II. Greenhouse gas markets, carbon dioxide credits and biofuels[17]

The previous chapter analysed mandatory blends and utilization targets as policy measures that can provide incentives for expanded biofuels production. GHG policies[18] that create a carbon price either through an emissions trading system or directly by taxing GHG emissions also generate increased demand for biofuels. They do so by raising the price of burning the fossil fuels with which biofuels compete. GHG policies thus represent yet another way to stimulate biofuel production.

It is widely believed that the biofuels industry has a unique role in climate policy because it represents a low-carbon alternative to fossil fuels. Nevertheless, the industry may face challenges in taking full advantage of this potential if CO_2 markets do not take into account all emissions related to biofuels production and use. Indeed, the effectiveness of biofuels as a low-carbon alternative depends on how they are produced and how emissions related to land use are managed.

At a high level of demand for biofuels, the overall need for cropland requires significant conversion of land from less intensively managed grass and forestland. This initial disruption leads to significant carbon dioxide release from soils and vegetation. If mature forests are converted, it can take decades of biofuels use to make up for the initial carbon loss. Given the increasing competition for the use of land, which can result in higher agricultural, land and food prices, it becomes relevant to address the potential outcomes from land conversion.

This chapter argues that it is necessary to have a full assessment of the emissions linked to biofuels production and use, including emissions related to direct and indirect land-use changes. Therefore, we discuss potential ways of expanding "cap and trade" systems by including terrestrial carbon sinks and forests, in order to ensure that biofuels are produced in a sustainable manner.

The chapter starts with an analysis of the interactions between the biofuels industry and GHG policies, followed by a discussion on the carbon neutrality of biofuels. Finally, we address the issues related to the inclusion of emissions from land-use change in a cap and trade system.

A. GHG policies as a way to boost biofuel demand

Increased focus on the mitigation of greenhouse gas (GHG) or carbon dioxide (CO_2) emissions can provide incentives for expanded biofuels production through a variety of policy measures, such as the mandatory blends, utilization targets and low-carbon fuels standards analysed in the previous chapter. GHG policies that create an emissions trading system such as the cap and trade mechanism can also stimulate the production of biofuels by imposing a cap on carbon emissions and allowing trade of emissions permits (allowances). In practice, such a

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[17] This chapter was prepared by Sergey Paltsev, John Reilly and Angelo Gurgel, Joint Programme on the Science and Policy of Global Change, Massachusetts Institute of Technology, Cambridge, United States.

[18] Most GHG proposals focus on carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6) emissions. As CO_2 is the main greenhouse gas related to human activities, the terms "carbon policy", "CO_2 policy" and "GHG policy" are often used as synonyms. We follow this convention, unless otherwise specified.

system creates a price for carbon, similarly to the imposition of a tax on GHG emissions. Box 2.1 defines the cap and trade system in more detail.

Box 2.1. Creating tradable emissions reductions

There are two main approaches to create tradable emissions reductions (Ellerman et al., 2000). The first is a cap and trade system in which a central authority sets a limit or cap on the amount of a pollutant that can be emitted. Companies or other groups are required to hold an equivalent number of allowances (or credits) that represent the right to emit a specific amount. The total amount of allowances and credits cannot exceed the cap. Covered entities may purchase allowances if they need them or sell extras as long as they have enough to match their emissions. The transfer of allowances is referred to as trade. Differences among entities in terms of their costs of abatement determine the demand and supply for allowances and their market price.

An alternative approach is a baseline and credit system. Polluters not under an aggregate cap can create credits by reducing their emissions below a baseline level of emissions. These credits can be purchased by polluters that are under a regulatory limit. The baseline is established on a project-by-project basis. Applying for approval of projects that produce such credits is voluntary. To be effective, a credit system needs to be part of a mandatory system (i.e., cap and trade or tax). Credits have value and entities have an incentive to produce them since they can be used by entities under the mandatory cap and trade (or tax) system instead of issuing allowances (or paying the tax). An entity not covered by the cap has an economic incentive to enter the credit market if its baseline is established in such a way that it can produce credits through abatement at less than the market price of allowances. Interest in the credit system depends thus on the baseline and the allowance price. Non-covered entities that choose not to enter the credit system are not required to make any reductions, and can increase emissions without any penalty. The main concerns with a credit system are the voluntary nature of participation and the bureaucracy of establishing a baseline for each project.

