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Hybrid Electric Vehicles and CO_2 Emission Mitigation in Tunisia: A LEAP Model Analysis

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ABSTRACT

Tunisia has embarked on an energy transition aimed at reducing its carbon emissions by 13 41% by 2030, with a major contribution from the energy sector. The road transport sector, the largest consumer of final energy and main emitter of CO_2, is a key lever for achieving these objectives. This study assessed the environmental impacts of electric mobility and improving energy efficiency in Tunisian road transport using an approach based on the LEAP model. The methodology adopted is based on the assessment and projection of energy demand and emissions of the road fleet according to four scenarios: Business As usual (BAU), fleet electrification (EV), energy efficiency (EE) and sustainable mobility (SM), over the period 2015-2050. The results show that the electrification of end uses is a key strategy for a low-carbon scenario, subject to a renewable-dominated electricity mix. Thus, Tunisia should strengthen the transition towards electric mobility and optimize the energy efficiency of the transport sector to honor its environmental and climate commitments.

Keywords: Scenario Analysis, Road Transport, LEAP Model, Energy Transition, CO_2 Emissions
JEL Classifications: Q41, Q42, Q48, R41, Q54

1. INTRODUCTION

All developed and emerging countries are subject to two main constraints: Energy security and environmental protection. Tunisia is among the Mediterranean countries most exposed to the impacts of climate change, the effects of which are real and increasingly affecting the vital sectors of the country. Tunisia has made considerable efforts to implement various environmental protection and energy management policies and has engaged in international climate actions.

Since 2001, Tunisia has formulated various strategies to counter climate change in key sectors (agriculture, health, energy, and tourism). Reducing carbon emissions by 13-41% by 2030 is a crucial objective, with a particular focus on the energy sector, which accounts for 75% of the projected reductions. Tunisia has integrated climate change into its constitution and development plans.

Tunisia submitted its first NDC in September 2015, the objective of which was to reduce the carbon intensity of all sectors of the economy by 41% by 2030 compared to 2010. In the NDC updated in 2021, Tunisia committed to reducing carbon intensity by 45% in 2030 and aimed for carbon neutrality by 2050-2060. Energy efficiency and renewable energy are the two main levers for achieving the objective assigned to the energy sector, which aims to reduce carbon intensity by 45% in 2030 compared to its level in 2010.

The transport sector as a sub-sector of the energy sector is the largest consumer of final energy (the road sector alone accounts for more than 90% of the final energy consumed) and among

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the main carbon emitters in Tunisia. Thus, Tunisia has initiated several measures to mitigate the effects of climate change in the transport sector and electric mobility has become an imperative in a constantly changing world. From there, our objective is to determine the environmental of electric mobility and energy efficiency in the road transport sector in Tunisia.

To address this issue, a two-step methodology was adopted:
(1) Evaluation and projection of the total future energy demand for each type of vehicle and each type of fuel consumed, in the road transport sector, and of the total emissions of the entire road fleet using the LEAP model;
(2) Analysis of the environmental impacts of different scenarios of energy transition and improvement of energy efficiency in the road transport sector.

2. ENERGY CONSUMPTION AND CO_2 EMISSIONS OF THE TRANSPORT SECTOR IN TUNISIA

The transport sector is characterized by several negative externalities, particularly greenhouse gas emissions. The transport sector in Tunisia is one of the main economic activities that consume a large part of the energy. In 2010, the transport sector occupied the second place in terms of energy consumption with a share of 34% of total energy consumption after the industrial sector (35%). Permutations between the three "big" sectors, namely industry, transport and residential, were observed between 2020 and 2021: the consumption of the transport sector increased to the detriment of the residential sector. In fact, in 2021, the transport sector is responsible for 32.6% of total energy consumption (Table 1), thus occupying the first place. The residential sector follows, with 27.4% of final demand, ahead of the industrial sector (25.2%). The energy consumed in the transport sector comes almost entirely from oil. In 2020, consumption in the transport sector was naturally dominated by petroleum products (94%) (NOEM[1], 2021).

The Tunisian transport system is composed of 5 sub-sectors, namely: Road transport, rail transport, pipeline transport, maritime transport and air transport. The road sector alone accounts for more than 90% of the final energy consumed. According to the NOEM, road transport occupies first place in 2021 with 89.4% of the total final demand of the transport sector (Table 2).

The road transport vehicle fleet has doubled since 2005, reaching 2.5 million vehicles in 2021, including 80% of light vehicles (passenger cars, commercial vehicles, and utility vehicle fleets such as trucks, vans and coaches). This development has generated a final energy consumption of approximately 2.4 million toe in 2021 (90% of which comes from petroleum products).

CO_2 emissions from road transport increased from 1.75 million metric tons in 1980 to 6.5 million metric tons in 2014, representing more than 27% of total CO_2 emissions, reaching 8.22 million metric tons in 2021 as shown in figure 1. This is explained by the fact that road transport activity in Tunisia is closely linked to the consumption of fossil fuels, particularly gasoline (32.5%) and diesel (67%) in 2021.

