# Perspectives on achieving sustainable energy production and use

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The traditional definition of sustainability calls for policies and strategies that meet society's present needs without compromising the ability of future generations to meet their own needs. Through the 1970 National Environmental Policy Act, U.S. policy formally established the goal of creating and maintaining "conditions under which [humans] and nature can exist in productive harmony, and fulfill the social, economic and other requirements of present and future generations of Americans." However, we have not yet succeeded in making sustainability operational. The long-standing and current debates on setting energy policy, regulating greenhouse gases, and promoting alternate fuels illustrate the complexity of making sustainability operational. Achieving operational sustainability requires three critical elements: advances in science and technology, application of effective government regulations and policies, and green business practices. Not only are these elements necessary, all three must work together across the economy. A key lesson drawn from the history of environmental regulation and especially in the climate debate is that sustainability cannot be advanced without a convergence of government and business interests even when the requisite technology is available. The biofuel system presents an immediate and tangible test case for the successful interaction of these three critical elements. The massive investments in science and technology by both government and industry to develop new feedstocks and conversion methods are showing promise. From a regulatory perspective, existing statutes and new mandates impact all parts of the biofuel supply chain—a complex system involving feedstocks, conversion technologies, transport, storage, handling, and end use. Forward-looking businesses in the biofuel sector are integrating sustainability objectives into their business strategies, such as designing feedstock conversion processes to generate biofuel coproducts that can add substantial revenue. The combination and coordination of such activities have the potential to achieve sustainable biofuel production and to demonstrate the kind of critical approaches that are essential to making sustainability operational in this and other energy sectors. © 2010 U.S. Government. [doi:10.1063/1.3384210]

# **I. INTRODUCTION**

In the first half of the 21st century the world's population is expected to grow by 50% and its economy by 500%, while its energy consumption and manufacturing activity are likely to increase by at least 300%.<sup>1</sup> These increasing demands on our planet make it obvious that if the goal of achieving sustainable energy is critical today, it will be essential in the decades ahead.

The Energy Information Agency (EIA) of the Department of Energy (DOE) projects that from 2006 to 2030, assuming unchanged laws and policies, U.S. energy use will grow by 14% and world energy use by a rate three times faster (44%) than the U.S.<sup>2</sup> The current worldwide eco-



FIG. 1. Projected world annual production of biofuels for the reference case (source: Ref. 4).

nomic downturn is dampening world demand for energy as well as for manufacturing and consumer goods and services, but with economic recovery anticipated after 2010, most nations are likely to return to the earlier trends for both economic growth and energy demand.

From 2006 to 2030 the EIA report projects that the most rapid growth in energy demand will be in nations outside the Organization for Economic Cooperation and Development (OECD), especially in the emerging economies of China, India, Brazil, and Russia; total non-OECD energy use is expected to grow by 73% compared to an increase of 15% in the OECD countries. Strong long-term gross domestic product (GDP) growth in the non-OECD countries—projected at an average annual rate of 4.9%, compared to 2.2% in the OECD countries—drives the global growth in energy demand.<sup>3</sup>

EIA projects that fossil fuels (petroleum and other liquid fuels, natural gas, and coal) are expected to continue supplying much of the energy used worldwide. The share of liquid fuels in world energy use however is expected to fall from 36% in 2006 to 32% in 2030, as high oil prices will likely lead many energy users, especially in the industrial and electric power sectors, to switch from liquid fuels to lower-priced solid fuels. Among liquid fuels, those derived from unconventional sources (including oil sands, extra-heavy oil, biofuels, coal-to-liquids, and gas-to-liquids) in both Organization of Petroleum Exporting Countries (OPEC) and non-OPEC nations are expected to become increasingly competitive economically. World production from these liquid energy sources, which totaled just  $3.1 \times 10^6$  barrels/day in 2006, is expected to reach 13.4  $\times 10^6$  barrels daily and account for 13% of the world supply of liquid fuels in 2030.<sup>3</sup>

