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Can the environmental benefits of biomass support agriculture?—The case of cereals for electricity and bioethanol production in Northern Spain

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Abstract

Recent policy documents, such as the EC Communication on an Energy Policy for Europe (January 2007) make emphasis on the opportunities that energy applications can offer certain agricultural commodities, especially in the framework of a progressive dismantling of the Common Agricultural Policy. This paper analyses whether this can be true for wheat and barley farmers, using the real example of a straw-based power plant in Northern Spain and a theoretical factory for bioethanol production fed with cereal grain. The outcomes of such an exercise, in which their relative environmental benefits vis-à-vis fossil fuel alternatives are worked out with the aid of a simplified life-cycle approach, show that the characteristics of the electricity and biomass markets, the baseline scenario and the fuel prices are crucial for the future of the sector.

Keywords: Environmental externalities; Biomass; Bioethanol

1. Introduction

Agricultural production in Spain is facing uncertain times. High production costs, low yields and competition from other countries challenge its future. In the absence of the direct and indirect protection provided by the Common Agricultural Policy (CAP) of the European Union, few farms would be profitable.

Yet, at the same time, increasing environmental and energy security concerns are making renewable energies more attractive. The European Union recently endorsed[1] a target of achieving 20% of energy consumption in the EU coming from renewables by the year 2020. This includes a 10% target for biofuels, which opens up enormous opportunities for certain agricultural commodities that can be used for energy purposes. A key issue now is how to combine the environmental and energy security advantages of renewable energy without significantly distorting markets and at a minimal cost to society. An instrument that meets these objectives, which also helps to simplify agricultural subsidies that exist in the EU would be ideal.

The aim of this paper is to analyse the following situation: what would be the effect upon the profitability of certain EU cereal farms if the internalisation of "green" electricity and biofuels' environmental benefits took place? Would it be enough to ensure the viabilitiy of our cereal farms, so that they could compete without the support of the CAP? In order to answer these questions, the paper is structured as follows. Section 2 presents a brief outline of the possible impacts of CAP dismantling on cereal farms located in Northern Spain. Section 3 explains the economic value of environmental impacts due to electricity generation. First, the results of a simplified life-cycle analysis (LCA) recently carried out by one of the authors for the Spanish electricity generation system are summarised. Then, we examine the environmental impacts of biomass electricity production, applying the same methodology and using data from a real plant situated in the Northern region of Navarre that uses straw as fuel. The choice of an operational plant allowed us to examine the importance of

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local factors on the value of its environmental impact and also the spillover effects of this activity on other economic sectors. Section 4 looks at the impact upon farmers' income of different possibilities of sharing with them the financial incentives of renewable electricity. Section 5 introduces the environmental benefits of bioethanol distillation from cereal grain, this time through a discussion of different hypothetical situations. Section 6 finally concludes.

2. Potential impact of CAP dismantling on selected cereal Spanish exploitations

Spain is a net importer of cereals, despite the fact that almost half of its agricultural land is dedicated to herbaceous crops—6.4 million hectares, most of which are wheat and barley (Ministerio de Agricultura, 2007). Cereal productivity is low in comparison with that of the EU (except for maize), even when the new Member States are taken into account. However, large differences exist and Northern regions such as Navarre and La Rioja perform better. This is illustrated in Table 1.

Table 1
Yield comparison for the main cereals cultivated in Spain, years 2004 and 2005 (kg/ha)

	Common wheat 04	Common wheat 05	Barley 04	Barley 05	Maize 04	Maize 05
Navarre	3847[a]	4529[a]	4092	3955	7730	8454
La Rioja	4983[a]	4247[a]	4119	3060	8659	8514
Spain	3580	2210	3350	1420	10070	9680
EU-15	7200	6640	5020	4250	9200	8940
EU-25	6500	5990	4750	4050	8440	8400

Source: Ministerio de Agricultura (2007), European Commission (2007b).
[a]Refers to all wheat, but most of the wheat cultivated in Spain is common wheat.

An eventual phasing out of the CAP and, in general terms, the reduction of the support that EU farmers may receive in the future, opens the question of whether Spanish farmers would be able to survive without this protection, and what alternatives do they have.

The *costs* of cereal farms have been reviewed by a number of studies, either at national level or by regional authorities. According to these sources,[2] average production costs of Northern farmers are 12.02–14.42 €cent/kg for wheat, and 13.22–15.03 €cent/kg for barley, divergences depending on the source used and on technical issues (sample selection, farm size, specialisation, mechanisation, etc.), as well as the concrete circumstances of the year analysed, such as the existence or not of a drought. Indirect costs are the most important ones, while direct costs account for at least another 20%.[3] Hired work is almost non-existent and reflects the nature of a typical Spanish family farm; variable costs specific to grain production differ between locations, but can be situated in a range of 4.50 and 6.10 €cent/kg approximately.

