone: pumps to feed the process and to reach the pressure conditions
- High-temperature-and-pressure zone: high-pressure units for heat exchange and reaction

When the **feed** to be treated is ready, it is **pressurised** by means of different pumps up to the desired pressure. After pressurisation, reaction mixture is **heated** to reach the supercritical state. Thanks to a heat integration system, the heat produced during the **reaction** is used to preheat the inlet stream, which leads to a huge **save of energy**. The supercritical co-oxidation takes place in the reactor due to the injection of a controlled **pure oxygen** stream to mantain the reaction within the set-up parameters. The installation allows the **continuous treatment** of a feed stream composed by **sludge and other co-substrates**, an advantage regarding annual capacity and resources (time and energy) required to reach the steady state.

The **reaction products** exit the reactor yielding **three fractions** after the separation tank:
- The gaseous compounds are non-harmful, so they can be legally dumped to the atmosphere.
- The liquid effluent contains water and ammonia, so it may be reused as building blocks of fertilisers.
- The inorganic solid residue contains phosphorous, so it may be reused as raw matter for P-recovery.

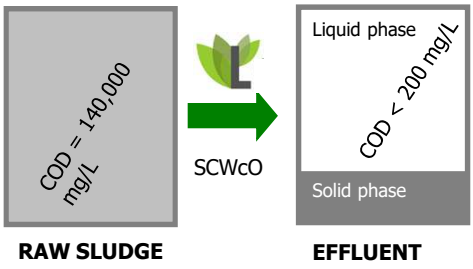
Results achieved

The **Lo2x project has taken advantage of the high versatility of supercritical water to oxidise organic compounds** for treating **sewage sludges** together with a wide range of **wastes as co-substrates (drencher wastewater, olive mill waste water, landfill leachates and cow and pig manure),** being able to treat feeds with undesirable compounds such as **pesticides**. This performance makes the **supercritical water co-oxidation process suitable for replacing/enhancing well-established technologies** such as **anaerobic digestion**.

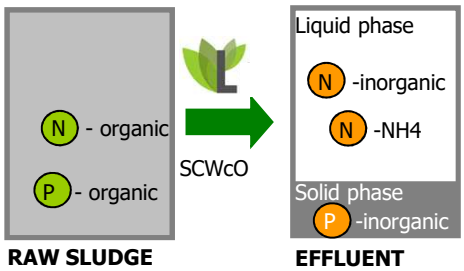


LIFE Lo2x SCWcO process

>99% elimination of organic matter. The COD of SCWcO effluent is in average lower than 200 mg/L, reaching lower values than 25 mg/L.



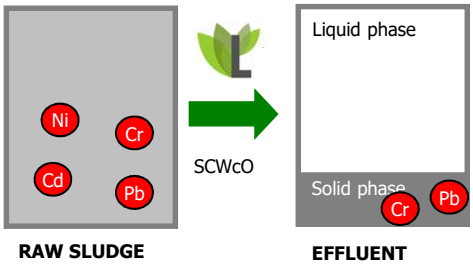
Recovery of nutrients. Mineralisation of nitrogen and phosphorous facilitates the nutrient recovery in order to be used as building blocks of fertilisers. Nitrogen occurs in the liquid (NH_4~2 g/L) while phosphorous is present in the solid phase (P_2O_5~25%).



100% elimination of pesticides. Imazalil is degraded up to 350 mg/kg, removing its presence in the effluent.

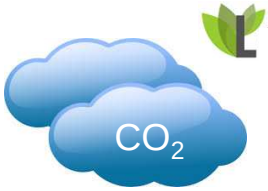
100% elimination of pathogens. *Escherichia coli, Clostridum perfringens* and *Salmonella spp*. are completely eliminated. SCWcO leads to a complete sterilisation.

>85% heavy metals are recaptured for safe handling. Heavy metals are mainly detected in the inert solid of the SCWcO effluent.



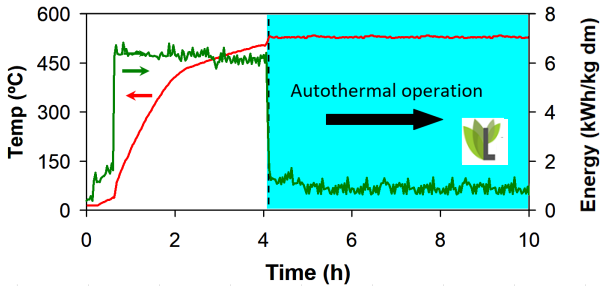
Results achieved

- **Disposable non-harmful gases are produced.** CO_2 is the main gas generated by SCWcO. NO_x and SO_x gases, typical undesired byproducts of combustion processes, are not formed.

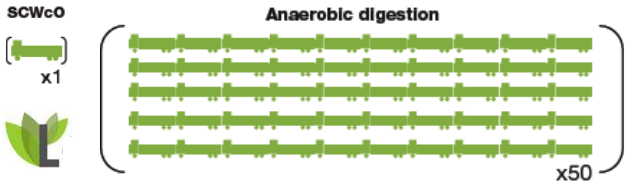


NO < 1.0 ppm
NO_2 < 0.1 ppm
NH_3 < 1.0 ppm
SO_2 < 0.5 ppm

- **Zero heat consumption.** The SCWcO process releases heat (exothermic reaction) that is recovered, so that pumping becomes the only energy-consuming step.

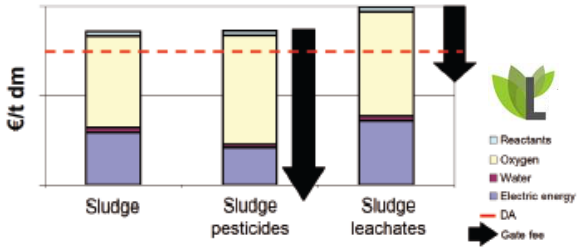


- **>98% reduction of sewage sludge leaving WWTP.** Total solid reduction higher than 90%. Inert solid from SCWcO is a resource for phosphorous industry whereas wastes from anaerobic digestion may end up in the landfills.