An example of carbon emissions trading system is the European Union Emissions Trading Scheme (EU ETS). In the United States, Senators McCain and Lieberman (Climate Stewardship Act of 2003) and Senators Warner and Lieberman (Climate Security Act of 2007) tried to introduce a similar system, but the legislation was not approved by the United States Congress. Nevertheless, a similar bill is expected to be approved soon.

Cap and trade systems may or may not include agriculture in a sectoral coverage, but such CO_2 pricing systems often include a mechanism whereby credits from activities not directly covered by the trading system (or the carbon tax) can be used to offset emissions from covered entities.[19]

Policies that create a carbon price either through an emissions trading system or directly by taxing GHG emissions can also stimulate the production of biofuels.

The main international agreement currently addressing GHG mitigation is the Kyoto Protocol (United Nations Framework Convention on Climate Change (UNFCCC), 1997).[20] Under this agreement, 37 industrialized countries and the European Community are committed to reduce their overall emissions of greenhouse gases by at least 5 per cent below 1990 levels during the period 2008–2012. Countries under the cap are referred to as “Annex B countries”.

The Kyoto Protocol establishes the use of three market-based mechanisms to facilitate GHG emission-reduction targets: (a) Emissions Trading, which allows the international transfer of national allocations of emission rights between parties with commitments under the Kyoto Protocol (Annex B countries); (b) The Clean Development Mechanism (CDM), which allows Annex B countries to implement emissions reduction projects in developing countries that generate certified emission reduction (CER) credits; and (c) Joint Implementation, which allows

[19] Most of the current American proposals exclude agriculture (both emissions and sinks) from direct coverage of the cap and trade system, but so-called “offsets” from project-type credits from agriculture are allowed. In principle, agricultural emissions and sinks can and should be included into cap and trade, as we argue in this chapter.

[20] The Protocol was adopted in Kyoto, Japan, in December 1997 and entered into force in February 2005; 183 parties of the convention have ratified the protocol to date.

the creation of emissions reduction credits through transnational investment between Annex B countries (and/or companies from those countries).

Emissions reductions generated under any of these mechanisms are referred to as “carbon credits”. One carbon credit represents one ton of CO2-e (carbon equivalent) non-emitted or reduced. The Kyoto Protocol, along with the EU ETS, created the largest market in the world for trading carbon credits. Therefore, countries under the Kyoto Protocol or other cap and trade systems that allow credit creation by non-covered entities have incentives to finance credit-generating projects elsewhere or to purchase approved credits.

Biofuel is considered a low-carbon emissions fuel, and therefore a biofuel production project is a potential candidate for eligibility under the CDM or Joint Implementation mechanisms.[21] CDM projects are approved on a case-by-case basis; the CDM Executive Board avoids approving projects that would have happened despite the carbon policy and seeks to ensure that projects reduce emissions more than would have occurred in the absence of the projects. So far, none of the existing biofuels projects in developing countries has been approved for CDM, but there are several biofuels CDM projects at the validation stage, including biodiesel projects in China, Indonesia and Thailand.

The Kyoto Protocol paved the way for a GHG credit market by establishing the CDM and Joint Implementation mechanisms. The demand for credits depends, however, on the establishment of binding limits within each country, but not all Annex B countries have allocated caps to individual emitters, who could in turn acquire allowances or CDM/Joint Implementation credits to meet their targets. To the extent that these credits are fully fungible in different countries, a de facto international emissions trading system would be created, equalizing the price of CO_2 credits in all markets.[22]

Europe implemented its emissions trading scheme in January 2005, as part of the Kyoto Protocol. The EU ETS works on a cap and trade basis, forcing companies either to emit less CO_2 than their determined cap of emissions for all installations or to buy EU Emission Allowances (EUA) from elsewhere.[23]

Even without explicit GHG markets that allow for CO_2 credits, demand for biofuels is likely to expand unless another low-carbon alternative in the transportation sector emerges.

Apart from European countries that are under a cap and trade system, countries that have not attributed a cap to individual firms but face commitments under the Kyoto Protocol also represent a potential source of demand for credits. For example, Canada and Japan have not moved yet to set up a market trading system but face their commitments under Kyoto, and entering the carbon credit market is one likely avenue for them to meet their reduction targets.

Nevertheless, we believe that, even without explicit GHG markets that allow for CO_2 credits, the demand for biofuels is likely to expand unless another low-carbon alternative in the transportation sector emerges. Moreover, bioenergy production will likely increase even in the

[21] On the other hand, projects that encourage land use as a carbon sink are also eligible for CDM and can thereby limit the amount of land available for biofuels production.

