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SESSION 2: ENERGY AND AGRICULTURE: THE FUTURE OF BIOFUELS

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Biofuels are receiving increased attention worldwide. The International Energy Agency projects that global consumption of ethanol and biodiesel will increase nearly fivefold over the next two decades, accounting for four percent of global transportation fuels by 2030, up from one percent today (IEA, 2008). Growth is expected to be even more pronounced in Europe: biofuels consumption is expected to quadruple there even as total oil consumption falls, vaulting biofuels' share of the transportation fuels market from one to seven percent. Similar trends are forecast for the United States.

These "business as usual" projections, however, are extremely tentative. They are based on hard-to-make predictions about future commodity prices and, critically, on the assumption that no new policies will be put in place to promote biofuels growth. But the future will almost certainly be different. Concerns about energy security, climate change, and food prices, will yield new policies in Europe and elsewhere, which will in turn change the biofuels landscape. The most bullish pictures see biofuels providing nearly half of the world's liquid transportation fuels by 2030 (Vattenfall, 2007). Other estimates of a carbon-constrained world are foresee a much smaller role for biofuels, but one that is still substantially greater than in the business as usual case (IEA, 2007; IEA, 2008).[2]

This paper explores the basic factors and policy decisions that will shape the future of biofuels. It then provides several basic recommendations for policymakers. Crafting the best biofuels strategy possible will require policymakers to carefully balance multiple objectives and to draw on policy tools from beyond the biofuels sphere.

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[2] (IEA, 2008) projects increased biofuels use in its climate-constrained scenarios but does not provide numbers. The "Alternative Policy Scenario" in (IEA, 2007), which is consistent with stabilization at 550 ppm CO_2e, projects an increase in biofuels' share of global transportation fuels in 2030 from 3% to 6%.

ENERGY SECURITY

Concerns about overdependence on oil have historically been the primary driver of biofuels policy. Oil security concerns typically have several elements.

Countries have long worried about the possibility of oil supply cutoffs, which can, in theory, wreak economic, social, and political havoc. These concerns trace back to the 1970s. They are less salient, however, today. Oil is traded on global markets; as a result, lost supply from one source can be replaced by imports from another (though typically at higher prices.) Wealthier oil-importing countries, including those of Europe, have also developed a system of Strategic Petroleum Reserves (SPRs), several-month stores of oil that can be released during supply crises to blunt those crises' impacts.[3] Concern about supply cutoffs not a good reason to promote biofuels.

Nonetheless, the lack of flexibility in fuel options for transportation can lead to high and volatile prices. That, in turn, hurts economic growth. Expanding fuel options – including through investment in greater use of biofuels – can, if done right, help moderate and stabilize fuel prices. In addition, substitution of domestically produced biofuels for imported oil can help alleviate balance of payments problems, again with positive economic effects. High oil prices and consumption levels also enrich many corrupt and undemocratic regimes. International security is generally enhanced if greater production of biofuels lowers oil prices and lowers global oil imports from such countries.

Expanded production of reasonable-cost biofuels is, however, only one of many policy levers available for addressing these energy security challenges. Curbing overall demand for liquid fuels, whether by using energy more efficiently in transportation or by shifting to greater use of electricity to power cars and trucks, will be a critical element of any effective energy security strategy. The legitimate role of biofuels will also depend on whether they can be produced at a reasonable cost compared to gasoline and diesel. That in turn will depend both on how the price of oil evolves, on how biofuels technologies and business models develop, and on the future prices of inputs for biofuels, including feedstocks, energy, fertilizer, and land. It is thus impossible to dictate now with any confidence precisely how central biofuels should be in future energy security strategy.

While oil is central to biofuels' energy security calculus, it is also important to remember that natural gas should be part of biofuels' energy security equation. Current biofuels technologies generally consume large amounts of natural gas in making fertilizer and in processing feedstock into fuel. Natural gas consumption presents an energy security problem in Europe, and greatly expanded biofuels production could exacerbate that. (It is worth noting that natural gas is less of a security problem in the United States, since most supply there is either domestic or from friendly and stable states.) Still, biofuels will not be a central determinant of European energy security vis-à-vis gas.

