SOUND PRINCIPLES AND AN IMPORTANT INCONSISTENCY IN THE 2012 UK BIOENERGY STRATEGY

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Background

In April of this year, the UK government came out with its Bioenergy Strategy. Department for Transport, DECC, DEFRA (2012), *UK Bioenergy Strategy* (London). Perhaps the most critical bioenergy issue facing the UK government right now is the extent of support for the use of biomass for electricity. In actual operation, that mostly means the use of wood pellets generated from the harvest of whole trees, which will come primarily from the United States and Canada. The Bioenergy Strategy included a call for properly subjecting this biomass to sound greenhouse gas accounting and to support only the uses of biomass that would reduce emissions between now and 2050 substantially. On pages 29-31, it also showed how the use of whole trees for electricity would violate these principles and concluded "The use of the entire tree for bioenergy is undesirable as it is generally associated with sub-optimal carbon scenarios and can result in increased greenhouse gas emissions." Such findings are consistent with a broad range of peer-reviewed papers as referenced at the end of this paper.

Later in the document, however, the Bioenergy Strategy provides another analysis that purports to show that using biomass to replace coal achieves cost-effective greenhouse gas reductions and should be a central part of UK energy strategy. The inconsistency between these two sections of the Strategy appears to have gone unnoticed. This paper briefly explains the conflict and its cause. That cause is that the justification for use of biomass for electricity in the later part of the document relied on the outdated method of greenhouse gas accounting rejected by the first part of the strategy.

Since the Strategy, the government has announced a higher rate of subsidy for conversion of biomass to electricity. Although the government has introduced a cap for new, dedicated biomass power plants, the cap would be set at the relatively high level of 1GW. These proposals are out for consultation along with a new sustainability and new greenhouse gas accounting standard.[1] To be consistent with the Strategy, these new accounting standards must properly account for the emissions from the use of whole trees, which would result in their disqualification for subsidies. To inform that discussion, this paper explains the inconsistencies in the Strategy and their source.

Sound Accounting Principles

The Bioenergy Strategy establishes four principles for future Government policy in this area, two of which are central to greenhouse gas results. Principle one calls for supporting only bioenergy that delivers "genuine carbon reductions that help meet UK carbon emissions objectives to 2050 and beyond" (p. 15). Principle two calls for pursuing bioenergy only to the extent those reductions are cost-effective in comparison with other forms of renewable energy. In short, bioenergy must deliver genuine and cost-effective greenhouse gas reductions by 2050.

The Strategy also includes explicit and important principles for greenhouse gas accounting. First, the strategy requires that this analysis look "at carbon impacts for the whole system" including indirect land use change (P. 18). Second, the accounting must include "the emissions resulting from redirecting biomass from other uses which store carbon," including the carbon storage if trees were "left in the forest to complete their natural lives" (p. 18).

This last statement is critical because it avoids crediting bioenergy for reducing or eliminating the world's forest carbon sink. The world's forests are accumulating large quantities of carbon on both a gross and net basis, due in part to regeneration from prior logging and in part to forest responses to increases in carbon dioxide.[2] Climate change would be far worse without this forest carbon growth. Indeed, this forest carbon sink is a major part of the reason that, on average, only half of each ton of carbon emissions emitted stays airborne: the ocean absorbs roughly one quarter and the forests another quarter. Some

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1 http://www.decc.gov.uk/en/content/cms/consultations/biomass_ro/biomass_ro.aspx

2 Y. Pan et al. (2011), A large and persistent carbon sink in the world's forests, *Science* 333:988-993; H. Haberl et al. (2012), Correcting a fundamental error in greenhouse gas accounting related to bioenergy, *Energy Policy* 45:18-23 (largely reproducing the opinion on bioenergy of the European Environmental Agency Science Committee of 2011).

