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The impact of the EU car CO_2 regulation on the energy system and the role of electro-mobility to achieve transport decarbonisation

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HIGHLIGHTS

- Car CO_2 regulation effective policy to reduce transport CO_2 emissions.
- Learning rate above 12.5% can lead to sharp increase in electric vehicle deployment.
- Electric vehicles can foster the deployment of variable renewable electricity.
- Policies for other modes needed to curb transport CO_2 growth.

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ABSTRACT

We analyse the impact of the current and an alternative stricter EU CO_2 car legislation on transport related CO_2 emissions, on the uptake of electric vehicles (EV), on the reduction of oil consumption, and on total energy system costs beyond 2020. We apply a TIMES based energy system model for Europe. Results for 2030 show that a stricter target of 70 g CO_2/km for cars could reduce total transport CO_2 emissions by 5% and oil dependence by more than 2% compared to the current legislation. The stricter regulatory CO_2 car target is met by a deployment of more efficient internal combustion engine cars and higher shares of EV Total system costs increase by less than 1%. The analysis indicates that EV deployment and the decarbonisation of the power system including higher shares of variable renewables can be synergistic. Our sensitivity analysis shows that the deployment of EV would sharply increase between 2020 and 2030 at learning rates above 12.5%, reaching shares above 30% in 2030. Finally, the study highlights that, besides legislating cars, policies for other transport sectors and modes are needed to curb transport related CO_2 emission growth by 2030.

1. Introduction

Significant improvements in the specific fuel consumption of passenger cars in the EU (European Union) have been achieved over the last years (Fontaras and Dilara, 2012). Nevertheless, because of the growth of car transport, this has not fully translated into the same level of reduction of CO_2 emissions from passenger cars in the EU. The transport sector is the only sector which emissions were growing in the EU (by 19%) when comparing 2013 to the baseline year 1990 (Eurostat, 2016). Moreover, passenger car transport is expected to further grow over the next decades (European Commission, 2013a). Therefore, the EU recently adopted a CO_2 legislation, setting specific CO_2 emission targets of the average new fleet at 130 g/km for 2015 (EC, 2009a) and 95 g/km by the end of 2020 and onwards (EU, 2014a). This legislation is currently based upon type approval values and CO_2 emission measurements, done according to the New European Drive Cycle (NEDC). Historically (up to 2005), the CO_2 emissions measured in the NEDC were in average around 15% lower than the real drive CO_2 emissions on the road. Publications indicate that this gap may have increased recently (Fontaras and Dilara, 2012; EEA, 2014; ICCT et al., 2014), however the European Commission proposed a package including new testing procedures to limit the emission gap between test

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and real driving conditions (European Commission, 2016). Furthermore, the European Commission has proposed to reduce the total greenhouse gas (GHG) emissions in the EU by 40% in 2030 over the 1990 levels (European Commission, 2014a).

This policy has an impact on the technological mix in the transport sector, but also affects the overall energy sector due to the substitution of fuels: oil may be substituted by e.g. natural gas or electricity, when new technologies enter the market. In particular, an increased use of electricity by car transportation may have impacts on costs and CO_2 emissions in the electricity generation sector, which could trigger changes in other sectors due to changes of relative costs of energy sources – and due to the restrictions of the European Emission Trading Scheme (ETS). The assessment of the impact of the CO_2 car regulation policy on total GHG emissions in the energy sector therefore has to rely on a systemic approach.

In the past, many legislative measures and scenarios in the transport sector were primarily analysed with tools focussing on the transport sector only, which often use exogenous scenario assumptions for the evolution of fuel or energy supply (Fontaras et al., 2007; Pasaoglu et al., 2012; Sorrentino et al., 2014; Thiel et al., 2014; Bauer et al., in press). A number of publications have analysed various aspects of different powertrain technologies, such as (i) well-to-wheel emissions, efficiencies, and total cost of ownership (Thiel et al., 2010; Bishop et al., 2014; Millo et al., 2014; Waller et al., 2014), (ii) impacts on air pollution in cities (Donateo et al., 2015), and (iii) behavioural aspects (Tran, 2012). Brouwer et al. (2013); Foley et al. (2013); Loisel et al. (2014); Verzijlbergh et al. (2014) study the interaction between electric vehicles and power supply, markets, and interconnection, but do not assess impacts on the whole energy system.

