Implementation Plan 2015

of the Spanish bioenergy sector

BioPlat
SPANISH BIOMASS TECHNOLOGY PLATFORM

UNION EUROPEA
FONDO EUROPEO DE DESARROLLO REGIONAL

GOBIERNO DE ESPAÑA

MINISTERIO DE CIENCIA E INNOVACIÓN

Implementation Plan 2015

The BIOPLAT Implementation Plan 2015 represents the outcome of the results of the analysis surrounding the implementation of BIOPLAT's Strategic Lines of Implementation published in 2009 for the Spanish bioenergy sector.

Such analysis has allowed identifying in which technological areas have both the most and least number of R&D&i projects been developed over the last years. Once this information regarding the degree of implementation was obtained, those strategic R&D&i areas that continued to have greater priority for the sector as well as those that did not were identified, so as to obtain a group of areas where implementation remained key for the Spanish bioenergy sector. This information was used as a baseline for the work carried out by all members of the Platform, led by Work Group and Subgroup Coordinators who, based on the strategic areas that continued to remain important, began working on all the value chains in the bioenergy field (from raw materials, through the technology used to transform these to energy to final energy consumption) in order to determine which of them had higher priority in terms of technological development considering the 2015 outlook.

In order to conduct this analysis of bioenergy priority value chains, criteria from BIOPLAT members and related national technology platforms were considered in addition to European R&D&i bioenergy trends captured in the European Strategic Energy Technology Plan (SET-Plan), both those of the European Industrial Bioenergy Initiative (EIBI) and the Joint Programme of Research in Bioenergy of the European Energy Research Alliance (EERA) as well as in the various European bioenergy technology platforms that mirror the Spanish one, namely the European Biofuels Technology Platform (EBTP) and the European Technology Platform on Renewable Heating and Cooling (RHC-Platform). This comprehensive information followed by one year of intensive synthesizing, prioritization and consensus work have allowed identifying those priority value chains that must be further developed by the Spanish bioenergy sector over the coming years. It is considered that their implementation will contribute to drive substantial advances in the learning curve of bioenergy technologies, resulting in greater impact on the domestic (first) and international markets followed by the implementation of bioenergy industries in our country that are to be ever more competitive both inside and outside our borders while generating high employment.

BIOPLAT members are the drivers that have turned the Platform into an increasingly useful tool year over year, not only for themselves but for all agents with which it interacts, both public and private, and at all levels including local, regional, national and European. We thank you for your constant support, for making this Platform yours and for feeling proud of it. This is where BIOPLAT's strength and all the value coming from it reside.

Many thanks also to BIOPLAT Coordination Group members for always steering the Platform along the path of excellence and for constantly bringing forward not only their priceless criteria but also the countless hours of dedication and excitement capable of turning any challenge facing BIOPLAT into reality, no matter how difficult it may be.

And of course, our gratitude to the Spanish Ministry of Science and Innovation and particularly to the General Sub directorate for Public-Private Collaboration Strategies for making the existence of BIOPLAT possible, and, just as with IDAE, CDTI and CIEMAT, for collaborating and backing all initiatives and activities undertaken at BIOPLAT.

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List of Figures:

List of Tables:

1 Introduction

Bioenergy is a key renewable energy source that is essential for meeting the energy targets set forth in Europe and in Spain. Such targets attempt to increase the level of diversification of energy sources as well as reduce the current high foreign energy dependency and greenhouse gas emissions.

The magnitude of the bioenergy sector in Spain is undeniable given our country's enormous biomass potential. The studies that have been conducted to assess the potential that will enable to establish the actions that must be implemented in order to reach the new Renewable Energy Plan (PER) 2011-2020 (Plan de Energías Renovables PER 2011-2020) targets have quantified the available potential that exists in Spain with a 2020 outlook for all bioenergy applicable uses, as described next:

- Biofuels

  It is estimated that Spain's bioethanol production potential for 2020 will be 402 ktoe/year, taking into account the production capacity forecasted for such date. This estimate includes also the bioethanol production capacity from lignocellulosic materials (the so-called second generation bioethanol) that would appear in the Spanish market in the middle of the decade and which could amount to 13% of the overall bioethanol production potential in 2020.

  Likewise, PER estimates biodiesel production potential in Spain to be 4,373 ktoe/year, taking into account the production capacity forecasted for 2020. The estimates assume that up through 2020 products obtained from lignocellulosic biomass through thermochemical processes known as BtL (Biomass-to-Liquid) will be entering the market, resulting in a market share of about 2% in 2020.

  It must be pointed out that in the case of biofuels, the production potential may not match the consumption potential, which is influenced by different variables that include, among others, any obligations that may be set forth, the development of labeled mixtures, availability of raw materials, diesel and gasoline technical specifications and biofuel export.

  Therefore, according to PER 2011, the consumption potential of bioethanol in 2020 would equal 498 ktoe, whereas in the case of biodiesel, the value would vary between 2,458 ktoe and 5,329 ktoe, based on the degree of commercial penetration reached by the B30 labeled mixture (30% biodiesel and 70% diesel).

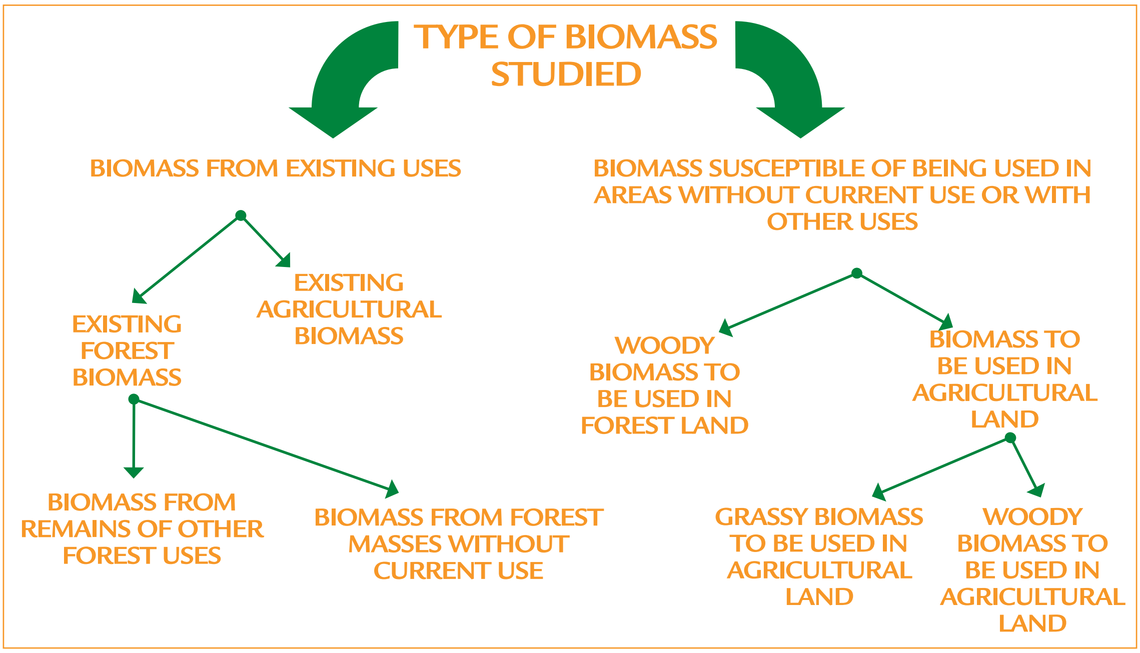
- Biogas

  In order to assess Spain's total accessible (the part of the total potential that can be collected, transported and stored) and available (the part of the available potential less the part destined to alternative use) biogas generation potential (technically biodigestible biomass), the following biodigestible biomass resources have been quantified fundamentally: livestock droppings, food industry waste, sub-products from biofuel plants and food distribution and waste from the food industry, which produce the so-called agro-industrial biogas. Only the organic content of municipal solid waste (MSW) and wastewater treatment plant (WWTP) sludge are also susceptible of being biodigested. Furthermore, biogas production from landfill degasification has also been considered, which is expected to decrease due to existing EU legislation that points toward a progressive reduction of the amount of biodegradable waste that is dumped in landfills.

	Total potential (ktoe)	Accessible potential (ktoe)	Available potential (ktoe)
Agro-industrial biogas	3,467.5	1,887.4	1,425.1
Biogas from the Organic Fraction of Municipal Solid Waste (OFMSW)	778.1	311.2	124.5
Biogas from WWTP sludge	164.4	123.3	123.3
Landfill biogas	957.9	208.8	145.6
TOTAL	4,589.8	2,321.9	1,818.5

SOURCE: PER 2011-2020.
Table 1, Biogas potential.

- Biomass
  Biomass of non-industrial origin (agricultural and forest only) has been quantified to assess Spain's biomass potential:



SOURCE: PER 2011-2020.
Figure 1, Types of biomass studied in PER 2011-2020

Thus obtaining the potential biomass values that are shown in the following table:

ORIGIN		BIOMASS POTENTIAL (t/year)	PER 2020 TARGET (t/year)
Existing forest masses	Remains of timber logging operations	2,984,243	9,639,176
	Full use of tree	15,731,116	
Agricultural remains	Grassy	14,434,566	5,908,116
	Woody	16,118,220	
Grassy mass susceptible of being used in agricultural land		17,737,868	2,518,563
Woody mass susceptible of being used in agricultural land		6,598,861	
Woody mass susceptible of being used in forest land		15,072,320	
SPAIN'S TOTAL BIOMASS POTENTIAL Data in green tons (45% moisture)		**88,677,193**	**18,065,855**

SOURCE: PER 2011-2020.

Table 2, Potential biomass vs. biomass necessary to meet the targets (tons/year).

As a reference to help appreciate the magnitude that the annual 88 plus million tons of agricultural and forest biomass existing in Spain imply, it is worth noting that over 8 million tons were consumed in 2006, meaning that the available potential for the expansion of biomass in Spain is, at least, extraordinary.

- Other biomass residues

According to Directive 2009/28/CE on the promotion of the use of energy from renewable sources, biomass can be defined as the biodegradable fraction of products, waste and residues of biological origin from agricultural activities, forestry and associated industries, including fishing and aquaculture, as well as the biodegradable fraction of industrial and municipal waste. As a result, the following potentials must be considered:

WASTE	% RENEWABLES	ktoe RENEWABLES	MW / GW RENEWABLES
Recovered solid fuels from MSW	50%	243	-----
MSW	50%	2,125	824 MW renewables
Paper industry waste	59%	460	1,339 GWh_e renewables
Out of use vehicles	18%	48	139 GWh_e renewables
Used tires	25.5%	10	30 GWh_e renewables
Recovered wood	100%	408	1,187 GWh_e renewables
WWTP sludge	100%	89	258 GWh_e renewables
Construction and demolition waste	50%	662	1,925 GWh_e renewables
TOTAL		**4,045**	

FUENTE: PER 2011-2020.

Table 3, Other potential biomass wastes.

Although in accordance with what is established in Annex II of Royal Decree 661/2007, which regulates the production of electric energy under the special regime, not all these wastes may be considered as biomass according to Spanish legislation (despite the fact that such Royal Decree takes the definition given by the European Directive), hence the reason why some of them are included under Category c) 'Waste' of said Royal Decree instead of Category b) 'Renewable Energy', where biomass is included.

Although Spain has this enormous potential to generate bioenergy in addition to a fully consolidated and mature, business, scientific and technology sector, this renewable energy has not experienced the level of development expected in any of its aspects, neither as a source of thermal and electric energy nor as a source of biofuel for transportation. How this can be possible is the big question.

With respect to the biomass sector in terms of thermal and electric energy generation, countless calls for attention have sprung up from the sector in Spain to raise flags about the low evolution observed over the last few years, an evolution that the Comisión Nacional de Energía -CNE- (National Energy Commission) itself estimates to amount to 166 months, which is the estimated time required to reach the biomass based electricity production target set forth in the previous PER 2005-2010. That is, given the historical rate of implementation observed ($MW_{installed}$/month), the target of 1,317 MW established for 2010 could be reached fourteen years later. With respect to the degree of penetration of biomass destined to thermal use, understanding the data is rendered complicated since no official registry exists for thermal renewable energy; however, estimates contemplated in PER 2011-2010 provide a value of 3,655 ktoe consumed in 2010, which is equally far fetched from the established target.

There is an extremely complicated outlook in the case of biofuels, particularly in the biodiesel sector. Despite the important increase in installed production capacity over the last few years, the volume of biodiesel produced has remained way below such capacity, causing the 49 existing plants to reach a critical situation. In order to be able to promote greater consumption of biofuels in Spain and to harness its production potential, the sector understands that it will be necessary to introduce a series of urgent regulatory measures.

On the one hand, the biofuels consumption target of 5.83% for 2010 was not reached (in energetic terms) as forecasted in PER 2005-2010 and Ministerial Order ITC/2877/2008, reaching instead a consumption quota of biofuels over gasoil and gasoline of only 4.99% according to PER 2011-2020 data.

On the other hand and despite increasing consumption targets between 2005 and 2010, the domestic biodiesel market has been distorted as a result of illegal and disloyal commercial practices, first, on the part of the United States (a matter in its most part resolved by regulations adopted by the European Commission in 2009 and 2011) followed by Argentina and Indonesia, due to differential export rates applied by these countries.

With respect to the bioethanol sector and although the operating ratio of the four Spanish plants (80%) exceeds that of biodiesel plants, the worrying increase observed in bioethanol imports may also put this sector under a difficult situation.

The development of the biofuels sector over the next decade demands concrete measures to stop current disloyal commercial practices, which should be necessarily accompanied by actions driven at promoting R&D&i in order to guarantee the competitiveness and sustainability of the sector in the medium and long term.

This is due to the fact that the increasing cost of raw materials and the need to comply with strict mandatory sustainability criteria established by the EU make the development of new biomass materials destined to the production of biofuels essential, such as lignocellulosic materials, waste or algae, as well as the improvement of current productive processes and the promotion of alternative production technologies. Such development and its implementation will favor compliance with mandatory consumption targets established in Spain for the years 2011, 2012 and 2013 and with the minimum mandatory target set forth by the Renewable Energy Directive which establishes that 10% of the energy used in the transportation sector must come from renewable sources. Both the National Renewable Energy Action Plan 2011-2020 (Plan de Acción Nacional de Energías Renovables -PANER- 2011-2020) and PER 2011-2020 forecast that such target would be reached fundamentally through the use of biofuels.

With respect to biomass for thermal and electricity use, the stagnation of the sector contrasts with official published data on Spain's great raw biomass material potential. This data also demonstrate that an invaluable opportunity to develop a renewable energy whose benefits for Spain not only include the production of energy but also a number of key positive effects on environmental and socio-economic areas at rural, regional and national scales is being missed.

