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Simulation-based appraisal of tax-induced electro-mobility promotion in Iceland and prospects for energy-economic development

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ABSTRACT

Transition to electric vehicles (EVs) requires multidimensional policy measures incorporating vehicle fleets, energy systems, consumer behaviours, and socio-economic developments. The main objective of this paper is to evaluate the implications of a tax-induced EV transition in Iceland for GHG mitigation, energy security, and economic benefits. The analytical tools include a techno-economic simulation model of the integrated energy-transport system which is linked to an Icelandic macroeconomic general equilibrium model. The impact of a new tax reform proposal by the government is compared with the current vehicle tax policy. The government proposal scenario is also examined under further inducements for EVs incorporating a value added tax exemption and banning the sale of new petroleum fuel vehicles. All scenarios are examined under a wide range of future changes in petroleum fuel prices and EV cost reduction. The results indicate that the overall macroeconomic benefits will be negligible, but they are expected to be positive in the long term as road electrification is deepened. The results show that although the tax-induced technological solution aimed at encouraging the adoption of EVs will enable a deep GHG emissions reduction in the long term, it will not be enough to meet the short-term climate targets.

1. Introduction

The Icelandic government has proposed climate policies and action plans to accelerate the transition to a carbon-neutral energy system by 2040 and to participate in the EU Paris Agreement target of greenhouse gas emissions (GHG) cut of 40% by 2030 from 1990 levels (European Commission, 2014). Internal EU mitigation targets are broken into targets for sectors that fall either under the EU ETS system (e.g. energy intensive industries and power plants) or Effort Sharing, which includes e.g. transport. The mitigation targets for ETS sectors are on average 43% compared to 2005 levels, and a maximum 30% for Effort Sharing compared to 2005 levels (European Commission, 2014). Both the Paris agreement target and the internal EU targets call for a systemic change within the integrated energy and transport sectors. Since the road transport sector can considerably contribute to achieve these targets, the government aims for a 30% share of renewable fuels in the road transport by 2030. Abundant renewable energy resources with low electricity production costs make an electro-mobility transition a viable step towards the above goals. The role of electric vehicles (EVs) will be more important in a longer-term perspective as the government has also presented a climate action plan imposing a ban on the new registration of diesel and gasoline vehicles beyond 2030 (Ministry of Environment and Natural Resources, 2018).

Electro-mobility has been recognized as a significant part of future transportation in many countries with substantial incentives aimed at supporting its market growth (Harvey, 2018). In Iceland, the adoption of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) has risen over the last few years. Fig. 1 shows that the share of newly registered EVs (BEVs and PHEVs) that accounted for over 10% of the total number of new cars sold in 2017. Nevertheless, it takes a long time for older vehicles being discarded from the fleet and replaced by new EVs. Fig. 1 shows that the share of EVs within the total vehicle stock has risen in recent years, but it was only around 2% by 2017.

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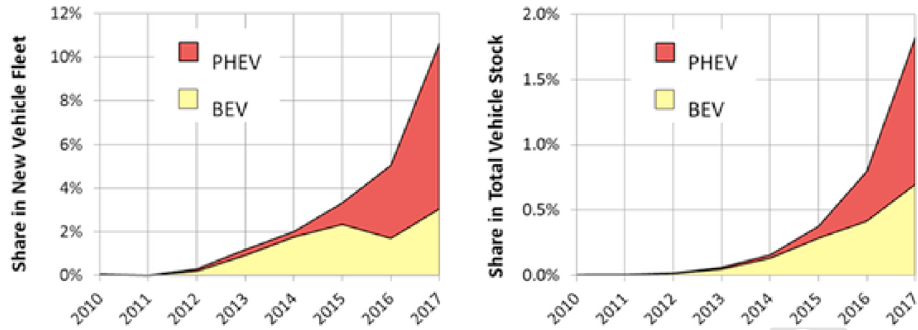

Fig. 1. Historical share of EVs within new registered (left) and total stock (right) of light vehicles during 2010–2017, data from (Icelandic Transport Authority, 2018).

Along with the rising affinity with EVs in Iceland, the number of public recharging stations has increased in recent years. The spread of charging stations will have a crucial influence on the attractiveness of EVs for local residents as well as tourists travelling across the country. Currently, over 99% of electricity in Iceland is produced by renewable energy resources with abundant utilization potential and competitive development costs. For this reason, the expected benefit from a transition to EVs could be remarkable in terms of GHG mitigation, enhanced energy security, and stable energy prices for Iceland (Shafiei et al., 2015). However, transition drivers such as fiscal incentives, initial investments, and regulatory-push strategies could be initially costly but with long-term implications for energy-economic systems. Specific consideration must be given to the best way of dealing with technological improvement and international energy indicators to choose the policy actions that ensure long-term economic and environmental benefits. In addition, a systemic change within the integrated energy-transport sector and transition to a sustainable mobility is a long-term process and requires co-evolutionary developments of multiple dimensions (Geels, 2012; Köhler et al., 2009). It calls for multidimensional policy measures that involve vehicle fleets, energy systems, consumer behaviours and socio-economic developments. It is also important to formulate and implement effective and efficient policies at the right time.

While several energy-system studies have been carried out on the potential impact of transition to EVs in Iceland (e.g. Shafiei et al., 2018, 2017a, b, 2015, 2014) only one previous study by (Shafiei et al., 2018) has assessed the implications of different fiscal incentives for consumer costs and government revenues. The fiscal incentives in this previous research were defined based on the current transport tax scheme in Iceland. The contribution of the present study compared to (Shafiei et al., 2018) is twofold. Firstly, the present study evaluates some realistic scenarios and action plans for future. A government committee has recently proposed a revision of taxation on vehicles and fuels (Ministry of Finance and Economic Affairs (2018)) with the aim of encouraging consumers to choose environmentally friendly vehicles as well as securing tax revenues. The proposed tax reform tightens the existing limits on emission levels for the formulation of excise duty tax on vehicles with value-added tax (VAT) being equally imposed on all vehicle types. This newly proposed vehicle tax reform will be combined with regulations banning petroleum fuels as well as VAT exemptions for BEVs. Furthermore, it will be evaluated in different conditions taking into account a range of variations in the future trend of EV costs, international oil price, and fuel taxes. The second contribution pertains to the scope of transition consequences and the used analytical tools. Compared to (Shafiei et al., 2018), which has focused on consumer and government costs, the present analysis gives a comprehensive picture of the macroeconomic impact of EV transition scenarios by linking an integrated energy-transport system model to a macroeconomic model. Therefore, the implications of vehicle tax reform for the electrification of road transport, GHG mitigation, fuel import cost, government and consumer benefits, economic growth, unemployment, inflation, and interest rates can be evaluated.

The structure of the paper is as follows. In Section 2, the analytical tools and modelling framework are briefly introduced. In Section 3, the vehicle and fuel tax structure in Iceland is explained. In Section 4, the main assumptions and scenarios to support EVs are defined. In Section 5, the results of scenario analysis and policy assessments are discussed. Finally, in Section 6, the conclusions and policy implications are presented.

2. Analytical tools

The analytical tools include two components as shown in Fig. 2. This figure shows that consumer costs on vehicle purchase and usage, government tax revenue from the road transport sector, domestic fuel supply cost, and total import costs for vehicles and fuels are derived from the simulation results of a system-dynamics model that covers transportation and the energy system in Iceland. The results are then transferred to a macroeconomic model to assess the macroeconomic consequences of electro-mobility transition. The total consumer cost, which is evaluated using a bottom-up approach by incorporating detailed vehicle and fuel data, includes vehicle ownership costs and the respective tax components. To inform the macroeconomic model, which deals with costs exclusive of taxes, the total government revenue is deducted from the total consumer cost. In this study, a unidirectional impact of EV transition on the macro-economic indicators is assumed. Hence, the possible effects of GDP or unemployment on consumer costs or tax revenues have not been considered.

