

IEA Bioenergy Task 33

Gasification of biomass and waste

Country Report Spain 2021



CENER biomass gasification plant, Aoiz (Spain)



IEA Report Task 33

Country Report Spain

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1. Introduction

OVERVIEW

Thermal gasification of biomass and wastes offers a combination of flexibility, efficiency, and environmental acceptability that makes it highly attractive compared to other biomass utilization routes. Thermal gasification favourably competes with direct combustion in certain applications because the generation of a gaseous fuel increases the opportunities of use. Project experiences over the last decade in Spain has shown that thermal gasification performs favourably in co-firing in existing boilers and, when sufficiently cleaned, for feeding gas engines and turbines to generate electricity.

In Spain most of the main gasification plants erected during 2000-2015 were small to medium size CHP plants using relatively clean biomass, forest residues and agricultural residues such as the by-product of olive oil industry. Combining biomass/waste gasifiers with operating fossil power plants, despite interesting, have not reached commercial status and only some disperse experiences were carried out. Although the finest utilization route is the synthesis of biofuels and chemicals, no commercial experience exists yet in Spain.

After some successful stories of biomass gasification in Spain the situation changed in 2012 because of the abolition of Feed-in Tariffs (Primas) by Spanish Government (RD-2012) (1). Before that year, the electricity production from biomass gained subsidy for electricity production of up to 140-200 €/MWh. After the RD-2012 most of existing plants stopped and the new projects for electricity generation from biomass were abandoned. Since 2012 only a few companies remain exploiting some plants based on biomass gasification. Nowadays, the price of electricity is in the order of 50-55 €/MWh, making economic exploitations of biomass gasification plants unfeasible. Similar situation has occurred in Europe where plants such as Güssing and others have stopped their operation once the subsidies have finalized after some years of exploitation.

After the declining in electricity generation the interest turned towards the gasification of wastes for thermal applications. An increased R&D activity has been carried out and a few plants are currently in commercial operation. Though, there seems to be still technical challenges that must be addressed.

More recently the production of biofuels from biomass and waste, especially the production of hydrogen is attracting the main attention in Spain. The various strategies recently approved by Spanish government makes the future of biomass to electricity production in a delicate position (since technologies based on PV and wind are being promoted). It seems that finding more attractive ways to produce biofuels and hydrogen with energy storage capability are the major room of interest for biomass gasification. This technology can be adapted to the new scenarios by different strategies to produce biofuels with energy storage potential and electricity production with dispatchability.

In the present report the main progress realized during the last years on thermal gasification in Spain is summarized. In addition, the prospects of the technology are outlined, together with the challenges and opportunities within the new policy frame set out by the Spanish Government during the period 2020-2030 and beyond.

TECHNICAL, ECONOMIC AND POLICY CONTEXT

Thermal gasification has become a mature technology in the last decade from the technical point of view and a variety of gasification methods and technologies has been developed. Although biomass gasification has been the matter of a considerable effort during the last two decades in Spain, a variety of technical difficulties still penalizes its economy and has prevented it from reaching full commercial status. To understand the state of implementation of gasification in Spain several issues must be taken into account including technical, economic, policy and strategic factors.

Still, technical efforts must be made to improve the technical and economic aspects of the gasification process in order to optimize the process successfully. Specifically, there are some factors that still limit gasification compared to combustion like the lower carbon (so thermal) conversion efficiency, especially in fluidized bed designs. In addition, in cold gas applications, such as the use of the gas in engines, the sensible heat of the gas could be lost unless a heat recovery system is included, which is difficult at small/medium scale to implement from the economical point of view. Finally, if the temperature in the gasifiers is not high enough, the tar content in the gas produced can make the process unfavorable from a technical or/and economical point of view. For very strict gas cleaning applications such as the use of syngas in synthesis, gas cleaning, conditioning, and upgrading makes the process complex, reducing its competitiveness compared to other methods.

Traditionally the main potential market niche in Spain to apply thermal gasification is the power production at small (<1MW_e) to medium (<10 MW_e) scale. This is because, within this power range, gasification may favourably compete with combustion in terms of the ratio of power/heat. As the heat demand over the whole year is not as favourable in Spain as in other northern countries, the increase in that ratio makes technologies based on thermal gasification more favourable from the economic exploitation point of view in southern countries.

