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Gaseous fuels, a windfall for artisanal lagoon transportation in Abidjan, Ivory Coast

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Abstract
In Abidjan, the daily movements of people are made from different means of transport. Among these different means of transport is artisanal lagoon transport. This one shares the lagoon water body with other modern transport companies. For the operation of their activity, small-scale lagoon carriers use diesel, a fuel that continues to cause problems for small-scale lagoon carriers, so much so that it is important to think about palliative solutions such as the use of gaseous fuels. Thus, this study proposes to analyze the contributions of the use of gaseous fuels (LPG) in artisanal lagoon transport on the lagoon water body of Abidjan. To do this, the survey focused on the artisanal lagoon carriers, the lagoon environment monitoring structures that are the DOMSE and the CIAPOL. Research shows that the use of gaseous fuels in the field of artisanal lagoon transport would allow artisanal carriers to make economic gains. It would be an asset in the face of competition from other modern and semi-modern societies by playing on prices and distances, and would be a more ecological source of energy than other commonly used fuels.

Keywords: gaseous fuel, artisanal lagoon transport, Ivory Coast

Introduction

> No other mode of transport can offer urban mobility to such a large number of people with a degree of safety and efficiency comparable to that of public (public) transport. This is why improving public transport systems is also the only way to successfully meet the future challenges posed by urban growth, mobility, sustainable economic development and climate change (International Union of Public Transports, 2009, p. 1 -2).

Indeed, public transport is an imperative for both Western and African metropolises. Abidjan, the economic capital of Ivory Coast is no exception. Given population growth and increased transport needs, Abidjan populations use different means of transport for travel. These are buses, SOTRA bus boats, minibuses (gbaka), municipal taxis (called wôrô-wôrô) and artisanal pinnaces.