2.1. Integrated energy-transport model

The integrated energy-transport system model for Iceland (UniSyD_IS), which has been developed using the system-dynamics simulation approach, is used for the analysis of transition towards EVs. The UniSyD_IS model enables us to simulate the impact of road transport tax schemes on electro-mobility promotion during 2018–2050.

The model simulates the evolution of vehicle fleets considering the interactions among fuel supply, recharging infrastructure, energy market dynamics, and road transport fuel demand. The model simulates the energy market by incorporating renewable energy resources and technologies (geothermal, hydro, and wind), and a detailed classification of vehicles at the demand side. In modelling future development of the road transport sector, changes in travel distance, vehicle fleet mix, and fuel demand mix are evaluated. Light-duty and heavy-duty vehicles are modelled separately. Light vehicles weigh less than 3.5 tonnes with an average weight of 1.4 tonnes and the engine power of 90 kW. Heavy-duty vehicles are assumed to weigh more than 3.5 tonnes with an average weight of 9 tonnes and an average engine power of 375 kW (Shafiei et al., 2018). The powertrain technologies within both fleets are: internal combustion engine (ICE), hybrid electric (HEV), plug-in hybrid electric (PHEV), and battery electric vehicles (BEV). The vehicle stock for each light and heavy fleet grows over time in accordance with the growth rates of population and vehicle-per-capita. The vehicle-per-capita indicator is assumed to asymptotically approach a saturation

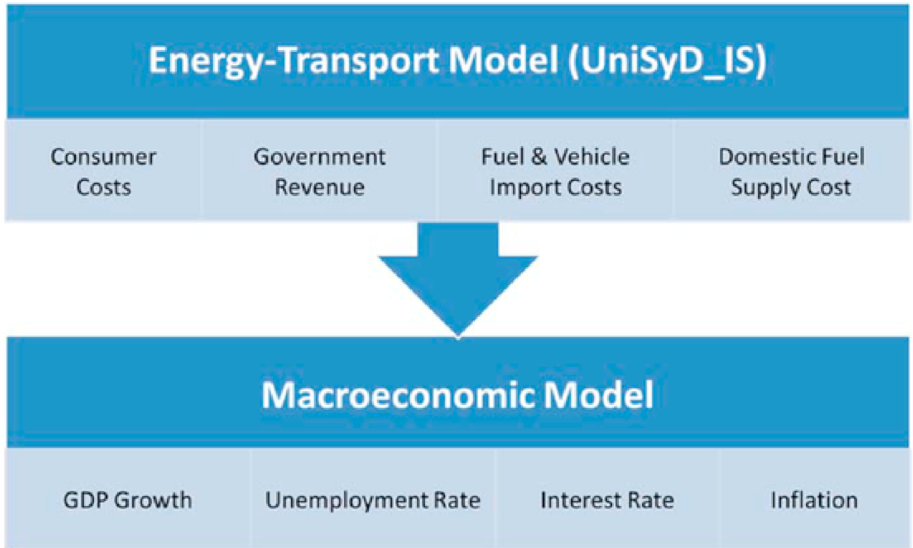

Fig. 2. Set of models for the assessment of electro-mobility transition.

level for each fleet (Shafiei et al., 2014). Once the future fleet size is determined, the model allocates these changes among different vehicle technologies. The allocation is based on a Multinomial Logit (MNL) framework, which determines the market share evolution of different vehicles based on consumer utility function. It considers both tangible costs including vehicle purchase price ($), fuel cost ($/km), annual maintenance cost ($/year), and battery replacement cost for electric vehicles ($), as well as intangible costs such as vehicle driving range (km), and refuelling/recharging service availability. For more details on the UniSyD model structure see (Shafiei et al., 2015, 2017b, 2016).

A synthetic consumer utility function is assumed in which its coefficients are calibrated using basic economic assumptions (Greene, 2001; Meyer and Winebrake, 2009). In this context, the vehicle purchase price coefficient is calibrated using the real elasticity data for vehicle demand in Iceland. The purchase price coefficient is then used as a scaling factor for the estimation of the other utility coefficients (Shafiei et al., 2014).

The main important input data to the model includes techno-economic characteristics of the fuel supply system, vehicle attributes (such as costs, fuel economies, range), vehicle and travel demand elasticities, vehicle-per-capita growth, fuel and vehicle tax rates, carbon tax, and international oil price. The main model outputs include the market share evolution of vehicles, fuel demand mix, GHG emissions, consumers' vehicle ownership costs, government tax revenue, energy supply cost, and import cost of vehicles and fuels.

2.2. Macroeconomic model

The model is a dynamic general equilibrium model consisting of households, firms, a government, a central bank and a foreign sector. The households own the capital stock and lend capital and labour to firms receiving rent and wage income. The households use their income to buy domestic and foreign (imported) consumption goods, to invest in the capital stock (buy domestic and foreign investment goods) as well as buying domestic and foreign bonds, from which they receive interest income. Households' savings consist of their purchases of investment goods and bonds. The firms use capital and labour to produce consumption and investment goods sold to domestic and foreign (exports) households. The firms decide on the prices of their products by taking into account demand for their goods in the domestic and foreign markets, i.e. monopolistic competition in goods markets is assumed. The government collects lump-sum tax from households and uses its tax income to purchase domestic and foreign goods for public consumption. The central bank decides on domestic interest rates taking inflation and output gap in the economy into consideration, i.e. it is assumed to base its decisions on the so-called Taylor rule.

Parameter values in the model are obtained directly or modified from (Seneca, 2010), where the parameters of the dynamic stochastic general equilibrium (DSGE) model for Iceland are estimated using quarterly Icelandic data for 1991–2005. The model is simulated using exogenous paths for consumer costs (affecting private consumption), government revenue (affecting taxes collected from households) and import costs (affecting imports) in 2018–2050. Since the model assumes a balanced government budget, an increase (decrease) in government revenue is assumed to decrease (increase) annuitized taxes collected from households.

Output from the UniSyD model, including consumer cost, government revenue, import cost of vehicles and fuels, and domestic fuel supply cost is fed to the macroeconomic model to reveal the macroeconomic impact of electrifying the vehicle fleet. The macroeconomic output variables are unemployment, interest rates, inflation and economic growth.

3. Vehicle and fuel tax structure in Iceland

Vehicle, road, and fuel taxes are key sources of revenue for governments, however, there are wide differences between the tax rates and fees related to the registration, ownership and use of vehicles across European countries (Dvir and Strasser, 2018; Gerlagh et al., 2018). The main purpose of the current analysis is to compare the impact of the new tax reform proposal by the Icelandic government with the current regulations on vehicle and fuel taxes.

Taxes on vehicles include excise duty, value added taxes (VAT), and annual road tax. Currently, the VAT rate is 24% for all conventional vehicles in Iceland. Since 2012, there has been a discount on the VAT for BEVs and PHEVs (Alþingi, 2016), which are to expire in 2021. Hence, for simplicity, we assume a simple equal VAT rate of 24% for all vehicles in both current and new tax reform proposal during the study period. The main changes, however, are in the excise duty and weight tax rates. The excise duty on light vehicles is currently based on CO_2 emissions declared by car manufacturers for combination of city and road driving. Fig. 3 compares the excise tax rates for light vehicles in the current and in the new tax reform proposal (Alþingi, 2010; Ministry of Finance and Economic Affairs, 2018). Considering the current structure of excise tax in Iceland, BEVs are exempted from excise tax. The structure of excise duty tax is different for heavy-duty vehicles.

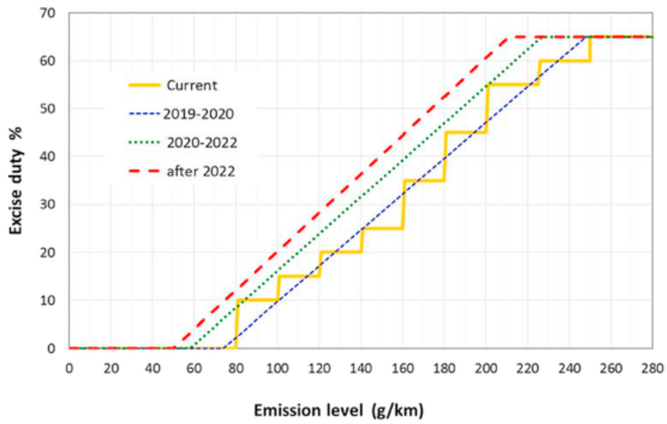

Fig. 3. Comparison of the excise tax rate in the current and the new tax reform proposal based on registered CO2 emissions for light vehicles (Alþingi, 2010; Ministry of Finance and Economic Affairs, 2018).

