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Pedersen, Rasmus Bo Bramstoft; Skytte, Klaus

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DECARBONISING THE SWEDISH TRANSPORT SECTOR WITH ELECTRICITY OR BIOFUELS

Rasmus Bramstoft, DTU Management Engineering, +45 22560216, rabpe@dtu.dk
Klaus Skytte, DTU Management Engineering, +45 93511085, klsk@dtu.dk

Overview

Sweden has set long-term energy policy targets which aim at eliminating net greenhouse gas (GHG) emissions by 2050 [1]. Since the production of power and district heating in Sweden is already close to be carbon neutral, a further reduction of GHG emissions have to be seeked in other sectors, for example the transport sector. By 2011, approximately 90% of the total fuel consumption in the transport sector stems from fossil fuels, accounting for around 45% of the GHG emissions in Sweden [1]. Therefore, the Swedish transport sector will have to face a major transformation in the next future, if the ambitious targets of a carbon neutral transport system by 2050 and of being independent from fossil fuels in the vehicle fleet by 2030 have to be achieved [1]. To meet the energy policy targets, radical restructuring of the fuel use and vehicle stock in the transport sector is required. In this context, this paper develops two alternative scenarios for the transport sector by 2050 – an Electric Vehicles Scenario (EVS) which include a high percentage of electric vehicles and a BIOfuel Scenario (BIOS) with a high percentage of biofuels. The scenario results are compared to the Carbon Neutral Scenario (CNS), adopted from the Nordic Energy Technology Perspective (NETP) 2013 [2]. The alternative scenarios for the transport sector are developed by means of an energy system model which includes the power, heat and transport sectors, taking into account possible synergies among the sectors. The energy system model computes the socio-economic value of the total annual system cost which then allows for a comparative analysis between the investigated scenarios.

Methods

By utilising an holistic energy system perspective, two alternative scenarios for the transport sector are investigated while taking into account its future synergies with the power and heating sectors. To facilitate the modelling process, the power and heating systems by 2050 are taken from the CNS outlined in NETP 2013.

Energy system modelling tool. The different energy system scenarios are developed in the STREAM (Sustainable Technology Research and Energy Analysis Model) energy system model, a public-domain open source model (http://www. streammodel.org). The STREAM model is a scenario building tool that provides an overview of the complete energy system on both the demand and supply side. Moreover, STREAM computes the socio-economic value of the total annual system cost and simulates the system integration of the transport sector with the power and heating sectors by utilising an hourly time resolution.

In the STREAM model, the transport system is divided into four independent sectors: passenger, freight, agriculture and fishery. The current transport work (passenger-kilometer, tonne-kilometer and energy consumption in agriculture and fishery) is specified, while the projection for the demand in the year of simulation is computed by defining metrics for expected economic growth and specific energy intensity factors. Driven by the calculated demand, the transportation sectors are described along with their synergies with the energy system. Furthermore, the transport work is allocated by vehicle type (e.g. car, bus, train, plane, bike, etc.), the utilisation degree (or stocking density), the composition of fuels for transportation means for both passenger and freight transport along with agriculture and fishery is defined according to the purpose of the scenario. Associated costs and emissions related to fuel production and consumption as well as vehicle acquisition and maintenance are accounted for. Finally, the modelling of flexible fuel production and charging of electric vehicles (EV) is facilitated by the use of the Duration Curve model.

Results

The results of the study include a comparative analysis of the total annual system cost which subsequently is disaggregated into the following key indicators: Cost of Energy Savings, Capital Cost, O&M Cost, Fuel Cost and CO_2 Cost. This is done in order to identify the main drivers for discrepancies between the investigated scenarios. In addition, the results of the hourly electricity production, non-flexible- and flexible demand are computed in order to provide information regarding the benefits of integrating e.g. smart charging EV into the power system.

The EVS achieves a total annual system cost which is 3.5% lower than the CNS. The EVS have higher capital cost compared to the CNS, while the O&M cost, fuel cost and CO_2 cost are reduced. The drivers for the increase of the total capital cost are the capital cost of electric-driven transportation and the investment cost in additional electricity generation capacity which is needed to meet the increased electricity demand. In the EVS the fuel and CO_2 cost saved in the transportation sector exceeds the increase in capital cost, explaining the lower total cost of the scenario when compared to the CNS.

The BIOS achieves a total annual system cost which is 2% higher than the CNS. The drivers for BIOS being more expensive compared to the CNS are identified to be the increased investment costs in the transport sector and for bio-refinery processes. In the BIOS, excess heat from the bio-refinery processes is used for district heating which implies reductions in the fuel consumption in e.g. CHP plants.

The results of the model point out that the EVS yields to the lowest system cost in Sweden compared to the other investigated scenarios. This show that Sweden might benefit from using a higher share of EV rather than relying on biofuels, at least for light transport. Furthermore, the EVS can add more flexibility to the electricity demand and, thereby, facilitate the system integration of variable electricity generation such as wind energy.
The robustness of the results obtained in the quantitative assessment is tested by separately varying four parameters,
i.e. prices of bioenergy, CO_2 price and cost (investment and maintenance) of both EV and biofuel cars and by evaluating their effects on the total annual system cost. Each of the scenarios was highly sensitive to changes in bioenergy prices, however introducing identical bioenergy prices in all scenarios, the results did not lead to different best performing solutions. Moreover, it was shown that the scenario results were sensitive to changes in the costs (investment and maintenance) of biofuel cars and EV, the key technologies of the two alternative scenarios, underlining the importance of the future development of these two vehicle technologies.

Conclusions

The study shows that the use of electricity or biofuels in ensuring decarbonisation of the Swedish transport sector by 2050 can be facilitated. The alternative scenarios for the transport sector are developed by means of an energy system model which includes the power, heat and transport sectors, allowing possible synergies.

It was found that a Swedish transport sector including a high share of EV at least for light transport leads to the most cost-efficient solution under the given assumptions by 2050. Furthermore, the main driver for an even more cost- efficient EVS was identified to be a lower capital cost for EV, while for the BIOS the key parameter is a lower cost of biofuel-cars and bio-refineries.

References

[1] IEA: 2013, Energy Policies of IEA Countries – Sweden – 2013 review, International Energy Agency (IEA)

[2] NETP: 2013, Nordic Energy Technology Perspective 2013 – Pathways to a Carbon Neutral Energy Future, International Energy Agency (IEA) and Nordic Energy Research (NER)