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Multi-criteria decision analysis of fiscal policies promoting the adoption of electric vehicles

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Abstract

In many countries, electric vehicles provide an opportunity to cut the demand for fossil fuels and GHG emissions. Thus, governments have implemented incentive policies to stimulate the adoption of EVs. In this study, by linking Multi-criteria decision analysis and an energy system model, an evaluation framework of fiscal policies for the adoption of electric vehicles is developed. Primarily, the energy system model for Iceland is applied to compare the impacts of five fiscal policy incentives with BAU until 2050, in terms of government revenue, consumer's vehicle ownership cost, the GHG mitigation potential and energy security. Then, the policy scenarios are compared using the TOPSIS method. According to the estimated performance indexes for policy scenarios, Feebate+Tax scenario receives the highest rank. This ranking is consistent across different normalization norms and objective weights. In the Feebate+Tax scenario, a fee equivalent to 20% of conventional ICEV price is imposed on both petroleum ICEVs and HEVs, while an equivalent rebate value is provided to the purchase price of light-duty BEV and heavy-duty PHEV. In addition, an extra excise duty and a carbon tax are levied on petroleum fuels. The sensitivity of rankings with respect to the effects of different battery characteristics for EVs, is explored. Based on Pareto efficiency, the Feebate+Tax scenario was found to be the only non-dominated option across three objective weights. Thus, the recommendation of Feebate+Tax as the promising policy is unaffected by the variation in the range and cost of batteries.

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Keywords: Multi-Criteria Decision Analysis; Energy System; Fiscal Incentives; Electric Vehicle; TOPSIS method

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1. Introduction

Transportation was responsible for more than 64% of the global oil use in 2014 [1], and for nearly 23% of energy-related GHG emissions [2]. The significant rise of 71% in emissions since 1990 was driven by road transportation, which accounted for three quarters of transportation emissions in 2014 [2]. To cope with these challenges, alternative vehicle technologies including Electric vehicles (EVs) are receiving increasing attentions [3]. Thus, governments employ financial incentives to promote the adoption of EVs [4] in response to barriers such as the high purchase price and access to charging stations [5]. Such incentives include financial incentives (price subsidies, and tax credits), technology support and charging stations [6]. A few recent studies have investigated the efficiency of fiscal policy instruments [7,8]. However, these analyses are unable to suggest a consistent choice among fiscal policies, mainly due to conflicts of interests between consumers, the government, oil companies, automakers and environmentalists

Nomenclature

bbl	barrel	BEV	Battery Electric Vehicle
CRITIC	CRiteria Importance Through Intercriteria Correlation	DM	Decision Maker
EM	Entropy Measure	EV	Electric Vehicle
GHG	Greenhouse Gas	HDV	Heavy-Duty Vehicle
HEV	Hybrid Electric Vehicle	ICEV	Internal Combustion Engine Vehicle
LDV	Light-Duty Vehicle	MCDA	Multi-Criteria Decision Analysis
MW	Mean weight	PHEV	Plug-in Hybrid Electric Vehicle
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution		

Multi-criteria decision analysis (MCDA) provides a systematic methodology for a comprehensive evaluation of fiscal policy instruments. It is an operational assessment and decision support method suitable for addressing issues such as conflicting objectives [9]. Montibeller et al 2007 [10] proposed the combination of Scenario Planning and MCDA to provide decision support in strategic decisions. In the context of transition to alternative fuel vehicles, a multi-criteria evaluation framework was proposed for the choice of alternative fuel/technology options for LDV fleet in a mid-term horizon for Portugal, considering five metrics of user's acceptance, emissions to atmosphere, risk of the technology development, transition costs, and availability of fuel supply [3]. Recently, Onat et al., [11] applied a combined life-cycle sustainability assessment and multi-criteria decision-making framework to identify the optimal U.S. passenger car fleet, by comparing seven vehicle types in terms of sixteen sustainability impacts. Several researchers applied MCDA methods in the context of EV adoption. For example, Zubaryeva et al [12] identified the potential lead markets for EVs within EU27 member states, based on a set of economic, social, environmental, and transport-related factors. A few recent studies utilized MCDA methods to assess the impacts of EV policy measures [6]. However, the selected criteria do not capture the preferences of government and consumers simultaneously. Thus, the aim of this study is to link an Energy System Model (ESM) with MCDA framework, mainly to perform a quantitative assessment of fiscal policies for EV adoption in Iceland, and secondarily, to inform policy makers about the most effective policy measure in increasing the adoption of EVs using four key criteria of government revenue, consumer's vehicle ownership cost, the GHG mitigation potential and energy security.

2. Methodology

The aim of this paper is to link an energy system model and multi-criteria decision to assess the impacts of fiscal policies for EV adoption in Iceland on consumers and government.

2.1. Energy System Model

The integrated energy and transport system in Iceland is analyzed using the UniSyD_IS model as a partial-equilibrium system-dynamics model with a detailed description of energy technologies and vehicle fleets. The model