Ethanol, biodiesel, and other biofuels will constitute an increasingly important portion of unconventional liquid fuels, reaching  $5.9 \times 10^6$  barrels/day globally in 2030, according to the EIA report. Particularly strong growth in biofuels consumption is projected for the U.S. where, as mandated by the Energy Independence and Security Act (EISA) of 2007, its production is expected to increase from  $0.3 \times 10^6$  barrels in 2006 to  $1.9 \times 10^6$  barrels/day in 2030. Other regions with large projected increases in biofuel production include the OECD nations in Europe and non-OECD economies in Asia and Central and South America. Growth in U.S. and European biofuel production is projected to be about equal to that for the rest of the world between 2005 and 2030, with the U.S. increase being about the same as the increase in world production, less Europe and Brazil (see Fig. 1).<sup>4</sup>

Although biofuels are expected to provide a growing share of U.S. transportation energy, the nation will remain dependent on imports of oil and gas in the decades ahead. Oil-related concerns for national security and energy independence will remain important until relevant new technolo-

gies and sustainable energy policies are developed and implemented. A major component of the U.S. strategy for reducing dependence on imported energy is to increase production and use of biofuel. Because biofuel relies on sustaining feedstock production across a range of ecosystems, it presents a clear example of the close connection between energy independence and sustainability.

Since the 1972 oil embargo, U.S. dependence on oil and gas imports has been a significant political and economic issue, with nearly every president calling for energy security and independence; President George W. Bush in 2007 made virtually the same appeal as did President Nixon in 1972. Yet the Council on Competitiveness has concluded in a recent review that government efforts of the last 40 years to achieve sustainable energy systems "have been to no avail."<sup>5</sup>

Recent decades have seen improvements in energy efficiency and significant reduction in critical air pollutants, but the progress to date is far short of the potential that new policies could achieve even with existing technologies, according to a 2009 McKinsey & Co. study, which highlighting significant opportunities to enhance energy efficiency that business and government have missed. While the U.S. has succeeded in producing more goods and services with less energy, the McKinsey report shows that the U.S. could further reduce its annual nontransportation energy consumption by roughly 23% by 2020, eliminating more than \$1.2 trillion in waste—well beyond the \$520 billion upfront investment (apart from program costs) that would be required. The reduction in energy use would also result in the annual abatement of 1.1 Gtons of greenhouse gas (GHG) emissions—the equivalent of removing the entire U.S. fleet of passenger vehicles and light trucks from the roads.<sup>6</sup> According to the McKinsey report, such energy savings will be possible only if the U.S. can overcome widespread and persistent barriers, which will require an integrated set of solutions—including information and education, incentives and financing, codes and standards, and deployment of resources well beyond current levels.

The reports of the EIA, the Council on Competitiveness, and McKinsey & Co. all point to the need for more efficient and sustainable energy systems. The technical and policy challenge is how to achieve such a goal.

# **II. DEFINING SUSTAINABILITY**

The traditional definition of sustainability calls for policies and strategies that meet society's present needs without compromising the ability of future generations to meet their own needs. While the U.S. recognized this concept as early as 1970, its implementation, like that of sustainable energy systems, has been virtually "to no avail." The 1970 National Environmental Policy Act (NEPA) formally established as a national goal the creation and maintenance of "conditions under which [humans] and nature can exist in productive harmony, and fulfill the social, economic and other requirements of *present and future generations of Americans* [emphasis added]." This concept of sustainability was promulgated in a 1981 White House Council on Environmental Quality report, which underlined the global dimensions of sustainability: "The key concept here is sustainable development. If economic development is to be successful over the long term, it must proceed in a way that protects the natural resources base of developing countries."<sup>7</sup>

Over the past 20 years the concept of sustainability has evolved to reflect the perspectives of the public and private sectors. A policy definition of sustainability centers on meeting basic economic, social, and security needs now and in the future without undermining the natural resource base or environmental quality on which both life and the economy depend. From a business perspective the goal of sustainability is to increase long-term shareholder and social value while reducing industry's use of materials and any negative environmental impacts; from this perspective, sustainable development favors an approach based on capturing system dynamics, building resilient and adaptive systems, anticipating and managing variability and risk, and making a profit.<sup>8</sup> Common to both the public policy and business perspectives is the need to support a growing economy (which does not necessarily imply growth in consumption) while reducing the social and economic costs of economic growth. Sustainable development need not reflect a trade-off between business and the environment but rather synergy between them; it can foster policies that integrate environmental, economic, and social values in decision making.

