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Roadway to self-healing highways with integrated wireless electric vehicle charging and sustainable energy harvesting technologies

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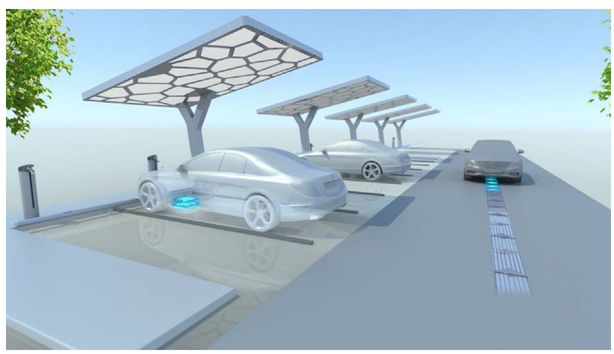
HIGHLIGHTS

- Imminent combination of roadway technologies creates opportunities and challenges.
- Sectional roads and mosaic integration create exciting combinational possibilities.
- Nissan LEAF completing its A12 highway trip with 30.3% on-road contactless coverage.

GRAPHICAL ABSTRACT



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ABSTRACT

Development of electric mobility and sustainable energy result in new technologies such as contactless electric vehicle charging and roadway energy harvesting methods, but also self-healing asphalt roads. By combining these technologies a new concept of Future Sustainable Roads for Electric Mobility is created and presented in the paper. This paper bridges the gap created by these unilateral technology developments using a multi-disciplinary approach including placing cautions when necessary and suggesting viable alternatives for optimal utilization of these energy transfer and conversion techniques. Through theoretical analysis, simulations, and tests on lab-scale experimental prototypes, the impact of our proposal is showcased. Thermal and loss models are developed for self-healing asphalt. Also, integration study of solar roads and contactless charging is performed. Applying the insight gained from the results, it is discussed how some challenges also pave a way towards interesting opportunities, for instance, infrastructure sharing for material use optimization and efficient mosaic integration. Finally, an economic viability case study is presented for a future Dutch highway with such newly emerging components.

1. Introduction

Electric mobility will reduce the CO_2 footprint, pollution level and help combat anthropogenic climate change [1]. A sustainable balance is thus struck between limited resources and socio-environmental demands. EVs can be further categorised as Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV), Range Extender Electric Vehicle (REX) and Battery Electric Vehicle (BEV) [2]. However, only BEVs are ZEVs (zero emission vehicles) at the point of use considering the dependence of fossil fuels in the other forms of EVs [2]. The low

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Nomenclature

$[\frac{dT}{dt}]$	heating rate, K s^{-1}
$[\rho]$	volumetric density, kg m^{-3}
$[C_p]$	specific heat capacity, J kg^{-1} K−1
$[q]$	volume related power density, W m^{-3}.
$[W]$	wind velocity, m s^{-1}
$[k_{a/c}]$	thermal conductivity asphalt/concrete, W m^{-1} K^{-1}
h_c	convective heat transfer coefficient, W m^{-2} K^{-1}
$[R_{a/c}]$	thermal resistance of asphalt/concrete, K W^{-1}
$[Q_{in}]$	heat input, W
$[A]$	area, m^2
$[L_1,L_2,M]$	self and mutual inductances, H
$[S_{out,max}]$	uncompensated power transfer, V A
$[V_{out,oc}]$	open circuited voltage, V
$[I_{out,sc}]$	short circuited current, A
$[P_{in,max},P_{out,max}]$	input/output power, W
$[\omega]$	angular frequency, radian/s
$[R_1,R_2,R_M]$	resistance of primary, secondary and due to combined field, Ω
$[N_{primary},N_{pickup}]$	number of turns primary, pickup, –
$[k]$	magnetic coupling coefficient, –