[22] An exception would be a country with a cap and trade system that generated a price below the international price, if its allowances could not be traded internationally. There would be no incentive for firms within that region to purchase the more expensive credits elsewhere.

[23] The European ETS (EC, 2003; EC, 2005) was in its test phase during the years 2005–2007; when CO_2 prices reached over 30 euros per ton, great interest was generated in Kyoto’s Clean Development Mechanism. After a collapse to under 1 euro per ton in 2007 (discussed in Reilly and Paltsev, 2006), the price of the ETS during the Kyoto period (2008–2012) remains in the range of 20–25 euros. For a detailed analysis of the ETS, see Ellerman and Joskow (2008).

absence of climate policy due to higher oil prices.[24] The last seven years have been characterized by an unprecedented, sharp and volatile rise in oil prices. Prices have risen for seven consecutive years from $26 per barrel in 2001 to over $140 per barrel in July 2008. After the price spike in July, oil prices declined in September and went down to below $50 in December 2008, as growth of demand weakened. However, prices remain very volatile, with daily swings.

Under a scenario of increased biofuels production, key issues remain to be addressed: the long-term impact on food prices and land use and the extent to which it translates into deforestation and ecosystem disruption. In the present analysis we focus on this second issue, which is closely linked to the discussion of whether biofuels are indeed carbon neutral.

Box 2.2. The competitiveness of biofuels

Apart from GHG policy, recent movements in the crude oil price have changed the competitive picture for biofuels. The IMF (2007) provides cost estimates for ethanol and biodiesel production, compared to gasoline and diesel. Assuming a $65 per barrel crude oil price and 2006 agricultural prices, only sugar cane-based ethanol has a lower production cost (about $0.25/litre versus $0.30/litre for gasoline). If free trade is allowed, these cost estimates suggest that Brazil, India and Malaysia would be major biofuels exporters. Asian (Indonesia, Philippines and others) and African countries (Benin, Burkina Faso, Ghana, Kenya, Madagascar, Nigeria, the United Republic of Tanzania and others) with a similar climate and available land may also become important biofuel exporters. With a crude oil price of $120/barrel (May 2008), the production cost of gasoline and diesel is around $0.90/litre (IEA, 2006). At that level, biofuels from any of the feedstocks available (maize, wheat, sugar beets, palm oil, soybean oil, rapeseed oil and others) become competitive, even without mandates or a further CO_2 price on fossil fuels. On the other hand, the level of oil prices has already returned to about $45/barrel (December 2008) and is likely to remain so, or decline even further, given the recent financial crisis and consequent global slowdown.

B. Is biofuel carbon neutral? The importance of land-use change and deforestation

When biofuels are burned, there is CO_2 emission; however, when vegetation re-grows, it again takes CO_2 out of the atmosphere. A cycle of growth, harvest, and re-growth can thereby be carbon neutral (i.e., zero net emissions over the harvest and re-growth cycle).

Since GHGs have a long life, a cropping cycle of a year or less (or even a decade in the case of a fast rotation woody crop), would not lead to significant changes in GHG concentrations. On this basis, an emissions trading system might exempt biofuel use from the cap and thereby not require allowances to cover CO_2 emissions from biofuels. A GHG credit could be created through the CDM or Joint Implementation to the extent that the production of biofuels replaces fossil fuel use (outside of capped countries). Thus, the amount of CO_2 emissions avoided would determine the number of GHG credits generated by the project.

But are biofuels indeed carbon neutral? Some biofuels use significant amounts of fossil fuel in production and the correct offset ratio may be as small as 0.3 unit of credit for every unit of fossil fuel CO_2 avoided. Moreover, the issue of land-use change and deforestation needs to be considered. A mature "old growth" forest or one that has been undisturbed for decades contains a large stock of carbon in the woody parts of the plant and in the soil. Deforestation leads to the release of much of this carbon and depletion of the stock of carbon.

A short rotation biofuel crop would get credit for offsetting fossil fuel use, but should be debited for the depletion of carbon that occurred with land-use change. The carbon loss from initial conversion is essentially a one-time loss which, through annual harvests of biofuels that are credited for offsetting fossil fuel use, eventually makes biofuels a net positive contributor to

[24] Box 2.3 illustrates recent climate policy developments in Europe and the United States that are likely to increase demand for biofuels. Box 2.2 briefly discusses the relation between oil prices and biofuels production.

reducing carbon emissions. How long it takes to pay off the carbon debt depends on the quantity of carbon previously stored in the disturbed ecosystem and on the net fossil fuel use offset. Regarding the latter, we need to take into account any fossil fuel used in growing, transporting or processing the biomass/biofuel. If biofuel crops are established on degraded or nutrient-limited land, it is possible that intensive management of the crops could actually increase the carbon stock by adding to the soil the unharvested stubble/roots of the crop.

