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TEN YEARS OF THE RENEWABLE FUEL STANDARD:
WHAT'S BEEN THE IMPACT ON ENERGYAND THE ENVIRONMENT?

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Moderator:

TED GAYER
Vice President and Director, Economic Studies
The Brookings Institution

Panelists:

BRUCE BABCOCK
Cargill Endowed Chair of Energy Economics and Professor, Iowa State University
Director, Biobased Industry Center

TERRY DINAN
Senior Advisor, Microeconomic Studies Division
Congressional Budget Office

CHRISTOPHER KNITTEL
William Barton Rogers Professor of Energy Economics, Sloan School of Management
Massachusetts Institute of Technology

TIMOTHY D. SEARCHINGER
Research Scholar, Woodrow Wilson School of Public and International Affairs,
Princeton University
Senior Fellow, World Resources Institute

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P R O C E E D I N G S

MR. GAYER: Good morning, everybody. Welcome to our session today at Brookings. Welcome -- also, we have people listening by Webcast, which is always exciting.

I am Ted Gayer, and this event is on the renewable fuel standard. You should have out there bios for our speakers, so I'm going to give a very quick bio, and then we're going to jump into content, get a conversation going up here, and then look for questions from the crowd in the last 20, 25 minutes or so of the session, which we're due to end at around 11:45.

So, moving from that side to this side, we are pleased and grateful to have our speakers. First, Bruce Babcock holds the Cargill Chair in Energy Economics and directs the Biobased Industry Center at Iowa State University. Terry Dinan, to might right, is a senior advisor at the Congressional Budget Office. Chris Knittel, to my left, is the William Barton Rogers Professor of Energy Economics in the Sloan School of Management and directs the Center for Energy and Environmental Policy Research at MIT. And Tim Searchinger, on the end, is a research scholar at the Woodrow Wilson School of Public and International Affairs at Princeton University and a Senior Fellow at the World Resources Institute.

So, like I said, we are here to discuss the Renewable Fuel Standard. The Renewable Fuel Standard was enacted in legislation 10 years ago in 2005 and then ramped up considerably in legislation in 2007. Just as a brief overview of what it is, it mandates a minimum amount of renewable fuels to be blended into our transportation, our ground transportation fuel supply. There are nested categories of mandates, so there is an overall mandate for total renewable fuel. There's, then, a subcategory for advanced renewable fuel, and within that there is biomass-based diesel, which is typically made from soybean or other vegetable oils and cellulosic with a mandate for that, as well, made from various plant materials.

Each of the categories has to meet requirements for reducing the life cycle -- we'll talk about that coming up -- the life cycle of greenhouse gas levels, so they each have various percentages that they must reduce of life-cycle GHGs.

And something else that I'm sure we'll allude to -- EPA has authority to wave these requirements, and they have in the past based on the feasibility of meeting them. One thing we were just talking before we started, the law actually sets levels, volume levels, for each of these mandates, and then those volume levels are translated into percentages. So, as the demand or even the supply of fuel changes over time, the percentages could change given a certain mandate level for the volumes.

So, that gives you kind of a brief overview. Our goal is to touch on a number of subjects, and we'll try to do it as efficiently as possible while also getting in-depth and getting various opinions from the stage, and then, like I said, questions from you guys.

The four categories that I've kind of laid out for the speakers are as follows. One is essentially a sense of how we've done with our renewable fuel standards moving up into this point. And as I said it started in 2005 and expanded in 2007. EPA has used their waiver authority, so there's a question of how far we've met the legislated mandate levels; what are the impediments to meeting these levels as they tighten moving forward? For that, I'm going to look to Terry to kick us off.

Just so we have it all on the table, the other issues that I think we're going to hope to talk about is what is the effect of the renewable fuel standard on fuel prices and food prices -- something that comes up frequently. What is the effect on greenhouse gases when you take a life-cycle view of various different biofuels relative to standard petroleum-based fuel? And then where we kind of hoped to end up also is kind of an overall assessment of the program of the renewable fuel standard: How good is it? How cost effective is it for achieving our goals, specifically for pollution reduction, relative to other policies that we might adopt? What are the options of reforming the current renewable fuel standard either through as it stands now or through new legislation?

So, we're going to kind of bounce around between those topics, but I'd like to start off with Terry just to give us a sense of how close we've been able to meet the mandates. What has EPA done with these waivers? What are these future mandated levels looking like? What are the impediments and challenges? So, why don't I, with that, turn to Terry to kick us off on that conversation?

MS. DINAN: Okay, thank you, Ted.

Before I start, I'd just like to clarify that my comments are informed by work that CBO has done, but my comments here today are really my own views and shouldn't be attributed to those of the Congressional Budget Office.

So, as Ted explained, the RFS is a somewhat complicated rule with a nested structure of requirements. Just to be clear, I think that nested structure is intended to gradually bring more advanced biofuels with greater emission reduction potential into the market. I think it's fair to say that the rule is intended to be a technology forcing rule.

Going forward, implementing and complying with the rule really entails two primary challenges. The first is producing the amount of cellulosic ethanol that is required by the law; and the second is absorbing the growing amount of renewable fuels that the law requires be used into a shrinking pool of transportation fuels. So, to date the renewable fuel standard has primarily been met by blending corn ethanol, which is made from corn kernels, the corn starch, into gasoline and selling it as E10, which is what most of us fill up our cars with.

Going forward, the Energy, Security, and Independence Act of 2007, which is what defines the requirements of the RFS, requires rapidly growing quantities of cellulosic fuels be used, and those cellulosic fuels are made from plant substances such as corn stover, the cornstalks that are left on the field, or materials such as switch grass. By 2022, fuel suppliers would have to use 16 billion gallons of cellulosic fuels. That is actually equal to the total amount of renewable fuels that have to be blended into the transportation fuels today.

Meeting the cellulosic requirements stated in ESA has been a challenge ever since the beginning. The law first required that they be used in 2010, but the first plant didn't go into production until 2013 when roughly 6 million gallons of cellulosic fuels were produced in contrast with the 1 billion gallons that were required to be used under ESA.

The reason for this limited production is that converting cellulose into fuel is far more complex and costly -- it's very capital intensive -- than converting sugar, such as the cornstarch and corn kernels, into fuel. Moreover, using cellulosic materials -- cellulosic materials are very bulky, so transporting them is costly, and storing them is also costly.

The second challenge associated with the complying with the RFS is that even if it were feasible to reproduce the amount of cellulosic fuels that were required under the law using the total volume of renewable fuels required by ESA would be challenging. And the reason for this is that 10 percent is the maximum amount of ethanol that can be blended into gasoline and then used by virtually all vehicles currently on the road.

However, the amount of renewable fuels that can be blended into the fuel supply --

because the amount of gasoline that's projected to be used over time is shrinking and the renewable requirements are increasing, using the required gallons of renewable fuels is going to push the renewable fuel content of transportation fuels well beyond 10 percent. We estimated that it would be up over 20 percent by 2022 if we would comply with the law.

