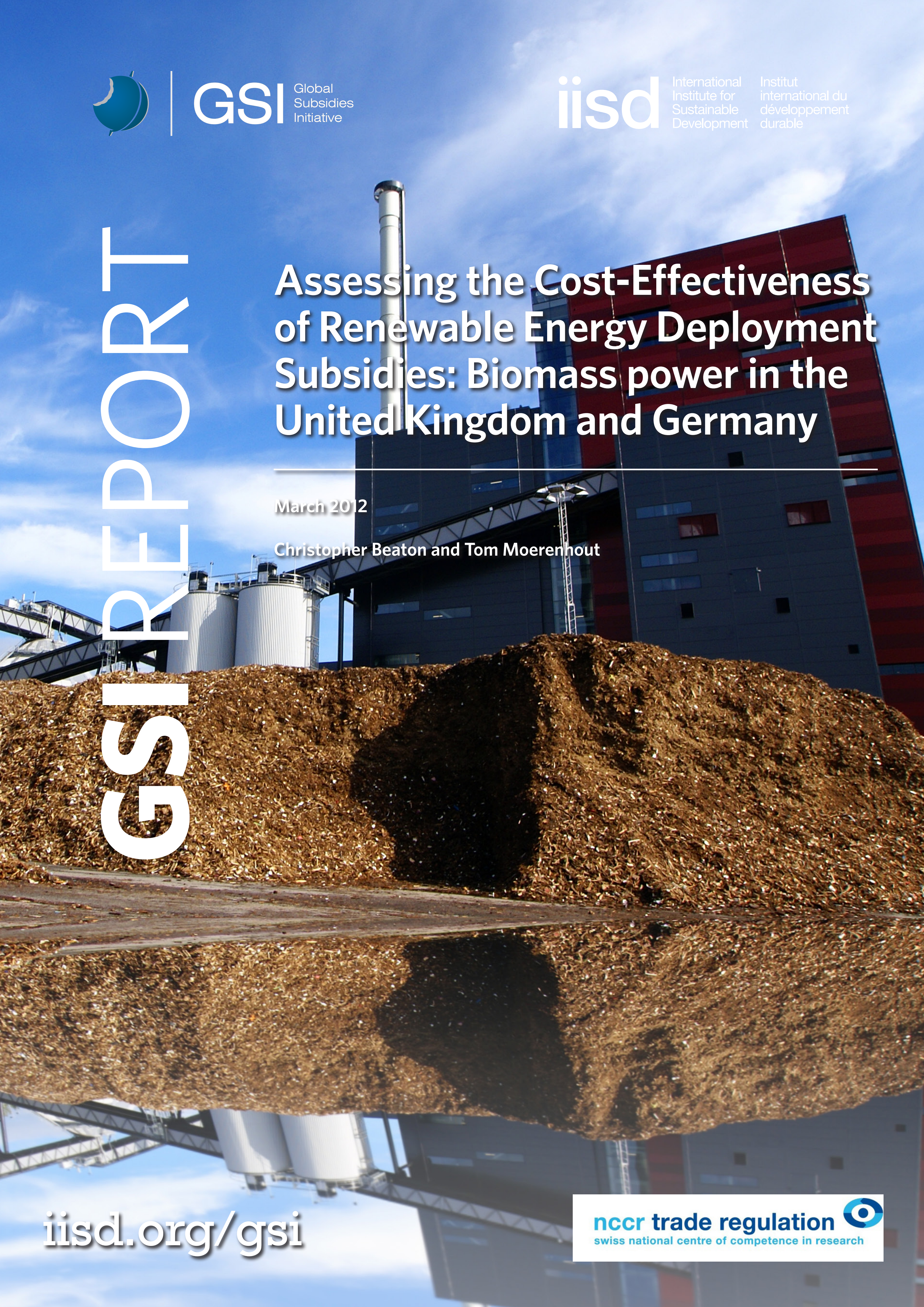

GSI Global Subsidies Initiative

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GSI REPORT

Assessing the Cost-Effectiveness of Renewable Energy Deployment Subsidies: Biomass power in the United Kingdom and Germany

March 2012

Christopher Beaton and Tom Moerenhout

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About GSI

GSI is an initiative of the International Institute for Sustainable Development (IISD). GSI is headquartered in Geneva, Switzerland and works with partners located around the world. Its principal funders have included the governments of Denmark, the Netherlands, New Zealand, Norway, Sweden and the United Kingdom. The William and Flora Hewlett Foundation have also contributed to funding GSI research and communications activities.

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Acknowledgements

This study forms one of a series of three looking at the cost-effectiveness of renewable energy deployment subsidies, each one focusing on different technologies and countries. The increased deployment of low-carbon energy is one of the principal interventions required to avoid catastrophic climate change. At the same time, the success of deployment will depend upon government policy that is effective and that uses resources efficiently. This is central to maximizing the amount of renewables deployed given the resources that are available, and to ensuring that subsidies for renewables remain politically viable. These studies represent a first effort to develop an appropriate multi-criteria framework for evaluating the cost-effectiveness of renewable energy subsidies, taking into account all costs and the wide range of potential benefits. The evaluation of subsidy policies is a core function of the Global Subsidies Initiative (GSI) and this methodology will continue to be developed in the coming years. If you have any comments, questions or recommendations, please contact us via our website, http://www.iisd.org/gsi.

The authors are grateful for the assistance of Peter Wooders (IISD-GSI) for his guidance steering this series of papers on renewable energy subsidy cost-effectiveness. The authors are also grateful for the comments of reviewers Thomas Cottier (WTI), Richard Bridle (IISD) and Lucy Kitson (IISD). Their comments greatly improved the paper. Any mistakes remain the responsibility of the authors.

This series of papers on the cost-effectiveness of renewable energy subsidies could not have been undertaken without the generous support the World Trade Institute (WTI). GSI also receives support for its ongoing program from the governments of Denmark, Norway, Sweden and Switzerland. The views expressed in this study do not necessarily reflect those of the GSI's funders, nor should they be attributed to them.

Table of Contents

1.0 Introduction

In the last decade, a growing number of countries have employed subsidies to increase the deployment of renewable energy technologies (RETs). The subsidies have been credited with a wide range of positive outcomes, and some advocate that more countries around the world should introduce similar schemes. The policies have also attracted critics, who question whether the subsidies are the best way to achieve the stated policy objectives and whether the costs can be justified. This paper explores how policy-makers might go about assessing the cost-effectiveness of subsidies to biomass power technologies. How can they quantify subsidies for deployment? How can they measure the benefits that are achieved and assess their value?

In considering these questions, this paper focuses on deployment subsidies for electricity-generating biomass technologies in two European countries, the United Kingdom and Germany.

As an exploratory study, this paper is unable to draw definitive conclusions about cost-effectiveness. Its primary goal is to explore the methods required to assess cost-effectiveness and to estimate the general magnitude and range of benefits in several key areas.

2.0 Methodology

In this study, cost-effectiveness is assessed in two steps: first, estimating the effectiveness of the subsidies, which is to say, the extent to which they have brought about their intended outputs and outcomes, as stated or implied in policy objectives; and second, estimating the costs of the policies, and asking if the identified outputs and outcomes can be considered to have been achieved at a "reasonable cost," defined as the value of the benefits being equal to or greater than the cost of the policy.

The common objectives that governments set out to achieve through subsidies for renewable energy deployment, broken down into intended outputs and outcomes, are listed in Table 1.