The various viable technologies for converting biomass into electric and thermal energy in Spain include combustion, gasification and biodigestion (all of which are succinctly explained in BIOPLAT's document Vision for 2030). These are technologies that when combined with the wide diversity of biomass fuels available transform the latter into a particularly versatile type of renewable energy, by allowing biomass recovery based on the availability of specific biofuels from each agent and the thermal and electric energy production potential, which is also based on the available quantity of such biofuels. Biomass therefore becomes a practicable type of renewable energy for anyone that has access to a continuous supply of biofuels, and it is the reason why it also becomes attractive to a wide range of agents from the agriculture, forestry, livestock, food and other sectors where biomass raw materials are produced. The latter occasionally become a problem to these sectors since such raw materials are essentially wastes that result from their primary activities that must be adequately managed in order to prevent abandonment, burial, uncontrolled dumping or incineration.

Energy recovery thus represents the clear solution for managing such biomass. It is estimated that the following volumes are generated annually:

Biomass from the PRUNING OF OLIVE TREES	2 to 3 t/ha per year
Biomass from the PRUNING OF VINES (excluding the thousands of ha. of pulled-out vines that are burned and not recovered)	0.75 a 1.5 t/ha per year
Biomass from the PRUNING OF FRUIT TREES	1.5 a 4 t/ha per year
GREENHOUSE VEGETAL WASTE	40 a 50 t/ha per year

SOURCE: APPA Biomass.
Table 4, Biomass generation estimates.

Compliance with the previous PER 2005-2010 targets alone would have avoided uncontrolled dumping of 7 million tons of waste; nevertheless, the biomass waste generation potential that is generated annually in the rural environment, such as grassy and woody agricultural waste, livestock waste, waste from the food industry, among others, becomes tremendously important as evidenced by PER 2011-2010 data (see tables 1, 2 and 4, as well as the supporting study for the preparation of the 2011-2020 Renewable Energy Plan 'Evolution of the Biomass Potential') as reflected in the following table:

Intensive livestock farming → Manure	64 mill.t/year
Intensive livestock farming → Liquid slurries	53 mill.t/year
Waste from olive oil production	2 mill.t/year
Waste from the food industry	1.3 mill.t/year
Waste from dry fruits and rice husks	0.3 mill.t/year
WWTP sludge:	1.2 mill.t/year (of which 0.8 mill.t/year are discharged on fields)

SOURCE: APPA Biomass.
Table 5, Potentially recoverable waste.

Forest fires that devastate the Spanish mountain landscape deserve separate mentioning. Adequate management including implicit energy recovery of forest biomass resulting therefrom would prevent 50 to 70% of forest fires, according to the Spanish Forestry Organization Confederation (Confederación de Organizaciones de Selvicultores de España -COSE-).

All of the key aforementioned environmental benefits also carry important savings in terms of reforestation, restoration, etc. and the overall environmental conditions that are affected as a result of the abandonment of forest biomass. One of the most important benefits corresponds to the one deriving from the production of biogas at biomass biodigestion facilities, which incorporates the added effect brought about by the considerable savings that result from the prevention of discharge of animal droppings, whose decomposition generates significant amounts of methane (a contaminant with a global warming potential 23 times greater to that of CO_2).

Controlling such biodigestion in the reactors where biogas is generated for the subsequent production of thermal and/or electric energy or its injection into gas grids implies savings for Spain (in economical terms) in the purchase of 9.2 million tons of CO_2 equivalent in emissions rights annually, according to calculations by the 'Unión por el Biogas' (Union for Biogas), a coalition that includes APPA Biomass and the Association of Companies for Negative Environmental Impacts caused by Animal Liquid Slurry (Asociación de Empresas para el Desimpacto Ambiental de los Purines -ADAP). Likewise, it is important to adequately manage agro-industrial waste and/or the organic fraction of municipal solid waste.

In addition to the production of thermal and electric renewable energy and the transformation of numerous biomass raw materials from waste into resources, the development of these sectors would bring about the setup of biomass facilities and industries in the rural environment whose operations would drive economic revitalization, by generating a considerable number of both direct and indirect jobs (essentially linked to biomass supply logistics) coupled with subsequent wealth creation and long-needed population settlement.

The below data was extracted from the study 'Economic Balance of appreciated retributions from electricity production from biomass', conducted by Analistas Financieros Internacionales (AFI) on behalf o APPA Biomass (July 2011). The data demonstrate that biomass based electricity generation plants that were operational on July 2011 in Spain, despite representing a MW volume that was far from the one established in the 2010 target, implied economical benefits that exceed the premiums that were paid out and linked to electricity production by almost forty-six million euro. That is, biomass projects have the capability to exceed by far the return on borrowed investment:

ECONOMIC BALANCE OF THE APPRECIATED RETRIBUTION FROM ELECTRICITY PRODUCTION FROM BIOMASS (PLANTS UNDER OPERATION - APPA BIOMASS MEMBERS)

EFFECTIVE PREMIUM: 138,5 MILL €

TOTAL CONTRIBUTION: 184.4 MILL €

Aggregate fiscal contribution:	93.6 mill €
Savings from avoided forest fires:	52.7 mill €
Savings from avoided unemployment benefits:	23.9 mill €
Savings from avoided CO_2 emissions:	14,1 mill €

POSITIVE ECONOMIC BALANCE: 45.9 MILL €

SOURCE: AFI – Economic Balance of the appreciated retribution from electricity production from biomass.
Table 6, Summary economic balance from biomass remuneration.

The same study demonstrates that, if improvements to the regulatory and biomass remuneration framework were to be introduced, the projects that are currently being processed could be eventually developed (according to APPA Biomass 2011 Member Plant Inventory), which would

imply a quantified net annual economical gain for Spain of seventy-two million euros, as shown in the following table:

ECONOMIC BALANCE OF BIOMASS (PLANNED PLANTS - APPA BIOMASS MEMBERS)			
EFFECTIVE PREMIUM:	695.7 MILL €	Aggregate fiscal contribution:	402.6 mill €
TOTAL CONTRIBUTION:	767.8 MILL €	Savings from avoided forest fires:	245 mill €
		Savings from avoided unemployment benefits:	79.6 mill €
POSITIVE ECONOMIC BALANCE:	72.1 MILL €	Savings from avoided CO_2 emissions:	43.4 mill €

Table 7. Economic balance of biomass.

Likewise, achieving the PER 2011-2010 biogas target would imply an increase in Spain's installed biogas production capacity from agricultural and livestock activities equal to 223 MW up to 2020. Given the practically non-existent development of biogas initiatives from agricultural and livestock activities in Spain (14 MW installed until December 2011), it becomes evident that the development of the sector is conditioned by the improvements that must be implemented in both its regulatory and remuneration frameworks; if these were to be undertaken they would allow achieving the 2020 target, resulting in a positive economic balance for the sector capable of generating fifty-nine million euros annually:

ECONOMIC BALANCE OF BIOGAS (PLANNED PLANTS - APPA BIOMASS MEMBERS)			
EFFECTIVE PREMIUM:	233.1 MILL €	Aggregate fiscal contribution:	175.9 mill €
TOTAL CONTRIBUTION:	292.7 MILL €	Savings from avoided forest fires:	83.6 mill €
		Savings from avoided unemployment benefits:	20.6 mill €
POSITIVE ECONOMIC BALANCE:	59.5 MILL €	Savings from avoided CO_2 emissions:	12.4 mill €

Table 8. Economic balance of biogas from agricultural and livestock activities.

In order to develop the biomass-based thermal and electric energy production sector (including biogas), both the regulations and support measures that may be implemented (in addition to being the appropriate ones) must be done so in a coordinated fashion. The Spanish Ministry of Industry, Tourism and Commerce and the Spanish Ministry of Environment, Rural and Marine Affairs must approach and consider the sector as a whole, once and for all, as the benefits stemming therefrom would also return to Spain as a whole. Similarly, the regions or Autonomous Communities must become integrated into the development and implementation of the policies that lead toward success. Political will will be key to launch this new industrial sector in Spain, one with the capacity to generate renewable energy based on national technology and fuels whose recovery supposes in many cases avoiding serious environmental problems and associated costs, while acting as an important vehicle for job creation at the local level.

In the case of biofuels, its development also has significant positive effects on the environmental and socio-economic areas. Beyond the key role biofuels generally play in the reduction of greenhouse gas (GHG) emissions, the diversification of the energy supply in the transportation sector and the secure supply of energy, the important benefits resulting from biofuel production from waste, residue, non-food cellulosic material and lignocellulosic materials must be highlighted.

These types of biofuels guarantee savings of GHG emission between 83 and 95% in comparison with substituted fossil fuels, according to calculations made by the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas –CIEMAT- (Center for Energy, Environmental and Technology

Research). Likewise, the use of waste and residue for the production of biofuels eliminates waste management needs, resulting in positive repercussions on numerous sectors including the oil and animal fat rendering industry, the food industry, etc.

The potential for the production of raw material in Spain is also quite considerable. In the case of biodiesel produced from used household oils, for example, PER 2011-2020 estimates indicate that about 280,000 tons may be potentially collected, in contrast with the 90,000 tons that are collected at present.

All efforts from the bioenergy sector must also point toward compliance with the European Renewable Energy Directive 2009/28/CE, which sets forth the following targets:

- Reaching a minimum 20% share of energy from renewable sources in overall Community energy consumption by 2020.
- 10% of the total energy consumption from renewable energy sources in the transport sector.

To this end, players in the sector (system-science and technology-business) must continue to bet on R&D on a daily basis. It is therefore of strategic importance to the sector to have the BIOPLAT tool available as a public-private reflection, analysis and discussion group on bioenergy matters, from which to encourage both inter-company and business to innovation agent cooperation with the purpose of promoting scientific and technological research among the latter and to establish important synergies that can drive improvements in technological capacity. This would result in increasing levels of competitiveness of the Spanish bioenergy sector and the creation and consolidation of an innovative Spanish bioenergy market.

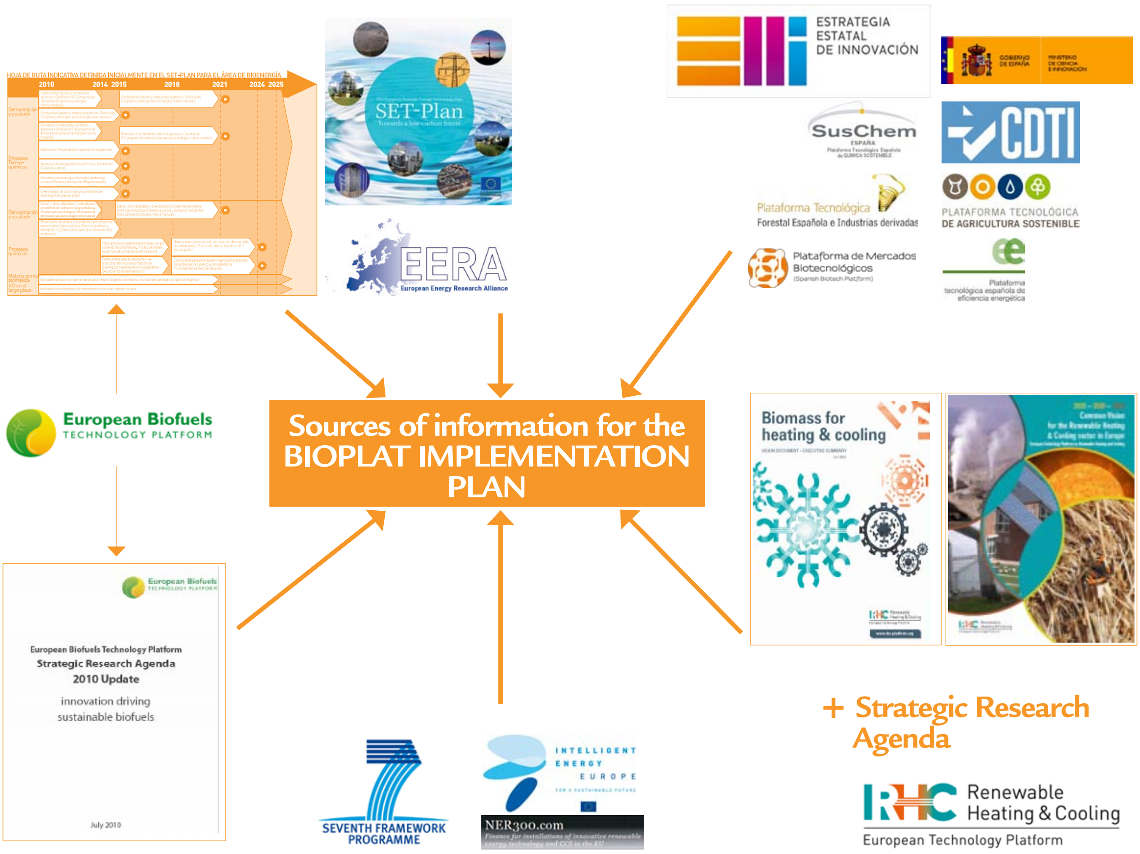
All of the above within the scope of the State Innovation Strategy (E2i – Estrategia Estatal de Innovación) with which the Spanish Ministry of Science and Innovation plans to contribute to the transformation process toward a sustainable economy that includes high added-value jobs that can show greater stability against economic cycle fluctuations.

The State Innovation Strategy establishes five lines of action with the purpose of placing Spain on the ninth position globally in the field of innovation by 2015. The five lines of action make up the so-called 'Innovation Pentagon' and include:

- The creation of a favorable financial environment for business innovation.
- Dynamization of innovative markets through regulation and public purchase.
- Territorial integration of policies for the promotion of innovation.
- Internationalization of innovative activities.
- Empowerment of individuals by incorporating talent and innovative capacity in the productive sector.

SOURCE: Spanish Ministry of Science and Innovation.
Figure 2, E2i Strategy Scheme.

Given such domestic framework and considering the European R&D&i context in general and particularly with respect to bioenergy, the BIOPLAT 2015 Implementation Plan was developed taking into account first the technological priorities of the Spanish bioenergy sector as per the 2015 outlook (evaluating previously the implementation process experienced through BIOPLAT's Strategic Implementation Lines established in 2009), as well as the contents of the bioenergy section included in the SET-Plan, particularly those corresponding to EERA's Joint Programme of Research in Bioenergy and fundamentally those of EIBI, in addition to the contents produced by the European Technological Platforms linked to BIOPLAT such as the European Biofuels Technology Platform and the European Technology Platform on Renewable Heating and Cooling, as well as National Technology Platforms that are linked to the bioenergy sector.



Using all this information as a starting point and as the basis for kicking off the process of preparing BIOPLAT's 2015 Implementation Plan, all BIOPLAT Work Groups led by BIOPLAT's Coordination Group (made up of Work Group Coordinators) have worked intensively during one year to produce this document on the basis of common ground, prioritization and consensus.