So, there are basically two ways around this blend wall dilemma. The first is to use increasingly large quantities of E85, which is a blend of 85 percent ethanol and gasoline, and that fuel can be used in what's called flex-fueled vehicles. The good news about this is that there's currently a substantial number of flex-fueled vehicles already on the road. And the reason why this is, is that automobile manufacturers get CAFE credits for producing these flex-fueled vehicles even if they never burn any E85.

The challenge associated with the increasing use of E85, however, is that there's currently a limited number of fueling stations that are equipped to provide E85. I think it's around 2 percent of all filling stations. And also consumers are unlikely to substantially increase their use of E85 unless they get a subsidy for doing so. The reason for that is that the energy content of ethanol is about two-thirds that of gasoline. So, you can go less far on a gallon of E85 than you can on E10, and you have to fill up your car more often. So, you need to be able to get a lower cost if you're going to do it.

Another way around the blend wall would be to use what's called E15. It's a blend of up to 15 percent ethanol and gasoline. Using this has been a little bit controversial in that EPA has certified that cars built since 2001 are equipped to use it without having corrosion problems. However, auto manufacturers have disagreed with that so that's led to some controversy. Filling these stations would require new storage tanks and could create concerns about liability if someone inadvertently put E15 into a car that was only equipped to burn E10.

So, just briefly to conclude, how has EPA responded to these challenges? Well, Ted already alluded to that, but specifically for cellulosic requirements, the EPA has basically waived them. They waived them -- eliminated the requirements for 2011 and 2012. In 2013 they reduced they mandate from 1 billion gallons to 6 million. In 2014, they proposed to reduce the requirements for cellulosic from 1.75 billion gallons to 33 million.

Up until its most recent set of proposals for 2014, 2015, and 2016, when EPA reduced the amount of cellulosic biofuels required, they did not simultaneously reduce the overall amount of renewable fuels that had to be used. Most recently however, that's what the EPA has done. They have lowered the total advanced requirement, and they've lowered the overall renewable fuel requirement. And so that has been somewhat controversial.

So, I think when the EPA decides how to address these challenges, they face this basic tradeoff between containing the cost of the rule and providing strong incentives to push these fuels into market, push the market for cellulosic, and push the demand for E85 and E15.

MR. GAYER: Great. Thanks, Terry.

I want to come back to some of these issues, but I first want to just go through some of the other questions of other speakers. I think the question of how effective or if RFS is the right approach in kind of forcing the technology on cellulosic or kind of busting through the blend wall I think are key issues. But let's tackle a little bit from each of these questions, and then we're going to circle among all of us to drill down on some of these.

Next I want to ask Bruce about the impact of fuel on food prices, so except for Terry everybody here is just coming into D.C. And in D.C., not surprisingly, whenever there's any energy policy, I'm sure even outside of D.C., the question of what does this means for fuel prices is always front and center.

As an environmental economist, sometimes making the economic claim that fuel prices should go up is not always the politically popular thing to do. But from an RFS standpoint, we should talk a little bit on the economics of it. What RFS essentially is doing is it's coupling a tax on low biofuels that are low biofuel-based and kind of mapping it with a subsidy on more biofuel-based fuels. And the questions I have, and others, are: What does that mean, as far as prices go, to the consumers? What does it do as far incentivizing things that reduce greenhouse gases? And of course since we're talking about, in many cases, corn and other inputs, what does this do for the food market?

So, with that, I'm going to leave it to Bruce to take it away from there, and then we'll kind of go to the rest and circle back on these topics.

So, Bruce, take it away.

MR. BABCOCK: All right, thanks.

What I want to do is kind of look back in time, since it's been about 10 years since we've had this commodity boom in agriculture that many attribute to the RFS. And lots of things have been attributed to the RFS, including starvation; including that fuel prices will go through the roof by the oil companies. And what I want to do is just give you my perspective on what has been the impact on food and fuel prices in the last 10 years or so. And a summary, in case I don't get to it is -- a summary of my view is there hasn't been much impact. So, let me explain, starting with U.S. food prices.

U.S. food CPI -- the Consumer Price Index for food -- has risen just a little bit on an average annual basis more than all prices in the United States. Yet, commodity prices -- corn, soybeans, and wheat -- have more than doubled in real terms over this time period. I'm talking 2006 to 2014. So, how can it be that commodity prices more than double and food prices don't go up much relative to all other prices in the economy?

Well, one reason is that food is not commodities. Food is produced by taking some agricultural commodities and combining them with capital, labor, energy, marketing, transportation -- all of that stuff -- in order to get what we eat as food. And the commodity share of the food dollar is small and shrinking. So, if you double commodity prices and the commodity share of the food dollar, the consumer food dollars -- 10 percent -- you're, at most, going to get a 10 percent increase, a one-time 10 increase in food prices. And the actual amount of the food price increase will be less than 10 percent, because companies that produce food will move away from the high-priced commodities and they'll substitute a way. Consumers will look at high-priced commodities or food items and switch, and so the actual impact on consumers will be less than at 10 percent.

It's simply fallacious to equate commodities with food. It's also fallacious to equate commodity calories that are produced on the farm with what we eat. You can't use one -- the commodity price -- or the amount of commodity calories to indicate what the RFS is on food prices. That's why the World Bank, which publishes this Food Price Index, which is really an index of corn, soybean, wheat, and rice prices, is such a misnomer. It's not food; it's commodities.

It's also important to remember that the appropriate measure of the impact of the RFS is what would food prices be without the RFS? So, in this non-RFS world, all the things that have affected food prices over the last 10 years, except the RFS, would still have occurred.

That record draught that was in 2011 in the Southwest that decimated the cattle herd -- that still would have happened. The beef prices that we see today that are high -- they would still be high today with or without the RFS. On the 2012 draught that occurred in the Corn Belt that doubled corn prices in a year -- that still would have occurred. China demand for soybeans that has just been growing non-stop over the last 10 years -- that still would have occurred. The pig virus -- PED -- which killed 10 million piglets and caused pork prices to spike -- that would have occurred. The weak dollar and the increasing Asian demand for milk -- that would have occurred. That caused milk prices to spike in 2013. Bird flu that decimated the egg-laying population in Iowa -- and any of you go to the supermarket and buy eggs? What's happened to egg prices? That has nothing to do with RFS. It has to do with the bird flu. So, we would have still had the Great Recession. Oil price spikes up; oil price spikes down. All of these phenomena explain why food prices have changed over the last 10 years, up and down, but none of these events have anything to do with the RFS.

So, the effect of the RFS on consumer food prices in the U.S. is much less dramatic, more gradual, and just about lost in the volatility caused by events over the last 10 years.

With regards to food prices in developing countries, the share of commodity prices in their consumer food dollar is higher, suggesting that an increase in commodity prices will translate into a higher increase in food prices in developing countries.

