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**TOWARDS A SUSTAINABLE TRANSPORT IN ALGERIA:  
THE REQUISITE OF ENERGY TRANSITION IN THE ROAD  
TRANSPORT SECTOR**

**Summary.** Less than ten years ago, Algeria embarked on an energy transition with the objectives of sustainable development. Although it concerns all economic sectors, efforts made in the field of road transport, as the main polluter and energy consumer at the national level, are far from being sufficient despite its inclusion in policy statements. This sector is operational exclusively on fossil and exhaustible energies whereas its atmospheric pollutants and gaseous emissions are highly harmful to the environment, public health and the economy. Thus, this paper points out the emergency of an energy transition in the road transport sector to clean and renewable energy as a necessity rather than a choice. It highlights, first, the characteristics of the Algerian automobile fleet and its various impacts and damages on the environment, public health and the economy. Furthermore, it evaluates the various policy initiatives towards sustainable transport and their deficiencies. Hence, the right attitudes and regulatory instruments towards sustainable transport in Algeria are recommended.

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## 1. INTRODUCTION: TRANSPORTATION AND CLIMATE CHANGE FROM GLOBAL TO THE ALGERIAN ISSUE

Until the use of engines in the 19th century, the consumption of fossil fuels and air pollution from means of transport became significant [11, 27]. The gases escaping from these sources are more difficult to evacuate than those released through the chimneys of buildings or industries [23, 24, 28]. The Intergovernmental Panel on Climate Change (IPCC) confirms that recent anthropogenic greenhouse gas (GHG) emissions are the highest in at least 800,000 years [20]. In fact, the concentrations of the related pollutants reached 11.70 *gigatons of CO<sub>2</sub> equivalent* (GtCO<sub>2</sub>-eq) between 1750 and 1970. However, this same quantity has been emitted in the last 40 years only giving a cumulative amount of 23.5 GtCO<sub>2</sub>-eq [20]. Although the land and oceans have absorbed 60% of these emissions, 40% of them are presently free in the atmosphere with adverse consequences on humanity and the entire planet. These consequences have manifested in recent years through floods, excessive heat waves, decline in crops, rising sea levels, warming of the atmosphere and oceans, etc. [11, 20, 28]. In response to this crisis, the United Nations has been urging since 1987 for a "socio-ecological" transition, asking humanity to find new ways to move, live, produce and consume according to the sustainable development goals [33]. In 2006, the IPCC experts reiterated the call for this transition by confirming that the continuation of the current model of economic development driven by the expansion of motorised transport and growing urbanisation, will result in a significant increase (+2 to +6.4°C) in the temperature of our planet by 2100. This will severely threaten the survival of human societies, animal and plant species [20].

However, being able to participate in various daily life activities requires a certain ability to move around as well as easy spatio-temporal accessibility [14]. This means increased recourse to motorised modes, particularly in developing countries such as Algeria where environment-friendly alternatives are greatly lacking [5, 6, 8, 18]. In fact, Algeria has known an accelerated expansion of motorised and non-sustainable means of transport following its strong demographic growth [9, 13, 24, 43]. As with urban sprawl, the large separation of the place of residence and workplace has led to a sharp rise in travelling distances, which increased demand for transport [9, 13, 32]. As road transport is the most dominant mode in Algeria [8, 26, 32], road traffic has also experienced significant growth, particularly over the last 20 years [13]. The National Economic and Social Council (CNES) estimated it at 7% per year [9]. Whether for passengers or goods, more than 85% of Algerians use the road daily [18]. The development of road infrastructure in Algeria is to the detriment of the maritime and rail infrastructure, which have removed geographical barriers by offering motorists better accessibility to places [14], explains mainly this trend [8, 9, 32]. Nevertheless, the increases of motorised modes combined with the effects of climate change are seriously converging to the point of threatening the stability of the whole country. In other words, increases in mobility, both in terms of daily commuting and in terms of the fossil fuels consumed, directly affect the local environment and lead to strong pressures on economic development, public health and quality of life of Algerians, particularly in urban areas [5, 22].

To address these problems and demonstrate its firm willingness to participate in the international effort to minimise the consequences of climate change (on natural ecosystems and the sustainability of socio-economic development), Algeria signed the United Nations

Framework Convention on Climate Change (UNFCCC) in 1993 as well as the Kyoto Protocol in 2005. Furthermore, in 2010, it insisted through the National Scheme of Land Use (SNAT) to integrate sustainability as a prior preoccupation in the field of urban and national planning [32]. The experts of this scheme adopted some measures to mitigate GHG emissions in the energy sector as a major challenge for the country [32]. Accordingly, they prioritised the "energy transition" by promoting the use of renewable energy in some fields [5, 8]. Despite these efforts at addressing these environmental, economic and energy issues, they seem, however, insufficient and ineffective since they failed to link the issue of sustainability to that of road transport, which constitutes the main energy consumer and emitter of GHGs on a national scale [3, 5, 15]. Thus, reducing GHG emissions from road transport has become a major challenge for Algeria in particular [1, 15, 18, 26].

