created to develop bioenergy and jointly coordinate the activities of these bodies, to define development policies, and above all to include scientists, academics, peasant organizations, entrepreneurs, Pemex, and other stakeholders.

Financial incentives should target not only biomass generation: comprehensive support should be given to rural development as a whole, and also to scientific and industrial development for the efficient transformation of biomass not only into biofuels but also into high-value-added products. The construction of biorefineries provides scientific, technological, and financial support for the production of biofuels, but the creation of a national biofuel research center would be desirable in the short term. Various national scientific institutions have the capability to develop part of these processes, reason enough not to wait for technologies conceived in developed countries to reach maturity and be marketed in Mexico. Domestic technology and its application on a commercial scale should be encouraged, not only to generate biofuels, but, as mentioned, to set up biorefineries. VM

NOTES

[1] This article is the product of the Engineering Research Group on the Metabolic Pathways of Bacteria. The authors wish to acknowledge the support of Conacyt, Proinnova grant 2011/2012/154298, and DGAPA/PAPIIT/UNAM IT200312-2.

[2] Biomass is the biological material derived from animals and plants, which is generally not used as food; for example, agricultural, domestic, and livestock waste, etc.

[3] According to the Food and Agriculture Organization (FAO), food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. About this definition, see World Food Summit 1996 document, June 6, ftp://ftp.fao.org/es/esa/policybriefs/pb_02.pdf.

[4] Lignocellulose biomass is a type derived from plants, made up of compounds that humans and many animals cannot digest. Some common lignocellulosic residues include the stalks and leaves of corn, wheat, and sorghum; forestry residues such as shavings, sawdust, and firewood; and sugarcane and agave bagasse.

[5] Secretaría de Energía, “Ley de promoción y desarrollo de los bioenergéticos,” http://dof.gob.mx/nota_to_imagen_fs.php?codnota=5029330&fecha=01/02/2008&cod_diario=213102. [Editor’s Note.]

[6] See this legislation at http://dof.gob.mx/nota_to_imagen_fs.php?codnota=5094933&fecha=18/06/2009&cod_diario=220873. [Editor’s Note.]

[7] Anhydrous ethanol does not contain water and must be subjected to another process after distilling, while non-anhydrous ethanol is alcohol containing 96 percent ethanol and 4 percent water, the maximum concentration reached after the distillation process.

[8] Secretaría de Energía, http://www.sener.gob.mx/res/0/Acuerdos_SENER_131109.pdf. [Editor’s Note.]

[9] Energy plantations are plantations of trees or fast-growing plants whose specific purpose is to produce energy by burning directly or through transformation to produce a biofuel.

[10] Frontier technologies are those that are not yet commercially available and still require basic research using knowledge recently developed by researchers in many disciplines, such as the case of the bio-technology under discussion.

Energy and GHG Policy Options For Mexico’s Private Transport

Arón Jazcilevich*

INTRODUCTION

According to reports by the U.S. Department of Energy published in 2011, world oil demand will grow about 53 percent by 2035, and production capacity is already being used. In the same time frame, oil prices are expected to rise to about US$125 per barrel and green house gas (GHG) emissions will grow about 53 percent. In addition, oil production is expected to decrease by 70 percent in 30 years, though this may be delayed by a few years due to new deep-water oil discoveries

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in Brazil, and by oil and gas sources using fracking techniques in the United States (the Marcellus fault), Poland, and other parts of the world.

This general trend can already be seen in Mexico, where oil demand is increasing, and proven reserves are dwindling (Figure 1). The large Chicontepec oil field is not producing as planned, and deep-water oil fields in the Gulf are currently not exploitable because of Pemex's lack of technology. According to the International Energy Agency (IEA), deep-water oil production may not start until 2035. Compounding the problem is the fact that about 70 percent of primary energy in Mexico is obtained from oil, and transportation is totally dependent on fossil fuels.