But the RFS does not directly affect developing countries' commodity prices. It affects them only to the extent that the RFS raises world commodity prices, which it probably does, but then that country has to be integrated with world markets in order to get that price translated, transmitted into the domestic country.

Nicholas Minot of IFPRI has done probably the most careful studies of the degree to which at least the countries he studied in Africa are integrated with world markets, and he finds very weak integration, which means that most of their price changes are caused by domestic supply and demand, not world supply and demand.

So, clearly, the RFS had some impact on world prices, but that does not equate to an impact in developing countries' prices unless they're fully integrated with world markets.

Now, turning to fuel prices, as Terry said, the main impact of the RFS has to have been to replace 10 percent of the petroleum gasoline with ethanol. I mean, that's really the big effect that's been out there. This change has had a number of effects. The first one is it has facilitated the U.S. to become a net exporter of gasoline rather than a net importer. It might have happened anyway, but with 10 percent more ethanol, it increased the net exports of gasoline. Moving from a net importer to a net importer lowers domestic prices of gasoline -- fossil gasoline.

The RFS has also decreased refining costs, because the blend stock that is used to blend ethanol and gasoline together is an 85 octane blend stock now. They get the octane now from 10 percent ethanol. It costs less to produce an 85 octane blend stock than an 87 octane blend stock, so that decreases domestic gasoline prices. RIN prices, as was mentioned, is a tax on gasoline. That's raised domestic gasoline prices some, that's for sure. But RIN prices are a subsidy to ethanol. So, our recent study that we're trying to almost get published basically says those two offset each other, so it's a wash.

So, no one can tell what the net effect of all this is, but from what I've seen and modeled, I believe that there's likely a net, overall, small, negative impact on U.S. fuel prices, even if you take into account the 3 percent lower BTU content of the fuel.

So, in this quick run-through of how the RFS is connected to food and fuel prices, I hope I raised some issues and questions that lead will to some discussion.

MR. GAYER: Thank you, Bruce. And, like I said, we'll come back to this.

I want to turn now to the question of greenhouse gases. Obviously, one of the goals of the Renewable Fuel Standard, as well as some of our policies, is to reduce our carbon emissions. So, I will turn to Tim to give us a sense of how effective he thinks that has been.

MR. SEARCHINGER: Well, thank you very much, and I actually have some of these slides -- against all the rules -- so, you you might want to look at them as we go along.

So, I want to explain the basic principles, which I think allow us to have a better understanding of what the likely greenhouse gas consequences of biofuels are. And the short is that biofuels are a way of using land to produce plants to substitute for fossil fuels. But using land has costs, and the question is: Do you have a net gain, or is the cost greater than the benefit?

So, when you do a life-cycle analysis of biofuels versus gasoline, you start by looking at the emissions in the production process. And in the production process, all the life-cycle analyses agree that it takes more emissions, takes more energy to produce biofuels than fossil fuels, and that's for obvious reasons, that the actual mining and refining of fossil fuels is not where the greenhouse gas emissions are. It's in the burning of the fossil fuels. So, you've got a substantial increase in emissions at the production stage.

So, then the question is: What happens to the fuel? Now, when you burn a biofuel, you're also putting carbon into the atmosphere. And in fact when you burn ethanol, you're not only putting the same amount of carbon into the atmosphere from the tailpipe of your car as when you when burn gasoline, but you are also putting in an additional 50 percent more, because when you refine starches into alcohol, a third of the carbon goes off into the atmosphere.

So, if you'd look just directly at what happens from the direct admissions of the production process and what comes out of the car and comes out of the refinery, you will always have a large increase in greenhouse gas emissions from any biofuel. And in the case of corn, it's probably at least double. Almost any grain, even a simile for biodiesel, would be too close to double the emissions.

So, why does the life-cycle analysis conclude that you get a greenhouse gas benefit? The answer at the convention was to ignore the actual carbon admitted from the biofuel. And the theory on that is that the biofuel starts with plant growth, and so you credit the biofuel with the carbon absorbed by the plant growth. And the key thing to understand is that is an offset theory. So, the direct use and production of the biofuel increases admissions, but it's offset by plant growth. And the first rule of any offset is it has to be additional.

So, then the question is: Is it additional? So, if you look at the second slide here, here's an example of where it is additional. You take completely unproductive land -- let's say it's bare. You irrigate it. You grow additional crops to produce the biofuel. And what happens is that crop land absorbs additional carbon. So, what comes out of the car remains exactly the same. It's offset by that additional plant growth.

But then if you'll look at the third slide, what you realize is that most of the time with biofuels -- we're not taking unproductive or bare land and using it to produce biofuels. We're simply taking crop land that was going to produce biofuels anyway. And so what happens is there's no additional plant growth, right? The Iowa farmland was going to produce corn one way or the other. There's no direct offset. So, you don't start of at this stage with any basis for justifying that huge credit for plant growth, because there hasn't actually been any additional plant growth.

So, then you go on to say, well -- so you ended the analysis here, so these life-cycle analyses that simply stopped there were just mathematically wrong. So, then you go into -- look, there's a market-driven effect. When you divert that corn, you get an increase in prices, and three things can happen. The first thing that can happen and the best thing that can happen would be that farmers produce more crops on the same land. And if they produce more crops on the same land, they are actually producing additional plant growth, and I think the evidence for that actually being a market response is very small, but we can go into that. And we know that over time, crop prices have dropped enormously over 45, 50 years and yields have gone up, because what drives yield gains above all is exogenous.

Now, the second thing that can happen is because prices go up, we don't replace all the crops, which means someone is eating less. Now, that actually gives you a greenhouse gas benefit. Why is that? Because what happens to the carbon in corn when it gets eaten by us or by livestock, we breathe it out. We're literally emitting carbon. I am emitting carbon right in front of you. You're emitting carbon. I recommend you continue to emit carbon. But if we eat less food and livestock eat less food, there is literally a greenhouse gas reduction, and the way that the life-cycle analyses work is implicitly they are attributing that reduction in greenhouse gas emissions to the biofuel, giving it a credit for the offset.

Now, that sounds kind of funny, but in fact all the government models -- we had a paper published in *Science* in, I think, March -- all of the government models that find greenhouse gas reduction from biofuels, grain-based biofuels, estimate that from a quarter to half of the carbon and the calories aren't replaced, and without that reduction, their own models -- not my model -- those models would have estimated an increase in gas emissions. So EPA, you may recollect, actually found that there was an increase in emissions for corn ethanol in 2012, 2017 but a potential small reduction in 2022. A hundred percent of that reduction -- more than a hundred percent of that reduction was due to their model's estimate of reduced food consumption.

So, then the last thing that can happen is that you expand area. And if you expand area, you have the benefit of growing more crops, absorbing more carbon, but obviously at the expense of the carbon that was stored or could have been absorbed there elsewhere. And that is almost always going to be a net increase in greenhouse gas emissions.

