CARBON PERFORMANCE OF PEAT POWER PLANTS IN RWANDA

November, 5 2014

Carbon Footprint of Peat Fire Power Plant Compared with Diesel Generated Electricity

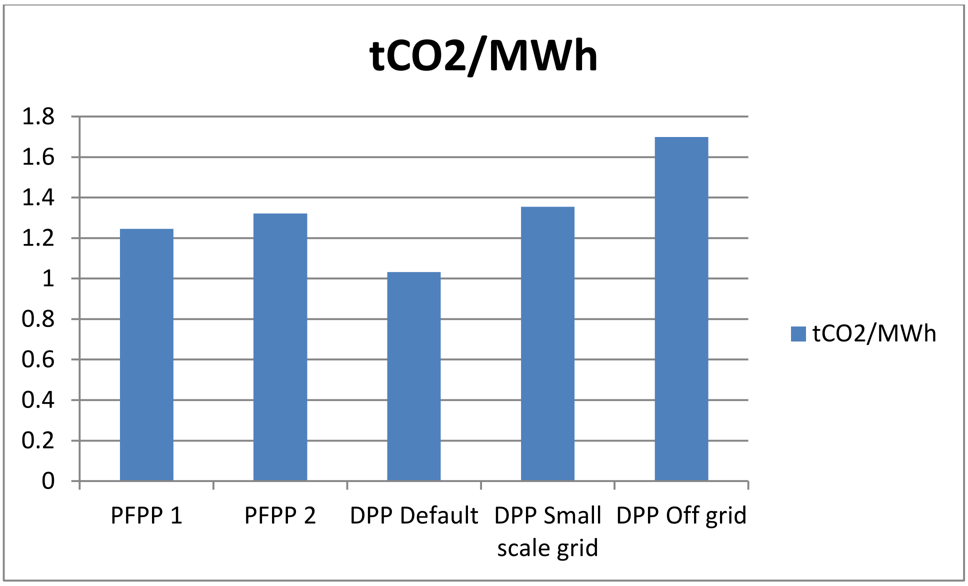
DRAFT FINAL REPORT

16:35

EXECUTIVE SUMMARY

This report provides a comparison between emissions from a peat fired plant and three diesel plant scenarios when producing 1MWh electricity. The emissions related to the peat land, whether it is untouched, cultivated or harvested vary to a large extent. Rewetting the harvested peat land will mitigate emissions significantly. The scenarios for the peat land is (i) end use cycle and (ii) fuel cycle, and the scenarios for diesel plants contain the scenarios: (i) default diesel plant; (ii) off-grid, stand alone and micro grid connected diesels; and (iii) standardized baseline (CDM) developed by UNDP for a group of African countries.

The figure summarizes the emissions in tonnes CO_2 per MWh, showing the Peat Fired Power Plant (PFPP) scenarios 1 and 2, and the three diesel power plant (DPP) scenarios.



The results indicate that peat-fired power plants perform similar to diesel generators in terms of emission per unit produced MWh in the case the diesel generators are grid connected with 100% load factors (diesel scenario 2) and can outperform diesel generators in the case the peat generators replace inefficient stand-alone connected diesel generators with limited load factors (diesel scenario 3). CDM stands for Clean Development Mechanism, for which methodologies with emission factors are developed for different project types. The existing grid connected diesel power plants in Rwanda would in their performance lie close to diesel scenario 1.

A brief country analysis show that the installed capacity in Rwanda is very limited, as is the current level of electrification. The development of peat fired power plants should be understood as part of the Rwandan government to engage the private sector, to increase the amount of installed capacity, and to provide a basis for an ambitious rural electrification program.

Content

INTRODUCTION

USING PEAT FOR ELECTRICITY GENERATION

Peat lands cover an estimated area of 400 million ha, equivalent to 3% of the Earth's land surface. Most (c. 350 million ha) are in the northern hemisphere, covering large areas in North America, Russia and Europe. Tropical peat lands occur in mainland East Asia, Southeast Asia, the Caribbean and Central America, South America and southern Africa where the current estimate of undisturbed peat land is 30-45 million ha or 10-12% of the global peat land resource. It can be argued that the maintenance of large stores of C in undisturbed peat lands should be a priority for climate change reasons. However, peat is a valuable source for horticultural purposes and for energy, i.e. electricity and/or heat generation.

Extracting peat and using the peat for electricity production will release greenhouse gases to the atmosphere and the sink (CO_2 uptake) effect of the peat land will disappear. Nevertheless, extracting peat and use it as fuel for electricity supply can be motivated if the social and economic benefits are high, if the carbon footprint is reasonable and not at least if it constitutes a reliable source of energy in countries with an energy (electricity) deficit.

In developing countries, and in particular in Africa, where diesel generators (off grid) is a main source of electricity, peat fired power plants may turn out to be a promising and competitive alternative. In addition, as part of the energy policy in Rwanda, peat is one of the sources that are expected to replace the use of wood (which would reduce deforestation and the burning of non-renewable biomass)[1]. The climate impact by peat extraction can be mitigated by rewetting the peat land.

ENERGY IN RWANDA: POLICIES AND INSTITUTIONS

Rwanda is a small country located at the heart of the African continent and one of the most densely populated countries in Africa. Roughly 90 % of the population are engaged in agriculture, mainly subsistence farming, the main export goods are tea and coffee.[2] Rwanda has a made remarkable recovery since the 1994 genocide and the government has worked efficiently together with different donor countries and multilateral finance institutions in order to improve living conditions in Rwanda.

