| **Research Area 6-1. Identify life-cycle analysis costs/benefits of biofuel production.** | |
|---|---|
| Statement of Need | Develop water-balance LCA for biofuel production from biomass sources by thermochemical, biochemical, and chemical processes. |
| Research Objective | There is a need to identify LCA costs/benefits of biofuel production processes so that the most energy/water appropriate technologies and research paths are followed. |
| Impact/Benefits | Provide public decision making tools for comparing feedstock/ process/ biofuel production technologies. Prioritize R&D, policy, and commercialization strategies. Identify the most cost efficient and sustainable processes. |
| Priority | Really high |
| Summary Scope of Work | Developing and integrate existing models and databases with new tools for evaluating water analysis in LCA. |
| Technical Approach | Integrate energy-water nexus tools with energy and material balance LCA. Start with existing processes including grain to ethanol and oil seed to biodiesel. Extend to new feedstocks and new processes. Compare energy and water balances between these processes. Identify synergies of multi-processes in integrated biorefineries. Evaluate regional differences and potential barriers. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | National Laboratories with Universities develops the tools. Data input and review by industry and state/local agencies. |
| Potential Collaborative Govt. Agencies | DOE, USDA, Bureau Reclamation, DOT, EPA |
| Leverage Opportunities with Existing Programs | Leverage existing water, energy, and material LCA models. Incorporate industry models as available. |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Access to information and data, cooperation, communication. Tool verification, validation and acceptance. |
| Estimated Cost | $5 M per year for 3 years. Will require ongoing maintenance and updates. |
| Execution Horizon (early, mid, late) | Early. The tools are needed to guide allocations of funds and policy. |
| Schedule/Duration | Three years to develop, ongoing once program is in place. |
| Level of Development/Level of Maturity at completion | Usable linked model for decision making with an effective user interface. |
| Additional comments | |

| **Research Area 6-1a. Water supply, irrigated land and energy impacts of expanded ethanol from corn or cane production.** | |
|---|---|
| Statement of Need | An expanded ethanol production base would lead to increased demands for crops used in production, land used to grow the crops and possibly water to irrigate those lands brought into production. The amount of land and water brought into production is not known and this research project would lead to a better estimate of the likely impact on land and water needed to increase ethanol production. |
| Research Objective | |
| Impact/Benefits | The information provided by this study would allow DOE and other agencies interested in promoting ethanol production a better idea of the likely economic costs of increased production as well as the environmental impacts of this production. |
| Priority | High |
| Summary Scope of Work | Focus on ethanol from corm production from Midwest and ethanol from cane in Hawaii. |
| Technical Approach | 1. Estimate the net impact on cropland of increased demand for ethanol.<br>2. Estimate the net increase in demand for cropland net of feed byproduct that is produced with ethanol and would substitute for corn feed. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | LBNL, ORNL<br>DOE, academic institutions (UCBerkeley) |
| Potential Collaborative Govt. Agencies | USDA, USBR |
| Leverage Opportunities with Existing Programs | ORNL is doing work in this area<br>UCBerkeley ERG department is very active in this area<br>Ohio State University, other academic groups have done good work estimating …across price elasticities of demand for corn and corn feed |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | There is a data challenge, but not a policy problem |
| Estimated Cost | $1M for two years |
| Execution Horizon (early, mid, late) | Early |
| Schedule/Duration | 2007-2009 |
| Level of Development/Level of Maturity at completion | Mature policy model and results |
| Additional comments | |