Now, the life-cycle calculations about indirect land-use change, it's really about that land-use cost. And when you think about biofuels, you get a benefit from using land-displaced fossil fuels, and there's a cost to not using that land in some other way to absorb carbon. So, now here's the best way to think about this. For corn ethanol, the estimate generally is that you get one ton of corn ethanol in the U.S. One hectare of land devoted to corn ethanol -- after accounting for byproducts -- gives you a one ton of carbon benefit per hectare per year.

Now, the opportunity cost is not using that land for something else. And if you took typical corn land in the United States and just did nothing, just left it alone, it would regenerate forests probably at a minimum rate of three tons of carbon per hectare per year. If you chop down the forest, it's probably more like six tons. If you just let it regenerate grass, it's one ton of carbon per hectare per year.

So, unless land, highly productive land, has this extremely low carbon opportunity cost, it is going to more than offset the benefit of using that land to replace fossil fuels. The only way biofuels can produce greenhouse gas emissions is if you estimate that land is practically free from a carbon standpoint, and that's true for cellulosic ethanol as well. So, if you more than double cellulosic ethanol yields in terms of switchgrass yields, triple yields really -- well, what you could do today -- you would get about three tons per hectare per year. And that is a very, very low carbon cost for reasonably productive land. That's the carbon benefit of just leaving that land alone, let alone if you plow up anything, it's going to be more.

So, the last thing I'll say is: Why is that? Why do biofuels -- is it an inefficient, bad use of land? And there's a very, very simple reason for it. It's stunningly inefficient. So, sugarcane ethanol is the most efficient biofuel in the world by far, and it converts about 0.2 percent of solar radiation into usable energy. Not 2 percent. 0.2 percent. That's growing a perennial crop, high yield on some of the best farmland in the world. That's as good as you're going to get.

If you put a solar cell, if you put a solar farm -- foolishly -- on the best farmland in Brazil, you will get 11 percent today. You will get at least 50 times more usable energy. If you then convert that to electric engine, you're going to triple that.

On 75 percent of the world's land, the benefit of using solar cells today compared to optimistic use of cellulosic ethanol in the future is a minimum of a hundred times more energy. So, when you take a step back, here's the basic point. We need land to produce food. We need land to produce forests. It does a pretty good job of doing all that. It is extraordinarily inefficient at producing energy that we can use. And that explains why -- we can go into all the models; the models are over the map. But unless you assume that and is practically free, you will discover that you will always have an increase in greenhouse gas initiatives.

Thank you.

MR. GAYER: All right, lots to go back and forth on that. But I want to turn to our final speaker, Chris. Chris has kind of the challenging task as I've laid out of giving an overall assessment of renewable fuel standard as far as the social welfare effects. A lot of what you've heard today, you know, kind of there's underneath it a lot of uncertainty, which makes the challenge leaving harder. So, I asked him to kind of give us an overall assessment of the program relative to other policies that we might take, idealize economist dreams policies or realistic policies or whatever else he can dream up.

So, anyway, I'll leave it to you, Chris, to give that rap.

MR. KNITTEL: Sure. Thank you. So, I actually thought I had the easiest job among the panel. (Laughter)

So, I'll start by sort of sweeping aside everything Tim just mentioned and talk about some recent work that we've been doing comparing the Renewable Fuel Standard with carbon tax or a capital trade program, as well as the old ethanol subsidies that we had on the books and a new type of policy which is called the Low Carbon Fuel Standard, which California has already adopted and a few other Western states are looking into.

So, by sweeping aside all the points that Tim mentioned, what I mean by that is what we did in this work -- and it was on the desk in the back there -- is that we just flatly assumed that corn-based ethanol reduced CO_2 emissions by 20 percent and these advanced biofuels between 40 and 60 percent. So, obviously if we take Tim's view that the reduction is much less than 20 percent, everything I'm going to mention will be magnified.

And then we also started with the premise that the goal of the policy is to reduce greenhouse gas emissions, and I think we can circle back to that whether or not that's actually the goal and discuss other -- and I'll circle back as well -- and discuss other potential goals.

So, the reason why I said that this is an easy task is that economists pretty much largely agree that the most efficient way to reduce greenhouse gas emissions is either through a carbon tax or a cap-and-trade program. That makes us about as unpopular as one can be both in D.C. and at cocktail parties, but we continue to say it, and we will continue to say it. So, from the qualitative perspective, it's really easy to realize that the renewable fuel standard, if the goal is to reduce greenhouse gas emissions, is going to be an inefficient way to do that relative to these other policies.

The modeling's efforts is to say how much less efficient will it be. And what we've found at least is that when you compare the renewable fuel standard with a carbon tax or a cap-and-trade program it achieves the same CO_2 reduction, so you're doing an apples-to-apples comparison that the Renewable Fuel Standard is roughly two and a half times more expensive. That is, you're spending two and a half times more dollars to reduce the same amount of greenhouse gas emissions.

And I'll mention that this also ignores something that Terry brought up and that I'm sure we'll talk about -- the blend wall. So, we're ignoring the blend wall, which I think will just exacerbate this result, because it's now more costly to put the same amount of greenhouse gas emissions into the economy.

And then to go back to what Tim was mentioning, one of the other implications of this is that when you achieve that same reduction in greenhouse gas emissions, the carbon tax or the cap-and-trade program is doing its -- it's really leaning on reductions in driving way more than the Renewable Fuel Standard, which is leaning on replacing gasoline with ethanol. So, if there are these indirect land-use implications, that second policy, the Renewable Fuel Standard, is going to be way worse than that metric. And one of the things that we analyze is that because we don't know very well what the land-use implications are, that's a riskier policy from a greenhouse gas perspective than a carbon tax, because a carbon tax isn't relying on land-use changes as much as possible. So, it's less efficient two and a half times.

The next question one should ask is: Well, is it still better than nothing? Right? We're in D.C., I don't see a carbon tax happening any time soon, at least today. So, it might be the case that it's less efficient, but it's better than doing nothing. And the way to answer to that question is to look at the actual average cost per ton of greenhouse gas abated and compare it to the social cost of carbon, which we now have on the books. We find that in 2022, so this is the policy fully implemented that you're spending $90 per ton abated under the Renewable Fuel Standard. Now, that's more than twice the social cost of carbon. So, what that implies is that the policy is actually doing worse than doing nothing in the sense that you're spending $90 for something you value at $40, okay? So, we can debate on whether or not that's ultimately the case.

So, how do you save it? So, there are two potential ways to save the Renewable Fuel Standard, I think. One is that maybe it's not all about greenhouse emissions. Maybe there's some other market failure or economist call, some other problem with the market that it's also trying to fix. Or maybe it has other goals. So, it's certainly the case that both of those might exist.

