Testimony on

Advancements in Biofuels: Balancing Federal Research and Market Innovation

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Before the
Subcommittee on Energy and Subcommittee on Environment
Committee on Science, Space and Technology

U.S. House of Representatives
2318 Rayburn House Office Building
Washington, D.C.

Tuesday July 25, 2017

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SUMMARY STATEMENT

I wish to thank the chairmen, ranking members and other members of the Committee and Subcommittees for the opportunity to testify.

The question being addressed today, that of the right balance between fundamental scientific research and government intervention in the marketplace, is crucially important. The focus on biofuels is telling because it involves so many aspects of the question. Indeed, federal biofuels policy provides a morality tale of how things go wrong when the right balance is not maintained.

Before delving into the problems, however, I want to emphasize the importance of maintaining a robust federal investment in research across all fields of study. Funding for science is crucial to maintain American leadership and foster the innovation that leads to high-quality job growth. Federal support for university research is especially crucial for training a new generation of Americans who can fill those jobs.

To summarize my written testimony, here are the key points:

1. Protecting the climate from a worsening disruption due to excess CO_2 in the atmosphere is now a top challenge for energy research and policy.

2. The choice of what technologies to deploy must be left to the marketplace, to industries and entrepreneurs who take risks with private money rather than rely on public funds. Policies to address non-market concerns such as CO_2 should therefore be technology neutral and well informed by independent science.

3. The climate challenge should not be an excuse to pick winners through demonstration and deployment programs, subsidies and technology mandates. Federal resources are best leveraged when through fundamental R&D and technology-neutral regulation.

4. Federal biofuels policy has overstepped these bounds. The result is not only wasted tax dollars, but excess costs for consumers and harm to the environment. Biofuels are making CO_2 emissions worse and the Renewable Fuel Standard has been damaging in that regard.

5. The federal push for advanced biofuels has failed. DOE and other agencies have supported bioenergy research, demonstration and deployment for many decades and with billions of dollars. None of the promised cellulosic fuels have become commercially viable, even with subsidies amplified by mandates.

In short, it's time to go back to basics on these issues, to revisit biofuel policies that the science and economics now show to have been ill premised.

I realize that my work contradicts longstanding assumptions about biofuels. Twenty years ago, I accepted the notion that biofuels such as ethanol and biodiesel were inherently carbon neutral, meaning that the CO_2 emitted when they are burned does not count because it is taken from the air when crops grow. In reality, however, all CO_2 emissions increase the amount of CO_2 in the atmosphere regardless of where the carbon comes from. The correct question is whether feedstock production speeds up how quickly CO_2 is removed from the air. That doesn't happen when productive land is used for biofuels instead of food or forests that sequester carbon.

Last year we published research to evaluate what actually happened as the RFS ramped up. We found that ethanol and biodiesel are not carbon neutral and their use provided no significant direct CO_2 reduction. Once indirect impacts are considered, it turns out that biofuels have caused higher CO_2 emissions than petroleum fuels. In short, biofuels are a false cure that is worse than the disease.

We do need to address emissions from motor fuel use along with those from the power plants and other sources. The best ways to do that are improving vehicle efficiency, controlling emissions during oil production and offsetting tailpipe CO_2 through reforestation.

If biofuels policy were restricted to basic R&D, we would learn some things and help students build science and technology skills. Those are worthwhile outcomes even if the research does not yield successful products. Research is risky by nature; not all of it bears fruit and that's why the portfolio should be diverse. University research is broadly beneficial in that regard. In contrast to when they are used for subsidies and demonstration projects, federal funds go a long way when shared with many schools to support students and young scientists.

Thank you again, and I'll look forward to your questions.

INTRODUCTION

Support for biofuels has been part of U.S. energy policy since the 1970s. It has included not only federal funding for biofuel research, development, demonstration and deployment (RD^4) but also subsidies and other programs to foster production of biofuel feedstocks as well as synthesis and production of various biofuels themselves. Although the dominant political support for biofuel programs is tied to the corn and soybean industries, the vision of biomass-based fuels as renewable replacements for petroleum fuels has broad support, including by many environmental organizations. These agribusiness and environmental rationales have been amplified by concerns about energy security, which provides a large part of the general rationale for the non-weapons programs of the U.S. Department of Energy (DOE). Given this triad of public policy support, biofuel programs have enjoyed significant federal funding (though at varying levels) for over 40 years.

