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IEREK Interdisciplinary Series for Sustainable Development

Khanneh Wadinga Fomba · Bertrand Tchanche Fankam · Abdelwahid Mellouki · Daniel M. Westervelt · Michael R. Giordano *Editors*

Advances in Air Quality Research in Africa

Proceedings of the First International Conference on Air Quality in Africa (ICAQ'Africa 2022)

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Advances in Science, Technology & Innovation

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ISSN 2522-8714 ISSN 2522-8722 (electronic)
Advances in Science, Technology & Innovation
IEREK Interdisciplinary Series for Sustainable Development
ISBN 978-3-031-53524-6 ISBN 978-3-031-53525-3 (eBook)
https://doi.org/10.1007/978-3-031-53525-3

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Contents

Assessment of Carbon Dioxide Emission Factors from Electricity Generation in Burkina Faso

Bernard Nana, Hamadi Zalle, Issoufou Ouarma, Tizane Daho, Arsène Yonli and Antoine Béré

Abstract

Electricity generation is the second largest emitter of greenhouse gases, notably carbon dioxide (CO_2), in the Burkinabe energy sector. Until now, Burkina Faso has used the default emission factors provided by the Intergovernmental Panel on Climate Change to assess its CO_2 emissions from electricity generation, particularly in the context of the National Communications on Climate Change, due to the lack of country-specific emission factors. This study presents the assessment of CO_2 emission factors of electricity generation in Burkina Faso. The Burkinabe National Electricity Company was chosen as the scope of the study. The evaluation of emission factors for combustion is based on the experimental/calculation method through an analysis of the fuels consumed by the thermal power plants. After evaluating a CO_2 emission factor of 76,903.31 kg/TJ for the combustion of Heavy Fuel Oil (HFO) and 73,524.54 kg/TJ for the combustion of Distillate Diesel Oil (DDO), we evaluate the CO_2 emissions of electricity production at 579.83 Gg. The CO_2 emission factor for thermal generation is estimated at 0.663 kg/kW h and that of the electricity generation mix is 0.569 kg/kW h. The use of renewable energies in electricity generation avoided 16.7% of CO_2 emissions in 2018. Also, there is a decrease in the emission factor of the generation mix with the increase in the share of renewables in the generation mix.

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Keywords

Electricity generation · Greenhouse gases · Emission factor · Carbon dioxide

1 Introduction

Combating air pollution and the adverse effects of climate change is one of the most important environmental issues of our time. According to the Intergovernmental Panel on Climate Change (IPCC), the increase in the concentration of GHGs (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) etc.) in the atmosphere as a result of human activities is the main cause of global warming (GIEC, 2021). According to the 6th IPCC report, net global anthropogenic GHG emissions are estimated to be 59 $GtCO_2$ in 2019 (of which 44 Gt CO_2), i.e. an increase of about 54% compared to the 1990 level (GIEC, 2022).

GHG emissions from anthropogenic sources come from several sectors of activity, including the energy sector. In the energy sector, GHG emissions come mainly from the use of primary fossil fuels for electricity generation and transport. According to a report by the International Energy Agency (IEA), global primary energy consumption is estimated at 14.3 Gtoe in 2018, of which 80.55% is fossil-based; and energy-related CO_2 emissions in the same period reached 33.14 Gt, an increase of 1.7% compared to 2017, the majority of which comes from electricity generation (IEA, 2019a).

Africa's contribution to energy-related CO_2 emissions is about 2% of cumulative global emissions, yet it is at the foreground of climate change impacts (IEA, 2019b). West Africa is already experiencing loss of life, human health impacts, biodiversity loss, reduced economic growth etc. (CDKN, 2022).

K. W. Fomba et al. (eds.), *Advances in Air Quality Research in Africa*,
Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-53525-3_1

In the face of climate change, reducing CO_2 emissions is a major priority. The member states of the United Nations Framework Convention on Climate Change (UNFCCC) have committed to reducing their GHG emissions. According to the Paris Climate Agreement, the objective of this reduction is to keep the increase in global average temperature well below 2 °C above pre-industrial levels and to continue efforts to limit this increase to 1.5 °C (Nations Unies, 2015).