Many might see sustainability as a form of insurance policy aimed at reducing or eliminating

practices that threaten the long-term quality of our economy, environment, and lives. However, sustainability can be a positive force for spurring innovation in industry, strengthening competitiveness, and enhancing quality of life. A recent study by Nidumolu *et al.* examined the sustainability initiatives in energy and manufacturing of 30 large corporations, finding that "sustainability is a mother lode of organizational and technological innovations that yield both bottom-up and top-line returns" and concluding that in fact "there is no alternative to sustainable development."<sup>9</sup>

The Environmental Protection Agency's (EPA's) new Assistant Administrator for Research and Development, Paul Anastas, has been a leader in promoting sustainability and green chemistry. Now at the EPA Anastas made it clear that his vision for EPA research is to make sustainability our "true north" and that scientific and technological innovation is essential to the success of our mission.

Among the practical questions raised by the ambitious goals of sustainability, the most important is "What kind of policies, strategies, and practices are needed to advance sustainability, and how will such changes impact economic development?" Such practical questions often result in conflicts between business and government on policies to produce energy security or regulate emissions from energy systems. Nowhere is this conflict better seen than in the challenge of regulating GHGs and the current debate on energy security.

## **III. THE CLIMATE CHANGE DEBATE**

For decades scientific uncertainty and the cost of a regulatory approach to address global climate change have been at the root of the climate debate. A 1983 U.S. EPA report evaluating the effectiveness of specific energy policies to reduce GHG emissions elicited highly polarized responses from Congress, business, and federal agencies.<sup>10</sup> A sense of urgency among some congressional leaders emerged in 1986 as Senators Chafee, Stafford, Bentsen, Durenberger, Mitchell, Baucus, Leahy, and Gore declared themselves "deeply disturbed" by the implications of published reports on carbon-dioxide-induced climate change and began to pressure the White House to take action on the issue.<sup>11</sup>

When President George H. W. Bush took office in 1988, he declared "Those who think we're powerless to do anything about the greenhouse effect are forgetting about the White House effect. As President I intend to do something about it." However President Bush may have underestimated the underlying economic challenges. After briefing the cabinet on climate change and the prospect for an international climate convention, EPA administrator William Reilly reported to EPA colleagues the responses of some of the briefing participants. Office of Management and Budget director Richard Darman called the concept of a climate convention "clean air for the whole world." However despite growing agreement among climate modeling groups, White House Chief of Staff John Sununu declared that the climate models were fundamentally flawed and that the best atmospheric scientists had yet to become involved in climate research. Moreover Council of Economic Advisors chairman Michael Boskin advised the president that an international treaty on climate change was a "bet-your-economy decision."<sup>12</sup> Listening to such advice (and to much current congressional debate) would scare anyone already worried about destabilizing the U.S. economy.

Questions on the costs of reducing GHG emissions—and who will bear them—have long been a concern for policy makers. To those most concerned over cost, there is no good time to move forward. In 2002 the Bush administration saw an economy with a meager 1.6% growth rate in the GDP as the nation struggled to recover from bursting of the high tech bubble and the 9/11 attacks. Even by 2007 the U.S. GDP growth rate was only 2.2% and projections of just 1.9% prevailed in 2007.

In 2009, with the U.S. and global economies adjusting to near-collapse in the financial sector and drops in employment and economic output, concerns continued to be raised about the cost of reducing GHG emissions. As we will discuss below, these concerns echo others, also frequently raised although often unfounded, concerning other environmental initiatives. Despite the serious downturn in the economy, the time is right to launch a new era of government-business cooperation in which GHG regulations and green energy initiatives together stimulate the economy while protecting human health and natural systems.

## **IV. MAKING SUSTAINABILITY OPERATIONAL**

The complexity of making sustainability operational is illustrated by the long-standing scientific and political debate on setting energy policy, regulating GHGs, and promoting alternative fuels. Today it is clear that three critical elements are needed to make sustainability operational throughout the economy: advances in science and technology, application of effective government regulations and policies, and green business practices. The trick is that all elements must work together now and for the foreseeable future.