Some studies have taken a systemic view into account and employed energy system optimisation models in order to analyse future vehicle scenarios in the context of an overall energy decarbonisation strategy (Ichinohe and Endo, 2006; Bahn et al., 2013; Anandarajah et al., 2013; Rösler et al., 2014; Seixas et al., 2015). The use of these models has the advantage that, rather than using prescriptive exogenous scenario assumptions, the cost-optimal deployment of technologies is endogenously determined by the model. However, those studies have been conducted with a low disaggregation of the vehicle technologies, which limits the capability of the models to fully explore the potential of the most important available low-carbon technologies in the sector. Additionally, only Rösler et al. (2014) and Seixas at al. (2015) had a look at Europe specifically, and none of the studies assessed the EU car CO_2 regulation.

In this exploratory study we therefore use a TIMES[2] based energy system model (Loulou et al., 2005) to analyse, how a specific policy, the EU CO_2 car legislation, can contribute towards an overall EU 40% GHG reduction target and how it may foster the deployment of electro-mobility in Europe. While this analysis starts from the basis of the impact assessment that accompanied the proposal of the 40% GHG reduction target (European Commission, 2014b) and builds upon earlier other studies that were performed with TIMES/MARKAL energy system models (Ichinohe and Endo, 2006; Bahn et al., 2013; Anandarajah et al., 2013; Rösler et al., 2014; Seixas et al., 2015), we study the car sector at a much higher technology detail in the context of the car CO_2 legislation. We discuss in detail the role that electro-mobility could play in order to achieve the EU's objectives on decarbonisation and energy independence and we perform sensitivity analyses to test the robustness of the model outcomes under variations of assumed learning rates for EV technologies, considering recent evidence of increased progress in battery cost reduction (Nykvist and Nilsson, 2015). EV in this study comprises battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and hydrogen fuel cell (HFC) cars.

The remainder of the article is structured as follows: Section 2 describes the data and methods applied in this analysis, Section 3 describes the results while Section 4 discusses these. Section 5 draws conclusions and highlights policy implications.

2. Methods and data

This chapter describes in sub-Section 2.1 the JRC-EU-TIMES energy system optimisation model and in sub-Section 2.2 the design of scenarios as well as the design of the sensitivity analysis.

2.1. JRC-EU-TIMES energy system optimisation model

The JRC-EU-TIMES model is used for this study that focusses on passenger cars and does not consider differentiated scenarios for other modes of transportation. JRC-EU-TIMES is a linear optimisation bottom-up energy system model generated with the TIMES model generator. Its objective function minimises the total energy system costs over the entire modelling horizon. The minimisation is subject to constraints, for example primary resources supply bounds, technical constraints, balance constraints for energy and emissions, timing of investment, and the satisfaction of a set of demands for the energy services of the economy. TIMES based model applications are used by numerous research teams for a variety of analyses at a sector, country, region or multi-region level that require an energy system perspective. See besides the above mentioned publications for example Vaillancourt et al. (2014), Daly et al. (2014) and Cayla and Maïzi (2015), or for a wider overview of recent TIMES model applications Giannakidis et al. (2015). The JRC-EU-TIMES model represents the EU28 (the 28 member states of the EU) energy system plus Switzerland, Iceland, Norway, and the Western Balkan countries from 2005 to 2050, where each country is modelled as one region. It includes the following sectors: primary energy supply; electricity generation; industry; buildings; agriculture; and transport (Fig. 1).

As a partial equilibrium model, JRC-EU-TIMES does not model the economic interactions outside of the energy sector. Nevertheless, they are considered to some extent via price elasticities of service demands. In this analysis, JRC-EU-TIMES' demands are sensitive to price changes as described in Kanudia and Regemorter (2006). The price elasticity for car passenger kilometres is assumed to be -0.3 and symmetrical. A 10% increase in the endogenous total cost of a passenger kilometre will lead to a 3% decrease of this particular demand and vice versa. For cost reductions, this feature reflects rebound effects that would typically not be considered in supply oriented cost-minimisation models.

The most relevant model outputs are the annual stock and activity of energy supply and demand technologies for each region and period, with associated energy and material flows including emissions to air and fuel consumption for each energy carrier. Besides these, the model computes operation and maintenance costs, investment costs, energy and materials commodities prices. Each year is divided in 12 time-slices that represent an average of day, night and peak demand for every one of the four seasons of the year.

The model is supported by a detailed database, with the following main exogenous inputs: (1) end-use energy services and materials demand; (2) characteristics of the existing and future energy related technologies, such as efficiency, stock, availability, investment costs, operation and maintenance costs, and discount

[2] TIMES: The Integrated MARKAL-EFOM System; MARKAL: Market Allocation; EFOM: Energy Flow Optimisation Model.