Through this paper, we want to demonstrate why the energy transition in the field of road transport is quite essential and urgent in Algeria, and why this sector needs to significantly reduce its dependence on petroleum products and move toward renewable and sustainable options. Subsequently, we have chosen to structure our paper according to five fundamental elements. First, we highlighted the characteristics of the Algerian automobile fleet in terms of growth, composition and age. Second, we demonstrated how this sector alone consumes such a large share of the country's energy (essentially petroleum products) and why it is ahead of other economic sectors in this regard. Third, we presented the main pollutants and gaseous discharges from the fuels consumed by road transport means in relationship with the characteristics of motor vehicles. Thereafter, we highlighted the strong contribution of the road transport sector to air pollution in Algeria by presenting the emission rates for each of the pollutants previously discussed. Fourth, we evaluated the economic costs related to energy consumption and the various environmental and human damages generated by this sector. Finally, we analysed the different options and policies undertaken by the government to mitigate atmospheric pollutants and gaseous emissions issued from road transportation. It is important to note that this study is based on statistics gathered from several national offices, reports and inventories.

## **2. THE ALGERIAN AUTOMOBILE FLEET AND ITS CHARACTERISTICS**

### **2.1. Automobile fleet's growth**

According to the statistics provided by the National Statistics Office (ONS), while the number of inhabitants increased by 53.50% passing from 28.56 million in 1996 to 43.85 million in 2020, the Algerian automobile fleet increased by 141.83% passing from 2.78 million motor vehicles to 6.73 million motor vehicles over the same period (Figure 1). The estimated level of motorised transport in Algeria was 95 vehicles per 1000 habitants in 2000 [13], increasing to 153.66 vehicles per 1000 habitants in 2020 [37].

The Algerian automobile fleet consists of many categories. As illustrated in Figure 2, private cars represent the bulk of the Algerian car fleet with 63% of the total fleet, followed by vans and lorries, 20% and 7% in 2020, respectively. Indeed, private cars experienced the fastest growth over the last 20 years [8, 42]. The increase in income level [24] and the reduction of the purchase price of vehicles [42] motivated the introduction of the automobile credit in 2001, which is the heart of the acquisition of private cars among several Algerian families, even the middle classes [1, 24, 42]. The implementation of the aid scheme, within the framework of the National Agency for Support to Youth Employment (ANSEJ) for young people wishing to

set up transport companies since 1996, allowed several unemployed young people to acquire a van or a truck for professional use [18], which explains the rates below. Other factors contributed to this rapid evolution of the Algerian transport system and the keen interest in mobility. The most significant are: the liberalisation of the automobile market in 1988 [1, 8, 13], the good economic situation of the last decade of the country [9], the low cost of fuel and the acquisition of driver's licence developing among youths and women [1, 13]. This has led to the over-consumption of fuels, which in turn increases the intensity of atmospheric pollution. Indeed, many studies showed that road traffic in Algeria is mostly generated by private cars, which constitute the main source of congestion, and consequently, the major source of pollution in urban areas [9, 22, 24, 26]. Thus, road transport and particularly private cars have proven to be the major cause of the bad air quality in Algerian [2, 3, 6] as well as in European cities [12].

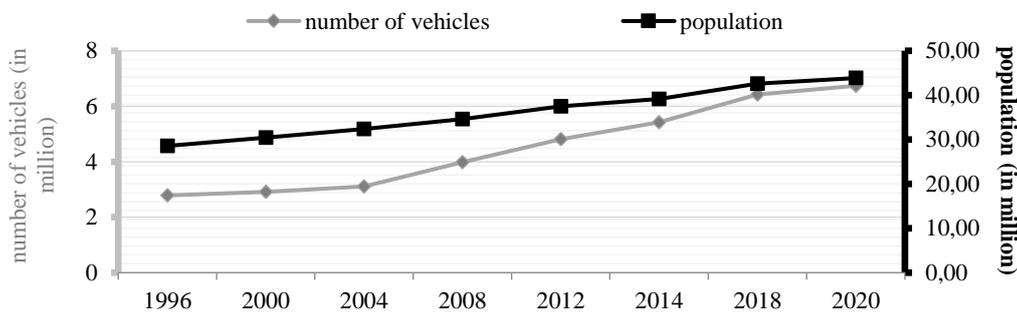


Fig. 1. Evolution of the Algerian automobile fleet according to population growth  
Source: Graph produced by authors based on the ONS statistics [37]

