

Electric Roads: Energy Supplied by Local Renewable Energy Sources and Microgrid Distribution System

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Summary

The electric road system is an emerging concept in this modern era. The advancement of technology has made it possible to give a real shape of this concept (electric road system). However, the energy which is provided to the electric roads is still been produced by the non-renewable energy sources which is completely unhealthy and harmful for the society. Furthermore, the traditional grid is not suited to integrate with decentralized/localized energy generation and distribution systems. It is an ineffectual and environmentally extravagant system. Therefore, the preliminary contribution of this research is to introduce a decentralized/localized energy generation system based on renewable energy sources and energy distribution to electric roads through the emerging technology of microgrid and smart grid systems which have capability to easily integrate with renewable energy sources. Thus, producing electricity with renewable energy sources are environmentally friendly, less expensive and available without having any charges. However, each source of energy has some environmental impacts as well as cost differences. A brief description of environmental and cost impact of renewable energy sources (wind, solar) is also presented.

1 Research Questions / Purpose of the Study

The aim of this study is to explore the decentralized/localized energy generation system with renewable energy sources such as; solar and wind and energy distribution system to electrified roads with microgrid/smart grid and their economic and environmental impacts in order to lower carbon-dioxide emission at a low cost.

2 Methodology

To explore the environmental and economic impact of energy production through renewable energy sources and distribution through smart decentralized way (microgrid) to electrified roads, a literature study has been performed through the largest databases, such as; ABI/Inform Global, ACM digital library, IEEE, Emeralds journal and ScienceDirect. In order to get the complete picture, different keywords have been used to search the literature on electric roads such as; environmental and cost impacts, renewable energy sources, smart grid and decentralized distribution systems.

3 Results

Transportation system plays a crucial role in satisfying the needs of everyday life. However, transportation has its negative effects on people's health as well as environmental effects due to emissions from fossil-fuels

(coal, oil and natural gas) in the form of sulphur oxides, nitrogen and carbon dioxide. Not only fossil fuels are depleting in the world, but it is expensive to install the huge power plants needed to produce and distribute electricity to electrified roads.

According to Schulte et al. [1] in the EU 24.4% of greenhouse gases as well as 33% of overall energy usage is contributed to transportation. In Sweden almost half of the gas emissions are caused by the transport sector, especially road transport which causes 93% of overall CO₂ emissions. For comparison, in Europe 24.4% of overall CO₂ is emitted by transport sector in which road transport causes 72.6% of emissions. In the USA transport sector is responsible for 26% of emissions [2]. Especially lorries are responsible for one fourth part of gas emissions. The reducing of gas emissions and switching to renewable energy sources have become essential parts of European laws and regulations, such as the Paris agreement. Teske et al. [3] stated that an important step in building a sustainable society is to make more electric cars since they are not emitting hazardous gases to the atmosphere. Electric vehicles or EVs has become a widespread research object. Since trucks emit more gases, making electric trucks could be a panacea for reducing emissions in the transportation sector.

In Sweden road transport has the biggest part in overall emissions. Nevertheless, when it comes to the electricity market Sweden shows positive results because in 2015 47% of overall electricity was generated from hydropower, second place was nuclear power 37% and wind power 10.5%. Consequently, gas pollution on roads can be reduced through building electric roads and the amount of electricity that is provided to electrified roads should be produced through renewable energy sources and more EVs [2].

Power Generation / Supply to Electric Roads

Electric roads will not be a solution to reduce greenhouse gases if the power is generated through the centralized power generation system as this system requires coal boilers and fossil fuels which emits gases. The centralized power generation system is completely outdated, insecure and inefficient, as it cannot be efficiently integrated with renewable energy sources and smart energy equipment. Furthermore, the cost is very high to generate and distribute electricity to the electrified roads as it requires heavy power generation plants and huge transmission lines. Whereas, decentralized/localized power generation system is the advanced and updated system as renewable energy sources and advanced technological energy equipment can easily be integrated. Moreover, decentralized/localized power generation systems can be located close to the energy consumption side which saves the transmission and supply cost. Although, the initial cost of the system is high but operational cost is low as it uses renewable energy sources to produce electricity.