#### A. Science and technology

Science and technology drive change and must be a critical element of any sustainability strategy. A 1997 National Academy of Engineering study called for "the creative design of products, processes, systems, and organizations, and the implementation of smart management strategies that effectively harness technologies and ideas to avoid environmental problems before they arise."<sup>13</sup> A 2001 National Academy of Sciences study called on government and business to develop a "quantitative understanding of the global budget of materials widely used by humanity and how the life cycles of these materials may be modified."<sup>14</sup> Reflecting the growing scarcity of many natural resources and the rising prices of energy and commodities that impact nearly every business sector, these studies underscore the importance of increasing the efficient use of energy and materials and avoiding negative environmental impacts.

Technical frameworks for achieving these ends such as these gained increased attention in the late 1980s and early 1990s, as the scientific and technical communities developed methods for designing systems to prevent, rather than repair, environmental problems. Since that time, considerable effort has developed such concepts into formal approaches, including their adoption by the International Organization for Standardization (ISO).<sup>15</sup>

Advances in green chemistry have focused on maximizing the efficiency of energy and material use while minimizing wastes and on designing chemicals and processes from which any waste or unused materials do not pose long-term health or environmental risks.<sup>16</sup> Life cycle assessment seeks to quantify the environmental impacts across the entire life of a product—from the collection of raw materials through the product's manufacture and use and ultimately to disposition at the end of its useful life.<sup>17</sup> Industrial ecology moves beyond impact quantification into an active effort to design an industrial system in which waste materials from one process become feedstocks for others, thereby mimicking natural ecological systems and their utilization of all available materials, waste or otherwise.<sup>18</sup>

## B. Regulations and policy

Society now confronts a suite of issues related to economic growth, demographics and aging, urban development and redevelopment, energy and material use, nonpoint sources of pollution, ecosystem destruction, and new chemical and biological risks. In today's world, while regulating dangerous pollution and toxics certainly remains a necessary and vital task, altogether eliminating the use of noxious materials is a better, more sustainable alternative. It is therefore not surprising that as environmental pressures grow and new risks are identified, EPA programs have moved toward green chemistry, life cycle analysis, green design, green engineering, smart growth, and industrial ecology. EPA's changes parallel a new management approach taken by many businesses that is more system-oriented and gives more attention to what goes into a product rather than simply what is emitted.<sup>19</sup>

In the area of waste management, a similar shift is transforming thinking from managing *waste* to managing *materials*. This new attitude reflects the belief that, as expressed by an EPA workgroup, "developing new approaches for conserving resources, reducing the amount of toxic

materials in society and the toxicity of materials that remain, and managing wastes properly can and should be an important part of responding to this challenge of making a more sustainable world."<sup>20</sup>

Responding to growing trends in waste management and toxic chemicals, the European Union (EU) has enacted several directives with important environmental implications throughout the world—including EU directives for the Restriction of Hazardous Substances, Waste Electrical and Electronic Equipment (WEEE), and Registration, Evaluation and Authorization of Chemicals. These directives regulate input rather than outputs, manage material rather than waste, promote use of life cycle assessment and cradle-to-grave management, apply green engineering and green chemistry principles, shift the burden of proof to industry, and measure and manage future financial risk and liabilities. Combined with pressures from insurers, risk managers, and accounting that incorporates asset retirement obligations, these directives advance the movement to sustainability.

As Nidumolu and his colleagues have pointed out, many companies in the "vanguard of compliance" can identify new business opportunities related to meeting regulatory requirements.<sup>9</sup> In response to the WEEE directive that requires hardware manufacturers to pay for costs of recycling their products, HP has teamed up with Sony, Braun, and Electrolux to create a European recycling platform that works with over 1000 companies in 30 countries. Such innovative management led to savings of more than \$100 million from 2003 to 2007.

### C. Green business strategies

Industry has historically responded to proposed environmental or health regulations with warnings of impending economic disaster. For example, following the creation of the EPA in 1970, the director of the U.S. Chamber of Commerce warned of the potential collapse of entire industries from pollution regulations.<sup>21</sup> Given the current crisis in the automobile sector, it is ironic to recall Lee Iacocca's 1972 prediction that "If EPA does not suspend the catalytic converter rule, it will cause Ford to shut down and would result in reduction of GDP by \$17 billion, increase unemployment by 800 000, and decrease tax receipts of \$5 billion all levels of government."<sup>22</sup>

