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VALUATION OF CO_2 EMISSIONS REDUCTION FROM RENEWABLE ENERGY AND ENERGY EFFICIENCY PROJECTS IN AFRICA. A CASE STUDY OF BURKINA FASO.

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A thesis submitted to the Pan African University Institute of Water and Energy Sciences (including Climate Change) in partial fulfilment of the requirements for the degree of Master of Science in Energy (Policy option).

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THESIS APPROVAL

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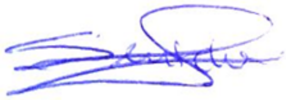
Rice Verouska Seutche Nono		30/09/2020
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DEDICATION

I dedicate this thesis to my family, especially to my beloved parents, Pouemi Julienne and Nono Octave, for whom my success is an achievement.

STATEMENT OF THE AUTHOR

By my signature below, I declare that this thesis/dissertation is my work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis, and completion of this thesis or dissertation. I have given all scholarly matter recognition through accurate citations and references. I affirm that I have cited and referenced all sources used in this document. I have made every effort to avoid plagiarism.

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BIOGRAPHICAL SKETCH

Rice Verouska Seutche Nono is a MSc in Energy Policy Candidate at the Pan African University of Water and Energy Sciences (PAUWES) in Tlemcen/Algeria. Rice holds a Master of Science degree in Petrochemical Engineering from the University of Kinshasa/DR Congo, where she is a Research Assistant. She has a combined practical experience in petroleum products analysis, petroleum product logistics (supply, storage and distribution), planning, organising and coordinating administrative and operational procedures and project management. While at PAUWES, she attended trainings offered by the Imperial College of London and the Association for Sustainable Innovation in the field of Low Carbon Economy. She is self-motivated, polyvalent with proven skills in communication, multitasking, interpersonal relationships and very adaptive. She is passionate about access to clean energy by all; and the role of policies for its achievement. Rice is developing strong interest in GHG emission reductions/Carbon footprint and is currently researching on the clean development mechanism potential of some renewable energy and energy efficiency projects implemented in Africa.

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ABBREVIATIONS

2iE	International Institute for Water and Environmental Engineering
ABC	Bilan Carbone Association
ABER	Rural Electrification Agency of Burkina Faso
ABREC	African Biofuel and Renewable Energy Company
ACM	Approved Consolidated Methodology
ADF	African Development Fund
AfDB	African Development Bank
AM	Approved Methodology
AMS	Approved Methodology for Small scale projects
ANEREE	National Agency of Renewable Energy and Energy Efficiency
AR-ACM	Afforestation and Deforestation Approved Consolidated Methodology
AR-AM	Afforestation and Deforestation Approved Methodology
ATF	African Task Force
BAU	Business as Usual
CCWG	Climate Change Working Group
CDM	Clean Development Mechanism
CEG	General Education Centre
CER	Certified Emission Reduction
CF-A	Carbon Finance Assist
CH_4	Methane
CMA	Medical Centre with Surgical Antenna
CO_2	Carbon dioxide
COP	Conference of Parties
CPA	Component Project Activities
CPDN	Contribution Prévue Déterminée au niveau National
CSPS	Social Centre for the Promotion of Health
DDO	Distillate Diesel Oil
DGEE	Department of Energy Efficiency
DGER	Department of Renewable Energies
DNA	Designated National Authority
DOE	Designated Operational Entity
DRC	Democratic Republic of Congo
EB	Executive Board
EE	Energy Efficiency
ESMAP	Energy Sector Management Assistance Program
EU ETS	European Emission Trading Scheme
FDE	Rural Electrification Development Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GES	Gaz à Effet de Serre
GHG	Greenhouse Gas
HFC	Hydro Fluoro Carbon
HFO	Heavy Fuel Oil
HPL	High Pressure Mercury
IDC	Industrial Development Corporation
IEA	International Energy Agency

INDC	Intended Nationally Determined Contribution
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
ISO	International Standards Organisation
LBN	Livre Blanc National (National White Paper)
LDC	Least Developed Country
LED	Light Emitting Diode
LSPE	Lettre de politique sectorielle de l’énergie
MCIA	Ministry of Industry, Trade and Handcraft
MDP	Mécanisme pour un Développement Propre
MEDD	Ministry of the Environment and of Sustainable Development
MEMC	Ministère de l’Energie, Mines et Carrières
MINEFID	Ministry of Finance
N_2O	Nitrous Oxide
NAMA	National Appropriate Mitigation Action
NAP	National Adaptation Plan
NAPA	National Action Program for Adaptation to Climate Change
NGO	Non-Governmental Organizations
PDD	Project Design Documents
PFC	Poly Fluoro Carbon
PoA	Programme of Activities
PRODERE	Program of Development of Renewable Energy and Energy Efficiency
PV	Photovoltaic
RE	Renewable Energy
REC	Réduction d’Emission Certifiée
REREC	Rural Electrification and Renewable Energy Corporation
RET	Renewable Energy Technology
SE4ALL	Sustainable Energy for All
SF_6	Sulfur hexafluoride
SHP	High Pressure Sodium
SIDS	Small Island Developing State
SONABEL	Burkina Faso National Electricity Company
SONABHY	Burkina Faso National Company of Hydrocarbons
SSA	Sub Saharan Africa
tCO_2e	Ton of equivalent carbon dioxide
tCO_2éq	Tonne de CO_2 équivalent
TDL	Transmission and Distribution Losses
TPES	Total Primary Energy Supply
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars
WAEMU	West African Economic and Monetary Union
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute

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ABSTRACT

Africa contributes to about 2% of global energy related carbon emissions but remains the most vulnerable region to the impacts of the global rising temperatures caused by them. 52 African countries including Burkina Faso are parties to the Kyoto Protocol that promotes sustainable development by contributing to the development of low carbon projects in less developed countries through the clean development mechanism (CDM). Africa is host to only about 3% of the registered CDM projects as at 2020.

Like many other African countries, Burkina Faso is host to many renewable energy (RE) and energy efficiency (EE) projects that are not registered to the CDM. The main aim of this study was to determine these projects' impact on the level of GHG emissions in the country, and to determine their CDM potential by quantifying their greenhouse gas (GHG) emission reductions using appropriate CDM methods. The CDM methods applied were AMS-II.C., AMS-II.L., AMS-I.A., AMS-I.F., AMS-I.D. and AMS-III.AR. according to the projects. 34 projects were identified, but only the 28 for which data was available were considered.

The results revealed that the total annual energy saved by the EE projects is 68709.424MWh, while the total energy displaced by the RE projects is 9430.446MWh, accounting respectively for 36871.701 tCO_2e and 11285.967 tCO_2e emissions reduced annually, giving a total of 48157.668tCO_2e emissions reduced annually by all these projects. This represents a shift in emissions from 76300.098 tCO_2e in the baseline scenario to 28142.430 tCO_2e in the project scenario, accounting for about 63.12% emission reduction. The total amount of emissions reduced could generate about 48157.668 Certified Emission Reductions (CERs) per year and 481576.68 CERs in 10 years, assuming a fixed 10 years crediting period for all the projects. Considering a carbon price of \$10/tCO_2e, these CERs will generate a total revenue of about \$481576.68 annually and \$4815766.8 in the 10 years crediting period, and consequently increasing the sector's attractiveness to investors. The RE and EE projects implemented in Burkina Faso actually contribute to the reduction of GHG emissions and represent a huge potential for the CDM, ready to be harnessed.

Like Burkina Faso, many other African countries are hosts to similar projects, at a bigger scale in some cases. It is therefore essential to register these projects to the CDM in order for the individual countries and the region in general to benefit from the sustainable development it offers, added to its contribution to the achievement of their Intended Nationally Determined Contributions (INDCs). This will also increase the representation of African countries in the CDM, where they are still very poorly represented, yet endowed with enormous CDM potential. Meanwhile, more programs like the CDM Assist program should be put in place in Burkina Faso and other African countries for awareness enhancement and capacity building with hands on experience in real CDM projects. This is to help the country/region to attract more CDM projects, to develop and manage them. This study put more focused on Burkina Faso, similar studies done in other African countries and on more scopes covered by the CDM are openings for future research.

Keywords: Renewable energy, Energy efficiency, GHG emission reduction, CDM, CER, Sustainable development, Burkina Faso, Africa

Résumé

L'Afrique contribue à environ 2% des émissions mondiales de carbone liées à l'énergie mais reste la région la plus vulnérable aux impacts de la hausse des températures mondiales provoquée par celles-ci. 52 pays africains dont le Burkina Faso sont des partis au protocole de Kyoto qui promeut le développement durable en contribuant au développement de projets bas carbone dans les pays moins développés à travers le Mécanisme pour un Développement Propre (MDP). En 2020, l'Afrique n'héberge qu'environ 3% des projets enregistrés au MDP.

À l'instar de nombreux autres pays africains, le Burkina Faso héberge de nombreux projets d'énergies renouvelables (ER) et d'efficacité énergétique (EE) qui ne sont pas enregistrés au MDP. L'objectif principal de cette étude était de déterminer l'impact de ces projets sur le niveau des émissions de gaz à effet de serre (GES) dans le pays, et de déterminer leur potentiel MDP en quantifiant leurs réductions d'émissions de GES à l'aide de méthodes MDP appropriées. Les méthodes MDP appliquées étaient AMS-II.C., AMS-II.L., AMS-IA, AMS-IF, AMS-ID et AMS-III.AR. selon les projets. Des 34 projets identifiés, seuls les 28 pour lesquels des données étaient disponibles ont été pris en compte.

Les résultats ont révélé que l'énergie totale annuelle économisée par les projets d'EE est de 68709,424MWh, tandis que l'énergie totale déplacée par les projets ER est de 9430,446MWh, soit respectivement 36871,701tCO_2éq et 11285,9670tCO_2éq d'émissions réduites annuellement, soit un total de 48157,668tCO_2éq d'émissions réduites annuellement par tous ces projets. Cela représente un déplacement des émissions de 76300,098 tCO2éq dans le scénario de référence à 28142,430tCO_2éq dans le scénario des projets, soit une réduction de 63,12%. Le montant total des émissions réduites pourrait générer environ 48157,668 Réduction d'Emission Certifiée (RECs) par an et 481576,68RECs en 10 ans, en supposant une période de crédit fixe de 10 ans pour tous les projets. Considérant un prix du carbone de 10 $ / tCO2éq, ces RECs généreront un revenu total d'environ $481576,68 par an et $4815766,8 au cours de la période de crédit de 10 ans, augmentant ainsi l'attractivité du secteur aux investissements. Les projets d'ER et d'EE mis en œuvre au Burkina Faso contribuent en effet à la réduction des émissions de GES et représentent un énorme potentiel pour le MDP, prêt à être exploité.

Comme le Burkina Faso, de nombreux autres pays africains hébergent des projets similaires, à plus grande échelle dans certains cas. Il est donc essentiel d'enregistrer ces projets au MDP afin que les pays et la région en général puissent bénéficier du développement durable qu'il offre, ajouté à sa contribution à la réalisation de leurs Contribution Prévue Déterminée au niveau National (CPDN). Cela augmentera également la représentation des pays africains au niveau du MDP, où ils sont encore très mal représentés, mais dotés d'un énorme potentiel MDP. Entre-temps, davantage de programmes comme le programme CDM Assist devraient être mis en place au Burkina Faso et dans d'autres pays africains pour améliorer la sensibilisation et renforcer les capacités avec une expérience pratique de véritables projets MDP. Il s'agit d'aider le pays / la région à attirer plus de projets MDP, à les développer et à les gérer. Cette étude a mis davantage l'accent sur le Burkina Faso, des études similaires réalisées dans d'autres pays africains et sur davantage de domaines couverts par le MDP sont des pistes pour de futures recherches.

Mots clés: Énergie renouvelable, Efficacité énergétique, Réduction des émissions de GES, MDP, REC, Développement durable, Burkina Faso, Afrique

1. INTRODUCTION

1.1. Background

The desire for a better living standard and the rising global population has led to growing energy consumption over the last decades (Bose, 2010). Rapid global economic growth also contributed to increase the global energy demand, and consequently adding the carbon dioxide (CO_2) emissions, since most of the energy needs for the past 100 years have been met through conventional energy sources. This led to an increasing global energy related carbon dioxide emissions from 20.5 Gt CO_2 in 1990 to 33.1Gt CO_2 in 2018 as shown in

Figure 1 below (IEA, 2019c). Although Africa has only contributed about 2% to these emissions, it remains the most vulnerable region in the world when it comes to the impacts of the universe's changing climate (IEA, 2019a). The low level of emissions in Africa is due to the low economic activities, low level of industrialisation and poor access to electricity in the region (Calvin et al., 2013). In case of global failure to prevent the climate catastrophe, Africa will pay the highest price meanwhile it has the most underpowered, inefficient, and unequal energy systems (Africa Progress Panel, 2015).

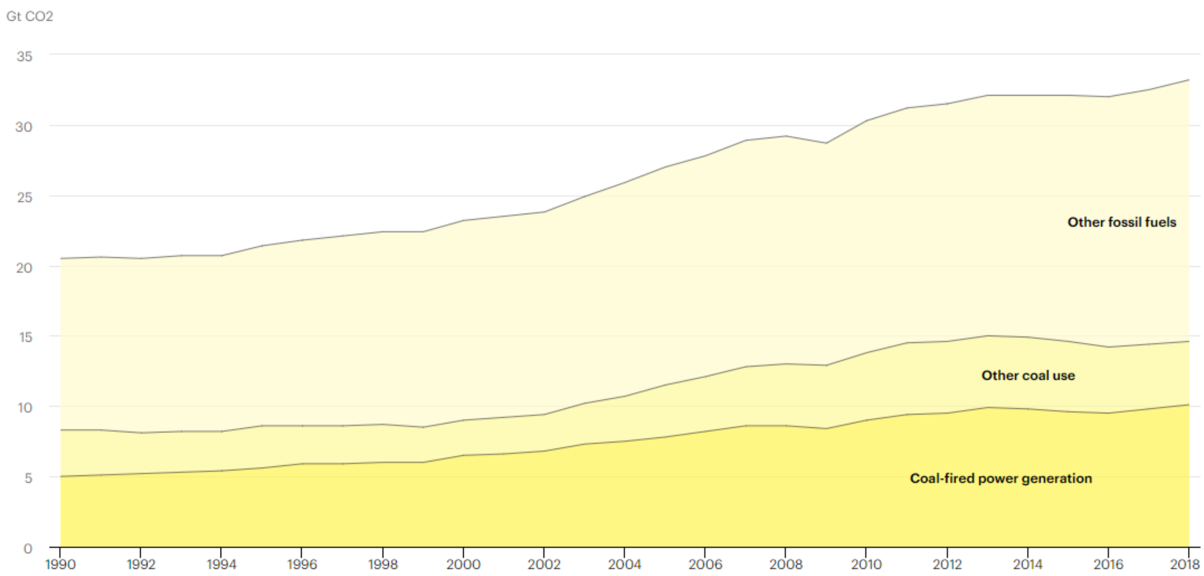

Figure 1 : Global energy-related carbon dioxide emissions by source, 1990-2018 (IEA, 2019c).

Despite the expansion of the global economy, the emissions were stable from 2014 to 2016 (

Figure 1) as a result of the deployment of low carbon technologies and some improvements in energy efficiency measures. However, the low carbon alternatives did not scale fast enough to meet the rising energy demand over the last 2 years. Consequently, for every 1% addition in global economic output, the emissions rise by ~0.5%, compared to an average increase of 0.3% in 2010. Nonetheless, the implementation of renewables and nuclear energy has had a positive impact as at 2018, with the rate of emissions growth being 25% slower than energy demand (IEA, 2019c).

While the world population rose from 1.6 billion in 1900 to 7.2 billion in 2016, the total global energy production increased from 23 million to 548 million tera joules. This energy demand will continue to grow as the population is projected to rise to 10.9 billion by 2100 (Jones & Warner, 2016), with about 25% living in Africa (Calvin et al., 2013). For every two people added to the world between 2019 and 2040, one is predicted to come from Africa, which is estimated to become the most populated region of the globe, ahead of India and China. The population growth in Africa is more intense in the urban areas, with an estimation of above 500 million people increasing by 2040. The rapid increase in the African urban population will result in growing need for industrial production, cooling, heating and mobility. This will unfailingly require more energy, and if unrestrained, increase CO_2 emissions. The way Africa tackles its rising energy demand is crucial for its economic and energy future, as well as for global trends (IEA, 2019a). A serious and concerted effort of humanity is the way to significantly diminish CO_2 emissions and save the world from the consequences of global warming.

In an effort to curb greenhouse gas (GHG) emissions, the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1997 and entered into force in 2005. This protocol shares the same objectives as the UNFCCC, but goes further by committing industrialised countries to reduce carbon emissions (UNFCCC, 2011c). 192 parties have so far ratified the protocol, including many African countries.

Burkina Faso, on which the present study is focused, ratified it in 2005 and is a non-Annex 1 party (UNFCCC, 2020a). One of the three tools put in place by the Kyoto Protocol to achieve its objectives is the Clean Development Mechanism (CDM). This mechanism enables industrialised countries with emission reduction targets to either finance or develop greenhouse gas mitigation projects in non-Annex 1(developing) countries in exchange for certified emission reductions (CERs) (Pillay, 2016). Countries which host these projects have multiple benefits, such as technology transfer, financial support from CER sales, contribution to the achievement of their intended nationally determined contributions (INDCs), economic development and poverty reduction. Contributing to the sustainable development of non-Annexe 1 countries is also amongst the objectives of the CDM. However, even though 52 African countries have ratified the protocol, the continent currently hosts only 253 registered CDM projects (with less than 10 in Burkina Faso), representing only about 3% of such projects globally (UNEP DTU Partnership, 2020).

1.2. Problem Statement and Justification

Burkina Faso, like other countries of the Sahel region, is highly vulnerable to climate change. It is actually suffering from a temperature increase faster than the global average, with changes in the distribution of rainfall over time and an increase in the occurrence of extreme rainfall events and the duration of droughts. This threatens strategic sectors of the country like water, agriculture, livestock and forestry (Dayamba & Coulibaly, 2018). There is need for action to mitigate these impacts.

Furthermore, the country has a 20.3% access to electricity, with less than 2% and about 58% in the rural and urban areas respectively. About 84% of the installed capacity is fossil fuel based, and the rest comes from hydro and solar energy (Power Africa, 2019). All the fossil fuel used in the country relies on imports, as Burkina Faso does not produce any of them. Almost 80% of the energy consumed consist of solid biomass such as firewood, charcoal and agricultural residues (inefficient and highly emits CO_2), accounting for close to 100% of energy supply in the rural areas (Moner-Girona et al., 2016). Moner-Girona et al. (2016) recommends distributed mini grids powered by renewable energy resources for the country's rural electrification plan; for a quick connection of more people to power, while mitigating fossil fuel consumption and carbon emissions.

In order to promote the use of local energy resources and boost efficient energy consumption, the government, in line with the Sustainable Energy for All (SE4ALL) country action put in place the Renewable Energy and Energy Efficiency Action Plans. The targets are achieving 50% access to electricity in rural areas (95% country wide), bringing renewable energy (without biomass) in the electricity mix to 50% and reaching a 100% access to clean cooking energy in urban areas and 65% in rural areas, all by 2030 (SE4ALL, 2019). This will also help the country to meet its INDCs and reduce its dependency on fossil fuel imports.

Some projects in line with these targets have already been implemented by the government through some national agencies like the National Agency of Renewable Energy and Energy Efficiency (ANEREE) and the Rural Electrification Agency of Burkina Faso (ABER). It is therefore imperative to assess their impacts on CO_2 emission levels, as they could be highly contributing to the reduction of emissions, making them potential opportunities for the CDM. Even though renewable energy technologies are gradually becoming competitive with the conventional technologies, high upfront cost and lack of access to technology still remain barriers to renewable energy deployment. Therefore, capitalising the emission reductions resulting from these projects, through the CDM is important to boost the implementation of more renewable energy (RE) and energy efficiency (EE) projects in the country, and consequently, to mitigate carbon emissions as well as climate change.

Moreover, some scholars identified low carbon project opportunities in Burkina Faso (UNEP RISØ, 2013) and in Africa (Burian & Christof, 2014; Christof et al., 2011; Timilsina et al., 2010), which if implemented could represent potential projects for the CDM. However, this study seeks to pull the attention to projects already implemented, and determine their CDM potential (possible emission reductions), which could be harnessed and contribute to the implementation of the project opportunities identified.

1.3. Research Questions

In order to address the problem highlighted in this study, the following questions will guide the research:

- What is the current level of GHG emissions in Burkina Faso?
- How do the RE and EE projects implemented in the country, but not registered to the CDM influence the level of carbon emissions?
- Why are these low carbon projects not registered to the CDM?

1.4. Hypotheses

The non-registered CDM RE and EE projects initiated by the Ministry of Energy in Burkina Faso, through the ANEREE and ABER contribute to the reduction of the level of GHG emissions, which could be valued through the CDM.

1.5. Research Objectives

This study seeks to investigate on how the low carbon projects implemented in Burkina Faso have impacted the level of CO_2 emissions, in order to capitalise the emission reduction and improve the country's energy infrastructure where required. This will accelerate the achievement of the country's INDCs and contribute to its sustainable development, as this will improve access to clean energy across the country. All these added to the multiple benefits of the CDM. This research also aims to show that Burkina Faso is not the only African country hosting such potential CDM projects which are wasted, as they are not registered to the CDM. The specific objectives hereafter are needed to achieve our main goal:

- Identify non CDM registered RE and EE projects implemented in selected African countries; for illustration purposes.
- Make an inventory of the RE and EE projects already implemented and operational in Burkina Faso.
- Investigate on the Business as Usual (BAU) scenario before the implementation of these projects, and determine the difference in emission levels resulting from the projects' implementation.

- Determine the local constraints to the registration of these projects to the CDM.
- Draw policy recommendations based on the findings made during the study. The aim is to raise awareness about this CDM opportunity; and make suggestions which could be considered by the government to promote the development of energy related CDM projects in the country, thereby engaging in the carbon market (CER) and boosting the development of RE and EE in the country.

1.6. Methodology

The CDM projects types considered in this study are those in the category of renewable energy and energy efficiency. An inventory of such projects implemented in Burkina Faso, but not registered to the CDM was done. The secondary data about the projects was provided by different national entities, including the Ministry of Energy through the ANEREE, the ABER and the National Electricity Company (SONABEL), and the International Institute for Water and Environmental Engineering (2iE). Other information was directly gotten online from open access journals, reports and different websites. Of all the projects identified, only those for which relevant data was available were selected for further analysis.

One of the key criteria for a project to be registered to the CDM is a proof of its additionality. This entails amongst others, showing the emissions savings that are solely a result of the project's activities and would not have occurred without the implementation of the project concerned (CDM, 2020). This is where this study comes into play, aiming to determine the emission reductions of the projects implemented.

For each of the selected projects, the additionality, the baseline emissions (BAU scenario), the actual emissions with the projects (project scenario) and the quantity of annual emission reductions were determined, giving room to estimate the number of CERs which they could generate if they were registered to the CDM. The crediting period of each of the projects were also considered to determine the total number of CERs they could provide. It is worth noting that the list of RE and EE projects implemented in Burkina Faso, which is presented in this study is not exhaustive, due to difficulties in obtaining data.

As for Africa in general, few RE and EE projects in some African countries were identified online, and presented here for the purpose of illustration. This is to show that Burkina Faso is not the only African country with these unharvested low hanging fruits. The confirmation that these projects are not registered to the CDM was done by searching on the UNFCCC CDM project search, and also through information gotten from the institutions which provided the data.

Given that the present study is meant to encourage project registration to the CDM, the approved CDM methodologies are those considered herein to determine the emission reductions and the proof of additionality of the projects selected. The CDM methodologies considered are AMS-II.C., AMS-II.L., AMS-I.A., AMS-I.F. and AMS-I.D, and will be specified in each case.

1.7. Significance of the Study

This study would enable the government of Burkina Faso, as well as the other stakeholders of the projects to have a clue on the effectiveness of the low carbon projects implemented in the country in terms of reduction in carbon emissions. Furthermore, the policy recommendations made from the findings of the present study will assist the government in creating an enabling environment for the development of more of such projects in the country.

The registration of these operational RE and EE projects to the CDM, as well as the implementation of more of such CDM projects in Burkina Faso would contribute in facilitating the importation of clean technologies and increase finance for low carbon projects. This will thereby quicken the deployment of RE and EE projects across the country, improve the country's energy infrastructure and energy security, and raise its contribution to the mitigation of climate change and its impacts. Moreover, diminishing carbon emissions via the low carbon projects will as well benefit other areas of the society, by generating more job opportunities, improving health conditions, and augmenting access to clean energy and food security, all these contributing to Burkina Faso's sustainable development. The study also serves to raise awareness about this unharnessed CDM potential in other African countries.

1.8. Scope and Limitations of the Study

This study focuses on making an inventory of RE and EE projects implemented and operational in Burkina Faso, but not registered to the CDM. A quantification of the emission reductions resulting from these projects is done, as well as some investigations regarding the rationales behind them not been registered to the CDM. Some examples of similar projects implemented in other African countries and not registered to the CDM are also presented for illustration purposes.

This study produced pertinent and helpful results, however, some level of challenges and deficiencies were encountered in the course of the research. The research timeframe and resources could not enable us to cover more than a country. The covid-19 pandemic cancelled the possibility to travel to the case study area for data collection, thereby delaying the process and making it difficult to obtain all the relevant data on time. In addition, the list of projects for which the emissions savings are quantified in this study is not exhaustive due to difficulties in obtaining relevant data. Due to the same reason, plus the lack of standardised baseline emissions data for the region, some default values for emission factors and grid losses (technical) proposed by the CDM approved methods applied were considered in the study.

1.9. Structure of the Research

This study is structured in five chapters. The first chapter presents an introduction to the study, followed by the second chapter which provides an extensive and relevant review of the literature on the research topic. The third chapter deals with the methodology used in conducting the research. The results of the study are then presented and discussed in the fourth chapter, followed by a conclusion and some recommendations in the fifth and last chapter.