An important step in the search for solutions to reduce emissions is to identify the most significant sources of GHG emissions. This is done through an inventory of GHG emissions and the development of programs to reduce the consumption of petroleum products and to increase the consumption of low GHG emitting products.

Burkina Faso, a member of the UNFCCC and a country not included in Annex I of the Convention, has joined the GHG emissions reduction process. Indeed, it has prepared National Communications under the UNFCCC. These communications show that in 2015 the energy sector was the second largest GHG emitting sector and electricity production was the second largest contributor to GHG emissions in this sector after transport in 2015 (PRBA, 2021). CO_2 typically accounts for 95% of energy sector emissions (GIEC, 2006a). CO_2 alone accounted for more than 99% of GHG emissions from electricity generation in Burkina Faso in 2015 (PRBA, 2021).

Several methods for estimating GHG emissions exist in the literature (CITEPA, 2020): the continuous measurement method, the material balance method and the calculation method using emission factors. The IPCC provides three tiers for estimating GHG emissions from stationary combustion (GIEC, 2006b): Tier 1 is the basic method, Tier 2 is the intermediate method and Tier 3 is the most demanding method in terms of complexity and data requirements. Emission factors are specific to the emission source and are determined either by analogy (default value), life cycle analysis, or experimentally and by calculation (studies/research). CO_2 emission factors for fossil fuel combustion depend mainly on the carbon content of the fuel and its calorific value. The CO_2 emission factor may include the oxidation factor (case of national emission factors).

Until now, Burkina Faso has assessed its GHG emissions attributable to electricity production with the default EFs provided by the IPCC due to the lack of country-specific EFs. However, a rigorous estimation of the sector's contribution to GHG emissions requires quality EFs. It is therefore important to develop specific EFs for Burkina Faso in the power generation sector. Moreover, as the reduction of GHG emissions is one of the key areas for combating climate change, the challenge for all countries is to implement a transition to a safer and less CO_2 emitting energy system such as renewable energy without hampering socio-economic development. It is in this context that the objective of this study is to assess the CO_2 emission factors of the electricity generation sector in Burkina Faso.

2 Materials and Methods

2.1 Burkinabe Electricity Generation

Burkina Faso's national electricity production in 2018 was 1052.8 GW h, of which 1020.7 GW h was produced by the Burkinabe National Electricity Company (SONABEL) (ME, 2018a). SONABEL's production is made up of 85.75% diesel thermal source; 8.95% hydro and 5.3% solar PV. The electrical energy delivered to distribution is 1,844.2 GW h and is provided by SONABEL (1,815.4 GW h) for the national interconnected network on the one hand and by the electricity cooperatives (28.8 GW h) for the isolated networks on the other (ME, 2018a, b). The study area considered is SONABEL because it is the main supplier of electricity in Burkina Faso with 97% of total national generation and nearly 96.5% of national thermal generation.

The number of functional power plants by type in 2018 was 19 for SONABEL (including 13 diesel thermal plants, 04 hydroelectric plants and 02 solar PV plants).

Figure 1 shows the location of SONABEL’s power plants for the year 2018.

In 2018, thermal power plants consumed 186,805 tonnes of fuel (SONABEL, 2018). The share of HFO is 86.5% and that of DDO is 13.5%; that is, 161,586,325 kg of HFO and 25,218,675 kg of DDO.

2.2 Methodology

The CO_2 EFs of the fuels for combustion and the CO_2 EF of the electricity production of fossil thermal power plants depend on the characteristics of the fuels (carbon content, calorific value etc.) and do not depend on the technology used. The GHG emitting activities in this study are the activities of fuel combustion for electricity generation by power plants. The activity data used in this study are the actual quantities of fuels consumed and the electricity production for the year 2018.