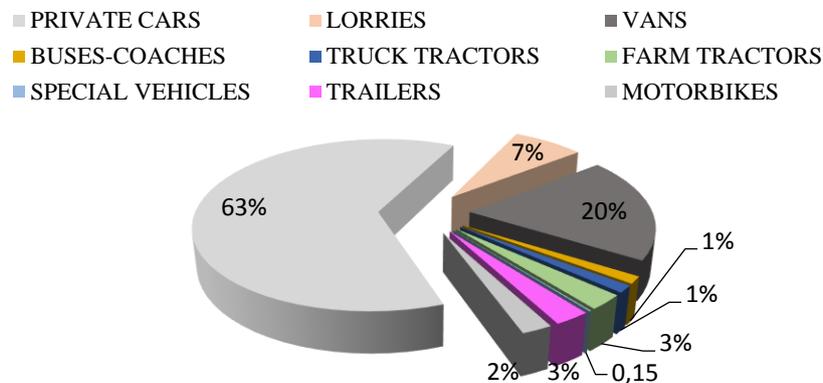


Fig. 2. Distribution of the Algerian automobile fleet by type of vehicles  
Source: Chart produced by authors based on the ONS statistics [37]

## 2.2. Automobile fleet age

It is a well-known fact that the amount of pollutants emitted by engines is largely related to the automobile fleet age [11, 13]. In other words, older vehicles consume more fuel, and consequently, emit more pollutants [8]. By the developed world standard and according to the distribution of the Algerian automobile fleet by age in 2020 (Figure 3), we confirmed that the latter and its technologies are dilapidated. The average age of the vehicles remains high with 62.13% of vehicles older than 10 years, whereas those aged less than 5 years represent 20.15%.

We note that due to the measures adopted in 2005, prohibiting the import of used vehicles and introducing compulsory roadworthiness tests [1, 34], the automobile fleet has been relatively renewed, given that in 2003, 87% of vehicles were aged more than 10 years [24].

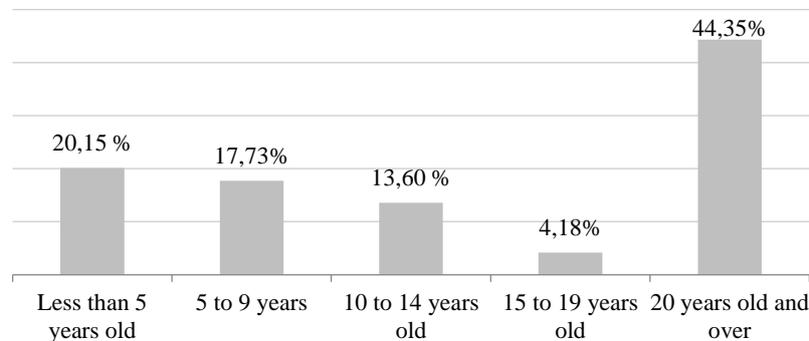


Fig. 3. Distribution of the Algerian automobile fleet by age of vehicles  
Source: Chart produced by authors based on the ONS statistics [37]

### 3. THE ROAD TRANSPORT SECTOR: A LARGE CONSUMER OF ENERGY AND FOSSIL FUELS IN ALGERIA

Energy consumption is the amount of energy (liquid, gaseous, electrical, etc.) consumed in a given geographic area in a given year [2]. It can be measured per capita, by sector of economic activity (agriculture, industry, transport, household, etc.) or by sub-sectors (road, sea, air transport, etc.). According to the annual report of the Ministry of Energy and Mines, energy consumption is growing constantly and in most sectors in Algeria as well [13, 29, 30]. Analysis of Figure 4 allows us to say that transport sector (all modes combined) is one of the most energy-consuming sectors at the national scale. Its consumption tripled in 20 years from 5 million tonnes of oil equivalent (Mtoe) in 2000 to 15.28 Mtoe in 2020, which represents 31.73% of the total energy (all types combined) consumed in the whole country. In terms of fossil fuels only (with exception of electricity), the transport sector consumption is largely ahead of the consumption of the residential and construction sector (11.7 Mtoe in 2020) despite the large number of investment projects undertaken on the national territory and the significant needs of this sector in terms of energy [18].

We noted that almost 93.86% of the transport-related energy was consumed by road means. The remaining 6.14% is divided between rail and air transport (2.09% and 3.98% – Figure 4). In other words, out of 15.28 Mtoe of energy consumed by the transport sector, all modes combined, a quantity of energy equal to 14.34 Mtoe was exclusively devoted to road transport, which is heavily dependent on petroleum products (gasoline and diesel). This dependence has been growing steadily, particularly, in the last two decades. In 2000, means of road transport consumed 87% of fossil fuels [2], whereas in 2020, this rate increased to 94.65% [3]. According to APRUE, this consumed energy is made up of 9.31% Mtoe of gasoline (64.95%), 4.14 Mtoe of diesel (28.89%), 0.76 Mtoe of Liquefied Petroleum Gas fuel “LPG” (5.35%), and 0.11 Mtoe of Compressed Natural Gas “CNG” (0.81%). Many studies confirm that private cars are the main energy consumers in Algeria over the two last decades, which explains the high levels of pollutants and gaseous emissions especially in urban areas [6, 15, 19, 22].