TABLE 1: DEPLOYMENT SUBSIDIES FOR RETS: A SUMMARY OF POLICY OBJECTIVES, INTENDED OUTPUTS AND INTENDED OUTCOMES

POLICY OBJECTIVES	INTENDED OUTPUTS	INTENDED OUTCOMES
Environmental goals: • Mitigation of climate change • Reduction of local pollution	Increased deployment of renewable energy	Renewable energy generation will offset carbon-intensive energy sources, resulting in less carbon dioxide emissions and reduced local air pollution.
Economic and social goals: • Industry creation • Job creation • Regional development		Increasing deployment of renewable energy technologies can: • Foster national industries, creating jobs in manufacturing, installation and maintenance, and allowing for the export of RETs and related services • Allow for the export of renewable energy to other countries By influencing the location of investments, this economic wealth can promote the development of specific regions.
Energy security goals: • Increased energy security		Increasing the share of renewable energy will increase the diversity of the energy supply mix, making a country less reliant on other sources of supply, notably imported fossil fuels.
Development of RETs: • Cost reductions		According to "learning-by-doing" models, as a rough rule of thumb costs will be reduced by a fixed percentage every time the installed capacity of a renewable energy technology doubles. Market support for RETs will also stimulate private investment in research and development (R&D). These cost reductions will, in turn, lead to increased deployment of RETs, contributing to all three of the outcomes listed above.

In addition to these general objectives, some countries state a specific target for the increased deployment of various RETs, and occasionally state targets for specific outcomes too—for example, absolute or relative amounts of biomass technologies deployed by a certain date, specific reductions in carbon dioxide emissions or ambitions for job creation. In this analysis, specific targets were not considered. Effectiveness was identified as the impacts of the policy with respect to each of the general objectives listed above.

The analysis then moves to explore cost-effectiveness by considering how the value of the achieved benefits can be estimated in financial terms, and then comparing that to the estimated financial burden of the subsidies. The net present value of costs and benefits throughout the study has been estimated assuming an annual inflation rate of 2 per cent in both countries and a social discount rate of 3.5 per cent. The social discount rate was chosen following the United Kingdom's HM Treasury (2011) and the European Commission (2008).

3.0 Defining Biomass

Although biomass power plants are often grouped with other renewable energy technologies such as solar photovoltaic (PV) modules and wind turbines, they stand out in at least two respects.

First, while the inputs of other RETs are mostly freely available and vary according to resource intensity of a geographic location, biomass technology is based on the combustion of fuel derived from organic feedstocks. That is to say, using biomass means harnessing the energy inherent in organic materials, many of which are already inputs or outputs in the human economy, such as dedicated energy crops; residue and waste from agricultural, forestry, paper and food industries; or municipal waste and sewage sludge (Inetrnational Energy Agency [IEA], 2007).

The second difference is that "biomass" refers to a larger spread of technologies than many other renewables. In part, this reflects the variety of feedstocks: different processes may be required to convert them into a combustion-ready fuel. Once processed, biomass fuels can be in solid, liquid or gaseous form, and used alone or in combination with fossil fuels, meaning a range of technologies is also needed to transform them into energy.

Strictly speaking, biomass is one of mankind's oldest fuels and remains a significant source of global energy needs: in 2007 it contributed around 9.7 per cent of total world primary energy demand (IEA, 2009). Much of this derives from the reliance of low-income, developing country households on wood and charcoal, often burned inside homes for heating and cooking. Such uses are not considered part of the group "renewables," because domestic combustion is related to significant impacts on respiratory health and the fuel may not be sourced sustainably. In this context, biomass is considered the bottom rung on an energy "ladder," where cleaner burning fuels such as kerosene and liquefied petroleum gas are an intermediary step and electricity is the summit, allowing full access to modern energy services (IEA, 2002).

In using the term "biomass," this report focuses on modern uses of organic fuel for electricity generation—instances where organic material is used to produce electricity, or electricity and heat together, beyond the household level. This includes co-firing and technologies for harnessing energy from solid, liquid and gaseous biomass in dedicated plants and in combined heat and power (CHP) plants. Because of the challenges involved in analyzing biomass technologies with highly different characteristics, the report does not include energy produced from landfill gas, sewage gas or heat-only applications when employing the term "biomass."

4.0 Assessing Outputs: Deployment

4.1 United Kingdom

In 2002 the United Kingdom generated 1 terawatt-hour (TWh) of electricity from biomass, not including landfill gas or sewage gas.[1] At this time, the United Kingdom's subsidy mechanism—the Renewables Obligation (RO)—was first introduced. By 2009 electricity generation from biomass had increased to around 3.7 TWh.

The RO was conceived as a Renewable Portfolio Standard mechanism, meaning that it set a quota for renewable energy generation, allowing the market to then determine an appropriate price to incentivize deployment efficiently. In 2009 it was amended to introduce "banding," providing varying levels of support for specific technologies and applications and creating a hybrid system with elements of both a Renewable Portfolio Standard and a feed-in tariff scheme.

In terms of biomass power, the RO was most successful in stimulating growth in biomass co-firing. This is when existing fossil energy plants substitute a share of their fossil fuel supply with biomass feedstocks. This is one of the lowest-cost ways in which renewable energy can be introduced to the electricity mix, hence its success under the RO; but it is also a form of generation that has been highly criticized, as it drives renewable energy subsidies towards existing fossil-fuel energy producers, holding back the development and deployment of technologies that promise more fundamental changes to energy infrastructure. From 2006 a cap was tightened on the amount of co-firing that could be used, and from this point onwards, a larger share of biomass power generation was produced by other processes.

Despite this, little generation from biogas and CHP plants has been stimulated in the United Kingdom. In 2009 the RO was amended to reduce support for co-firing and increase support to standalone biomass, CHP and advanced conversion technologies, though the impact of these changes is yet to be seen on deployment. Some studies are sceptical about the extent to which the attractiveness of CHP has been increased (Thornley, Brammer, Rogers, Huang & Rezvani, 2009).

4.2 Germany

In 2000 Germany generated just under 1.4 TWh of electricity from biomass, not including sewage gas, landfill gas and energy from the biogenic share of waste. By 2010 this had increased to around 27 TWh.

Unlike the United Kingdom, Germany's subsidy mechanism—the Renewable Energy Sources Act (the Erneuerbare-Energien-Gesetz [EEG])—is a feed-in tariff scheme and it has largely stimulated electricity generation exclusively using solid biomass and biogas, with some generation based on liquid biomass. When the scheme began, the exact rate of the tariff was determined by the size of the biomass power plant. In 2004 and 2008 the scheme was amended to include a range of tariff rate bonuses for certain technologies, technology crops and the use of CHP, intended to increase the share of such technologies in the generation mix. This has resulted in faster development of CHP plants in Germany, with an average yearly growth of 23 per cent between 2004 and 2008 (IEA, 2010).

[1] Note that all references to "biomass" throughout this report do not include energy generated by landfill gas or sewage gas. See "Defining Biomass."

5.0 Assessing Outcomes

5.1 Environmental Impacts

The environmental impacts of biomass technology depend on many variables. Among these, it is necessary to know the impacts of: a feedstock's cultivation on land use (direct and indirect) and biodiversity; the fossil inputs that have gone into growth, harvest, transportation and conversion; the diversion of the feedstock from its previous application; any waste outputs; and the offsetting of existing power technologies. If a biomass power generation facility changes feedstock for any reason, the environmental impact will change accordingly. The relative efficiency of different installations will also influence the environmental impact per unit of energy produced.

The European Union's Renewable Energy Directive (RED) (European Commission [EC], 2009) has set out binding sustainability criteria for biofuels and bioliquids. These must be met if biofuels are to count towards the European Union's renewable energy targets and in order to qualify for financial aid. No binding environmental standards have been established for solid biomass and biogas, although the RED did mandate the EC to investigate and report on possible sustainability requirements for solid and gaseous biomass sources in electricity, heating and cooling. The resulting study did not propose binding criteria. Instead, it recommended that member states ensure that national sustainability schemes for solid and gaseous biomass are "in almost all respects… the same as those laid down [for bioliquids] in the Renewable Energy Directive" (EC, 2010), with some exceptions and additions.

