Emission and Abatement Cost projections

submitted to

UK Department of Energy and Cliamte Change
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by
IIASA - International Institute for Applied Systems Analysis
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Table of Contents

Table of Contents 2
1. Project overview..... 3
2. Task 1: Update of Global Forestry Emissions Projections and Abatement Costs 4
3. Task 2: Report as of Intended Nationally Determinied Contribution (INDC)..... 7
4. Task 3: Non-CO2 emissions as of the agricultural sector 11
5. Project team 13
6. Ownership of data 14
References.....15
Annex I – Detailed model description 19
GLOBIOM model description.....19
G4M model description ..... **Error! Bookmark not defined.**

1. Project overview

This is a proposal in response to the tender on **Emission and Abatement Cost projections** as put forward by the UK Department of Energy and Climate Change. The approach chosen by the consortium to resond to the tasks of the project is to combine well-established modeling tools with an analysis of available and relevant literature and the opinion, insights, and experience of a series of experts.

The main aim of the **Task 1** is to to provide updated baseline forestry emissions projections and associated Marginal Abatement Cost Curves (MACCs) for individual countries, based on economic, social and policy drivers. The scenarios will cover deforestation, afforestation, and forestry management, along with a report explaining the key results and their drivers. The global model tools G4M and GLOBIOM, developed at IIASA, will be applied to provide the MACCs. GLOBIOM uses global scenarios of population, diet, GDP and energy demand to inform G4M about future land and commodity prices and demand for bioenergy and timber. G4M projects emissions from afforestation, deforestation and management of existing forests. Mitigation measures can be simulated by introducing a carbon tax. From the results of both models abatement cost curves will be derived. The most up to date data sources will be used for the assessmet including FAOFRA 2015 data.

Based on the BAU and MACCs as assessed in Task 1, **Task 2** will assess the **Intended Nationally Determined Contributions** (INDCs) as submitted to the UNFCCC in preparation for the adoption of the Paris Agreement in December 2015. The report will assess the 156 Parties (representing approximately 90% of global greenhouse gas emissions in 2012) that had submitted their INDCs by 29 October 2015. The report will contrast the BAU developments and mitigation potentials as for the LULUCF sector as produced within Task 1 as to the data as provided with the INDCs to provide insights as to the efforts that the countries have put forward. Contrasting information as to BAU and mitigation potentials will be discussed, key uncertainties concerning as to emissions and pools as considered will be described, and the implication of Current and Additional policies will be developed.

2. Task 1: Update of Global Forestry Emissions Projections and Abatement Costs

This section describes the modelling approach as will be applied for providing input data as to GLOFAC in terms of Business As Usual (BAU) emissions projections and associated Marginal Abatement Cost Curves (MACCs) for international greenhouse gas (GHG) emissions. The methodology as described will be applied to provide MACCs for individual countries, based on economic, social and policy drivers. The forestry activities cover deforestation, afforestation, and forest management.

Updated data sources

redacted

General approach as will be applied

To produce consistent projections of CO_2 emissions from forestry activities at country level until 2050, two different models, an economic land use model (GLOBIOM) and a detailed forestry model (G4M) communicate as shown in the Figure 1 below. The economic land use model GLOBIOM is located in the centre of the framework. The model uses recent baseline projections by WEO (2015) for future bioenergy demand and related assumptions on population growth, economic development (GDP), and technical progress rates as macro-economic drivers. GLOBIOM represents the forestry, agriculture, bioenergy and livestock sectors for in world regions.

For baseline and policy scenarios, the economic land use model projects domestic production and consumption, net exports and prices of wood and agricultural products. The sector specific information from the economic model is used by the forest model to project GHG emissions and removals for detailed land management options. The forestry model is applied to estimate emissions and removals from forest management and afforestation/reforestation activities. Based on a baseline projection it also provides abatement cost curves for the selected land use activities.