The pinnacle of federal policy support for biofuels is the Renewable Fuel Standard. The RFS was originally established by the Energy Policy Act of 2005, which amended the Clean Air Act to require that 7.5 billion gallons of renewable ethanol be blended into the nation's gasoline supply by 2012. The program was greatly expanded by the Energy Independence and Security Act of 2007 (EISA), which targets a total of 36 billion gallons of renewable fuel by 2022.

EISA also set specific requirements for certain categories of biofuels to meet given thresholds of greenhouse gas (GHG) reduction, relative to the petroleum-based fuels they replace, as determined by the Administrator of the Environmental Protection Agency (EPA) through lifecycle analysis (LCA). Starch-based ethanol from facilities placed into operation after the enactment of EISA must meet a lifecycle GHG intensity ("carbon intensity" or "CI") threshold, specified as being 20% lower than that of baseline 2005 petroleum fuels. Starch-based ethanol (largely from corn) from existing facilities is "grandfathered" by the RFS and faces no LCA-based GHG requirements. Biofuels categorized as "advanced" (the nominal subject of today's hearing) are required to have a CI 50% lower than baseline fuels, a threshold shared by the requirements for certain volumes of biomass-based diesel fuel. The expansive mandate was justified by the promise of cellulosic biofuels, required to achieve a 60% GHG reduction with a Congressional target of 16 billion gallons by 2022. Such proposed fuels include cellulosic ethanol as well as "drop-in," i.e., fully fungible, fuels derived from biomass that can be readily incorporated into existing transportation fuel distribution and use systems. The economical production of such cellulosic biofuels has been the main goal of DOE's longstanding bioenergy research programs, as seen in the Bioenergy Technologies Office (BETO) and its predecessor offices over the years.

In energy policy, a common assumption is that renewable fuels are inherently "carbon neutral," meaning that the CO_2 emitted when they are burned is fully offset by CO_2 uptake during feedstock growth. That assumption leads many scientists to presume that environmental

impact assessments need only consider production-related GHG emissions throughout a biofuel's lifecycle. The carbon neutrality assumption is built into the LCA models used to compare the CI of various fuels. Such is the case for the GREET model[1] developed and maintained by Argonne National Laboratory (ANL) with support from DOE. It is also the case for the LCA models developed to administer the RFS, as seen in EPA's statement that "CO_2 emissions from biomass-based fuel combustion are not included in their lifecycle emissions results."[2] Nevertheless, biofuel carbon neutrality is just an accounting convention and when it is used uncritically in lifecycle comparisons of biofuels with fossil fuels, it results in greatly misleading estimates of the actual impact of fuel substitution. Such erroneous comparisons underpin not only EPA's analyses for the RFS, but also California's LCA-based fuels regulation known as the Low-Carbon Fuel Standard (LCFS)[3] as well as numerous GREET analyses,[4] including those used to claim GHG reductions for the RFS.[5]

As explained in my testimony here two years ago, such LCA studies grossly overstate the environmental benefits of biofuels and in fact claim GHG reductions even in cases where biofuel production is making net CO_2 emissions worse. That is the finding of my recently published study that took a rigorous look at the CO_2 impacts of the RFS from 2005-2013.[6] Before delving into those issues, however, this testimony emphasizes the high value to the nation of maintaining federal support for fundamental science. Although research priorities should change as knowledge is gained and new problems emerge, the overall level of federal investment needs to be increased and made sustainable for the United States to maintain its global leadership and successfully confront the many challenges, both in the realm of energy and in other arenas, of the decades ahead.

THE IMPORTANCE OF FUNDAMENTAL SCIENTIFIC RESEARCH

Although Federal renewable fuels policy is itself in great need of reform, it remains crucial for the United States to maintain a robust level of investment in fundamental scientific research, not just in energy, but in many fields. Funding for scientific research and higher education is critical for ensuring continued American leadership in innovation, which will in turn foster productivity gains and create new products and services that lead to job growth.