Together, this would result in the following recommended standards:

- Biomass power should achieve greenhouse gas (GHG) reductions of at least 35 per cent, rising to 50 per cent on January 1, 2017, and, for all installations starting production on or after January 1, 2017, rising to 60 per cent from January 1, 2018. Emissions should be estimated using default values as set out in the EC's report (2010), adjusted to the efficiency of the installation in question.
- Biomass from waste should be exempt from meeting GHG performance criteria, because it is hard to estimate default GHG values and the sector routinely achieves high savings.
- Biomass fuel should not be derived from land with high biodiversity value or high carbon stock, as defined by the RED.
- Biomass fuel should be obtained in accordance with direct support schemes' regulations on the environment, if cultivated in the European Community.
- States should differentiate support schemes to stimulate energy conversion processes with higher efficiency.

The EC (2010) report also sets out estimates of GHG savings from a range of solid biomass sources. For electricity generation, these range from roughly 18–95 per cent savings compared to fossil fuels. The highest savings are from European Union-sourced chips and pellets from forest residue, although miscanthus, European Union-sourced wheat straw and EU-sourced chips and pellets from short coppice rotation also score highly. Sourcing biomass from tropical regions generally reduces GHG savings by around 30–45 per cent. The study deduces that the sustainability risk of biomass from the European Union is "low" on the basis that, at present, it is largely derived from forest residues and industrial by-products, and that European Union countries have strong forest management governance structures. The EC also generalizes that solid and gaseous biomass are likely to achieve higher GHG savings than biofuels because conversion processes tend to consume less energy. Similarly, where biomass is not sourced from agricultural crops, fertilizer is unlikely to have been used and GHG emissions are likely to be lower.

The EC's sustainability guidelines for liquid biofuels have been criticized because they do not attempt to take into account environmental impacts related to indirect land-use change, and the same is true of its recommendations regarding solid biomass and biogas. Indirect land-use change takes place when biofeedstocks are grown on existing agricultural land, but the crops that have been supplanted are then grown on land that needs to be converted for agricultural use. The omission of this dynamic could significantly influence GHG saving estimates. The United Kingdom's Environment Agency (2009b) has calculated that land-use change can reduce, and in some cases reverse, carbon savings. Converting fallow land to energy crop production was estimated to reduce emissions savings by up to 10 per cent, and in two cases the conversion of grasslands was estimated to increase net GHG emissions. The agency also found that the use of fertilizer and the transportation of feedstock over long distances can reduce emissions savings by between 15 and 50 per cent.

The European Union's sustainability guidelines on liquid biofuels have also been questioned for their practical and potential legal ramifications. It is not certain that accountability mechanisms can be established cost-effectively to ensure the accuracy of the information that is disclosed, and any such scheme risks creating unfair trade barriers. As concluded by a review of biofuel certification and the law of the World Trade Organization (WTO), standards focused on processes and production methods, as opposed to final product characteristics, are usually viewed unfavourably and may be distrusted as "disguised protectionist measure[s]" (Echols, 2009). However, a WTO complaint could potentially be defended under exceptions to WTO rules on the grounds of environmental protection (Echols, 2009).

Aside from climate change, land use and biodiversity impacts, the Intergovernmental Panel on Climate Change has identified a number of other potential environmental impacts that could be related to biomass use. These include: concerns related to genetically engineered feedstocks, such as cross-pollination, hybridization, pest resistance and disruption of ecosystem functions; the fact that bioenergy tends to require greater water resources than fossil-fuel production; the potential for pesticides and fertilizers to damage aquatic ecosystems; and potential impacts of feedstock growth on soil resources (Chum, Faaij & Moreira, 2011). Local air pollution is also a potential concern. Biomass combustion can result in emissions that are harmful to human health and the environment, such as nitrogen oxide, sulphur dioxide, mercury emissions, volatile organic compounds and heavy metals (Jacobson & High, 2008). A report by the IEA (2011) provides a comparison of emissions from renewable and non-renewable technologies for two local pollutants (nitrogen oxide [NO_x] and sulphur dioxide [SO_2]). The report finds that biomass combustion is generally associated with higher emissions of NO_x than coal or natural gas combustion. In practice, air pollution is regulated in both Germany and the United Kingdom, and air pollution impacts in both countries are built into permitting processes, using detailed site-specific emission modelling to determine the impacts on the local environment. This means that high emissions of air pollutants from biomass plants may restrict the areas where facilities are built.

The United Kingdom and Germany are both in the process of establishing sustainability schemes for solid and gaseous biomass. In the United Kingdom, solid and gaseous biomass sustainability criteria were sent out for consultation in September 2011 by electricity and gas regulator Ofgem (2011c). The criteria require that biomass installations larger than 50 kilowatts should emit no more than 79.2 grams of carbon dioxide-equivalent per mega joule of electricity produced and not be sourced from certain types of land, such as primary forest, protected areas, peatlands and wetlands. Certain forms of biomass are exempt from some of the strictures. The criteria also make clear that Ofgem expects suppliers to establish a "mass balance" system, whereby data should be maintained about the individual feedstocks, regardless of how they might be mixed and processed through the supply chain. No specific verification of sustainability criteria is required beyond the measures associated with the environmental and quality-management systems. From April 2013, eligibility for the United Kingdom's subsidy scheme will be dependent on compliance with the criteria. In the meantime, generators are only required to report how they perform. During this period, receipt of subsidies is contingent upon the act of reporting itself, even if companies can only report that various pieces of information are currently "unknown."

According to the latest available draft of its National Biomass Action Plan (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety [BMU], 2009b), Germany has established two ordinances setting out binding sustainability requirements that must be met if biofuels and bioliquids for electricity production are to receive financial support. No equivalent ordinance has yet been issued with respect to solid and gaseous biomass, but the Renewable Energy Sources Act 2009 (Federal Republic of Germany, 2010) has given authorization for the BMU and the Federal Ministry of Food, Agriculture and Consumer Protection to enact such an ordinance.

5.1.1 Estimating Offset Carbon Emissions

As an exploratory exercise, this study did not have the resources to attempt a comprehensive environmental impact assessment of biomass power in the United Kingdom and Germany, which would take into account all of the variables described above. Instead, only impacts on carbon emissions were estimated.

Even considering carbon emissions alone, substantial data are required to establish robust estimates. It is necessary to know the share of energy delivered by different feedstocks, life-cycle emissions factors for each feedstock, the specific energy technology displaced and the type of biomass technology employed (CHP, for example, offsetting greater emissions than co-firing). Other impacts are more complex. Comprehensive accounting of land use through time would be needed to assess the impacts of land-use change, and various methodologies exist for estimating indirect land-use change (Chum, Faaij & Moreira, 2011). For these reasons, land-use change impacts are not taken into account in the estimates on carbon emissions below. Readers are encouraged to interpret the resulting estimates in light of uncertainties around these and other non-quantified environmental impacts.

In the United Kingdom, a range of savings are estimated in both the short term (impacts of the policy across the period in which actual performance data are available, 2002–2009) and the long term (the entire period in which currently installed generators are allowed to continue receiving subsidies under the policy, with the most recently installed facilities receiving their final support in 2028). This is based on carbon dioxide-equivalent life-cycle emissions saving factors reported by the Environment Agency (2009a). Although the most recent submissions under the United Kingdom's sustainability reporting scheme provide detailed data about the type and origin of feedstocks used in 2010 (Ofgem, 2011a), it was not possible to incorporate this level of detail into these exploratory calculations, and no data was identified on the primary incumbent generation technologies being offset. A range of estimates was therefore calculated, using emission factors sensitive to the provenance of the feedstock (European Union or North America) and whether gas or coal-generating technologies were being primarily offset.

