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Inventory of greenhouse gas emissions in the city of Al Hoceima

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Abstract: The present work consists in the realization of an exhaustive inventory of the sources emitting greenhouse gases (GHG) at the level of the city of Al Hoceima located in the North of Morocco, and this, in order to be able to measure the emissions related to the various components of use of the ground, while being based on the guidelines of the Protocol of the Intergovernmental Panel on Climate Change (IPCC) for the inventories of the GHG emissions and by retaining the principal sources in connection with the sectors: energy, agriculture, forestry and waste. More specifically, this exhaustive and transparent inventory has been elaborated in order to establish a state of the art at the level of the city of Al Hoceima allowing to orientate the territorial managers in their choice of priorities to be retained for the reduction of GHG emissions. The necessary data were collected from several local state and private services, under the year 2019, a year before the containment related to the COVID - 19. The results obtained show that the main sector producing the most CO_2 emissions in the city of Al Hoceima is related to road transport. This sector has produced on average over the year studied, 71.13% of total emissions with an emission quantity of about 147.86 Gg of CO_2 equivalent. The second emitting sector is energy, related to the production of electricity, wood and butane gas, which represents 21.47% of total emissions. Following the results obtained at the end of this work, concrete and sustainable solutions have been proposed so that the city of Al Hoceima can take advantage of all the opportunities related to its development and under low emissions.

1. Introduction

"The fight against climate change will take place in the cities. Cities can be the problem or the solution. Either way, we need to know what is happening in the cities": this was the statement of Anderew Steer, President of the World Resources Institute (Global protocol for community-scale greenhouse gas emission inventories (GPC), 2014). Indeed, cities are both responsible for and victims of climate change. They are responsible for more than 70% of global GHG emissions, the main cause of global warming, mainly in certain key sectors, even though they occupy only 2% of the Earth's surface. In the same way, the effects of climate change, such as extreme weather events, sea level rise or salinization of groundwater in coastal areas, have negative and harmful consequences on cities.

The impacts of climate change on cities affect various vital aspects, including the ecosystem, society (particularly in terms of poverty and population displacement), infrastructure, food, water and health security, economic development, etc. The related effects depend on several factors characterizing the cities, including their geographical location and their capacity to adapt or resilience .

Awareness of this phenomenon has led to the establishment of an international legal arsenal with the objective of limiting the impact of GHG emissions. In order to comply with these regulations, it has become necessary to specify the contribution to global warming on a national scale, but also on a territorial or even communal scale (Kabisch *et al.*, 2016; Macassa *et al.*, 2022). This is an inventory of the different sources and levels of GHG emissions. These same data make it possible to propose adaptation and/or mitigation measures for climate change in order to consider them in urban planning. It is in this perspective that the present study falls. It consists in the realization of an exhaustive inventory of the sources emitting GHG at the level of the city of Al Hoceima, in order to be able to measure the emissions related to the various components of use of the ground, while being based on the guidelines of the Protocol of the IPCC for the inventories of the GHG emissions.

By measuring these emissions, the authors of this study aim to: (1) - Understand the evolution of emissions and the main emitting sources involved in order to determine optimal mitigation and resilience measures, (2) - Describe how the city of Al Hoceima contributes to climate change and to national and international efforts to mitigate it.

It should be recalled that Morocco has signed and ratified several international agreements, conventions and protocols related to climate change and environmental protection. It then joined several of these multilateral agreements related to global warming, sustainable development and energy efficiency. These commitments have been at the origin of the development and implementation of laws and enforcement texts adapted to the national context and international requirements.

Since the Earth Summit held in Rio in 1992, Morocco has committed to contribute to international efforts to combat the effects of climate change. This commitment is reflected, among other things, by:

- The ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1995, and its accession in 1996 ;
- The ratification of the Kyoto Protocol on January 25, 2002, which entered into force on February 16, 2005

The inventory of its GHG emissions. In this sense, and even if Morocco contributes very modestly to global emissions, it has undertaken several concrete actions on its territory .

In 2001, Morocco hosted the seventh Conference of the Parties to the UNFCCC in Marrakech (COP7), which was marked by the adoption of the Marrakech Accords that served to concretize three economic flexibility mechanisms, namely: the clean development mechanism (CDM) (Ouharon, 2002).

In 2010, Morocco submitted the Copenhagen Accord to the UNFCCC Secretariat, setting out actions to be implemented for the mitigation of its emissions by 2020 as part of its National Plan to Combat Global Warming (le Bureau Indépendant d'Evaluation du FEM, 2016).

In 2015, 193 states, including Morocco, made a joint commitment to achieve 17 Sustainable Development Goals (SDGs) by 2030. Thanks to the efforts made in this field, Morocco has made considerable progress, but it still faces a number of challenges and is therefore undertaking new strategies to face them and progress towards the achievement of the SDGs related to climate change. Despite its low GHG emissions, Morocco is committed to reducing its GHG emissions by 42% by 2030 and has initiated a disaster risk management strategy .

In 2016, Morocco ratified the Paris climate agreement (during the COP21), which provides in its Article 4 (NATIONS UNIES, 2015) the communication of a Nationally Determined Contribution (NDC) every five years starting in 2020. Morocco was among the first countries to publish a nationally determined contribution to combat climate change in 2016 and an update in 2021. In these, the country commits to slowing its GHG emissions to 18.3%, which could be raised to 45.5% by 2030, if it receives sufficient international financial support (4ème communication nationale du maroc à la convention cadre des nations unies sur les changements climatiques, 2019). In November 2018, Morocco hosted the COP 22 in Marrakech. Conference of action, par excellence. Ahead of it, Morocco hosted the MEDCOP CLIMAT, Held in Tangier in July 2018; the objective being to develop action plans for Local Authorities, NGOs, associations and companies for both mitigation and adaptation to climate change. Aware of the socio-economic consequences of climate change, the Kingdom of Morocco has adopted a voluntary, integrated, participatory and responsible approach in its adaptation and mitigation efforts, especially since Morocco is already experiencing the impacts of this irreversible phenomenon, which manifests itself through an increase in average temperature and the disruption of the average precipitation regime, which may affect its various ecosystems, ecosystem services and human systems, this could result in a significant impact on the country's economy ("Ministère de la transition énergétique et du développement durable," 2022) .