In turn, the estimated *revenue* derived from agriculture in the absence of direct and indirect support can be proxied by the "producer support estimate (PSE)" worked out by the OECD.[4] In the EU in 2003 (see Organisation for Economic Cooperation and Development, OECD, 2005) the PSE was 48% for wheat and barley, which means that the earnings obtained by EU farmers for the sale of cereals are more or less twice what they would get in the absence of the CAP. This figure helps work out the feasibility of a grain farm in Northern Spain, were public support policies to disappear, and without any other source of revenue. Outcomes show that the "average" wheat and barley exploitation would not be competitive, as production costs are almost twice as high as earnings. Surely, this proxy is rough, because the standard deviation of costs is not known, but keeps its validity for the purposes of this paper and supports the idea that many cereal farms in Northern Spain would disappear.

An alternative method to find out the feasibility of cereal exploitations in Spain comes from the use of *elasticity indicators*, as calculated by a number of authors (see, for instance: Garrido et al., 2002; European Commission, 2004; Antón, 2003). Although demand and supply elasticities need to be analysed with extra care, due to the non-marginal nature of the changes involved, and to its validity on a limited timeframe only, they show that, in the short term, the immediate impact of the CAP disappearance would be not that high—supply elasticities having a value in the 0.40 and 0.60 range-but determinant on a longer period. This range of variation is based on estimates for cereal crops in Northern Castille, and on the official elasticity figures calculated by both the European Commission and the OECD in their reports for Spain.

No matter what methodology is used, the conclusion remains clear: the absence of the support provided by the CAP would make it extremely difficult for many cereal farms to survive. Even considering the likely increase of world market prices due to the induced diminished supply (of around 14% approximately in the long term, according to Ritson and Harvey, 1997) the sector would shrink notably if no alternative source of income is found.

[2](Comunidad Foral de Navarra, 2000, 2001, 2002a, b; Gobierno de la Rioja, 1999; Lafarga, 2004; Ministerio de Agricultura, 2002a, b; Zúñiga, 2004).

[3]Direct costs include seeds, fertilizer, labour and machinery. Indirect costs comprise generic expenditure such as electricity, water, gas, some types of labour—administrative, for instance—depreciation and taxes.

[4]The Producer Support Estimate (PSE) indicates the monetary value of the annual gross transference received by a farmer, independently of its nature, objectives and impact. The PSE can be expressed in monetary value, or as a percentage of the gross annual income gained by the farmer. If the second option is used, as in this article, it implies that in 2003, 48% of the annual income received by an EU wheat and barley farmer came from subsidies and support measures others than market prices. Such figures are not calculated at national level.

3. Methodological approach to the economic value of environmental externalities due to electricity generation in Spain

On the other hand, the recognition that energy production and consumption can cause severe environmental damage has entailed a growing social concern of which the recently endorsed CO_2 emission reduction and renewable energy targets are only two examples. As energy can be obtained from a variety of sources, the quantification of their respective environmental impacts becomes of crucial significance and explains the abundant literature that has appeared from the mid 1980s onwards on the topic. The most well-known in Europe is the ExternE project (European Commission 1995a, b, 2001, currently being updated again) which identified, compared and valued the environmental costs and benefits associated to different electricity production processes in several countries, including Spain.

Besides, we were able to complete, during 2004, a comprehensive study for the Spanish Energy Agency IDAE, called ''Economic Valuation of the Environmental Impacts of Electricity Generation in Spain: a comparative analysis'' (see Azqueta et al., 2004) in which an adapted LCA was used. The method applied does not substantially differ from that of ExternE (bottom-up approach that quantifies and values the stages relevant for each energy technology from ''cradle to grave'') but simplified the physical-chemical calculations which translate emitted quantities of air pollutants into effective doses absorbed by the recipient environment through the use of a ''world uniform model'' (see Spadaro and Rabl, 1999), adapting transformation and disappearance velocities of pollutants to the Spanish conditions.

As one can expect, these and other studies diverge in methodological aspects and data treatment, but share some common features, like the preference for bottom-up approaches or the classification of environmental damage into four broad categories: impacts on human health; impacts on agricultural crops and, more widely, on the biological chain; impacts on buildings and materials; and impacts on climate change. It is important to note here that these studies go beyond the usual calculation of GHG emissions and their contribution to climate change. Instead, they look at a much more comprehensive range of effects. The next section summarises such findings for the Spanish electricity sector, and constitutes the basis for the comparison that is made afterwards with the concrete case of a straw power plant in Northern Spain.

3.1. *Environmental impacts linked to electricity production using the Spanish electricity mix*

The objective of this section is to present monetary values for the environmental impacts associated with eight different energy generation technologies in Spain: lignite, oil, anthracite and soft coal, natural gas combined cycle, wind, solar photovoltaic, hydropower and biomass (from forest residues),[5] summarising the main results of a previous work (Azqueta et al., 2004).

