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Circular Economy as an Important Lever to Reduce Greenhouse Gas Emissions: Case of an Electricity Distribution Company in Morocco

Salma El Majaty†, Abdellatif Touzani and Youssef Kasseh
Laboratoire de Géophysique Appliquée, Géologie Géotechnique, L'Ingénieur et L'Environnement (L3GIE)
École d'ingénieurs Mohamedia 10200, Rabat, Maroc
†Corresponding author: Salma El Majaty; salma.elmajaty@gmail.com

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ABSTRACT

This article discusses the major challenges related to greenhouse gas (GHG) emissions in the electricity sector and their impact on global climate change. The electricity sector is responsible for about a quarter of total global GHG emissions. To address these challenges, Life Cycle Assessment (LCA) is used to measure the environmental impact of different energy sources and electricity generation and distribution processes. The circular economy is presented as a promising approach to reducing the carbon footprint of the electricity sector. By optimizing the use and value of materials throughout their life cycle, this approach contributes to waste minimization and resource efficiency. Morocco is committed to reducing its GHG emissions and has adopted policies and regulatory frameworks to combat climate change. This study aims to calculate the climate change impacts of electricity distribution phases by applying a life-cycle approach to the case of an electricity distribution company in Morocco. This assessment makes it possible to identify significant contributors from each area. In the context of this company, it is a question of demonstrating how the application of the principles of the circular economy concepts contributes to the reduction of greenhouse gas emissions, in particular, that of scope 3. This study may be useful for other similar companies.

INTRODUCTION

Greenhouse gas (GHG) emissions are one of the major challenges to addressing global climate change issues and promoting sustainable development in the electricity sector. Globally, the electricity sector is responsible for emitting approximately 13.7 gigatons of CO_2 equivalent ($GtCO_2$) each year, or nearly one-quarter of total GHG emissions (Chanda & Bose 2020).

To develop effective and cost-effective strategies, it is imperative to measure GHG emissions in the electricity sector. The use of environmental assessment tools, such as Life Cycle Assessment (LCA) applied to different energy sources and electricity production and distribution processes, provides a better understanding of the environmental impact of these activities (Kiss et al. 2020).

The electricity industry also faces the challenge of effectively managing "scope 3" of GHG emissions, which includes indirect emissions from upstream and downstream activities of the company, such as the production and transportation of fuels used to generate electricity. According to the Carbon Disclosure Project (CDP) (Ott et al. 2017), indirect "scope 3" emissions represent, on average, 80% of a company's total electricity-related emissions). Reducing these indirect emissions requires a holistic approach involving collaboration between different stakeholders in the energy supply chain.

The concept of circular economy has attracted increasing interest in recent times due to its great potential to significantly reduce the carbon footprint, including through waste minimization and resource efficiency (Al-Hamrani et al. 2021). For an electricity distribution company, the circular economy offers an innovative approach to optimizing the use and value of materials throughout their life cycle while actively contributing to waste minimization.

In Morocco, the electricity sector is booming. It plays a crucial role in the economic and social development of the country. However, due to its dependence on fossil energy sources, it is also one of the main contributors to greenhouse gas (GHG) emissions in the country. These emissions include both direct emissions from electricity generation and indirect emissions from inputs and activities upstream of the company's value chain.

Morocco's direct greenhouse gas emissions reached 85,224 Gg CO_2e (gigagrams of CO_2 equivalent). The energy sector was the largest emitter, contributing 47,890 Gg CO_2e, accounting for 63.5% of net national emissions in 2020 (Khan et al. 2022).

Morocco has adopted a proactive policy in the fight against climate change since its participation in the Rio Conference in 1992. The country has put in place regulatory frameworks, such as the National Greenhouse Gas Inventory System (SNIGES), and developed national strategies for sustainable development and adaptation to climate change (Schilling et al. 2012).

In terms of mitigation, Morocco has pledged to reduce its greenhouse gas emissions by 17% by 2030, with the possibility of raising this target to 42%, depending on international support (Okpanachi et al. 2022).

This study aims to calculate the climate change impacts of electricity distribution phases by applying a life-cycle approach to the case of an electricity distribution company in Morocco. This assessment makes it possible to identify significant contributors from each area. In the context of this company, it is a question of demonstrating how the application of the principles of the circular economy concepts contributes to the reduction of greenhouse gas emissions, in particular, that of scope 3. This study may be useful for other similar companies.

In China, Song et al. (2023) assessed the carbon footprint of the electricity sector using the life cycle assessment approach. The study identified coal-fired power plants as the main source of emissions in the electricity sector. To reduce this carbon footprint, the researchers recommended adopting renewable energy sources such as solar, wind, and hydropower, as well as developing carbon capture and storage technologies to minimize emissions from coal-fired power plants.