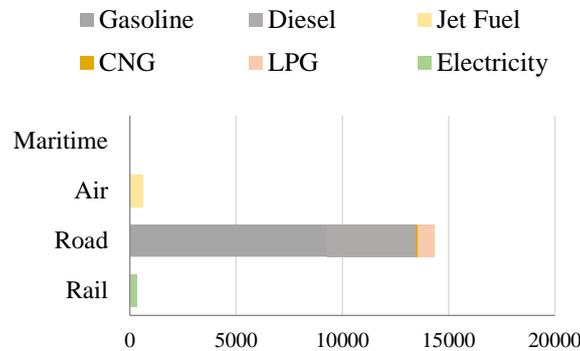
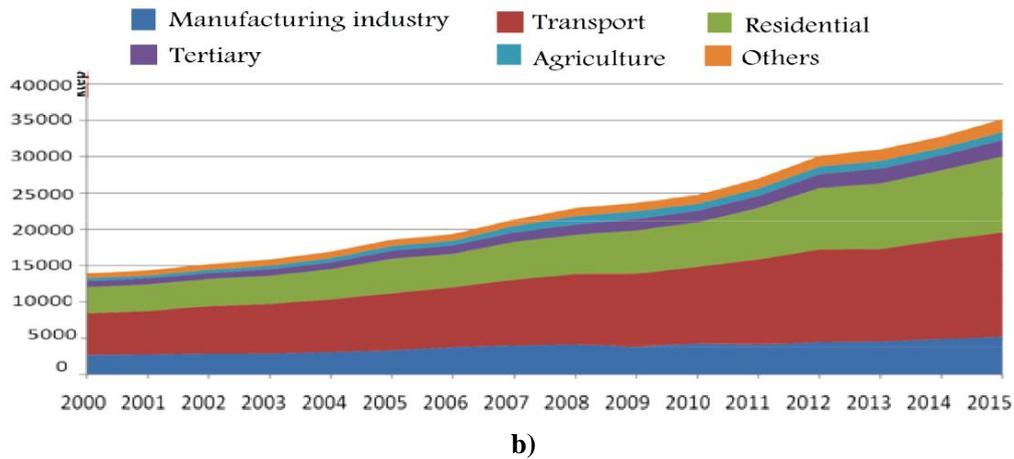


Fig. 4. Final energy consumption (in kilo tonne oil equivalent [Ktoe]) in Algeria in 2020: a) by economic activity sectors, b) by transport modes (NB: 1000 Ktoe = 1 Mtoe) Source: APRUE [3]

#### 4. ROAD TRANSPORT SECTOR: THE MAIN ATMOSPHERIC POLLUTER IN ALGERIA

##### 4.1. Main pollutants and gaseous emissions by road transport means

Pollutants emitted by road transport, are multiple but the main ones that affect the environment and contribute to climate change, and affects public health are seven. These and their origins are summarised in Table 1.

Tab. 1

Origins of pollutants and gases emitted by road transport vehicles

Name	Chemical symbol	Origin
Carbon monoxide	CO	Incomplete and rapid combustion of fuels, especially in <b>traffic jams</b> where its emission increases while vehicles are idling. 50% of CO emissions come from road transport. It occurs during the oxidation of unburned hydrocarbons especially in <b>gasoline</b> -powered vehicles (emission rate 93%).

Carbon dioxide	CO <sub>2</sub>	All engines running on fossil fuels release CO <sub>2</sub> into the atmosphere. A 56-litre tank of gas corresponds to a release of 135 kg of CO <sub>2</sub> . Different types of engines have roughly similar emissions. The CO <sub>2</sub> emitted by road transport tends to increase in connection with the increase in the number of vehicles.
Nitrogen oxides	NO <sub>x</sub>	Nitrogen monoxide (NO) increases with fuel combustion under high-temperature. It transforms quickly into Nitrogen dioxide (NO <sub>2</sub> ). The higher NO concentration, the larger its transformation into NO <sub>2</sub> . These are considered much more dangerous than CO since they are mainly emitted by road transport (whose emission rate exceed 60%) and are much more concentrated in urban areas.
Sulfur dioxide	SO <sub>2</sub>	Combustion of sulfurous fuels emitted by <b>diesel engines</b> . About 100 000 tonnes of SO <sub>2</sub> are released yearly. In Algeria, the dieselisation of means of transport is progressing further, which means that emissions of this pollutant are clearly increasing.
Particulate Matters. Dusts	PM	Combustion of fuels (especially <b>diesel</b> ) by road transport means, which emit them in the form of fine dust. The more diesel-powered the automobile fleet, the higher the PM concentrations. Algeria has opted for the dieselisation of its vehicle fleet since 2002 (34% in 2015) without, however, taking care of the polluting emissions whose impacts on public health are delicate.
Volatile Organic Compounds (Hydrocarbons)	VOC (HC)	Evaporation of <b>gasoline</b> and incomplete combustion of fuel and engine oil. Motor vehicles account for more than 40% of total HC emissions into the air. In heavily trafficked streets, they are present at levels reaching tens of thousands of micrograms per m <sup>3</sup> .
Tropospheric ozone	O <sub>3</sub>	Reaction of some of the above pollutants under the effect of solar radiation
Lead compounds	Pb	Lead additives contained in certain <b>gasoline</b>