[3] By minimizing the potential impact of any supply shock, SPRs also serve as a deterrent to politically motivated supply cutoffs.

CLIMATE CHANGE

The second big force shaping biofuels policy is concern over climate change. Emissions of greenhouse gases – primarily carbon dioxide (CO_2) produced by burning coal, oil, and natural gas to produce energy – are steadily accumulating in the atmosphere, leading to temperature increases and corresponding changes in climate.

Greenhouse gases are different from ordinary local pollution: they typically remain in the atmosphere for decades or centuries after they are emitted. As a result, unless global emissions are slashed in the coming decades, the world will probably see severe temperature rises and a wide range of associated climactic impacts.

Biofuels have the potential to play a significant role in addressing this predicament, since substituting biofuels for oil will generally lead to lower net emissions. The plants that are used to make biofuels absorb carbon dioxide from the atmosphere as they grow; that carbon is stored in the plants themselves as well as in the underlying soil, reducing global greenhouse gas concentrations. At the same time, greenhouse gases are emitted in cultivating biofuel crops, in converting them to liquid fuel, and, ultimately, in burning ethanol or biodiesel in vehicle engines. What is the net result? Viewed over its full "life cycle" – from the planting and growth of biofuels crops to burning the resulting biofuels – emissions are generally lower those from the gasoline or conventional diesel that they displace. How much lower depends strongly on the particular feedstock used to make biofuels. Ethanol made from corn, for example, probably reduces net greenhouse gas emissions very little; ethanol from sugar beets cuts roughly halves emissions; and ethanol made from sugarcane cuts emissions by about ninety percent (Sims, 2008).

This logic, however, is not without problems. In many cases, land is cleared specifically so that biofuels crops can be grown, which releases large quantities of greenhouse gases into the atmosphere. For example, conversion of peat to growing palm for biodiesel is responsible for a large fraction of Indonesian greenhouse gas emissions. Those emissions can overwhelm any savings that accrue from shifting from conventional oil to biofuels. Indeed even if sensitive land is not explicitly converted to biofuels cultivation, increased production of biofuels can lead indirectly to increased emissions. (This phenomenon is referred to as "indirect land use change".) For example, in Brazil, agricultural pasture is often converted to growing sugarcane for ethanol production. Ranchers now require other land to graze their cattle on – and if they develop that land by clearing rainforest, as is often the case, very large emissions result.[4]

Quantifying these phenomena is notoriously difficult. This is particularly true in the case of indirect land use change, where complex models must be used to predict how biofuels production in one place will affect land use elsewhere. In perhaps the most prominent analysis, a group of researchers estimated that emissions savings from U.S. production of corn ethanol would take 167 years to make up for emissions from indirect

[4] This paper does not address the impact of biofuels production on water use, which has also raised environmental concerns.

land use change. They also estimated that if ranchers displaced by Brazilian sugarcane cultivation decided to convert rainforest in order to gain new grazing land, it would take 45 years for the savings from ethanol use to make up for the initial emissions (Searchinger, 2008). This analysis has, however, been vigorously challenged on a wide range of grounds.[5] While it is clear that converting carbon-rich lands such as tropical forest to produce biofuels has a net negative climate impact, the net impact of converting less carbon-rich lands, especially if done with care, is still unknown (Kim, 2009).

Biofuels are, of course, only one of many options for cutting greenhouse gas emissions. Energy can be consumed more efficiently, electricity can be produced in ways that yield lower emissions, industrial plants can adopt technologies that lower their pollution, and new fuel sources – including biofuels – can be used in transportation. Figure 1 shows one set of authoritative predictions for the role biofuels might play. The precise mix, however, will depend on how technologies evolve and on policies governments choose. That mix is impossible to predict.

