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Potential impact of transition to a low-carbon transport system in Iceland

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HIGHLIGHTS

- UniSyD_IS is an energy system model with endogenous road transport energy demand.
- Possible transition paths to low-carbon road transport system in Iceland are explored.
- Vehicle choice sector accounts for social influences and consumers' preferences.
- Supply-push costs can be offset by mitigation benefits and fuel cost savings.

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ABSTRACT

This paper develops a system dynamics model of Iceland's energy sector (UniSyD_IS) that is based on the UniSyD_NZ model of New Zealand's energy economy. The model focuses on the energy supply sector with endogenous representation of road transport energy demand. Equilibrium interactions are performed across electricity, hydrogen, biofuels, and road transport sectors. Possible transition paths toward a low-carbon transport in Iceland are explored with implications for fuel demand, greenhouse gas (GHG) emissions and associated costs. The consumer sector simulates the long-term evolution of light and heavy-duty vehicles through a vehicle choice algorithm that accounts for social influences and consumer preferences. Through different scenarios, the influences of four fundamental driving factors are examined. The factors are oil price, carbon tax, fuel supply-push, and government incentives. The results show that changes in travel demand, vehicle technologies, fuel types, and efficiency improvements can support feasible transition paths to achieve sufficient reduction in GHG for both 4 °C and 2 °C climate scenarios of the Nordic Energy Technology Perspectives study. Initial investment in supply infrastructure for alternative fuels will not only mitigate GHG emissions, but also could provide long-term economic benefits through fuel cost saving for consumers and reduced fuel import costs for government.

1. Introduction

Over 85% of total primary energy supply in Iceland is derived from low-carbon renewable resources. Geothermal and hydropower resources are used to generate over 99% of total electricity in the country, and over 90% of all houses are heated with geothermal energy (NEA Energy Statistics, 2013). Electricity and heat prices are relatively low, and given the nature of the energy resources utilized, GHG emissions from the energy supply system are low. Only transportation and the fishing industry still rely on imported fossil fuels. Due to the increase in vehicles-per-capita and in the size of vehicles bought, GHG emissions from road transport have increased by 39% since 1990. Iceland's long-term vision includes deep reductions of net GHG emissions of 50–75% by 2050, from the 1990 level (Ministry for the Environment and Natural Resources, 2007; NORDEN and IEA, 2013). In order to achieve this goal, a deep reduction in GHG emissions from the

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transportation sector is required, yet such reduction is challenging in terms of associated costs, security of energy supply and technological improvement. Transitioning toward a low-carbon sustainable transport system requires successful development, diffusion and adoption of both improved conventional internal combustion engines (ICEs) and alternative fuel vehicles (AFVs). During recent years, a number of efforts have been initiated in Iceland to reduce the share of petroleum products by supporting AFVs such as biogas and electric vehicles. However, the successful transition to a sustainable energy supply system and a low-carbon transport is a complex process and, thus, a robust policy analysis requires comprehensive analytical tools that can integrate various energy and vehicle markets.

To shed light on the transitions toward environmentally friendly technologies, analytical models should be dynamic to represent the temporal and interdependent elements, focus on the transition process to understand how to get to the sustainable system (Welch, 2006) and contain endogenous representation of both supply and demand sides. In recent years, many researchers have been interested in modeling the future viability and diffusion patterns of AFVs using System-Dynamics (Janssen et al., 2006; Struben and Sterman, 2008; Leaver et al., 2009; Meyer and Winebrake, 2009; Leaver and Gillingham, 2010; Park et al., 2011; Shepherd et al., 2012; Shafiei et al., 2013).

Two previous works have addressed the evolution of LDVs in Iceland. The first study used an agent-based framework to study the market share evolution of passenger electric vehicles in Iceland (Shafiei et al., 2012). The second work examined a hybrid agent-based and system-dynamics framework through a simplified test case of Iceland's energy and LDV transport system (Shafiei et al., 2013). No comprehensive study has been conducted to evaluate the interactions between energy markets and AFVs in Iceland. In this study, we use the system dynamics approach to analyze potential development paths of the energy and transportation systems.