There are three main structural conditions that may hamper economic growth in Rwanda[3]: (i) the private sector plays so far a very limited role for investments; (ii) the physical infrastructure is still inadequate, and (iii); limited institutional and technical capacity. These structural constraints are also key concerns for the government in relation to the power sector. Thus, the encouragement of greater private participation in the energy sector was a key element in the government's 2009 draft energy policy.

The 2009 draft energy policy paper outlined strategic directions to be further developed and approved by the government[4]:

(i) Development of domestic energy resources
(ii) Efficient use of energy
(iii) Energy pricing and subsidy
(iv) Institutional development of the energy sector

[1] National adaptation programmes of action to climate change. NAPA-Rwanda. (2006) Ministry of Lands, Environment, Forestry, Water and Mines
[2] Bensch, Kluve and Peters (2010), Rural Electrification in Rwanda - An Impact Assessment Using Matching Techniques, Ruhr Economic Papers no. 231, page 7
[3] African Development Bank (2013) Rwanda Energy Sector Review and Action Plan, p. 19
[4] African Development Bank (2013) Rwanda Energy Sector Review and Action Plan, p.21

(v) Capacity building

The Ministry of Infrastructure (MININFRA) has the primary responsibility for energy policy and strategy which includes responsibility for developing renewable and domestic energy sources such as methane, peat, geothermal, solar and wind energy. Since resources are widespread over the country, collaboration takes place between MININFRA, the Ministry of Local Government (MINALOC) and local governments. The Ministry of Natural Resources (MINIRENA) is responsible for policies relating to the use of biomass (wood fuel, charcoal, energy from solid waste landfills etc) together with the Ministry of Agriculture and Animal Resources (MINAGRI). The Energy and Water and Sanitation Authority (EWSA) is responsible for generation, transmission and distribution as well as retailing. EWSA plans to purchase electricity from large generation projects planned for development by the private sector[5]. Power production, transmission, distribution and trading are governed by the law N° 21/2011[6].

ENERGY IN RWANDA: CURRENT SITUATION

Rwanda's power supply in 2012 was based on about 100 MW of installed capacity (of which 64.5 MW of hydropower) and 93 MW of available capacity. The energy resource base in Rwanda could provide about 1500 MW of installed capacity. At the end of 2012, installed capacity was expected to amount to 132 MW, of which 48 is domestic hydro, 15.5 regional hydro, 29.2 methane power, 37.8 thermal plans, and 0.25 solar power.[7]

The per capita electricity consumption (42kWh) is one of the lowest in the world, compared to e.g. 478 kWh in sub-Saharan Africa and 1,200 kWh for developing countries as a whole, and concentrated in the main cities.[8]

The Electricity Master Plan (EMP) includes a revised demand forecast reflecting the goals of a new Electricity Development Strategy (2011-2017) for the country, which predicts the development of 1,000 MW of generation capacity by 2017 as compared the 300 MW planned according to the EDPRS I (Economic Development and Poverty Reduction Strategy) and Vision 2020[9].

The plan would have an estimated investment cost of at least $500 million/year of which about $200 million/year is designated to be undertaken by the public sector and the rest by the private sector.[10]

ELECTRIFICATION PROGRAMS

The framework for development policies in Rwanda was set by the Economic Development and Poverty Reduction Strategy (EDPRS) that in its previous phase covered the period 2008-2013. The EDPRS contains the program Vision 2020 which entails a plan for rural development. In order to realize the objectives of EDPRS and Vision 2020 the new government approved in 2010 a strategic investment program that contain six projects, of which the electricity roll-out program was one. This program set out to increase household grid

[5] African Development Bank (2013) Rwanda Energy Sector Review and Action Plan, p. 25
[6] http://www.mininfra.gov.rw/uploads/media/Electricity_Law.pdf
[7] African Development Bank (2013) Rwanda Energy Sector Review and Action Plan, p. 36
[8] African Development Bank (2013) Rwanda Energy Sector Review and Action Plan, p. 31
[9] African Development Bank (2013) Rwanda Energy Sector Review and Action Plan, p. 32
[10] African Development Bank (2013) Rwanda Energy Sector Review and Action Plan, p. 8

connections from 6 % in 2008 to 50% by 2017, a figure that was raised to 70% by the Leadership Forum 2012[11]. The previous Electricity Access Roll out Program, financed predominantly by the World Bank and the Netherlands, had the objective to attain a national electrification rate of 16 % by 2012.

The aggressive program to increase the access to the electricity shows an increase of 160% during the period 2008 and 2011 however 84% of the household still lack connection to the grid. The revised electrification plan includes the national target of increasing electricity access to 70% by 2017. [1]

AIM OF STUDY

Sweco as Owner's Engineer for Hakan Mining and Electricity Generation Inc. has been asked to perform a study that compares the carbon footprint of the peat fired power plant per MWh generated taking into account the extraction of peat and the power generation process with the carbon footprint of power generation per MWh using diesel as a fuel (or any other fossil substitute to peat, which would be used in case the peat fired power plant would not be constructed).

It should be taken into account that the diesel generators in Rwanda are not of latest technology, hence, they might be inefficient in fuel consumption and with emissions; and Transportation of diesel should also be taken into account.

Key points from the introductory section relating to the carbon footprint comparison between peat and diesel is (i) the limited installed capacity for electricity power generation and (ii); the limited level of rural electrification.