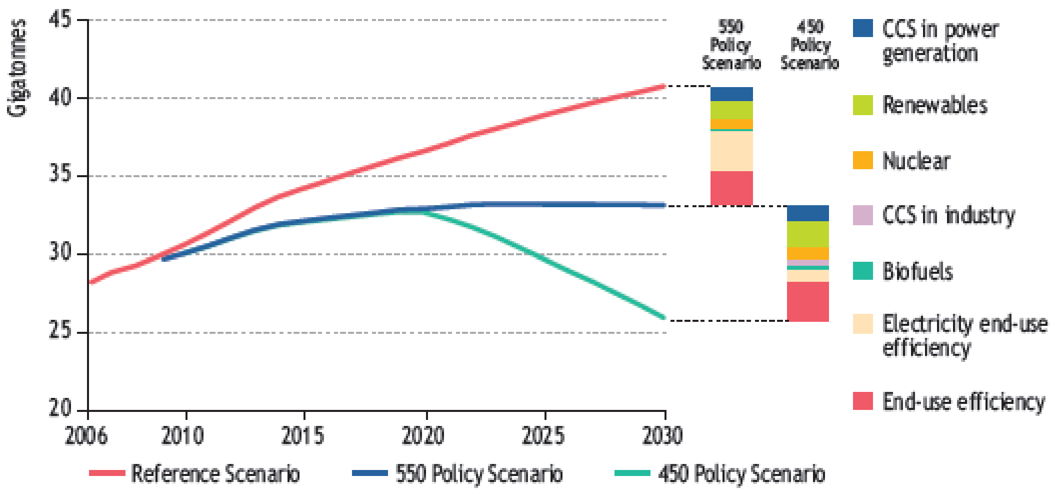

Figure 1. The top line shows global emissions projections for "business as usual". The bars on the right show the roles of various emissions-cutting technologies in moderate (550) and aggressive (450) policy scenarios. Note that increased vehicle fuel efficiency is included in "End-use efficiency". Figure from (IEA, 2008).

[5] In particular, see the letters to the editor in response to (Searchinger, 2008) in several subsequent issues of *Science*.

FOOD SECURITY

The third major factor shaping biofuels policy will be concern about its expected effect on global food prices. Policies that increase demand for biofuels also increase demand for feedstocks. If those feedstocks have alternative uses as food (as is the case, for example, with corn- or wheat- based ethanol or with soy-based biodiesel), this in turn drives up food prices. Even biofuels production that uses feedstocks that are not in demand as food can lead indirectly to increased food prices. Cultivating biofuels crops on high-quality land that might otherwise have been used to grow food, for example, increases the cost of good land and hence food prices. Fertilizer-intensive biofuels production similarly drives up the cost of growing many other crops.

Skyrocketing food prices have focused policymakers' minds on this tension between food and biofuels, though the global economic slowdown has brought a temporary reprieve. While there has been much debate over the underlying causes of the rise in agricultural commodity prices that occurred over the last several years, there is a general consensus that government support for biofuels played at least some role. More important, there is broad agreement that all else being equal, massive future increases in biofuels production could have severe effects on food prices worldwide. Unless policymakers can resolve that tension, there will be substantial and legitimate pressure to curtail efforts to promote biofuels growth.

The near-term challenge may be particularly acute, since currently mature biofuels technologies all use land that could otherwise be cultivated for food production. This limits the tools available to policymakers, leaving them with two basic options for dealing with the tension. The first involves lowering demand for biofuels by cutting back existing subsidies and mandates biofuels production. Any such step would be controversial both because it would affect agricultural communities and because concern about energy security makes policymakers hesitant to scale back their ambitions for moving away from oil. The tension between food and fuel might also be defused if global agricultural productivity could be improved and if the functioning of international agricultural markets could be enhanced. While such developments would not remove the effect of biofuels on food prices, they could offset them through other means. These steps would also have the benefit of helping keep food costs down even if the role of biofuels in causing high food prices turns out to be overstated.[6]

