Replacement of Vehicle Fleet with EVs Using PV Energy

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1. Introduction

Electric vehicles is both a development opportunity and a challenge. An extensive use of electric cars can reduce consumption of imported and national oil, the availability of which tends to decrease in next decades, with the consequent increase in the cost [1]. Differently, the production of green energy shows a growing trend, and also its cost is decreasing, but different new aspects have to be faced such the one related to the simultaneous request for refuel electric cars, which mainly takes place by connecting to the low voltage grid. An excessive demand could lead to power peaks, for which the low voltage grid is not equipped in the size of cables and transformers [2]. An interesting concept of charging stations for electric cars with minimal impact on the supply network has been traced in [3] and in [4] different charging strategies and demand response management have been investigated. Policies adopted by various governments can help overcome technical problems, unlocking funds and benefits, such in the Norway case, where the decision to reduce the impact of emissions of fossil fuels has led to surprising results [5-7].

In order to support the possibility of a wiser use of vehicle fleets, an analysis of the ability to limit the consumption of fossil fuels in favour of the use of electric vehicles to reduce medical expenses incurred in Italy, it was initially traced in [8].

This study want to present a more complete research of the impact, in terms of vehicle fleet fueled with different sources, for example gasoline, LPG, methane or diesel and the possibility to replace these vehicles with electric vehicles. This is possible using the energy production of renewable resources and in particular, the attention is on photovoltaic systems. Starting from data collected, the following analysis proposes a study of the feasibility between the vehicles replacement not green with green vehicle using renewable energy with different percentages.

The paper presents a description of the diffusion of renewable energy (Section 2) and the fleet vehicles classified with different fuel supply (Section 3) in Italy. The case of study with the data collection used for this analysis and the variables used are described in the Section 4. Section 5 presents the analysis of results for all Regions and finally conclusive remarks.

2. Diffusion of Renewable Energy in Italy

These recent years have been characterized by significant growth in renewables. This trend is justified by the high public incentives. In 2014, systems powered by renewable sources in Italy reached 656,213 units with a total installed capacity to 50,595 MW. Compared to 2014, the installed capacity grew by 1.5% over the previous year [9].

This growth is mainly due to systems powered by geothermal plant (+6.2% in installed capacity over the 2014), to new wind farms (+1.7% in installed capacity over the 2014) and to photovoltaic systems (2.3% in installed capacity over the 2014), bio-energy (+0.3% in installed capacity over the 2014) and hydroelectric plant (+0.3% in installed capacity over the 2014). During the decade from 2004 to 2014, the installed capacity of systems using renewable sources increased from 20,220 MW to 50,595 MW. In Italy, the renewable energy is mainly characterized by systems exploiting the hydro source, whose installed capacity has remained constant in recent years (+0.3% annual average). If in the past, the capacity of hydropower systems accounted for 90% of the installed capacity from renewable sources, now it accounts for only 35%, due to the exponential growth of solar, bioenergy and wind power. At the regional level, Lombardy is the first region in Italy in terms of installed capacity with 8,049 MW and 95,353 units, followed by Puglia with 5,219 MW and 42,155 units and Piedmont with 4,541 MW and 46,878 units. Since 2007, production from renewable sources has each year set new records. In 2014, it reached a new record level of 120,678 GWh. Hydropower has represented the source that provided the greatest contribution to the production of electricity that with 58,545 GWh it accounted for 48% of the total production from renewable sources. In recent years the importance of solar, wind and bioenergy has increased, so that in 2014 represent the 52% of national electricity production from renewable sources. Figures 1-5 show the evolution of wind, solar, geothermal, biomass and hydroelectric sources from 2007 to 2014.

Wind systems in Italy at the end of 2014 have amounted to 1,847 with a total installed capacity of 8,703 MW and they are shown in Fig.1. Due to the environmental and territorial characteristics of our country, 95% of the installed capacity in Italy and 80% of systems are situated in the Regions of Southern Italy, where the wind conditions, topography and site accessibility are favourable for the installation of wind farms. The region with the highest installed capacity is Puglia (2,339 MW and 572 units), followed by Sicily and Campania, respectively, with an installed capacity of 1,747 MW and 191 units and 1,251 MW and 221 units.

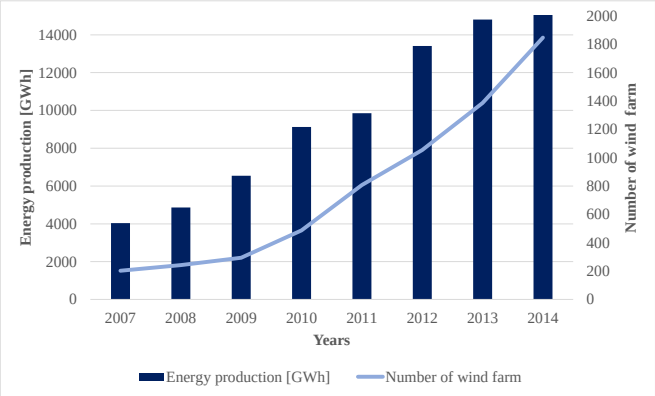


Fig. 1. Energy production and number plants for wind farm in Italy.

