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"Team Play" between Renewable Energy Sources and Vehicle Fleet to Decrease Air Pollution

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Abstract: The reduction of air pollutants for the purpose of maintaining or improving air quality across the globe is a fundamental concern to which all modern governments are allocating varying amounts of attention and resources. The successful amelioration of air pollution requires strategic investments in the commercialization and adoption of "clean energy technologies" by both private and public entities, the conversion of contemporary houses to "smart houses", the diffusion of Renewable Energy Sources (RES) including photovoltaic systems (PV), wind farms, and different forms of bioenergy, and the integration of electric-powered vehicles. In concert with these ideas, this paper aims to discuss the possibility of undertaking a feasibility study in two countries Canada and Italy concerning the integration of electric vehicles (EVs) and electric motorcycles (EMs). The proposed feasibility study would seek to assess the prospect of replacing the current vehicle fleets in these two countries with EVs in a manner that utilizes renewable energy sources and, thus, does not generate new toxic emissions. In conclusion, this study demonstrated that a pronounced introduction and distribution of RES, EVs, and EMs can operate as a great opportunity for both the environment and the capacities and needs of energy production. Today, the EV is not widespread. With this contribution, it is shown how EVs can be well integrated with renewable energy. Therefore, it is the duty of governments to implement policy strategies, in order to spread them across more territory.

Keywords: electric vehicles (EV); renewable energy resources (RES); vehicle fleet; environmental; emissions

1. Introduction

Air pollution is a major environmental risk to health. A substantial proportion of the world's population live in cities [1,2], where exceedances of air quality standards occur [3–6]. The most important greenhouse gases (GHGs) directly emitted by human activities include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several other fluorine-containing halogenated substances. The primary source of carbon dioxide is from the combustion of fossil fuels for the purposes of energy production. Carbon emissions from power plants for electricity generation represent about 40% of total GHG emissions worldwide, and are among the largest and highest-increasing sources. According to a study performed by the IEA, the emissions from coal power plants have substantively increased from 66% to 72% during the period 1990–2011. It is forecasted that this trend will continue rising and will result in 2040 to the greatest share of CO_2 emissions. Changing this path down is then a key major universal challenge. In Canada, 79% of electricity is generated from non-GHG-emitting sources for e.g., renewables, hydro, and nuclear, representing one of the highest percentages in the world, ranking Canada a worldwide leader in clean electricity. The high level of clean energy production in Canada indicates that emissions from power plants for electricity generation are a relatively small part of total emissions, accounting for only 12% in 2014. Compared to the U.S. and China, non-GHG-emitting sources provide less than one third and one fifth, respectively [7,8]. The environmental problems related to the use of fossil fuels in transport, such as greenhouse gas emissions and air pollution is severe. In the EU, including Italy, transport accounts for about 20% of total GHG emissions which were continuously increasing over the last decades [9,10]. Emissions from transport in general, comprising passenger, freight, and off-road emissions were the second major contributor to Canada's GHG emissions in 2012, accounting for 24% of total GHGs [6].

These emissions problems are the major motivation for the growing interest in electrification of mobility. In recent years, there have been important efforts to study the effects of strategies to reduce on-road traffic emissions and the consequent effects of these emissions on air quality. Presently, the main objectives of these approaches are either (a) reducing the emission per vehicle by adopting lower-polluting fuels and technologies, such as usage of renewable fuels or biofuels, natural gas vehicles, fuel cell vehicles; or (b) implementing mobility management approaches such as for example decreasing the maximum speed of circulation. Fleet electrification is one of the proposed strategies for reducing air pollutant emissions and improving air quality in cities. It comprises a broad selection of alternative mobility solutions ranging from plug-in hybrid electric vehicles (PHEVs) to pure electric battery vehicles (EBVs). Based on the type of power plant which supplies electric energy for EVs (electric vehicles), other possible benefits that may be attributable to fleet electrification are an increase in energy efficiency, and decreases in conventional energy reliance, fossil fuel consumption, and GHG emissions. Nonetheless, EVs require additional electrical load on the power supply causing a rise in emissions from electrical generation plants, reliant on power mixture [3]. Moreover, renewable energy sources such as wind, photovoltaic systems and solar energies have been broadly used to provide energy in many countries. Renewable energy sources are generally utilized as distributed generations in traditional power distribution networks and new smart grids because they usually produce small-scale power on the sites that are close to the users [11–13].

Considering the above-mentioned concerns, the purpose of this paper is to discuss the possibility of undertaking a feasibility study concerning the potential impact of replacing the current vehicle fleet of Canada and Italy with electric vehicles. Such a transition is indeed possible given the existent production of renewable resources in Canada and Italy, particularly in the form of photovoltaic systems (PV) and wind farms. Beginning with a discussion of the collected data, this work addresses the feasibility of replacing "non-green" vehicles with "green vehicles" via the use of renewable energy with different percentages.

The reason to consider the two countries is because the present work is part of a funded collaborative research project between Canada and Italy, aiming at development of user-friendly and cost-effective tools for assessing the impact of replacing current vehicle fleet with electric vehicles through the use of renewable energy sources. Moreover, the authors did not find any work related to such investigation and comparison between a North American and European country. Given that it is difficult to find data, this study will be useful for not only scientists, engineers, but also for policy and infrastructure planners.

The paper begins by offering a description of the diffusion of renewable energy in the Canadian and Italian settings (Section 2). Next, the report reviews the vehicle fleets (classified as automobiles and motorcycles) in these two countries as well as the nations' CO_2 emission trends (Section 3). The next part of the paper discusses methods of data collection, including the variables, used in the analysis (Section 4). Finally, the results, in terms of potential reductions in CO_2 emissions for both Canada and Italy, are addressed in the concluding remarks (Section 5).

2. Renewable Energy in Canada and Italy

The various types of information consulted by this report regarding Italian and Canadian electric power production will be presented first, covering a relatively expansive time period of 2000 to

2014 [14–16]. The focus here is on the electric power production obtained via the use of renewable sources such that polluting emissions are effectively canceled out [17].

It is very important that the governments lead the way to a fundamentally new energy direction based on clean renewable energy. However, in this moment many governments, including the U.S. government, continue to use coal, oil, or gas because this change requests time.

Figure 1 reports different profiles of the energy produced from different Renewable Energy Sources (RES), respectively for Canada and Italy.