The Implementation Plan is structured in a set of innovative bioenergy related value chains that either continue to be a R&D&i priority for the Spanish bioenergy sector or constitute new R&D&i needs yet undeveloped in Spain and the EU. These new priority R&D&i areas of bioenergy do not exist at commercial scale and it is understood that its large-scale implementation (in large units or with a greater number of smaller units) could contribute substantially to the development of the bioenergy market, always under the criteria established by the European Renewable Energy Directive (2009/28CE).

The specific targets of BIOPLAT's 2015 Implementation Plan include:

- **The identification and prioritization of R&D&i needs in Spain in the field of bioenergy for inclusion in regional, national and European financing programs. This would entail maximizing the possibilities to implement the Plan and subsequently translate into considerable advances and progress in the Spanish bioenergy sector.**

- **Grow and consolidate Spain's bioenergy market while enabling the trade of advanced bioenergy related technology with a 2015 outlook, by pursuing competitive production costs in contrast to fossil fuels and ensuring that biofuels reach a sufficient degree of development that would enable them to provide an autochthonous, reliable and sustainable response to Spain and Europe's energy demand.**

- **From Spain and through the implementation of this Plan, contribute to the strengthening of this industrial sector, which shows important growth potential.**

The core of activities of this Plan revolves around the construction and commissioning of demonstration and/or flagship plants for innovative bioenergy value chains that display great market potential. Similarly, projects that are in the research stage are also included in the scope of the Plan.

Due to the high investment required and the risks that must be faced (e.g. technological, raw materials, end product markets, regulatory framework), the greatest obstacle for large scale commercial progress and implementation of these innovative bioenergy technologies is the financing required in the last stages of development. This represents a great challenge for this Plan, one that can be dealt with through the promotion of public-private consortia that are run by a combination of efficient management with (also) efficient financing resources.

BIOPLAT's 2015 Implementation Plan has identified ten bioenergy value chains whose implementation could act as an important catalyst for the achievement of renewable energy consumption targets both in Spain and the EU. Each of these 'generic' value chains features different processes that have been identified based on the raw biomass material selected, the type of conversion technology and/or attainable products, thus bringing forward a wide range of possible implementation venues that can be made available to the different agents from the science-technology-business system that make up this sector (businesses, public and private technology centers, universities, foundations, etc.).

BIOPLAT's 2015 Implementation Plan proposes a pragmatic approach to selecting the most promising options on the basis of transparent criteria as well as on a set of expected socio-economic and environmental benefits. The Plan is flexible enough to accommodate adjustments as a function of both Spanish and EU needs, by strengthening the development of innovation in the bioenergy space both in Spain and Europe as well as national technology agents and the industry, so as to reach the capacity and scale that would significantly contribute toward EU climate and energy targets in addition to competing in a global market.

In this Implementation Plan and in line with such climate targets, sustainability becomes a cross-cutting issue. Economic, social and environmental sustainability applied to the entire value chain is a key item of the proposed criteria used to evaluate and select projects within this initiative (see section 3.1). In this sense, a complementary value chain has been proposed that deals with all cross-cutting issues relative to raw biomass material, including critical supply logistics aspects.

THIS PLAN DESCRIBES THE ACTIVITIES THAT ARE NECESSARY TO ACHIEVE IMPLEMENTATION OF THE VALUE CHAINS DESCRIBED EARLIER BETWEEN 2012 AND 2015; TO THIS END, ESSENTIAL R&D&I ACTIONS HAVE BEEN IDENTIFIED AND RECOMMENDED TO STEER THE DIFFERENT TECHNOLOGIES TOWARD THE COMPETITIVE COMMERCIAL PHASE, BOTH IN THE CASE OF THE MOST PROMISING OPTIONS WHICH WOULD ALREADY BE READY FOR IMPLEMENTATION AT INDUSTRIAL OR PRE-INDUSTRIAL SCALE AS FOR PROJECTS THAT MAY BE IN LESS DEVELOPED RESEARCH STAGES. THESE ACTIONS WILL BE CARRIED OUT THROUGH THE USE OF CURRENTLY AVAILABLE AND FUTURE NATIONAL AND EUROPEAN TECHNOLOGICAL DEVELOPMENT AND R&D&I DEVELOPMENT PROGRAMS.

2 Implementation actions for the period 2012-2015

2.1 GENERAL OVERVIEW OF MAIN ACTIVITIES

In line with EIBI and EERA's Joint Programme of Research in Bioenergy, the main implementation activities or actions established for the 2012-2015 period seek to build and set in motion an initial number of projects which may include demonstration and/or flagship plants that can be further developed. This Plan fully sets forth the expected reach of high-potential value chains defined by the Spanish bioenergy sector integrated in BIOPLAT. Initially, within each of these ten 'generic' value chains there are 'specific' value chains that can be developed from pilot and demonstration scale through industrial scale based on existing technology and know-how. In practice, the Public Body in charge of managing R&D&i promotion funds will be the one deciding on how to limit the scope of certain value chains depending on the type, sources and amounts financed. BIOPLAT's 2015 Implementation Plan presents a program that is consistent and flexible, as well as capable of adjusting to different financing sources and mechanisms, considering that these parameters usually vary through time.

The ten value chains that have been established in BIOPLAT's 2012-2015 Implementation Plan are listed next and reflect the variety of existing raw materials and processing technologies that can be implemented during such period in the Spanish bioenergy market. Each of the ten value chains must be understood in and of itself from a biorefinery concept standpoint. Thus, the various co-products that may be produced in parallel to final energy ones (i.e. fuel, electricity and heat) must be taken into account if they contribute to the viability of the project.

BIOENERGY VALUE CHAINS CONTAINED IN BIOPLAT'S 2012-2015 IMPLEMENTATION PLAN.

ENERGY SEGMENT		VALUE CHAIN
Thermoelectric	I	Use of solid biofuels through direct combustion
	II	Production and use of solid biofuels for gasification
	III	Biogas production and use
Transportation	IV	Conversion of sugar and starch to bioethanol
	V	Conversion of lignocellulosic biomass to alcohol through biochemical processes
	VI	Gasification of biomass and catalytic or biochemical conversion to biofuels
	VII	Biomass digestion for biogas generation
	VIII	Thermal pyrolitic and catalytic conversion of lignocellulosic biomass and upgrading
	IX	Catalytic conversion of sugar to fuels and chemicals
	X	Oil platforms (conventional conversion + hydrotreatment + pyrolisis + standalone or combined treatment with fossil fuels in other refinery units)

Table 9, Value chain list.

Each of the value chains defined in BIOPLAT's 2012-2015 Implementation Plan face two types of challenges: technological and those linked to end use. Technological challenges are those aspects which, through the length of the value chain, possess a technological margin for improvement that will become a priority when optimizing the value chain as a whole, therefore making the latter susceptible of being assimilated into those R&D&i projects that can allow such a transition. Challenges linked to end uses of the value chain (some may be considered as non-technological challenges) can be identified as the direct effect on the Spanish bioenergy market that would occur should all technological challenges making up the value chain be overcome.

BIOENERGY VALUE CHAINS INCLUDING TECHNOLOGICAL AND END USE CHALLENGES CONTAINED IN EACH.

	VALUE CHAIN	TECHNOLOGICAL CHALLENGES (listed according to priority)	END USE CHALLENGES (listed according to priority)
I	**Use of solid biofuels through direct combustion**	i. Development of combustion installations for multiple biomass fuels. ii. Emission reduction of small combustion equipment. iii. Reduction of combustion equipment sintering and corrosion. iv. Development of grassy and woody biomass boilers and combustion equipment whose combustion generates medium to high ash content. v. Hybridization with other technologies. vi. Improvement of combustion equipment cycle efficiency. vii. Recovery of ash and slag. viii. Development of absorption cycles in order to reach higher yields in biomass based cooling processes.	i. Integrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.). ii. Development of a biomass heating and cooling market.
II	**Production and use of solid biofuels for gasification**	i. Gasification gas cleaning systems. ii. Development of multiple biomass fuel gasifiers. iii. Improving grates systems. iv. Hybridization with other technologies. v. Increasing gasification technological reliability for electricity generation. vi. Char recovery. vii. Reduction and treatment of leachate.	i. Integrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.). ii. Improving the viability of biomass use through gasification and emission parameters.
III	**Biogas production and use**	i. Optimizing digester design and operation. ii. Biogas conditioning. iii. Co-digestion: maximizing biogas production yield. iv. Hybridization with other technologies. v. Digestate recovery.	i. Integrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.). ii. Fuel certification. iii. Improving emission parameters. iv. Injection into grid. v. Legislative aspects and waste treatment regulations.

	VALUE CHAIN	TECHNOLOGICAL CHALLENGES (listed according to priority)	END USE CHALLENGES (listed according to priority)
IV	**Conversion of sugar and starch to bioethanol**	i. Process optimization and increasing energy efficiency.	i. Sustainability certification. ii. Sub-product recovery. iii. Increasing the percentage mixture with conventional fuels.
V	**Conversion of lignocellulosic biomass to alcohol through biochemical processes**	i. Development of new enzymes, production cost reduction and optimization of enzyme mixtures. ii. New hydrolysis and fermentation configurations. iii. Optimizing biomass pre-treatment and fractioning systems.	i. Sustainability certification. ii. Development at pre-industrial demonstration scale.
VI	**Gasification of biomass and catalytic or biochemical conversion to biofuels**	i. Development of synthesis gas purification, cleaning and conditioning systems. ii. Incorporating process intensification strategies and unit process integration aimed at improving the efficiency: biorefinery concept. iii. Optimizing catalyzer design and operation.	i. Development at pre-industrial demonstration scale. ii. . Fuel certification. iii. Sustainability certification. iv. Fleet tests. v. Infrastructure development for product use.
VII	**Biomass digestion for biogas generation**	i. Optimizing digester design and operation. ii. Biogas conditioning. iii. Co-digestion: maximizing biogas production yield. iv. Digestate recovery.	i. Fuel certification. ii. Optimizing storage systems used for biogas transport. iii.Injection into grid. iv. Legislative aspects and waste treatment regulations.
VIII	**Thermal pyrolitic and catalytic conversion of lignocellulosic biomass and upgrading**	i. New catalyzers to increase process performance. ii. Improving pyrolysis oil stability. iii.Process upgrading in refinery units. iv. Pyrolysis of waste with limited combustion capacity; other possibilities pertaining the recovery of this waste.	i. Oil hydrogenation pilot and demonstration projects. ii. Fuel certification. iii. Integration with other industrial units (e.g. refineries).

IX	**Catalytic conversion of sugar to fuels and chemicals**	i. Research in catalyzers and sugar conversion processes. ii. Research in the use of microorganisms for advanced conversion of sugar. iii. Development of associated component extraction processes. iv. Stream purification processes required for conversion.	i. Fuel certification. ii. Certification of other non-energy product applications.
X	**Oil platforms (conventional conversion + hydrotreatment + pyrolisis + standalone or combined treatment with fossil fuels in other refinery units)**	i. Optimizing catalytic systems to improve the technical viability of the process. ii. Integrating the process with conventional fuel production processes (refineries), in order to seek pre-industrial demonstration scale. iii. Developing transformation processes to obtain biofuels.	i. Fuel certification.

Table 10, Value chains of thermoelectric and transportation segments.

In addition to the ten main value chains, an intermediate value chain has been established which points out the technological and end use needs of the so-called bioenergy carriers that include drying, grain size reduction, densification, torrefaction and pyrolysis. These bioenergy carriers represent the pre-treatment or treatment processes that enable biomass processing, with the purpose of improving its physico-chemical properties so as to ensure that such improvements allow optimizing the efficiency of other subsequent processes that must be carried out (e.g. successive chemical processes for biofuel generation, direct appreciation in gasifiers, etc.).

VALUE CHAIN OF INTERMEDIATE BIOENERGY CARRIERS INCLUDING ASSOCIATED TECHNOLOGICAL AND END USE CHALLENGES.

VALUE CHAIN	TECHNOLOGIES IDENTIFIED	TECHNOLOGICAL CHALLENGES	END USE
Study on the possibilities of using torrefaction, pyrolysis and densification as pre-treatment.	Densification.	i. Improving the design to attain cost reduction and increase in quality.	i. Showcasing the product in its different final uses and logistic chains.
	Pyrolysis.	ii. Demonstrating the technology at pilot scale (in the case of torrefaction and pyrolysis technologies).	ii. Pyrolysis char recovery.
	Grain size reduction.	iii. Widening the range of raw materials that can be used and reaching the capacity to design 'customized' biofuels.	
	Drying.	iv. Development of biomass solar drying schemes.	
	Torrefaction.		

Table 11, Value chain of bioenergy carrier segments.

IN CONTRAST TO OTHER ENERGY TYPES WHERE NO FUEL INTERVENES, THE HANDLING, MANAGEMENT AND LOGISTICS OF BIOMASS RAW MATERIALS REPRESENT A FUNDAMENTAL ASPECT THAT IS INEXTRICABLY LINKED TO YIELD AND ASSOCIATED EFFICIENCY LEVELS DURING THE LATTER'S TRANSFORMATION INTO ENERGY.

To that end, a number of technological challenges that must be tackled in the period 2012-2015 have been identified for each of these biomass raw materials. It is important to highlight that the Spanish bioenergy sector does not consider nor shares the idea that the required handling and management of biomass raw material that exists prior to its recovery may constitute 'an issue'; on the contrary, the Spanish bioenergy sector understands that it is in fact in the handling and management of such raw material where this type of renewable energy's key added value is generated, as numerous jobs – both direct and indirect – are intrinsically linked thereto, skill and labor being required to process raw materials at origin (fields, mountain areas, etc.) in addition to transporting them all the way to the plants and other locations.

IDENTIFIED RAW MATERIALS FOR THE ABOVEMENTIONED BIOENERGY VALUE CHAINS INCLUDING ASSOCIATED TECHNOLOGICAL AND END USE CHALLENGES.

LIST OF IDENTIFIED RAW MATERIALS	TECHNOLOGICAL CHALLENGES	END USE CHALLENGES	CROSS-CUTTING CHALLENGE
Algae.	· Downstream development (harvesting and processing). · IIncreasing scale of projects. · Development of harvesting technologies (improvement of materials and inflow optimization). · · Selection of species.	· Regulatory development.	Unification of sustainability criteria and indicators.
Forestry biomass.	· Technological development to reach biomass extraction/cost profitability.	· Development of methodologies for the study of production and market potential coupled with sustainability criteria.	
Grassy energy crops.	· Inflow optimization: efficient use of resources, equipment development, improving the development of logistic processes, chemical and mechanical control treatment optimization.		
Woody energy crops.	· Selection and improvement of vegetal material.		
OFMSW.	· Pre-treatment improvements.	· OFMSW regularization.	
Agricultural waste. Livestock waste. Industrial waste.	· Increase the number of materials that are susceptible of being treated through anaerobic digestion.	· Eliminate restrictions between food and energy use.	

