



MOBILISING CEREAL STRAW IN THE EU TO FEED ADVANCED BIOFUEL PRODUCTION



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EXECUTIVE SUMMARY

The Renewable Energy Directive (RED), with its target of 10 per cent of transport fuel to be from renewable sources by 2020, has created a significant demand for biofuels in the EU. Primarily this has been for conventional biofuels and the development of advanced biofuels has not advanced as rapidly as many expected. Over the past few years an increasingly fierce debate has emerged about the environmental benefits of conventional biofuels, most notably as a result of concerns about indirect land use change (ILUC) impacts and associated emissions. Given these concerns, attention has turned to the greater use of biomass residues, including agricultural residues, for producing bioenergy as a means of alleviating the pressures on land and other environmental resources at the same time as producing considerable greenhouse gas (GHG) savings compared to fossil transport fuels.

Objectives

This report considers the use of one particular agricultural residue, straw, for the production of cellulosic ethanol and considers ways in which it can be mobilised more effectively for this purpose. It assesses the (energy) potential of agricultural residues and in particular straw; reviews the competing uses of straw and the associated environmental effects of mobilising straw for biofuel production; considers the opportunities and barriers for increasing the use of straw for bioenergy production; and examines the potential role and need for public support through EU funding instruments, such as the CAP and Cohesion Policy.

Potential availability

A number of studies have estimated the potential of different biomass residues available for energy conversion, some for the EU as a whole and some for specific Member States. Estimates of technical potential vary considerably between studies, as a result of a range of different factors (definitions of 'agricultural residue', different timescales used, different constraints incorporated into the models etc). However, all highlight the fact that technically there appears to be significant volumes of straw that could be mobilised, and potentially used for the production of cellulosic ethanol. However, it is important to note that these estimates of technical potential are not the same as economic potentials. Economic potentials are much lower, given that they are constrained by the market, competing uses of straw within and outside the agricultural sector and underdeveloped supply chains. In addition, the technical potential studies tend to assume a uniform straw extraction rate, whereas in reality the volumes of straw available vary geographically and year on year. In addition, with the growth in interest in the bioeconomy more generally, it is unclear how great a demand there will be for straw to be used as a material input in other industrial sectors, such as the emerging bio-materials and bio-chemicals sectors. All these factors serve to increase the uncertainty of the estimates of economic potential for the use of straw for cellulosic ethanol production.

Competing uses for straw

One of the main factors influencing the uncertainty regarding the potential availability of straw for the production of advanced biofuels is the degree to which existing uses compete for this resource. The most common uses today are for animal bedding, as a soil improver (through the incorporation of straw into the soil to increase organic matter and improve

structure) and as a mulch for use in vegetable and mushroom production. However, it is difficult to quantify the proportion of European straw production used for these different purposes as this varies between Member States and between years. Nonetheless there are situations where a surplus of straw exists. This tends to happen where there is a lack of technical capacity to incorporate the straw into the soil; where soil incorporation limits have been reached; where the use of straw in the soil is not required (for example where there is already high organic matter content); or where the straw is not demanded by, or cannot be supplied to, other sectors.

Environmental constraints

Apart from competing uses, environmental constraints are key in determining sustainable extraction rates and therefore potential availability of straw in the longer term. One of the main environmental implications of diverting increased volumes of straw to biofuel production is the potential impact on soil organic matter. It is very difficult to draw conclusions for Europe as a whole on the amount of straw needed to remain on the field, as to prevent reductions in soil organic matter and soil functionality, because this depends on local soil and climatic conditions. Local soil studies are therefore needed to determine sustainable extraction rates. Under the RED sustainability scheme, changes in soil carbon stocks from straw removal are currently not accounted for in determining the lifecycle greenhouse gas balance of biofuels. Given the potential adverse impacts, it is important to extend the lifecycle assessment approach of the RED to take such impacts into account.

Sourcing straw for biorefineries

The evidence shows that there has been limited investment in biorefinery capacity so far in the EU, with the first commercial plant to produce cellulosic ethanol being established in Italy. One of the issues is that biorefineries need to be fairly large-scale to operate profitably. For example, it has been suggested that around 50 million litres of ethanol output/year is required, corresponding to an approximate figure for straw input of around 200,000 tonnes/year. It appears from talking to industry representatives that companies in the EU currently still experiment with different arrangements for sourcing straw, the exception being Denmark. What seems to emerge rather clearly is that securing the amount of straw biomass needed to run biorefineries necessitates flexible arrangements. This may include flexibility between long-term contracts and short-term buying of straw on the market, flexibility with regard to the geographical provenance of the straw, as well as flexibility between the use of straw and alternative feedstocks.

The straw supply chain and persisting barriers

Despite the interest from farmers in increasing the market for straw as a feedstock for energy purposes and a demand from biorefineries for straw for this purpose, five key types of barriers were identified that affect the current functioning of the straw supply chain between farmers on the one hand and the processors on the other. These are:

- *Underdeveloped markets and lack of market information:* to a large extent, the lack of supply chains for straw for bioenergy purposes is related to underdeveloped markets. With the notable exception of Denmark, the energetic use of straw is not an established practice EU wide. The marketing of straw for these purposes is at different stages of development in different EU regions and is still embryonic in many places.

- *Competing existing uses of straw:* straw is not an agricultural residue without alternative uses. Not only does it play an essential role as a soil improver, but other markets have developed over centuries for straw that is in excess of on-farm needs. Given these alternative uses and the underdevelopment of the bioenergy market for straw, farmers in many places are still to be convinced that it is worth their while in the long term to change existing practices.
- *Lack of guidance on optimal use of straw as a soil improver and associated farming practices:* while some farmers carry out detailed soil analyses as well as an analysis of the nutrient and mineral content of their straw to ensure optimal levels of incorporation, this does not happen in the majority of cases. This can lead to an unnecessary level of straw being incorporated into the soil, which then reduces the surplus available for extraction for other purposes.
- *Lack of infrastructure:* one of the issues facing land managers who might be interested in supplying straw to biorefineries is the lack of investment in appropriate on-farm machinery and infrastructure for straw handling and baling to meet the requirements of the processors.
- *Variability of straw supply:* from the processors' perspective, a major issue is the variability in the quantity and quality of straw available year to year and region to region, as a result of climatic conditions and fluctuating straw yields.

Many of the barriers facing the mobilisation of agricultural residues, and straw in particular, for use in the production of advanced biofuels, are the result of the nascent nature of the market in this area and the lack of certainty about its long term future. To resolve this requires changes to EU energy policy and most interviewees for this study argued that if this were done, then solutions to the other barriers relating to the supply chain would be found through the normal operation of the market.

European policy considerations

Nonetheless, this study has identified some areas where the CAP and Cohesion policy within the EU could play a role. Any use of straw for advanced biofuel production must be sustainable and avoid any adverse environmental impacts, for example by reducing the levels of straw incorporated into the soil and thereby potentially depleting soil organic matter. Perhaps the most important role that the CAP could play is by introducing environmental safeguards to ensure soil protection. This could occur both through the use of cross compliance as well as using rural development measures to develop guidance and tools for farmers to calculate the humus levels of their soils in order to make informed judgements about the optimal level of straw to be incorporated back in to the soil and therefore how much is available for other purposes. Other possibilities include support for cooperation between farmers in managing straw, the setting up of producer groups or the development of new businesses, for example for the baling and transport of straw, including the provision of capital investment for the purchase of suitable machinery. Cohesion policy could play a role in providing investment capital for the development of pilot or demonstration plants for processing, where these are seen to be beneficial.

In generic terms, the EU level policy tools and measures are in place within the current policy frameworks to allow Member States to pursue these options if they wish. The draft legislative proposals for both the CAP and Cohesion Policy beyond 2013 retain this

possibility. Much will depend, however, on the priorities that Member States choose as the focus of their next generation of Rural Development (EAFRD) or Operational Programmes (Cohesion) and the subsequent structure, design and implementation of measures at the national and regional level. Attention will turn in this direction over the coming months as initial planning for the 2014-2020 programming period gets underway.

1 INTRODUCTION



The EU Renewable Energy Directive (RED) calls for a 10 per cent share of renewable energy in transport by 2020. The National Renewable Energy Action plans (NREAPs) that were submitted to the European Commission have shown that Member States anticipate meeting the bulk of this target (over 90 per cent) through conventional biofuels. From this it appears that the RED provision allowing for a double counting towards the target of advanced biofuels from ‘wastes, residues, non-food cellulosic material, and ligno-cellulosic material’ (Article 21(2)) has not been effective in bringing these to the market¹.

From an environmental perspective, one of the reasons for interest in advanced biofuels is the potential they offer to deliver environmental benefits by providing higher lifecycle greenhouse gas savings, compared with the environmental issues associated with conventional biofuels, most notably the greenhouse gas emissions and biodiversity impacts of associated direct and indirect land use change. Their environmental potential is linked to the fact that advanced biofuels, based *inter alia* on enzymatic, biochemical technologies, can utilise a broader feedstock base, particularly agricultural and forestry residues and therefore need not take up additional land or displace crops used for other productive functions (food, timber etc) for their production.

Given the concerns about the direct and indirect impacts of bioenergy production on land, emphasis has turned to the role of biomass residues in producing bioenergy. Indeed, a recent opinion by the Scientific Committee to the European Environment Agency (EEA) concluded that only bioenergy derived from additional plant growth or from residues not otherwise used or contributing to carbon sequestration should be used as a source of energy (EEA Scientific Committee, 2011). Biomass residues were also highlighted as the first choice as bioenergy feedstocks in a recent IEEP report on establishing an environmentally responsible bioenergy sector in the UK (Kretschmer *et al*, 2011). This proposed a biomass feedstock hierarchy that favours first and foremost the use of genuinely residual wastes, followed by arisings produced by habitat conservation and landscape management,

¹ This point is also made in the article ‘Next-generation biofuel needs old-style policies’ by Tony Long (WWF) and Steen Riisgaard (Novozymes) published in European Voice on 10.03.2011, <http://www.europeanvoice.com/article/imported/next-generation-biofuel-needs-old-style-policies/70496.aspx>.

agricultural and forestry co-products and residues (including straw) and biomass harvested from new and existing woodlands as preferential to dedicated energy crops. More precisely, this hierarchy sets out, in priority order, those sources of biomass that:

- can create win-win situations by, for example, improving biodiversity and providing renewable energy simultaneously through habitat management, or managing waste while providing renewable energy by using unavoidable organic waste;
- would otherwise contribute least to carbon sequestration; and/or
- have least impact on other environmental objectives (for example the protection of biodiversity, water quality, soil functionality etc).

The Polish EU presidency in the second half of 2011 facilitated an exchange of views among Agriculture Ministers from different Member States on the 'energy use of biomass of agricultural origin as an important element of the Common Agricultural Policy'. The majority of Member States agreed that the main purpose of agricultural policy was to promote food production and therefore, that in promoting the use of biomass for energy purposes, the CAP should 'focus on a better use of by-products and [...] residues'².

There are many types of agricultural residues that have the potential to be used as bioenergy feedstocks, including, for example, animal slurries and manure as well as crop residues such as cereal straw, maize stover and sugar beet residues³. Of these, cereal straw⁴ is a particularly important source for advanced ethanol production.

This report, therefore, focusses on the potential for cereal straw in bioenergy production. It considers:

- the (energy) potential of agricultural residues and in particular straw;
- the competing uses of straw and associated environmental effects of mobilising straw for biofuel production⁵;
- the opportunities and barriers for increasing the use of straw for bioenergy production; and
- the role and need for public support through EU funding instruments, such as the CAP and Cohesion Policy.

The findings of the report are based on a review of the existing literature, supplemented by interviews with agricultural sector and industry representatives.

² Council of the European Union (2011) Press Release: 3110th Council meeting. Brussels, 20.09.2011, 14374/11, http://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/agricult/124682.pdf.

³ Residues from sugar beet processing (pulp) are different from the other agricultural residues mentioned here as they are a residue accruing from an industrial process rather than on farm.

⁴ This mostly refers to wheat straw given that wheat accounts for roughly two thirds of cereal output in the EU) and the fact that barley and rye yield higher value straw that is predominantly used for animal bedding or feed. The higher value of barley and rye straw is due to their higher nutrient content and marginally softer consistency.

⁵ A separate study by the German Biomass Research Centre (DBFZ) and Oeko-Institut (unpublished) addresses the environmental effects in more detail. This study has been summarised by Lübbecke and Anderson (2012).

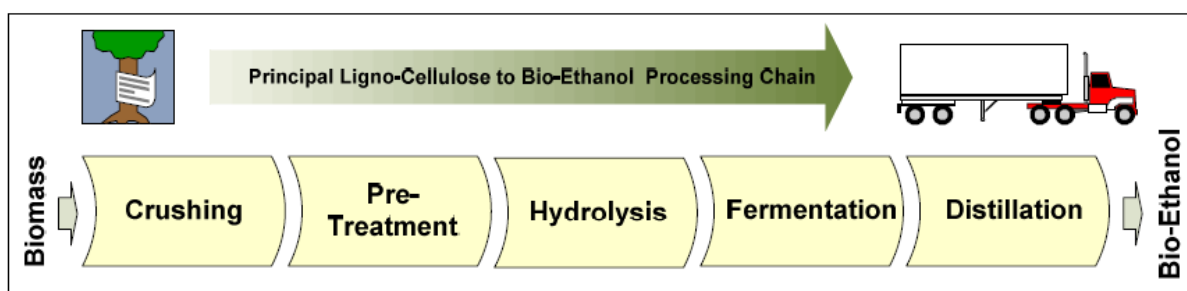
2 REVIEWING THE EU POTENTIAL OF STRAW AS A BIOENERGY RESOURCE



This section compares the potential of cereal straw as a potential bioenergy resource with that of other agricultural residues. Particular attention is given to the potential of straw as a feedstock for advanced ethanol production in comparison with figures of anticipated biofuel demand in the EU by 2020.

In this report, the term straw is used to describe the dry stalks of cereal⁶ crops that remain following the removal of the grain and chaff during the harvesting process. Straw yields depend on the type of crop and crop variety, the way in which it is harvested as well as environmental factors affecting crop growth, such as weather and soil conditions. Straw can be used to produce energy through conventional technologies, such as burning to generate both heat and power, or using more novel technologies to produce liquid biofuels. For example, cellulosic ethanol, a substitute for conventional gasoline, is produced using enzymes to release sugars from (ligno-) cellulosic material that are then fermented (see Figure 1).

Figure 1: Processing steps in ligno-cellulosic ethanol production



Source: Bacovsky et al, 2010, p16

Biofuel production and use in the EU is heavily influenced by the EU renewable energy policy and in particular the 10 per cent target for renewable energy in transport stipulated

⁶ Cereal farming is used to refer to the production of grains from crops such as barley and wheat. It is recognised however that 'straw' can be defined more broadly in some Member States and can include the 'stalks' of oil seed rape and other seed crops, or the 'stovers' of maize crops.

in the Renewable Energy Directive (RED)⁷. However, according to the National Renewable Energy Action Plans (NREAPs) it is anticipated that around 90 per cent of the renewable energy needed to meet this target will come from conventional or first-generation biofuels⁸ produced from conventional food and feed crops⁹ (for example Bowyer, 2011). The conventional biofuels have come under scrutiny increasingly and their environmental performance has been questioned as a result of evidence demonstrating detrimental effects associated with (indirect) land use change (Boywer, 2011; Kretschmer, 2011; modelling studies such as Edwards *et al*, 2010; Laborde, 2011;). This has redirected attention to biofuels derived from wastes and residues, which, it is hoped, will alleviate pressures on land use.

2.1 Estimates of the potential of agricultural residues

A number of studies have estimated the potential of different biomass residues available for energy conversion, some for the EU as a whole and some looking at individual Member States. The studies reviewed by DBFZ and Oeko-Institut (unpublished) give a technical potential of straw in the range of 50 and 110 million tonnes of straw dry matter per year (or between 674 to 1,829 PJ), below the potential calculated for the Biomass Futures project of about 2,063 PJ in 2020, summarised below. Another study undertaken by the DBFZ estimated a straw potential for the EU-27 of 60 million tonnes dry matter. However, this is based on 2008 data rather than a projection to 2020. Also, the estimates of potential in this study were based on what was considered a conservative assumption that 20 per cent of agricultural straw residue could be used for energy purposes, once competing uses had been taken into account (BMVBS, 2010). DBFZ and Oeko-Institut summarise important drivers that explain differences in results across studies:

- The category of agricultural residues is not defined uniformly and in some instance includes wood waste and manure, while in other cases only cereal crop residues are included;
- Confusion between different potential classifications such as theoretical, technical and economic (see footnote 10);
- Different projection periods (eg current, 2020 or 2030 potential estimated);
- Differences in the modelling of restrictions such as sustainability considerations and the proportion of straw potentials going into competing uses.