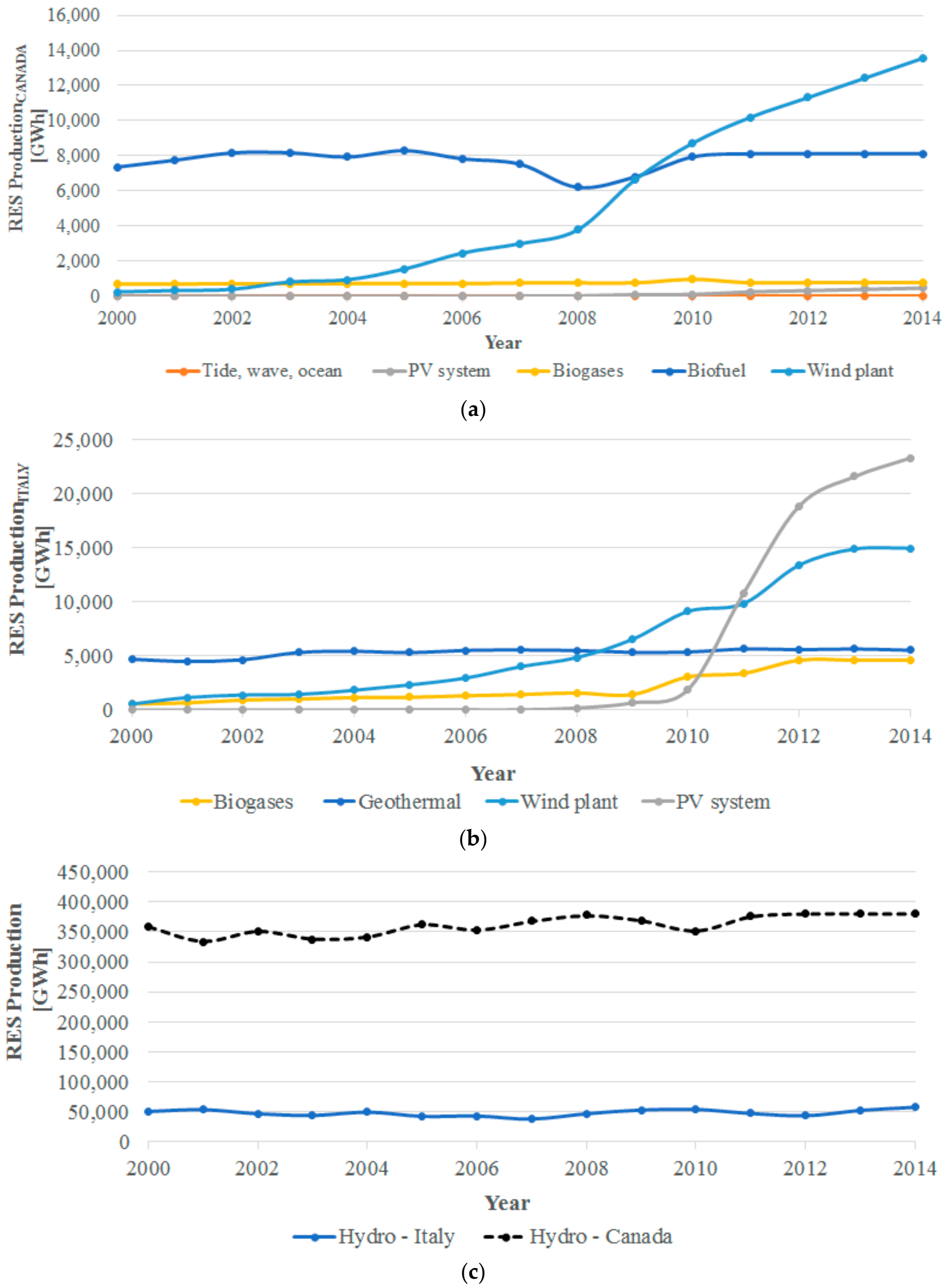


Figure 1. Production of electric energy for different renewable sources [14–16] for (**a**) Canada; (**b**) Italy; and (**c**) hydroelectricy for Canada and Italy.

Figure 1 reveals that the use of different renewable sources of energy has continuously increased in Italy, especially from 2006 onward. In particular, the boom in renewables can be traced to the diffusion of photovoltaic systems, with the most notable diffusion occurring from 2011 to 2014. Of all renewable energy sources, photovoltaic systems success is ranked second relative to hydropower, which provided 23.4% of Italy's electricity in the same time period. Wind farms and geothermal power plants contributed a further 5.8% and 2.0% of energy, respectively. In general, Italy's wind farms are situated in the southern regions of the country, where the wind conditions, topography, and site accessibility are favorable for the installation and operation of this form of renewable energy [18–20].

The situation is rather different in Canada, where one can observe a strong production of renewable energy for hydroelectric sources and wind plants. Photovoltaic systems are concentrated most heavily in the province of Ontario, with the provinces of Alberta, British Columbia, and Saskatchewan following thereafter [16]. Figure 2 displays trends concerning differences over the years in the production of energy derived from wind farms and photovoltaic systems.

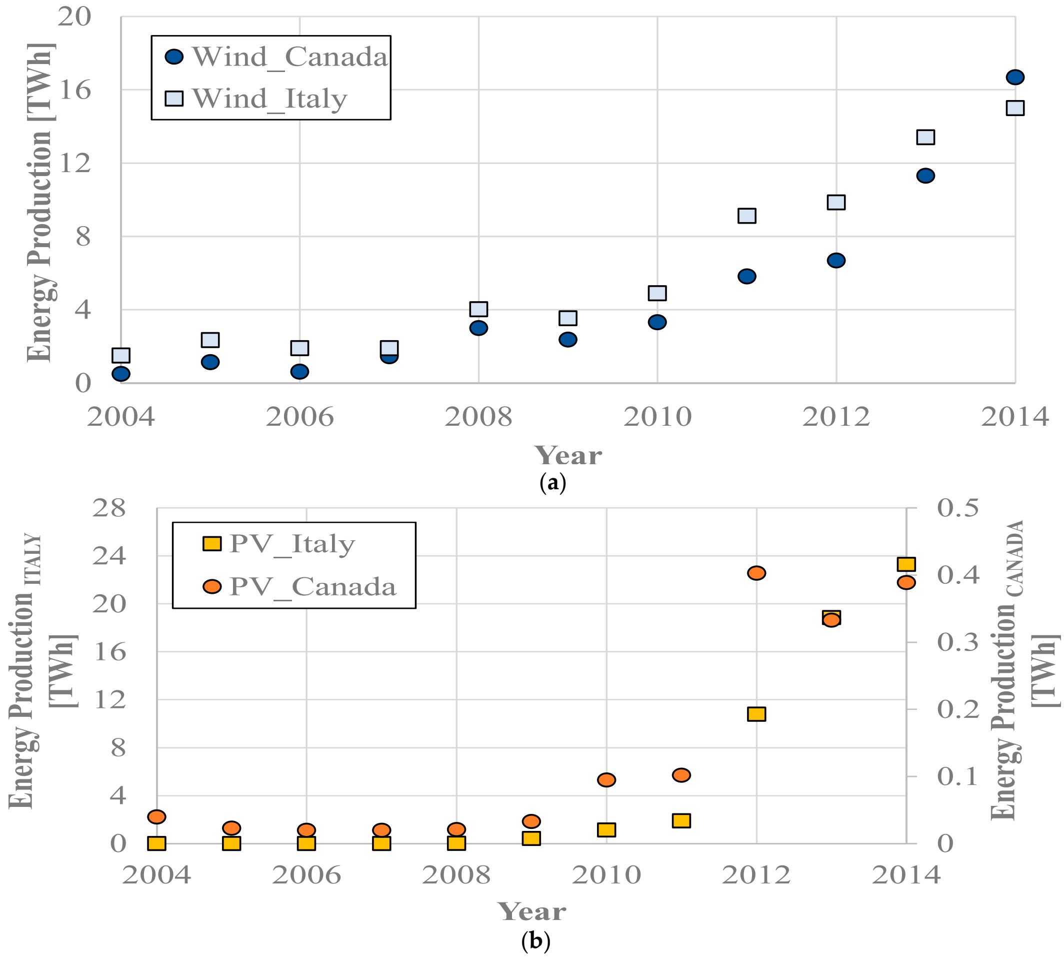


Figure 2. Energy produced from (**a**) Wind farm; and (**b**) Photovoltaic systems for Canada and Italy.

3. Air Pollutant Emissions and Vehicle Fleet

The production of electric energy originating from renewable sources *versus* non-renewable sources varies across the different sectors in both Canada and Italy [21]. In fact, the data show decreases in energy consumption levels for some sectors such as industry and household users in order to save energy and reduce pollution to have a substantial health improvement.

On this aspect, the governments have taken action. In the 1998, the Kyoto protocol has given the goal to lower overall emissions from six greenhouse gases—carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) [22].

There are several divisions of air pollutant emissions. Primary air pollutants can be produced by primary sources or secondary sources. The pollutants that are produced directly from the process are named primary pollutants. A typical example of a primary pollutant would be nitrogen oxides, carbon monoxide, and sulfur dioxide emissions released from power plants [23].