In the Netherlands, (Moretti et al. (2022) assessed the carbon footprint of the electricity sector using the national inventory approach. The study found that coal and natural gas power plants were the main sources of emissions. To address these emissions, the researchers advocated for the increased use of renewable energy sources, such as offshore wind and biomass, as well as the implementation of energy storage systems to promote the integration of renewables into the electricity grid.

In Nigeria, Oluseyi et al. (2016) assessed the carbon footprint of the oil and gas sector using the life cycle assessment approach. The study identified gas flaring and oil spills as the main sources of emissions. To mitigate these emissions, the researchers recommended the adoption of renewable energy sources, such as solar and biomass, as well as environmental remediation measures to minimize the impacts of oil and gas activities on the environment.

The circular economy is based on several key principles, such as designing durable and easy-to-repair products, promoting the functional economy where services are privileged over property ownership, and optimizing waste management systems to recover and recover end-of-life materials. This economic model is emerging as a promising approach to addressing environmental challenges, such as climate change, by reducing greenhouse gas emissions and conserving natural resources (Deutz 2020).

In the electricity sector, the circular economy offers significant potential to reduce its carbon footprint. By integrating circular practices such as the use of renewable energy sources, the optimization of logistics flows, and the reuse of equipment, electricity distribution companies can not only reduce their indirect emissions but also contribute to a transition to a more sustainable and climate-resilient energy model (Chishti et al. 2023).

Geissdoerfer et al. (2017) explored the concept of the circular economy as a new sustainability paradigm. Researchers highlighted the importance of the circular economy in reducing GHG emissions by promoting the design of sustainable products and services, extending the life of products through reuse and recycling, and optimizing supply chains. The article also highlighted the potential economic and environmental benefits of the circular economy in the electricity sector.

Ghisellini et al. (2016) offered an in-depth analysis of the circular economy with a focus on the balance between environmental and economic systems. The study explored how the circular economy can reduce GHG emissions by promoting more efficient use of resources, minimizing waste, and promoting the regeneration of materials. The article also highlighted the political, economic, and social implications of the transition to a circular economy.

Yin et al. (2023) reviewed circular economy practices, guidelines, frameworks, and standards. They examined how these instruments can be applied in the electricity sector to reduce GHG emissions and improve environmental sustainability. The article also identified the challenges and opportunities associated with adopting the circular economy in the specific context of the electricity sector.

The literature review confirms the need to integrate the circular economy to act on scope 3 of the carbon footprint of the electricity sector and thus reduce GHG emissions from this sector.

The case study subject of this research proposes EC's concrete actions to act on scope 3 of the carbon footprint of an energy distribution company in Morocco.

Life Cycle Assessment (LCA) is the main tool used to assess the potential environmental impacts of products or services throughout their life cycle, from the extraction of raw materials to their disposal or recycling (Halvaei Khankahdani et al. 2023). LCA follows a four-step iterative model defined by the International Organization for Standardization (Keiser et al. 2023). These steps include defining the purpose and scope of the analysis, inventory analysis to collect data on materials and energy used, assessing environmental impacts throughout the life cycle, and finally, interpreting the results obtained.

The studies highlight the importance of adopting circular practices and promoting renewable energy sources in the electricity sector to reduce the carbon footprint.

MATERIALS AND METHODS

As shown in the methodology, Fig. 1 is carried out in several stages.

The greenhouse gases (GHGs) considered in this study are those defined by the Kyoto Protocol (Pata & Ertugrul 2023), which include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs) and nitrogen trifluoride (NF3) [29] (Chanda & Bose 2020)

Emission elements are classified according to three fields of application: scope 1, which includes the energy consumption of buildings; scope 2, which includes direct GHG emissions from stationary and mobile sources, such as fuel for light- and heavy-duty vehicles and other fuels and hydrocarbons; and scope 3, which includes other indirect emissions such as the purchase of undistributed water (losses), the purchase of works and services, the purchase of goods and chemicals, fixed assets (buildings, vehicles, IT), employee commuting and other energy-related emissions (excluding combustion). To assess the GHG emissions associated with each element of the organization's activity, emission factors are used. An emission factor is a measure of the mass of GHGs (measured in $kgCO_2eq$) emitted per unit of an activity input.

Scope of the Greenhouse Gas Emissions Inventory

The company is a public service operator that manages the distribution of electricity in a major city in Morocco. In addition to its main activity, emissions associated with the administrative management of the company and the procurement of goods and services are also taken into account.

