Research and Education Priorities in Agriculture, Forestry and Energy to Achieve the 25x'25 Renewable Energy Vision[1]

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Abstract

This paper lists the high priority research and education foci, as identified by a variety of public and private sector scientists who provided input, in order to achieve the vision, that "by 2025, America's farms, ranches and forests will provide 25% of the total energy consumed in the United States, while continuing to provide safe, abundant and affordable food, feed and fiber."

The benefits of renewable energy are many: water, geothermal, wind and solar energy conversion contribute to reduced atmospheric carbon, biomass conversion to transportation fuels enhances national security by reducing dependence on imported petroleum, and all contribute to the economic vitality of rural America. The priorities reflect that scientists recognize major logistic challenges, especially linking energy source to locations and patterns of energy consumption, and the massive biomass requirement for significant production of transportation fuel.

Highest research priorities include modeling of systems to mesh variable wind and solar generated electricity with other sources; assessing the relative efficiencies of multiple biological and thermochemical technologies in yielding consumable energy forms (ethanol, biodiesel, gasoline, syn-gas, bio-oil, or other biofuels); increasing per acre biomass yields and the processing efficiency traits of grasses, woody species, and grains while holding neutral or enhancing impacts on soil, water and the environment; and modeling systems for efficient handling of the biomass volume.

Highest education priorities include insuring that faculty are equipped to transmit cutting edge knowledge to the next generation of scientists, professionals and business leaders, curriculum development, and aggressive extension education that conveys knowledge and research output to policy leaders, conversion industry workers, biomass producers and the general public.

The paper recommends that national and state policy makers fund and encourage this research and education and that university and federal agency leadership increasingly focus resources and staff on the listed priorities.

Introduction

The current energy situation presents the United States and the world with both challenges and opportunities, especially for the U.S. agriculture and forestry sectors. It is evident these sectors can make a major contribution to reducing U.S. dependence on imported and fossil energy sources and, in so doing, enhance the country's economic security, move toward atmospheric carbon balance and bring more economic activity to much of rural America. Energy markets – including transportation fuels, electricity, and natural gas – are growing, and global competition for energy resources will only increase.

The greatness of the United States has always been its ability to cultivate human ingenuity and apply it to developing new technologies that will enhance the human condition. The agricultural and forestry sectors are prime examples of this greatness. Advances in plant and animal sciences have led to ever increasing production, resulting in more abundant and affordable food and other products. Though less dramatic, there have been parallel advances in the knowledge base for maintaining and enhancing soil and water quality and decreasing energy consumption per unit yield.

A 28-member steering committee of agriculture and forestry leaders has advanced the vision, "By the year 2025, America's farms, ranches and forests will provide 25% of the total energy consumed in the United States, while continuing to provide safe, abundant and affordable food, feed, and fiber." Rural land not only provides biomass for transportation and other fuels, the rural land is where much of the solar and wind energy capture will occur. Unstated in

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this vision, but assumed as a basic premise for achieving it, is that the natural resource base (soil, water, and biological diversity) and atmospheric environment can and will be preserved or enhanced in the process. The 25x'25 Action Plan outlines major policies and actions deemed necessary to achieve the vision:

- Increasing renewable energy production
- Delivering renewable energy to the market (infrastructure)
- Expanding renewable energy markets (demand)
- Improving energy use efficiency and energy productivity
- Strengthening conservation of natural resources and the environment

Constraints, such as government policy, government regulations, inertia, leadership, investment, and knowledge, may exist in every sector. This paper makes no attempt to recommend or prioritize specific changes in such policies or other such constraints. Rather, it focuses on knowledge constraints, as well as consumer, citizen, and policy-maker awareness of renewable energy features, potential and societal impact.

The purpose of this paper is to list high priority research and education needs. Such a priority list will allow the 25x'25 steering committee and the 600 plus vision-endorsing partners, as well as Congress and state legislatures, to more effectively support and encourage federal agency, university, community college, state agency and private sector administrators, scientists and educators in their endeavors.

Responsibility for carrying out research and education efforts lies largely with federal agencies, universities, community colleges and the private sector. USDA (including ARS, FS, CSREES, ERS and other units) leads and coordinates nation-wide research and extension education in the agricultural and forestry sectors. DOE (including NREL, Sandia National Laboratory and other units) leads and coordinates nation-wide research and education in the energy sector, and there is a strong coordination relationship between the two agencies. For example, a joint USDA/DOE bioenergy task force is working with related agencies to develop a definitive assessment of biomass research and education.

Both agencies finance research and education efforts within agency facilities and, through grants and contracts, similar endeavors in universities and colleges, state university extension services and the private sector. Corporations, industry organizations, and private foundations also provide considerable funding in concert with universities and federal labs.