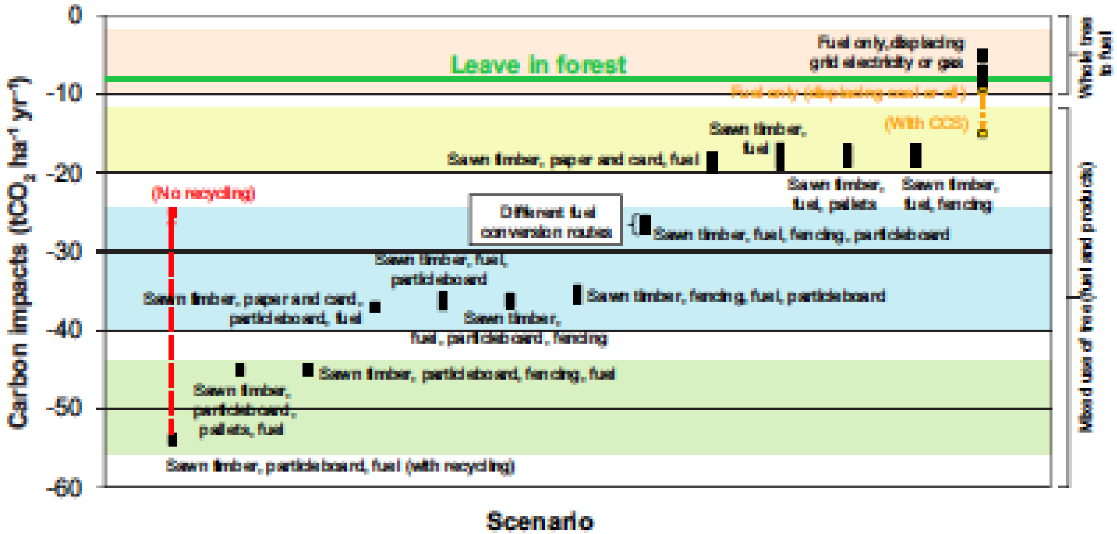
bioenergy analyses, including a report commissioned by DECC, [3] have assumed that biomass harvests are carbon free so long as carbon stocks in forests are maintained at the present level. In other words, harvests may eliminate the carbon sink and still be considered carbon free so long as they do not turn forests into a net source of carbon. But reducing any single ton of carbon sink is equivalent to adding a ton of carbon to the air from fossil fuels or any other source.

Analysis of Using Whole Trees for Electricity on Pages 29-31

Pages 29-31 of the Strategy apply these principles to the harvest of woody biomass from UK forests. Figure 4 of the Strategy, reproduced below, shows DECC's estimated emissions from the use of tree harvest for energy based on a study by Forestry Resources and North Energy Associates (see reference n. 3). Only the black and yellow bars to the extreme right represent scenarios that involve directly harvesting and burning wood. The black bars show that even after 100 years, the harvest and combustion of whole trees to replace electricity from natural gas or from the general grid would not reduce greenhouse gas emissions compared to the alternative, represented by the green bar, that involves leaving the wood unharvested. The small yellow bar calculates that there would be small savings, on the order of 2 tons of carbon dioxide per hectare per year, if electricity from wood replaced electricity from coal, and then only over 100 years.

[3] Portions of a background report commissioned by DECC made this error. *Forestry Research & North Energy Associates (2012), Carbon Impacts of Using Biomass in Bioenergy and Other Sectors: Forests (DECC, London).* That report treated the "resumption of management," i.e., harvest, of forests as a source of greenhouse gas emissions but treated the ongoing "management" (harvest) of forests as inherently carbon neutral. Because the alternative to harvest would either be leaving those forests in place or using the wood for wood products and other alternatives, the harvest comes with a carbon cost. That cost would either be less carbon in the forest or emissions from the increased use of alternatives to wood products, e.g.. concrete, plastic or steel.