The percentage distribution of PV plants in Italy has shown a higher concentration of installations in the North about 54%, the Centre has installed about 17% in the south the remaining 29%. Nevertheless, if many small size power plants characterize the North Italy, in the South Italy is characterized by high power systems installations. In 2014, photovoltaic systems in Italy are 648,418 photovoltaic installations in Italy with an installed capacity of 18,609 MW (Fig.2). The region with the highest number of systems is Lombardy with 94,202 systems with an installed capacity of 2,067 MW, followed by Veneto with 87,794 with an installed capacity of 1,715 MW and Apulia with 41,527 systems with an installed capacity of 2,586 MW [10, 11].

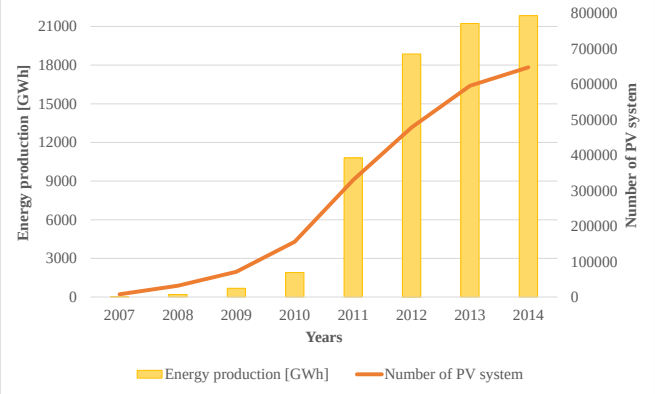


Fig. 2. Energy production and number plants for PV systems in Italy.

Geothermal systems in Italy at the end of 2014 have amounted to 34 with a total installed capacity of 821 MW and they are shown in Fig.3. The systems are concentrated in one region, Tuscany. As regards electricity production, in 2014, 5.916 GWh are produced.

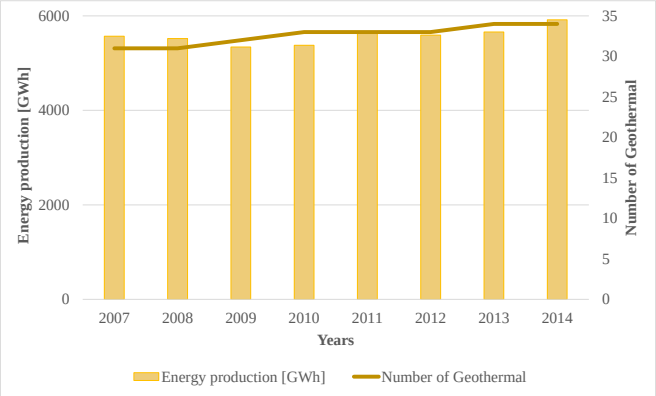


Fig. 3. Energy production and number plants for geothermal systems in Italy.

When it comes to bioenergy, it means energy produced from biomasses, biogases and bioliquid excluding municipal solid waste. The number of systems using bioenergy in Italy at the end of 2014 amounted to 2,482 with an installed capacity of 4,044 MW (Fig.4). The 75% of systems are situated in northern Italy and, in particular, Lombardy is the region with the highest number of systems equal to 95,353, followed by Veneto with 88,483 units and Central Italy accounts with 113,062 units, while southern Italy with 187,935 units.

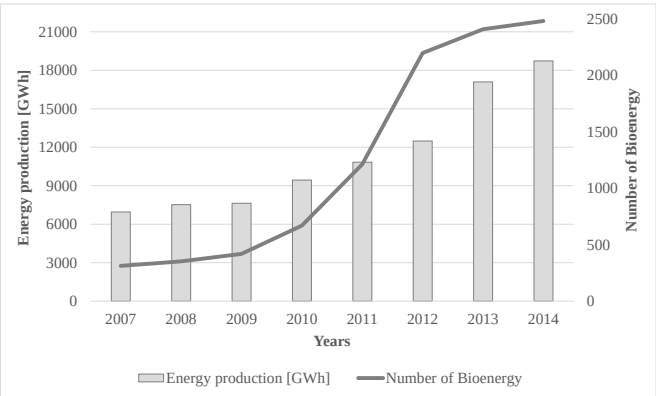


Fig. 4. Energy production and number plants for Bioenergy in Italy.

Hydropower systems in Italy at the end of 2014 have amounted to 3,432 with a total installed capacity of 18,418 MW. Despite the limited growth of hydropower, in 2014 the installed capacity of hydropower has accounted for 40% of the entire installed base of renewable systems. At the regional level, 80% of hydropower systems are installed in northern Italy. In particular, in Piedmont (709 systems), Trentino Alto Adige (703) and Lombardy (487).