Source: synthesised by authors [7, 11, 16, 20, 21, 27, 28, 39]

#### 4.2. Emission rates of road transport pollutants in Algeria

The contribution of the transport sector to overall GHG emissions was no more than 20% in the early 1990s. However, it increased recently to 66% making it the world's leading polluter [20]. In Algeria, this sector remains, however, the largest GHG emitter since 1971. Its contribution rate to the total CO<sub>2</sub>-eq emissions at the national scale has been increasing since 2001 as shown in Figure 5. According to the National Agency for the Promotion and Rationalisation of Energy Use (APRUE), the direct GHG emissions due to final energy consumption reached 147 MTCO<sub>2</sub>-eq in 2020, of which the contribution of the transport sector is almost 49 MTCO<sub>2</sub>-eq (33.33% of the total GHG emissions in Algeria). We observed that the highest contribution to these emissions is attributed to road transport whereas the contribution of other modes (rail, maritime, etc.) remains trivial [3]. While the World Health Organisation (WHO) recommends not to exceed an annual average of 2.2 tonnes of CO<sub>2</sub>-eq per capita across

all economic sectors (transport, construction, residential, etc.) [44], emission level per Algerian is equivalent to 2.26 TCO<sub>2</sub> of which 1.15 tons of CO<sub>2</sub>-eq per capita are related only to the use of road transport means [3].

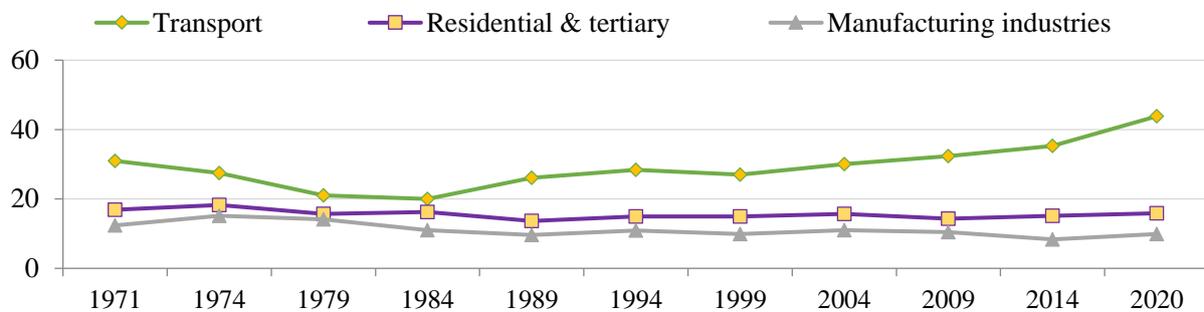


Fig. 5. Evolution of CO<sub>2</sub>-eq emissions in Algeria between 1971 and 2020 (in percentage of the total combustion of fuels)

Source: Designed by authors [45]

Despite the lack of recent inventories, it is still important to point out that road transport emissions of other pollutants far exceeded those of other sectors in 2012 (last inventory made in Algeria). The Ministry of Land Use Planning and the Environment estimated in its second communication to UNFCCC that some pollutants have increased significantly between 1994 and 2012: SO<sub>2</sub> (+43%) and CH<sub>4</sub> (+39%), while others have increased only slightly: CO (+5.4%), and NMVOCs (+5.3%) [33]. This is logical since 90% of the transportation of passengers and merchandise is by road means, which consumes almost exclusively petroleum products [24]. Air pollution related to this sector is exacerbated by the growth of the automobile fleet and the advanced average of its age. The prevalence of individual transport (private cars) compared to public transport (buses) on the roads contributes also to the Peak-hour traffic congestion and related pollution particularly in urban areas [24]. Furthermore, the lack of maintenance in combination with the non-existent and non-functioning pollution control systems accentuate this problem [1, 5, 18]. However, all of these pollutants have very harmful impacts on public health.

Given that, by 2025, freight and passenger traffic on land will more than double in Algeria [32], the reduction of GHG emissions inherent to the road transport sector remains a major challenge.