2. LITERATURE REVIEW

2.1. Introduction

This chapter presents a review of the literature on the effects of RE and EE on carbon curbing globally and in Africa. This is followed by an overview of the energy situation in Africa in general and in Burkina Faso in particular, including some energy policies and targets that promote the development of RE and EE in the continent, and specifically in Burkina Faso. GHG emission trends of Burkina Faso are then presented, with some mitigation scenarios proposed. Furthermore, an overview of the CDM is done with the following main points included: the benefits of the CDM and barriers to its development in general and specifically in Africa; the CDM and sustainable development; the CDM potential and its state in Africa and Burkina Faso; and a regional and sectoral scope distribution of CDM projects. Some tools for the assessment of GHG emissions are then presented, with an introduction to CDM approved methodologies. This review is crucial because it gives the situation at hand in our research field, providing lessons and gabs from previous studies that could be addressed in this study.

2.2. Renewable Energy (RE), Energy Efficiency (EE) and Carbon Curbing

Energy production and use account for about two third of global GHG emissions. This places the energy sector at the centre of the struggle to keep global average temperature rise below 2°C above the pre industrial values, in line with the Paris Agreement goals. The International Renewable Energy Agency (IRENA) emphasises that energy efficiency and renewable energy quick deployment can account for about 90% of the decarbonisation required to remain within the requirements of the Agreement (IRENA, 2017).

Recent analysis by Gielen et al. (2019) show that with the BAU scenario (current and planned policies), energy related carbon dioxide emissions would rise to 35 Giga tonnes by 2050, from 33 Giga tonnes as at 2015, meanwhile these emissions need to decline to 9.7 Giga tonnes by 2050 to remain within the 2°C limit. This study also reveals that, a 63% share of renewables in the total energy supply by 2050 from 15% in 2015, added to improved energy efficiency can account for over 90% of the emission curbs needed. However, enabling policy and institutional frameworks have to be put in place or amended for the accelerated transition required to occur. Additionally, an analysis of the mitigation of GHG emissions through energy efficiency, carried out for the period between 1995 and 2016 with datasets of 29 European countries indicated energy efficiency as a potential mechanism for long term reduction of GHG emissions (Akdag & Yıldırım, 2020). Moreover, Özbuğday & Erbas

(2015) investigated on the effect of industrialisation, renewable energy and energy efficiency on carbon emissions in 36 industrialised and developing countries between 1971 and 2009 and confirmed the significant impact they have on carbon curbing. About 0.55% and 0.11% of emissions was reduced for every single percentage of increase in energy efficiency and of renewable energy in the total energy used respectively.

As for Africa particularly, Prince & Okechukwu (2019) explored the effects of renewable and non-renewable energy consumption on carbon dioxide emissions in 19 African countries for the period between 1990 and 2014. This revealed that even though both energy types have varying effects on carbon dioxide emissions across countries, the tendency is that renewable energy consumption slightly reduces carbon emissions, while non-renewable energy consumption highly increases the emissions in Africa. Inglesi-Lotz & Dogan (2018) also analysed the link between these three parameters in the ten biggest electricity generators of sub-Saharan Africa (SSA) for the period between 1980 and 2011; they also confirmed that CO_2 emissions decrease with an increase in RE consumption and increase with increasing consumption of non RE.

2.3. Energy Situation in Africa

The current energy needs in Africa are predominantly met by biomass and fossil fuels. Almost half of the continent's total primary energy supply (TPES) is covered by biomass. Oil, natural gas and coal account for about 22%, 14% and 14% respectively. Hydropower represents only about 3% of this TPES, leaving less than 1% for the other renewables and electricity as shown in **Figure 2** below (IRENA, 2015).

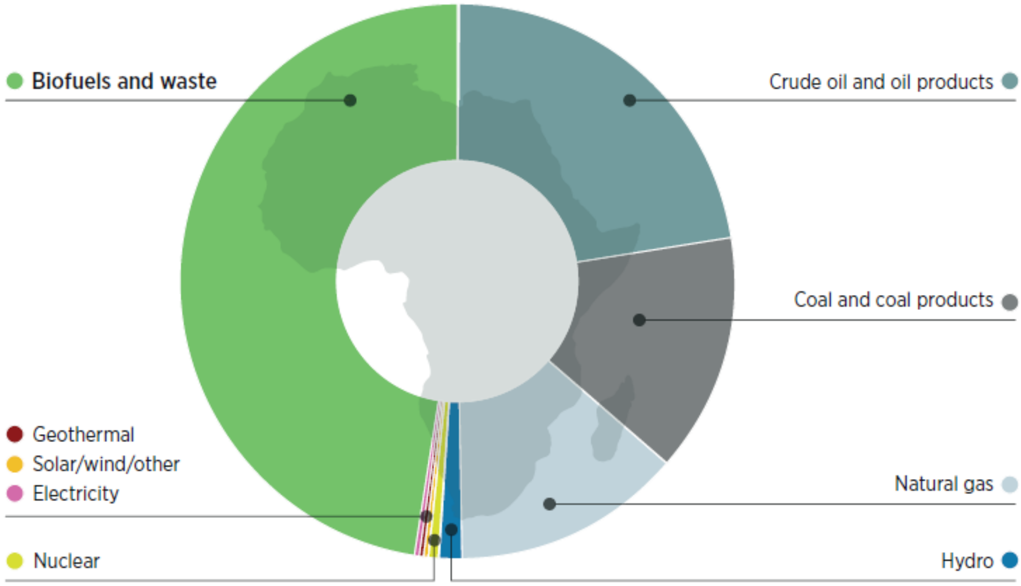

Figure 2: Total primary energy supply in Africa, 2013 (IRENA, 2015).

About 600 million people still (about 44.7% of the continent's population) do not have access to electricity on the continent; this challenge differs per region. Less than 2% of the Northern African population lacks access to electricity. On the contrary in SSA, almost half of southern and western African population, and about three quarter of the eastern and central African population are still deprived of electricity (**Figure 3**) (IRENA, 2015).

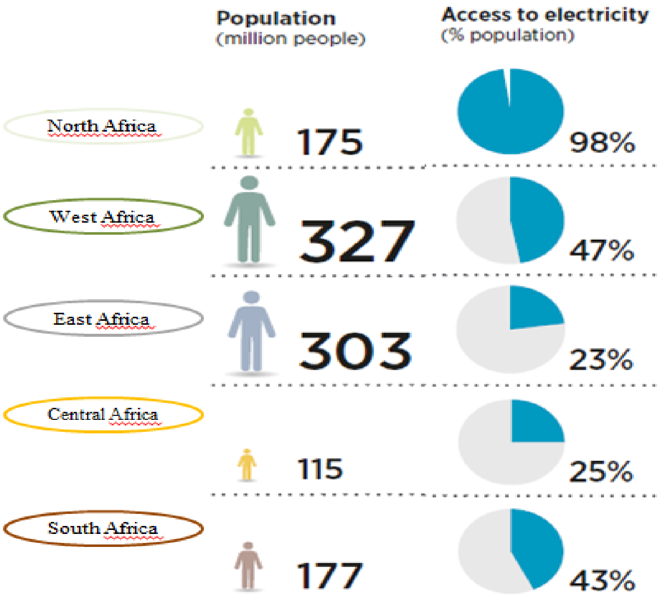

Figure 3: Population (2013) and electricity access (2012) in Africa per region (IRENA, 2015).

Nevertheless, as presented in **Table 1**, some African countries have put in place energy policies with set targets for sustainable increase in access to electricity for their populations. Most of the measures set to achieve these targets involve the use of renewable energy technologies and the improvement of energy efficiency applications, which are progressively being implemented. This also gives room for the implementation of more RE and EE projects on the continent. Both the implemented projects and those to be could be potential sources of carbon reductions, which could be valued through the sales of certified emission reductions (CERs) under the clean development mechanism (CDM).

Table 1 : Selected energy policies and targets in some SSA countries (IEA, 2014, 2019a).

Country	**Sector**	**Policies, targets and implementation measures**
Angola	Access	Rate of electrification increase from 30% to 60% by 2025
	Integration	Transmission lines Establishment with Namibia and Congo
	Power	Implementation of a new power market model with only one power purchaser and equal rights for public and private power purchasers.
Côte d'Ivoire	Access	National program of rural electrification: All towns of over 500 inhabitants connected by 2020, all regions by 2025, with reduced tariffs for poor households. Program of electricity for all: Electrification of a million households.
DR Congo	Access	Rate of electrification increase from 9% to 14% by 2015 and 26% by 2020.
	Power	Firmer standards for electric motors
Ethiopia	Access	Total access by 2025 Program of electrification (2017): Public-private off-grid programs for six million households; accelerated grid extension and decentralised systems to cover respectively 65% and 35% of the population by 2025.

Country	Sector	Policies, targets and implementation measures
Ghana	Renewables	Targets put in place for new renewables' (hydro, geothermal, wind) capacity.
	Efficiency	18% reduction of transmission losses by 2018; set labels and standards for air conditioners and lighting.
Kenya	Renewables	Establishment of Feed-in tariff (2011 Renewable energy act)
	Access	Total access by 2022. National electrification strategy (2018): $2.8 billion investment from 2018 to 2022. Off-grid solar access project: 250 000 solar home systems distributed to schools, households, agriculture and health facilities by 2030
	Buildings	Requirements for the installation of solar water heaters in buildings served by the grid; elimination of kerosene as household fuel by 2022.
	Efficiency	Set energy efficiency obligations for utilities and standards for electrical appliances; 2014 energy bill provides for the establishment of an Agency of energy efficiency and conservation to enforce the standards.
Mozambique	Access	Electrification rate increase from 39% to 85% by 2035
	Renewables	Installation of 2000 televisions powered by solar PV/wind turbine system, 100 000 solar water heaters, 50 000 lighting systems and 5000 refrigeration systems in off-grid regions by 2025.
Nigeria	Access	Provide reliable electricity to 75% of the population by 2020 and 100% by 2030, from 45% in 2014. Connecting averagely 1.5 million households annually.
	Buildings	Announced the design and implementation of minimum energy performance standards for appliances and industrial equipment.
	Power	According to the Roadmap for power sector reform, continue sector-wide reforms to enable private sector investment, establish a competitive market and achieve stable power supply.
Rwanda	Access	Full access by 2024. Rural electrification strategy and energy sector strategic plan: By 2024, 52% of households connected to the grid and 48% to decentralised systems; energy standards for appliances introduced; frequency and duration of interruptions reduced by 50%; all productive users connected.
	General	Share of bioenergy in primary energy consumption reduced to 50% by 2020; transmission network expanded by 2100 km by 2017.
Senegal	Access	Total access by 2025 National electrification program: 95% of rural clients electrified via grid extension; 4% via solar or hybrid solar-diesel mini-grids; and the remaining via solar home systems.
	Renewables	20% renewables in the total energy supply mix was target for 2017.

2.4. Energy Situation in Burkina Faso

2.4.1. Energy Resources

Burkina Faso is a landlocked and low income Sahelian country in West Africa with limited natural resources. With an estimated annual growth rate of 2.9%, the population of Burkina Faso stood at 19.75 million inhabitants in 2018, with over 70% living in rural areas (World Bank, 2019).

The main characteristics of the energy situation in Burkina Faso can be summarised as follows: a high solar potential (MEMC/MINEFID, 2016), a predominance of biomass (over 80%) in primary energy consumption, a low and unequal access to modern energy, a poor valorisation of endogenous energy resources and a total dependence on imports for fossil fuels (ADF, 2015; Moner-Girona et al., 2017). Access to electricity is still very low, with only 18.83% of the population having access, and only 2.3% of the predominant rural population having access to electricity (Moner-Girona et al., 2017). Moreover, the energy consumption per capita in the country is very low, estimated at 0.180toe (IAEA, 2016). In 2008, the energy consumed was derived from biomass at about 84%, petroleum products at about 10%, hydropower at about 6% and other renewable sources, particularly solar at less than 1% (REEEP, 2012). During the same year, the total primary energy consumed was estimated at 3.7Mtoe (Tatsidjodoung Parfait, Marie-Hélene Dabat, 2012).

Biomass, which is the main energy source used in the country, especially in rural areas (nearly 100%) was constituted of 91% fuelwood, 5% crop residues, 3% bagasse and 1% charcoal, in 2008. Almost 90% of the population still relies on biomass (firewood and charcoal) energy mostly for cooking (REEEP, 2012; Tatsidjodoung Parfait, Marie-Hélene Dabat, 2012). However, in urban Ouagadougou (capital city), about 44% of households cook with firewood, meanwhile approximately 16% and 40% use charcoal and gas respectively (Sana et al., 2019). The forests situated in the Sudanian and Sudano-Sahelian zones, in the Southwestern, the Western and the Eastern regions of the country are the main production sites of biomass resources, which are as well sufficiently available across the country (REEEP, 2012). However, as fuelwood consumption is gradually overweighing the production capacity, there is an increasing pressure on the already fragile forest ecosystem to meet the demand, making the system unsustainable (Tatsidjodoung Parfait, Marie-Hélene Dabat, 2012). It is therefore essential to harness this renewable resource in a sustainable way, and to diversify the energy resources used in Burkina Faso.

The lack of crude oil refineries and fossil fuel resources, which represent the 2nd most consumed energy type in Burkina Faso makes it totally dependent on the importation of all the hydrocarbons required to fuel different sectors of the country. Petroleum products are imported from neighbouring countries, especially Ivory Coast, 62% of which is used for transport, 21% for electricity production, 5% lighting and 5% cooking. As of 2008, heavy petroleum products such as fuel oil, distillate diesel oil (DDO) and diesel fuel accounted for almost 67% of the hydrocarbon imports, the rest consisted of the lighter ones, such as jet A1, gasoline and domestic gas (Tatsidjodoung Parfait, Marie-Hélene Dabat, 2012). Oil products supply is controlled by the National Company of Hydrocarbons (SONABHY), which is a state owned company supervised by the Ministries of Trade and Finance. Oil consumption keeps increasing over the years in Burkina Faso, in 2016 for example, it was at 23000 barrels per day, from 6574 barrels per day in 2000 (Worldmeter, 2016). The 2013 World Resources survey of the World Energy Council reported the presence of 10 square kilometres of untapped peat in the country (WEC, 2013).

Hydroelectric power in Burkina Faso is both produced in local plants and imports (about 20%) from neighbouring countries like Ivory Coast, Ghana and Togo. The installed capacity of hydroelectric power production is at 34.56 MW, generated in the following National Electricity Company’s (SONABEL) powers plants: Bagré (16 MW), Kompienga (14 MW), Niofila (1.5 MW), Tourni (0.5 MW) and Samandéni (2.56 MW). The hydroelectric power produced is totally connected to the national grid, and contributes for an average of 100GWh annually. Hydropower accounts for about 10% of the total installed electricity generation capacity (MEMC/MINEFID, 2016). The adverse hydro meteorological conditions in the country limit its hydropower potential.

Solar energy is the most abundant endogenous energy resource in Burkina Faso, and it is uniformly distributed across the country with an average specific yield of 620kWh/kWp/year (MEMC/MINEFID, 2016). On an annual basis, it receives 3000 to 3500hours of peak sunshine, which has the potential to generate an average of 5.5kWh/m^2/day. In spite of this high solar potential, it is still poorly harnessed with most of the installations been of low capacity; beneath 250kWp. Nonetheless, there are increasing numbers of installations of hybrid PV-diesel mini grids and solar kits (individual or collective) in the framework of the decentralised rural electrification program. The Zagtouli solar PV power with an installed capacity of 33MW, with a planned extension of 17MW, is one of the most recent (2017) solar PV projects implemented in the country. Solar energy has also been used for public lighting in the framework of the public lighting development program (MEMC/MINEFID, 2016; Moner-Girona et al., 2016).

The low wind speeds recorded in Burkina Faso, varying between 1 to 3m/s, with the highest value only recorded in the northern/Sahel regions makes wind energy the least preferred of the renewables in the country (Moner-Girona et al., 2016). Moreover, some studies suggest a better wind potential in Dori in the North, where the solar potential is higher than the country average (1,650kWh/kWp/year), and represents about 2.3 times the wind potential (700kWh/kWp/year) (Moner-Girona et al., 2017). Nonetheless, it is used in selective sites to run small scale desalination and water pumping systems (Moner-Girona et al., 2016; REEEP, 2012).

2.4.2. Electricity Mix

The electricity supplied in Burkina Faso is generated from three main sources comprising of hydropower, thermal-fossil fuel (distillate diesel oil {DDO} and heavy fuel oil {HFO}) generation and electricity imports. The key electricity operator which was vertically integrated, with a national monopoly on the generation and distribution of electricity in urban centres is the National Electricity Company of Burkina Faso (SONABEL). In 2014, its electricity supply reached 1125GWh (ADF, 2015) from 755GWh in 2008 (Tatsidjodoung Parfait, Marie-Hélene Dabat, 2012), generated in fossil fuelled thermal power plants. This very expensive source of electricity generation dominates the electricity mix with a share of 57%, followed by imported electricity at 36% (32% from Côte d'Ivoire and 4% from Ghana) and finally 7% from hydropower (ADF, 2015). The cheaper cost of imported electricity compared to that which is locally produced by thermal power fuelled by high cost imported fossil fuels, explains its relatively high share in the mix (Moner-Girona et al., 2017). The production park of the utility company disposed of 9 hydroelectric power units and 73 thermal power units with a total installed capacity of 325 MW (275MW thermal and 32MW hydro) as at 2015. This implied a 14% increase from 2014 due to an extension of the installed capacity of Bobo II thermal power station by 49 MW (SONABEL, 2015). Solar energy still accounts for less than 1% of the energy mix despite the acceleration of the implementation of solar photovoltaic (PV) projects in the country since 2014 at a rate of about 30% increase of the capacity installed per annum (Moner-Girona et al., 2017). The Yeleen solar PV project of 208MWc that would be implemented under the African Development Bank's Desert to power Initiative, between 2020 and 2024 would highly increase the % of solar power in the mix. The Yeleen is projected to avoid the emission of about 48000 tCO_2e yearly; a potential opportunity for the CDM (AfDB, 2019).

The increasing economic and mining activities in addition to the fast growing population led to an annual average of 13% increase in electricity demand, compared to 8% increase in the supply over the past decade. In 2015 for instance, the total available capacity was at approximately 200MW, for a peak demand of about 250MW, resulting in a deficit of 50 MW. Additionally, the annual consumption of electricity per capita estimated at 35 kWh is amongst the lowest in Africa (ADF, 2015), with the electricity access rate at approximately 18.83%, 59.88% and 3.06% at the national level, in urban and rural regions respectively (MEMC/MINEFID, 2016). Nonetheless, the cost of electricity which is currently at 0.22-0.25 USD/kWh in Burkina Faso remains amongst the most expensive in the region (Power Africa, 2019). It is therefore essential for Burkina Faso to consider an alternative energy mix that will extensively increase the national power supply to satisfy the rapidly growing demand, while reducing its dependence on imported petroleum products for power generation.

2.4.3. Institutional, Legislative and Regulatory Framework for the Energy Sector

Electricity is an undisputable necessity for quick economic growth and poverty lessening (Moner-Girona et al., 2016). Moner-Girona et al. (2017) confirm electricity as a significant factor in Burkina Faso's socio-economic development. However, as fore-mentioned, the country's electricity sector is challenged amongst others by the need to provide electricity to its population (urban and rural) and to improve the quality and reliability of its services. The government of Burkina Faso, through its Ministry of Mines and Energy (MMCE) put in place a number of policy instruments and strategies as presented in **Table 2** to alleviate these challenges (Moner-Girona et al., 2017). There is not one regulatory framework that defines the country's strategy for electricity access; it is however enclosed in several sustainable development policies as presented in **Table 2** below (Moner-Girona et al., 2016).

The law adopted in 2017 (Loi n°14 AN du 20 Avril 2017) eliminates the single buyer model, liberalises electricity production and distribution, and makes provisions concerning renewable energy and energy efficiency, just to name a few (Power Africa, 2019). Moreover, the implementation of the national renewable energy program will be promoted by the Department of Renewable Energies (DGER), the Department of Energy Efficiency (DGEE) and the National Agency of Renewable Energy and Energy Efficiency (ANEREE) recently established (Moner-Girona et al., 2017). ANEREE has the obligation to promote, monitor and implement every operation aimed at contributing to the development of renewable energies and energy efficiency in the country (ANEREE, 2017; AssembléeNationale, 2017).

Additionally, importers and distributors of solar equipment eligible to the criteria listed in the inter-ministerial decree of February 2020, and possessing an attestation of eligibility delivered by ANEREE are exempted from Value Added Tax on all solar equipment imported and sold in the country (ANEREE, 2020). This is to facilitate population access to solar equipment, thereby increasing use of indigenous renewable energy sources and the rate of access to clean, modern and affordable energy in Burkina Faso.

Table 2 : Regulations, Incentives and legislative energy framework at national level (Compiled by author from (ANEREE, 2020; ARSE, 2017; Moner-Girona et al., 2017))

Policy/Sector	Reference document	Description
Production and distribution of energy	Law 014-2017/AN General regulation of the Energy sector.	Electricity production and distribution opened to private sector; transportation network remains under the monopoly of SONABEL.
Electricity	Decree 089/PRES/PM/MCE (2003)	Establishment of the Rural Electrification Fund [Fond de Développement de l'Electrification Rurale (FDE)]
Electricity	National White Paper (LBN) (2006)	Envisaged the provision of modern energy services to the population of the whole country by 2020.
Energy efficiency	Energy savings National Action Plan (2013)	Short term measures to promote sustainable use of energy and improve energy efficiency.
Renewable energy	Inter-ministerial decree N°2020-033/ME/MINEFID/MCIA	Eligibility and modalities for the exoneration of value added tax on importation and sales of solar equipment.
Electricity (Renewable Energy Technology-RET)	Bidding for a target of 225MWp of grid connected solar PV by 2020	Construction started in 2016 of 33 MW_P being extended to $50MW_P$ (Ministry of Energy). A tender was launched and 5 operators recruited for the

Policy/Sector	Reference document	Description
		installation of 68.25MWp in 5 settlements. Development of 26 MWp (WINDIGA energy) Plan for another tender to recruit 5 other operators in 2017 for a total of 80 MWp.
Energy sector reform	Lettre de politique sectorielle de l'énergie (LPSE), 2016.	Renewable energy and energy efficiency identified as crucial axes for the development of the energy sector. Energy law voted 2017.
Renewable energy	Decret N°2016-1200/PRES/PM/MINEFID/MEMC for the establishment of the (Agence Nationale des Energies Renouvelables et de l'Efficacite Energetique-ANEREE)	Establishment in 2016 of the new agency (ANEREE) dedicated to the development of renewable energy Technologies and the implementation of energy efficiency measures in the country.
Energy efficiency	Decree N°2017-1014/PRES/PM/ME/MCIA/MINEFID	Focus on setting energy efficiency obligations/standards applicable to electrical appliances and equipment.

2.4.4. Fossil GHG Emissions in Burkina Faso.

The trend of fossil greenhouse gas (GHG) emissions in Burkina Faso has been an increasing one for several years. Methane accounts for over 50% of the total **Figure 4**, followed by N_2O, then CO_2 (Crippa et al., 2019; PerspectiveMonde, 2019).

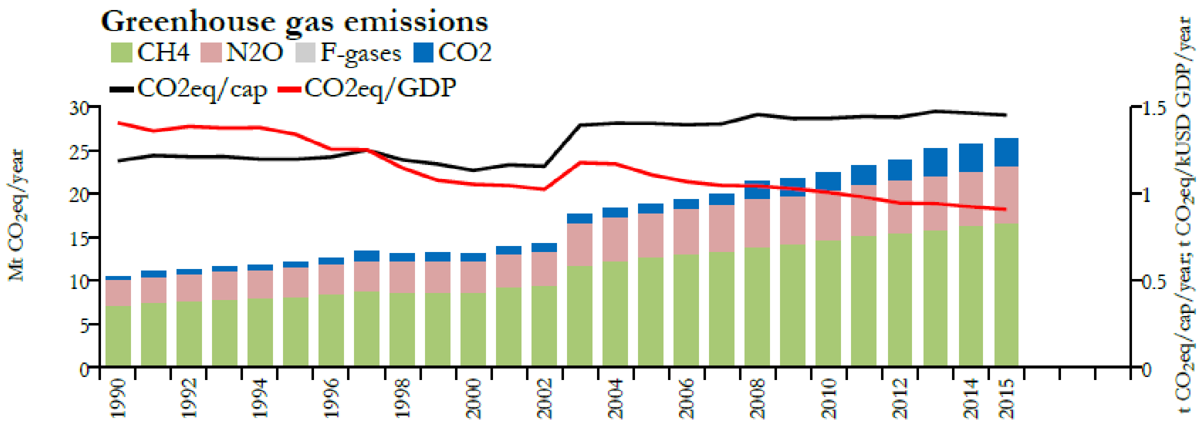

Figure 4 : Greenhouse gas emissions by type Burkina Faso (Crippa et al., 2019)

The National Institute of Statistics and Demography of Burkina Faso conducted an inventory of greenhouse gases which revealed that, carbon dioxide accounts for over 99% of the greenhouse gases emitted by the energy sector; with only traces of the other gases like CH_4 and N_2O appearing in the sector's emissions (MEDD Burkina Faso, 2014).

As shown in **Figure 5** below, fossil carbon dioxide emissions have known a gradual increase over the last decades in Burkina Faso. From about one million tonnes of carbon dioxide emissions estimated for Burkina Faso in the late 90s, in 2018, the emissions were estimated at about 3.7 million tonnes, with an average yearly increase rate of about 8.8%. According to Knoema's 2018 ranking of countries as per their yearly carbon dioxide emissions, Burkina Faso comes 128th out of 180 countries worldwide (Knoema, 2020). The country's carbon dioxide emissions account for about 0.01% of global carbon dioxide emissions from fossil fuels combustion and processes, which have also had an increasing trend (**Figure 6**) with a record of approximately 37 887 million tonnes in 2018, from about 22 637 million tonnes in 1990. It should be noted that the fossil carbon dioxide emissions considered are those resulting from fossil fuel combustion, flaring and in industrial processes (steel, cement, and chemicals) (Crippa et al., 2019).