There are other market failures in the market for fuels. You know, there's a chicken-and-egg problem inherently with fuels in the sense that maybe we know ethanol is the right way to go 20, 30 years from now. In order to get there, you need two -- there are actually two eggs. The chicken is the ethanol, and then there are two additional eggs that have to happen. One is you have to have the refueling infrastructure in place, so you have to have E85 pumps in place. And also you have to have flex fuel vehicles in place, right? So, maybe the Renewable Fuel Standard is just one way to solve this chicken-and-egg problem. I don't think the academic literature has fully answered that question. The only thing I'll mention is that we have been subsidizing one of the eggs for a long time through cap A standards, which has incentivized a lot of flex fuel vehicles into the marketplace that never actually see a drop of E85. So, maybe the chicken-and-egg problem isn't as bad as it might be. You still have to solve the refueling infrastructure.

And then the last thing -- and I'll end here -- is that maybe the RFS has other goals, and one potential goal that it might have is just to simply increase farmer wealth, you know? As an economist, I would say there are more efficient ways to do that, that the most efficient way to increase farmer wealth is just send them checks and don't make him or her change any other decision. Just send checks. Our simulations, our modeling, certainly imply that it increases farmer wealth. For example, we find that there's one county in Iowa -- it might be Bruce's county, I don't know -- that wealth increases by $6,000 per person per year because of the Renewable Fuel Standard. So, that's certainly going on, and if that is the goal I think the best thing is just to have an honest dialog -- and is this a fuel policy or is it a farmer wealth policy?

The last thing -- and I'll end here -- is that the other implication of the Renewable Fuel Standard is that it does mess up the incentives for innovation, and I think that our second paper, our follow-up paper, really dealt into that a little deeper. What I think is going on is the ultimate goal here is cellulosic ethanol. That's where I think most people say we have to be, that's where the big, potential reductions in greenhouse gas emissions are.

The Renewable Fuel Standard currently is mostly a corn ethanol policy, and what that means in terms of the innovation incentives is that there's probably a lot of R&D going into making corn ethanol cheaper so that we can get even a larger benefit under the Renewable Fuel Standard instead of putting that R&D money into making cellulosic ethanol cheaper, which is where ultimately most people agree we want to end up.

MR. GAYER: Great, thanks. Just one clarifying question that relates to the last one on the policy as situated toward cellulosic. Your $90 per ton abated estimate, that is a fully implemented RFS with the full cellulosic mandate, no waivers, and that's a (inaudible) estimate of that.

MR. KNITTEL: That's correct, the full implementation with also no blend wall.

MR. GAYER: No blend wall also. Okay, great.

So, I have lots of questions, but I'm also cognizant of the time for the crowd questions, but I think maybe the more efficient, since we're talking about an efficient way to do, is to actually go down the table and ask each participant if they have any responses to anything their colleagues said. If you can try and keep it short. Lots of things were raised about the blend wall, about whether or not technology-forcing policies are effectives, whether or not the life-cycle GHGs go up depending on the land use so, so let me start it then with Bruce, and if you can it short when we go down, hit on your few key points.

MR. BABCOCK: So, the life-cycle analysis practitioners have not bought into Tim's latest theory. They're still working on his theory about indirect land use. If you look at EPA, how they model it, Argon people model it, California Resources Board models it, so they still look at indirect land use.

So, we've had 10 years to look at how land use had changed in response to this commodity price spike that we saw, and all the models predicted lots of land-use changes. Now, over the last 10 years -- so, we looked at the FAO data. The update was just released up through 2013, and the world cultivated land has increased by about 35 million hectares over from 2006 to 2013, which is quite a bit, but the world population has gone up a tremendous amount. Of that 35 million hectares, about 20 of it has occurred in African countries that are not integrated with world markets. In fact, the African land-use change has occurred because of population growth and because incomes have risen and because of a lack of technology.

The big change that we've seen, which goes to Tim's point in terms of land-use change over the last 10 years, has been the intensification of land-use change. I'm not talking yields; I'm talking greater efficiency of land, more double-cropping, less fallow acreage, all the types of things that we want to see. And this has primarily occurred in land-locked countries, which we should have expected. China, India have expanded their intensive use of land -- not yield, just more harvested acres per area of land -- by about 30 million hectares together, which is equal to the total amount that is expanded around the country. So, in fact, the data suggest that the primary response to high prices has not been what the model said, which was expansion on the frontier; but, rather, it's been intensification of land use with some exceptions, and I'll just list them, then I'm done. It's Malaysia, Indonesia cutting down forests and for palm; Argentina in reaction to bad government policy; and a bit in Brazil.

MR. GAYER: Can I just put you on the spot, just for a second. The categories as they're defined in the statute have the 20 percent reduction, 50 percent reduction, 60 percent. These are really complicated questions, I know. Do you think the qualified fuels are meeting those reductions on a life-cycle basis, or is there just too much uncertainty?

MR. BABCOCK: If you were to adopt the life-cycle analysis as practiced by nearly everyone in the country, yes.

MR. GAYER: Thank you there, okay, great.

Terry, do you have any follow-up?

MS. DINAN: Sure. So, I just wanted to respond a little bit to Bruce's comments about the effects on prices for food and fuel. You know, I think the focus has been on what's been the effect over the last 10 years -- which is the focus of this workshop or conference -- but I think the bigger question is: What are the effects on food and fuel prices going forward? And I think that that could be different than what it's been in the past, because CBO looked at just out to 2017.

We looked at what if we were to repeal the RFS and, compared with what if in 2017 we just said the RFS is going to have to meet the standards -- people are going to have to meet the standards that were proposed earlier by EPA for 2014?

And then we have a third scenario: What if you actually had to meet what ESA said you had to do in 2017? And you get different answers. I think that to date the RFS really hasn't pushed the market very far. As Bruce pointed out, there are benefits to blending ethanol into gasoline up to E10, and so if you were to repeal the RFS we actually found that it really wouldn't affect food or fuel prices pretty much at all compared with meeting the 2014 proposed rule. However, if you actually had to meet what the law requires in 2017, you would start to see effects, not so much on food, because of the points that Bruce raised, but you'd start to see effects on fuel prices simply because it really does start to push the market beyond where it would go absent this rule. It really pushes a blend wall, and you actually have to really start bringing large volumes of advanced fuels if not cellulosic biofuels into production.

And just one more point I wanted to make with respect to -- a lot of the discussion about emissions has been focused on corn ethanol. But, again, moving forward we're now using about 13 billion gallons of corn ethanol. Under the law, we're only going up to 15 billion gallons. I think the big question is: What are the emission effects of advanced biofuels? -- because that's where the big growth is required to be. So, I just would like to bring that up and see what people think about that.

MR. GAYER: Okay, I'm going to -- we've got two more. Any follow-on comments? I'd ask that you try to keep it within a few minutes.

MR. KNITTEL: Yes, I'll just quickly mention things because I know we want to turn it to the audience.