## 5. THE ROAD TRANSPORT SECTOR AND ITS POLLUTANTS: SERIOUS DAMAGES TO PUBLIC HEALTH

Many research conducted around the world confirms that pollutants emitted by road transport, particularly in urban areas, cause multiple dysfunctions and physical disorders and constitute, therefore, a potential risk for public health. Similarly, the National Action Plan for the Environment and Sustainable Development (NAPE-SD) has confirmed that the most significant damages related to air pollution in Algeria affect mainly human health and quality of life [31]. In 2002, the WHO attributed 1.4% of all premature deaths worldwide to urban air pollution that comes mainly from the evaporation of gasoline (unburned hydrocarbons) and exhaust fumes [38]. In 2012, this pollution was responsible for approximately three million

premature deaths worldwide in both urban and rural areas [44]. Air pollution from road transport means is responsible for almost 3% of yearly deaths in Switzerland, France and Austria [7, 16, 17, 25, 38]. This mortality tends to increase especially among people living near major traffic routes [10, 17]. The main impacts of each pollutant and the corresponding health risks are summarised in Table 4.

Pollution peaks due to NO<sub>x</sub>, HC and the resulting O<sub>3</sub> have been correlated with increased respiratory morbidity in France since 1994, highlighted by a clear increase in hospitalisations, respiratory tract diseases and asthma attacks, particularly in children [10]. The correlation between the concentrations of CO, SO<sub>2</sub>, NO<sub>x</sub>, O<sub>3</sub> and the frequency of heart disease have been demonstrated in the United Kingdom since 1997 in the "Occupational and Environmental Medicine Journal". Indeed, 1/5 heart attacks are due to these pollutants and the increase in the frequency of related hospitalisation is linked to the increase in their emission rates [7, 19]. The PMs emitted by vehicle engines are closely responsible for respiratory tract disorders [16]. Depending on their size, these particles can affect the upper respiratory tract (especially the larynx), as they can be absorbed through the digestive tract and have extra-pulmonary effects [28]. In 2013, the International Agency for Research on Cancer (IARC) concluded that these PMs are closely associated with an increased incidence of various cancers, primarily lung, urinary tract and bladder cancers [10, 16, 25]. Furthermore, they can affect the course of pregnancies and the development of newborns as well as male fertility [44].

Tab. 2

The health risks associated with the various pollutants emitted by road transport

Pollutants	Health damages
CO	Respiratory and cardiovascular disorders - Anoxia - Migraine - Dizziness - Vision disorders
NO <sub>x</sub>	Irritation- Respiratory problems- Decreased immune defences - Impaired lung function- Eye discomfort
SO <sub>2</sub>	Respiratory and cardiovascular disorders - Impaired lung function - Acid rain (sulfuric acid)
PM <sub>10</sub>	Respiratory and cardiovascular disorders - Cancers
VOC/HC	Eye irritations - Coughing - Carcinogenic actions in crowded places
O <sub>3</sub>	Migraine - Eye irritation - Impaired lung function
Pb	Intoxications- Anaemia - Growth disorders - Renal insufficiency

Source: synthesised by authors [7, 10, 16, 17, 25, 28, 36, 43, 44]

In Algeria, the National Institute of Public Health (INSP) concluded in 1996 that 25% of the recorded cases of respiratory morbidity were attributable to urban air pollution, road traffic in particular. The figures at the time were worrying since the number of vulnerable people affected by air pollution was close to 136 000 asthmatics, 88 400 persons having chronic bronchitis and 380 people with lung cancer. As for the mortality rates, which were consequently high, they amounted to 16.69 deaths per 100 000 people with chronic bronchitis, 2.74 deaths per 100 000

people with lung cancer and 1.97 deaths per 100 000 people with asthma [31]. The results of the National Health Survey conducted in 2005 linked the above-mentioned morbidities to road transport means [38]. The report underlined that chronic pathologies occurred more in urban areas (with a rate of 15%) rather than in rural areas (11%). Furthermore, it highlighted respiratory disease provoked by transport pollutants as responsible for 11.65% of hospitalisations, affecting children (16.5%) more than adults (11%). The related morbidity rates were high in both urban (12%) and rural (11%) areas. Thus, cases of rheumatism (which appear following respiratory tract infections, and subsequently, cause cardiac problems) were rising sharply, with an average rate equal to 8.15% [19]. To protect public health according to the WHO recommendation, the Algerian regulation limited the annual average emission of PMs to  $50 \mu\text{g}/\text{m}^3$  [34]. Despite its importance, this value had been exceeded in many Algerian cities especially Algiers and Constantine [19, 33, 41]. Consequently, this excess value is responsible for 4.5% of hospital consultations [19]. Air pollution from road traffic would be the cause of 80% of respiratory diseases among the Algerian population in the long term [6].