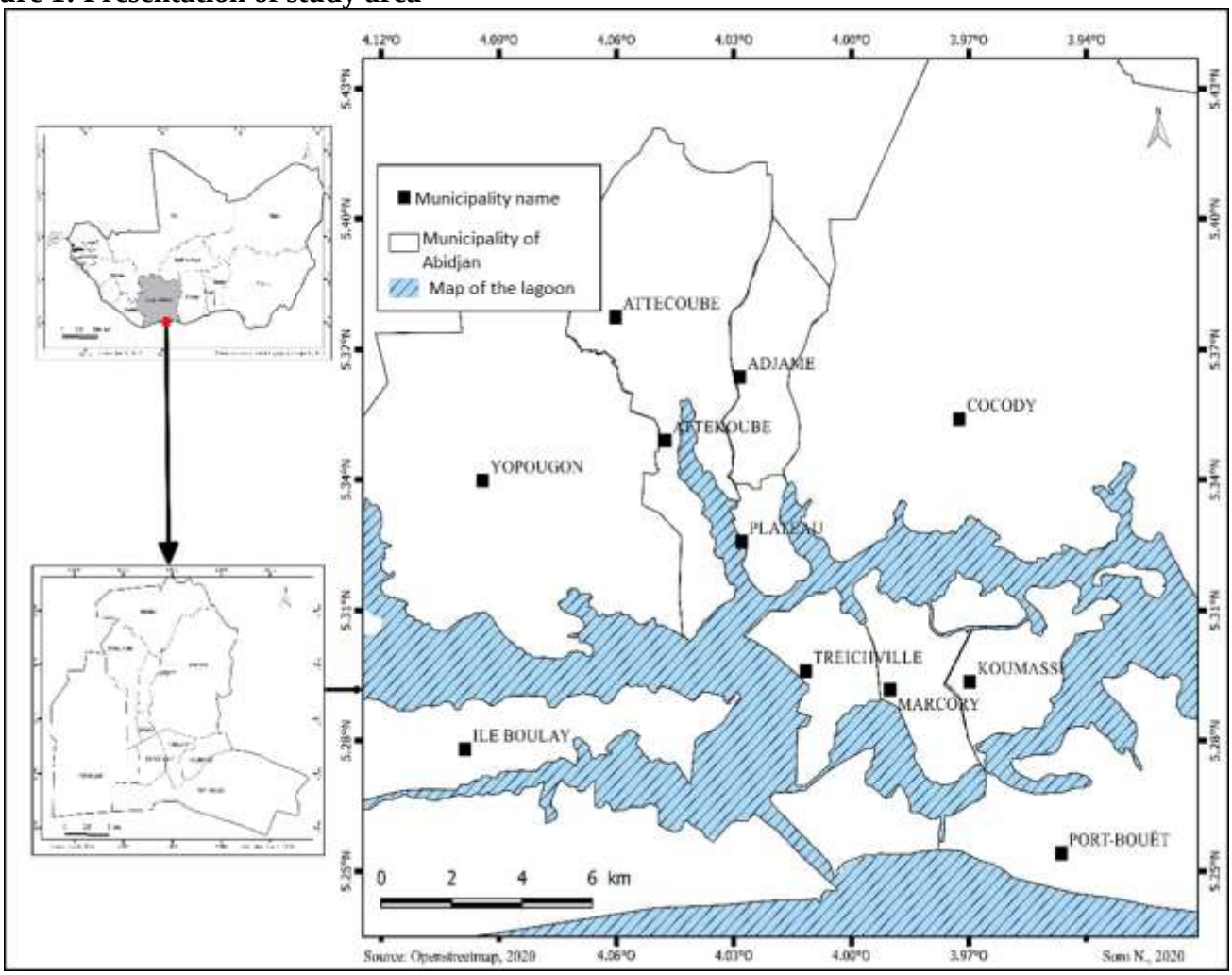
Regarding the activity of artisanal pinnaces (artisanal lagoon transport) in Abidjan, it is important for both the Ivorian economy and the consumer. It is a means of reducing distance-time and distance-cost and contributes to improve urban mobility. It is a means of fighting against poverty thanks to their competitive prices. Thus, the activity of the artisanal pinnaces which constitute a means of regulating travel through the lagoon play an essential role in the unblocking of economic activities in the city of Abidjan. It is probably in this capacity that authors address the issue of the importance of artisanal lagoon transport (H. Berron, 1980; A. Kouadio, 1988, N. Kablan, 2010). These address the question of the economic, strategic and social importance of small-scale lagoon transport. However, there is an insufficiency of writings concerning the advantages linked to the energy sources of artisanal lagoon transport vehicles (pinnaces) such as butane gas, even if the latter do not, for the moment, use this gaseous fuel which is popular with ground passenger carriers in some inland towns. In short, there is a lack of literature concerning the possible advantages that would be linked to the use of butane gas in artisanal lagoon transport. It is with these findings that the

following question *"what would be the advantages of using butane gas in the artisanal lagoon transport of people in Abidjan?"* finds its meaning. Indeed, this study proposes to examine possible advantages which would be related to the use of butane gas in the artisanal lagoon transport.

Methodological approach

The study area of this research concerns the lagoon water body of Abidjan in Ivory Coast (Map 1).

Figure 1: Presentation of study area



The collection of data for this study area (map 1) in relation to the research problem comes from documentary sources and fieldwork (direct observation, interviews and a survey). These are precisely cartographic data and statistical data relating to the possible advantages linked to the use of butane gas in the artisanal lagoon transport of people.

For the acquisition and processing of data, the first equipment used is *OMSTracker* for the location of pinnace stations. The second is the SPHINX software, which makes it possible to store, process and generate results in tables, graphs, etc. The third was the *Global Mapper* software; because, in addition to being a mapping software, it allows the conversion of several types of geographic data into other types of desired data. Thus, having data in GPX format, it was important to convert them to *Shapefile*, for better use. Finally, the fourth is the QGIS software, which is one mapping software among many others. At this level, all base maps have been obtained through *OpenStreetMap*. These were recorded at a scale of 1:200,000 because the different cartographic representations only take into account the city of Abidjan.

