# Planta de Carbonización Hidrotermal de la Ciudad de México: Tecnologías alternativas para el manejo de residuos orgánicos en países en vías de desarrollo

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**Resumen:**
Ante el incremento en la generación de residuos a nivel mundial, y particularmente en los países en desarrollo, resulta crucial implementar tecnologías que permitan dar un manejo ágil a la fracción orgánica de los residuos sólidos urbanos (FORSU), no solo con la intención de recuperar nutrientes y/o un posible combustible, sino para reducir las emisiones de gases de efecto invernadero asociadas a manejos inadecuados, insuficientes o inexistentes. La Planta de Carbonización Hidrotermal de la Ciudad de México (PCH-CDMX) es un proyecto de vanguardia con la misión de brindar a la CDMX una alternativa viable y de alto valor para el manejo de la FORSU. El desarrollo de la Fase I de la PCH-CDMX ha demostrado ser un éxito para la difusión no solo del propio proyecto, sino de la carbonización hidrotermal y su potencial técnico, energético, social y ambiental, tanto a nivel nacional como internacional. Uno de los principales retos de la tecnología radica en la creación de los mercados que permitan dar salida al hidrocarbón en mercados afines como la agricultura, la restauración de suelos, la industria, etc.

**Palabras clave:** Carbonización Hidrotermal (HTC), Fracción orgánica de los residuos sólidos urbanos (FORSU), Hidrocarbón (hydrochar); Manejo de residuos en países en vías de desarrollo, Planta de Carbonización Hidrotermal de la Ciudad de México (PCH-CDMX)

## Mexico City Hydrothermal Carbonization Plant: Alternative technologies for the management of organic residues in developing countries

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**Abstract:**

Given the increasing generation of waste worldwide, and particularly in developing countries, it is crucial to implement technologies that enable an agile management of the organic fraction of

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municipal solid waste (OFMSW), not only with the aim of recovering nutrients and/or a potential fuel, but also to reduce greenhouse gas emissions associated with inadequate, insufficient, or nonexistent waste handling practices. The Mexico City Hydrothermal Carbonization Plant (PCH-CDMX) is a cutting-edge project whose mission is to provide Mexico City with a viable and high-value alternative for managing its OFMSW. Phase I of PCH-CDMX has proven successful in disseminating not only the project itself, but also hydrothermal carbonization technology and its technical, energetic, social, and environmental potentials at both the national and international levels. One of the main challenges of the technology lies in developing the markets that will allow hydrochar to be placed in compatible sectors such as agriculture, soil restoration, industry, and others.

**Key Words**: Hydrothermal carbonization (HTC), Organic fraction of the municipal solid waste (OFMSW), Hydrochar, Waste management in developing countries; Mexico City Hydrothermal Carbonization Plant (PCH-CDMX)

## 1. INTRODUCTION

Waste on the global scale is expected to reach 3.4 billion tonnes per year by 2050, of which 44 % is estimated will be organic (1.5 billion tonnes; Kaza et al., 2018), with emissions reaching 2.6 billion tonnes of $CO_2e$ (R. Singh, 2023; UNEP & C&CAC, 2021). Inhabitants in developing countries, where disposal in landfills and open dumps is the norm and residue burning is common (Ferronato & Torretta, 2019), are disproportionately affected by the health and environmental problems caused by these inadequate practices. As population and the degree of urbanization increase, pressure over MSW management systems is expected to increase as well (Kumari & Raghubanshi, 2023; Maalouf & Agamuthu, 2023).

In Mexico, around 70 % of MSW is sent to landfills and open dumps (PROFEPA, 2022). One of the goals of the current Mexico Plan (Plan México; Gobierno de México, 2024) is to increase environmental sustainability by promoting investment in clean energy, solid waste management systems, and actions with community impact. Mexico City was estimated to generate around 12,500 tonnes of MSW per day in 2023, with 56 % of it (7,000 tonnes) comprised by OFMSW. The Bordo Poniente Composting Plant (PC-BP) was proposed as a solution to manage this material; however, over 70 % of the total production has historically accumulated within PC-BP (AGIR-CDMX, 2024; SEDEMA-CDMX, 2021a, 2022, 2023, 2024), reaching approximately 1.25 million $m^3$ of stored OFMSW-derived material generating methane ($CH_4$) emissions as shown in Figure 1 (AGIR-CDMX, 2024).


