Applied Energy 120 (2014) 31–40

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

A study aimed at assessing the potential impact of vehicle electrification on grid infrastructure and road-traffic green house emissions

Marco Sorrentino *, Gianfranco Rizzo, Luca Sorrentino

Department of Industrial Engineering, University of Salerno, Fisciano, Salerno 84084, Italy

HIGHLIGHTS

- Modular computational structure for extensive analyses of car electrification impact.
- Simplified market model to assess the CO_2 reduction potentialities of PEVs.
- Combining macro- with micro-level analyses of car electrification impact.
- Developing suitable methodologies to support energy planning for transportation.
- Worldwide analysis of electricity mix influence on CO_2 reduction potential of electrified cars.

ARTICLE INFO

Article history:
Received 14 May 2013
Received in revised form 23 December 2013
Accepted 12 January 2014
Available online 7 February 2014

Keywords:
Plug-in hybrid vehicle
Car electrification
Electric vehicle
Grid decarbonization
Greenhouse gas emissions

ABSTRACT

In the current paper a thorough analysis is conducted to assess, on one hand, the impact of vehicle electrification on electric grids and their related infrastructures, and, on the other, its potential contribution to GHG emission reduction. Such an analysis covers the timeframe 2011–2050, thus allowing to assess if the environment friendliness of both PHEV and BEV will be enough contributing, particularly towards the fulfillment of the objectives recently established both by official agreements among governments and research consortia (e.g. the International Energy Agency) as well. The expected time evolution of both PHEV and BEV private car fleets is modeled through a simplified market penetration model, along with the associated contribution in terms of well to tank and tank to wheel GHG emissions, thus providing the needed input data to the scenario analysis. Particularly, a longitudinal vehicle model is adopted to accurately estimate electric vehicle energy consumptions and related GHG emissions as a function of powertrain configuration, dimensions and mass.

The analysis was run on several countries, thus providing useful outcomes to assess the suitability of given energy mix to fully exploit vehicle electrification. Such indications will therefore be useful to determine to which extent progressive decarbonization of current grids is required to meet the GHG reduction target by 2050.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

In the last years, several political, social and economic issues have been contributing to strengthen the willingness to achieve a new, more environmentally friendly and sustainable mobility paradigm worldwide, particularly aiming at meeting actual mobility demand without constraining development expectations of future generations [3]. The most pressing arguments toward the finding of new solutions for personal mobility mainly include: Fossil fuels depletion; CO_2-related greenhouse effects, with dangerous and maybe dramatic impact on global warming and climate changes; worldwide increasing demand for personal mobility, especially in growing countries such as the BRICs. In this context, the electrification of automobile represents today a major research track for both the industry and academia towards a sustainable mobility. The use of electric energy as an energy carrier for passenger cars has the potential to decrease pollutant emissions in urban areas and, according to the adopted generation mix, also to reduce greenhouse gas (GHG) emissions from transportation. Moreover, new development opportunities are emerging, based on the growing interdependency between the transportation sector and stationary electric power generation, the latter also being increasingly based on renewable sources [4]. Such an aspect is of particular relevance today due to the upcoming introduction of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs), particularly

* Corresponding author. Tel.: +39 089964100; fax: +39 089964037.
E-mail address: msorrentino@unisa.it (M. Sorrentino).

http://dx.doi.org/10.1016/j.apenergy.2014.01.040
0306-2619/© 2014 Elsevier Ltd. All rights reserved.

Nomenclature

BEV	battery electric vehicle
BRIC	Brazil, Russia, India, China
CC	conventional car
CD	charge depleting
CS	charge sustaining
EG	electric generator
EM	electric motor
GHG	green house gas
HEV	hybrid electric vehicle
I	inverter
ICE	internal combustion engine
IEA	International Energy Agency
Mln	million
NA	not available
NEDC	new European driving cycle
NPI	non plug-in vehicles (i.e. CC + HEV)
PEV	plug-in hybrid-electric & pure-electric vehicle (i.e. PHEV & BEV)
PHEV	plug-in hybrid electric vehicle
SOC	state of charge
SOC_{up}	maximum SOC in charge sustaining operation
SOC_{lo}	minimum SOC in charge sustaining operation
UNISA	university of Salerno