Within the theoretical framework of an LCA, the first requirement is a soundly built inventory of all energy and material flows for each fuel cycle. *Sima Pro 5.1*[6] provided this *inventory*, linked to each stage of every fuel cycle: from the mining of mineral resources and the construction of plant facilities, to the final provision of electricity.[7] There were, nevertheless, some shortcomings:

- Impacts related to the dismantling of plants were not included, something that may affect, with different intensity, distinct fuel cycles.
- The inventory is heavily biased towards atmospheric emissions, with little attention being paid to impacts on other recipient environments, like water or landscape.

The next step in the analysis is to use this inventory as the main input for a *dispersion model* for each pollutant, so as to obtain the required *exposure factors* that would gravitate upon the affected units.

There are several possibilities open in this regard. At the European level, the most widely used dispersion model is *EcoSense 3.0*[8] (Krewitt et al., 1995), actually a software package compatible with *ExternE*, which allows for the assessment of environmental impacts and economic costs

[5]Nuclear energy, although covered in other similar studies, is not included in this exercise. First, the emission inventory from which most data were obtained does not include dismantling and decommissioning of plants, something actually very significant in the nuclear cycle. Second, there is a severe bias in public opinion when facing major accidents and catastrophic events that, even if recorded in the standard literature, will not show up in the conventional exposure–response functions.

[6]SimaPro® 5.1 software (first released in 1990 by *PRé*—Product Ecology—*Consultants*, from the Netherlands) has been designed to collect, analyse and monitor the environmental performance of products and services. It allows for a relatively simple modelling and analysis of complex life cycles in a systematic and transparent way. A new version (6.0) was released after this exercise was performed. It includes new features, among which a new treatment of data uncertainties in the inventory of burdens, through Monte Carlo techniques. SimaPro includes data from different inventories. For the purposes of this work, most data were obtained from the ETH-ESU 96 libraries, produced by the Zurich *Eidgenössische Technische Hochschule* (ETH).

[7]As one of our referees mentioned, this inventory is quite old, and should be updated to take into account not only technical advances but also changes in the legal framework. Yet, when comparing the emission loads of the inventory with those reported by the Spanish Energy Agency in 2002, the differences were not substantial.

[8]The *EcoSense* system is, above all, a flexible tool to integrate different scientific findings. It was designed within the *ExternE* Program (European Commission, 1998b). All its calculation modules (except for the ISC model) are designed in a way that they are a more a *model-interpreter* rather than a *model per se*. Model specifications such as exposure–response functions or monetary values are stored in the database and can be modified by the user. This concept allows an easy modification of model parameters, contributing again to the transparency of the analysis (as in SimaPro): the user can systematically trace back what the system is actually doing.

of any power facility located in Europe. *EcoSense* is the result of combining two main components:

- First, a database that includes all possible systems potentially affected together with their special characteristics: *EUROGRID*.
- Second, two transportation models for atmospheric pollution. On the one hand, and for locally dispersed pollutants (within a 10–50 km radius), a *Gaussian plume* model (ISC: *Industrial Source Complex Model*) developed at the *Environmental Protection Agency*, EPA, of the United States (Wackter and Foster, 1987; Brode and Wang, 1992). In this case, and given the short distance considered, there is no room for chemical transformation of *primary pollutants*. On the other hand, and for longer distances, the *Windrose Trajectory Model*. This model, based on the work of Hartwell and their *Path Models* (Derwent and Dollard, 1988), not only includes information about likely climatic conditions (based on past distribution functions), but also the chemical transformation of primary pollutants (i.e. emitted by a specific source) into secondary ones (through complex reactions).

The use of these models requires, of course, a precise definition of the plant under review, and of its principal features (fuel used, location, stack height, level of activity, etc.) but, once this has been achieved, it provides the analyst with a complete identification of the different pollutant loads that will appear in all EUROGRID cells.

However, and taking into account that the objective of this valuation exercise was to compute the cost associated with the environmental impacts of any fuel plant, clearly defined and identified in its major characteristics, but located somewhere in Spain, not in any specific site, EUROGRID had to be replaced by some other model. This is, precisely, the role played by the *uniform world model* (UWM). The UWM is a simple, approximate and robust solution to the impact assessment problem, when one or more parameters are assumed to be constant or uniform throughout the impact domain: see, e.g., Curtiss and Rabl (1996); Spadaro (1999) and Spadaro and Rabl (1999).

Furthermore, taking into account the specificity of the Spanish territory, located in a corner of Europe, surrounded largely by sea, with a lower population density than the EU average and a very different quality and morphology of its soils, the model needed to be calibrated to be able to take care of these particularities. The crucial variable in calibrating the UWM is the *depletion velocity* to be applied to both, primary and secondary pollutants. To do so, a theoretically sound alternative was to contrast the results regarding depletion velocity of the previous models and the *EcoSense* database, with the same information provided by a representative set of Spanish facilities. This was done by applying the *EcoSense* software to obtain the dispersion models for seven national facilities included in the Spanish report of *ExternE* (As Pontes, Compostilla, Foix, Litoral, Pasajes, Puertollano and Teruel). Finally, to calculate the values for the corresponding depletion velocities, it was assumed that their logarithm is normally distributed: this means that both the geometrical mean and standard deviation can also be obtained. The standard deviation, in its turn, introduces information regarding uncertainty.