As a result, the country has begun to develop its medium and long-term climate policy by developing a National Climate Plan for the 2030 horizon that includes, on the one hand, measures related to the adaptation of the most vulnerable sectors to the impacts of climate change and, on the other hand, measures to mitigate GHGs affecting the sectors that emit the most GHGs. Kuramochi et al. 2021, indicated in their paper on GHG emission scenarios in nine key non-G20 countries that Only Colombia, Iran, Morocco and Ukraine will likely meet their targets. They pointed out that Morocco is one of the few countries that strengthened their targets when converting INDC into NDC. Our analysis projects that Morocco will likely overachieve its unconditional NDC target and also meet its conditional target with existing policies. The strategy that Morocco has adopted to address the effects of climate change is based on the concept of sustainable development, which promotes a balance between the environmental, economic and social dimensions in its development strategy, with the aim of improving the living environment of its citizens, promoting rational and sustainable management of natural resources and encouraging economic activities that respect and protect the environment (le Bureau Indépendant d'Evaluation du FEM, 2016).

As such, Morocco is expected to put in place measures to achieve the thirteenth Sustainable Development Goal (SDG13) which aims to take urgent action to address climate change and its impacts on different sectors according to the targets related ("Sustainable Development Goal 13," 2022). Although it is a low GHG emitting country but vulnerable to the effects of climate change, the Kingdom of Morocco took its responsibilities early on by progressively drawing the contours of its own vision, while complying with measures undertaken at the global level. To this end, Morocco is fully aligned with the obligations under the international framework on climate change. The First (2001) and Second (2010) National Communications attest to its commitment to the UNFCCC. This commitment is confirmed by the Third National Communication (2015) which includes an inventory of its GHG emissions, and by the Second Biennial Report (le Bureau Indépendant d'Evaluation du FEM, 2016).

The Second Updated Biennial Report of Morocco presents a synthesis of the results of the national inventory of Moroccan GHG emissions/removals for the years 2010, 2012, 2014 and 2016, aggregated

and by emission/removal source (Ministère de l'energie, des mines et de l'environnement and département de l'environnement, 2019).

The energy sector produced the largest share of total GHG emissions generated in Morocco in 2016, with 56720.6 $GgCO_2$ equivalent or 67.6% of total emissions. The remaining 32.4% came largely from sources related to the agriculture sector (23.1%), industrial processes (7.0%) and waste (5.9%). Land Use, Land Use Change and Forestry (LULUCF) contributed to the absorption of about 1.6% of global GHG emissions in 2016 (2ème rapport biennal dans le cadre de la convention cadre des nations unies sur les changements climatiques, 2019). On a limited scale, and given its geographical location, the city of Al Hoceima benefits from interesting tourist potentialities that contribute to local development. However, these different activities represent a major part of the polluting activities and would induce in many cases negative externalities strongly impacting the territory: GHG emissions, impoverishment and pollution of soils, depletion of resources, etc.

In this context, the city of Al Hoceima is largely committed as a witness of an initiative already launched in the fight against climate change. Indeed, the city is involved in the Clima-Med project financed by the European Union, thanks to its attractive positioning on the Mediterranean. The city is also a member of the Euromed Cities network, whose main objective is the development of multilateral and bilateral cooperation, particularly around Euro-Mediterranean issues relating to (1) - youth employment; (2) - the fight against climate change and its consequences and (3) - city jobs ("Climamed, acting for climate in south mediterranean," 2022). These two inescapable assets now ensure that the city is evolving towards sustainable development in general, and actively contributing to the fight against climate change in particular. Within this framework of commitment, the city of Al Hoceima expresses its determination to place its economic, social, cultural and environmental development efforts in a sustainable perspective. Furthermore, in terms of mitigation, a GHG emissions inventory study (IEGES) is needed to identify the different sources and levels of emissions. Similarly, local authorities have a major responsibility in the resilience of territories to environmental changes through regional and national support contributing to the empowerment of these local authorities and their support in their efforts to design local climate initiatives, sustainable and resilient to the adverse effects of climate change.

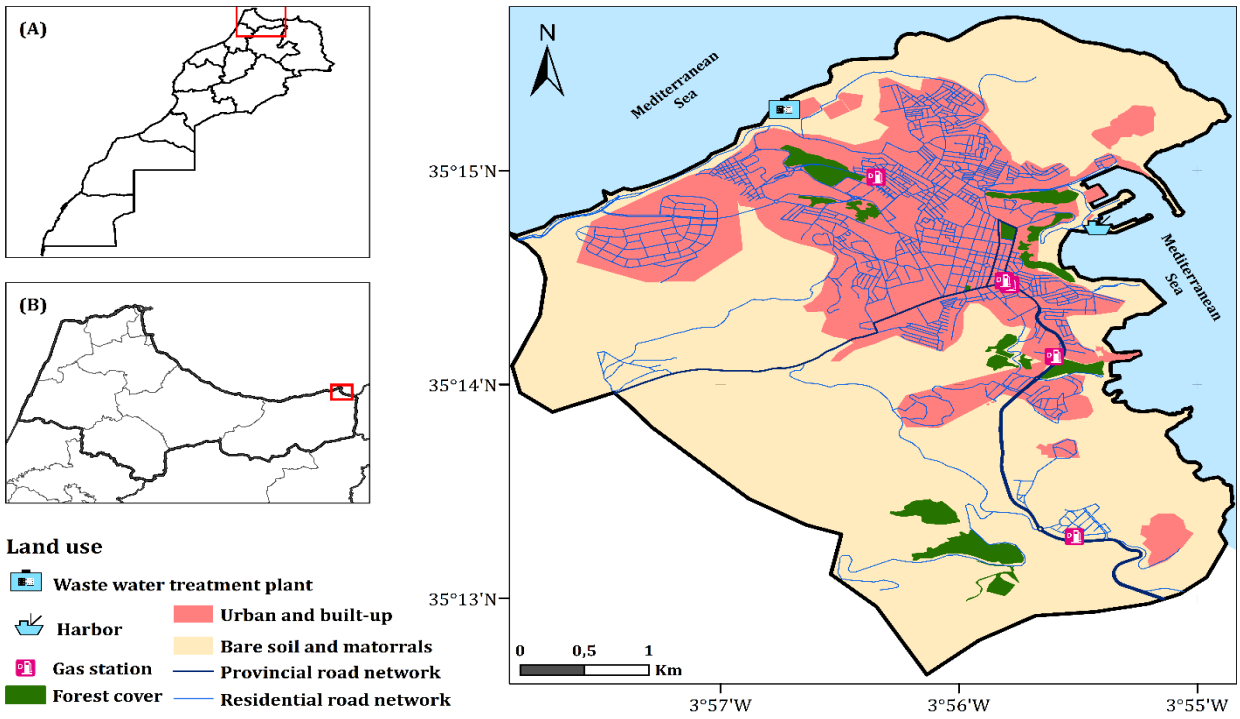
In this sense, the city of Al Hoceima is through its City Hall is part of the main networks of cities of the Covenant of Mayors that was launched in September 2014 on the occasion of the Climate Summit. Which Pact constitutes the largest global coalition of municipal leaders. The city of Al Hoceima as well as the other partners are taking action by collecting their adaptation and mitigation commitments, conducting inventories, setting targets to reduce their emissions, and developing action plans. Data on commitments and actions are made public ("Global covenant of mayors," 2022).