## 6. THE ROAD TRANSPORT SECTOR: COLOSSAL COSTS FOR THE ALGERIAN ECONOMY

### 6.1. Fuel and energy costs

Figure 6 shows the remarkable change in the way fuel has been used in Algeria since 1996, where gasoline vehicles are slightly decreasing while those running on diesel are slightly increasing. This can be explained by the low price of diesel as well as the lifespan of the diesel engine compared to the gasoline engine [1, 5]. The strong dependence of road transport on gasoline and diesel makes its share in the imports of this derived energy remain the largest. The share of these two products in the total imported derived energy is estimated at 34.41%, with quantities equal to 256 Ktoe and 275 Ktoe, respectively [2, 3]. In other words, out of 1543 Ktoe of imported derived energy (diesel, bitumen, electricity, etc.) in 2020, the amount of imported diesel and gasoline is equal to 531 Ktoe whose prices are exorbitant approaching, therefore, one billion dollars annually [4].

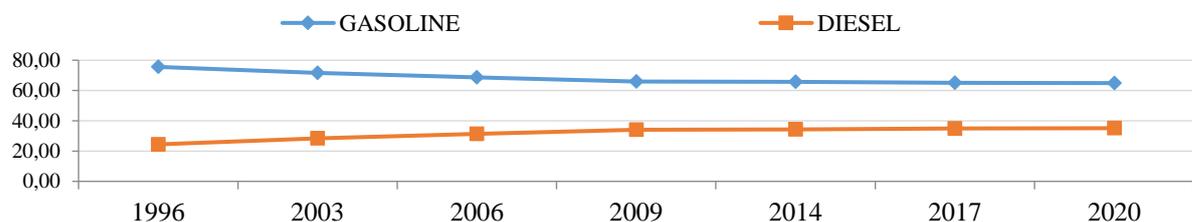


Fig. 6. Evolution of the Algerian automobile fleet (in %) according to the type of used energy  
Source: designed by authors based on the ONS statistics [37]

Idres and Kaïd Tlilane showed in their study that the fuel demand curve is proportionally increasing as a function of the increase in the vehicle fleet in Algeria, with a strong correlation rate equal to 86% [18]. According to them, the average energy consumption in Algeria is 0.25 Ktoe per 100 vehicles, compared to 0.10 Ktoe per 100 vehicles in France and Germany and 0.15 Ktoe per 100 vehicles in Norway. This difference in consumption is explained by the low

cost of fuel that encourages the mobility of motorists. While France, Germany and Norway showed a significant decline in fuel consumption during the fuel price increases, especially during the 2007 crisis, Algeria and Egypt did not show the same [18]. Due to heavy state subsidies, fuel prices were relatively low in the latter two, whereas they were high in Morocco, France, Germany, and particularly in Norway and vary according to fluctuations in crude oil prices on the international market [23]. Moreover, it should be noted that the Norwegian motorist pays 10 times more expensive his full tank of gasoline and almost 14 times more expensive his full tank of diesel than an Algerian motorist. The prices are \$ 2.27 for gasoline and \$ 2.11 for diesel in Norway against \$ 0.27 for gasoline and \$ 0.16 for diesel in Algeria, respectively. Such fiscal and energy rationality implemented by a rich natural resource exporting country like Norway reflects its determination to rationalise its expenditures and ensure its economic viability by investing in sustainable transport. Meanwhile, fuel imports in Algeria will continue to increase in the coming years because of the constant growth in daily mobility and the old age of the automobile fleet. In addition, we should not forget the energy deployed to illuminate road infrastructure, whose night lighting for public roads consumes 40% of the national electrical energy. The cost of this lighting amounts to 13 billion DA on the national scale [30].

## **6.2. Public health and environmental costs**

The costs of public health-related damages inherent to atmospheric pollution are very significant [31]. The economic losses thus incurred would amount to \$246 675 067 per year (that is, 0.52% of GDP), of which the direct cost of respiratory diseases was estimated at \$ 15 000 000 per year [32]. Moreover, the costs of annual environmental damage in Algeria amounted to 5.5% of GDP, of which 2% is associated with air pollution and GHG emissions [31, 32, 33]. As air pollution leads to a deterioration of the quality of life, many Algerian households living in urban areas were predisposed to bear an additional cost to improve air quality and prevent building degradation (painting, repair, etc.). Depending on the willingness to pay, this loss of well-being was estimated at nearly 0.12% of GDP. On the other hand, the economic losses related to the degradation of natural capital were higher and represented 1.84% of GDP, with impacts on biodiversity amounting to 0.21% of GDP. While the cost of damages related to CO<sub>2</sub> emissions was estimated at \$ 567 807 273 per year, which represents 1.2% of GDP [32].

## **6.3. Replacement costs**

The "replacement costs" are related to the various investments needed to mitigate the costs of damages induced by air pollution from motorised modes [31]. These costs amounted to \$ 62 132 937 per year, representing 0.17% of GDP. The main investment is represented by the conversion of 350 000 vehicles to LPG (Liquefied Petroleum Gas) over a period of 10 years. The annual investment cost of which was estimated at \$ 23 887 769 (0.05% of GDP).