Several technological options with high expectations around the world and Mexico have been proposed to ameliorate this impending crisis. Among others, they include the use of biofuels like ethanol and biodiesel and the introduction of new energy-saving vehicular technologies such as hydrogen cars, electric cars, and hybrid gas-electric vehicles (HEVs).

Expectations have been built up by focusing on the virtues of each technology, but often ignoring the chain of events that must be satisfied. If one or more of the links of this chain is weak, the whole scheme collapses.

As an example, we have the so-called "hydrogen civilization," with the development of hydrogen-fuel-cell cars at its core. In the United States, during his 2003 State-of-the-Union address, President Bush declared, "A simple chemical reaction between hydrogen and oxygen generates energy which can be used to power a car, producing only water, not exhaust fumes. With a new national commitment, our scientists and engineers will overcome obstacles to taking these cars from laboratory to showroom, so that the first car driven by a child born today could be powered by hydrogen and pollution-free."[1] As of 2011, this has not happened.

A second example is biofuels. In the late 1990s they were heralded as the environmentally sound solution for partial oil substitution. Probably because of the achievements of the Brazilian ethanol program, many considered ethanol a sure bet. Success of first generation biofuels is nevertheless put in doubt by some authors as discussed in "The False Promise of Biofuels," which appeared in *Scientific American* in August 2011.

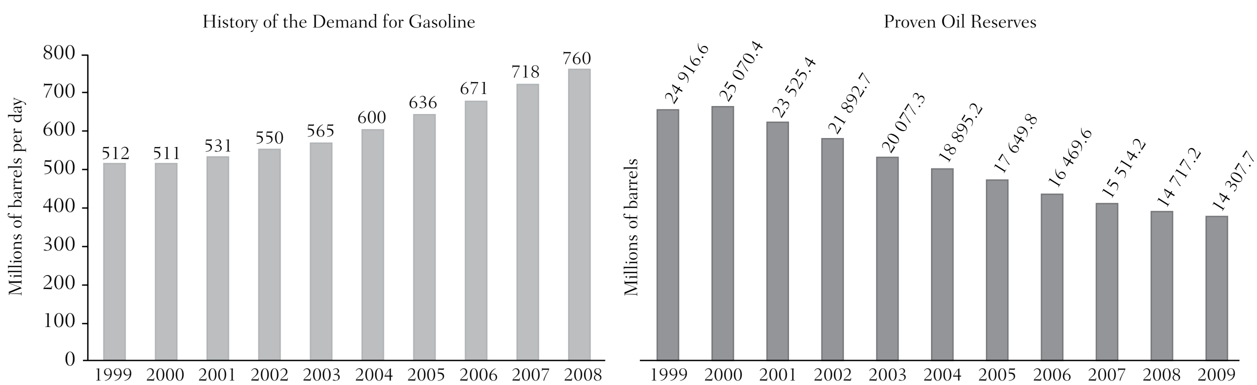
These experiences have prompted the consolidation of methodologies such as life-and-energy-cycle analysis, and scenario analysis. Some of these studies have helped identify technological and economic barriers and "hot spots" in a given chain process. Also, they are instrumental in identifying which technologies hold promise in the near future and

> Expectations built up by focusing on the virtues of each technology often ignore the chain of events to be satisfied. If a single link is weak, the whole scheme collapses.

FIGURE 1

HISTORY OF DEMAND AND PROVEN OIL RESERVES IN MEXICO

Mexico's proven oil reserves are declining and the demand for gasoline is increasing.



Source: www.ri.pemex.com.

Lucas Jackson/REUTERS

Many considered ethanol a sure bet. Success of first generation biofuels is nevertheless put in doubt by some authors as discussed in the August 2011 article "The False Promise of Biofuels."

which have long or unrealizable developmental time horizons or costs. I should mention that, for the Mexican case, only a few of these studies have been published in peer reviewed journals, hampering a clearer and more objective view for planners and decision-makers to form technological and economic objectives.