Estimates on the EU-27 technical potential¹⁰ for biomass from agricultural and forestry residues, as well as from the organic component of waste that would otherwise go to

⁷ Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, OJ L140/16, 05/06/09.

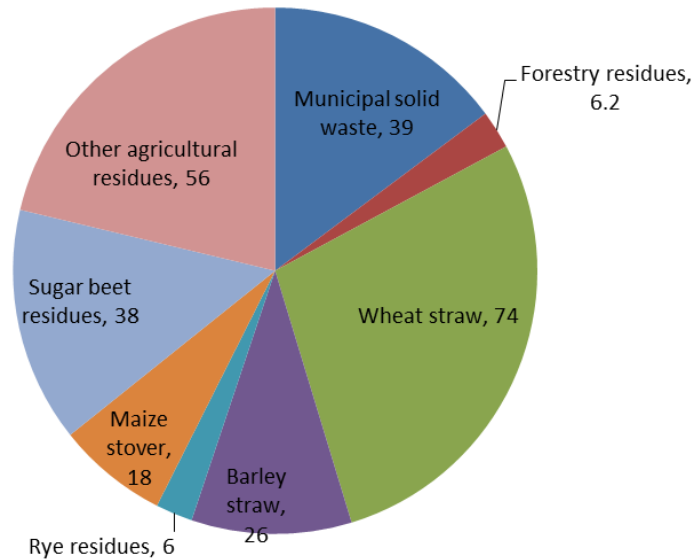
⁸ Throughout the report, we will use the term conventional biofuels and advanced biofuels as synonymous for first- and second-generation biofuels (unless differently used in direct citations).

⁹ These are starch and sugar crops for ethanol and oil crops for biodiesel.

¹⁰ The technical potential includes the total harvestable straw taking into account technical constraints such as the harvesting rate, but can (and in the BNEF study does) include also restrictions from competing uses, see

landfill, have been produced by Bloomberg New Energy Finance (BNEF, 2010)¹¹. This study suggests that, for agricultural residues, the amount of advanced ethanol that can be produced is estimated to be at least 180 million tonnes. Figure 2 illustrates that the bulk of the total residues potential (80 per cent) comes from the agricultural sector and within this category, the main potential is from straw (making up 106 million tonnes in the base case when wheat straw, barley straw and rye residues are added, equivalent to 60 per cent of the total agricultural residues potential).

Figure 2: Biomass residue availability in 2020; base case, in million tonnes; total of 180 million tonnes



Source: Own elaboration from BNEF (2010)

Table 1 introduces the main assumptions underlying the estimates of potential including the distinction between a *base case scenario* and a more optimistic *bull scenario*.

The Biomass Futures project is the most recent large European research project to calculate bioenergy potentials and therefore forthcoming results are included here. Biomass Futures work has identified a similar straw potential of 127 million tonnes for the EU-27 in 2020 (or in energy measures around 49.3 Mtoe¹² or 2063 PJ; straw refers to barley, wheat, rye, oats and other cereals)¹³. Although the potential estimates are similar, the derivation of this potential is different to that of the BNEF study as it includes results from the agricultural

table 1. An estimate of the economic potential, for comparison, would take into account the profitability of straw extraction determined by factors such as market conditions and policy framework.

¹¹ The study was commissioned by the biotechnology company Novozymes and the life sciences and materials sciences company DSM.

¹² Mtoe is million tonnes oil equivalent; PJ is petajoule.

¹³ Forthcoming results from the Biomass Futures study (Elbersen *et al*, forthcoming), to be published soon on www.biomassfutures.eu.

sector model CAPRI¹⁴, taking potential agricultural market feedback into account that could lead to bigger or smaller straw estimates depending on how supply and demand on agricultural markets develops.

Table 1: Assumptions and overall potential of biomass residue sources (as in BNEF, 2010)

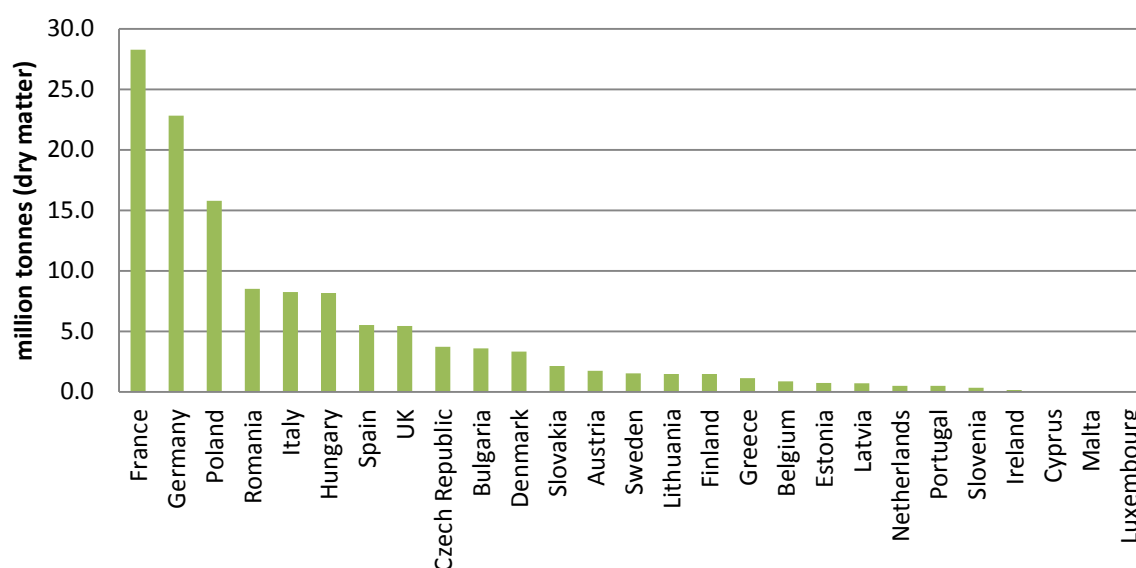
Agricultural residues	Forestry residues	Municipal solid waste
<p>Based on the 12 main EU food crops. Calculated based on 1990-2008 FAO data for area harvested and yields and linear projection to 2020.</p> <p>Main assumptions:</p> <ul style="list-style-type: none"> • <i>Harvest index</i>: Ratio of food weight over total crop weight; differentiated per crop, typically one third (the remainder are residues); • <i>Recoverability index</i>¹⁵: 25 per cent, ie 75 per cent of residues left on the ground; • Recovered residues are split further into: 10 per cent for power generation, 20 per cent for animal husbandry and 70 per cent for bioproducts; • Linear projections of production volumes, based on yield increases that are linearly extrapolated from 1990 to 2008 data in the <i>base case</i>; yield exceeds the historic trend by 5 per cent in the <i>bull scenario</i>. 	<p>Based on historical annual production data from 1990-2008 for 'sawn wood (sawn timber), plywood, fibreboard, chemical wood pulp, mechanical wood pulp and pulpwood'.</p> <p>Main assumptions:</p> <ul style="list-style-type: none"> • Wood residues used in the wood panel industry and the paper industry are subtracted to yield potential for energy recovery; • 80 per cent of bioenergy potential is used for power generation. 	<p>Based on EEA data on waste generation and Eurostat population data.</p> <p>Main assumptions:</p> <ul style="list-style-type: none"> • All countries with a landfill MSW shares >10 per cent reduce landfilling by 2.14 per cent annually until 2020. • Biodegradable part of MSW considered, 'organics, paper and paper board, and wood waste', assumed to amount to 57 per cent of landfilled MSW; • In the base case, 75 per cent of this is converted into bioproducts (100 per cent in bull scenario).
Total available biomass residues in 2020 in million tonnes (bull scenario in brackets)		
180 (212.6)	6.2	39 (51.4)

Figure 3 provides a breakdown of straw potential by Member State, with those characterised by large areas of arable land such as France, Germany and Poland showing the highest potential. However, a preliminary report from the Biomass Futures project highlights considerable regional differences in potentials, particularly within the aforementioned Member States. This is largely due to the distribution of arable land within the country (see Box 3 displaying the difference between dominant livestock and cereal production areas in the EU).

¹⁴ <http://www.capri-model.org>

¹⁵ Defined as 'percentage of the crop weight that can realistically be recovered after harvesting' (BNEF, 2010, p21).

Figure 3: EU27 straw potential in million tonnes (dry matter) for 2020



Source: Based on results from the Biomass Futures project, Elbersen et al (2012). The figures are based on results of the CAPRI model for 2020 and Biomass Futures elaborations¹⁶.

2.2 Estimates of biofuel production potential from agricultural residues

Based on the estimated potential availability of agricultural residues, some of the studies identified also calculate the amount of biofuels that can be produced based on these potentials. This is done by assuming biomass-to-ethanol conversion factors and multiplying these with identified residue potentials. The studies that have done so produce a large range of potential cellulosic ethanol production, highlighting the persisting uncertainty surrounding both biomass potentials as well as future conversion technologies.

For example, BNEF (2010) calculate the cellulosic ethanol potential based on the estimated biomass potentials, using biomass-ethanol conversion factors to show how much ethanol could be produced based on the maximum supply of biomass available. The authors point out that they do not attempt to come forward with an advanced ethanol supply forecast that would take into account changes in market conditions and the regulatory framework. Their estimates of ethanol production, amounting to close to 75 billion litres in 2020 (90 billion litres in the bull scenario) should therefore be interpreted as a technical potential. The calculations assume that 95 per cent of available biomass is used for ethanol and the remainder for biochemical production¹⁷. A similar approach is taken in an IEA study

¹⁶ Note the following: According to a Polish report, the 2008 surplus straw potential (15 per cent of all available straw) per year is around 4.5 million tonnes, much below the estimated 2020 potential in 2020 as displayed in Figure 3 above (http://www.4biomass.eu/document/file/Poland_final_1.pdf). The 2020 figure of over 15 million tonnes could be an overestimation but certainly reflects large anticipated yield increases.

¹⁷ The BNEF study further assumed increases in the ethanol/biomass yields of 20 per cent over 2010 to 2015 (from 250 to 300 litres per tonne of biomass) and of 17 per cent (300 to 350 litres/t) from 2015 to 2020, yielding average annual increases of 4 per cent and 3.3 per cent for the first and second period, respectively (BNEF, 2010, p6).

(Eisentraut, 2010), where the calculations are based on global agricultural and forestry residues potentials for the year 2030 and two scenarios, assuming 10 and 25 per cent of residues are collected. Using a lower straw potential as well as more conservative conversion efficiencies DBFZ and Oeko-Institut (unpublished) have produced much more conservative estimates.

The potentials derived from these three studies are presented in Table 2. Here the resulting ethanol yield (in litres and ktoe) is compared with anticipated biofuel use in 2020 as derived from Member States NREAPs. The BNEF ethanol estimates derived from all agricultural residues by far outstrip total ethanol and even total biofuel demand in 2020¹⁸. The amount of ethanol derived from straw only is still twice as much as 2020 ethanol demand and almost two thirds of 2020 biofuel demand. Given the range provided by lower and upper estimates of straw potential, DBFZ and Oeko-Institut (unpublished) estimate that cellulosic ethanol could contribute less than half up to more than twice to EU ethanol demand in 2020 or just over half to total biofuel demand.

One of the issues with the studies of potential reviewed is that they commonly assume an average rate of 'sustainable straw extraction', whereas in fact this figure is highly variable at the regional and sub-regional level and determines the extent to which residues can be extracted in a sustainable way. The variability of regional specific extraction rates is also highlighted by DBFZ and Oeko-Institut (unpublished), who review a range of potential studies, yielding a range of straw extraction rates of between 25 and 75 per cent and conclude that sustainability issues have not been considered in a consistent way across the different studies. Evidence gathered from a number of national experts¹⁹ in different parts of the EU suggests a smaller range of 25 to 30 per cent after competing uses are taken into account. These figures are supported by slightly higher, but consistent figures, from other reports. For example the European Environment Agency estimates between 33-37 per cent to be available Europe wide within a range of sustainability scenarios (EEA, 2007).

¹⁸ In fact, based on forecast gasoline demand and taking into consideration technical constraints in blending levels, BNEF predict that under the bull scenario next-generation ethanol could contribute up to 62 per cent to total EU gasoline demand in 2020.

¹⁹ Experts were consulted in the UK (England), Germany, France, Spain, Italy, Czech Republic, Denmark, and Poland.

Table 2: Cellulosic ethanol potential and NREAP EU27 biofuel demand

Scenario	Agricultural Residue Potential (million tonnes/year)	Straw Potential (million tonnes/year)	Ethanol Potential from Agricultural Residues/Straw (billion litres/year)	Ethanol Potential (Ktoe/year)**
BNEF lower (2020) ¹	180		60	30,260
BNEF upper (2020) ¹	213		71	35,741
BNEF lower (2020) ¹		106	35	17,820
IEA lower ³ (2030) ²	90.3*		29	14,662
IEA upper ⁴ (2030) ²	225.7*		72	36,605
DBFZ & Oeko-Institut lower ⁵		50	5.5	2,781
DBFZ & Oeko-Institut upper ⁶		110	33.0	16,685
Estimated use	Biofuel (Ktoe)	Advanced Biofuel (Ktoe)	Advanced Ethanol (Ktoe)	Ethanol (Ktoe)
NREAP 2020	29,633	2,101	583	7,126

Source: Own compilation based on data from: IEA referring to Eisentraut (2010), BNEF (2010) and DBFZ and Oeko-Institut (unpublished). The figures on advanced biofuel use taken from the NREAPs (as compiled by Bowyer, 2011) refer to advanced biofuels as defined in Article 21(2) of the RED as *biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material*.

Notes: ¹ethanol potential projections based on a projected 2020 conversion factor of 350 litres of ethanol per tonne of biomass and assuming that 95 per cent of residues are available for biofuel production, the remainder being used as biomaterials; ²ethanol potential projections based on a conversion factor of 321 litres of ethanol per tonne of biomass; ³assuming 10% of residues are collected; ⁴assuming 25% of residues are collected; ⁵assuming a conversion factor of 110l/ton dry matter of straw; ⁶assuming a conversion factor of 300l/ton dry matter of straw*dry weight; **Conversion factors: 1l ethanol = .00079t; 1t ethanol = .64 toe.

2.3 Uncertainties in the availability of supply of agricultural residues

Taking this variability in the availability of cereal straw into account makes the calculation of biomass and energy potentials much more complex or even unfeasible particularly when trying to estimate potential supply at the scale of larger geographic regions. Another issue creating uncertainty is the variability in relation to changing crop use year on year. Changing market conditions, such as changes in crop prices and changes in trade flows, as well as changes in the policy framework can all impact on the amount and the type of cereals cultivated (and those available for use) in a region and hence affect the available supply of straw. Box 1 provides an example of straw shortages arising in a technically high-potential region because farmers switch to the cultivation of energy maize. Other issues discussed below affecting the availability of straw for ethanol production are the allocation of the agricultural residue potential across different uses, the use of straw for heat and electricity generation as well as the (future) use as a material input into other industrial processes, such as biochemical and other bioproducts.

Likewise, the allocation of the agricultural residue potential across different uses, both within and outside the agricultural sector is variable. In part this is determined by existing competing uses and these are explored in more detail in section 3.1. There are particular difficulties when trying to compare the proportions of straw needed, or indeed used for different purposes and in different sectors given the variability in different Member States. For example, the ploughing-in of straw accounts for as little as 11 per cent of the total straw resource in Poland, but 30 and 40 per cent of the total supply in England and the Czech Republic and as much as 60 to 70 per cent in France. For energy use the proportions of

straw available (ie not used for other purposes already, also see section 3.1) range from 17 per cent in the Czech Republic to 30 per cent in Poland and France. These estimates are based on a range of studies and through consultation with different national experts²⁰, but no individual studies have provided a consistent methodology to account for the relative proportions of straw either needed or used in different sectors.

Box 1: Technical versus economic potential – the example of Schleswig-Holstein

Schleswig-Holstein is a German Land (region) that has a rather high technical potential in terms of the use of cereal straw for bioenergy use, as shown by studies on potential conducted by the German Biomass Research Centre (DBFZ)²¹. However, in 2011 Schleswig-Holstein experienced straw shortages because of the rainy summer but also because farmers grow energy maize increasingly at the expense of traditional cereal crops. A recent TV report²² investigated this issue and interviewed local horse owners that experience difficulties buying straw for their horses and/or face high prices. Larger horse stables have even resorted to importing straw from Poland and Hungary. While this is a very German-specific example because of the particularities of favouring renewable resources as part of renewable energy policy, it does stress and illustrate the importance of distinguishing between technical and economic potentials of straw.