[11] African Development Bank (2013) Rwanda Energy Sector Review and Action Plan, p. 8

METHODOLOGY AND DATA COLLECTION

INTRODUCTION

Data and data quality

This study has been carried following the principles of the ISO standard for carbon foot print of products[12]. Which type of data that is available will have an impact on the accuracy of the estimation of the carbon footprint. The ISO 14067 standard refers to:

Primary data which is quantified value of a unit processes or an activity obtained from a direct measurement or a calculation based on direct measurements at its original source

Site-specific data which is data obtained from a direct measurement or a calculation based on direct measurement at its original source within the product system

Secondary data which is data obtained from sources other than a direct measurement or a calculation based on direct measurements at the original source

For this study, data sources mainly consist of official data but also contain data specific to the site. This implies that a Tier 1 method mainly has been applied but with the use of Tier 2 method when data and emission factors have been available.

Introduction to the three Tier levels

The Tier 1 method is fuel-based, since emissions from all sources of combustion can be estimated on the basis of the quantities of fuel combusted (usually from national energy statistics) and average emission factors. Tier 1 emission factors are available for all relevant direct greenhouse gases. The quality of these emission factors differs between gases. For CO2, emission factors mainly depend upon the carbon content of the fuel. Combustion conditions (combustion efficiency, carbon retained in slag and ashes etc.) are relatively unimportant. Therefore, CO2 emissions can be estimated fairly accurately based on the total amount of fuels combusted and the averaged carbon content of the fuels. However, emission factors for methane and nitrous oxide depend on the combustion technology and operating conditions and vary significantly, both between individual combustion installations and over time. Due to this variability, use of averaged emission factors for these gases that must account for a large variability in technological conditions will introduce relatively large uncertainties.

In the Tier 2 method for energy, emissions from combustion are estimated from similar fuel statistics, as used in the Tier 1 method, but country-specific emission factors are used in place of the Tier 1 defaults. Since available country specific emission factors might differ for different specific fuels, combustion technologies or even individual plants, activity data could be further disaggregated to properly reflect such disaggregated sources. If these country-specific emission factors indeed are derived from detailed data on carbon contents in different batches of fuels used or from more detailed information on the combustion technologies applied in the country, the uncertainties of the estimate should decrease.

In the Tier 3 methods for energy either detailed emission models or measurements and data at individual plant level are used where appropriate. Properly applied, these models and measurements should provide better estimates primarily for non-CO2 greenhouse gases, though at the cost of more detailed information and effort. When considering using measurement data, it is good practice to assess representativeness of the sample and suitability of measurement method. The best measurement methods are those that have been developed by official standards organisations and field-tested to determine their operational characteristics.

[12] Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication (ISO/TS 14067:2013, IDT)

In the case where emissions factors are presented as intervals, the medium value has been used.

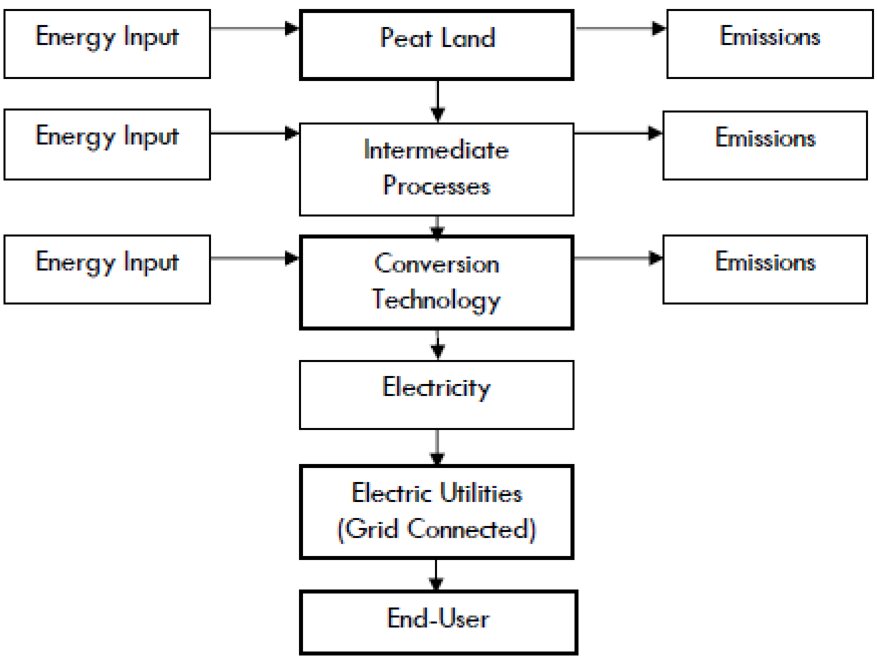
METHODOLOGY

Systems boundary and reference output

In a comparative study it is important to carefully select and define a reference output. In this case, 1 MWh of electricity will be used in all comparisons. In comparative studies it is also important to select and utilise the same system boundaries[13]. The analyses performed for this study includes the entire energy system, from the natural resource to the delivered reference entity, i.e. 1 MWh of electricity.