In this modern world, where technology is evolving and bringing revolution in different sectors, similarly the advancement of technology has proved that the distribution of electricity with traditional grid is entirely an old and obsolete system, as it is basically a one-way channel system where power distribution system cannot receive immediate information if the electricity is terminated at the consumption side. The grid is incompetent to bear maximum load if it exceeds its projected demand. Moreover, it is not suited to integrate with decentralized/localized and renewable power generation sources. Therefore, traditional grid does not have sufficient capacity to fulfill the increasing demand for electricity [4]. On the otherside, smart grid and microgrid can be fully equipped with innovative technologies and be able to fulfill the future demand for electricity. Smart grid is a system, combination of innovative sensors, two-way communication system, intelligent electricity supply equipment and completely computerized system. Smart grid and microgrid systems can quickly adapt revolutionary enhancements in economics, reliability, efficiency, and sustainability of different electricity services. The beauty of microgrid and smart grid is that, networked intelligent sensors can be integrated with long-distance transmission lines which can be profited in increasing efficiency, improving operations and synchronizing alternative and even small power sources. By enabling the core functionality of plug-in electric vehicles, renewable sources, micro-grids and of other technologies would make it possible for smart grid to penetrate and integrate with these technologies. Finally, microgrid and smart grid can fulfill the future demand for electricity and the need for power for electric vehicles and electrified roads. Moreover, it is well capable of keeping environmental concerns[4].

Environmental Impacts of Renewable Energy Sources

Here, only two technologies, wind and solar, have been focused.

Wind Power

According to Macintosh et al. [5] producing energy with the wind is one of the lowest environmental impacts of all energy sources. Wind turbines can be installed on agricultural land and it occupies less land area than any of the other sources and technologies use to produce energy and still it is compatible with crops and grazing. It provides clean energy without emitting any gas or pollution during its operation. Klugmann-Radziemska [6] stated that modern turbines are designed to significantly reduced the noise and rotate slowly enough so that they are no hazard to birds. Furthermore, Leventhall [7] mentioned that infrasound and low frequency sound which are emitted by artificial sources (traffic, air conditioning) and by natural sources (wind and rivers) are everywhere in the environment. The modern design of wind turbine blades (upwind instead of downwind) have significantly contributed in reducing the level of infrasound. Health authorities and scientific research have proved that the low level of infrasound which are emitted by wind turbines have no health risks.

It is possible that during the sun set shadow flicker can be created by the wind turbines near residences. However, it can easily be avoided by turning off the turbines for the few minutes of the day when sun is at the angle that causes shadow or place the wind turbines at the suitable place [8]. According to Sovacool [9] a comparative study has been conducted in the United States on avian mortality in which it has been assessed the number of birds killed per kilowatt hour when power is generated through different sources, such as; wind electricity, fossil fuel and nuclear power systems. The study estimates that there is a higher chance of birds striking to wind blades or wind turbine towers but there is also a high mortality rate of birds with electricity produced with fossil fuels as it impacts on the climate change which destroys the habitats that birds depend on.

Solar Power (PV)

As compare to different electricity generating sources and technologies, photovoltaic is been proven a fundamentally safest technology with lower environmental risks. A photovoltaic module produces more electricity over its estimated life than the electricity uses to produce a single unit. A photovoltaic unit is noiseless and pollution free operational system. Almost over two tonnes of CO₂ are prevented with a 100W PV module. However, the substances which are used in photovoltaic cells can be released at the installation site and in the air [6]. The photovoltaic devices are manufactured with the combination of different chemicals and materials. The amount of different types of chemicals varies according to the types of cell being manufactured. The types and the amount of chemicals varies based on the different kinds of cells being manufactured. Furthermore, a research has been done on the six photovoltaic manufacturing companies' "Toxics Release Inventory System" database in the US, it has been found out that the amount of chemicals released to the air is almost negligible which cannot even be reported by the PV manufacturing companies. However, the two chemicals, air stack emission and fugitive air emission have been reported which are released to the air by the photovoltaic services. The air stack emission is used for etching and cleaning reported by all the six photovoltaic companies [10].

The environment is been impacted by the space occupied for the solar PV services. The habitat loss and land degradation issues could be raised if the solar services are provided on the larger scale and the important location is been chosen. These issues can be solved if the solar systems are placed at the lower quality locations such as; transmission corridors or mining land [11].