| Research Area 6-2. Thermochemical processesing. | |
|---|---|
| Statement of Need | Need thermochemical processes to maximize efficiency in integrated biorefineries. |
| Research Objective | Develop thermochemical processes that are energy and water efficient, sustainable, and cost-effective for conversion of biomass to biofuels and biobased products. |
| Impact/Benefits | Thermochemical processes expand the components of biomass that are converted to biofuels (or biobased products). Incorporating thermochemical processes decreases biofuel production costs and increases the likelihood of commercial success of integrated biorefineries. |
| Priority | High |
| Summary Scope of Work | Develop a thermochemical conversion program that evaluates water management using a range of biomass feedstocks to produce a substrate suitable for downstream conversion. |
| Technical Approach | Need R&D in thermochemical conversion (gasification and pyrolysis), and substrate conversion (syngas or pyrolysis oil). Thermochemical conversion requires dry biomass.<br><br>Dewatering of biomass improves thermochemical conversion (gasification or pyrolysis) efficiency. Depending on the moisture content of the feedstock, dewatering can add energy requirements to the process. Reuse or release of the water could be benefit or detriment depending on the quality of the water. Develop thermochemical conversion processes that provide water suitable for beneficial reuse or appropriate water conservation. Gas cleanup and conditioning may require water for process cooling. Heat and water integration with the rest of the biorefinery will be beneficial.<br><br>Substrate conversion will be converted by catalytic, biochemical processes (described elsewhere) or used for power. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Forest products industry, chemical industry, national laboratories, universities. |
| Potential Collaborative Govt. Agencies | DOE, USDA, Bureau of Reclamation, EPA |
| Leverage Opportunities with Existing Programs | Coal, pulp & paper, power, and chemical industries have extensive knowledge of thermochemical conversion and substrate utilization. |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Policies or regulations that favor specific feedstocks or conversion technologies. Acceptance that thermochemical conversion provides a flexible approach that could use most feedstocks. |
| Estimated Cost | $5 M per year for 5 years. |
| Execution Horizon (early, mid, late) | Early start to provide input to the LCA analysis. As barriers are identified in LCA, will need to develop technical approaches to those barriers. |
| Schedule/Duration | Initial development to support the LCA analysis (2 years). Further development to facilitate the integrated biorefinery (5 years). |
| Level of Development/Level of Maturity at completion | Demonstrated at pilot scale. |
| Additional comments | |

| **Research Area 6-4a. Novel biochemical processes.** | |
|---|---|
| Statement of Need | Need biochemical processes to maximize efficiency in integrated biorefineries. |
| Research Objective | Develop biochemical processes that are energy and water efficient, sustainable, and cost-effective for conversion of biomass to biofuels and biobased products. |
| Impact/Benefits | Biochemical processes require significant water use. Improved water efficiency will decrease biofuel production costs and increases the likelihood of commercial success of integrated biorefineries. |
| Priority | High |
| Summary Scope of Work | Biochemical processes are largely water dependent. Efficient recovery |
| Technical Approach | Improve solids handling for chemical and biological pretreatment to reduce water requirements.<br><br>Develop microbial organisms that overcome substrate and product inhibition to reduce water needs in biofuels and biobased products production.<br><br>Recycle water in all of these processes to reduce overall water inputs and reduce discharge of impaired water.<br><br>Develop energy-efficient separations technologies for effective water management. Integrate conversion and product separations (e.g. membrane bioreactors) to improve water management. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Academia, national laboratories, agriprocessors, and biotech companies |
| Potential Collaborative Govt. Agencies | DOE, USDA, EPA, DOE GTL program |
| Leverage Opportunities with Existing Programs | Existing biofuel, fermentation-based, pharma industries. |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Development of integrated biorefineries in regions with limited water resources. Facility distribution and plant size impacts on water availability. Use of impaired for processing. |
| Estimated Cost | $10 M per year for 7 years. |
| Execution Horizon (early, mid, late) | Early |
| Schedule/Duration | Solids handling: Develop technologies in three years.<br><br>Tolerance: Initial development is a genomics approach that will lead to organism screening, engineering and development. Develop organisms suitable for deployment in commercial fermentation.<br><br>Separations: Develop membrane technologies in five years |
| Level of Development/Level of Maturity at completion | Demonstrate each individual platform technologies at the pilot scale. |
| Additional comments | |

| Research Area 6-4b. Novel chemical processes. | |
|---|---|
| Statement of Need | Need chemical processes to maximize efficiency in integrated biorefineries. |
| Research Objective | Develop chemical processes that are energy and water efficient, sustainable, and cost-effective for conversion of biomass to biofuels and biobased products. |
| Impact/Benefits | Chemical processes expand the potential product portfolio produced from biomass. Incorporating chemical processes could decrease biofuel production costs and increase the likelihood of commercial success of integrated biorefineries. Chemical processes inherently use less water than biochemical processes and could be advantageous in water limited regions. |
| Priority | Medium |
| Summary Scope of Work | Develop a chemical conversion program that evaluates water management using a range of biomass feedstocks to produce existing and new biofuels. |
| Technical Approach | Develop new or improved catalysts that are: robust, selective, inexpensive, and can be readily regenerated. These catalysts will be used for hydrogenation, transesterification, decarboxylation, or specific conversion of biomass components to produce alcohols, diesel, and alkanes. Substrates will be syngas, oils, sugars, or lignin and are described in the previous topics.<br><br>Separations for efficient water recovery will be important for transesterification, hydrogenation, and other conversion processes. Separations technologies will be developed in other areas in parallel. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Chemical industry, academics, national laboratories, materials companies. |
| Potential Collaborative Govt. Agencies | DOE, EPA, NSF |
| Leverage Opportunities with Existing Programs | Chemical industry has extensive catalysis expertise |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Use of caustic or toxic catalysts outside of areas of expertise (rural facilities). Policies or regulations that favor specific feedstocks or conversion technologies. |
| Estimated Cost | $5 M per year for 5 years. |
| Execution Horizon (early, mid, late) | Mid term based on success in biochemical and thermochemical technologies. |
| Schedule/Duration | Improvements to existing catalysts to address robustness would take 1-2 years. Screening and development of new catalysts for selectivity, robustness, and cost would take 5 years. |
| Level of Development/Level of Maturity at completion | Catalysts suitable for deployment. |
| Additional comments | |

