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Global climate-oriented transportation scenarios

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HIGHLIGHTS

- ► Scenarios are developed whereby transportation CO_2 emissions reach zero by 2100.
- ► These scenarios address concerns about peak oil and global warming.
- ► A comprehensive mix of technical and behavioural changes is considered in 10 world regions.
- ► Efficiency improvements and a shift to plug-in hybrid vehicles are the most important measures.

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ABSTRACT

This paper develops scenarios whereby CO_2 emissions from the transportation sector are eliminated worldwide by the end of this century. Data concerning the energy intensity and utilization of different passenger and freight transportation modes in 2005, and per capita income, in 10 different socio-economic regions of the world are combined with scenarios of population and per capita GDP to generate scenarios of future transportation energy demand. The impact of various technical options (improvements in the energy intensity of all transportation modes, changes in the proportions of vehicles with different drive trains, and a shift to biomass or hydrogen for the non-electricity energy requirements) and behavioural options (a shift to less energy-intensive LDV market segments, a reduction in total passenger-km of travel per capita, and an increase in the share of less energy-intensive passenger and freight modes of transport) is assessed. To eliminate transportation fossil fuel emissions within this century while limiting the demand for electricity, biofuels or hydrogen to manageable levels requires the simultaneous application of all the technical and behavioural measures considered here, with improvements in vehicle efficiencies and a shift to plug-in hybrid and battery-electric drive trains for light duty vehicles being the most important measures.

1. Introduction

The purpose of this paper is to identify plausible combinations of aggressive measures to reduce the use of fossil fuel for transportation that are consistent with (a) the high likelihood that the global supply of oil will peak sometime between now and 2020 at a level not substantially above the current supply of about 85 million barrels per day, and (b) the need to rapidly reduce global emissions of greenhouse gases (GHGs) so as to avert what will otherwise likely be catastrophic warming of the climate. The measures considered involve improved efficiency in the use of all transportation modes, shifts in passenger travel and freight movements from energy-intensive to less energy-intensive transportation modes, shifts to less energy-intensive light-duty vehicles (LDVs) within the share of travel by LDVs, and shifts in the mix of fuels used for transportation (fossil fuels, biofuels, or hydrogen) or from fuels to electricity. Constraints on total passenger travel (particularly by air) are considered as an additional option to limit total transportation energy demand; such constraints could arise automatically through market-driven increases in the price of petroleum as the peak in global oil production arises, or as a result of government climate policy.

1.1. Peak oil

Projections for the timing in the peak in global oil production, beginning in the early 1970s through to the present, have consistently predicted a peak between 2000 and 2030 (Bentley et al., 2007, their Table 2; De Almeida and Silva, 2009, their Table 1). Based on an in-depth review of more than 500 studies of likely future oil supplies, the analysis of industry databases, and a detailed comparison of 14 global supply forecasts, Sorrell et al. (2010a, 2010b) conclude that a peak in conventional oil production before 2030 is likely and that there is a significant risk of a

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peak before 2020. Bentley et al. (2007) makes a strong case that peaking in oil supply is imminent (no later than 2020) and that there are serious flaws in most economic analyses of oil supply and in official forecasts, including those by the International Energy Agency (IEA) and the US Geological Survey. Meng and Bentley (2008) rebut many of the common arguments against the idea of a near-term peaking in oil supply. They argue, instead, that the long term observed decline in the rate of discovery of new fields and the observed rates of decline of production from oilfields that have already reached their individual output peaks, makes a near-term decline in conventional oil supply a certainty. Höök et al. (2009) show that the rate of decline of fields that have already passed their peak production averaged about 3%/yr for oil fields that peaked in the 1960s, steadily increasing to an average decline of 12.5%/yr for fields that peaked in the 2000s. This is due to the increasing success of enhanced oil recovery techniques (such as water flooding, gas injection, and fracturing) in maintaining production and delaying the peak of fields that were developed later. As many giant oilfields are in an extended plateau phase with enhanced production techniques, a rather precipitous decline can be expected once these fields enter their decline phase.

Jakobsson et al. (2009) show that the projections of global oil supply increasing from about 80 million barrels per day (Mb/d) in 2005 to 105 Mb/d in 2030 according to the IEA or 103 Mb/d according to the US Energy Information Agency depend on rather extreme and implausible assumptions concerning rates of decline in production from existing fields, a conclusion reinforced by Sorrell et al. (2012). Oil supply from unconventional sources (such as shale oils and tar sands) can slow the decline following the peak, but cannot materially affect the timing of the peak (Aleklett et al., 2010). Hirsch (2008) discusses a number of scenarios concerning the variation in oil supply at and after the peak (ranging from a broad plateau followed by decline by 2–5%/yr, to a sharp peak followed by an abrupt 2–5%/yr decline exacerbated (for importing countries) by partial with-holding of supplies by exporters). Friedrichs (2010) discusses various socio-political responses, ranging from predatory militarism to socio-economic adaptation.

