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Assessing the Cost-Effectiveness of Renewable EnergyDeployment Subsidies:biomass in the United Kingdom and Germany.

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This study is a working paper. Until the final draft is published it should not be referenced or cited without permission from the authors. We would appreciate any comments and criticisms in the course of finalizing the paper for publication. Please contact us at cbeaton@iisd.org.

Contents

List of Acronyms

BMU	BundesministeriumsfürUmwelt, Naturschutz und Reaktorsicherheit [the Federal Ministry for the Environment, Nature Conversation and Nuclear Safety]
CHP	Combined heat and power
EEG	Erneuerbare-Energien-Gesetz [the Renewable Energy Sources Act]
ETS	Emissions trading system
GHG	Greenhouse gas
IEA	International Energy Agency
R&D	Research and development
RED	Renewable Energy Directive
RETs	Renewable energy technologies
RO	Renewables Obligation

1 Introduction

In the last decade, a growing number of countrieshave employed subsidies to increase the deployment of renewable energy technologies. 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 statedpolicy objectives and whether the costs can be justified. This paper explores the cost-effectiveness of subsidies to electricity-generating biomass technologies. How much has been spent supporting the industry? What value can be assigned to the benefits that have been achieved?

In considering these questions, this paper focuses ondeployment subsidies for electricity-generating biomass technologies in two European countries, the United Kingdom and Germany, and considers what lessons other countries might draw from their experience.

2 Methodology

In this study, cost-effectiveness is assessedin two steps: first,estimatingthe 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 thought of as having been achieved at a 'reasonable cost'.

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

Table 1: Deployment subsidies for RETs (Renewable Energy Technologies): 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		Renewable energy generation will offset carbon-intensive energy sources, resulting in less CO_2 emissions and reduced local air pollution.
Economic and social goals: • industry creation • job creation • regional development	Increased deployment of renewable energy	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 other countries By influencing the location of investments, this economic wealth can be targeted at 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 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.

In addition to the general objectives listed in the table above,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 CO_2emissions or ambitions for job creation.In this analysis, specific targetswere 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 assess cost-effectiveness by estimatingthe economic value of the achieved benefits compared to the estimated financial burden of the subsidies.

3 Defining biomass

Although biomass is often grouped with other renewable energy technologies such as solar photovoltaic modules and wind turbines, it stands out from other renewables in at least two respects.

First, while the inputs of other RETs are the for the most part freely available, and vary according to resource intensity of a geographic location, biomass technology is based around 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(IEA, 2007).

The second difference is that 'biomass' refers to a larger spread of technologies than manyother renewables. In part, this reflects the variety of feedstocks:differentprocesses may be required to convertthem into a combustion-readyfuel. Once processed, biomass fuels can be in a solid, liquid or gaseous form, and used alone or in combination with fossil fuels, meaning a range of technologies is also needed totransform 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% of total world primary energy demand (IEA, 2009).Much of this derives from the reliance of poor households on wood and charcoal, often burnt inside homes for heating and cooking. Such uses are not normally considered part of the group 'renewables' because domestic combustion is related tosignificant 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 the summit, allowing full access to modern energy services.

In using the term'biomass', this report focusesonmodern uses of organic fuel for power generation – instances where organic material is used to produce electricity, or electricity and heat together, beyond the household level. This includesco-firing andtechnologies 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 analysing biomass technologies with highly different characteristics, the report does *not* include energy produced from landfill or sewage gaswhen employing the term'biomass'.

4 Estimating the effectiveness of deployment subsidies for biomass

4.1 Increased deployment

In the year 2002, the UK generated1TWh of electricity from biomass.[1]By 2009, this had increased to around 3.6TWh. In its early years, the UK's subsidy mechanism– the Renewables Obligation (RO)– was most successful in stimulating growth in 'co-firing'. This is when existing fossil energy plants substitute a share of their fossil fuel supply with biomass. From 2006, when a cap was tightened on the amount of co-firing that could be used, a larger share of generation was produced by other biomass technologies. Little generation frombiogas and CHP plants has been stimulated in the UK. In2009, the ROwas amended to increase support to these technologies.Some studies are still sceptical about the extent to which the attractiveness of CHP has been increased by the changes(Thornley, Brammer, Rogers, Huang, & Rezvani, 2009).