Based on the heavy fleet composition, the average excise duty of 0.5% is assumed for heavy-duty vehicles (Shafiei et al., 2018).

The annual vehicle road tax includes weight tax, distance tax, and disposal tax components. In the current vehicle tax policy, the weight tax for vehicles, with a total weight of 3.5 tonne or less, is ISK 11,620 (about \$110) per year for the release of up to 121 g-CO_2/km, and ISK 278 (or \$2.6) per gram of excess CO_2. Considering the registered CO_2 emissions for BEVs, their owners only need to pay the minimum road tax (Alþingi, 2016). However, according to the new tax reform proposal, the weight tax will increase up to ISK 36,000 (\$340) per year in 2023 for all light vehicles. For heavy vehicles, with the weight exceeding 3.5 tonne, the weight tax is linearly related to the vehicle weight. Considering the average weight of heavy vehicle fleet, the weight tax is estimated to be ISK 134,360 (\$1268) per year. Based on the new tax reform proposal, the weight tax for heavy vehicles will slightly increase to ISK 137,090 (\$1293) per year.

The distance tax, which depends on the weight and the annual distances travelled, is applied only to the heavy vehicles with a weight of 10 tonne or more (Article 13 - Alþingi, 2004). Based on the heavy vehicle fleet composition in Iceland, a simplified distance tax will be estimated as 0.74 × annual distance travelled in ISK currency (Shafiei et al., 2018). This term will remain unchanged in the new tax reform proposal. A disposal charge of ISK 700 (\$6.6) per year is added to the above values (Alþingi, 2002), in both current and new tax reform proposal, to form the total annual road tax. Table 1 briefly summarizes the comparison between the vehicle tax rates in the current and in the new tax reform proposal.

The prices of gasoline and diesel fuel in Iceland have three taxes components: excise duty tax, VAT and carbon tax charge. The excise duty taxes on gasoline and diesel fuels are \$0.67/litre and \$0.58/litre, respectively (Alþingi, 2016). A VAT rate of 24% is applied to all fuels including electricity (Alþingi, 2014). The average carbon tax on gasoline and diesel fuels is around \$40/tonne-CO2eq (Ministry of Finance and Economic Affairs, 2018).

4. Scenarios and assumptions

In order to evaluate the current and the alternative proposed tax policies for the support of electro-mobility transition in Iceland, four scenarios are compared, as explained in Table 2. The BAU scenario reflects the vehicle and fuel tax policies that are currently in place in the country. The BAU scenario is based on the extension of current regulations on vehicle and fuel taxes, which are assumed to remain unchanged until the year 2050. In this scenario, the VAT and excise duties on vehicles and fuels are implemented according to the assumptions presented in Section 3.

The Proposal scenario reflects a simplified structure of a new tax scheme proposed by the Ministry of Finance and Economic Affairs, 2018. For simplicity, some temporary and conditional VAT rates until 2020 are ignored in both BAU and Proposal scenarios and, as shown in Table 1, an equal VAT rate is assumed for all vehicles from the beginning of the study period. The Premium scenario incorporates further incentives to Proposal in terms of VAT exemptions for the purchase price of BEVs within both light and heavy vehicle fleets beyond 2020.

In the Banning scenario, the proposal tax scheme is evaluated under a banning condition in which the new purchase of ICEs and HEVs (with petrol or diesel fuels) will not be permitted from 2030 onward. Namely, only the purchase of PHEVs and BEVs will be allowed after 2030. Such a banning regulation has been proposed in a government climate action plan (Ministry of Environment and Natural Resources, 2018).

Other important factors that influence the adoption of EVs include the manufacturer's suggested retail price (MSRP) of vehicles, oil price, carbon tax, and petroleum fuel excise duties. To incorporate uncertainties in the future trend of these parameters, each scenario is investigated under three conditions: i) Low case, ii) Medium case, and iii) High case. The High case, as the most optimistic case, motivates the consumers to adopt EVs. Conversely, the Low case reflects discouraging conditions for the uptake of EVs. The Medium case will be in between representing moderate changes in the value of parameters. Fig. 4 shows the structure of scenario tree. The assumptions for the definition of each case are presented in the following sections.

4.1. Vehicle purchase cost

The MSRP of BEVs has been falling in recent years and it is expected to reach that of conventional ICE vehicles in the near future (IEA, 2017; McKinsey & Company, 2017; Nykvist and Nilsson, 2015; Soulopoulos, 2017).

The key capital cost component of EVs is the cost of battery, which is calculated based on the required battery size and driving range. The

Table 1
Comparison of the current and proposed tax structure for vehicles (Alþingi, 2016, 2010; Ministry of Finance and Economic Affairs, 2018; Shafiei et al., 2018).

Type of tax	Unit	Current tax regulation		New tax reform proposal	
		Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
Excise duty	% of import price	Stepwise increase according to Fig. 3	0.5%	Linear increase according to Fig. 3	0.5%
VAT	% of total price including excise tax	24%	24%	24%	24%
Road tax	ISK/year (1 USD = 106 ISK)	12,320 + 278*(g/km-121)	135,060 + 0.74*annual km	until 2019: 12,550 + 284*(g/km-121) 2019–2021: 12,550 + 178*(g/km-61) 2021–2023: 24,700 + 96*(g/km-51) after 2023: 36,700	137,790 + 0.74*annual km

Table 2
Definition of scenarios.

Scenarios	Tax on fuels & vehicle use	Tax on vehicle purchase
BAU	Current fuel & vehicle usage tax	Equal VAT rates + current excise duty
Proposal	New tax proposal assumptions	New tax proposal assumptions
Premium	New tax proposal assumptions	New tax proposal assumptions + VAT exemption for light & heavy BEVs after 2020
Banning	New tax proposal assumptions	Ban on the new sales of ICE and HEV from 2030

assumptions on the specific battery cost for Low, Medium and High cases are presented in Fig. 5. Battery cost assumptions are based on data in (IEA, 2017; McKinsey & Company, 2017; Soulopoulos, 2017; Witkamp et al., 2017) with minor modifications. The floor battery cost of 78 $/kWh was calculated in a manner that the MSRP of a BEV with a 300-km driving range gets equal to the average MSRP of a conventional petroleum ICE vehicle. According to Fig. 5, different battery cost reduction rates are assumed so that the MSRP parity can be achieved at 2025 (rapid reduction in the High case), 2030 (moderate reduction in the Medium case), or 2035 (slow reduction in the Low case).

Based on the estimates by (Soulopoulos, 2017), it is assumed that the battery capacity requirement will drop up to 15% by the parity year. It means that a typical light BEV with a driving range of 300 km will need a battery size of 51 kWh by the parity year, down from 60 kWh in 2017. Such technology improvements will lead to an increase in the fuel economy of EVs.

Fig. 6 compares the MSRP of vehicles (i.e. import cost of vehicles before tax) with the estimated purchase price of vehicles (after applying the tax structure) in different cases and scenarios. The figure reflects the effects of exogenous improvements in vehicles' capital cost as well as the effects of fuel economy improvements on vehicle prices through emission-differentiated excise duty rates as explained in Section 3. The fuel economies of non-EVs are assumed to increase until 2030 in accordance with the assumption on EVs' fuel economy growth by the parity year.

MSRP as the average imported price of $25k/vehicle is assumed for light conventional petrol and diesel ICE vehicles (IEA, 2018). Average imported price of BEVs is calculated as the sum of non-battery and battery costs. The initial cost of $23k is assumed for the non-battery cost component (Soulopoulos, 2017), which is decreased to the floor cost of $21k by the respective parity year in different cases. Battery cost component is calculated based on battery size requirement (kWh) and specific battery cost ($/kWh) in different scenarios. All price and cost values are in constant US$ at 2017 prices.