TECHNOLOGICAL PROSPECTS

The future of biofuels will be determined in large part by how biofuels technology develops in the coming decades. Biofuels on the market today, including ethanol made from sugar beets, corn, wheat, and sugarcane, as well as biodiesel made from soybeans, rapeseed, and palm oil, are referred to as first generation biofuels. Such biofuels,

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[6] In the very short term, of course, the global economic downturn will keep food prices relatively low regardless. But if policymakers should take advantage of the opportunity to fix the underlying problems, high food prices are almost certain to reoccur.

however, tend to be relatively ineffective at cutting greenhouse gas emissions, because producing them consumes large amounts of energy and hence generates substantial emissions. Many are also relatively expensive, limiting their value on the energy security front. The notable exception to these rules is sugarcane ethanol, which takes relatively little energy (and is also inexpensive) to produce; as a result, switching from gasoline to sugarcane ethanol is broadly believed to be a cost-effective way of cutting emissions – though concerns about indirect land use change still plague even this particular biofuel.

The limitations of first generation biofuels have prompted policymakers, entrepreneurs, and scientists to focus increasingly on so-called second generation biofuels. These biofuels, none of which are produced at commercial scale yet, do not exploit feedstocks that have alternative uses as food. Instead, they use so-called "cellulosic" feedstocks. These could include crop residues (such as cornhusks) and woody biomass (such as wood chips).

Cellulosic feedstocks have the potential, in theory, to reduce the lifecycle emissions from fuel production, thereby making biofuels better candidates for cutting greenhouse gas emissions while strengthening energy security. This is because the feedstocks involved would require either less energy to grow or less energy to process into fuel – or both.[7] (Using crop residues, for example, would essentially eliminate any emissions associated with growing feedstocks specifically for fuel.) At the same time, by focusing either on using land that is not suitable for growing food, or by using the same land for food and fuel production simultaneously, second generation biofuels present the possibility of addressing the tension between food and fuel production.

It remains to be seen, however, whether second generation biofuels will fulfill their promise. Breaking down cellulosic biofuels into a form that can be converted to fuel is difficult, and while a variety of technology options are well understood, none have been demonstrated at reasonable cost or at commercial scale. The ultimate fate of second generation biofuels will depend on whether costs can be brought down to competitive levels and on whether the scope of production can be expanded by many orders of magnitude. This will depend not only on scientific developments but also on the business models that develop around different technologies and feedstocks, which themselves will have major impacts on viable cost and scale of biofuels production (Sims, 2008).

A shift from first to second generation biofuels will also have important implications for agriculture. First generation biofuels are generally grown on agricultural lands; they also use many of the same inputs that traditional agriculture does. Demand for first generation biofuels thus tends to have a strong impact on agriculture. The impact of second generation biofuels is, however, less clear.

Some paths promise new commercial opportunities for farmers. Demand for crop residues that can be converted to fuel, for example, will make those crops more valuable.

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[7] Crops that needed less fertilizer would also reduce emissions of nitrous oxide, a potent greenhouse gas.

Meanwhile, if lands that are currently used only in some seasons can be put into use producing biofuels feedstocks during the rest of the year, that will open up new opportunities too. Other trends will be neutral: for example, growth in the use of wood chips for fuel production will leave farmers largely unaffected, since these inputs for making fuel will come from a different sector. That said, if second generation biofuels become viable, demand for first generation biofuels may drop, removing opportunities that currently exist for many farmers. The paths that ultimately materialize will depend in part on where technology investment is directed and in part on the luck of which technologies turn out to be most promising.

WHAT ROLE SHOULD GOVERNMENTS PLAY?

Governments have to date supported biofuels development through a mix of subsidies and tax incentives for both producers and consumers of biofuels. But while singling out biofuels for subsidies and mandates may appeal to the narrow interests that benefit from them, these policies cost taxpayers large sums of money and can also drive up gasoline and diesel prices at the pump. They should be phased out over time – indeed it is widely agreed that current policies are inefficient at best (OECD, 2008). But what approach is wisest?

