Future of Farming in Washington: Energy

The purpose of this working paper is to provide a framework that: (1) briefly summarizes the relationship between agriculture and energy, (2) provides brief discussion on how the larger context (and uncertainty) regarding global energy supplies may impact agricultural production over the next 20 – 40 years; (3) provides some discussion on the potential opportunities and concerns regarding the role agriculture might play as a "provider" of energy; (4) a description of the existing assets and tools that the state has that can be utilized to improve agricultural management and decision-making in light of a changing global energy context; and (5) a description of the areas of potential investment by the state.

Description of correlation between agriculture and energy

Modern human society is largely dependent on agricultural production for the provision of food and fiber for human sustenance. Because humans cannot directly capture and convert solar energy, we depend on plants and animals to do the primary and secondary conversion of solar energy to useable calories, proteins, and other essential nutrients. Unlike traditional societies that largely "harvested" naturally occurring forms of organic energy by hunting and gathering, the scale of modern society requires that humans actively and systematically manage some of our "natural" systems to improve the consistency, quality and productivity of food and fiber production. Over time, through the improvement of mechanization, genetics and utilization of energy inputs, humans have developed the highly integrated agriculture and food system we depend on today. The production, development, and use of fossil fuel products in agriculture (particularly those created from petroleum and natural gas) can be largely credited for the increase in global food production since the 1950s.

The modern food system uses various energy inputs throughout the food chain to provide safe and reliable calories for human consumption. Plants capture and convert solar energy into various organic compounds through photosynthesis. Humans can then consume these organic compounds directly (fruits, vegetables, nuts, grains, etc.) or indirectly after an additional level of biological processing by animals (meat, milk) or mechanical processing by humans (flour, juices, etc.). In addition, many raw plant and animal products are further refined (with energy inputs for processing, packaging, and storage) to improve the quality, convenience, shelf-life, or desirability of the food product. Energy is also used to transport food from the point of production to the point of use where final inputs of energy are used to store, cook and prepare food for consumption.

A review paper by Hendrickson (1994) entitled "Energy Use in the US Food System" illustrated the changing use and dependence on energy for the US agriculture and food system over the latter part of the 20th century. Aside from the general growth in energy use by the sector, a disturbing trend of *decreased energy efficiency* –

identified by the increase in caloric input of energy relative to output – is also the hallmark of our modern food system. Most of this increase is attributed to energy investments post-farm-gate (processing, distribution, storage, preparation, etc.), but production practices are not immune to the trend. Large investments of synthesized fertilizers, as well as changes in cropping systems enabled by modern technology (i.e., reduced use of legumes, separation of crop and animal farming systems), have increased total *output* but decreased *energetic efficiency*. Many of these trends were recognized in the 70s and 80s and efforts at conservation and efficiency improvements have been made. However, increasing risks of constrained global energy supplies may require "re-designing" some or all of our agricultural production and food systems over the next 20 years.

As society awakens to the more negative consequences of our precarious "addiction to oil" (price volatility, dependence on unstable regions of the world, climate change, etc.) agriculture is in the throes of an energy crisis. While the recent spikes in global energy prices (2X - 3X over three years ago) are considered to have a curbing effect on global GDP of less than 5%, energy costs now represent well in excess of 50% of some commodity production budgets.

Potential impacts of future global energy context on agriculture

As stated above, massive changes are occurring in current global energy markets with substantial consequences for both agricultural production specifically and, more generally, for the food system. *Even the most optimistic forecasters (e.g., US Department of Energy) now concede that volatility and disruptions in the global energy market are likely to continue or even increase in the foreseeable future. Change in the global energy arena has far-reaching consequences for continued agricultural production in Washington State and should be one of the highest priorities for assessment, investment and technological innovation for the state and the industry.* The three primary areas of interest related to supply of energy for agriculture are liquid fuel, fertilizers, and heat / power.

Liquid fuel

Numerous authorities and pundits (e.g., Paul Roberts, Kenneth Deffeyes, Colin Campbell, Matthew Simmons) recently raised concerns regarding the global availability and sustained production of conventional liquid fuels from fossil fuel sources such as petroleum. Volatility and instability in liquid fuel markets already creates hardship for energy-dependent industries like agriculture. Because Washington is almost completely dependent on imported liquid fuels, continued supply disruptions, whether due to production factors or external influences such as acts of terrorism, create a substantial source of vulnerability for the agriculture industry over the next 20 years. Viable, near-term liquid fuel alternatives – especially for the heavier, distillate fuels so important for agricultural production and distribution – are *extremely* limited from in-state sources.