Program Categories

Emission elements are classified into three domains. Scopes are a method of classifying the greenhouse gas (GHG) emissions of a business or activity. They are defined by the Kyoto Protocol and widely used to assess a company's environmental impact and develop emission reduction plans.

- Scope 1 encompasses all direct GHG emissions generated by a business or activity, such as emissions from fuel combustion for vehicles and stationary equipment. Emissions related to the production of energy from fuel sources, such as power plants, are also included in this category.
- Scope 2 includes indirect GHG emissions generated by the energy supply of a company or activity, such as electricity, heat, or cold consumption. It also includes electrical losses that occur during the transmission and distribution of energy.
- Scope 3 is a broader category and includes all other indirect emissions generated by a company or activity, such as supplier emissions, production of raw materials, purchases of goods and services, emissions related to product use, and emissions related to employee commuting.

Fig. 1: Methodology.

Table 1: List of activity data and source.

Data	Entities
Number of employees by type of job and activity Human Resources Branch	HR Department
Electricity consumption of buildings	Logistics Department
Water supply and sanitation operations	Operations Department
Electrical and street lighting operations	Operations Department
Process fuel consumption Electricity and street lighting	Operations Department
Number and area of buildings Department of Water and Sanitation Operations	Logistics Department
Department of Information Systems of Computer Assets	IT Department
Purchase of paper	Logistics Department
Chemical procurement Water and sanitation operations	Operations Department
Purchase of goods and services	Operations Department
Fleet	Procurement Department
Employee commuting	Department of Logistics
Drinking water system losses	Estimate based on the number of employees and a survey on travel patterns in Morocco
Quantity of sludge produced Water and sanitation	Operations Department
Electricity grid losses	Operations Department
Office waste	Operations Department

The data necessary for the development of the carbon footprint were collected from the departments concerned. Where data were not available, a number of assumptions were used to estimate them from existing data. Table 1 summarizes the data collected for the carbon footprint and its sources: either the department that provided it or the assumptions used to estimate it.

Data Source

The data necessary for the preparation of this study were collected from the departments concerned. Where data were not available, a number of assumptions were used to estimate them from existing data. Table 1 summarizes the data collected for the carbon footprint and its sources: either the department that provided it or the assumptions used to estimate it.

RESULTS AND DISCUSSION

Total emissions amount to 375,000 TeqCO_2 (with an uncertainty of about 12%). The electricity distribution activity accounts for more than 50% of this balance (Fig. 2 and Fig. 3).

Table 2 shows the distribution of emissions by scope. 80% of emissions are related to electricity consumption. These emissions (Fig. 4 to Fig. 6) associated with electricity are mainly classified in Scope 2 (73% of emissions), with the exception of upstream emissions related to fuel extraction, which are included in Scope 3. Direct scope 1 emissions represent only 1% of total emissions. Scope 3 accounts for 26% of emissions, which are mainly based on the purchase of products and services and emissions related to fuel extraction and transportation.

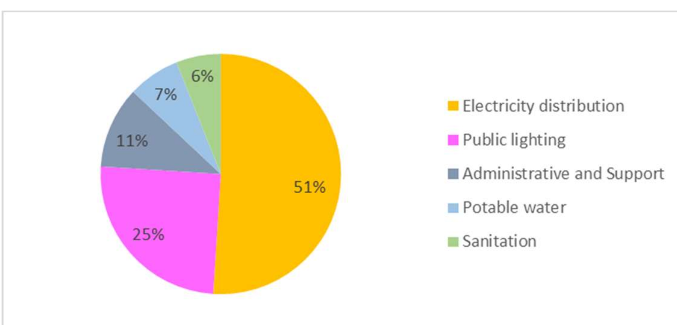

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Fig. 2: Breakdown of total GHG emissions by activity.

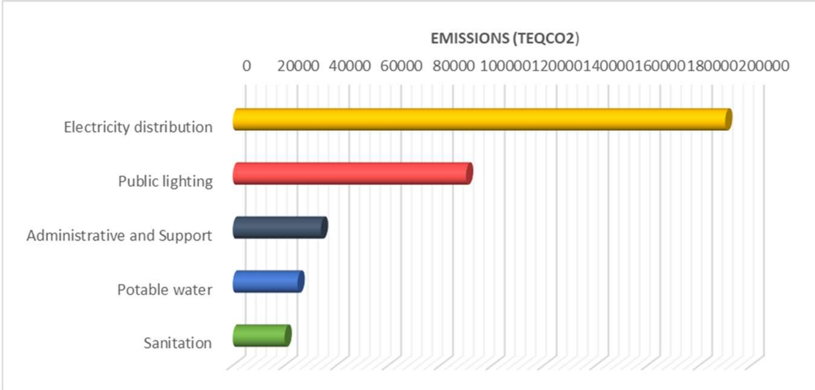

Fig. 3: Volume of GHG emissions by activity.