Regarding the survey, given the number of pinnaces (48), all were taken into account for the study. As for the structures in charge of the management, in general, of the lagoon water body, there are two: the DOMSE (Department of maritime operations, security and the environment) and the CIAPOL (Ivorian Center for anti-pollution). It was necessary to take into account only the directors of these structures, so one director per structure.

After determining the number of respondents, it should be mentioned that they were surveyed in different ways. A hierarchical multiple-choice questions (HMCQ), multiple-choice questions between several proposed answers (MCQPA) and single-choice questions between several proposed answers (SCQPA) type questionnaire was sent to the artisanal lagoon carriers. These three types of questions were combined to form a single questionnaire. As for the managers of the structures, they were interviewed with the same type of questionnaire. Thus, we find ourselves with 2 structure directors and 48 pinnace carriers to investigate according to the objectives of the study (Table 1).

Table 1: Types and number of respondents according to the objectives

Types of respondents	Number	Objectives researched
Carriers	48	Transporters' earnings, fuel purchase costs, machinery consumption, frequency of machinery breakdowns, types of breakdowns, number of lagoon transport companies, capacity of transport machinery, the influence of companies on the activity of the pinnaces, the environmental standards required by the regulatory authority
DOMSE	1	The environmental standards required in the context of lagoon transport, the environmental level observed in lagoon transport, the level of pollution of pinnaces.
CIAPOL	1	
Total of respondents	40	

Source field work, 2020

The processing of field data made it possible to have digital data. For the management and storage of this data, it was appropriate to use the Sphinx software. The use of this software made it possible to cross-reference the data of the different cities, to bring out cross-tabulations and graphs. From these data, it was also necessary to calculate averages and highlight percentages. The software adapted to this type of treatment was Excel, hence its use in this study. For spatialization purposes, the various pinnace stations have been georeferenced. The most accessible and suitable tool for this purpose was OSMTracker, hence its use. Having georeferenced data that must be represented, we used QGIS, the most accessible cartographic material among many others. Thus, we used cartography to support the explanations and present the study area.

These different treatments have made it possible to highlight the possible advantages likely to be linked to the use of butane gas in artisanal lagoon transport.

Results

At the end of the processing of survey data concerning artisanal lagoon transport in Abidjan in Ivory Coast, three fundamental results emerged as exposed in the following bridges.

Use of butane gas in the field of small-scale lagoon transport, an economic advantage

The use of gaseous fuel (butane gas) in small-scale lagoon transport would enable carriers to make up for the loss of earnings linked to the use of diesel. Compared to diesel and gasoline, this fuel is economical to purchase **and consume (Table 2).**

Table 2: Comparison between diesel/petrol and butane gas

	Diesel/ Petrol	**Butane Gas**	**Additional profit that would be favored by the use of LPG**	**Loss of profit from the use of diesel**
Purchase cost of 45 L (FCFA)	25 650	18 600	7 050	7 050
Salary cost	7 500	7 500	0	0
Maintenance expenditure / month (Fcfa)	15 000	10 000	5 000	5 000
Maximum revenue (FCFA)	80 000	80 000	-	-
Daily gain (FCFA)	31 850	43 900	12 050	12 050
Daily gain (2 days/week)	63 700	87 800	24 100	24 100
Estimated monthly gain (FCFA)	254 800	351 200	96 400	96 400
Estimated annual gain (FCFA)	1 019 200	1 404 800	385 600	385 600

1 liter = 600 FCFA (1 € = 656 FCFA)

Source : Field work, 2020

From table 1, we note that gaseous fuels, more precisely butane gas, proves to be interesting because when using it, the carrier will come out with a daily gain (43,900 FCFA, or approximately 67€) significantly higher than the daily earnings of a transporter who uses petrol or diesel (31,850 FCFA, or around €49) (Table 2). In addition, butane gas would allow the transporter who uses it to make a monthly gain of 351,200 FCFA, the one who uses diesel or gasoline stagnates at 254,800 FCFA, i.e. a difference of almost 100,000 FCFA (table 2).