Figure 4: Carbon sequestered and emissions avoided (saved, compared to a reference scenario) by harvesting UK conifer forests and using the wood in different applications to displace non-wood products and fossil fuels



Source: Forest Research and North Energy Associates, Carbon Impacts of using biomass in bioenergy and other sectors: Forests, 2012

Notes: Carbon impacts are calculated over a 100 year time horizon and wood is assumed to be disposed of at end of life by burning in a Waste Incineration Directive-compliant power only plant. For clarity,

Figure 4 shows savings per hectare not savings per kilowatt-hour compared to the use of coal. Fortunately, DECC has since provided the underlying data behind this figure for the harvest of wood from conifer trees to replace coal for electricity. Conifer trees are among the fastest growing tree species, and therefore produce the best greenhouse gas results. I show the calculations in Appendix A and I have confirmed these calculations with DECC. In short, the DECC analysis assumes that electricity from coal generates 1,042 gCO_2/KWh, and estimates that replacing coal with conifer wood results in:

- a 14% GHG reduction over 100 years (902 g/KWh)
- a 49% increase over 40 years (1557 g/KWh)
- an 80% increase over 20 years (1879 g/KWh)

Accordingly, in the text accompanying Figure 4, the Strategy appropriately rejects the use of whole trees. It concludes: "The use of the entire tree for bioenergy is undesirable as it is generally associated with sub-optimal carbon scenarios and can result in increased greenhouse gas emissions" (p. 30). This same judgment applies to "small roundwood," i.e., small trees. "Using small roundwood and sawlogs as a source for <u>materials</u> . . . is often the optimal use of forest wood" (p. 30, emphasis supplied). I interpret these statements as diplomatic given the analysis showing that harvesting whole trees of any size will result in increased greenhouse gas emissions compared not just to optimal scenarios but also to the simple alternative of leaving the wood in the forests. By contrast, the report endorses using "bark and branchwood as a source for bioenergy." (P. 30) Bark and branchwood are typically left to decompose on the forest floor or in the mill and are therefore the constituents of what are normally considered to be residues.

Possible Misinterpretations of Figure 4

Although Figure 4 and the accompanying text are ultimately clear, elements of the presentation could result in some misunderstandings.

First, Figure 4 presents a large number of fuel alternatives under the title of "carbon impacts of harvested wood," and most of them look highly favorable. A casual reader might mistakenly assume favorable results from the harvest of wood generally for bioenergy. Yet, all of these favorable alternatives involve using wood first for various products and then burning the wood for energy only after their useful product lives. Such biomass is conventionally viewed as a form of waste because it must be collected when products are thrown away or demolished. Such uses will reduce greenhouse gas emissions.

Second, the presentation of results in Figure 4 based on a 100-year time horizon obscures the large increases in emissions estimated over several decades. That discussion is incompatible with the Strategy's explicit principle that bioenergy must contribute to the UK's 2050 greenhouse gas goals. As the UK has announced goals for reducing greenhouse gas emissions by 80% by 2050, uses of bioenergy that increase emissions over such time periods obviously help to meet these goals. I also note that these kinds of goal are implicit in the commitment to trying to hold global temperature increases anywhere near 2 degrees C, which requires large cumulative carbon reductions between now and 2050. [4]

In fact, UK accounting rules established for bioenergy in the Renewables Obligation already require that biomass accounting focus on a 20-year period..[5]

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[4] M.R. Allen et. al. (2009), Warming caused by cumulative carbon emissions towards the trillionth ton, *Nature* 458:163-1166

[5] Ofgen, *Renewable Obligation: Sustainability Criteria for Solid and Gaseous Biomass for Generators (greater than 50 kilowatts) Guidance* (Reference No. 184/11, 19 December 2011) p. 63. This section applies to accounting of emissions from land use change.

This rule is consistent with standards agreed by the European Commission as part of the Renewable Energy Directive (2009/28/EC).

Moreover, even over a period of 100 years, the emissions would violate Principle Two of the Bioenergy Strategy, which requires bioenergy GHG reductions to be cost-effective compared to the alternatives. That means electricity from biomass must meet a certain emission standard per kilowatt-hour. The existing standard is 285 g/KWh, and DECC has proposed that this figured be lowered to 240gCO_2/KWh for new dedicated biomass power plant and maintained at 285 for co-firing of biomass in coal power plants. As DECC's estimated emissions for electricity from whole trees are 902 g/KWh even over 100 years, the use of whole trees obviously does not qualify.

