LOW CARBON ROAD PASSENGER TRANSPORTATION SYSTEM DESIGN USING COMBINED ENERGY AND MATERIALS SYSTEMS MODELING

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Overview

Design and transition to future road passenger transportation systems require the consideration among other aspects of fuel and engine type and materials to be used in vehicle manufacturing. Vehicles for road passenger transportation constitute a significant stock of materials in the economy, particularly iron and steel. Production of new vehicles and disposal of old ones affect materials and energy flows, depending on the choice of fuel and engine type and materials for vehicle components. Traditional approaches for road passenger transportation systems design have considered energy and materials dimensions independently, studying the problem of fuel and engine type in the transportation sector and the materials transformation and product fabrication for vehicle production in the industrial sector. In contrast, we consider that the responsible design of road passenger transportation systems should not be limited to fuel and engine type selection only; but must include the disposal of current stock of vehicles, manufacture of future vehicles, and their consequences for energy and materials flows. This work considers the effect of vehicle fleet energy efficiency improvement and fuel substitution with less carbon-intensive fuels for vehicle use on the materials and energy flows in the system; while other measures like modal shift and load reduction have not been considered. This paper uses the systems approach for combined energy and materials flows to design future low carbon road passenger transportation systems, in order to understand the possible carbon emissions reductions and the variations in energy demand, cash flows and materials flows configurations in the system.

Using the systems approach for combined energy and materials flows, a model was developed in LEAP (Long-range Energy Alternatives Planning System), to assess possible low carbon road passenger transportation system configurations for 2050 and the paths to get there from the current status. Transition from the current vehicle fleet to a modern one that uses carbon neutral fuels and carbonless fuels was modeled, considering energy flows during vehicle production, use and disposal, as well as material flows for steel, the most representative material in vehicle composition. The case of Colombia, where there is potential for biofuels production and low carbon electricity was studied. The rest of the paper is organized as follows: second section describes the methodology, model and scenarios formulation, and the description of the case of study. Third section presents the results of the model, the discussion, and the sensitivity analysis. Finally, the conclusions of the study are presented, as well as recommendations for further work.

Methods

The combined energy and materials flows in the system were modelled using LEAP. The model is a national level accounting framework that describes energy flows and steel flows during the production, use and disposal of vehicles for road passenger transportation. A time horizon between 2000 and 2050 was selected. Four scenarios were considered, in addition to the business as usual scenario, considering different penetration levels of biofuel powered vehicles, electric plug-in vehicles and hydrogen fuel cell vehicles; as well as two possibilities for development of the iron and steel industry, considering energy efficient technology adoption. Road passenger in Colombia is presented as case of study.

Results

Energy demand, steel demand, CO_2 emissions and total costs for the system are estimated for the five scenarios. The increment of stock turnover of vehicle fleet, with the aim of phasing out old vehicles, causes an increment in the system capital costs. Energy demand is expected to decrease when newer and more efficient vehicles are adopted. CO_2 emissions are reduced as a consequence of lower energy demand and increased use of carbon neutral or carbonless fuels. Local pollutants follow the same trend, reaching minimum levels when electric plug-in vehicles and hydrogen fuel cell vehicles are used.

Share of secondary steel in steel production grows as a consequence of the increment in scrapped vehicles. This fact leads to larger electricity consumption in the steel industry. If additionally, DRI-EAF route is preferred over BOF route for primary production of steel, electricity use grows more and the specific CO_2 emissions in iron and steel industry are further reduced. Steel demand increases as a consequence of the demand for new vehicles; however, recycling of the used vehicles contributes partially to satisfying steel demand without the use of primary produced steel.

Conclusions

Future road passenger transportation systems will influence energy and materials demand according to the preferred type of fuel, engine and materials for vehicle manufacturing. The use of the combined energy and materials systems approach gives information about the transition from the current status of the system to the future possible configurations. Replacement of current vehicle fleet with more energy efficient vehicles using carbon neutral or carbonless fuels decrease energy demand and carbon emissions in road passenger transportation. At the same time, it increases demand for materials, particularly iron and steel, and availability of steel scrap. If steel scrap is recycled, energy intensity and carbon emissions intensity of steel industry can be reduced. Reductions are larger if energy efficient technologies in steel making are adopted.

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