The presence of heavy tars in the syngas produced in biomass and waste gasification is still the main bottleneck for its use in internal combustion engines for power production, and a great effort is still being carried out to find cheaper solutions to make the small to medium scale CHP plants economically feasible. These plants are still based on tar cleaning devices based on water or regenerative oil scrubbers; the first one generates a condensable stream difficult to dispose, while the second option is too expensive for this type of plants. The use of cheap and poisoning resistant catalysts for tar conversion is an interesting alternative and an extensive research has been conducted over the years by manufacturers in collaboration within R&D centres in Spain. Although great advances have been achieved, the economy of the plants to produce heat and power at small to medium scale are still not competitive compared to combustion.

More recently there is a major interest in applications to raw gas for the synthesis of fuels or chemicals. Second-generation biofuels like Fischer-Tropsch biodiesel can be produced by thermal gasification of biomass by upgrading the syngas for the synthesis. Several projects have received attention in the world, and a lot of R&D activity has been carried out in Spain. Although biodiesel currently has subsidy benefits such as exemption from CO₂ tax and mandate for mixing biofuels, the technology is still far from competitive with fossil diesel and 1st generation biodiesel.

The status in Spain of Renewable Energy in general, and bioenergy in particular, must be understood by taking into account the more recent actions and plans approved by the Spanish Government in the last 2 years, including the National Integrated Plan for Energy and Climate 2021-2030 (NIPEC 21-30) [1].

These plans set out that the biomass represents a very modest percentage of the electricity generation mix in Spain. Among the most innovative storage systems, renewable hydrogen seems that will play a key role in reducing emissions from sectors that are difficult to decarbonize, from high-temperature industrial processes or from multiple conventional means of transport, ranging

from vehicles light to heavy, buses or trains. Spain already has a "Hydrogen Roadmap: a commitment to renewable hydrogen" to promote its deployment [2]. The main projects in Spain are summarized in [3]. The NIPEC 21-30 also establishes the Roadmap setting out the national objectives to promote renewable hydrogen by 2030 and, based on them, designs a vision for 2050, when Spain will achieve climate neutrality and have a 100% renewable electricity system, consistent with the goals that the European Commission has set in its Hydrogen Strategy. The plan seems to rest on renewable hydrogen from electrolysis using the electricity surplus from non-dispatchable technologies such as the photovoltaic solar and wind. However, hydrogen from biomass possesses great potential through biomass gasification and a future market is prospected. In addition, biomass hybridized with other renewable technologies such as the solar thermal can become highly competitive by storage technologies on a large scale in future scenarios.

In summary, thermal gasification can be a key technology for the achievement of new solutions consistent with the new Spanish Renewable Energy strategy and EU strategies by a base technology to be hybridized with other renewable technologies, for hydrogen production, biofuels for transportation also contributing to schemes with dispatchable electricity, an essential aspect in the future decarbonized energy system. The use of thermal gasification of biomass for distributed power seems to be much less attractive than a decade ago. Only waste gasification for thermal applications seems to keep some potential for specific locations with thermal demand and feedstock availability.

2. R&D&I Institutions

A few institutions have been actively working during the last two decades in thermal gasification of biomass and wastes, especially research centers and universities, but also the R&D departments of some companies, a few of them erecting bench and pilot plants to demonstrate some key aspects of the technology. The main R&D institutions and companies that have worked in biomass/waste gasification and related activities are reviewed in this section. Only a few of them remains active after 2015 due to lack of incentives for electricity production in Spain and the technical difficulties using wastes.

The following is the updated information including the main topics that they have investigated/developed, most significant research facilities and contact information. The information has been updated after an inquest in January 2021. The detail information of the poll is included in the Annex. The few companies that have implemented commercial plants are treated separately in the next Chapter.

ACTIVE R&D&I INSTITUTIONS

There are several institutions that traditionally have worked on biomass gasification in Spain. Many of them have stopped their activity during the last decade due to the lack of feasibility of many projects (especially those for electricity generation) after the RD 2012 mentioned in the Overview. Only four centers remain active in Spain and their activity is summarized with some details below. The rest of institutions have been briefly mentioned, updating the information after verification through the inquest.

University of Seville (US, Sevilla)

The Chemical and Environmental Engineering Department at the University of Seville has worked during the last 25 years on thermochemical conversion of biomass and waste (gasification, pyrolysis and combustion), synthesis of biofuels and bioproducts and biorefineries. More recently new developments are being carried by hybridization of biomass and waste in high-temperature solar technologies and solar reactors for thermochemical conversion and solar fuels. The institution has

assisted and advised leading industrial companies in the energy sector such as Abengoa, Inerco, Cepsa, Total Petrochemical, BP, etc.