Fertilizer and products

Fertilizer supply and availability are also a source of concern for the agriculture

industry in the state, as indicated by greater than three-fold increases in costs for fertility inputs over the past four years. The two fertility products of immediate concern are nitrogen and phosphorous, each having different sources for concern. Most commercial nitrogen fertilizers used in Washington are currently synthesized using fossil fuels (most notably natural gas). While the earth's atmosphere has plenty of nitrogen gas, the same global energy supply constraints facing liquid fuels impact synthesis of useable forms of nitrogen fertilizers. Most commercial sources of phosphorous are mined and transported great distances to reach the state. Unlike nitrogen, conventional long-term sources of phosphorous (i.e., phosphate rock) in North America have a limited lifespan (projections range up to 100 years). For both nitrogen and phosphorous fertilizers, securing long-term supplies of conventional fertilizer products likely means depending on currently unstable and/or competing regions of the world such as the Middle East, Russia and China. Investments in technological breakthroughs for alternative nitrogen and phosphorous supplies and improvements in fertilizer use efficiencies should be extremely high priorities.

Nitrogen is the most plentiful element in the earth's atmosphere (~78%); however, it is not in a reactive or plant useable form. For nitrogen to be useful as a source of fertility for plants it must be converted or "fixed" (through a series of chemical changes) from nitrogen gas (N_2) to nitrate (NO_2). This conversion process is an extremely energy-intensive process, whether it is fixed biologically (by plants or microbes) or synthesized thermo-chemically (by industry). *Most* ecological systems (including agro-ecological systems) are limited in productivity by the lack of nitrogen available in a form that is useable for plants. The advent of synthesized nitrogen products in the early 1900s by Nobel-prize winning scientists Haber and Bosch (combined with improved genetics and mechanization) enabled the increase in industrial food production necessary to support the exploding global population of the 20th and 21st centuries. Galloway and Cowling (2002)[1] estimate that 40% of the present global population is sustained by food produced from Haber-Bosch nitrogen and likely to climb to 60% by mid-century. Haber-Bosch sources of nitrogen are one of the reasons that current production levels for Washington crops are among the highest in the world. As with liquid fuels, Washington has limited conventional resource options for in-state production of Haber-Bosch synthesized nitrogen and will likely depend on imports or alternatives if supplies continue to tighten.

In addition to concerns regarding sources for nitrogen and phosphorous, both types of fertilizer products in their reactive states are known pollutants (phosphorous for water, nitrogen for air and water) because crop use efficiencies for these nutrients are low. In addition to the environmental concerns, such nutrient

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1 http://www.ametsoc.org/atmospolicy/documents/JamesGalloway_Nitrogen_March_21_2006.pdf

use inefficiencies represent a substantial loss of useable energy (and therefore cost to producers) for food production.

Power / Heat

Unlike the situation with liquid fuel and fertilizers, Washington's farms are, generally, in a low-risk position relative to electricity supply and use. This is due to both the extensive hydropower resource and readily available and relatively low-cost alternative sources of electricity. While there will likely be increased costs and competition for these resources, the potential for serious disruption is low. In addition, many investments in energy conservation and efficiency have already been made where large electrical energy use is substantial (irrigation pumps, etc.).

Similarly, the need for thermal energy for traditional agricultural uses such as crop drying is limited in Washington relative to other regions due to natural Mediterranean climatic patterns. If there is a shift to increased grain production in Western Washington (which is starting), there may be a need for additional sources of thermal energy for crop drying, but the relative scale of demand will be low. Use of thermal energy for food processing, packing, and storage is also likely an area of low vulnerability due to the existence of an alternative source of energy (hydro) in the Central Washington region where the need is greatest.

Role, opportunities, constraints, and concerns regarding farm-based energy production

The potential for farm-based production of energy in Washington has experienced a (perhaps unnecessary) roller-coaster ride of public opinion over the past five years. The theoretical opportunity for Washington farmers to diversify their portfolio of marketable crops to include "fuel" and other products is undeniably attractive for producers, rural communities, entrepreneurs and the political system. It also raises some serious questions about how such a theoretical opportunity may or may not become a reality, and what unintended consequences might result from such a shift. The simple reality is that Washington currently produces a limited amount of traditional "biofuel" feedstock crops (i.e., field corn, oilseeds), has substantial economic and technological obstacles to the introduction and expansion of these crops, and generally lacks the necessary infrastructure for processing these crops into energy products. Our state's cropping systems are dominated by high-value horticultural and forage crops / cropping systems in the Central and Western regions and a winter wheat dominated system in Eastern Washington that has more than a 100 year head start in genetic and agronomic adaptation. The introduction of new crops as feedstock for biofuels will be limited to their use as rotational crops with wheat or high-value vegetable-based systems. This means that biofuels crops will need to fit into existing cropping systems on the basis of their utility for weed and disease management, or soil conservation and restoration capabilities. *The likelihood of a substantial acreage of traditional biofuels crops being introduced or expanded in the state is low, and in-state*

biofuels production from crops will likely continue to be either niche production or imported feedstock.