Secondary pollutants are the ones that are produced by the coupling of mixing and chemical reactions of primary pollutants. Smog is an example of a secondary pollutant, which is generated by the chemical reactions of various primary pollutants [24].

The causes of air pollutions derive from different aspects, in particular, burning of fossil fuels, agricultural activities, exhaust from factories and industries, mining operations, indoor air pollution.

Pollution emitting from vehicles including trucks, jeeps, cars, trains, and airplanes cause immense amounts of pollution. We rely on them to fulfill our daily basic needs of transportation, but their overuse is killing our environment and toxic gases are polluting the environment.

Figure 3 reports the trends of CO_2 emissions in both Canada and Italy since 2000. The focus here on CO_2 emissions is justified by the fact that CO_2 emissions represent 82% of total toxic emissions, with the remaining emissions corresponding to 3% fluorinated gases, 5% nitrous oxide (N_2O), and 10% methane (CH_4).

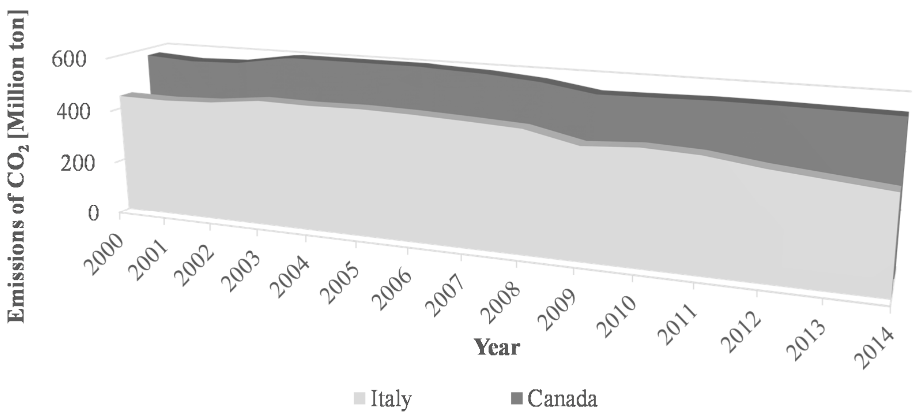


Figure 3. Total CO_2 emissions, respectively, for Canada and Italy.

For clarification purposes, the emissions indicated in Figure 3 are the sum of six different sectors as in Equation (1) below:

$$CO_{2tot} = CO_{2eg} + CO_{2ind} + CO_{2ag} + CO_{2tran} + CO_{2resi} + CO_{2com} \quad (1)$$

where all the components are expressed in million metric tons:

- CO_{2eg}—the amount of emissions obtained via electricity generation;
- CO_{2ind}—the emissions produced by the industry sector;
- CO_{2ag}—the pollution created by the agricultural sector;
- CO_{2tran}—the emissions generated by all forms of transport including all vehicle fleets; and
- CO_{2resi}—the emissions of the residential sector;
- CO_{2com}—the emissions produced by the commercial sector.

The impact of CO_2 emissions in percentage terms presents a different picture. In short, emissions deriving from electricity represent 31% of the total emissions; for transportation, the emissions amount to 27%; industry signifies 21%; and, finally, agriculture comes in at 9%, commercial at

6%, and residential at 6%. For this region, although different sectors clearly contribute dissimilar percentages of emissions, the focal concern in this contribution is that of the transportation sector [25,26]. The major task is to determine whether it is possible, via the use of renewable energy, to effectively replace the existent vehicle fleets, in particular cars and motorcycles/mopeds, in Canada and Italy.

The transportation sector, which encompasses trucks, buses, motorcycles, and cars, is a major contributor to air pollution in most nations. In fact, the air emissions generated by all forms of transport including all vehicle fleets represent about 25%–30%. Different typologies of fuel supply are presented; for example, gasoline and diesel. In recent years, the sector has witnessed an increase in the availability of new vehicles and, in particular, plug-in hybrid vehicles alongside electric vehicles.

In this study, the idea is to consider the full electric vehicles only. Today, different vehicles are presented in the world and, in particular, cars and motorcycles have different characteristics. In this way, the population can choose between different models with diverse characteristics as a function to the needs. However, buses and trucks are very difficult to be fully electric because the transport must be carried out over several kilometers and cannot stop for too long to recharge the battery.

Figure 4 shows the evolution of the vehicle fleet from 2009 to 2014, with a particular focus on cars and motorcycles/mopeds, over time in both Italy and Canada. These vehicles are fueled with conventional fuels (gasoline, diesel, *etc.*).

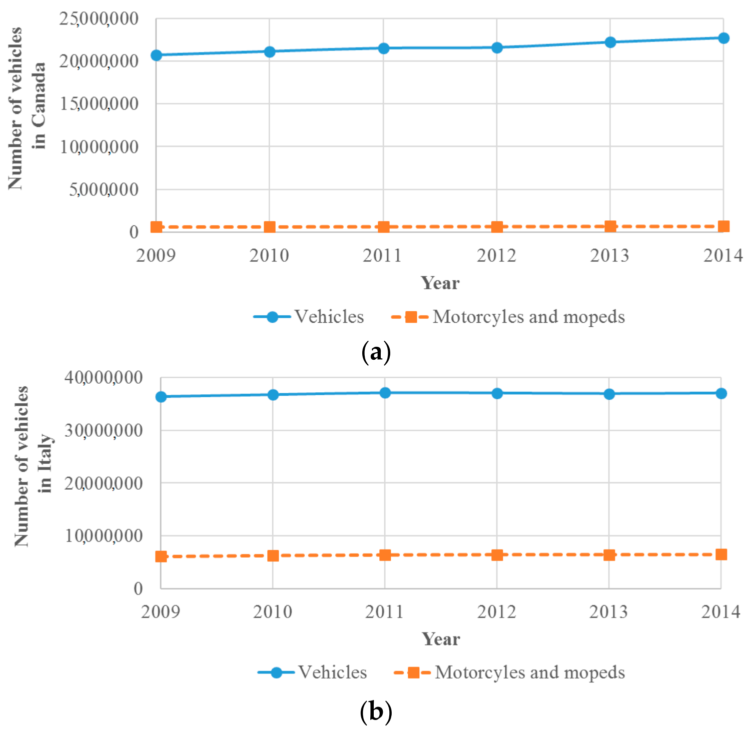


Figure 4. Vehicles and Motorcycles and mopeds in (**a**) Canada and (**b**) Italy in different years.

Based on these data, one can see that, whereas the number of motorcycles and automobiles differs little over time in Italy, Canadian automobiles have increased in quantity since 2012 whilst the number of motorcycles has remained relatively stable [27,28]. Furthermore, for both countries, approximately 51% of the vehicle fleet uses gasoline as a fuel supply, 41% relies on diesel. The circulation of electric vehicles in Italy is very low: in fact, these vehicles, which number 1097, have been available only since the year 2014. Contrastingly, the number of electric vehicles in Canada is much higher, with a total circulation of more than 10,000.

Insofar as the current number of “green vehicles” already on the road in these two countries is quite low, the potential for replacing the nations’ most polluting vehicles and motorcycles via the use of renewable sources and "green vehicles" is quite attractive. The focus here, thus, is on whether this is a feasible undertaking.

4. Case Study and Discussion of Results

The data under consideration here pertain to the energy production generated via different renewable sources (specifically, photovoltaic systems, and wind farms) and the different categories of vehicles across the total fleets of Canada and Italy (the focus is on cars and motorcycles) [29]. The choice of cars and motorcycles derive with the fact that on the market, there are different models fully electric and in this case it is possible to change the actual situation using vehicles totally green if they are fueled with the renewable energy.