4.2. International oil price

The initial international oil price is assumed to be $60/bbl. On the basis of scenario assumptions made by (U.S. Energy Information Administration, 2018) and (IEA, 2016), three cases of future oil prices are considered. Some own modifications are made to present simple but distinctive trends for the future oil prices as follows:

i) Low case: constant oil price of $60/bbl over the study horizon.
ii) Medium case: oil price increase from $60/bbl in 2017 to $115/bbl by 2050 (assuming a constant annual growth rate)
iii) High case: oil price increase from $60/bbl in 2017 to $160/bbl by 2050 (assuming a constant annual growth rate)

4.3. Carbon tax

The initial carbon tax in 2018 is $40/bbl. Three cases of future carbon tax values are proposed in the analysis to evaluate its impact on energy-economic indicators:

i) Low case: constant carbon tax of $40/tCO2-eq over the study horizon
ii) Medium case: carbon tax increase from $40/tCO2-eq in 2018 to $100/tCO2-eq by 2050 (assuming a constant annual growth rate)
iii) High case: carbon tax increase from $40/tCO2-eq in 2018 to $200/tCO2-eq by 2050 (assuming a constant annual growth rate)

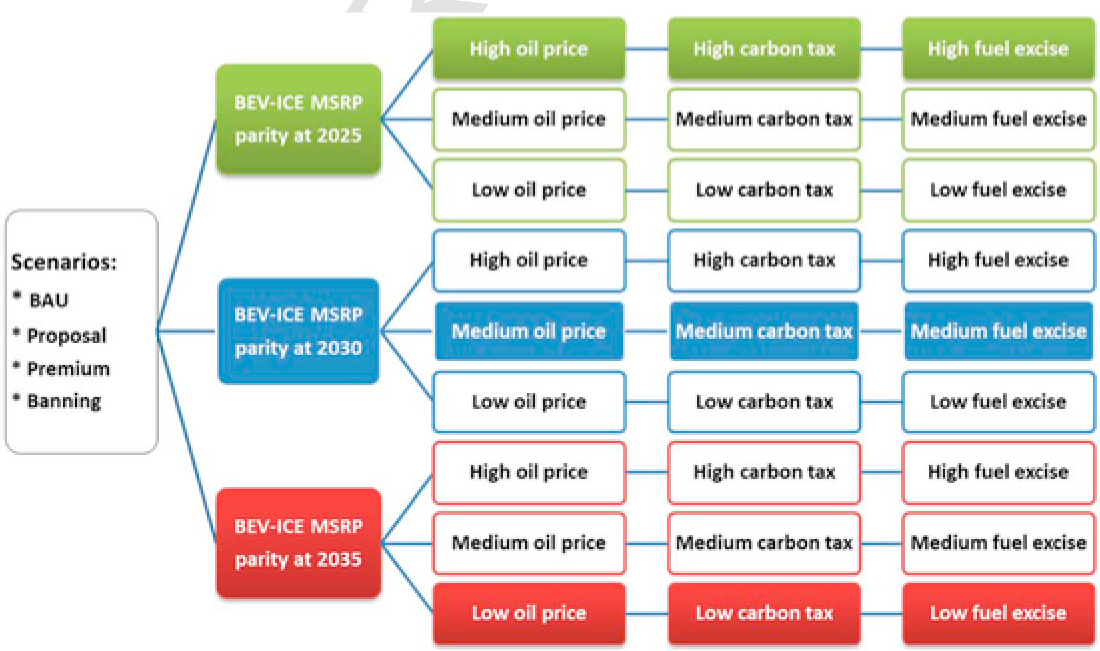

Fig. 4. Structure of scenario tree.

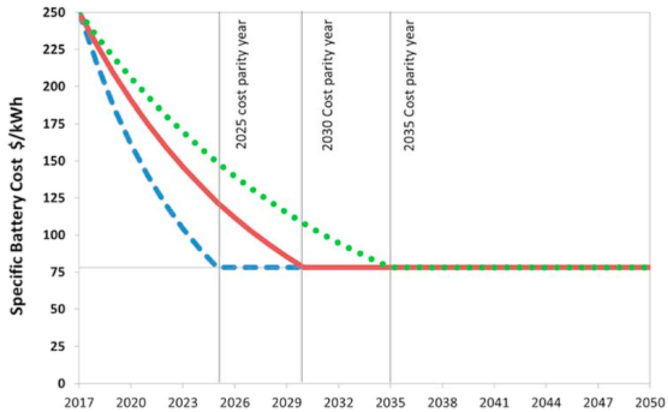

Fig. 5. Assumptions on specific battery cost over time in different cases, based on data in (IEA, 2017; McKinsey & Company, 2017; Soulopoulos, 2017; Witkamp et al., 2017) with minor modifications.

4.4. Petroleum fuel excise duty tax

The initial excise duty values for gasoline and diesel fuels are 0.67 and 0.58 $/litre (in 2017 prices), respectively. Three cases of future fuel excise duties are proposed in the analysis to evaluate their impact on energy-economic indicators:

i) Low case: constant values over time
ii) Medium case: annually increase to achieve a 50% growth by 2050 compared to 2018
iii) High case: annually increase to achieve a 100% growth by 2050 compared to 2018

5. Simulation results

5.1. Market penetration of EVs

Fig. 7 shows the share of light BEVs within both vehicle stock and new registered vehicle fleets. The corresponding results for the share of light EVs (including both BEVs and PHEVs) are presented in Fig. 8. For each scenario, the upper boundaries of the coloured area charts represent the High case condition as defined in Fig. 4 (i.e. high oil prices, high carbon tax, high fuel excise tax, and the MSRP parity year of 2025). The lower boundaries represent the Low case condition with low oil prices, low carbon tax, low fuel excise tax, and the MSRP parity year of 2035.

Despite the rapid growth in the sale of EVs within the new registered vehicles, it takes a longer time to see the effects on the total vehicle stock. The replacement of current vehicles with new EVs will be a slow process as an average vehicle life-time of 15 years is assumed.

The results indicate that the market share of EVs in the Proposal scenario is just slightly higher than that of BAU because higher excise duty rates are imposed on petroleum fuel vehicles. The Premium scenario has advantage over the Proposal scenario in the promotion of BEVs. When BEVs are exempted from VAT in the Premium scenario, their market share goes up to 40–58% by 2050. Although the transition processes and market growth patterns are quite different in the Premium and Banning scenarios, however, they give almost a similar market share condition for BEV in 2050. Nevertheless, a significant difference is expected for the share of EVs (i.e. BEV + PHEV) after 2030. In the Banning scenario, every new adopted vehicle will be either BEV or PHEV, leading to the EVs' market share of 85% by 2050. The reason the EVs cannot take the entire market share after 2045 in the Banning scenario is that the vehicle retirement is modelled based on an exponential decay distribution function with the mean life-time of 15 years.