However, establishing the extent to which land-use change emissions are attributable to biofuels is complicated by the fact that agricultural and potential biofuels markets are global in nature. In that sense, the presence of biofuels crops on degraded pasture and grazing land might have a neutral or positive effect on soil carbon on that parcel of land. However, if the displaced grazing activity leads to deforestation elsewhere, the emissions from that land-use conversion should be indirectly attributable to biofuels.

We argue that if emissions derived from biofuels productions are included in the trading systems, the issue of carbon neutrality of biofuels is mitigated.

1. A "comprehensive" CO_2 cap and trade or tax system would solve the issue of the carbon neutrality of biofuels

Questions related to the degree of carbon neutrality arise for biofuels in a CO_2 cap and trade or tax system when the system does not take full account of all emissions derived from biofuels production and use, as is currently the case. If biofuels production was itself under the cap, allowances would be required for any fossil fuel used. If land sinks and sources were under the cap, allowances would be required to offset emissions related to deforestation. Requiring allowances for biofuel production and land-use change would thus ensure the carbon neutrality of biofuels even if fossil fuels were used and land-use change occurred. Producers and landowners would have to procure CO_2 allowances that led to emissions reductions elsewhere to offset their own emissions.

Cap and trade systems like the ETS have so far not been extended to land-use emissions and do not cover production facilities of any kind, including biofuels, outside of the region with a cap and trade. In fact, the ETS does not include the transportation sector and therefore does not provide incentives for ethanol or biodiesel use in Europe. Nevertheless, the EU directive sets a target for the use of biofuels in transportation, and that requirement has already led to the perception that such incentives for expanded biofuel use can lead to non-sustainable production, i.e., deforestation that emits carbon and destroys unique ecosystems.

Below we discuss the issues related to the inclusion of land-use emissions in a trading system.

C. Expanding the carbon market to enhance the sustainability of biofuels

We argue that, for environmental effectiveness, it is important to bring all carbon-related activities into carbon markets. In addition to fuel-burning activities, land-use change affects emissions. Full protection of soils and vegetation (and fossil fuels used in processing biofuels) would allow biofuels to be credited for 100 per cent offset of the fossil fuel they displace. While full inclusion of land-use emissions and sinks under a cap and trade system would seem to be ideal, a number of practical issues and objections have arisen. In the following sections we consider how these emissions can be included in carbon markets. For a more complete discussion see Reilly and Asadoorian (2007).

Many analysts and policymakers argue that land's unique characteristics make it impossible or difficult to include it in a cap and trade system. Land, unlike other fossil fuel emissions, can be a source of emissions similar to coal combustion in a power plant, but it can also be a sink for carbon. However, we argue that this particularity (negative emissions or sinks) does not impede the inclusion of land in a trading system. Emissions are normally counted from zero to some positive amount, requiring allowances for all emissions above zero. For fossil emissions, the usual perception is that one could abate all of its emissions. However, nothing about a trading system inherently prevents abatement of more than 100 per cent of emissions. Thus, land can emit or capture carbon, and both land emissions and sinks can be included in a trading system.

Land can be included in a cap and trade system to fully account for biofuels' sustainability and carbon neutrality. However, agreeing on baseline land emissions can be challenging.

There is, however, an important distributional issue related to what is expected of a landowner or a country with large stock of land-based carbon. The natural approach is to establish a baseline at zero net flux of carbon to the atmosphere. Landowners (or countries) with a positive net flux would need to acquire allowances, while those with a negative net flux would be able to sell allowances. Nevertheless, other criteria can be used to establish a baseline for land-use emissions. If the objective is to not reward actions already taken, the landowners/countries could be required to meet an estimated path of uptake and only be permitted to sell allowances if they exceeded that uptake. Countries subject to deforestation could be given a baseline that allowed further deforestation but would then be allowed to sell allowances if that deforestation (or some part of it) was avoided.