| **Research Area 6-5. Cheaper methods of ultrafiltration.** | |
|---|---|
| Statement of Need | Impaired water is currently being wasted when it could be used for energy production. Inexpensive grey water treatment to be used in bio-fuel production. |
| Research Objective | Cleaning up grey water. Can grey water be used in bio-fuel production? |
| Impact/Benefits | Economic savings by not processing grey water to potable water. Results in water and energy conservation. |
| Priority | High |
| Summary Scope of Work | Identify/develop methods to utilize grey water for renewable energy production |
| Technical Approach | Categorize grey water; quantify sources; establish usage production specifications; develop regulations that fit end-use and equate quality requirements with use |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Industries that produce large quantities of grey water (pulp/paper; oil production; canning; food production; pharmaceuticals; CAFOs (confined animal feeding operations) |
| Potential Collaborative Government Agencies | EPA; USGS; USDA; DOE |
| Leverage Opportunities with Existing Programs | |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Public acceptance; public understanding (education); water standards; urban runoff (capture for process water) |
| Estimated Cost | $3M/3 years- in various regions |
| Execution Horizon (early, mid, late) | Early to Mid |
| Schedule/Duration | 3 years |
| Level of Development/ Level of Maturity at completion | Completed |

| Research Area 6-6. Unconventional water use in biofuel process. | |
|---|---|
| Statement of Need | Examine and analyze (life cycle analysis) the energy balance resulting from bio-diesel production in a wastewater treatment plant. |
| Research Objective | Understand the energy balance and health issues related to this process |
| Impact/Benefits | Use of existing infrastructure, waste stream, no additional water use |
| Priority | High |
| Summary Scope of Work | 1. research development of process (deployable process (use for Jf8 fuel)<br>2. Regional pilot demonstration project strategically placed; develop mobile unit to use as demonstration – using slip stream |
| Technical Approach | Bench-scale optimization of process followed by 2 year pilot scale demonstration |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Academia/national laboratories – Mississippi State University/SNL |
| Potential Collaborative Government Agencies | EPA, Army Research Office, COE, SeaGrant (NOAA); oil companies |
| Leverage Opportunities with Existing Programs | Existing DOE funding for oil conversion |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Public understanding and acceptance; bureaucratic inertia to make change; perceived risk; need for new standards (EPA and state); contamination of fuel |
| Estimated Cost | Energy balance (Sandia – algae) = $1M over 2 years for Mississippi State University (+ Sandia) |
| Execution Horizon (early, mid, late) | Early – already begun |
| Schedule/Duration | 2 years – bench<br>3 years – pilot |
| Level of Development/ Level of Maturity at completion | Pilot demonstration project |

| **Research Area 6-7. Explore the use of unconventional waters for biomass irrigation.** | |
|---|---|
| Statement of Need | Help conserve & protect scarce freshwater by investigating how unconventional water can be used to grow biomass feedstock |
| Research Objective | • Need to map & have a database showing where unconventional water is located.<br>• What is the pre-treatment that is needed to bring unconventional water to a quality that can be used to grow biomass feedstock?<br>• Can the biomass feedstock also be used to clean up unconventional water?<br>• How can we reduce the amount of unconventional/waste water that is produced?<br>• What are the regulations/liabilities on using unconventional water? How can they be revised, if needed?<br>• Psychological: Will the public accept unconventional water being used for irrigation of crops that have both energy & food use?<br>• Life cycle study of water use in energy production. |
| Impact/Benefits | • Conserve freshwater.<br>• Cost effective (esp. in arid areas). |
| Priority | High in arid areas, medium in rainy areas |
| Summary Scope of Work | • Determine minimum water quality & quantity levels needed (depends on feedstock type, location, etc.).<br>• Economic analysis: is there a cost savings from re-using unconventional water vs. the value of the biofuel produced?<br>• Public education & awareness: to increase acceptance of using unconventional water for biomass (and food) crops.<br>• Need to map & have a database showing where unconventional water is located.<br>• Educate policymakers so that they are aware that current policies are limiting unconventional water use; make appropriate changes to policies.<br>• Research into efficacy of plants such as cattails & water hyacinths to clean unconventional water and for use as biomass (dual-use plants). |
| Technical Approach | • Systems-level modeling.<br>• Evaluate how well different feedstock species respond to unconventional water. Specific projects depend on feedstock species & local unconventional water conditions.<br>• Designating responsibility for compiling & maintaining a broadly accessible database showing unconventional water sources & who's responsible for these unconventional water sources. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Academia, national laboratories, public utilities, possibly industry |
| Potential Collaborative Govt. Agencies | DOE, EPA, USDA, DOI, Army Corps of Engrs., Wildlife, state & local agencies, AwwaRF, USGS |
| Leverage Opportunities with Existing Programs | Utilize public utility programs on bioremediation<br>Utilize desal programs (e.g., at Sandia) |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Regulatory & policy: it can be difficult to implement technology depending on local regulations & policies |
| Estimated Cost | $5-10M |
| Execution Horizon (early, mid, late) | Should start now. Long term issue is figuring out what to do with brine. |

