INTERPLAY BETWEEN ELECTRICITY AND TRANSPORT SECTORS – INTEGRATING THE SWISS CAR FLEET AND ELECTRICITY SYSTEM

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Overview

Electric vehicles are seen by many as a promising future mobility option that responds to the today's energy-economic-environmental problems, such as increasing energy prices, climate change, inefficient resource usage, air and noise pollution in urban areas, and so on [7][16][1][15][4]. The Swiss Federal government has presented an energy strategy to 2050 which envisages a substantial introduction of electric cars (between 30-75% of the fleet by 2050) [2]. This is designed to support the goal of decarbonising the transport sector, given that the car fleet alone accounts for 63% of transport sector energy demand (and 18 % of total final energy consumption) [2]. However, the well-to-wheel CO_2 emissions (and primary energy use) depends on the primary sources of electricity supply. The current Swiss electricity is nearly decarbonised, with nuclear power contributing around 40%. However, the government has also decided to phase out this low-carbon source of electricity, raising challenges to the deployment of electric cars without increasing electricity-related CO_2 emissions. In addition to challenges for long-term electricity generation, the deployment of electric vehicles will affect power demand during periods of peak charging [17]. Therefore, potential interactions between the electricity and transport sectors must be considered in assessing the future role of electric mobility. Often measures to decrease transport fuel demand and CO_2 emissions in transportation are viewed as independent from the broader energy sector [11]. To our knowledge, the Swiss Energy Strategy adopted a similar sectoral approach, which may not fully represent important cross-sectoral tradeoffs and synergies. However, uptake and cost effectiveness of electric vehicle is likely to be highly dependent on the cost of electricity supply, and the characteristics of the generation capacity. For example, a high cost of electricity supply due to nuclear phase-out [9] may hinder the attractiveness of electric vehicles. To understand the interplay between the Swiss electricity and transport sectors, we analyse exploratory scenarios and generate insights related to cross-sectoral tradeoffs between electricity supply and electrification/decarbonisation of car fleets, in terms of technology deployment, CO_2 emissions and costs. For this paper, we present two electricity supply scenarios and their implication on evolution of car fleet.

Methodology

The analytical framework used for this analysis is the Integrated MARKAL/EFOM System (TIMES) – a technology rich, cost optimization modelling framework. The Swiss energy system is depicted from resource supply to end use energy service demands (e.g. in vehicle kilometre), via range of energy commodities, technologies and infrastructure, calibrated to the Swiss national energy statistics. The model has a time horizon of 2010-2100 with an hourly intra-annual representation of weekdays and weekends in three seasons (summer, winter, and an intermediate season). The model covers all end-use energy sectors and has detailed representation of the car fleet with a range of fuel and drivetrain options. Most importantly, car demand profile is included with endogenous battery charging to generate insights on contribution of electric mobility on the electricity system. We present two energy scenarios, *viz.* a business as usual (*BAU*) scenario comprising of a broad set of assumptions on existing and proposed polices; and a low carbon (*LC*) scenario with a total CO_2 emissions reduction target of 20% by 2020 and 60% by 2050 across the whole energy system. For the *LC* scenario, a variant without centralised gas power plants (*LC-NoGas*) is also included in the results.

Results

In the BAU scenario, today's conventional internal combustion engine (ICE) car is replaced with advanced (AD) ICE vehicles and then by hybrid ICE-battery (HYB) vehicles (Figure 1a). The change in vehicle efficiency results in a substantial reduction in fuel demand for cars (Figure 3a). Average CO_2 emission of the car fleet declines from 210 g-CO_2/km in 2010 to 81 g-CO2/km by 2050. In the *LC* scenario, plug-in hybrid cars (Plugin) begin to penetrate from 2035. From 2040 all new cars are full battery electric vehicles (Battery) (Figure 1b) and the average CO_2 emissions declines to 2 g-CO_2/km by 2050.

In the power sector, electricity demand is met with new investment in gas power plants in the shorter term, with renewables becoming more attractive in the long term as the gas prices increase (Figure 2a). In the *LC* scenario, uptake of renewables is high and gas-based generation still plays a major role and contributes to decarbonise the car fleet. However, in absence of the centralised gas-fired electricity production (*LC-NoGas*), the car fleet is decarbonised through natural gas hybrid vehicles (Figure 2b).