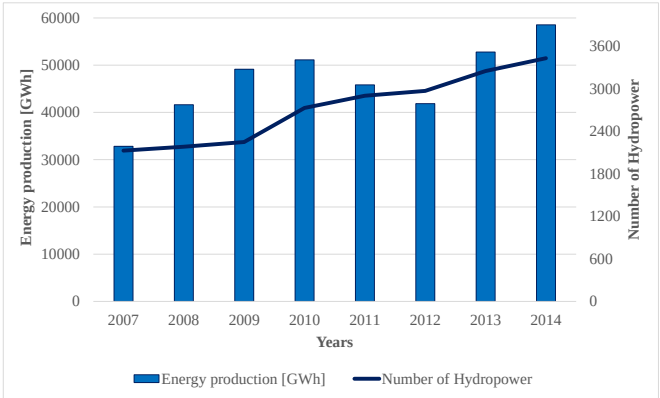


Fig. 5. Energy production and number plants for Hydroelectric power in Italy.

3. Classification of Vehicle Fleet in Italy

In general, the transportation of all types including trucks, buses, motorcycle and cars is a major contributor to air pollution in most nations. Different typologies fuel supply are presented in Italy, for example gasoline, diesel, LPG and methane. In these last years, there is a diffusion of new vehicles and in particular Plug-in Hybrid vehicles to finish with the electric vehicles [12]. Figure 6 shows the evolution of vehicle fleet in Italy in different years. It is possible to observe that 51% of the vehicle fleet is for fuel supply is to gasoline, 41% is to diesel and 2% is methane, 6% LPG and 0.2% Hybrid/EVs.

Since the rate of diffusion of green vehicles is very low, in this study, the attention is focused on this aspect, particularly it want to see how with some percentage of renewable sources it is possible to replace the most polluting vehicles on the road.

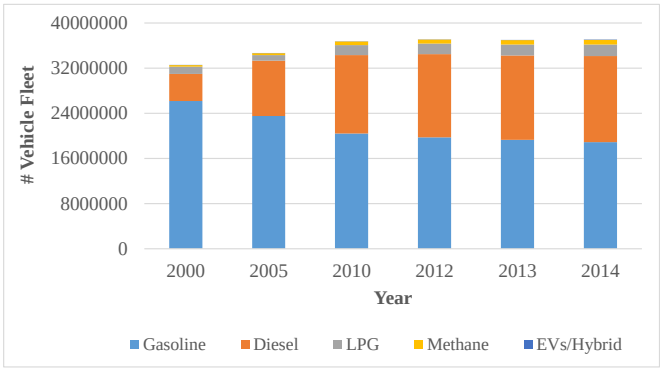


Fig. 6. Classification of Vehicle Fleet in Italy in different years.

4. Case of Study and Data Collected

The data collected for all Italian Regions, in particular the energy production obtained with photovoltaic systems, the different classification for fuel supply of the vehicle fleet have been processed in order to find the feasibility of the integration of electric vehicles with PV systems and to analyse the possible consequences of the replacement of

traditional vehicles with electric ones considering different scenarios. For this region, some variables have been considered:

- $E_{PV\ Regions}$ [GWh]: Energy production obtained to PV system in a specific region of Italy;
- E_{EVs} [kWh]: energy required for recharge the Electric Vehicles.

It is important to consider some information for the EVs, in particular: battery capacity (24 kWh), Depth Of Discharge (60% before a recharge), efficiency of the charging system (η is equal to 85%) and consumption of an electric vehicle (C_{ave} is equal to 0.213 kWh/km). In this case, this last value is the average obtained to different typologies of electric vehicle where the consumption varies according to the type of vehicle (small, middle and large size).

Another aspect considered in this study it is the different classification for fuel supply of the vehicle fleet, in particular:

- V_G: number of vehicles fueled to gasoline (G) for the transport in Italy;
- V_D: number of vehicles fueled to diesel (D) for the transport in Regions of Italy;
- V_{LPG}: number of vehicles that use liquefied petroleum gas (LPG) for the transport in Italy;
- V_M: number of vehicles fueled with methane (M) for the transport in Regions of Italy.

In this survey, different scenarios for the distance travelled per day are assumed:

- *Scenario 1*: distance travelled for Urban Use per day, it is equal to 12 km;
- *Scenario 2*: distance travelled for Travel Salesman per day, it is equal to 60 km;
- *Scenario 3*: distance travelled for Commuters per day, it is equal to 120 km

According to the computed average distance, it is possible to evaluate the energy required by the electric vehicles in the considered scenarios. In this mode, the energy required of EVs (E_{EVs}) on an annual basis can be determined as eq.1:

$$E_{EVs} = \left(D_{Scenario} \cdot C_{ave}\right) / \eta \qquad (1)$$

where $D_{Scenario}$ is based on the scenarios (1, 2 and 3) described above and it can assume values as 12 km, 60 km and 120 km.