Table 1: Tunisia's energy consumption by sector (%) 1980-2021

Sectors	1980	1990	2000	2010	2020	2021
The industrial sector	37.8	39.6	34.9	35	24.6	25.2
The transport sector	37.2	30.8	32.3	34	31.1	32.6
The residential sector	11.4	14.1	16.9	16	29.3	27.4
The tertiary sector	8.1	8.6	8.6	9	8.3	8.4
The agriculture sector	5.5	6.9	7.3	6	6.6	6.4

Source: (NAEC[2], 2021)

Table 2: The mod l shar e of en gy co sumpti on (%) from 1980 to 2021

Transport Modes	1980	1990	2000	2010	2020	2021
Road transport	66	70	71	76	93.6	89.4
Air transport	21	20	19	18	0.1	0.1
Maritime transport	3	2	1	3	5.7	10
Rail transport	10	8	9	3	0.6	0.5

Source: (NAEC, 2021)

In the field of transport, Tunisia recognizes its role as a major carbon emitter, being one of the main energy sectors responsible for these emissions. Tunisia has initiated several measures to mitigate the effects of climate change in the transport sector, including: (1) the National Urban Mobility Policy (2020-2025) which had as its main objective the continued development of low-carbon urban mobility, the reform and improvement of public transport and (2) the National Transport Master Plan for Horizon 2040 (2019-2040) which aims to identify sustainable and innovative energy resources, improve the environmental balance sheet and reduce fossil energy consumption.

Electric mobility has become an imperative in a constantly changing world. Various measures have been taken within the framework of the 2022 Finance Law to encourage electric mobility in Tunisia: (1) total exemption from customs duties for electric vehicles (cars, utility vehicles and buses), (2) 50% reduction in customs duties for hybrid cars, (3) reduction of customs duties on charging stations from 43% to 10% while VAT has gone from 19% to 7%, and (3) possibilities for financing the additional cost of the electric vehicle which is between 20,000 and 50,000 dinars and this through a subsidy ranging from 20% to 30% of the additional cost and a loan with reduced and preferential rates. Among the advantages to be prioritized in the 2024 finance law for the development of electric mobility, we cite the elimination of all duties and taxes imposed on electric vehicles, on charging stations and on components.

These measures aim to transform the transport sector in Tunisia by integrating sustainable practices, increased energy efficiency and better resource management to meet the challenges of climate change. In terms of consumption reduction potential, the transport

1 LEAP Model : Low Emissions Analysis Platform. 1 January 2018. Available online: https://www.sei.org/projects-and-tools/tools/leap long-range-energy-alternatives-planning-system/

2 National Agency for Energy Conservation

sector represents 25% of the energy efficiency potential by 2030. Thus, electric mobility and energy efficiency are the solutions to meet Tunisia's environmental commitment.

3. LITERATURE REVIEW

Climate change is a serious problem that threatens the existence of people around the world. Since transportation is a major contributor to global carbon emissions, and these emissions are a key factor in global warming, researchers have focused on this phenomenon (Xia et al., 2022; Al-Thani et al., 2020; Coutinho et al., 2020; Lv et al., 2018 etc.). They have studied transportation-related emissions using various modeling techniques, such as factor decomposition models (to analyze the influence of different factors on emissions), econometric models (to explore the relationship between economic activity and transportation emissions), and comprehensive models (to simulate complex systems and their interactions, potentially integrating climate, economic, and transportation data).

Wang et al. (2021) studied the potential environmental benefits of a mass transition to electric vehicles. Their research provides additional arguments in favor of this transition, particularly with regard to reduced air pollution and public health policies. The study by Jiang et al. (2021) provides a comprehensive analysis of the geographical distribution of road vehicle emissions. This information could help develop more efficient traffic management strategies and improve urban air quality. Daldoul and Dakhlaoui (2018) analyzed the main factors influencing carbon emissions from the transport sector in Tunisia, taking into account its different modes (roads, railways, civil aviation and waterways) over the period 1991-2016. Using the LMDI decomposition method, their study highlights that the sharp increase in these emissions is mainly attributable to the growth of the transport sector in Tunisia, with a marked predominance of road transport. An analysis by Guo and Meng (2019), using the logarithmic mean divisia index (LMDI) method, explored the determinants of CO_2 emissions from the transport sector in the Beijing-Tianjin-Hebei region of China. Their results indicate that transport energy intensity and economic factors are the main contributors to the increase in CO_2 emissions. Conversely, energy structure, freight volume per unit of industrial output, and industrialization have contributed to a reduction in CO_2 emissions from the transport sector. Mazzarino (2000) used a decomposition approach to analyse the main factors influencing the evolution of CO_2 emissions in the transport sector in Italy between 1980 and 1995. His study highlights that GDP growth is the main driver of this variation.