One important aspect is that if a great parcel of the existing uptake is allowed to be credited (e.g., the baseline is implicitly zero net flux), this will relax an overall carbon emissions target. However, that can be offset by further cutting the number of allowances allocated to other emitters. At this point it is important to outline the definition and distribution of property rights. At one extreme, landowners have the right to convert all land they own (and release the carbon associated with it) unless they get paid for avoided emissions. At the other extreme, they are responsible for maintaining (or restoring) carbon in land and vegetation at its natural level and must purchase allowances if the stock is below this level. What matters for efficiency (and for the incentive to preserve carbon) is the value of carbon at the margin. In either of these extreme cases (or others in between) the landowner values carbon at the going price, either because (s)he faces the opportunity cost of not being able to sell allowances or must acquire allowances for maintaining the natural level of carbon in land and vegetation

If land use is completely within a carbon cap and trade system, the most direct implication for biofuels is that landowners would balance the market price for biofuels (reflecting its value in terms of offsetting fossil fuel use) with the cost of acquiring allowances to cover emissions from land-use conversion for biofuels production. On the other hand, by producing biomass in a manner that increases the stock of carbon on degraded or poor quality land, landowners would benefit from both the price of biomass and the ability to sell carbon credits. However, if pasture or grazing land was converted to biofuels, livestock producers would need to consider the carbon implications of converting other natural lands to pasture or grazing since this would imply the need to acquire carbon allowances to cover carbon emissions.

Many policy and science discussions about biofuels posit that substantial amounts could or should be produced on degraded or poor quality land, and therefore would not result in significant land-use conversion. When land-use decisions are market-driven and the pricing of carbon emissions from land includes the cost of converting land with large stocks of carbon, there are incentives to use degraded or poor land for biofuels production.

D. Issues of sinks in policy discussions

Analysts have raised a number of issues related to the incorporation of sinks[25] into a cap and trade system. These issues are often used as justifications for the impossibility or difficulty of including them in the carbon market. Nevertheless, we believe that none of the issues pose insurmountable challenges for including land use fully under a cap and trade system and that the claim that land use is different from fossil emissions is often exaggerated. Below we summarize each of these issues.

1. Payment for land-use emissions

How much to pay for an additional ton of sequestration, compared to an avoided ton of emissions? Among the various approaches proposed to determine the payment for land-use emissions, many focus on establishing the value of a temporary storage of carbon (Herzog et al., 2003). Landowners are paid a rental value (an annual amount for each ton). However, since the landowners' responsibility for future changes in the stock of carbon is not well defined, the rental rate is often based on some presumption of how long the carbon will remain in the land, and requires that the public agency establishing the rental price determine the time path of the carbon price. Like a credit system, landowners must be perpetually bid into the system. McCarl et al. (2005) and Lewandrowski et al. (2004) provide a comprehensive review of different approaches.

We propose that, to ensure consistency with a cap and trade system, landowners should instead pay the full price, or receive the full credit for each ton emitted or taken up over a period. They are permanently under the cap so that future changes in the carbon stock are subject to the cap, and landowners bear permanent responsibility for the carbon. Decisions about what to do with a parcel of land are reversible at any time but must take into account the carbon implications of the change and the market price of carbon at that time, as well as expectations about future changes in the price. If this becomes the principle for managing land carbon, then private intermediaries can devise payment schedules or contracts that remove risk from unexpected changes in the carbon price (Reilly and Asadoorian, 2007).

Without this type of provision, there are concerns about the permanence of carbon sinks, with attempts to penalize landowners for not maintaining the carbon, as discussed further below. Such provisions could be important given the growing biofuels industry. Biofuels production ought to be responsible for land-use emissions but if the demand for biofuels is strong, conversion of land may be warranted, and if allowances for carbon are purchased to offset such emissions then the net impact on the atmosphere is neutral. Without this flexibility to convert land when demand for biofuels (or food) is unexpectedly high, the price of land and of food could rise unnecessarily.

2. High variability in carbon uptake and release on land

The quantity of carbon taken up by plants varies dramatically from year to year depending on the weather (e.g., Felzer et al., 2004; Sarmiento and Gruber, 2002). Events such as wildfires can lead to sudden release of much of the carbon stored in the area subjected to the fire (Zhuang et al., 2003). However, we argue that natural phenomena that generate variability are not different from the average situation landowners face: inclement weather that leads to relatively little carbon uptake, and possibly net emissions, is not different from inclement weather leading to crop failure and financial loss.

[25] A carbon sink is a reservoir of carbon that accumulates and stores carbon for an indefinite period. Oceans and plants (through photosynthesis) are the main natural sinks.

