***Analysis of Policies Aimed at Increasing Use of Natural Gas in the Transportation System***

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## Overview

The main objective of this paper is to examine the possible policies that would encourage use of compressed natural gas (CNG) in the US transportation sector with two objective outcomes : decreasing greenhouse gasses (GHG), and reducing oil imports thereby increasing energy security . With the advent of shale gas, the US has over a hundred years of natural gas available at a reasonable cost. The National Petroleum Council has estimated that even with very intensive use in the power sector, the price of natural gas will not exceed $6, which is equivalent to $36 crude oil. If the natural gas is not effectively demanded in the US, it could end up being exported to other countries (where natural gas prices are much higher) rather than being used to satisfy domestic energy needs. There are readily available technologies for using natural gas in the transportation system using CNG and liquefied natural gas (LNG). Thus, there is ample opportunity to increase use of natural gas in the transportation sector. Yet, to date, there has been very little analysis of alternative policy options for stimulating use of natural gas in the transportation sector. This is true despite the fact that we have aggressive policies for deployment of electric vehicles and biofuels and for increasing fuel economy (CAFE standards).

The cost of using natural gas greatly varies based on specific use in the transportation sector. Cost of using natural gas as CNG for transit bus fleets, school bus fleets and garbage truck fleets greatly varies due to technological differences, fleet sizes and average vehicle miles demanded. Any methodology used for this typ0e of analysis must cover all these dimensions and be able to handle different infrastructure needs and assoicated costs. In addition to fleets, the low-hanging fruit, we will also examine light duty vehicles which is the largest portion of transportation sector.

To have a clear picture of the interactions between current policies and the proposed CNG policies we have included in addition: a) CAFE standard in detail in the modelling database, b) Renewable Fuel Standards including biofuels technologies for thermochemical and biochemical conversion c) MARKAL-MACRO which couples the standard MARKAL model with a macroeconomic model that enables feedback between the macro economy and energy demands and GDP growth (Sarica and Tyner, 2013). In other words, we get an accurate representation of energy demands and can estimate the GDP costs of the alternative policies. We can measure costs of each policy option in terms of GHG reduction and reduction in oil imports.

## Methods

## Our approach is to use a well-established bottom-up energy model named MARKAL (MARKet ALlocation). Bottom-up means that the model is built upon thousands of current and future prospective energy technologies and resources. These energy resources supply projected energy service demands for the various sectors of the economy. In addition to the standard MARKAL model, we also have adapted a version of the MARKAL-Macro model which permits us to include feedbacks between energy prices and economic activity. Thus the GDP effects of alternative energy policies are captured as well as technology and supply impacts. For these reasons, MARKAL-Macro is an ideal tool for this kind of analysis.

MARket ALlocation (MARKAL) is a widely applied, dynamic, perfect-foresight, technology-rich linear programming, energy systems, optimization model. In its standard formulation, its objective function is the minimization of the discounted total system cost which is formed by summation of capital, fuel and operating costs for resource, process, infrastructure, conversion and end use technologies. The general framework enables the calibration of a model to local, national, regional or multiregional energy systems. Model applications include, but are not limited to, climate policy, impact assessment of new technologies, taxes, subsidies, and various regulations. Further details regarding the methodology can be found in ([Loulou et al., 2004](#_ENREF_3)).

The US EPA MARKAL is a standard MARKAL model where energy service demands are inelastic, exogenous, and model structure is linear. A database that represents a particular energy system must be developed to use with MARKAL. The U.S. EPA ([2006](#_ENREF_7)) developed MARKAL databases that represent the US energy system at the national and regional levels. Both databases cover the period 2005 through 2055 in five-year increments and represent the sectors: resource supply, electricity production, residential, commercial, industrial and transportation sectors. The original model has now been updated to 2010 data. In this study we use the national single region US EPA MARKAL model.

Characterizations of current and future energy demands, resource supplies, and technologies within the databases were developed primarily from the Energy Information Agency’s 2010 Annual Energy Outlook report, extrapolated to 2055 using National Energy Modeling System (NEMS) outputs published by DOE ([2010](#_ENREF_2)). Additional data sources include the AP-42 emission factors from US EPA ([1995](#_ENREF_6)), and Argonne National Laboratory’s Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation (GREET) model ([Burnham et al., 2006](#_ENREF_1)). Further details regarding US EPA MARKAL can be found in Shay et. al. ([2006](#_ENREF_4)).

One set of changes is the update of natural gas resource supply curves in the US EPA MARKAL database based on the MIT Energy Initiative report ([The MIT Energy Initiative, 2011](#_ENREF_5)). Natural gas is expected to be available at low cost for the US, due to shale gas and other technological improvements. Due to the expectation of improvements in gas extraction techniques, the high availability case is quite plausible as suggested by the MIT Energy Initiative Report ([The MIT Energy Initiative, 2011](#_ENREF_5)). With this expectation we make the use of high availability case supply curve in the modified MARKAL database.

## Results

## We will report results on GDP, primary resource mix, electricity sector price and generation source changes, detailed transport sector analysis, and impacts on domestic GHG emissions. In each case, we will compare the reference case with the proposed CNG policies in transportation sector.

## Conclusions

 In this analysis we develop incentives for nautral gas use in transportation that are equivalent to the incentives currently provided for plug-in electric vehicles. We find that with equivalent incentives for CNG/LNG, there is significant penetration of natural gas use in CNG fleets. However, these incentives are not adequate to stimulate substantial penetration of natural gas into the light duty vehicle fleet.

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