Fundamental R&D is risky by nature, and that is why public investment is needed. The private sector conducts applied research focused on the maintaining a firm's competitive edge for the products and services it markets. A distinction is drawn between competitive research and what is known as "pre-competitive" research, and public R&D funding must remain in the pre-competitive realm. Market competition is itself risky, but it is that very risk -- the risk of losing money -- that is so critical from separating winning innovations from ideas that might good on paper or in the lab but are not good enough to deliver the market returns needed for commercial success. It is for that reason that public funding, which risks tax dollars rather than private dollars, should not be directed to R&D that has an objective of trying to commercialize certain

technologies. Moreover, commercialization efforts are very costly in comparison to basic research. Federal dollars are best focused on generating basic knowledge, monitoring the world around us, and pursuing R&D with long time horizons that industry often views as too risky.

It is basic research, particularly fundamental science -- including physical, biological and social sciences -- and engineering at universities that provides the knowledge base, new ideas and creative problem-solving that is the foundation for solutions to our country's many challenges. Federally supported basic research is crucial for addressing the problems that Americans face in health, in safety, in national security and other areas of concern in addition to energy and the environment. University research, as supported by DOE's Office of Science and often done in partnership with the national laboratories, pays the added dividend of training students and young researchers, which is essential for nurturing a new generation of skilled, science- and tech-savvy Americans who will provide the country with a competitive workforce in the years ahead. It is crucial for building the next generation of scientists and engineers; each year, many thousands of students, including undergraduates as well as graduate students and junior researchers obtain their most important experience through projects funded by federal research grants. It is that training experience that enables them to become sought-after employees needed by the technology-driven industries that enable our economy to grow.

Federal investments in basic research as well as in supporting the research infrastructure at universities and other institutions, provides the nation with capabilities essential for ongoing leadership and levels of deep expertise that would otherwise be unavailable to industry. It is such publicly financed fundamental research that leads to groundbreaking discoveries about the world around us, from levels subatomic through cosmological as well as in life science, earth science and social science. It is also the wellspring for technological innovations that enable private sector achievements and American competitiveness across the range of industries includes those related to energy production and utilization. Public funding for scientific research consistently pays large dividends, with an ongoing return on investment that benefits America's economy, health, environment and national security. A major share of economic growth can be attributed to gains in scientific knowledge and technological progress, much of which would not have occurred without federal investments in university-based research.

All of these general principles for supporting basic research apply to energy. Moreover, energy research is interdisciplinary in nature. Providing consumers with the energy they need in ways that are affordable, reliable and environmentally sound requires ongoing public investment in research not only to develop technologies, but also to monitor the performance of energy systems, to assess their ecological impact, to understand consumer perceptions and to evaluate the economics of the various options. Although I am an engineer by training, my work has always been interdisciplinary because I realize how critical it is to base energy policy on a firm foundation of both physical and social science.

THE CLIMATE PROTECTION CHALLENGE

As times change, so do the priorities for national energy strategy. Such changes happen slowly because the conversation about policy priorities must balance the concerns of diverse segments of the public through a process of discussion and debate of which hearings such as today's are a part. A longstanding tension in U.S. energy policy is the need to balance consumers' desire for energy that is affordable and reliable with industries' need to cover their costs and make a profit. Historically, much of energy policy has centered around fostering production of energy, whether the hydropower, coal, oil and gas that have been the primary sources for many years, the 20th century resource of nuclear power or the now expanding renewable energy technologies that are likely to become increasingly important in the 21st century.

As the nation and its energy demand grew over the past century, the scale of energy use and its side effects generated widespread public concern about its environmental impacts. Unlike the challenges of energy production to meet market demand, environmental concerns are not solved by market forces alone. Their solution requires government intervention to address the inadvertent harms associated with energy utilization as well as other economic activities. Thus, the environmental consideration has created a new dimension of the tension inherent in energy policy, which must now balance consumers' needs for reliable and affordable energy and their desire for a clean and healthy environment with the costs to industry for not only energy production but also environmental protection.