This variability does not suggest per se that land use cannot come under a cap and trade system. Rather, we suggest that the squaring up period (how often a landowner is required to measure the carbon stock) should be relatively long, in the order of 10 or 20 years. As such, the issue of high variability would be attenuated, since landowners would be able to bank and borrow emission allowances against the future (Reilly and Asadoorian, 2007).

3. Direct human responsibility for sequestration

One of the most problematic aspects of the Kyoto Protocol is that it limits the generation of carbon credits to “direct human-induced change” (article 3). However, there are several natural or indirectly human-induced changes that can cause an increase/decrease of GHG emissions in the atmosphere. For example, nitrogen deposition, along with increased ambient levels of CO_2, enhances forest growth and carbon uptake (Felzer et al., 2004); tropospheric ozone and other pollutants damage vegetation and reduce uptake (Felzer et al., 2005). Climate change itself affects plant growth – these are examples of “indirect effects” that the Kyoto Protocol excludes. We believe that article 3 creates considerable difficulties in defining what constitutes direct human-induced changes versus natural changes or those indirectly caused by human action. The problem is very similar to the issue of carbon emissions directly or indirectly related to biofuels expansion. Therefore, a cap and trade system should include rules that require responsibility for carbon on the landowner’s parcel of land, regardless of the cause (direct or indirect). These rules would minimize endless challenges and controversy.

4. Permanence and leakage

Another issue is the presence of leakage in the context of a cap and trade system. Physical leakage happens when, in a specific project or land parcel, parts of the carbon originally stored returns to the atmosphere. This phenomenon is also often referred to as an issue of the “permanence of the sink”. A particular form of leakage is what has come to be known as “indirect” emission. These occur in a cap and trade system when more emissions enter the atmosphere due to an increase in emissions by entities that are not under the cap, which offset reductions made by regulated entities.

We believe that physical leakage can be addressed if landowners have permanent responsibility for carbon stocks. As discussed above, physical permanence is not necessarily desirable because there may be good reasons to reverse decisions to build up carbon stocks. That is not a problem if allowances are required to offset losses whenever conversion occurs. However, spatial and temporal leakage from a policy regime occurs when the policy is incomplete in the sense that it covers some sources but not all, or provides incentives for a period of time but not indefinitely (Reilly and Asadoorian, 2007).

Policy-induced leakage is a particular problem for biofuels. This is a fairly homogenous product for which one would expect there to be an international market. As a result, a country that includes land use in a cap and trade system might discourage unsustainable biofuels production within its borders, but that could result in imports of biofuels (or of food and forest products) from countries without such controls. Therefore, an efficient carbon control system needs to discriminate among sources of biofuels. Indeed, policies prescribing biofuels or low-carbon fuels usually include criteria related to biofuels’ production method or origin. As long as land-use emissions are incompletely controlled such discrimination remains necessary. However, discriminating against a country or a particular production technology does not create direct incentives for producers to improve their processes, whereas a complete carbon management system including land-use emissions would.

5. Pre-existing distortions

Due to the presence of taxes, subsidies and other unregulated externalities, prices do not exactly reflect the real marginal cost of goods. Therefore, a policy that results in equating marginal costs of carbon reduction among countries or across sectors may not be the most effective policy (Babiker et al., 2004). Some countries impose heavy taxes on fuels, for example, which affect the cost-effectiveness of carbon policy (Paltsev et al., 2007). Likewise, agricultural subsidies affect the efficiency of carbon pricing (currently there is no study on this effect). There are also positive externalities (ancillary benefits) from carbon sequestration and emissions reductions: for example, emissions reductions by fuel switching may reduce the emissions of other air pollutants (Matus et al., 2008) and carbon sequestration may reduce soil erosion and leaching agricultural chemicals, thereby reducing water pollution (Marland et al., 2001).

Biofuels production presents its own set of positive and negative externalities that depend, in part, on what it is replacing. If biofuels replace row crops or severely degraded grazing land, this could result in benefits in terms of reduced soil erosion or reduced use of chemicals pesticides. However, sustained production of biofuels would likely require fertilizer inputs, generating the negative externality of N_2O emissions from nitrogen fertilizer. It seems possible to provide a single price signal to cover major greenhouse gases (CO_2, CH_4, N_2O) by using Global Warming Potentials (GWPs) to convert non-CO_2 GHGs to CO_2-equivalent emissions. Thus, a cap that covers land-use emissions should also include N_2O and CH_4 emissions, powerful greenhouse gases that, if not included, could undermine biofuels' value in offsetting fossil fuel emissions. In summary, we believe that pre-existing distortions should be treated on a case-by-case basis, depending on the nature of the distortion.