The goal is to assess the feasibility of the integration of electric vehicles with renewable sources and to analyze the possible consequences of replacing traditional vehicles with electronic ones with respect to different scenarios regarding the habits of citizens in the year 2014. The following variables have been considered:

- $E_{PVCanada}$ and $E_{PVItaly}$—the energy production expressed in GWh generated via photovoltaic systems in Canada and in Italy;
- $E_{WINDCanada}$ and $E_{WINDItaly}$—the energy production expressed in GWh generated via wind farms in Canada and in Italy;
- E_{EVs} and E_{MVs}—the energy required, expressed in kWh, for the recharging of electric vehicles and electric motorcycles.
- $N_{VFCanada}$ and $N_{VFItaly}$—the number of cars in circulation in Canada and Italy in 2014; and
- $N_{MFCanada}$ and $N_{MFItaly}$—the number of motorcycles in circulation in Canada and Italy in 2014.

Various facts about electric vehicles should be stressed and considered:

- Battery capacity ($C_{batteryEVs}$) is equal to 24 kWh;
- η is the efficiency of the charging system (85%); and
- Consumption of an electric vehicle (C_{EVs}) is equal to 0.213 kWh/km. This quantity is an average derived from different kinds of electric vehicles where the consumption rates vary according to the type of vehicle (small, middle and large size).

During the use of the electric car, the Li-ion batteries are discharged up to the minimum values of state of charge (ΔSOC, State of Charge) of 40%, where SOC is the percentage of residual energy stored in the batteries. For EVs, it is not recommended that vehicles fall below this value, especially in terms of remaining capacity. However, even with PHEVs trying to maintain a ΔSOC > 40% to safeguard the life of the battery is applicable. Frequent deep discharges lead to an increase of the internal resistance and a decrease of the useful capacity, and it may also increase the failure rate and result in premature aging of the cell.

Following the above considerations, maximum depth of discharge (DoD) is assumed to equal to 60%, and then the minimum state of charge (SOC) is equal to 40%.

Additionally, for electric motorcycles, it is necessary to make some assumptions:

- Battery capacity ($C_{batteryEMs}$) is equal to 9 kWh;
- η is Efficiency of the charging system (85%); and
- Consumption (C_{EMs}) is equal to 0.115 kWh/km again. This value is an average derived from different kinds of electric motorcycles.

Similarly, for motorcycles the same considerations apply to the DoD and the SOC. In fact, the maximum DoD is equal to 60% and then the minimum SOC is equal to 40%.

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

- S_1: distance travelled for urban use per year is equal to 4000 km;
- S_2: distance travelled for travel salesman per year is equal to 15,000 km;
- S_3: distance travelled for commuters per day is equal to 40,000 km; and
- S_4: distance travelled for long distance per year is equal to 75,000 km

The assessment of the energy flows within the charging system requires the knowledge of the daily production curves of the photovoltaic systems and wind farms as well as the demand curves of the electric vehicles. In this work, the analysis addresses different percentages of the energy produced by photovoltaic systems and wind farms distributed in Canada and Italy, observing how electric vehicles can replace the current vehicle fleet.

Since a vehicle fleet consists in different vehicle typologies for different missions, a more suitable value for distance travelled D_{Travel} has to take into account all of them. Consequently, the equivalent distance travelled per year can be calculated as follows Equation (2):

$$\begin{gathered} D_{travel} = \alpha \cdot S_1 + \beta \cdot S_2 + \gamma \cdot S_3 + \delta \cdot S_4 \\ \text{where } \alpha + \beta + \gamma + \delta = 1 \end{gathered} \tag{2}$$

with α is equal to 0.5, the value of β is 0.25, γ is 0.15 and δ is equal to 0.1. These variables γ, β, and α are derived of the daily habits of the people.

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 on an annual basis can be determined as Equation (3):

$$E_{EVs} = \frac{(D_{travel} \cdot C_{EVs})}{\eta} \tag{3a}$$

$$E_{EMs} = \frac{(D_{travel} \cdot C_{EMs})}{\eta} \tag{3b}$$

where the consumption is different for vehicles (C_{EVs} equal to 0.213 kWh/km) and motorcycles (C_{EMs} equal to 0.115 kWh/km) and η is the efficiency of the charging system that for electric vehicles and motorcycles is equal to 85%.

After that, it is possible to calculate the number of electric vehicles using the energy production obtained from wind farms and photovoltaic systems determined with Equation (4):

$$\begin{cases} N_{EVwithWIND} = \dfrac{E_{WIND}}{E_{EVs}} \\ N_{EVwithPV} = \dfrac{E_{PV}}{E_{EVs}} \end{cases} \tag{4}$$

Given that renewable energy (E_{WIND} and E_{PV}) obtained per year is used for different purposes, different percentages (5%–100% with a step of 5) have been suggested with respect to the amounts to be used for the recharging of electric vehicles.

Different percentages of green energy from renewable sources are important to consider because different energy demands from the users are to be taken into account; for example, the case of the industry where the energy is to be used not only for the company fleet but also for lighting, heating, *etc*.

The same considerations have been made also for motorcycles and using the energy production obtained from wind farms and photovoltaic systems, it is possible to determine with Equation (5):

$$\begin{cases} N_{EMwithWIND} = \dfrac{E_{WIND}}{E_{EMs}} \\ N_{EMwithPV} = \dfrac{E_{PV}}{E_{EMs}} \end{cases} \tag{5}$$

The distance that electric vehicles (EVs) and electric motorcycles (EMs) could travel based on the amount of energy supplied by wind farms in accordance with Equation (2) is shown in Figure 5.

In the figure are reported different percentages of number of cars and motorcycles for 2014. For example $N_{VFCanada90\%}$ are the 90% of vehicles on the total number of cars in circulation in Canada or $N_{VFCanada15\%}$ are the 15% of vehicles on the total number of cars in circulation in Canada. The same assumptions are valid for both motorcycles, for both the Italian cases.

Note that the idea of considering different percentages of vehicles needed is to figure out how many polluting vehicles can be replaced with electric vehicles powered by electricity from green sources.

It can be seen that in neither Canada nor Italy would it be possible to generate the energy from wind power needed to successfully replace all extant cars. As shown in Figure 2, it seems likely that wind power could potentially provide the energy required to sustain most, but not all, electric vehicles in Canada, whereas this would not be possible in Italy where wind power is available only in some areas of the region. Figures suggest that, in Canada, using only 10% of available wind energy could potentially replace 5% of cars currently on the road; alternatively, with the use of 82% of available wind energy, a total of 7,965,987 electric vehicles could be powered. The situation is quite different in Italy: 63% of available wind energy could charge only 15% of the vehicle fleet.