Timilsina and Shrestha (2009) used the LMDI method to identify the determinants of CO_2 emissions in 20 Latin American countries over the period 1980-2005. Their results show that the increase in CO_2 emissions in the transport sector in these countries is mainly attributable to economic growth. Analyzing road traffic emissions in Qatar, Al-Jabir et al. (2023) used the LEAP model to project future trends and quantify current emissions. This study aims to identify policy reform needs to mitigate greenhouse gas (GHG) emissions in the transport sector, filling a gap in the literature on transport emissions in the Gulf region. The authors evaluated three main scenarios: A historical scenario, a business-as-usual (BAU) scenario, and a public transport-focused scenario with sub-scenarios including improved energy efficiency, electrification, and the use of compressed natural gas (CNG). Their main results indicated a dominance of CO_2 emissions in all scenarios, with light-duty vehicles being the main source in the BAU scenario. The authors concluded that substantial emission reductions are possible through improved public transport, adoption of cleaner fuels, and reduced reliance on private vehicles. This first comprehensive analysis of transport emissions in Qatar provides crucial information for future research and policy in the region. Shabbir and Ahmad (2010) employed the LEAP model to analyze urban transport emissions and energy demands in Rawalpindi and Islamabad. Projecting future scenarios, they assessed the impact of various urban transport policies on energy consumption and emissions. Their findings indicated a dramatic increase in both under a Business As Usual (BAU) scenario. However, alternative scenarios, which included population reduction, public transport promotion, and the adoption of natural gas vehicles, offered the potential for significant reductions in energy use and pollutant levels. These alternatives suggested possible decreases in NOx, SO2, and PM10 emissions by 15-20% compared to the BAU scenario. Saisirirat et al. (2022) analyzed the biofuel sector in Ghana, assessing its potential to mitigate greenhouse gas (GHG) emissions from road transport. Their research also explored the policies and regulations needed for widespread adoption of biofuels. The study projected a reduction in energy demand of 6.7-8.2% by 2030 and 7.4-7.8% by 2036, when combining the use of biofuels with vehicle electrification and natural gas, compared to a business-as-usual (BAU) scenario. Furthermore, alternative (ALT) and extreme (EXT) scenarios could reduce GHG emissions by 8.4-11.1% in 2030 and 11-16.7% in 2036, respectively, compared to the BAU scenario.

Fitriana et al. (2023) explored Indonesia's potential for transitioning to electric vehicles (EVs) to achieve carbon neutrality in the transport sector. Using energy models (NEMO and LEAP) comparing business-as-usual (BAU) and net-zero emissions (NZE) scenarios, the study found that EVs, combined with energy conservation measures, could significantly reduce energy consumption and greenhouse gas (GHG) emissions. The NZE scenario, with its emphasis on renewable energy and EV adoption, projected substantial declines in reliance on fossil fuels, particularly gasoline, with a complete shift to electric motorcycles by 2058 and increasing use of hydrogen after 2035. This transition, supported by a carbon-neutral energy sector by 2079, would significantly reduce the transport sector's contribution to overall GHG emissions by 2100. In an analysis of the Moroccan energy system, Raouz (2015) used LEAP software to model the impact of different strategies on emissions from the energy and transport sectors. The study developed and compared four prospective scenarios for energy demand, electricity production and greenhouse gas (GHG) emissions, based on historical data, projections and assumptions. The analysis found that Morocco's dependence on fossil fuels and its growing energy consumption are significant obstacles. However, the exploitation of oil shale deposits, coupled with new policies, could increase the share of renewable energy in electricity production to 42% by 2020. The study also estimated that a mitigation strategy could reduce GHG emissions by 50 million tonnes of CO_2. Despite this potential, the current legal and institutional context is hampering the sustainable development of clean energy in Morocco. Rivera-González et al. (2020) assessed the potential of sustainable transport policies in the Ecuadorian road sector using the LEAP model. Four scenarios – business as usual (BAU), energy optimization and mitigation (EOM), alternative fuels (AF), and sustainable mobility (SM) – were developed and compared. The SM scenario, with its emphasis on public transport and reduction in private vehicle use, projected the largest reductions in energy demand (−30.43% compared to the BAU scenario by 2035), GHG emissions (−11.70% compared to the BAU scenario), and fuel costs (contributing to total savings estimated at USD 26,720 million across scenarios). Although all scenarios recorded an increase in the vehicle fleet, the SM scenario reduced the number of vehicles by 2.3 million due to its emphasis on public transport. The study highlights the potential benefits of sustainable mobility policies in emerging economies.

Another study by Meng et al. (2024) analyzed the energy transition of the Japanese road sector and possible pathways toward carbon neutrality by 2050. Using the LEAP model, the study simulated different scenarios of electric vehicle (EV) and fuel cell (FC) adoption. Six scenarios, including a business-as-usual (BAU) scenario and a combined scenario integrating various policies, assessed the energy consumption and emissions associated with four major energy sources and pollutants. The results showed a significant decrease in total energy consumption in all scenarios, with the combined scenario achieving an emission reduction of up to 66% compared to the BAU scenario by 2050. The study highlighted the need for the transportation sector to reduce its emissions to 50 million tons by 2050 to meet Japan's GHG reduction targets, providing valuable insights for the development of future EV adoption policies and emission standards.

To our knowledge, this study is the first to exploit the LEAP model to simulate different energy transition and energy efficiency scenarios in the road transport sector in Tunisia. This methodological contribution constitutes a significant contribution to research on transport decarbonization, by providing a detailed assessment of road traffic emissions and the impacts of different mitigation strategies. The ultimate objective is to estimate these emissions and analyze how various measures can shape three distinct scenarios influencing their evolution. Given that transport policy reform is a key lever for reducing greenhouse gas emissions and combating climate change, this scenario analysis provides an essential theoretical framework to guide the design and implementation of effective and sustainable public policies in Tunisia.

4. METHODOLOGY

In order to address our problem, we adopted a two-step methodology: (1) Assessing and projecting the total future energy demand for each vehicle type and fuel consumed in the road transport sector, as well as the total emissions of the entire road fleet using the LEAP model; (2) Analysis of the environmental impacts of different energy transition and energy efficiency improvement scenarios in the road transport sector.