Procedure

In May, 2007, 20 scientists and educators were identified for initial input to this prioritizing effort. Members of the group ranged from published renewable energy-focused scientists in economics, engineering, forestry, agronomy and related disciplines to directors of university-wide energy centers and federal laboratory directors to leaders in extension education and college curriculums.

Each was asked to identify what they believed to be the highest research and education needs in order to achieve the 25x'25 vision. Consideration of the responses prompted identifying additional persons for input to an initial priority-summarizing draft.

Over a three month period, June through August, a series of refined drafts were prepared and reactions solicited from those who had provided input. In September, a near final draft was distributed for any suggestions and reaction to a small sample of 25x '25 partners, mostly national commodity and interest groups that had endorsed the 25x '25 vision. In this total process, no questionnaires were sent to large numbers of scientists or educators; there was no offering of topics on which such persons might vote or prioritize.

In early October a final draft was accepted and endorsed by the 25x '25 steering committee, then edited to insure clarity for posting on www.25x25.org

Research Needs

Though most of the research focus within the agriculture and forestry sectors tends to be on biofuels from biomass, we considered all renewable energy in this priority setting effort. Much of the conversion of wind, water, solar and geothermal energy to electricity and other consumable forms, plus maintenance and service of their storage facilities and transmission infrastructure, is part of the rural economy.

Not all energy conversion areas are mentioned among research priorities. For example, technologies for converting animal manure to methane and other products are rather well known and implemented, therefore additional research was not deemed to be a high priority by the scientists and educators who provided input. Further, not all research and education needs are listed. The paper focuses on high priority items. As technologies and economic conditions change, other needs may emerge as warranting priority status.

Science-wide and Sector-wide

Interest in renewable energy is so high that not a week goes by without a conference dedicated to some aspect of it; however, the program content is understandably focused on the sponsoring group's interests, whether it be production, transmission, investment, or environmental concerns. From the standpoint of renewable energy science and the related agricultural and forestry interests, the following priorities are identified:

1. A national scientific renewable energy forum for discourse among all contributing disciplines, preferably hosted by a federal research agency. This is especially needed in the biofuels sector to help insure

comparative attention to multiple and competing feedstocks, conversion technologies and products by both senior scientists and students. (A series of such forums on biomass technologies, initiated by NREL, occurred in the mid-1990s.)

2. Research on the likely impacts of various policy drivers and incentives, such as reductions in carbon emissions per BTU, incentives for energy product volume or proportions, or increases in vehicle fuel efficiency. Emphasis is suggested on identifying policy options that:

a) provide a level playing field among technology options
b) focus on desired societal and economic security results, and
c) include energy conservation

3. Assess consumer behavior and attitudes towards renewable energy. What are consumers excited about and if there are concerns, what are they and why?

Water and Geothermal

No research priorities are listed. Conversion technologies are mature, relative to those of other energy sources, and, though efficiencies in both conversion and integration with other energy product may continually be sought, research needs were not deemed to be as high a priority as for other sectors.

Wind and Solar

Scientist input focused on the quantifying the potential to reduce atmospheric carbon and to provide other environmental benefits, plus minimizing constraints on integrating the electricity product at both the grid and consumer levels, e.g. home and industrial installations. High priority research includes:

1. Modeling of systems to mesh variable wind and solar generated electricity with other generation sources. Examples: Computerized control and integration of multiple source generating facilities. Wind turbine proximity to transmission lines. Energy storage systems.

2. Modeling of collection and transmission systems to link wind and solar electricity sources with geographic areas of high consumption.

3. Advancing photovoltaic manufacturing techniques for lower cost and lifetime durability.

4. Increasing the performance of thin film, high efficiency photovoltaic components to enhance solar conversion efficiency.

5. Developing nanomaterial technologies, which hold promise of high solar conversion efficiencies.

6. Lowering the cost of concentrating solar energy in the trough system, including energy receivers and thermal storage.

7. Advancing the technology to capture low wind speed (especially significant for most of the eastern half of the U.S. and areas such as California's central valley) and wind forecasting.

Biomass Conversion Technologies

Because biomass is the only renewable resource for liquid transportation fuels, the agriculture and forestry sectors can make a major contribution to national security by helping to reduce dependence on imported oil. In addition, there is strong potential for high-value co-products, which will impact the economics of individual biomass technologies. Hence, considerable attention is given to biomass in this and in following sections.