Although policy development always involves difficult and sometimes contentious negotiations, such discussions are part of our country's democratic process. The results include the bipartisan environment legislation of a generation ago which has done so much to clean the nation's air, ensure clean and safe water supplies, minimize public exposure to toxic substances and protect vital habitats. The regulations promulgated to implement these laws has imposed costs on industry that are in turn passed on to consumers in the costs of energy and energy-consuming products. Nevertheless, retrospective evaluations of U.S. environmental policy show that, overall, the public benefits exceed the costs by a wide margin.

The country is in the midst of another difficult debate, this time about whether and how to address global warming and the attendant climatic risks tied to CO_2 emissions. That debate is not the subject of this hearing and neither is climate science my own area of expertise. However, I have accepted the grave threat of climate change since Dr. James Hansen raised the alarm in his Congressional testimony of 1988. That was the year I completed my doctorate in engineering and I was one of the then-young scientists who became motivated to find solutions to the CO_2 problem. Within a few years I narrowed my focus to addressing the transportation sector, examining ways to reduce CO_2 and other greenhouse gas (GHG) emissions from fuel use by motor vehicles. It is through that lens that I evaluate options such as biofuels, which have been

justified by a belief that they will help reduce CO_2 emissions as well as improve energy security and increase income for many farmers and other agricultural firms.

Elevating climate protection as a priority for U.S. energy strategy does not, and need not, mean downplaying the traditional challenge of balancing the needs of the diverse energy consumers with those of energy-related businesses. Moreover, it is all the more reason to harness the power of markets to find solutions to society's problems including climate.

THE PRIMACY OF THE MARKETPLACE

All of the major goods and services enjoyed by the public are mediated by markets. Competition in the marketplace drives innovation that enables producers to gain greater profits even as consumers enjoy lower prices, better products and often a combination of both. This dynamic is and always has been the main determinant of the motor fuels market, much more so than for, say, the provision of electric power which was historically treated as a public service. Proponents of alternative fuels often claim that they need government policy support through subsidies or mandate to bring "more competition" to the fuels market. However, that is really just an excuse to support products that have lower value than hydrocarbon fuels. The reason why alternative fuels -- whether biofuels or other options such as gaseous fuels and electricity -- have not made headway in spite of decades of policy promotion is that they are fundamentally inferior to liquid hydrocarbons for the vast majority of transportation needs.

All of the measurable, large-scale progress made in reducing air pollution from motor vehicles and other forms of transportation has come from improvements in conventional vehicles and fuels. EPA set progressively more stringent standards without picking winners and the automotive and petroleum industries responded with improved engines, more effective emission control systems and cleaner reformulated fuels. The market was not left to its own devices, but neither did the government overstep its role. By setting technology-neutral, performance-based standards, the respective industries were able to innovate in ways that were least costly and most effective. Different firms often took different approaches, with the best technological solutions diffusing across the industry in typically decade-scale time frames. The standards now used to regulate both conventional smog-causing air pollutants and GHG emissions from vehicles, and the standards used to remove first lead and more recently sulfur from fuels, are examples of flexible, market-based regulations that focus on environmental outcomes while leaving the choice of technologies to achieve those outcomes to the private sector.

Alternative fuel vehicle (AFV) policies deviate from market principles because they attempt to pick winners -- with which technologies are the supposed winners often varying over political cycles -- and are indeed premised on attempting to make petroleum a loser in the market. After more than 40 years and many billions of dollars, it clearly hasn't worked. At the same time, competitively driven innovation in oil and gas production has opened up new sources of supply, restoring America to global leadership in production, and doing so rapidly when oil

price rose. Rather than the fears of running out of oil (a fear that was always groundless in my view), the world has again entered a period of oversupply, resulting in lower prices. At the same time, market forces continue to work, enabling newer oil production technologies such as hydraulic fracturing to fall in cost as the industry "learns by doing." Like any major industry, the oil and gas industry enjoys a level of subsidy through tax breaks; however, that industry has never been dependent on public subsidies to enable it to profitably supply consumers with high-quality fuel products.