The use of straw for heat and electricity generation has the potential to develop into an important market across the EU and this could increase further the uncertainty about the amount of straw available for the biofuel industry. For example, the UK National Farmers Union (NFU) considers supplying straw to combustion plants more feasible at the moment. While the supply chain challenges are similar for ethanol producing plants, the scale of the challenge is typically larger, as straw burning plants can operate commercially on a smaller scale²³. The German farmers' association (Deutscher Bauernverband) is sceptical about ambitious plans for cellulosic ethanol production based on straw in Germany (the situation potentially being different in other European countries). This is because of the prevailing regulatory framework with strong support for using residues for renewable electricity production under the Renewable Energy Sources Act (Erneuerbare-Energien Gesetz, EEG). It is therefore likely that straw in Germany will increasingly feed biogas plants instead, with novel technologies developing in that market segment²⁴. Straw use in the energy sector is of particular relevance in Denmark with a long history of using straw for power generation. According to industry representatives from DONG Energy, who offer energy services including both power generation and cellulosic ethanol production, this is not seen as a competition that is harmful for the biofuel industry, as straw supply is sufficient to meet the demand from both biofuel and power plants. Around one million tonnes of wheat straw are

²⁰ Sources include Scarlat *et al* (2007); Pointereau, *pers comm*; Clarke, *pers comm*; Weger, *pers comm*; Sergej Ustak, *pers comm*.

²¹ <http://strohpotenziale.dbfz.de/>

²² From NDR Fernsehen, 'Die fatalen Folgen des Biogasbooms', *Menschen und Schlagzeilen*, 18 October 2011.

²³ Jonathan Scurlock, NFU, *pers comm*.

²⁴ Cecilia Luetgebrune, Deutscher Bauernverband, *pers comm*.

used for heat and electricity generation in Denmark currently. Partly straw is burned in coal co-firing plants and since coal firing is meant to decrease as part of Denmark's renewable energy and climate policies, this would free up future resources for enhanced use in biofuel plants.

Finally, it is unclear how much straw will be used as a material input in other industrial processes such as the emerging bio-materials and bio-chemicals sectors. For example, the assumption in BNEF (2010) that 95 per cent of available biomass is used for ethanol and the remainder for biochemical production could turn out to be unrealistically high in the framework of an increased focus on the bioeconomy²⁵.

²⁵ In this context note the recent Communication of the European Commission: Communication COM(2012) 60 final from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 13.2.2012 on 'Innovating for Sustainable Growth: A Bioeconomy for Europe'.

3 ENVIRONMENTAL CONSIDERATIONS FOR USING STRAW AS A BIOENERGY RESOURCE



This section considers the impacts of using straw for biofuel production on the other existing uses of straw in the agricultural sector. It reflects on the potential environmental implications this might entail, particularly in relation to soil organic matter, as well as taking into account the anticipated environmental benefits in the form of reduced greenhouse gas emissions from replacing fossil fuel use, considering how advanced biofuels compare to conventional biofuels in this respect.

3.1 Current uses of straw and environmental effects of increased competition

One of the main factors influencing the uncertainty in estimating the potential availability of straw for use in bioenergy production is the degree to which existing uses compete for this resource. This is not only an important consideration in terms of supply but also in terms of the impact that a diversion of straw to the energy sector could have on these existing uses and any associated environmental impacts that might ensue.

3.1.1 Current uses of straw in the EU

For centuries straw has been a widely available agricultural resource generated as a by-product of the cereal harvesting process. During this time it has been utilised for a number of different applications ranging from a short-term supplementary fuel source, as a source of livestock bedding to its use for building materials (either bales, or applied to mud to make cob bricks, or as thatching). Over time these uses have transformed this agricultural residue into an important agricultural resource in demand for a range of applications.

Today the most common uses of straw in the EU are for animal bedding (and in some cases supplementary livestock fodder), as a soil improver (through the ploughing-in of straw to increase organic matter and build soil structure), and as mulch for use in vegetable production (acting as frost prevention) and mushroom production (as a growth substrate). Table 3 outlines some of the conventional uses of cereal straw both within and outside the agricultural sector together with their conventional alternatives.

Table 3: Examples of the main conventional uses of cereal straw

	Use	on/off site	Alternative
Uses within the agriculture sector	Soil improver	ON	Manure, commercial (fossil fuel based) fertilisers, green manure and cover crops
	Animal fodder supplement	OFF/ON	Hay, silage, commercial feed, out grazing
	Animal bedding	OFF/ON	Sawdust, wooden slats, other dried plant residues.
	Mushroom production (growth substrate)	OFF	Compost, sawdust, other lingo-cellulosic material
	Frost prevention in horticulture	OFF	Limited commercial alternatives, plastic sheeting is used, but still requires some straw
	Strawberries (preventing damage to fruit)	OFF	Matting or plastic sheeting
	Compost industry	OFF	Wood chip, other plant fibre with low nitrogen content
Outside the agriculture sector	Thatching	OFF	Straw thatching is locally specific. Reeds are a common alternative
	Traditional building materials (combined with mud to make cobb bricks, used as insulation, or combined with wood chippings to make fibreboard.)	OFF	Alternatives include all common building materials.
	Energy (heat and power, fuels)	OFF	Other combustible residues depending on boiler structure / other biofuel feedstocks

Source: Own elaboration based on a review of existing literature and interviews with national experts.

Note: Off and On site represents the prevailing trend in the EU - the actual proportion used on and off site will vary with farm type.

As elaborated in section 2, it is difficult to quantify the proportions of straw available to the different uses as these vary between years as well as within and between Member States. Indeed a number of uses are interlinked, such as the use of straw as livestock bedding, which then becomes gathered with manure and composted before being applied back to land as a soil improver.

One of the most common uses or markets for straw is in the **livestock industry**, mostly as a form of bedding but also as a feed supplement during the winter or in times of reduced availability of other higher nutrient value food (Edwards *et al*, 2005). Straw is not only a convenient bedding material for animals given its availability, but it plays an important factor in the welfare of farmed animals and its use is embedded in EU legislation under

Council Directive 91/630/EEC²⁶ which requires that *'pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust...'*. Examples of how these requirements are translated into national law are shown in Box 2.

Box 2: Example of animal welfare guidelines in England

In England the welfare of farmed animals regulations (Statutory Instrument 2007 No. 2078) require that comfortable, adequately drained, dry bedding must be available at all times. This does not have to be straw and can include fine woodchip and sawdust as alternatives. Supplementary guidance (The Department for Environment Food and Rural Affairs (Defra) cattle code guidelines (Defra, 2003)) suggests appropriate uses of straw, not only as bedding (straw yards for dairy herds where appropriate, and the changing of straw daily) but also as roughage in the animals' diet.

A similar requirement exists in Denmark which requires rooting and manipulable materials to be available to pigs. Under Danish legislation, pens must be provided with straw or other materials to satisfy the pigs' rooting and foraging requirements.



The welfare-friendly image of farm animal housing systems using straw is largely supported by the scientific literature, however the benefits and necessity to different livestock types varies (Tuytens, 2005). The use of straw for bedding, rooting²⁷, and feed has been demonstrated to be particularly important for pigs, and to lesser extent cows, where other alternatives provide only some of these benefits (Tuytens, 2005). Traditionally, when mixed farming was the predominant farming system, the straw harvested from cereal production would have been utilised on-farm for livestock as still happens in mixed farming systems today. However following the specialisation of agricultural production there is often a geographical disconnection between where straw is produced and where it is needed (Box 3).

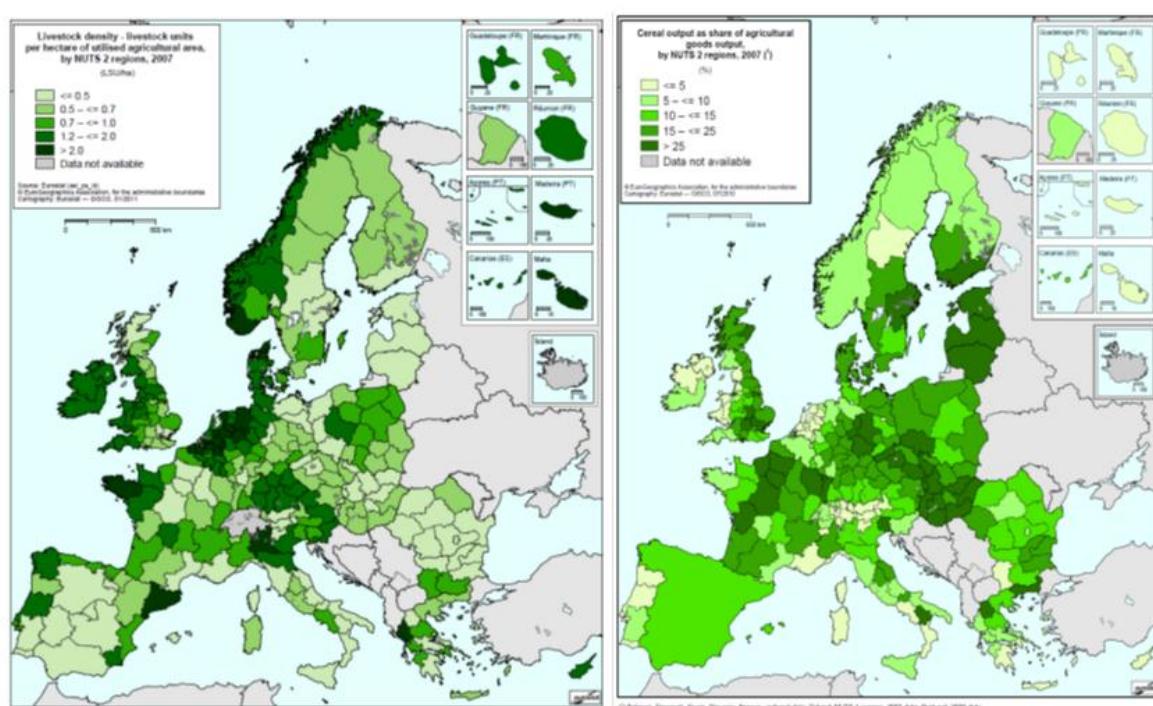
²⁶ COUNCIL DIRECTIVE of 19 November 1991 laying down minimum standards for the protection of pigs as amended

²⁷ Straw facilitates the natural desire of omnivorous animals such as pigs to forage through natural vegetation.

Box 3: Structure of agricultural production in the EU

Over time there has been an increase in the specialisation of agricultural practices with a separation of those farms that produce crops and those that produce livestock. This specialisation has occurred to differing degrees both within and between Member States and has led, not only to a separation in production, but also in the utilisation of straw. In addition, the livestock sector in a number of different areas within the EU has declined in favour of arable farming where this has been economically more productive. This has been particularly noticeable in the EU12. For example, by 2004 in Poland the share of cereals had increased to 75 per cent of UAA (from 54 per cent in 1985). In comparison, by 2002 45 per cent of all farms had no livestock. With this specialisation of farming the source of straw for many agricultural uses is rarely on-farm, confined only to smaller, mixed or organic/integrated farms. The majority of livestock farmers rely on the buying-in of straw produced on arable farms often over considerable distance.

Difference between dominant livestock and cereal production areas in the EU:



Left = Livestock density, Right = Cereal output

Source: Livestock density - livestock units per hectare of utilised agricultural area, by NUTS 2 regions, 2007 (LSU per ha) - Source: Eurostat (aej_ps_ld)

Cereal output as a share of agricultural goods output by NUTS2 regions, 2007 – Source: Eurostat

Although in many cases straw is the preferred choice for bedding and is still widely used in the livestock industry in many parts of the EU, alternatives are available, such as sawdust, wooden slats, other dried vegetative material, or more modern equivalents such as synthetic matting. The volume of straw use per head of cattle is estimated to be on average between 0.1 and 2 tonnes per year (Edwards *et al*, 2005, Scarlat *et al*, 2008). Its use for this purpose, however, is highly variable and depends particularly on the different types of livestock production (for example whether cattle are out wintered, whether grazing takes place in lowland or upland areas etc) and differs from year to year depending on stock numbers. Changes in the way livestock are managed is another determinant of straw use

within the livestock sector. For example, an increasing proportion of manure management in Denmark is based on slurry, which does not use straw (or only in limited amounts)²⁸.

In certain Member States, the use of straw as a soil improver is particularly important, driven by reduced capacity to source other types of soil improvers. For example, in the Czech Republic around 30 - 40 per cent of straw is utilised in this way due to the significant decrease in the livestock industry that has led to a reduction in the availability of animal manure, combined with the relatively high cost of chemical fertilisers²⁹. A similar situation is apparent in Slovenia, where the incorporation of straw into soil is necessary to build better soil functionality on particularly poor soils (Scarlat *et al*, 2008). In addition, these Member States commonly use pig slurry and cattle liquid manures as fertilisers and the addition of straw to these high nitrogen inputs helps provide a more balanced carbon to nitrogen ratio (which has also been demonstrated to increase yields). The addition of straw in this way can also act to lock in excess nitrates at the end of a harvesting cycle to prevent leaching into water courses (particularly important in Nitrate Vulnerable Zones) and provide increased fertilisation towards the beginning of the following season. However, factors which affect the breakdown of straw fibres such as the amount of soil moisture, nitrogen content and temperature, can limit how much straw can be incorporated within an annual rotation. As a consequence of these limitations, it is common for farmers, particularly in southern and eastern Member States to incorporate straw into the soil in only two out of three years.

Despite the common use of straw as a soil improver and the importance of this role in many Member States, a range of widely available alternatives exist, including conventional fertilisers, manures and composts. However, the substitution of fossil fuel derived fertiliser for straw, if this were triggered by increased usage of straw for energy purposes would challenge the environmental viability of straw derived biofuels and long term sustainable soil management.



*Cereal straw used for frost prevention in horticulture.
Mundesley, Norfolk, UK*

There are some uses of straw which at present have very limited alternatives and where the use of straw supply is a key component of agricultural production. Examples include its use as a growth substrate in **mushroom production** and as a frost protection measure in **vegetable growing**. Although the proportion of straw used in these industries is relatively small in comparison to that used in the livestock sector, for example, the fact that there are currently few alternatives (if any) for providing these functions, makes it a particularly

²⁸ Jørgen E. Olesen, Faculty of Agricultural Sciences, Aarhus University, *pers comm*.

²⁹ Jan Weger, *pers comm*.

valuable resource in these two sectors. In addition the economic value of the produce from the horticulture and mushroom industries is considerable. This, and the lack of alternatives, implies that the producers' demand for straw is likely to be less price sensitive than in other sectors.

Beyond the defined end uses for straw as outlined above, there are some situations where a surplus of straw exists. This tends to happen under the following circumstances:

- where there is a lack of technical capacity to incorporate the straw into the soil;
- where soil incorporation limits have been reached;
- where the use of straw in the soil is not required (for example existing high organic matter content); or
- where the straw is not demanded by, or cannot be supplied to other sectors.

'Surplus' straw is frequently considered by farmers as a burden and is either collected and left at the edges of fields, or burned. Quantities of excess straw tend to be more prevalent in Southern and Eastern Europe, where the risks of over-incorporation of straw into the soil to long-term soil fertility are generally higher (Edwards *et al*, 2005). On those farms where there is the ability to incorporate straw, ploughing-in is seen as an effective means of disposing of this surplus and is relatively low cost where technical capacity exists. The means of disposal of surplus straw is largely decided at the Member State or regional level with restrictions placed on certain activities. One of the traditional and more convenient approaches to removing straw is through burning. However the burning of straw and stubbles has been banned in most Member States³⁰ under compulsory Good Agricultural and Environmental Condition (GAEC)³¹ standards as applied under the CAP. Some Member States also ban straw and stubble burning under national legislation. For example in Denmark straw burning has been banned since 1991 and in England straw burning (of a significant scale) was banned under the introduction of the Crop Residues (Burning) Regulations (Statutory Instrument 1993 No.1366). Such restrictions on the use of straw provide an added incentive for its incorporation into the soil or used for other farming purposes.

It is the quantities of this 'surplus' straw that are of particular interest to new and emerging markets, however estimating the volume of this surplus is problematic given the need to take into account a combination of situations where there is a genuine need as well as where it is used simply for convenience (see Table 3) (for example Panoutsou *et al*, 2009; Edwards *et al*, 2005). Some factors driving the use of straw can be quantified, such as the requirement for increased soil organic matter in particularly vulnerable soils or the requirements of livestock producers, yet other factors such as farmer attitudes and supply chains are much more subjective. A number of these factors will be discussed further in section 4.2.