Table 12, List of raw materials and associated challenges.

2.2 SCALABILITY OR PROJECT TYPES IN WHICH TO IMPLEMENT VALUE CHAINS

A description of the different scales at which the value chains established in BIOPLAT's 2012-2015 Implementation Plan could be implemented is provided next:

i. **Research at laboratory scale:** installations designed to obtain information on a specific physical or chemical process that allow determining whether the processes are technically viable, as well as establishing the optimal operating parameters of such processes for subsequent design and escalation.

ii. **Pilot plants:** installations designed to cross-check technologies and which yet allow flexibility to introduce technical modifications to processes without supposing great structural changes to such technologies.

iii. **Demonstration plants:** representing the last non-economic[1] step to demonstrate results and the viability of value chain critical points, such that the first commercial unit may be designed based on guaranteed performance levels.

iv. **Flagship/representative plants:** represents the first commercial unit operating in an economically viable scale. The economically viable scale is that in which economic agents involved in the project (raw material suppliers, technology developers, plant operators, investors, etc.) are willing to assign resources in return of benefits. The construction and commissioning of these plants implies costs

1 The start-up of these demonstration projects with the purpose of overcoming the technological barriers will not generate economic returns or, will not generate high enough returns to pay off the investment and cover operating expenditures.

and risks that are higher than those of demonstration plants and which are due fundamentally to scale. In spite of this, subsequent commercial plants developed after the initial one will benefit from the advances attained in the learning curve and will lower risk premiums associated with the equity required to finance these projects.

Demonstration stage must have been passed successfully, otherwise it must be explained why the demonstration step is not necessary. It is highly recommendable that projects include a sustainability assessment on the basis of its own life cycle analysis covering the full value chain, from raw materials to final product.

2.3 ECONOMICAL APPRAISAL OF THE IMPLEMENTATION PLAN

An approximate implementation cost has been estimated for each value chain as a function of the scale at which it could be developed (not all chains are susceptible of being implemented at all scales, as each of them are currently at different stages of technological development). These are estimated values and their fundamental purpose is to guide technology fund managers on the costs involved to develop the various value chains.

Spanish experts belonging to each of the areas described have conducted the economic assessments taking into account R&D&i costs for each project included in the value chains and considering the number of projects per each type of challenge that could be undertaken in the period 2012-2015. Using this information, a total cost has been estimated for each value chain at the corresponding scale they could be implemented at. In this sense, it is worth noting that in some cases reference is made to installations and processes whose commercial phase does not exist currently, meaning that costs displayed are only approximate.

The processes to be followed for each defined value chain are depicted below schematically:

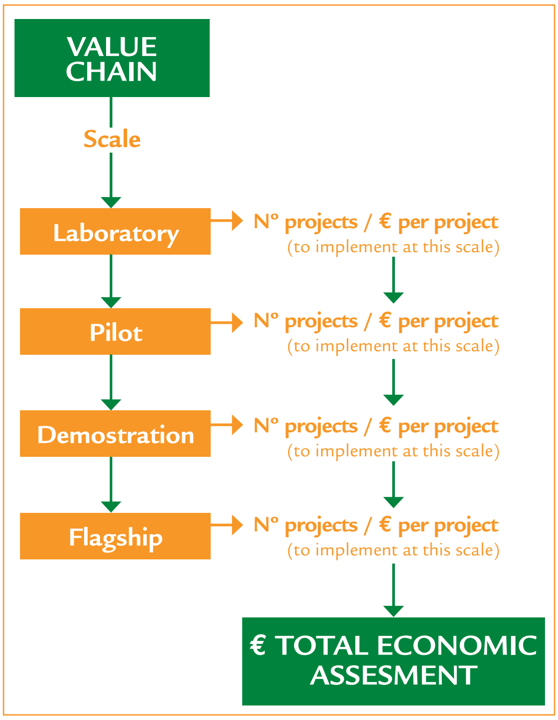


Table 13, Estimation scheme for conducting economic assessments of value chains.

R&D&i AT LABORATORY SCALE			
SEGMENT		**VALUE CHAIN**	**TOTAL (million €)**
Thermoelectric	II	Production and use of solid biofuels for gasification	1
	III	Biogas production and use	0.5
Transportation	IV	Conversion of sugar and starch to bioethanol	2
	V	Conversion of lignocellulosic biomass to alcohol through biochemical processes	10
	VI	Gasification of biomass and catalytic or biochemical conversion to biofuels	17
	VII	Biomass digestion for biogas generation	1
	VIII	Thermal pyrolitic and catalytic conversion of lignocellulosic biomass and upgrading	4
	IX	Catalytic conversion of sugar to fuels and chemicals	13
Intermediate bioenergy carriers	Intermediate bioenergy carriers	Study on the possibilities of using torrefaction, pyrolysis and densification as pre-treatment.	8.5

Table 14, Economic assessement of the implementation of the value chain for R&D&i at laboratory scale.

R&D&i AT PILOT SCALE			
SEGMENT		**VALUE CHAIN**	**TOTAL (million €)**
Thermoelectric	I	Use of solid biofuels through direct combustion	2.4
	II	Production and use of solid biofuels for gasification	7-20
	III	Biogas production and use	2
Transportation	IV	Conversion of sugar and starch to bioethanol	20
	V	Conversion of lignocellulosic biomass to alcohol through biochemical processes	20
	VI	Gasification of biomass and catalytic or biochemical conversion to biofuels	20
	VII	Biomass digestion for biogas generation	6
	VIII	Thermal pyrolitic and catalytic conversion of lignocellulosic biomass and upgrading	9
	IX	Catalytic conversion of sugar to fuels and chemicals	20
	X	Oil platforms (conventional conversion + hydrotreatment + pyrolisis + standalone or combined treatment with fossil fuels in other refinery units)	25-65
Intermediate bioenergy carriers		Use of solid biofuels through direct combustion	14.5

Table 15, Economic assessement of the implementation of the value chain for R&D&i at pilot scale.

R&D&i AT DEMOSTRATION SCALE			
SEGMENT		**VALUE CHAIN**	**TOTAL (million €)**
Thermoelectric	I	Use of solid biofuels through direct combustion	27-107
	II	Production and use of solid biofuels for gasification	6-28
	III	Biogas production and use	5
Transportation	V	Conversion of lignocellulosic biomass to alcohol through biochemical processes	50
	VI	Gasification of biomass and catalytic or biochemical conversion to biofuels	50
	VII	Biomass digestion for biogas generation	5
	VIII	Thermal pyrolitic and catalytic conversion of lignocellulosic biomass and upgrading	35
	X	Oil platforms (conventional conversion + hydrotreatment + pyrolisis + standalone or combined treatment with fossil fuels in other refinery units)	65
Intermediate bioenergy carriers		Use of solid biofuels through direct combustion	5

Table 16, Economic assessement of the implementation of the value chain for R&D&i at demonstration scale.

R&D&i AT FLAGSHIP SCALE			
SEGMENT		**VALUE CHAIN**	**TOTAL (million €)**
Thermoelectric	I	Use of solid biofuels through direct combustion	40-60
	II	Production and use of solid biofuels for gasification	5-20
Transportation	IV	Conversion of sugar and starch to bioethanol	23
	V	Conversion of lignocellulosic biomass to alcohol through biochemical processes	300
	VI	Gasification of biomass and catalytic or biochemical conversion to biofuels	300

Table 17, Economic assessement of the implementation of the value chain for R&D&i at flagship plant scale.

The following values are defined in the case of raw materials:

LIST OF RAW MATERIALS IDENTIFIED	TECHNOLOGICAL CHALLENGES		TOTAL (million €)
Grassy bioenergy crops	Assessment and development of species and sustainable harvesting conditions from an environmental, energy and economic standpoint in Spanish soil-climate conditions: optimization of water use in irrigation crops, optimization of chemical and mechanical control treatment and in the use of fertilizers, development of sustainable harvesting techniques (e.g. direct sowing, protective crops, etc.) and selection of the most sustainable species for energy production in Spain in addition to technical and economical conditions (including possible aid) to attain viable commercial implementation		4.5-9
	Genetic improvements in order to increase grassy crop sustainability used for energy production		2-4
	Production potential and energy crop market assessments under sustainability criteria		1
Woody energy crops	Production potential and energy crop market assessments under sustainability criteria		1
	Vegetal material	Genetic improvements	2-4
		Selection of species	4-8
	Inflow optimization: efficient use of resources, equipment development, improving the development of logistic processes, optimization of chemical and mechanical control treatment		3-6
Grassy energy crops **Woody energy crops** **Forest biomass** **Agricultural waste**	Development of improvements and innovations in logistic chains (collection, transport, storage, pre-treatment) for supplying large biomass needs, with the aim to optimize guarantees, costs and quality of supplied biomass		0.5-3
Agricultural waste **Livestock waste** **Industrial waste**	Increase the number of materials that are susceptible of being treated through anaerobic digestion. Residual biomass stockpiling logistics		0.5-2
OFMSW	Pre-treatment improvement		0.8
Algae	Development of harvesting technologies (bioreactors, improvement of materials, inflow optimization)		0.3-6
	Selection of species		0.1-2.5

Table 18, Economic assessment of the implementation of challenges associated with raw materials.


ONE WAY

3 Suggested implementation modes:

Selection criteria and monitoring mechanisms.

3.1 GENERAL PRINCIPLES OF PROJECT SELECTION PROCEDURES. ELIGIBILITY CRITERIA PROPOSAL

The Spanish bioenergy sector that is integrated in BIOPLAT (science-technology-business system) has worked jointly on a proposal that defines a robust system for criteria eligibility and selection, financing schemes and selection procedures.

The set of criteria that reflect the basic characteristics of BIOPLAT's 2015 Implementation Plan has been defined by the Spanish bioenergy sector itself with the purpose of providing insights into how demonstration projects and flagship plants that are to be developed should be assessed and selected.

The following basic principles help put together the assessment and eligibility criteria structure:

- **Degree of relationship with the value chains proposed by BIOPLAT.**
- **Technical quality:** ensuring that a reliable technological novelty in technical, economical and environmental terms is proposed as well as in terms of work organization and methodology (compliance with delivery dates, scope of proposals, conformity with financing program administrative specifications, etc.).
- **Availability of raw materials:** supply of sustainable biomass raw material at reasonable cost in addition to overall system efficiency improvement. Establish a preference for raw material whose origin is Spain or the European Union.
- **Economic and financing characteristics:** the consortium must have the necessary operating and financing capacity to implement proposed innovations.

- **Maturity/Scale (for demonstration and/or flagship plants):** the scale should be large enough in order to cross-check the project's technical and economical results, providing valid data such that technology may be escalated in a viable way at the industrial level once the demonstration phase has proven successful.
- **Socioeconomic impact:** : reasonably assess the economic viability of the proposal in the market.
- **International impact:** : exportability of the project.

3.2 PROJECT MONITORING MECHANISMS: IMPLEMENTATION INDICATORS

'Development level indicators' or 'key performance indicators' of R&D&i projects (known as 'KPI') are a fundamental instrument to measure the level of success in the achievement of project results established within the scope of the value chains that have been defined. Quantifying these will also allow measuring the level of implementation of this Plan. BIOPLAT's Secretariat itself could undertake the task of collecting and handling this information in order to understand and assess the degree of implementation of the Plan.

The indicators proposed next make reference to those project magnitudes or characteristics that are deemed fundamental to enable progress monitoring from a technological standpoint. Determining the limit values for these parameters has been left out of the scope of this Plan as it represents a task that is currently being developed in Brussels with the aim to homogeneously apply such limit values to projects across all Member States that fall within the scope of the SET-Plan. These values must be defined based off of consensus with appropriate balanced criteria that adjust to the reality of the sector both at the European and Spanish level. Therefore, the methodologies that must be applied in order obtain the required KPI must also be arrived at by consensus, in order for the results that are obtained for the same KPI in different projects may be comparable.

In order to evaluate the level of fit and progress of the project portfolio and to successfully monitor this Plan, two types of indicators – generic and specific – are foreseen for each value chain.

1. GENERAL PLAN INDICATORS

Bioenergy is used as an alternative to the use of fossil based energy and as such, greenhouse gas emission reductions are used in the majority of cases to evaluate the added value that bioenergy brings in terms of environmental protection. Therefore, it is important to consider the savings that result from emission reductions and the costs of achieving these as a bioenergy R&D&i project KPI. Three indicators are thus proposed below, given the EU's target to reach a minimum 20% share of energy from renewable sources in the EU's final gross energy consumption by 2020:

- Reduction of greenhouse gas emissions in comparison to equivalent fossil fuels. The methodology and associated information on sustainability criteria of the European Renewable Energy Directive (2009/28/CE) transposed to the Spanish regulatory framework by virtue of Royal Decree 1597/2011 on the Sustainability of Biofuels and Bioliquids shall be used.
- Maximum and minimum costs of bioenergetic products (€/MWh) for each value chain.
- Total bioenergy production of Plan projects (TWh/year.).

In addition, the following indicators are considered in order to analyze the overall degree of implementation of the Plan:

- Cumulative number of approved projects based on the technologies that are specified by BIOPLAT's Implementation Plan in all value chains.
- Cumulative invested equity in projects that are based on the Plan's value chains from the date of publishing.
- Availability[2] of operational plants at commercial scale.

2. VALUE CHAIN SPECIFIC INDICATORS

To assess the degree of implementation of each value chain individually, three types of indicators are considered: technological, resource based and socio-economic:

2.2.1 Technology indicators

- Demonstration/Flagship plant availability.
- Greenhouse gas emission reduction in comparison to reference fossil fuels.
- Cost of investment equity of bioenergy products (e.g. €/l,€/MWh).
- Production cost (e.g. €/l, €/MWh).
- Cost for each saved ton of greenhouse gas emission (e.g. €/CO_2 equivalent).
- Net efficiency[3], based on the lower calorific value (LCV) of conversion of biomass raw material, from the time it enters the plant until a commercial product is obtained.

2.2.2 Resource based indicators

- Cost of the biomass resource delivered at the entry of the plant (e.g. €/MWh).
- Annual volume of biomass consumption at the entry of the plant (e.g. MWh/year).

2.2.3 Socio-economic indicators

- Number of permanent jobs generated by the projects, including those associated with the plant itself and biomass supply and distribution chains (data broken down to indicate job locations within an approximate radius of 150 km, in addition to a breakdown by job qualification level).

2 Availability is defined as the percent value of the degree of a piece of equipment's uptime under operational and time conditions, measured in hours per each 8,760 hours.
3 Net efficiency represents the percentage between final harnessed energy (comercial bioenergectic products) and the sum of the inputs (biomass energetic inputs less the energy content of non-energetic comercial bioproducts).

Annex:

Value chains, summarized description and examples of on-going projects.