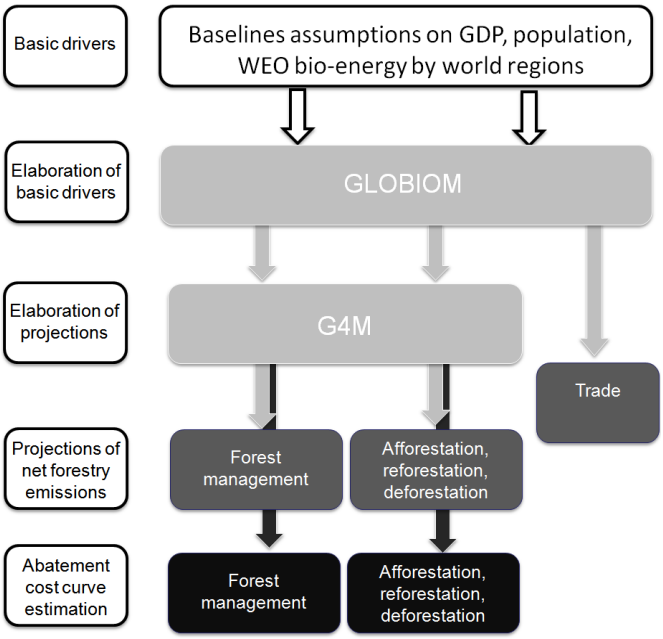

Figure 1: *Overview of general modelling approach.*

The models use several sources of input data: some available for each grid, some in country aggregates, and others are global. The data supporting the values in **Error! Reference source not found.** are known for each grid. Some of the values are also available for time series.

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Baseline construction

The MACCs, computed with the aid of the GLOBIOM and G4M models, will ben estimated based on the following assumptions.

redacted

Technical mitigation potential (MAC curves)

Annual MACCs are to be provided based on the following construction and can be provided based on the following assumptions.

redacted

Sector and geographic coverage as of MACC

The data as provided will cover the following elements.

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Carbon price approximation as of MACC

As specified above, we will be provided for 20 carbon price steps. If DECC would like to see further granularity as of carbon steps, the contractor can apply a linear interpolation method to provide data as for further carbon steps. Such an approach has been successfully tested and evaluated within other projects and can be applied to create MACCs for each 5 $/tC price steps as in between the price steps as assessed by the G4M modelling framework. In other words, if required, the linear approximation approach can be used to provide MACCs as for each 5 $/tC price step as between the 20 carbon price steps (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 90, 100, 200, 300, 500, 1000, 2000) as assessed by G4M.

The linear interpolation as successfully applied within previous projects is set up in the following manner. Assuming that you would like to estimate the emissions from above and below ground biomass related to deforestation (em_df_bm mtco2year) for the carbon price step (c), and that the price step is between the two carbon price steps (c_0) and (c_1). If the emissions for the carbon price steps (c_0) and (c_1) are (em_0) and (em_1) respectively, then the emissions (em) for the carbon price step (c) is estimated as:

$$\boldsymbol{em = em_0 + (em_1 - em_0)\frac{c - c_0}{c_1 - c_0}}$$

Data Report

The data as prepared within Task 1 will be provided in an excel sheet as to DECC. Accomondating the data, a report as of Task 1 will also be provided detailing key assumptions as of the approach selected and data being used. The key elements that will be specified within the report are as follows:

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3. Task 2: Report as of Intended Nationally Determinied Contribution (INDC)

This section describes the report that will be delivered within the project addressing the INDCs as submitted to the UNFCCC in preparation for the Paris Agreement in December 2015 (hereafter referred to as the "INDC report"). The INDC report will assess the 156 Parties (representing approximately 90% of global greenhouse gas emissions in 2012) that had submitted their INDCs by 29 October 2015 and particularly assess to what extend these countries consider the LULUCF sector and provide key information as to the mitigation potential as taken by the countries concerning the LULUCF sector. Furthermore, the report will contrast the LULUCF BAU and mitigation potential as of the INDCs to that assessment as Task 1.

Coverage as of the LULUCF sector within the INDC reports

Of the 156 parties that submitted an INDC, the contractor has found that 95 countries explicitly state that emissions and removals from land use activities (LULUCF) are included in the mitigation component of their INDC. However, only 36 of these 95 countries provide details as of measures or specific targets for the LULUCF sector. Some countries provide information of their LULUCF developments over time in terms of business-as-usual and INDC development (e.g. Madagascar, Mali), or refer to a complementary report where such information can be found (e.g. Brazil, South Africa). Other countries only provide emission levels for the LULUCF sector considering the effect of reductions measures. Many countries reported an estimated emission reduction due to the certain measures and policies related to the LULUCF sectors (e.g. Japan, Guyana). Some INDCs provided information about the area which will be afforested or the amount of carbon that will be sequestered due to forest stock management (e.g. China, India).