³⁰ Only four Member States do not impose a ban on the burning of arable stubbles under cross compliance GAEC standards - Cyprus, France, Ireland, and Slovenia

³¹ GAEC standards related to soil are laid down in Annex IV to Regulation (EC) No 1782/2003

This section has highlighted that cereal straw is already widely used for a range of purposes in the EU and it is generally accepted that the existing agricultural resources, soil characteristics, site conditions and different agricultural farming practices should be taken into account when considering the removal of straw for bioenergy production (for example Scarlat *et al*, 2010; Scarlat *et al*, 2008; D'Allemand, 2007). The diversion of straw for other purposes, including the production of biofuels, should also take account of the impact on such uses and any resulting environmental implications that may ensue.

3.1.2 Environmental Impacts of using straw for the production of biofuels

This section builds on existing work in this area and provides a summary of the impacts on the environment of mobilising straw for use outside the agricultural sector. The previous section identified the main existing uses of cereal straw within the EU. Although the large scale diversion of straw from these uses would have impacts, not all will have environmental implications. The main direct environmental impacts of extracting straw from agricultural areas are the reduction in soil functionality and the potential impacts on fauna resulting from modifications to stubble heights and straw management *in-situ*. Indirect effects of straw removal are seen in respect to potential intensification or expansion of cereal cultivation, the use of alternative chemical soil improvers and indirect land use change due to expansion of production.

One of the most common uses of straw in the EU is the ploughing-in of cut straw following the cereal harvest to help maintain soil functionality³². The straw used for this purpose is generally sourced on-farm, with no evidence suggesting that straw is sold or supplied to other farms to meet this need. It is generally recognised that the maintenance of straw (or any agricultural residues) on or within the field is an important factor in maintaining soil organic matter. For example Ericsson and Nilsson (2006), in their review of potential biomass supply in Europe suggest that, as a general rule, only part of the residues should be harvested for bioenergy use to avoid depletion of organic matter in the soil and thus to ensure long-term productivity (supported by Börjesson, 1996; DBFZ and Oeko-Institut, unpublished).

Recognition of the role of straw in improving soil organic matter is an important consideration to ensure that any increase in straw extraction does not occur in places where this would substantially reduce sequestration from the ploughing-in of straw, particularly given that this loss in sequestration potential would challenge the low carbon nature of bioenergy derived from straw (see also EEA Scientific Committee, 2011).

A recent report for the European Commission on soil organic matter management (Gobin *et al*, 2011) analyses the effect of different management systems on soil organic matter in the EU. The study looks at the use of crop residues and straw for bioenergy purposes *inter alia*.

³² Soil functionality can be described in relation to a range of parameters that enable the continued ability of soil to function naturally. These parameters include the proportion of organic matter, the level of susceptibility to erosion by wind and water, the soil's structure and capacity for infiltration, the health of its biota and its level of contamination (JRC, 2009).

In particular, extraction rates of 30 and 50 per cent, as well as an extreme scenario of 100 per cent residue extraction, are compared to a business as usual (*bau*) extraction of 10 per cent of crop residues. The residues considered are cereal straw, oilseed straw and sugar beet residues. Based on a range of input data including crop yields as well as climatic conditions, humified organic carbon content (ie stable soil organic carbon) is estimated. The results for cereal straw show that with 30 and 50 per cent extraction, humified organic carbon is, respectively, seven and 21 per cent lower than in the *bau* scenario. The study shows that leaving straw in the field compared to extracting it completely can double the humified carbon input to soils. The largest absolute effects from incorporating (and removing straw) are found in those countries characterised by high yields. The fact that the effects are regionally distinct means that establishing minimum shares of residues to be incorporated in the soil (discussed further in Section 5) could not be established at the EU level and would need to be based on regional bio-geographic characteristics (Gobin *et al*, 2011; DBFZ and Oeko-Institut, unpublished). Box 4 shows the benefits of using crop residues to improve levels of soil organic matter.

Box 4: Crop residue management and soil organic matter levels in Jutland (DK)

A recent soil management study commissioned by DG Environment (Gobin *et al*, 2011) includes a case study set in Denmark on crop residue management. In particular, the case study evaluates the effects of different crop residue management options on soil organic matter levels in Jutland. The study uses barley field trials, conducted over a period of 30 years. It finds evidence for positive effects of straw incorporation on soil carbon content. This finding holds for a range of different soil types and the effect amounts to ‘an average increase in soil carbon storage of 13 per cent (over a 30 year period)’, based on an annual straw incorporation of four to five tonnes per hectare. It was found that straw incorporation combined with catch crop use increases soil organic matter further.

The conclusions reached in this case study stress the need to take into account implications for SOM when making decisions about the most environmentally beneficial use of straw. Above all they highlight the need to source ‘real’ surplus straw, ie straw from areas where additional incorporation does not provide additional benefits to soils.

Source: Gobin et al, 2011, Annex II

As with livestock requirements, the degree to which straw is ploughed back in to the soil varies in different parts of the EU, between farm type and size and for a range of different reasons (including soil types). The practice tends to be more prevalent in those areas where there is a high level of technical capacity³³, often on larger more specialised farms with the machinery and ability to incorporate straw into the soil³⁴. Mixed and organic farms with on-site livestock have the ability to utilise straw for both animal bedding and as a soil improver, with the preferred option being to incorporate animal manure, combined with straw for added fertilisation and structure benefits, into the soil. Farms operating integrated

³³ Javier Calatrava, *pers comm*, and Andrea Povellato, *pers comm*.

³⁴ In some cases, for example small traditional farms in Spain, the lack of machinery, or the cost to contract in machinery can prevent the ploughing-in of straw. In Italy where there are good networks/cooperatives for machinery use the ploughing-in of straw is more common, even on smaller farms.

production systems (with or without livestock) may be required to incorporate straw under certain certification systems or as a condition of support provided through measures within Rural Development Programmes³⁵. Outside of integrated management certain agri-environment schemes have similar requirements including the ploughing-in of crops and stubbles and or straw residues. These requirements tend to be confined to Mediterranean Member States particularly Spain and Italy where soil organic matter content is lower than the EU average and soil erosion issues predominate³⁶ however examples are also found in Poland and other more northern Member States.

In addition to ploughing-in of straw and residues there are also significant environmental benefits that result from leaving the cut residues on the surface of the soil. These include increased water infiltration and decreased evaporation; reduced soil erosion from wind and water; more stable soil temperatures and more humid soil surface conditions, all of which could help to maintain soil fauna and biological activity in the soil. Erosion and soil humidity considerations do not necessarily impose an additional constraint on straw extraction as long as SOM maintenance is ensured. DBFZ and Oeko-Institut (unpublished) found that the amount of straw needed for erosion protection as well as for humidity regulation would not exceed that needed for maintaining SOM levels (based on average assumptions). In addition, there are a variety of other means of reducing soil erosion such as the use of continual cover crops, particularly green cover over the winter period, some of which are already supported through agri-environment schemes. However, an increase in early ploughing of stubbles to develop green cover crops would probably have significant detrimental impacts on species that benefit from the sparse cover and availability of spilt grain and other plant seeds (such as many declining farmland birds).

Apart from the aforementioned environmental hazards with regard to reducing the amount of straw incorporated back into the soil, intensified straw extraction could also lead to an increase in the use of alternative soil improvers with potentially adverse consequences. While alternatives such as compost, (green) manure and cover crops are available, the use of chemical improvers could have greater adverse implications for water quality through the effect of diffuse pollution.

Investigating the biodiversity impacts of straw extraction, one question frequently raised is the impact on farmland birds. A potential concern is a reduction in stubble height that could reduce cover for small farmland birds and therefore increase their predation risk. However, it should be remembered that such changes would not affect vulnerable nests and chicks in the breeding season, and predation by diurnal birds of prey in winter is probably not a cause of mortality in most farmland birds. Therefore, changes in stubble height induced by straw extraction for bioenergy feedstocks are unlikely to have a significant impact on populations

³⁵ For example according to the Guidelines for Integrated Crop Management (ICM, part of Slovenian Environmental Programme in Agriculture), where the humus content of the soil is lower than 1.5 per cent the straw must be incorporated and can not be taken off site or disposed of through burning.

³⁶ Examples are found in Italy (Campania, Emilia Romagna, Sicily, Toscana, Umbria, Veneto), Spain (Balearic Islands, Basque Country, Castilla y Leon, Galicia, Madrid, Castilla la Mancha, Valencia).

of farmland birds. The impacts on some farmland birds could furthermore be mitigated to some extent by an increased planting of cover crops as part of an optimised crop rotation that provide alternative winter fodder ground for birds.

There is also little evidence that straw extraction would have negative impacts on soil biodiversity such as on invertebrates and invertebrate feeders, even though soil organic matter is a critical component of the soil habitat. By providing resources in the form of nutrients available to plants, it often constitutes hotspots of soil activity and is fundamental in maintaining fertile and productive soils (Tiessen, Cuevas *et al*, 1994; Craswell and Lefroy, 2001, as cited in Turbé *et al*, 2010). However, soil biota are also influenced by a wider range of factors including climate, temperature and moisture, soil texture and soil structure, salinity and pH and it is therefore difficult to establish a direct causal link between soil biota and the extraction of straw residues, an area that requires further research.

Beyond the direct implications of straw extraction for the environment, there are a number of indirect impacts that could result from an increased use of straw for energy purposes. These are impacts associated with a potential market driven increase in cereal cultivation either through intensification of the current area or expansion into other areas. The expansion of the cropped area brings with it consequences for other land uses that can be environmentally damaging, for example where this result in the ploughing up of biodiversity-rich grasslands. Expansion, particularly into current cropland, also has potential indirect land use change (ILUC) effects on other land cover types. The impacts of increased intensity of agricultural production are well documented³⁷. No studies exist currently, however, that have modelled the potential for increased straw use to trigger ILUC by increasing wheat production. For straw to become the driver of land use change, a switch in co- and main-product between straw and grain would have to occur, something that seems rather unlikely currently.

3.2 Reviewing lifecycle balances of different biofuel pathways

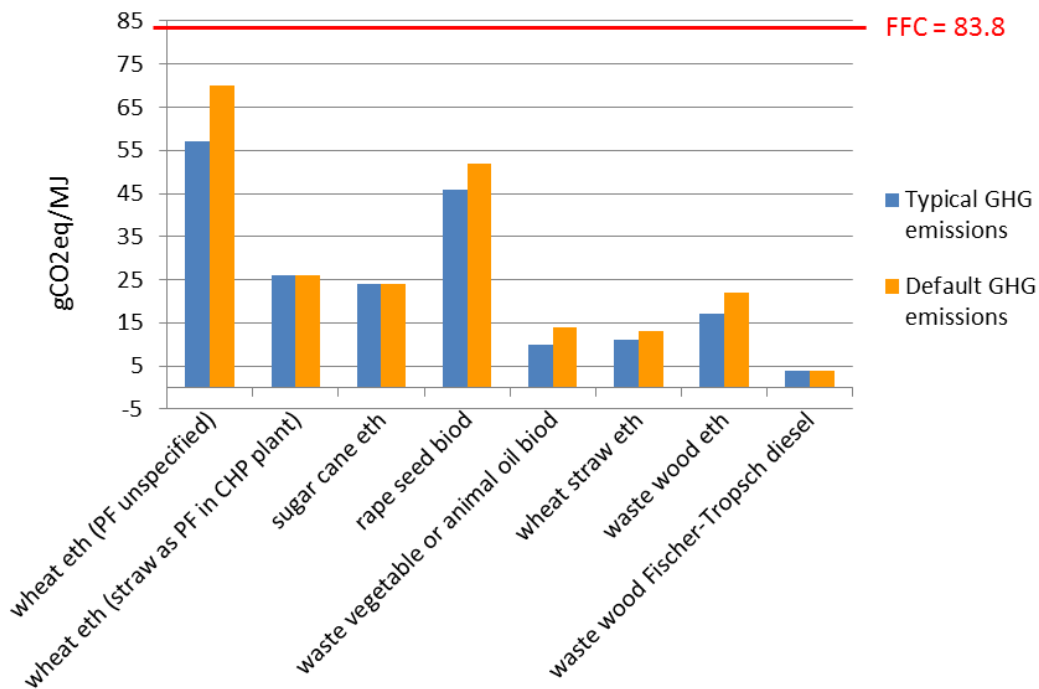
One of the main reasons for promoting advanced biofuels is that greenhouse gas emission savings vis-à-vis fossil fuels are anticipated to be higher than the potential savings achieved by conventional biofuels. Figure 4 represents typical and default lifecycle emissions for selected conventional and advanced biofuel pathways, as contained in Annex V of the Renewable Energy Directive³⁸, assuming no land use change takes place. According to the estimated values contained in the RED, wheat straw ethanol has relatively low lifecycle emissions and therefore, where it is used to replace fossil fuel, is estimated to provide emission savings of around 85 per cent, using the fossil fuel comparator used in the RED. These savings significantly exceed those associated with the use of wheat to produce

³⁷ See for instance Baldock *et al*, 2010; Hart *et al*, 2011; Tester and Langridge, 2010; Royal Society, 2009; Gantioler *et al*, 2008 and EEA, 2006.

³⁸ The terms 'typical' and 'default' are defined in the Renewable Energy Directive as follows: Typical value 'means an estimate of the representative greenhouse gas emission saving for a particular biofuel production pathway' (Article 2(n)). Default values incorporate conservative assumptions compared to normal, or typical production processes (Article 19(7)(b)).

ethanol (based on conventional processing) which are calculated to be 32 per cent and even those from wheat ethanol produced by using straw as a process fuel in an efficient combined heat-power plant (69 per cent).

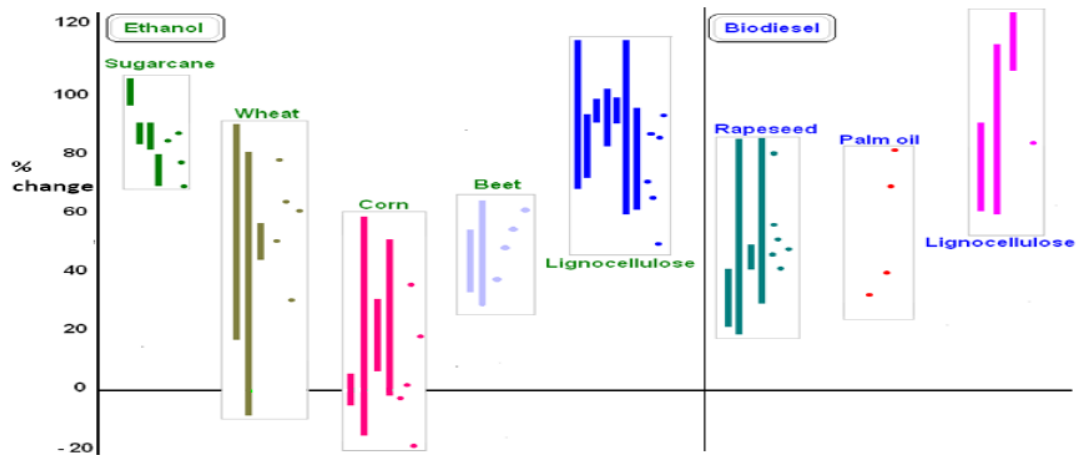
Figure 4: Emissions from cultivation, processing, transport and distribution of selected conventional and advanced biofuel pathways.



Source: RED Annex V. Notes: 'PF' process fuel, 'FFC' fossil fuel comparator. The last three pathways are advanced pathways 'that were not on the market or were on the market only in negligible quantities in January 2008' according to the RED Annex V and hence represent estimated values.

The case for advanced biofuels over conventional biofuels is demonstrated in several reviews of existing life-cycle analysis (LCA) studies (Figure 5). A caveat, however, is that while LCAs for conventional biofuels are much more established, given the existence of an established industry and hence of historic data, the LCAs for advanced biofuels are based on 'theoretical biofuel production concepts that are only just at the pilot/demonstration stage and not yet operating on a commercial scale', which increases the uncertainty surrounding their results (Eisentraut, 2010, p80, referring to OECD, 2008).

Figure 5: Comparison of well-to-wheel emission changes of different biofuels compared to fossil fuels



Source: IEA, 2008c based on IEA and UNEP analysis of 60 published life-cycle analysis studies giving either ranges (shown by the bars) or specific data (shown by the dots).

