PROBABILISTIC APPROACH IN ENERGY MODELING OF THE CZECH TRANSPORT SECTOR

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Overview

The transport sector is one of the largest emitters of CO2, with road transport causing significant environmental and health damages. Local air and noise pollution affects millions of inhabitants in cities worldwide. Therefore, there is an urgent need to substantially improve the environmental efficiency of road transport, which is a paramount challenge for our current society.
The share of Battery Electric Vehicles (BEVs) in Central and Eastern Europe is lower than in Western Europe, but it is on an increasing trend. The transition of the Czech transport sector from fossil fuels to renewables and electricity could be more challenging compared to countries with higher GDP per capita, higher market saturation of passenger cars, and greater purchasing power.
In the Czech Republic, approximately 400 passenger cars are newly registered annually, evenly split between private individuals and firms. While firms purchase over 80% of new cars, private individuals buy only 33% of new cars, with 66% being imported second-hand cars. The trend of importing older vehicles is particularly concerning. Until 2014, most imported vehicles were 5-10 years old, but by 2015, the 10-15 year category became the most represented (36%), and the category of vehicles over 15 years old rose from 2% in 2009 to 12% in 2015. This increase came at the expense of the 1-3 year age group (a reduction of nearly two-thirds) and the 3-5 year age group (down from 22% to 13%).
The share of conventional petrol and diesel vehicles remains dominant. In 2023, BEVs accounted for 0.34% of the total passenger vehicle fleet, while Plug-in Hybrid Electric Vehicles (PHEVs) accounted for 0.15%. Approximately 8,800 BEVs (both new and imported second-hand) were registered in 2023, an increase of about 4,000 vehicles year-on-year. Nearly one-fifth (17.8%) of registered BEVs are second-hand, with repeated registrations, and for PHEVs, this figure is 15.5%. Almost 80% of registered electric vehicles are company-owned, while 22% are registered to non-business individuals.
We have developed a detailed model of the Czech transport sector, incorporated into the TIMES-CZ energy model, to evaluate measures that could lead to a low-carbon transport sector. One of the key innovations of this paper is the incorporation of consumer preferences into the TIMES-CZ model using an asymptotic logistic function. This allows the model to more accurately reflect real-world consumer behavior and preferences, which is crucial for predicting the adoption rates of different vehicle types and the overall transition to a low-carbon transport sector. By incorporating these preferences, the model can better simulate how consumers might respond to various policy measures and market conditions, providing more reliable projections and insights.
Another significant contribution of this paper is the modelling of second-hand car imports into Czechia. The transport module of the TIMES-CZ model is based on individual data from the Czech vehicle register, including mileage, which allows for detailed modelling of the second-hand car market. This is particularly important for the Czech Republic, where a substantial portion of the passenger car fleet consists of imported second-hand vehicles. By including this aspect in the model, we can better understand the dynamics of the second-hand car market and its impact on the overall transition to a low-carbon transport sector.
Overall, the detailed model of the Czech transport sector incorporated into the TIMES-CZ energy model provides a robust framework for evaluating various measures that could lead to a low-carbon transport sector. The incorporation of consumer preferences and the modelling of second-hand car imports offer valuable insights into the potential pathways for the Czech Republic's transition to sustainable transport.

Methods

TIMES-CZ is a technology-rich, bottom-up, cost-optimizing integrated assessment model developed using the General Algebraic Modelling System (GAMS) code within the flexible TIMES model generator. The model searches for an optimal energy mix solution that satisfies predefined (exogenous) aggregated energy demand with the least total discounted costs over the analyzed period. TIMES-CZ encompasses the entire energy balance of the Czech Republic, from primary energy sources to the final consumption of energy services.

The transport module of TIMES-CZ is based on individual data from the Czech vehicle register, including mileage, which allows for the modeling of the second-hand car market in the Czech Republic. The model represents more than 200 technologies, reflecting the size, power, age, and fuel type of passenger cars.

We employ a probabilistic approach, utilizing an asymptotic logistic function to replace a discrete decision process with a smooth switch function that incorporates agents' preferences in investment choices. This approach leverages a recently developed feature of the TIMES model generator called Logit Market Share Allocation. This feature accounts for the total cost of technology while incorporating a more complex decision-making process that considers the value of risk, uncertainty, and intangible costs. The parameters of the function are derived from a discrete choice experiment and applied to the TIMES-CZ energy system model.

Results

Our preliminary results reveal several key insights into the transition of the Czech transport sector to a low-carbon future. The model forecasts a gradual increase in the adoption rates of BEVs and PHEVs. However, their overall share remains relatively low compared to conventional petrol and diesel vehicles. This trend is influenced by factors such as consumer preferences, purchasing power, and the availability of supporting charging infrastructure.

The import of second-hand cars, particularly older vehicles, continues to play a significant role in the Czech passenger car market. Notably, the increasing availability of imported second-hand BEVs is expected to accelerate their adoption rate in the 2030s.

The transition to a low-carbon transport sector is projected to yield substantial environmental and health benefits. These include reductions in CO2 emissions, local air pollutants, and noise pollution, which are anticipated to improve air quality and public health, especially in urban areas.

Conclusions

The transition of the Czech transport sector to a low-carbon future presents both challenges and opportunities. Our detailed modelling using the TIMES-CZ energy model highlights several critical insights. While the adoption rates of BEVs and PHEVs are projected to increase gradually, their overall market share remains low compared to conventional petrol and diesel vehicles. This underscores the need for targeted policies and incentives to boost the adoption of cleaner vehicle technologies.

The significant role of second-hand car imports, particularly older vehicles, poses a challenge to the transition. However, the increasing availability of imported second-hand BEVs is a positive trend that could accelerate their adoption in the coming decades. Policies aimed at regulating the import of older, less efficient vehicle technologies and promoting modal shift to other transportation modes will be crucial

In conclusion, the transition to a low-carbon transport sector in the Czech Republic is a complex but achievable goal. By leveraging detailed modelling and incorporating consumer preferences, policymakers can develop effective strategies to navigate the challenges and capitalize on the opportunities presented by this transition.