4.1. Road Transport in the LEAP Model

Long-range energy alternatives planning system (LEAP) is a software developed by Stockholm Environment Institute (SEI) that allows to compare several energy scenarios and to evaluate their environmental and economic impacts.

LEAP is configured with parameters based on the 2015 reference year organized in two main modules:

(1) Key assumptions module, where data of socio-economic variables are entered (GDP, Population and economic growth rate: a crisis situation, a catch-up situation and an acceleration situation)
(2) Demand module, where the final energy demand data of each subsector are entered with their corresponding branches. In this case, the vehicle classes with their particular technologies and the fuels consumed.

The hierarchical structure of the LEAP model applied to road transport (cargo + passengers) in Tunisia is grouped as follows:

Figure 2 shows that the road transport sector concerns the transport of cargo and passengers. Road passenger transport consists of 6 categories of vehicles: Private car, mixed car, individual taxi, administrative car, minibus and bus. Road cargo transport includes 4 categories of vehicles: Van, truck, road tractor and motorcycle. In addition, the figure shows that the vehicles used for passenger and cargo transport run on Gasoline, Diesel and LPG.

The statistical data come from the national survey on energy efficiency indicators in the road transport sector carried out by the National Institute of Statistics (NIS). These data were used in LEAP to establish all the scenarios while considering the year 2015 as a reference year. Table 3 describes the main variables for all the scenarios of the reference year 2015.

According to Rivera-González et al. (2020), energy consumption in the road transport sector for each vehicle class by fuel type is defined by:

$$EC = \sum TSV_i(t) \times VKT_i(t) \times FE_{ij}(t) \quad (1)$$

Or

- TSV is the total stock of vehicles of class i;
- VKT is the average annual vehicle kilometer traveled of the class i;
- FE is the average fuel economy of class i of the fuel type j (vehicle kilometer/liter) in years t.

Emissions forecasts were estimated by:

$$EC = \sum EC_j(t) \times EF_{jk}(t) \quad (2)$$

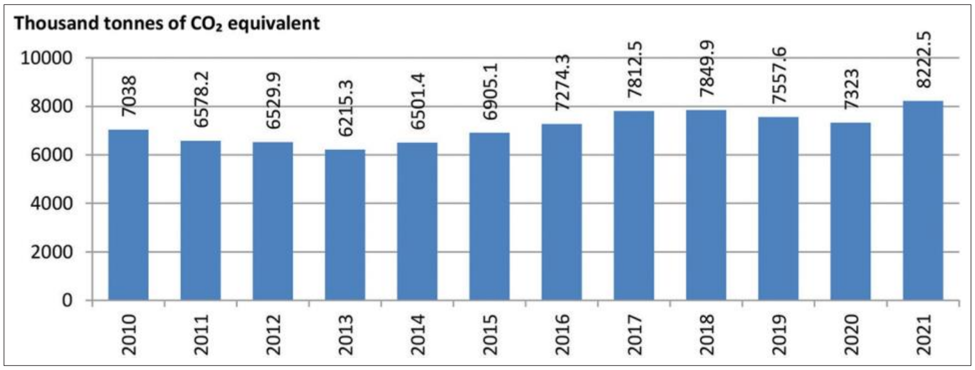
Or

- EC is the energy consumption of the fuel type j
- EF is the emission factor of pollutant type k under fuel type j in year *t*.

4.2. Presentation of Scenarios

Using the LEAP system, hierarchical relationships were established

Figure 1: GHG emissions from the road transport sector in Tunisia (from 2010 to 2021)



Source: (NAEC, 2021)

Figure 2: Structure of road transport in Tunisia in the LEAP model

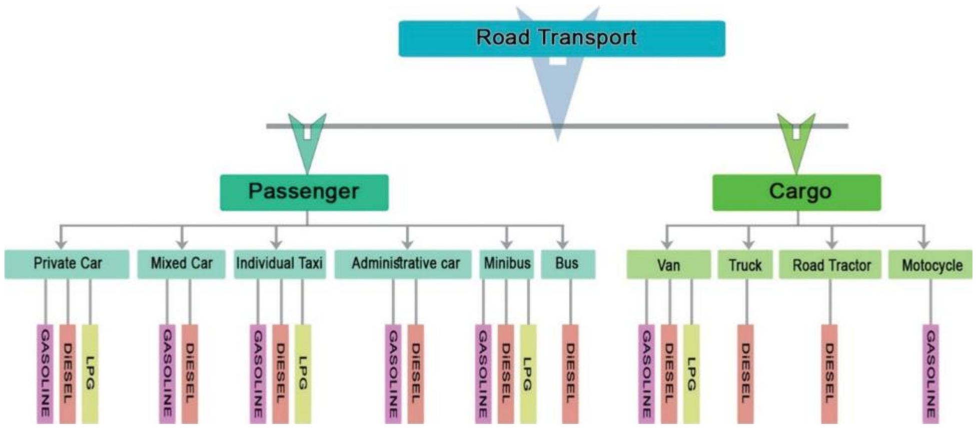


Figure 3: Design of scenarios in the LEAP model for the road transport sector in Tunisia