Potentially Contradictory Analyses on Pages 45-57

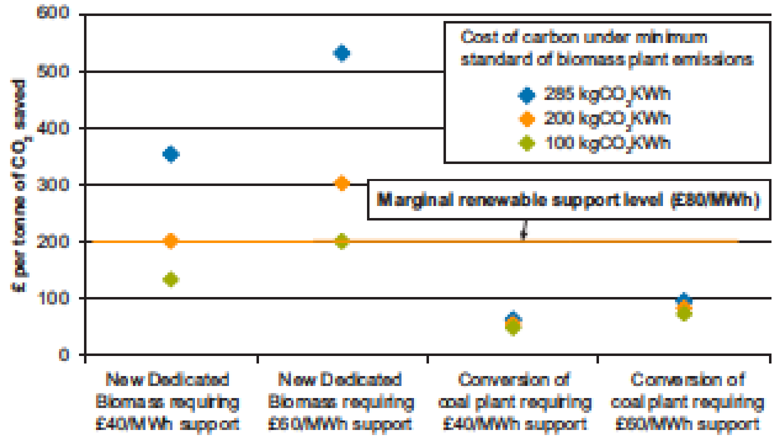
The inconsistencies in the Bioenergy Strategy arise from the discussion of biomass for electricity on pages 45-47, including Box 14. This discussion addresses Principle 2 and the extent to which electricity from "non-waste biomass" can be a cost-effective source of greenhouse gas reductions compared to other renewable fuels. The strategy states:

> "Use of biomass for co-firing with coal and conversion of existing coal fired plants is both a low cost renewable energy and a technology that is highly likely to meet the requirements of Principle 2. Because biomass will be displacing coal the £/tonne of carbon is significantly lower than the alternative technology (see Box 14)." (P. 45)

In turn, Box 14, reproduced here, analyses the costs of carbon abatement using "non-waste biomass" at three different possible emissions levels for biomass: 00, 200 and 285 gCO2/kWh. With coal emissions estimated at 909 kgCO2/KWh, the result is cost-effective mitigation. (Note that Box 14 has a typographical error, identifying emissions in one place at kilograms of CO2 both per "KWh" and in another at kilograms per "MWh." The correct units for the figures cited should be kg/MWh or g/KWh.)

Box 14: Carbon cost effectiveness of non-waste biomass in power (new build dedicated plants and conversions/co-firing)

Figure 9: Illustrative carbon cost effectiveness of new dedicated biomass against conversions and alternative renewable generation



Source: DECC analysis

Notes: Assumed emissions are related to the "feedstock used" only. No 'capital' GHG emissions of building or converting a biomass, CCGT or other renewable plant are included. New dedicated biomass emissions are against CCGT emissions of 398 kgCO_2/MWh while conversions are against coal generation at 909 kgCO_2/MWh.
Analysis assumes that higher CO_2 standards do not impact the required support for the plants.

How then can we make sense of Box 14? Put another way, how can Box 14 assume bioenergy emissions of 100-285 g/KWh even though Figure 4 uses an estimate for whole trees of 902 g/KWh even over 100 years? The explanation is simple. The illustrative range of emissions in Box 14 from 100 to 285 gCO2/KWh represent estimates of emissions solely from the production of the biomass, and they exclude emissions that result from the change in forest carbon. In other words, they represent emissions from the fossil energy used to grow, harvest, process and transport the biomass, not from the decrease in forest carbon stocks, foregone carbon sequestration or from land clearing. (Nor do the numbers include emissions from the diversion of timber from other uses that help hold down emissions, which is implicitly shown in Figure 4 as well.)