In Germany, point estimates were calculated for both the short term (2000–2010) and the long term (with the most recently installed power plants continuing to receive subsidies up until 2030). This is based on biomass-specific GHG saving estimates reported by the German government every year. These estimates are based on emission-saving factors that are disaggregated by technology and the exact proportion of coal and gas being offset. It is assumed that they are also based on knowledge about the type and origin of feedstocks.

Because there are different levels of uncertainty in the emission factors and assumptions made in each country, caution is urged in comparing them.

TABLE 2. ESTIMATED CARBON SAVINGS IN THE UNITED KINGDOM AND GERMANY

	UNITED KINGDOM		GERMANY	
Total biomass power generation	3.7 TWh in 2009		26.9 TWh in 2010	
	2002-2009	Lifetime of 2002-09 installed capacity	2000-2010	Lifetime of 2000-10 installed capacity
Total CO_2 savings (million tonnes)	11.2-39.5	40.2-140.8	88.8	371.3

Assessing the value of emission offsets is difficult, as no consensus exists over the "right" price for carbon, and the market-determined price of carbon in any given period will change as cheaper mitigation options are exhausted. This study looked at existing and projected prices for emission trading schemes in order to assign a financial value to the carbon offset. As a lower band, the European Union Emission Trading Scheme (EU ETS) price of carbon was used. This has never climbed higher than €35 per tonne and has generally remained below €15 per tonne since the scheme was launched (Environmental Audit Committee, 2010), at some points with a value of close to zero. For medium and high band, values were derived from integrated assessment models of the emissions cost needed to limit carbon dioxide levels to 550 parts per million, from sources whose estimates ranged from USD$135 to $380 (€105–€295) by 2060 (International Monetary Fund, 2008). In order to illustrate how a cost-effectiveness assessment would vary under conservative and generous assumptions, low, medium and high values of €15, €50 and €200 were assigned.

In the United Kingdom and Germany, it should also be noted that the EU ETS co-exists with each country's national subsidies to promote renewable energy. This has led to criticism that renewable energy subsidies have simply reduced the price of carbon under the EU ETS, and so prevented emissions being achieved more cheaply elsewhere in the European Union. This study assumes no such effect and assesses the value of carbon reduced, assuming no leakage.[2]

TABLE 3. VALUE OF CARBON OFFSETS IN THE UNITED KINGDOM AND GERMANY

	UNITED KINGDOM		GERMANY	
Total biomass power generation	3.7 TWh in 2009		26.9 TWh in 2010	
	2002-2009	Lifetime of 2002-09 installed capacity	2000-2010	Lifetime of 2000-10 installed capacity
Total CO_2 savings (million tonnes)	11.2-39.5	40.2-140.8	88.8	371.3
Value (€ billion) of carbon saved at prices of:				
€15/tonne	0.2-0.7	0.5-1.9	1.5	4.7
€50/tonne	0.6-2.2	1.8-6.3	4.9	15.5
€200/tonne	2.5-9.0	7.2-25.2	19.6	62.1

In absolute terms, these estimates indicate that the EEG in Germany has achieved higher carbon dioxide reductions than the RO in the United Kingdom. It is not possible to determine if these savings are higher or lower per kilowatt-hour of energy generated, as the range of potential carbon savings in the United Kingdom is very wide. This is largely due to uncertainty over the exact electricity technologies being offset. It is difficult to judge where in this range actual

[2] For a more in-depth discussion of this potential complication, see the report on solar PV systems in this series on subsidies to renewable energy (Bridle & Beaton, 2012), as well as Philibert (2011).

savings might lie. On the one hand, the large amount of co-firing in the United Kingdom would indicate that more coal has been offset than gas, suggesting higher carbon dioxide savings. At the same time, co-firing generation was significantly reduced after 2006 and, according to Korhaliller (2010), much of the feedstock used in co-firing is imported from distant countries.

As noted above, these figures do not take into account potential direct or indirect land-use change. If the estimates are biased in either direction, therefore, they are more likely to be over-generous in their estimation of carbon reductions.

5.2 Economic and Social Goals

Deployment subsidies often include a policy goal of encouraging sustainable economic growth, sometimes referred to in the context of a "green economy." These impacts might be measured in terms of gross jobs created, the growth in renewable energy industries or the overall impacts on a country's economic performance.

Gross direct jobs related to domestic electricity generation from biomass are one of the easiest impacts to measure. The number of gross jobs related to biomass power is likely to be greater than those associated with renewables such as solar PV or wind turbines, because of the additional operational requirements for activities relating to the handling of fuel, ash and maintenance. A review of studies by Wei, Patadia and Kammen (2010) reports employment factors per megawatt (MW) of installed capacity from 2001 that show biomass requiring around 14–38 per cent of the jobs that solar PV creates in construction, installation and manufacturing—but from 1.5 to 10 times the jobs that solar PV creates in operations and maintenance. One study reviewing the employment from biomass power plants found an average gross employment of 1.27 person years per gigawatt-hour (Thornley, 2008). The European Biomass Industry Association argues that, as bioenergy is a decentralized energy option, these jobs can contribute to rural development by creating business and employment opportunities in rural areas.

The benefits from job creation are not necessarily realized within the subsidizing country. Operations and maintenance jobs will certainly be local, but where local feedstock supplies are not plentiful and plants are constructed around transport infrastructure—attached to ports, for example—it is possible for jobs related to feedstock production to take place in any country.

In addition to jobs related to generation activities, subsidies might also help build a globally competitive domestic biomass industry. This could be measured in terms of jobs, exports or turnover related to the development of new technologies, manufacture of components and the construction of plants. The development of an industry is often associated with technologies that are in the course of maturing, as a country can try to place itself at the forefront of technological development. Compared with other renewable energy technologies, there are currently few major manufacturers of large biomass plant power islands, with many of the major companies, such as Metso Power and Foster Wheeler, being based in Scandinavia.

It is more difficult to estimate the net impacts that subsidy spending will have on general economic activity, including indicators such as multiplier effects, indirect jobs, net job impacts and effects on GDP. In some cases, biomass feedstocks are already being used by other economic sectors. Their diversion to energy production may be at the benefit or cost of these industries. A study conducted by the United Kingdom's wood panel industry, for example, argued that large-scale biomass deployment had put 8,700 jobs at risk by increasing average wood prices by over 30 per cent (Renewable Energy Focus, 2010). Where biomass feedstocks compete for land with food production, there is also the risk that deployment subsidies might contribute to food insecurity, with significant economic and social impacts.

The opportunity costs of subsidy expenditure must be taken into account too: could the same funds promote greater economic activity elsewhere? Where subsidy mechanisms lead to increased electricity prices—as is in the case in both the United Kingdom and Germany—this will also have impacts through household spending elsewhere in the economy and the profitability of energy-intensive industries. In Germany, for example, the BMU reports that between 2000 and 2009 the average electricity bill per household per month rose from €46.67 to €65.97. Of this, the cost incurred by the Renewable Energy Resources Act (the EEG, which includes a number of RETs, and not just biomass) increased from €0.58 to €3.10 (BMU, 2009a).