Source: from Eisentraut, 2010, p80

One important aspect to consider that could lead to rendering the GHG balance of cellulosic biofuels less favourable are emissions from changes in soil carbon stocks due to straw removal, discussed in section 3.1.2 above. This issue is not taken up in the RED, which considers agricultural residues to be zero emission up to their collection, an assumption that is not appropriate given the potential impacts of straw removal on soil carbon stocks³⁹. At the same time, an increased use of straw would transfer other sustainability concerns that are currently valid for conventional fuels to advanced fuels. As Cherubini *et al* (2009) point out, the substantial savings that can be achieved by advanced biofuels produced from residues may be weakened when the marketing of the residue increases the economic attractiveness of the main activity. A subsequent expansion of wheat cropping, for example, could occur with potential direct and indirect land use change effects. While it seems rather unlikely currently that straw becomes the driver of land use change, as pointed out in the previous section, such land use effects are not well understood as yet and therefore a proper, integrated understanding of the environmental effects of advanced biofuels is lacking, as Sims *et al* (2008) point out, noting that ‘understanding land use change issues is as important for 2nd technologies as it is for 1st generation’ (p34).

Another important determinant of the greenhouse gas performance of conventional biofuels is whether or not co-products are taken into account. Co-products, such as dried distillers grains with solubles (DDGS) from wheat or corn ethanol and oilseed cake from biodiesel production, are valuable animal feed or can alternatively be used for energy

³⁹ RED Annex V, part C, paragraph 18 states that ‘[wastes], agricultural crop residues, including straw, ... shall be considered to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials.’ However, DBFZ and Oeko-Institut (unpublished) point out, SOM is addressed indirectly in RED for at least EU derived residues by referring to the cross compliance requirements under the CAP that include measures to maintain soil organic matter levels (RED Article 17(6)).

generation, as is typically done with sugar cane bagasse, a residue from sugar cane processing. The production of co-products reduces the amount of process energy attributed to biofuel production and/or reduces the need for the cultivation of animal feed that might otherwise have taken place, thereby reducing emissions associated with these activities. Whitaker *et al* (2010) compare LCA studies that account for co-products with those that do not. They find that their inclusion reduces average GHG emissions for all conventional biofuel chains by up to 50 per cent for wheat ethanol. Including co-products consequently appears to reduce the GHG emissions difference between conventional and advanced biofuels, although it does not close the gap entirely⁴⁰.

The same study shows also the effects of applying different methods of allocating lifecycle GHG emissions between the main product and co-products, which include methods based on energy content, economic value or system expansion (Whitaker *et al*, 2010). A key issue in this regard, important for determining the lifecycle balance of straw ethanol (as well as other biofuel pathways based on residues/by-products), is the question of whether straw is treated as a residue or by-product from crop cultivation and the consequences of this for the allocation of GHG emissions from the crop cultivation stage. In the RED, which follows an energy allocation method, agricultural residues including straw are *excluded* from this allocation, ie emissions from cultivating wheat are not split between wheat output and straw yield. Doing so would allocate an excessively large share of cultivation emissions to the main product wheat and hence would reduce or even reverse the beneficial life-cycle emissions of straw ethanol.

Allocation based on economic value or system expansion would be more suitable. An economic value allocation would change with the market conditions of straw: if straw were increasingly used as an energy source, its price and hence economic value would rise. The distinction between main activity and co-product in wheat cultivation would consequently cease to be clear cut, and straw would appropriately be allocated a larger part of cultivation emissions. The system expansion approach implies that the lifecycle analysis would take into account the effects of co-products, such as use for animal fodder, as well as the effects of straw extraction on soil carbon⁴¹. Although such effects are locally specific and therefore difficult to deal with in generic LCA studies, they are nevertheless important considerations that should be taken into account. Such an approach would go beyond the considerations set out in the RED currently and take into account the full implications of straw extraction both pre and post collection.

⁴⁰ For second-generation biofuels, the use of waste lignin for generating process heat and electricity is included by all studies reviewed in the first place (Whitaker *et al*, 2010).

⁴¹ Whitaker *et al* (2010) explain the three approaches of including co-products in LCA studies as follows: 'In energetic and economic allocation, the energy requirements and GHG emissions are allocated between the main product and coproducts either by energy content [energetic (or physical) allocation] or economic factors (economic allocation). With system expansion (also known as substitution), the products which are potentially substituted by the coproduct are included within the analysis, and the energy and GHG emissions saved by substitution are calculated as a credit' (p102).

4 BUILDING STRAW SUPPLY CHAINS



The preceding sections have ascertained that there is a certain proportion of surplus straw available, albeit varying significantly in different parts of Europe and year to year, and that this surplus could be used to supply biorefineries. This section considers the opportunities for harnessing this potential as well as the barriers that exist in the straw supply chain that constrain the use of cereal straw for bioenergy production. A number of potential solutions for overcoming these barriers are also discussed.

4.1 Prevailing plant structure and sourcing patterns

The production of advanced biofuels, including cellulosic ethanol, is not well advanced in the EU. As the NREAPs have demonstrated, advanced biofuels are not expected to play a major role in the share of liquid fuels in 2020, if current projections provided by Member States are met (see for example Bowyer, 2011 for NREAP projections). Indeed, advanced technologies remain largely at the developmental stage, with the focus to date being on the development of pilot and demonstration scale plants, with only five plants constructed on commercial scale (Eisentraut, 2010; Bacovsky *et al*, 2010).

The IEA Bioenergy Task 39 ‘Commercializing Liquid Biofuels’ has gathered data on advanced biofuels demonstration facilities at a global level and has identified 66 projects currently being pursued and note that ‘only few facilities in the demonstration scale are actually operating’ (Bacovsky *et al*, 2010). An online database has been developed, which maps biorefinery plants (in commercial operation, pilot or demonstration stage or under construction) as well as commissioned projects along with a range of other information, for example on the scale of the different projects and the type of conversion technology used⁴².

Table 4 summarises the information on the total number of advanced biofuel plants in the EU. With regard to different conversion technologies, biochemical processes prevail over thermochemical and ‘other innovative’ processes⁴³.

⁴² <http://biofuels.abc-energy.at/demoplants/projects/mapindex>

⁴³ Other innovative processes include the conversion of oils/fats into biodiesel, biobutanol production, advanced biogas production technologies and microwave technology to produce biodiesel.

Table 4: Total number of advanced plants in the EU

Technology	Commercial	Demonstration	Pilot	Total
Biochemical	1	5	8	14
-out of which use straw	0	5	8	13
Thermochemical	1	2	6	9
Other innovative	3	2	0	5
Total	5	9	14	28

Sources: <http://biofuels.abc-energy.at/demoplants/projects/mapindex>. Status options considered: announced, under construction, under commissioning, operational, on hold (plants that are 'planned' disregarded).

According to the database those plants that use straw as a feedstock include 13 biochemical plants and three using other processes. All of these plants are at the pilot or demonstration stage, with raw material inputs ranging from 200 to 35,000 tonnes per year, although one plant operates on a much larger scale, with a raw material input of 180,000 tonnes per year. This is the M&G Chemtex plant in Italy that has since become the first commercially operating plant currently being established (for a detailed table see Annex I, based on the same source as Table 4 that still labels the M&G plant as demo at the time of publication)⁴⁴.

As a result, there are few test cases for advanced biofuel production from straw on a larger scale. Typical plant sizes, focussing on the use of ligno-cellulosic material derived from energy crops rather than cereal straw, are set out in Table 5. The table gives an idea about the scale of biomass inputs required relative to fuel outputs, although this ratio would appear to be higher in the case of straw input, with feedback suggesting that much higher volumes of straw are needed to produce a litre of ethanol (see below). The data on truck movement and land area required can be considered to be rather sensitive to the choice of feedstock (ie dedicated energy crops versus residues use) and hence difficult to apply to the assessment of straw supply chains in the present study.

⁴⁴ The European Commission's European Bioenergy Industrial Initiative (EIBI) aims to bring forward demonstration and flagship projects for a range of advanced bioenergy value chains by establishing public-private partnerships. The implementation of the initiative was kicked-off by a Call for Expression of Interests (Eoi), which provides some more data on where the industry stands currently. A total of 53 Eois were submitted, out of which 26 for flagship plants, defined as 'the first commercial units of value chains operating at an economically viable scale'. Out of the 53, 17 were found compliant with EIBI criteria, out of which 10 flagship initiatives. <http://setis.ec.europa.eu/newsroom/library/setis-presentations/EIBIExpressionofInterestAnalysesreport.pdf>

Table 5: Typical scale of operation for various 2nd generation biofuel plants using energy-crop based ligno-cellulosic feedstocks

Type of plant	Plant capacity ranges, and assumed annual hours of operation	Biomass fuel required. (oven dry tonnes / year)	Truck vehicle movements for delivery to the plant	Land area required to produce the biomass* (% of total land within a given radius)
Small pilot	15 000-25 000 l/yr 2000 hr	40-60	3-5 / yr	1-3% within 1 km radius
Demonstration	40 000-500 000 l/yr 3000 hr	100-1200	10-140 / yr	5-10% within 2 km radius
Pre-commercial	1-4 Ml/yr 4000 hr	2000-10 000	25-100 / month	1-3% within 10 km radius
Commercial	25-50 Ml/yr 5000 hr	60 000-120 000	10-20 / day	5-10% within 20 km radius
Large-commercial	150-250 Ml/yr 7000 hr	350 000-600 000	100-200 / day and night	1-2% within 100 km radius

* The land area requirement would be reduced where crop and forest residue feedstocks are available.

Source: Sims et al, 2008, p41, own reformatting.

In addition to the information drawn from the literature, additional information on plant sizes was collected from interviews with industry representatives. This provides information on three different plants in Germany, Denmark and Italy of different sizes and in different stages of development:

- *Süd Chemie (Germany)*: According to Süd Chemie, the appropriate size for cellulosic ethanol plants, given farm structures and residue availability in the EU and the nature of their technology, is in the range of 50-55,000 t/year output (or 63-69 million litres⁴⁵), demanding around 250,000 t/year straw input. Assuming a transport radius of 40km around the plant, straw would need to be sourced from 10 per cent of that area (this is under the assumption that account is taken of soil organic matter and competing uses)⁴⁶.
- *DONG Energy (Denmark)*: Their current demonstration plant uses 30,000 t/year of raw material input (mainly wheat straw); a commercial plant would be much bigger than this - in the range of 300-500,000 t/year (yielding 60-100 million litres ethanol given current technologies). It is believed that smaller plants could be viable in some instances, but 50 million litres are considered a minimum level of output necessary for viability⁴⁷.
- *Chemtex, M&G Group (Italy)*: A demonstration plant is being built in Crescentino in Piedmont, with a capacity of 40,000 t/year (or 50 million litres⁴⁸) output and an

⁴⁵ Converted based on an average density for ethanol of 0.79g/ml.

⁴⁶ Jochen Gerlach, Süd Chemie, *pers comm*.

⁴⁷ Representatives from DONG Energy, *pers comm*.

⁴⁸ Converted based on an average density for ethanol of 0.79g/ml.

associated feedstock requirement of approximately 180,000 t/year. This is believed to be a suitable scale for which the feedstock requirement can still be supported by a short supply chain (actual radius depends on the crop and the location and concentration of arable land). The plant will utilise both dedicated energy crops and straw and the economic model is based on a supply chain within a 70 km radius⁴⁹.

The numbers provided in this small sample, suggest an ethanol yield of around 200 litres per tonne of straw, with 50 million litres of fuel output per year estimated to be approximately the minimum scale for cellulosic ethanol plants. This is well below the estimate for 2020 in the BNEF study, which estimated yields of 350 litres of fuel per tonne of biomass (BNEF 2010). Looking at the number of plants, the EU straw potential of 60 million tonnes per year as identified in BMVBS (2010) could sustain 240 plants using 250,000 tonnes of straw as an input (or a total of 120 larger-scale 500,000 tonne-plants). The production process of cellulosic ethanol also yields by-products that can be used as process energy and ashes that can provide mineral inputs to soils (Box 5).

Box 5: By-products from cellulosic ethanol production

The different steps of producing cellulosic ethanol are illustrated in Figure 1. By-products occur at different stages of the process and the way in which they are used could provide opportunities to help foster straw supply chains. The breaking up of cellulosic material, which in biochemical processes is done with the help of specifically designed enzymes, yields cellulose and lignin in roughly equal proportions. Lignin cannot be broken down further and mostly consists of carbon. The fermentation step of the production process furthermore yields fermentation residues, such as slop, which can be used to produce biogas.

The biogas derived from the fermentation residues together with the energy derived from burning lignin, can meet the entire electricity and heat demand of a typical cellulosic ethanol production process, hence maximising GHG reductions of ethanol when compared to using gasoline for these purposes. The digestates accruing from biogas production can be used again as an energy input so that the only residues at the end of the entire chain are ashes left from burning. These can be applied onto arable land to provide mineral inputs to soils. Research is on-going to investigate the effects of bringing back lignin to the field directly as a potential alternative residue use. One industry representative mentioned that farmers have approached the company about developing a kind of 'barter trade' of straw in return for lignin.

A number of different arrangements exist for sourcing cereal straw by bio-refineries. However, given the variability of responses and the lack of commercially operational plants, it has not been possible to present a representative pattern of current sourcing practices. Nevertheless, a few interesting observations have been made from talking to industry representatives and these are set out below:

- *Süd Chemie* is currently working on setting up a demonstration plant in Straubing (Bavaria) to operate as of the beginning of 2012. For this purpose, straw is being

⁴⁹ Michelle Marrone, Chemtex, and Dennis Leong, EVP of Chemtex, *pers comm*. Since we have been in contact with Chemtex, the M&G plant has started operation as the first commercial plant in Europe of its kind.

sourced from all parts of Europe in order to test different varieties of straw coming from different climatic regions. Part of the reason for locating the plant in Straubing is the nearby Danube harbour. While transport of straw via road is only economical within a 40km radius, the use of multimodal transport routes including rail and boat could increase the sourcing radius substantially. The Danube link might allow for the import of straw from Eastern Europe in the future⁵⁰.

- *DONG Energy* has a very elaborate sourcing process that is organised via a tendering system (see Box 7 in section 4.4) and this reflects the long history of straw use for energy purposes in Denmark. Apart from agricultural residues such as wheat straw, their Inbicon biofuel plants can handle corn stover, sugar cane bagasse and energy grasses. But in fact, they use mostly locally sourced straw⁵¹.
- At the *Chemtex* plant 'high yielding energy crops grown on low productivity/marginal lands' are preferred as an input to achieve economic viability. Feedstock costs are a main determinant in achieving economic viability. While the process also works well with agricultural residues, their higher costs due to a longer supply chain and lower yields per hectare make them a less favourable option. But ultimately Chemtex anticipates using a mix of raw materials. Raw material related questions are addressed by an 'in-house team of agronomy experts' that specialise in supply chain logistics and energy crops. The arrangements between the plant and feedstock providers are project specific and can take different forms, 'including long term supply agreements, partnerships and/or other mechanisms'⁵².
- *Sleaford plant (UK)*: Sleaford is a UK based straw power plant that plans to use around 240,000 t/year of straw as a fuel input. The operators work on the basis of a mixture of supply arrangements, but most contracts are concluded with bailing companies and the majority of contracts (around 70-80 per cent) are long-term contracts (12 years)⁵³.
- Another respondent, who asked to remain anonymous, pointed to the existence of a subsidiary company that secures the supply of straw and other agricultural residues for the parent company. This includes the signing of contracts with farmers directly as well as with intermediary straw suppliers.

This set of responses gives an idea about the range of practices that advanced biofuel producers experiment with currently. While straw sourcing is well established in Denmark, companies in other countries still 'experiment', to varying degrees, with different sourcing practices. What seems to emerge rather clearly, however, is that supplying sufficient biomass necessitates flexible arrangements. This includes flexibility between long-term contracts and short-term buying of straw on the market, flexibility with regard to the geographical provenance of the straw, as well as flexibility between the use of straw and

⁵⁰ Jochen Gerlach, Süd Chemie, *pers comm*.

⁵¹ Representatives from DONG Energy, *pers comm*.

⁵² Michelle Marrone, Chemtex, and Dennis Leong, EVP of Chemtex, *pers comm*.

⁵³ Andrew Toft, ECO2, *pers comm*.

alternative feedstocks. The following two sections focus more specifically on the barriers that are encountered in supplying and sourcing straw as well as the identification of potential strategies to address them.