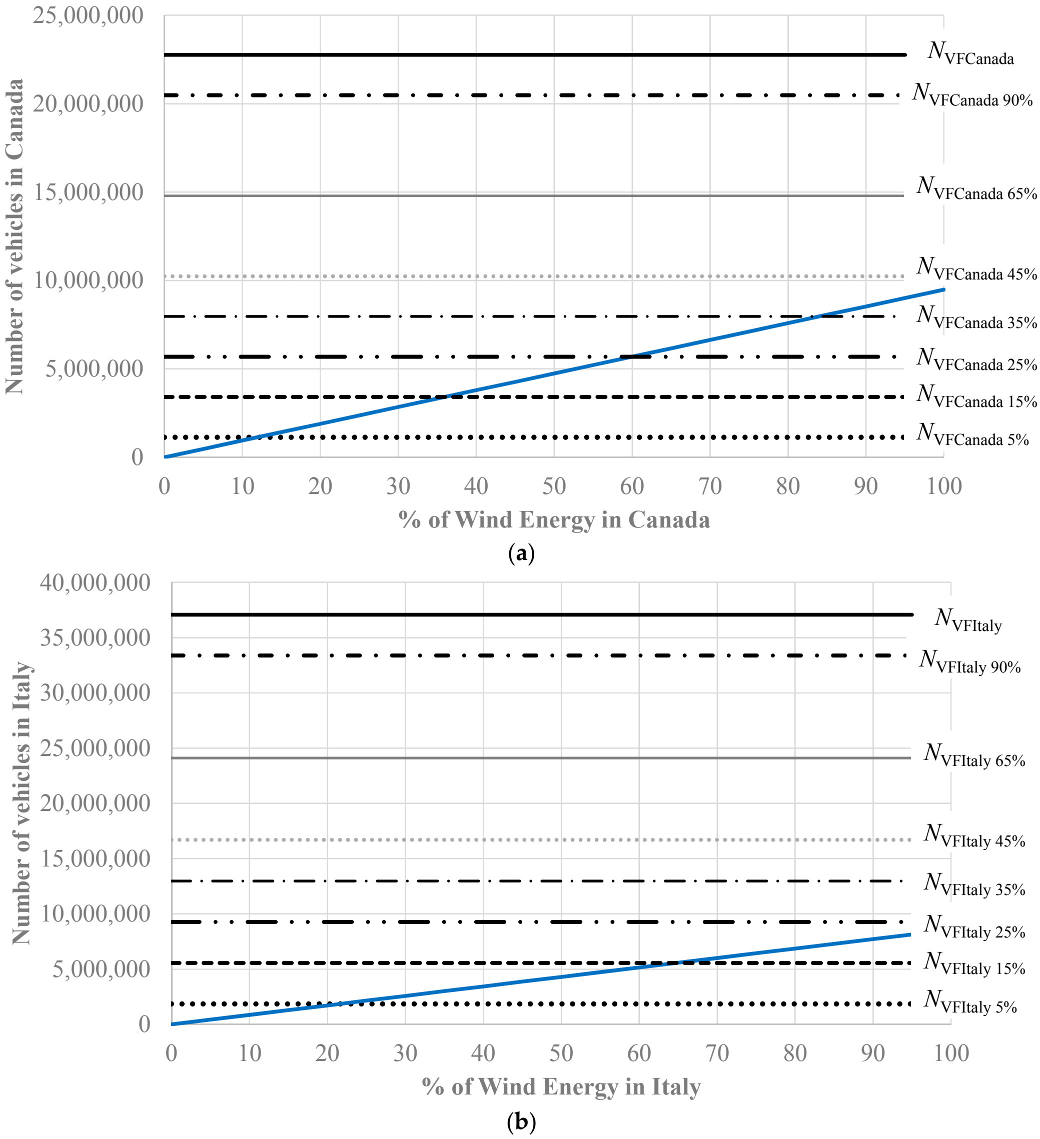


Figure 5. Possible electric vehicles recharged with wind energy in (**a**) Canada; and (**b**) Italy.

Figure 6 reports the amounts of energy required to replace the extant fleet of motorcycles/mopeds in Canada and Italy. Data show that the available energy is sufficient to replace all motorcycles with electric motorcycles. In fact, only 5% of Canada's energy output from wind farms would be needed to charge all electric motorcycles; this means that the remaining 95% of energy produced could be reserved for different uses. However, in Italy, a much higher percentage, *i.e.*, 40% of the country's energy supply would be required for the equivalent task.

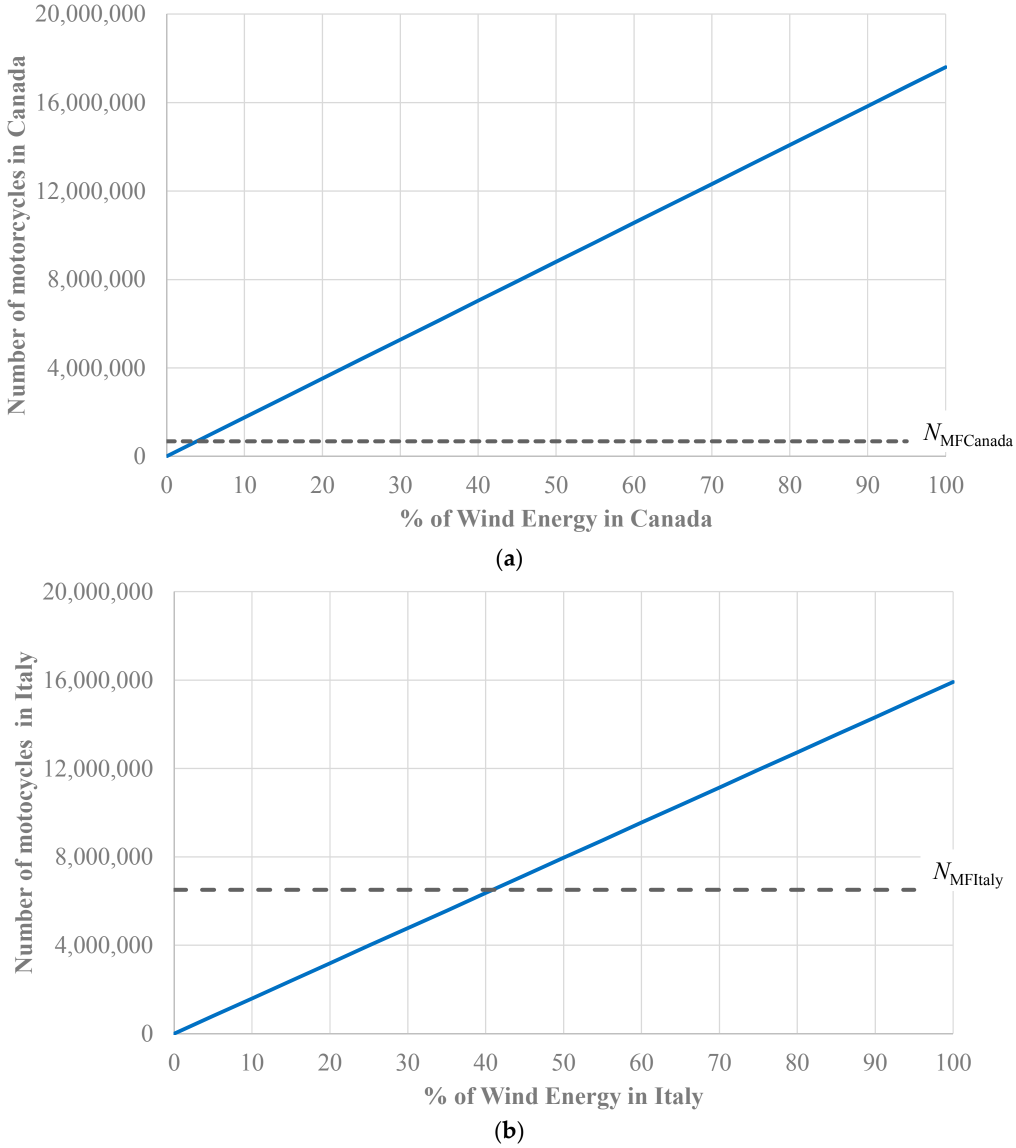
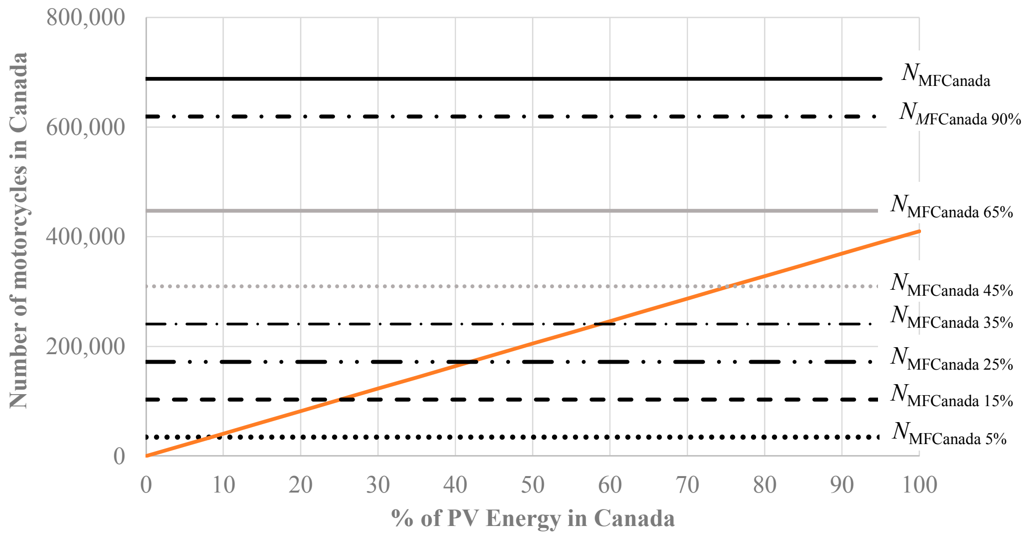
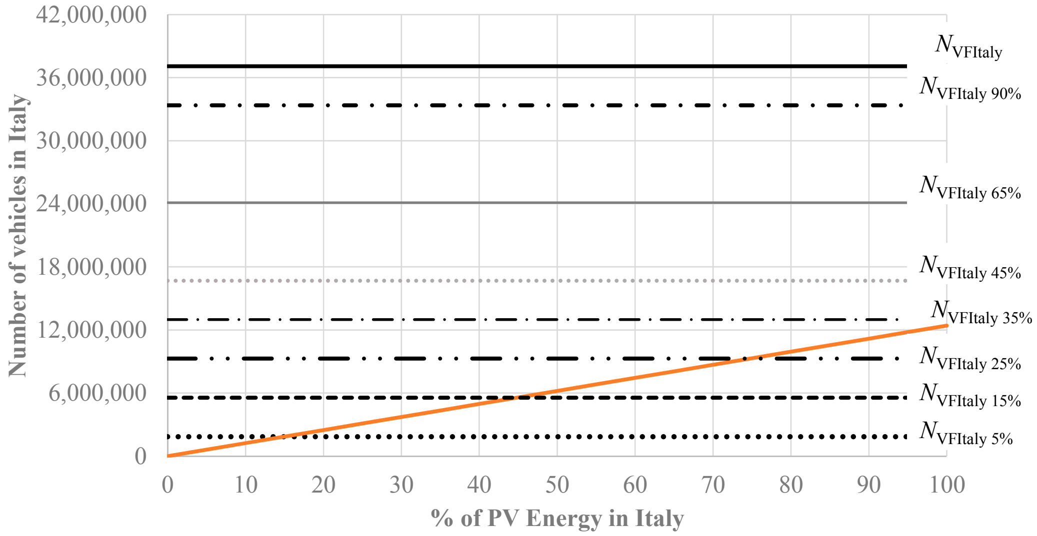