2. Data and method

2.1 Description of the study area

The city of Al Hoceima is located in the north of the Kingdom of Morocco, between latitudes 35°10' and 35°20' North and longitudes 3°50' and 3°60' West (figure 1). It is bounded to the north and east by the Mediterranean Sea, to the south by the municipality of Ajdir and Ait Youssef Ou Ali and to the west by the municipality of Izammouren. Geologically, the city is located at the level of the Rifian domain. More specifically, Al Hoceima is located at the level of the Bokkoya chain, composed of varied geological material (Azzouz et al., 2002), with Devonian and Lias limestone levels, Triassic

dolomites and Silurian shales (Margaa and Abdelgader, 1998). The prevailing climate is semi-arid with an average annual rainfall of over 400 millimeters (Byou et al., 2021). Seasonal alternation combined with the abruptness of rainfall and the reduction of vegetation cover aggravate the effect of rainfall on



the soil and often promote erosion and landslides.

Figure 1: Land use in the city of Al Hoceima and its geographical location in relation to the Region of Tangier - Tetouan - Al Hoceima (B) and Morocco (A)

2.2 Methodology

2.2.1 Principle of the method

For this study, GHG emissions were estimated based on the "Revised 1996 IPCC Guidelines for National GHG Inventories," the "IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories from IPCC GPG 2000," and the "IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry from IPCC GPG 2003".

The methodology is described in detail in the "2006 IPCC Guidelines for National Greenhouse Gas Inventories ("Lignes directrices du GIEC pour les inventaires nationaux de gaz à effet de serre," 2006).

The inventory covers the three sectors: (1) - Energy, (2) - Agriculture, Forestry and Land Use (AFLU) and (3) - Waste (2ème rapport biennal dans le cadre de la convention cadre des nations unies sur les changements climatiques, 2019).

Emissions of the three GHGs listed below are estimated at the study area level:

- CO_2: Carbon dioxide expressed as CO_2, excluding LULUCF "Land Use, Land Use Change and Forestry" or LULUCF included;
- CH_4: Methane expressed as CH_4;
- N_2O: Nitrous oxide or nitrous oxide expressed as N_2O.

The following is the formula used to estimate GHG emissions:

Emission = Activity data x Emission factor

This formula has been adapted taking into account the specific information of each sector. The general steps developed in order to estimate GHG emissions and to elaborate the national GHG inventory are data collection, data processing, emissions calculation and data archiving.

2.2.2. Data Collection

2.2.2.1. Energy sector

As the city of Al Hoceima has no energy industry and no manufacturing and construction industry, the IEGES was limited to road transport, fishing, maritime navigation, electrical energy consumption, as well as the use of wood in baths (2 units) and traditional ovens (11 units) in addition to emissions from the use of butane. The information on the consumption of fuel used in maritime fishing was provided by the Delegation of Maritime Fishing of Al Hoceima (Ministry of Agriculture and Maritime Fishing) and the National Agency of Ports for Maritime Navigation. The information on the consumption of hydrocarbons (Diesel/Gasoline) used in road transport was collected directly from the 5 service stations of the city concerned. Information on the consumption of electrical energy in municipal buildings, residences and public lighting was provided by the municipality of the city of Al Hoceima. The data on wood consumption in traditional ovens and baths was collected directly, following a field survey. For butane, the related information was communicated directly from the local distributor.

2.2.2.2. AFAT sector

The data retained for this sector are from the Provincial Statistical Yearbook of Al Hoceima for the year 2019 (Haut Commissariat au Plan, Direction Régionale de Tanger - Tétouan - Al Hoceima, Direction Provinciale à Al Hoceima, 2019).

2.2.2.3. Waste Sector

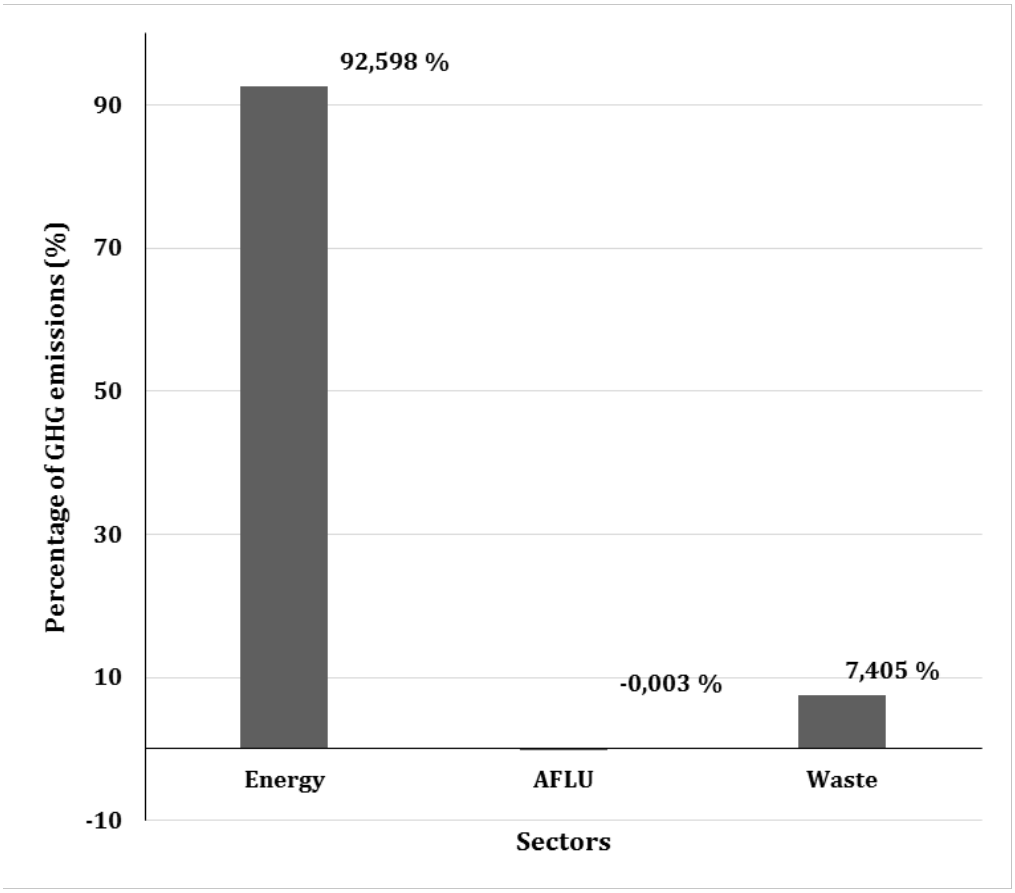
The information on the quantity of solid waste collected in the city of Al Hoceima and disposed of in landfills was obtained from the urban commune of Al Hoceima. The household waste and similar generated in the city of Al Hoceima are collected and put in a controlled landfill by the company "PIZZORNO" since 2008. This is a landfill and recovery center for solid waste in Al Hoceima, Class 1 according to national regulations, which currently provides sorting of a fraction received waste, burial of solid waste and treatment of leachate to tertiary stage by reverse osmosis. The city of Al Hoceima has generated in 2019 a quantity of about 20,264 tons of household waste. On the other hand, and from the point of view of liquid discharges, the flow of collected and treated wastewater and all the related characteristics were obtained from the wastewater treatment plant (WWTP). Indeed, the city of Al Hoceima has a WWTP, operated by ONEE - Water Branch. It operates under an activated sludge system with a tertiary ultraviolet treatment. The nominal flow of treated wastewater is about 9600 m3 per day.