A group of 59 of these 95 countries states in their INDCs that the LULUCF sector is covered but do not provide LULUCF projections, nor quantifiable information concerning LULUCF mitigation policies. For example, several countries delivered projections from the agriculture, forestry and land-use sector (AFOLU) without additional data which can help to distinguish LULUCF emissions (e.g. Mauritania). In some INDCs the list of measures and policies in the LULUCF sector can be found but without data that may help to estimate emission reductions in LULUCF sector (e.g. Indonesia, Jordan). A number of countries stated in the INDCs that the LULUCF sector is covered but no exact reduction level or mitigation measures are specified (e.g. Russia, New Zealand).

42 Countries explicitly state that LULUCF emissions are not included in their INDC, but do propose measures or policies to reduce LULUCF emissions (e.g. Chile, Georgia). Some of these countries also state that a decision to include or not the LULUCF sector will be taken by 2020 (e.g. EU, Thailand).

The remaining 19 countries state that LULUCF emissions are not covered and do not propose measures or policies for reducing LULUCF emissions. Some of these countries do not mention the LULUCF sector in the INDCs (e.g. Moldova, Andorra) while some countries still consider possibility to include LULUCF sector later (e.g. South Korea, Montenegro). This is summarized in Table 1.

Table 1. *Categorization of countries according to the information concerning the LULUCF sector as provided within the submitted INDCs.*

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The INDC report

An INDC report will be delivered by the contractor in line with the requirements as of the tender. The report will focus as on the 95 Parties that explicitly state of their INDC that LULUCF is covered. The main chapters as of the INDC report and what they will cover will be as follows.

Chapter 1. National Business-as-Usual development as of INDC's

The chapter will provide information as to the LULUCF BAU as described with the parties INDC's. Full GHG information as to the LULUCF BAU and INDC development as described by the parties in their INDCs will be provided within this chapter of the report.

It should be noted that most parties do not provide explicit information for the LULUCF sector as of their BAU and INDC developments within their INDC submission. It is our assessment that of the 36 countries that provide details as of measures or specific targets for the LULUCF sector, only 11 countries provide BAU and INDC development according to INDC submission. LULUCF LULUCF emissions/removals projections can on the other hand be complemented and provided based on other reliable sources of information as made publically available by the countries such as National Communications and supplementary information as quoted in INDCs and National Communications. As such, projections of future emissions/removals will in the chapter be developed and assessed based on information as provided by countries themselves in terms of National Communications, INDCs, and supporting information as officially provided.

Table 2 summarizes the information as intended to be used to provide LULUCF BAU and INDC development according to INDC submission for the 95 Parties that explicitly state in their INDC submission that the LULUCF sector is covered. The full dataset of LULUCF BAU and INDC development as specified will be delivered to DECC.

Table 2: *Information as intended to be used to construct the business-as-usual and INDC emission projections for the LULUCF sector for the countries that state in their INDC submission that the LULUCF sector is covered. For the countries that state that LULUCF is covered but do not provide quantifiable details as of measures or specific targets for the LULUCF sector, the business-as-usual and INDC emission projections for the LULUCF sector are based on the information of the National Communications.*

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Chapter 2. Contrasting view on Business-As-Usual developments

Based on the information as provided in chapter 1, the chapter will showcase the contrasting views as of LULUCF BAU developments between that of the contractor (Task 1) and the BAU LULUCF developments as the INDCs.

The contrasting view will be described first of as the level of all the 95 countries as considered within the analysis, and thereafter for 2 individual contrasting countries. The decision as of which two contrasting countries as to be described will be taken in joint discussion between the contracting party and DECC.

Chapter 3. Contrasting view on mitigation potentials

Based on the information as provided in chapter 1, this chapter will showcase the contrasting views as of LULUCF mitigation potentials between that of the contractor (Task 1), and the INDC LULUCF developments as the stated by the countries as of their submitted INDCs.