The following section provides a summary of each value chain and some provide examples of on-going projects.

	VALUE CHAIN	TECHNOLOGICAL CHALLENGES (listed according to priority)	END USE CHALLENGES (listed according to priority)
I	**Use of solid biofuels through direct combustion**	i. Development of combustion installations for multiple biomass fuels. ii. Emission reduction of small combustion equipment.. iii. Reduction of combustion equipment sintering and corrosion. iv. Development of grassy and woody biomass boilers and combustion equipment whose combustion generates medium to high ash content. v. Hybridization with other technologies. vi. Improvement of combustion equipment cycle efficiency. vii. Recovery of ash and slag. viii. Development of absorption cycles in order to reach higher yields in biomass based cooling processes.	i. Integrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.). ii. Development of a biomass heating and cooling market.

II	**Production and use of solid biofuels for gasification**	i. Gasification gas cleaning systems. ii. Development of multiple biomass fuel gasifiers. iii. Improving grates systems. iv. Hybridization with other technologies. v. Increasing gasification technological reliability for electricity generation. vi. Char recovery. vii. Reduction and treatment of leachate.	i. Integrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.). ii. Improving the viability of biomass use through gasification and emission parameters.
III	**Biogas production and use**	i. Optimizing digester design and operation. ii. Biogas conditioning. iii. . Co-digestion: maximizing biogas production yield. iv. Hybridization with other technologies. v. Digestate recovery.	i. IIntegrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.). ii. Fuel certification. iii. Improving emission parameters. iv. Injection into grid. v. Legislative aspects and waste treatment regulations.
IV	**Conversion of sugar and starch to bioethanol**	i. Process optimization and increasing energy efficiency.	i. Sustainability certification. ii. Sub-product recovery. iii. Increasing the percentage mixture with conventional fuels.
V	**Conversion of lignocellulosic biomass to alcohol through biochemical processes**	i. Development of new enzymes, production cost reduction and optimization of enzyme mixtures. ii. New hydrolysis and fermentation configurations. iii. Optimizing biomass pre-treatment and fractioning systems.	i. Sustainability certification. ii. Development at pre-industrial demonstration scale.
VI	**Gasification of biomass and catalytic or biochemical conversion to biofuels**	i. Development of synthesis gas purification, cleaning and conditioning systems. ii. Incorporating process intensification strategies and unit process integration aimed at improving the efficiency: biorefinery concept. iii. Optimizing catalyzer design and operation.	i. Development at pre-industrial demonstration scale. ii. Fuel certification. iii. Sustainability certification. iv. Fleet tests. v. Infrastructure development for product use.

	VALUE CHAIN	TECHNOLOGICAL CHALLENGES (listed according to priority)	END USE CHALLENGES (listed according to priority)
VII	**Biomass digestion for biogas generation**	i. Optimizing digester design and operation. ii. Biogas conditioning. iii. Co-digestion: maximizing biogas production yield. iv. Digestate recovery.	i. Fuel certification. ii. Optimizing storage systems used for biogas transport. iii. Injection into grid. iv. Legislative aspects and waste treatment regulations.
VIII	**Thermal pyrolitic and catalytic conversion of lignocellulosic biomass and upgrading**	i. New catalyzers to increase process performance. ii. Improving pyrolysis oil stability. iii. Process upgrading in refinery units. iv. Pyrolysis of waste with limited combustion capacity; other possibilities pertaining the recovery of this waste.	i. Oil hydrogenation pilot and demonstration projects. ii. Fuel certification. iii. Integration with other industrial units (e.g. refineries).
IX	**Catalytic conversion of sugar to fuels and chemicals**	i. Research in catalyzers and sugar conversion processes. ii. Research in the use of microorganisms for advanced conversion of sugar. iii. Development of associated component extraction processes. iv. Stream purification processes required for conversion.	i. Fuel certification. ii. Certification of other non-energy product applications.
X	**Oil platforms (conventional conversion + hydrotreatment + pyrolisis + standalone or combined treatment with fossil fuels in other refinery units)**	i. Optimizing catalytic systems to improve the technical viability of the process. ii. Integrating the process with conventional fuel production processes (refineries), in order to seek pre-industrial demonstration scale. iii. Developing transformation processes to obtain biofuels.	i. Fuel certification.

Table 10, Value chains for thermoelectric and transportation segments.

VALUE CHAIN: Use of solid biofuels through direct combustion

Thermal and electrical energy production through direct combustion of solid biomass constitutes one of the most consolidated biomass energy applications, with fully developed technologies at commercial scale.

Nevertheless, technological development aimed at energy cost reduction and increasing the efficiency of energy production and biofuel quality is required both at the level of preparation of solid biofuels and existing thermal and electric energy production equipment and systems.

Likewise, the development of these markets requires the incorporation of new biomass as an addition to existing ones. In many cases, the characteristics of new potential biomass sources require technological developments to ensure viability of use, from a technical, economical and environmental standpoint.

Raw materials:

- Agricultural waste.
- Energy crops.
- Forest biomass.
- Industrial waste.
- OFMSW.

Technologies:

- Direct combustion.

End use:

- Domestic thermal installations:
  Used both in small individual equipment (heaters, fireplaces, kitchens, small boilers) and collective ones, including centralized equipment (e.g. residential communities) and district heating and cooling.
- Industrial thermal installations:
  At present, in the majority of cases the raw material used is the waste generated by the very same industries that use the energy, that is, it is a sector where self-consumption is predominant.
- Electrical installations that export electricity to the grid.
- Electrical installations that use part or all the electricity (self-consumption).

Technological challenges:

- Development of combustion installations for multiple biomass fuels:
  This entails a strategy to optimize biomass costs and guarantee supply, mainly in the case of large combustion plants. The development of biomass preparation and feeding systems together with combustion technology and combustion equipment design make up the key points of action in this field.
- Reduction of emissions of small combustion equipment:
  This field requires fundamentally the reduction of particles through the use of measures applied inside the equipment and/or to external cleaning equipment that are viable from a technical and economic standpoint.
- Reduction of sintering and corrosion of combustion equipment:
  This target can be achieved, among other possibilities, through the use of adequate additives and/or the use of biomass mixtures where at least one of them shows a small tendency to become sintered or corroded.
- Development of boilers and combustion equipment for grassy and wooden biomass whose combustion generates medium to high ash content:
  This challenge is, on the one hand, related to the earlier one in that it is the materials that

have the highest ash content the ones that show a greater tendency toward causing equipment sintering and corrosion. Moreover, it requires technological development of equipment design as well as the incorporation of effective ash removal systems.

» Hybridization with other technologies:

  For example, solar thermal: biomass could supply the complementary energy necessary to avoid excessive cooling of the thermal fluid during nighttime or low solar thermal supply situations.

» Improvement of combustion equipment cycle efficiency:

  The efficiency of combustion equipment can be increased by manipulating the chemistry of the ashes inside combustion equipment, including the already-mentioned use of additives. In steam cycles, this strategy can help attain a reduction of maintenance costs and even increase steam temperature, thus improving production efficiency.

» Recovery of ash and slag.
» Development of absorption cycles in order to reach higher yields in biomass based cooling processes.

End use challenges:

» Integrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.).
» Development of a biomass heating and cooling market.

II VALUE CHAIN: Production and use of solid biofuels for gasification

The gasification process is a biomass thermochemical thermal degradation process that uses a quantity of air that is lower than the stoichiometric value, or in other words, that which is necessary to achieve full fuel combustion. Gas with low calorific power is thus obtained as a result of this transformation, which is commonly known as producer gas. Afterward, the gas must be conditioned to fit the characteristics of its final application such as its use in a boiler and/or internal combustion engine.

Raw materials:

» Agricultural waste.
» Forest biomass.
» Grassy energy crops.
» Industrial waste.
» OFMSW.
» Woody energy crops.

Technologies:

» Gasification + boiler.
» Gasification + Internal combustion engine / Gas turbine.

Once conditioned, the gas may be used in combustion in a boiler to produce thermal energy or in an alternative internal combustion engine or gas turbine for power generation, thermal energy production, or both simultaneously (combined heat and power -CHP-).

End use:

The end use of the energy produced may be classified according to the following categories:

- Domestic thermal installations.
- Industrial thermal installations.
- Electrical installations that export electricity to the grid.
- Electrical installations that use part or all the electricity (self-consumption).

Technological challenges:

Gasification technologies are not yet fully mature and therefore its different potential applications have not yet been developed commercially. Efforts must thus still be made to conduct research in the different areas. The main technological challenges that have been identified by the Platform include the following:

- Gasification gas cleaning systems:
  The production of tars and other compounds, mainly during the thermochemical transformation process continues to be a problem hindering the technology's durability and reliability.
- Development of multiple biomass fuel gasifiers:
  Providing gasification systems with a certain degree of independence or versatility with respect to the type of biomass feed allows increasing the possibilities to attain greater integration of the technology as a way to harness the energy. The current specificity of the behavior of gasification technology must be tackled for all systems that are part of it in order to bring more reliability and durability to the system.
- Improving grates systems:
  Fixed bed gasification system grates continues to be a fundamental characteristic as well as a weakness affecting its large-scale commercial implementation. The development of grates systems that allow controlling the process as well as providing reliability to the system continues to be a commercial pitfall.
- Hybridization with other technologies.
- Increasing gasification technological reliability for electricity generation:
  Implementation of equipment and systems that are able to operate more than 7,500 h/year and with maintenance costs that allow project economic sustainability. This would include organizing preventive maintenance during operations by duplicating critical equipment. Applicable to biomass that generate high levels of tar.
- Char recovery.
- Reduction and treatment of leachate.

End use challenges:

- Integrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.).
- Improving the viability of biomass use through gasification and emission parameters.

III VALUE CHAIN: Biogas production and use

Readily biodegradable raw materials offer many possibilities in terms of biogas production that could later be used for electricity production, harnessing of thermal energy, biofuel, injection into transportation and/or natural gas grid or used in fuel cells.

According to the last data published in the Biogas Barometer released by EurObserv'ER in November 2010, over three quarters of the biogas produced in Spain comes from landfills, a little over 5% from wastewater treatment plants and the rest from other raw materials whose potential is not being taken advantage of partially due to the great variety of resources existing in Spain.

Achieving the technological and non-technological challenges captured in this document would enable the proliferation of biogas production and transformation plants across the Spanish geography. A point worth highlighting refers to R&D&i projects that are under way in Spain, one good example being the strategic singular project PSE PROBIOGÁS as well as those that are being carried out by companies from the sector that make use of aid from public entities.

Raw materials:

» Algae.
» Agricultural waste.
» Energy crops.
» Industrial waste.
» Livestock waste.
» OFMSW.

Technologies:

» Anaerobic digestion + boiler.
» Anaerobic digestion + Internal combustion engine / Gas turbine.
» Anaerobic digestion + conditioning + injection to grid.

Anaerobic digestion is a biological process in which organic matter becomes degraded to a gaseous compound known as biogas by the action of a series of micro-organisms known as methanogenic bacteria, under adequate temperature conditions and always in the absence of oxygen. This gas is composed mainly of methane, carbon dioxide, sulphydric acid, etc. in percentages that can vary depending on the type raw material that is initially used. Likewise, such process also generates a compound known as digestate, which can be subject to recovery processes for example in the production of compost.

The gaseous biofuel obtained can be introduced in a boiler, alternative internal combustion engine or gas turbine to be transformed according to each case or conditioned for injection into the grid.

End use:

» Domestic thermal installations.
» Industrial thermal installations.
» Electrical installations that export electricity to the grid.
» Electrical installations that use part or all the electricity (self-consumption).

At present, it can be said that the use of biogas is captive, as its transformation into energy takes place in the same installation where it was produced. Reducing this captivity would allow increasing its use considerably given the great degree of versatility displayed by this gaseous biofuel.

Technological challenges:

- Optimizing digester design and operation:

  In order for anaerobic digestion to take place under the most effective conditions (based on the type of raw materials used) a number of environmental parameters must be controlled, such as pH, alkalinity, the presence of bacterial inhibitors, etc. and those of an operational nature such as temperature, stirring, retention time, etc.

- Biogas conditioning:

  Development of biogas conditioning systems for injection into the grid (biomethane) in addition to gas separation systems and other contaminant cleaning systems to attain a high percentage of methane in the gas stream.

  Development of biogas conditioning systems (particle and contaminant elimination) to increase energy harnessing

- Co-digestion: maximizing biogas production yield:

  Co-digestion is the process by which joint anaerobic digestion of readily digestible organic material takes place. Through this process, synergies are achieved as a result of the availability of resources that are complementary, as some of these are either seasonal or have a composition based on which no biogas would be generated in sufficient quantity or quality. It is important to highlight at this point the pre-treatment steps that are necessary in each particular case, depending on the types of raw materials used.

- Hybridization with other technologies:

  The biogas that is produced may be used in conjunction with other renewable and conventional energy generation technologies. An example would be hybridization with solar thermal energy, which would allow increasing its dispatchability, bringing associated advantages when used for electricity production from a national energy grid management standpoint.

- Digestate recovery:

  Harnessing the fertilizing value of nutrients (nitrogen, phosphorus, potassium) and existing oligoelements, as well as their value as an organic soil amendment for agricultural use. Development of contaminant separation and pathogen elimination methods.

  Assessing the agronomical benefits of the use of different digestates as partial substitutes for mineral fertilizers.

End use challenges:

- Integrating the use of biomass for thermal and electric energy generation in other industrial units (refineries, cement plants, etc.):

  At present and as mentioned earlier, the captive nature of biogas makes its use difficult in locations that are far away from production centers. There are a number of facilities in Spain whose energy consumption levels stand out, such as for example sugar processing facilities, brick manufacturing facilities, refineries, cement plants, etc. where this biofuel could be used to a greater or lesser extent depending on the case. This would bring about advantages from an environmental perspective, as emissions to the atmosphere would be avoided when replacing conventional energy sources.

- Fuel certification:

  A minimum number of biogas composition parameters should be established in order for the latter to be used directly in gas engines. Required parameters may vary depending on its mode of transportation, (liquefied tanks or through the grid). In any case, the participation of gas engine manufacturers is key, given the existing experience in other European Union countries.

» Improving emission parameters:

Depending on the type of biogas application, the emissions resulting from the energy transformation process must adjust at all times to existing applicable legislation.

» Injection into grid:

A framework must be defined under which all biogas producers may be incorporated, thus enabling the injection of biogas into the grid which can later be used at locations far away from production centers, such as in electricity generation applications (either individually or as a hybrid with others renewable or conventional energy technologies), harnessing thermal energy (at the individual or industrial level), as fuel for the transportation sector, fuel cells, as a precursor to other products, etc. In any case, information must be gathered on the chemical composition that such biogas should have in order to be injected into the grid as well as all legal requisites that the producer must comply with before the gas distribution and supply system and the owner of natural gas transportation and/or distribution grid. Likewise, an economic remuneration framework for each injected unit must be defined, which must be similar to the regulatory framework set up at the time in the electricity sector for the production of electricity from renewable sources.