After that, it is possible to calculate the number of electric vehicle ($N_{EV\_Regions}$) using the energy production obtained to photovoltaic systems obtained from different Regions ($E_{PV\_Regions}$) determined with eq.2:

$$N_{EV\_Regions} = E_{PV\_Regions} / E_{EV} \qquad (2)$$

Given that renewable energy is used for different purposes (for example residential uses, industrial uses, etc.), for this reason, different percentages (5-100% with a step of 5) have been suggested in order to be used for the recharge of electric vehicles.

4.1. Description of the charging system

The charging system analyzed in this work is composed of charge point to fuel electrical vehicles that can be supplied, in this case only Renewable Energy Sources (RES) and in particular using photovoltaic systems installed. This choice has been done not considered the energy obtained to electric grid (Fig. 7). In this mode, the vehicle is totally green and not generate pollution.

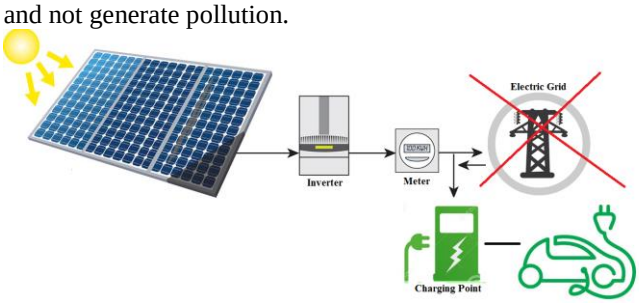


Fig. 7. Diagram of the charging system.

5. Analysis of Results

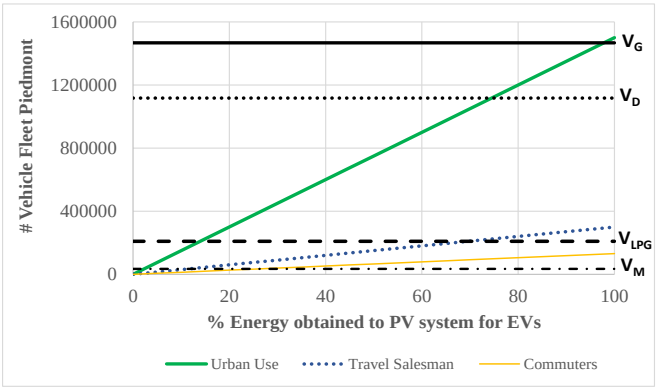
In this section it has been analysed the number of electric vehicles that can be recharged with the energy produced by PV systems distributed in different Italian Regions using different percentage. In this case, to understand which the best percentage of renewable energy is needed to replace the current vehicle fleet with electric vehicles. Italy is subdivided into 20 Regions, of which eight are in Northern Italy (Aosta Valley, Piedmont, Liguria, Lombardy, Emilia-Romagna, Veneto, Friuli-Venezia Giulia, Trentino Alto-Adige), four (Lazio, Marche, Tuscany and Umbria) are in Central Italy, six are in South Italy (Abruzzo, Apulia, Basilicata, Calabria, Campania and Molise) and finally two are Insular Italy (Sardinia and Sicily), all Regions with different characteristics.

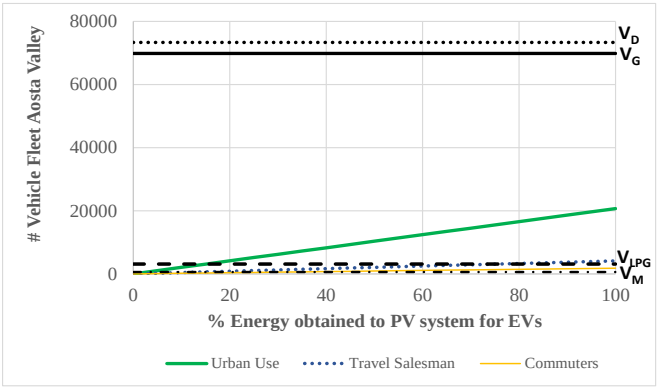
Figure 8 shows details for Regions in Northern Italy, in particular the total number of cars with different fuel supply and the number of green vehicles obtained using energy of PV systems in different scenarios (1, 2 and 3) with different percentage.