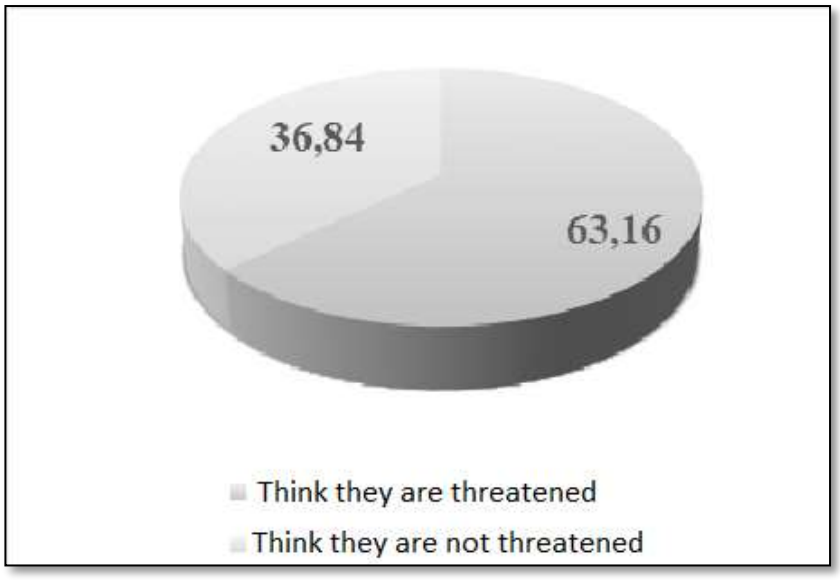
In short, the loss of earnings for a user of diesel or gasoline will be an asset for the user of butane gas. It is in this that at the end of a year of operation for two similar pinnaces but from different energy sources, when the user of butane gas will have a gain of 1,404,800 FCFA (2,141€) that who uses diesel or gasoline has a gain of just over 1,000,000 (1,019,200, or €1,554). Butane gas would then allow higher money gains than diesel and gasoline.

In addition to monetary gains, the use of butane gas would make it possible to stand up to modern and semi-modern companies.

The use of butane gas, an advantage in the face of competition from modern lagoon transport companies

The presence of other lagoon transport companies: CITRANS (Aqualines), Lagoon Transport Society (LTS) and semi-modern companies) constitutes a threat to the existence of the pinasse activity. Indeed, in recent years, there has been the appearance of modern lagoon passenger transport companies in addition to the state company: SOTRA. This presence worries artisanal lagoon carriers because they feel threatened. In other words, 63% of small-scale lagoon carriers believe they are aware of the competition and the risk of their activity disappearing (graph 1).