U.S. electric utilities claimed that the cost of meeting the 1990 Clean Air Act Amendments would reach \$4–5 billion per year. However by 1996, utilities were actually saving \$150 million per year due to new practices brought about by the Act. In 1993, automobile manufacturers warned that regulation of chlorofluorocarbons would increase the price of new cars by up to \$1200. Just 4 years later, the industry admitted that costs of adhering to the new rules had declined to as little as \$40.<sup>23</sup> When the EPA announced a phase-out of substances that damage the ozone layer, many industries claimed that alternative substances did not exist or were too expensive. Recent studies by Hwang and Peak have found that "the target industries dramatically and consistently overestimate the costs that regulations would impose on them and dramatically underestimate the innovation they would inspire."<sup>24</sup>

In all of these cases the costs of complying with environmental regulations were far lower than industry—and even government—had expected. Also the more favorable outcomes would be ever more positive if they included savings in the form of improved human and environmental health fostered by compliance with the regulations.

Businesses that rely on natural resources are particularly aware that environmental sustainability is crucial to their own sustainability. An aggressive Weyerhaeuser core policy, for example, provides for continually improving its environmental performance, recognizing that the firm's corporate health depends on the health of the forests it manages, which is the first step in its supply chain.<sup>25</sup> FedEx, with a fleet of 700 aircraft and 44 000 motor vehicles that consume  $4 \times 10^6$  gal of fuel a day, is upgrading its aircraft fleet and as noted by Nidumolu *et al.* has set up a 1.5 MW solar energy system at its distribution hubs in California and Cologne, Germany. FedEx has replaced more than 25% of its fleet with more efficient vehicles, switching to hybrid vans that are 42% more fuel efficient than the vehicles they replace.<sup>9</sup>

Corporate actions such as these reflect a new business perspective on regulations that emphasizes potential economic advantages. With its "ecomagination" initiative, GE launched in 2005 the notion that "green can be green." The GE effort is part of a broader greening of industry detailed



FIG. 2. Venture capital investments in clean technology in North America, Europe, Israel, China, and India, in billions of U.S. dollars (source: Ref. 28).

in the dozens of interviews carried out by Esty and Watson with key industrial leaders.<sup>26</sup> For example, many large corporate members have joined GE in the U.S. Climate Action Partnership in which they are energetically advocating national legislation to limit GHG emissions.

Clear evidence demonstrates the role of major firms in this current convergence toward sustainability.<sup>12,27</sup> Esty and Winston concluded from their dozens of interviews that environmentally smart companies—which they call WaveRiders—are responding to environmental and social pressures by developing forward-looking and profitable business strategies. These innovative companies consistently behave in several recognizable patterns: anticipating environmental issues and addressing them, staying ahead of new regulatory requirements, managing government mandates to gain advantage in the marketplace, designing innovative or greener products, pushing suppliers to become better environmental stewards, setting metrics and collecting data to track progress, and partnering with nongovernmental organizations (NGOs) and other stakeholders.<sup>26</sup>

Investments in green and sustainable businesses are increasing faster than any other sector.<sup>28</sup> Venture capital firms have increased investments in green businesses by a factor of 15 over the past 8 years—a growth rate of over 40%/year (see Fig. 2).

#### D. Convergence of government and business policies

The key lesson from the climate change debate and from environmental regulation in general is that sustainability cannot be advanced without a convergence of government and business interests. As Fiksel of Ohio State University's Center for Resilience has pointed out, much of the technical infrastructure—transportation, water, and waste management—that is crucial to supporting economic activity is publicly managed, demonstrating the imperative of close—or, according to Fiksel, "extraordinary"—collaboration among industries and governments.<sup>29</sup>

Government-business convergence must also include developing and advancing new technologies, setting carbon limits, facilitating implementation of new regulations, and creating new incentives for industry. Corporations must put aside tired refrains of resisting federal regulations as inherently antibusiness. Strong federal support for regulation of GHG emissions and for research and development on new technologies to reduce GHG emissions is essential. Incentives for both can enhance economic competitiveness and protect the environment. Both government and business must see the role of environmental regulations in a new light, recognizing the shortcomings of past actions. Both government and business, with support from NGOs and the public, must agree on the sense of urgency and work together to implement new strategies.

Biofuel production offers a good case study to test how government and business can make sustainability operational. At a relatively young state of technological policy and business development, it presents the opportunity for innovative approaches to supplement or replace conventional policies and practices that can hinder the adoption of sustainable strategies.