Contact information

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Main topics of R&D related to biomass/waste gasification

- Steam gasification of biomass using solar energy and dual fluidized beds. Solar chemical looping gasification for hydrogen production. Hybridization of biomass in concentration solar power plants (CSP)
- New design of gasifiers (staged gasification). Tar conversion using char for syngas cleaning for small and medium electricity plant gas engines
- Fluid-dynamics of fluid bed gasifiers for improved operation of FBG (gasification performance, optimized char conversion system with recirculation)

Main facilities

- Pilot plant: 100 kW_{th} bubbling FB gasification of biomass and waste using different gasification agents: steam / O₂ / CO₂ / air and blends
- Pilot plant: 50 kW_{th} staged FBG consisting of a bubbling biomass devolatilizer and a moving bed char filter for char and tar conversion
- Bench scale plant for tar scrubber (1-3 Nm³/h syngas)

Other related facilities

- Gas filtration pilot plant for catalytic synthesis of biofuels and chemicals
- Laboratory of catalytic synthesis of biofuels and chemicals: 3 bench scale reactors for catalyst synthesis and a pilot plant for separation of alcohols mixtures
- 2D Quartz high-temperature FB with visual capability for detailed monitoring of FB conversion tests (single or multiparticle conversion tests)
- Cold models for fluid dynamic characterization: Circulating FB (150 mm ID; 6 m height) and Staged FB (300 mm ID; 6 m height)

Current Projects and interest of biomass gasification (2018-2022)

- Solar Gasification of Biomass and Waste in a novel integrated system for renewable fuel production. Convocatoria MIT (Massachusetts Institute of Technology). Fundación La Caixa. Project no. LCF/PR/MIT18/11830011 2018-2020
- Calcium looping gasification of biomass assisted by solar energy (CALGASOL) (P18-RT-4512). PAIDI 2020: Proyectos I+D+I (Junta de Andalucía, Consejería de Economía y Conocimiento) 2020-2022
- Optimal design of fluidized bed reactors for thermochemical storage systems in concentration solar energy plants Ministerio de Ciencia, Innovacion y Universidades of Spanish government.

2019-2020 (Massachusetts Institute of Technology).

- Desarrollo de una Tecnología para la Valorización Material y Energética de Residuos Urbanos Mediante Optimización Simultánea de la Gasificación y Estabilización de las Cenizas. Plan Nacional. CTM2016-78089-R. 2016-2019
- Estudio y Puesta al Día de Tecnologías Termoquímicas e Hidrotermales para la Valorización Energética de la Fracción de Rechazo de Residuos Sólidos Urbanos (ETVERU-3) Contrato 68/83 (ES-2039/35/2020) (2020) Company: TRAGSATEC
- Diseño de un Sistema de reintroducción de carbonizado para un gasificador de lecho fluido burbujeante. (CHAR RECYCLE – BFB) Contrato 68/83 (2018) (ES-1793/35/2018). Company: Waste to Energy Advanced Solutions SL (WtEnergy)

Collaboration with Companies (companies technically assisted by the centre during the last 3-5 years)

- Waste to Energy Advanced Solutions (WtEnergy)
- Inerco
- Kurata Systems
- Neoelectra/Careco

CIEMAT (Madrid, Soria)

CIEMAT (Center for Energy, Environmental and Technological research) is a public research body assigned to the Ministry of Science and Innovation under the General Secretariat for Research, focusing on energy and environment and the technologies related to them. It collaborates with other R&D&I institutions, universities and business in the sector to transfer the knowledge and technology that it has generated, supporting and encouraging innovation and changing the economic model. The studies developed in CIEMAT range from laboratory scale to semi-industrial size plants (in the latter case in collaboration with the Thermal Conversion Processes Unit of CEDER (Centre for the Development of Renewable Energy Sources), which is located a few kilometers from Soria.