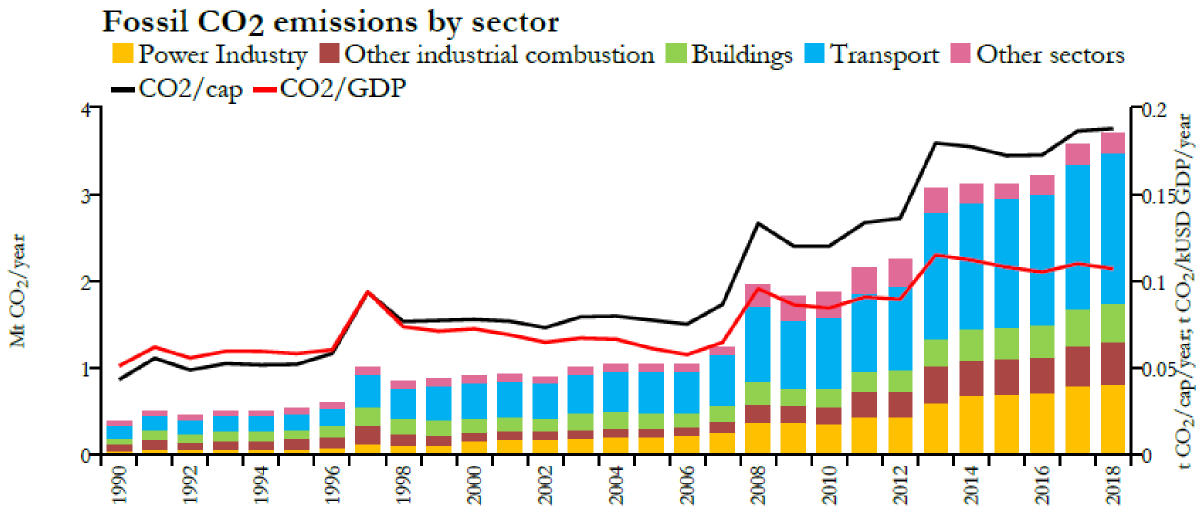

Figure 5 : Fossil CO_2 emissions by sector Burkina Faso (Crippa et al., 2019)

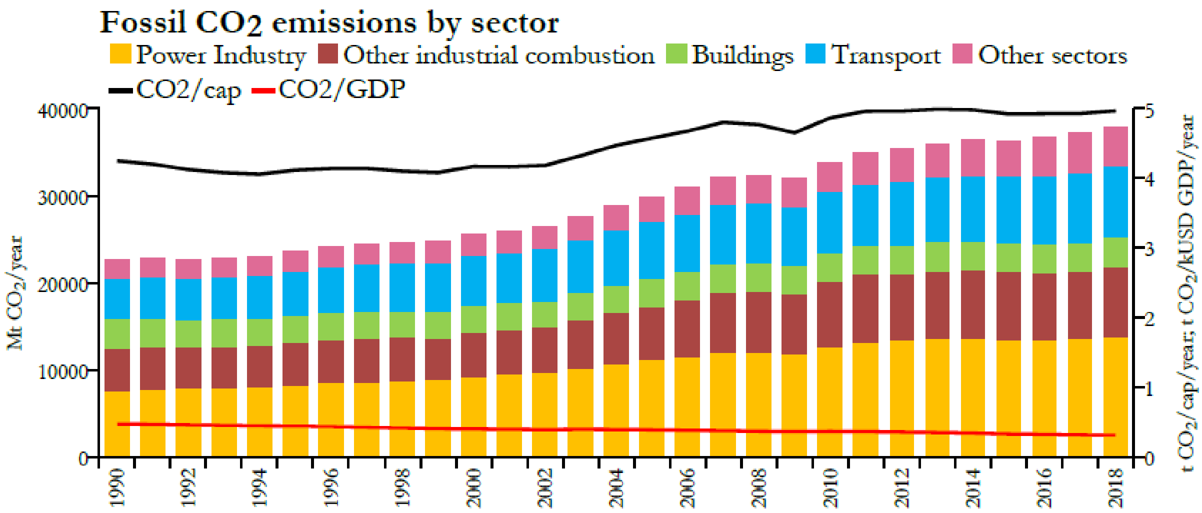

Figure 6 : World Fossil CO_2 emissions by sector (Crippa et al., 2019)

At the global level, since 2010, transport and the generation of heat/electricity accounted for about 67% of total carbon dioxide emissions; industries and buildings are responsible for the rest (IEA, 2019b). It is almost the same tendency in Burkina Faso, but the transport sector is the main emitter. As at 2011, the transport and power industry accounted for approximately 51% and 12% respectively of the country's fossil CO_2 emissions. Buildings, other industrial combustion and non-combustion processes followed, accounting for about 19%, 11% and 7% respectively (Worldometers, 2016). The Ministry of Environment and sustainable development (MEDD) of Burkina Faso categorises the emissions from the energy sector differently. The categories it considers are transport, energy industries, manufacturing/construction industries and the residential sector; accounting respectively for about 60%, 27%, 9% and 4% of carbon dioxide emissions from the energy sector (MEDD Burkina Faso, 2014). In all the sets, transport still remains the highest emitter, followed by the energy industry, buildings and other industries.

A scoping study carried out in 2007 in Burkina Faso by the United Nations Development Program (UNDP) in collaboration with the government revealed a total carbon dioxide emissions mitigation potential of the energy, transport, agriculture, waste and forestry sectors of about 15 million tons between 2007 and 2015 (UNEP RISØ, 2013).

2.4.5. INDC Targets and GHG Emission Reduction Potential of Burkina Faso

In line with the provisions of the UNFCCC and the Kyoto Protocol Burkina Faso ratified in 1995 and 2005 respectively, some country policy and strategy documents were developed and adopted over the years. They include the 2001 National Strategy for implementing the Climate Change Convention, the 2007 National Action Program for Adaptation to Climate Change (NAPA), the Development in 2008 of a framework for a National Appropriate Mitigation Action (NAMA) and the 2014 National Adaptation Plan (NAP) (MEEVCC, 2015).

In December 2015, over 160 countries adopted the International Climate Agreement at the 21st Conference of Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) in Paris. Prior to the COP21 each country presented its Intended Nationally Determined Contributions (INDCs), which outlines its intentional post 2020 climate actions, both mitigation and adaptation to be taken under the new international agreement (WRI, 2020). Burkina Faso was among these countries. Its Ministry of Green Economy and Climate Change made the country's INDCs document available in September 2015. This document presents a Business as Usual (BaU), a conditional and an unconditional mitigation scenarios from the agriculture, waste and energy sectors as shown in **Table 3** below. By 2030, the mitigation scenario is estimated to reduce 21 574.63 million tCO_2e, which accounts for 18.2% reduction of the total carbon emissions (118 323 million tCO_2e) in the BaU scenario by 2030. According to both the conditional and unconditional mitigation scenarios, the energy sector has to address 3.1% and the agricultural sector 15% of the emission reduction target, but the cost of implementation of the projects in the energy sector is way higher than that of the others. About 40% of the total investment cost of mitigation actions falls under the conditional category (MEEVCC, 2015). However, all the adaptation scenarios with a total implementation cost estimated at about $5.8 billion are conditioned by international provisions of implementation means (World Bank, 2016). Therefore, the achievement of both mitigation and adaptation targets highly depends on the obtainment of international funds or investments.

Table 3 : Emission Reduction and related costs of investment for the mitigation scenarios (MEEVCC, 2015)

Scenarios/Sector	Reduction of emissions at the 2030 horizon		Investment cost (in USD)
	In million tCO_2e	In % of reduction	
BaU (subtotal)	188 323		
Unconditional			
Agriculture	7236.3	6.1	21 646 581
Waste	-	-	-
Energy	572	0.5	1 063 272 580
Subtotal Unconditional	7808.3	6.6	1 084 919 161
Conditional			
Agriculture	10 560	8.9	64 939 743
Waste	76.30	0.1	81 228 000
Energy	3130	2.6	609 866 667
Subtotal Conditional	13 766.3	11.6	756 034 410
Subtotal mitigation	**21 574.63**	**18.2**	**1 840 953 571**

Some of the suggested adaptation measures in the energy sector were the diversification of energy resources (wind, biogas, solar) and the promotion of energy efficient technologies in industry and construction processes. Still in line with the achievement of the INDCs, some adaptation actions to be implemented are the production and distribution of 540 000 improved household cook stoves in more than half of the semi urban and urban areas by 2030; this is projected to save about 610 000tonnes of CO_2 per year. There is also the promotion of the use of improved cook stoves by dolo beer brewers, the target is achieving 80% (180000 dolo cook stoves) adoption by 2030 with 95% and 100% in the rural and urban areas respectively; also expected to save about 610000tons of CO_2 emissions yearly (MEEVCC, 2015). Both improved cook stove projects have an estimated implementation cost of about $88 million.

Among other mitigation actions envisaged, there is the implementation of renewable energy based and hybrid mini networks, pico hydro, solar PV and wind systems. The total estimated cost of implementation of these actions is $235.67; 70% of which is conditional. Additionally, the introduction of low consumption bulbs, the reduction of losses from the electricity network, the production of biogas from waste as well as that of biofuels are envisaged. One of the mitigation targets is to install 20MW of solar PV connected to the grid every decade, starting from 2015 (World Bank, 2016).

2.5. The Clean Development Mechanism (CDM)

Tackling climate change issues heavily necessitates both private and public investments. It will only be possible and relevant to attract investments into low carbon projects if in addition to the financial returns; there are clear emission reductions as a measure of the environmental advantages. International carbon markets are one of the strategies put in place in order to clearly and straight forwardly link the decarbonisation effectiveness of the low carbon projects with the financial returns. The Clean Development Mechanism (CDM) developed in the Kyoto Protocol of the UNFCCC came into play at the level of the carbon markets, to bridge these markets in developed/industrialised countries with the struggle to reduce emissions in developing countries (UNEP FI, 2011). According to the CDM, in order to meet part of their emission reduction/limitation commitment, industrialised countries invest in decarbonising projects in developing countries and get credits for the emission reductions achieved. These credits are called Certified Emission Reductions (CERs) and each of them is the equivalent of one ton of equivalent carbon dioxide (tCO_2e) emission reduced (UNFCCC, 2020a).

The emission reduction is obtained from the difference between the amount of greenhouse gas emissions of the project and that which would have been produced within a given period without the project; that is the business as usual scenario used as baseline. This difference is also part of the proof of the project's additionality, which the project developers have to demonstrate in order to qualify for CDM eligibility or accreditation.

2.5.1. Life Cycle of CDM projects

As presented in **Figure 7**, this is the process that a project has to follow in order to be accredited to obtain emission reduction credits. Firstly, the project developer identifies, designs a project idea and describes the method used to calculate the GHG emission reduction; with other important details in the Project Design Document (PDD) as recommended by the CDM. The next step is the validation of the PDD by the Designated National Authority (DNA) of the host country, who submits it to the Designated Operational Entity (DOE), an independent third party certifier. The DOE after analysis and validation submits the PDD and approval document to the CDM Executive Board for registration. The project is then implemented (if not yet done) by the developer who monitors the emission reductions of the project activities; these reductions are verified by the DOE for project certification. If all the criteria are met, the CDM Executive Board or the Designated Authority issues the emission reduction credits to the project developer (Leonardo, 2011; UNDP, 2015b; UNFCCC, 2018a). International carbon markets and certain emissions trading schemes like the European Emission Trading Scheme (EU ETS) are the available markets for CERs.

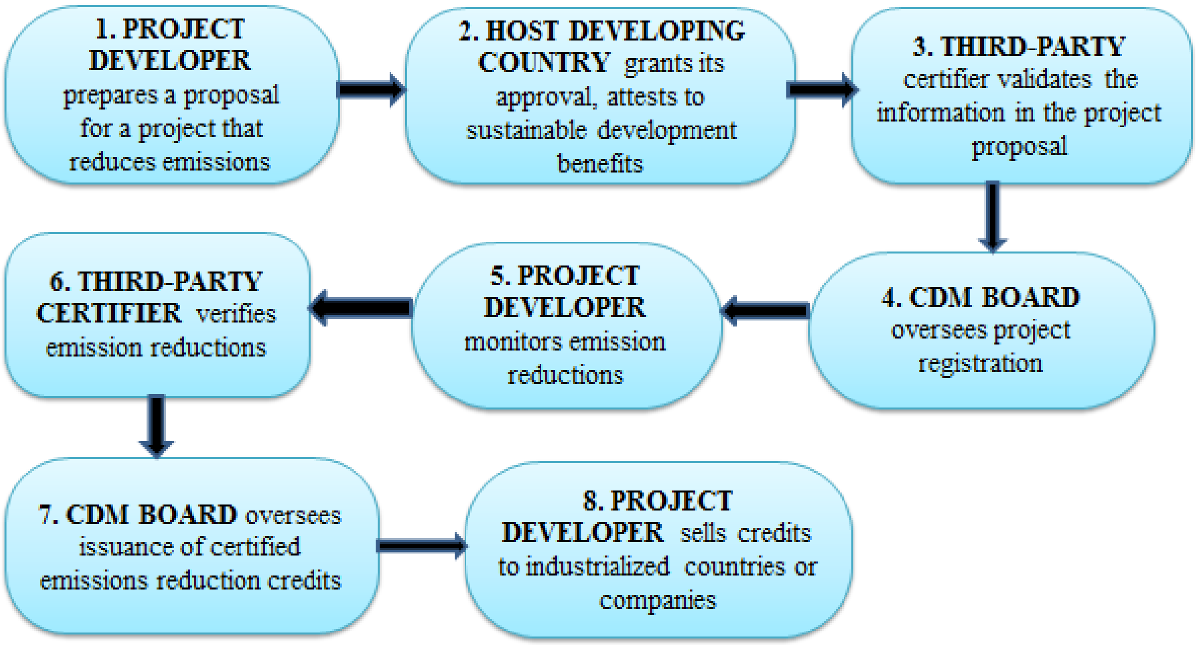

Figure 7 : CDM Project Cycle (UNFCCC, 2018a)

2.5.2. Project Categories Eligible for the CDM

CDM (2012) and UNDP (2015) group these projects in the following categories:

- Energy Efficiency: This includes increasing building efficiency, increasing commercial and industrial energy efficiency. This may include fuel switch such as shifting from more carbon intensive fossils (coal, oil) to less carbon intensive fossils (natural gas). Technology-switch with or without changing energy source can also be applied. For instance, shifting to energy efficient appliances, upgrading instrumentation, controls and/or equipment.

- Renewable Energies: This includes power generation from renewable energy, either by replacing the fossils to the renewables where the energy needs are completely covered or supplying the unmet energy demand using renewable energy sources. For example, solar home systems for powering rural households, electricity generation (on or off grid) by solar farm or wind farms, just to name a few.

- Methane Destruction, Recovery and Formation Avoidance: Methane destruction by Landfill gas flaring. Capturing and utilising methane from landfills, fugitive gas from gas pipelines, sewage/industrial waste treatment facilities, anaerobic digestion of animal waste and others. Avoidance of methane formation from biomass decay through controlled combustion, gasification or mechanical/thermal treatment.
- Agriculture: Using animal waste for energy generation (methane recovery), reduction of N_2O emissions from fertilisers, energy efficiency improvements like switching to low carbon energy sources for water pumping and irrigation.
- Transport: Changes in vehicles and/or fuel type, for example switching to electric vehicles or from fossil fuels to biofuels. Reducing the frequency of the transport activity.
- Cogeneration: Utilising waste heat from electricity generation, such as exhaust from gas turbines, for industrial or heating purposes.
- Industrial process changes: All industrial processes leading to the reduction of GHG emissions
- Carbon capture related projects.

Projects figuring in some of the categories above have been implemented in Africa in general and in Burkina Faso in particular. Nevertheless only RE and EE projects for which data are available will be considered in our study; giving few examples for some African countries and a more comprehensive presentation for Burkina Faso.

2.5.3. Benefits of the CDM and its effectiveness in carbon curbing

In order to be effective, the response to climate change has to be universal and include all the huge emitters. The CDM incentivises countries with or without formal commitments to reduce emissions, to engage in carbon curbing activities, which automatically make them contribute to climate change mitigation or adaption. Additionally, the CDM provides opportunities to developing countries to be attractive to commercial investments, which will locally abate poverty and promote socioeconomic development through the implementation of local infrastructure, technology transfer and job creation in an environmentally friendly approach in line with article 12 of the Kyoto Protocol (UNFCCC, 2020d). As at 2015 (**Figure 8**), only about 2.5% of emission reductions in Africa was covered by the CDM's emission reduction credits, ranking Africa 5th worldwide in terms of CDM effectiveness in curbing carbon emissions (Pillay, 2016). What if the remaining 87.5% were valued in the same way?

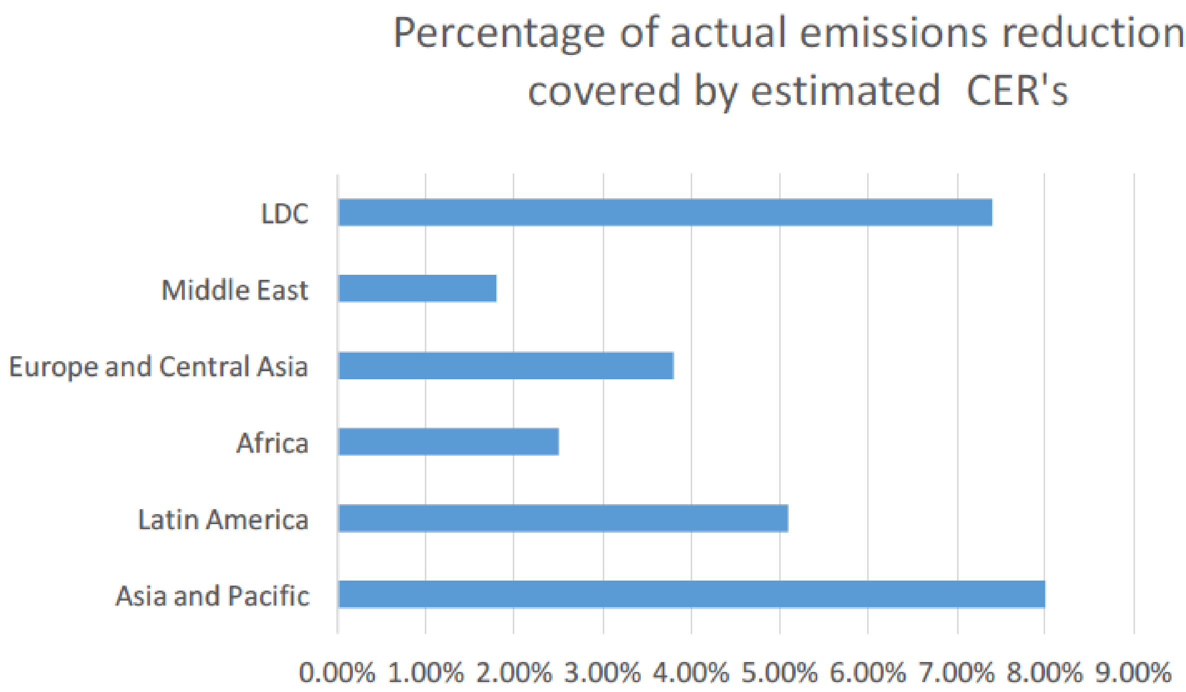

Figure 8 : Impact of CDM on Emission Reduction (Pillay, 2016)

2.5.4. CDM and Sustainable Development

The two main purposes why the CDM was designed were to enable developed countries (CERs buyers) to meet their emission reduction targets and contribute to the achievement of sustainable development in developing countries (host country). The concept of sustainable development involved a number of elements grouped in three main categories: economic, social and environmental. According to some academic findings, the level of GHG emission reduction resulting from CDM projects (**Figure 8**), and the percentage of regional GDP covered by the CERs is considerable (**Figure 9**), attesting the mechanism's contribution to regional environmental and economic development. In spite of the very low representation of Africa (3%) regarding CDM projects worldwide, CERs account for about 40% of the GDP in the continent, ranking it 4th out of the 6 regions so far as CDM contribution to the economy is concerned (Pillay, 2016). The results could be more appealing if Africa could value its huge emission reduction potential and be better represented in the CDM projects globally.

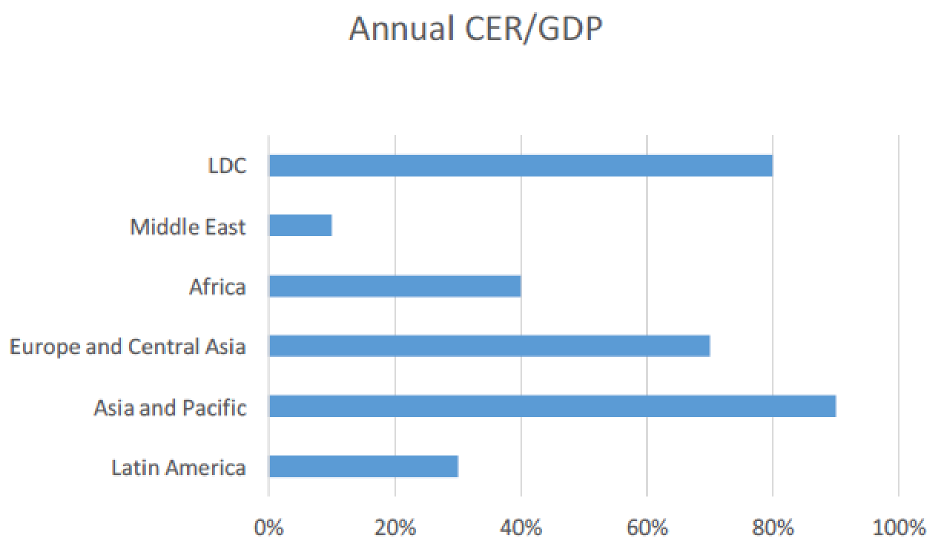

Figure 9 : Macro-economic contribution of the CDM around the world (Pillay, 2016)

However, the view regarding the CDM contribution to environmental and economic development may not be the same at country level. Studies carried out in Nigeria by Pillay (2016) and in South Africa by Pillay (2015) show that in both cases, the CDM projects are unevenly distributed countrywide, both region and sector wise. Also, the objectives of these projects are more directed towards emission reduction and very little focus is placed on education, health and job generation. As a result, most of the benefits of sustainable development related to health, economic growth and technology transfer are secondary products of the GHG emission reduction. They suggest CDM policies that are not mainly focused on reducing emissions, but which promote sustainable development criteria as a whole.

2.5.5. Registered CDM projects distribution by region and by sectoral scope

CDM projects have so far been very inequitably distributed worldwide (**Table 4**). The Asian and Pacific region alone host about 81% of these projects, while Africa where the development of CDM projects and the deployment of carbon finance are insignificant is still at about 3% (UNEP DTU Partnership, 2020). Unlike many Asian and Latin American countries, most countries in sub-Saharan Africa deeply rely on foreign support to design and implement such projects (Michaelowa, 2007); and they remain very poorly represented globally in carbon markets despite their huge unharnessed and attractive financial and environmental potential for CDM. This should urge Africa to take action to harness this potential; a way forward is the valuation (through the CDM) of the emission reductions resulting from the implemented RE and EE projects in the region. Additionally, regarding the distribution of registered CDM projects by sectoral scope, **Figure 10** shows that the energy industry (renewable and non-renewable energy) dominates, as it accounts for over three quarters of all the registered projects. It is worth noting that a project activity can be linked to more than one sectoral scope (UNFCCC, 2020b).

Table 4: Regional Distribution of CDM Projects (UNEP DTU Partnership, 2020)

Region	Number of projects	Proportion per Region
Asia and Pacific	6817	81.4%
Latin America	1111	13.3%
Africa	253	3.0%
Middle East	112	1.3%
Europe and Central Asia	84	1.0%
Total	8377	100%

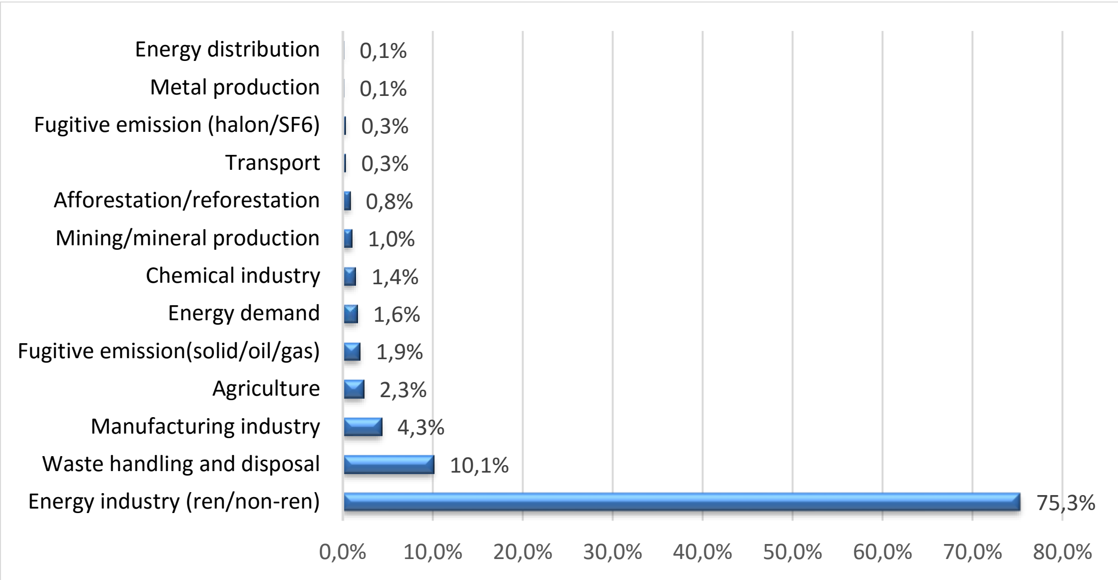

Figure 10 : Registered CDM projects distribution by sectoral scope (UNFCCC, 2020b).