In the year 2000, Germany generated just under 1 TWh of electricity from biomass, not including sewage gas, landfill gas and energy from the biogenic share of waste. By 2009, this had increased to around 23 TWh. Germany's subsidy mechanism – the Renewable Energy Sources Act (the Erneuerbare-Energien-Gesetz, EEG) – has largely stimulated electricity generation exclusively using solid biomass and biogas, with some generation based on liquid biomass. In 2004 and 2008, the EEG was amended to offer bonuses to certain technologies, technology crops and the use of CHP, increasing the share of such technologies among the generation mix.This has resulted in faster development of CHP plants in Germany, with an average yearly growth of 23% between 2004 and 2008(IEA, 2010).

4.2 Environmental goals

4.2.1 Policy frameworks for assessing environmental impacts:life cycle analysis and certification

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; diverting a feedstock from its previous application; any waste outputs; and the offsetting of existing power technologies.If a generating facility changes feedstock for any reason,the environmental impact will change accordingly. The relative efficiency of different biomass installations will also influence the environmental impact per unit of energy produced.

The European Union's Renewable Energy Directive (RED)(EC, 2009) has set out binding sustainability criteria for biofuels and bioliquids.These must be met if fuels are to count towards renewable energy targets and qualify for financial aid. No binding standards have been established for biomass and biogas. The RED has, however, mandatedthe European Commission to report on possiblesustainability requirements for solid and gaseous biomass sources in electricity, heating and cooling.The resulting

[1] Note that these figures and all figures throughout the report do not consider energy generated by landfill gas or sewage gas. See 'Defining biomass'.

study(EC, 2010) 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 in the Renewable Energy Directive", with some exceptions and additions.

Together, this would result in the following recommended standards:

- Solid and gaseous biomass should achieve greenhouse gas reductions of at least 35%, rising to 50% on 1 January 2017 and, for all installations starting production on or after 1 January 2017, rising to 60% from 1 January 2018. Emissions should be estimated using default values as set out in (EC, 2010), adjusted to the efficiency of the installation in question.
- Biomass from waste should be exempt from meeting greenhouse gas performance criteria, because it is hard to estimate default greenhouse gas values and the sector routinely achieves high savings.
- Solid and gaseous biomass should not be derived from land with high biodiversity value or high carbon stock, as defined by the RED.
- Solid and gaseous biomass 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 report also sets out estimates of greenhouse gas savings from a range of solid biomass sources. For electricity generation, these range from roughly 18-95% savings compared to fossil fuels.The highest savings are from EU-sourced chips and pellets from forest residue, although miscanthus, EU-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%. 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 EU countries have strong forest management governance structures. The Commission also generalizes that solid and gaseous biomass is likely to achieve higher GHG savings than biofuels becauseconversion 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 tobe lower.

The EC's sustainability guidelines for liquid biofuels have been criticised because they do not attempt to take into account environmental impacts related to indirect land-use change, and 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 elsewhere on land that needs to be converted for agricultural use. The omission of this dynamic could significantly influence greenhouse gas saving estimates. UK government body the Environment Agency (2009) has calculated that land-use change can reduce and in some cases reverse savings.Converting fallow land to energy crop production was estimated to reduce emissions savings by up to 10% and in two cases the conversion of grasslands was estimated to increasenet GHG emissions. The agency also found that the use of fertilizer and thetransportation of feedstock over long distances can reduce emissions savings by between 15 and 50%.

The EU'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 biofuels 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]".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 IPPC 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).

The United Kingdomand Germany are both in the process of establishing sustainability schemes for solid and gaseous biomass.

In the UK, solid and gaseous biomass sustainability criteria were sent out for consultation in September 2011 by electricity and gas regulator Ofgem(Ofgem, 2011). The criteria require that biomass installations larger than 50kW should emit no more than 79.2 gCO_2eq 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 made 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 verification is required though operators are expected "to be confident that they are reporting accurate and reliable information". From April 2013, eligibility for the UK'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(BMU, 2009), 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 (Germany, 2010)has given authorization for the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) to enact such an ordinance.