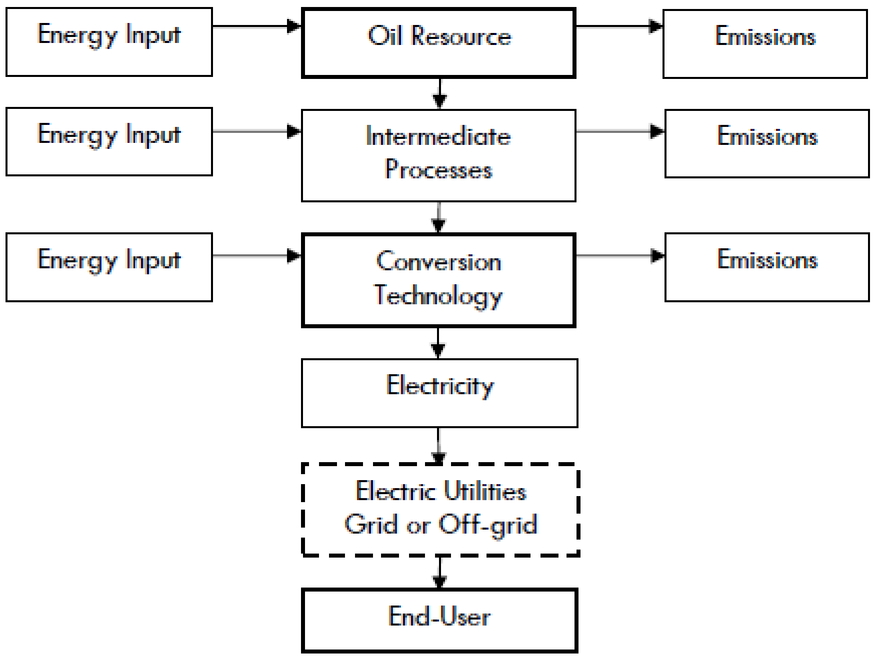
Both peat-based electricity generation and diesel-based electricity systems boundaries are defined as in Figure 1 and Figure 2.

Figure 1: Systems boundary of peat-based electricity generation



[13] ISO (1997) Environmental Management – Life Cycle Assessment – Principles and Framework; Schlamadinger et al (1997) Towards a standard methodology for greenhouse gas balances of bioenergy systems in comparison with fossil energy systems, Biomass and Bioenergy, 13 (6) 359-375

Figure 2: Systems boundary of diesel-based electricity systems.



The energy contained in the materials and incorporated into the construction of the facilities (e.g. in power plant buildings, cables for the electricity network and the production of trucks) has not been included. The energy embodied in a conversion plant is very small compared with the energy content of the fuels used during its lifetime, hence this has been excluded. The input energy required for, and emissions from, ash recirculation was not considered but is expected to be very low from peat combustion, hence this was also excluded.

Energy required and emissions from producing of reference output:

At each stage of the energy chain, the emission of CO_2 (and CH_4) and the energy input required for these stages were estimated when the reference entity was produced by the systems. The energy loss, energy input and energy efficiency of each stage were taken into consideration, which gives the total primary energy use of a system. The total emission of a system was calculated by adding together the emissions of all the processes in the system. CO_2 and CH_4 were expressed as CO_2 equivalents, assuming that 1 kg of emitted CH_4 is equivalent to 23 kg C relative to the global warming potential (GWP) of CO_2 over 100 years.

Scenario analysis and assumptions:

The following scenarios have been assessed for the reference output of producing 1 MWh of electricity.

Scenarios	Treatment of peat	Remarks
Electricity generation from grid-connected diesel power plant	peat is untouched	Baseline emission from peat is accounted
Electricity generation from off-grid diesel power plant	peat is untouched	Baseline emission from peat is accounted
Electricity generation from peat-based grid connected power plant	peat is harvested	Emission from peat harvesting is accounted, no baseline emission from peat

In the scenario analysis, full-cycle CO_2 emissions are compared for diesel-based electricity generation (off-grid and grid-connected) and peat-based grid connected power plants. In the scenario analysis, if diesel-based power plants are implemented, baseline emissions from peat land will continue.

Also when comparing reference output from peat-fired and diesel-based electricity both plants shall supply same amount of electricity. For example, capacity of peat-fired plant is 70 MW. Installed capacity of diesel should also be 70 MW in order to compare emissions from same reference unit.

Calculation

A spread-sheet based calculation tool has been developed. Each process of the peat and diesel energy systems has been considered when estimating energy requirements and emissions from the relevant process.

The following scenarios were developed for the peat-fired power plant (PFPP) system:

- PFPP (43.9 tonne/hour feed, calorific value based on 42% H20 in peat) (end-use)
- PFPP (43.9 tonne/hour feed, calorific value based on 42% H2O in peat) (fuel-cycle)

In end-use conversion, emissions emitted from the combustion process were calculated. In the fuel-cycle option, a full fuel supply-chain process has been considered. For PFPP, the following processes in peat supply-chain were considered:

- Peatland (untouched)
- Peatland – cultivated
- Peatland – harvested (assuming peat drying is combined with peat harvesting before reaching at plant gate, only drainage is assumed)
- Production/harvesting of peat
- Transportation/distribution of peat
- Stockpiles of peat

For diesel-based electricity systems (Diesel Power Plant – DPP), both end-use emissions and fuel-cycle emissions have been considered. For DPP following processes, network option (grid) and load factor have been considered:

Processes in diesel supply-chain:

- Upstream emissions (production of diesel)
- Transportation/distribution
- Storage

Network options:

- DPP-Non-Grid (CDM) – off-grid (not connected to grid or stand-alone)
- DPP-Grid (CDM) – on-grid (grid connected)
- DPP – Off-grid (CDM Standardized Baseline)

Load-factors:

- Mini grid (with 24 hour, 25% load factor)
- Productive applications (50% load factor)
- Mini grid (100% load factor)

Data and assumptions:

It is assumed that if diesel-based power plants are implemented, baseline emissions from peat land will continue. Hence, emissions from peat land 'untouched' will be added if electricity requirement (70 MW) is to be met by diesel in absence of PFPP.