4.2 Agricultural sector barriers to straw supply chains

A range of barriers to the mobilisation of straw resources have been identified by talking to a range of farmers, farmer representatives and other agricultural sector experts. They can be summarised as follows:

- Lack of appropriate infrastructure, particularly specialist machinery for baling;
- Natural and climatic conditions;
- Competing existing uses of straw and farming practices;
- Economic factors;
- Underdeveloped markets and lack of market information;
- Lack of information and guidance on the use of straw in relation to the sustainable management of soils.

A common barrier found in many Member States is the ***lack of infrastructure*** which in turn relates to the insufficient (or completely lacking) financial incentives for farmers ‘to collect and transport agricultural residues from the field to the biorefinery gate’ (BNEF, 2010, p16). Straw has traditionally been used as a soil improver, typically mixed with manure on mixed farms. With more specialised farming systems, new technologies have been developed to find ways of efficiently incorporating straw back into the soil. Investments have been made in machinery that facilitates shredding and subsequently ploughing straw back in rather than baling it. Where farms (typically the large ones) do have baling equipment, it is often older equipment making round bales instead of rectangular bales that are typically demanded for energy production, for example⁵⁴. One of the reasons for underdeveloped supply chains and logistics is a lack of demand for straw in sufficient quantities from biorefineries. Given the existence of already well established uses for straw both on and off the farm, there is little incentive to the farmer to change their practices or suppliers, given the investment this would require both in terms of financial outlay and time taken to build new business relationships with buyers.

Limited machinery and equipment at the farm level provide a niche for intermediaries between straw buyers and sellers. In England, for example, the supply of straw is determined to a large degree by straw merchants who source and supply straw from and to different markets. These can include straw bailers, who collect and bail the straw from the individual farms, or may contract work out to dedicated companies or individuals who carry out such work. In discussion with straw merchants in the UK, the distance which straw is supplied from field to its end destination is largely determined by the price of the straw, which is in turn dictated by demand in relation to available supply. In England, it is economically viable currently to transport straw from one side of the country to the other,

⁵⁴ In this context, Vanessa Zeller (DBFZ) further mentioned the complete lack in Germany of bale retrievers, modern machinery to pick up straw bales from the field.

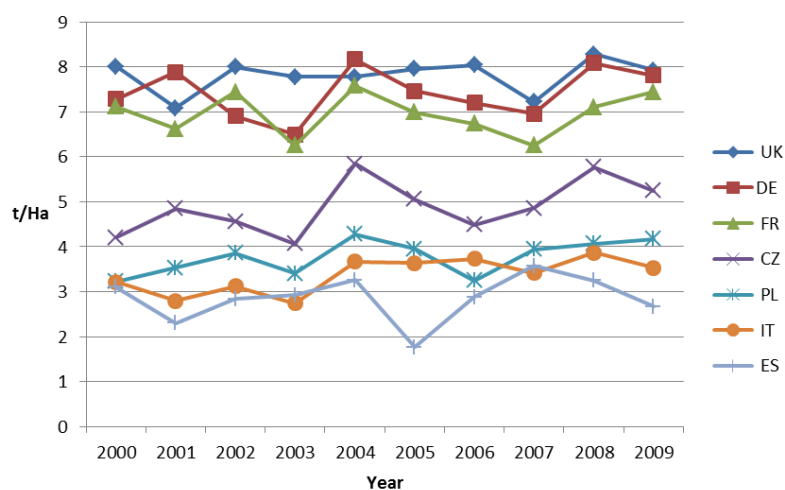
or even export straw to continental Europe, given the high price of straw due to restricted straw supply as a result of particularly dry growing seasons and wet harvesting seasons.

Another factor influencing straw supply is **climatic and weather conditions**, which have a direct impact on the use and availability of straw. Extended dry weather during the growing season can result in stunted crops with shorter stems (and hence less straw), making baling difficult. Furthermore a high level of precipitation during the harvesting period can make the extraction of straw particularly difficult. With limited storage capacity on farms and the reluctance to bale wet straw, this makes ploughing-in an attractive option, even where this does not result in wider benefits, for example improved SOC content⁵⁵.

The impact of weather therefore creates large variations in supply and thus in market prices for straw. This variation in weather patterns can vary throughout a Member State. In years of bad harvests, when straw supply is limited, there will be increased competition for the resource. Figure 6 shows wheat yield data over the last decade for a selection of Member States. A decrease in the 2007 wheat yield is clearly seen for the northern and western Member States (England, Germany and France) as a result of summer droughts.

Climatic conditions also impact on the suitability and choice of how straw residues are used. For example, in areas that are characterised by low levels of rainfall farmers cannot plough in as much straw as they might like because it does not decompose quickly enough with adverse effects for soil conditions and yields.

Figure 6: Wheat yields in tones per hectare over 2000-2009. Source: based on FAOSTAT data



Source: <http://faostat.fao.org>

⁵⁵ Ibid.

In addition to the value of straw through its role as a soil improver, there are **existing and competing uses of straw** both within and outwith the agriculture sector (section 3.1). Such existing uses represent an important demand for straw, particularly as a free resource, and are a traditional component of many agricultural systems. The importance of straw as a free resource in certain farming systems should not be underestimated and is a significant factor in the decisions of farmers on how to utilise such resources⁵⁶. The DBFZ project (see Box 6) showed, in the example of Uecker-Randow, that farmers might be unwilling to sell their straw because of a preference for preserving current farming practices. Farmers in the region are characterised as rather conservative, in favour of organic farming practices and have declined offers from industry to sell straw, even though excess straw is available according to scientific studies⁵⁷. Increasing the use of straw for bioenergy purposes may involve, therefore, more substantial behavioural shifts in the farming sector than might be anticipated. These could happen naturally as a result of demographic changes. For example younger farmers tend to be more willing to diversify their agricultural income streams⁵⁸ and hence look into new revenue sources.

Economic factors are another key factor influencing the supply of straw and are again highly variable between farms and Member States. One factor that is particularly important, albeit difficult to quantify, relates to the value of straw to the farm on which it has been produced. For example in the Czech Republic (as with many other Member States) cereal straw was traditionally used largely in the livestock sector, with the manure from this sector being applied back to the land as a form of fertiliser. However, following the declines of livestock production in the country and the resultant decrease in available animal manure, the value of the direct application of straw in maintaining soil functionality, particularly in building SOC, has increased considerably. It is estimated that between 30 and 40 per cent of straw is used in this way⁵⁹.

In some cases, **financial support** exists to promote the use of straw for certain purposes. For example, in a number of Member States, under the agri-environment measure of the second Pillar of the CAP (Rural Development), the use of straw as a soil improver is incentivised through payments which require straw to be left on the field following harvest, to its incorporation (ploughing-in) either following the harvest or before cultivation in the spring. In addition, these Rural Development Programmes provide financial support to farmers and land managers to change to organic or integrated production systems.

⁵⁶ David Caley, *pers comm*.

⁵⁷ Vanessa Zeller, DBFZ, *pers comm* and as above.

⁵⁸ Example of young farmers in Poland, Mariusz Maciejczak, *pers comm*.

⁵⁹ Jan Weger, *pers comm*.

Box 6: Studying straw supply chains in German NUTS 3 regions

A project by the Deutsche BiomasseForschungsZentrum (DBFZ, German Biomass research Centre) has investigated the use of agricultural residues for bioenergy production and has conducted interviews with farmers, farmer representatives, and public administrations in four 'model agricultural regions' within Germany⁶⁰. The study was done on the *Landkreis* level (German NUTS 3 level). The German agricultural sector is characterised by very heterogeneous farming structures ranging from many small scale farms primarily in the South of Germany to large farms in former East Germany but also in more Northern parts of Germany (for example Lower Saxony). The four *Landkreise* were chosen to represent different farming structures:

- 1) *Landkreis* Roth (Bavaria): Characterised by many small farms, around 1500, high share of livestock farming with a lot of dairy cattle and laying hens;
- 2) *Landkreis* Sömmerda (Thuringia): Characterised by large farms, around 260, "Commercial crop production [possibly just commercial arable farming] farms including fruit, vegetables and cereal production" dominated by intensive cereal cropping; also pig and poultry farming with less straw requirements;
- 3) *Landkreis* Uecker-Randow (Mecklenburg-West Pomerania): Characterised by large farms, around 250, mix of cropping and livestock (cattle, pigs);
- 4) *Landkreis* Vechta (Lower Saxony): Characterised by intensive agriculture including intensive pig and poultry breeding, many biogas plants.

Interviewing farmers from the different regions revealed that few are currently marketing their straw (for any purpose) but there are differences and exceptions across and within regions. The perceptions of farmers range from scepticism in **Uecker-Randow** (more information in the main text below) to a very market oriented approach in **Vechta**, where straw is seen as a traded commodity just as any other agricultural output that is readily sold as soon as the price received reflects costs. The study found that in the region around Vechta contractors either lend straw harvesting equipment or do the baling and transporting to then sell the straw to the Netherlands, where it is used in horticulture and vegetable growing and in orchards. Due to small farm structures and the importance of the livestock sector in **Roth**, the straw is mostly used on farm and is not traded. There have been examples, however, where due to straw deficits in the foothills of the Alps, supply chains involving contractors have been set up to export straw from Bavaria to Austria. In **Sömmerda**, farmers are struggling with a lack of demand for their straw, apart from some horse stables, leaving large surpluses, and ploughing it all back in can decrease soil quality and productivity.

The coordinator of the study stressed that while the four model regions were selected to reflect the diversity of the German agricultural sector, the study is still based on a limited number of four model regions and hence limited interview partners and therefore cannot be considered as producing conclusions representative for Germany as a whole. This again stresses the important regional or even local dimension underlying straw usage.

Underdeveloped markets and a lack of information on prevailing straw demand and supply and on appropriate market prices of straw reflecting its economic value among the actors

⁶⁰ The following information is all derived from: Vanessa Zeller (project coordinator, DBFZ), *pers comm*, concerning the results of the case study analysis, carried out within the project: „Basisinformationen für eine nachhaltige Nutzung landwirtschaftlicher Reststoffe zur Bioenergiebereitstellung“; funded by BMU, 2009-2011: <http://www.energetische-biomassenutzung.de/en/projects/projects-list/details/projects/43.html>.

concerned is another key factor shown to influence straw supply chains⁶¹, with the result that straw is often not marketed⁶² and is 'disposed of' by other means (for example ploughing-in, which does not always have benefits for soil quality, as was pointed out in section 3.1.1, particularly where straw does not decompose quickly).

While limited harvesting windows are one factor contributing to such a 'quick disposal' strategy, another factor is the lack of market information on the right price for straw, characterised by mistrust among cereal growers, livestock farmers and 'middle men' dealing with straw baling and transport in places where farmers lack the appropriate infrastructure. The need to outsource the handling of their straw, together with a perception of insufficient revenues from its sale, can decrease the willingness of farmers to market their straw.

The importance of straw prices as the key incentive for farmers to sell their straw was also one of the main broad conclusions from the DBFZ project: as long as the price is right, farmers will sell their straw (provided that it is not required on farm for livestock in the case of mixed farming systems). This is also demonstrated by the example from Bavaria where the agricultural sector has reacted quickly to straw shortages in Austria and contractors have facilitated the build up of supply chains (see Box 6, which summarises case studies in straw supply chains in Germany)⁶³. In line with this, the UK National Non-Food Crops Centre (NNFCC) has assessed the value of straw in the UK. They derive a wheat straw value of £32 per tonne, 'around 18 % higher than that currently offered in the market place [...]. Clearly margins on sale of cereal straw currently offer little opportunity of return on the cost invested [...]. However, the farming industry is quick to capitalise on any opportunities offered by a rise in the price of straw' (Copeland and Turley, 2008, p13).

As mentioned before, the production of straw varies not only between but also within the Member States. This, linked to the demand for straw, affects the price of straw in different areas. For example in England the price of straw varies up to 17 per cent (barley straw, 10 per cent for wheat straw) from the lower price in the central and eastern counties where cereal production is high, to the higher prices in the north east and south west where production is more limited⁶⁴.

Finally there is a **lack of information** that would enable farmers to take informed decisions on what to do best with surplus straw. The use of straw as a soil improver across much of the EU is partly driven by a convenient way of to dispose of straw following harvest, often with little assessment made of the quantities of straw needed to maintain soil functionality over the longer term. In many cases this can lead to an unnecessary level of straw incorporation reducing the surplus available for extraction for other purposes. This is not

⁶¹ Jonathan Scurlock, NFU, *pers comm*.

⁶² *Ibid*.

⁶³ Vanessa Zeller, DBFZ, *pers comm* and as above.

⁶⁴ Source: http://www.farming.co.uk/prices/baled_hay_straw/ 25th October 2011.

true in all cases, however, with some farmers carrying out detailed soil analysis as well as an analysis of the nutrient and mineral content of their straw to ensure the right levels of incorporation. This analysis has wider benefits by allowing the more efficient use of supplementary fertilisers and soil improvers and potentially freeing up more straw for extraction. Beyond these efficiency benefits within the farming system also there could be economic gains to the farmer by selling the surplus straw to other uses and markets.

4.3 Barriers in straw supply chains – the industry’s perspective

As highlighted earlier, the cellulosic ethanol market has not yet reached the stage of technology diffusion to warrant widespread commercial operation. The industry currently seems to struggle with a ‘chicken-egg problem’ of infrastructure development, where the lack of an established market and demand for agricultural residues and hence persisting uncertainty, prevents farmers or potential intermediaries to invest in necessary harvesting and transport infrastructure (Sims *et al*, 2008, p34). More specifically the most important barriers according to the interviews conducted with bioenergy industry representatives are the following (in no particular order):

- Heterogeneous practices and regulations governing straw use in the EU;
- Variable availability of straw;
- High production costs of cellulosic ethanol.

A striking feature of the market for agricultural residues, which was highlighted by both industry and agricultural sector representatives, is its variability and lack of predictable patterns. An industry representative pointed out that, in sourcing straw, they have come across a **heterogeneous set of rules and practices as well as market mechanisms** in Europe. As an example of a market barrier, it was mentioned that, in the south of Bavaria, farmers are selling much of their straw to Austria to be used in the livestock sector⁶⁵. The industry stressed also that it struggles with the **variable availability of straw**, given that cereal yields fluctuate with the prevailing weather conditions over the growing, as well as harvesting, period.

Industry representatives did not specify any particular hurdles related to raw material sourcing in scaling up the production of advanced biofuels. For example, the biofuel demonstration plant operated by the M&G Group in Crescentino, Italy, does not foresee any barriers in scaling up production, and feedstock sourcing is not seen as a barrier. However, this is largely due to the fact that their ligno-cellulosic biomass conversion technology handles a range of feedstocks, including dedicated energy crops with shorter supply chains⁶⁶. For DONG Energy/Inbicon, the reason for their operation still being below commercial scale are the **production costs**, which continue to be considerably higher than conventional biofuel production costs. Sourcing the raw material for the resource base, which in their case is cereal straw, is not a hurdle for them (see also Box 7 in section 4.4), but this is perhaps unique to the Danish situation.

⁶⁵ Jochen Gerlach, Süd Chemie, *pers comm*.

⁶⁶ Michelle Marrone, Chemtex, and Dennis Leong, EVP of Chemtex, *pers comm*.

5 DEVELOPING A FRAMEWORK OF PUBLIC SUPPORT



Previous chapters have demonstrated the potential for the use of straw that is excess to soil improvement or other essential on farm requirements, as a feedstock for the production of advanced biofuels. However the use of straw and other agricultural residues for this purpose is still in its infancy and chapter 4 has outlined a number of the barriers that constrain currently the supply and sourcing of straw as a bioenergy feedstock. This chapter considers whether or not there is a role for EU public policy to play in helping to overcome these barriers through the provision of EU funding. It considers in particular the potential for financial support through the Common Agricultural Policy (CAP) and Cohesion Policy (CP).

5.1 Summary of the key barriers to straw supply and sourcing

Despite the interest from farmers in increasing the market for straw as a feedstock for energy purposes and a demand from biorefineries for straw for this purpose, a range of barriers currently affect the functioning of the straw supply chain between farmers on the one hand and the processors on the other. These are varied in nature and the need for a policy response, particularly one which involves funding or investments using EU public money, differ according to the issue. Five key types of barriers have been identified as follows:

- 1) *Underdeveloped markets and lack of market information:* to a large extent, the lack of supply chains for straw for bioenergy purposes is essentially related to underdeveloped markets. With the notable exception of Denmark, the energetic use of straw is not an established practice EU wide. The marketing of straw for these purposes is at different stages of advancement in different EU regions and is still embryonic in many places.
- 2) *Competing existing uses of straw:* straw is not an agricultural residue for which there are no alternative uses. Not only does it play an essential role as a soil improver, but other markets have developed over centuries for straw that is in excess of on-farm needs. Sourcing straw for bioenergy purposes has to compete against these other established markets and, as a result of the underdevelopment of the bioenergy market for straw, in many places, farmers are still to be convinced that it is worth their while in the long term to change existing practices.
- 3) *Lack of guidance on optimal use of straw as a soil improver and associated farming practices:* while some farmers carry out detailed soil analyses as well as an analysis of the nutrient and mineral content of their straw to ensure optimal levels of

incorporation, this does not happen in the majority of cases. This can lead to an unnecessary level of straw being incorporated into the soil, which then reduces the surplus available for extraction for other purposes.