4.2.2 GHG reductions in Germany and the UK

Substantial data are required to establish robust estimates ofthe environmental impacts of biomass technologies. In order to estimate carbon reductions alone, 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,offsettinggreater emissions than co-firing). Other impacts are more complex. For example, comprehensive accounting of land use through time would be needed to assess the impacts of land-use change, and various methodologiesexist for estimating indirect land-use change(Chum, Faaij, & Moreira, 2011).

For these reasons, this report focuses only onthe value of greenhouse gas savings, not including emissions related to land-use change.It then encourages readers to interpret the resulting estimates in the light of uncertainties that might be considered by environmental impacts that have not been estimated.

In the UK, a range of savings are estimated. This isbased on CO_2–equivalent life-cycle emissions saving factors reported by the Environment Agency (2009). Although the most recent submissions under the UK's sustainability reporting scheme provide a wealth of data about the type and origin of feedstocks used in 2010 (Ofgem, 2011), it was not possible to incorporate such complex data into this exploratory study. A range of estimates were therefore calculated, using emissions 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, a point estimate is calculated. This is based on biomass-specific greenhouse gas saving estimates reported by the German government every year. These estimates are based on emissions saving factors that are disaggregated by technologyand 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.

Savings are estimated for the period in which current data is available about each policy (2002–2009 in the UK and 2000–2010 for Germany) and up until the end of the period that generatorsare allowed to continue receiving support under each scheme.Because there are different levels of uncertainty in the emissions factors and assumptions made in each country, caution is urged in comparing them.

Assessing the value of emissions offset is difficult as no consensus exists over the 'right' price for carbon. Prices also change with time, as cheaper mitigation options are exhausted. This study looked at existing and projected prices for emissions trading schemes in order to assign a financial value to the carbon offset. As a lower band, the EU Emission Trading Scheme (ETS) price of carbon was used. This has never reached 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 a medium and high band, values were derived from integrated assessment models of the emissions cost needed to limit CO_2 levels to 550ppm, from sources whose estimates ranged from US$ 135–380 (€105−295) by 2060(IMF, 2008). For the purposes of analysis, low, medium and high values of €15, 50 and 200 were assigned to indicate the range of possible carbon prices.

In the UK and Germany, it should also be noted that the EU Emissions Trading System (ETS) co-exists alongside each country's national subsidies to promote renewable energy. According to some authors, this means that renewable energy subsidies have simply reduced the price of carbon under the ETS and so prevented emissions being achieved more cheaply elsewhere in the EU. This study assumes no such effect and assesses the value of carbon reduced assuming no leakage. For a more in-depth discussion of this potential complication, see the report on solar PV in this series on subsidies to renewable energy.

Table 2.Value of carbon offset in the UK and Germany

	United Kingdom		Germany	
	2002-2009	Lifetime of 2002-09 installed capacity	2000-2010	Lifetime of 2000-10 installed capacity
Total CO_2 savings (tonnes)	11,240,312 – 39,518,419	40,151,056 – 140,816,067	88,800,000	371,343,000
Value of carbon saved				

(€ billion)				
At €15 / tonne	0.17 – 0.60	0.60 – 2.11	1.33	5.57
At €50 / tonne	0.56 – 1.98	2.01 – 7.04	4.44	18.57
At €200 / tonne	2.25 – 7.90	8.03 – 28.16	17.76	74.27

In absolute terms, these estimates indicate that the EEG in Germany has achieved higher CO_2 reductions than the RO in the UK. It is not possible to determine if these savings are higher or lower per kWh of energy generated as the range of potential carbon savings in the UK 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 savings might lie. On the one hand, the large amount of co-firing in the UK would indicate that more coal has been offset than gas, suggesting higher CO_2 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-optimistic than over-conservative.