3. Results and Discussion

3.1. Results

Figure 2 below illustrates the fraction of GHG emissions by sector. From table 1 and figure 2, we can see that the main source of GHG emissions in the city of Al Hoceima is related to the energy sector with an estimated contribution of 92.60% of total emissions, these findings agree those found in

literarure (Arora and Chaudhry 2015; Al-Qahtani, 2018). The second emitting source is related to the waste sector with a contribution of 5.33% compared to total emissions. On the other hand, the AFAT sector would contribute to the sequestration of almost 5.6 tons CO_2 equivalent. The emissions rate per Kg CO_2 equivalent per capita calculated for the year 2019 is 3432.50. Due to the lack of available data, this ratio has been corrected to account for the change in population between 2014, the date of the national census, and 2019, the reference date of this inventory. The industrial sector is represented by units located outside the territory of the city of Al Hoceima and has not been considered in this



inventory. Hereafter, we present the results of emissions by category of each sector emitting GHG.

Figure2 : GHG emission rates of the three sectors involved

3.1.1. Energy sector

The total emissions of the energy sector calculated in the study is 192.48 $GgCO_2$ equivalent. Figure 3 shows the percentage distribution of emissions in each category of this sector. Road transport contributes about 72% of the emissions related to the energy sector, and more than 67% of the total GHG emissions at the city level. This rate is justified by the presence of a significant amount of road traffic related to the transport of goods, commuting of various employees, etc., followed by residential. As a result of the city's characteristic fishing activities, the maritime fishing sub-sector contributes about 4% of the energy sector's GHG emissions, i.e. 3.7% of the city's total GHG emissions, with over 7.7 kilotons of CO_2 equivalent (Charabi *et al.* 2020; Al-Qahtani, 2018). On the other hand, the low activity of pleasure boats and maritime traffic, which only develop during the summer period, are in favor of very low or even zero emissions (1%).