## **7. ALGERIAN POLICIES IN FAVOUR OF SUSTAINABLE TRANSPORT**

Since 1993, Algerian efforts to mitigate atmospheric pollutants and GHG emissions have focused on the:

- reduction of the quantities of gas burned by torches of the National Company of Hydrocarbons, Research, Production, Transport, Transformation and Marketing;
- reduction of ozone-depleting substances (refrigeration, aerosols, foams, solvents);
- dieselisation of the automobile fleet (to reduce CO and CO<sub>2</sub> emissions) knowing that Algeria has become an importer of diesel [31]. Meanwhile, this fuel emits more NO<sub>x</sub> and PM that have negative consequences, especially on public health.

In 2015, the Ministry of Energy and Mines, through APRUE, initiated “The development of energy efficiency programme at horizon 2030”. This programme aimed to promote Liquefied Petroleum Gas fuel (LPG/c) and Compressed Natural Gas fuel (CNG). These were the most available and least polluting fuels, representing less than 5% of fuel consumption in Algeria. The generalisation of their use in individual and collective means of road transport will make it possible, in the long term, to cover up the deficit in the national fuel market by enriching the fuel supply structure. Moreover, it will help to mitigate the health and environmental damages related to the use of gasoline and diesel, particularly in the most populated urban areas [29]. To get involved, APRUE similarly set up in 2019 “The National Energy Management Programme for the transport sector by 2030”. This programme is based mainly on the conversion of more than 1.1 million vehicles (private cars and public means of transport) to LPG/c by 2030. Its objectives are mainly: (1) The reduction of fuel imports, which have been increasing in recent years because of the increase in the number of vehicles. (2) The substantial reduction of exhaust fumes in cities, and consequently, the protection of public health. (3) The provision of an affordable and environment-friendly alternative energy source for road transport means and users. (4) Job creation through the LPG conversion chain.

To achieve these objectives, this programme benefits in particular from:

- technical support from APRUE, notably through the drafting of specifications relating to the quality of the LPG/c kits as well as the rules concerning installation, maintenance and after-sales service;
- support for installers and capacity building;
- overall monitoring of programme implementation;
- the design and launch of an awareness campaign to engage potential beneficiaries.

Complementary measures have been taken by APRUE to carry out its programme such as:

- ban on the import of used vehicles since 2005;
- compulsory vehicle technical inspection for vehicles over 2 years old;
- mandatory energy audit for transport companies that consume more than 1000 toe/year.

## 8. CONCLUSION AND RECOMMENDATIONS

By investigating the relationship between road transport, energy consumption, GHG emissions and the associated impacts and damages, this study presents a new perspective to the ongoing debate about sustainable transport in Algeria. Since the liberalisation of the transport market in 1988, there has been an important increase in the number of vehicles as well as the consumption of fuels. These very crucial increases have stressed the resources, posing a major threat to the atmosphere and the environment both locally and globally. The road transport sector's heavy dependence on non-renewable energy sources confronts it with multiple economic challenges related to excessive consumption of fossil fuels, exorbitant costs resulting

from environmental and human damages, etc. Hence, to achieve the ecological transition set out since the Rio Conference, the energy transition in this sector has proved to be of paramount importance, especially in recent years in Algeria. However, ignoring the strong relationship between the issue of sustainability, road transport and energy transition shows the limits of what should be a systemic approach towards sustainable transportation [14, 23].

The implementation of the conditions related to transportation within the framework of preserving the environment and promoting the national economy requires the road transport sector to reduce amply its GHG emissions. This objective raises the urgency to accelerate the energy transition within this sector, which constitutes both the main polluter and energy consumer on a national scale. This transition should not be based solely on the generalisation of LPG and CNG as undertaken by the Algerian policy makers but must include other environment-friendly sources of energy. In other words, encouraging the use of LPG and CNG as alternative fuels is a good initiative to be implemented to reduce the air pollution and GHG emissions emanating from road transport. However, no single measure is sufficient on its own; to overcome this rigorous problem, different solutions from several fields must be combined and implemented together.

Solar, wind and water are all renewable sources capable of producing as much energy to run our means of transport and meet daily needs, especially in terms of daily commuting. As proof, many cities around the world have excelled in making new environment-friendly road transport means that depend solely on renewable energy sources such as electric cars, electrically assisted bicycles, solar-powered tricycles, etc. Algeria's energy policy must therefore be articulated with fuel price policy as well as road infrastructure policy. This is very crucial as the growth model currently advocated in Algeria generates more costs than benefits in the transport sector. Finally, the sustainability of transport policy in Algeria can only be achieved at some expense such as:

- the raise of vehicle costs, which can, however, be offset by the low costs of LPG and CNG,
- the establishment of a network to measure air pollution periodically,
- make inventories of GHG emissions accessible for public,
- the serious technical control of emissions especially from private cars.

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