4.3 Economic and social goals

Deployment subsidiesoften include a policy goal ofencouragingsustainable economic growth, sometimes referred to in the context of a 'green economy'. These impacts might be measured in terms of 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. Because biomass requires a low level of capital compared to technologies like solar PV or wind turbines, a relatively larger number of jobs is likely to be found in the producing fuel and the running and upkeep of plants. A review of studies by Wei et al. (2010)reports employment factors per MW of installed capacity from 2001 that show biomass requiring around 14–38% 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. The European Biomass Industry Association (EBIA) argues that as bioenergy is a decentralised energy option, these jobs can contribute to rural development by creating business and employment opportunities in rural areas. Although operations and maintenance jobs will certainly be local, it is possible for jobs related to feedstock production to take place in any country.

Subsidies might also help build a globally competitive domestic biomass industry. This could be measured in terms of jobs,exports or turnoverrelated 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.

It is more difficult to estimate the net impacts that subsidy spending will have on general economic activity, including indicators such as 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 UK'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%(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 spending 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 UK and Germany – this will also have impacts on 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 solar PV) increased from €0.58 to €3.10 (BMU, 2009).

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, is hard to estimate, particularly because price fluctuations in the cost of feedstockscangreatly influence the cost of energy production.

4.3.1 Jobs relatedbiomass in the UK and Germany

Given the relative complexity of estimating most other indicators, this study focuses on direct gross job creation as a proxy 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 the biomass industry. 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 job numbers reported by the German government for the years 2008 and 2009, which are based on industry surveys of actual employment in the sector(BMU, 2010). 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 factorswere then used to derive an estimate of biomass-related employment in the UK, as summarized below.Thisassumes that there are relatively similar technologies and fuel markets in each country.

Table 3: Employment estimates

	Employment estimate (gross jobs)			Lifetimeof installed capacity
	2008	**2009**	**2010**	
United Kingdom				
MW installed capacity	868	1,178	No data	1,178 MW over 20 years
Gross jobs	2,881	3,741	No data	54,293
Germany				
MW installed capacity	3,559	4,134	4,600	4,600 MW over 20 years
Gross jobs	29,665	35,703	36,042	472,460

The estimate of German jobs is higher than the estimate of UK jobs because Germany has a higher overall installed capacity. Each unit of capacity in Germany also generates a higher amount of electricity on average than in the UK, so estimates of jobs in fuel production, operations and maintenance are higher. Germany also has a higher share of biogas capacity (almost 50% of total capacity), which, according to the employment factors derived fromBMU data, appear to involve a higher number of jobs per MW. As regards the estimates in the UK, it should also be noted that almost three quarters of installed capacity are made up of co-firing installations. Jobs related this technologycan be considered part of the renewable energy sector but 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. By contrast, the EEG is only granted to installations exclusively using biomass. In both countries, it not clear whether feedstock production would largely involve pre-existing or additional job.

Given the lack of data and the simplicity of the estimation method used, however, these estimates should be interpreted cautiously. Given the various assumptions involved and the fact that no negative job impacts have been estimated, it is likely that these figures are more biased towards being over-optimistic than over-conservative, especially in the case of the UK.

Analysis from other studies implies that estimates of net jobs using economic modelling are significantly more conservative than those presented here. According to a modelling exercise conducted for the European Commission, 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% 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%. In the UK, the models projected, respectively, thatthere would be a loss of 11,000–1,000 jobs by 2020,witha loss in GDP of 0.1%; oran additional 10,000 jobs, with less than 0.1% 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 countries, such as Spain, large levels of investment compared to GDP were projected to be able to cancel out such effects.

4.4 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 threatssuch 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 towards 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 benefitsto 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 ofvariations in other renewable energy technologies. Biomass energy is not without risks,however, as outlined by Ölz et al.(2007).Uncertaintyisinvolved 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 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 beenachieved 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. Absent a full analysis of the UK 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 biomassin the United Kingdom and Germany was approximately 1.1% and 4.2% respectively. Although far from trivial, this level of deployment is also unlikely to greatly affect thereliance of each country onother energy technologies and their relatedrisks. 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% and 16.1% of electricity, respectively (DECC, 2011; BMU, 2010). However, this is outside the scope of this study.