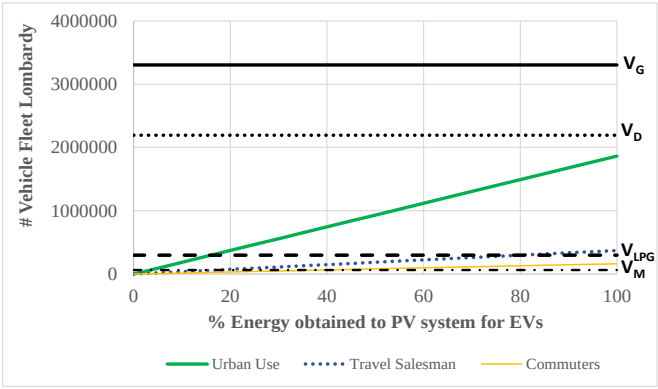
In particular, for the Figs. 8 - 11, the different horizontal lines represent the number of vehicles that they change for Regions, according to fuel supply. In fact, for all lines there is a specific reference, for example V_G are total vehicles in a specific Regions fueled with gasoline. The other lines are respectively the number of electric vehicles which may be substituted with the vehicles not green in different scenarios using different percentage of green energy.

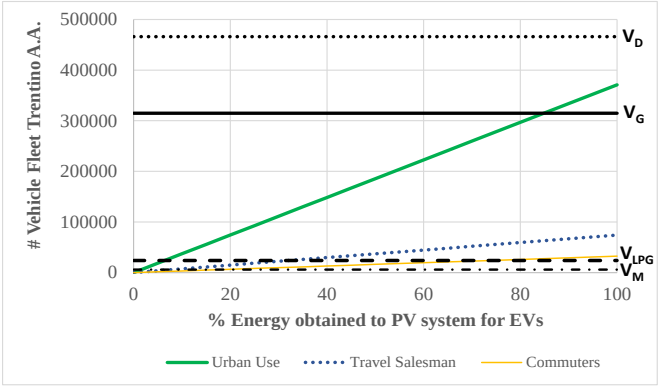
Lombardy, Aosta Valley and Liguria have not the energy sufficiently to replace the vehicles fleet fueled with gasoline

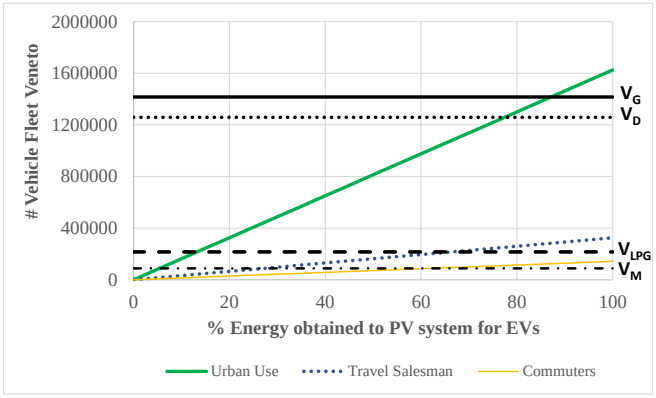
and diesel. In a range from 65% to 100% for the scenario 1, it is possible to do this change for other Regions in North Italy.

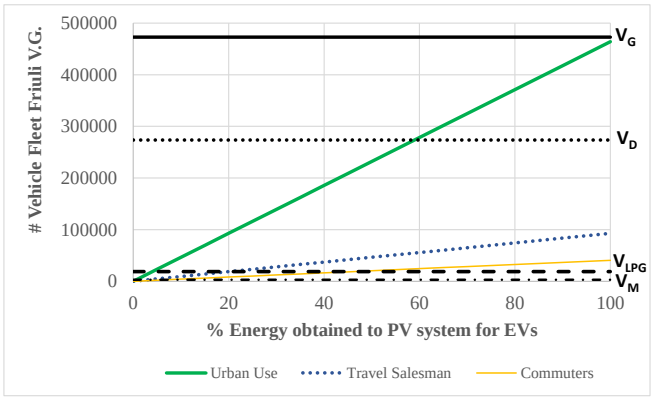


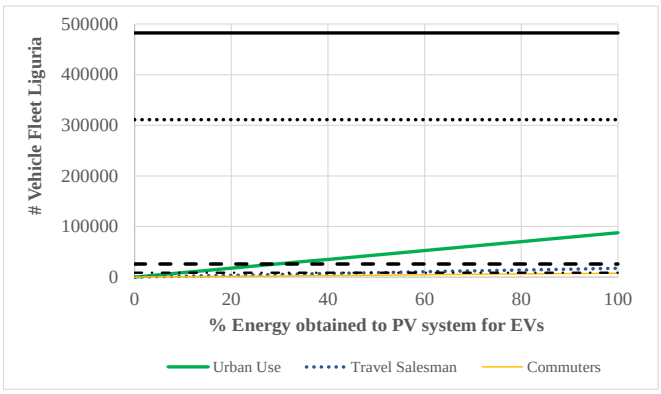












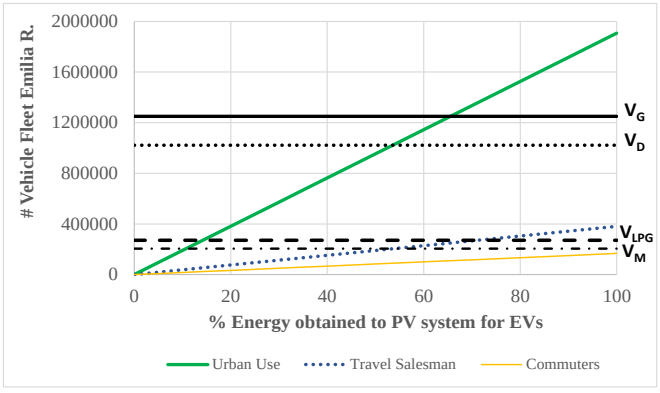


Fig. 8. Northern Italy indicating vehicle Fleet recharged by PV systems.