Following this procedure, the marginal value of different impacts associated to electricity generation is summarised in Table 2.

European and North American case studies have consistently shown that health impacts are, by far, the most relevant ones when dealing with atmospheric pollution from power generation, and this is well reflected in our results. At the same time, there is also a wide consensus in the literature as to the fact that this damage is mainly due to the impact of atmospheric pollution on the incidence of respiratory diseases and premature mortality. Once the relevant parameters have been obtained from the exposure-response functions, the UWM adjusted for the Spanish case was applied to obtain the marginal impacts of different pollutants (SO_2, PM_{10}, NO_x, sulphates, O_3) upon the different segments of the affected population (infants, asthmatics, etc.). The next step was to get monetary estimates of these damages: for this purpose, the unit cost value (€ per case), taken from the *ExternE* Program was used. Of paramount importance at this point is the choice of a correct indicator to measure the value that a person confers to health. In the case of mortality changes, whether the so-called ''value of a statistical life, VOSL'' or a fraction of it known as the ''value of a year lost, VOYL[9] ''should be used is something subject to controversy. The values range of VOSL from 814,488€ (as used by the German Ministry of Transport: see European Commission, 1999) to 3.36 million € (calculated in ExternE).

A similar procedure was followed with respect to damages to agriculture, infrastructures and climate change. In this latter case, the price of ''CO_2 reduction emission certificates'' was applied. During the past three years, at least six CO_2 markets of this nature have been created, and the price of a ton of CO_2 has attained levels of more than 20 €/ton in the European Union. This is surely not the place to deal with the question of whether such prices reflect the environmental impact prevented, or are the consequence of speculative and adjustment movements. The important point is to state that the analyst has a complete sample of prices for this impact, and is free to

[9]VOSL estimates an individual's willingness to pay for a marginal change in the risk of death as a consequence of an increase of air pollution. This willingness to pay can be ascertained by a variety of methods: contingent valuation, defensive expenditure or hedonic wages. VOYL, on the other hand, modifies the calculation of VOSL under the hypothesis that air pollution specially affects people with previous health problems and who, at any rate, would have had a limited life expectancy. VOYL is a percentage of VOSL, corrected by a certain discount rate.

Table 2
Marginal damages associated with the airborne pollutants produced by the fuel cycles assessed [€/kWh]

	Lignite	Coal	Oil	CC N gas	Biomass	Nuclear	Hydro	SPV	Wind
Health	0.239701	0.067094	0.066122	0.003998	0.003793	0.001301	0.000124	0.005084	0.001058
Materials	0.000752	0.000180	0.000196	0.000007	0.000006	0.000003	0.000000	0.000014	0.000002
Crops	0.000481	0.001177	0.000917	0.000311	0.000376	0.000031	0.000006	0.000140	0.000028
Value without climate change	0.240934	0.068451	0.067235	0.004315	0.004175	0.001334	0.000130	0.005238	0.001088
Total with climate change, 5 €/ton	0.247099	0.073715	0.071750	0.006767	0.004412	0.001499	0.000149	0.005909	0.001224
Total with climate change, 20 €/ton	0.266359	0.090157	0.085856	0.014425	0.005153	0.002011	0.000209	0.008002	0.001646

Source: Azqueta et al. (2004).
NA: not available data.

choose the one most suited to her perception. Certainly, a sensitivity analysis should accompany the choice made, in the form of different prices; taking all this into account, in the exercise we are summarising, it was considered more appropriate to work with a rather conservative assumption: a core value of 5 €/ton of CO_2.

All in all, and as it appears in Table 2, the different technologies can be classified in three main categories concerning their environmental costs, and the way these are distributed along the life cycle:

- A first group is composed by what could be dubbed as "traditional" technologies: lignite, carbon and fuel oil. These are characterised by high environmental costs, mostly concentrated on the generation phase, where over 90% of the most relevant emissions take place. Therefore, performing a complete LCA does not add significantly to the outcomes drawn from the analysis of the generation process itself.
- A second group, comprising biomass and natural gas combined cycle presents lower environmental costs and a different distribution among the stages of the life cycle, if used for meeting peak demand. In that case, construction and dismantling account for a significant percentage of emissions (38% of particulate matter in the case of natural gas combined cycle). The same phenomenon applies to biomass, although this time it is the biomass growing phase, as opposed to biomass combustion, responsible for a non-negligible share of emissions.
- Finally, the group of other renewable energy sources: hydropower, wind energy and solar photovoltaic energy. For both wind and hydropower, the former trend is stressed: not only are environmental costs much lower, but also the importance of stages other than energy generation is much higher. The characteristics of solar photovoltaic energy are somewhat different: the share of emissions originated in the generation stage is almost non-existent but environmental costs emerge in the manufacturing of solar photovoltaic cells, a highly energy-intensive operation. In these cases, LCA is simply unavoidable: otherwise, environmental costs of renewable energies would be underestimated.