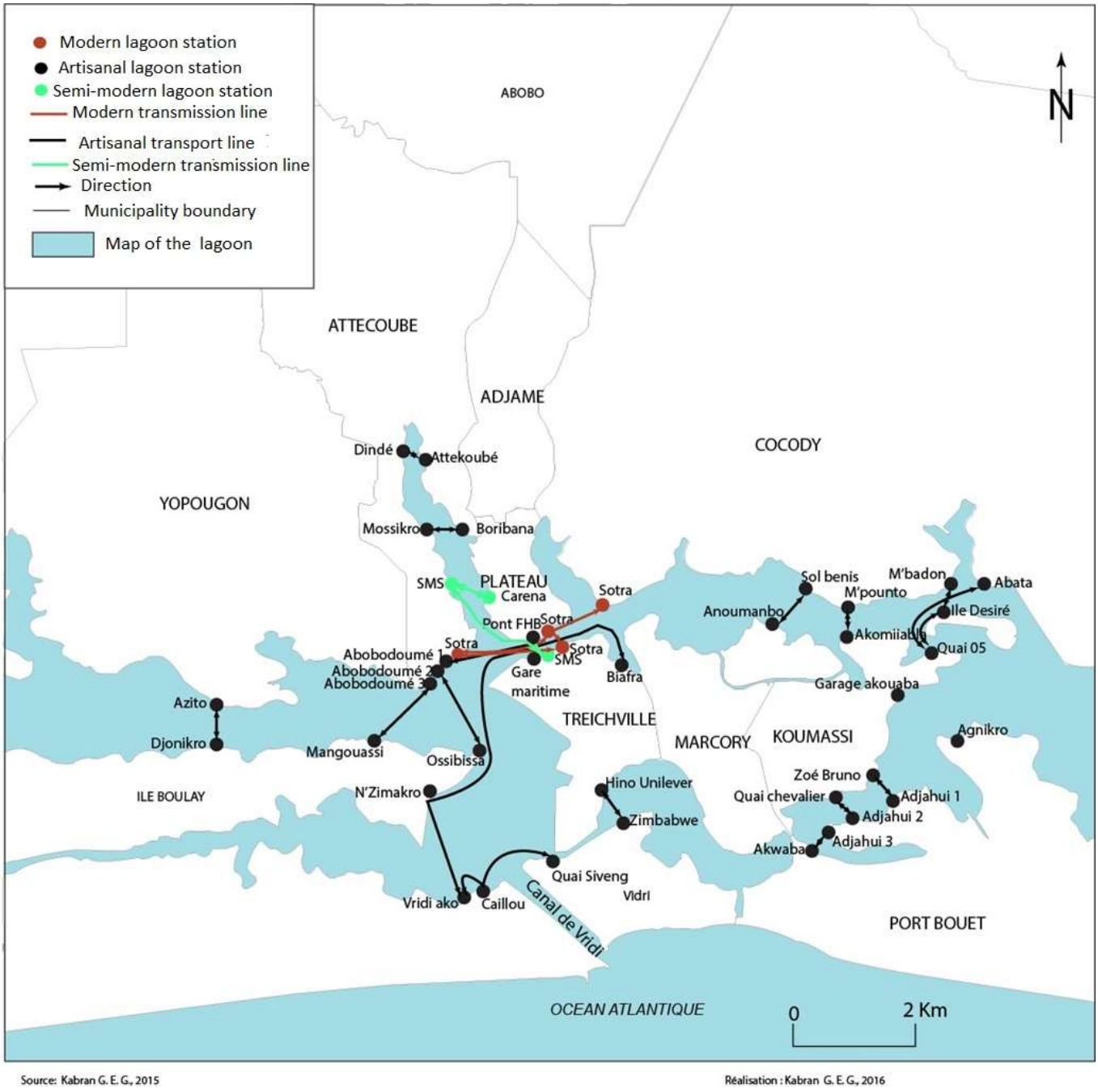
Graph 1: Opinion of small-scale lagoon carriers concerning the presence of modern lagoon transport companies



Source: Field work, 2020

Faced with the awareness of this perpetual competition and the risk of disappearance, different resilience strategies among many others can be explored. It is in this that this study considers the energy aspect. Thus, the new energy sources would allow artisanal lagoon carriers to maintain dominance of the lagoon water body (Map 2).