I have chosen a few examples from the private transportation sector to illustrate the scope and usefulness of the aforementioned techniques. To promote further discussion, I have included my opinion and information about specific options for Mexico. We start with the hydrogen car, since, as mentioned, it is probably the strongest example of a seemingly infallible technology that has nevertheless met with enormous difficulties in its implementation.

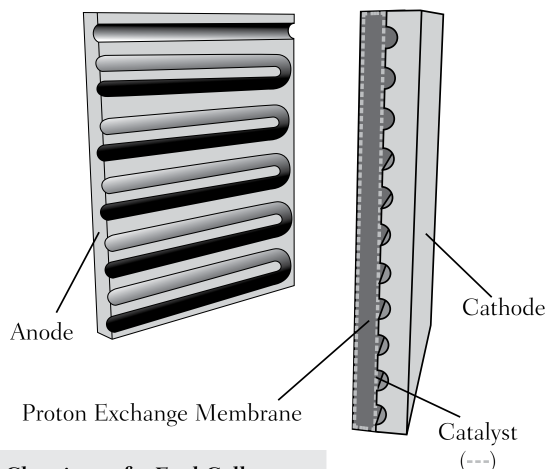
Hydrogen Fuel-Cell Vehicles

Hydrogen fuel cells were first proposed by William Grove in 1839. They were successfully used by the USSR and U.S. space programs beginning in the 1960s. They are simple, and their operation is based on combining hydrogen and oxygen to provide electricity. The only emission is water, which the cosmonauts and astronauts could use as an extra supply. The energy efficiency limits of such devices theoretically reach 75 percent and their main advantage is their reliability. The operation principle is depicted in Figure 2. It is basically an electrolysis process in reverse: hydrogen and oxygen are combined to obtain water and electricity.

Why has this technology not fulfilled its promise? Here are some explanations.

Figure 2
Operation of a Hydrogen Fuel Cell
Using a Proton Membrane

How Fuel Cells Work



Chemistry of a Fuel Cell
Anode side: $2H_2 \Rightarrow 4H^+ + 4e^-$
Cathoide side: $O_2 + 4H^+ + 4e^- \Rightarrow 2H_2O$
Net reaction: $2H_2 + O_2 \Rightarrow 2H_2O$

Source: *How Stuff Works*, www.howstuffworks.com/, 2000.

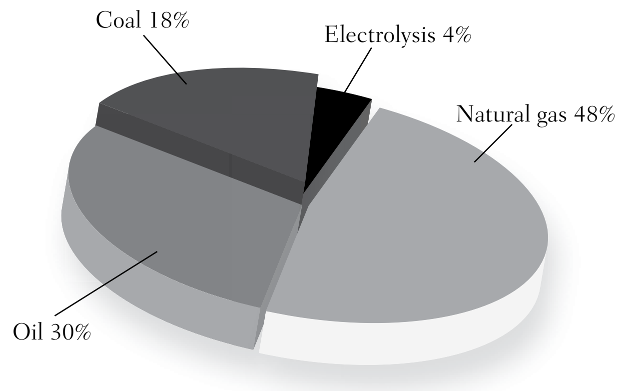
Hydrogen GHG Emissions Cycle

As mentioned, one of the justifications for hydrogen-cell cars is their beneficial emission: pure water. Figure 3 shows the percentage of hydrogen produced in the world by different means. Most of the hydrogen produced (78 percent) uses hydrocarbons such as methane as part of a high-energy process called reformation. If hydrogen obtained this way is used to feed fuel-cell-powered cars, no GHG savings are expected.

Only if hydrogen is produced through electrolysis using renewable forms of energy such as wind, photo-voltaic, or hydroelectric energy are savings in GHG emissions expected. This leaves only Iceland as a possibility for the "hydrogen civilization," since they generate their electrical power with hydroelectric dams. Nevertheless, if renewable energy is used to produce other types of secondary energy instead of hydrogen, vast GHG emissions savings could be achieved. This is shown in Figure 4.