# V. CASE STUDY: SUSTAINABLE BIOFUEL PRODUCTION

Sustainable biofuel production holds the potential to enhance energy security, stimulate economic development, and reduce GHG emissions. Making the biofuel system sustainable provides a test case for the convergence of the three critical elements needed to make sustainability operational: advances in science and technology, effective government policies and regulations, and green business practices.

## A. Science and technology

On the science side, both government and business recognize that advanced biofuels derived from non-food-related feedstocks are needed for meeting biofuel goals in an environmentally sound manner. For the transition to advanced biofuels, advances in science and technology are critical. The investment by the DOE and U.S. Department of Agriculture (USDA) of billions of dollars for research to advance biofuel development and assess its environmental impact is crucial for the development of sustainable biofuels.<sup>30</sup> For example, the conversion of different feedstocks into liquid fuel requires enhanced understanding of complex biological systems and conversion technologies that can be scaled up to support growing requirements. Companies including BP, DuPont, and ExxonMobil have invested additional billions of dollars to develop advanced biofuel production processes.<sup>31</sup>

A crucial element of sustainable biofuel production is ensuring that there are no irreversible impacts on the environment and, to the extent possible, no unintended consequences. This is not simply an environmental ideal but is at the heart of ensuring that the environment is able to support the production of food, feed, fiber, and fuel at adequate levels for a growing population. Assessing the environmental impacts of biofuel production using life cycle assessment methodologies will be essential. The large investments by both government and industry are developing new feedstocks and conversion methods that show promise for substantially changing how we convert biomass into energy for transportation through supply chains quite different from what we may anticipate.<sup>32</sup>

Advances in algae-based biofuels can result in a major shift away from feedstocks that are grown with conventional agricultural practices but carry serious implications for water demand. New catalysts that produce hydrocarbons directly from biomass could move the supply chain away from alcohol-based fuels and reduce the need for major changes in fuel distribution and storage and for changes in engines so that they can use higher proportions of ethanol. Breakthroughs in storage of electric energy could push manufacturers more quickly toward all-electric and plug-in hybrid vehicles and accelerate the use of biomass as a fuel for electricity production. These are but a few examples of how on-going research could result in a biofuel supply chain and its environmental footprint—substantially different from our current expectations.

Beyond the development of new technologies, research is also crucial for determining the extent to which biofuel-related activities are sustainable. The recent controversy over the potential impact of increased biofuel feedstock production in the U.S. on land use practices abroad<sup>33</sup> highlights the need to more fully understand the potential direct and indirect consequences of biofuel policies and practices. One recent study assessing the state of our understanding about next-generation biofuels concluded that "significant uncertainty remains" regarding the sustainability of producing these fuels at commercial scale.<sup>34</sup>

The fact is that complete certainty is never achieved. Even so, the information, data, and technologies generated by scientific and technological endeavor must be applied in practice. In the



FIG. 3. The five principle steps through which the biofuel supply chain may be analyzed (source: Ref. 35).

absence of regulations and policies that provide the appropriate incentives and remove barriers to implementation, the research that has been done to date could easily remain merely a promise of what is possible.

## B. Regulations and policies

On the regulatory side, existing statutes and new mandates impact all parts of the biofuel supply chain (see Fig. 3), the complex system involving the production and distribution of different feedstocks, conversion technologies, transport and storage, and end use.<sup>35</sup> Existing federal legislation and regulations concerning air, water, waste, toxic substances, and emergency response apply to nearly all elements of the biofuel system. The long list of federal laws that many biofuel practices and facilities are subject to includes the NEPA, the Clean Air Act, the Clean Water Act, the Resource Conservation and Recovery Act, the Toxic Substances Control Act, the Federal Insecticide, Fungicide, and Rodenticide Act, the Federal Food, Drugs and Cosmetic Act, and the Energy Policy Act of 2005. Within statutory limits EPA, state, and local environmental agencies are responsible for assessing and controlling air emissions, water discharges, toxic substances, microbial application, pesticide application, and waste disposal.

From a sustainability perspective, the energy efficiency and environmental soundness of the entire biofuel system, along with market conditions and government interventions, determine the degree to which biofuels reduce reliance on fossil fuels. Given the reliance of the biofuel system on natural resources, assuring that the system proceeds in an environmentally sound manner is essential for its success, as well as for human health and ecosystem functioning.