3.2. Environmental impacts linked to electricity production using biomass: the case of Sangüesa straw power plant

Taking our previous study and, to a lesser extent, that of the ExternE team as a basis, a subsequent analysis has been completed, this time with only one technology, straw combustion for electricity generation, using data corresponding to a plant situated in the municipality of Sangüesa (Blanco, 2004).

3.2.1. Technical and financial features of Sangüesa power plant

The installation opened in 2004 and is one of the largest in Europe, with a capacity of 25 MW, capable of supplying 6%[10] of the regional electricity consumption. It requires 160,000 tons of straw, approximately 50% of the amount collected in Navarre, a good reflection of the impact that this energy activity is having on local agriculture. According to the figures offered by the owner of the plant (see http://www.acciona.com) the plant worked around 8000 h in 2004, which means that it has been designed to satisfy base load, although it can occasionally be used to meet intermediate and peak demand, when hydro plants are incapable of doing so. This situation is relatively common in Spain and the other Mediterranean countries that have unstable hydraulicity cycles.

The straw collected in the fields is stored in pairs of bales, and the trucks transport them to the warehouse inside the plant. Depending on the supply needs, the automatic control system picks ups the bales and places them on a conveyor belt that takes them to the boiler. The combustion of the straw heats the water that circulates through the walls and the superheater of the boiler until it is converted into steam. The steam drives a turbine connected to a generator, which produces electricity at 11 kV. After it is transformed to 66 kV this energy passes through underground mains as far as the network substations of the electric utility company.

At the same time, the water vapour that has passed through the turbine is sent to a condenser cooled by water from a channel running through the facility. As a result of this drop in temperature the steam is converted back into

[10] 200 million kWh per year.

liquid, and the process starts over again. Finally, the straw combustion produces unburnt residue and fly ash, which is retained in the tank of the sleeve filter before the gases are removed through the stack. The percentage of waste is 5% in relation to the fuel used.

The initial investment in the plant was 50 million €. For reasons of confidentiality, other financial indicators have not been made available to the authors of this article. However, some ratios can be worked out, based on more general studies that exist, notably the Spanish Renewable Energy Plan and the estimates of the European Commission (see Instituto para la Diversificación y Ahorro de la Energía, IDAE, 2005; European Commission, 2005).

According to those, the average *production cost* of electricity from agricultural waste ranges from *6 to 8 €cent/kW;* the investment cost will be of approx. 1800 €/kW; fuel costs of 4.5 €cent/kWh and O&M costs of 0.9 €cent/kWh. In this type of installation, the collection and transport costs of the biomass exert a strong effect on the finances of the plant.

3.2.2. Summary of the environmental valuation exercise at Sangüesa

As explained in Section 3.1, we assessed the environmental impacts coming from Sangüesa power plant thanks to a simplified LCA designed to take into account the characteristics of the Spanish environment. The main phases studied were cultivation of the cereal, collection and transport of the straw, electricity generation and waste treatment. The air pollutants modelled included: CO_2, SO_2, NO_x, CH_4, N_2O, NH_3, particulate matter, cadmium, copper, niquel, selenium and zinc. Other impacts, such as visual intrusion or water consumption were looked at in a more qualitative manner.

The main findings can be summarised as follows

- *Health impacts* are low, but still account for most of the (negative) externality registered: between 59% and 88% of the total, depending on the assumptions made. Particulate matter and sulphur dioxide are the most harmful substances; the majority of them appearing during the generation phase and, to a lesser extent, while transporting the straw. Of special significance is the indicator selected to appraise changes in mortality and morbidity rates (either the VOSL or the VOYL), which can multiply the impact by a factor of 2. Such a striking difference reinforces the conclusion derived in the previous section about the need for improving and agreeing upon a single indicator on human health damage.
- Quantifiable impacts on *agricultural crops* showed that SO_2 emissions exert a fertiliser effect in the recipient environment surrounding the power station, and that the global value of this externality is modest—although negative-, with a range of between 6.80% and 10.33% of the total recorded externality. *Damage to buildings* also follows the general observed pattern for other technologies, and accounts for 0.01 €cent/kWh, less than 1% of the externality cost.
- The impact of biomass electricity production on *climate change* was formulated taking into account that the power plant is CO_2 emission free during the combustion stage (as the carbon dioxide released in that moment is offset by the amount purified by the plant that produced the straw during its life) but not in all the other phases of its life cycle. With regard to CO_2 prices, several possibilities were tested as part of a sensitivity analysis, with prices ranging from 5 to 20 €/ton. Results show that CO_2 prices have a limited impact on the global value of the externality; this is due to the low level of emissions of this technology.