Contact information

- Jose María Sánchez Hervás (Senior Researcher)
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- www.ciemat.es, <http://rdgroups.ciemat.es/web/valer>, also in www.ceder.es (pilot plants installations)

Main topics of R&D in the related to biomass/waste gasification

- Evaluation of biomass and waste in gasification processes to obtain a gas for thermal applications (heat and steam), internal combustion engine and for value chemical products (hydrogen, synthetic methane, hydrocarbons, biofuels, etc.)
- Study of waste derived from the process, gaseous emissions (H₂S, HCl, NH₃), tars, ashes, their sampling, analysis and diagnosis
- Characterization and preparation at semi-industrial scale of solid feedstocks from biomass and wastes (classification, size reduction, drying and palletization) for thermal conversion

Main facilities

- 150 kW_{th} pilot auto-thermal bubbling fluidized bed gasifier (for biomass and wastes) CEDER-CIEMAT – Soria
- 500 kW_{th} pilot auto-thermal circulating fluidized bed gasifier (operational, but out of work the last three years) CEDER-CIEMAT – Soria

Other related facilities

- Lab-scale test units for catalysts and sorbent performance studies.
- High Temperature, high pressure pilot plant for gasification gases treatment and pyrolysis/liquefaction products upgrading

Main Projects and interest of biomass gasification (last 3 years)

- LIFE DRY4GAS Project: Waste Water sludge solar DRYing FOR energy recovery through gasification GAS (LIFE Programme of the European Union)
- HIBRI2: "Integrated System for Renewable Energy Production in Isolated Areas in Cuba. Phase II". AECID, Cooperation Actions for Development Call 2018, 2019-2021. (<http://projects.ciemat.es/web/hybridus>)
- ECOSGAS, PE-Retos, ENE2016-75811-R, 2017-2020: Removal of organic Sulphur compounds from gasification gases by adsorptive reaction at high temperature for integration in renewable fuels production (SNG, biofuels, DME)
- RETOPROSOST, CM S2013/MAE-2907, 2014-2018: Sustainable production and industrial symbiosis within the Autonomous Community of Madrid; wastes valorization through gasification

Collaboration with Companies

- Aitesa (www.aitesa.es) partner in LIFE DRY4GAS Project where a solar drying and gasification prototype will be installed in the WWTP located in San Javier (Murcia). The gasifier will be a 220 kW_{th} pilot bubbling fluidized bed gasifier (for drying sewage sludge). Expected launch in 2022.

University of Basque Country (UPV, Bilbao)

The Department of Chemical Engineering of the UPV/EHU-University of the Basque Country investigates fundamental processes for producing raw materials and fuels using biomass and wastes, the development of sustainable refineries to produce fuels and raw materials providing an alternative to petroleum by using biomass and other waste materials like plastics, tyres, etc. Conical spouted beds are the key to the high energy efficiency of these refineries.

Contact information

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Main topics of R&D related to biomass/waste gasification

- Steam gasification of biomass and wastes
- Bio-oil steam gasification

- Hydrogen production by a two-step process of pyrolysis and steam reforming
- Spouted bed gasifier design and development
- Primary catalysts for tar elimination

Kinetic studies Main facilities

- 2 bench scale spouted bed gasifiers

Other related facilities

- 1 micro reactor for kinetic studies
- 2 cold units for hydrodynamic studies and scale up
- Analytical and characterization equipment

Current Projects and interest of biomass gasification (2018-2022)

- Biomass gasification with negative carbon emissions through innovative CO₂ capture and utilization and integration with energy storage. European Commission. HORIZON H2020-MSCA RISE-2018-Grant N° 823745. 1/1/2019-31/12/2022.
- Development of fountain confined spouted bed technology for the valorization of biomass and waste by steam gasification. RTI2018-098283-J-I00. Spanish Ministry of Science, Innovation and Universities. 1/10/2019-30/9/2022.
- Integrated process for the oxidative reforming of the volatile stream from the pyrolysis of biomass and plastics. PID2019-107357RB-I00. Spanish Ministry of Science and 2020-2023.
- New raw materials based on technologies and processes for the chemical recycling of plastics from the industrial sector in the Basque Country by following the concept of circular economy. KK-2020/00107. Basque Government. ELKARTEK strategic projects. 2020-2021.

Partner Company (company manufacturing/operating gasifier to which the R&D centre technically assist)

- W.R. Grace & Co.

University of Extremadura (UNEX, Badajoz)

The UNEX has conducted research on biomass/waste thermochemical characterization, pyrolysis and gasification. They constructed a pilot 200 kW_{th} pilot plant in collaboration with EQTEC. They did not answer the Inquest so no further updated information could be collected.