The contrasting view will be described first of as the level of all the 95 countries as considered, and thereafter for the 2 individual contrasting countries as selected and described in chapter 2.

Chapter 4. Contrasting view on mitigation potentials

Based on the information as described in chapter 2 and 3, this chapter will discuss how the submitted INDCs can be assessed in terms of their robustness. The main question as will be addressed in this chapter is that of how large is the contrasting view as of GHG emission from the LULUCF sector and what are the potential underlying reasons as to the differences in mitigation potentials.

Chapter 5. Where does policies take us in terms of GHG emissions from the LULUCF sector?

The chapter will discuss and present what BAU, Current Policies, Additional Policies, and INDC developments would lead to in terms of total greenhouse gas for major emitting countries. The first goal of the chapter is to describe the extent as to which the various policy scenarios will reduce yearly greenhouse gas emissions as related to the Business-As-Usual development. In other words, the assessment will highlight how far an implementation of various policy targets would take the countries towards a reduction of their GHG emissions as of 2030.

From there on, the role of the LULUCF sector within the mitigation potential will be discussed. The chapter will highlight for individual countries how much of the total emission reduction can be expected to come as from the LULUCF sector. An important point as to be made for the countries as assessed is if the LULUCF sector is expected to change from being a net source of emission, to become a net sink of emissions.

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Chapter 6. Uncertainty as to considered LULUCF development of the INDCs

The chapter will discuss and present uncertainty range of the assessed LULUCF emissions as of the BAU and INDC projections. Key uncertainties will described for key countries as to how their INDC has been produced and what assumptions have been made concerning the development of the LULUCF sector.

Aspects as to be considered are as follows:

- Which pools and sources of emissions/sink are considered by the country as of their INDC (e.g. are below ground biomass)? What is the implication as of if there are contrasting sources of emissions/sink as considered between the contractor and that of the country?
- What data sources have potentially been used for the production of the national INDC's and how do they contrast to other sources of data as publically available?

- How does changes in key assumptions affect the assessment of the LULUCF mitigation potential of the INDC (e.g. current forest carbon stock, deforestation rates, and carbon emission related to deforestation/afforestation emissions)?

An uncertainty range as the reduction of global land use emissions through the full implementation of submitted INDCs will be provided at the level of all the 95 countries as considered. Furthermore, brief explanation of key uncertainties and their potential impacts will be provided as for the 5 countries as found to have to have the largest uncertainties as to future emissions from the LULUCF sector.

Chapter 7. The potential to end the loss of natural forest by 2030.

Based on the data as collected within the project and the assessment of mitigation potentials, the chapter will discuss the likelihood of at least half the rate of loss of natural forests by 2020, and strive to end it by 2030. The analyse will take as starting point the BAU development as of Task 1 to assess the deforestation and afforestation rates as of 2020 and 2030. From there on, a discussion will be formed as from an overall carbon tax that would have to be implemented for the target to be reached as foretold by the MACCs. Further information as to the likelihood of reaching the goal will also be taken from the of the INDC specifications. A number of INDCs do explicitly mention the goal of reducing deforestation and this information will be brought in to further elaborate on the potential contribution as of individual countries.

Data Report

The data as prepared for the INDC report will be provided in an excel sheet as to DECC. The key elements that will be specified within the report are as follows:

- BAU and INDC LULUCF projections for the 95 Parties that explicitly state of their INDC that LULUCF is covered.
- Data will be provided for: 2020, 2025, and 2030.
- Tables clearly specifying the data as used for the definition of the BAU and INDC LULUCF projections.

4. Task 3: Non-CO2 emissions as of the agricultural sector

Updated data sources

Non-CO2 mitigation options for the agricultural sector have been implemented based on EPA (2006) data in GLOBIOM. Options include the impacts on GHGs (N_2O, CH_4), productivity, costs and adoption rates for the crop- and livestock sector and are taken directly from the EPA mitigation options database (EPA, 2006). For EU28 mitigation options have been compared and adjusted to a certain extent to GAINS data (Höglund-Isaksson et al., 2013). Furthermore, antibiotics and bovine somatotropin as a livestock sector mitigation option are not available in the EU (Dervilly-Pinel et al., 2014; Maron et al., 2013) due to current legislation.