In summary, the emissions estimates used by DECC to establish that biomass electricity offers a cost-effective means of reducing emissions from power are based on a methodology for lifecycle analysis that Principle One of DECC's strategy rejects outright and corrects on pages 29-31.[6] Effectively,

[6] This can be seen even in the Bioenergy Strategy document itself by comparing the emissions figures used in Box 14 with those in Figure 14 on page 66. There, the same source is cited to show emissions from clean wood waste, which are in the same general

although Box 14 claims to judge use of "non-waste" biomass to be cost-effective, that judgment properly applies to the use of waste biomass.

Potential Confusion about the Term Land Use Change

Potential ambiguities about the term "land use change" may also help to explain these inconsistent results. The definition of the term "land use change" explains the difference between the correct greenhouse gas accounting called for in Principle One of the Bioenergy Strategy and the flawed accounting for bioenergy emissions under the existing rules for the Renewable Obligation.

Much of the Bioenergy Strategy emphasizes the importance of avoiding and accounting for emissions from land use change. Box 19 on page 63 also states that under the Renewables Obligation, lifecycle assessment for the greenhouse gas emissions from non-waste biomass must already consider "any direct land use change." Readers might therefore infer that the Renewables Obligation already builds in proper accounting and protection against the use of directly harvested forest material.

Yet, under the Renewables Obligation, the term "land use change" only means changes from one land use *category* to another. For example, the term applies to a change from grassland or forest to a bioenergy crop, or more subtly, from natural forest to a forest plantation[7]. But the harvest of trees from an area that will remain a forest does not constitute a land use change under this definition, and therefore the resulting emissions are not counted.

Under the Bioenergy's Strategy's first principle (illustrated on page 31), the loss of carbon storage from tree harvest must be counted, including any net reduction in future carbon sequestration. The key changes that must be made to

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range. The notes for Figure 14 indicate that the emissions shown are only those from the production, transport and conversion process, and do not include changes in carbon on land. (In general, of course, wood waste does not incur a land use cost.) The ultimate source of the estimates is J. Bates et al. (2009), *Minimizing greenhouse gas emissions from biomass energy generation* (Environment Agency for England and Wales). This study presented results from the same BEAT2 model referred to in Box 14 of the Bioenergy Strategy, but calculated emissions from land use change separately. (Caution that Bates presents emissions per unit of energy in the fuel itself rather than emissions per unit of delivered electricity, which are roughly three-times higher.)

[7] OFGEM, *Renewables Obligation: Sustainability Criteria for Solid and Gaseous Biomass* for Generators (Greater than 50 kilowatts), p. 38 n. 75 ("Land use change is defined as a change in *land category*."[7])

the carbon accounting of biomass is to include reductions in forest-based carbon, including that foregone future sequestration.

Similar Findings by Other Studies

Many other studies have come to the same conclusion as that shown in the Forest Energy report used by DECC that harvesting whole trees to replace even coal for electricity increases greenhouse gas emissions compared to the alternative of leaving the trees unharvested. These studies have addressed a wide range of forests and a wide range of harvesting techniques. They include:

Bernier, P., Pare D. (2012), Using ecosystem CO2 measurements to estimate the timing and magnitude of greenhouse gas mitigation potential of forest bioenergy, Global Change Biology Bioenergy (advance online publication July 16, 2012) DOI: 10.1111/j.1757-1707.2012.01197.x;

Holtsmark B (2011) Harvesting in boreal forests and the biofuel carbon dept. Climatic Change, DOI: 10.1007/s10584-011-0222-6;

Hudiburg, T. et al. (2011), Regional carbon dioxide implications of forest bioenergyproduction, Nature Climate Change 1:419-423;

Mckechnie J, Colombo S, Chen J, Mabee W, Maclean H (2011), Forest Bioenergy or Forest Carbon? Assessing Trade-Offs in Greenhouse Gas Mitigation with Wood-Based Fuels. Environmental Science & Technology, 45, 789-79;

Mitchell, S., Harmon, M., K. O'Connell (2012), Carbon debt and carbon sequestration parity in forest bioenergy production, Global Change Biology, Bioenergy (advanced online publication May 11, 2012), DOI: 10.1111/j.1757-1707.2012.01173.x;