4.5 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.

The potential for technological development varies among different biopower technologies. According to analysis conducted by the Electric Power Research Institute, 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% biomass repowering. Still others are in the research and development stage, including bio-hydrogen, pressurized gasification and high-rate co-firing (EPRI in Bracmort, 2010). There are also a number of research opportunities in the cultivation and processing of feedstock.

The rationale behind deployment subsidies is thatthey will provide opportunities for cost reductions in the deployment stage through'learning by doing', as well as promoting R&D among private investors. It is hoped that eventually this will lead to grid parity, allowing the technologies to compete in the energy marketplace without support.

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 the 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 which 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.

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: 'learning by doing' in production and research and development into feedstock production and biopower generation. For a more in-depth discussion of this, see the report on solar PV in this series on subsidies to renewable energy

4.6 Effectiveness Summary

To assess whether the subsidies have had their desired effects, each of the goals listed earlier is now presented alongsideestimates of the actual outcomes of the policies(see Table 4).

Table 4: Summary table of effectiveness objectives, outputs and outcomes

Policy objectives	Outputs	Intended outcomes	Estimates of actual outcomes
Environmental goals: • mitigation of climate change • reduction of local pollution	Increased deployment of renewable energy (installed capacity): UK – from 333 MW in 2002 to 1,178 MW in 2009 Germany –from 258 MW in 2000 to4,600 MW in 2010	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	Carbon savings:[1] UK – 11.2–39.5 million tonnes CO_2 Germany – 88.8 million tonnes CO_2
Economic and social goals: • industry creation • job creation • regional development		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.	Total 'job years' over lifetime of installed capacity: UK – 54,293 Germany – 472,460
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 any one source of supply.	Proportion of electricity from biomass: UK – 1.1% Germany – 4.2%
Development of RETs: • cost reductions		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 R&D. These cost reductions will, in turn, lead to increased deployment of RETs, contributing to all three of the outcomes listed above.	No appropriate indicators identified

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

Overall, the indicators suggest that both subsidy programmeshave succeeded in achieving their desired outputs (increased deployment) and outcomes.

In comparing the two countries, it would appear that Germany's policy has in all cases achieved greater effects thanthe United Kingdom's. This is in part due to greater spending and 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 UK. It is likely Germany has achieved greater additional employment per MW of capacity installed. This is because the employment factors that were derived indicate that Germany's biogas installations may involve higher employment than the UK's primarily solid biomass facilities, and in light of the qualitative knowledge that many UK jobs related to co-firing are unlikely to be additional.

Having established thatboth policiesappear to have achieved some oftheirdesired effects, it is necessary to ask if the policy can be considered cost-effective– were its objectives achieved at a 'reasonable cost'?

5 Cost effectiveness

An assessment of the cost-effectiveness of these subsidies must first begin by estimating their costs. Then, two lenses of analysis can be applied. First, were the policies cost-effective in an 'absolute' sense – in other words, would other policy tools be more effective at the same cost? Second, were the policies cost-effective in a 'relative' sense – was one subsidy scheme designed in a way that made it more efficient than the other? In this study, only absolute cost-effectiveness was considered, as the lack of robust data on carbon offsets and job creation in the UK reduced the validity of a relative comparison.

5.1 Calculating scheme costs

In the UK, 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(Ofgem, 2011; 2010; 2009; 2008). 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 2002−2009 – for each plant that is installed, a maximum of 20 yearsfrom 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 costs of the subsidies was estimated using data on subsidy tariffs, biomass electricity generation and biomass electricity capacity as reported by the BMU and the German Association of Network Operators(BMU, 2011; 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 2000−2010– 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, range of spending is reported, based on the assumption of 'low' and 'high' power prices in future years.