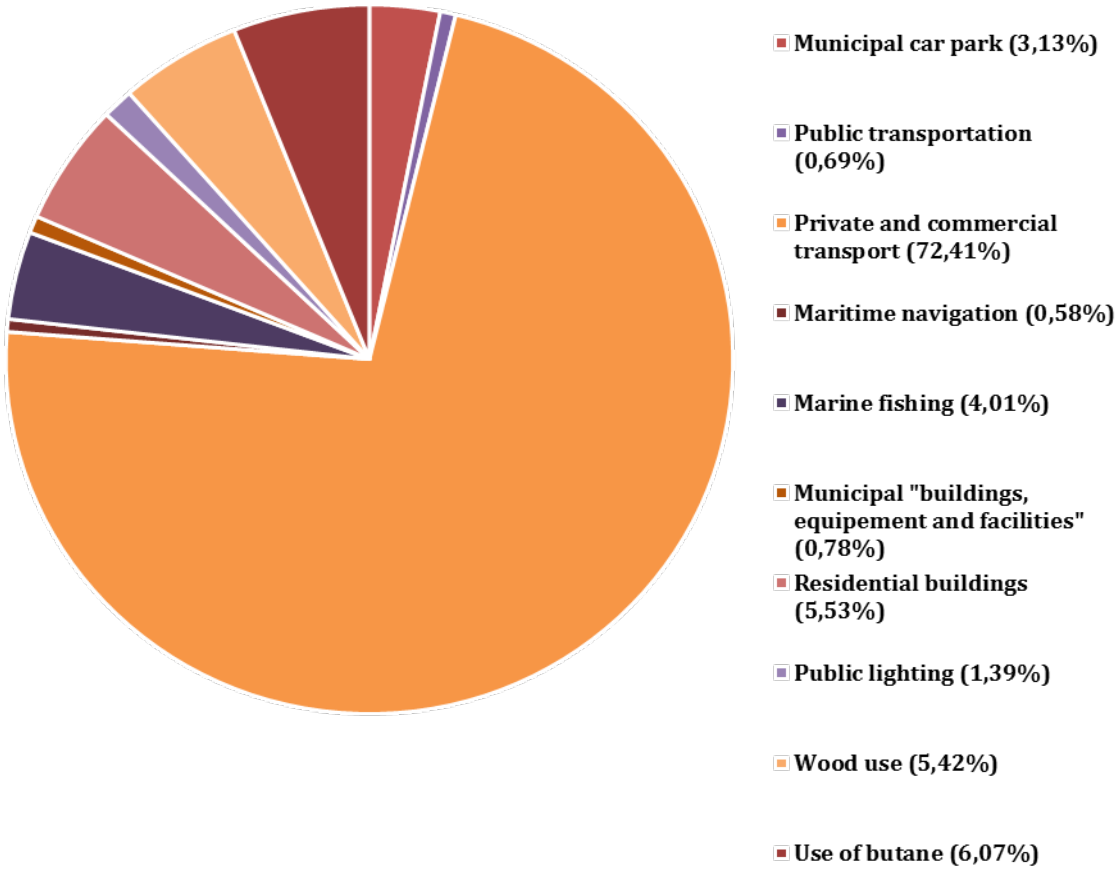


Figure3 : Percentage distribution of GHG emissions by category

3.1.2. AFLU sector

The main GHG emitting categories related to the AFAT sector and retained in the framework of this study are livestock and forests. Livestock is a source of GHG emissions with a contribution of approximately 80.4 tons of CO_2 equivalent, in the form of methane gas (CH_4). This gas is generated from enteric fermentation of livestock in the municipality of Al Hoceima, mainly sheep that represent 93.28% of emissions and to a lesser extent by goats that contribute to about 6.72% of total emissions (figure 4). The land cover, especially the forest cover, contribute to the sequestration of about 86,03 tons CO_2 equivalent of GHG emissions (Bošković & Radivojević, (2023).

3.1.3 Waste Sector

This sector is dedicated to the treatment of solid waste and liquid discharges. For the year 2019, GHG emissions from this sector were estimated at 15,3924 $GgCO_2$ equivalent (table 1). 95% of the emissions related to the waste sector, i.e. 14.5548 $GgCO_2$ equivalent are linked to the burial of solid waste at the controlled landfill of Al Hoceima, the remaining 5%, i.e. 0.8376 $GgCO_2$ equivalent being emitted at the WWTP of Al Hoceima (figure 5). Emissions from solid waste are about 100% related to CH_4 (figure 5), due to the abundance of organic matter in the household and similar waste received at the landfill of Al Hoceima, as elsewhere in Morocco, which is in favor of a methanogen fermentation produced by the microbial flora that degrades the organic matter. The CO_2, being entirely derived from biomass, has not been included in the waste sector in this study. Liquid waste treatment also contributes to the waste sector emissions, producing up to 100% N_2O (0.3876 $GgCO_2$ equivalent). This gas is emitted

during the wastewater treatment of the city of Al Hoceima during the nitrification phase, which eliminates the nitrogen (in the form of ammonium NH_4^+) in these waters (Abdoun *et al.* 2021; Benkaddour *et al.* 2020). In Sweden, the results show that in large-scale utility applications, the cradle-to-gate GHG emissions from the HESS contribute to a major share of the life cycle GHG emissions due to an under-utilization of the cycle life (Jiao & Mansson, (2023).

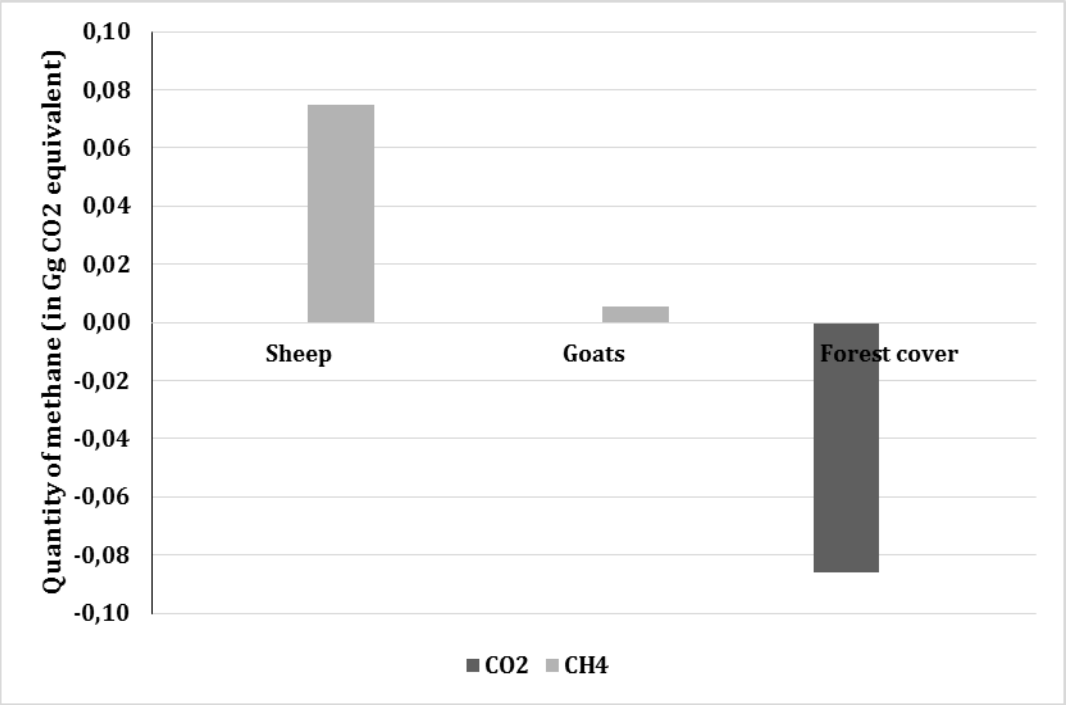


Figure 4: Amount of methane emitted by livestock and the amount of CO_2 sequestered by the forest cover in $GgCO_2$ equivalent