There may also be a counterbalancing impact on energy prices, the "merit order effect." This takes place when renewable energy offsets electricity from traditional sources. Electricity from the most expensive sources will be offset first; and, as the most expensive electricity at any given time will typically set the price for the rest of the market, this can reduce the overall market price for non-renewable electricity. A more detailed discussion of this can be found in the report in this series on on-shore wind (Moerenhout, Liebert & Beaton, 2012) and in Sensfuss, Ragwitz & Genoese (2007).

Finally, the longevity of economic gains must be considered. Short-term jobs, such as those in installation, are not as economically valuable as long-term jobs, and any infant industry must be able to operate without support once the subsidy is eventually withdrawn. The competitiveness of biomass in the future and the related economic impacts are hard to estimate, particularly because price fluctuations in the cost of feedstocks can greatly influence the cost of energy production.

5.2.1 Gross Jobs Related to Biomass in the United Kingdom and Germany

Given the complexity of estimating net economic impacts, this study focuses on direct gross job creation as a simple measure for the economic impacts of renewable energy. This does not capture positive economic impacts that are unrelated to direct gross job creation—for example, jobs created in industries supplying raw materials for biomass technologies—though it does include fuel supply. It also does not capture potential negative economic impacts, such as the effects of increased electricity prices on households and industries.

No estimates of employment factors for biomass energy before 2001 were identified. This study has therefore derived employment factors from the gross number of job years reported by the German government for the years 2008 and 2009, which are based on industry surveys of actual employment in the sector (BMU, 2010b). As the BMU does not distinguish between jobs related to electricity and heat, it was assumed that the share of jobs related to biomass electricity production is equal to the share of biomass electricity as a part of total biomass energy production. These factors were then used to derive an estimate of biomass-related employment in the United Kingdom, as summarized below. This assumes that there are relatively similar technologies and fuel markets in each country.

TABLE 4: EMPLOYMENT ESTIMATES

	RECENT YEARS			FROM POLICY INCEPTION TO POINT OF LATEST DATA (UK: 2002–2009; GERMANY: 2000–2010)	LIFETIME IN WHICH CURRENTLY INSTALLED CAPACITY WILL CONTINUE TO RECEIVE SUPPORT
	2008	2009	2010		
United Kingdom					
Additional capacity (MW)	140	310	no data		
Total installed capacity (MW)	870	1,180	no data	1,180	1,180 MW over 20 years
Gross jobs (job years)	2,490	3,260	no data	16,240	30,240
Germany					
Additional capacity (MW)	540	570	500		
Total installed capacity (MW)	3,400	3,980	4,440	4,440	4,440 MW over 20 years
Gross jobs (job years)	26,580	29,840	30,410	184,300	479,280

The financial value of the jobs created by the policy in each country was estimated simply, by multiplying the number of estimated job years in each country by the average annual earnings in the electricity sector, with a sensitivity of ± 25 per cent (World Salaries, 2008). Based on an average United Kingdom electricity sector wage of €34,000, this resulted in an estimated value of €0.5 billion-€0.9 billion from 2002–2009 and of € 0.8 billion-€1.7 billion across the lifetime in which currently installed capacity can benefit from the subsidy policy. In Germany, where an average electricity sector wage is roughly €40,000, this resulted in a value of €6.2 billion-€10.3 billion from 2000–2010 and €12.7 billion-€21.2 billion across the lifetime in which currently installed capacity can continue to receive the subsidy.

The estimate of German job years and their financial value is higher than the United Kingdom because Germany has a higher overall installed capacity and does not support co-firing, which is likely to rely on existing employment. Each unit of capacity in Germany also generates a higher amount of electricity on average than in the United Kingdom, so estimates of ongoing jobs in fuel production, operations and maintenance are higher per MW installed. Germany also has a higher share of biogas capacity (almost 50 per cent of total capacity), which, according to the employment factors derived from BMU data, involves a higher number of jobs per MW.

The most important influence on United Kingdom job estimates is co-firing: almost three quarters of installed capacity are made up of co-firing installations. Jobs related to this technology can be considered part of the renewable energy sector, but low-rate co-firing does not require additional construction and installation and most operations and maintenance positions are unlikely to be additional—that is to say, jobs already in existence may simply have switched their function from working with coal to working with biomass for a small share of the time. Job years related to co-firing have therefore not been included in employment estimates for the United Kingdom. In both countries, it is unclear whether feedstock production would largely involve pre-existing or additional jobs. The estimates have erred on the side of generosity and therefore assumed that all fuel-supply-related jobs are additional.

Given the lack of data and the simplicity of the estimation method used, these estimates should be interpreted with caution. Given the various assumptions involved and the fact that no offsetting negative job impacts have been estimated, it is likely that these figures are significantly biased towards being over-optimistic.

Analyses from other studies imply that estimates of net jobs using economic modelling are significantly more conservative than those presented here. According to a modelling exercise conducted for the EC, based on policies in place in 2005, the net employment gain for Germany with respect to all renewable energy technologies—not just biomass—was estimated at around 25,000–33,000 jobs by 2020, with the higher range representing an "optimistic exports" scenario. GDP was projected to grow by 0.10–0.14 per cent compared to a no-policy scenario. Another model in the same project estimated that there would be a net loss of employment in Germany of around 10,000 jobs, although GDP gains were still projected at 0.1 per cent. In the United Kingdom, the models projected, respectively, that there would be a loss of 10,000-11,000 jobs by 2020, with a loss in GDP of 0.1 per cent, or an additional 10,000 jobs, with less than 0.1 per cent additional GDP (Ragwitz et al., 2009). Where negative effects were projected, this was largely attributed to the increased cost of energy in both countries as a result of their subsidy policies; though in some of the other countries analyzed, such as Spain, it was projected that large levels of investment could cancel out such effects.

5.3 Energy Security

Energy security is another common target of renewable energy deployment subsidies: if the overall share of imported energy is reduced, the country will become less sensitive to threats such as price volatility, political instability in energy-exporting countries, competition for limited resources, industrial action, market manipulation and the disruption of infrastructure due to adverse weather, natural disasters or terrorism. In many world regions, such concerns are focused on liquid transport fuels. Nonetheless, the diversification of electricity generation can still contribute to increased energy security. The potential importance of electricity in energy security could also increase in the future if electric vehicles become a dominant form of motor transport.

Biomass has a number of benefits to offer in terms of energy security. Unlike technologies such as solar PV and wind power, it is not a "variable" type of renewable energy—that is to say, supply does not vary in the short term as the result of natural phenomena such as the weather. This means that biomass can provide a reliable source of generation, including the provision of base load and the balancing out of variations in other renewable energy technologies. Biomass energy is not without risks, however, as outlined by Ölz, Sims and Kirchner (2007). Uncertainty is involved in securing feedstock supplies over the longer term, especially where there is competition for limited resources. Feedstock supply, although not "variable" in the sense of wind and solar PV, can fluctuate over the medium term due to seasonal cycles. And biomass combustion is not responsive enough to balance sudden changes in energy supply, so its role balancing other technologies may be most appropriate for predictable shortfalls, such as the need to back up solar plants at night. Nonetheless, the authors of the study also note that these challenges are not insurmountable. Long-term contracts with suppliers are one option that can mitigate the risk of future supplies, and the ease with which fuel can be stored and transported is a hedge against seasonal cycles. The very act of diversifying towards a different kind of energy input should improve energy security by distributing risk.

It is difficult to estimate the energy security benefits that have been achieved by deployment subsidies to biomass in the United Kingdom and Germany. A country's energy security situation is highly individual and assessments of security draw on many criteria and are often qualitative. Similarly, it is very difficult to assign financial value to whatever benefits can be identified. In the absence of a full analysis of the United Kingdom's and Germany's energy security dynamics, and the bigger picture of deployment subsidies for all renewables—both of which are outside the scope of this report—the most that can be said is that the proportion of electricity generated by biomass-generated electricity in both countries suggests a positive effect on energy security.