Since the tax inducements in BAU, Proposal and Banning scenarios are mostly focused on light vehicles, the changes in the market share of BEVs and EVs within the heavy vehicle fleet will be similar in these scenarios, rising up to the maximum values of 8% and 34%, respectively by 2050. In the Premium scenario, due to the VAT exemption in-

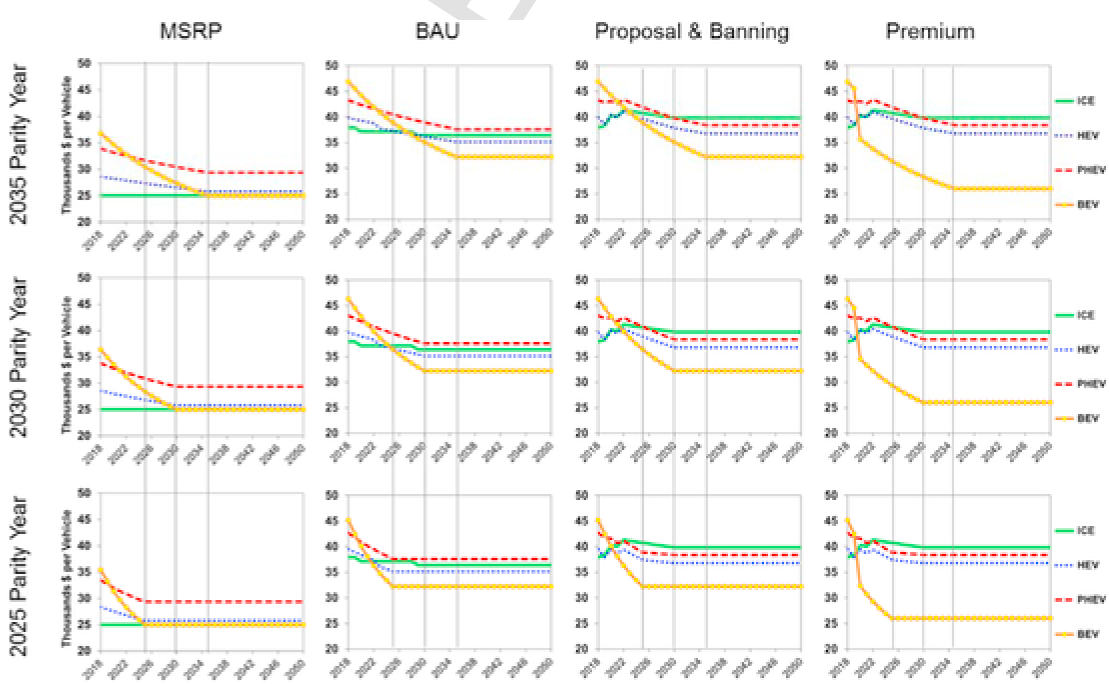

Fig. 6. Comparison of manufacturer's suggested retail price (MSRP) and consumer purchase price of vehicles in different scenarios during 2018–2050, assuming electric range of 300 km for BEV and 40 km for PHEV.

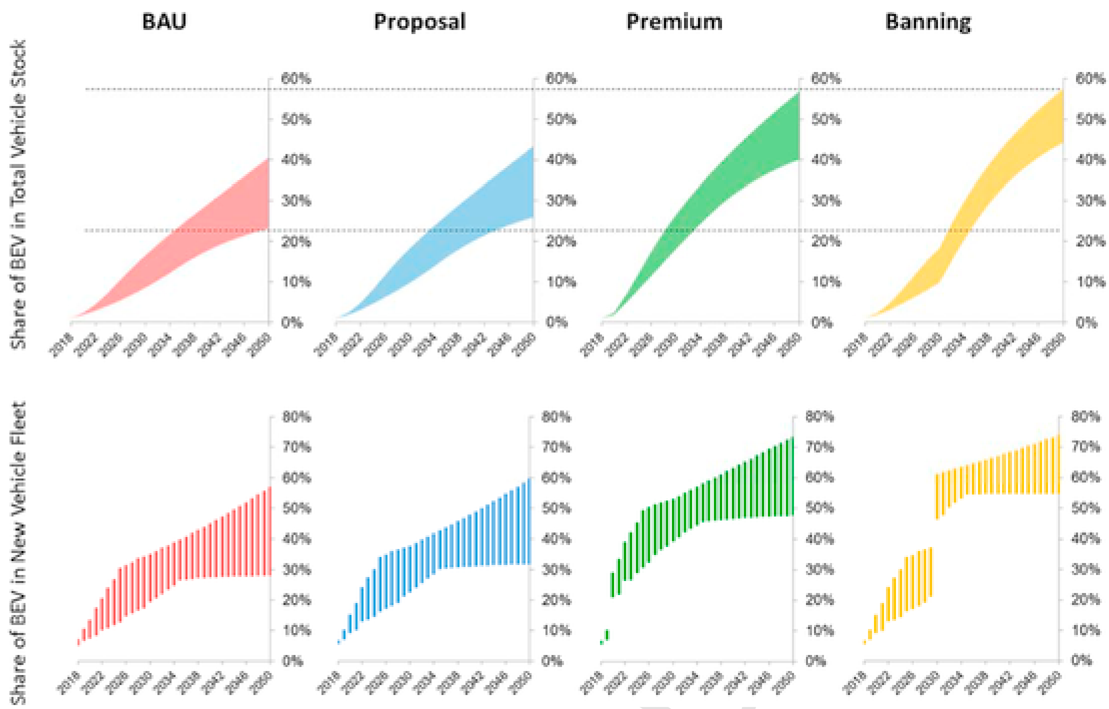

Fig. 7. Share of light BEV in vehicle stock (top) and new adopted vehicle fleet (bottom).

Fig. 8. Share of light EVs (i.e. BEV + PHEV) in vehicle stock (top) and new adopted vehicle fleet (bottom).

centives, the maximum share of BEVs and EVs within heavy vehicles can reach to 18% and 40%, respectively by 2050.

5.2. Share of renewable fuel

Changes in the composition of vehicle fleets influence the fuel demand mix. The current petroleum fuel demand in the road transport sector is around 13 PJ. The uptake of EVs within both light and heavy vehicles along with the use of more fuel-efficient vehicles such as HEVs reduce the use of petroleum fuels by 28–57% in BAU, 30–58% in Proposal, 37–64% in Premium, and 42–63% in Banning by 2050. With the increased utilization of EVs, the electricity demand for the road transport sector will increase from about 18 GWh in 2018 up to 297–438 GWh in BAU, 323–461 GWh in Proposal, 432–588 GWh in Premium, 532–596 GWh in Banning by 2050.

Fig. 9 shows the share of electricity in fuel demand mix. This share in the Banning scenario will be the highest, going up to 20–30% of total road transport fuel demand by 2050, corresponding to 36–50% for light vehicles' fuel demand. Looking at 2030, the share of renewable electricity in total fuel demand will range from 4% to 10%, based on

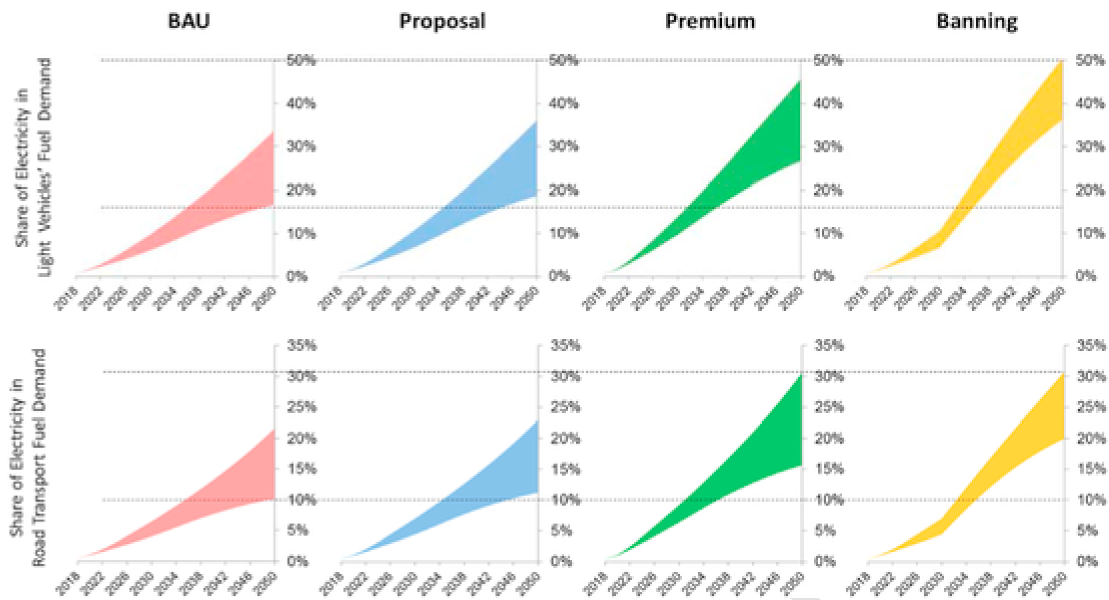

Fig. 9. Share of electricity in light vehicles' (top) and total road transport (bottom) fuel demand.

different scenarios and cases. From the light vehicles' perspective, this share will be between 6 and 14%. If the multiplier factor of 2.5, suggested by the Renewable Energy Directive (European Parliament, 2009), is assumed for the renewable electricity consumed by EVs, the highest share of renewable fuels in total road transport will be 25% by 2030, which is still less than the national target of 30%.