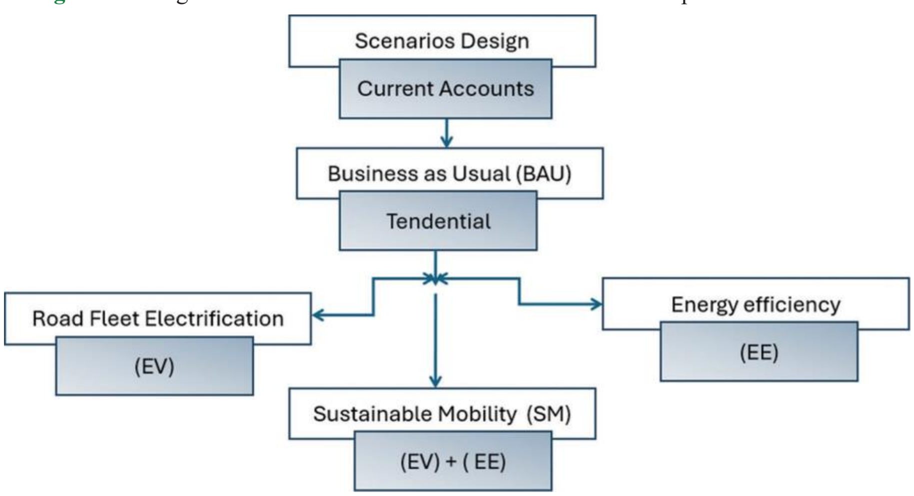


Table 3: Vehicle classes and fuel consumption in the road transport sector in Tunisia in 2015

Mode of transport	Passenger						Merchandise			
Category	Private car	Mixed car	Individual taxi	Administrative car	Minibus	Bus	Van	Truck	Road tractor	Motorcycle
Total VKm per year (million km/year)	14913.80	2540.05	1455.59	815.18	1367.52	688.07	10250.40	1098.78	1045.32	73.01
Total VKM per year (%)	68.47	11.66	6.68	3.74	6.28	3.16	82.22	8.81	8.38	0.59
Fuel consumption (%)										
Gasoline	73.41	0.51	30.79	70.52	0.63	-	1.19	-	-	-
Diesel	26.16	99.49	63.06	29.48	99.32	100.00	98.79	100.00	100.00	100.00
LPG	0.43	-	6.15	-	0.05	-	0.02	-	-	-

Figure 4: Projection of the number of vehicle-km traveled by road transport with the assumption of an increase of 5%/year

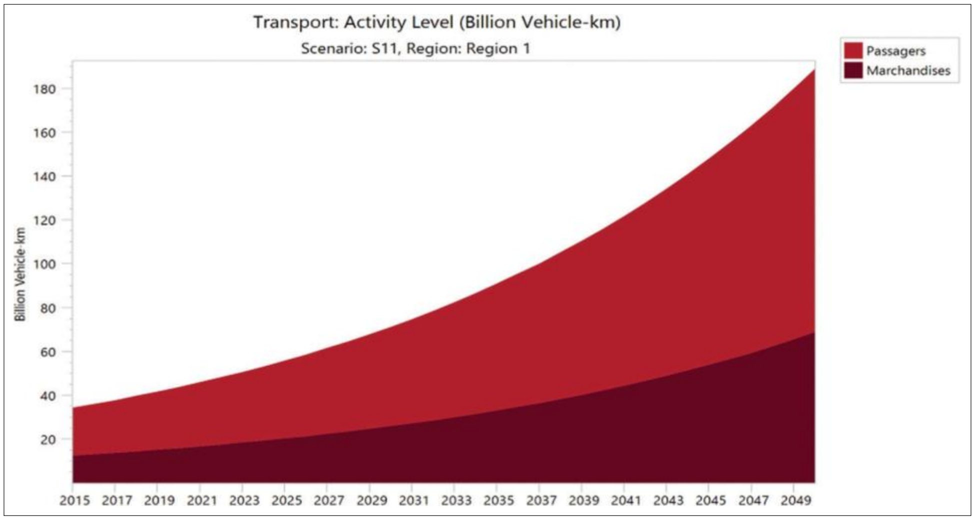
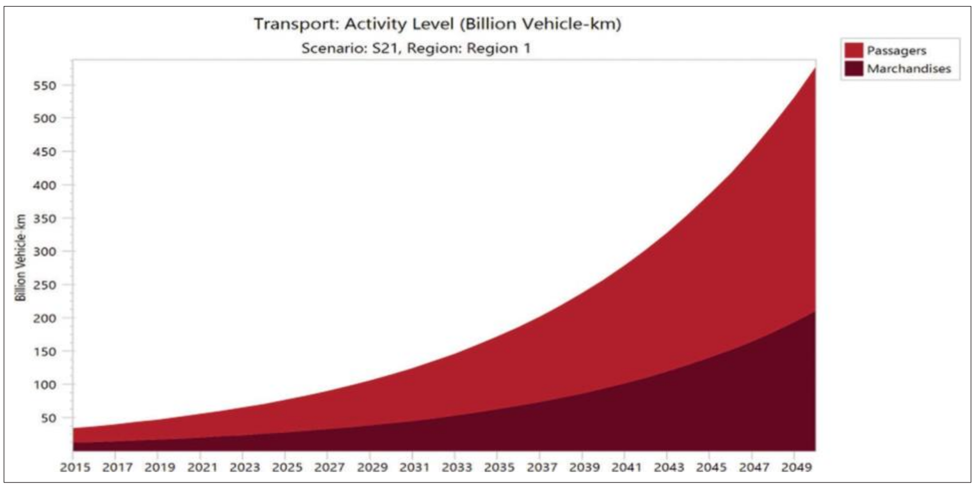


Figure 5: Projection of the number of vehicle-km traveled by road transport with the assumption of an increase of 8.4%/year



between the following four alternative scenarios between 2015 and 2050: Business As Usual (BAU), Fleet Electrification (EV), Energy Efficiency (EE) and Sustainable Mobility (SM) (Figure 3).