In 2009 the proportion of electricity generated by biomass in the United Kingdom and Germany was approximately 1.1 per cent and 4.2 per cent respectively. Although far from trivial, this level of deployment is also unlikely to greatly affect the reliance of each country on other energy technologies and their related risks. Rather than biomass alone, a more appropriate lens of analysis for considering energy security might be deployment subsidies to all renewable energy technologies in each country, which as of 2009 generated 6.7 per cent and 16.1 per cent of electricity, respectively (Department of Energy and Climate Change, UK, 2011; BMU, 2010a). However, such a broad lens of analysis is outside the scope of this study.

It was also not considered feasible for this exploratory assessment to assign a meaningful "financial value" to energy security impacts, as measured by the above metric. Energy security impacts are therefore considered a qualitative element in the final cost-effectiveness assessment.

5.4 Development of RETs

Reducing costs over time is essential for renewable energy technologies and a key objective of support mechanisms—lower costs will allow for increased deployment at any given level of spending, with attendant impacts on the cost-effectiveness of any environmental, economic and energy security benefits that are achieved. It is hoped that eventually this will lead to grid parity, allowing the technologies to compete in the energy marketplace without support. The rationale behind deployment subsidies is that they will provide opportunities for cost reductions in the deployment stage through "learning by doing," as well as promoting R&D among private investors.

The potential for technological development varies among different biopower technologies. According to analysis conducted by the Electric Power Research Institute (EPRI), some are already mature, such as anaerobic digestion, CHP plants and low-rate co-firing. A number of technologies have advanced past research and development and need to mature further through deployment, such as pyrolysis, medium-rate co-firing and 100 per cent biomass repowering. Still others are in the research and development stage, including bio-hydrogen, pressurized gasification and high-rate co-firing (EPRI as cited in Bracmort, 2010). There are also a number of research opportunities in the cultivation and processing of feedstocks.

There are significant challenges to estimating the cost reductions that might have been brought about by deployment subsidies. It is possible to map how average generation costs have developed over time, but no accepted method exists to determine how much of these costs might be attributed to a single country's deployment policy. It is also difficult to parse out the impacts that can be attributed to deployment policy and those that should be attributed to research and development policies or the efforts of private actors. Future technological cost reductions are often projected using "learning curves," which predict, as a rough rule of thumb, that costs fall at a constant rate with each doubling of cumulative production during a "linear learning" phase of a technology's development. However, there is large uncertainty in such methods, and bi-directional causation makes it difficult to determine which cost improvements have taken place because of deployment and which cost improvements have driven deployment.

In addition, unlike other renewable technologies, the cost of electricity generated from biomass is related to the costs of biomass feedstocks. Much of the combustion technology that is applied to the conversion of biomass could be equally applied to other forms of thermal conversion. Reduced capital costs and operational improvement may have limited scope to improve the economics of biomass power generation compared to the underlying biomass cost.

Given the difficulty of determining the cause of cost reductions and the uncertainty of future projections, this study considered it unfeasible to assess the extent to which deployment subsidies had incentivized technology development. Broadly, it seems clear that the costs of biomass are likely to reduce in two main ways: (a) "learning by doing" in production and (b) research and development into feedstock production and biopower generation. Between the two countries, Germany is likely to have achieved the highest impacts in this area. This is because, in its early years, the United Kingdom scheme was largely focused on stimulating generation of biomass power through low-rate co-firing, a mature power generation process, whereas Germany has provided additional support for specific, less mature technologies.

6.0 Outputs and Outcomes Summary

To assess whether the subsidies have had their desired effects, each of the goals listed earlier is now presented alongside estimates of the actual outcomes of the policies (see Table 5).

<table>
<tr><th>POLICY OBJECTIVES</th><th>OUTPUTS</th><th>INTENDED OUTCOMES</th><th>ESTIMATES OF ACTUAL OUTCOMES</th></tr>
<tr><td>Environmental goals:
• Mitigation of climate change
• Reduction of local pollution</td><td rowspan="4">Increased deployment of renewable energy (installed capacity):

UK – from 330 MW in 2002 to 1,180 MW in 2009

Germany – from 260 MW in 2000 to 4,600 MW in 2010</td><td>Where increased renewable energy generation is greater than growth in demand, it will offset carbon-intensive energy sources, resulting in less CO_2 emissions and local pollution</td><td>Carbon savings over the lifetime of currently installed capacity:
UK – 40.2 million –140.8 million tonnes CO_2
Germany – 371.3 million tonnes CO_2
No estimates developed for local pollution.</td></tr>
<tr><td>Economic and social goals:
• Industry creation
• Job creation
• Regional development</td><td>Increasing deployment of renewable energy technologies can:
• Foster national industries, creating jobs in manufacture, installation and maintenance, and allowing for the export of RETs and related services.
• Allow for the export of renewable energy to countries that are not generating enough renewable energy to meet their own targets.
By influencing the location of investments, this economic wealth can be targeted at the development of specific regions.</td><td>Total "job years" over the lifetime of currently installed capacity:
UK – 30,240
Germany – 479,280</td></tr>
<tr><td>Energy security goals:
• Increased energy security</td><td>Increasing the share of renewable energy will increase the diversity of the energy supply mix, making a country less reliant on any one source of supply.</td><td>Share of electricity currently produced by biomass power:
UK – 1.1 per cent
Germany – 4.2 per cent</td></tr>
<tr><td>Development of RETs:
• Cost reductions</td><td>According to "learning-by-doing" models, costs will be reduced by a fixed amount every time the installed capacity of a renewable energy technology doubles. Market support for RETs will also stimulate private investment in research and development (R&D). These cost reductions will, in turn, lead to increased deployment of RETs, contributing to all three of the outcomes listed above.</td><td>No appropriate indicators identified</td></tr>
</table>

[1] UK range is dependent on fuel type being offset: at the lower end, gas, and at the higher end, coal.

Overall, the indicators show that both subsidy programs have succeeded in achieving their desired outputs (increased deployment) and, where metrics could be identified, have achieved progress against their intended outcomes.

In comparing the two countries, it would appear that Germany's policy has, in all cases, achieved greater effects than the United Kingdom's. This is in part due to the greater levels of spending and thus deployment achieved by Germany's EEG policy. On a measure of impacts per MW installed, it is unclear which country might have achieved the greatest GHG reductions, given uncertainty over the range of potential GHG reductions in the United Kingdom. It is likely Germany has achieved greater additional employment per MW of capacity installed. This conclusion is based on the fact that that the employment factors used in estimations showed biogas installations—a significant source of biomass power in Germany—involve higher levels of employment than solid biomass facilities, and in light of the fact that United Kingdom jobs related to co-firing were not counted, given the high likelihood that they are based in the fossil-fuel energy sector and are not additional.

7.0 Assessing Costs

In the United Kingdom, the total cost of the subsidies was estimated using data on the distribution of subsidy certificates, certificate values, biomass electricity generation and biomass electricity capacity, as reported by the national electricity and gas regulator (Ofgem, 2008, 2009, 2010, 2011b). Estimates take into account changes made in 2009 to the subsidy rates received by different technologies. The estimate of "total commitment" is the sum of all subsidies due to be paid to the capacity that was installed between 2002 and 2009—for each plant that is installed, a maximum of 20 years from its date of accreditation. For this period, a range of spending is reported, based on the assumption of "low" and "high" certificate prices in future years.