5.3. GHG mitigation

The reduction in petroleum fuel use and the rising contribution of electricity in fuel demand, as discussed in section 5.2, will affect GHG mitigation from the transport sector. Fig. 10 compares different scenarios in terms of GHG emissions. Assuming the most discouraging condition (i.e. the Low case defined in Fig. 4), all scenarios can reach the 2005 emission level only after 2030. In this condition, the Banning scenario with the highest mitigation potential can approach the 1990 emissions level by 2050. Assuming the most encouraging condition (i.e. the High case defined in Fig. 4), both Premium and Banning scenarios lead to the highest mitigation potential of 34% below the 1990 level by 2050. The corresponding values in 2030 will be 28% and 33% above 1990 level in Premium and Banning, respectively. In case of discouraging condition for EV promotion (i.e. low petroleum fuel prices and slow battery cost reduction), the cumulative GHG emissions in the Banning scenario will be slightly lower than in Premium. However, by assuming more encouraging conditions (i.e. higher petroleum fuel prices and more rapid battery cost reduction), the cumulative GHG emissions of Banning will be higher than Premium.

The potential for GHG emissions reduction during 2018–2050 will be 28–57% in BAU, 30–58% in Proposal, 37–64% in Premium, and 42–63% in Banning. Looking at 2030, the mitigation level will be 14–26% in BAU, 14–27% in Proposal, 17–30% in Premium, and 14–27% in Banning. Because of the slow growth of EVs within heavy vehicle fleets, the emissions reduction for the light vehicle fleet will be much faster than in total transport sector. For example, assuming the encouraging High case condition, a mitigation level of close to 80% by 2050 will be possible for the light vehicle fleet in the Premium and Banning scenarios.

5.4. Fuel and vehicle import cost

In the analysis of policies supporting the transition to EVs, it is important to evaluate the changes in the import cost of petroleum fuels. Fig. 11 shows that in the Low case, which assumes a constant oil price over the study period, the cost value of imported fuels is significantly reduced in all scenarios. For the Medium and High cases, however, only the Premium and Banning policies can reduce the fuel import cost. It should be noted that the expansion of fleet size over time (i.e. the number of vehicles) is an influential factor in determining the fuel import costs. The assumed increasing vehicle-per-capita along with the population growth in the model lead to 35% growth in the size of vehicle fleets by 2050. Decoupling the fuel import cost from the fleet size effect will result in declining patterns for all cases.

Fig. 11 (bottom row) also shows the changes in overall fuel and vehicle import costs. Since the scenarios in the current analysis have re-

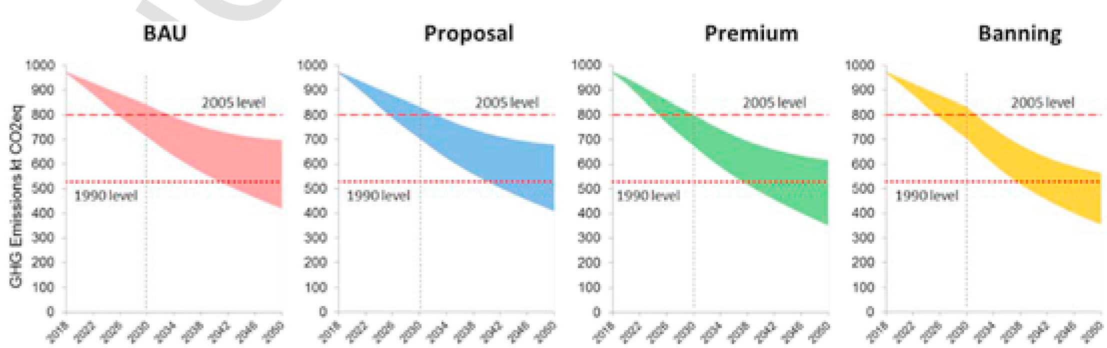

Fig. 10. GHG emissions reduction in the road transport sector (i.e. tank-to-wheels emissions from light- and heavy-duty vehicles).

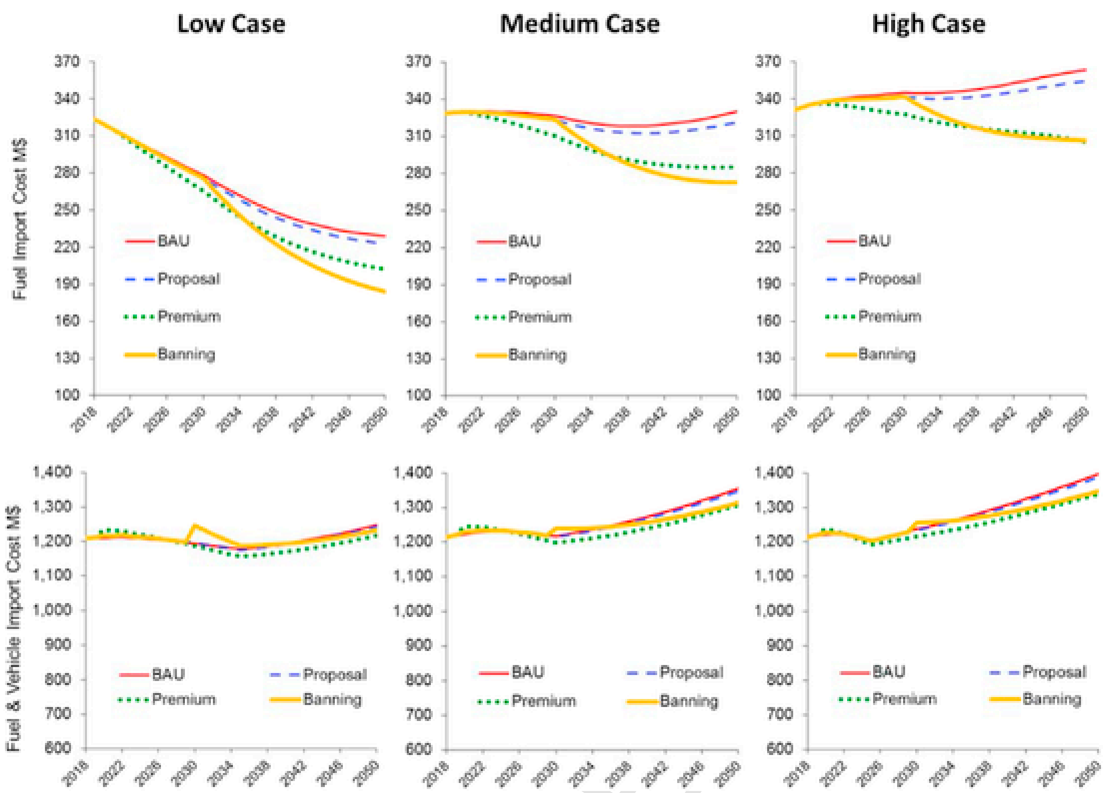

Fig. 11. Comparison of fuel and vehicle import costs in different scenarios and cases.

lied on MSRP parity assumptions (see Section 4.1), the results do not show notable differences between vehicle import costs, particularly after the parity years. Therefore, due to the effect of fuel import cost component, the Premium and Banning scenarios lead to the lower cost values for the overall fuel and vehicle imports in the long term.

5.5. Government tax revenue and average vehicle costs

Fig. 12 compares the overall government tax revenue from the road transport sector. The results indicate that the BAU scenario leads to the government revenue shrinkages of 18% in Low case, 9% in Medium case, and 2% in High case by 2050, relative to 2018. In comparison, the Proposal scenario enhances the government tax revenues from the road transport sector, leading to a stable level over time. The Premium scenario exhibits the highest revenue loss for the government in the long term, especially when encouraging conditions (i.e. higher petroleum fuel prices and lower battery cost) are assumed. It should be noted that by removing the effects of fleet size growth, the average tax revenue per vehicle in all scenarios and cases will significantly decrease over time.