Whereas centrally-controlled economies have tended to choose one technology to address a societal need and put all government money and incentives on that technology, the U.S., with multiple research agencies and research universities, plus the private sector (where creativity and ingenuity often short-cut technology advances), has generally pursued multiple technologies and has more rapidly achieved needed and efficient technologies. However, there are limits to both public and private funds; hence the following priorities:

1. Assessing the relative economic and energy efficiencies of available and proposed biological and thermochemical technologies in yielding useable fuels (e.g., ethanol, bidiesel, biogasoline, syn-gas, bio-oil, direct combustion) by feedstock, region, water supply, energy demand, and infrastructure. This includes assessing fundamental research for its potential application to multiple conversion technologies.

2. Increasing the efficiencies of biomass conversion technologies, especially those with the highest economic and energy potential. In biological conversion, for example, lowering the enzyme cost for converting cellulose to sugar, developing stable enzyme sources that will ferment both five and six carbon sugars, and/or fractionating biomass inputs for multiple processing streams and products (such as separating hemicellulose from wood chips, the former going to fermentation, and the latter to higher quality particle board or paper). In thermochemical conversion, for example, developing systems for feeding biomass feedstock into high pressure gasifiers.

3. Testing and refining small volume (1 to 2 ton per day) biomass conversion systems. Biomass conversion involves a variety of technologies that may involve fractionators, fermenters, separators, conveyors, temperatures, catalysts, and processing streams, as well as feedstock of varied structure and composition. Integrating the system components and scaling up carry high failure risk.

4. Integrating biomass conversion technologies with existing petroleum refining, pulp, paper and solid wood processing technologies and facilities.

5. Developing limited scale, perhaps portable, conversion or pre-conversion facilities for handling

cellulosic biomass to minimize transportation and other costs.

Biomass Production and Handling

Regardless of the conversion process or the fuel product, large volumes of biomass feedstock are needed. At the same time, global food demand continues to increase. The result is that intensifying biomass production will put enormous pressure on the soil and water resource base. High biomass priorities include:

1. Genetics (molecular, quantitative and selection) and production management research with grasses and woody species to increase per acre yields and improve characteristics for processing efficiencies. (This parallels the decades of intensive genetics and production management research with grains.)

2. Minimize non-genetic (soil structure, water, pests, and cultural practices) constraints to yield. Though DNA translocation and gene stacking have helped insure recent grain yield increases, it is not known how much genetic potential remains. The need is to reassess for grains and assess for grass and woody species the nutrient, pH, plant population, soil management, carbon sequestration, nitrous oxide release and other features of production..

3. Assess potential positive and negative impacts of acreage conversion to biomass crops and of alternative biomass production systems and practices on soil, water and wildlife. Of most importance is identifying policies and practices that could insure neutral or positive impacts.

4. Determine the most efficient systems or regimes to produce cellulosic biomass by region of the country. Assess the efficiencies of both single and multiple species systems, including infrastructure requirements and environmental impacts.

5. Develop and evaluate systems for harvesting and assembling cellulosic biomass, by region and feedstock, and including the sizing of enterprises. Examples: gathering tops, limbs and other residue from timber harvest areas or gathering grass species in the Corn Belt or Great Plains.

6. Determine the potential supply of vegetable oils, animal fats, and other feedstocks for biodiesel production. This includes increasing the oil content of soybeans and other oil crops, finding and assessing potential new crops and capturing oils from ethanol feedstock, conversion by-product and waste streams, such as domestic or industrial waste water.

Products and Co-Products

Although many of the following items relate to biomass conversion technologies, they are prioritized in this separate section because of their current economic and political prominence.

1. Develop or identify products from biorefinery streams that may have pharmaceutical, industrial, and other high-value applications and develop the extraction and refinement systems for such products.

2. Develop higher-value products, such as human foods or construction materials, from distiller's grains or other fermentation by-products.

3. Assess the value and demand for ethanol and other alcohols as oxygenates, octane enhancers and fuel extenders.

4. Develop animal feeding systems for efficient and economic use of fractionation residue of feedstock and conversion by-products. Examples are the protein and fiber portions of the corn kernel or the protein, oil, and fiber of distillers' grains.

Education

The education needs for achieving the 25x'25 vision are three-fold. A) Extension education (technology transfer, continuing education, etc.) for each sector of the renewable energy arena, including biomass producers, managers and staff of wind, solar biomass or other conversion facilities, and professionals and practitioners in related areas. B) University undergraduate and graduate curriculums and student experiences to prepare for renewable energy work the next generation of professionals and scientists, plus classroom training of workers to staff the development, design, and operation of energy conversion and biomass production enterprises. C) In order to expand the renewable energy market, education of consumers, service workers in the energy consuming arena and policy-makers. Following are specific education priorities:

1. Ensure that university faculty are intellectually and professionally equipped, on the cutting edge of both science and industry applications, to transmit knowledge to the next generation of scientists, professionals and business leaders. This can be aided by well-funded research activity in university laboratories, engagement by university and federal scientists in collaborative projects, the national scientific forum mentioned in the Science-Wide and Sector-Wide section of this paper, aggressive university use of sabbatical leaves and faculty involvement with the private sector.