6. Measurement, monitoring and enforcement

Concern exists regarding the feasibility of monitoring and enforcing changes in land-use emissions. Despite progress in the development of methods to measure soil and vegetation carbon, there is an ongoing debate on whether direct measurements are needed or whether a list of practices associated with specific carbon levels is enough. Given the high carbon variation associated with different practices, we believe that some form of direct observation and assessment is needed. Nevertheless, it is necessary to evaluate the trade-off between the cost of monitoring and the accuracy required. The value of good monitoring and measuring instruments and protocols increases with the presence of higher quantities of carbon in vegetation and soils, and with increasing biofuel production.

7. Carbon stored in products

Harvested material from forests and farms compounds a variety of product streams. Some are relatively short-lived such as food or pulp and paper. Others may remain "stored" for decades or hundreds of years (e.g., lumber used in buildings or furniture). The lifetime of carbon in biofuels is very short (weeks or months), from the time the biomass leaves the field to the moment it is finally used in a vehicle. For this reason, biofuel is often considered neutral with respect to atmospheric carbon: carbon taken up by plants is released when biofuels are combusted and recaptured when plants re-grow. Therefore, over a period of a year there is no net change in atmospheric carbon. Schlamadinger and Marland (1999) provide estimates and discuss issues related to carbon in the product stream.

This raises a key question: should the harvested product be tracked until it decomposes, and only then counted as an emission of carbon requiring an allowance? In principle, the answer is yes: this would provide an incentive to not finally dispose of the product, if it can be reused. In doing so, it would accurately account for the time between harvest and decomposition, during which the carbon remained out of the atmosphere. However, this would require a complex tracking system both of the product and its owners. Such a system would presumably favour products with longer-term storage of carbon (which is not the case of biofuels).

A simpler approach would be to ignore the storage and assume that the carbon will ultimately return to the atmosphere. Yet another approach is to apply an average discounted ton factor as an offset to the total harvest.[26] Both approaches do not create incentives to prolong the life of carbon stored by not destroying structures or by recycling used lumber. Crediting via a discounted ton approach brings the problem of estimating this discount factor, which is not a trivial task (Herzog et al., 2003).

Schlamadinger and Marland (1999) find that, in cases of massive cutting of forests with large amounts of biomass, the level of carbon may never return to the pre-disturbance level. Similarly, disturbed cropland often has significantly less carbon than in its pre-disturbed state. To correctly account for such land conversion losses of carbon or non-sustainable management of land, land used to produce biomass would need to come under a cap. In that way, correct incentives to maintain carbon stocks in soils or in standing vegetation would be provided. Because the bioenergy would be combusted relatively quickly after production (e.g., weeks, months or a few years at most), one could then exempt emissions from fuel combustion (e.g., at power plant or by vehicles using a liquid fuel). This approach could be applied to other product streams that are short-lived, reducing the monitoring problem to the land parcel without the need to follow the product stream.

And what happens if biomass is not finally converted to fuels? If a large portion of biomass not converted to biofuels is instead used as process energy, then the carbon would be released to the atmosphere. To the extent that some portion of the biomass ends up in animal feed, it too would end up mostly emitted as carbon dioxide with relatively fast turnaround. One exception to this would be process facilities that include carbon capture and storage (CCS), similar to that envisioned with power generation. Under this circumstance, biofuels could create a net sink: the fuel produced would offset fossil fuels and the carbon emitted in the production process would be stored (for example, in deep aquifers). Moreover, biofuels production processes that utilize gasification can benefit from the same carbon capture and storage technologies as those applied for coal gasification. For fermentation/distillation conversion processes, "end of pipe" capture methods would be needed.

The issue of carbon contained in products presents a further measurement and monitoring issue that could add considerable complexity to any system. The lifetime of the product matters, and further investigation is needed as to whether a monitoring system for long-lived products, tracking their fate until their eventual decomposition, would improve efficiency or present a costly burden with little benefit.