Figure 3

Production of Hydrogen by Different Processes



Source: World Nuclear Association, "Transport and the Hydrogen Economy," www.world-nuclear.org/info/inf70.html, accessed in February 2012.

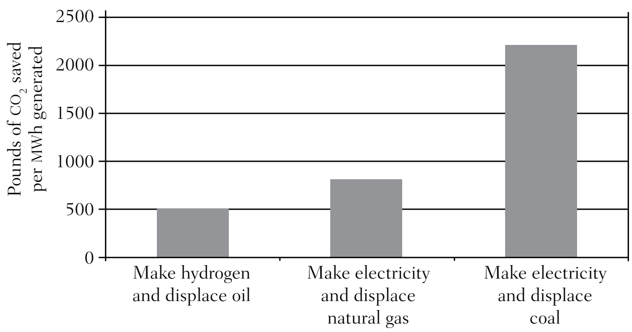
> Only if hydrogen is produced through electrolysis using renewable forms of energy such as wind, photo-voltaic, or hydroelectric energy are savings in GHG emissions expected.

The Hydrogen Energy Cycle

A peer-reviewed study carried out in Norway by Ann Mari Svensson and collaborators, published in the journal *Energy,* shows that an electric car whose battery is charged with electricity generated from a natural gas plant is 35 percent more efficient than a fuel-cell vehicle. This analysis is well-to-wheel: it takes into account the beginning of the process to generate electricity, then its use to produce hydrogen, to its final use to generate mechanical power. This means that in a fuel-cell car, we must include steps such as first converting electricity to hydrogen, then hydrogen to electricity that in turn is converted to mechanical power. In an electric car, electricity is converted to mechanical power directly, resulting in a higher efficiency. Another factor is that if reformation with natural gas is used as discussed above, water (steam) and methane are mixed at high temperatures (700-1100°C). The reaction needs 191.7 kJ/mol to take place. This places the thermodynamic efficiency of the process lower than an internal combustion engine. Though some of this energy may be recovered in a secondary reformation step with CO, recovering 40.4 kJ/mol, the overall energy cost is still high. Other well-to-wheel comparisons in the same study show that a gas-electric hybrid car, or HEV, is about 27 percent more energy efficient, and a conventional combustion engine car is 14 percent more efficient than the fuel-cell car.

Figure 4

Emissions Reduced by Renewable Electricity



The bar on the left represents the CO_2 savings from renewable electricity used to make hydrogen, assuming the hydrogen is used in a fuel-cell car and displaces the fuel from a hybrid car. The middle bar represents the savings from renewable power displacing electricity from combined cycle natural gas power plant. The bar on the right represents the savings from renewable power displacing electricity from typical coal plant.

Source: Joseph J. Rohm, *The Hype About Hydrogen* (Washington, D.C.: Island Press, 2004).

As of 2012, oil production shows a negative trend while consumption is increasing, but Mexico has not begun to diversify its liquid fuel supply or implement vigorous energy-saving policies in the transport sector.

Scenario Building, Or the Chicken and the Egg

If fuel-cell hydrogen cars are to substitute conventional cars, it is estimated that 50 000 to 90 000 hydrogen charging stations will be needed in the United States. Unless they are built in great numbers (at least regionally), no hydrogen cars will be able to compete on the market because of the inconvenience of finding where to refill the hydrogen tank. If the stations are built first, a gamble in the billions of dollars will be made in the hopes that hydrogen fuel-cell cars will be successful in the long run. These scenarios also need to take into account severe leakage problems for hydrogen storage. Argonne National Laboratories estimate that the cost for a complete system of hydrogen stations is about half a trillion dollars.