Several provisions of the 2007 EISA specifically promote sustainable biofuel production. This Act calls for the development of "cellulosic and other feedstocks that are less resource and land intensive and that promote sustainable use of resources, including soil, water, energy, forest and land, and ensure protection of air, water, and soil quality." The act also establishes a roadmap to increase to  $36 \times 10^9$  gal by 2022 annual production of renewable fuels—which include corn-based ethanol, ethanol derived from cellulosic materials, and other advanced biofuels derived from materials other than corn starch, such as biomass-based diesel.

EISA requires full life cycle analysis of biofuel production and provides standards providing for renewable fuels to reduce life cycle GHG emissions to 20%–60% less than the levels of conventional fossil fuels. To ensure appropriate checks and balances, the act also mandates that EPA, in consultation with USDA and DOE, assess and report to Congress every 3 years on the impact of current and future biofuel production in the U.S. and abroad on *environmental* issues (including air and water quality, pesticides, sediment, and nutrient and pathogen levels), on *conservation* issues (including soil conservation, water availability, energy recovery from secondary materials, and ecosystem health and biodiversity), and on *growth and effects of cultivated invasive or noxious plants* and their impacts on agriculture and the natural environment.

In support of EISA, several federal agencies are collaborating on a host of activities including development of a set of criteria and indicators for benchmarking and evaluating progress toward a sustainable biofuel system. These important social, economic, environmental, and energy-security criteria and indicators can be a biofuel dashboard that agencies track over time, ensuring that relevant trends are moving in the right direction and triggering corrective actions when necessary.

The EISA mandates to reduce life cycle emission, representing the first time that legislation has called on the EPA to implement such requirements, are bringing about a fundamental shift in how the agency assesses environmental impacts—changing from evaluating end-of-pipe emissions to seeking a more complete understanding of the direct and indirect emissions associated with the production and use of biofuels.

The need for change is particularly evident for alternative feedstocks that have previously been considered wastes regulated as undesirable materials rather than as potential feedstocks for energy production. Revising such policies can remove barriers to a more sustainable system that enables wastes from one process to be used as feedstocks for another.

#### C. Green business practices

On the business side, biomass producers are sensitive to public concerns about competing uses of biomass for food, feed, fuel, and fiber, as well as issues related to natural resource protection. Hence sustainability objectives are being integrated into many biofuel business strategies for feedstock conversion, including the generation of important biofuel coproducts that can account for 25% or more of the revenue of the conversion facilities. Coproducts often find significant new uses in the marketplace, presenting both environmental benefits and challenges. Some biofuel coproducts may replace chemicals derived from fossil fuels, leading to less consumption of fossil fuels in chemical manufacturing and thus also contributing to sustainability, partnerships are forward-looking opportunities for environmental and corporate sustainability, partnerships are forming between companies—such as between Chevron and Weyerhaeuser—that would have seemed strange several years ago.<sup>36</sup>

Even accounting for businesses' sensitivities about public concerns, several aspects of the biofuel system are likely to fall outside the scope of a firm's interest, such as changes in land use practices and environmental impacts that are outside the firm's control. Hence, EPA has an important role to play in partnering with business to ensure that both the development process and end products meet environmental and health standards.

EPA and other government agencies also have a major role in coordinating policies and informing decisions that occur at different levels. Decisions at the farm level about what crops to plant and tilling practices to use, for instance, may be driven by factors in conflict with nationallevel policies designed to reduce petroleum consumption or support rural economic development. For a truly sustainable biofuel supply chain, factors that drive decision making at all scales need to be understood and, to the extent possible, aligned. Coordination across federal and state agencies, close interaction with biofuel and feedstock producers, and understanding of how energy, agriculture, finance, and environmental systems interact are all needed to develop and implement policies that promote sustainable practices.

# **VI. CONCLUSIONS**

Few can argue with the idea of sustainability as a general concept and long-term goal. Making it operational is where conflicts can arise between government policies and regulations and business strategies. There is evidence that government policies and businesses strategies in a number of areas are in fact converging on sustainability.

The combination and coordination of activities—effective regulations, policy approaches, and business strategies, combined with advances in science and technology—have the potential to promote sustainable biofuel production. Success would demonstrate critical ways to make sustainability operational in biofuels and other parts of the energy sector.

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