Table 3
Monetary value of environmental impacts at the Sangüesa power plant ($€cent_{2000}$/kWh)

Damage category	Monetary value (5 €/ton)	Monetary value (20 €/ton)
Health	0.87	0.87
Crops	0.10	0.10
Materials	0.01	0.01
Climate change	0.01	0.03
Total	0.99	1.02

Source: Own elaboration on the basis of Blanco (2004).

Table 3 shows the results obtained in the two main scenarios.

3.3. Externality values of electricity production and their usefulness for the formulation of energy policies

Comparing the result obtained in Section 3.2 with the average external costs of electricity generation in Spain, the analyst should be able to estimate the net economic advantage of this biomass power plant. Yet, the identification of the baseline scenario is not simple:

(a) If the biomass plant replaces the production from an old plant due to close down, then the baseline should be the externality level of the plant replaced, probably an old coal or lignite plant, or a nuclear power station.[11]
(b) If the biomass plant helps satisfy an increase of the electricity demand, then the correct baseline scenario should rely on the emission load that would have taken place if an alternative new technology had been chosen. In Spain, most of the new power generation plants installed since the mid 1990s are natural gas combined-cycle plants or wind farms.
(c) Finally, if the biomass plant production is used to meet a peak of demand at any moment in time, it has to be

[11]The Socialist party that is now in power has included into its political programme the progressive dismantling of nuclear plants and, to a lesser extent, of old lignite and coal plants to replace them by renewables.

compared with technologies that provide the same service, which are mainly hydro, but also fuel, combined-cycle plants and coal if required.

In Spain, base load is normally covered by nuclear and, to a lesser extent, by coal and lignite plants. Gas combined-cycle plants were designed to operate under base and intermediate load but are sometimes utilised to cover demand peaks. Hydroelectric plants are partly used to satisfy base load and partly used to meet peak demand, although the irregular nature of hydraulicity in the Mediterranean climate (see Section 3.2) sometimes obliges to put other power plants into operation. Spain does not have a specific indicator to measure the kind of plant that covers demand peaks, but the indicator of ''number of hours used'' can be used as a proxy (see, for instance Red Eléctrica de España, REE, 2006a, b).

The biomass plant has been conceived to provide base load, but can occasionally be used for intermediate and peak demand. For that reason, we have decided to use as a baseline the level of externality that reflects the mix of technologies used in the national pool, instead of the externalities of the oldest or the newest options available. For comparison, a sensitivity analysis is carried out in order to evaluate the impact of this hypothesis on the economic viability of the plant.

Fig. 1 shows the contribution of different energy technologies to Spanish electricity production in 2005; multiplying their relative weight by the economic value of the externality, as given in Azqueta et al., one finds the level of damage caused by the generation of a kWh in Spain which, using the reference period 1998–2002 amounts to 4.27 €cent/kWh.

The value of the environmental externality originated by the biomass power plant will be lower than the one generated by more conventional electricity generation:

- Making the comparison with the Spanish mix, and assuming a price of 5 €/ton CO_2, the net benefit of producing biomass electricity is of 3.28 €cent/kWh.
- If biomass electricity production is compared with a lignite station or with a coal plant, its relative benefit equals 23.71 €cent/kWh in the first case, and 6.38 €cent/kWh in the second.
- Finally, if the comparison is performed with a natural gas combined-cycle plant the relative environmental benefit almost disappears.

As expected, when the price of CO_2 increases up to 20 €/ton, the advantage of Sangüesa increases up markedly in all scenarios. Such considerations show the crucial importance of defining the baseline scenario correctly, also on the basis of particular conditions of the power station under consideration.

4. Potential impacts on farmer's revenue of transferring the environmental rents from clean energy generation

The figures summarised previously open the possibility of sharing the environmental benefits of ''green'' electricity between the renewable energy power plant and the farm that supplies the straw. The question is whether this would be enough to cover the deficit faced by the farmer and transform the energy use of cereals in an alternative for the agricultural sector.