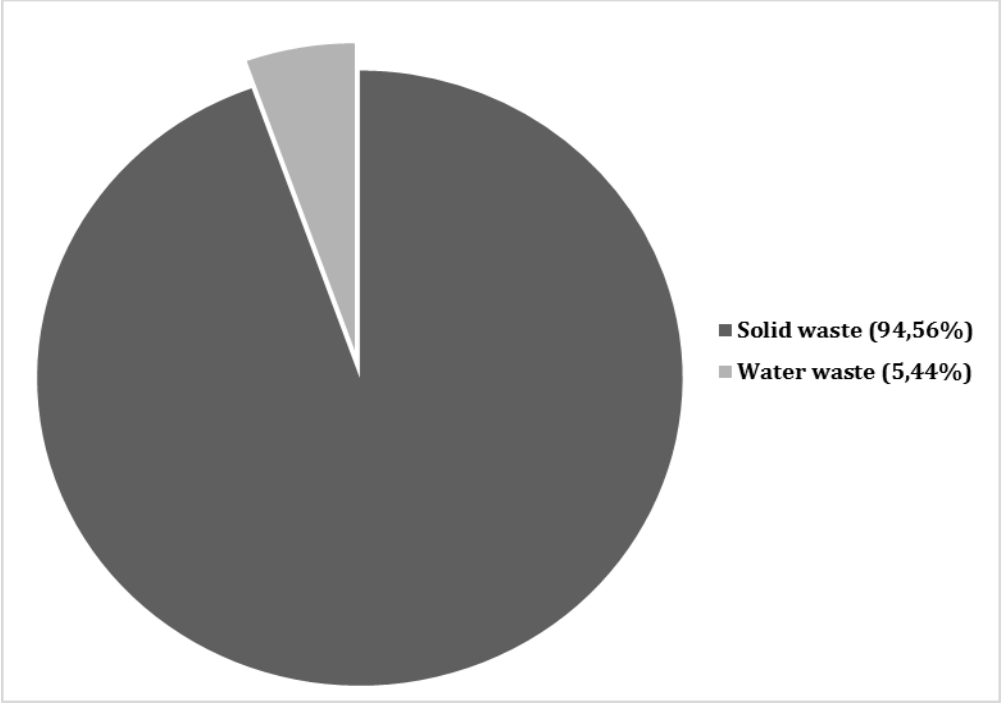


Figure 5: Distribution of GHG emissions for the waste sector

3.2 Description and interpretation of GHG emissions:

- **Carbon Dioxide (CO_2):** CO_2 remains the most significant GHG, accounting for over 91% of total emissions. It is mainly produced by road transport.
- **Methane (CH_4):** Methane is often emitted from solid waste, enteric fermentation of livestock and others, with an amount of about 15.72 $GgCO_2$ equivalent, or 7.56% of GHG emissions.
- **Nitrous Oxide (N_2O):** N_2O emissions are generated mainly from road transport and wastewater treatment. These emissions cover the smallest fraction of the three gases studied, i.e. 1.42%.

Table 1: Summary of total emissions by sector and by greenhouse gas

Sector	Categories				CO_2 equivalent emissions (in Gg)			Total CO_2 equivalent (in Gg)
					CO_2	CH_4	N_2O	
Energy	Transport	Municipal Vehicle Fleet			5.9265	0.0093	0.0822	6.0180
		Public transport			1.3319	0	0	1.3319
		Private and commercial transportation			137.2563	0.2166	1.9133	139.3862
		Maritime navigation			1.1152	0.0033	0	1.1185
	Sub-total				145,6299	0.2292	1.9955	147.8545
	Other categories	Sea fishing			7.6822	0.0312	0	7.7134
		Residential	Electricity consumption	Municipal buildings. equipment. facilities	1.4999	0	0	1,4999
				Residential Buildings	10.6408	0	0	10,6408
				Public lighting	2.6659	0	0	2,6659
			Sub-total		14.8066	0	0	14.8066
			Ovens and Moorish Baths		9.5659	0.7686	0.0901	10.4246
			Use of butane		11.6031	0.0543	0.0292	11.6866
	Sub-total				43.6578	0.8541	0.1193	44.6311
	Total				189.2876	1.0833	2.1147	**192.4856**
AFAT	Enteric fermentation	Cattle			0	0	0	0
		Sheep			0	0.0750	0	0.0750
		Goats			0	0.0054	0	0.0054
	Sub-total				0	0.0804	0	0.0804
	Forests				-0.0860	0	0	-0.0860
	Sub-total				-0.08603	0	0	-0.0860
	Total				0	0.0804	0	**-0.0056**
Waste	Solid waste				0	14.5548	0	14.5548
	Wastewater				0	0	0.8376	0.8376
	Total				0	14.5548	0.8376	**15.3924**
Total GHG emissions (in Gg)					**189.2016**	**15.7185**	**2.9523**	**207.8725**

3.3 Emissions projection to 2030

The IPCC Fifth Assessment Report makes links between climate change and development, where economic and population growth are key factors contributing to increased CO_2 emissions. Also, cities are identified as major actors in reducing GHG emissions (cinquième rapport d'évaluation du groupe d'experts intergouvernemental sur l'évolution du climat, 2015). Thus, each municipality has a key role to play in changing the local, national and global profile of GHG emissions. The municipality or city must therefore be well placed to respond proactively to the impact of climate change, which implies moving towards a low-carbon development path. For the city of Al Hoceima, it is possible to calculate the final target based on the results of the emissions balance and by forecasting the CO_2 emissions in its territory by 2030 using a Business As Usual (BAU) scenario (Amheka *et al.* 2021). This is a baseline scenario assuming that the Sustainable Energy and Climate Action Plan (SECAP) is not implemented. On the basis of this assumption, the JRC "Joint Resource Centre" has calculated national coefficients, which indicate the projection of the relative increase in GHG emissions between the year of the inventory and the year 2030. In the BAU scenario, the emissions recorded in the base year are multiplied by the national coefficient k, according to the following formula (cinquième rapport d'évaluation du groupe d'experts intergouvernemental sur l'évolution du climat, 2015) :

$$\textbf{Emissions}_{BAU\_2030} = \textbf{Emissions}_{IEGES\_2019} \times k$$

With:

k : National coefficient listed in Table 3, selected according to the selected base year.

Emissions $_{IEGES\_2019}$: Emissions during the inventory year.

Emissions $_{BAU\_2030}$: BAU emissions estimated for 2030.

Table 2: National Coefficient (K)

Reference year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
K (Morocco)	1.82	1.75	1.71	1.67	1.63	1.59	1.54	1.5	1.45	1.41	1.36
Reference year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
K	1.32	1.28	1.23	1.19	1.15	1.11	1.07	1.04	1	1	

Source: 2030 BAU Coefficients for CoM South Countries (Lo Vullo et al., 2021)

The maximum amount of emissions not to be exceeded by 2030 in order to achieve the reduction target μ (in %) under a 2030 emissions mitigation scenario is given by the following formula (cinquième rapport d'évaluation du groupe d'experts intergouvernemental sur l'évolution du climat, 2015) :

$$\textbf{Emissions}_{Atténuation\ 2030} = \textbf{Emissions}_{IEGES\ 2019} \times K\ (1-\mu)$$

With :μ is the emission reduction rate that the municipality is committed to achieve. This rate of emission reduction by 2030 corresponds to the unconditional target of 17% of Morocco's Nationally Determined Contribution (NDC) (Contribution déterminée au niveau national, 2021).