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Emission reduction potential

Mitigation potentials in terms of % emission savings per head or ha are taken directly from the EPA mitigation options database (EPA, 2006). Looking at the technical potential of the different mitigation options inside EU28, especially anaerobic digesters offer big emission reduction potential (85% CH4 from manure management), followed by propionate precursors (15-30% CH4 from enteric fermentation), anti-methanogen vaccination (15% CH4 from enteric fermentation), improved breeding (8% from CH4 from enteric fermentation) and improved grassland management (3-13% from CH4 from enteric fermentation). In the crop sector, nitrogen inhibitor tend to reduce soil N2O emission by around 19-23% and improved fertilizer management through split application results in average emission decreases by 10-14%. Percentage emission savings for different mitigation options are multiplied with GLOBIOM production system specific (crop- or livestock sector) emissions to calculate absolute emission savings per management system in GLOBIOM. For anaerobic digesters, we only consider liquid manure from indoor housing being available, thus not considering manure dropped by ruminants directly on pasture. Moreover, we assume anaerobic digestion being available for all cattle, sheep and goats including replacement and fattening heifers. We also corrected for the time spent on the pasture for propionate precursors as this option require daily administration (Reference). However, we assume 1/3 of the emission saving effect for grazing ruminants due to breeding of malate enhanced pastures grasses (Höglund-Isaksson et al., 2013).

Mitigation costs

Costs for the non-CO2 mitigation options are also based on the mitigation options database from EPA (2006). Costs include annual costs of the different mitigation options (including direct costs and labour costs, change in input costs) and for certain options i.e. anaerobic digesters investment costs. Costs have been extracted in terms of $ per head or ha and do not include revenue changes for farmers due to productivity in- or decreases related to the application of a technology. These revenue changes are directly accounted for endogenously in GLOBIOM. Costs for propionate precursors have been corrected for the time animals spend on the pasture. In the EU28, improved grassland management (5-8 USD/head) and anti-methanogen vaccination (8-23 USD/head) rank among the cheaper options, while breeding (37-45 USD/head) and propionate precursors (35-95 USD/head) are considered more costly. For anaerobic digesters, costs are lower for digesters with engine due to energy savings (around 5-9 USD/head) and higher without engine (28-40 USD/head). Application of nitrogen inhibitors results in additional costs of around 20 USD/ha while

costs for improved fertilizer management through split application vary around 5-11 USD/ha. In our base year 2000, we calibrate initial adoption rate of anaerobic digesters to GAINS data (Höglund-Isaksson et al., 2013) inside Europe while we assume no dissemination of other options in our base year globally.

Technical maximum adoption rate

With respect to adoption rates of different options we defined mitigation exclusive mitigation option bundles for the crop- and livestock sectors. While for the crop sector we assumed that only one option can be applied per ha (full competition between the options), for the livestock sector we defined two bundles (the enteric fermentation options and manure management options) which can be both implemented at the same time. For Europe, we exclude antibiotics and bovine somatotropin as a livestock sector mitigation option (Dervilly-Pinel et al., 2014; Maron et al., 2013) due to current legislation. For anaerobic digesters, we limited the maximum adoption rates based on country specific GAINS adoption potentials (Höglund-Isaksson et al., 2013) which consider farm structure. Consequently, maximum adoption of anaerobic digesters is limited to around 47% of dairy cows, 41% of beef cattle and 48% of pigs in EU28 (thereby assuming farm structure not to change until 2030).

General approach as will be applied

Same as in Task 1

Baseline construction

The non-CO2 MACCs, computed with the aid of the GLOBIOM model, will be estimated using the same Baseline specifications as described in Task 1:

redacted

Technical mitigation potential (MAC curves)

Annual MACCs are to be provided based on the following construction and can be provided based on the following assumptions.

redacted

Sector and geographic coverage as of MACC

The data as provided will cover the following elements.

redacted

Data Report

The data a prepared within Task 3 will be provided in an excel sheet as to DECC. Accomondating the data, a report as of Task 3 will also be provided detailing key assumptions as of the approach selected and data being used. The key elements that will be specified within the report are as follows:

redacted

5. Project team

The proposed project team consists of experts on land use modelling, LULUCF, INDCs, and emissions. The team has extensive experience of conducting impact assessments, economic analyses, modeling, and scenario building in the fields of land use, forestry, and agriculture. The project team bring the necessary depth and breadth of skills to meet the requirements of the different study tasks as well as additional expertise in related sectors and policy areas.