1.2. Global warming

This situation is equally or more serious with regard to global warming, albeit on a longer time frame. There are several independent lines of evidence that indicate that the so-called climate sensitivity – the eventual global mean warming of the climate for a fixed doubling of the CO_2 concentration – lies between 1.5 and 4.5 °C (Harvey, 2012). Given the concurrent increase in the concentration of other greenhouse gases (GHGs), a CO_2 concentration of 400–450 ppmv would be the radiative (heat-trapping) equivalent of a CO_2 doubling. Positive feedbacks between climate and the carbon cycle are likely to push the effective CO_2 concentration well beyond an initial doubling, even if anthropogenic emissions were to be reduced sufficiently to otherwise stabilize the concentration at a CO_2 doubling. A variety of increasingly severe impacts on water resources, agricultural production, and ecosystems can be expected as global mean warming increases beyond 1 °C above the pre-industrial mean (Schneider et al., 2007). The ultimate goal of the United Nations Framework Convention on Climatic Change (UNFCCC), which has been ratified by almost all nations in the world, is the stabilization of GHG concentrations at levels that avoid "dangerous anthropogenic interference in the climate system". Harvey (2007a, 2007b) presents the case that the *present* concentration of CO_2 already constitutes dangerous interference in the climate system. Irrespective of the change in climate accompanying the CO_2 increase, absorption of CO_2 by the oceans causes ocean acidification, with likely severe and worsening impacts on marine life as the CO_2 concentration increases above 450 ppmv (Gattuso and Hansson, 2011).

1.3. This analysis

The primary outputs of the study presented here are scenarios for global demand for fuels and electricity by the transportation sector to the year 2100. These scenarios will be used, along with scenarios of fuel and electricity demand for buildings (Harvey, 2013) and industry, as input to a follow-up study in which scenarios of C-free energy supply are developed and used to produce scenarios for global emissions of CO_2 that are consistent with the goal of stabilizing atmospheric CO_2 concentration at a value of about 450 ppmv (compared to 280 ppmv pre-industrial and 395 ppmv as of 2012). Some scenarios are also consistent with a near-term peaking in oil supply.

Several other transportation scenarios that are consistent with stringent climate-related CO_2 emission targets have been published recently. At the global level, these include WBCSD (2004), which presents scenarios whereby emissions in 2050 are 0–100% those in 2000; the *Global Energy Assessment* of the International Institute for Applied Systems Analysis (IIASA), which contains scenarios whereby fossil fuel emissions across all sectors reach zero by 2100 (Riahi et al., 2012); the latest *Energy Technology Perspectives* report of the International Energy Agency (IEA, 2012), in which transportation and overall CO_2 emissions are about 85% below the 2009 emissions by 2075; and passenger scenarios of Girod et al. (2012), in which CO_2 emissions drop to about 55% of the 2010 level by 2050 and to near zero by 2100. With the exception of WBCSD (2004), for which all the spreadsheets used to generate the scenarios are freely available, relatively few details are presented concerning the specific technological and other assumptions that were used to derive the emission scenarios. At the national level, Anable et al. (2012) present a scenario for the UK in which total surface distance travelled per capita decreases by about 20% by 2050 compared to 2007, distance travelled by car is reduced by 74%, and total passenger transport fuel demand decreases by 40%, while Huo et al. (2012) present a scenario for China in which fuel demand by all modes of transport is slightly below the 2005 demand in 2050 (but 72% below the business-as-usual demand scenario), with fuel demand by LDVs being only 40% of the 2010 demand.

This paper shows how a climate-oriented target of zero global transportation CO_2 emissions by 2100 could be achieved in terms of specific measures at the regional level that in turn could be adopted as concrete policy targets. All of the assumptions that go into the scenarios presented in this paper are fully documented and justified here and in the Electronic Annex. The scenarios presented in this paper have been created in Excel, and the complete set of Excel worksheets is provided as Electronic Annex material so that the interested reader can perform additional sensitivity tests of his or her own choosing or develop alternative combinations of actions that satisfy various climate constraints and assumptions concerning future supplies of oil. In this way, specific regional policy subtargets can be developed and used as a basis for developing specific policy packages aimed at achieving the various subtargets.

2. Decomposition and projection of future transportation energy demand

Annual passenger transportation energy demand E_p at the national or regional level can be given as the product of population