Table 2: Breakdown of GHG emissions by scope and category.

Program categories	No.	Issuance stations	Potable water	Sanitation	electricity	Public lighting	Admin and Support	Total	%
Direct GHG emissions	1	Direct emissions from stationary combustion sources		14				14	0%
	2	Direct emissions from mobile heat engine sources	451	607	576	158	2 210	4 002	1%
	3	Direct emissions from non-energy processes						-	
	4	Fugitive direct emissions						-	
	5	Emissions from biomass (soils and forests)						-	
	Subtotal		451	620	576	158	2 210	4 016	1%
Indirect emissions associated with energy	6	Indirect emissions related to electricity consumption	11 074	11 291	164 731	83 308	-	270 403	72%
	7	Indirect emissions linked to the consumption of steam, heat, or cold						-	
	Subtotal		11 074	11 291	164 731	83 308	-	270 403	72%
Other indirect GHG emissions	8	Energy-related emissions not included in items 1 to 7	1 146	1 214	15 295	7 697	641	25 993	7%
	9	Purchases of products or services	11 792	7 861	7 249	2 010	33 698	62 611	17%
	10	Capital assets	2 051	2 698	3 220	716	1 395	10 080	3%
	11	Waste	21	33	24	8	367	453	0%
	12	Upstream freight transport						-	
	13	Business trips						-	
	14	Upstream leased assets						-	
	15	Investments						-	
	16	Transportation of visitors and customers						-	
	17	Downstream goods transport						-	
	18	Use of products sold						-	
	19	End of life of products sold						-	
	20	Downstream deductible						-	
	21	Downstream leasing						-	
	22	Home-to-work travel	96	131	122	34	564	947	0%
	23	Other indirect emissions						-	
	Subtotal		15 106	11 938	25 910	10 465	36 665	100 083	27%
Total			26 631	23 849	191 216	93 931	38 875	374 502	100%

Circular Economy Strategy to Reduce Emissions

Morocco's ambition to reduce its GHG emissions and develop renewable and recovery energies should lead the Moroccan electricity mix to evolve in the coming years. However, more than 81% of the company's emissions are attributable to the electricity mix distributed on the grid. A "greening" of electricity production in

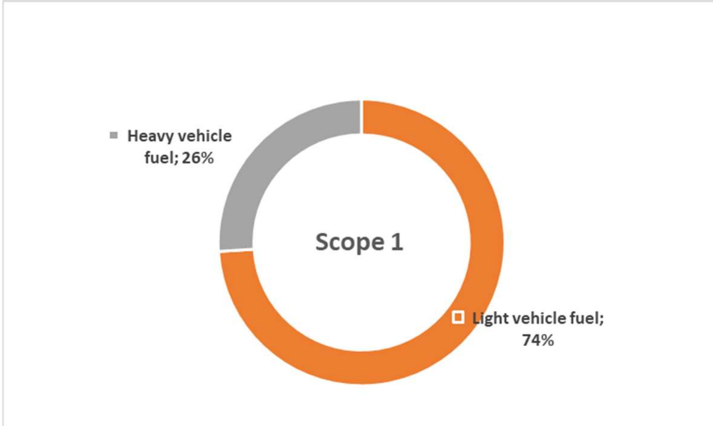

Fig. 4: Scope 1 of GHG emissions.

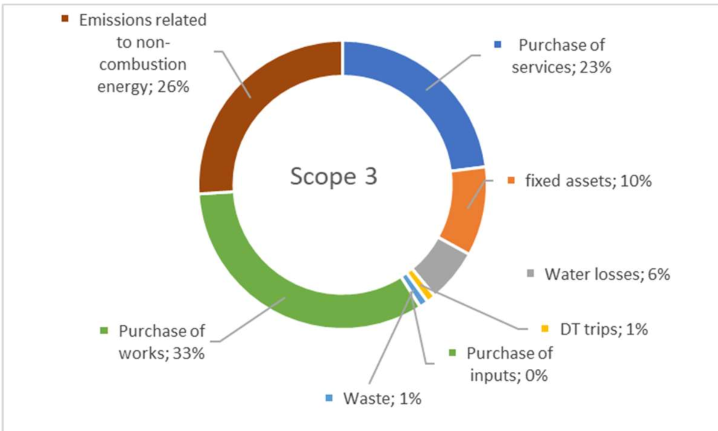

Fig. 5: Scope 2 of GHG emissions.