Fig. 13 shows the contribution of different components in the total tax revenue. According to Table 1, the road tax in BAU will be lower than that of Proposal (which is the same as in Banning and Premium). After 2023 the road tax in the Proposal scenario will be applied to all vehicles including both BEVs and Non-BEVs in the same way. As a result, by increasing the total number of vehicles over time (and thereby increasing the total annual distance travelled), the road tax revenue in the BAU scenario will be lower than in the other scenarios. Fig. 13 shows the trade-off between the reduction of excise duty and the increase of road tax. The figure shows that the loss to the tax revenue will not be significant even if such a high share of BEVs is achieved in the Banning scenario.

5.6. Transition benefits for consumers and government

Fig. 14 shows how government and consumer benefits evolve in different scenarios and cases. All percentage values have been calcu-

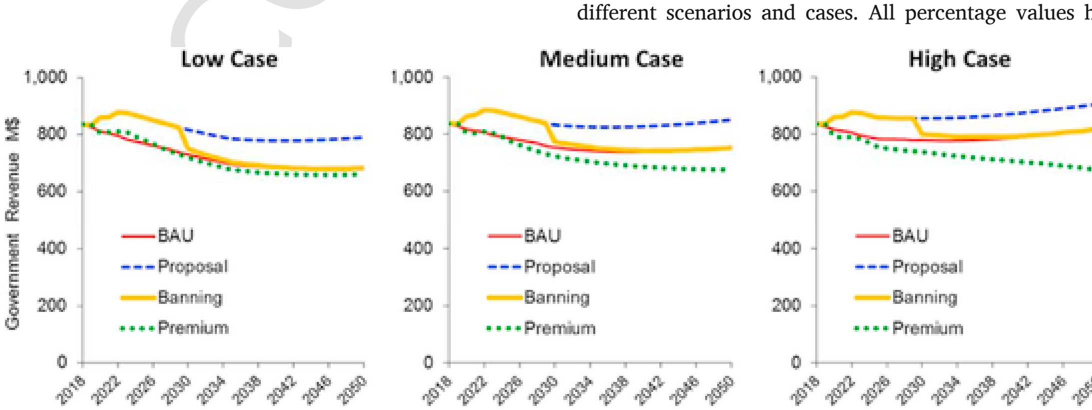

Fig. 12. Government tax revenues in different scenarios and cases.

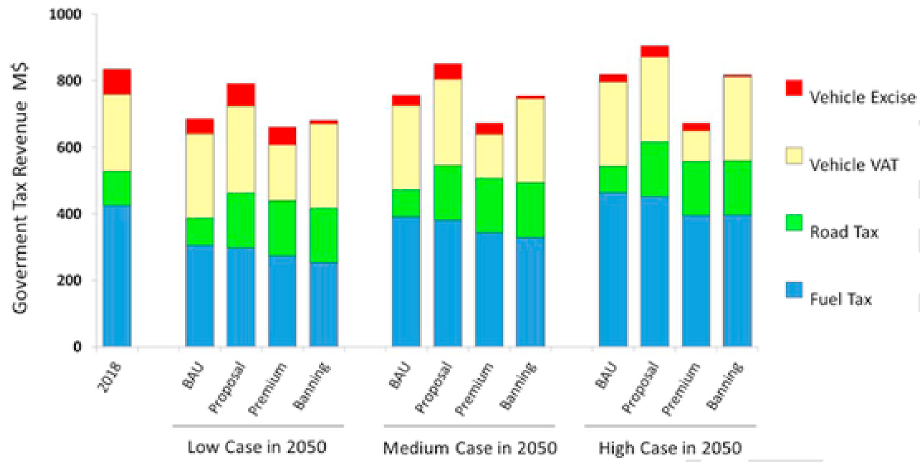

Fig. 13. Main components of government tax revenue in 2018 (which is almost the same for all scenarios) and in 2050 for different scenarios and cases.

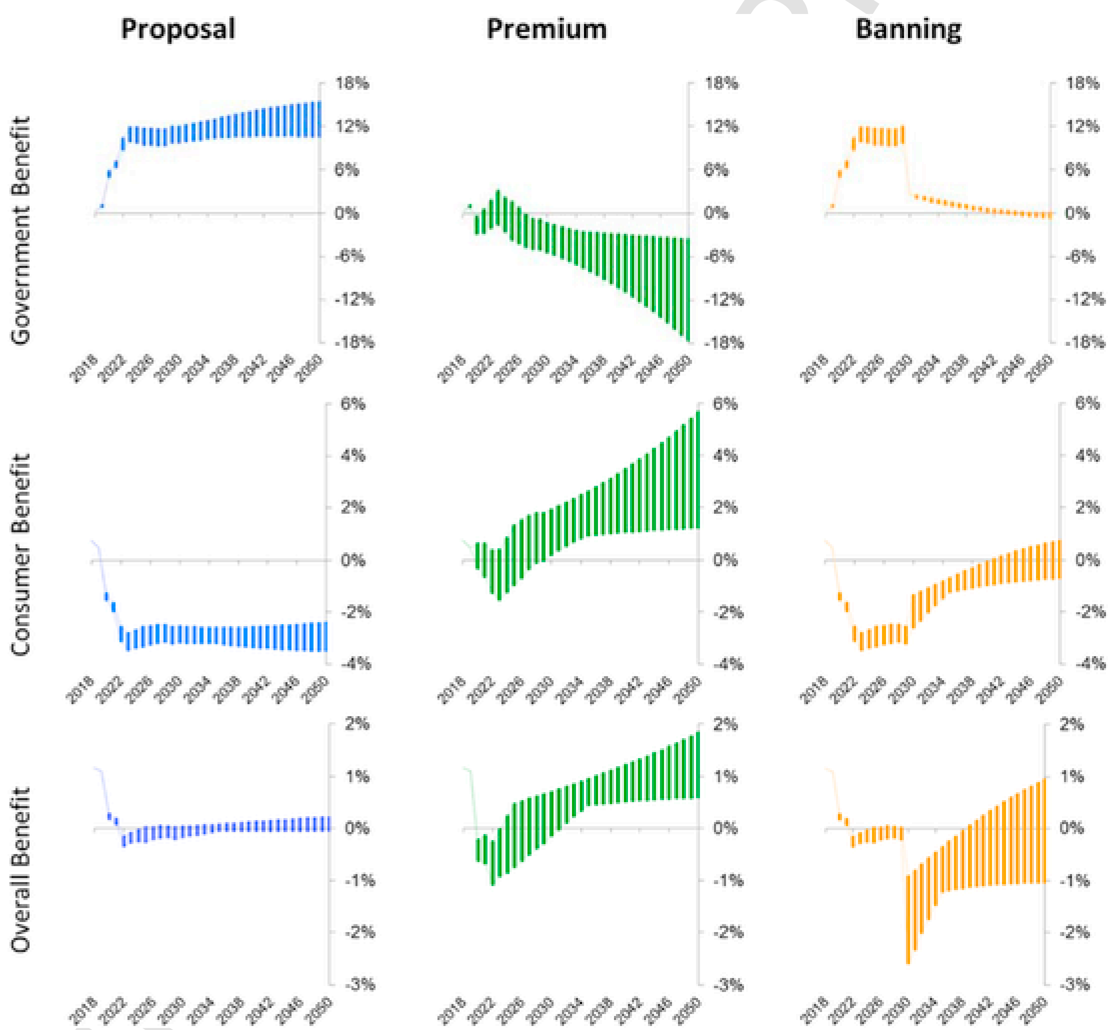

Fig. 14. Government and consumer benefits compared to BAU.

lated compared to the BAU cases. The simulation results for the Proposal scenario indicate that the government revenue from the purchase and use of vehicles will be fairly stable for the future, but it will be higher than that of BAU. In the Proposal scenario, the government revenue in 2050 is expected to grow by 11–15% compared to BAU. The Premium scenario provides the government with the lowest income because of VAT exemption on BEVs. It will result in the tax shrinkage of 4–18% by 2050. In the Banning scenario, the government will receive more revenue from vehicle usage taxes (i.e. additional road tax as in Table 1) and less revenue from upfront vehicle excise duties, comparing to BAU. Altogether, the government benefit in this scenario is expected to be negligible in the long run.