Table 5: Key indicators on the financial cost of biomass deployment subsidies

	UK	Germany
Total subsidy in 2002-2009 / 2000-2010	1.5	11.7

Total commitment 2000−2009 (€ billion)	4.1−5.3	46.2−60.4
Average spending per year (€ billion)	0.1−0.2	1.5−1.9
Total TWh of electricity generated	64.38	543.06
Average cost per kWh (€/kWh)	0.059−0.082	0.085−0.11

Notes: Estimates for both countries are stated in 2010 euros, assuming a constant 2% inflation rate and a GBP/EUR exchange rate of 1.17.

Although the costs of Germany's subsidy policy are higher on a per kWh basis, it should also be borne in mind that until 2009 the UK's policy was structured to promote the most cost-effective technologies, regardless of their maturity. This has resulted in almost 75% of the UK's biomass power being 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.

It should be noted that this study only estimates the costs of each country's most high-profile deployment subsidy. Most countries offer a range of financial incentives for the deployment of renewable energy and these have not been mapped out or estimated in the United Kingdom and Germany. In reality, therefore, these cost estimates are likely to be conservative.

5.2 Absolute 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. Estimates were made for the financial value of carbon emissions offset and jobs created in each country. The financial benefit of carbon savings was estimated as reported earlier 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 an assumed minimum and maximum value of €25,000 and €50,000 per job, respectively.

A comparison of costs and benefits is shown 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 UK and German biopower to date

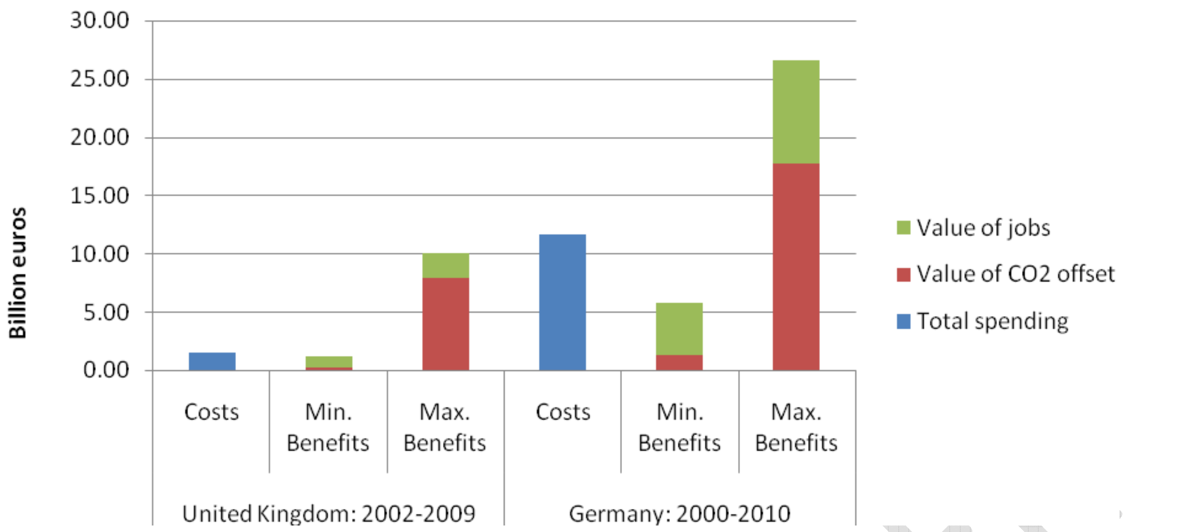
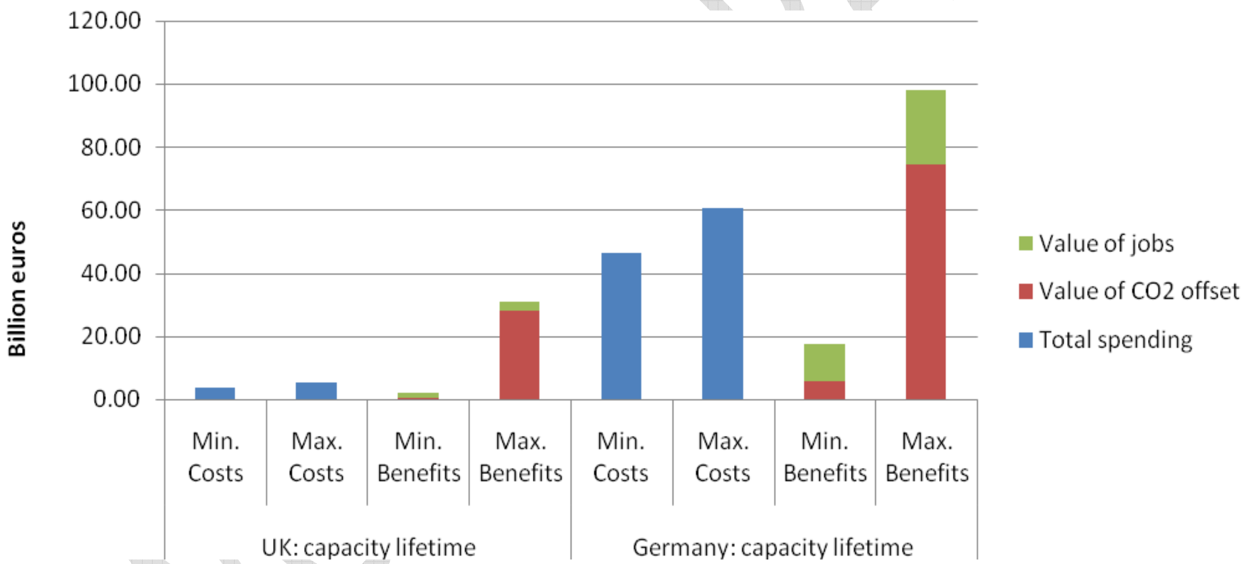