**Figure 1** - PC-BP site and overlay of methane plume (blue). Origin of plume is the orange point encircled in purple, PC-BP outlined in red, PCH-CDMX outlined in green. Source: Adapted from Carbon Mapper (Carbon Mapper, Inc., n.d.).

The Integrated Waste Management Program for Mexico City 2021-2025 (Programa de Gestión Integral de Residuos para la Ciudad de México 2021-2025) contemplates the continued operation and future expansion of the Mexico City Hydrothermal Carbonization Plant (PCH-CDMX) as one of its key actions (AGIR-CDMX, 2024; SEDEMA-CDMX, 2021b).

Hydrothermal Carbonization (HTC) is a process that transforms high-moisture biomass into a carbon-rich solid called "hydrochar" with various possible uses from soil amendment to substitute for coal. Hydrothermal carbonization does not require dry material as it takes place under pressurized aqueous conditions. Several experiments have been conducted that showed benefits arising from hydrochar application on soils of various characteristics and under several crops (Huang et al., 2023); however, large-scale implementation remains scarce.

The difficulties inherent to establishing an adequate MSW/OFMSW management strategy provide an opportunity for the HTC technology to be implemented as part of waste management strategies in Mexico and in other developing countries. Through HTC-based management, health, environmental and societal impacts of an inadequate waste management are addressed. Although PCH-CDMX was intended to manage organic waste, large-scale hydrochar production represents a great potential for the recovery of nutrients, the production of carbon-rich soil amendments, and the decarbonization of coal-consuming industries.

Phase I of PCH-CDMX (19° 27' 36.56'' N, 99° 01' 16.51" W), consisting of an industrial pilot plant with one 72-tonnes-per-day HTC module, finished construction in 2023 and has been operating in staged increases. Phase II, scheduled to begin front-end engineering and design (FEED) in 2027, comprises ten additional HTC modules and represents the first approach to large-scale replication of the HTC technology for OFMSW management in Mexico, and likely one of the first and largest in the world (Farru et al., 2024).

## 2. DEVELOPMENT OF THE INNOVATION EXPERIENCE

By 2018, the shortcomings of composting at PC-BP had become apparent in the form of over one million cubic meters of accumulated and piled-up OFMSW (Figure 2). With the intention of reducing greenhouse gas emissions from PC-BP, then Mexico City Mayor, now President, Dr. Claudia Sheinbaum approached the National Autonomous University of Mexico's Institute of Engineering (IINGEN-UNAM) with the objective of exploring alternatives for the management of Mexico City's OFMSW. Together, IINGEN-UNAM and G 2 E, S.A.P.I. de C.V. (G 2 E) concluded that the most robust and strategically sound option would be Hydrothermal Carbonization. The overall PCH-CDMX project was designed as a 36-HTC-module facility; however, the decision was made to divide the project into four Phases and begin with a single pilot plant with a 72-tonne-per-day HTC module. Through a long-standing strategic alliance between IINGEN-UNAM, a renowned and storied institution, and G 2 E, a technical and dynamic company, but considerably small, funds for the project were secured from the Federal Government's Ministry of Energy (Secretaría de Energía, SENER) through its Fund for Energy Transition and Sustainable Energy Use (Fondo para la Transición Energética y el Aprovechamiento Sustentable de la Energía, FOTEASE). Established in 2008, FOTEASE is a public trust fund created to further the adoption of clean and sustainable energy to reduce reliance on hydrocarbons, and to increase energy use efficiency (SENER, 2016, 2025).

**Figure 2** - OFMSW accumulation. Source: Authors' own elaboration.

The location of PCH-CDMX was to be within the grounds of PC-BP. Deploying the infrastructure where the separately-collected OFMSW is already received precluded the need to develop new transport networks and avoided affectations in other areas of the city. By locating the facility within this already heavily-and-historically-impacted site, any negative impacts from process water or gases, however unlikely given the comparatively small scale of Phase I, were negated while the opportunity to assess the best technical solutions to extract value from nutrient-rich process water and to neutralize process gases, mainly $CO_2$, was enabled.

Originally, a 25-tonne-per-day wood-fed gasification module would provide the fuel to generate electricity for the facility and heat for the HTC process. However, challenges arose that made the use of gasification inviable, requiring an immediate and cost-effective alternative. Being adjacent to the once largest landfill in Latin America, the former Bordo Poniente Landfill, PCH-CDMX was able to tap into the existing landfill gas (LFG) collection infrastructure which has mostly been used to flare LFG to avoid $CH_4$ emissions.