Box 2.3. Recent developments in climate policies in the United States and Europe

United States. While the United States did not ratify the Kyoto Protocol, its Congress has introduced legislation (the McCain and Lieberman Climate Stewardship Act of 2003 and the Warner and Lieberman Climate Security Act of 2007) that, if passed into law, would create a nationwide cap and trade system. This legislation did not gain enough support in Congress, but as the newly elected United States President is in favour of a cap and trade system, it is expected that similar legislation will be introduced again soon. The United States Administration also announced a significant goal for the utilization of alternative fuels for transportation (Renewable Fuel Standards, 2005), driven by climate and energy security purposes. More importantly in terms of actual market dynamics, the ban on the use of MTBE (methyl tertiary butyl ether) generated additional demand for biofuels, as refineries in the United States decided to switch to ethanol as an oxygenate substitute. Ethanol use as a direct gasoline replacement is still limited but is increasing, since it requires the penetration of flexible fuel vehicles and the development of infrastructure to deliver E85 and biodiesel to consumers. This, in turn, is likely to involve a major change in capital investment plans for refineries, car manufactures and gas stations.

[26] Concerned that the carbon may not remain stored, the concept of "discounted" tons was created, whereby a fractional discount factor would be applied to account for possible return of carbon in the future (i.e., physical leakage).

In December 2007, President Bush signed into law the Energy Independence and Security Act. A major feature of the legislation is the requirement to produce 9 billion gallons of ethanol by 2008 and 36 billion by 2022. The act distinguishes between conventional corn-based ethanol, biomass-based diesel, cellulosic ethanol and advanced biofuels from other sources (such as sugar starch, waste materials and biogas). The CO2 emissions associated with production are a concern and must meet a minimum improvement of 20 per cent for life cycle greenhouse gas emissions compared with gasoline. Biomass-based diesel and advanced biofuels should have at least 50 per cent less of life cycle greenhouse gas emissions compared to the fuel they replace, and for cellulosic biofuels the requirement is at least 60 per cent less life cycle emissions. Biofuels that achieve 80 per cent or more reduction in life cycle greenhouse gas emissions are eligible for further subsidies (section 207(b)(2)). The legislation also has specific carve-outs for cellulosic biofuels and other non-conventional biofuels (e.g., biodiesel). However, recent reports indicate that the United States Department of Energy believes that the long-term target may not be fully achievable and some members of the United States Senate would like to see the short-term requirements relaxed to take pressure off of food prices.

Finally, in April 2007 the Supreme Court ruled (Massachusetts v. EPA) that carbon dioxide and other heat-trapping emissions are “air pollutants” under the Clean Air Act, and that the United States Government has the authority to curb them. Various states have already proposed to limit CO2 emissions through fuel standards or cap and trade systems.

Europe. Europe’s 20/20/20 proposal for 20 per cent reduction in greenhouse gases, 20 per cent improvement in efficiency and 20 per cent generation of energy from renewables (10 per cent from renewables in the transport sector) by 2020 is also expected to spur demand for biofuels. On 17 December 2008 the European Parliament adopted the directive on the promotion of the use of energy from renewable sources, which includes the above-mentioned targets.

E. Concluding remarks

The establishment of a carbon dioxide (CO_2) price creates incentives for the development of a global biofuels market either directly through enticements to substitute biofuels for fossil fuel use in countries with greenhouse gas (GHG) policy or indirectly through the Clean Development Mechanism (CDM). Nevertheless, it is reasonable to assume that bioenergy production will increase even in the absence of climate policy.

However, efforts to promote biofuels amid concerns about climate change have led to the perception that the efficacy of biofuels as a low-carbon alternative to fossil fuels depends on how they are produced and how land-use emissions are managed. At high levels of biofuels demand, there would be no incentive to protect carbon in the soils and vegetation through a credit system. Landowners would instead tend to convert land to biofuels or more intense cropping. Therefore, the provision of carbon credits to biofuels producers would increase biofuels production even more. This disruption would lead to significant carbon dioxide release from soils and vegetation.

We believe that the inclusion of land-use change emissions in emission trading systems (such as the EU ETS cap and trade system) would create incentives to control both direct and indirect land-use emissions and enhance land sinks. No allowances would be required when biofuels are used; however, they would be necessary to cover fossil fuel emissions related to biofuels production and any direct or indirect carbon losses associated with land conversion. There has been reluctance or a lack of understanding of how to extend a cap and trade system to land-use emissions, but we argue that many of the concerns that analysts and policymakers have expressed are easily addressed.

Another important factor that could play a crucial role in improving the environmental performance of biofuels is the development of second-generation technologies, which will be the focus of analysis of the next chapter.

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