» Legislative aspects and waste treatment regulations.

Biogas generation incentives come from its direct use during the production of electrical energy. Nevertheless, biogas has other possible uses that can be of great interest, however the inexistence of applicable legislation hinders such alternative uses. Those aspects that must be developed include:

- Regulations and standardization affecting technical and physico-chemical limitations for biogas injection into the distribution grid according to the standards that are currently under development in Europe.
- Remuneration framework for the injection of biogas into the distribution or transportation grid, similar to the special regime that governs the electrical energy production from renewable sources.
- Regulations and standardization of the use of biogas in the transportation sector.
- Standardization of digestate use in agricultural applications.

IV VALUE CHAIN: Conversion of sugar and starch into bioethanol

Bioethanol production pathways from sugar and starch represent the current way in which the industry produces the bioethanol that is used as biofuel. These pathways use grains from crops.

The processes consist mainly in the production of sugar from species that have high sugar or starch contents (sugar cane, beet, cereal) and the conversion of the latter to bioethanol through fermentation by means of alcoholic fermentation processes. This a commercial technology and Spain's current bioethanol production installed capacity amounts to 600 million liters per year, the majority of which is produced from cereal whereas the remainder comes from wine alcohol.

Cereal/sugar based bioethanol production technologies are already mature since they are soundly implemented at industrial level. Nevertheless, challenges still remain in terms of making them more efficient and sustainable.

Raw materials:

- Algae.
- Agricultural waste.
- Grassy energy crops.
- Woody energy crops.

Technologies:

- Conventional fermentation:

In all cases, bioethanol production technology is based on the alcoholic fermentation of glucose of vegetal origin.

Variations are established depending on the type of raw material used, such that this glucose may be more or less accessible, requiring therefore more or less aggressive processes.

Sugar (cane or beet): sugar (glucose) is produced through the mere grinding and dissolution of raw materials.

Cereal: cereal is subject to milling, cooking and processes involving enzymatic action that break polymer starch chains existing in the grains in order to produce glucose.

$$(C_6H_{12}O_6)_n \text{ (starch)} + H_2O \xrightarrow{\text{yeast}} N\,(C_6H_{12}O_6)$$

The glucose stream that is dissolved in water is processed inside fermentation vessels using industrial yeast, which during metabolism convert glucose into ethanol and carbon dioxide according to the following reaction:

$$2C_2H_6O \text{ (ethanol)} + 2CO_2 \xrightarrow{\text{yeast}} C_6H_{12}O_6 \text{ (glucose)}$$

Lastly, the stream resulting from the fermentation consisting of solids that have not fermented (protein and fiber mostly), ethanol and water undergoes a distillation process whereby the ethanol-water mixture becomes separated until reaching an ethanol purity specification of 99.5%.

When the raw material used is cereal, the solid fraction (fundamentally protein) generates a product called DDG[4] that is used as cattle food due to its high nutrient content. If the raw material is sugar, the final solid fraction is called bagasse and is used to produce energy in biomass boilers.

4 Dried distillers' grains.

End use:

» Bioethanol:

Bioethanol is a natural substitute to gasoline, since its number of octanes is over 110. It has been widely used indirectly, having been transformed into ethyl butyl ether (ETBE) as an oxygenated additive to gasoline or directly mixed with the latter. Currently, up to 2% is directly mixed domestically during the winter period with gasoline having an octane index of 95 supplied through logistic facilities that are adapted to prepare these types of mixtures.

Technological challenges:

Given that the technology already exists at commercial stage, technological challenges focus on its optimization in order to increase sustainability and production efficiency.

» Process optimization and increasing energy efficiency:

The previously described technology has a high-energy consumption due to the necessary thermal supply required for cooking and distilling the ethanol-water mixture (15% ethanol) and drying of the final product. Natural gas is normally used in the industry to supply this required energy.

Optimizing this energy consumption and using renewable energy sources such as the biomass itself will positively impact the product's life-cycle emissions.

End use challenges:

» Sustainability certification:

Sustainability will constitute a requirement for producers in order to comply with the European Renewable Energy Directive 2009/28/CE, which is incorporated into the Spanish regulatory framework through Royal Decree 1597/2011 and whereby a series of requisites linked mainly to greenhouse gas emission reduction and the use of the soil that is associated with raw materials are set forth, so that the product may be accounted for in order to meet biofuel use targets and receive fiscal incentives. To achieve this, clear procedures and accessible tools must be developed to enable producers to certify their products as sustainable.

» Sub-product recovery:

Applications aimed at increasing the value of sub-product streams must be developed, which would translate into higher plant profitability. These sub-products are currently used as livestock food or energy.

» Increasing the percentage mixture with conventional fuels:

Although the use of bioethanol is permitted in gasoline mixtures up to 10% volume, in the majority of conventional gasoline engines, a greater effort is required to drive further product market penetration in addition to introducing the so-called flexible vehicles that can run on mixtures of up to 85% bioethanol.

V VALUE CHAIN: Conversion of lignocellulosic biomass to alcohol through biochemical processes

The biochemical conversion pathway of lignocellulosic biomass is analogous to cereal or sugar cane processes, with the exception that in this case sugar comes from polymers that are present in the lignocellulosic biomass, namely, cellulose and hemicellulose. These sugars are fermented by yeast (or other organisms) to produce bioethanol (or other alcohols) in the same way as the technology applied to cereal does.

The main difficulty of this pathway rests in that the lignocellulosic biomass matrix is much more inaccessible than that of starch, and cellulose polymer links are much more resistant than those of starch, meaning that highly innovative and very specific processes are required to free up the corresponding sugars.

It can be said then that this technology is currently at demonstration stage, as there are a number of installations where bioethanol from agricultural waste has been produced at pre-commercial scale. In Spain, Babilafuente (Salamanca province) is home to a 5 million liter production capacity bioethanol plant operated since 2009 by ABENGOA BIOENERGÍA; similarly, the PERSEO project in L'Alcudia (Valencia region) in which CIEMAT participates involves a plant that has been operating since 2010 with a daily OFMSW processing capacity of 70 tons. Other demonstration plants exist in Europe such as the Denmark's DONG ENERGY plant, which has been in operation since 2009 and has a production capacity of 5 million liters.

Raw materials:

In general, raw materials are those that contain low-cost cellulose.

- Agricultural waste.
- Forestry biomass.
- Grassy energy crops.
- OFMSW.
- Woody energy crops.

Wheat straw or corn bagasse, among others, would be included in the agricultural waste types.

Technologies:

The process basically consists in obtaining sugar from selected lignocellulosic materials. In general, biomass consists of three main molecules that are intertwined in a homogeneous matrix as follows:

- Cellulose: which are the glucose polymers.
- Hemicellulose: five-carbon sugar polymers, mainly xylose.
- Lignin: complex molecules that have a strong presence of phenol rings. Lignin is not transformed during the process.

Therefore, the technology will entail the separation of these molecules in order to obtain and ferment the sugar.

- Advanced fermentation and enzymatic hydrolysis. The process consists of the following steps:

  Pre-treatment: which is the process necessary to make the biomass matrix more accessible to subsequent enzymatic processes. These processes are usually a combination of thermal processes (steam explosion, high pressure hot water) and chemical processes (diluted sulfuric acid, ammonia, carbon dioxide, organic solvents, etc.). The aggressive nature of this pre-treatment normally triggers the hydrolysis of xylose into five-carbon sugars.

  Enzymatic hydrolysis: consisting in breaking cellulose polymers in the corresponding monomer, that is, glucose. This enzymatic process requires the action of complex and expensive enzymatic 'cocktails' to generate the monomers efficiently.

Fermentation: fermentation is the action of organisms that transform sugar to ethanol. In the case of glucose (six-carbon sugars) the organism may be the same used in the fermentation of cereal, since the sugar is identical to that from starch. In the case of five-carbon sugars, commercial organisms are incapable of processing them, which is the reason why fungi, bacteria and yeasts capable of metabolizing these sugars to produce ethanol are currently being developed.

Product separation: it is the mixture of solids (untransformed lignin and cellular material), water and ethanol that must be separated. The ethanol-water mixture is separated through distillation. Lignin must be purified so that it may be used in specific applications.

More recent developments include working with microorganisms that are capable of converting sugar to other alcohols with higher number of carbons such as butanol. This product brings certain advantages in transportation applications or when used as a chemical intermediate. The general process is analogous to that described for ethanol with the exception of the fermenting microorganism involved.

End use:

- Bioethanol.

Being the same product as the one in the previous value chain, and, given that ethanol is a pure compound, the rationale explained in value chain IV above shall apply here.

Technological challenges:

- Development of new enzymes, reduction of production costs and optimization of enzyme mixtures.

  Enzymes are today the factor of greatest importance in the costs associated with lignocellulosic bioethanol production. Therefore, work must focus on the development of microorganisms that are capable of producing these enzymes at a lower cost as well as on the development of more active enzymatic 'cocktails' that reduce the specific consumption of the former while positively impacting production costs.

- New hydrolysis and fermentation configurations:

  Improving fermentation may optimize the process, thus making the conversion to five-carbon sugars more efficient.

- Optimizing biomass pre-treatment and fractioning systems:

  The initial pre-treatment process has a great impact on the efficiency of biochemical processes downstream, as well as on the energy efficiency of the overall process. This indicates that it would be convenient to optimize the process in order to make it less aggressive so as to degrade raw materials as little as possible. Likewise, it is possible to carry out fractioning processes whereby the biomass fractions may be separated after being treated with pure xylose, cellulose and lignin streams that are processed separately. This would result in a positive impact on the quality of the lignin and the efficiency of fermentation.

End use challenges:

- Development at pre-industrial demonstration scale:

  Given that ethanol production technologies from lignocellulosic biomass have proven successful, the next step entails making the jump to pre-industrial scale and produce cellulosic bioethanol at commercial scale.

- Sustainability certification:

  The same as what has been explained for value chain IV applies in this case.

VI VALUE CHAIN: Gasification of biomass and catalytic or biochemical conversion to biofuels

The main characteristic of the gasification and synthesis pathway is the initial conversion of biomass to synthesis gas through a process known as gasification, which generates a mixture of gases including fundamentally carbon monoxide and hydrogen. These gases are converted to different products via catalytic (and sometimes biologic) processes. A vast range of products may be produced through this common pathway such as hydrogen, methanol, ethanol, higher alcohols, hydrocarbons (gasoline, diesel, kerosene), methane and dimethyl ether.

Gasification and synthesis technologies that create products through catalytic processes are used commercially in the industry to produce hydrogen, methanol, ammonia, diesel, kerosene, gasoline, etc. but using fossil resources such as coal, natural gas or very heavy crude oil grades. The main challenge that must be overcome entails being capable of generating a synthesis gas from biomass resources in the same conditions of cleanliness and purity as that which is currently obtained in the industry. Once such synthesis gas is obtained, the rest of the processes may be adapted in a more or less viable way.

It can be said that gasification technologies used in the production of biofuels are currently in the demonstration stage, as plants at this scale have been operating in the European Union. The Beta plant of CHOREN INDUSTRIES GmbH in Freiberg (Germany) has showcased the production of diesel from biomass at a 50 MW_{th} scale; similarly, methanol dimethyl ether mixtures at 15 MW_{th} scale have been produced from residual black liquor from pulp and paper plants at the CHEMREC AB plant located in Piteå (Sweden). In Spain, the National Renewable Energy Center (CENER) will carry out the largest gasification and synthesis experiment at its 2nd Generation Biofuels Center facilities, equipped with a 15 MW_{th} gasifier.

Raw materials:

Initially, gasification processes can process any carbon-bearing raw material, meaning that any type of biomass would be susceptible of constituting the raw materials required by this technology.

- Agricultural waste.
- Forest biomass.
- Grassy energy crops.
- Industrial waste.
- OFMSW.
- Woody energy crops.

Technologies:

The technology consists of two fundamental blocks: the generation of synthesis gas from biomass followed by the conversion of synthesis gas to biofuels.

- Gasification of biomass and catalytic or biochemical conversion to biofuels. The technology consists of the following three steps:

Pre-treatment: depending on the gasification technology, it may be necessary to transform the biomass into materials that can be fed to the gasifier. These pre-treatment processes may simply be mechanical (grinding), thermal (drying) or thermochemical (pyrolysis, torrefaction).

Gasification: a reducing process that takes place at very high temperatures, between 800 °C and 1,500 °C, in which biomass is transformed to synthesis gas, that is, hydrogen and carbon monoxide mixtures as well as other components such as methane and light hydrocarbons, carbon dioxide, water vapor and heavy hydrocarbons (also known as tar), sulphydric acid, ammonia, etc. whose proportions may vary based on the particular gasification technology used. This gasification technology may involve a fluid bed, fixed bed or entrained flow setup. In general, gasification technologies must avoid high nitrogen content in the product gas, meaning that air-based gasification is discarded (oxygen must be used during gasification or by indirectly transmitting the heat).

Gas cleaning: components such as tar must be removed from the synthesis gas, as they hinder gas manipulation. The main component to be eliminated includes tar, which are heavy hydrocarbons that condense when then gas is cooled below 400 °C.

Gas conditioning: once the synthesis gas is clean, it must attain the conditions necessary for the synthesis process. The main parameters that must be controlled include: adjusting the hydrogen-carbon monoxide ratio, eliminating carbon dioxide and sulfuric acid and compressing the gas, since synthesis processes generally take place at atmospheric pressure.

Synthesis: it consists in the conversion of synthesis gas to the different biofuels inside catalytic reactors. This way, methanol, ethanol and higher alcohols, hydrocarbons (through the synthesis process known as Fischer Tropsch), dimethyl ether and hydrogen are produced. In addition, technologies are currently being developed to enable biochemical synthesis, that is, microorganisms that metabolize the synthesis gas to produce ethanol.

Product refining: different product refining processes must take place further downstream, based on the synthesis process itself:

Synthesis	Final product	Refining process
Methanol	Methanol Dimethyl ether Olefin Gasoline	No Methanol dehydration Methanol to olefin Methanol to gasoline
Ethanol and alcohols	Ethanol	Multi-component distillation
Fischer Tropsch	Diesel Kerosene	Hydrotreatment and isomerization
Dimethyl ether	Dimethyl ether	No
Methane	Synthetic natural gas	No

Table 19, Refining according to synthesis processes.

End use:

» **Bioethanol**

The same as what has been explained for value chain IV applies in this case.

» **Synthetic diesel, gasoline and kerosene:**

These products' specifications are practically identical to those derived from petroleum, meaning they can be introduced into distribution grid.

» **Synthetic natural gas**:

The considerations applicable to the use of synthetic natural gas shall be the same as those corresponding to biogas, since its main component (methane) is the same.