The system dynamics model for the Iceland energy system (UniSyD_IS) has been developed using the UniSyD_NZ model of national energy and economic systems created by the Unitec Institute of Technology, New Zealand, in cooperation with Stanford University, USA. UniSyD_NZ is a multi-regional partial equilibrium model, originally developed for New Zealand's energy economy. The model has been used to assess the impacts of alternative vehicle fleet technologies on New Zealand's energy economy (Leaver et al., 2009, 2012a,b; Leaver and Gillingham, 2010).

The UniSyD_IS model has been improved, calibrated, and applied for the Iceland's energy and transport system. In this paper, we focus on the road transport sector to evaluate the possible transition paths toward a low-carbon future in Iceland and implications for fuel demand and associated costs. The impact of climate policies on transitions to a low-carbon transport is assessed, and effective policies to achieve deep cuts in GHG emissions are identified. The application of the UniSyD_IS model has potential to provide important policy insights as it enables policy analysis at both supply and demand sides and can simulate the impact of different policy instruments such as taxes and incentives on both fuels and vehicles. To analyze the transition to a low-carbon transport system, the modeling framework includes changes in travel demand, vehicle technologies, fuel types, and efficiency improvements. Model structure and methodology are presented in Section 2. Section 3 describes the main assumptions and data sources for application of the proposed model in Iceland. Scenarios are defined in Section 4 and then the simulation results are presented in Section 5. Finally, conclusions, discussions, and prospects for future research are provided in Section 6.

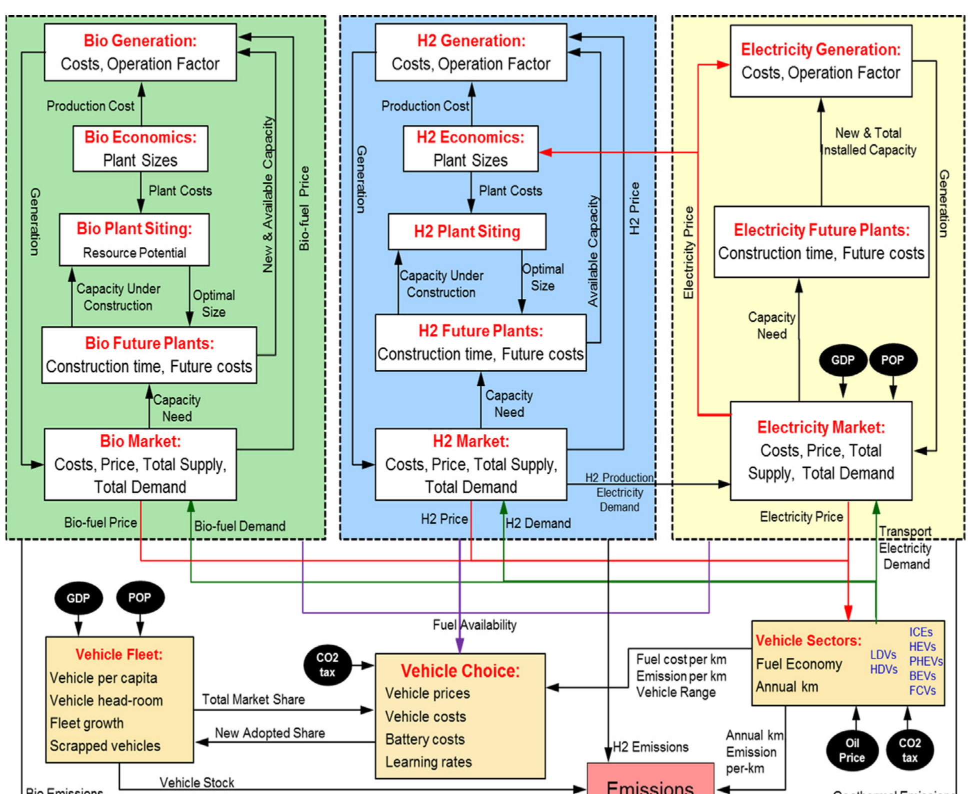

Fig. 1. Overview of UniSyD_IS structure (exogenous drivers are circled).