R&D&I INSTITUTIONS NOT ACTIVE IN THE FIELD (LAST 5 YEARS)

These are institutions that had traditionally worked on the field of biomass gasification but stopped their activities during the last 5 years. A summary of their capability and the current status is briefly reported.

- **University of Valladolid (Valladolid):** They assisted in the development of fixed bed gasification for electricity through gas engines. Extensive campaigns with 100 kW_e scale Pilot plant in collaboration with CIDAUT and current demonstration project (100 kW_e + 200 kW_{th}) in collaboration with Foundation CIDAUT.

- **University of Zaragoza (Zaragoza):** with a 50 kW_{th} pilot fluidized bed gasifier in their campus. They assisted during the development of fixed bed gasification with TAIM-Weser, and fluidized bed gasification with Cadagua.
- **UCM (Ciudad Real):** They have worked gas engine developments, investigated entrained gasification of biomass and co-gasification with coal in lab and assisted during trial in a commercial IGCC plant in Elcogas.
- **Universidad Carlos III (Leganés, Madrid):** They worked for some time on biomass gasification in a small lab FB. Currently the work on fundamental research on fluidization, fluidized-bed monitoring and modelling and solar energy. In the field of biomass, they are currently focused on pyrolysis and no activity on biomass or waste gasification have been done during the last 5 years.
- **IREC (Barcelona):** They actively worked in RDF gasification in fluidized bed at lab scale during the period 2010-2018 but the IREC has closed the area of Gasification in the Institute and no more activities has been done since 2018.
- **Other Research centers** in Spain with related activities: CIRCE (Zaragoza), LITEC (Zaragoza), UCM (Madrid) and other. They do not work on biomass/waste gasification anymore. No activity has been detected during the survey made by authors.

3. Companies

ACTIVE COMPANIES

There are three companies actively working on thermal gasification of biomass and waste in Spain: EQTEC, Waste to Energy Advanced solutions, and Neoelctra. These three companies have commercial plants in operation and several gasification projects in Spain and other countries for the next years. These companies are reviewed first, and the commercial plants described later in the next chapter.

The rest of companies are briefly reviewed since they do not have commercial plants although they have developed an intense R&D&I activity in the field during the last decade. Some of them are in standby with some interest (submitting commercial offers, searching opportunities in the market and in some case submitting project proposals to readapt their commercial products to the new market) but their activity is of very low intensity in the last 3-4 years.

EQTEC (<https://eqtecplc.com/technology/>)

EQTEC offers a Gasifier Technology ("EGT") based on a bubbling fluidized bed reactor suitable for a wide range of waste and biomass. They offer a modular generation plants ensuring environmental compliance with existing regulations. EQTEC has provided the gasification facility using olive pomace waste in Movialsa (Campos de Criptana, Ciudad real) described in the next chapter. EQTEC has an agreement with UNEX (Badajoz, Spain) and University of Lorraine (France) where they developed some R&D works in their pilot plants, especially to test new wastes. EQTEC has delivered gasification plants in East Europe as illustrated in Table 1.

	Installed Power	Start-Up Date	Location	Type
Syngas	1 MW	2015	Italy	Commercial
Karlovo	4 MW	2016	Bulgaria	Commercial
Sense Esco	1,2 MW	2016	Croatia	Commercial

Table 1. Gasification plants delivered by EQTEC in East Europe

Waste to Energy Advanced Solutions SL (<http://www.wte-as.com/>)

The company Waste to Energy Advanced solutions (WtEnergy) implements advanced technologies for thermochemical conversion into energy from biomass and waste. The company offers a technology based on bubbling fluidized bed, both for thermal and electrical applications. The company comes from the former Technoholding, which licensed the patent from Careco-USA, which also shared the license with Careco Energy, Combustibles Alternativos Renovables Ecológicos (Ecological Renewable Alternative Fuels).

The first gasification plant constructed in Spain with this technology was located in Jativa (Valencia) generating 1.6 MW_e. The plan was to supply heat in ceramic-bricks kilns (but the construction crisis hindered this initial development and the final generation was just based on electricity). This plant run for more than 18 000 hours of operation and was stopped after RD 2012. In spite of this, the technology was proven to be reliable and the company constructed some more plants: 2 MW_e IDERMA CHP in Ejea de los Caballeros, Zaragoza; 10 MW_{th} MBM Gasification in Aldeaseca de la Frontera Salamanca and a 16 MW_{th} meat and bone meal (MBM) gasification in Porto, Portugal. These three plants (reported below) are still in operation.