Figure 9 shows details for regions in Central Italy. The critical situation is for Tuscany and Lazio Regions because the energy production do not permit to replace the vehicles fueled with diesel and gasoline. In this case, for the scenario 3 (Commuters) there is not the percentage sufficient to

replace the vehicle fleet. Only for scenario 1 (Urbane Use) using respectively 10% and 15% of the energy it is possible to replace the vehicles fueled GPL and methane with the electric vehicle. While for scenario 2 (Travelled Salesman) using, in one case 45% of energy and another case using 75% it is possible to respectively to replace the vehicles fueled with methane and to replace the vehicles fueled with GPL.

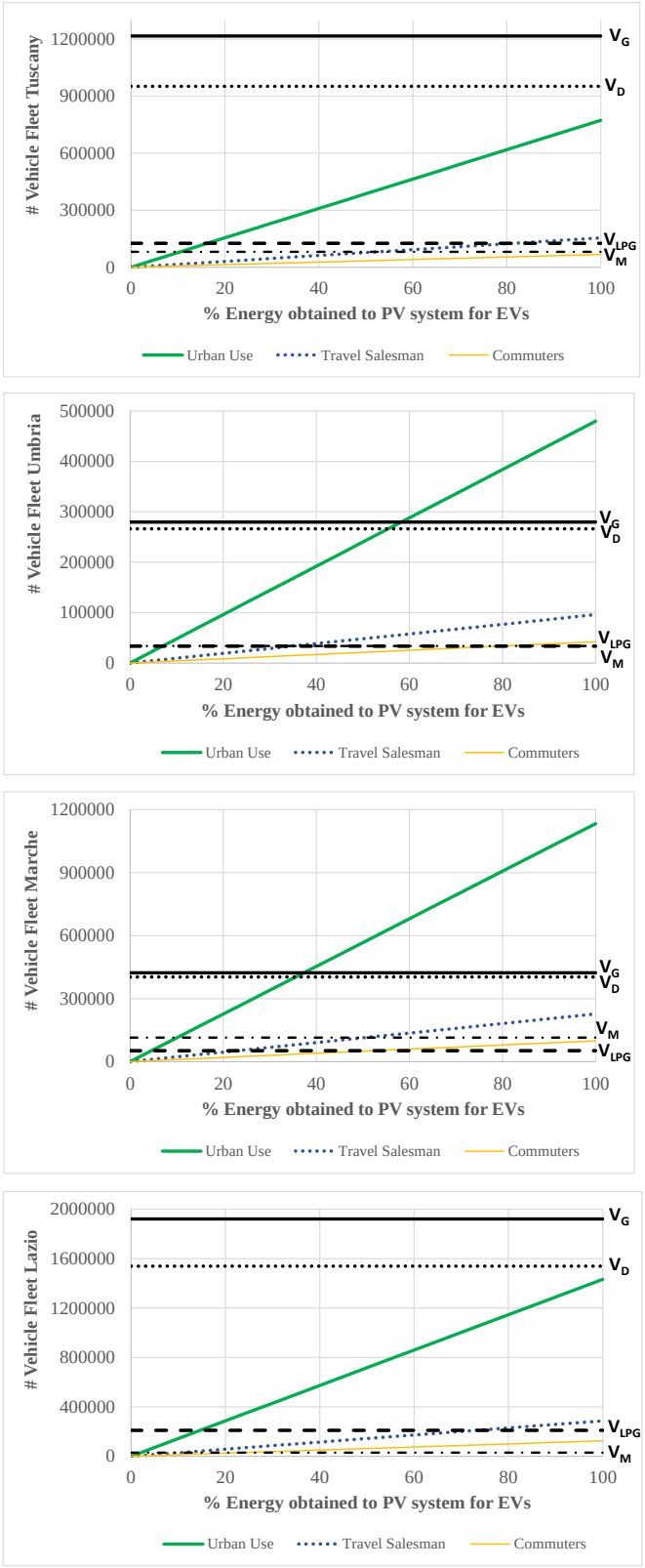
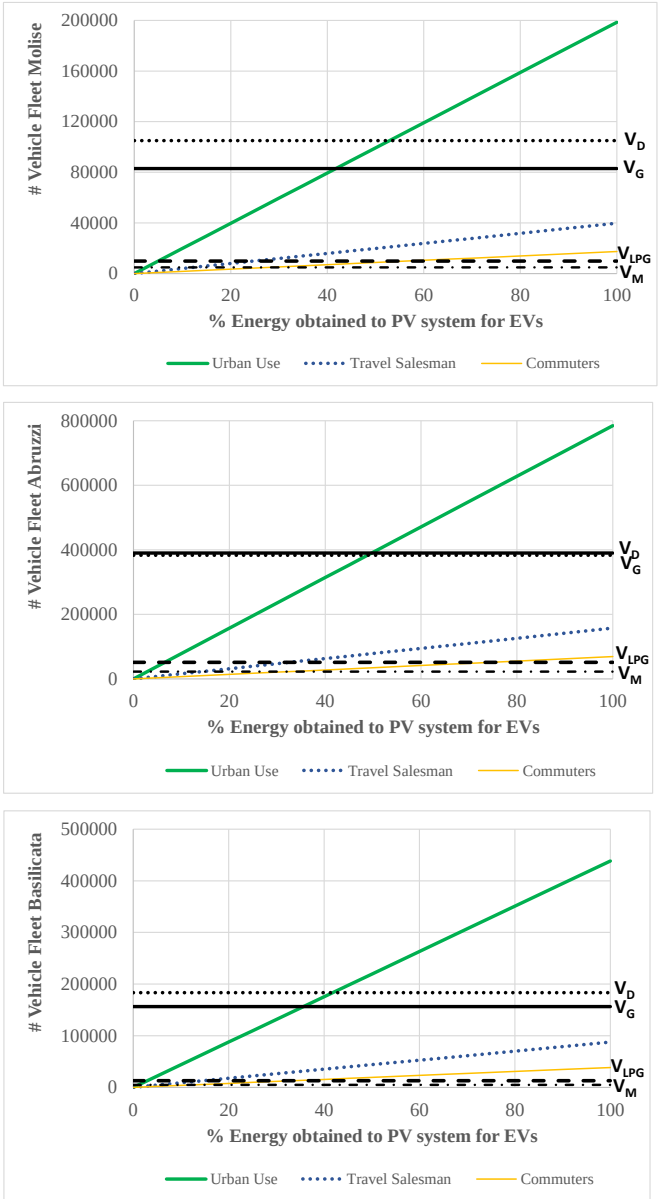