Technological challenges:

» Development of synthesis gas purification, cleaning and conditioning systems:

Technologies for the efficient, viable and lasting removal of tar and inorganic components such as alkalines, ammonia, chloride, etc. must be developed, making use of the sensible heat of the effluent gas from the gasifier. Many technologies are being researched currently, including the cleaning of gases with organic compounds, catalytic reforming or thermal cracking. These cleaning requirements are far more stringent than those established for synthesis gas thermal or electricity applications.

» Incorporation of process intensification strategies and unit process integration aimed at improving the efficiency: biorefinery concept.

Process intensification is a technological strategy for high efficiency reaction system design and application that enables to reduce the size and costs of chemical plants. These technologies are very adequate for very fast and exothermic chemical reactions. Thus for example, advances in the development of new high efficiency catalytic reactors (micro reactors) should be sought after. In addition, the integration/combination of unit processes that also improve energy efficiency and productivity of the reaction should be considered. These include, for example, the use of catalytic membrane reactors that can improve reactive conditions via the removal of products in the middle of the reaction or through the incorporation of the biorefinery concept itself where the overall process is designed, considering the harnessing of product streams and/or residual heat from different partial processes.

» Optimizing catalyzer design and operation:
  The activities must run along two lines; on the one hand, with the objective of developing new and more efficient catalyzers for processes that are not yet at commercial stage such as ethanol synthesis; on the other hand, with the aim to develop innovative reaction systems that can optimize synthesis reactions.

End use challenges:

» Development at pre-industrial demonstration scale:
  Given that the technology has proven successful, the next step would entail jumping to pre-industrial scale in order to produce diesel, kerosene, dimethyl ether, etc. at commercial scale.

» Fuel certification:
  In order for the new fuels to be used massively and to minimize engine related risks while avoiding rejection from manufacturers they must be certified under clear usage standards.

» Sustainability certification:
  The same as what has been explained for value chain IV applies in this case.

» Fleet tests:
  Demonstrating the quality of these biofuels by testing it in captive fleets where fuel can be closely controlled, then providing enough visibility of the results obtained to generate end user confidence.

» Infrastructure development for product use:
  Fuel distribution infrastructure grids must be developed to drive market penetration and make fuel available to consumers. This has a particular impact in the case of synthetic gaseous fuels (such as synthetic natural gas or dimethyl ether), as the current infrastructure is almost exclusively designed for liquid fuels.

VII VALUE CHAIN: Biomass digestion for biomass generation

It has already been mentioned in the section corresponding to biogas production and use value chain of the thermoelectric segment (value chain III) that their possibilities of use are considerable and in many cases are not being taken advantage of in Spain. One of these options involves its use as biofuel either directly or after injection into the network.

In any case, the goal is to identify both the technological and non-technological challenges associated with biogas production and subsequent use as biofuel in the transportation sector.

Projects such as the 4-year long BIOGASMAX (2006-2010), which was co-financed by the European Commission, demonstrates the possibilities of using biogas in the transportation sector in different environments using different raw materials or its injection into the grid.

Raw materials:

- Algae.
- Agricultural waste.
- Energy crops.
- Industrial waste.
- Livestock waste.
- OFMSW.

Technologies:

- Anaerobic digestion.

Using the comments provided in the equivalent value chain of the thermoelectric segment described earlier, once the biogas has been produced it could be used in vehicles either directly or indirectly (injecting it into the grid after subjecting it to the corresponding gas cleaning processes).

End use:

- Biogas.

As remarked above, eliminating captivity would translate into an increase of this gaseous biofuel's potential.

Technological challenges:

The same as what has been explained for value chain III applies in this case.

- Optimizing digester design and operation.
- Biogas conditioning.
- Co-digestion: maximizing biogas production yield.
- Digestate recovery.

End use challenges:

The same as what has been explained for value chain III applies in this case.

- Fuel certification.
- Optimizing storage systems used for biogas transport.
- Injection into grid.
- Legislative aspects and waste treatment regulations.

VIII VALUE CHAIN: Thermal pyrolytic and catalytic conversion of lignocellulosic biomass and upgrading

Pyrolysis is the thermal decomposition of organic matter in the absence of oxygen. The organic compounds subjected to this process are decomposed into gases, condensable hydrocarbons and a carbon residue known as char. All of these products that are generated through pyrolysis can be used in different ways.

Fast pyrolysis allows producing a liquid biofuel known as bio-oil that can replace fuel oil in heat or electricity generation systems. This process, which is still in the development stage, can achieve performances of up to 70% (considering a dry biomass feed). Furthermore, reusable gas and char are produced in the process, meaning that no residual streams are generated.

The fractions of products generated through the pyrolysis of organic matter present the following characteristics:

a. Gases: these are made up of H_2, CH_4, CO, CO_2 and other organic compounds. The proportion of each compound depends on the pyrolized material and operating conditions (temperature, residence time). In total, they may amount to about 20% of the energy content of the original material.
b. Condensables: these are liquids at ambient temperature that are made up of a group of tars and/or oils that contain chemical agents such as acetic acid, acetone and methanol. They typically contain about 65-70% of the energy content of the original material.
c. Coke or char: it consists of almost pure carbon mixed with the inert material contained in the product that is pyrolized. In total, it can represent 10-15% of the energy content of the original material.

The resulting condensable product from the pyrolysis of biomass can be used as fuel since its LCV can reach 6,000-7,000 kcal/kg.

From a logistical point of view, pyrolysis is of great interest due to its capacity to convert solid biomass to a high energy density liquid, which, in addition to improving transportation economics, is easy to manipulate, as it can be pumped to subsequent processes that work under pressurized conditions (e.g. gasification + synthesis). In addition, it is possible to emulsify the char produced during the process in the bio-oil itself, which results in greater energy density. Therefore, pyrolysis is a sound candidate when considering the transport of biomass to future biorefineries that use thermochemical processes. Bio-oil can be seen as a ‘bio petroleum’ for use in biorefineries.

Raw materials:

» Algae.
» Agricultural waste.
» Forest biomass.
» Grassy energy crops.
» Industrial waste.
» Livestock waste.
» OFMSW.
» Woody energy crops.

Technologies:

» Lignocellulosic biomass pyrolysis and upgrading.

Three pyrolysis processes may exist from and operational standpoint: conventional pyrolysis, fast pyrolysis and flash pyrolysis. Operating conditions and the characteristics of the major products generated during each of these processes are detailed in the following table:

Process	Temperature (°C)	Heating velocity (°C/s)	Residence time	Major product
Conventional	500	2	Gases: 5 s Solids: hours	Char and condensates
Fast	400-800	> 2	Gases: < 2 s	At 500 °C, condensates
Instantaneous	> 600	> 200	Gases: < 0.5 s	Gases and light hydrocarbons

Table 20, Pyrolysis processes.

Fast pyrolysis offers the greatest advantages in terms of development over the three abovementioned processes, since conventional pyrolysis generates great quantities of char and gases, while flash pyrolysis is very complex from a technological standpoint. Through fast pyrolysis, biomass is decomposed into vapors and some coke. After a solid separation phase (char) and another phase involving cooling and condensation, a dark brown liquid high in calorific power is obtained. The main objective of this process is to produce the greatest amount of bio-oil possible. To this end, it is critical that the biomass be at an optimal temperature that minimizes coke generation while maximizing bio-oil production.

End use:

» Diesel, kerosene, synthetic gasoline.
  Generation of biofuels for transportation, which must be verified in thermochemical biorefineries. In addition to producing chemical products through extraction. Biomass conditioning stage prior to synthetic fuel generation stages.
  Heat and electricity generation from complex residues (high metal and ash content) through treatment at high temperatures over 600 °C as a solution to combustion related emissions.

Technological challenges:

» New catalyzers to increase process performance.
  Evaluate the possibility of using catalyzers to increase process efficiency, improve the quality of the resulting bio-oil, reducing oxygenated compounds, etc.

» Improving pyrolysis oil stability.
  Assess the possibilities of improving pyrolysis oil stability for storage and subsequent use in various applications such as engines, turbines, etc.

» Upgrading for unit processing in refinery units.
  Assess the necessary stages to include a pyrolysis bio-oil line in an existing refinery as well as in future biorefineries.

» Pyrolysis of waste with limited combustion capacity; other possibilities pertaining the recovery of this waste.
  Researching the possibilities surrounding complex waste recovery or those having a high metal and ash content that are susceptible of being sintered at approximately 500-600 °C.
  New MSW recovery possibilities.

End use challenges:

» Oil hydrogenation pilot and demonstration projects.
  Pilot projects of a technical and economical viability that matches the escalation of this type of installations under continuous/pre-industrial operating modes.

» Fuel certification.
  Characterization and upgrading necessary for fuel certification in a similar way to other types of standardized fuels.

» Integration with other industrial units (e.g. refineries).

IX VALUE CHAIN: Catalytic conversion of sugars to fuel and chemicals

Catalytic sugar conversion processes come up as a variant to fermentation processes used to produce bioethanol, although instead of involving 'simple' fermentation of sugars to produce bioethanol the latter can be transformed into other products such as more or less long hydrocarbon chains that could act as a replacement to gasoline, diesel or jet fuel, or, other chemical products such as butanol, furanic or farnesene carboxylic acids (adipic, succinic, malic) that may be used as fuel in vehicles or as platforms for the production of other more complex fuels. The technology therefore consists of a first sugar generation phase that is analogous to the one that exists in the production of bioethanol from cereal, sugar cane or lignocellulose, followed by a second phase where sugars are converted to other chemical products through catalytic or biochemical processes.

The main technological challenges to overcome in order to take these technologies to the market deal mainly with the production and purification of sugar streams to a high enough quality so that they may be processed, and the development of catalytic and biochemical technologies capable of converting these sugars into products. Lastly, secondary transformation processes must also be developed and adapted to convert primary products into other products of greater interest.

This set of alternatives comprises a high number of technologies that may give way to many possibilities, the majority of which are currently at a very incipient stage of development including laboratory and pilot tests. Nevertheless, the possibility of using existing sugar production and purification technology that is used in the case of bioethanol implies that development could be speeded up using the knowledge built up around these two other options.

Raw Materials:

In general, any type of raw material composed of sugar (sugar cane, starch, cellulose, xylose) may be used. The types of materials would include:

- Agricultural waste.
- Grassy energy crops.
- Woody energy crops.

Technologies:

- Catalytic transformation of sugars:
  Transformation of sugars into advanced products:
  - **Pre-treatment and hydrolysis:** the steps required to produce sugar are the same as those of bioethanol production chains from cereal and lignocellulose.
  - **Purification:** in many cases and due to the subsequent conversion technologies, very high purity levels in the sugar stream must be reached, meaning sugar streams must be treated in order to be purified.
  - **Biochemical conversion of sugars:** fermentation processes are carried out by the action of microorganisms, through which sugars are converted into intermediate products such as hydrocarbon mixtures or other oxygenated products.
  - **Catalytic conversion of sugars:** sugars are converted to other molecules in liquid phase catalytic reactors.
  - **Product refining:** products generated by the above processes in general do not have a direct application (although in some cases this may be the case) which means they have to be transformed into other compounds. These processes are catalytic in general and are normally used in the petrochemical industry, examples of which include hydrogenation, polymerization, dehydration, etc. These processes can also be applied to alcohols that are formed in ethanol value chains.

End use:

- New biofuels to be certified:
    - Gasoline.
    - Jet fuel.
    - Diesel.

- In addition to their use as fuel, compounds thus generated can replace other products obtained conventionally from crude oil derivatives such as:
    - Surfactants.
    - Materials (plastics).
    - Solvents.
    - Lubricants.

Technological challenges:

- Research in catalyzers and sugar conversion processes:

  Development of catalyzers that can convert sugars into identified products and execute the associated process leading to catalytic reaction. These catalyzers must be heterogeneous (to avoid complex separation processes), be constructed with cheap materials and be sufficiently robust to withstand the presence of biomass components.
- Research in the use of microorganisms for advanced conversion of sugars.

  Microorganisms that are specifically designed to carry out desired sugar conversions to selected products must be developed by applying molecular biology techniques.
- Development of associated component extraction processes.

  The products generated by the abovementioned processes do not directly apply to the majority of cases, meaning they have to be separated and transformed into other final compounds. The processes used are standard in the petrochemical industry but must be adapted to any new application.
- Stream purification processes required for conversion.

  Sugar streams coming from biomass carry many impurities, which means that in many cases those components that inhibit catalyzers or microorganisms downstream must be removed; moreover, even sugars may have to be extracted from the stream in order to reach high purity levels.

End use challenges:

- Fuel certification:

  The fuels produced in this value chain consist in many cases of new molecules whose use is not currently certified. Therefore, all necessary steps must be taken to certify the corresponding fuels (gasoline, diesel and jet fuel).
- Certification of other non-energy product applications.

  For all other applications that have been highlighted, all necessary steps must likewise be taken to certify the new products so they can replace those products that are currently used in their corresponding applications.

X VALUE CHAIN: Oil platforms (conventional conversion + hydrotreatment + pyrolysis + standalone or combined treatment with fossil fuels in other refinery units)

LThe main characteristic of this value chain is that it contemplates the existence of various integrated process units, which allows processes to become configured in several ways so they can better adapt to the great variety of raw materials they are able to accept, all the while producing also a great variety of products that are similar to those obtained in oil refineries.

The raw materials that can be processed include those of 100% biologic origin, whether they include vegetal oil, bioliquids (e.g. latex) or feed (lignocellulosic material, algae) that are transformed into oil and may be processed together with the aid of fossil fuel.

The installations considered could integrate processes that are exclusive to bioenergy with existing refinery units that currently process fossil fuels. Among the specific biomass units, pyrolysis, transesterification and dedicated hydrotreatment can be considered. Pyrolysis technologies are at demonstration stage and their greatest technological barrier is the quality of the oil that is obtained for subsequent processing. It is expected that such barrier affecting this value chain be overcome by mixing pyrolysis oil with mineral crude. The transesterification process is a commercial process and as such is subject to improvements. Hydrotreatment of vegetal oil is a process that is susceptible of undergoing great developments, since although a commercial process (developed by NESTE OIL) in addition to a demonstrated process that has possibilities to obtain licenses (developed by UOP) exist, the great variety of possible raw materials and products that can be obtained leaves the door open to the process design framework.

All conversion units in a refinery (among which, those that use hydrogen treatment stand out) may be included among existing crude oil processing units. The challenge resides in the integration with the rest of the units and in the possible processing of streams of different nature that have metal, chlorine and nitrogen content that differ considerably from conventional crude oil.

The products obtained include biodiesel, biokerosene, hydrobiodiesel, biogas (excluding methane: propane, butane) and other non-conventional ones that would require specific certification processes.

Raw materials:

Initially, any carbon-bearing raw material can be processed, meaning that any type of biomass would be susceptible of constituting the raw materials required by these technologies.