The Mexico City Hydrothermal Carbonization Plant was conceived not only as a disruptive demonstration of alternative OFMSW-management technologies, but also as a demonstration of social inclusion in personnel, and as a nexus to further research, education, and interest in STEM areas. By hosting visits from stakeholders across multiple sectors and levels, PCH-CDMX aims to disseminate information on HTC, its viability as an OFMSW-management strategy, and the vast possibilities that the adoption of hydrochar holds as a biogenic soil amendment for soil improvement and a coal-substitute for industrial decarbonization. By holding visits from students and researchers, PCH-CDMX contributes to the education of future stakeholders that they may be better prepared to provide solutions for agriculture, alternative fuels, and waste management, and to foster research on novel topics by providing a plentiful source of industrially produced hydrochar.

As a core part of their commitment to increase accessibility to employment for people suffering from scarce formal education and employment opportunities, IINGEN-UNAM, G 2 E, and PCH-CDMX perform extensive work on training programs assisted by augmented and virtual reality (AR and VR). By using detailed digital twins in an AR/VR environment, the trainee will be able to interact with a faithful digital representation of the plant and train on operative procedures with safety. Additionally, an always-available AR assistant will allow personnel to access interactive AR demonstrations that guide them through various procedures in real time, enabling a deep understanding of the information, consequently increasing access to employment opportunities, proficiency at work, and the overall safety of the installation.

## 3. RESULTS

Despite its size (72 tonnes per day of OFMSW), the impact Phase I of PCH-CDMX has achieved technically, socially, and politically, and the lessons it has provided, far exceed expectations.

From a funding perspective, PCH-CDMX demonstrates how strategic alliances with renown technical institutions allow small companies with disruptive proposals to access funds usually reserved for larger companies; also, continued financial support from the Federal Government has demonstrated how governmental commitment to spear-tip disruptive and innovative projects steadily contributes to the crystallization of novel alternatives to solve historical difficulties through high-value solutions. Additionally, Phase I showed how the characteristic agility of small companies allowed the team to face unexpected challenges through all deployment stages with speed and flexibility. From a feasibility standpoint, Phase I demonstrated how technical understanding in the authorities and political will invested in seeing the project through are required to execute a disruptive project based on locally unproven and unavailable technology.

Most previous industrial HTC infrastructure was designed to process sewage sludge. When first conceived and built (2018 - 2023), Phase I of PCH-CDMX was amongst the first facilities in the world built to process OFMSW in one of the largest HTC reactors in the world. It was also the first time both HTC and gasification coexisted as part of an integral design (Farru et al., 2024). As gasification proved inviable, the adoption of LFG as an energy source represents the inclusion of another low-carbon technology, proving the flexibility and capacity to exploit various alternatives that HTC facilities present. The general process of the facility is presented in Figure 3. Figures 4 and 5 show the inside and outside of the facility.