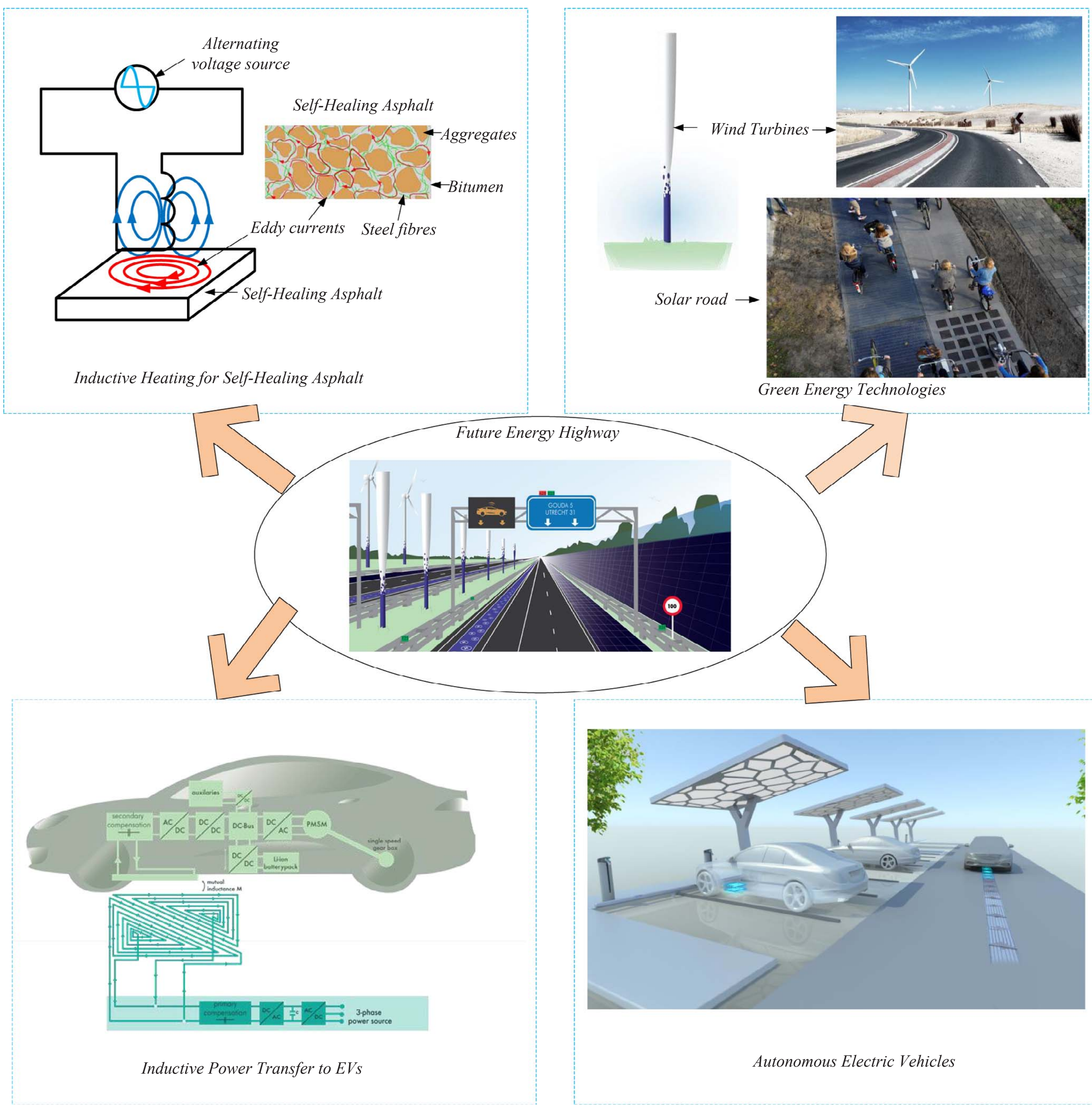

Fig. 1. Future energy highway integrating inductive coils for both inductive power transfer and induction heating, with green energy technologies for (autonomous) electric mobility.