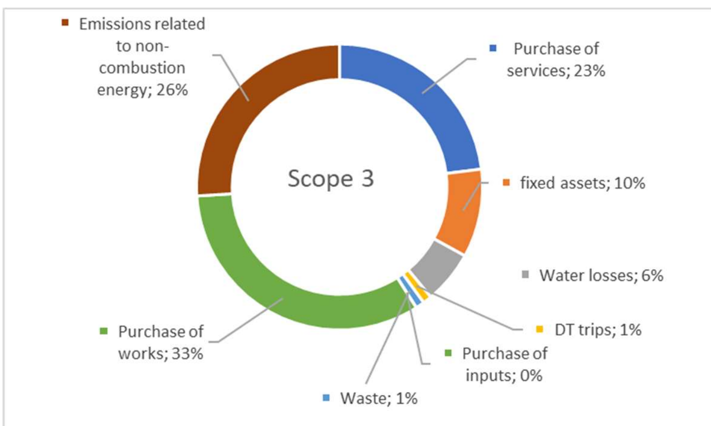

Fig. 6: Scope 3 of GHG emissions.

Morocco would, therefore, have a positive impact on the reduction of GHG emissions from this company's balance sheet.

The objective set by Morocco is to reach by 2030 a share of renewable energy in electricity production of 52% in installed capacity. In 2020, it was estimated at 36.80%, below the national target of 42%. In 2018, it was 34% in installed capacity, for a real share in electricity production of 19% (11% wind, 4% solar, 4% hydro). The emission factor given by ADEME for electricity distributed on the Moroccan grid was 0.718 kgCO2/kWh (Ourya et al. 2023).

Assuming a share of renewable energies in electricity production that would increase proportionally to the installed capacity (according to the national target), i.e., +53% between 2018 and 2030, the emission factor of the Moroccan electricity mix in 2030 would be about 0.63 $kgCO_2$/kWh.

This estimate is deliberately conservative to avoid overestimating the impact of renewable energy development over the next decade. However, it can be assumed that this emission factor is likely to be lower than this Fig. If we assume that the electricity purchased by the company will follow this same trend, the GHG emissions associated with consumption or the loss of 1 kWh on the grid would lead to 12% lower emissions in 2030.

To take into account this probable evolution of the energy mix, it was decided to determine the following:

A conditional trend trajectory A conditional reduction scenario, which corresponds respectively to the trajectory of "normal business" emissions until 2030, assuming that the Moroccan electricity mix improves, and to the objectives that the company sets itself to achieve in 2026 and 2030, assuming that the Moroccan electricity mix improves.

Following the estimation of the evolution of the activity and the evolution of the Moroccan electricity mix, the trend trajectory and the conditional trend trajectory can be defined in the following Table 3.

Table 3: Trend in GHG emissions.

Trajectory	Total GHG emissions ($teqCO_2$)		
	2022	2026	2030
Trend trajectory	375 000	387 000	393 000
Conditional trend trajectory (taking into account the development of renewable energies in the Moroccan electricity mix)	375 000	362 000	355 000
Lower emissions are related to the improvement of the electricity mix compared to the trend trajectory.		-6,5%	-9,8%

Table 4: Objectives scope by scope.

Scope	Objective	Comment
Scope 1	-46%	The targets are based on a -46% trajectory of scope 1 emissions compared to the trend trajectory. As the trend trajectory is based on 2022 emissions, this corresponds to a -46% decrease in scope 1 emissions between 2022 and 2030.
Scope 2	-29%	The targets are based on a trajectory of -29% of scope 2 emissions compared to the trend trajectory. Scope 2 is particularly heavy since it counts emissions related to electrical losses on the network and those related to public lighting. It is directly linked to the deployment of an essential service for the city's population, which explains why it is more complex to reduce, even if orientations 1 and 2 have significant potential for reduction.
Scope 3	-16%	The targets are based on a 16% decrease in scope 3 emissions compared to the trend trajectory in 2030 (i.e., a 15% decrease in scope 3 emissions compared to the initial situation in 2019).

Table 5: Evolution of emissions between 2022 and 2030, according to the trend trajectory and the reduction target, and comparison of emissions in 2030, by item. Emissions are in thousands of $teqCO_2$.

Post	Emissions 2022	Emissions 2030 (trend trajectory)	2030 emissions (reduction target)	Emissions lower than trend if targets are met
Electrical losses	175	162	118	-27%
Public lighting	91	112	76	-32%
Electricity consumption	30	40	25	-36%
Fuel	5	5	3	-46%
Water loss	6	7	6	-14%
Shopping	57	57	46	-19%
Other travel	1	1	1	-19%
Fixed assets	10	10	10	-6%
Rubbish	0,5	0,5	0,3	-30%
Total	375 000	393 000	284 933	-28%

Taken scope by scope, the objectives correspond to the following evolution (Table 4).