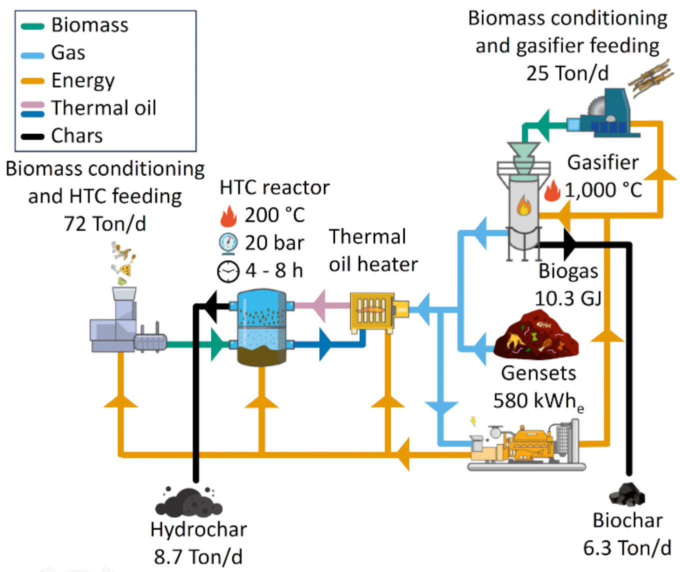


**Figure 3 -** General process flow diagram, PCH-CDMX Phase I. Source: Author's own elaboration.

**Figure 4 -** Inside view of PCH-CDMX. Source: Author's own elaboration.

**Figure 5 -** Outside view of PCH-CDMX. Source: Author's own elaboration.

As operation ramped up during the past two years, several operational challenges have been identified with many of them successfully addressed, increasing operational safety, process throughput from less than 1 tonne per hour to 2.3 tonnes per hour, and extending the continuous operation from one week to over three weeks. Other operational challenges, of which complexity and cost are higher, have been designed and will be implemented during the Phase II expansion. In parallel, substantial expertise in a previously unavailable technology in Latin America has been acquired, both in engineering and operation. Amongst the solutions yet to be implemented, a highly robust and automatized biomass conditioning system able to receive raw MSW and output clean, pumpable material will be deployed as part of Phase II, further increasing system throughput and lifespan.

Hydrothermal carbonization has achieved broad visibility through Phase I of PCH-CDMX through on-site visits, appearances in the media, and presence in national and international fora that have reached thousands of people. Phase I of PCH-CDMX has hosted over 150 visits featuring international delegations including the European Union, the Italian Embassy to Mexico, GGGI, and USAID; diplomats such as former US Ambassador to Mexico, Ken Salazar; national and foreign research universities including Oxford, MIT, UNAM, and the National Polytechnic Institute (IPN); national chambers of industry such as CONCAMIN; private sector entities including Holcim, Bimbo, and Mitsui & Co.; and multilateral development banks such as IDB and the World Bank. The project and related research have been presented in fora such as Biochar III (Tomar, Portugal; Gutiérrez-Fernández et al., 2023a, 2023b), Rhizosphere 6 (Edinburgh, Scotland; Espinosa-Hernandez et al., 2025a, 2025b), and the "Biochar, alternative for the sustainable management of soil" held in 2025 in Mexico City jointly organized by the Institutes of Geology (IGL-UNAM) and Engineering of UNAM, the University Program on Interdisciplinary Studies on Soil (PUEIS-UNAM), and the International Biochar Initiative (IBI), with Professors Johanes Lehmann from Cornell University and Stephen Joseph from the University of New South Wales as special guests (DGCS-UNAM, 2025). Instances of academic collaborations focusing on hydrochar application on soil include ongoing PhD projects and professional research in the College of Postgraduates (COLPOS), the International Maize and Wheat Improvement Center (CIMMYT), and IGL-UNAM. Of particular interest have been the visits of President Claudia Sheinbaum, which generated a great deal of media coverage and video tours of the facility (Gobierno de la Ciudad de México, 2023).

Although work remains to be done, dissemination and experimentation are setting the conditions that will enable the creation of currently non-existent markets to unload hydrochar production, which is particularly relevant as the ten-fold expansion of Phase II begins working on FEED. Large-scale field demonstrations of hydrochar soil amendment in collaboration with the Ministry of Agriculture of the State of Mexico and encompassing eight types of crops and over ten producers, are being planned to validate the results observed in greenhouse and to certify hydrochar as an effective and officially-approved biogenic soil amendment.

## 4. CONCLUSSIONS

Phase I of PCH-CDMX shows the synergy achievable when the private sector, academia, and government collaborate on well-grounded solutions built on a shared understanding of the project's needs, constraints, and opportunities.
The philosophy behind the phased implementation of the PCH-CDMX project has allowed unforeseen operational challenges to be addressed which would have jeopardized the viability of the project if multiple modules had been built at once.

Given Phase I's size, current actual environmental and operational impacts are small. This notwithstanding, the far-reaching impacts it has achieved on technical, social, academic, political, and economic areas will be the foundation upon which future HTC projects will draw to facilitate adoption and reduce execution costs and timelines. Facility performance continues to improve, and the insights gained steadily strengthen the HTC proposal developed by IINGEN-UNAM and G 2 E, further demonstrating HTC's potential as an OFMSW management strategy and a source of industrial hydrochar.

It is fundamental, however, to not lose sight of the fact that the problem, that is OFMSW management, is not over once the organics have been transformed into hydrochar; to truly achieve viability and financial self-sufficiency, the markets to absorb production must be not only explored, but more likely than not, created, which implies a deep interaction between project executors and potential public and private stakeholders and market channels where value for the material might be found.

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