In Germany, the total cost of the subsidies was estimated using data on subsidy tariffs, biomass electricity generation and biomass electricity capacity, as reported by the BMU (2011) and the German Association of Network Operators (Verband der Netzbetreiber, n.d.). Estimates take into account changes made in 2004 and 2008 to the rates received by different technologies. The estimate of "total commitment" is the sum of all subsidies due to be paid to the capacity that was installed between 2000 and 2010—for each plant that is installed, a maximum of 20 years from its first coming online, not including its first year online. For this period, a range of spending is reported, based on the assumption of "low" and "high" power prices in future years.

TABLE 6: KEY INDICATORS OF THE FINANCIAL COST OF BIOMASS DEPLOYMENT SUBSIDIES

	UK	GERMANY
Total subsidy in 2002–2009/2000–2010 (€ billion)	1.8	12.6
Total commitment 2000–2009 (€ billion)	3.0–3.8	38.7-49.3
Average spending per year (€ billion)	0.1-0.1	1.2-1.6
Total TWh of electricity generated	64	543
Average cost per kWh (€/kWh)	0.05-0.06	0.07-0.09

Notes: Estimates for both countries are stated in 2010 Euros, assuming a constant 2 per cent inflation rate, a social discount rate of 3.5 per cent and a GBP/EUR exchange rate of 1.17.

Although the cost of Germany's subsidy policy is higher on a per kilowatt-hour basis, it should also be borne in mind that until 2009 the United Kingdom's policy was structured to promote the most cost-effective technologies, regardless of their maturity, so this is a reflection of policy design. It is also the reason why 75 per cent of the United Kingdom's biomass power has been provided by co-firing. By contrast, the German EEG only subsidizes installations using biomass exclusively and has for some years offered higher subsidy rates via bonuses to less mature generating technologies.

There are also different levels of commitment to honouring future payments in the two countries. The United Kingdom has specifically stated which technologies are guaranteed to retain the level of subsidy they received at the time of commissioning ("grandfathering"). For technologies that are not "grandfathered," including co-firing, the generating stations receive the available subsidy subject to future changes, with the level of support for co-firing already having been reduced in 2009. This allows flexibility over the committed scheme costs at the expense of some investor certainty—though, in the case of low-rate co-firing, few impacts on investors should be expected, as no significant investments are required to introduce a small proportion of biomass feedstock into conventional thermal generation facilities.

It should be noted that this study only estimates the costs of each country's most high-profile deployment subsidy: in the United Kingdom, the RO, and in Germany, the EEG. Most countries offer a range of complementary support measures for the deployment of renewable energy, such as low-cost loans, tax breaks, accelerated depreciation and low-cost access to land, at both the national and subnational levels. These types of complementary mechanisms have not been mapped out or quantified in the United Kingdom and Germany. In reality, therefore, these cost estimates are likely to be conservative.

8.0 Assessing Cost-Effectiveness

Studies looking at the cost-effectiveness of renewable energy technologies have often focused on one particular outcome. This can result in the entire cost of the policy being compared to the value of a single benefit. The approach taken by this analysis is to estimate a financial value for as many of the outputs as possible and to compare this to the absolute cost of the scheme.

As described in the earlier sections of this report, estimates were made for the financial value of carbon emissions offsets and jobs created in each country. Because of significant uncertainty surrounding the exact impacts and their financial value, a range of estimates were derived in most cases. This does not give a conclusive cost-benefit analysis, but illustrates the range of uncertainty, and the variables which—depending on their value—will make the scheme more or less cost-effective. The financial benefit of carbon savings was estimated according to a minimum and maximum carbon value of €15 and €200, respectively. The financial benefit of an average job in the biomass industry was estimated according to assumed minimum and maximum values based on sector average earnings with a sensitivity of ± 25 per cent (World Salaries, 2008).

The comparison of costs and benefits is illustrated below: first, in Figure 1, from the start of the subsidy scheme to the latest year of available data, and second, in Figure 2, projected across the lifetime over which installed capacity will receive subsidy payments under each scheme.

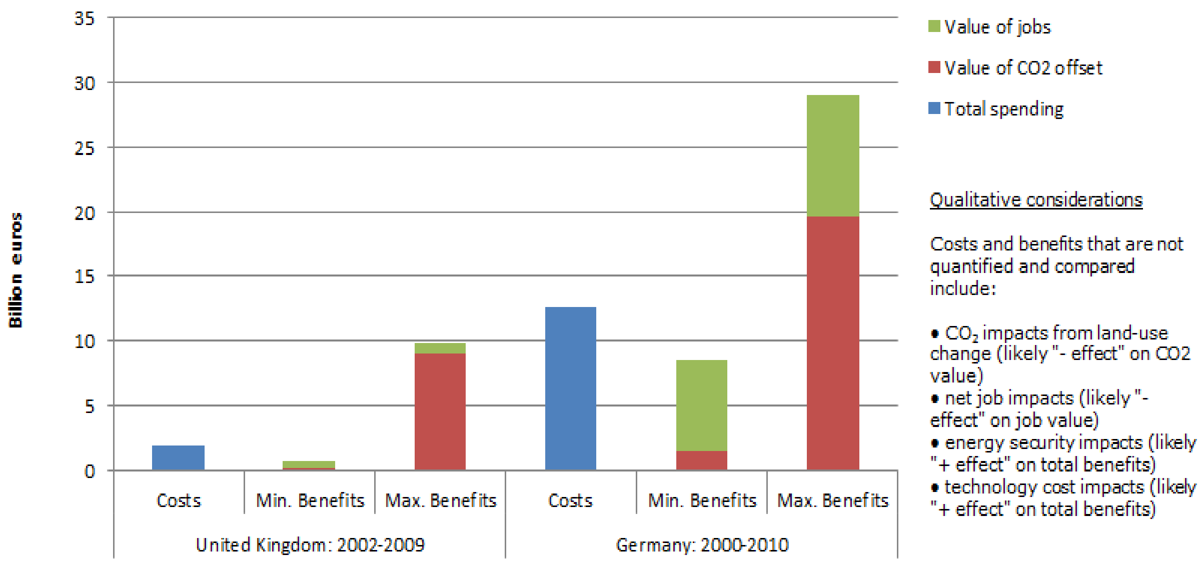

FIGURE 1. ESTIMATES OF COSTS AND BENEFITS OF UNITED KINGDOM AND GERMAN BIOPOWER BETWEEN 2002 AND 2009.

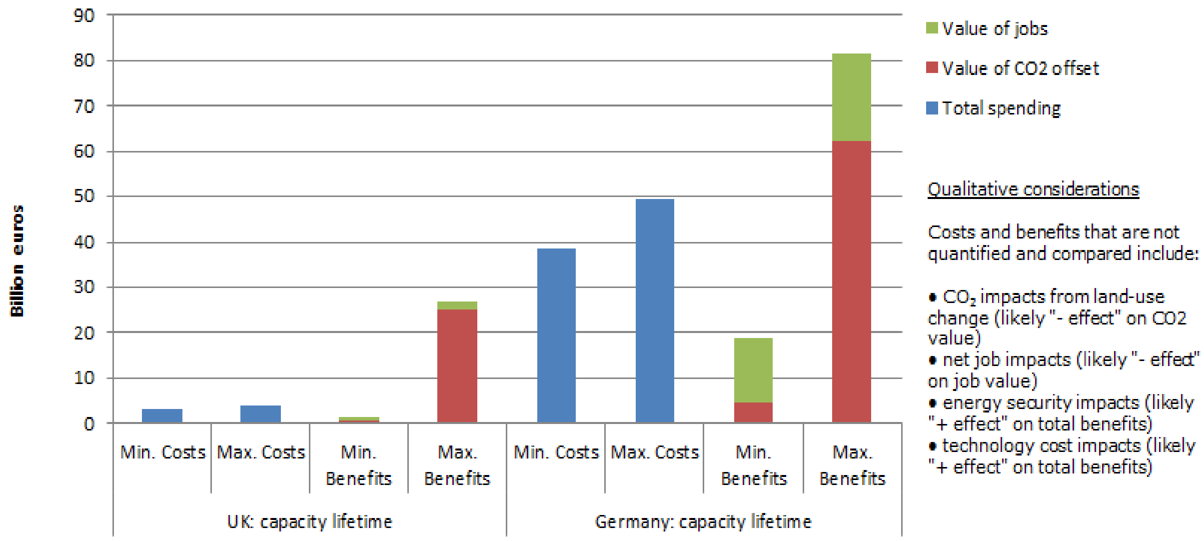

FIGURE 2. ESTIMATES OF COSTS AND BENEFITS OF UNITED KINGDOM AND GERMAN BIOPOWER ACROSS THE POLICY LIFETIME FOR CURRENTLY INSTALLED CAPACITY