Figure 2. Estimates of costs and benefits of UK and German biopower across the policy lifetime for currently installed capacity



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 CO_2 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 is 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 period 2002-2009 in the UK, the 'break-even' price for carbon – at which the subsidies could be fully justified by carbon savings alone – is equal to €41–146, depending on the exact feedstock being used in the country and its associated carbon offset factor. For the period 2000-2010 in Germany, it is equal to €131, based on carbon offsetting data as reported by 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.

Jobs also appear to represent a significant benefit compared to subsidy costs in both countries, though of a lower maximum value compared to carbon savings. Caution, however, should be exercised in interpreting these figures, given the fact that employment factors were derived with considerable uncertainty; many jobs that are reported may not be additional; and 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 European Commission has estimated modest job gains and even potential for net job losses related to the deployment of renewable energy in both the UK 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.

It should also be noted that two elementsare missing fromthe graphs above – namely,benefits relatedtoenergy security and technological development. It has not been possible to estimate a financial value for these policy goals, though both would 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 may 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. The UK would be unlikely to see significant 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 in this area.

6 Conclusions

This study estimates that the United Kingdom and Germany have committed significant subsidies to stimulate the deployment ofelectricity-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 €3.81–5.26 billion on biomass. In Germany, capacity installed between 2000 and 2010 commits it to an estimated €46.17–60.42 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% and 4.2% of electricity generation, respectively.

In attempting to conduct an exploratory cost-effectiveness analysis, this study yields many methodological findings. The first and foremost of these is that any such analysis, if pursued earnestly, is extremely 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 to identify detailed data on feedstocks and technologies in use and a break-down of emissions savings and employment factors for different feedstocks and technologies. The environmental impacts of biomass technology are also particularly complex and data-intensive, as they ideally require a consideration of land-use change and other impacts related to feedstock growth and collection.

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 biomass subsidies in the United Kingdom and Germany may achieve benefits that balance their costs. However, this is highly dependent on the assumption that no other significantly costly deployment policies should have been identified and estimated; and that CO_2 benefits would notbe greatly reduced by consideration of land-use change and that an estimate ofnet job creation would be of the same order of magnitude as the gross job creation estimated here.Energy security benefits and technology development benefits are also missing from the numerical analysis, given the difficulties involved in estimating benefits and their financial values, though these would likely represent a net financial gain.

If countries are committed to subsidizing the deployment of renewable energy, further analysis of cost-effectiveness could – and should – usefully shed light on how these policies can better make use of scarce fiscal resources.

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