2. Interdisciplinary graduate education programs that include laboratory and field experience, and that are designed to equip the next generation of energy-related scientists and professionals to function in a multi-discipline environment.

3. Undergraduate agriculture and forestry curriculums attuned to energy as a major product and designed to prepare the next generation of needed professionals. This includes not only selecting courses within and outside the professional college, but also the content of those courses and research experience in energy related projects or internships in the private sector.

4. Community college curriculums and courses designed and staffed to prepare technicians for production and processing jobs in the renewable energy arena, from wind system operators to quality control or process technicians in biofuel plants. Many

of these curriculums and courses will be generated by individual community colleges and prompted by the employee needs of local renewable energy projects. Experience to date suggests about 80 % of the curriculum content parallels that needed for other industries (process control, instrumentation, safety, hydraulics) and about 20 % specific to the energy sector.

5. Extension education programs involving a wide spectrum of university disciplines and delivery systems (such as the University/Cooperative Extension Service, Forest Service, state foresters, NRCS, and DOE) and often targeted to specific audiences:

a. Societal cost-benefit of renewable energy, such as military and political protection of energy import flow vs. renewable energy, relationships to the environment and food supply, or wind turbine or other conversion facility siting. Local, state and national policy makers should be a specific audience target.

b. Production intensification of both grains and grass/woody species that will be required to accommodate, in an ecologically sound and economically efficient way, the biomass needs for food, feed, fiber and energy.

c. Carbon balance, cycling and sequestration.

d. Biomass production and handling, including integration into cropping systems and forest operations.

e. Conversion of animal manure to methane or other useful products.

f. Harnessing biomass reservoirs, such as landfills, and biomass streams, such as wood or food processing waste.

g. Biomass conversion technologies, likely involving specialists in chemical, mechanical or civil engineering, microbiology, and other disciplines.

h. Co-product technologies and utilization, in polymer and other industries.

i. Renewable energy product features and standards, especially those of liquid fuels, (for example, education targeted to auto technicians and sales personnel), process and product certification, and the federal preferred procurement program for bio-based products.

j. Energy conservation in design features – home, office, manufacturing structures – as well as farm, forestry, transportation and processing operations.

6. Objective and science-based "state of technology" papers targeted to policy decision-makers. Credible sources that complement universities and the agencies previously mentioned include the Council on Agricultural Science and Technology (CAST), comprised of about 35 scientific societies, and the National Academy of Sciences.

7. Renewable energy curriculum materials for secondary, middle, and primary schools.

8. FFA and 4-H projects focused on renewable energy.

9. Workshops, summer experiences and curriculum materials for grades 7 to 12 teachers so they can incorporate energy concepts into instruction programs.

Summary and Recommendations

Based on input from consulted scientists, educators and industry leaders, this paper lists high priority research and education areas that warrant major investments and attention.

Recognizing the extraordinary research and education capacity and collaborative experiences of the public and private sectors, the 25x'25 steering committee recommends that:

1. Research and education leadership and staff focus attention and resources on the priorities listed, in accord with the skills and talents of the respective research or education entity.

2. Policy-makers (the Administration, Congress, governors, state legislators and other leaders) fund and encourage research and education programs that attain the needed outcomes, recognizing that wind and solar conversion contribute strongly to atmospheric carbon balance, that biomass conversion contributes strongly to economic and energy security, reduced dependence on imported oil, and that all contribute to increased economic activity in much of rural America.

3. Policy-makers recognize that, whereas "feedstock" for solar, wind or geothermal conversion is essentially limitless (though dependent on location), feedstock for biomass conversion is limited, and that sharply increased biomass volume will be required for a major reduction in foreign oil dependence. Achieving that increase will require aggressive research, development and extension education.

4. USDA, DOE and other federal agencies maintain close communication and coordination of their funded programs, with the understanding that DOE's stronger focus is on conversion technologies and USDA's stronger focus is on biomass feedstock and rural development.

5. A systems approach to renewable energy development be fully supported with appropriate federal agency coordination of funded in-house, university, and private sector efforts.

6. Aggressive and coordinated extension education by University/Cooperative Extension staff to consuming public, biomass producers, and conversion businesses on related technologies and societal features of renewable energy, as well as energy conservation.

7. Curriculum in universities and community colleges be developed in response to employment needs and citizen understanding of renewable energy.