Figure 6. Possible electric motorcycles/mopeds recharged with wind energy in (**a**) Canada; and (**b**) Italy.

The availability and diffusion of photovoltaic systems is different in Canada *versus* Italy. As shown in Figure 2, the energy produced by photovoltaic systems in Canada is not sufficient to sustain electric vehicles but this energy could be used to recharge electric motorcycles. In fact using 58% of available energy it is possible to recharge 240,871 electric motorcycles as shown in Figure 7. However, in Italy the situation is dissimilar: 28% of energy would be required to account for electric motorcycles, and by dedicating 75% Italy could recharge 5,689,990 EVs.



(**a**)



(**b**)

Figure 7. Possible electric vehicle fleet recharged with PV energy in (**a**) Canada; and (**b**) Italy.

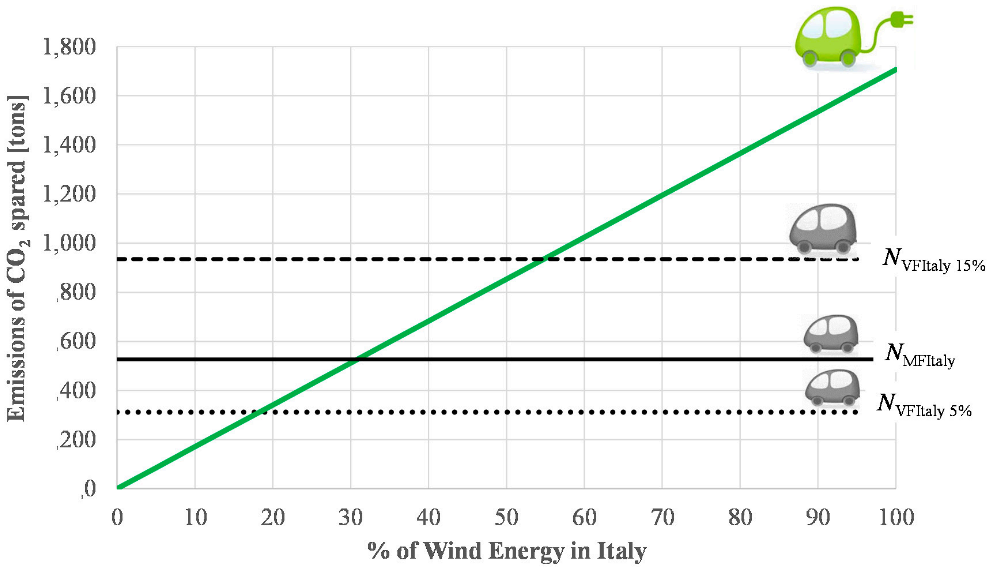
5. Pollutant Emissions Reduction

Across the globe today, efforts are being made to help the energy sector improve its air pollution emission performance; specifically, governments aim to advance clean electricity and cleaner energy production, increase the production capacity and use of alternative fuels, and improve end-use energy efficiencies. Concerning this last method in particular, governments have supported strategic investments in the commercialization and adoption of clean energy technologies with the goal, for instance, to incentivize the deployment of wind farms or photovoltaic systems or tax breaks for the purchase of electric vehicles. These developments are driven by a variety of factors, in particular those associated with the Kyoto Protocol and certain problems resulting from the use of fossil fuels (such as the greenhouse effect, acid rain, and climate change) [20,21]. Insofar as renewable energies have spread rapidly in recent years whereas, at the same time, the availability of electric vehicles has remained relatively low, and taking in account the discussion in Section 4 above, there are potentially huge advantages associated with implementing these new vehicles, especially in terms of quality of life improvements [22,23].