Map 2: Distribution of lagoon stations and direction of traffic



Source: Kabran G. E. G., 2015 Réalisation : Kabran G. E. G., 2016

The state-owned company (SOTRA) does not control transport on the Abidjan lagoon water body (map 2). It is rather dominated by artisanal transporters, but we must not lose sight of the rise of modern companies which aim to set up and dominate the sector. The following strategies are then necessary for the resilience of artisanal lagoon transporters. First, there is the reduction in transport costs thanks to the introduction of the use of butane gas. The use of this gas would allow artisanal transport to reduce travel costs thanks to the reduction in the cost of purchasing daily fuel and the reduction in monthly mechanical maintenance expenditure. Therefore, part of the daily gain, which will increase, can be used to compensate for possible losses due to the reduction in transport cost. Thus, transporters who use butane gas will find themselves with daily earnings similar to those of diesel users but with lower transport costs, defying all competition. Then there is the recovery of lines that were deemed unprofitable because of the use of diesel. Indeed, some lines are considered less profitable because of various factors such as the low number of passengers both during peak and off-peak hours. The increase in savings linked to the use of butane gas would allow artisanal lagoon transporters to maintain the connection of these lines in order to encourage, in the future, the necessary crowds, both at peak and off-peak hours, to greater profitability of their activity. In addition, there is the extension of the distances traveled by the pinnaces at a lower cost thanks to the use of butane gas. In other words, some lines are slow to see the light of day because of the amount that would be fixed for the distance to be covered. These are N'Zimakro-Gare Maritime (9.4 km), Vridi Ako-N'Zimakro (2.4 km).

Small-scale lagoon transporters will then be able to operate these lines with an emphasis on reducing consumption and reducing mechanical maintenance costs while remaining efficient. Finally, butane gas would allow artisanal lagoon transporters to resist competition from modern and semi-modern lagoon transport companies, in short, to be resilient vis-à-vis other competitors in order to maintain dominance. The use of butane gas would allow small-scale lagoon carriers to maintain a monopoly in the sector and better still, this gaseous fuel would make this activity ecological.

The use of butane gas, a greener source of energy

The combustion of any hydrocarbon produces more or less dangerous residues. These residues depend on the type of fuel, the maintenance of the machine and the combustion mode of the engine. Also, the older the machine, the more pollutants it emits after combustion. Concerning the pinnaces which circulate on the lagoon water body, 60% of these have second-hand engines "France bye bye" which are around 16 years old. For this age, the engines are at their maximum emission of pollutants and worse, for some pinnaces, those are ordinary car engines which are adapted for their activity. Thus, it was interesting to compare the possible emissions of pollutants from different types of fuels (Table 3).

Although all the pollutants listed are dangerous, the analyzes focused more on three of them, because in addition to being dangerous, they have significant values. These are carbon dioxide (CO2), carbon monoxide (CO) and unburnt hydrocarbons (HC). CO2 is a greenhouse gas that contributes to the increase in the temperature of the Earth's atmosphere, thus causing climate variations. As for CO, it is a very dangerous gas: it is odorless, it passes into the blood, binds to hemoglobin instead of oxygen and prevents the transport of the latter to the cells. A content of 0.2% CO in the air leads to death in less than half an hour. Concerning unburnt hydrocarbons, they consist of carbon (C) and hydrogen (H) atoms. They can affect the nervous system, blood cells and platelets. These disorders can cause a loss of consciousness in the individual. These are the reasons for the accentuation of the analyzes on these three pollutants.

In the present analyses, a difference has not been made between petrol engines and diesel engines due to the slight nuance observed in terms of pollutant emissions apart from carbon monoxide.

In addition, the use of butane gas in small-scale lagoon transport in Côte d'Ivoire would reduce pollutants linked to emissions from heat engines or internal combustion engines. This fuel would make it possible to go from a daily emission of 267,907.5 kg of CO2 per day to an emission of 168,682.5 kg of CO2, therefore a reduction by half of the carbon dioxide emitted by the pinnaces per day above of the Ivorian lagoon water body. In terms of carbon monoxide, in a single day of work, the pinnaces emit 6,944.75775 kg of CO. While with butane gas, they would emit seven times less carbon monoxide, that is to say 991.1475 kg of CO per day for the same intensity of activity and the same working time. The same goes for unburned hydrocarbon (HC) emissions. With gasoline engines, there is a significantly higher emission than with other engines. For one day of activity, the pinnaces would release around 10,000 kg of HC (more precisely 991.25775 kg of HC/day) while with butane gas, these releases will only be around 500 kg HC/day (495 .0225 kg of HC/day).