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| Schedule/Duration | 2-5 yrs |
| Level of Development/Level of Maturity at completion | Deployable technology. Continuous improvement also good. |
| Additional comments | Discussion:<br>- Regulatory, capacity, & supply chain constraints in going from raw material to feedstock (e.g., pressing seeds in Europe – not enough capacity to press all the seeds that are needed)<br>- Biomass is the wrong thing to do in solving the U.S.'s oil problem. For example: Solar produces ~2X more energy than biomass/plants.<br>- The research should focus on resource use, land use, water use impacts of all alternative energy sources.<br>- Would like to see research on water quantity & quality needs on forest residue, crop residue, algae, & other major sources of biomass.<br>- The key aspects of water resource research are quality, quantity, & timing. What are the hydrologic impacts of developing biomass resources?<br>- Also need ecosystem modeling & understand ecosystem impacts.<br>- How to clean up waste water & waste products from producing biomass (e.g., from cleaning the product)?<br>- What is the impact (e.g., rivers, aquifers, etc.) of producing the major feedstocks on hydrology?<br>- Re-use of waste water from biomass production & water conservation.<br>- Research in use of feedstock crops in bioremediation?<br>- What is the expansion in corn land use (for biomass & livestock)? What impact would this expansion have on irrigation & land use needs? |

| **Research Area 6-7a. Water quantity/water quality impacts of biomass production in natural and managed ecosystems.**<br><br>**NB. Moved from Research Area 1-29.** | |
|---|---|
| Statement of Need | Need to understand water quantity/water quality impacts of biomass production in natural and managed ecosystems. This is one of the least studied and least understood aspects of biomass production and use for energy. |
| Research Objective | Understand the critical role of water in sourcing biomass for energy from natural and managed ecosystems. This should include: forest land, agricultural cropland, agricultural Conservation Reserve Program lands, aquatic and marine systems. Modeling should be focused on understanding water constraints on "high impact" energy contributions from biomass. |
| Impact/Benefits | Help the Nation establish realistic expectations for biomass contributions to the energy sector based on water use and quality issues. The research will help answer questions about the potential net cost, water and energy savings associated with biomass energy. |
| Priority | This is the Achilles heel of biomass for energy production. No other issue is more critical. |
| Summary Scope of Work | Integrated systems approach (comply with ISO 14000 life cycle assessment standards). Must tie into non-energy water related issues. The work is highly multidisciplinary, requiring ecologists, biologists, and engineers to implement an ecosystem perspective on the impacts of biomass production for energy. Requires regional and local focus to understand ecosystem impacts ("All biomass is local). |
| Technical Approach | Use hydrologic and ecosystem models to quantify water related impacts on natural and managed ecosystems. Combine this with life cycle systems analysis to quantify the full scope of impacts for biomass production. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Natural Resources Ecology Laboratory at CSU (Keith Paustian). Ohio State College of Natural Resources (R, Lal). Univ of Washington College of forest resources (authors of LMS Land Management System). Oak Ridge National Laboratory (Robin Graham). Hank Stelzer at Univ of Missouri (forest management).National Renewable Energy Laboratory, |
| Potential Collaborative Government Agencies | Link up with California Energy Commission PIER (Public Interest Energy Research) program) Mandate to USDA to produce energy from forest and ag lands. This is motivating ecosystem modeling of energy production that should be tied into. Other agencies that need to be involved: USGS, USEPA, Department of Interior. DOI forest management programs. |
| Leverage Opportunities with Existing Programs | CEC PIER (see above), DOE Office of Biomass, USDA Farm Bill, USDA ARS programs, Woody Biomass Utilization Group chartered under the Biomass R&D Act. |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | This work often falls between the cracks of institutional responsibility. It crosses lines among various federal and state agencies. |
| Estimated Cost | $10 to 20M per ecosystem (forest, cropland, CRP, aquatic and marine systems) |
| Execution Horizon (early, mid, late) | Early. This work is needed immediately |
| Schedule/Duration | 3 to 5 year effort per ecosystem |
| Level of Development/ Level of Maturity at completion | Provides building blocks for further work. |