The GHG emissions reduction target would reduce its annual emissions by nearly 110,000 teqCO_2 by 2030, and avoid emissions of nearly 600,000 teqCO_2 over the decade 2020-2030. Table 5 shows the expected emission reductions on the various items.

Estimation of Reduction Potential By Orientation

The purpose of the action plan is not to set a specific GHG emission reduction target at the action level since GHG emissions are not a directly measurable indicator for monitoring the implementation of an action. The evaluation of the emission reduction impact of each action, therefore, serves, above all, the overall vision (Fig 7): to identify an order of magnitude of reduction in order to determine the achievable objectives. It can also be used to estimate the reduction potential associated with each of the identified orientations. It is thus a question of highlighting the prioritization of orientations.

RECOMMENDATIONS

Encourage the Supply of Renewable Energies to the Grid

Law 13.09 obliges the distributor to buy back electricity from renewable sources from medium-voltage producers (Fritzsche et al. 2011). Bill 40.19 aims to allow network operators to obtain supplies from renewable energy production facilities connected to the MV grid to compensate for the energy used for network management and technical losses (Hawila et al. 2014) within the limit of 7% of the total annual volume distributed (i.e., nearly 300 GWh for the company) the possibilities that the evolution of the legal framework allows it to increase the share of RE on its network.

Responsible Low-carbon Procurement Policy

Many researchers are developing green and sustainable supply chain networks to diminish greenhouse gas release (Abbasi & Ahmadi Choukolaei 2023). The following actions were recommended to identify the main purchasing items requiring further study and identify during workshops the main impacts of energy consumption, resource conservation, and biodiversity protection, review scoring grids to request minimum requirements on environmental criteria. Involve standardization management, act first on the energy performance of equipment, then on its eco-design, and identify relevant labels and certifications to be required.

It is also important to educate buyers about environmental issues. Sustainable development training has already taken place with buyers and should be renewed regularly and provided to each newcomer.

Support suppliers in their transition. As an important economic player in the industry of the city, the company has a role to play in the evolution of the practices of its ecosystem. To support immature suppliers, the first steps can be taken, starting with reporting and transparency requirements.

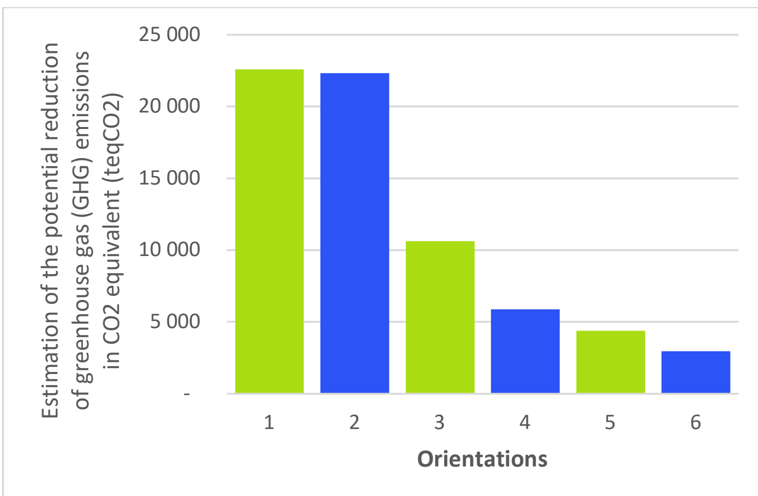

Fig. 7: Estimated GHG emission reduction potential.
Orientation 1: Reducing emissions from electrical losses, Orientation 2: Performance of public lighting, Orientation 3: Responsible low-carbon procurement policy, Orientation 4: Business Process Performance, Orientation 5: Management of buildings and sites, Orientation 6: Reducing travel-related GHG emissions, Orientation 7: Anchoring the DD/environment reflex internally

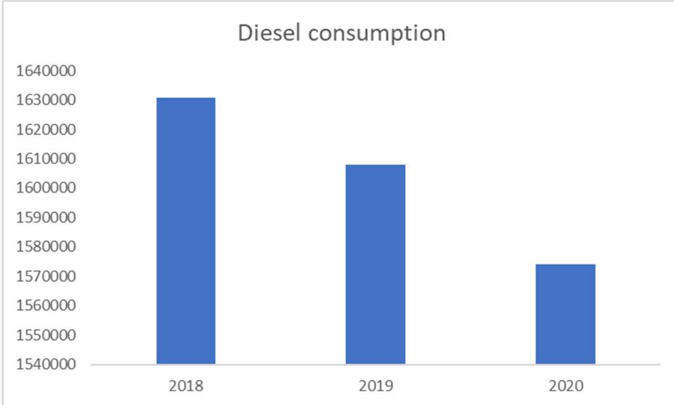

Fig. 8: Diesel Consumption.