2.5.6. Barriers to the development of CDM projects globally and in Africa specifically

There are currently a total of 8377 registered CDM projects worldwide expected to generate about 8024571 CERs by 2020 (UNEP DTU Partnership, 2020). However, there still exist some persisting constraints to the smooth development and implementation of CDM projects in different instances. These barriers may appear at diverse stages of the project cycle, changing with time and affecting countries/regions according to their context. A study conducted by the Organisation for Economic Co-operation and Development, and the International Energy Agency (IEA) categories these barriers relatively common to many CDM projects globally into four main groups. They may be at the National level, whether CDM related or not, at the project level itself or at the international level (Ellis & Kamel, 2007). Some examples are given below:

- **Constraints not precisely related to the CDM at the national level**, such as unconducive legislative/ policy framework for CDM project operations. For example, national monopoly or regulations that restrain electricity production by independent power producers (IPPs); and the general atmosphere for private investment and business viability.

- **Constraints related to the CDM at the national level**, like weak institutional capability and effectiveness, as well as lack of knowledge about the potential of the CDM. The lack of capacity of the local regulators delays CDM project approval in host countries and hinders CDM project development. Also, some CDM opportunities remain unharnessed as a result of project owners and potential investors been poorly informed about the CDM.
- **Constraints at the project level**, such as the very risky nature of some projects which raise the uncertainty of their performance and render them unfeasible.
- **Constraints at the international level**, such as those related to the eligibility of some projects. Some rules of CERs buyer countries consider the credits of certain CDM projects ineligible.

The poor achievement of the CDM objectives in the developing countries, especially in SSA is due to some specific constraints they face. For instance, in sub Saharan African countries, the projects usually have a low commercial attractiveness because they are small, meanwhile the costs of transactions applied are high. Moreover, in some cases, they still rely on foreign expertise to produce the project design document needed for the CDM project registration process, revealing the need for local capacity building for both the public and private stakeholders. Furthermore, the processes of decision making for the delivery of letters of approval for example are often lengthy and unfortunately arbitrary, because of the lack of capacity and transparent rules within the Designated National Authority (DNA). In addition to the absence of Designated Operational Entities (DOEs) in Africa due to the reduced scale of CDM processes in the region, the international DOEs lack the expertise and know how adapted to the local context. Additionally, in order to define the baseline of a project, the emissions data for the Business as Usual scenario is needed. "Simple" emission reduction opportunities may be identified, but the lack of the baseline data hinders their progress to CDM projects. Besides the above mentioned barriers, SSA countries also poorly score when it comes to the institutional setting, the knowledge of the local situation by investors as well as the attractiveness of the political and socioeconomic environment for private investments; which are all crucial for the viable development of CDM projects (UNEP FI, 2011). Therefore, an enabling legislative/policy framework, appealing CDM opportunities and an attractive investment environment are factors which combined, would drive the emergence of the CDM activity of countries globally and in Africa in particular.

In a bid to enable African countries to play their role and benefit from the CDM, a CDM Assist program funded by the Energy Sector Management Assistance Program (ESMAP) and other bilateral sponsors was put in place. The program focused on awareness enhancement and capacity building with hands on experience in real CDM projects. The purpose been to improve the continent's ability to attract CDM projects and to build the capacity necessary to develop and manage them. For instance, coaching the countries on processes related to the negotiation, generation and transfer of CERs (ESMAP, 2005; World Bank, 2001).

A number of African countries showed interest for this program, amongst which were Kenya, Burkina Faso, Benin, Ghana, Nigeria, Malawi, Mauritius, Senegal, Togo, Swaziland, Madagascar, Uganda, Zimbabwe and Zambia. Each country requested support from the CDM Assist for specific issues, such as for the baselines assessment and monitoring, auditing, verification, risks and cost assessments as well as certification of project activities (ESMAP, 2005).

2.5.7. The CDM potential and state of the CDM in Africa

Timilsina et al. (2010) investigated the technical potential of the energy sector in sub Saharan Africa (SSA) to reduce GHG emissions, focusing on 22 selected technologies in 44 SSA countries. They found that 3227 CDM projects including 361 programs of activities could be developed in this part of the continent. Using approved CDM baseline and monitoring methods, they estimated these projects' total mitigation potential at 740.7 million tCO_2e annually and about 9.8 billion tCO_2e through the CDM project life (10 or 21 years depending on the project type). South Africa presents the highest potential with 2325.1 million tCO_2e and Cape Verde the list with 0.7 million tCO_2e (**Table 5**). According to this study, these projects could significantly boost the economic development of the region if implemented, as they could attract a total investment of over $200 billion. Added to that, $7.4 billion and $98 billion is what could be generated respectively yearly and through the project life from the sales of the CERs generated, considering a carbon price of $10/ tCO_2e. In addition, 21.5 GW of added generation capacity could be avoided by the energy efficiency CDM projects, meanwhile 149 GW of clean electricity generation capacity could be added by the other projects. However, the realisation of this CDM potential entails setting strategies to overcome some technical, financial, institutional and regulatory barriers.

Table 5 : Distribution of potential CDM projects and emission reductions by country (Timilsina et al., 2010)

Country	Project		Emission reduction	
	No.	% of the total	Million tCO_{2e}	% of the total
Angola	251	5,2	520,5	5,3
Benin	51	1	80	0,8
Bissau Guinea	16	0,3	10,4	0,1
Botswana	42	0,9	128,9	1,3
Burkina	30	0,6	82,7	0
Burundi	13	0,3	6,5	0,1
Cameroon	70	1,4	167,6	1,7
Cape Verde	4	0,1	0,7	0
Central African Republic	27	0,6	127,4	1,3
Chad	45	0,9	98,9	1
Comores	12	0,2	1,1	0
Congo Dem	170	3,5	696,8	7,1
Congo Rep	34	0,7	116,5	1,2
E. Guinea	33	0,7	62,5	0,6
Ethiopia	163	3,3	485,5	5
Gabon	56	1,1	108,9	1,1
Gambia	8	0,2	0,8	0
Ghana	149	3,1	187,4	1,9
Guinea	41	0,8	115,7	1,2
Ivory Coast	251	5,2	233,3	2,4
Kenya	317	6,5	265,9	2,7
Liberia	22	0,4	23,8	0,2
Madagascar	107	2,2	143,9	1,5
Malawi	90	1,8	90,7	0,9
Mali	37	0,8	94,8	1
Mauritania	36	0,7	32,3	0,3
Mauritius	26	0,5	12,9	0,1
Mozambique	123	2,5	415,7	4,2
Namibia	37	0,8	223,8	2,3
Niger	24	0,5	54	0,6
Nigeria	563	11,6	1 503,90	15,4
Rwanda	13	0,3	7,6	0,1
Senegal	55	1,1	102,9	1,1
Seychelles	5	0,1	5,7	0,1
Sierra Leone	22	0,5	26,9	0,3
Somalia	67	1,4	253,8	2,6
South Africa	834	17,1	2 325,10	23,8
Sudan	389	8	118,1	1,2
Swaziland	18	0,4	13,7	0,1
Tanzania	194	4	332,3	3,4
Togo	52	1,1	53,1	0,5
Uganda	144	3	160,8	1,6
Zambia	159	3,3	297,6	3
Zimbabwe	70	1,4	160,4	1,6
Sub-Saharan Africa Total	**4 871**	**100**	**9785**	**100**

Christof et al. (2011) also researched on the CDM project technical potential in SSA focusing on 11 countries, namely Zambia, Uganda, Rwanda, Senegal, Tanzania, Mozambique, Mali, Malawi, Ethiopia, Democratic Republic Congo (DRC), and Burkina Faso. The sectors considered for the CDM potential evaluation include waste potential, renewable energy, energy efficiency, transportation and potentials in mining, charcoal and cement production. The investigation concludes that the total annual emission reduction potential of these countries amounts to about 128.6 million tCO_2e, representing about 128.6 million CERs generated annually. Ethiopia tops the list with an emission reduction potential of about 32 million CERs per year, and Rwanda presents the list potential of about 2.3 million CERs per year (**Table 6**). They also pointed out lack of finance, limited technical and human resources as well as lack of institutional capacity as constrains that need to be alleviated to enable the exploitation of this potential. Burian & Christof (2014) also confirm Africa's huge potential to abate CO_2 emissions, and places emphases on the weakness of the institutional framework as a factor that slows down the development of CDM projects in the continent.

Table 6 : Emission reduction potential of selected SSA countries (Burian & Christof, 2014)

Country	Emission reduction potential (million CERs/year)
Ethiopia	32.00
Tanzania	24.51
DRC	18.08
Uganda	17.66
Mozambique	8.70
Malawi	7.21
Zambia	6.47
Senegal	6.12
Burkina Faso	2.96
Mali	2.63
Rwanda	2.26
Total	**128.60**

Although Africa has a very significant GHG abatement potential, till date only 253 out of the 8377 projects in the CDM pipeline are in Africa. Africa will account for only 3.5% of the CERs issued by 2020, given that they would yield a total of 280 327 000 CERs (about 280.3 million CERs) by the end of this year (UNEP DTU Partnership, 2020).

2.5.7.1. Examples of successful CDM projects for illustration

Despite all the challenges that constrain the implementation of CDM projects in Africa, thereby slowing down the achievement of the CDM driven sustainable development in the region, a study by the Climate Change Working Group (CCWG) and African Task Force (ATF) of the United Nations Environment Programme Finance Initiative (UNEP FI) identified some successful CDM projects in the continent. These CDM projects have been implemented successfully, with the generation of environmental, developmental and financial returns. These successful achievements were the result of the commitment and good practices of both private and public sector stakeholders which could be followed by others for contextualised replication and expansion within the countries in particular and region in general. Few examples of these successful projects are given below to serve as a push for Burkina Faso and other African countries to activate strategies and actions necessary to join the flow. Each case is compared with Burkina Faso because it is our case study area. These examples are also to encourage the owners of similar existing projects in the region, to register to the CDM and take advantage of its benefits.

Firstly, there is the Landfill gas recovery and electricity generation project at Mtoni landfill in Tanzania. The purpose of the project is to collect and flare the biogas mainly composed of methane emitted from the landfill. This reduces carbon equivalent emissions as methane's Global Warming Potential is 21 times that of carbon dioxide. The next phase of the project would involve the use of the gas to generate electricity. The estimated quantity of emission reduction by the project is about 2 million tonnes of CO_2e, on a crediting duration of ten years. UNEP FI (2011) gives details on the challenges and success factors of this project and others in Africa. Burkina Faso has a proven potential for landfill biogas which can be productively exploited through the CDM. In 2018 for example, the Polesgo landfill in Ouagadougou capital city emitted over 40 025 tonnes of CO_2e, a good demonstration of wasted potential (Haro et al., 2019).

Secondly, there is the improved cook stove project of the Nkhata Bay district in Malawi, which is estimated to reduce about 32 672 tonnes of CO_2e emissions on an annual basis, with a crediting period of 10 years (CDM, 2020b). The project provides more efficient cook stoves, which consume less fuelwood and produces less smoke compared to the traditional three stone fire. As a result, in addition to reducing emissions, the project abates deforestation as well as respiratory diseases in the population. More details on the economic, environmental and social benefits of the project, as well as some constrains are available on the Carbon Offset platform of the UNFCCC (UNFCCC, 2020b). Burkina Faso has the proven potential to reduce about one million tonnes of CO_2e annually through the use of improved cooking stoves (UNEP RISØ, 2013). There are already existing projects related to efficient cook stoves in the country, but they need to be registered as CDM projects in order to have access to the mechanism's benefits.

Lastly, there is the Nova Power solar PV project in Korhogo, in northern Cote d'Ivoire. The project provides a grid-connected solar PV power plant of an installed capacity of 25MW. Its annual emission reduction capacity is of about 22 679 tonnes of CO_2e, with a crediting period of seven years (CDM, 2020d). In addition to the benefits of CDM projects, this project helps among others to reduce the burden of growing electricity demand on the grid; it increases renewables in the country's electricity mix while increasing access to electricity in the country in an environmental friendly fashion. Cote d'Ivoire is a "good" example for Burkina Faso, as it is one of the main countries from where Burkina Faso imports part of its electricity. Burkina Faso's potential to reduce emissions through the exploitation of solar energy is undoubtable, given its huge solar potential. There are so far three solar PV CDM projects in the country with a total estimated annual emission reduction capacity of about 47 836 tonnes of CO_2e (CDM, 2020a, 2020h, 2020e). This is encouraging, but a lot more needs to be done in order to productively harness the natural potential through the CDM. A good start would be to register the already existing projects in this sector to the CDM.

2.5.7.2. RE and EE projects implemented in other African countries, but not registered to the CDM

In **Table 7** below are presented some examples of RE and EE projects which have been implemented in some African countries, but which are not registered to the CDM. The installed capacity of each project is given and where applicable (available data), the emission reduction is also provided. This is an illustrative way to show that there are also countries in Africa other than Burkina Faso which are hosts to unharnessed CDM potential.

Table 7: Renewable Energy and Energy Efficiency Projects implemented in some African Countries but not registered to the CDM.

Country	Region in Africa/Inauguration year	Project/Developer	Installed capacity (MW)	Annual energy savings (MWh/year)	Est. Annual emission reduction (tCO_2e)	Source
Kenya	East/2019	Garissa Solar PV power plant/ Rural Electrification and Renewable Energy Corporation (REREC), Kenya.	50	---	64 190	(REREC, 2020)
Senegal	West/2017	Malicounda Solar PV power plant/Solaria Kima	22	---	---	(ECREEE, 2018)
Ghana	West/2018	Gomoa Onyoadze Solar PV power plant/ Meinergy Ghana.	20	---	---	(Ngounou, 2018)
	West/ 2009	National compact fluorescent lamp exchange program/Ministry of Energy, Ghana.	---	172 800	112 320	(Amoah et al., 2018)
	West/ 2012-2016	Refrigerator rebate and exchange scheme; about 10000 fridges exchanged/ Government, UNDP, Global Environment Facility (GEF).	---	8 150	---	(Graphic Online, 2016; UNDP, 2015a)
Benin	West/2017	Djougou Solar PV plant	5	---	---	(ECREEE, 2017)
Algeria	North/2016	High plateau East Adrar solar PV plant/ Built by Sinohydro Corp	90	---	---	(USC Africa, 2016)

		(PowerChina), Yingli Green Energy Holding, HydroChina.				
		High plateau Centre Adrar solar PV plant/ Built by Sinohydro Corp (PowerChina), Yingli Green Energy Holding, HydroChina.	90	---	---	
DR-Congo	Central/ 2019	Hybrid Solar PV – Genset power plant in Goma/ Nuru	1.3	---	---	(Takouleu, 2020)
Zambia	South/2019	Bangweulu Solar PV plant Zambia /Neoen and Industrial Development Corporation (IDC)	54	---	---	(Takouleu, 2019)

2.5.8. The CDM potential and state of the CDM in Burkina Faso

According to a study done by the UNDP Burkina Faso in collaboration with the Designated National Authority (DNA), different sectors/technologies in Burkina Faso have potential opportunities for the CDM. **Table 8** presents an estimate of each sector's annual emission reduction potential, with the CDM method used for estimation. The total annual emission reduction potential of the country, for the sectors considered amounts to about 108.5 million tCO_2e. The study considered a number of technologies, each of which contributes none negligibly to this abatement. Some of them are: Solar PV, Improved stoves, biodiesel, Afforestation/Reforestation, solar lighting and gold mining. Even though these estimations where specified not to be precise, they at least reflect the country's relative attractiveness for carbon finance (UNEP RISØ, 2013).

Table 8 : Emission reduction potential per technology type, Burkina Faso (UNEP RISØ, 2013).

Technology type	Emission Reduction Potential per year (tCO2e)	Baseline Methodologies
REDD + / avoided deforestation	9, 672,652	Historical baseline
Afforestation/Reforestation	96, 726,520	AR-AM1, AR-AM3, AR-AM4, AR-AM5, AR-AM9, AR-AM10, AR-AMS1, AR-ACM1, AR-ACM2
Charcoal	455,525	AMS-I.C., AMS-III.K., AM41
Biodiesel	3,600	ACM0017, AMS-III.AK., AM0041
Bagasse	17,390	ACM2, ACM6, AM36, AMS-I.D., and AMS-I.C.
Liquid Waste (manure)	242,488	AMS-I.A,C,D. AMS-III.H. AMS-III.D., AMS-III.F., AMS-III.I., ACM14, AM25, AM80
Solid Waste	15,700	AM36, ACM6, ACM2, AMS-I.C., AM36, ACM6, ACM2, AMS-I.D., AMS-I.C., ACM6, ACM2, AMS-I.D. and AMS-I.C.
Hydro	68,250	ACM2, AMS-I.D., AM26, AMS-I.A., AM5, AM26, AMS-II.B., ACM11, ACM12, AM52
Solar lighting	180,000	AMS-I.A., AMS-II.J.

Technology type	Emission Reduction Potential per year (tCO2e)	Baseline Methodologies
Solar PV	42,000	ACM2, AMS-I.A., AMS-I.C., AMS-I.D.
Improved stoves	1, 000,000	AMS-I.C., AMS-I.E., AMS-II.G.
Cement	5,300	ACM12
Mining (gold)	100,000	AM64 ACM8
Brewery	3,600	Depends
TOTAL	**108533025**	

Nevertheless, till date, Burkina Faso hosts only three CDM registered solar photovoltaic power plant projects; the Zagtouli, the Zina, and the IAMGOLD Essakane SA Gold Mine with respective installed capacity/annual emission reduction potential of 17 MW/ 14,696 metric tonnes CO_2e, 22MW/ 13,236 metric tonnes CO_2e and 15MW/ 19,904 metric tonnes CO_2e. Burkina Faso is also among the host countries of some program of activities (PoA), related to the promotion of efficient stoves dissemination and use in West Africa, the West African bio digester and the landfill gas capture, flaring and utilisation program in Africa (CDM, 2020b, 2020g, 2020d, 2020e, 2020f, 2020c).

Burkina Faso has shown its will to promote the implementation of CDM projects in the country. It is amongst the African countries that engaged in the CDM Assist program funded by the Energy Sector Management Assistance Program (ESMAP) and other bilateral sponsors. During this awareness and capacity building program, Burkina Faso focused on baselines assessment and monitoring, auditing, verification, risks and cost assessments as well as certification of project activities (ESMAP, 2005). Burkina Faso was also involved in some capacity development programs implemented by the Carbon Finance Assist (CF-A), which is a multi-donor trust fund set up as a capacity building and technical assistance program in complement to the World Bank's Carbon Funds. The program is to promote the full participation of developing countries and economies in transition in the carbon markets (World Bank, 2008). So far, Burkina Faso has a Designated National Authority (DNA), it hosts few registered CDM projects and is involved a number of Programs of Activities. However, there is still a lot of CDM potential (RE and EE projects) that could be exploited to actually enable the country to benefit from the Clean Development Mechanism.

2.6. Tools for GHG emissions assessment

As defined by the international standard ISO 14064-1 and the greenhouse gas protocol, greenhouse gas emissions can either be direct or indirect. The direct emissions represent those whose sources are owned or controlled by the entity (company, organisation, facility, etc), while the indirect emissions are those that occur as a result of the activities of the entity reporting, but at sources which are owned or controlled by another entity (ADEME, 2017;

GHG Protocol, 2020). All these emissions are grouped into three wide scopes (**Figure 11**). The first called scope 1 includes all the direct greenhouse gas emissions, such as those from on-site electricity/heat generation, fugitive emissions (like refrigerants), etc. The second called scope 2 includes the indirect greenhouse gas emissions originating from the generation of purchased energy (heat, steam or electricity). Finally, scope 3 includes all the other indirect emissions that occur throughout the entity's value chain, such as emissions from the extraction and production of purchased fuel and material, waste disposal, transport activities using vehicles not controlled or owned by the entity, etc (GHG Protocol, 2020; Keoleian, 2019). There exists a number of calculation tools used to account for GHG emissions. Some of which are: Bilan Carbone®, GHG Protocol and ISO 14064, and are compatible with each other.

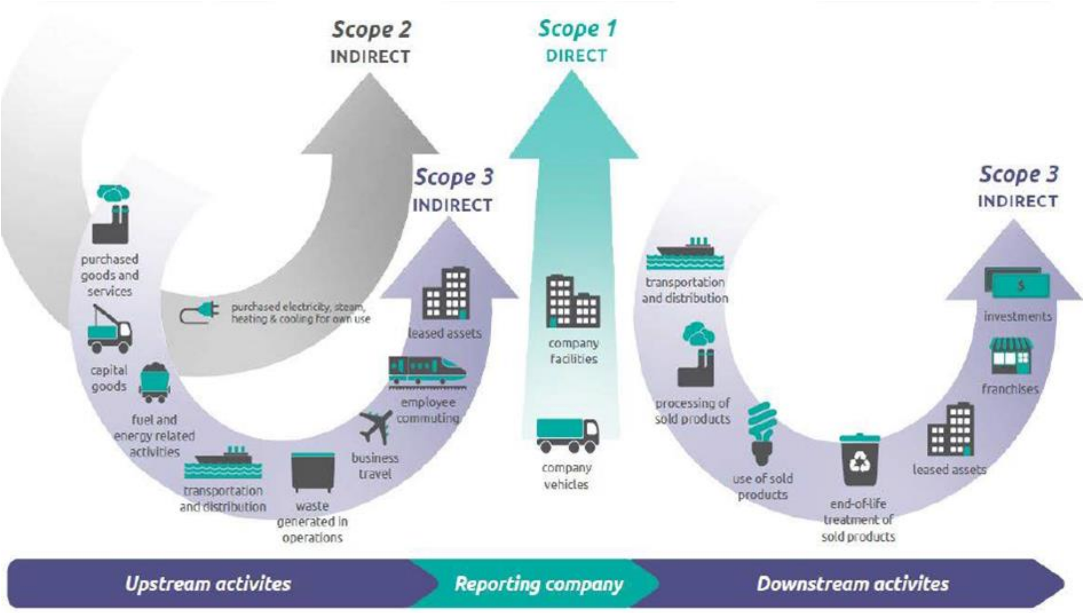

Figure 11 : GHG Protocol scoping approach (Keoleian, 2019)

2.6.1. Bilan Carbone®

Bilan Carbone® is a method developed by the Environment and Energy Mastery Agency (ADEME) and the Bilan Carbone Association (ABC) for the exhaustive evaluation of the GHG emissions of organisations, projects and events. It also guides them in identifying and implementing emission reduction pathways. This method is quite inspired by the international standard ISO 14064. The GHG emission calculation tool it provides considers all GHG covered by the Kyoto Protocol (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) (ADEME, 2017). The approach of this method is to identify all the physical flows (energy, people, objects, etc.) and assign to each the GHG they emit. However, GHG emissions are rarely directly measured, it is instead their concentration in the air which is measured (Jancovici, 2003). The main data set required by this tool are activity data and related emission factors. Meanwhile the activity data should be verifiable and representative regarding the activities within the scope of evaluation defined, the emission factors should as well be reliable and coherent with the type of activity data (ADEME, 2017). With this data, the GHG emissions are calculated as follows:

GHG Emissions = Activity level x corresponding emission factor

2.6.2. GHG Protocol

The GHG Protocol initiative provides internationally accepted standards which are very widely adopted, to account and report GHG emissions at corporate and project levels. It was developed by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) in partnership with non-governmental organizations (NGOs), businesses, governments and others and launched in 1998. In addition to providing calculation tools for GHG accounting which may be sector specific, cross sectoral and country specific, it also offers data such as some emission factors. These tools consider all GHG covered by the Kyoto Protocol (GHG Protocol, 2020; WBCSD, 2020).

2.6.3. ISO 14064

In 2006 was published the ISO 14064 standard, which is in the series of the ISO 14000 related to environmental management. The ISO standard 14064 offers a set of tools for the quantification, monitoring, reporting and verification of GHG emissions to businesses, governments and other organisations. It also assists organisations to engage in voluntary and regulated programmes such as public reporting and emissions trading schemes using a standard recognised globally. It includes three parts; parts one (ISO 14064-1) and two (ISO 14064-2) specify the requirements and principles for quantifying, monitoring and reporting GHG emissions and removals at the organisational and project level respectively. Meanwhile, part three (14064-3) deals with principles, requirements and guidance for the verification and validation of GHG declarations both at the project and organisation levels (ISO, 2018, 2019a, 2019b).

2.6.4. CDM approved methodologies

There are methodologies approved by the CDM’s Executive Board for specific project types. The methodological tools to which these methodologies refer address specific aspects of the project activity. For instance, a tool may address the calculation of GHG emissions from specific sources. These methodologies are grouped into five main categories:

- Large scale CDM project activities’ methodologies;
- Small scale CDM project activities’ methodologies;
- Large scale afforestation and reforestation CDM project activities’ methodologies;

- ➢ Small scale afforestation and reforestation CDM project activities' methodologies;
- ➢ Carbon capture and storage project activities' methodologies.

The approaches used in these methodologies for the calculation of GHG emissions are also in line with those of the other tools afore mentioned, but with little peculiarities for each project category. Projects which are projected to register to the CDM must apply adapted approved baseline and monitoring methodologies to determine the baseline emissions and the projects emissions. This enables the project developer to determine the project's emission reductions or net removal, which will give way to the determination of the number of CERs generated by the low carbon project (UNFCCC, 2019a). Given that the present study is meant to encourage projects' registration to the CDM, the approved CDM methodologies are those considered herein to determine the emission reductions of the projects selected. The large number of existing methodologies (UNFCCC, 2020c) does not allow us to include them here; nevertheless the CDM methodology considered will be specified in each case.

2.7. Summary

The review has shown the importance of RE and EE in the struggle to abate carbon emissions globally (Akdag & Yıldırım, 2020; Gielen et al., 2019; Özbuğday & Erbas, 2015) and in Africa (Inglesi-Lotz & Dogan, 2018; Prince & Okechukwu, 2019). Also, we find that over 40% of the African population still lacks access to electricity, with SSA being more affected. Nevertheless, most countries have put in place energy policies and set targets involving RE and EE measures to tackle this issue. Burkina Faso highly depends on fossil fuel and imports for electricity supply, with less than 1% of solar energy in its electricity mix, despite its huge solar potential. Access to electricity in the country is less than 20% (Moner-Girona et al., 2017). There are however institutional and legislative frameworks creating an enabling environment to promote RE and EE in the country. The country has shown increasing GHG emissions over the years, but it remains negligible (0.01%) besides the global level (Knoema, 2020). There are already mitigation scenarios suggested to abate these emissions.