The analysis indicates generally positive results, suggesting that subsidies to biomass in both countries might begin to qualify as "cost-effective" under relatively middle-of-the-road assumptions about their impacts on carbon dioxide and jobs and the associated value of those impacts. It should be stressed, however, that this analysis is highly limited, having employed relatively simplistic estimation methods as an initial exploration of these questions. Fuller accounting of costs and benefits would be required to draw any conclusive findings, especially given qualitative information about benefits that are not captured in this numerical analysis, as outlined below.

Of the two benefits estimated in the graphs above, carbon savings has the greatest potential to influence whether or not the subsidies might be judged cost-effective. This is largely due to the significant uncertainty around an appropriate price for carbon. For the lifetime of the biopower capacity installed during the period 2002–2009 in the United Kingdom, the "break-even" price for carbon savings—at which the subsidies could be fully justified by carbon savings alone—is between €23 and €102. This very wide range is due in large part to uncertainty about the exact feedstocks being used in the country and its associated carbon offset factor, the lowest value assuming European Union feedstocks offsetting coal power generation and the highest value assuming North American feedstocks offsetting gas power generation. For the capacity installed in the period 2000–2010 in Germany, the "break-even" price for carbon savings is between €104 and €133. In this case, the variation is solely due to uncertainty around the full costs of the subsidy program, which are dependent on future power prices, as price carbon offsetting data are reported by Germany's federal environment ministry (the BMU). In both countries, however, it is possible that carbon savings might be smaller than estimated here, if direct and indirect land-use change were to be taken into account. This uncertainty suggests that any bias in these estimates is towards over-valuation of carbon savings.

Jobs also appear to represent a significant benefit compared to subsidy costs in Germany, though of a lower maximum value compared to carbon savings. Caution, however, should be exercised in interpreting these figures, given that employment factors were derived with considerable uncertainty, and that potential job losses associated with rising energy prices have not been taken into account. This last factor in particular may be instrumental in assessing cost-effectiveness, given that modelling conducted for the EC has estimated much more modest job gains—in the realm of 25,000–33,000 new jobs on a net basis by 2020, as compared to the 184,000 job years on a gross basis in the biopower sector alone, as estimated by this study (Ragwitz et al., 2009). The same study projects that there is even the potential for net job losses related to the deployment of renewable energy in both the United Kingdom and Germany (Ragwitz et al., 2009). There is also significant uncertainty around what an appropriate financial value should be for an average job related to biomass energy. Therefore, these estimates should be interpreted cautiously and are highly likely to represent an over-valuation of job impacts.

It should also be noted that four elements are missing from Figures 1 and 2: the costs of complementary deployment subsidies and the benefits of energy security, technological development and the merit order effect. It has not been possible to estimate a financial value for these costs and policy impacts, though the latter three would all be expected to contribute a net benefit. The fact that biomass represents only a small percentage of electricity in each country suggests that the value of energy security improvements may be modest, though this would be greater within the wider context of each country's strategy for renewable energy deployment. The potential benefits related to technological development would vary by country. In this respect, the United Kingdom would likely see lower benefits, as its policy to date has largely promoted technologies that are already near maturity. By contrast, Germany's subsidy policy has focused additional support on relatively immature technologies and would therefore expect to yield greater gains.

9.0 Conclusions

This study estimates that the United Kingdom and Germany have committed significant subsidies to stimulate the deployment of electricity-generating biomass technologies, not including landfill or sewage gas. In the United Kingdom, capacity installed between 2002 and 2009 commits the country to spending an estimated €3.0 billion–€3.8 billion on biomass power. In Germany, capacity installed between 2000 and 2010 commits it to an estimated €38.7 billion–€49.3 billion of spending. The scale of costs is to some extent a reflection of the success that these policies have achieved in stimulating biomass deployment, which in 2009 represented 1.1 per cent and 4.2 per cent of electricity generation, respectively.

In conducting an exploratory cost-effectiveness analysis, this study yields more methodological findings than it does conclusive evidence about the absolute cost-effectiveness of either country's policy. The first and foremost of these is that any such assessment, if pursued earnestly, is difficult to do in a robust and comprehensive manner. Biomass poses particular research challenges because of the variety of technologies qualifying under the rubric "biomass" and the need for data that are broken down accordingly. Even in the United Kingdom and Germany, two countries with extremely high standards for data transparency, it is challenging, without significant resources, to identify detailed data on feedstocks, installed technologies and a breakdown of emissions savings and employment factors for different feedstocks and technologies. The environmental impacts of biomass technology are particularly complex and data-intensive, as they ideally require a consideration of land-use change and other impacts related to feedstock growth and collection—and there is unlikely to be easy consensus over an appropriate measurement for these impacts.

The estimates of cost-effectiveness in this study should be interpreted cautiously, as it was only possible to employ simplistic estimation methods of benefits, and these involve significant uncertainty. The study suggests that, under fairly middle-of-the-road assumptions within a very wide sensitivity analysis, biomass subsidies in the United Kingdom and Germany may achieve benefits that balance their costs. However, this is highly dependent on the assumptions holding true that:

- No other significantly costly deployment policies should have been identified and estimated.
- Carbon dioxide benefits would not be greatly reduced if the impacts of land-use change were taken into account.
- An estimate of net job creation would be of the same order of magnitude as this study's estimates of gross job creation.

Other gaps in the analysis would likely have an effect in the opposite direction. Energy security and technology development impacts are missing from the comparison of costs and benefits, because it is difficult to measure these benefits, not to mention their financial values—but their inclusion would be likely to increase the case for cost-effectiveness.

Some of the above uncertainties could certainly be reduced through dedicating resources to a full and exhaustive assessment. Others, however, such as the financial value of carbon, or of impacts related to energy security and technology cost reductions, are inherently uncertain for methodological reasons and subjective judgments about value, and are likely to remain so. Impacts on energy security and technology costs could be better assessed through qualitative analysis.

This exploratory exercise therefore suggests two things. First, if countries are committed to subsidizing the deployment of renewable energy, cost-effectiveness assessments can—and should—inform policy-makers how to best make use of scarce fiscal resources. In situations where there is a large discrepancy between costs and benefits, assessments can identify policies that are not cost-effective. And even where no conclusive judgment can be made, they can still identify the extent to which policies are actually achieving their stated outcomes, and identify opportunities to improve cost-effectiveness. Second, there are limits to a purely quantitative analysis. In many cases, the gap between measurable costs and benefits may not be sufficiently wide to provide a compelling finding in terms of absolute cost-effectiveness. In such situations, policy-makers must be made aware of areas of key uncertainty and the need to use their professional judgment to weigh impacts that can be confidently measured and valued alongside those that cannot.

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