Neoelectra (<https://neoelectra.es/services/generation/>)

Neoelectra, a company that generates energy from agro-livestock waste purchased in 2019 the 90% of Careco Energy, Ecological Renewable Alternative Fuels, a company that transforms slurry into electrical energy and industrial heat (which helps to partially solve the serious problem of animal droppings). The company has constructed two commercial plants and it is working on various projects for three new commercial plants.

COMPANIES NOT ACTIVE IN THE FIELD (LAST 5 YEARS)

These are companies that traditionally worked on the field of biomass gasification but stopped their activities during the last 5 years.

Inerco (<https://www.inerco.com/en/energy-technologies/biomass-gasification/>)

The company offers a technology developed in close cooperation with the University of Seville both for thermal and electrical applications. It is based on a bubbling fluidized bed technology with oil-scrubbing (for electrical applications). They developed the technology by several R&D&I projects during 10 years (2005-2015) with the construction of three demo gasification plants: a 3 MW_{th} in Alcalá de Guadaira (Seville) in 2006, 3 MW_{th} in CIUDEN in Cubillos de Sil (León) in 2011, and a 2 MW_{th} in CENER Aóiz (Navarra) in 2012. The plant in Seville was dismantled in 2013 after the RD 2012 and the other two plants are still available for research projects but have been out of service during the last 5 years.

GreenE (www.greene.es)

The company developed a technology for waste gasification and owns a 500 kW_e pilot plant in Torrellano, Elche, Alicante. There are news that the company is planning to start up a new pilot plant in Algimia de Alfara, Valencia but no technical information could be collected. They did not respond to the Inquest. However, its web is very active and they report different actions that the company seems to be carrying out.

Cidaut (<https://www.cidaut.es/en/biomass>)

Cidaut (Foundation for Transport and Energy Research and Development) developed a small-power gasification technology. They own an experimental plant in Mojados, Valladolid (Spain) (100kW_e). Activity has not been carried out during the last 4 years.

Cadagua

They constructed a pilot plant of for 100 kg/h fluidized bed gasification of sewage sludge in CEDER Soria and operated it during 10 years. The plant is not in operation. The company answered the Inquest by confirming they are not active in the field of thermal gasification anymore.

TaimWeser

They constructed a demo 500 kW_e pilot plant in Zaragoza for power generation through a downdraft gasifier through, gas cleaning and a Jenbacher internal combustion engine during several years from 2003. Operation was used for research and demonstration, but no commercial operation was implemented. According to our information, the company has finished its activity in the area of thermal gasification of biomass: they did not answer the inquest, we have verified that they do not provide updated information in the web within the last 2-3 years.

Hera (Plasco Technology)

They operated a Plasma gasification pilot plant of 100 kg/h in Castellgalí (Barcelona) producing electricity in the range of 0.09-0.1 MW_e. According to our information, the company has finished its activity in the area thermal biomass gasification: they did not answer the inquest, we have verified that they do not provide updated information in the web within the last 2-3 years.

4. Commercial plants

There are 5 commercial thermal gasification plants in operation in Spain (and one in Portugal, which is included below since the engineering firm is from Spain and has a twin plant in Spain). Out of six plants, four of them produce electricity from biomass or agricultural waste, two burning the gas in combustion engines and the other two in gas steam boilers integrated in a Rankine cycle. The other three plants gasify biomass residues of various types and wastes (meat and bone meal) and burn the product gas in a boiler incinerator/thermal oxidizer to produce steam for industrial applications. The description of the plants and updated operational performance is given below grouped by the supplier of the technology.

EQTEC

EQTEC has provided the gasification facility using the olive pomace waste stream and it is in operating in Movialsa (Campos de Criptana, Ciudad real) since 2011. The facility includes 4 gasification lines with installed capacity of 6MW_e and has over 111,000 operating hours with the 3 Jenbacher engines. Figure 1 shows a picture of the plant and its operational performance. Besides the electricity it produces 5,600 kg/h of saturated steam at 6 bar for a distillery and 160 m³/h of hot water at 90°C with a total (heat + power) efficiency of about 65%. The audited operation performance achieved during the last years is shown in Table 2.