Final residue disposal comparative

- **Favorable economics (cash-flow) due to cosubstrate gate-fees.** The gate-fees for co-substrate treatments by current technologies mitigate the costs associated to sludge treatment by SCWcO, so that they might be below the baseline.

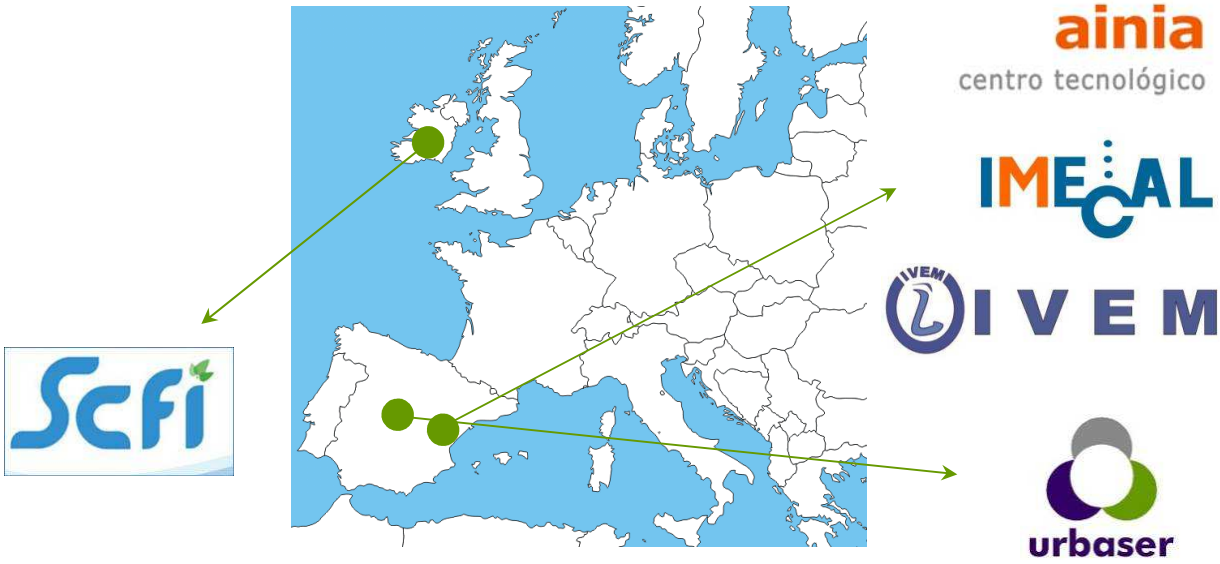


Influence of co-substrate gate fees

Summing up, **LIFE Lo2x project has demonstrated the interesting potential of the proposed technology (SCWcO) for the synergetic valorisation of sewage sludges and other wastes**, as well as some challenges to be tackled to make possible to apply the process at full scale.

Long-term benefits of the project

- **Mitigation of overall environmental pollution**, since the multi-waste treatment and resource recovery approaches of the Lo2x project contribute to reduce the environmental impact of traditional WWTPs.
- **Improvement of water cycle**, since a high-quality effluent is produced, as contaminants (i.e. pesticides, pathogens, etc.) are eliminated and heavy metals are mainly in the final solid residue.
- **Enhancement of nutrient cycles**, thanks to mineralisation and the potential use of effluent fractions as valuable sources to recover nitrogen and/or phosphorus for fertilising uses.
- **Enhancement of air quality**, due to clean direct emissions without undesirable and toxic compounds (NOx, SOx, etc.) and reduction of indirect greenhouse emissions linked to residue disposal transport.
- **Reduction of quantities of sludge to be managed** and their associated **economical costs** (sludge management costs represents, at least, the 50% of the total cost related with conventional WWTP´s operation).
- **Availability of a treatment alternative suitable for dangerous wastes**.
- **Positive contribution to highly-qualified human resources and entities,** as the ones involved in the project have integrated new knowledge and skills, that are both required to build up new plants and to operate WWTPs involving the SCWcO technology.



AINIA is a RTD (Research Technological Development) centre focused in the agro-food sector and related industries, with a long experience dealing with envinromental and supercritical fluid technologies. The aim of the centre is to promote research and technological development in the agro-food sector to increase quality in production, improve competitiveness and promote modernisation and diversification.

www.ainia.es

IMECAL is a SME founded in 1979 as an engineering company in the metal sector. IMECAL is currently working on demand, manufacturing all type of metal-mechanical equipment for civil works, Petro-refineries and Petrochemical, Transportation, and Manufacturing, Refrigeration industry, Industrial Auxiliary Motor and Ceramics industry.

www.imecal.com

IVEM founded in 2003, is formed by a group of engineers that have focused their activity in the development of electric and mechanical projects, automation of installations, control and supervision systems, water treatment and industrial safety. At present, the main activity of the company focuses on services operating, servicing and maintenance of sewage water treatment plants.

www.ivem.es

SCFI is an Irish company that develops technologies to treat organic wastes and generate renewable energy for industrial and municipal markets. SCFI's patented technology, AquaCritox, uses supercritical water oxidation to destruct highly contaminated wastewaters and wet sludges while producing renewable energy.

www.scfi.eu

URBASER is a worldwide reference in the area of environment, dedicated to activities in street cleaning, waste removal and transporting, urban waste treatment and recycling and comprehensive management of the water cycle and urban landscape and gardening.

www.urbaser.es

Lo2x project

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