At the level of the city of Al Hoceima, the emissions generated in 2019 are estimated at 207872.46 tons of CO_2. The national coefficient k for the reference year 2019 of Morocco being 1,41 (table 2). Therefore, the projection of emissions according to the BAU scenario and the projection of emissions reduction according to the mitigation scenario with the NDC targets by 2030 are plotted in figure 6. In

the framework of the PAAEDC, the city of Al Hoceima commits itself to reduce its emissions by 1% by 2030 compared to the trend scenario determined above. This translates into a 17% reduction of the city's projected emissions in 2030 amounting to 293,10 $GgCO_2$ equivalent, i.e. 49,827 $GgCO_2$ equivalent of reduction.

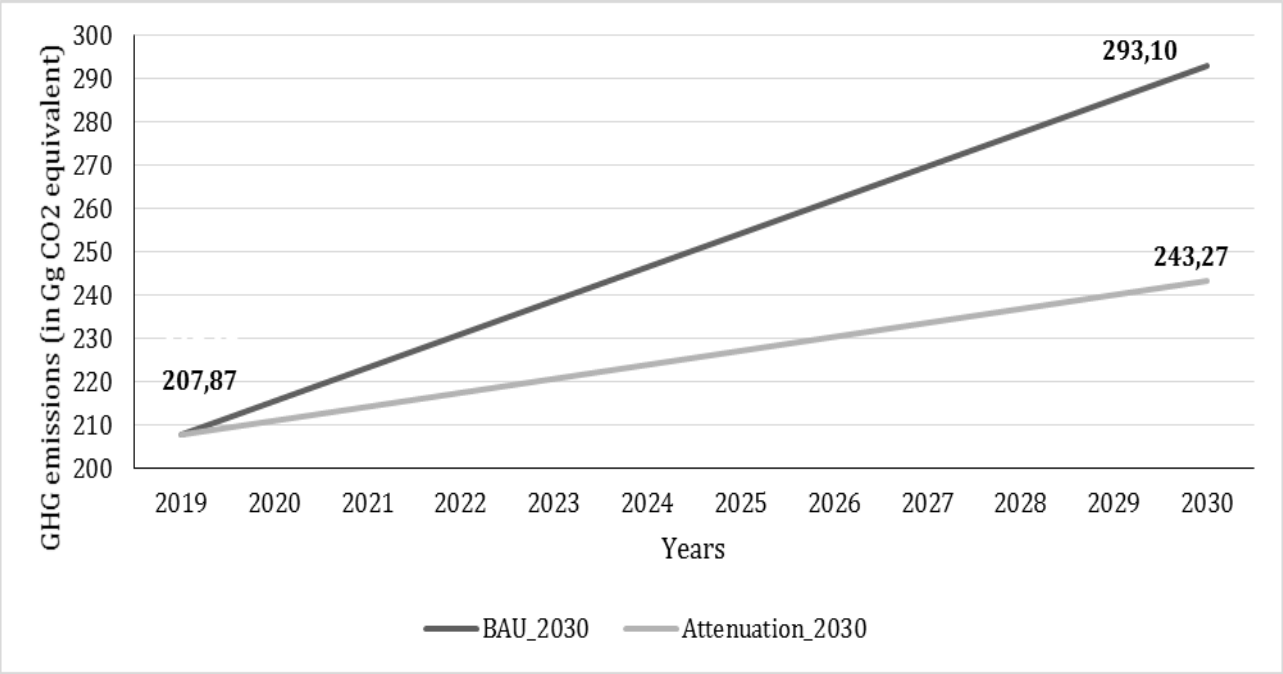


Figure 6: Evolution of GHG emissions in $GgCO_2$ equivalent in Al Hoceima according to the two scenarios BAU and Mitigation by 2030

4 Conclusion and Perspectives

The inventory of GHG emissions in the city of Al Hoceima shows that road transport is the most emitting sector, and this, in connection with motor vehicles whose number is growing rapidly.

This inventory highlights other GHG emitting activities, such as solid waste, generating a significant amount of CO_2. On the other hand, the consumption of electricity at the residential scale, significantly increases the GHG emissions in Al Hoceima.

Such an inventory allows us to discuss ways to reduce GHG emissions, to contribute to the preservation of the local and global climate from the danger of GHG emissions and to establish a platform of information at the service of territorial actors, decision makers and other stakeholders involved in the formulation of action plans and mitigation of GHG emissions. The potential improvements described in this work are not trivial, neither in their implications for future inventories nor in their increased complexity. Nevertheless, our results demonstrate that the IPCC methodology generates reasonable estimates of GHG emissions.

The result of the GHG inventory for the city of Al Hoceima is in favor of a low emission city. However, in order to maintain this situation, and even anticipate its resilience, we propose through this study sustainable and proactive solutions integrated into an action plan to better manage each GHG emitting sector (tables 3, 4 and 5).

Table 3: Action plan for the management of GHG emissions in the city of Al Hoceima - Energy sector

Category	Title of the action	Objective / limit to be reached	Strategic measures	Technical, awareness and communication measures
Road transport	**Readjustment of the urban traffic plan**	▪ Organization of the city's traffic; ▪ Smoothing of traffic flow in the city; ▪ Reduction of fuel consumption; ▪ Improved air quality; ▪ Reduction of GHG emissions.	▪ Financial support for the renewal of the road transport fleet that is at least 20 years old between 2025 and 2030 (2ème rapport biennal dans le cadre de la convention cadre des nations unies sur les changements climatiques, 2019); ▪ Promotion of electric and hybrid vehicles and engines; ▪ Financial support for the purchase of low carbon cars (electric and/or hybrid).	▪ Optimize public transit; ▪ Reducing empty trips and promoting non-motorized travel, especially by foot and bicycle.
Residential: Consumption of electricity, wood and butane gas	**Establishment of an information and awareness desk on energy and climate**	▪ Informing the public about the climate and the various actions to be taken; ▪ Raising public awareness of the benefits of measures and actions to combat global warming for the population; ▪ Involvement of the local civil society; ▪ Changing the behavior of the population regarding the use of energy and water resources and the use of motorized transport in the city.	▪ Implementation of a communal communication program on climate change and its impact on the natural territorial system.	▪ Edition of manuals, leaflets and brochures on environmental education; ▪ Elaboration of didactic supports, notably digital, for the benefit of schools; ▪ Creation of an audiovisual content on the rational use of electricity; ▪ Creation of awareness videos on social networks; ▪ Involvement of the Faculty of Science and Technology of Al-Hoceima and the National School of Applied Sciences of Al-Hoceima in the awareness campaigns.
	Generalization of the use of LED lamps for public lighting	▪ Optimization of public lighting; ▪ Reduction of energy consumption; ▪ Reduction of light pollution; ▪ Improvement of the city's image; ▪ Reduction of GHG emissions.	▪ Implementation of a communal program to generalize the use of low energy light bulbs for public lighting.	▪ Replacement of mercury and sodium lamps with LED lamps; ▪ Modulation of lighting according to usage.
	Improve the city's energy efficiency	▪ Reduction of energy consumption; ▪ Reducing energy costs; ▪ Use of clean and sustainable energy sources; ▪ Promote the use of clean energy in the city.	▪ Conducting an energy audit at the city level; ▪ Supporting local companies for the installation of solar panels; ▪ Setting up mechanisms to encourage the use of clean energy by facilitating the procedures for setting up companies operating in this field.	▪ Installation of photovoltaic panels on the roofs of public buildings; ▪ Encourage public institutions and the local population to install solar systems.