Work for the implementation of centralized and automatic reporting of activity data (energy consumption, energy production, number and type of air conditioners, water consumption, vehicles, materials, waste). A dashboard for monitoring energy or even environmental data would be an effective decision-making tool.

Reducing Travel-Related GHG Emissions

One of the primary goals of the current program is centered around enhancing the energy efficiency of the vehicle fleets. An assessment of the fuel consumption of the fleet and a corresponding action plan featuring suggestions to curtail environmentally detrimental emissions have been formulated. The transport energy audit serves as a valuable opportunity to comprehend the energy usage of the company's vehicle fleet and the financial outlay linked to this usage and to pinpoint strategies for streamlining energy consumption (such as adopting eco-friendly driving practices and maintaining tires properly).

To further refine fleet optimization, particularly from an economic standpoint, a comprehensive evaluation of the vehicle fleet was conducted. The objective was to evaluate the appropriateness of vehicle usage in relation to the company's requirements. This evaluation provided a basis to advocate for the incorporation of alternative mobility solutions (like electric vehicles and electric-assisted bicycles) or the reduction in the number of vehicles by embracing shared alternatives (such as car-sharing and bicycle-sharing).

As indicated in Fig. 8, the consumption of diesel fuel exhibited fluctuations, decreasing from 1,630,723 liters in 2018 to 1,607,909 liters in 2019, and further down to 1,574,135 liters in 2020. This translates to reductions of approximately 1% and 2% for the respective years, with a cumulative change of around -1.4% and -2.1% in 2020.

It was recommended to encourage alternative modes of transport for commuting and between sites, conduct a travel survey to know the modes of transport of employees, propose solutions for greening travel (carpooling applications, partnership with the public transport organization, bicycle subsidy...), promote the geographical mobility of agents for more coherence between the place of life and the workplace, lead a reflection on teleworking, and the use of videoconferencing instead of inter-site travel for short meetings and encourage initiatives around new modes of travel. Thus, a test of electric vehicles was carried out. If this technology appears for the moment as expensive and immature, this type of initiative is to be encouraged (hybrid vehicles, CNG trucks, multi-trip optimization software, etc.) in order to identify potentially interesting solutions.

CONCLUSION

In conclusion, the article highlights the urgent need to decarbonize the energy sector to mitigate the adverse effects of climate change. Morocco has implemented various measures to transition to renewable energy sources and improve energy efficiency. However, reducing the carbon footprint of the energy sector remains a major challenge, especially in the electricity distribution sector, which contributes significantly to greenhouse gas emissions. The case study of the Moroccan electricity distribution company provides useful information on strategies that can be implemented to reduce carbon emissions. The energy transition offers significant economic and environmental opportunities for countries like Morocco.

REFERENCES

Abbasi, S. and Ahmadi Choukolaei, H. 2023. A systematic review of green supply chain network design literature focusing on carbon policy. Decis. Analytics J., 6: 100189. https://doi.org/10.1016/j.dajour.2023.100189

Al-Hamrani, A., Kim, D., Kucukvar, M. and Onat, N. C. 2021. Circular economy application for a Green Stadium construction towards sustainable FIFA World Cup Qatar 2022TM. Environ. Impact Assess. Rev., 87: 106543. https://doi.org/10.1016/j.eiar.2020.106543

Chanda, C.K. and Bose, D. 2020a. Challenges of Employing Renewable Energy for Reducing Greenhouse Gases (GHGs) and Carbon Footprint. Elsevier, The Netherlands, pp. 346-365.. https://doi.org/10.1016/B978-0-12-803581-8.11170-1

Chishti, M. Z., Dogan, E. and Zaman, U. 2023. Effects of the circular economy, environmental policy, energy transition, and geopolitical risk on sustainable electricity generation. Util. Policy, 82: 101585. https://doi.org/10.1016/j.jup.2023.101585

Deutz, P. 2020. Circular economy. In Int. Encycl. Human Geogr., p. 193-201. Elsevier. https://doi.org/10.1016/B978-0-08-102295-5.10630-4

Fritzsche, K., Zejli, D. and Tänzler, D. 2011. The relevance of global energy governance for Arab countries : The case of Morocco. Energy Policy, 39(8): 4497-4506. https://doi.org/10.1016/j.enpol.2010.11.042

Geissdoerfer, M., Savaget, P., Bocken, N.M.P. and Hultink, E.J. 2017. The circular economy: A new sustainability paradigm? J. Clean. Prod., 143: 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048