Power plant:
- 70 MW peat fired plant (Sweco)
Efficiency 31.2% (Sweco)
Yearly operating hours = 8000 (assuming low maintenance based on higher measures)

Amount of peat:

Amount of peat required.

- 43.9 tonne per hour of peat feed (Sweco)

Net Calorific Value (NCV) 9.2 MJ/kg (based on 42% H_2O in peat) (Sweco Report)

Peat land:

The power plants will use local peat from areas that have more than ten meters depth. Considered peat bogs are: HL-A, HL-B, IL-A and IL-B bogs (see Annex IV); i.e. those bogs that shall be opened during the first ten years of the project.

Following emissions factors have been sourced from literature:

Scenarios	Emissions Factor	Remarks
Peat land untouched	Present net C uptake may be in the range of 500 g C m-2 yr-1 (~1800 g CO2 m-2 yr-1). Temporal studies of peatlands reveal that they may act as CO2 sinks in some years and sources in others, depending on climate.	Strack (2008)
Peat land cultivated	20.0 ± 90% tonne CO2-C per ha and year, best estimate 8 -13.5	Tropical peat land, source Cauwenberg (2009)
Peat land harvested	21 ton/a 2.0 (0.06-7.0) per ha and year, best estimate 8	UNFCCC fact book Cauwenberg (2009)

To be conservative the upper ends of the emission factors have been used.

Emission from peatland (if untouched) = 1800 g CO_2/m2 year = 0.0018 tonne CO_2/m2 year

Peat land harvested = 13.5 tonnes CO_2 per ha = 0.00135 tonne CO_2 per m2

Peat land harvested = 8 tonnes CO_2 per ha = 0.0008 tones CO_2 per m2

Emissions from Peat:

- Peat area (depth more than ten meters) per peat bogs (surface area by hectares) (source: Sweco)
- Emissions from peat land: the IPCC emission factors for tropical peat land vary largely. The consideration of cultivated peat land has been applied since there is some farming going on the peat bogs (Cauwenberg 2009). Factors: emissions from harvested peat land, ditching and

harvesting (source: IVL, Sweden). The table below contains figures from Nordic settings, machinery figures (new methods) may apply in Rwanda case.

Table 1. Emission factors for peat extraction

Oxidation from milled peat harvested land	400 -1020 g CO_2 m2 yr -1		
Emissions from ditching	0.4 - 4.5 g CH_4 m2 yr -1		
N_2O emissions	06 - 0.5 g N_2O m2 yr-1		
Stock piles	250 +/- 125 g CO_2m-2 yr-1		
Stock piles	19.5 g CH_4 m2 yr-1		
Machinery old method / MJ peat	1g CO_2	0.7 mg CH_4	0.025 mg N_2O
New method/MJ peat	0.5 g CO_2	0.35 mg CH_4	0.012 mg N_2O

Emission from peat extration was assumed to be 0.5 gCO_2/MJ peat based on new method.

Transportation of peat:

The peat is dried on the peat bogs, initially transported appr. 1 km and later from longer distances: up to 3 km.

The dried peat (42% H_2O) will be transported by tractors pulling wagons with 50 ton peat on each occasion. Truck data are sourced from a report by IVL, Sweden, it has been assumed that they are applicable in situation of Rwanda.

Leakage:
No leakage emissions (for example due to fire) have been considered.

Power plant:

- 70 MW (2X35 MW) peat fired plant (Sweco)
- Efficiency 31.2% (Sweco)
- Yearly operating hours = 8000 (assuming low maintenance based on higher measures)

Diesel:

It is assumed that not all electricity demand will be met by diesel as some area will be difficult to connect with national grid. Electrification program will replace fire wood and maybe kerosene, but if not getting access to the grid, the likely baseline would be small scale diesel generators.

Net Calorific Value (NCV) of diesel: 43 TJ/Gg (IPCC)

Diesel Power Plant Efficiency = 42.3 % (Wartsila 2012)

Diesel power plant information (power plant capacity, emission factors) was sourced from:

- Approved CDM methodologies: AMS[14]-I.F, AMS-I.A, AMS-I.L., and CDM Standardised Baseline (all information are available via UNFCCC CDM Portal)

[14] Approved Small Scale Methodology

- Emissions factors close to 0.7. The DNA in Rwanda will soon release its GEF (Grid Emission Factor) and it will be around 0.7 including 10% off grid
- Emissions from diesel fuel-chain:
    - It is assumed that diesel is likely to be imported from UAE to refineries in Tanzania and Kenya and then transported by truck.
    - An emission factor for truck transport 0.297 kg CO_2 per tonne-mile has been used
    - Driving distance from Dar-es-Salaam to Kigali is 1764 km, trucks going empty back means 3528 km, several oil storage sites are located around Kigali. Assuming large tank trucks can take up to 35 000 litres (source: DAF truck brochure)
    - Sea Transport: 5 grams of CO2 emissions per tonne-km of transport for oil tanker (Cristea et al 2013) has been used
    - Sea distance from Abu Dhabi port to Dar-es-Salaam port is 5273 km (according to a sea logistics web page), hence 26,365 grams of CO2 for freighting one tonne crude oil from UAE to Tanzania (assuming oil tankers go empty back).