Thus, the most cost-effective regulations are those that set technology-neutral standards based on objective metrics closely tied to measurable environmental outcomes. The traditional motor vehicle and motor fuel standards developed by EPA under the Clean Air Act (CAA) are exemplary in this regard, with costs to industry well under the margins of economic safety that enabled the automotive and petroleum industries to thrive while tailpipe emissions were cut to progressively lower levels. Even though the negotiations were tough every step of the way, the balancing of diverse interests that EPA brokered now proves that vehicles powered by internal combustion engines running on low-sulfur gasoline and diesel fuel no longer need be a threat to public health.

Corporate Average Fuel Economy (CAFE) standards, which since 2010 have been closely coordinated with the newer CAA-based motor vehicle greenhouse gas (GHG) emissions standards, are a similar success story. They have pushed fleet-average fuel economy to levels higher than the market would provide on its own, and keep fuel economy from sliding backward as far as it otherwise might when oil prices fall. The result has been lower car and truck CO_2 emissions rates, also accomplished in a highly cost-effective manner. In short, sound policies do not ignore the marketplace, but rather harness market forces in ways that address non-market problems ("externalities") while leaving maximum discretion to industry and consumers about how to reduce the adverse side-effects of economic activity.

FEDERAL BIOFUEL PROGRAMS VIOLATE PRINCIPLES OF GOOD POLICY

Unfortunately, federal biofuel policies have not followed these principles, and for that reason it should come as no surprise that, on balance, they have done more harm than good. Among AFV policies, the one that has had the greatest impact on the market to date -- and caused the most harm -- is the RFS. Building on many years of subsidies such as the Volumetric Ethanol Excise Tax Credit (VEETC, now phased out), the RFS has resulted in a large ramp-up of ethanol use and a significant increase in biodiesel use over the past decade. While its proponents hail the RFS as a success, it is a success only along the narrow dimension of raising incomes for the segments of agriculture, mainly corn and soybean producers and processors, that provide its main base of political support. The RFS has raised grain prices to levels higher than they would be without the renewable fuel mandates, thereby increasing costs to other segments of agriculture as well as American consumers and grain consumers throughout the world.

The RFS is a politically scripted mandate for particular biofuels that is partly masked by complex but only semi-scientific LCA provisions to qualify certain categories of renewable fuel according to claimed GHG reduction levels. However, LCA is a deeply flawed and misleading tool in this regard. It is nothing like the truly measurement-based methods used for the traditional vehicle emissions and fuel quality standards set by EPA. When applied in an attempt to quantify the GHG emissions of fuels, LCA yields numbers that are determined largely by subjective modeling assumptions rather than objective data. I addressed the serious shortcomings of LCA and its misleading results in my testimony here two years ago.[7] Since then, my subsequent studies have confirmed the finding that the RFS, and therefore U.S. biofuel use, has resulted in net CO_2 emissions higher than those that would have resulted from using petroleum fuels.[6]

ADVANCED BIOFUELS ARE A FAILURE

Many of you, and many in the public, have heard claims that the RFS is a success and that it is paving the way to an future of even more and better advanced biofuels. Nothing could be further from the truth. In spite of many years and many billions of dollars of federal spending, DOE's programs have yet to yield commercially viable advanced biofuel technologies. A sober look at the BETO's latest list of accomplishments[8] reveals that the program is still more about making promises than it is about delivering real value for the nation.

The failure is apparent in how cellulosic biofuel volumes have consistently fallen far short of the RFS targets. EPA's latest proposal, for 2018, is for 238 million gallons of cellulosic biofuel. That is only 3% of the 7 billion gallon target established by EISA. Moreover, much of even that small volume is comprised of biogas, rather than the liquid motor fuels that were the main objective of the program. This large shortfall continues a pattern, now seen every year since the program started, which demonstrates that the cellulosic biofuels in which DOE and others have invested many millions of both public and private dollars are not living up to what was promised by their proponents. The volumes of biofuels now classified as "advanced" by EPA amount to 4.2 billion gallons, of which biomass-diesel is a part. However, though qualified as advanced because they meet the 50% CI reduction threshold based on LCA, such fuels are still largely crop-based. Moreover, as pointed out below, the LCA methods used to qualify these fuels as advanced are unsound and so it is very unlikely that these so-called advanced biofuels actually result in net CO_2 reductions.