In contrast to crops, Washington has a substantial quantity (~17 million tons annually) of under-utilized organic materials that can be efficiently converted into energy and other products (Frear, et.al. 2005)[2]. Approximately 1/4th of this material is in the agriculture and food processing sector and most of the "low-hanging fruit" is collected manure and food processing and packing wastes. In addition to raw commodity energy (fuel, power, heat), these materials have a diversity of potential nutrients and chemicals that can be used to produce consumer, industrial, and agricultural products.

Non-biomass renewable (solar, wind, geothermal)

Substantial renewable resource opportunities that theoretically could benefit Washington farmers exist, particularly in Central and Eastern Washington. High-resolution wind maps are currently available from NW SEED (North West Sustainable Energy for Economic Development) at http://www.windmaps.org/default.asp. Investment in wind power development historically has been utility scale due to the capital investments required, but producers have benefited from long-term land leases and rural tax revenues. Smaller scale wind is also a possibility.

Washington has excellent solar energy potential. Though the relative cost of solar power is still high, it is currently a viable energy technology for remote off-grid applications (e.g., electric fencing, water pumps) and the cost of solar is expected to decline and become more viable over time. Use of passive solar design technology as a thermal energy source is also very realistic.

Geothermal energy offers an interesting option for meeting some low-grade thermal energy needs, particularly in areas of Central Washington with relatively high ground-water temperatures.

Biobased fuels – current and future

The often-stated Catch-22 of current biofuel technology is whether the processor or the crops need to come first. Recognizing that large-scale processors were not likely to invest in a region without substantial acreage dedicated to biofuel crops, the Washington made a significant financial investment in a number of small oilseed processing start-up companies through the Energy Freedom Program in 2006. It remains to be seen whether this will spur crop production, but early results have been limited due to high wheat prices and limited production success with oilseeds. The likelihood is that oilseed production will continue to be limited in scope due to competition with other higher value crops. However, as oilseeds are adapted to local micro-climates and additional production questions are answered, there is real potential that oilseeds can become viable rotational crops used for specific weed and disease control on far more acres than it is currently produced.

[2] http://www.ecy.wa.gov/biblio/0507047.html

The US Department of Energy's long-term vision (5 – 30 years) is that most biofuel production will come from cellulosic conversion of raw biomass as opposed to fermentation (i.e., corn ethanol) or trans-esterification (i.e., biodiesel) of food-grade crops. Cellulosic technology opens up opportunities for feedstock production in Washington State that will be much more conducive to introduction / expansion. Much of the feedstock from Washington will likely be existing forest residuals, but the potential also includes production of perennial grasses. A range of genetic differentiation for grasses that can produce in different micro-climates of the region will be needed. The potential for producing biofuels feedstock grasses on highly-erodible or degraded soils (with a dual conservation benefit), along roadways, in circle corners, or in mixed use / canopy systems is realistic. For this opportunity to be realized, a combination of factors will need to be in play, including further development of cellulosic conversion technology, genetic / agronomic development of perennial grasses, and establishment of processing and transportation infrastructure.

The critical biofuel technology that seems to be overlooked in all of the biofuels hype is probably the lowest hanging fruit for bioenergy production in the state: anaerobic digestion of wet organic materials like manure. Anaerobic digestion is a commercially viable technology for biologically processing wastes such as manure and food processing wastes into biogas, a low-grade form of natural gas. Biogas can be used for combined heat and power production (standard use), but also as a source of liquid fuel, fertilizer (through the Haber Bosch process) or anything else that natural gas is used for. In addition, anaerobic digestion releases many of the nutrients that are organically bound in manure and other wastes for potential recovery as fertility products; and much of this technology is on the precipice of commercial viability. Anaerobic digestion is a bioenergy technology that is currently ready for investment in the state.