Table 3: Quantities and categories of pollutants according to the types of hydrocarbons

Diesel (or Diesel or Oil)	**Quantity consumed**	**Type and quantity of pollutants in kg/l**							
		CO_2	**C0**	**H_20**	**NOx**	**SO_2**	**Hydrocarbure (HC)**	**Aldéhydes**	**Particules**
Consumption	1 L	2,7	0,00999	1,05	0,00199	0,00019	0,00109	0,00029	0,2
Average consumption of a pinnace per day	45 L	121,5	0,44955	47,25	0,08955	0,0855	0,04905	0,01305	9
Approximate consumption of pinnaces on the Ebrié lagoon per day (49 pinnaces)	2 202 L	267 907,5	991,25775	104 186,25	197,45775	188,5275	108,15525	28,77525	19 845
Petrol									

Consumption	1 L	2,3	0,06999	1,05	0,00199	Traces	0,00999	0,00029	Faible
Average consumption of a pinnace per day	45 L	103,5	3,14955	47,25	0,08955	-	0,44955	0,01305	-
Approximate consumption of pinnaces on the Ebrié lagoon per day (49 pinnaces)	2 205 L	228 217,5	6 944,75775	104 186,25	197,45775	-	991,25775	28,77525	-
butane Gas: Liquefied Petroleum Gas (LPG))									
Consumption	1 kg	1,7	0,00999	2,3	0,00149	Traces	0,00499	0,0001	Faible
Average consumption of a pinnace per day	45 kg	76,5	0,4495	103,5	0,0670	-	0,2245	0,0045	-
Approximate consumption of pinasses on the Ebrié lagoon per day (49 pinasses)	2 205 kg	168 682,5	991,1475	228 217,5	147,735	-	495,0225	9,9225	-

Legend : *Pollutant level*

High *Average* *Low*

Thus, according to the color hierarchy that has been made (Table 3), for the three types of pollutants closely observed, butane gas does not reach the "high" rating and only reaches the "medium" rating once. This fuel is then positioned as the source of energy that would make the activity of artisanal lagoon transporters more ecological in a context of transport sustainability advocated by climate defenders around the world.

Discussion

The analysis of the importance of the use of gaseous fuels (LPG) in artisanal lagoon transport on the Abidjan water body has made it possible to highlight the advantages that would be linked to its use by pinnaces.

First, this study showed that the use of butane gas in the field of artisanal lagoon transport would allow artisanal transporters to make more economic gains compared to the use of diesel and gasoline. This result is explained by the fact that butane gas is less expensive to purchase and generates fewer mechanical maintenance costs, thus increasing daily savings. These advantages are only possible with the use of butane gas as fuel in the pinnaces. This result corroborates the writings of K. Karantao (2009). It appears from these writings that drivers change energy sources for economic reasons. This is why a driver says "*a 12 kg bottle of butane gas, charged at 4,000 FCFA brings me 8,000 FCFA in profit, yet with 8,000 FCFA of gasoline, I do not make more than 10,000 FCFA revenue, which gives a profit of 2,000 FCFA. It is not comparable to butane gas"* (K. Karantao, 2009, p. 1). P. Koudjo (2015, p. 3) in his writing on the means of transport that use butane gas as fuel in the city of Lomé in Togo, reached the same results in his works which emphasize the economic advantages linked to the use of this gaseous fuel in the field of transport. This would explain the validity of its use in the field of artisanal lagoon transport.