THE RFS HARMS THE ENVIRONMENT

Last year we published research to evaluate what actually happened as the RFS ramped up. We found that ethanol and biodiesel are very far from being carbon neutral and that the biofuels provided no significant direct CO_2 reduction. Once indirect impacts are considered, the result is that U.S. biofuel use has caused higher CO_2 emissions, more than if we had just been using petroleum fuels.

The research we conducted on this question provided the first retrospective, national-scale evaluation of the effect of substituting petroleum fuels with biofuels based on field data rather than computer modeling. All of the modeling used to justify and administer biofuel policies (including the RFS and California's LCFS) assumes that biofuels are inherently carbon neutral, meaning that only production-related GHG emissions need to be accounted for when comparing them to fossil fuels. This assumption was never tested; it was just presumed to be always true. However, farm data for testing this assumption are readily available from USDA, and those are the data on which we relied for our evaluation of the RFS. Our analysis directly evaluated both the CO_2 absorbed by crops and the CO_2 and other GHG emissions released when processing and burning both biofuels and fossil fuels. Instead of assuming that biofuels such as ethanol and biodiesel were completely carbon neutral, we compared CO_2 uptake on cropland to the biogenic CO_2 emitted during biofuel production and consumption. The analysis also accounted for motor fuel consumption, fuel processing operations and resource inputs, including the use of cropland for biofuel feedstocks. We found that instead of being completely (100%) carbon neutral, the gain in CO_2 uptake on cropland was enough to offset only 37% of the biofuel emissions over the 2005-2013 period. Once one factors in process emissions and the very large CO_2 emissions released from land conversion (which occurs because farmers must grow more crops elsewhere to compensate for the corn and soybeans devoted to biofuel production), the conclusion is that U.S. biofuel use has led to a net increase rather than a net decrease in CO_2 emissions relative to petroleum fuels.

These excess GHG emissions are not the only environmental harm caused by the RFS. Other researchers at University of Michigan documented how the cropland expansion due to the rising use of corn ethanol has destroyed habit for waterfowl and other wildlife.[9] The expanded corn production worsens water pollution, contributing to algae blooms and oxygen-starved zones in the Gulf of Mexico and Lake Erie.[10] Biofuel processing releases other forms of air pollution; for example, research has found that one of the country's largest corn ethanol refineries emits 30 times more air pollution than was assumed for the RFS regulatory analysis.[11] Ethanol's corrosive properties are also incompatible with many cars already on the road and degrade the operation of lawn mowers, motor boats and other gasoline-powered equipment used by homeowners and businesses alike.

CONCLUSION

Many aspects of federal biofuels policy are in need of major reform. From an environmental perspective, policies to subsidize or regulate biofuels into the market should be repealed or at least greatly scaled back. Reform is also needed in the DOE offices and affiliated national laboratory divisions involved in biofuels analysis. The LCA and related analytic tools they developed and promote are unsound scientifically and so a major effort is needed to have them critically examined by other scientists who do not have a vested interest in either the methods or

biofuel promotion. At the same time, there is a need to invest in developing and testing new tools that correctly address the dynamics of biofuel systems.

On the biofuel technology R&D side, DOE should face up to the fact that the advanced biofuel work has not only not failed to deliver commercially viable results, but also may be poorly grounded as an area to emphasize in support of climate mitigation. Bioenergy R&D should be greatly pared back and the resources shifted into terrestrial carbon management and other approaches for increasing carbon sequestration by ecosystems. Reforming biofuel research is a much-needed course correction for the federal energy research effort, which will be strengthened if ill-premised and poorly performing programs are phased out in favor of efforts more in line with the urgent need to mitigate CO_2 emissions.

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