Symbols

A	frontal area (m^2)
$CO_{2,grid}$	CO_2 emissions yielded by electrical grid (g/W h)
C_r	rolling resistance
C_x	wind resistance
D_{year}	annual distance (km)
EC	electricity consumption (W h/km)
FE	fuel economy (km/l)
M	mass (kg)
M_{body}	vehicle body mass (kg)
M_c	mass of a single battery cell (kg)
m_{EG}	EG unit mass, equal to 0.83 (kg/kW) [1]
m_{EM}	EM+Inverter unit mass, equal to 1 (kg/kW) [1]
m_{gear}	gearbox unit mass, equal to 0.48 (kg/kW) [2]
m_{ICE}	internal combustion engine unit mass, assumed equal to 2 (kg/kW), on average, for SI engines [2]
N_B	number of battery cells
N_{car}	private car fleet population (mln)
P	power (W)
t	time (s)
$T_{ch,BEV}$	BEV charging time (h)
$T_{ch,PHEV}$	PHEV charging time (h)
UF	utility factor
v	vehicle speed (m/s)

Greek symbols

α	road grade (rad)
η	efficiency
ρ	ambient air density (kg/m^3)
ρ_{PtW}	power to weight ratio

Subscript

B	battery
f	final
r	road
T	transmission

Superscript

*	nominal value

with the prospective diffusion of vehicle-to-grid (V2G) technologies [5,6].

Therefore, the urgent need to transform policy statements into concrete action has prompted the International Energy Agency (IEA) to develop a series of roadmaps, for some of the most important technologies, aimed at outlining the correct developmental paths to be followed to achieve a substantial reduction of energy-related CO_2 emissions [7]. These roadmaps also include special focuses on developing technologies in emerging economies, thus enhancing international collaboration with the final aim of strengthening the efforts toward the targeted global reduction in greenhouse gas emissions.

The target set by the IEA "blue-map" scenario [7] corresponds to an overall reduction of 50% of global energy-related CO_2 emissions by 2050, as compared to current levels. In this context, the transport sector is requested to contribute by guaranteeing 2050 CO_2 emissions be 30% lower than current value. On the other hand, the roadmaps traced for plug-in vehicles (PEVs) market are functional to effectively achieving blue-map objectives. Achieving such results requires that battery electric vehicles (BEV) and plug-in hybrid electric vehicle (PHEV) technologies for passenger cars evolve rapidly over time, with very aggressive rates of market penetration. Particularly, the PEV rate of penetration is influenced by several factors: technology supplier, vehicle offers, charging infrastructure features and costs, increase in maximum grid power (i.e. to ensure PEV, and especially BEV, be charged when needed) and customers demand. Since government policies strongly influence these factors, their role will be crucial to guarantee rapid electrification of the fleet [8,9]. Therefore the next decade will be a key "make or break" period for BEVs and PHEVs: governments, the automotive industry, electric utilities and other stakeholders must work together to implement the vehicles and infrastructure in a coordinated manner and, furthermore, to ensure that the car customers will be ready to buy. The hope is that the IEA roadmaps will add further attention and urgency to the international debate on the importance of PEV propulsion as a viable technical solution to well-known environmental and energy saving issues.

The current worldwide road transport scenario is largely based on vehicles powered by internal combustion engines, which rely almost exclusively on petroleum-based fuels and are responsible for over 74% of the overall GHG amount emitted by the entire transport sector [10]. The use of electric energy as a fuel for passenger cars has the potential, on one hand, to contribute toward the reduction of corresponding GHG emissions and, on the other, to create new development opportunities based on the growing interdependency between transport sector and stationary electric power generation [11,12]. Such an aspect is particularly relevant today due to the expected fast increase of PHEVs [13,14] and BEVs [15] into the market.

Abundant literature is now available on the potential benefits associated to vehicles' electrification on worldwide mobility. Many researchers concentrated their efforts on verifying technical and economical feasibility in the short to long term scenarios, mainly focusing on analyzing [16–19] and eventually improving [11,20,21] the vehicle–grid interaction. Others focused on the social [9,22] and environmental [23] impact of car electrification, as well as on the psychological barriers [8] to be overcome to make electric vehicles deployment really and effectively take place in the near

Download English Version:

https://daneshyari.com/en/article/242762

Download Persian Version:

https://daneshyari.com/article/242762

Daneshyari.com