4.2.1. Business as usual (BAU) scenario

This scenario serves as a reference point for comparison with alternative scenarios and policy options. Our study used a respective growth rate of 5%, 8.4% and 13.5% (economic situation) of the number of vehicles for each class and type of fuel it consumes, which means that the number of vehicle-km travelled on the roads will also increase by 5%, 8.4% and 13.5%/year respectively.

According to the results, the number of vehicle-kilometers traveled is expected to increase significantly over time, from 34.2 trillion VKM in 2015 to 188.9 trillion VKM in 2050, as shown in Figure 4, assuming a 5% annual increase. Furthermore, assuming an 8.4% increase per year, we demonstrate that the number of vehicle-kilometers traveled by road transport is expected to reach 576.3 trillion VKM and 2,880.6 trillion VKM in 2050, respectively, as shown in Figures 5 and 6.

4.2.2. Road fleet electrification scenario (EV)

This scenario is based on Tunisia's national policy, which aims to implement ambitious programs for the electrification of uses, particularly transport, through a proactive policy for the distribution of electric vehicles, with a view to decarbonizing the sector.

The Tunisian government has put in place various incentives to encourage the adoption of electric vehicles (tax exemptions, purchase subsidies and the development of charging infrastructure). These measures aim to make electric cars more accessible and affordable for Tunisian citizens.

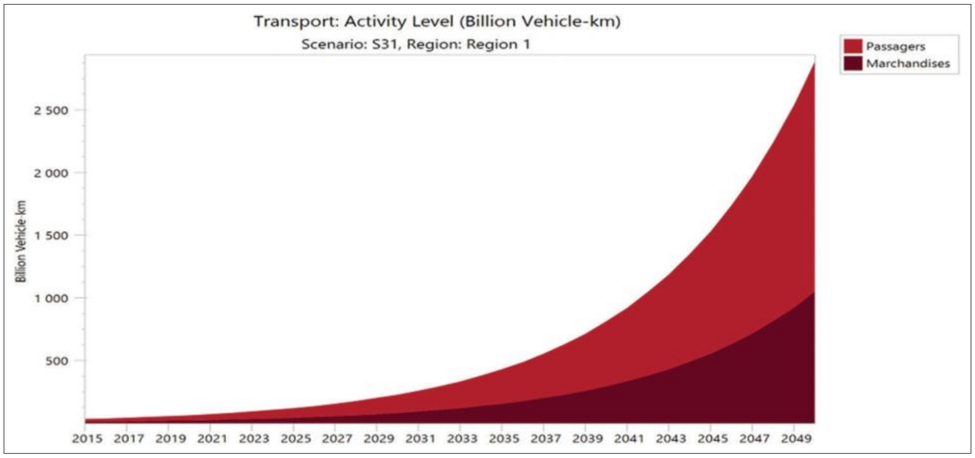
According to NAEC, Tunisia aims for 5,000 electric cars by 2025, and this figure should reach a number between 130 and 150 thousand electric cars in Tunisia by 2030.

4.2.3. Energy eficiency (EE) scenario

In this scenario, relevant studies and initiatives focused on energy efficiency have been implemented.

Transport represents 25% of the energy saving potential by 2030 thanks to these measures.

Figure 6: Projection of the number of vehicle-km traveled by road transport with the assumption of an increase of 13.5%/year



Among the most important initiatives that have been integrated:

- Promoting low-carbon urban mobility.
- Reform and improvement of public transport and the encouragement of economical driving.
- Carrying out energy audits and program contracts that have resulted in significant energy savings. Since 2010 and up to 2022, 47 energy audits and 145 program contracts have been signed in the transport sector with a total investment of 29 MDT and total energy savings of around 23.1 ktep.
- Use of suitable technologies and fuels to optimize vehicles.
- Updating urban travel plans for major cities.
- The use of new information and communication technologies (ICT) such as real-time vehicle tracking systems.

4.2.4. Sustainable mobility (SM) scenario

For the design of this scenario, all energy efficiency characteristics, as well as electric mobility scenarios were inherited via a hierarchical structure into the LEAP model.

5. RESULTS AND DISCUSSION

5.1. Forecasting Energy Demand

Figure 7 shows the evolution of energy demand in road transport for each scenario between 2015 and 2050. The differences in demand between the scenarios started to be visible from 2030. The most significant difference in demand is between the BAU (higher) and SM (smaller) scenarios, with a difference of 311 Million GJ, which would indicate a reduction in energy demand of 44.13% in 2050. Thus, the estimates show that over the entire analysis period, the average energy demand would be 520.8 Million GJ.