Diesel Scenarios

The three diesel scenarios are based on CDM methodologies since data on off grid and micro grid connected diesels in Rwanda is not (publicly) available. The first scenario uses a default value (IPCC) as emission factor (0.8) which is the value used for diesel generators above the size of 200 kW. This value should also be close to the relatively large grid connected diesel generators currently installed in Rwanda. The second scenario uses the emission factors included in the small scale methodology AMS-I.F which suggests different values for different sizes of diesel plants and for different load factors. The factors vary between 1.2 to 2.4 for small-scale generators and the value reflecting 100% load factor was applied in scenario 2. The third scenario contains the emission factor developed as part of a standardized baseline, the emission factors employed is 1.7. (see Annex I for details)

RESULTS

CARBON FOOTPRINT FROM PEAT FIRED POWER PLANT

Figure 1 shows the result of applying the peat fired power plant scenario but two calculation based on only end-use emission and fuel-cycle emission.

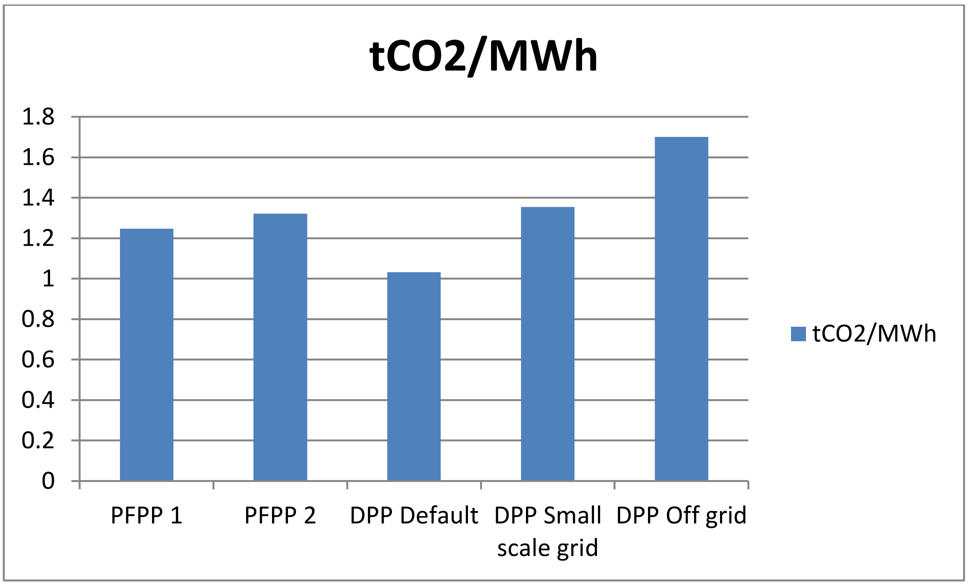
1. PFPP (43.9 tonne/hour feed, calorific value based on 42% H20 in peat) (end-use)
2. PFPP (43.9 tonne/hour feed, calorific value based on 42% H2O in peat) (fuel-cycle)

Three main scenarios were used for the diesel generated electricity

1. DPP-Default (CDM) – default value for DPP over 200 kW
2. DPP- Small Scale Grid (CDM) – small scale grid connected
3. DPP – Off-grid (CDM Standard Baseline)

For an introduction of CDM approaches to emission factors for diesels see Annex I. (The third scenario for diesel does not contain upstream and downstream emissions.)

Figure 3. Results of Comparison



The results indicate that peat-fired power plants perform similar to diesel generators in terms of emission per unit produced MWh in the case the diesel generators are grid connected with 100% load factors (diesel scenario 2) and can outperform diesel generators in the case the peat generators replace inefficient stand-alone connected diesel generators with limited load factors (diesel scenario 3). CDM stands for Clean Development Mechanism, for which methodologies with emission factors are developed for different project types (see above and Annex I). In the diesel scenarios, emissions from peat land (untouched) will also continue. In this scenario, cumulative emissions would be higher taking into account emissions from peat land (untouched) as calculated about 3363 tonnes CO2 per year.

BACKGROUND INFORMATION

ANNEX I EMISSION FACTORS FOR OFF GRID AND MICRO GRID CONNECTED DIESEL POWER PLANTS

Work has been done e.g. by UNDP to prepare for the development of standardized baselines in Sub Saharan Countries[15] (. The report states that the standardized baseline will probably be most applied in projects that use CDM methodologies AMS-I.A. and AMS-I.L. The applicability of these methodologies includes the introduction of renewable electricity to households, Small and Medium Enterprises (SMEs) and small communities that lack access to power or only have access to small-scale fossil fuel-based power generation. Even though these methodologies concern the introduction of renewable energy, the interesting part is the baseline emissions.

Generation of electricity with small diesel generators is presumably the default off-grid electricity generation option in most countries in sub-Saharan Africa. For the six countries selected for the development of a grouped standardized baseline in the UNDP study, the assumed baseline technology is an inefficient diesel generator with a low energy conversion coefficient and a Load Factor of 25% or even lower. Making use of the calculation approach in the CDM guidelines[16] for preparing a standardized baseline, gives a baseline emission factor of around 1.7 tCO2 / MWh.

The report states that baseline emissions are calculated as power consumption multiplied with an emission factor for which the default value of 0.8 tCO2e / MWh may be used. However, in relation to the development of small scale CDM-projects, the proponent may, with adequate justification use a higher emissions factor from Table I.F.1 (see table 2 below) under the category AMS-I.F “Renewable electricity generation for captive use and mini-grid”[17].