One is I think the issues about prices, whether they're food prices or fuel prices and so on I think tend to be overblown. You know, Terry's point about what's going to happen in the future is a good one, but -- and I'll say on both sides, right?, so the concerns that food prices are going through the roof because the U.S. is pumping in 15 billion gallons of ethanol. World food prices aren't going to move very much, and even if they did, as Bruce was saying it's a pretty small share of many people's incomes. With that said, there's a lot of heterogeneity there, and these sorts of things can have different implications for different income brackets, and so I do think we need to worry about that.

And then on the other side, this idea that's out there in some way or another that because of the ethanol that we are producing gasoline prices are way cheaper than they -- that's probably way overblown, too, and I have some work that suggests that's the case.

One thing I will mention though is that the blend wall is real and we're seeing RIN prices that are very high that are leading to lots of money changing hands. And I think -- hopefully, we'll get back -- we'll get into the discussion of how one could change the policy to potentially get RIN prices down to more reasonable levels.

MR. GAYER: Great, and Tim just a couple of minutes on the final word.

MR. SEARCHINGER: So, first of all, what I've described is in direct land, but other people call in a direct land exchange. It's not really indirect. It is -- this is what's actually going on, that what you're really talking about is simply trying -- there's a cost to using land, and there's a benefit to using land. And the calculation is: Is your benefit greater than your cost?

Now, with regard to actually what's happened with land use, actually, since the early 2000s we've had the largest expansion in harvested area the world has ever seen. From about 1980 till the early 2000s, there was no expansion of harvested area for the 15 major crops, and they've been growing about 10 million hectares per year since. Now what Bruce is claiming is that it's all claiming from double-cropping. And unfortunately here is where you need to understand the origin of statics.

So, the FAO has two numbers. One is harvested area -- the number of hectares that are harvested each year, and the same hectare can harvest two hectares per year; and the other is cropland area. And so the area of cropland hasn't gone up as much. The problem is the cropland data is basically nonsense, and the reason is it's extremely hard to know what cropland is. The definition is it as to have been cropped one time in the last five years, that particular tract of land, and nobody really knows it, and when you look at the FAO data on cropland, it basically -- nothing happens, then there's a big change.

And I've talked to people at FAO. You cannot use the FAO data on cropland. Even the U.S. data on cropland is wildly off when you compare it to a satellite photograph.

With regard to Africa, the actual study that Bruce was talking about did find a huge impact on prices in Africa in 2007, '8, and '9. If you know anything about Africa, you know that there were millions of hectares of at least attempted land acquisitions by foreign entities. And Africa actually is the largest import-dependent continent for staple calories.

Sub-Saharan Africa relies on imports for 20 percent of its calories. And the idea that it is not responding to world crises is, in my view, ridiculous. And we can talk more about some of the other studies and then. But the bottom line is what we are seeing is a massive expansion of harvested area. Probably in India it is coming from double-cropping, which requires further mining of groundwater. But what we are seeing is exactly what we'd expect to see.

MR. GAYER: Okay, now I'm going to turn it over to the crowd for questions. We have people circulating with mics, so when you're called on, please wait for the mic. Please be cognizant of our time limit, so we ask that you ask a succinct question, not a statement. Any questions from the crowd? If not I'll -- I've got somebody right here.

Wait for the mic, please, and then if you could introduce yourself.

SPEAKER: Thank you very much for the (Inaudible).

MR. GAYER: I can't hear. Is it on? One more time. It's on. All right, you may have to -- apologies. The Webcast people won't be able to hear it.

SPEAKER: You can repeat the question.

MR. GAYER: 'll repeat your question. Go ahead.

SPEAKER: Yeah, my name is (inaudible).

MR. GAYER: Great, thank you.

So, the question is on third generation biofuels. Is there someone here -- you want to start in, and Bruce, do you -- all right, go ahead.

MR. BABCOCK: I don't know if (inaudible).

MR. GAYER: How's it now? All right, go ahead.

MR. BABCOCK: So, first of all, let me just mention, most of what I'm going through today is in a paper called "Avoiding Bioenergy Competition for Food Price and the Land." It's kind of a -- it's a WRI publication, so it's easier to read than all the academic stuff. And we go into algae in that paper. And I wish -- it would be great if algae biofuels could emerge, but there are a number of basic problems.

One is they use massive quantities of water, and so they're basically -- you know, there was one estimate that said if you did algae just right in exactly the right places and at high efficiency, you could only have to use 30 percent of U.S. irrigation water to meet the cellulosic ethanol part of the mandate, which is a tiny amount of U.S. energy. Well, we don't have 30 percent irrigation water. Tell that to California. And it also actually uses more land than you think, so the Natural Resources Council actually came out with a report on cellulosic out of the biofuels and said, no, not now.

But I'm still interested in algae, and here's the key thing about algae. Algae produce a lot of protein and a lot of vegetable oil, and they're very valuable. And if we ever learn how to make algae officially, its use as an animal feed and as a vegetable oil source, particularly for fish oil, will be so much higher than its possible use as a biofuel. No one would ever use it as a biofuel. It's not quite like this, but it would be like making steak and then burning steak in your tank. It's really valuable -- algae -- if we ever learn how to make it, and we won't use it for biofuels.

MR. GAYER: Any questions? We have a hand right there, Mike.

MS. VIKAMINER: Hi, I'm Kara Vikaminer. I come to this from the perspective of how to move forward.

We know that electrification is very challenging, especially in the aviation sector. Liquid fuels provide a very unique source of energy to power our transportation sector. Given the fact that the RFS is in place, the challenges that are here -- what's the best path forward? How can we make it work if we want a cleaner transportation sector?

MR. GAYER: There is a subtext to that question. Are we talking about making the current RFS work through amending -- you know, through current -- the discussion (inaudible 00:57:11, coughing) performing it or doing something through other Websites, but anyway (inaudible)?

MR. SEARCHINGER: Yeah, that's a tough question to answer. I guess I would say that I'm pessimistic about just about every technology out there, all technology there. But I am very optimistic about markets, and I think this is where economists come in with the idea that if you correct the externality through a carbon tax or a cap-and-trade market, then I don't have to know what the right technology is. People out there -- my heart science colleagues at MIT will find out what the right technology is.

So, it's really -- what that's saying is it can be very costly to put sort of -- be choosing your technology through these very specific policies, and that's one other additional advantage to a more general pricing strategy like a carbon tax.

MR. GAYER: I'll just add one small point just so my short history of RFS I think when I was at Treasury --

There was a subversive element, I think, for some people, some economists of the RFS. You may recall when it was first being debated there was this notion of the safety valve and that if a safety valve binds you wouldn't have to meet the mandate, you could just essentially pay a fine -- essentially. And the subversive element of that is -- we talked about before that the RFS is a tax on kind of a petroleum-based fuel, then subsidy in biofuel, and if you have a binding safety valve, you are essentially lopping off, I think, the subsidy and sort of through a back channel getting a gas tax.