Technological and Market Barriers

According to auto industry experts, a hydrogen car will be competitive with conventional cars when a 400-kilometer fuel range is achieved. Technological hurdles must be overcome to reach this target. Though research is already in progress, hydrogen cars with this range will not be ready for the market for many years, as discussed in "Gassing up with Hydrogen," published in 2007 by *Scientific American*.

Electric Cars

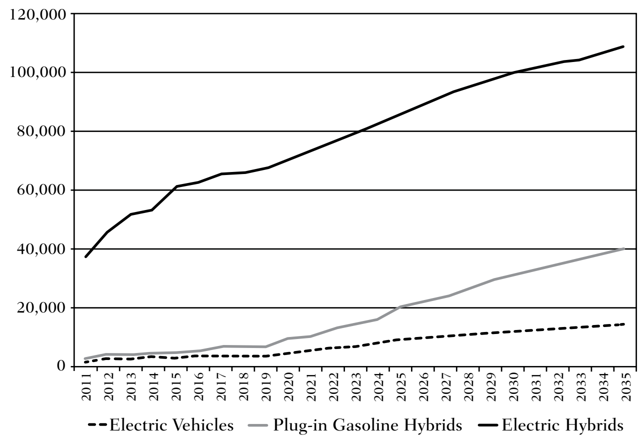
We can apply some of the techniques discussed above to electric cars. Since they run exclusively on batteries, the target of the 400-kilometer range is also present. Nissan's Leaf, the first fully electric mass-produced car on the market, has a range of only 117 kilometers, creating the need for a network of recharging stations. Therefore, a chicken-and-the-egg problem also exists, although to a lesser degree. Infrastructure is needed for quicker recharge times of about 30 minutes and for locating recharging stations on highways or in workplaces.

A life-cycle analysis of overall GHG emissions shows that they depend on the source of the electricity being used to recharge the battery: if it is from a thermoelectric plant, there are net GHG emissions; from a natural gas plant, there are savings; while hydroelectric plants offer the most emission savings. In the case of Mexico, where 70 percent of the electricity is produced using oil, no GHG emissions savings will be achieved. Change to natural gas or other, renewable sources is needed to obtain an advantage. Nevertheless, better energy use may be accomplished using these cars, and air quality may be improved in urban areas.

Can we build a scenario to find out how much time it will take to have an electric car fleet make a difference? If the U.S. market can be used as a guide, future accepted market scenarios in Figure 5 show that in 2035, no more than 2 percent of cars sold will be electric.

Figure 5

Sales Scenarios for Hybrid, Electric, and Plug-in Hybrid Vehicles



Annual sales (2011-2035)

Source: United Department of Energy Information Administration, "2012 Energy Outlook," www.eia.gov/, accessed in February 2012.

Gas-Electric Hybrid Cars (HEVs)

Figure 5 also shows a scenario for hybrid electric cars, already successful in the U.S. market. They will outsell new technology cars and represent more than 30 percent of the car fleet by 2035. As discussed by Svensson, their GHG and production energy cycle are slightly higher, but competitive with conventional cars. The overall energy and GHG cycle, taking into account production and usage, turns out to be advantageous.

Is there a chicken-and-the-egg problem? No, since these cars are electrically self-recharged and no public infrastructure is needed.

In a study published in the *Journal of Power Sources* by this author and colleagues, during the car's use, energy and emissions savings (both GHG and criteria pollutants) were obtained for the Mexico City case. If prices become competitive in Mexico, as is the trend in the U.S. market, this technology is promising. An optimistic scenario for year 2026 places 20-percent gas-electric hybrids in Mexico City's car fleet. By that time, benefits in energy and public health will already outweigh costs, mainly private.

Bio-fuels: Sugar Ethanol

As shown in Figure 6, Mexico exports sugar, but as of 2012, it does not produce ethanol. The costs and GHG emissions cycle for sugar-ethanol in Mexico have been investigated by Carlos García and Fabio Mancini as published in the journal *Solar Energy* in 2011. Although overall GHG emissions savings are obtained *vis-à-vis* the continued use of mineral gasoline, the land-use changes needed to substitute about 10 percent of gasoline with ethanol makes this option not as desirable as previously thought.