- 4) *Lack of infrastructure*: one of the issues facing land managers who might be interested in supplying straw to biorefineries is the lack of appropriate on-farm machinery and infrastructure for straw handling and baling to meet the requirements of the processors.
- 5) *Variability of straw supply*: from the processors' perspective, a major issue is the variability in the quantity and quality of straw available year to year and region to region, as a result of climatic conditions and fluctuating straw yields.

The Commission's Communication on the bio-economy reflects these findings, stating that 'Enhancing a productive and sustainable bioeconomy requires more research, rural, marine and industrial infrastructures, knowledge transfer networks and improved supply chains'. It continues by stressing that 'various funding sources, including private investments, EU rural development or cohesion funds could be utilised to foster the development of sustainable supply chains and facilities'⁶⁷.

5.2 The need and role of CAP and Cohesion policy to support solutions for overcoming the barriers identified

Not all obstacles to the efficient operation of the supply chain require policy intervention as a means of their resolution. Even where a policy response is justified, this can take a number of different forms and does not necessarily require the provision of financial support from the public purse. There are a number of justifications for intervening in the operation of markets through public policy. In relation to supporting the supply of straw for advanced biofuels, there would appear to be two core arguments. Firstly, if support is required to deliver public goods that would not otherwise be provided through the market – these might be environmental public goods or social public goods, such as capacity building and awareness raising. Secondly, there may be a case for supporting the development of an emerging market that is of value to society, for example where this is environmentally or socially beneficial and requires some form of short term support (financial or non-financial) to provide the necessary impetus and security in the market to facilitate its development and any investment needed.

In the case of developing the market for advanced biofuels, it is clear from the barriers identified, that there are a number of roles that policy, in its broadest sense, could play. First is a role in providing political support for the development of this industry within the context of the development of the bio-economy and more specifically the production of biofuels that do not lead to negative environmental impacts. Second is the provision of specific financial support to actors as part of the supply chain to encourage its improved functioning. Third policy plays an important role in ensuring that sufficient environmental

⁶⁷ Communication COM(2012) 60 Final from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 13.2.2012 on 'Innovating for Sustainable Growth: A Bioeconomy for Europe', http://ec.europa.eu/research/bioeconomy/pdf/201202_innovating_sustainable_growth.pdf

safeguards are in place. The CAP and Cohesion Policy can contribute to the second and third of these roles. However, there are other barriers that cannot be overcome by policy. This includes (world) market prices for different agricultural outputs, making cereal production and hence the production of straw more or less profitable, and thereby influencing crop choice.

5.2.1 Market development

One of the biggest barriers to the uptake and expansion of advanced biofuels is related to the infancy of the market and the lack of certainty about the long term future of advanced biofuels. This is not something that can be resolved by the CAP or Cohesion policy. In relation to the development of markets for other uses of straw where market demand exists, for example from (remotely located) livestock farmers, other agricultural practices including horticulture and vegetable growing or the energy sector, supply chains have developed in response to this demand, without requiring any policy support.

However, the investments in technology and infrastructure needed to support the production of advanced biofuels are high. Although some companies have invested in the establishment of biorefineries for advanced biofuels, it is likely that greater financial investment in this area would be seen if the policy signals promoted this form of bioenergy production. However, this is an issue for EU energy policy to address, if this is deemed appropriate, for example through the inclusion of suitable commitments within the Renewable Energy Directive (RED). BNEF (2010) highlighted the approach taken in the US, whereby 'in August 2009 the US government provided a matching payment of up to \$50 per dry tonne for biomass producers to overcome this problem' and argue that 'the introduction of similar EU legislation would drive forward the development of an agricultural residues supply chain'. The European policy framework (the RED) currently permits the double counting of advanced biofuels towards the renewable energy target for the transport sector. However, as stated earlier, the data on advanced biofuel use put forward in the NREAPs suggest that this measure has been ineffective. A frequently discussed option for creating a market for advanced biofuels in the EU is the use of a sub-quota, ie prescribing Member States to meet part of their renewable energy requirements in the transport sector through advanced biofuels. Dedicated tax incentives or enhanced production support are other measures that have been proposed, A discussion on the relative desirability of these different options, however, is not within the scope of this study.

In terms of securing the supply of agricultural residues, in particular straw, for this market, it will be important to ensure that information on the opportunities for using straw for this market are transparent and that the mechanisms to support its efficient operation are in place. Straw merchants could play an important role in this respect, as they are the intermediaries between the farmers and the end users of the product and therefore need to understand the potential of the full range of markets for straw.

There is a range of actions that can be taken that do not require any policy intervention at all. Indeed, most of the interviewees for this study, representing both the advanced biofuel processors and the farming industry did not highlight the need for policy support as means of ensuring the effective working of the supply chain. They implied, rather, that the barriers

currently experienced could be resolved through the normal functioning of the market if the demand for straw for the production of advanced biofuels were to increase and be seen to have a long term future.

One innovative market incentive to encourage the supply of straw to biorefineries is the idea that the contract with farmers might include them receiving process residues (mainly ashes) back from energy plants to use as soil improvers to maintain soil carbon matter and productivity. Some of the farmers and farmers' organisations interviewed for the purposes of this study expressed an interest in such arrangement. However, in an example from England, the ash is already being used commercially as a separate enterprise, rather than as part of a supply contract with farmers. In this case, the ash is collected by a third party from the CHP factory, who combines it with other minerals to produce fertilisers which are in turn sold back to farmers⁶⁸. Nevertheless, there may be opportunities to explore this option further⁶⁹.

5.2.2 The role of the Common Agricultural Policy

Some of the barriers to the sourcing and supply of cereal straw may be overcome by the provision of specific support through the CAP, particularly through the use of measures within the European Agricultural Fund for Rural Development (EAFRD). The ways in which the CAP can help are varied. Some measures could help facilitate the supply of cereal straw to biorefineries to improve the functioning of the supply chain. The CAP also plays a critical role in ensuring that sufficient environmental safeguards are in place to ensure that any sourcing of straw for commercial purposes is done sustainably and that soil organic matter is protected. Other measures, therefore, could help improve information and advice on locally specific requirements for the incorporation of straw into soils to improve soil functionality, to ensure that more accurate calculations on the availability of excess straw for different purposes are undertaken.

The proposals for Pillar 2 of the CAP for 2014-2020 highlight the use of agricultural residues, such as straw, as a source of bioenergy within one of the six European priorities for rural development. Under the objective for 'promoting resource efficiency and supporting the shift towards a low-carbon and climate-resilient economy in the agriculture, food and forestry sectors', 'the supply and use of renewable sources of energy, of byproducts, wastes, residues and other non food raw material for purposes of the bio-economy' is identified as a

⁶⁸ Andrew Toft, ECO2/Sleaford CHP plant, *pers comm*.

⁶⁹ In the context of small and medium scale agro-biomass frameworks in Denmark and Sweden such as on-farm heat production that were analysed by Voytenko and Peck (2012), ash residues from straw burning are brought back onto the fields. This is possible due to the much smaller scale (straw inputs of 140 to 4000 tonnes/year) and a therefore less complex organisational system. Also for large scale straw burning plants in Denmark this practice is found, however, the authors note that the straw supply contracts in Denmark 'do not regulate the proportion of ash returned to the farmers, and thus its amount does not depend on the amount of straw delivered to the plant, which is considered imperfect' (Voytenko and Peck, 2012, p44 citing Hinge, 2009).

core focus⁷⁰. In addition, measures to promote an improved understanding on soil needs in relation to straw would help meet the objective of 'restoring, preserving and enhancing ecosystems dependent on agriculture ... with a focus on ... improving soil management'.

The importance of innovation in relation to developing the green economy, as highlighted in the EU2020 strategy, also flows through into the priorities for the future CAP. Not only is innovation a cross cutting objective of the EAFRD, but resources will contribute also to the forthcoming European Innovation Partnership (EIP) for agricultural productivity and sustainability, through supporting the setting up of EIP operational groups and the overarching EU EIP network.

Many of the policy measures that could be used to overcome the barriers highlighted above are already available within current rural development policy or the legislative proposals for its revision post 2014. However, although bioenergy production, particularly of conventional biofuels, has been supported through rural development policy in a number of Member States, it has not been used to such an extent to encourage the supply of agricultural residues for the production of advanced biofuels.

The key areas where it is envisaged that the CAP could play a role in supporting the increased use of straw as a feedstock for advanced biofuels include:

- The inclusion of environmental safeguards to ensure the protection of soils;
- The development of guidance and tools for farmers to optimise the levels of straw incorporated into the soil to ensure the volumes of excess straw available for other uses are environmentally sustainable;
- Development of initiatives to help improve the functioning of the supply chain for agricultural residues; and
- Developing innovative relationships between producers and processors.

Each of these is addressed in turn below.

Environmental safeguards

As highlighted in Chapter 3, evidence shows that a minimum percentage of residues from crops need to be retained in soils to maintain their nutrient content as well as soil organic carbon stocks so as not to increase carbon dioxide concentrations in the atmosphere (Gobin *et al*, 2011). However, the proportion of residues that is optimal to incorporate back into the soil varies regionally and this needs to be taken into account in the development of any safeguards that are put in place.

Farmers could be obliged to retain a certain percentage of agricultural residues to replenish soil organic matter on their fields through the introduction of relevant standards of Good Agricultural and Environmental Condition (GAEC) under cross-compliance. This is addressed to some extent under the current CAP proposals, whereby a new GAEC standard is proposed

⁷⁰ Article 5(5)(c) of COM(2011) 627 final/2 – Proposal for a Regulation of the European Parliament and of the Council of support for rural development by the European Agricultural Fund for Rural Development (EAFRD)

which will require Member States to put in place requirements for the ‘maintenance of soil organic matter level including ban of burning arable stubble’⁷¹.

One of the benefits of cross compliance GAEC standards is that Member States are given the flexibility to design the standards to take account of regional bio-geographic characteristics. Where regionally specific information is available, therefore, on the minimum percentage of residues that should be incorporated back into the soil for soil carbon and nutrient purposes, there would be considerable merit in including such minimum percentages within the Member State specific requirements for the implementation of GAEC 6.

The introduction of these kinds of safeguards could be reinforced if, as also suggested by DBFZ and Oeko-Institut (unpublished), biorefinery operators were required to investigate the local humus balances in regions where plants are to be installed and commit to only sourcing agricultural residues where these are not depleting soil organic carbon or other soil nutrients.

Such environmental safeguards would need to be combined with the provision of appropriate advice and guidance (see section below).

Developing advice, guidance and tools

The proportion of straw that is currently incorporated back into soils to improve soil organic matter and levels of soil carbon is very variable, even between similar types of farm. Part of this variability is due to the differing quantities of straw needed to maintain soil functionality in different types of soils. However, while some farmers do carry out detailed soil analysis as well as an analysis of the nutrient and mineral content of their straw to ensure the right levels of incorporation, this is not the norm. Indeed, its incorporation into the soil in many Member States is viewed more as a way of disposing of straw following harvest, rather than as a means of improving soil quality, with little assessment made of the quantities of straw needed to maintain soil functionality over the longer term. In some situations, this can lead to an unnecessary level of straw being incorporated into the soil and reduce the surplus available for extraction for other purposes.

In order to optimise sustainably the availability of agricultural residues for other purposes, more information is needed for farmers to identify the optimal proportion of residue that will be beneficial to be incorporated back into the soil in any given year. The environmental safeguards highlighted above are one way of achieving the incorporation of minimum levels of residues into the soil. In a number of Member States, agri-environment schemes, operated through Pillar 2, also include measures to encourage the use of residues for this purpose. However, what seem to be missing currently are the availability of simple tools or guidance that allows farmers to carry out their own field based assessment on the humus levels of their soil, including an assessment of their nutrient and mineral content to inform decisions on the quantity of residue to plough back in and therefore how much is available for other uses.

⁷¹ GAEC 6, Annex II of COM(2011) 628/3, Proposal for a Regulation of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy.

General advice could be developed through the Farm Advisory Service (FAS), which all Member States are required to put in place and which is currently linked primarily to the implementation of cross compliance. In the CAP proposals, the minimum scope of the FAS has been extended to cover a range of issues relating to the implementation of cross compliance as well as the use of certain Pillar 2 measures in relation to climate change mitigation and adaptation, biodiversity, water protection, the notification of animal and plant diseases and innovation⁷². Soil protection is notable by its absence currently. This needs to be rectified to ensure that the FAS can be used as a means of ensuring the long term protection of soils.

In addition to the FAS, the EAFRD proposals contain specific measures to fund the setting up of advisory services ‘for the improvement of the economic and environmental performance as well as the climate friendliness and resilience of their holding, enterprise and/or investment’⁷³. This is a continuation of a similar measure available in the current EAFRD. In the current programming period this measure has been used in a variety of different ways, and it would be worth exploring the value of encouraging Member States to use this measure to raise awareness about the key role that straw plays as an organic fertiliser. It could also be used to build on research and pilot studies in different Member States⁷⁴ to develop soil carbon calculators, for example, that can be used widely by farmers to inform their soil management decisions.

In a broader sense, the Leader approach has the potential to be used to promote the sustainable use of agricultural residues for bioenergy production as part of a broader awareness raising campaign in relation to energy efficiency and renewable energy issues. Box 7 shows how the Leader approach has been used in Germany for this sort of purpose.

⁷² Annex 1 of COM(2011) 628/3, Proposal for a Regulation of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy.

⁷³ Article 16 of COM(2011) 627/3, Proposal for a Regulation of the European Parliament and of the Council on support for rural development by the European Agricultural fund for Rural Development (EAFRD)

⁷⁴ For example a number of Member States have been funded under LIFE+ to look at these issues. See, for example, the DEMETER project (Belgium) or the AGRICARBON project in Spain. Information available at: <http://ec.europa.eu/environment/life/news/press/index.htm#annexes2010>

Box 7: Jena-Saale-Holzland – A Bio-Energy Region

Summary: This bio-energy Leader project aims to increase the percentage of bio-energy from 15 - 30% in the region. Alongside energy saving measures, PR and educational initiatives include building a sustainable bio-energy centre to raise awareness.



Background: In 2000, when applying for LEADER+ support, local groups and individuals started promoting sustainable development in the region's rural areas. Future energy supply was a key issue and the potential benefits of bioenergy production for the agricultural community were recognised. In 2009 the Saale-Holzland RAG was one of 25 regions to win a Federal Bio-energy competition, and installed a dual function network that uses existing resources.

Objective: The objective was to promote local bio and renewable energy production alongside the existing network, increasing efficiency and reducing costs. The aim was to raise the local share of electricity and heating from around 15% to 30% by 2020, with an increase in the agricultural biomass share to 75%. Apart from the financial benefits, this would enable some local waste recycling plants to be closed.

Main activities: Activities of this Leader project include: i) Education and PR to strengthen the Players Network and educate the local population; ii) a bio-energy centre to combine activities and conceive new ideas; iii) professional-technical consultancy to optimise existing heating systems and increase crop diversity, and; iv) the creation of the Schloben 'show village' to demonstrate bio-energy concepts and the potential of straw as a renewable fuel.

Results and benefits: Collaboration between the actors involved has increased, a climate protection week was held in 2010, youth and childhood training schemes have been introduced, the use of biogas in two existing heating systems has been improved, a bio-energy village has been set up to promote the concept and establish a heating network and biogas system and finally research has been conducted into using residues such as ash for fertiliser, CO₂ for greenhouses, and realising the potential of forests.

Project location: Germany, Deutschland-Thüringen. Located in the central part of Germany.

Total project cost (€):500 000 EAFRD contribution (€): 22 000 National contribution (€): 400 000 Private contribution (€):78 000

Project website: <http://www.bioenergie-region.de/>

Source: ENRD project database: <http://enrd.ec.europa.eu/>

Improving the functioning of the supply chain

There are many ways in which the CAP can be used to improve the functioning of the supply chain. In relation to the barriers identified within this report, key areas include:

- Providing support for investments in new machinery needed for the baling of straw;
- Setting up producer groups or contracting services, where these do not currently exist, for the baling and transportation of straw;
- Improving the communication and awareness about the potential for the use of agricultural residues for advanced biofuel production.