Now, you can -- so, this kind of pivots a little bit with Chris' kind of tried and true economist view, which is let's price the darned thing and not kind of pick and choose winners. And so there was an element of that, I think, somewhere in the process of -- now, of course, the safety valve has a lot of skeptics out there and as a result didn't make it into the legislation. But I'll just add that that was something at one point that was seen as a way of making it less prescriptive and more broad.

MR. GAYER: Do you have a (inaudible)? Go ahead, Tim, and then --

MR. SEARCHINGER: When you look at the transportation sector in decarbonizing it, you have to distinguish between the short term and the long term. So, fuel switching is about the most expensive way we could try to reduce greenhouse gas emissions today. Almost anything else you can do to produce greenhouse gas emissions in the economy will be cheaper. But we know that we have to switch fuel in the long run, because if you don't (inaudible 00:59:41 -- recording skipped) replace cars with something else.

So, the strategy you want to focus on fuel is a technology-forcing strategy. And when you think about technology-forcing, the only possible way to do it is electricity. Not only can electric engines be a lot more efficient, but when you look at the efficiency of solar from a land-use perspective, it is so overwhelmingly greater than bioenergy. You would need vast, vast quantities in the United States to produce any meaningful amount of energy, and you'd have to use really good land. You can use a very small amount of land, relatively speaking, and dry land and you'd produce it just as dramatically, increasing efficiency.

MR. GAYER: Go ahead, Chris.

MR. KNITTEL: Yes, just really quick. This is where I fight with a lot of my engineering colleagues at MIT. It's not necessarily about efficiency; it's about cost, right? So, you could have a technology that's very, very efficient but cost an infinite amount of dollars, and you don't want to do that efficient technology. And that's where -- again, I'm a broken record here -- markets are really good at uncovering the most cost-effective ways to do something.

MR. BABCOCK: I agree with that, and the only thing is when you focus -- we shouldn't even be mandating transportation changes now except as a technology-forcing strategy. So, that is a supplement toward a market strategy. We shouldn't be using a market strategy for the transportation sector today. We should be using a technology-forcing strategy.

MR. GAYER: Do you have a question -- up front?

SPEAKER: Yes.

MR. GAYER: Go ahead.

MR. ERNSPECT: Yeah, Howard Ernspect.

We've had a lot of talk about ethanol, you know, the focus, and I think the point has been made that a lot of ethanol would be blended, even absent the RFS. So, no one has had anything to say about biodiesel where you don't have these issues of, you know, octane advantage, other things. So, it is also biodiesel is the place where the proposed standards are, say, higher than what's in the legislated targets as opposed to lower than what's in the legislated targets. So, I'm wondering whether someone could speak to that.

I'm also wondering whether somebody could speak to the effect of low oil prices on the cost of whatever it is we are, you know, buying, so to speak. I know there's a dispute about the amount of greenhouse gas reduction and how you account for it, but how does a lower price of oil affect some of those calculations?

So, I guess it's a couple of questions all rolled up.

MR. BABCOCK: In part of that -- in terms of lower petroleum prices, if you look at what's happened to RIN prices, which really is what commerce calls the marginal cost of compliance with the RFS. The RIN prices have not really changed all that much, even with lower gasoline prices. However, it's hard to say that it is caused -- I mean, if you were -- the RIN prices are also a reflection of what people think the EPA's going to do with the RFS. So, it's not clear how you can translate those. But in terms of feasibility of meeting any EPA RFS, lower gasoline prices actually increase the ability because we're consuming more gasoline. It's easier to meet any given target.

With regards to biodiesel, again, I look at the RIN prices to tell me how costly is it to convert at the margin whatever the feedstock is into diesel substitute, and those RIN prices now are at about -- if I look at it, it's about 68 cents or 60 cents a RIN, which translates to about a dollar a gallon of biodiesel. So, really, what you're doing is -- the cost of producing biodiesel is about 70 to a dollar a gallon more than the replacement value of the diesel.

MR. ERNSPECT: Just one question. How does that calculation take into account this other very weird thing, because the ethanol tax credits are gone but the biodiesel tax credits are kind of gone but seem to come back retroactively, and they're incorporated in the -- you know, so using just the RIN price when there's this potential -- so, are you saying the price is, like, a dollar a gallon or more and we're mandating, what, I mean, the EPA proposal is 1.6, 1.7, 1.8 billion gallons? You know, I'm just kind of curious.

MR. BABCOCK: I'm saying at the margin it's about a dollar. Now, if you can tell me how the market is going to figure out what Congress is going to do retroactively with the tax credit and how that's going to get priced into the RIN. That's a hard question.

MR. ERNSPECT: These are hard questions.

MR. BABCOCK: So, that RIN price does include some expectation of how much a tax credit is going to be if I hold onto that RIN, I agree.

MR. ERNSPECT: One quick thing -- oh, sorry.

MR. GAYER: Terry --

MS. DINAN: Oh, I was just going to chime in a little bit on the facts of the lower petroleum prices.

When we did our paper, we looked at calculations of what the RIN price would have to be to get sufficient quantities of E85 into the market to comply with ESA in 2017. Coming today -- knowing I was coming today, we re-ran our estimates, taking into account lower fuel prices, but what we found is that because corn prices have also fallen, it ended up being pretty much a wash. So, just because of the effects of corn prices and oil prices, I don't think it's changed that much. Thank you.

MR. GAYER: And Chris.

MR. KNITTEL: Yes. I was just going to say biodiesel actually plays a really important role here, because it doesn't face the blend wall that you mentioned, and it's really effectively -- the only way around the blend wall right now is to sell more biodiesel than we otherwise would absent the corn ethanol policies.

And then the last thing about cheaper oil price. Remember, we had cheaper natural gas prices, too, and natural gas is pretty -- Bruce can speak to the actual numbers, but a component of making ethanol.

MR. BABCOCK: Obviously (inaudible) comes from vegetable oil, and the global marginal source of vegetable oil is palm oil. And that's because palm oil is basically producing vegetable oil. And the other big source is soybean oil, but two-thirds of the price of soybeans is the cake. So, when you actually look at the market and you look at what happened in Europe, which has been (inaudible) the consumer, it's all indirectly being supplied by expansion of palm oil imports into Europe. And palm oil is basically grown in Malaysia and Indonesia, and a lot of it is on peatlands that emit enormous amounts of carbon where Bruce even agreed that there was a lot of deforestation going on. So, from a greenhouse gas perspective, biodiesel is the worst. And what you have -- this is a strange thing, because I think of really flawed modeling where you'll see some models claiming that palm oil is really terrible, that soybean oil is okay or better and not as bad. It's going to come from palm oil. And you can even talk to people who are in just the vegetable oil world trading business. They'll tell you that it's going to come from palm oil. And so they should be roughly the same. Whatever your calculation is, all biodiesel, regardless of the source, should be pretty similar from a greenhouse gas perspective.

MR. GAYER: Right here, here. I'll take -- in fact, why don't we just have short questions -- all three -- and then the panelists can go through that.