3 Fuel Analysis by Characterisation

Molecular characterisation of fuels. A sample of the two fuels consumed by SONABEL's thermal power plants is taken and subjected to analysis. This characterisation provides the different constituents in terms of HFO and DDO

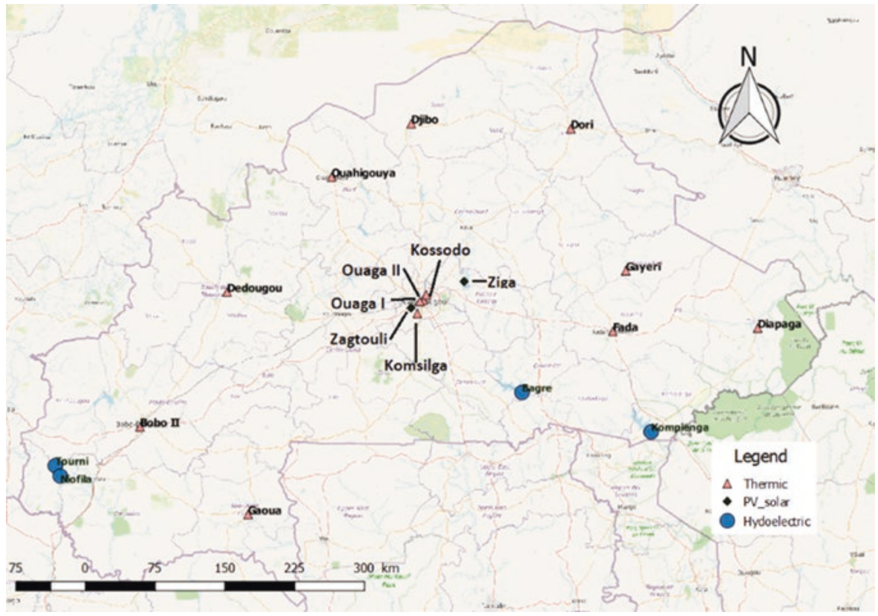

Fig. 1 Location of SONABEL's power plants in the country in 2018

molecules. The knowledge of the molecules constituting each fuel and their fraction in mass makes it possible to determine the chemical formula and the elementary composition in mass of the fuels. If $C_xH_yO_zN_uS_t$ is the chemical formula of the fuel, then:

$$x = \sum_{i=1}^{n} p_i x_i;\ y = \sum_{i=1}^{n} p_i y_i;\ z = \sum_{i=1}^{n} p_i z_i;\ u = \sum_{i=1}^{n} p_i u_i;\ t = \sum_{i=1}^{n} p_i t_i \quad (1)$$

where p_i is the mass fraction of each constituent present in the mixture and x_i, y_i, z, u_i, t_i represent respectively the number of carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sulphur (S) atoms of each constituent i in the mixture.

The molar mass is defined as the average value of the molar masses of its constituents.

$$M_{C_xH_yO_zN_uS_t} = \sum_{i=1}^{n} p_i M_i \quad (2)$$

M_i is the molecular weight (in g/mol) of molecule i in the fuel.

The following atomic molar masses in g/mol are considered:

$$M_C = 12; M_H = 1;\ M_O = 16; M_N = 14; M_S = 32$$

Method of determining the density of fuels. The density of each fuel at temperature T is determined experimentally by the densimeter method. This method is based on the standardised method NF T60 101 (Guillermic, 1980). As HFO has variable characteristics and given its very high share in consumption (86.5%), three (03) samples of different origins (Cotonou, Lomé and Abidjan) were submitted to the analysis. For DDO, only one sample from Cotonou was submitted for analysis (Fig. 2).

The equipment used consisted of: a 500 mL capacity graduated cylinder, a densimeter graduated from 0.950 to 1 for HFO and 0.800 to 0.900 for DDO, a HANNA Checktemp digital thermometer and a Potence.

The following equation is used to reduce the density at the measurement temperature T to the reference temperature 15 °C (Guillermic, 1980).

$$d_4^{15} = d_4^T + A\,(T - 15) \quad (3)$$

where: d_4^T is the density at temperature T, d_4^{15} is the density at 15 °C and A is the density correction factor.

To choose the coefficient A, we use the table given by Guillermic (1980).

The density at 15 °C of the HFO will be the average of the densities at 15 °C of the three samples.

Method for determining the lower heating value of fuels. The lower calorific value of fuels is estimated using the following equation (Sawerysyn, 1993).

$$LCV = HCV - w\,L_v \quad (4)$$

LCV: lower calorific value (in kJ/kg).
HCV: higher calorific value of the fuel (in kJ/kg).
w: Total mass of water in kg released by the combustion of 1 kg of raw fuel.
L_v: the latent heat of vaporisation of water (in kJ/kg).