Fig. 9. Central Italy indicating vehicle Fleet recharged by PV systems.

Figure 10 shows details for regions in South Italy. The critical situation is for Campania. In this region, there are many vehicles and in fact, for the vehicles fueled with gasoline and diesel for the different scenarios there is not sufficiently energy to replace with green vehicles. Calabria has not energy for replace the vehicle with gasoline while using 98% the energy it is possible to change the vehicle fueled with diesel. The situation is different for Abruzzi, Molise, Basilicata and Apulia. In these Regions, in a range from 30% to 50% for scenario 1 it is possible to change the vehicles fueled with gasoline and diesel with EVs.



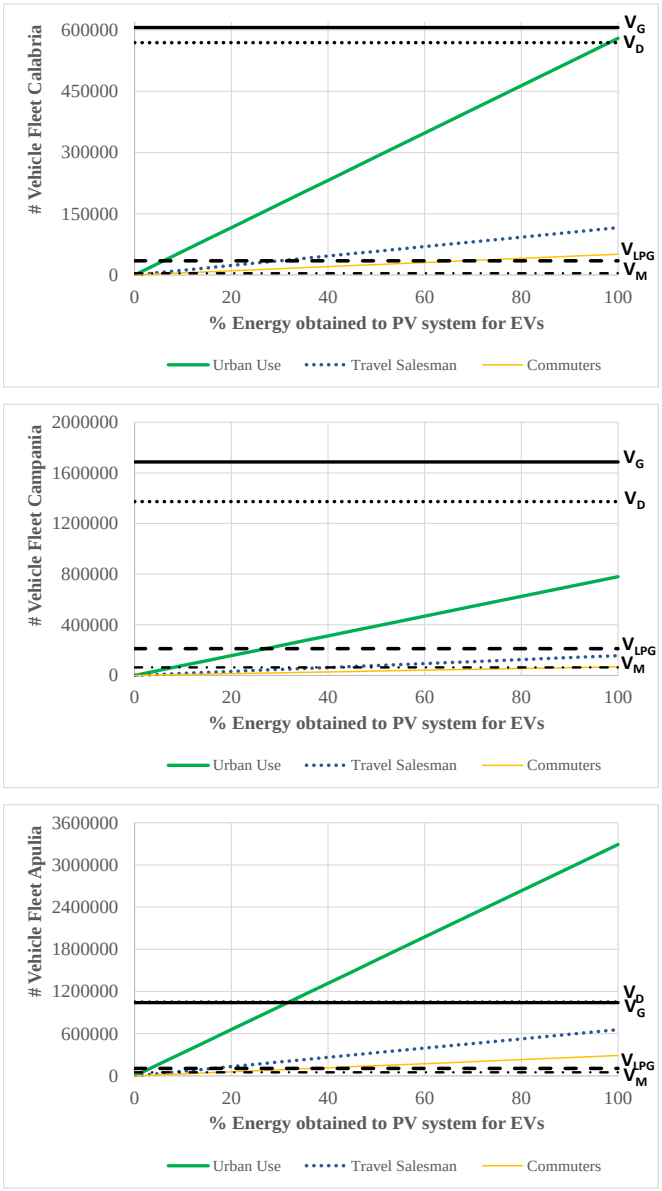


Fig. 10. South Italy indicating vehicle Fleet recharged by PV systems.

Figure 11 shows details for Regions in Insular Italy, in particular Sicily and Sardinia. In this case, it is possible to observe that for Sicily and Sardinia using 20% of the energy production obtained to PV system, the vehicles fueled with LPG and methane it is possible to replace them with electric vehicle for the scenario 2 and 3.

The situation is different for the scenario 1, in the case of Sicily region using the 75% of the energy, it is sufficient to replace the vehicles fueled by diesel while it is not possible to replace the vehicles fueled with gasoline. The situation is different for Sardinia where using 45% of the energy it is possible to replace the vehicle fueled by diesel and using 65% of the energy is possible to replace the vehicle fueled by gasoline.

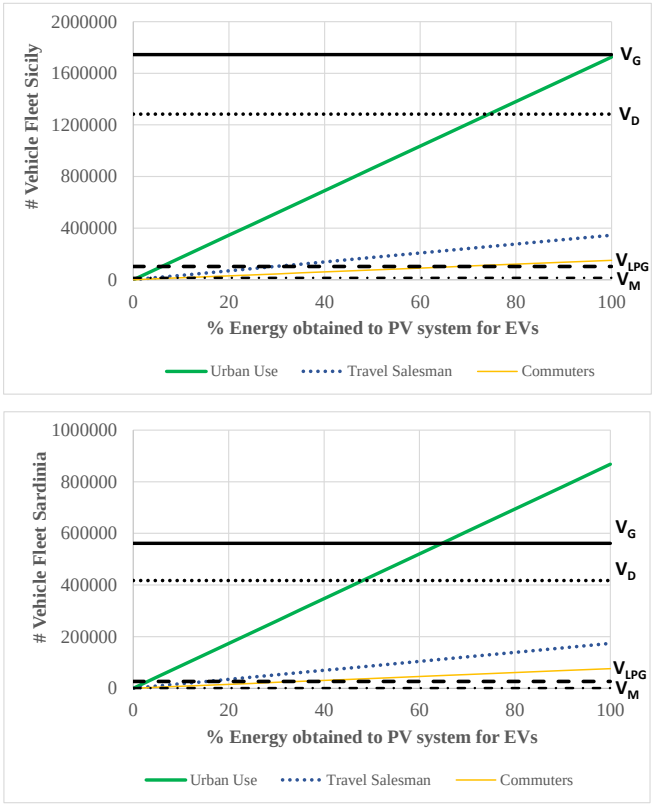


Fig. 11. Insular Italy indicating vehicle Fleet recharged by PV systems.

6. Conclusion