Ghisellini, P., Cialani, C. and Ulgiati, S. 2016. A review on circular economy : The expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod., 114: 11-32. https://doi.org/10.1016/j.jclepro.2015.09.007

Halvaei Khankahdani, Z., Ghazimoradi, M.M. and Abdollahi, M. 2023. Life cycle assessment. In Ref. Module Biomed. Sci., p. B9780128243152007000. Elsevier. https://doi.org/10.1016/B978-0-12-824315-2.00735-1

Hawila, D., Mondal, M.D., Kennedy, S. and Mezher, T. 2014. Renewable energy readiness assessment for North African countries. Renew. Sustain. Energy Rev., 33: 128-140. https://doi.org/10.1016/j.rser.2014.01.066

Keiser, D., Schnoor, L.H., Pupkes, B. and Freitag, M. 2023. Life cycle assessment in aviation : A systematic literature review of applications, methodological approaches, and challenges. J. Air Transp. Manag., 110: 102418. https://doi.org/10.1016/j.jairtraman.2023.102418

Khan, Y., Oubaih, H. and Elgourrami, F.Z. 2022. The effect of renewable energy sources on carbon dioxide emissions : Evaluating the role of governance and ICT in Morocco. Renew. Energy, 190: 752-763. https://doi.org/10.1016/j.renene.2022.03.140

Kiss, B., Kácsor, E. and Szalay, Z. 2020. Environmental assessment of future electricity mix – Linking an hourly economic model with LCA. J. Clean. Prod., 264: 121536. https://doi.org/10.1016/j.jclepro.2020.121536

Moretti, C., Hoefnagels, R., Van Veen, M., Corona, B., Obydenkova, S., Russell, S., Jongerius, A., Vural-Gürsel, I. and Junginger, M. 2022. Using lignin from local biorefineries for asphalts : LCA case study for the Netherlands. J. Clean. Prod., 343: 131063. https://doi.org/10.1016/j.jclepro.2022.131063

Okpanachi, E., Ambe-Uva, T. and Fassih, A. 2022. Energy regime reconfiguration and just transitions in the Global South : Lessons for West Africa from Morocco's comparative experience. Futures, 139: 102934. https://doi.org/10.1016/j.futures.2022.102934

Oluseyi, P.O., Babatunde, O.M. and Babatunde, O.A. 2016. Assessment of energy consumption and carbon footprint from the hotel sector within Lagos, Nigeria. Energy Build., 118: 106-113. https://doi.org/10.1016/j.enbuild.2016.02.046

Ott, C., Schiemann, F. and Günther, T. 2017. Disentangling the determinants of the response and the publication decisions : The case of the Carbon Disclosure Project. J. Account. Public Policy, 36(1): 14-33. https://doi.org/10.1016/j.jaccpubpol.2016.11.003

Ourya, I., Nabil, N., Abderafi, S., Boutammachte, N. and Rachidi, S. 2023. Assessment of green hydrogen production in Morocco, using hybrid renewable sources (PV and wind). Int. J. Hydrogen Energy, 03: 898. https://doi.org/10.1016/j.ijhydene.2022.12.362

Pata, U.K. and Ertugrul, H.M. 2023. Do the Kyoto Protocol, geopolitical risks, human capital, and natural resources affect the sustainability limit? A new environmental approach based on the LCC hypothesis. Resour. Policy, 81: 103352. https://doi.org/10.1016/j.resourpol.2023.103352

Ray, A. and De, S. 2020. Renewable Electricity Generation – Effect on GHG Emission. In S. Hashmi & I. A. Choudhury (Eds.), Encyclopedia of Renewable and Sustainable Materials, p. 728-735. Elsevier. https://doi.org/10.1016/B978-0-12-803581-8.11015-X

Schilling, J., Freier, K.P., Hertig, E. and Scheffran, J. 2012. Climate change, vulnerability, and adaptation in North Africa with a focus on Morocco. Agric. Ecosyst. Environ., 156: 12-26. https://doi.org/10.1016/j.agee.2012.04.021

Song, M., Zhang, L., Gao, Y. and Li, E. 2023. Spatiotemporal evolution and influence mechanism of the carbon footprint of energy consumption at the county level in the Yellow River Basin. Sci. Total Environ., 883: 163710. https://doi.org/10.1016/j.scitotenv.2023.163710

Yin, S., Jia, F., Chen, L. and Wang, Q. 2023. Circular economy practices and sustainable performance : A meta-analysis. Resour. Conserv. Recycl., 190: 106838. https://doi.org/10.1016/j.resconrec.2022.106838