- The average production cost of a kWh of electricity similar to Sangüesa ranges from 6 to 8 €cent. Biomass fuel constitutes the single largest contributor to the cost, but encompasses many different processes. What is

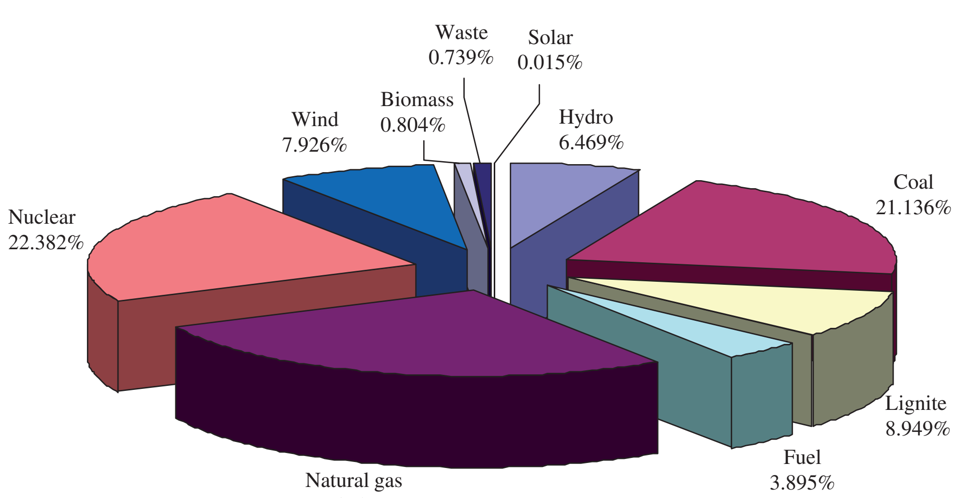

Fig. 1. Structure of electricity generation in Spain, 2005. *Source*: Spanish Ministry of Industry, Tourism and Trade/IDAE.

really paid to the farmer is in the order of 14% of total costs, although this percentage depends on the biomass type.

- On the other hand, the electricity price in Spain stands at around 4–5 €cent/kWh. This implies that, in the absence of additional income, electricity from biomass is not viable.[12]
- The introduction of a payment that compensates biomass plants for their relative environmental advantage could imply; in a plant like the one analysed here, an extra payment of around 3.28 €cent/kWh (when comparing with the Spanish mix). The total price received by the owner of the power plant would be 7.28–8.28 €cent/kWh at a central value of 5 €/ton CO_2. This amount is barely able to cover long-term marginal generation costs of the plant used in our example.[13]

In these circumstances, the internalisation of the relative environmental benefit of electricity production with cereal straw is not enough to fill the gap of the cereal farmer; albeit all extra revenue was devoted to this production factor (let us remember that this deficit was of around 6 €cent/kg).

Which one of the three baseline scenarios outlined in Section 3.3 is chosen becomes crucial. If we assume that the biomass plant would replace a lignite station, then the sharing of its environmental benefits would be enough to ensure the viability of cereal farms in the region. However, if it is a coal plant the one to be replaced, the sharing of these benefits would be insufficient to cover the financial gap of the farmer, despite the fact that these benefits are twice as high as in the previous case. Finally, if the plant to be replaced is a natural gas-combined cycle one, there are practically no environmental benefits to be shared, let alone to guarantee the survival of cereal farms.

It would certainly be interesting to simulate what should be the economic value of the environmental benefit related to biomass electricity generation that would allow to reach the amount of 6 €cent/kg[14] needed to balance the budget of the cereal farmer, plus the amount needed to cover the production costs of the power plant (around 3 €cent/kWh).

Assuming as our baseline scenario the Spanish electricity mix, this could happen, for instance, for a price of 85 € for a CO_2 reduction certificate; a figure well above the peak levels achieved by European markets recently and also greater than the results of most climate prediction models. Yet, if the comparison is made with a more polluting option, like a coal power plant, then a price of 16 € would have been enough.

On the other hand, an increase in the value of VOSL, VOYL and, to a lesser extent, pollution-related illnesses, would substantially raise the environmental benefit of the plant, and thus cover the gap of the farmer. Eventual changes in the categories of buildings and biodiversity will have limited impact.

In summary, the environmental benefits of electricity production with biomass could be just enough, in the central case adopted here, to ensure the feasibility of the power plant, but not that of the farmer supplying the straw. The survival of plants similar to the one analysed here thus requires and depends either on the maintenance of the CAP or on sharing the environmental benefits of "clean" electricity production if these benefits, for whatever reason, reach a higher value.

Could the environmental benefits of clean transport fill in the gap? Section 5 finally turns to this last possibility.

5. Environmental benefits of the production of bioethanol from cereal in Spain

The combined use of straw to produce electricity (as above) and grain to distillate bioethanol may well be a solution, in trying to make cereal crops profitable, provided that their environmental benefits are acknowledged. This is probably one of the main reasons, together with the search for greater independence in the sector (being biofuels the only short-term alternative to oil for the transport sector), behind the recently adopted target of satisfying 10% fuel consumption with biofuels by 2020.