The scope of this paper is to understand if the energy production obtained to renewable sources is sufficient to recharge of electric vehicles. The analysed period considers 2014 year. The study has been carried out for the 20 Italian Regions. For each region, they are been collected data regarding the vehicular fleet with different fuel supply (Gasoline (G), Diesel (D), Liquefied Petroleum Gas (LPG) and Methane (M)) and energy obtained to renewable sources and in particular photovoltaic systems.

The choice to consider only the energy obtained to photovoltaic systems derives because in all Regions this source is widely distributed, a concept that does not apply to wind farm, biomass, hydropower or geothermal. Moreover, the use of photovoltaic systems are not used only for recharging electric vehicles but in general, they can be used for another uses, for example to domestic use, industrial use, etc., and then for this reason it has been considered different percentages for the use of this renewable energy. Three scenarios (Urban Uses (Scenario 1), Travel Salesman (Scenario 2) and Commons (Scenario 3)) based on the habits of citizens depending on how many kilometres run through the year have been analysed.

The obtained results show that in general, it is possible to replace the actual vehicle fleet using not all energy obtained to PV systems to recharge electric vehicles. Only scenario 1, where the number of kilometres is low respect other scenarios permits to replace the total vehicle fleet fueled with gasoline or diesel. Obviously, this thing does not

possible in some Regions, for example Lombardy, Aosta Valley, Lazio, Tuscany, Liguria. All scenarios permit to replace the vehicle fueled with LPG and methane using low percentage of energy. This change permits to reduce the pollution that today is the critical aspects.

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