For this survey, it is necessary to consider some further variables:

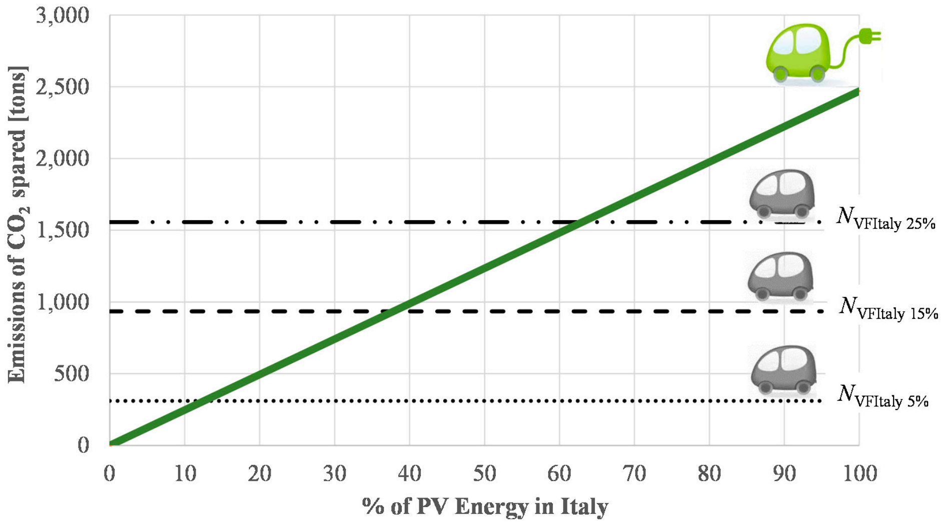
- *Coeff*$_{M1}$—the emission factor for motorcycles/mopeds that it is equal to 82 g/km in scenario S_1 where, in most cases, the use of motorcycles/mopeds is restricted to urban roads;
- *Coeff*$_{M234}$—equal to 93 g/km. In this case, this value is used for scenarios S_2, S_3, and S_4. This value is the average generated from different roads, in particular urban streets, extra-urban roads, and highways;
- *Coeff*$_{V1}$—the emission factor for vehicles. In scenario S_1, the use of car is typically for urban roads, and this value is equal to 203 g/km;
- *Coeff*$_{V234}$—the emission factor for vehicles, equal to 170 g/km. Here, this value is used for scenarios S_2, S_3, and S_4. This value is the average generated from different roads, in particular urban streets, extra-urban roads, and highways; and
- *Coeff*$_{V}$ and *Coeff*$_{M}$—the emission factors for vehicle which, in this case, is equal to 168 g/km whereas for the motorcycle/moped is equal to 81 g/km. The values are obtained from the average of different kinds of vehicles such that the consumption varies according to the type of vehicle (small, middle, and large size) and the type different fuel used.

Considering the above assumptions, in the Figures 8–10 one can see the amount of CO_2 emissions spared in accordance with the percentage of energy to be used to fuel vehicles or electric motorcycles. Figure 8 reports the Italian case where it is possible to observe that the energy obtained from wind farms or photovoltaic systems can sustain, in one case 15% of vehicles, and in another case 25% of the total vehicle fleet, excluding buses, trucks, and trailers. A key point to keep in mind is the fact that "green vehicles" produce no pollution since they are fueled by renewable energy. In this case, it is possible to observe that about 1000 metric tons are avoided using 55% of wind energy replacing 15% of the vehicles ($N_{VFItaly15\%}$) with fully electric vehicles. Obviously, if the wind energy is low, for example it is used only the 20% with 5% of vehicles ($N_{VFItaly5\%}$) fueled with RES, in this case the emissions avoided are about 350 tons. If all motorcycles are replaced with electric motorcycles ($N_{MFItaly}$), the CO_2 emissions are equal to 550 tons. If the EVs or EMs use photovoltaic systems for recharging, then in that case because the production is very high, it is possible to replace totally the 25% of vehicles. In this mode, the CO_2 emissions avoided are equal to 1600 tons.



(a)

Figure 8. *Cont.*

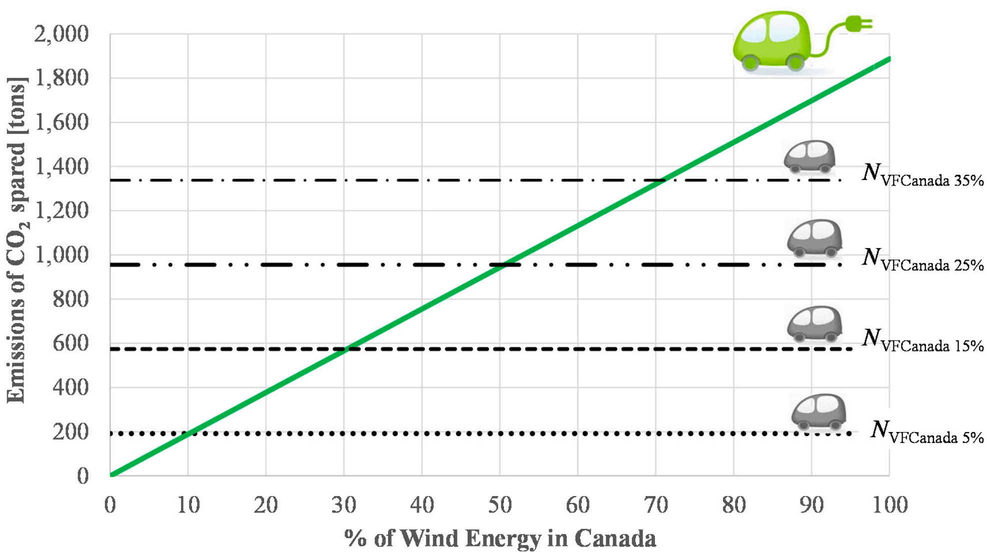


(**b**)

Figure 8. Emissions of CO_2 spared replacing the vehicles using (**a**) Wind farm; and (**b**) Photovoltaic system for Italy.

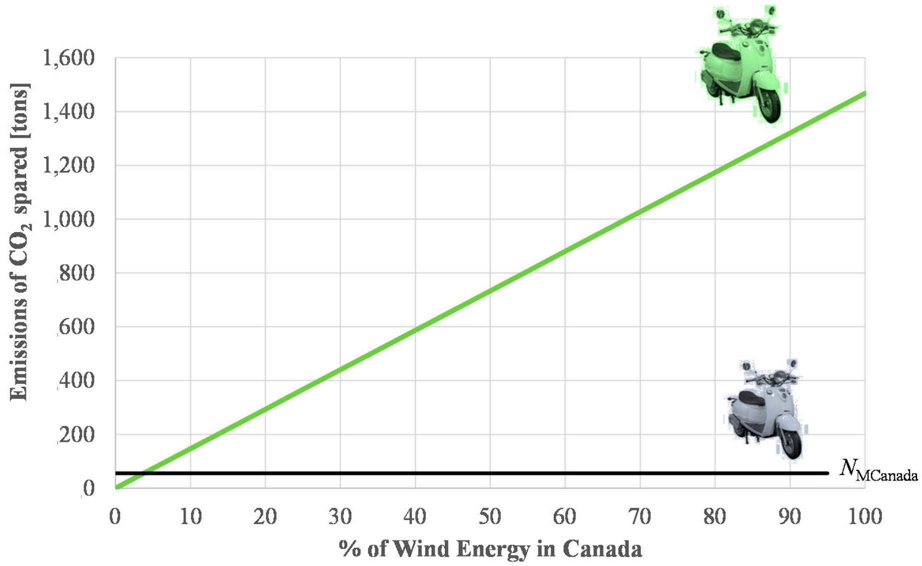
The situation in Canada differs from that in Italy: the diffusion of renewable energy is low concerning photovoltaic systems, leaving only wind energy—however, wind energy is useful because 35% of vehicles and all motorcycles/mopeds can be replaced with total electric transportation as shown in Figure 9. In this case, it is possible to observe that about 900 tons are avoided using 50% of wind energy replacing 25% of the vehicles ($N_{VFCanada25\%}$) with fully-electric vehicles. Obviously, if the wind energy is low, for example it is used only 10% with 5% of vehicles ($N_{VFCanada5\%}$) fueled with RES, then in that case the emissions avoided are about 200 tons. On the other hand, using 70% of energy obtained from wind farm and replacing 35% of the vehicles ($N_{VFCanada35\%}$), then CO_2 emissions avoided are equal to 1300 tons.