According to some scholars, the CDM actually contributes to Africa's environmental and economic development, with 2.5% of emission reductions in the continent and 40% of the continent's GDP covered by CERs (Pillay, 2016). Some academic findings demonstrate Africa's huge potential for the CDM (Christof et al., 2011), but Africa is host to only about 3% of registered CDM projects globally (Burian & Christof, 2014; Christof et al., 2011; Timilsina et al., 2010), for which the energy industry accounts for over 75% (UNFCCC, 2020b). It is also the case with Burkina Faso which is host to less than 5 CDM projects till date despite its proven CDM potential. These CDM potential estimations were done based on identified project opportunities, and not real implemented projects. The main barriers identified for the development of CDM projects in Africa are technical, financial, institutional and regulatory (Burian & Christof, 2014; Christof et al., 2011; UNEP FI, 2011). However, programs like the CDM Assist program to which several African countries including Burkina have shown interest, have been put in place to enable these countries to attract CDM projects and build the capacity required to develop and manage them (ESMAP, 2005). Burkina Faso for instance already has a Designated National Authority (DNA) (UNEP RISØ, 2013).

As mentioned above, previous studies estimated the CDM potential based on identified CDM opportunities and not real implemented projects. Meanwhile, the African continent in general and Burkina Faso in particular is host to several implemented and operational RE and EE projects that could be potential opportunities for the CDM. This study seeks to present some of these projects in some selected African countries, and make a detailed inventory of such projects in Burkina Faso. Moreover, it seeks to make use of appropriate approved CDM methodologies to determine their emission reduction potential, in order to determine their attractiveness for the CDM. These are low hanging fruits that could be exploited through the CDM in a short term, and start gaining the CDM's advantages while envisaging to materialise other identified project opportunities.

3. RESEARCH METHODOLOGY

3.1. Introduction

In this chapter, the RE and EE projects implemented in Burkina Faso that where inventorised in the course of this study are presented. Moreover, the CDM methods used to determine these projects' emissions reduction are given, and the emission reductions are calculated. Furthermore, the state of additionality of each project is given in accordance with the appropriate CDM method.

3.2. Scope

The CDM projects types considered in this study are those in the category of renewable energy and energy efficiency. An inventory of such projects implemented in Burkina Faso from 2012 to 2020, but not registered to the CDM was done. The secondary data about the projects and some country data were provided by the 2iE and different national entities, including the Ministry of Energy through the ANEREE and the ABER. Other information was directly gotten online from open access journals, reports and different websites. Of all the projects identified, only those for which relevant data was available were selected for further analysis.

One of the key criteria for a project to be registered to the CDM is a proof of its additionality. This entails amongst others, showing the emissions savings are solely a result of the project's activities and would not have occurred without the implementation of the project concerned (CDM, 2020a). This is where this study comes into play, aiming to determine the emission reductions of the projects implemented.

For each of the selected projects, the additionality, the baseline emissions (BAU scenario), the actual emissions with the projects (project scenario) and the quantity of annual emission reductions were determined, giving room to estimate the number of CERs which they could generate if they were registered to the CDM. The crediting period of each of the projects were also considered to determine the total number of CERs they could provide. It is worth noting that the list of RE and EE projects implemented in Burkina Faso, which is presented in this study is not exhaustive, due to difficulties in obtaining data. The confirmation that these projects are not registered to the CDM was done by searching on the UNFCCC CDM project search, and also through information gotten from the institutions which provided the data.

The crediting period of a proposed CDM activity can either be a fixed (non-renewable) period of ten years or a period of seven years, renewable at most two times (UNFCCC, 2011a). The renewal of a registered CDM project activity's crediting period is only possible if the original baseline data is still valid, or has been updated in accordance with the new data where applicable. The DOE concerned verifies these parameters and informs the CDM executive board who grants the renewal where applicable (UNFCCC, 2011b). In this study, a fixed crediting period of 10 years will be considered for all the projects to estimate the number of CERs they could generate within that timeframe.

Given that the present study is meant to encourage projects' registration to the CDM, the approved CDM methodologies are those considered herein to determine the emission reductions and the proof of additionality of the projects selected. The CDM methodologies considered are: AMS-II.C., AMS-II.L., AMS-I.A., AMS-I.F., AMS-I.D and AMS-III.AR.; they will be specified in each case. The calculation approaches applied are provided for individual projects, given that the parameters to be considered may vary even within the same method with different factors like project type and data available. The grid emission factor of the country's electricity system used in this study is of 0.7 tCO_2e/ MWh (Moner-Girona et al., 2017; UNEP RISØ, 2013). The emission factors used in other cases are default values proposed by the CDM method applied.

3.3. CDM Methods Applied

A. Energy Efficiency Related Projects

The energy efficiency related projects inventorised herein fall under the specific groups below as per their classification in the most recent edition (11th edition, November 2019) of the CDM Methodology Booklet (UNFCCC, 2019a).

a) AMS-II.C. : Small-scale Methodology, Demand-side energy efficiency activities for specific technologies - Version 15.0

This method concerns the installation of new energy efficient equipment such as lamps, air conditioners, refrigerators, pumping systems, ballasts, fans and motors, at one or more project sites as retrofit or Greenfield projects. The mitigation action here involves the use of more efficient technologies to displace more GHG intensive services. The main conditions for this method to be applicable are cases where the installed project energy efficient equipment's service level (such as rate capacity or output) ranges from 90% to 150% of the baseline equipment's service level. For example, the service level of lighting equipment like a lamp is its light output. Also, the aggregated annual energy savings by one project should not be more than the equivalent of 60GWh/year (UNFCCC, 2016). As presented in **Figure 12**, in the BAU, less energy efficient equipment is used, resulting in more energy consumed and consequently more GHG emissions. However, in the project scenario, the equipment is more energy efficient, implying less energy consumed and therefore less GHG emitted.

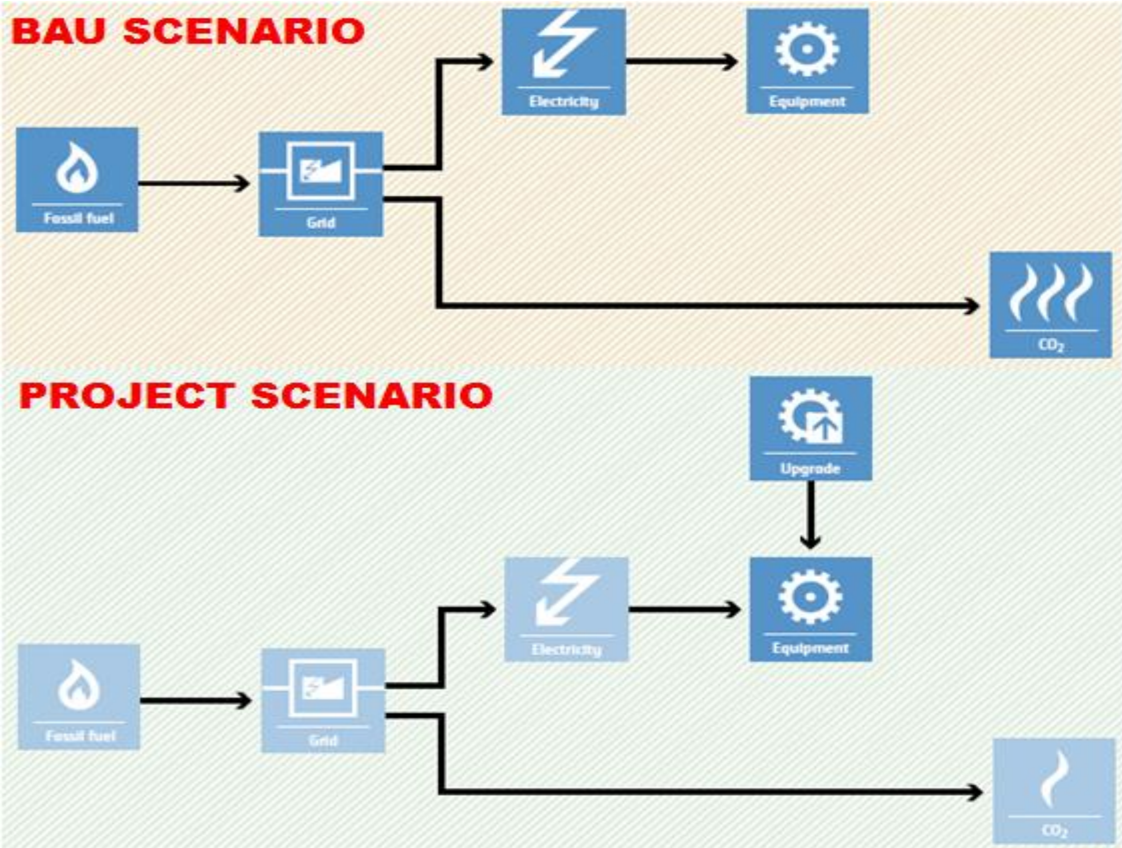

Figure 12: BAU Scenario and Project Scenario of CDM method AMS-II.C. (UNFCCC, 2019a)

b) AMS-II.L.: Small-scale Methodology, Demand-side activities for efficient outdoor and street lighting technologies - Version 02.0.

This method involves the replacement of less efficient lamps and/or fixture combinations by more efficient ones in public or utility owned street lighting systems, thereby reducing electricity consumption and consequently reducing GHG emissions (**Figure 13**). The mitigation action considered is therefore the displacement of less efficient lighting technologies by more efficient ones. This methodology can be applied for project activities involving amongst others: one for one and/or multiple for multiple lamps replacements, Greenfield and/or retrofit installations, continuous replacement of failed lamps, the installation of lamps whose lighting performance is equivalent or better than that of the baseline, and the identification of baseline technology for Greenfield using the region's data (UNFCCC, 2019a). Also, the aggregated annual energy savings by one project should not be more than the equivalent of 60GWh/year (UNFCCC, 2013).

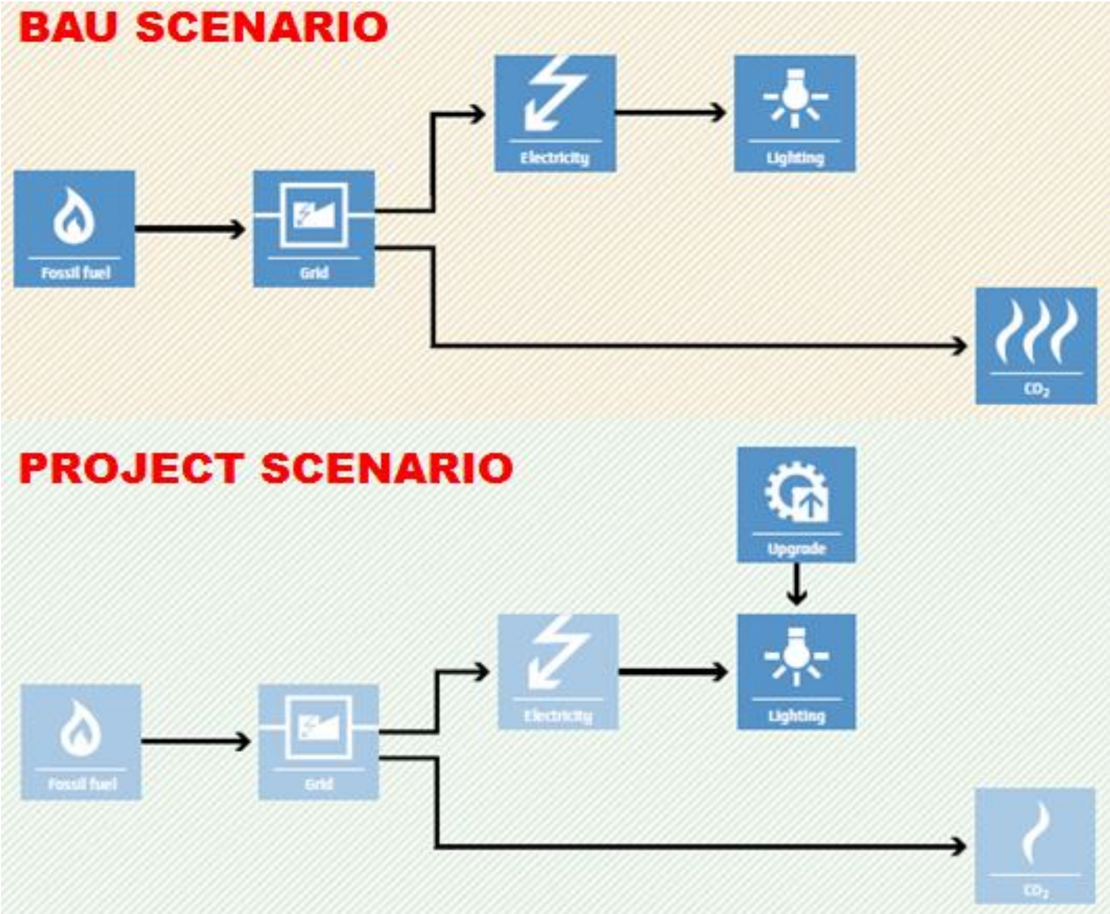

Figure 13 : BAU Scenario and Project Scenario of CDM method AMS-II.L. (UNFCCC, 2019a)

B. Renewable Energy Related Projects

The renewable energy projects inventorised herein fall under the specific groups below as per their classification in the most recent edition (11th edition, November 2019) of the CDM Methodology Booklet (UNFCCC, 2019a).

a) AMS-I.A.: Small-scale Methodology, Electricity generation by the user --- Version 17.0.

This method involves the generation of electricity by individual households/users, or a group of households/users from renewable energy sources such as hydro, wind, solar and biomass. The project activities should not be connected to the grid, and may either involve new installations (Greenfield) or the replacement of existing onsite fossil fuel fired generation. The mitigation action concerns the displacement of more GHG intensive, non-renewable electricity applications by renewable energy technologies. The method is to be applied in cases where the users are in off-grid locations, except in situations where they are grid connected, but the grid electricity is available for less than 36 hours monthly, or the grid connected household coverage nationwide is less than 50%. The total installed capacity of the renewable energy generating systems shall not exceed 15MW for the project activity to qualify as a small scale project. Under this method, the project emission is zero (PE=0) for all projects, but for cases of emissions resulting from geothermal plants operation and those from the water reservoirs of hydro plants. There are no such projects in the present study, implying PE=0 for all the selected projects that fall under this category (UNFCCC, 2019b).

As illustrated in **Figure 14** below, according to the BAU scenario, the services like lighting and refrigeration would have been provided by fossil fuel based technologies such as kerosene lamps and diesel generators, thereby emitting GHG. As for the project scenario, GHG emissions are avoided as the end-users produce electricity using renewable energy technologies (RET) such as solar home systems for lighting and to power other domestic electrical appliances (UNFCCC, 2019a).

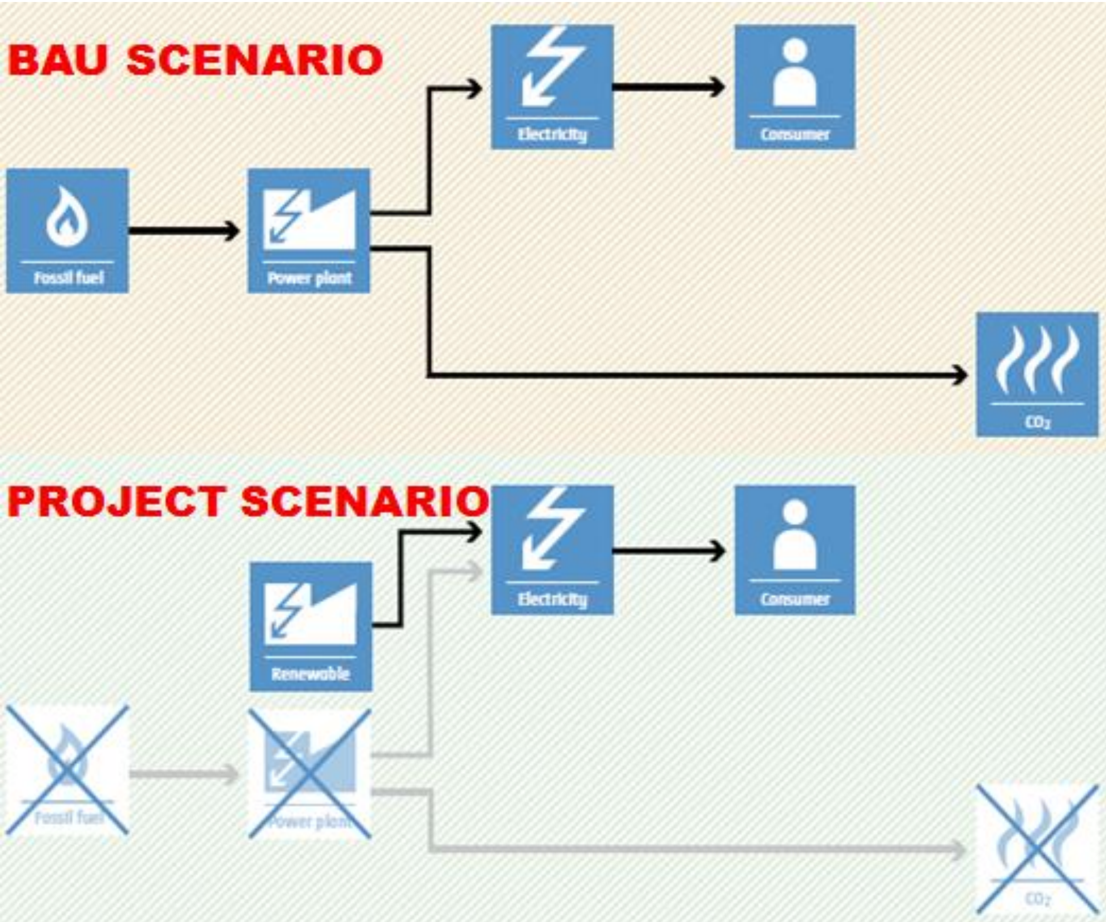

Figure 14: BAU Scenario and Project Scenario of CDM method AMS-I.A. (UNFCCC, 2019a)

b) **AMS-I.F.: Small-scale Methodology, Renewable electricity generation for captive use and mini-grid ---Version 03.0**

The mitigation activity is the displacement by RET of electricity that would have been produced by more GHG-intensive technologies, as the project activity involves electricity generation using RET like tidal/wave, geothermal, solar PV, hydro and renewable biomass. The end users may or may not be connected to the grid before the project implementation;

they may be supplied with electricity from a fossil fuel fired captive power plant or a carbon intensive mini-grid (UNFCCC, 2014b). Also, the renewable energy system may be connected to the grid, and supply excess electricity produced to the grid when applicable (UNFCCC, 2014a). Like all small scale projects, the total installed capacity should not be above 15MW. Greenfield plants, replacement, retrofit or capacity addition of existing plants are all eligible for this method. Under this method, the project emission is zero (PE=0) for all projects, but for cases of emissions resulting from geothermal plants operation and those from the water reservoirs of hydro plants. There are no such projects in the present study, implying PE=0 for all the selected projects that fall under this category (UNFCCC, 2014b).

As illustrated in **Figure 15** below, in the BAU scenario, electricity is supplied by GHG-intensive energy sources like grid (national or regional) or a fossil fuel fired mini grid or captive power plant. Meanwhile in the project scenario, electricity is produced using RET, which are less carbon intensive (UNFCCC, 2019a).

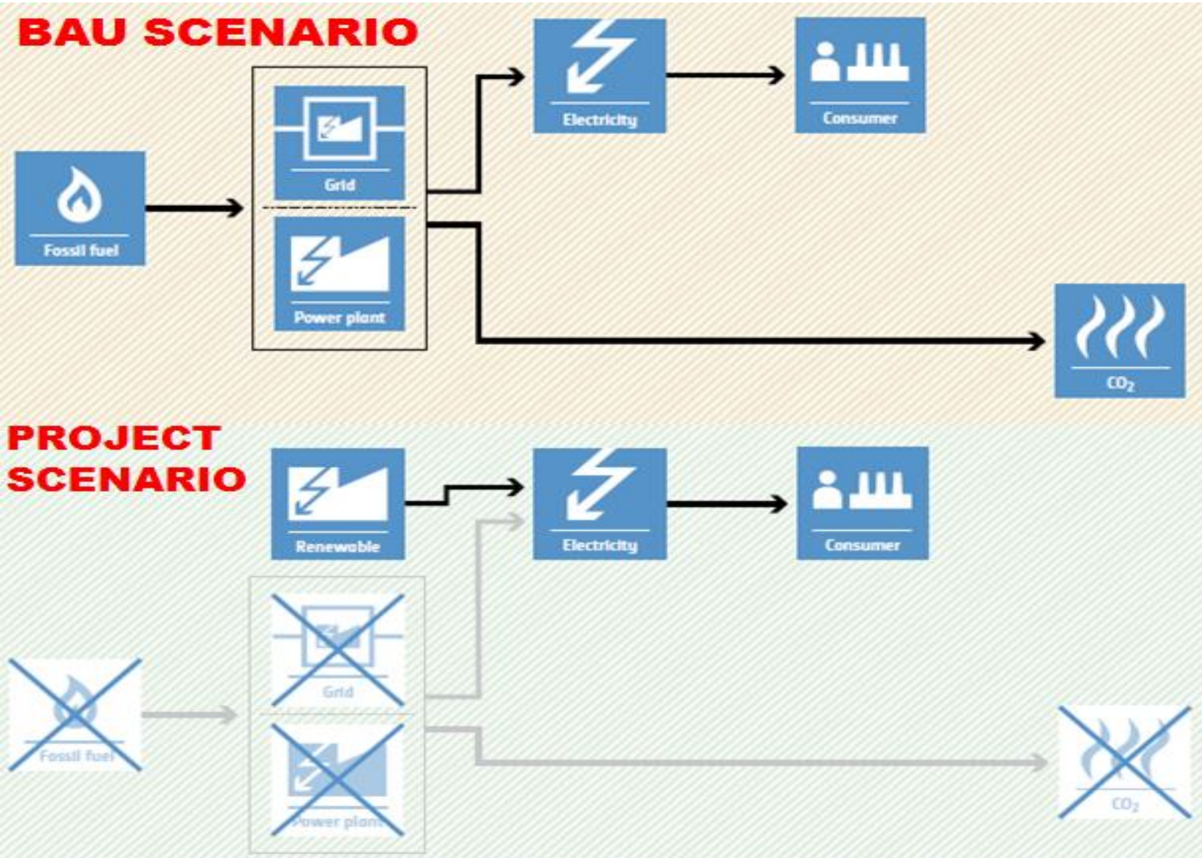

Figure 15 : BAU Scenario and Project Scenario of CDM method AMS-I.F. (UNFCCC, 2019a)

c) **AMS-I.D.: Small-scale Methodology, Grid connected renewable electricity generation ---Version 18.0.**

This method involves the construction and operation of a new power plant, or the retrofit, the replacement or the capacity addition of an existing power unit. The project activity must use renewable energy sources for electricity production and supply electricity to the grid, thereby applying the mitigation action consisting of the displacement of electricity supplied to the grid by more GHG-intensive technologies. Projects involving combined heat and power generation are not eligible for this method. In case the new power plant is composed of both renewable and non-renewable components, the 15MW maximum capacity for small scale projects would apply only to the renewable component. Under this method, the project emission is zero (PE=0) for all projects, but for cases of emissions resulting from geothermal plants operation and those from the water reservoirs of hydro plants. There are no such projects in the present study, implying PE=0 for all the selected projects that fall under this category (UNFCCC, 2014a).

As illustrated in **Figure 16** below, in the BAU scenario, electricity is supplied to the grid by more carbon intensive means, meanwhile in the project scenario, electricity is supplied to the grid using RET, which are less carbon intensive (UNFCCC, 2019a).

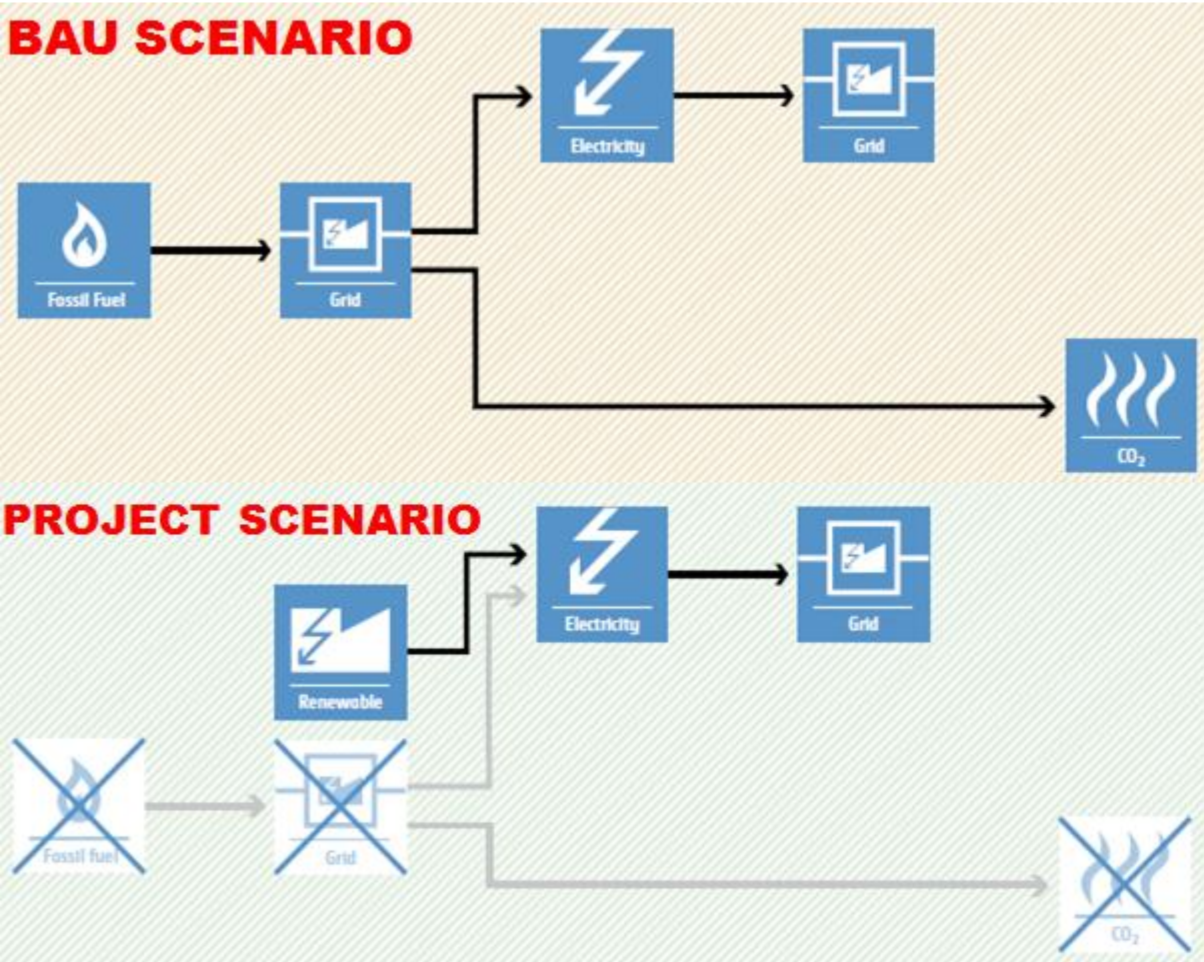

Figure 16: BAU Scenario and Project Scenario of CDM method AMS-I.D. (UNFCCC, 2019a)

d) AMS-III.AR.: Small-scale Methodology, Substituting fossil fuel-based lighting with LED/CFL lighting systems ---Version 06.0

This method involves the replacement of portable fossil fuel based lamps (e.g wick-based kerosene lanterns) with battery-charged LED or CFL based lighting systems in residential and/or non-residential applications (e.g ambient lights, task lights, portable lights). The mitigation action here involves the displacement of a more GHG intensive service (lighting) as shown in **Figure 17** below; and it covers both renewable energy and energy efficiency. It is applicable only to project lamps whose batteries are charged using a renewable energy system (e.g solar PV), a standalone distributed generation system (e.g a diesel generator set) or a national/regional grid. The project lamps must be certified to have a rated average operational life of at least, 5,000 hours where project lamps are assumed to operate for two years after distribution to end-users (i.e. emission reductions are not credited beyond two years); or 10,000 hours where project lamps are assumed to operate for up to seven years after distribution to end-users (i.e. emission reductions are not credited beyond seven years). Under this method, the project emission is zero (PE=0) for all the lamps charged using a renewable energy source like solar PV (UNFCCC, 2018c).