Table 2. Emission factors for diesel generator systems (in kg CO_2e/kWh) for different levels of load factors

Cases:	Mini-grid with 24 hour service	(i) Mini-grid with temporary service (4-6 hr/day); (ii) Productive applications; (iii) Water pumps	Mini-grid with storage
Load factors [%]	25%	50%	100%
<15 kW	2.4	1.4	1.2
>=15 <35 kW	1.9	1.3	1.1
>=35 <135 kW	1.3	1.0	1.0
>=135<200 kW	0.9	0.8	0.8
> 200 kW***	0.8	0.8	0.8

*A conversion factor of 3.2 kg CO_2 per kg of diesel has been used (following revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories)

**Values derived from figures reported in RETScreen International’s PV 2000 model retrieved from: <http://retscreen.net/>

***Default values

[15] UNDP (2013) Standardized Baseline Assessment for Rural Off-Grid-Electrification in Sub-Saharan Africa

[16] https://cdm.unfccc.int/Reference/Guidclarif/meth/meth_guid42.pdf

[17] https://cdm.unfccc.int/methodologies/DB/9V3T8W0N5PMCJH4YVEA04YYFTVHP3Q

Using the default value of 0,8 is allowed and conservative, but not necessarily very realistic. Since the default value of the emission factor is set to 0.8. A study in Nigeria suggests that only large diesel generators may approach numbers close to 0.6 while the smallest typically have values of more than the double[18].

Following the work done under the frame of the CDM (and IPCC), the low case scenario for diesel generators should be 0.8 and there is strong reasons to believe that the emission factor reflecting the current practice in Rwanda is higher. The question here is if the emission factor for diesel reflects an alternative containing modern large scale diesel generators or the emission factor should reflect the current situation in Rwanda.

Table 3. Off-grid electrification baseline scenarios for small scale CDM methodologies

<table>
<tr><th>Methodology</th><th>Baseline emission factor</th></tr>
<tr><td>AMS-I.A.</td><td>• The default baseline emission factor can be set at: 0.8 tCO_2/MWh or
• An alternative is the use of conservative factors from Table I.F.1 "Emission Factors for diesel generator systems" under AMS-I.F.[11], where factors range from 0.8 to 2.4 tCO_2/MWh (for off-grid mini-grids), depending on the load factor and whether there is storage capacity.
• Another alternative is applying the approach from scenario B of the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption". This approach calculates the emission factor based on the actual power production and fuel consumption.</td></tr>
<tr><td>AMS-I.L.</td><td>This methodology applies default baseline emission factors based on the amount of electricity consumed per year.
<table><tr><th>Tranche of power consumption</th><th>Baseline emission factor</th></tr><tr><td>Below 55kWh/year</td><td>6.8 tCO_2/MWh[13]</td></tr><tr><td>Between 55-250kWh/year</td><td>1.3 tCO_2/MWh</td></tr><tr><td>Above 250kWh/year</td><td>1.0 tCO_2/MWh</td></tr></table></td></tr>
<tr><td>Standardized baseline</td><td>Most the diesel generators in sub-Saharan Africa are inefficient and have a Load Factor of 25% or even lower. This gives a baseline emission factor of around 1.7 tCO^2/MWh.[13] (Please note that this calculation is based on a stand-alone diesel generator, mini-grid systems from Table I.F.1 under AMS-I.F. may yield higher emission factors)</td></tr>
</table>

[18] http://www.cgdev.org/blog/how-can-nigeria-cut-co2-emissions-63-build-more-power-plants

ANNEX II EMISSIONS FROM PEAT BOGS

Carbon flux in peat lands

Peat lands represent a major store of soil carbon, sink for carbon dioxide and source of atmospheric methane. Nitrous oxide (N2O) emissions are generally low from natural peat lands but those used for agriculture could be releasing significant amounts of nitrous oxide.

The greenhouse gas (GHG) balance of a peat land depends on relative rates of net CO2 uptake or efflux and methane (CH4) and N2O efflux. Temporal studies of peat lands reveal that they may act as CO2 sinks in some years and sources in others, depending on climate. Emissions of CH4 and N2O are similarly variable in space and time.

When considering the role of peat lands in atmospheric GHG balances, it is important to consider that they have taken up and released GHGs continuously since their formation and thus their influence must be modelled over time. When this is considered, the effect of sequestering CO2 in peat outweighs CH4 emissions.

Overall, methane emissions from tropical peat land are very low irrespective of whether it is natural peat swamp forest or drained and degraded or used for agriculture. N2O emissions from natural tropical peat lands are low but evidence is emerging that suggests that these increase following land use change and fire.

Farming on peat bogs

Appropriate water management is important in order to minimise GHG emissions from agriculture on peat lands. Increasing the water table decreases emissions of CO_2 (by up to 20%) and N_2O, but may increase emissions of CH_4.

The loss of water from the upper peat by drainage, followed by oxidation, leads to compaction and subsidence of the surface. Drainage of peat increases the emissions of CO_2 and N_2O but decreases the emission of CH_4. Emission rates depend on peat temperature, groundwater level and moisture content.

Extraction of peat

Agriculture, forestry and peat extraction for fuel and horticultural use are the major causes of peat land disturbance. As these land-use changes require alteration of peat land hydrology, peat oxidation results and the greenhouse gas balance of the peat land is altered.

In the process of peat extraction, the GHG sink function of the peat land is lost. Emissions also arise in the preparation of the surface for cutting (removing vegetation and ditching), extraction of peat and its storage and transportation and after-treatment of the cutaway area.

Peat land emissions

The planned project will obviously change the GHG balance of the peat lands. The change will depend on whether the baseline is use of the peat land for crops or if it is uncultivated natural land. The second issue is what emissions factors should be used for the estimation of the baseline peat emissions.