The scientific research devoted to quantify and value the environmental impact of biofuels vis-à-vis fossil fuels has started later than for electricity production, but is growing fast. The main effort has been carried out by the ExternE team (European Commission, 1999), Concawe (1995, 2002), VIEWLS (2005) and more recently, by the well-to-wheel study (Concawe, the European Commission Joint Research Centre, 2006). A comprehensive synthesis of research works can be found in the Communication of the Commission that accompanies the biofuels report released in January 2007 (European Commission, 2007a)

The outcomes of these studies show that the environmental performance of biofuels, including bioethanol from cereals, is not clear-cut and is strongly influenced by the agricultural practices adopted during the cultivation of the biomass. In a limited number of cases (see, for instance, Lechón et al., 2005 for a Spanish case), the overall life-cycle approach may even show a negative environmental impact. This is surely not the place to go into the detail of these works, which would deserve a separate article, but we can conclude that the use of biofuels will normally entail a net environmental benefit vis-à-vis fossil fuel alternatives, but that this benefit will be very sensitive to agricultural practices and to other factors, such as the energy consumption that is needed during the production process

[12]If there *is* biomass electricity production in Spain it is due to the existence of a "feed-in" tariff under RD 436/2004 (Ministerio de Economía, 2004) that compensates each kWh produced with RES with a certain amount that, for biomass, is not very different from the result of the internalisation exercise presented in this article.

[13]And we are talking about costs, not prices, the latter including factors such as risk.

[14]Equivalent to revenue of 4.50 €cent/kWh (1 kg produces 1.33 kWh of electricity).

and the opportunity costs of by-products such as lignin and animal feed.[15]

In order to know if the environmental benefits of bioethanol could cover the gap that farmers face in the absence of the CAP, the production cost of bioethanol is needed. According to the best estimates that we have (see Ministerio de Economía, 2001; Villarías de Moradillo, 2003), these arise to around 50 €cent/l in Spain, of which raw material (cereals) are responsible for two thirds of the total.[16] The production cost of gasoline fuel was 48 €cent/l in 2006 and substantially lower the previous years (e.g. 32 €cent in 2003).[17]

The consequences of this analysis are the following: if the fuel price is low (2003 levels, for instance), the relative environmental benefit of bioethanol would need to be really substantial –around 18 €cent/l—to cover the difference in production costs (bioethanol being around 1.56 times more costly than gasoline fuel). Current studies do not support that figure. If the fuel price peaks again to the levels attained in 2005 and 2006, the cost gap would be reduced and bioethanol could be sustained by the market plus its environmental advantages.

Naturally, higher payments entail the possibility to share part or all of the surplus among production factors, including cereal grain, conditional on their elasticities of supply and demand. The joint use of straw for electricity generation and grain for bioethanol distillation widens the range of payment possibilities to improve the "survival" opportunities of cereal farmers in Spain, which seem to depend very much, as analysed in this article, on the price of oil.

6. Summary and conclusions

The five previous sections lead to the formulation of some conclusions with regard to the possible use of cereals in Spain for energy production that can be summarised as follows:

(a) An important part of cereal land currently cultivated in the Northern regions of Spain would become unprofitable without the support of the CAP, and grain and straw production would be significantly reduced in the medium term.

(b) The environmental impact of electricity produced with cereal straw, as observed in the region of Navarre, is lower than its fossil fuel alternatives, and could justify the application of a compensatory payment.

(c) The level of the environmental compensation depends critically on assumptions like the choice of a baseline scenario, the "value of the statistical life" indicator; and the price at which CO_2 is traded.

(d) The sharing of this environmental benefit would improve the rent of a cereal farmer, but not to the extent of covering costs in the absence of CAP. For this to be so, environmental benefits should be multiplied by a factor of two, a figure that will hardly be achieved with an increase solely of CO_2 price.

(e) On the other hand, the disappearance of cereal production in the area will force Sangüesa power plant to change its source of fuel. The adaptation costs to the new situation, including the net environmental costs, should also be taken into account when deciding whether to support cereal production in the region or not.

(f) The distillation of bioethanol from cereal grain does not constitute a sufficient complement either, unless oil prices reach the high levels that they did during 2005 and 2006. In the medium term, improvements in bioethanol technology and process are expected, together with high oil prices; the combination of those two factors can modify the conclusion.

In this whole analysis, we have disregarded the contribution that renewable energy sources make to energy security. This is a fundamental factor behind the support of renewable energies today, in the same way that "food" security was behind the approval of the CAP in its early days. Should we include these parameters into our study, the results may change.

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[15]Furthermore, a complete LCA of grain production should be carried out, including the environmental impacts of nitrogen fertilizer production, which are far from negligible (von Blottnitz et al., 2006). In the case of the straw biomass plant, however, this would not be necessary because fertilizer use is linked to the production of grain, not to the production of straw (we thank an anonymous referee for mentioning this point).

[16]Again, this includes not only the price paid to the farmer, but also costs of collection, transport and intermediate storage.

[17]Final price to the consumer is normally double than the production cost, due to the addition of the several taxes applied to energy products. For more information, please see the periodical reports of the AOP (Associacion Española de Productores de Productos Petrolíferos) or the Oil Bulletin of the European Commission. http://www.aop.es/informes_-sector.asp http://ec.europa.eu/energy/oil/bulletin/index_en.htm.

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