The taxation decisions by the government directly affect the consumers' costs in terms of both the purchase and use of vehicles. Hence, as displayed in Fig. 14, the consumer benefits in different scenarios show inverse patterns to those of government benefits. It simply means that the government revenue grows at the expense of consumers' cost increase. From a consumer perspective, the Premium scenario is the most advantageous policy, leading to the gain of 1.3–6% by 2050. Conversely, the Proposal scenario will be costly to consumers and leads to a net loss of 2.4–3.5%.

From the overall consumer-government view, the Proposal scenario will remain in a balanced state with a gain/loss being minuscule. In the Premium scenario, the overall benefit is increasing, indicating that the government loss due to the VAT exemptions for BEVs brings more overall economic gains through consumers' behavioural change (i.e. shift to more efficient vehicles and change in travel demand). The regulatory intervention in banning new petroleum fuel vehicles, leads to a sharp reduction of overall benefits in 2030. Thereafter, the overall benefits in the Banning scenario will be growing mainly because of rising consumer's gains from the use of EVs.

5.7. Macroeconomic indictors

Table 3 shows the simulated effects on selected macroeconomic variables (i.e. GDP growth, unemployment, inflation and interest rates), compared to the BAU case. Table 3 shows the effects on the variables in 2050 and the average effects in 2018–2050. A positive value for a variable should be interpreted as it being larger than in the BAU case. As an example, the growth in the Premium case is −0.0031% in 2050 saying that GDP growth would be 0.0031% lower in 2050 in the Premium case than in the BAU case. Further, GDP growth in 2018–2050 is on average 0.0002% higher in Premium case than in the BAU case. Overall, Table 3 shows that the direct macroeconomic impact is very small with statistically non-significant differences between the scenarios. As a result, the macroeconomic results indicate that pushing for electrifying the vehicle fleet does neither have positive nor negative direct impact on the macro-economy in the long term.

6. Conclusions and policy implications

In this study a techno-economic model of integrated energy-transport system was employed to evaluate the market penetration of EVs, fuel demand mix, GHG emissions, fuel import costs, consumer costs, and government tax revenue. The results were fed into a general equilibrium macroeconomic model to examine the implications of EV transition for selected macroeconomic indicators.

A tax-induced EV promotion scenario in the context of a new tax reform proposal by the Icelandic government was compared to a BAU scenario as an extension of current policies to future. In addition, the Proposal scenario was combined with two different EV promotion policies: i) VAT exemptions for BEVs to build the Premium scenario, and ii) prohibition of the sale of new petroleum fuel vehicles from 2030 to define the Banning scenario. All scenarios were examined under a wide range of future changes in the oil price, battery cost, carbon tax, and petroleum fuel excise duties.

Table 3
Macroeconomic impact in 2050 and average % difference 2018 to 2050 (Medium case compared to BAU).

Scenarios	Proposal	Premium	Banning
Growth%	−0.0009	−0.0031	−0.0053
Average%	0.0000	0.0002	0.0001
Unemployment %	0.0006	0.0043	−0.0033
Average%	0.0023	0.0041	−0.0056
Inflation %	−0.0004	−0.0036	0.0056
Average%	−0.0067	−0.0066	−0.0165
Interest rate %	−0.0001	−0.0023	0.0101
Average%	−0.0081	−0.0071	−0.0178

The results show that the share of EVs can increase significantly in all scenarios but with different patterns and sensitivities with respect to petroleum fuel prices and battery costs. The results indicate that the level of electrification and GHG emissions would be comparable in the BAU and Proposal scenarios. The market growth patterns of EVs are quite different in the Premium and Banning scenarios, but in the end, they give comparable electrification and mitigation levels by 2050.

The results indicate that continuing the current vehicle tax policy under BAU leads to a government tax revenue shrinkage. In comparison, the implementation of the new tax reform under the Proposal scenario significantly enhances the government tax revenues from the transport sector. It can be considered as an important advantage of the Proposal scenario as the increase in the government income will occur at a comparable effectiveness level with BAU (i.e. the level of electrification or GHG mitigation). Although the Proposal scenario helps to preserve the current level of government revenues over time, however, by removing the effects of fleet growth, the tax revenue per vehicle will still be decreasing. One way to preserve the tax revenue per vehicle, while the share of EVs and GHG mitigation level remaining unchanged, could be a rise of annual road tax on all vehicles in the Proposal scenario. Since the tax revenue rises at the expense of consumer costs, the Proposal scenario will be a costly policy for consumers. Coupling this scenario with VAT exemptions for BEVs (to implement the Premium scenario) would be the most advantageous from a consumer perspective. The finding showed that the larger the share of electricity, the less would be the cost of vehicle ownership. From an overall consumer-government view, the Proposal scenario will move forward in neutral with balanced gains and losses. The Premium scenario brings positive benefit in the long term. The Banning strategy will be at a disadvantage when the intervention takes place, but it comes with a growing benefit thereafter.

The findings from the modelling and scenario analysis indicate that the overall impact of electro-mobility transition would be positive in the long term, both in terms of economic benefits and GHG emissions reduction. Impact on macroeconomic variables such as economic growth, unemployment and interest rates is neutral. The impacts on consumers and government, however, will depend on the type of policy instruments. The electrification of road transport seems to be initially costly for Iceland. However, in the long term, electro-mobility will be economically affordable for the country while resulting in a significant reduction of GHG emissions. The Premium scenario is the best strategy with the aim of rapid emissions reduction with relatively low costs from the overall consumer and government perspective. The Proposal scenario closely fits the goal of preserving government tax revenues, but the progress in GHG mitigation will be much slower. The level of electrification and GHG mitigation are comparable in the Premium and Banning scenarios by 2050. However, the emissions in 2030 will be higher in the Banning scenario. In addition, the effectiveness of the Banning scenario on cumulative GHG emissions is increased in case of discouraging condition for EVs (i.e. low petroleum fuel prices and slow battery cost reduction).

In conclusion, the overall net benefit of a deeper electrification is positive, both with respect to macroeconomic impacts if external benefits are accounted for and consumers' perspectives. The direct impacts on macroeconomic variables are negligible. In addition to the direct macroeconomic impact of tax-induced EV promotion, EVs have positive external effects including GHG mitigation, improvement in air quality, and increased energy security.

The performed analysis provides an understanding of the role of EV support policies in achieving emissions reduction targets. The environmental impact is positive, although much deeper and faster electrification of transportation will be required to meet the short-term climate targets such as Paris agreement goals. As the scenario analysis showed, it is unlikely that the EV transition can meet the national targets by 2030 in terms of a 30% share of renewable fuels and 40% GHG reductions from the transport sector, compared to 1990 levels. The technological solution, and in particular the EV transition, will be an essential part of achieving the goals of emissions reduction, but since the changes in the fleet mix take a long time, tax-induced EV promotion needs to be coupled with additional incentives or regulatory supports. Hence, with regard to the technological solution, more stringent regulatory-push policies such as the renovation of fleets will be required. In addition, it is important to keep in mind that other renewable fuels such as hydrogen, biogas, and biodiesel exist in Iceland that can also be considered as supplements to the mitigation goals.

Finally, as the results confirmed, although the technological solution aimed at encouraging the adoption of EVs will effectively enable a deep emissions reduction by 2050, it will not be sufficient to achieve the national climate target in the short term by 2030, assuming it applies to all sectors equally. Further policy measures such as travel modal shifts (e.g. an increased use of public transport, biking, and walking) as well as behavioural and organizational changes to reduce travel demand will be necessary.

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