Biobased products

Potentially, the most profitable investment related to using agricultural biomass for refined energy products is in the refining of bioproducts such as nutrients, food additives, and chemicals. The diversity of Washington's agricultural products (and thus biochemistries) provides ample opportunity for development of valuable refined products. This is an arena that will take a large investment in research and development. Bio-based products represent a clear opportunity to add value to existing and new agricultural commodities, as well as provide sources for new "energy" inputs to sustain agricultural production systems as traditional inputs become more expensive.

Existing assets and tools

Energy production inventories (wind maps, biomass inventory, etc.)

The two most critical *existing* energy inventories that we have in Washington are the NW SEED wind maps (http://www.windmaps.org/default.asp) and the Washington Biomass Inventory Assessment and Characterization

(http://www.ecy.wa.gov/biblio/0507047.html) funded by the Department of Ecology and completed by Washington State University. The Biomass Inventory has been a multi-stage process determining (by type and geography) the various sources of biomass in the state as well as the chemical composition of the biomass.

In addition to these completed inventories, some modeling efforts related to inventorying potential production of biofuels feedstock crops have been completed by Washington State University using the CropSyst model.

R&D Infrastructure

A substantial R&D infrastructure to support improvements in agricultural energy use and production exists within the state. Washington State University's College of Agriculture, Human and Natural Resource Sciences (CAHNRS), in cooperation with the USDA's Agricultural Research Service, has more than 50 faculty that have worked in one or more aspects of agriculture and energy from plant genetics to agronomy to extension education. In addition to the R&D brain-trust within CAHNRS, WSU has expansive research capabilities in the broader arena of future energy systems. A new partnership being formed between WSU and the USDOE's Pacific Northwest National Lab at the Bioproducts Sciences and Engineering Lab (BSEL) in Richland will solidify one of the leading bioproduct research to commercialization facilities in the world.

In the private sector, Washington has an innovative agricultural industry that has already made investments in various bioenergy technologies, as well as cropping systems technologies and practices that improve water and fertilizer use efficiency as well as overall agriculture energy use. The diverse characteristics of Washington's agricultural landscape have created the "necessity of inventiveness" to develop technologies and practices suited to each growing region and conditions. Washington's agriculture industry is well-positioned for investment in improving agriculture energy use and production.

Electricity, Transportation, and Water Infrastructure

Washington agriculture is highly dependent on the continuation of existing in electricity, transportation and water delivery infrastructure. The existence of the highly dependable, low-cost hydropower-based electricity system is a critical asset supporting the large amount of processing, packing, and storage facilities which drive the high-value crop industry (apples, potatoes, etc.). Moving substantial volumes of biomass from distributed production lands to nodes for processing, packing, storage, and further transportation is highly dependent on the upkeep of an extensive network or rural roads which will become increasingly more costly to maintain as global energy prices increase. Furthermore, the transportation infrastructure could see substantial increases in use if DOE's biomass energy strategy is fully implemented, and massive amounts of biomass (rather than just grains) are transported from fields to storage and processing sites. Alternative transportation infrastructure such as rail may need to be enhanced for DOE's strategy to be fully realized in Washington. Extensive improvements to water delivery infrastructure have been made throughout the irrigated region (enclosed piping vs. open ditch, more efficient sprinklers, etc.), but there are still

opportunities for improvement. Some irrigated regions lack necessary water supply and/or storage infrastructure to continue business as usual if predicted climate change scenarios bear out. There are numerous on-going public policy discussions regarding water infrastructure issues. However, if all the proposed water infrastructure / supply upgrades are not made, it would likely have impact on choices regarding production of biomass sources for energy products.

Energy Efficiency Tools / Capabilities

There are numerous commercially available tools and practices that can be employed by Washington farmers today to reduce energy use. Producers in virtually every area of the state have tried and used various technologies with success (technical and financial). Rising energy prices are spurring new interest in energy efficiency technology. Continued investments in improving energy efficiency provide the most substantial opportunity for near-term mitigation of increasing energy costs and should likely be included as high priorities for investment.

a. Conservation Tillage, etc.