Overall, the team combines the key experts, in Europe and globally, on low carbon development strategies in the land use sector, mitigation potentials, forestry, land use, and land use change. It therefore provides a unique set of qualities that will enable the delivery of high quality outputs:

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Team experts

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6. Ownership of data

The data as will be produced within the framework of this project is commercial and will only be provided to DECC in confidence. As such, the data as provided by the contractor to DECC should in turn not be made publically available nor provided to any second hand party. Final MACCs can in agreement between DECC and the contractor be made public if grouped together at a global level for agreed carbon steps.

The internal report and final reports as to be submitted should be seen as internal documents only for DECC and not circulated unless agreed upon in written form with the contractor.

The contractor also retains that outputs, raw data and tools developed in the research can still be used by the contractors for purposes other than the work for DECC.

7. Timetable of work

The project duration is 10 months from the signing of the contract, with an expected contract starting date as of 03 December 2015 and expected duration of the project until 17 March 2016. The table below provides a basic overview of the planned timetable of activities

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8. Quality Assurance plan

In line with the DECC Code of Practice for Research Michael Obersteiner will assume full responsibility of QA in this project. Based on the consultation on QA matters with DECC he will produce a QA report covering in detail the two QA focus areas of MAC curves and Historical data documenting the decisions made on data used and assumptions made and their technical implementation in the models. The two models G4M and GLOBIOM to be use in this project have been quality assured and documented in previous contracts and the scientific quality has been also documented through numerous academic journal articles. Thus, the QA measures in this project will mainly focus on the modelling related activities as described in the DECC QA Guidance document for models Version 2.

Quality assurance of model outputs will involve all areas of the DECC QA guidance for models Version2. In particular, we will focus on QA to two areas mainly related to the QA areas of "Assumptions" and "Data":

MAC curves:
GLOBIOM and G4M can, depending on model specification, exhibit negative MACC price points or points where abatement decreases for an additional price point ("backwards bending curves"). If such results occur in the production of the MACC curves we will produce a small report to DECC describing the modelling logic explaining this phenomena. We will also provide recommendation if smoothing would be a viable options to produce classical MAC curves or alternatively if such discontinuities should be maintained by producing conditional MAC schedules. If conditional MAC schedules appear as the mode of choice we will make a technical proposal on how to construct such conditional MACs.

Historical data:
By first principle and for reasons of overall consistency we will base the production of MAC curves on FAO and in particular for the forest sector FRA2015 data. However, for a number on countries it will be recommendable to use alternative sources of information as FAO data relies on self-reporting of countries, which not always fully reflects realities on the ground. We will analyse alternative sources of mostly land cover/ forest cover data, but also review again other input data such as land use, production and trade data. These data issues will be discussed before a decision is made on which data the models will be calibrated to. DECC will supply a calibration spreadsheet containing FRA data for the contractor to populate. We will subsequently populate the spreadsheet and show differences between the different sets of data and provide a rational for the decision which data will finally be used based on scientific criteria and evidence. Furthermore, we will consult with DECC and jointly agree how close calibration to FAO/FRA data needs to be and what level of difference needs an explanation entered into the calibration spreadsheet. The explanation will be made in view of the impact of the assumptions on the quality of MACC information. In addition, we will communicate to DECC all relevant information and recommendation on what actions DECC might want to take in handling the output data from this project.

A more detailed QA plan will be discussed at the beginning of the project including delivery dates. Finally, a QA log will be filled in at project completion to demonstrate the QA undertaken covering shortly all QA areas according to the guidance document and in more detail for the two focus areas.

9. Budget

The following budget is proposed for the contracting party as for the Tender. The time allocation of the various expters within the team has has been prepared in consideration as to the budget of the various task as in the Tender specification.

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Total cost including travel is £79,114 (excluding VAT)

References

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Annex I – Detailed model description

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