SPEAKER (inaudible): Okay, Bernie (Inaudible), University of Tennessee.

The RFS is based on volume, and if we want -- and that causes infrastructure issues and the blend wall to come into play. If we want cellulosic ethanol -- say, cellulosic fuels, biofuels -- shouldn't we change the RFS to something that recognizes the difference in BTUs in the fuel?

MR. GAYER: Okay, good -- all right, let's go here and then the third one there, and then we'll go through.

MR. HADLEY: James Hadley, Carbon Tax Center. I just wanted to say thanks to Chris for his comments (laughter) about faith in the markets. I'm going to ask a politically economy question. We're at a point now where we've got a political constituency that's invested in biofuels, and this is a problem with government policies that tend to subsidize or mandate particular technologies, and I spend a lot of time thinking about how to get away from the situation we're in now where we've got a constituency in a business, really, that's invested in a particular technology and move toward a broad-based price on carbon that would incentivize new technologies and better technologies and more efficient technologies that don't have these unintended consequences.

So, I guess that's sort of an open question, but it really seems to me like we've made some big mistakes. Biofuels are probably one of the worse examples, but you see in a lot of other areas where we've written in mandates or subsidies for particular technologies. Congress has tried to be the engineer, and it's not working very well.

MR. GAYER: Okay, and then one more. I think it was in the aisle, if I recall. Was it -- oh, right there. Last question, and then we'll go to the panel for wrap-ups.

MR. LEMON: Michael Lemon, Biogas Researchers.

When looking at the RFS and trying to meet the congressional intent of the program, where do you see cellulosic biogas-based electricity playing a roll, which was recently identified in the RFS as a cellulosic fuel about a year ago? And a pathway has remained pretty much entirely dormant, unused. So, I was just wondering, when you think about the future of the RFS, do you think electric?

MR. GAYER: Great. So, I'm going to turn to the panelists.

Just supplementing Burt's question here on should we change the volume-based nature of RFS (inaudible) changing to percentage. You're talking about BTU-based. My recollection is once upon a time there was talk of making kind of a GHG equivalent conversion that you would essentially credit lower GHG fuels more. So, any thoughts on that? I can jump in on political (inaudible), too, but I'll leave it. And we are wrapping up, so answers to the questions and any final thoughts, and we'll go down the table.

MR. BABCOCK: Quickly, you know, the BTU base is already there, so biodiesel has 50 percent more or -- so, you get more wind credit for higher BTU.

Also with regards to your question about you've invested in the sector. But the RFS was targeted at the transportation sector, and it was supposed to be a forcing technology, that they wanted technological change specific to the transportation sector. What you're saying is you only won't get that if you do a broad-based carbon tax, which is where you're coming from. But whenever you focus on a specific sector, you're going to get this capital investment, and that's what was intended. So, unless you're going to get out of the transportation sector, move to a carbon base -- and I'll just repeat what Chris said -- if you're going to move to a carbon tax, you're not going to get a lot of movement in the transportation sector, because that's high-cost abatement in the transportation sector relative to the power sector.

MS. DINAN: Just in terms of overall efficiency of different policies, CBO has done a lot of work looking at carbon tax cap-and-trade programs and has also made the point that in general if your goal is to reduce greenhouse gases at the lowest cost way, those tend to be policies that would achieve that more efficiently than specific policies that target specific sectors, such as the transportation sector, specific technologies.

MR. GAYER: I'll just add my two cents on this.

The political economy of carbon tax is something we've kind of talked about. It's challenging. It's like a menu for tackling it. It seems like all this -- to the extent the economists are talking political economy and feasibility of a carbon tax is always on what you do with the revenue. So, I would just -- that's still my kind of standard refrain, like, if you're looking to get voter support, you do have a lot of revenue coming out of carbon tax, how you use that to garner support I think is essential. Otherwise, you do have the standard political economy argument that it's a lot easier to kind of focus your targets on areas that might have diffused costs but narrow benefits. And this is a way to kind of translate those revenues into benefits, targeted benefits.

MR. KNITTEL: I'll be brief. So, if you think about -- let's just set aside again all of Tim's issues with the greenhouse gas emission reductions, but let's just take those as fact. The world that we think we need to go to is a world of E85 cellulosic ethanol, right? That's ultimate -- you think corn-based ethanol is going to do it? I'm saying if we're going to --

SPEAKER: (Inaudible 01:13:53, off mic).

MR. BABCOCK: Okay, not ethanol. Look (laughter) I'm setting that aside, too. If we think ethanol is the right answer, we need to be in a world of E85 cellulosic ethanol. What has to happen for that to be the case? One is we need cellulosic ethanol, and then we need the cars, and then we need the refueling infrastructures. If I could redo the RFS today and keep those as the goal, getting to that world -- and we can question whether or not that's the goal -- why not make the RFS only about cellulosic ethanol? That is a necessary condition for us to ultimately get where we want to get to. Why go through the added cost of getting the infrastructure in place now and the cars in place right now and then blending corn-based ethanol, which we know isn't the solution. So, let's at least incentivize -- see if we can incentivize and see if we could actually get cellulosic ethanol to be cost effective. The answer might be no, but since we know corn-based ethanol isn't the ultimate solution, why is the RFS about corn-based ethanol in the first place?

MR. GAYER: Okay --

MR. SEARCHINGER: One, the idea of using biomass for electricity would be dramatically less efficient even in ethanol. So, all those efficiencies I showed you, you drop them down even further. No one will ever do it, except at some total distortion of government policy.

Second, I think people -- I want to try to disabuse people of the idea that cellulosic ethanol is significantly better. It's still staggeringly inefficient. It still uses land. And so I'll just leave you with a last couple of numbers.

So, a 10 percent goal -- the goal to make 10 percent of global transportation fuel for biofuels, which would produce about 2 percent of global energy, would require about 30 percent of all of the energy in all the world's crops today. There are people who talk about targets of 20 percent bioenergy by 2050. And if you're thinking of transportation (inaudible), right?, that requires about 220 exajoules of biomass. So, you know, biomass has an intrinsic energy, so you can't invent around it. That's just what's in the electron bond so you can oxidize.

How much of the world's plant material goes into 220 exajoules? A hundred percent of everything we harvest on the planet today. All the world's crops only have about 75 exajoules. When you add up all the world's crops, all the world's crop residues, all of the world's grassy (inaudible), all of the world's wood, it adds up to just enough that we're harvesting today. If we stopped consuming biomass, we could produce 20 percent of the world's energy supply.

Now, you could be a 15-year-old and do that calculation. So, when people are talking about these large bioenergy mandates, they haven't done the most basic, basic physics.

So, I'll leave you with that.

MR. GAYER: All right, we're a little bit overtime, but I just want to thank again all the panelists for participating today, and thank you all for coming.

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Carleton J. Anderson, III

(Signature and Seal on File)

Notary Public in and for the Commonwealth of Virginia

Commission No. 351998

Expires: November 30, 2016