Relying purely on markets is ill advised. Biofuels may deliver significant benefits for climate change and energy security, but, left alone, markets will not fully value those. Without special incentives, then, biofuels production may be substantially less than the social optimum. Many of the most promising future biofuels developments will also require substantial investment in research, development, and demonstration (RD&D) activities. Private actors, however, tend to underinvest in RD&D because of the high risks involved and because the benefits of success accrue not only to them but also to their competitors. Lack of government policy that addresses this market failure will also lead to less than optimal investment in biofuels. Meanwhile, even if biofuels subsidies and mandates were eliminated, biofuels development might still ultimately place strong and undesired pressure on food prices – an outcome that government policy (including the promotion of properly functioning agricultural markets) would need to address.

This suggests that government has three basic roles to play. First, it should take steps to make sure that the energy security and climate change benefits of biofuels are directly reflected in their market prices. On the climate change front, this can be done by including biofuels production and consumption in any cap-and-trade or other carbon pricing scheme that is used, which would raise the price of gasoline relative to that of biofuels. On the energy security front, to the extent that governments are focused on oil consumption, it can be accomplished by levying lower taxes on biofuels than on traditional gasoline. Done right, neither of these steps would be as strong a support for biofuels as the current subsidy and mandate regimes are, since they would let other solutions to energy security and climate change problems compete in the market. But they would still lead to substantially greater use of biofuels that the market would if left to itself.

Second, governments should support RD&D in second generation biofuels both through direct investment and by providing incentives (beyond carbon and gasoline pricing) to private sector innovators. Subsidies and mandates may have some role to play here in order to provide the market scale necessary to attract sufficient investment in innovation. But this should be done carefully, with an eye toward phasing out such support as markets mature, and in a context where other targeted policies are used whenever possible. Meanwhile, it is important to ensure that investment in new technologies is not overly concentrated in any particular country or region. Different places may prove promising for different feedstocks and – equally important – different supply chain and business models. International cooperation in RD&D can also promote harmonized standards for assessing the emissions from different technologies and processes, which in turn could help facilitate international biofuels trade.

These steps will help the two critical downsides of biofuels promotion just discussed. But governments must also look beyond biofuels policy. They should adopt measures that broadly discourage tropical deforestation and other damaging land use change, which would blunt concern that biofuels cultivation is leading to climate-harming activities. As a start, consuming countries should adopt policies that avoid promoting the use of biofuels produced on recently converted carbon-rich land. This includes much of the biodiesel Europe currently produces using Southeast Asian palm oil.

That will not, however, address the challenge of indirect land use change. To confront that problem, government should work to develop incentives for countries that avoid dangerous land use change and deforestation, something that is under active discussion in international climate negotiations. This would tend to steer new land conversion – whether directly or indirectly the result of biofuels cultivation – away from sensitive lands. Such efforts should combine financial compensation for countries that leave potentially valuable land undisturbed with technical assistance in establishing property rights and enforcing land-use laws that encourage sustainable land use.

Governments should also confront the tension between food and fuel by working to strengthen global agriculture. Serious efforts to improve agricultural productivity will require, among other things, promoting agricultural biotechnology. Improving the functioning of international agricultural markets will also require that the West, including the United States and Europe, cut back on subsidies and tariffs. In the long term, as technologies for cutting emissions and improving energy security develop, and as the factors driving food prices become better understood, policymakers may also want to deliberately discourage the dedicated use of agricultural lands for fuel production. In the near-term, if renewed economic growth leads again to dangerously high food prices, governments will need to seriously consider relaxing their biofuels mandates on a faster schedule than they might otherwise adopt.

Despite much recent criticism, biofuels have the potential to play an important role in addressing our energy security and climate change challenges. But they will only do so effectively – and responsibly – if we think broadly and carefully in designing policy and begin to shift course now.

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