DIFFUSION PROSPECTS FOR ELECTRIC VEHICLES, INFRASTRUCTURE REQUIREMENTS AND CO2 IMPLICATIONS: THE CASE OF TURKEY[1]

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Overview

The Turkish Plug-in Electric Vehicles (PEVs) market is currently under its infancy, yet inherits a potential for rapid growth especially with the recent launch of a national car manufacturing project, unveiled to be a range-extended electric sedan. The main intention of this study is to develop an electricity demand and infrastructure projection for PEVs in Turkey for the period 2017-2057, evaluate the electricity sector and CO_2 emission impacts under various diffusion scenarios.

For that purpose, first the electricity demand forecasting of the transport sector has been carried out by taking into consideration official estimates, energy infrastructure needs, sector-specific growth and development expectancies. A survey for end user perceptions towards electric vehicles has also been conducted. Second, the Boğaziçi University Energy Modeling System (BUEMS) is calibrated under various scenarios to evaluate the impact of additional electricity demand on the power generation mix and CO_2 emissions. The diffusion prospect for solar-assisted charging stations is elaborated in particular, based on a GIS analysis depicting cost-minimizing charging station locations.

Model results show that the Turkish transport sector electricity demand grows at an average annual rate of 6.7% without PEVs during the planning horizon, triggered by rail transport, while the introduction of PEVs ramps up the annual growth rate to 17%. The electricity consumption of PEVs exceeds that of trains already by 2027. It is essential to evaluate the rapidly growing domestic demand in terms of investment requirements and CO_2 emissions, and to benchmark against other countries in order to better understand the state of electricity demand, PEVs and charging infrastructure needs.

Methods

i) Survey: Comprises questionnaires with 600 participants (possible end users) and interviews with experts from transport industry to evaluate the diffusion prospects

ii) GIS: Geographical Information Systems (GIS) is an important tool used in facility site selection problems with its ability to present locational and un-locational data together. It is used in the identification of the best locations for solar-assisted charging stations, based on data layers including power transmission lines, population density, solar irradiation potential, existing charging station locations, road infrastructure map and multi-criteria decision support criteria from an AHP analysis

iii) AHP: Analytic Hierarchy Process *(*AHP*)* is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. Using together GIS with multi-criteria decision making has recently become popular for facility site selection studies. As making analyses with GIS, alternatives are weighted with AHP and proper charging station locations are suggested. Determining Criteria's Weight with AHP Criteria comparision is based on the expert interviews.

iv) BUEMS: The Boğaziçi University Energy Modeling System (BUEMS) is a bottom-up modeling framework that includes a partial equilibrium representation of the energy system, describing it in great detail and trying to find the least-cost combination of energy technologies to meet energy demand that restricted by technological availability, the potential of energy sources and emissions. The power and accuracy, suitability of the model for this study comes from

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its sectorally detailed structure featuring an analysis of intersectoral interactions under an extensive and reliable database. The technological database, taken from the United States Environmental Protection Agency EPA, yet includes minor modifications to reflect Turkish conditions. In particular, the impact of additional electricity demand due to EVs on the electricity sector is evaluated using BUEMS with implied changes in the power generation technology mix and resulting CO_2 emissions.

Results

As opposed to the common understanding that the diffusion of PEVs is a sustainable shift, results for Turkey show that there is neither economic nor environmental sustainability under reference assumptions. The lack of economic sustainability is due to the absence of subsidies or tax incentives in the reference case. Under those circumstances the relative cost of PEVs remains higher than oil and gas-based transportation, and cost-minimizing BUEMS does not invest into PEVs. Assuming economic incentives for PEVs and relying on survey results, i.e. expert expectations for the diffusion of PEVs, the environmental sustainability is investigated by comparing CO2 savings in the transport sector with the CO2 increase in the electricity sector due to the additional electricity demand caused by PEVs. As depicted in Figure 1, the increase in emissions remains higher than the savings throughout the planning horizon. This is because the additional electricity demand is predominantly met by coal-fired power generation.

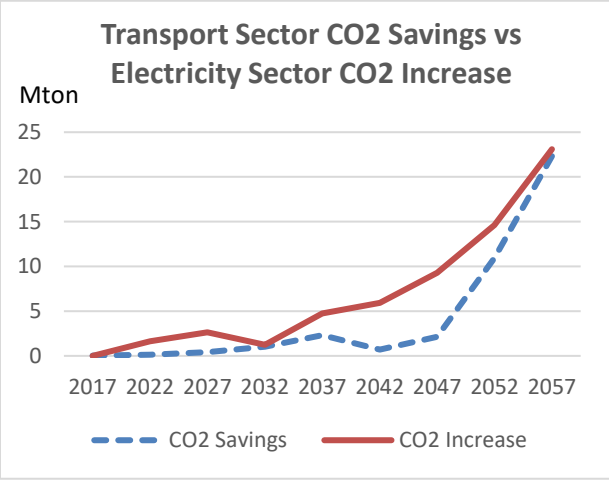

Figure 1. The CO2 Impact of PEVs

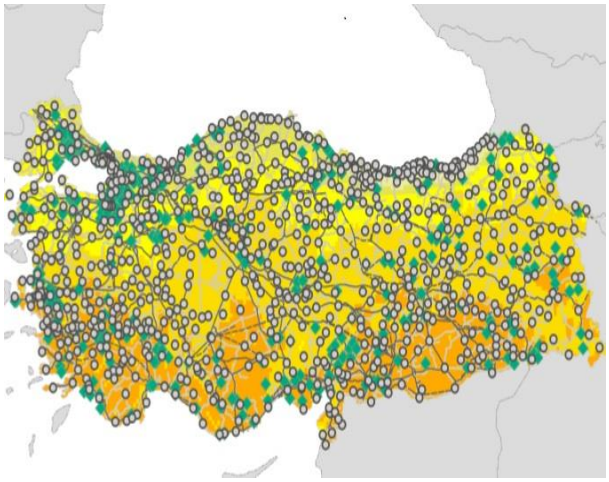
Figure 2. Solar-assisted optimal charging station locations

In order to feature an environmentally sustainable diffusion, the additional electricity demand of PEVs (which reaches 0.6 TWh in 2027, exceeding that of trains) needs to be met by sustainable electricity generation. As such, optimum locations for solar-assisted charging stations are identified by GIS as depicted in Figure 2.

Conclusions

The future penetration of PEVs into personal automobile markets may be heavily influenced by changes in technology and government policies. Many governments have enacted policies encouraging PEV sales, ranging from direct monetary incentives to time-saving measures. The desire to reduce on-road vehicle emissions and lower the carbon intensity of transportation is often cited as the primary motivation for PEV incentives. The diffusion of PEVs reduces indeed petroleum-based fuel consumption. However, the electrification of transport is not necessarily a sustainable move as shown in this study. It needs to be ensured that the electricity generation itself is sustainable.