The estimation of GHG fluxes in the AFOLU[19] sector can be done in two ways according to the IPCC guidelines (2006).

1) as net changes in C stocks over time (used for most CO_2 fluxes) and

2) directly as gas flux rates to and from the atmosphere (used for estimating non-CO2 emissions and some CO_2 emissions and removals). For non-organic (mineral) soils the IPCC (2006) Guidelines suggest C stock estimates to be carried out for the upper 30 cm only (Tier 1 & 2). In organic (peat) soils, the soil layer

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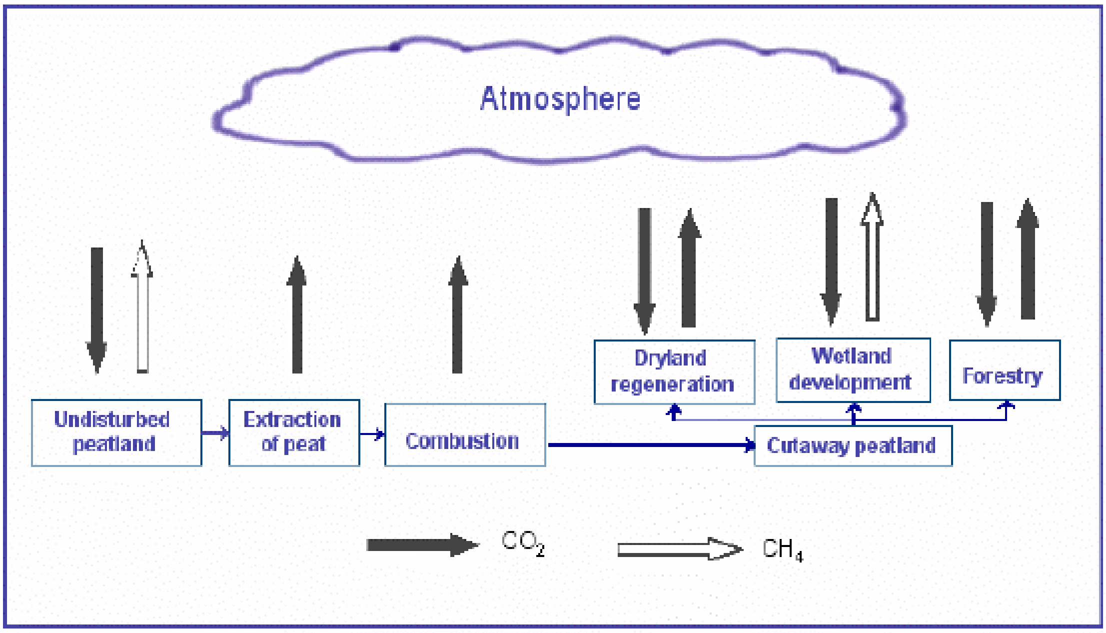
becomes thinner when degrading, because organic material constitutes a major and often dominant component of the soil. This means that a stock approach should take the entire depth of the organic soil layer into account and cannot limit itself to the upper 30 cm. Such total stock estimates are complex and the IPCC (2006) Guidelines use estimates based on flux data also for CO_2 emissions. Measuring gas fluxes from organic (peat) soils can be difficult and reliable measurements are rare.

On-site emissions comprise emissions from the area under extraction itself as well as from peat decomposition in stockpiles. The IPCC (2006) Guidelines provide estimated emission factors derived from flux measurements in boreal peatlands not necessarily under extraction and there are studies covering emission factors for peat mining areas as well as for stockpiles, covering not only CO_2, but also CH_4 and N_2O emissions. Best estimates for CO_2 emissions related to peat extraction lie far above the IPCC (2006) default values. Direct measurements from temperate or tropical peat extraction areas are lacking, but emissions likely surpass those from boreal sites.

Figure 4. Carbon Flux of Peat to Energy[20]



The estimations of emissions from peat emissions, as well as estimating the baseline emissions from the peat land, will be the most difficult part of the carbon footprint analysis. This section is likely to be characterized by uncertainties.

The carbon footprint will depend on to what extent the peat land has been cultivated before peat extraction since this tends to increase baseline emissions. In European LCA studies, the surrounding area affected by drainage has also been included which also affects the result. Finally, previous studies also show that after -treatment of the peat land where the extraction has taken place can have significant effects on the carbon footprint[21].

There are emission factors available (IPCC) for peat lands, drained peat lands and cultivated peat lands in tropical zones, however, one part of the project will be to find out if there are emission factors available specifically for Southern Africa and collecting data that supports the selection of a reasonable emissions factor.

20 Lappi and Byrne (2xxx) *Greenhouse Gas Budgets of Peat Use for Energy in Ireland,* IEA Bioenergy Task Force 38

21 Höglund and Martinsson (2013) *Comparative Review of Variations in LCA Results and Peatland Emissions from Energy Peat Utilisation,* IVL

The focus of this report is on HL-A, HL-B, IL-A and IL-B bogs; i.e. those bogs that shall be opened during the first ten years of the project (table 4).

Table 5. Area size of peat bogs

	Corrected exploitable surface area (Ha)	Depth (m)	Volume in situ (million m^3)
DL	995	7	70
EL	425	7	30
ER	629	7	44
FL	185	4	7,4
GL	72	4	2,9
HL-A	ca. 300*	> 10	30
HL-B	ca. 380*	> 10	38
IL-A	ca. 170*	> 10	17
IL-B	ca. 680*	> 10	68
JL	ca. 270*	> 8	22
KL	ca. 410*	> 13	53
Total	ca. 4 500		ca. 382

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