Abstract

In Denmark, the energy system should be close to fossil-free by the mid of the century. This puts an enormous challenge to the transition of the transport system, and there are questions both about what the system will look like in 2050 and, also, what technologies and fuels that will be facilitating the transition. This is the point of departure of the current study. Further, natural gas has been important in the Danish energy system over the last decades and now the production of biogas is sharply increasing. Could gas vehicles and gas in transport play a role in the transition to an almost fossil free transport system?

Thus, the objective of the study is to analyse cost-effective deep decarbonisation transport solutions until 2050 under a variety of assumptions. What technologies and fuels will dominate? Which are important transition technologies and fuels? Is there a role of gas?

Given the complexity of the energy system and the objective of a cost-effective system optimization, a modelling approach was chosen. Given that both technological detail and a good demand side representation was deemed necessary, a bottom-up technology rich model was required and the choice fell on the cost-optimising TIMES (The Integrated MARKAL-EFOM Model) model. It is a perfect foresight, partial equilibrium linear programming, bottom-up, technology rich and demand driven optimisation model. The objective function minimises the total discounted system cost for the whole modelling period.

In this study, the existing TIMES-DK model, representing the entire energy system of Denmark, developed in collaboration between DTU Management Engineering and the Danish Energy Agency, was further developed to suit our purpose and applied for the analysis. Emphasis was given to gas transport technologies for both road- and maritime transport applications. The model assumes disaggregated transport technological details and service demands, and an endogenized fuel infrastructures. In particular gas infrastructures are modelled in a detailed fashion. The model covers the time period of 2010-2050 and was explored under a number of market, policy and technical scenarios. Marginal CO_2 abatement costs were also explored

The results are presented both as fuels and as vehicle technologies. In the base case, allowing biomass imports, and not including fuel demand from aviation and international maritime transport, liquid biofuels used in conventional internal combustion engines (ICE) dominate the cost-effective solutions. With a lower assumed battery price, the importance of electric vehicles (EVs) increase but EVs do not dominate the cost-effective solutions for personal cars, which is however does for heavy road transport due to economies of scales. If instead assumptions of a lower fuel cell price are applied, fuel cells become an important solution for the dominating personal car segment. They are also the favoured option in light freight transport.

If biomass imports are assumed not feasible (not allowed in the model) this will results in a clear reduction in reliance of biofuels for transport not so much during the transition time but in particular towards the end of the studied time horizon. Instead, upgraded biogas, both in the form of compressed and liquified gas, takes a considerable share of the transport fuel market. Under the assumption of a considerably tighter competition for constrained biomass resources, assuming that also aviation and international maritime transport should be included in the climate objectives and compete for non-fossil resources, all available options

are utilized and the final, 2050, cost-effective solutions for the personal car segment include similar shares of liquid biofuels, hydrogen (primarily produced at distributed dispenser sites), electricity, and biogas. Natural gas is a transition fuel in the personal car segment under all assumed and applied scenarios.

The starting point of the study was that despite the huge possible importance of use of natural gas and biogas in transport for a transition to a fossil-free transport system, this is not well explored in scenario analysis. It was concluded that the by the model chosen technologies and fuels are highly sensitive to technology cost and fuel economy assumptions. That is that the found solutions are not very robust and that there are a number of possible solutions and mix of technologies and fuels with similar system costs, and that the chosen solutions depends strongly on assumptions of future cost developments. Further, it was clear that competition for constrained biomass resources has a major impact on the cost-effective technology and fuel choices and stimulates the uptake of emerging transport technologies such as battery and fuel cell vehicles.

In a number of scenarios, natural gas is important as a transition fuel and biogas as a fuel in the end-year fossil-free transport system. The results were sensitive to the added cost of gas vehicles compared to standard ICE vehicles.