Then, butane gas would enable small-scale lagoon carriers to withstand competition from modern lagoon carriers. This can be explained firstly by the fact that its use by pinnaces would favor a drop in transport costs following the drop in expenses linked to the operation of the activity, secondly by the recovery of lines deemed unprofitable following the increase in the gains linked to the use of butane gas by the carriers of the pinnaces and thirdly, to extend the distances traveled by the pinnaces at a lower cost. The implementation of all these strategies against competition would only be possible with the use of butane gas in artisanal lagoon transport. This result is in line with that of K. Kouassi (2014 p. 269) who believes that the use of butane gas in passenger transport in Bouaké allows communal taxis to resist competition from other means of transport

of people such as motorcycle taxis. It is in this sense that its use in the lagoon transport sector is a capital contribution for the survival of the activity of pinnaces on the lagoon water body.
Finally, new energy sources would make the activity of small-scale lagoon transporters more ecological. Indeed, its use promotes a reduction in pollutants emitted by heat engines after combustion. Given this ecological efficiency, butane gas is positioned as the most ecological source of energy compared to diesel and gasoline. This opinion is shared by Picbleu (2008, p. 4) who believes that LPGs are perceived and often presented as "clean fuels". In terms of ecological balance, they benefit from an absence of particle emissions unlike diesel which, even equipped with a particle filter, lets out 10% of fine particles. The latter are carcinogenic and considered more harmful than the filtered particles. It emits very little carbon monoxide, benzene and formaldehyde. He goes further by stating that in terms of "emissions related to the extraction and refining of fuels from conventional crude", its production leads to significantly fewer emissions than that of gasoline and diesel (9 grams of CO2 emitted per megajoule, compared to 13 for gasoline and diesel for the same quantity produced). This opinion is shared by P. Doucet (2012, p. 2) who adds that LPGs pollute less than gasoline and especially than diesel, because they diffuse little nitrogen oxide (Nx) and do not propagate no particles. Its CO2 emissions are on average 16% lower than gasoline and diesel emissions. For this, M. Pesnel (2017, p. 4) states that LPG can become a key element in the world since it combines environmental advantages, economic advantages and significant public health benefits. Hence the need for its use in the pinnace transport sector in Abidjan**.**

Conclusion

This analysis shows that butane gas is a godsend for artisanal lagoon transport in Abidjan. Through this study, it results that its use in the artisanal lagoon transport sector promotes more economic gains compared to the use of diesel and gasoline. In other words, it will be the object of more daily gain unlike diesel and gasoline because of its low purchase cost and low expenditure on mechanical maintenance. In addition to monetary gains, the use of butane gas makes it possible to resist modern and semi-modern companies, to adapt to competition from modern lagoon transport companies. This would be made possible thanks to the reduction in transport costs allocated to the use of butane gas, the recovery of lines which are deemed less profitable and the extension of the distances traveled by the pinnaces while keeping the cost of transport low. which defies other competitors. All of this will only be possible with the return to use of butane gas in this transport sector. In addition to keeping these players in the sector, the use of butane gas makes this transport sector ecological or at least less polluting. Thanks to its use, the daily carbon dioxide emissions from pinnaces on the lagoon water body would be halved. As for carbon monoxide, it will be reduced to one seventh.
Ultimately, the use of butane gas in artisanal lagoon transport in Ivory Coast firstly allows artisanal transporters to make more economic gains compared to the use of diesel and gasoline, then to resist competition from modern lagoon transport companies and finally, makes the activity of small-scale lagoon transporters more ecological.
Artisanal lagoon transport in Ivory Coast shares the same activity space with other companies. These are semi-modern companies such as Marine System Company (MSC) and modern companies such as SOTRA, STL and CITRANS. Faced with a whole society, there are small-scale lagoon carriers in a context of permanent competition and ambition to conquer new lines or stations. Thus, the ideal outcome for these artisanal lagoon transporters in the years to come would be a fundamental change in the organization and operation of their activity. This will only be possible with the entry into use of butane gas in artisanal lagoon transport**.**

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