5.2. Fuel Demand Projections

The fuel demand forecast for each scenario shows that the BAU maintains its trend and there is no significant change compared to the historical behavior (Figure 8). In this scenario, gasoline keeps a constant contribution of 70.56% between 2015 and 2050. In the case of diesel, its contribution is around 28.97% for the period 2015-2050. For LPG demand, its overall contribution is barely 0.46%. It is therefore indisputable that diesel and gasoline remain the main energy sources, concentrating 99.54% of the total in 2050.

Figure 7: Forecast of total energy demand of road transport for each scenario from 2015 to 2050

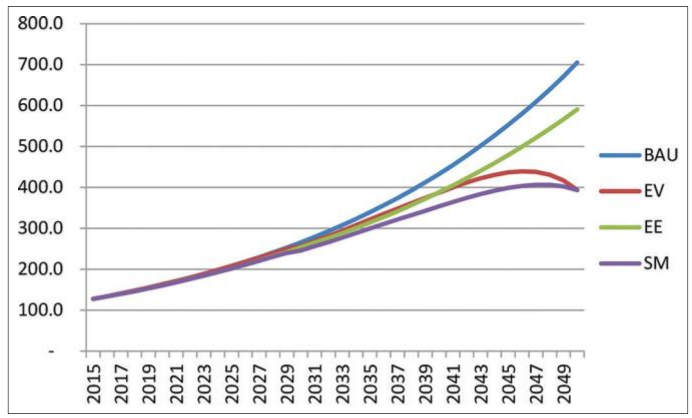
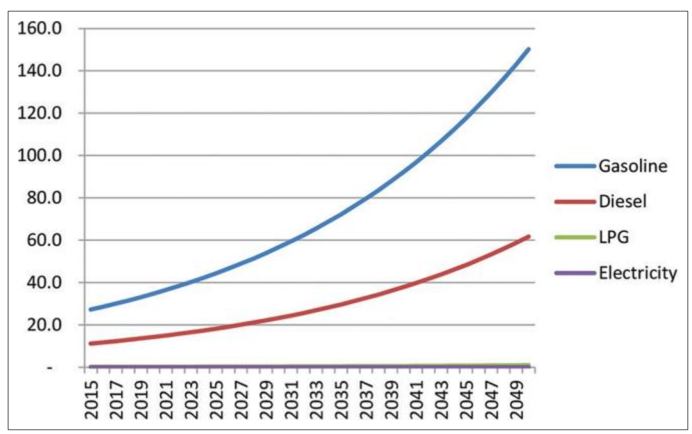


Figure 8: Fuel demand by energy source in the BAU scenario from 2015 to 2050



In the EV scenario, electricity demand increases significantly, especially from 2024 (Figure 9). This increase seems consistent with the transition to electric transport in Tunisia. This growth in electricity demand is correlated with an inverse trend observed in the demand for fossil fuels (diesel, gasoline, LPG) towards the end of the analysis period.

In the EE scenario, the energy demand percentages are very similar to those in the BAU scenario. Gasoline has a contribution

Figure 9: Fuel demand by energy source in the EV scenario from 2015 to 2050

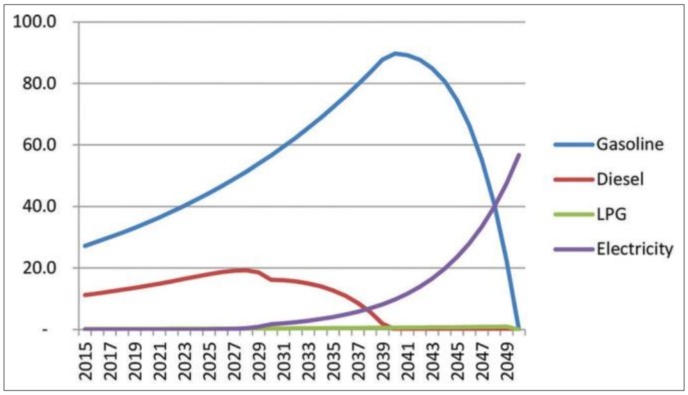
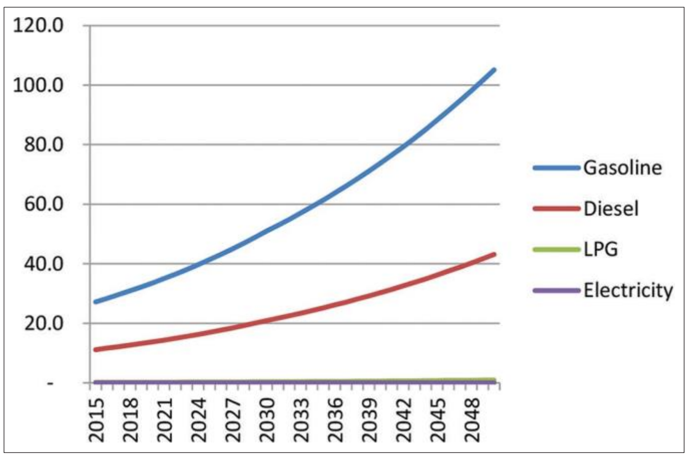


Figure 10: Fuel demand by energy source in the EE scenario from 2015 to 2050



of 70.56% and diesel of 28.92% by 2050. However, between 2015 and 2050, the total demand for gasoline and diesel for EE/BAU decreases by 471.9 and 193 million GJ, respectively (Figure 10). The total fuel demand decreases by 665.6 million GJ. This very significant result confirms that through the application of energy efficiency policies, a considerable saving in energy demand could be guaranteed.