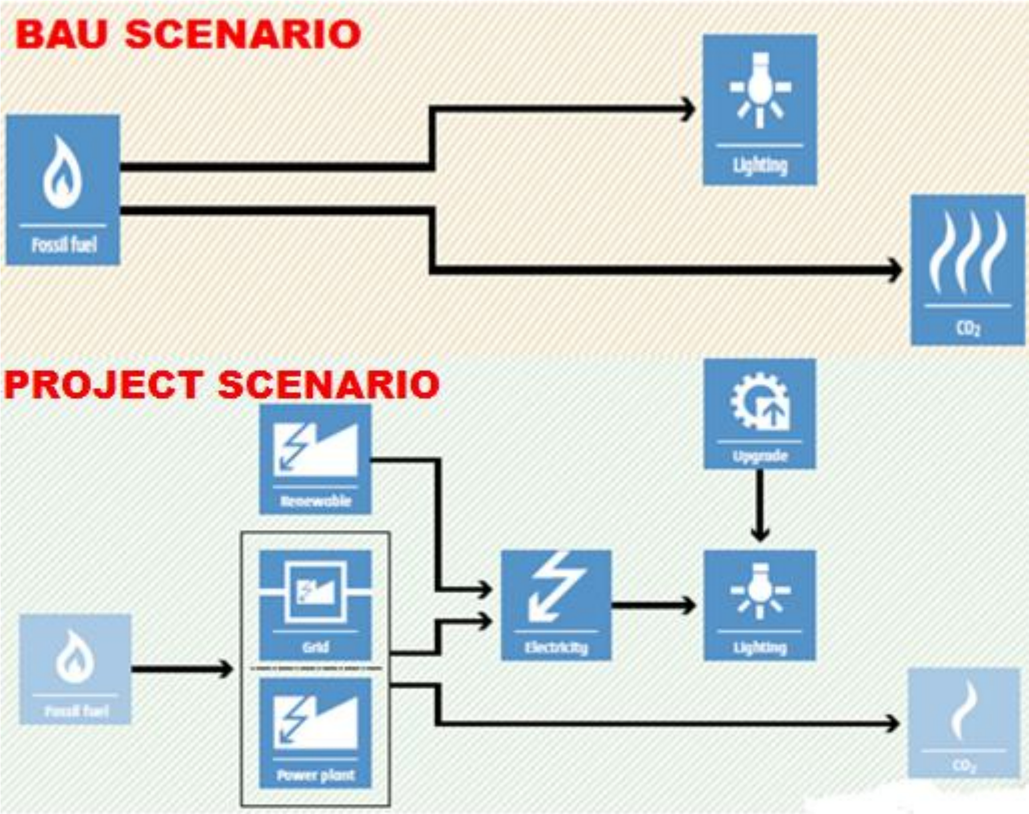

Figure 17 : BAU Scenario and Project Scenario of CDM method AMS-IIII.AR. (UNFCCC, 2019a)

3.4. State of Project Additionality and Calculation of Project Emission Reductions

A. Energy Efficiency Projects

The two CDM methods deemed appropriate to determine the additionality and the emission reductions of the EE projects identified were the AMS-II.C.; Small-scale Methodology, Demand-side energy efficiency activities for specific technologies - Version 15.0, and the

AMS-II.L.; Small-scale Methodology, Demand-side activities for efficient outdoor and street lighting technologies - Version 02.0.

a) AMS-II.C.; Small-scale Methodology, Demand-side energy efficiency activities for specific technologies - Version 15.0.

i) State of Additionality

According to article 15 of the method AMS-II.C., version 15.0, a project activity under this category is deemed automatically additional if the lamps distributed in the project activity are self-ballasted LED lamps. It is the case for all the projects for which this method is applied; making them additional.

ii) Calculation of CO_2 emission reductions

The project activity's emission reduction is calculated as follows:

$$ER_y = (BE_y - PE_y) - LE_y \quad (1)$$

Where:

ER_y= Emission reductions during year y (tCO_2e)

BE_y = Baseline emissions during year y (tCO_2e)

PE_y= Project emissions in year y (tCO_2e)

LE_y= Leakage emissions in year y (tCO_2e)

There are no refrigerants involved in the project activities considered; therefore, all the values regarding refrigerants will be zero.

- Calculation of Baseline Emissions

For this calculation, Option 1 (Constant load equipment) of the AMS-II.C tool is applied. The baseline emission is calculated as follows:

$$BE_y = E_{BL,y} \times EF_{CO2,ELEC,y} + Q_{ref,BL} \times GWP_{ref,BL} \quad (2)$$

$$E_{BL,y} = \sum_i (n_i \times \rho_i \times o_i/(1 - l_y)) \quad (3)$$

Where:

BE_y= Baseline emissions during year y (tCO_2e)

$E_{BL,y}$= Energy consumption for the baseline during year y (MWh)

$EF_{CO2,ELEC,y}$ = Grid emission factor (tCO_2e/MWh) during year y

$Q_{ref,BL}$= Average annual quantity of refrigerant used in the baseline to replace the refrigerant that has leaked (tonnes/year)

$GWP_{ref,BL}$= Global warming potential of the baseline refrigerant (tCO_2e/t refrigerant)

n_i = Number of pieces of equipment of the group of *i* baseline equipment replaced or that would have been replaced.

ρ_i= Electrical power demand (W) for the group of *i* baseline equipment (e.g 20W incandescent lamp)

o_i = Average annual operating hours for the group of *I* baseline equipment.

l_y = Average annual technical grid losses (transmission and distribution) for year *y*.

$\sum_i$= Sum over the group of *i* baseline equipment replaced or that would have been replaced.

$Q_{ref,BL}$ and $GWP_{ref,BL}$ are not applicable in this case, since refrigerants are not involved.

- Calculation of project emissions

The project emission is determined as follows:

$$PE_y = EP_{PJ,y} \times EF_{CO2,y} + PE_{ref,y} \quad (4)$$

Where:

PE_y = Project emissions in year *y* (tCO_2e)

$EP_{PJ,y}$ = Energy consumption of project activity in year *y* (MWh)

$EF_{CO2,y}$ = Grid emission factor (tCO_2e/MWh) during year *y*

$PE_{ref,y}$ = Project emission from physical leakage of refrigerant from the project equipment in year *y* (tCO_2e/y)

For the energy consumption of the project activity in year *y* ($EP_{PJ,y}$) , the same formula used for the baseline energy consumption (3) in year *y* is applied, but with project activity data. Also, due to the lack of reliable data concerning the grid technical losses (transmission and distribution), the default value of 0.1 proposed by the method will be applied.

- **Projects under the method AMS-II.C.**

1. 600 LED lamps installed in university residence to replace fluorescent lamps.

In this project, 400 fluorescent lamps of 23W and 200 fluorescent lamps of 45W were respectively replaced plant 400 LED of 9W and 200 LED of 18W, with a lifetime of 30000 hours. The average daily operating duration considered during the pre-project implementation energy audit was 8hours, the same is considered in this study for 365 days per year. Equations (3), (2), (4) and (1) are used below to calculate the annual energy consumption of the baseline and project activity, baseline emissions, project emission and emission reduction respectively.

Equation (3): $E_{BL,y}$ = (400 × 23 × 2920/1-0.1) + (200 × 45 × 2920/1-0.1) = 59.04889 MWh

Equation (2): BE_y = (59.04889 × 0.7 + 0 × 0) tCO_2e = **41.33422 tCO_2e**

Equation (3): $EP_{PJ,y}$= (400 × 9 × 2920/1-0.1) + (200 × 18 × 2920/1-0.1) = 23.36 MWh

Equation (4): PE_y = 23.36 × 0.7 + 0 = **16.35200 tCO_2e**

Equation (1): ER_y = (41.33422 - 16.35200) – 0 = **24.98222 tCO_2e**

Annual energy savings: 59.04889 MWh - 23.36 MWh = **35.68889MWh < 60GWh**

The project "600 LED installed in university residence to replace fluorescent lamps", therefore prevents **24.98222 tCO_2e** from been emitted on an annual basis. Its annual energy savings is **35.68889MWh,** less than **60GWh** as recommended by the method.

2. 1 500 000 LED lamps in 375 000 households to replace the same number of fluorescent lamps.

There were actually 2 projects of 750 000 lamps each. In the first, 750 000 fluorescent lamps of 40W were replaced by the same number of 18W LED lamps, while in the second, 750 000 fluorescent lamps of 20W were replaced by the same number of 9W LED lamps , with a lifetime of 30000 hours. The average daily operating duration considered was 6 hours, 365 days per year. Equations (3), (2), (4) and (1) are used below to calculate the annual energy consumption of the baseline and project activity, baseline emissions, project emission and emission reduction respectively.

Equation (3): $E_{BL,y}$ =(750000 × 40 × 2190/1-0.1)+ (750000 × 20 × 2190/1-0.1)= 109500 MWh

Equation (2): BE_y = (109500 × 0.7 + 0 × 0) tCO_2e = **76 650 tCO_2e**

Equation (3): $EP_{PJ,y}$=(750000 × 18 × 2190/1-0.1) + (750000 × 9 × 2190/1-0.1) = 49275 MWh

Equation (4): PE_y = 49275 × 0.7 + 0 = **34 492.5 tCO_2e**

Equation (1): ER_y = (76 650 - 34 492.5) – 0 = **42 157.5 tCO_2e**

Total annual energy savings for both projects: (109500 - 49275) MWh = **60 225 MWh**

Both projects therefore prevent **42 157.5 tCO_2e** from been emitted on an annual basis. Their annual energy savings is of **60 225 MWh,** which taken individually would be less than **60GWh** as recommended by the method.

b) AMS-II.L.; Small-scale Methodology, Demand-side activities for efficient outdoor and street lighting technologies - Version 02.0.

i) State of Additionality

This method refers to the CDM methodological tool "Demonstration of additionality of microscale project activities", version 09.0, for additionality demonstration. According to article 12 of this tool, a project activity under this category is deemed automatically additional if its annual energy savings is less than or equal to 20GWh, and if it is hosted by a least developed country (LDC) or a small island developing state (SIDS)(UNFCCC, 2018b). It is the case for all the projects for which this method is applied; making them additional.

ii) Calculation of CO_2 emission reductions

The project activity's emission reduction is calculated as follows:

$$ER_y = NES_y \times EF_{CO2,ELEC,y} \quad (5)$$

Where:

ER_y= Emission reductions during year *y* (tCO_2e)

NES_y= Net electricity saved in year *y* (kWh)

$EF_{CO2,ELEC,y}$= Grid emission factor (tCO_2e/MWh) during year *y*

- Calculation of net electricity saved (NES)

$$NES_y = \sum_{i=1}^{n} ES_{i,y} \times \frac{1}{(1 - TD_y)} \quad (6)$$

Where:

$$ES_{i,y} = \left(Q_{i,BL} \times P_{i,BL} \times O_{i,BL} \times \left(1 - SOF_{i,BL}\right)\right) - (Q_{i,p} \times P_{i,p,y} \times O_{i,y} \times \left(1 - SOF_{i,y}\right)) \quad (7)$$

$$SOF_{i,BL} = AFR_{i,BL} \times OF_{i,BL} \quad (8)$$

$$SOF_{i,y} = AFR_{i,y} \times OF_{i,y} \quad (9)$$

Where:

$ES_{i,y}$= Estimated yearly electricity savings (kWh) for lamp type *i* in year *y*

TD_y= Average annual technical grid losses (transmission and distribution) for year *y*

y= Year considered

i= Counter for lamp type

n= Number of lamps

$Q_{i,BL}$= Quantity of baseline lamps of type *i* that were replaced

$Q_{i,p,y}$= Quantity of project lamps of type *i* installed year *y*

$P_{i,BL}$= Rated power of type *i* baseline lamps

$P_{i,p,y}$= Rated power of type *i* project lamps, year *y*

$O_{i,BL}$=Annual operating hours for the baseline lamps

$O_{i,p,y}$= Annual operating hours of project lamps, year *y*

$SOF_{i,BL}$= System outage factor for type *i* baseline equipment

$SOF_{i,p,y}$= System outage factor for type *i* project equipment

OF_i= Outage factor; the average time in hours elapsed between failure of type *i* lamps and their replacement, divided by annual operating hours ($O_{i,y}$). $OF_{i,BL}$ for baseline values and $OF_{i,p,y}$ for project values in year *y*.

$AFR_{i,}$= Annual failure rate of type *i* lamps, calculated as a fraction of *Q*. $AFR_{i,BL}$ for baseline values and $AFR_{i,p,y}$ for project values, year *y*. In ex-post estimations, AFR_i =actual fraction of lamps that fail annually, while in ex-ante estimations, AFR_i = annual operating hours divided by rated average life for project equipment (lamp). The ex-ante approach is applied in this study due to lack of data regarding the ex-post approach.

- **Projects under the method AMS-II.L**.

1. 10500 LED lamps installed for street lighting in cities of Burkina Faso in replacement of high pressure sodium and mercury lamps.

In the frame work of this project, 10500 LED lamps were provided. 10946 high pressure sodium (SHP) and mercury (HPL) lamps were replaced by 10946 LED lamps, which are less energy intensive **Table 9**. The remaining 446 LED lamps were placed in the reserve. Gaoua, Koupéla, Tenkodogo and 25 other cities of Burkina Faso were beneficiaries of the project. The average life is of about 24000hours and 50000hours for the high pressure sodium and mercury lamps and the LED lamps respectively. The lights are assumed to be on from 18hours in the evening to 6hours in the morning, implying 12 operating hours daily, which gives a total of 4380 hours annually. The average time which elapses between the failure of a lamp and its replacement is estimated at 72hours.

Table 9: Category and quantity of lamps replaced and installed in the 10500 LED lamps projects

Baseline : Lamps replaced					
Lamp category	**SHP 150W**	**SHP 250W**	**HPL 125W**	**HPL 250W**	**TOTAL**
N° of Lamps	3489	3987	1634	1390	10500
Project activity : Lamps installed					
Lamp category	**AC 65W**	**AC 110W**	**ST13-50W**	**ST13-100W**	**TOTAL**
N° of Lamps	3489	3987	1634	1390	10500

- Determination of annual electricity savings ($ES_{i,y}$)

Following equations (8) and (9), $SOF_{i,BL}$ and $SOF_{i,p,y}$ are determined below:

$SOF_{i,BL}$ = (4380H / 24000H) × (72 H/ 4380H) = 0.003

$SOF_{i,p,y}$ = (4380H / 50000H) × (72 H/ 4380H) = 0.00144

Following equation (7), the annual electricity saving ($ES_{i,y}$) is determined below:

$ES_{i,y}$ = [((3489×150) + (3987×250) + (1634×125) +(1390×250)) × 4380× (1-0.003)] - [((3489×65) + (3987×110) + (1634×50) +(1390×100)) × 4380× (1-0.00144)]

$ES_{i,y}$ = 5172.14652MWh

- Determination of Net Electricity saved annually (NES_y)

Following equation (6), NES_y is determined below:

NES_y = 5172.14652 × (1/1-0.1)

NES_y = 5746.82946 MWh

- Determination of annual emission reduction (ER_y)

Following equation (5), annual emission reduction ER_y is determined below:

ER_y =5746.82946 MWh × 0.7 tCO2e/ MWh

ER_y = 4022.78062 tCO2e

This project therefore prevents **4022.78062 tCO_2e** from been emitted on an annual basis. Its annual energy savings is of **5746.82946 MWh,** which is less than **20GWh** as recommended by the method.

2. 4500 LED lamps installed for street lighting in Ouagadougou and Bobo Diolasso to replace high pressure sodium and mercury lamps.

In the frame work of this project, total of 4120 high pressure sodium (SHP) and mercury (HPL) lamps were replaced by 4120 LED lamps (380 extra LED lamps placed in the reserve), which are less energy intensive **Table 10**. The average life is of about 24000hours and 100000hours for the high pressure sodium and mercury lamps and the LED lamps respectively.

Table 10 : Category and quantity of lamps replaced and installed in the 4500 LED lamps projects

Baseline : High pressure sodium and mercury lamps replaced						
Lamp category		**SHP 150W**	**SHP 250W**	**HPL 125W**	**HPL 250W**	**TOTAL**
N° of Lamps	**Ouaga**	193	1895	114	418	2620
	Bobo	110	1085	65	240	1500
	TOTAL	303	2980	179	658	**4120**
Project activity : LED Lamps installed						
Lamp category		**60W/LD60D2 2M**	**80W/LD80H2 3M**	**80W/LD80H2 5S**	**120W/LD120H2 3M**	**TOTAL**
N° of Lamps	**Ouaga**	193	1895	114	418	2620
	Bobo	131	1196	82	91	1500
	TOTAL	324	3091	196	509	**4120**

- Determination of annual electricity savings ($ES_{i,y}$)

Following equations (8) and (9), $SOF_{i,BL}$ and $SOF_{i,p,y}$ are determined below:

$SOF_{i,BL}$ = (4380H / 24000H) × (72 H/ 4380H) = 0.003

$SOF_{i,p,y}$ = (4380H / 100000H) × (72 H/ 4380H) = 0.00072

Following equation (7), the annual electricity saving ($ES_{i,y}$) is determined below:

$ES_{i,y}$ = [((303×150) + (2980×250) + (179×125) +(658×250)) × 4380× (1-0.003)] - [((324×60) + (3091×80) + (196×80) +(509×120)) × 4380× (1-0.00072)]

$ES_{i,y}$ = 2764.48225MWh

- Determination of Net Electricity saved annually (NES_y)

Following equation 6, NES_y is determined below:

NES_y = 2764.48225× (1/1-0.1)

NES_y = 3071.64694MWh

- Determination of annual emission reduction (ER_y)

Following equation (5), annual emission reduction ER_y is determined below:

ER_y =3071.64694 MWh × 0.7 tCO2e /MWh

ER_y = 2150.15286 tCO2e

This project therefore prevents **2150.15286 tCO_2e** from been emitted on an annual basis. Its annual energy savings is of **3071.64694 MWh,** which is less than **20GWh** as recommended by the method.

3. 1926 solar LED lamps installed for street lighting in Ouagadougou.

In the frame work of the program of development of renewable energy and energy efficiency (PRODERE) in member states of the West African Economic and Monetary Union (WAEMU), the African Biofuel and Renewable Energy Company (ABREC) installed 1926 solar luminaires in the city of Ouagadougou. This was a Greenfield project in which the lamps installed were LED with a power rating of 50W, and an average life of about 50000hours. Since it is a Greenfield project, as mentioned in article 9 of AMS.II.L, the baseline technology is assumed to be the prevailing street lighting technology in the region. In this case, they are high pressure sodium and mercury lamps. Like in the 10500 LED lamps project, the power rating considered here is 125W, with an average life of about 24000hours.

- Determination of annual electricity savings ($ES_{i,y}$)

Following equations (8) and (9), $SOF_{i,BL}$ and $SOF_{i,p,y}$ are determined below:

$SOF_{i,BL}$ = (4380H / 24000H) × (72 H/ 4380H) = 0.003

$SOF_{i,p,y}$ = (4380H / 50000H) × (72 H/ 4380H) = 0.00144

Following equation (7), the annual electricity saving ($ES_{i,y}$) is determined below:

$ES_{i,y}$ = [1926×125 × 4380 × (1-0.003)] - [1926×50 × 4380× (1-0.00144)]

$ES_{i,y}$ = 1051.32155 – 421.18662

$ES_{i,y}$ = 630.13493 MWh

- Determination of Net Electricity saved annually (NES_y)

Following equation (6), NES_y is determined below:

NES_y = 630.13493 × (1/1-0.1)

NES_y = 700.14992 MWh

- Determination of annual emission reduction (ER_y)

Since the project street lights are solar based, their emission would be taken as zero as recommended by the CDM methods. Therefore, only the baseline electricity consumption would be used to quantify the emissions reduced. Following equation (5), annual emission reduction ER_y is determined below:

ER_y =1051.32155 MWh × (1/1-0.1) × 0.7 tCO_2e/ MWh

ER_y = 817.69454 tCO_2e

This project therefore prevents **817.69454 tCO_2e** from been emitted on an annual basis. Its annual energy savings is of **700.14992 MWh,** which is less than **20GWh** as recommended by the method.

4. 1400 solar LED lamps installed for street lighting in rural localities (Project of electrification of 175 rural localities).

In the frame work of this project, 1400 solar luminaires were installed in some rural localities of the country as presented in **Table 11** below. This was a Greenfield project in which the lamps installed were LED with a power rating of 50W, and an average life of about 50000hours. Since it is a Greenfield project, as mentioned in article 9 of AMS.II.L, the baseline technology is assumed to be the prevailing street lighting technology in the region. In this case, they are high pressure sodium and mercury lamps. Like in the 10500 LED lamps project, the power rating considered here is 125W, with an average life is of about 24000hours.total of 4120 high pressure sodium (SHP) and mercury (HPL) lamps were replaced by 4120 LED lamps (380 extra LED lamps placed in the reserve), which are less energy intensive Table 2. The average life is of about 24000hours and 100000hours for the high pressure sodium and mercury lamps and the LED lamps respectively.

Table 11 : 1400 Street lights installed in rural localities in Burkina Faso

Region	**N° Solar street lights**
Haut Bassin	104
Boucle du Mouhoun	107
East	64
Nord	143
North Central	240
South West	96
Cascade	118
East Central	128
West Central	131
South Central	117
Central	7
Central Plateau	145
TOTAL	**1400**

- Determination of annual electricity savings ($ES_{i,y}$)

Following equations (8) and (9), $SOF_{i,BL}$ and $SOF_{i,p,y}$ are determined below:

$SOF_{i,BL}$ = (4380H / 24000H) × (72 H/ 4380H) = 0.003

$SOF_{i,p,y}$ = (4380H / 50000H) × (72 H/ 4380H) = 0.00144

Following equation (7), the annual electricity saving ($ES_{i,y}$) is determined below:

$ES_{i,y}$ = [1400 × 125 × 4380 × (1-0.003)] - [1400 × 50 × 4380 × (1-0.00144)]

$ES_{i,y}$ = 764.20050 – 306,15849

$ES_{i,y}$ = 458.04200 MWh

- Determination of Net Electricity saved annually (NES_y)

Following equation (6), NES_y is determined below:

NES_y = 458.04200 × (1/1-0.1)

NES_y = 508.93556 MWh

- Determination of annual emission reduction (ER_y)

Since the project street lights are solar based, their emission would be taken as zero as recommended by the CDM methods. Therefore, only the baseline electricity consumption would be used to quantify the emissions reduced. Following equation (5), annual emission reduction ER_y is determined below:

ER_y =764.20050 MWh × (1/1-0.1) × 0.7 tCO_2e/ MWh

ER_y = 594.37817 tCO_2e

This project therefore prevents **594.37817 tCO_2e** from been emitted on an annual basis. Its annual energy savings is of **508.93556 MWh,** which is less than **20GWh** as recommended by the method.

B. Renewable Energy Projects

The four CDM methods deemed appropriate to determine the additionality and the emission reductions of the EE projects identified were the AMS-I.F.; Small-scale Methodology, Renewable electricity generation for captive use and mini-grid - Version 03.0, the AMS-I.A.; Small-scale Methodology, Electricity generation by the user - Version 17.0, the AMS-I.D.; Small-scale Methodology, Grid connected renewable electricity generation - Version 18.0. and the AMS-III.AR.; Small-scale Methodology, Substituting fossil fuel-based lighting with LED/CFL lighting systems -Version 06.0.

a) AMS-I.F.; Small-scale Methodology, Renewable electricity generation for captive use and mini-grid - Version 03.0.

i) State of Additionality

This method refers to the CDM methodological tool 19, "Demonstration of additionality of microscale project activities", version 09.0, for additionality demonstration. According to article 11a of this tool, a small scale project activity employing renewable energy, with an installed capacity of at most 5MW, and located in a least developed country is automatically deemed additional (UNFCCC, 2018b). It is the case for all the projects for which this method is applied; making them additional.

ii) Calculation of CO_2 emission reductions

Equation (1) also applies here for the calculation of emission reductions. However, since the *PE=0* and *LE* is not applicable for this category of projects, *ER=BE*.

$$BE_y = E_{BL,y} \times EF_{CO2,y} \qquad (10)$$

Where:

$E_{BL,y}$= Quantity of net electricity displaced due to the implementation of the project activity in year y (kWh). This is considered as the quantity of electricity generated by the project activity during the same year.