Use of soil conservation tillage technology (no-till, direct-seed, strip-till, etc.) can provide substantial savings in liquid fuel energy use. Reductions in use of "conventional" tillage (i.e., moldboard plow, etc.) in the dryland region are spreading, but significant opportunities for additional technology option remain, particularly in the high-rainfall dryland and irrigated regions. The energy savings of these changes are extremely significant, with producers reporting between 35 and 70% savings on fuel (and wear and tear on machinery). Historically, these energy savings have not overcome the capital costs of purchasing no-till equipment (analogous to buying fuel efficient cars) or the learning curve necessary for the transition of farming systems, but higher prices are shrinking that gap. Continued research on technology and cropping systems will be necessary to support additional shifts toward conservation tillage.

b. Precision Agriculture

Recent advancements in site-specific farming technology (hardware and software) coupled with rapidly increasing costs for farm energy inputs like fertilizer and herbicides will likely drive rapid adoption of an advanced suite of energy conserving technologies in Washington, particularly in the dryland grain production region. Fertilizer savings using this different complements of available equipment have ranged from reports of 5 to 25% over conventional fertilizing strategies, and can lead to rapid recovery of capital costs under high fertilizer prices. Adoption of precision nitrogen management technology by Washington grain growers could result in net fossil fuel energy savings (i.e., reduced Haber-Bosch natural gas) equivalent to all of the diesel fuel required for conventional tillage for the same acreage!

c. Electrical and thermal efficiency

Electrical and thermal energy efficiencies in agriculture are not unlike similar issues in other industries, and have been promoted successfully through traditional energy efficiency programs (utilities, state policy, etc.). Where electrical energy use is significant (irrigation pumping, food processing plants, etc.), substantial investment has been made. One key electrical vulnerability is irrigation pumping in the "deep well" irrigation region of the Columbia Basin. As the aquifer has been drawn down over time, the cost of energy to pump water for irrigation has become substantial and has already forced shifts in production opportunities (i.e., toward crops with lower water demand and historically lower values).

d. State biofuels policy

The state has already made several primary legislative investments supporting biofuels development in the state, including but not limited to:

- The Energy Freedom Program which co-funded the development of two farm-based manure digester projects and a few oilseed processing facilities. One digester project, two oilseed processing facilities and one biodiesel production facility have been constructed, with other projects still at various stages of development.
- A Renewable Fuels Standard of 2% for biodiesel and ethanol was passed to encourage the use of biofuels in the state.
- An investment in "Near-term biofuel crop, co-product and anaerobic digestion research" was made in Washington State University.
- An investment was made in Washington State University for economic policy analysis related to biofuels.

Potential investments

Agricultural Energy Use Inventory

One critical gap in the capacity to assess agricultural energy consumption in the state of Washington is the lack of an extensive agricultural *energy use* inventory. Certain energy use aspects are very well understood (e.g., fuel use for motive power) or can be estimated from base enterprise budgets and crop models (e.g., nitrogen use). However, an inventory of energy use that enabled tracking of energy use trends over time as well as identifying high-leverage opportunities to invest in efficiency and conservation at a state-wide level would be a valuable investment. Inventory tools would also be useful to producers for generating farm energy audits which can identify opportunities for on-farm energy savings at the enterprise level.

Improvements in transportation structure

The nature of agricultural production systems – which is exacerbated in Washington due to the distribution of production lands – is that biomass is distributed extensively across the landscape and must be transported to decentralized nodes where it can be densified and transported further for storage,

processing, and further distribution to consumers. Much of the existing transportation infrastructure is aging and represents an obstacle to the development or enhancement of many potential opportunities such as biofuels production as well as simply standing up to the rigors of existing demands.

Potential for strategic production shifts toward less energy-intensive systems
One important strategy that may require public sector leadership is in the development and demonstration of less energy-intensive farming systems. Prior to the recent spike in commodity prices, many Washington farm enterprises were perilously close to folding under increased energy input costs. Even the most efficient farm enterprises experienced unexpected strain as the reality of the energy intensity of modern farming systems hit home. While the first order of action is always to look for opportunities to improve the efficiency of existing farming systems, in some cases most of those efficiencies have been exploited (due to general economic completion) or certain systems already operate too close to the margins of energetic returns to begin with. As rising energy costs make economic realities reflect energetic realities more closely, many farmers may need to shift production "systems" to remain viable as enterprises.

Conclusions

The energy issue currently presents one of the greatest challenges to the future of farming in Washington, and will likely become an increasingly difficult challenge for the next 20 years. While there are a number of available options for reducing energy use and improving energy efficiency in agriculture, the rate of change for energy prices cannot continue without severe, adverse impacts on agriculture and food systems, some of which are already showing (substantial commodity price increases, increased land rents, etc.). It is unclear whether the rapid changes over the past three years will continue at the same rate of change or whether they will level out, but it does indicate that energy issues create a substantial point of vulnerability for nearly every farm and food enterprise in the state, and that the agriculture industry in general is one of the most vulnerable industries to rising energy costs.

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