In the SM scenario, the most significant changes in terms of energy demand are observed compared to the other scenarios (Figure 11). The cumulative total demand for gasoline shows a decrease of 919 Million GJ (35.3%) and, in the case of diesel, a decrease of 748.7 Million GJ (69.9%) compared to the BAU. These values are examples of significant energy savings for Tunisia (faster adoption of electric vehicles, substantial improvement in energy efficiency, accelerated transition to renewable energy sources). The most relevant result is that the total energy demand decreases by 35.8% compared to the BAU scenario.

5.3. Emissions Forecasting

GHG emissions estimates are measured in CO_2 equivalent (CO_2e) units, which are presented for all scenarios in Figure 12.

Figure 11: Fuel demand by energy source in the SM scenario from 2015 to 2050

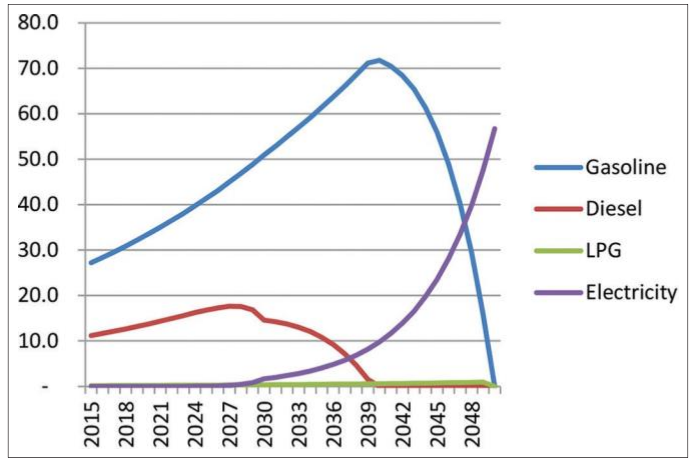
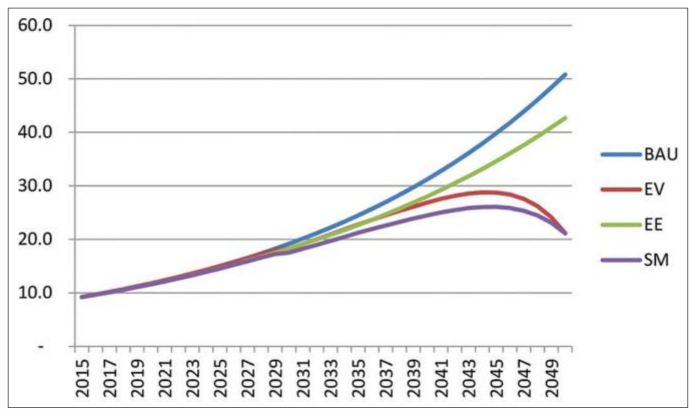


Figure 12: Cumulative GHG emissions for each scenario from 2015 to 2050



5.3.1. EV/BAU scenario

Accumulated GHG emissions decreased by 18.8% between 2015 and 2050, representing a reduction of 166.3 Mt CO_2e (million tonnes) due to the decline in demand for diesel and gasoline and the gradual electrification of the road fleet. The electrification rate of end uses is a fundamental characteristic of low-carbon scenarios, provided that the electricity mix is predominantly renewable. Tunisia should therefore strongly promote the electrification of uses, in particular through the transition to electric transport.

5.3.2. EE/BAU scenario

The reduction in GHG emissions started to be visible from 2030, i.e. a reduction of 16.3% in 2050. Technological innovations and more efficient consumption practices could be key factors in this reduction.

5.3.3. SM/BAU scenario

The most significant reductions in CO_2 emissions, i.e. 23.6% between 2015 and 2050. The electrification of the vehicle fleet and the improvement of energy efficiency could play important roles in reducing CO_2 emissions from road transport in Tunisia.

6. CONCLUSION

The objective of this paper is to determine the best path towards sustainable road transport in Tunisia by assessing the relationship between road traffic, energy and the environment. The quantified results, analyzed via the LEAP model over the period 2015-2050, shed light on this path by comparing different energy transition scenarios. The study demonstrates that the electrification of end uses, particularly in transport, is a pillar of low-carbon scenarios, provided that the electricity mix is strongly based on renewable energies. Tunisia should therefore actively promote the electrification of transport, alongside a significant improvement in energy efficiency, to achieve its environmental commitments. Comparative analysis of the scenarios highlights the importance of an integrated approach, combining the transition to electric vehicles and the optimization of energy consumption.

Beyond the environmental aspects, an assessment of the macroeconomic impacts of these scenarios, for example via the KLEM model, would allow to refine strategies and ensure a sustainable and beneficial transition for the Tunisian economy. Such a broader analysis would consider the effects on growth, employment, and competitiveness, thus allowing for a fairer and more inclusive transition.

As this study focuses on road transport, future research could extend the analysis to other modes of transport, such as air and maritime transport, also using the LEAP model. The tool could also be applied to other industrial sectors to forecast emissions for the country. This more comprehensive approach would improve understanding of emissions forecasts and help Tunisia to strategically allocate its resources and investments, setting realistic and achievable emissions reduction targets. Such a global and sectoral vision would provide a more robust framework for planning the country's energy transition and sustainable development.

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