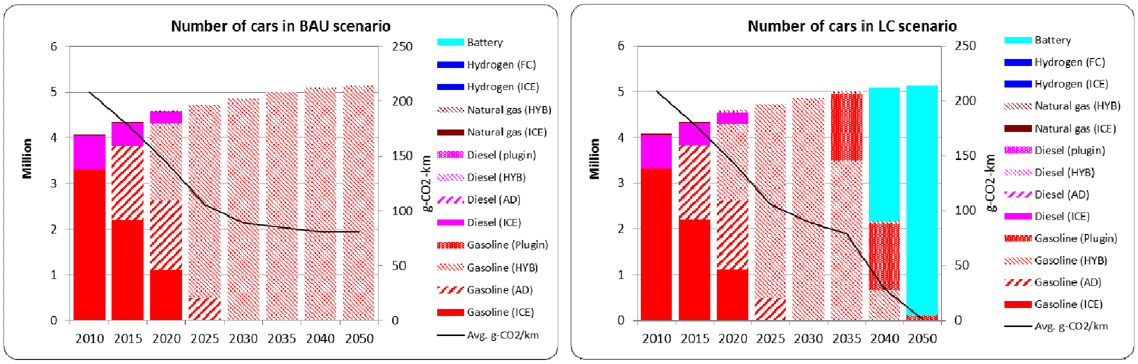

Figure 1: Transition of car fleet in *BAU* and *LC60* scenarios

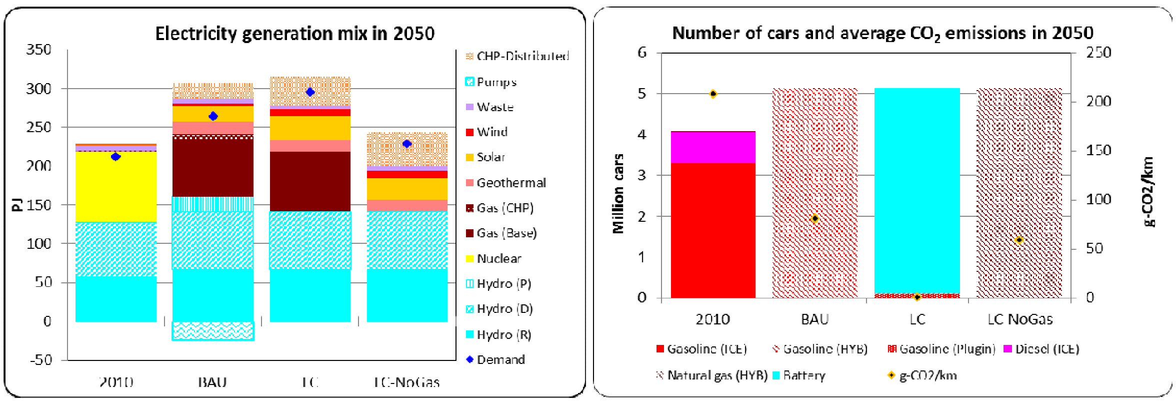

Figure 2: Electricity generation mix and vehicle in 2050

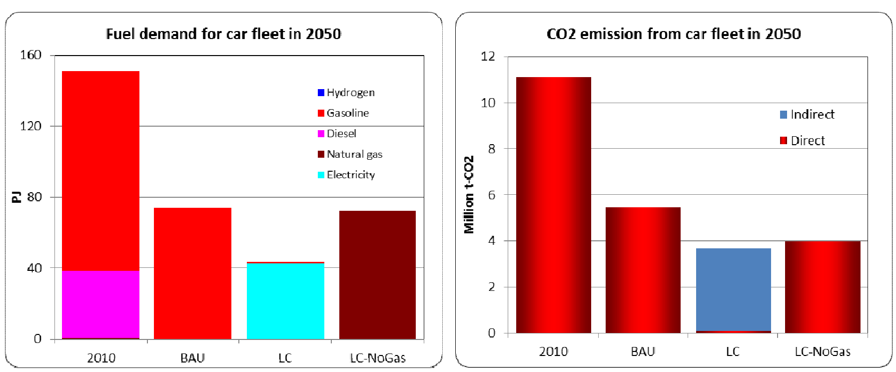

Figure 3: Fuel demand and CO_2 emissions from car fleet in 2050

In the *BAU* scenario, CO_2 emissions from car fleet decline to about 50% by 2050 from the 2010 level and to almost zero carbon in the *LC* scenario (Figure 3b). Even though 'direct' CO_2 emissions from the car fleet are substantially reduced in the *LC* scenarios, a large proportion of the CO_2 emissions are shifted to the power sector. For example, the electricity demand from car fleet attributes to about 3.5 Mt-CO_2 by 2050 (Figure 3b) as the electricity is produced from gas-fired power plants (Figure 2a).

An advantage of the hourly time resolution in the model is to provide insights on electricity generation schedule and cost optimal charging profile of electric cars. Figure 4 shows the electricity generation schedule from the *LC* scenario in 2050 on winter weekday. As can be seen, the batteries are charged during night time (brown shade in Figure 4b) using cheap imported electricity (orange shade in Figure 4a) and cars are driven during the daytime (Figure 4c).

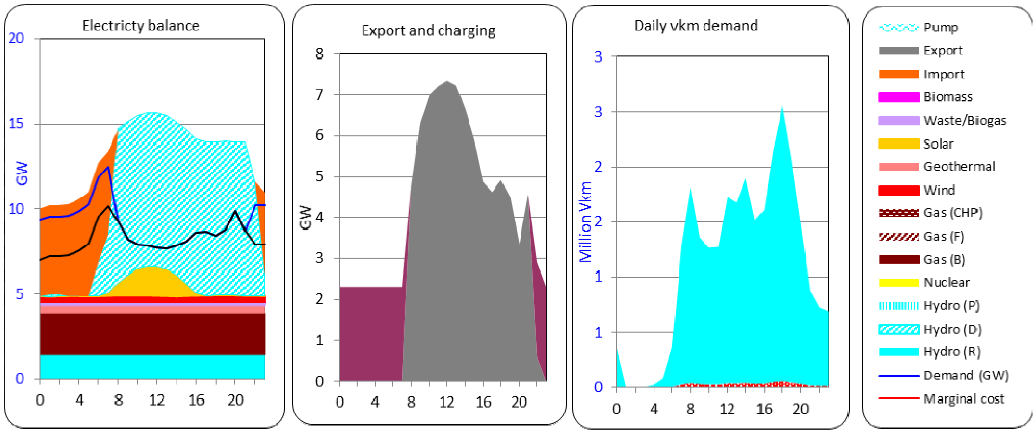

Figure 4: Load profile on winter weekday in 2050 in the *LC* scenario

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