If all motorcycles are replaced with electric motorcycles ($N_{MFCanada}$), the CO_2 emissions are equal to 150 tons using only 4% of energy obtained from wind energy.



(**a**)

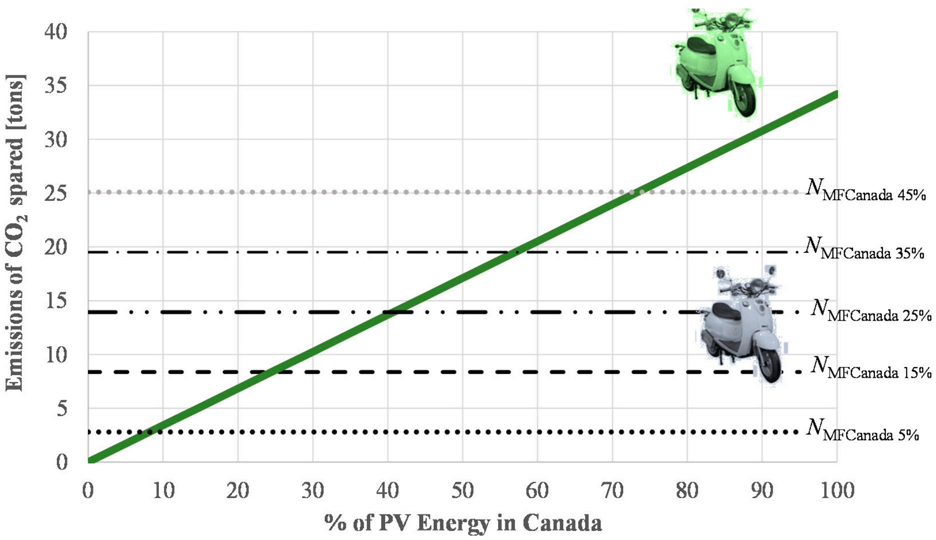
Figure 9. *Cont.*



(**b**)

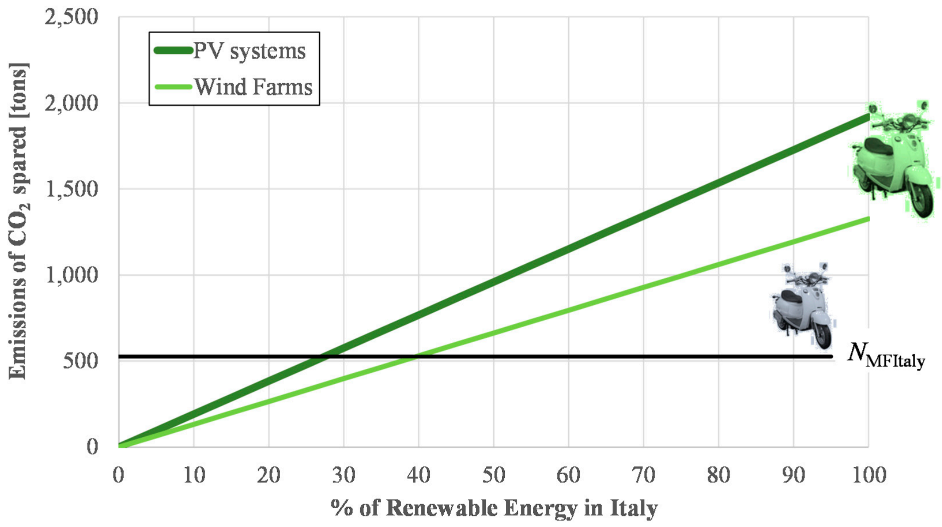
Figure 9. Emissions of CO_2 spared replacing (**a**) the vehicle fleet; and (**b**) motorcycles/mopeds using wind farms for Canada.

Using different forms of renewable energy, in particular for Canada in this case they are considered the PV systems and for Italy also wind farms. Figure 10 indicates that it is possible to use 72% of renewable energy to change 45% of motorcycles/mopeds in Canada for "green vehicles", whereas all motorcycles/mopeds in Italy could be replaced with the total electric transportation provided by the PV systems representing 26% of energy and wind farms, 40% for energy.



(**a**)

Figure 10. *Cont.*



(**b**)

Figure 10. Emissions of CO_2 spared replacing the motorcycles/mopeds park using renewable energy for (**a**) Canada; and (**b**) Italy.

6. Conclusions

Pollution is now a commonplace term. It can affect people and other living areas. In the world, there are currently numerous large cities with low air quality. Governments are now taking actions to reduce and cut as much as possible emissions of carbon dioxide and other greenhouse gases. One of the known approaches is through the Kyoto Protocol, which is an agreement between nations, stipulating CO_2 emissions reduction. Another way is to put taxes on carbon emissions or set higher taxes on gasoline. This latter method will provide more incentives and motivations to companies and individuals for energy conservation and pollution reduction.

For these reasons, this paper began by reviewing the present situation in terms of the availability of renewable energy in Canada and Italy, specifically regarding the state of CO_2 emissions and the extant vehicle fleets, which, in this case, refer only to cars and motorcycles/mopeds, excluding in the analysis trucks, buses, and trailers.

The decision to consider only vehicles and motorcycles is because there are different models available on the market for fully-electric vehicles.

The study has considered the habits of drivers with respect to proposed different scenarios based on the kilometers travelled during the year. The main focus has been to analyze how much renewable energy (in terms of percentage), in particular wind farms and PV systems, it is necessary in order to replace the current vehicle fleets present within Canada and Italy.

The choice to use different percentages of renewable energy emerged because renewable energy can be dedicated to other uses, for example domestic use, lighting public spaces, *etc*.

The results here show that in there is great potential for a better exploitation of 'green sources' within Canada, especially considering their widespread availability. Still, it is very important to increase the dissemination of renewable energies. The situation is different for Italy where there is already a significant amount of renewables available and so it is possible to hypothesize that future growth in the years to come will not be high. Generally speaking, the results reveal that it is possible to replace the actual vehicle fleets, and fuel the new vehicle fleet, using some but not all of the energy obtained via renewables.

Of course, the situation is critical when the cars concerned have very high values. For Canada, using 82% of the energy obtained from wind farms it is possible to replace 35% of the total vehicle in the form of electric vehicles; using 5% of energy, it is possible to replace all motorcycles/mopeds.

Conversely, using 60% of the energy obtained from PV systems Canada could replace 35% of the total motorcycles in the form of electric motorcycles. It simply does not appear possible to use the PV energy supply to successfully fuel the cars. The Italian context is different: in both cases, it is possible to use the energy to fuel "green vehicles". Using 60% of the energy from wind farms it is possible to replace 15% of the total vehicle fleet in the form of electric vehicles; 40% is required to replace all motorcycles/mopeds. Alternatively, using 75% and 28% of the energy obtained from PV systems, Italy can replace 25% of the total vehicle fleet into electric vehicles and all motorcycles/mopeds into electric motorcycles, respectively. These values are encouraging because they show that it is not necessary to allocate all available energy to the recharging of EVs and, thus, the remaining energy can be set aside for other uses, such as domestic or business uses.

In summary, then, the results of this study have been directed at exploring the possible benefits, in the form of reduced CO_2 emissions, associated with the potential implementation of the powering of EVs and electric motorcycles via renewables in the countries of Canada and Italy.

In conclusion, it is clearly shown that a pronounced introduction and distribution of Renewable Energy Sources (RES), electric vehicles (EVs) and electric motorcycles (EMs) can operate as a great opportunity for both the environment and the capacities and needs of energy production.

Finally, it should be recognized that today, the electric vehicle is not widespread. With this study, it is demonstrated how EVs can be well integrated with renewable energy. Therefore, it is the duty of governments to implement policy strategies; for example, by providing direct subsidies or fiscal incentives, in order to spread them to more territory.

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