Walker T. et al.,(2010), Biomass sustainability and carbon policy study. Manomet Center for Conservation Sciences, Brunswick Maine;

Zanchi G.A. et al. (2011), Is woody biomass carbon neutral? A comparative assessment of emissions from consumption of woody bioenergy and fossil fuel. Global Ch. Biol. DOI doi: 10.1111/j.1757-1707.2011.01149.x

In a paper of my own, I explain this result conceptually. Searchinger T. (2012), "Global Consequences of the Bioenergy Greenhouse Gas Accounting Error," in O. Inderwildi and Sir David King (eds.), *Energy, Transport, & the Environment* (Springer-Verlag, London). The reason is that the initial harvest of trees for bioenergy will generally double emissions compared to coal. That occurs in part because biomass cannot be burned as efficiently as coal from a carbon perspective (in light of its water content and higher carbon to energy ratio). It also occurs because harvesting wood results in additional unharvested residues (including some tops and branches and roots), which decompose and therefore emit carbon. In addition, if biomass is harvested from middle-aged trees, it probably decreases carbon sequestration rates for at least two to three decades because those trees would grow faster if left unharvested than the newly planted trees. The net change over that time is a larger carbon debt. Eventually new trees will grow faster, but the result over several decades is virtually always a large increase in emissions.

Appendix A

Figure 4 of the Bioenergy Strategy shows only the greenhouse gas consequences of harvesting trees for bioenergy per hectare, and only over 100 years. From DECC, however, I received additional numbers that went into Figure 4 that made it simple to calculate the extent to which such bioenergy increases or reduces emissions compared to coal over 20, 40 and 100 years.[8]

The percentage change in GHG consequences per megawatt hour (MWh) can be calculated by estimating the net consequences on emissions of harvesting wood for bioenergy per MWh and dividing that by the emissions estimated by DECC per MWh for coal-fired electricity. DECC's estimate for electricity from coal at existing plants is 1.048 tCO2/MWh (equal to 1,048 g/kWh). That makes it necessary only to calculate the GHG emissions estimated for the use of conifer trees.

First, the emissions start with the reduction in carbon storage and ongoing sequestration due to harvest. That in turn starts with the carbon stored per hectare if the forest is left unharvested. From DECC, I understand these numbers to be:

100 year: 8.2 tCO_2/ha/yr
40 year: 13.9 tCO_2/ha/yr
20 year: 16.7 tCO_2/ha/yr

However, the Forest Resources report estimated that the forest would continue to sequester 1.1 tCO_2/ha/year even if harvested. The net sequestration losses due to harvest are therefore 1.1 tCO2/ha/year less than those listed above. On the other hand, according to the DECC figures, the harvesting and processing of the wood for energy would generate emissions of 0.75 tCO2/ha/year, which must be added as an emission. As a result, the net emissions (including foregone carbon storage and sequestration) of harvesting wood for bioenergy are:

100 year: 7.85 tCO_2/ha/yr
40 year: 13.55 tCO_2/ha/yr
20 year: 16.35 tCO_2/ha/yr

[8] Raw tabular behind the Forestry Research and North Energy Associates (2012), *Report: Carbon Impacts of using biomass in bioenergy and other sectors: forests* (DECC). Data provided by correspondence with DECC by email dated July 27, 2012.

The Forest Resources study estimated that the harvest of wood would generate 7.2 oven dry tons per hectare per year, which would generate 8.7 MWh/ha/year. These emissions per hectare can therefore be expressed as emissions per MWh:

100 year:	0.902 tCO_2/MWh	(or 902 gCO_2/kWh)
40 year:	1.557 tCO_2/MWh	(or 1,557 gCO_2/kWh
20 year:	1.879 tCO_2/MWh	(1,879 gCO_2/kWh)

Using DECC's estimate of emissions from coal at 1.048 tCO_2/MWh., the percentage changes equal

100 year:	-14%
40 year:	+49%
20 year:	+79%