Combining options may offer the most feasible and efficient solution. Ethanol and HEVs may save more GHG emissions and energy together than each of them alone. Efficient public transport systems must be built and enlarged.

UNAM researchers are working on more precise full-energy and GHG-cycle analysis and an examination of hydrological and soil impacts of sugar cane production, detailed emissions by bio-fuels usage, their impact in the Mexico City atmosphere, and health consequences.

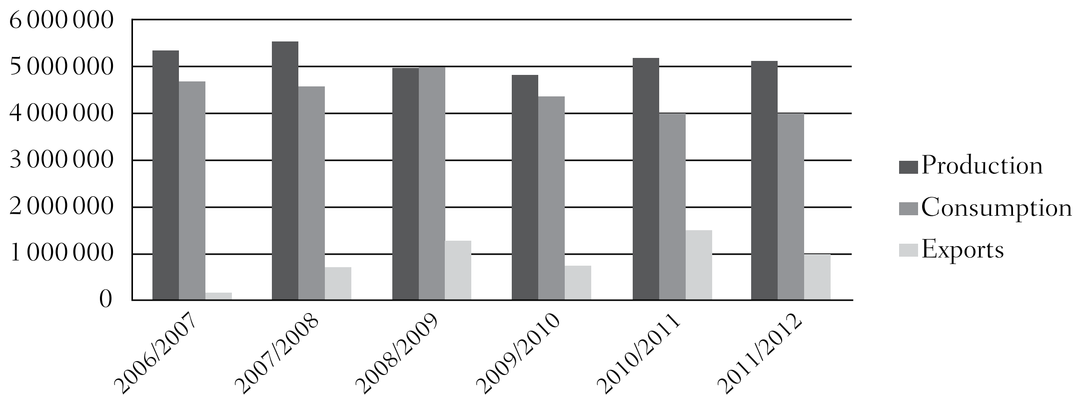
Comments and Conclusion

The scope of this article does not cover labor, market regulations, governance, or the internal organization of production, especially in the agricultural sector. These factors should be included in holistic studies to provide information to policy planners.

Even though oil production shows a negative trend while consumption is increasing, as of 2012, Mexico has not begun to diversify its liquid fuel supply or implement vigorous energy-saving policies in the transport sector. As exemplified here, methodologies such as life-and-energy-cycle analysis,

Figure 6

Sugar Production, Exports, and Internal Consumption in Mexico (metric tons)



Source: United Department of Energy Information Administration, "2012 Energy Outlook," www.eia.gov/, accessed in February 2012.

together with scenario analysis, can be used to decide which policies to use to deal with an impending energy crisis and what their limitations are. These methodologies show that there are no definitive technological solutions; some that appear perfect in one segment of their implementation may fail in another, ruling them out. A solution in one region may not work in another, or may only work to a lesser degree.

Combining options may offer the most feasible and efficient solution. For example, ethanol and HEVs may save more GHG emissions and energy together than each of them alone. Efficient public transport systems must be built and enlarged.

It will take time to implement any option enough so its impacts are felt. This is also the case for technologies already existing on the world market. Is there time for Mexico? VM

NOTES

[1] http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/benefits.pdf.

Biofuels and Sustainable Rural Development in Mexico

María Elena Goytia Jiménez*

Stringer/REUTERS

Global production of oil, a non-renewable resource, is expected to peak between 2010 and 2019, when conventional reserves in most oil-producing countries will have practically run out, and only Saudi Arabia, Kuwait, Iraq and the United Emirates will still possess this resource.

Recent studies show that Mexico hit its peak oil production levels in 2004,[1] and that from 2014 it will begin to have to import it. The political and financial costs will be high, since the Mexican economy is heavily dependent on oil, which contributes between 36 and 40 percent of the federal budget.

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