Location	Ciudad Real, Spain
Description	5,9 MWe IBGPP
Electrical efficiency	28%
Total efficiency (electrical + thermal)	64%
Feedstock	Olive Mill Pomace
Feedstock throughput	4 ton/h
Engine	3 x GE Jenbacher 620
Operating temperature range	720-750 °C
Operating hours	111,000+ (third party certificates available)

Figure 1. Movialsa Plant (EQTEC)

Parameter	Unit	Year				
		2015	2016	2017	2018	
Plant availability	h/year	8,600	7,300	7,060	7,800	
Biomass consumption	t/year	20,000	18,000	17,500	18,024	
Generated electrical power	MWh _e	28,790	25,855	24,200	25,400	
Useful thermal power	MWh _t	24,908	14,219	11,884	14,413	
Equivalent electrical efficiency	%	45	39	38	39	
Energy production ratio	kW _e /kg _{biomass}	kW/kg	1.4	1.4	1.4	1.4
	kW _t /kg _{biomass}	kW/kg	1.2	0.8	0.7	0.8

Table 2. Audited operational performance of Movialsa plant (EQTEC)

WASTE TO ENERGY ADVANCED SOLUTIONS, S.L.

They have three reference plants in operation:

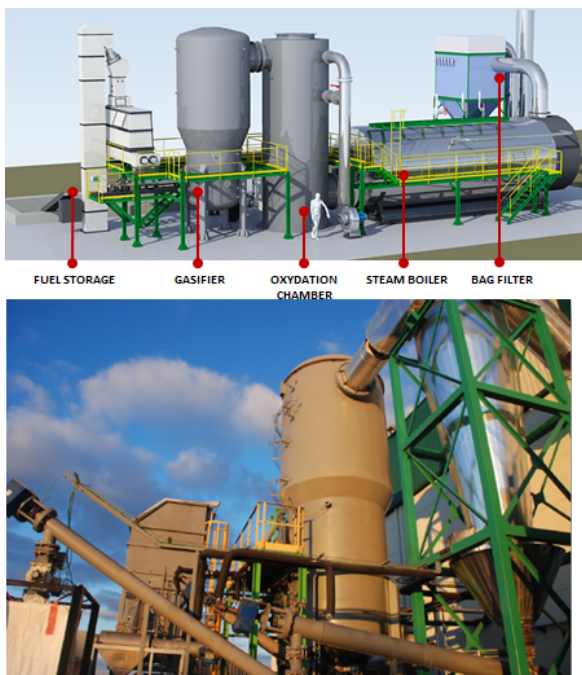
- 2 MWe IDERMA CHP in Ejea de los Caballeros, Zaragoza
- 10 MW_{th} MBM Gasification in Aldeaseca de la Frontera, Salamanca
- 16 MW_{th} MBM Gasification in Porto, Portugal

The main data and operational parameters are summarized in Figures 2, 3 and 4. The company is working in a new thermal plant of 18MW_{th} capacity located in Lyss (Switzerland). Startup date June-2021 (<https://youtu.be/ZzUvFgvEb10>).



Reactor	Bubbling Fluidised Bed
Thermal power	7,4 MW _{th} (2 MWe)
Application	CHP Electricity production 1,6 Mwe (GE Jenbacher JMS – 320 (x3)) Heat used for drying in briquettes manufacturing (variable heat required)
Gasifying agent	Air
Operation Pressure / Temperature	0,3 barg / 800°C
Biomass load	45 t/day
Start up date	2012
Biomass	Wood chips
Location	Ejea de los Caballeros (Zaragoza)

Figure 2. Iderma plant (WtEnergy)



Reactor	Bubbling Fluidised Bed
Thermal Heat	10 MW_{th}
Use	12 T/h saturated steam 10 bar
Gasifying agent	Air
Operation Pressure / Temperature	0,3 barg / 800°C
Start up date	2013
Biomass	Meat and bone meal (MBM) Cat01
Location	Aldeaseca de la Frontera (Salamanca)

Figure 3. Aldeaseca plant (WtEnergy) with indication of the Xylosteam process (Gasification + Thermal Oxidation + Heat Recovery Boiler)



Reactor	Bubbling Fluidised Bed
Thermal Heat	16 MW_{th}
Use	20 T/h saturated steam 10 bar
Gasifying agent	Air
Operation Pressure / Temperature	0,3 barg / 800°C
Start up date	2014
Biomass	Meat and bone meal (MBM)
Location	Sao João da Madeira (Porto, Portugal)

Figure 4. Porto plant (WtEnergy) (it is also based on Xylosteam process, see Figure 3)

NEOELECTRA

Neoelectra has two commercial plants in operation:

- 20 MW_{th} bubbling fluidized bed gasifier in Santa Perpetua de la Mogoda (Barcelona) processing wood and industrial waste (Figure 5). The product gas is burnt in a torsional combustion chamber coupled with a boiler to produce process steam
- 8 MW_e updraft gasifier in Villacañas (Toledo). The product gas is burnt in a torsional combustion chamber coupled to a steam boiler integrated in a Rankine cycle.