Investments in machinery: one of the issues often mentioned in relation to improving the sourcing of straw for advanced biofuel production, is that the equipment available on farm for baling the straw is often not suited to produce the rectangular bales that are needed by the processors. There is the potential to use the farm modernisation measure under the current EAFRD, included within the current proposals under article 18 for ‘investments in physical assets’, for this purpose, subject to a clear business case as to why this investment were justified and could not be funded using private funding. Examples of the use of this measure to purchase machinery and equipment on farm during the current programming period are often associated with plans for the machinery to be used collectively by a number of farmers within an area (for example through the setting up of machinery rings) or where the machinery purchase is part of a broader business plan to develop a new contracting business, using the machinery to provide a service to the wider local area. In these cases, the use of measures such as those for diversification and the setting up of small businesses to provide funding could also be relevant (see below).

Producer Groups / Contracting Services: Feedback from interviews undertaken as part of this study emphasised the important role that contractors or ‘middle men’ have to play in straw supply for different purposes, either by lending out equipment or by providing a service to farms to bale and pick up and transport straw. This is particularly relevant in areas where there is a prevalence of small farms, where straw output would be insufficient to justify the purchase of specialist machinery, even collectively. The EAFRD can provide funding to support the start up costs of such contracting businesses, subject to certain constraints, and this possibility has been carried through into the current proposals for the future EAFRD under article 20 concerning ‘farm and business development’.

Straw merchants are often an integral part of the supply chain. Some examples show that these also operate across borders and can make up for lack of infrastructure in neighbouring Member States as well as facilitating the export of straw from structurally straw rich to straw poor regions. As examples, contractors organise the baling and transporting of straw in straw rich regions in Germany (example of Vechta, Lower Saxony) to the Netherlands hence dealing with the lack of harvesting infrastructure in Germany and meeting excess demand in the Netherlands. Another example of this kind is the exporting of straw from Bavaria to Austria and from the straw rich East of England to livestock rich and straw poor West of England⁷⁵.

While straw merchants have developed in response to market demand and therefore do not require public funding, where support from the CAP may be beneficial is in helping to improve communication between straw producers, the intermediary baling and haulage companies, the straw merchants and the users of straw. This was a key issue highlighted in interviews with farming industry representatives. Linked to this, one of the issues that

⁷⁵ An EU funded project has practically dealt with a similar situation of small forest owners and suggested the setting up of Biomass Trade Centres so as to contribute to a reliable wood fuel supplies by *inter alia*: formalising the marketing of wood biomass for energy that was previously traded informally; creating regional wood fuel networks based on sustainable, local supply; ensuring a year-round availability of biomass (www.biomassradecentres.eu and Francescato *et al*, 2010).

industry representatives raised was the difficulties they face in addressing problems of variability of straw supply. One of the solutions identified was the possibility of using mixed supply solutions, which would involve working with a handful of contracted straw suppliers and sourcing the remainder depending on the market conditions. Straw merchants could play an important role here as, by sourcing their straw from different areas they would be able to diversify the risk of being affected by variables, such as adverse weather conditions.

Research carried out by Voytenko and Peck (2012) showed that actors in the supply chain have clearly defined roles that are set out in a hierarchical order. For large scale plants, they found that single straw suppliers are typically found at the bottom of hierarchy who supply straw to sub-contractors or farmers associations who then sign official supply contracts with straw conversion plants at top of the hierarchy.

Policy support may be appropriate to ensure effective communication at the farmer end of this supply chain, through for example the development of producer groups, or farmers' associations that would facilitate farmers working together as associations to supply the straw merchants with the type and quality of straw needed for use as a feedstock for advanced biofuels⁷⁶. Under the current programming period, examples exist of where rural development funding has been used to improve the functioning of supply chains, albeit more usually in relation to the production of agricultural products (see Box 8 for an example from Italy). However, there may be value in exploring how this concept could be applied to improve stability of supply in relation to agricultural residues, particularly given the increased emphasis on supporting 'co-operation approaches among different actions in the Union agriculture and food chain...' as well as 'the creation of clusters and networks' in the EAFRD proposals (article 36 of COM(2011) 627/3).

⁷⁶ This is for instance the role of Anglia Farmers Limited (www.angliafarmers.co.uk), a growers cooperative that provides marketing services for straw (Philip Brown, Anglia Farmers, *pers comm*). Voytenko and Peck (2012) mention DSSA, the Danish Straw Supply Association, as a powerful organisation in the Danish straw business.

Box 8: Improving of the Production Chain of Fruit and Vegetables in Lombardy

Summary: EAFRD funds through various measures (111,121, 123 and 124) assist the region of Lombardy to improve quality of production and obtain more profitable prices in the market, adapt farms to standards required by the market and improve farmers' income.

Background: The region of Lombardy has invested considerable resources on the design of agricultural production chains ("filière") with the belief that it can bring great benefit to farmers who participate in the projects. It has been noted that the measures implemented in this way have generated a lot of interest from beneficiaries.

Objective: The project aims to upgrade the regional horticulture production chains.
Main activities: This objective is expected to be achieved through the following activities: i) innovation of products (increasing the quality of production); ii) increase of food safety for the consumer; iii) definition of a common strategy for agricultural production; iv) establishment of marketing and integration chains; v) provision of technical and vocational training for the sector's operators.

Results & Benefits: The project has financial, human resource and IT benefits: i) increased income (more than 3% concerning the product's market price); ii) increased sales and higher profit for farms; iii) increased employment levels (more than 6%); and iv) definition of an information system to manage and control the production chain flows. The production chain project allows farms to develop different interventions to improve their performance.

Lessons learnt: The project has been supported by several measures which bring an integrated approach in using EAFRD funds and facilitate the getting together of many farms (organised in a chain). The success of this programming approach is thus demonstrated, because effective integrated actions offer a possible solution to support farms during times of economic crisis.

Project location: Lombardia (Provinces of Bergamo, Brescia, Cremona, Lodi, Mantova, Milano, Sondrio)

Total project cost (€): 57 749 007 EAFRD contribution (€): 37 663 007 Private contribution (€) 17 086 000

Source: ENRD project database: <http://enrd.ec.europa.eu/>

Feedback from the interviews suggested that when up-scaling from a pilot/demonstration plant to large-scale commercial production, tender systems as used in Denmark allow energy plants to manage a large amount of contracts (concluded with farmers' associations and contractors alike, see Box 9), whose number increases in the face of up-scaling production and the continuous need to deal with variable supply. Improved cooperation and the creation of producer groups or associations, particularly where many smaller farms exist in an area, could help to increase the ability of farmers to respond to such approaches to supply.

Box 9: Using auctions to source straw in Denmark

Representatives from DONG Energy, who among other energy serviced run the Inbicon cellulosic ethanol plant in Denmark, explained their process of sourcing straw which has evolved over the history of straw use for energy purposes on Denmark⁷⁷. The use of straw was historically policy driven as a response to the second oil crises and the aim to increase energy security by using a domestic energy source. Support was in the form of mandates and a higher price paid for electricity/heat generated from straw. This is the reason for today's good straw harvesting infrastructure in Denmark.

Traditionally energy companies would make individual contracts with farmers or farmers' associations and intermediary contractors that either lend straw handling equipment to farmers or buy bales from farmers to sell them to the energy sector. At some point there were complaints about the power companies as large buyers becoming a too dominant actor in the straw market and subsequently Danish regulators called for different arrangements that would prevent power companies from having excessive market power. The result of this was the emergence of a tender system that is the dominant form of contracting currently. DONG Energy typically opens three tender processes per year to source straw (based on contract of different terms, one to five years). Farmers submit their bids and DONG Energy then typically contracts the cheapest bidders up to the amount of straw demanded, paying each bidder the price per tonne of straw that was offered. Contracts are typically made in spring prior to the harvest season.

The typical amount of straw sourced per year are 600,000 tonnes spread over roughly 1000 contracts, with the size of individual contracts ranging from 100 to 30,000 t/year. This includes contracts with large associations but also small contracts that combine the limited straw resources from small farms.

The practices of small power generation plants represent and an exception to the tender system as these usually source straw directly from local farmers' associations without opening a tender process.

Developing new relationships between farmers and processors

Amongst the other ideas that have emerged from talking to selected agricultural sector and industry experts includes the possibility for cereal producers to enter cooperative arrangements in order to jointly invest in biorefinery plants to process their straw. The question has also been raised about whether or not investment capital might be sourced from EU rural development or cohesion funds for small farmers, who might not be able to access private financing on the capital market.

Experts suggest, however, that it is likely that it would be the large, business-minded farmers who would be most likely to be interested in such investments, the main condition always being that such investment would offer a competitive rate of return⁷⁸. This is confirmed by Voytenko and Peck (2012), who studied agro-biomass based energy systems in

⁷⁷ Representatives from DONG Energy, *pers comm*.

⁷⁸ Jonathan Scurlock, *pers comm*, Andrea Povellato, *pers comm*.

Sweden and Denmark ranging from small to large scale. However, even the large scale combined heat and power plants investigated by Voytenko and Peck (still smaller than the 200 thousand tonnes/year or higher typically encountered for commercial scale cellulosic ethanol plants) entail a high degree of system complexity and formalisation of, for instance, supply contracts (see section above). As a result, it would seem unlikely and impractical to see individual, particularly smaller farmers, organising themselves into a cooperative to invest in biorefinery plants. Given the amount of straw needed to feed a commercial cellulosic ethanol plant, some form of organisational structure with commercial sub-contractors aggregating straw and arranging supply contracts with straw processing plants is essential to ensure the efficient functioning of the supply chain, as explored in the section above.

5.2.3 The role of Cohesion Policy

Cohesion policy is the main investment instrument for supporting the key priorities of the Union as enshrined in the Europe 2020 strategy. In line with this, a series of thematic objectives have been set out for the policy for the period 2014-2020. Those relevant for the purposes of this study include the objectives of ‘strengthening research, technological development and innovation’ and ‘supporting the shift towards a low-carbon economy in all sectors’. The promotion of the production and distribution of renewable energy sources is articulated as a key sub-theme for contributing towards the development of a low-carbon economy.

Transition regions and more developed regions will be required to focus the largest part of their allocation (except for the European Social Fund) on energy efficiency and renewable energy, competitiveness of SMEs, and innovation. For example, in these regions, at least 60 per cent of the total European Regional Development Fund (ERDF) resources at national level are to be allocated to research, innovation and SMEs and 20 per cent to low carbon measures, particularly energy efficiency and renewable energy. Less developed regions will be allowed to devote their allocation to a wide range of measures. However, they will still need to allocate at least 50 per cent of the total ERDF to measures promoting research, innovation, SMEs and low carbon actions, out of which at least six per cent should target energy efficiency and renewable energy.

The introductory text to the proposals for the future ERDF make it clear that ‘the case for funding infrastructure is strongest in less developed regions where public authorities do not have sufficient funds for investment, and where the investment costs cannot be recovered as the population is low income. The case for investing in basic infrastructure in more developed regions is much weaker.’

Theoretically, therefore, the ERDF could be used for any investment to develop renewable energy generation capacities depending on national/regional needs. It is proposed also that the Cohesion Fund for the next period could also be used for climate related projects which was not the case before, with the rationale of helping poorer regions catch up in making progress towards meeting their greenhouse gas emissions targets. The Commission’s recent Communication on the bio-economy also emphasises the need for investment in renewable energy, stating that ‘more investment is needed for demonstration and scale-up activities and the development of entrepreneurship and advisory services for the whole supply chain’.

Despite this, however, there appears to be little agreement within the industry about the need for further demonstration plants for the production of cellulosic biofuels. There are certainly a number of pilot projects already in place, such as those described in this report, which some would argue have demonstrated sufficiently the potential of this technology. Others argue that there remains an 'absence of convincing large-scale demonstration plants for cellulosic biofuels'⁷⁹ or that more funding is needed for the piloting of demonstration plants⁸⁰ and that without this, the securing of long-term European investment will continue to be problematic. If such smaller scale pilots were thought to be needed by Member States, then Cohesion Policy may be one source of funding for such projects.

In summary, many of the barriers facing the mobilisation of agricultural residues, and straw in particular, for use in the production of advanced biofuels, are the result of the nascent nature of the market in this areas and the lack of certainty about its long term future. To resolve this requires changes to EU energy policy and most interviewees for this study argued that if this were resolved, then solutions to the other barriers relating to the supply chain would be found through the normal operation of the market.

Nonetheless, this study has identified some areas where CAP and Cohesion policy could play a role. Any use of straw for advanced biofuel production must be sustainable and avoid any adverse environmental impacts, for example by reducing the levels of straw incorporated into the soil and thereby potentially depleting soil organic matter. Perhaps the most important role that the CAP could play is by introducing environmental safeguards to ensure soil protection, through the use of cross compliance as well as using rural development measures to develop guidance and tools for farmers to calculate the humus levels of their soils in order to make informed judgements about the optimal level of straw to be incorporated back in to the soil and therefore how much is available for other purposes. Other possibilities include support for cooperation, the setting up of producer groups or the development of new businesses, for example for the baling and transport of straw, including the provision of capital investment for the purchase of suitable machinery. Cohesion policy could play a role in providing investment capital for the development of pilot or demonstration plants, where these are seen to be beneficial.

The tools and measures are in place within the current policy frameworks and the legislative proposals for the next financing period to allow these types of activities to be put into practice. Much will depend, however, on the priorities that Member States choose as the focus of their Rural Development (EAFRD) or Operational Programmes (Cohesion) and the subsequent structure, design and implementation of measures at the national and regional level. Attention will turn in this direction over the coming months as initial planning for the 2014-2020 programming period gets underway.

⁷⁹ Statement by Philippe Merchand, head of biofuels at Total, quoted in Agra Europe, February 14 2012 'CAP reform boosts prospects for European cellulosic biofuels'.

⁸⁰ The Structural Funds are proposed as a potential funding option for this purpose as part of a 'Biorefinery Feasibility Project' commissioned by the industry, but is not highlighted as a priority action.

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ANNEX I: ADVANCED BIOFUEL PLANTS IN THE EU

Table A1. Advanced biofuel plants in the EU that use straw as raw material input

Plant Name	Location	Technology	Plant type	Status	Total Input* (t/a)
Abengoa Bioenergy	Salamanca, ES	Biochemical	Demonstration	Operational	35000
Chempolis Biorefining Plant	Oulu, FI	Biochemical	Demonstration	Operational	25000
Inbicon (DONG Energy)	Kalundborg, DK	Biochemical	Demonstration	Operational	30000
Mossi & Ghisolfi - Chemtex / Italian Bio Fuel	Crescentino, Piedmont, IT	Biochemical	Demonstration	Under Constr.	180000
Sued-Chemie AG (Sunliquid)	Bavaria, DE	Biochemical	Demonstration	Under Constr.	4500
BornBiofuels optimization	Ballerup, DK	Biochemical	Pilot	Operational	3750-4000**
BornBioFuel 1 (BioGasol)	Ballerup, DK	Biochemical	Pilot	Operational	3750-4000**
EtanolPiloten i Sverige AB	Sweden	Biochemical	Pilot	Operational	NA
Inbicon (DONG Energy) Pilot 1	Fredericia, DK	Biochemical	Pilot	Operational	750-800**
Inbicon (DONG Energy) Pilot 2	Fredericia, DK	Biochemical	Pilot	Operational	7500-8000**
Mossi & Ghisolfi - Chemtex Italia	Tortona, Piedmont, IT	Biochemical	Pilot	Operational	200
Futurol Project (PROCETHOL 2G)	Pomacle, FR	Biochemical	Pilot	Operational	2700
Maxifuel	Copenhagen, DK	Biochemical	Pilot	Operational	450-480**
Bioliq (Karlsruhe Institute of Technology)	Karlsruhe, DE	Thermochemical	Pilot	Under Constr.	3750-4000**
Cutec	Clausthal-Zellerfeld, DE	Thermochemical	Pilot	Operational	NA
OFT Alyssa (BFT Bionic Fuel Technologies AG)	Aarhus, DK	Other Innovative Conversion	Demonstration	Operational	375-400**

Notes: Information taken from an updated online map underlying Bacovsky *et al* (2010), <http://biofuels.abc-energy.at/demoplants/projects/mapindex>. *Total raw material input, not necessarily just straw; **Own calculation based on an estimated operating hours of 7500-8000 hours per year; NA = not available. Plant type options: demonstration, pilot, commercial; Status options considered: announced, under construction, under commissioning, operational, on hold (plants that are planned disregarded).