Table 4: Action plan to reduce GHG emissions in the city of Al Hoceima - Waste sector

Category	Title of the action	Objective / limit to be reached	Strategic measures	Technical, awareness and communication measures
Solid waste	**Update of the urban waste collection scheme**	▪ Identification of the gaps in the municipal waste management plan and its dysfunctions for a better revision of the waste management scheme	▪ Diagnosis and inventory of the waste management system in order to highlight the weak and strong points of the current waste management system ▪ Formulation and proposal of better solutions to fill the gaps and correct the dysfunctions in order to improve the whole waste management process ▪ Opting for a waste recovery center rather than a classic landfill center, reducing the fraction of waste buried and increasing the recovery rate	▪ To improve the functioning of the current controlled landfill of Al Hoceima or technical landfill center: To improve the conditions of its exploitation, allowing a continuous covering of the compartments, and a continuous treatment of the leachate ▪ To eliminate the wild points even if they are already reduced in number
	Setting up of urban waste recovery channels	▪ Recovery of solid waste and production of compost for use in organic agriculture ▪ Reduction of the volume of waste sent to the technical landfill	▪ Not applicable	▪ Installation of a composting station on an independent site or at the level of the current technical landfill ▪ Involvement of associations in the development and use of the compost produced
	Recovery of methane gas from the landfill for electrical energy	▪ Improvement of the performance of the landfill and the production of electricity from the biogas of the landfill waste	▪ Not applicable	▪ Installation of biogas collection tools for the landfill and related equipment.
	Large-scale development of selective sorting of household waste at source	▪ Development of a source separation system ▪ Recovery of sorted household waste	▪ Development of a selective waste sorting system ▪ Support of cooperative or company of recovery and valorization of urban waste	▪ Awareness campaign ▪ Supervision of reclaimers
	Sludge recovery (energy, compost)	▪ Valorization of the sludge of the WWTP, energetically by generation of Biogas for the production of electric energy	▪ Elaboration of a study for the valorization of the sludge of the WWTP	▪ Installation of a sludge valorization system by methanization ▪ Installation of a composting center for sludge valorization in fertilizer for spreading
Liquid discharges	**Wastewater treatment at the Al**	▪ Elimination of untreated liquid discharges in the open air (secondary stage) ▪ Preservation of the natural environment	▪ Development of a management plan for purified urban wastewater	▪ Installation of the sewage reuse network ▪ Establishment of a steering committee to direct the actions of the preparation, implementation and monitoring of the plan,

Category	Title of the action	Objective / limit to be reached	Strategic measures	Technical, awareness and communication measures
	Hoceima WWTP at the tertiary stage	▪ Generation of unconventional water that can be used for watering the city's green spaces		to carry out a risk assessment of the reuse of treated water
	Capture of the biogas of the STEP of Al Hoceima	▪ Production of electrical energy	▪ Elaboration of a study for the valorization of the sludge of the WWTP	▪ Installation of a methanization and biogas collection unit ▪ Installation of a co-generator for the production of electricity from the collected biogas

Table 5: Action plan to reduce GHG emissions in the city of Al Hoceima - AFAT sector

Category	Title of the action	Objective / limit to be reached	Strategic measures	Technical, awareness and communication measures
Enteric fermentation	**Development of low methane emission livestock practices**	▪ Reduction of GHG emissions, especially CH_4.	▪ Not applicable	▪ Storing animal waste in confined areas and using it to produce energy through methanization ▪ Use of pastures to sequester GHG emissions from livestock (Follett and Reed, 2010)
Forest cover	**Establishment of an effective strategy for the sustainable management of forests and forest soils**	▪ Combat heavy deforestation; ▪ Increase the potential of carbon absorption; ▪ Fight against the loss of animal and plant biodiversity and soils; ▪ Fight against soil erosion.	▪ Implementation of a management plan for natural and technical risks (including fire); ▪ Setting up a plan for the preservation and reforestation of forest areas; ▪ Setting up a communal program in partnership with the Regional Directorate of Water and Forests for the reforestation and development of the urban forest, especially at the entrance to the city at the level of the hills and mountains linked to the city ▪ Mobilize non-conventional water (stored rainwater, purified wastewater, etc.) for plant irrigation as needed.	▪ Raising public awareness of the importance of forest ecosystems, urban forests and green spaces and their positive impacts on the climate; ▪ Strengthening the network of monitoring and prevention of forest fires; ▪ Planting of local forest species such as cedar, Aleppo pine, pistachio, oleaster, carob tree, Kermes oak, holm oak, dwarf palm. Even more: Use of species with high carbon sequestration potential during afforestation, such as Paulownia: a species that grows quickly, requires little maintenance and absorbs 10 times more CO_2 than other trees (HUMBERT, 2022).

List of abbreviations

GHG	Greenhouse Gases
GGE	Greenhouse Gases Emission
GIEC (IPCC)	Intergovernmental Panel on Climate Change
GgCO2	Gega gramme of CO_2
GPC	Global Protocol for Community
UNFCCC	United Nations Framework Convention on Climate Change
COP	Conference Of the Parties
HESS	hybrid energy storage systems
CDM	Clean Development Mechanism
SDG	Sustainable Development Goals
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organization
LULUCF	Land Use, Land Use Change and Forestry
IEGES (GHGEI)	GHG Emissions Inventory
GPG	Good Practice Guidance
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
AFAT (AFLU)	Agriculture, Forestry and Land Use
WWTP	Waste-Water Treatment Plant
ONEE	National Office of Electricity and Water
NH_4^+	Ammonium
BAU	Business As Usual
PAAEDC (SECAP)	Sustainable Energy and Climate Action Plan
LED	Light-Emitting Diode

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