The torsional combustion chamber and the updraft gasifier are technologies developed by the company BERKES (Uruguay), whereas the bubbling fluidized bed gasifier is owned by Neoelectra.



Reactor	Bubbling Fluidised Bed
Thermal power	20 MW _{th}
Application	Industrial steam generation
Gasifying agent	Air
Steam production	25 t/h
Start up	2018
Biomass	Biomass, plastic, RDF
Location	Santa Perpetua de Mogoda, Barcelona

Figure 5. Plant in Santa Perpetua de la Mogoda, Barcelona (Neoelectra)



Reactor	Updraft gasifier
Power	8 MW _e
Application	Electric generation
Gasifying agent	Air
Boiler	Water tubes of 44 t/h (460 °C, 40 bar)
Start up	2010
Biomass	Biomass
Location	Villacañas, Toledo

Figure 6. Plant in Villacañas, Toledo (Neoelectra)

5. Conclusions and outlook

In Spain most of the main gasification projects implemented during 2000-2010 were based on small to medium CHP plants using relatively clean biomass, forest residues and agricultural residues such as the by-product olive oil industry. After some successful stories the situation changed in 2012. Before that year, the electricity production from biomass gained subsidy for electricity production. Abolition of Feed-in Tariffs (Primas) by Spanish Government (RD-2012) stopped new projects of electricity generation from biomass.

The low price in electricity tariff and high price in clean biomass feedstocks pointed the interest in gasification for thermal applications using wastes during the following 5 years after the governmental decree. Gasification of wastes attracted more attention during 2015-2020; an increased R&D activity has been carried out in that period and a few plants are currently in commercial operation. Combination of biomass/waste gasifiers with operating fossil power plants, despite interesting, did not achieve commercial implementation and only some disperse experiences were conducted.

A few institutions have been actively working during the last two decades in thermal gasification of biomass and wastes, especially research centers and universities, but also the R&D departments of some companies, a few of them owning bench and pilot plants in cooperation with developers and companies. Only three of them (University of Seville, CIEMAT, UPV) has been verified to keep active in the field during the last years.

There are three companies actively working on thermal gasification of biomass and waste in Spain: Eqtec, Waste to Energy Advanced Solutions, and Neoelectra, with some commercial plants in operations in Spain (and other countries). There are currently 5 commercial thermal gasification plants in operation in Spain: three generating electricity from biomass or agricultural waste, two burning the gas in combustion engine and one in a gas steam boiler integrated in a Rankine cycle; the other two plants gasify wastes and burn the product gas in a boiler incinerator/thermal oxidizer to produce process steam for industrial applications.

After recent strategies and decrees by Spanish government it seems that the production of biofuels from biomass and wastes, particularly hydrogen, are attracting the main attention. More attractive ways to produce biofuels and hydrogen as energy vector with storage capability are gaining interest

and several pioneering projects are being developed. It seems that gasification can be adapted to the new scenarios to produce hydrogen and electricity with energy storage potential and dispatchability.

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Appendix 1 – Inquest

To update the information that has been included in this report, the authors of this report submitted by email in January 2021 a poll to R&D centers and companies working in thermal gasification of biomass and waste in Spain. Most of institutions answered (but not all) at least for confirming whether they were active or abandoned the field during the last 5 years. The questionnaire attached to the email submitted is included below.

Questionnaire (all questions are in relation with biomass and waste gasification). (fill in the table and send me back the file by email). [See example in the next page](#)

Name of the Centre/Company and person	
Topic of your interested	
Facilities	
Projects (on going and within the last 2-3 years)	
Service to industrial companies (name of the company, name of the action/project/main objective and results	
Comments/Info you would like to add and results	
Recommendation of bibliography (report, paper, web etc) relevant to the topic, updating information	

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