- Agricultural waste.
- Algae.
- Forest biomass.
- Grassy energy crops.
- Woody energy crops.

The types of raw materials that fit in this value chain are those that:

- Produce vegetal oil.
- Produce a liquid like latex from laticifer crops or algae oil whose triglyceride fraction is not major.
- Produce pyrolysis oil that will be fed to refinery units. Such feeding material will consist of bioliquids, meaning that, at first instance, the raw material that is considered in this value chain will be the solid biomass that is susceptible of producing them.

Technologies:

- Conventional conversion + hydrotreatment + pyrolysis + standalone or combined treatment with fossil fuels in other refinery units.

The technologies covered in this value chain correspond to existing successive oil refinery units that are combined with specific biologic raw material processes such as pyrolysis, transesterification and dedicated hydrotreatment. They offer different possibilities in terms of process combinations where one may not involve the other, although situations may exist whereby some processes may involve several units. Pyrolysis does not represent a conventional oil refinery unit, but is included only as a process used for conditioning raw material as described earlier in the 'raw material' section.

End use:

- Biodiesel (esters).
- Hydrotreated biofuels: biokerosene, hydrobiodiesel, biogas (propane, butane).
- New biofuels to be certified.

The epigraph 'New fuels to be certified' includes biofuels of a nature that differs from the so-called conventional fuels (FAME, ethanol or hydrotreated vegetal oil). This may include for example biofuels from the processing of latex from laticifer plants or liquid biofuel from algae oil whose triglyceride fraction is not major.

Technological challenges:

- Optimizing catalytic systems to improve the technical viability of the process.

  This is considered necessary since the system must admit different types of feeding materials whose key content may include metals, chlorine, etc. Furthermore, these different types of feed may require hydrocracking or hydroisomerization (by the catalyzer) that exclusively fossil materials would otherwise not require.
- Integrating the process with conventional fuel production processes (refineries), in order to seek pre-industrial demonstration scale.

  The challenge resides in integrating bioliquid processing at industrial scale, taking on the necessary modifications without generating operational pitfalls in the combined operation of the units.
- Developing transformation processes to obtain biofuels:

  These involve process related aspects in addition to catalytic ones, given the nature of processed bioliquids and their need for cracking/isomerization in order to design the desired product, as explained earlier.

End use challenges:

- Fuel certification:

  In order for the new fuels to be used massively and to minimize engine related risks while avoiding rejection from manufacturers they must be certified under clear usage standards.

INTERMEDIATE BIOENERGY CARRIERS

VALUE CHAIN	TECHNOLOGIES IDENTIFIED	TECHNOLOGICAL CHALLENGES	END USE
Study on the possibilities of using torrefaction, pyrolysis and densification as pre-treatment.	Densification.	i. Improving the design to attain cost reduction and increase in quality.	i. Showcasing the product in its different final uses and logistic chains.
	Pyrolysis.	ii. Demonstrating the technology at pilot scale (in the case of torrefaction and pyrolysis technologies).	ii. Pyrolysis char recovery.
	Grain size reduction.	iii. Widening the range of raw materials that can be used and reaching the capacity to design 'customized' biofuels.	
	Drying.	iv. Development of biomass solar drying schemes.	
	Torrefaction.		

Table 11, Value chain of bioenergy carrier segments.

The objective of this line of action is to reduce biofuel production and transportation costs and improving its quality. The following main lines of technological development can be cited in this section:

a. Production of pulverized biomass for co-combustion applications.
b. Development of biomass grinding and drying equipment at a lower cost than existing ones. In the case of drying equipment, special emphasis must be made on research surrounding solar based drying of biomass.
c. Development of pellet production for domestic use from medium ash content grassy and woody biomass.
d. Development of low cost densification systems for industrial use products.
e. Conversion to bio-oil through pyrolysis, thus obtaining a liquid energy carrier that is efficient for both transportation and feeding the equipment.

RAW MATERIALS

The fundamental objective of this BIOPLAT 2015 Implementation Plan roadmap consists in the implementation of the bioenergy value chains that are considered to be most important at present. A sustainable and reasonable supply of raw materials will constitute a critical factor for success when considering the long-term perspective of large-scale biomass technologies. This relates to the on-going efforts to improve productivity in these sectors, develop reliable and sustainable supply chains that boost the potential of raw materials and certification systems and to avoid distortion of agricultural and forestry markets. These challenges, which are not exclusive to the energy use of biomass, must be faced jointly by sharing the efforts with all other agents involved.

Adequate eligibility and selection criteria must be developed in order to ensure that developed projects are designed taking into account a global sustainability perspective with respect to the supply of raw materials.

LIST OF IDENTIFIED RAW MATERIALS	TECHNOLOGICAL CHALLENGES	END USE CHALLENGES	CROSS-CUTTING CHALLENGE
Algae.	· Downstream development (harvesting and processing). · IIncreasing scale of projects. · Development of harvesting technologies (improvement of materials and inflow optimization). · · Selection of species.	· Regulatory development.	Unification of sustainability criteria and indicators.
Forestry biomass.	· Technological development to reach biomass extraction/cost profitability.	· Development of methodologies for the study of production and market potential coupled with sustainability criteria.	
Grassy energy crops.	· Inflow optimization: efficient use of resources, equipment development, improving the development of logistic processes, chemical and mechanical control treatment optimization.		
Woody energy crops.	· Selection and improvement of vegetal material.		
OFMSW.	· Pre-treatment improvements.	· OFMSW regularization.	
Agricultural waste. Livestock waste. Industrial waste.	· Increase the number of materials that are susceptible of being treated through anaerobic digestion.	· Eliminate restrictions between food and energy use.	

Table 12, List of raw materials and associated challenges.

As observed from the table, there is cross-cutting challenge that corresponds to the unification of sustainability criteria and indicators.

The following research needs have been identified based on the type of raw material used:

Grassy and woody energy crops

Technological challenges:

- Inflow optimization: efficient use of resources, equipment development, improving the development of logistic processes, chemical and mechanical control treatment optimization.

In order to achieve a greater economic and energy balance (and therefore in terms of GHG emissions) in the production of biomass from energy crops, agricultural practices associated with the production of these crops must be further developed and improved.

In contrast to traditional crops, energy crops are in the first stages of development, that is, selection of varieties, genetic improvements, design of specific equipment, establishing agricultural climatic requirements as well as defining optimal agronomical conditions and crop management practices.

Aspects such as those laid out next should be the object of a continuous research and improvement process:

- Soil and climatic conditions of energy crops, so as to understand clearly and unequivocally which are the most adequate crops according to the agricultural and climatic conditions of a given territory, in addition to expected production.
- Hydraulic and fertilization requirements of crops in order to understand optimal agricultural inflow levels specific to each type of crop.
- Study and optimization of products and processes related to plague and crop disease control.
- Development of specific equipment and machinery for the production of energy crops, especially that which relates to harvesting and sowing or planting processes.
- Development and optimization of biomass processing logistic, storage and transportation processes.
- Studying new possible improved vegetal species that have energy crop potential.

Therefore, continuous development and improvement of agricultural practices associated with the production of energy crops are deemed necessary, in order for the agricultural sector – a key sector in Southern European countries – to attain a greater level of understanding, both theoretical and practical, of the development of biomass production and associated renewable energy targets stemming therefrom.

- Selection and improvement of vegetal material:

  Selection and improvement in relation to production, taking into account both adaptation to site conditions and efficient use of resources.

End use challenges:

- Development of methodologies to assess production and market potential under sustainability criteria.

  Technological development aimed at reaching biomass extraction/cost profitability. Estimating potentially extractable biomass without generating productivity losses in forest systems:

  Both the Directive 2009/28/CE on the promotion of renewable energy and the report from the European Commission on sustainability requirements for the use of solid and gaseous biofuels as an energy source for the electricity, thermal and transportation sectors, establish a series of criteria relative to the origin of biomass which must be satisfied in order to guarantee the sustainability of the sector. Special mention must be made regarding cultivated biomass (energy crops) and the lands where they are produced.

  Both documents as well as the aforementioned Royal Decree 1597/2011 promote the production of biofuels in degraded and/or highly contaminated lands, as well as in restored degraded lands or unexploited lands for agriculture before January 2008, by adding a premium of 29 g CO_2eq/MJ to be accounted for in terms of GHG when producing biofuels. Similarly, biofuels produced from raw material coming from primary forests and other forest areas ['*...forests and other forest areas that include native species, when no visible signs of human activity exist and ecological processes are not significantly disturbed...*'], zones designated as nature preserves or for the protection of species or rare or threatened ecosystems as well as prairies and pasture lands rich in biodiversity or lands having high carbon reserves (with certain exceptions as set forth in articles 17.3-17.5 of said Directive) are not considered as sustainable.

  The Commission shall be the one ['*...capable of deciding that lands that are included in a national or regional program for the reconversion of severely degraded or highly contaminated lands correspond to the criteria...*'] that have been summarized earlier. Even so, the Commission has not yet established the specific values or criteria that a piece of land must satisfy in order to be classified under one of the land types mentioned above.

  In addition, studies on the biomass production potential conducted until now have left out or have not focused on assessing these types of lands that are in the Commission's sight for the production of biofuels. Consequently, the type of response that energy crops and specifically their productivity may have as result of such crops being harvested on degraded and/or contaminated lands also remains unknown.

  As a result of all the above, it is considered necessary to take these issues into account in every strategic research agenda and in the preparation of research programs and plans, independently of the sector or value chain (thermoelectric or transportation) in question, since raw materials constitute a cross-cutting segment with respect to the end use of the energy that is harnessed from the biomass..

Forest biomass

As a biofuel, forest biomass constitutes an intermediate quality biomass among the grassy biomass category, with a high ash and alkaline compound content in addition to wood industry waste, which is increasingly being used in thermal applications both in industrial, household and tertiary sectors and in electricity generation. High collection and logistic costs and the existence of alternative markets are the main barriers to the use of this type of biomass in Spain.

Technological challenges:

- Technological development to reach biomass extraction/cost profitability.

End use challenges:

- Development of methodologies for the study of production and market potential under sustainability criteria.

The grassy and woody energy crops and forest biomass epigraph includes both the species that may be considered conventional and new species that are not deemed to be used as energy crops until now. Identifying these last ones adds to the list of defined technological challenges that bring added complexity if insufficient knowledge of these species exists.

Agricultural, livestock and industrial waste

Agricultural waste, mainly that of a grassy nature (e.g. cereal straw) are seldom used for energy purposes since the pitfalls in this case are associated with collection and logistic aspects, including also the existence of non-energy alternative markets and a high degree of annual production variability, which are circumstances that affect its viability as fuel.

Forestry and agricultural industry waste represent the most widely used type of solid biomass at present due to the advantages that result from centralized production and low costs as well as, in many cases, their high quality as a fuel.

Technological challenges:

- Increasing the number of materials that are susceptible of being treated through anaerobic digestion.

End use challenges:

- Eliminate restrictions between food and energy use.

OFMSW

The definition of biomass as captured in Directive 2009/28/CE includes the biodegradable fraction of industrial and municipal waste. These constitute a renewable source that at present is being only partially harnessed. Despite that according to Royal Decree 661/2007, which regulates the production of electrical energy under the special regime, *biomass shall include the biodegradable fraction of products, sub products and waste from agricultural activities (including substances of vegetal and animal origin), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste,* OFMSW is not included in the group of renewable energy types of said Royal Decree. In addition, the waste legislation establishes the obligation to reduce in the medium term the amount of OFMSW destined to landfills, therefore making treatment and recovery essential. OFMSW represents a highly abundant and well-localized resource that offers great renewable energy generation potential that is currently being underused, while creating environmental problems. Currently, part of this biomass is treated in biomethanization units, a process that generates biogas that may be recovered (see value chains III and VII). Nevertheless, OFMSW is in and of itself a fuel type that can be directly recovered in thermal processes, as in the case of MSW energy recovery units. Such units use the rejected fraction resulting from MSW treatment processes as fuel, whose biomass content must be determined.

Technological challenges:

- Pre-treatment improvements
- Determining the biomass content of the fuel.

End use challenges:

- Legislating on and standardization of OFMSW.

Algae

This promising sector brings a series of yet potential advantages (high photosynthetic efficiency, possibility to harvest algae both in seawater and with residual effluents, harnessing of CO_2 from industrial processes, etc.) in contrast to conventional biomass production technologies and crops; above all, it offers the possibility to achieve proposed targets with a positive energy balance. For more details on algae biomass it is recommended to consult the document titled 'Energy from algae: present and future' published by BIOPLAT in 2010, which captures in greater detail the challenges herein described.

Technological challenges:

- Downstream development (harvesting and processing).

  Harvesting is a fundamental aspect surrounding the problematic of algae production as biomass. In the case of microalgae (the harvesting of organisms measuring between 2 and 200 µm and which in addition are normally harvested in low harvesting densities) equipment and energy are very costly, especially if the harvesting technology is based on centrifugation as it is at present. Raceway densities are lower than in photobioreactors, pushing harvesting costs even higher.

- Incrementing the scale of projects.

  As research progresses, it would be necessary to count on pilot facilities that do not necessarily need to be excessively large and where development work may be verified and demonstrated so that the data obtained allow the implementation of algae production for large scale energy purposes. As far as possible, these pilot facilities should have readily access to CO_2, seawater and/or wastewater emission points. Research must allow the development of industrial modules and scalable harvest systems that allow sustainable large-scale production.

- Development of harvesting technologies (improvement of materials and inflow optimization).

  Decreasing production costs and maximizing profit must be accompanied by an increase in the efficiency of biomass production. To this end, harvesting costs must be reduced, such as for example fertilizer and CO_2 costs, and water consumption must be minimized.

  The supply of free CO_2 at minimum cost in addition to low energy consumption is essential to ensure the energetic and economic viability of the process.

  In addition, the product's added value should be increased so as to not only obtain biofuels but also other products of interest from residual biomass, that is, by developing the concept of biorefinery.

  With respect to the improvement of materials, in the case of photobioreactors low cost recyclable plastic materials that are transparent to solar radiation, resistant, anti-adherent (antifouling), and rigid and can filter ultraviolet radiation should be developed.

- Selection of species.

  Algae make up a group of highly diverse photosynthetic organisms that have colonized a wide variety of aquatic and land ecosystems thanks to their high plasticity and metabolic diversity. Such high diversity must be further explored, as still 90% of the approximately 100,000 different species of algae that are estimated to exist remain yet to be assessed. Research challenges include obtaining microalgae species whose optimal balance between growth and lipid accumulation can be achieved, so as to optimize the process.

End use challenges:

- Regulatory development to guarantee the development of this technology.

  An adequate supporting and regulatory framework will always be key when backing the development of new technologies that are in development stages, such as the case of algae harvesting for biomass production.

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