Cost Analysis

In these days, when fossil fuels are depleting, and the demand of energy is rising day by day, the cost has become a big issue to choose a right source of energy and technology to produce electricity. The figure 1 and figure 2 represents the past and expected price tendencies of wind and solar energy. The curves in the figure 1 and 2 shows that the prices are declining slower than in the past. Moreover, the price differences between solar and wind energies will shrink according to the figures. Thus, the cost of renewable energy can be predicted whereas the prices of fossil fuels are more unpredictable. According to the report of US energy department, each year 5% to 7% of cost on PV systems declined from 1998 to 2011. Furthermore, the prices on PV systems keep declining from 11% to 14% during the period of 2010 to 2011 and it is expected to decline more in the future as well [12].

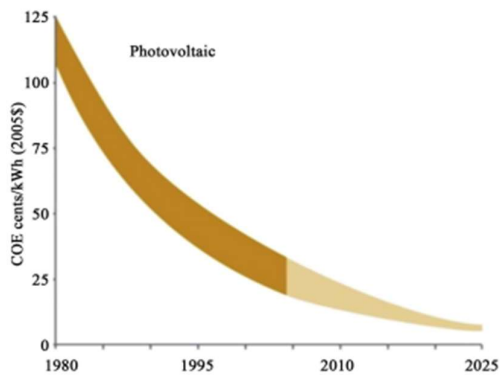


Figure 1: Declining cost of solar energy [13]

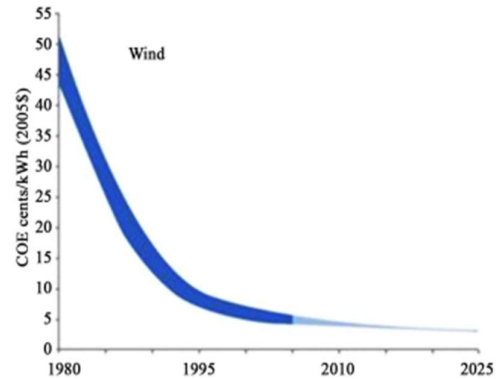


Figure 2: Declining cost of wind energy [13]

Timmons et al. [13] stated that even though the cost of producing energy with renewable energy sources are decreasing but it is too early to say that compare to the price of fossil fuels the price of renewable energy will be lower in the future market. The main cost issues of generating energy with renewable energy resources are the net energy obtained by the renewable energy sources and the discontinuity of the capital intensity. However, the cost of producing energy with wind and solar is lower per capita as once the energy production system is installed then little operating cost is required to produce energy. Therefore Bhatti et al. [14] pointed that to build a renewable energy plant which produces equal amount of energy as a fossil fuel plant requires higher capital investments but operation and distribution of energy is much cheaper than fossil fuels.

Electrifying roads with energy supplied by renewable energy sources is a safe and efficient way for creating emission-free transport system. Therefore, to fully use the potential of renewable energy sources such as solar and wind power, new systems should be developed that enable renewable energy sources to be integrated into the grid systems which is hardly done in today's old technology used by centralized grid systems.

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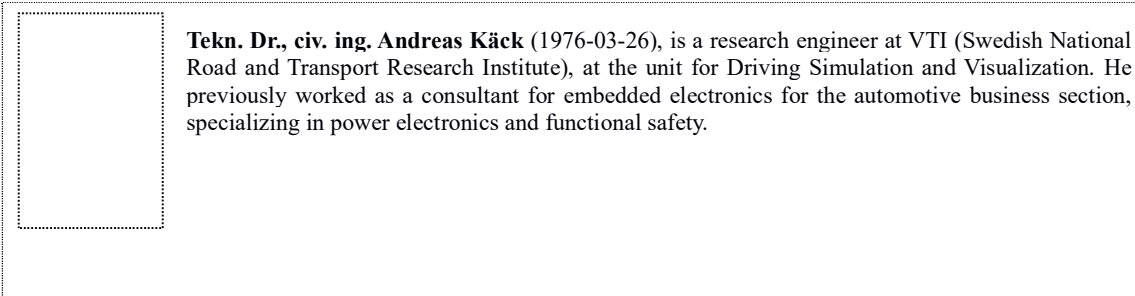


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