$EF_{CO2,y}$= Grid emission factor

$$E_{BL,y} = \sum_i \left(EG_{i,y} \times CF_B\right)/(1 - TDL) \qquad (11)$$

$$EG_{BL,y} = (P_P \times I_s \times K \times 365)/1kWm^{-2} \qquad (12)$$

Where:

$EG_{i,y}$= Electricity generated by project activity units type i in year y (kWh).

CF_B= Correction factor of total annual energy production by a project unit, adapted to the type of project beneficiary (end-user) *B*.

P_p= Peak power of the project production unit (kWp)

I_s= Average annual daily solar insolation (5.5 kWh/m^2/d in Burkina Faso)

K= Coefficient of losses in the system (0.55 – 0.75)

$1Kw/m^{-2}$= Solar irradiation in Standard Test Conditions (1000W/m^2; Air Mass: 1.5; cell temperature: 25°C)

Given that $EG_{i,y}$ obtained for the project activities takes into consideration all the 365 days of the year, a correction factor is applied for facilities considered not to be operational 7/7 throughout the year. Regarding the TDL, a default value of 10% is applied.

- **Projects under the method AMS-I.F.**

1. Project named “385 infrastructures”

It involves the supply and installation of solar PV systems in schools, general education centres (CEG), social centres for the promotion of health (CSPS) and maternities in different regions of Burkina Faso. The project was divided into 5 sets as shown in **Table 12**, **Table 13**, **Table 14**, **Table 15** and **Table 16** below; all the project beneficiaries were connected to the grid before the project implementation. The correction factor is taken as 5/7 (0.714) for schools and CEG, assuming they operate 5 days per week; meanwhile no correction is done for maternities and CSPS, assuming that they operate 7 days per week.

Table 12: Project 385 Infrastructures, Set 1

Set 1: Solar PV systems for schools in villages			
	Region	N° Villages	N° schools
1	Komki-ipala	9	13
2	Tanghin-Dassouri	18	19
3	Komsilga	24	25
4	Saaba	17	20
5	Pabré	12	12
6	Koubri	22	23
7	District 2 / Bobo	5	5
8	District 3 / Bobo	10	11
9	District 4 / Bobo	6	7
10	District 5 / Bobo	5	6
11	District 6 / Bobo	4	5
12	District 7 / Bobo	4	4
	TOTAL	136	150
	Capacity installed per school (Wp)		500
	Total installed capacity (Wp)		75000
	Total installed capacity (kWp)		**75**

Table 13: Project 385 Infrastructures, Set 2

Set 2: Solar PV systems for CEG and schools in rural and peri-urban zones			
	Region	N° Villages	N° schools/CEG
1	Komki-ipala	3	5
2	Tanghin-Dassouri	5	6
3	Komsilga	4	4
4	Pabré	1	2
5	Saaba	4	7
6	District 4 / Ouaga	3	4
7	District 7 / Ouaga	6	9
8	District 8 / Ouaga	6	8
9	District 9/ Ouaga	4	8
10	District 10 / Ouaga	3	4
11	District 11 / Ouaga	2	4
12	District 1 / Bobo	2	3
13	District 3 / Bobo	6	7
14	District 5 / Bobo	4	6
15	District 6 / Bobo	2	4
16	District 7 / Bobo	2	4
	TOTAL	57	85
	Capacity installed per school/CEG (Wp)		500
	Total installed capacity (Wp)		42500
	Total installed capacity (kWp)		**42.5**

Table 14 : Project 385 Infrastructures, Set 3

Set 3: Solar PV systems for schools and CEG in urban and peri-urban areas			
	Region	N° Villages	N° schools/CEG
1	Tanghin-Dassouri	2	2
2	Komsilga	2	2
3	Pabré	2	2
4	Koubri	3	3
5	Saaba	1	1
6	District 7 / Ouaga	2	2
7	District 9 / Ouaga	1	3
8	District 10 / Ouaga	4	4
9	District 11 / Ouaga	4	4
10	District 12 / Ouaga	1	1
11	District 1/ Bobo	2	2
12	District 3 / Bobo	2	4
13	District 4 / Bobo	3	3
14	District 5 / Bobo	2	3
15	District 6 / Bobo	1	1
16	District 7 / Bobo	1	2
	TOTAL	33	39
	Capacity installed per school/CEG (Wp)		1 000
	Total installed capacity (Wp)		39000
	Total installed capacity (kWp)		**39**

Table 15: Project 385 Infrastructures, Set 4

Set 4: Solar PV systems for CSPS in rural areas			
	Region	N° Villages	N° schools
1	Komki-ipala	6	7
2	Tanghin-Dassouri	8	8
3	Komsilga	6	6
4	Saaba	9	9
5	Pabré	12	12
6	Koubri	6	6
7	District 2 / Bobo	4	4
8	District 3 / Bobo	5	5
9	District 4 / Bobo	5	5
10	District 5 / Bobo	3	3
11	District 6 / Bobo	3	3
12	District 7 / Bobo	2	2
	TOTAL	69	70
	Capacity installed per school (Wp)		1 500
	Total installed capacity (Wp)		105000
	Total installed capacity (kWp)		**105**

Table 16: Project 385 Infrastructures, Set 5

Set 5: Solar PV systems for CSPS and maternities urban zones			
	Region	N° Villages	N° schools/CEG
1	District 2 / Ouaga	4	6
2	District 3 / Ouaga	2	2
3	District 4 / Ouaga	4	4
4	District 5/ Ouaga	1	1
5	District 6 / Ouaga	1	1
6	District 7 / Ouaga	1	1
7	District 8 / Ouaga	2	2
8	District 10/ Ouaga	3	2
9	District 11 / Ouaga	1	3
10	District 12 / Ouaga	3	1
11	District 1 / Bobo	4	4
12	District 2 / Bobo	3	4
13	District 3 / Bobo	2	4
14	District 4 / Bobo	4	2
15	District 5 / Bobo	2	4
	TOTAL	37	41
	Capacity installed per school/CEG (Wp)		1 500
	Total installed capacity (Wp)		61500
	Total installed capacity (kWp)		**61.5**

The total capacity of the solar PV systems installed in schools and CEG (sets 1, 2 and 3) is 156.5 kWp, while that installed capacity in CSPS and maternities (sets 4 and 5) totals 166.5 kWp. The project's emissions reduction is determined as follows:

Combining equations (11) and (12) enables to calculate $E_{i,y}$ as follows:

$E_{i,y}$= [((156.5 × 5.5 × 0.75 × 0.714) + (166.5 × 5.5 × 0.75)) × 365] / 0.9

$E_{i,y}$= **465474.006 kWh / year**

According to equation (10), BE_y= 465474.0063 kWh × 0.0007 tCO_2e/ kWh

BE_y= 325.83180 tCO_2e / year

Since PE=0, $BE_y=ER_y$

ER_y **= 325.83180 tCO_2e / year**

The project 385 infrastructures displaces **465474.006 kWh** from carbon intensive electricity generation technologies (grid), and saves **325.83180 tCO_2e** annually.

2. Installation of grid connected solar PV systems in medical centres with surgical antenna (CMA) and public buildings

These are actually 2 projects, one in CMAs and the other in public buildings. They involve the installation of grid connected solar PV systems of capacities varying between 10 and 60kWp, in grid connected medical centres and public buildings located in different regions across the country. During the years 2018 and 2019, the project was implemented in 25 medical centres and 12 public buildings, with and aggregated installed capacity of 970kWp and 445kWp respectively. There are 14 medical centres and 32 public buildings left to be covered in 2020 and 2021 with a planned total capacity of 530kWp and 495kWp respectively. Due to the unavailable data for the capacity installed in 2020, only those of 2018 and 2019 would be considered in the present study.

The medical centres are considered to be operational every day, while public buildings 5 days per week (CF=0.714). The project's emissions reduction is determined as follows:

Combining equations (11) and (12) enables to calculate $E_{i,y}$ as follows:

$E_{i,y}$= [((445 × 5.5 × 0.75 × 0.714) + (970 × 5.5 × 0.75)) × 365] / 0.9

$E_{i,y}$= **2154264.979kWh / year**

According to equation (10), BE_y= 2154264.979kWh × 0.0007 tCO_2e/ kWh

BE_y= 1507.98549 tCO_2e / year

Since PE=0, BE_y=ER_y

ER_y= 1507.98549 tCO_2e / year

This project therefore displaces **2154264.979kWh** from carbon intensive electricity generation technologies (grid), and saves **1507.98549 tCO_2e** annually.

3. Installation of solar PV systems in town halls

This project involved the installation of solar PV kits in 30 city halls across 6 regions of the country. All the halls were already connected to the grid, and in each was installed a solar PV system of 2000Wp, giving a total installed capacity of 60kWp (**Table** 17).

Table 17 : Capacity of Solar PV systems installed in town halls

Regions	**N° Town Halls**
South Central	7
East Central	9
Central Plateau	5
West Central	7
Central	2
TOTAL	30
Capacity installed per hall (Wp)	2000
Total installed capacity (Wp)	60000
Total installed capacity (kWp)	**60**

The town halls are considered to be operational 5 days per week (CF=0.714). The project's emissions reduction is determined as follows:

Combining equations (11) and (12) enables to calculate $E_{i,y}$ as follows:

$E_{i,y}$= (60 × 5.5 × 0.75 × 0.714 × 365) / 0.9

$E_{i,y}$= **71667.75kWh /year**

According to equation (10), BE_y= 71667.75kWh × 0.0007 tCO_2e/ kWh

BE_y= 50.16743 tCO_2e / year

Since PE=0, BE_y=ER_y

ER_y= 50.16743 tCO_2e / year

This project therefore displaces **71667.75kWh** from carbon intensive electricity generation technologies (grid), and saves **50.16743 tCO_2e** annually.

4. Solar Back up project

In the framework of this project, households and small enterprises across different regions of Burkina Faso received solar kits of varying capacities as presented in **Table 18**. All the project beneficiaries were connected to the grid. The total capacity of all the solar kits distributed and installed was 1291.305 kWp. Phase II is this project was recently launched, with the aim of distributing 3000 to 3500 additional kits.

Table 18 : Capacity installed in the framework of the Solar Back-up project

Solar kit capacity	N° of Beneficiaries	TOTAL
35	251	8785
60	1960	117600
300	38	11400
450	72	32400
1040	118	122720
1560	60	93600
3120	290	904800
Total installed capacity (Wp)		1291305
Total installed capacity (kWp)		**1291,305**

Due to lack of data regarding the exact number of households and small enterprises that benefited from the project, a correction factor 6/7 (CF=0.857) is applied, assuming an average of 6 operational days weekly. The project's emissions reduction is determined as follows:

Combining equations (11) and (12) enables to calculate $E_{i,y}$ as follows:

$E_{i,y}$= (1291.305 × 5.5 × 0.75 × 0.857 × 365) / 0.9

$E_{i,y}$= **1851330.527kWh /year**

According to equation (10), BE_y= 1851330.527kWh × 0.0007 tCO_2e/ kWh

BE_y= 1295.93137 tCO_2e / year

Since PE=0, BE_y=ER_y

ER_y= 1295.93137 tCO_2e / year

This project therefore displaces **1851330.527kWh** from carbon intensive electricity generation technologies (grid), and saves **1295.93137 tCO_2e** annually.

5. Installation of grid connected solar PV systems in ministries, research centres, banks and other institutions across the country.

This involves a group of different projects. As presented in **Table 19** below, grid connected solar systems were installed in a number of institutions, which were all connected to the grid before the project implementation.

Table 19 : Capacity of solar PV systems installed in different institutions

Institution	N° Operational days weekly	Installed capacity (kWp)
First Ministry	5/7	62
Ministry of Energy		40
Ministry of the Environment		75
Institute of research in applied sciences and technologies (IRSAT)		42
National centre of scientific research and technology (CNRST)		35
Other institutions		3000
TOTAL		**3254**
Société Générale (Bank)	6/7	85
TOTAL		**85**
Presidence	7/7	200
Koupéla Hospital		20
TOTAL		**220**

The project's emissions reduction is determined as follows:

Combining equations (11) and (12) enables to calculate $E_{i,y}$ as follows:

$E_{i,y}$ = [((3254 × 5.5 × 0.75 × 0.714) + (85 × 5.5 × 0.75×0.857) + (220 × 5.5 × 0.75)) × 365] / 0.9

$E_{i,y}$ = **4376686.256kWh / year**

According to equation (10), BE_y = 4376686.256kWh × 0.0007 tCO2e/ kWh

BE_y= 3063.68038 tCO2e / year

Since PE_y=0, $BE_y = ER_y$

***ER_y*= 3063.68038 tCO2e / year**

This project therefore displaces **4376686.256kWh** from carbon intensive electricity generation technologies (grid), and saves **3063.68038 tCO2e** annually.

b) AMS-I.A.; Small-scale Methodology, Electricity generation by the user - Version 17.0.

i) State of Additionality

The same conditions applied to prove projects' additionality under method AMS-I.F. also holds here. All the projects considered under the present method comply with the conditions, making them additional.

ii) Calculation of CO_2 emission reductions

The same steps for the determination of the project emissions reduction in method AMS-I.F. are applicable in this method, but with the peculiarities mentioned hereafter:

The baseline emissions would be calculated using option 2, article 22 of this method, which is based on the annual electricity generation by the project activity. Since the end-users are not connected to the grid, it is assumed that they would have used a diesel generator to produce electricity in the absence of the project activity. For the baseline calculation, the method provides a default emission factor of 0.8 $kgCO_2e$/ kWh, which is derived from diesel generation units. Also, since before project implementation the diesel generators were used at the consumption site, there was neither electricity transmission nor distribution. It is therefore assumed that there would have been no losses in this regard, implying that TDL=0. In this case, TDL represents the average technical transmission and distribution losses that would have been observed in diesel powered mini-grids installed in the region instead of the present project activity.

❖ **Projects under the method AMS-I.A.**

1. Installation of off-grid solar PV systems in schools, colleges and CSPS in 175 rural localities.

As shown in **Table 20**, the project involved the installation of off-grid solar PV systems of 500Wp each in schools, colleges and social centres for the promotion of health (CSPS). They are all located in rural areas of different regions across the country, without access to the grid.

Table 20 : Total installed capacity of off-grid solar PV systems in 297 schools and 152 CSPS in 175 rural localities

Region	N° Schools/Colleges	N° CSPS
Haut Bassin	29	12
Boucle du Mouhoun	31	11
East	14	8
Nord	37	18
North Central	43	22
South West	25	11
Cascade	26	12
East Central	24	12
West Central	23	13
South Central	23	13
Central	1	1
Central Plateau	21	19
TOTAL	297	152
Capacity installed per school (Wp)	500	

Region	N° Schools/Colleges	N° CSPS
Total installed capacity (Wp)	148500	76000
Total installed capacity (kWp)	**148.5**	**76**

Schools and colleges are assumed to be operational 5 days (CF: 0.714) per week and CSPS every day. The project's emissions reduction is determined as follows:

$E_{i,y}$ = [((148.5 × 5.5 × 0.75 × 0.714) + (76 × 5.5 × 0.75)) × 365]

$E_{i,y}$ = **274067.413kWh / year**

According to equation (10), BE_y = 274067.413kWh × 0.8 kgCO_2e/ kWh

BE_y= 219253.931kgCO2e / year

BE_y= 219.254tCO2e / year

Since PE_y=0, $BE_y = ER_y$

***ER_y*= 219.254 tCO2e / year**

This project therefore displaces **274067.413kWh** from carbon intensive electricity generation technologies (diesel generator), and saves **219.254tCO2e** annually.

2. Rural electrification; solar PV micro grids installed in 20 villages.

The project involved the installation of off-grid solar PV micro grids in 20 villages across different regions of the country, without access to the grid. The different regions concerned and the capacities installed are shown in **Table 21** below.

Table 21 : Rural electrification; Capacity installed per locality and total installed capacity

Region	Number of localities	Capacity installed per locality (kWp)	TOTAL (kWp)
East	5	20.74	103.70
East Central	1	20.74	20.74
Central Plateau	4	20.80	83.20
Sahel	3	24.96	74.88
West Central	1	24.96	24.96
Nord	2	24.96	49.92
Boucle du Mouhoun	2	24.84	49.68
Nord Central	2	24.84	49.68
Total installed capacity (kWp)			**456.76**

The project's emissions reduction is determined as follows:

Combining equations (11) and (12) permits to calculate $E_{i,y}$ as follows:

$E_{i,y}$ = 456.76 × 5.5 × 0.75 × 365

$E_{i,y}$ = **687709.275kWh / year**

According to equation (10), BE_y = 687709.275kWh × 0.8 kgCO2e/ kWh

BE_y= 550167.42 kgCO2e / year

BE_y= 550.167 tCO2e / year

Since PE_y=0, $BE_y = ER_y$

***ER_y*= 550.167 tCO2e / year**

This project therefore displaces **687709.275kWh** from carbon intensive electricity generation technologies (diesel generator), and saves **550.167 tCO2e** annually.

c) **AMS-I.D.; Small-scale Methodology, Grid connected renewable electricity generation -Version 18.0.**

i) **State of Additionality**

The same conditions applied to prove projects' additionality under method AMS-I.F. also holds here. All the projects considered under the present method comply with the conditions, making them additional.

ii) **Calculation of CO_2 emission reductions**

Equation (1) also applies here for the calculation of emission reductions. However, since the *PE=0* and *LE* is not applicable for this project activity, *ER=BE*.

$$BE_y = EG_{PJ,y} \times EF_{grid,y} \qquad (13)$$

Where:

$EG_{PJ,y}$= Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the project activity in year *y* (kWh). This is considered as the quantity of electricity generated by the project activity during the same year.

$EFgrid_{,y}$= Grid emission factor

- **Projects under the method AMS-I.D.**

1. 1.1MWp, Ziga solar PV power plant connected to the Grid

This involves the implementation of a Greenfield grid connected solar PV power plant of 1.1MWp in Ziga. The project's emissions reduction is determined as follows:

From Equation (12), $EG_{PJ,y}$ = 1100 × 5.5 × 0.75 × 365

$EG_{PJ,y}$ = **1656187.5 kWh / year**

According to equation (13), BE_y = 1656187.5 × 0.0007 tCO_2e/ kWh

BE_y= 1159.33125 tCO2e / year

Since PE_y=0, $BE_y = ER_y$

***ER_y*= 1159.33125 tCO2e / year**

This project therefore displaces **1656187.5 kWh** from carbon intensive electricity generation technologies (grid), and saves **1159.33125 tCO2e** annually.

2. Bilgo hybrid solar PV-diesel generator power plant connected to the Grid

This involves the implementation of a Greenfield hybrid solar PV – diesel generator power plant with a total solar PV installed capacity of 30KWp and 3 diesel generators (2 of 16kW and 1 of 24kW) in Bilgo. The solar PV installed capacity is of 30kWp. Only the RE (Solar PV) section of the plant will be considered while calculating the emissions reduction. The project's emissions reduction is determined as follows:

From Equation (12), $EG_{PJ,y}$ = 30 × 5.5 × 0.75 × 365

$EG_{PJ,y}$ = **45168.75 kWh / year**

According to equation (13), BE_y = 45168.75 kWh × 0.0007 tCO2e/ kWh

BE_y= 31.61813 tCO_2e / year

Since PE_y=0, BE_y = ER_y

ER_y= 31.61813 tCO2e / year

This project therefore displaces **45168.75 kWh** from carbon intensive electricity generation technologies (grid), and saves **31.61813 tCO_2e** annually.

d) **AMS-III.AR.; Small-scale Methodology, Substituting fossil fuel-based lighting with LED/CFL lighting systems - Version 06.0**

i) **State of Additionality**

This method refers to the CDM methodological tool 19, "Demonstration of additionality of microscale project activities", version 09.0, for additionality demonstration. According to article 13b of this tool, a small scale project activity employing renewable energy, with an emission reduction of at most 20 ktCO2e/year, which involves the use of solar lamps by households, communities or SMEs in a least developed country is automatically deemed additional (UNFCCC, 2018b). It is the case for all the projects for which this method is applied; making them additional.

ii) **Calculation of CO_2 emission reductions**

This method provides a default annual baseline emission factor of 0.092 tCO2e/ year for each of the lamps. This value is gotten using equation (14) and the default values below:

$$DV = FUR \times O \times U \times EF \div 1000 \times LF \times n \times NTG \quad (14)$$

Where:

DV = Lamp Emission Factor (default is 0.092 tCO_2e per project lamp)

FUR = Fuel use rate (0.03 liters/hour)

O = Utilization rate (3.5 hours/day)

U = Annual utilization (365 days/year)

EF = Fuel emissions factor (2.4 kgCO2/liter)

LF = Leakage factor (1.0)

n = Number of fuel-based lamps replaced per project lamp (1.0)

NTG = Net-to-gross adjustment factor (1.0)

- Calculation of baseline emissions

Equation (15) enables to calculate the baseline emissions:

$$BE_y = DV \times GF_y \times DB_y \times N \qquad (15)$$

Where:

BEy = Baseline emissions per project lamp in year y (t CO2e)

GFy = Grid Factor in year y,

- Equal to 1.0 when charging is done with a renewable energy source like solar PV;
- Equal to 1.0 if the project activity is for off-grid households/communities (defined as no grid access or less than 12 hours grid availability per day on an annual average basis);
- Otherwise it is equal to 1.0 minus (the fraction of time grid is available to the target households and communities/users in the region of project activity)

DBy = Dynamic Baseline Factor (change in baseline fuel, fuel use rate, and/or utilization during crediting period) in year y. Calculated as either:

- Option 1: default of 1.0 in the absence of relevant information;
- Option 2: value of 1.0+FFg where FFg is the documented national growth rate of kerosene fuel use in lighting from the preceding years (use the most recent available data for a three or five years average (fraction))

N = Total number of project lamps distributed

- **Projects under the method AMS- III.AR**

1. Distribution of 25000 certified solar lamps, Lighting Africa, in 400 primary schools in off grid rural areas.
2. Distribution of 8500 solar lamps to primary school pupils in off-grid rural areas.

Both projects involved the distribution of a total of 33500 certified solar lamps in primary schools located in off grid rural areas. Given that the emissions of the solar lamps as considered to be zero, the baseline emissions will be equal to the emission reduction of the project.

- Calculation of emission reduction

Following equation (15), the total baseline emissions is calculated as follows:

$BE_y = 0.092 \times 1 \times 1 \times 33500$

$BE_y = 3082\ tCO_2e$

Since PE_y=0, $BE_y = ER_y$

ER_y= 3082 tCO2e / year

These projects therefore reduce a total of **3082 tCO_2e** annually.

3.5. Summary

A total of 34 projects were identified, but suitable data could be obtained for only 28 of them. Out of the 28 projects, 21 were RE projects and 7 were energy efficiency projects, and they were all proven to be additional. The total annual energy saved by the EE projects is 67500.339 MWh, while the total energy displaced by the RE projects is 9430.446MWh. The total annual emission reduction of the 28 projects amounts to 48157.668 tCO_2e, generating about 48157 CERs per year and about 481570 CERs in the 10 years crediting period. The following approved CDM methods were applied:

- For EE projects:
  - AMS-II.C.: Small-scale Methodology, Demand-side energy efficiency activities for specific technologies - Version 15.0.
  - AMS-II.L.: Small-scale Methodology, Demand-side activities for efficient outdoor and street lighting technologies - Version 02.0.
- For RE projects:
  - AMS-I.A.: Small-scale Methodology, Electricity generation by the user - Version 17.0.
  - AMS-I.F.: Small-scale Methodology, Renewable electricity generation for captive use and mini-grid -Version 03.0.
  - AMS-I.D.: Small-scale Methodology, Grid connected renewable electricity generation -Version 18.0.
  - AMS-III.AR.: Small-scale Methodology, Substituting fossil fuel-based lighting with LED/CFL lighting systems ---Version 06.0

4. RESULTS AND DISCUSSION

4.1. Introduction

In this chapter, the results of the study are presented and discussed in line with the research objectives. The main results concern the state of additionality, the total annual energy savings, the total annual energy displaced and the total number of CERs that could be generated on a yearly basis by the RE and EE efficiency projects considered in this study. Some of the reasons why these projects are not registered to the CDM are also discussed.

4.2. Results

A total of 34 projects were identified, but suitable data could be obtained for 28 of them (**Table 22**). Out of the 28 projects, 21 were RE projects and 7 were energy efficiency projects, and they were all proven to be additional. The total annual energy saved by the EE projects is 68709.424 MWh, accounting for 36871.701 tCO_2e emissions reduced annually (**Table 23**), while the total energy displaced by the RE projects is 9430.446 MWh, accounting for 11285.967 tCO_2e emissions reduced annually (**Table 24**), giving a total of 48157.668 tCO_2e emissions reduced annually by all the selected projects (**Table 25**). This represents a shift in emissions from 76300.098 tCO_2e in the baseline scenario to 28142.430 tCO_2e in the project scenario, accounting for about 63.12% emission reduction. The total amount of emissions reduced could generate about 48157.668 CERs per year and 481576.68 CERs in 10 years (**Table 25**), assuming a fixed 10 years crediting duration for all the projects, and a constant quantity of annual emission reduction for each project throughout this period.

Table 22 : RE and EE considered and unconsidered

ENERGY EFFICIENCY PROJECTS		Method	C	UC
1	600 LED lamps installed to replace fluorescent lamps in University Hostels (2020).	AMS-II.C	✖	
2	1500000 LED lamps installed to replace fluorescent lamps in 500000 households connected to the grid.	AMS-II.C	✖	
3	10500 LED lamps for street lighting to replace high pressure sodium and mercury lamps in rural and urban localities.	AMS-II.L	✖	
4	4500 LED lamps for street lighting in Ouagadougou and Bobo Diolasso.	AMS-II.L	✖	
5	1400 solar street lights with LED lamps installed in rural localities. (Project 175 rural localities)	AMS-II.L	✖	
6	1926 solar street lights with LED lamps installed in Ouagadougou.	AMS-II.L	✖	
7	Acquisition and installation of 3500 smart meters for high and medium voltage customers. 1778 installed as at 2020			✖
8	Installation of energy efficient air conditioners in public buildings in replacement of			✖

	the old inefficient ones.			
RENEWABLE ENERGY PROJECTS				
1	385 Infrastructures; installation of off-grid solar PV systems in schools and health facilities in different regions across the country.	AMS-I.F	✖	
2	Installation of grid-connected solar PV systems in 25 medical centres with surgical antenna (CMA) in different regions across the country (2018 & 2019).	AMS-I.F	✖	
3	Installation of grid-connected solar PV systems in 12 public buildings in different regions across the country (2019).	AMS-I.F	✖	
4	Installation of off-grid solar PV kits in 30 City Halls in different regions across the country.	AMS-I.F	✖	
5	Off-grid Solar Back up project, installation of solar kits in households and small and medium enterprises in different regions across the country.	AMS-I.F	✖	
6	On-grid solar PV systems (200kWp) installed at the presidency of Burkina Faso.	AMS-I.F	✖	
8	On-grid solar PV systems (62kWp) installed at the country's First Ministry.	AMS-I.F	✖	
9	On-grid solar PV systems (40kWp) installed at the Ministry of energy.	AMS-I.F	✖	
10	On-grid solar PV systems (20kWp) installed at Koupéla hospital.	AMS-I.F	✖	
11	On-grid solar PV systems (75kWp) installed at the Ministry of the environment.	AMS-I.F	✖	
12	On-grid solar PV systems (42kWp) installed at the research institute in applied sciences and technologies (IRSAT).	AMS-I.F	✖	
13	On-grid solar PV systems (35kWp) installed at the national centre for scientific research and technology (CNRST).	AMS-I.F	✖	
14	On-grid solar PV systems (40kWp) installed at société générale Burkina Faso (SGBF).	AMS-I.F	✖	
15	On-grid solar PV systems (3MWp) installed in other institutions across the country.	AMS-I.F	✖	
16	Installation of off-grid solar PV systems in 297 schools and colleges and in 152 CSPS in 175 rural localities.	AMS-I.A	✖	
17	Rural electrification with solar PV micro grids installed in 20 villages (2018&2019).	AMS-I.A	✖	
18	Ziga solar PV power plant 1.1MW, connected to the grid.	AMS-I.D	✖	
19	Bilgo hybrid solar PV-diesel generator power plant, connected to the grid.	AMS-I.D	✖	
20	Distribution of 25000 certified solar lamps, Lighting Africa, in 400 primary schools in off grid rural areas (2016-2020).	AMS-III.AR	✖	
21	Distribution of 8500 solar lamps to primary school pupils in off-grid rural areas	AMS-III.AR	✖	
23	Decentralised rural electrification of 45 localities in the provinces of Ziro and Gourma (ERD-ZIGO). 36 localities electrified as at 2020.			✖
24	Installation of 343 solar water heating (SWH) systems in maternities of the same areas. 201 SWH installed as at 2020			✖
25	150 solar water heating systems (SWH) installed in CSPS in rural localities. (Project 175 rural localities)			✖
26	60 localities electrified as at 2020 in the framework of the electrification of 41 rural localities with solar PV systems.			✖

C: Considered, UC: Unconsidered.

Table 23: Annual energy savings and emission reductions by EE projects

Project	Annual energy savings (MWh/year)	Baseline annual emissions (tCO2e/year)	Project annual emissions (tCO2e/year)	Annual emission reductions (tCO2e/year)
600 LED lamps in University Hostels	35.689	28.698	11.353	17.345
1500000 LED lamps in 375000 households	60225.000	53217.000	23947.650	29269.350
10500 LED lamps for street lighting	5746.829	7036.928	3014.147	4022.781
4500 LED lamps for street lighting	1492.820	3319.432	1169.279	2150.153
1926 solar street lights with LED lamps installed in Ouagadougou.	700.150	817.695	0.000	817.695
1400 solar street lights with LED lamps installed in rural localities. (Project 175 rural localities)	508.936	594.78	0.000	594.378
TOTAL	**67500.339**	**65014.131**	**28142.430**	**36871.701**

Table 24: Annual energy displaced and emission reductions by RE projects

Project	Annual energy displaced(MWh/year)	Baseline annual emissions (tCO2e/year)	Project annual emissions (tCO2e/year)	Annual emission reductions (tCO2e/year)
385 Infrastructures, off-grid solar PV systems in schools and health facilities	465.474	325.832	0.000	226.220
On-grid solar PV systems in medical centres and public buildings	2.154	1507.985	0.000	1046.973
Off-grid solar PV kits in City Halls	71.668	50.167	0.000	34.831
Solar Back up project, off grid	1851.331	1295.931	0.000	899.747
On-grid solar PV systems installed in different institutions	4376.686	3063.680	0.000	2127.070
Off-grid solar PV systems in rural schools and CSPS	274.067	219.54	0.000	219.254
Rural electrification with solar PV micro grids	687.709	550.167	0.000	550.167
Ziga solar PV power plant	1656.188	1159.331	0.000	804.907
Bilgo hybrid solar PV-diesel generator power plant	45.169	31.618	0.000	21.952
Distribution of 25000 certified solar lamps, Lighting Africa, in 400 primary schools in off grid rural areas (2016-2020).	--	2300.000	0.000	2300.000
Distribution of 8500 solar lamps to primary school pupils in off-grid rural areas	--	782.000	0.000	782.000
TOTAL	**9430.446**	**11285.967**	**0.000**	**11285.967**

--: Not determined

Table 25 : Total energy saved, energy displaced, emissions reduced and CERs generated

Energy saved/year	68709.424 MWh
Energy displaced/year	9430.446 MWh
Emission reduced/year	48157.668 tCO_2e
Number of CERs/year	48157.668
Number of CERs for a 10years crediting period	481576.68

4.3. Discussion

The aim of this study was to investigate on how the low carbon projects implemented in Burkina Faso have impacted the level of CO_2 emissions, in order to capitalise the emission reduction and improve the country's energy infrastructure where required. This will accelerate the achievement of the country's INDCs and contribute to its sustainable development, as this will improve access to clean energy across the country. All these added to the multiple benefits of the CDM. This research also aimed to show that Burkina Faso is not the only African country hosting such potential CDM projects which are wasted, as they are not registered to the CDM.

An inventory of 34 projects was done, but only the 28 with available data were considered for the study as presented in **Table 22**. As per the study's findings, the EE and RE projects considered contribute to the reduction of GHG emissions by 36871.701 tCO_2e (**Table 23**) and 11285.967 tCO_2e (**Table 24**) respectively on an annual basis. The EE projects presented a way more attractive CDM potential than the RE energy projects; this may be explained by the fact that the scale of the projects identified in the EE sector are way bigger than those in the RE sector. An annual emissions reduction of 48157.668 tCO_2e (**Table 25**), resulting from the RE and EE projects considered account for 63.12% of what would have been emitted in the absence of these projects, that is in the BAU scenario. This is a huge reduction which concurs with the results of several studies done for either less developed countries, developed countries or for both, according to which the consumption of RE and the implementation of improved EE measures have a negative impact on carbon emissions, as they lead to a reduction of the level of these emissions (Akdag & Yıldırım, 2020; Gielen et al., 2019; IRENA, 2017; Özbuğday & Erbas, 2015). It is also in line with the findings of Inglesi-Lotz & Dogan (2018) and Prince & Okechukwu (2019), which confirmed that in African countries, RE consumption reduces carbon emissions while the consumption of non-RE increases them; given that the projects considered in this study either displace or reduce fossil fuel consumption, as the electricity used in the BAU scenarios either comes from the grid, which is mainly fossil fuel based or from the use of diesel generators. All the projects selected contribute to reduce the emission of 48157.668 tCO_2e per year, which represent 1.3% of Burkina Faso's total carbon emissions from fossil fuel combustion, flaring and industrial processes, which amounted to about 3.7 million tCO_2e in 2018 according to Knoema (2020).

The 48157.668 tCO_2e per year CDM potential of the already implemented and operational projects considered in this study is way less than that of the project opportunities in the energy sector in Burkina Faso that were identified by Timilsina et al. (2010). The GHG emission reduction or CDM potential they determined for these project opportunities amounted to 82.7 million tCO_2e per year. Moreover, the GHG emission reduction potential we found could yield about 48157.668 CERs annually, which is also way less than a total of 2.96 million CERs per year found by Christof et al. (2011). They considered project opportunities in different sectors including waste potential, renewable energy, energy efficiency, transportation and potentials in mining, charcoal and cement production. UNEP RISØ (2013) obtained 180000 tCO_2e and 48000 tCO_2e as the annual emission reduction potential of solar lighting and solar PV technologies respectively in Burkina Faso. All the RE projects considered in this study fall under these groups but the annual emission reduction potential we obtained is only 11285.967 tCO_2e.

Different reasons may justify the huge difference between the CDM potential of already implemented and operational RE and EE projects obtained in this study, and that of potential project opportunities in Burkina Faso identified by either Timilsina et al. (2010) or Christof et al. (2011). Some of which could be the scope of the sector of projects considered; the number and scale of the project opportunities they considered and that of those actually implemented and included in this study; the CDM methods and tools used to quantify the emission reductions as well as their version, given the fact that these methods and tools are improved and updated as years go by. This however shows that there is still enough CDM potential to be harnessed in the country.

The emission reduction potential of RE and EE projects obtained in this study is less than the reality in Burkina Faso for several reasons. Firstly, not all the projects identified were taken into consideration for the quantification of emission reduction because of lack of data for some projects as shown in **Table 22,** which could highly increase the results found. Secondly, in addition to the fact that there are planned projects yet to be implemented, most of the implemented projects identified are part of bigger national programs which are still ongoing, with more projects progressively being implemented. For instance, the second face of the solar back up project in which the distribution of 2789 solar kits of different capacities led to the reduction of 899.747 tCO_2e in the first face, is about to be launched with the aim of distributing 3000 to 3500 more solar kits (Masneang Laoundiki, 2020). There is also a total capacity of 530 kWh and 495 kWh left to be installed in medical centres with antenna (CMA) and in public buildings respectively across the country in 2020 and 2021, which will contribute in reducing the emissions by about 718.262 tCO_2e annually. The Yeleen project (implemented at 10% as at 2020) supported by the African Development Bank (AfDB), the French Development Agency (AFD) and SONABEL aimed at installing several grid connected solar plants in the country with a total installed capacity of 50MWp (AfDB, 2020) also represents a huge CDM potential, as it could reduce about 36586.688 tCO_2e annually. These are just to name a few as there are many other similar cases. Lastly, the list of the projects identified may not be exhaustive, as there could be relevant unidentified projects which may possibly reveal a higher total emission reduction potential of such projects implemented in the country.

Like Timilsina et al. (2010), considering a carbon price of \$10/ tCO_2e would imply a yearly yield of \$481576.68 by the projects considered, which gives a total of \$4815766.8 for a crediting period of ten years as shown in **Table 25**. This could be way more and will rise with time for the above mentioned reasons, providing a considerable source of revenue, which could be used for the expansion of the projects and the quick deployment of more of such projects across the country. This is also a factor that could make the sector more attractive for investors.

According to the INDC targets of Burkina Faso, the mitigation scenarios of emission reductions from the energy sector is predicted to reach 3702 million tCO_2e by 2030, where 572 million tCO_2e and 3102 million tCO_2e account respectively for the unconditional and the conditional mitigation scenarios. With the total emission reduction potential of 48157.668 tCO_2e found for the projects in this study, considering the count from 2020, the total emissions that would be reduced by these projects by 2030 would be 481576.68 tCO_2e. This is less than the target but it shows that these projects should not be neglected in the struggle to achieve the country's INDC targets.

As presented in **Table 25**, the total annual energy savings by the EE projects considered is 68709.424 MWh which can serve to satisfy other consumers. In addition to reducing emissions, such energy savings could contribute to the avoidance of extra capacity installation, enable quick access to electricity, reduce electricity imports and increase the country's energy security.

All the selected projects were proven to be additional; meaning that the emission reductions they produce are additional to what would have occurred without their implementation. This is a very essential and indispensable criterion for a project activity to be registered to the

CDM; since it ensures that the credits (CERs) would not be awarded for emissions that would have occurred with or without the project activity.

Some of the main reasons of the slow development of RE and EE projects in the country, as well as the reasons of the non-registration of those that are already implemented to the CDM were also identified. There exist national regulations, incentives and legislative energy frameworks **Table 2** in Burkina Faso that encourage the development of such projects in the country, however, the socio-political and security context of the country could hinder their implementation. Additionally, the lack of finance for such projects is the major constraint to their development. As for the projects' registration to the CDM, added to the high transaction cost involved in the registration of projects to the CDM, the lack of awareness regarding the CDM generally; its benefits and the specific steps to follow for a project to be registered to the CDM are factors that hinder project registration to the CDM. The slowness of the administrative procedures at the level of the Designated National Authority (DNA) that could be a result of inadequate expertise is also one of these disfavouring factors. These barriers to the development of CDM projects in Burkina Faso and in Africa as a whole are in line with those identified by UNEP FI (UNEP FI, 2011).

Burkina Faso is not the only African country with such unexploited CDM potential. RE and EE projects have been identified in Kenya, Senegal, Ghana, Benin, Algeria, DRC and Zambia, which are not registered to the CDM, and there are many other such cases in other African countries.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Renewable energy and energy efficiency projects actually contribute to the reduction of GHG emissions in Burkina Faso and in Africa in general. The renewable energy and energy efficiency projects implemented in Burkina Faso that were considered in the present study account for an annual decrease in carbon emissions of about 48157.668 tCO2e, which represents a 63.12% decrease from the baseline emissions. This is a great CDM potential, as these emission reductions could generate about 48157.668 CERs yearly, and 481576.68 CERs for a crediting period of 10 years fixed for each of the projects. With a carbon price of $10, exploiting this potential would imply securing a total revenue of $4815766.8 from CERs sales in a 10 year period; this contributes to increasing the sector's attractiveness to more investments. Moreover, the emission reduction of the RE and EE projects (48157.668tCO2e) gotten in this study is less than the reality on site. This is because the quantification of the project emission reductions was not done for some of the projects identified due to unavailable data; and the list of the projects resulting from the inventory is not exhaustive. All the projects considered in this study are not registered to the CDM, the main reasons being the lack of awareness regarding the CDM generally; its benefits and the specific steps to follow for a project to be registered to the CDM. The high transaction cost involved in the registration process of projects to the CDM, as well as the slowness of the administrative procedures at the level of the Designated National Authority (DNA), that could be a result of inadequate expertise is also one of these disfavouring factors.

The renewable energy and energy efficiency projects implemented in Burkina Faso represent a huge potential for the CDM, ready to be harnessed. Like Burkina Faso, many other African countries are hosts to similar projects, at a bigger scale in some cases, which are low hanging fruits just waiting to be harvested. There are also many of such projects still at the development or construction stage in Burkina Faso as well as in other African countries, which could also be considered for this mechanism. It is therefore essential to register these projects to the CDM in order for the individual countries and the region in general to benefit from the sustainable development brought about by this mechanism through technology transfer, financial support, contribution to the achievement of their INDCs, economic development and poverty reduction. This will also increase the representation of African countries in the CDM, where they are still very poorly represented, yet endowed with enormous CDM potential.

5.2. Recommendation

In Burkina Faso, some of the main barriers to the registration of projects to the CDM are lack of awareness and expertise, lengthy and complex registration process and high transaction cost involved; given that most of the projects are small scale projects. In order to tackle these constraints, project developers or governments could use the option of Programs of Activities (PoA) proposed by the CDM. The PoA is favourable for less developed countries in particular for a couple of reasons, amongst others, the fact that it serves as an "umbrella program" registered to the CDM, to which other individual projects called Component Project Activities (CPA) that comply with the eligibility criteria in the PoA Design Document (PoA-DD) can be added. This approach could also be considered for other African countries facing similar limits, as it simplifies the registration process, saves time, extends the access to the CDM to small projects which could not be viable as a regular project, and it reduces the transaction cost, the investment risks and uncertainties of CPA participants (Burian & Christof, 2014; UNFCCC, 2019a). Additionally, Burkina Faso already has a DNA, but policies that promote the implementation of more programs like the CDM Assist program should be put in place for awareness enhancement and capacity building with hands on experience in real CDM projects. This is to help the country attract more CDM projects, to develop and manage them. Like China, the government can go further to establish a CDM management centre to work in collaboration with the DNA, and that will amongst others have the following responsibilities:

- Assist project owners who want to register their project to the CDM
- Organise experts to review CDM projects and offer evaluation opinions
- Offer CDM project development and management information
- Monitor and supervise the implementation of CDM projects
- Produce a data base of country information about its CDM potential, CDM registered projects, number of CERs generated by CDM projects in the country, etc.

Furthermore, it was noticed that the reporting of low carbon projects in the country is done by different entities, which give similar information and at times with some divergence in some cases due to failure to update data by some parties. The CDM centre if established would also be responsible to consolidate all the data regarding these projects, as well as ensuring their timely update. This will as well facilitate access to reliable and accountable data for different stakeholders.

Moreover, potential CDM opportunities may not be harnessed in some cases due to lack of awareness of their existence by potential investors; therefore, at the government level, making available the statistics (on concerned Ministry or Agency website for example) regarding successful CDM projects hosted by the country, the country's CDM potential as well as its CDM opportunities is also a move to attract private investors and boost the implementation of such projects in the country. This is also applicable across the continent.

Lastly, the implemented EE projects that are considered in the present study appear to have a more attractive CDM potential than the RE projects, they could therefore be prioritised when registering these low carbon projects to the CDM.

5.3. Future research

The present study put more focus on quantifying the emission reduction potential of RE and EE projects implemented in Burkina Faso. Future research could go further and do same for the several other planned low carbon projects in the country, for revealing their CDM potential could increase their attractiveness for investments and therefore accelerate their development. Moreover, such studies could be done for other African countries as it has been proven that Burkina Faso is not the only country in the region with such unharnessed CDM potential. Additionally, projects other than RE and EE projects which are in other sectors included in the sectoral scopes of the CDM could be considered in future studies to optimise the quantification of these countries' CDM potential.

6. APPENDIX

6.1. Terms of reference to hire interns for data collection

Termes de Référence pour le recrutement d'un stagiaire pour collecte des données
Année Académique 2019-2020

Nom du Superviseur	Dr Marie Sawadogo
Nom du Chercheur	Seutche Nono Rice Verouska
Institution du Chercheur	Université Pan Africaine, Institut des Sciences de l'Eau et de l'Energie (PAUWES). Tlemcen/Algérie
Hébergement Institution / Département	2iE - ANEREE
Pays	Burkina Faso
Titre / Affiliation	Responsable du Laboratoire Energies Renouvelables et Efficacité Energétique
Sujet du Travail	Valorisation de la réduction des émissions de CO2 par des projets liés aux énergies renouvelables et à l'efficacité énergétique en Afrique : Cas du Burkina Faso

Résumé de l'étude

L'Afrique est l'une des régions les plus vulnérables aux graves impacts du changement climatique dans le monde. Bien que le continent ne soit pas un important émetteur de gaz à effet de serre (GES), représentant seulement 2 à 3% des émissions mondiales de CO_2 issues des sources industrielles/énergie, les pays Africains s'efforcent de réduire et de minimiser leurs niveaux d'émissions de GES en général et de carbone en particulier. Ceci est fait en introduisant les énergies renouvelables ainsi que des technologies innovantes et rentables en matière d'efficacité énergétique dans le cadre de leurs programmes respectifs de développement. De plus, le Mécanisme de Développement Propre (MDP) du protocole de Kyoto offre la possibilité d'échanger des réductions d'émissions de carbone contre des crédits carbone pour le développement de projets verts et économes en énergie. À ce jour, seulement 3% des projets enregistrés sous le MDP sont en Afrique. Le projet de recherche proposé vise à étudier, en collaboration avec l'Agence Nationale des Energies Renouvelables et de l'Efficacité Energétique (ANEREE) du Burkina Faso et l'Institut International d'Ingénierie de l'Eau et de l'Environnement (2iE), comment le pays peut capter et capitaliser l'impact des projets (énergie renouvelable et efficacité énergétique) implémentés sur la réduction des émissions de GES. Ceci permettra au pays non seulement d'améliorer et de développer son infrastructure énergétique, mais également d'atteindre les objectives de ses respectives contributions prévues déterminées au niveau national (CPDN), tout en bénéficiant des apports du MDP.

Contexte du recrutement du stagiaire

Le présent projet de recherche consiste entre autres à comptabiliser la quantité d'émission de CO_2 qui a été réduite ou évitée suite à l'implémentation et l'opération des projets dans les secteur des énergies renouvelables (EnR) et de l'efficacité énergétique (EE) au Burkina Faso. Pour se faire, un inventaire des projets du type sur-mentionné devrait être effectué. Des données techniques pour chaque projet devraient être collectées pour permettre d'effectuer les calculs d'émissions réduites. Des données tel que :

- le type de technologie employé par le projet,
- le type de technologie qui aurait été utilisée pour le même service en l'absence du projet,
- la capacité de production des centrales installées (cas des centrales solaires par exemple),
- le nombre et type de bénéficiaires du projet (population rurale, urbaine, ménages, bâtiments publics, centre de santé, écoles, etc.),
- le nombre et spécifications des anciennes et nouvelles lampes, climatiseurs, etc. dans le cas de remplacement des appareils à faible efficacité énergétique par des plus efficaces,
- etc

Ces données devraient être collectées au niveau des institutions concernées au Burkina Faso par la chercheure, qui n'a malheureusement pas pu arriver à cause de la pandémie. C'est ainsi qu'un stagiaire sera recruté pour accomplir ces tâches afin d'avoir les données pour mener à bien le travail.

Objectif

L'objectif est d'obtenir les données requises pour l'aboutissement du travail.

Rôles et responsabilités du stagiaire

A l'aide d'une fiche de collecte de données qui lui sera donnée, et progressivement mise à jour, collecter les données requises, sous orientation de la chercheure et la supervision du Directeur de travail, au niveau des institutions concernées tel que le 2iE, le Ministère de l'Energie, l'ABER, l'ANEREE, etc. et d'autres d'identifiées au cours du travail.

Résultats Attendus

- Faire un inventaire, le plus exhaustif que possible des projets EnR et EE implémentés au Burkina Faso au cours de ces dernières années.
- Pour chaque projet, avoir le plus de détails possible pour remplir la fiche adaptée à chaque projet. La fiche sera conçue par la chercheure au fur et à mesure que les projets seront identifiés, et sera donnée au stagiaire pour orienter la collecte des données.

Chronogramme

Tâches	Timeframe	
	Août 2020	Mi-Septembre 2020
Identification des projets		
Collecte des données spécifiques à chaque projet.		

6.2. Letter for request of data from the National Agency for Rural Electrification

2iE

Ouagadougou le 13/08/2020

Madame la Responsable
du Laboratoire LabEREE

N/Réf. : 2020/DG/SG/DR/LabEREE

A

Monsieur le Directeur
Général de l'Agence de Burkinabè de
l'Electrification Rurale

Objet : Demande de données

Monsieur le Directeur Général,

Dans le cadre des travaux de recherches menés au 2iE en collaboration avec l'Université Pan Africaine (PAUWES) portant sur le bilan des émissions de gaz à effet de serre des projets d'Energies renouvelables et d'efficacité énergétique au Burkina Faso, nous venons solliciter auprès de votre haute bienveillance une autorisation, afin de collecter les données y afférentes au sein de vos services.

L'essor des énergies renouvelables étant de plus en plus grand dans notre pays nous nous intéressons aux actions menées par le gouvernement dans le cadre de l'électrification rurale à travers la réalisation de projet en Energies Renouvelables mais aussi des travaux réalisés dans le domaine de l'Efficacité Energétique. Pour ce faire, nous aimerions solliciter la liste détaillée des projets implémentés ou en cours d'implémentation depuis 2015 dans les énergies renouvelables et l'efficacité énergétique afin de quantifier les réductions d'émissions de gaz à effet de serre dus à ces projets.

Dans l'attente d'une suite favorable, veuillez agréer Monsieur le Directeur, l'expression de notre franche collaboration.

La Responsable du LabEREE

Dr. Marie TIEMTORE/ SAWADOGO

6.3. Letter for request of data from the Department of Renewable Energy

2iE

Ouagadougou le 13/08/2020

Madame la Responsable
du Laboratoire LabEREE

N/Réf. : 2020/DG/SG/DR/LabEREE

A

Monsieur le Directeur Général des Energies Renouvelables

Objet : Demande de données

Monsieur le Directeur Général,

Dans le cadre des travaux de recherches menés au 2iE en collaboration avec l'Université Pan Africaine (PAUWES) portant sur le bilan des émissions de gaz à effet de serre des projets d'Energies renouvelables et d'efficacité énergétique au Burkina Faso, nous venons solliciter auprès de votre haute bienveillance une autorisation, afin de collecter les données y afférentes au sein de vos services.

L'essor des énergies renouvelables étant de plus en plus grand dans notre pays nous nous intéressons aux actions menées par le gouvernement dans le cadre de l'électrification rurale à travers la réalisation de projet en Energies Renouvelables mais aussi des travaux réalisés dans le domaine de l'Efficacité Energétique. Pour ce faire, nous aimerions solliciter la liste détaillée des projets implémentés ou en cours d'implémentation depuis 2015 dans les énergies renouvelables et l'efficacité énergétique afin de quantifier les réductions d'émissions de gaz à effet de serre dus à ces projets.

Dans l'attente d'une suite favorable, veuillez agréer Monsieur le Directeur, l'expression de notre franche collaboration.

La Responsable du LabEREE

Dr. Marie TIEMTORE/ SAWADOGO

6.4. Data collection form

PROJECTS ENERGIES RENOUVELABLES ET EFFICACITE ENERGETIQUES IMPLEMENTES ET OPERATIONNELS AU BURKINA FASO

Projet/ Année de mise en service	Technologie	Source d'énergie/Technologie remplacée	Service/ Produit	Lieu	Capacité installée (MW)	Capacité de production annuelle (kWh)	Observation

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