| Research Area 6-8. Develop more drought-tolerant biofuel crops that do not need irrigation. | |
|---|---|
| Statement of Need | Water is required for photosynthesis. Fresh water is scarce and has many competing interests. Using less water to produce feedstocks for biofuels is a win-win. |
| Research Objective | • Identify crops (Castor bean, Jatropha, Safflower, et al.) that achieve high oil/feedstock yield for the water used<br>• Genetically modify crops for higher water use efficiency.<br>• Identify supplements (i.e., foliar application of pNBA) for agriculture that increase water use efficiency in crop plants. |
| Impact/Benefits | • Conserve freshwater<br>• Increase the land usable for fuel production |
| Priority | High in arid areas, medium in rainy areas |
| Summary Scope of Work | • Several drought-tolerant crops exist that produce oil in large quantity, but have toxic byproducts (i.e., ricin in castor bean, cyanide in Jatropha) and toxin-less varieties need to be made or created by genetic modification.<br>• Salt-tolerant crops need to be modified to produce greater biomass. |
| Technical Approach | • Genetic modification or standard breeding of desirable crops to produce plants that meet the required specifications. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Academia, national labs, public utilities, possibly industry |
| Potential Collaborative Govt. Agencies | DOE, USDA, NSF |
| Leverage Opportunities with Existing Programs | USDA and Texas Tech already have projects to remove ricin from castor bean. (under-funded) |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Regulatory & policy: GMO crops may not be publicly accepted because these crops are multi-use. |
| Estimated Cost | $5 million for 3-4 years to modify the plant and grow out enough seed for commercial production |
| Execution Horizon (early, mid, late) | Has already started, but is not sufficiently funded to be completed in a reasonable time. |
| Schedule/Duration | 2-5 yrs |
| Level of Development/Level of Maturity at completion | Deployable technology. Continuous improvement also good. |

| Research Area 6-9. Investigation of alternative feedstocks for biofuel production. | |
|---|---|
| Statement of Need | Investigation on novel and alternative feedstocks for biofuel production is needed. Photosynthetic algae is regarded as an emerging energy source that offers the promise of enhanced yield and concomitant wastestream remediation and water conservation. |
| Research Objective | • Develop cost-effective large-scale photobioreactors.<br>• Genetic improvement of photoautotrophic strains.<br>• Understand biosynthesis and regulation of fatty acids/lipids.<br>• Integrate photobioreactors with waste stream treatment.<br>• Conduct technical and economic analysis of phototrophic algae-based biomass feedstock and production. |
| Impact/Benefits | • Cost effective large-scale photobioreactor system development.<br>• Integration of algae-based biofuel production with waste stream (wastewater/waste flue gases) treatment.<br>• Significant increase in biomass feedstock productivity on a per land basis.<br>• Utilization of land and water (saline/brackish/wastewater) which otherwise can not be used for conventional agriculture; thereby freeing land and water for other beneficial uses.<br>• Algae biomass/biofuel feedstock production process coupled with waste stream treatment will cleanup and recycle waste nutrients, thereby improving water conservation and the environment. |
| Priority | High |
| Summary Scope of Work | Technical and economical feasibility of algae biofuel feedstock technology will be critically reexamined and cost-effective large-scale bioreactors will be developed. |
| Technical Approach | A cooperative team involving phycologists, biochemists, algal technologists, chemical/electrical/mechanical engineers will be established to investigate individual identified tasks and integrate individual components into a synergistic system |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Lead investigators could be a combination of DOE, university and industry experts |
| Potential Collaborative Government Agencies | ASU (photobioreactor and algae expertise) SNL (system integration) CAFO operators (provide wastewater/land), power plants (provide flue gases) biodiesel firms (algae oil refinery) |
| Leverage Opportunities with Existing Programs | Would also leverage with EPA water conservation and USDA renewable biomass and bioenergy programs |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Maximum sustainable photosynthetic efficiency and oil productivity have to be determined<br>Capital costs of photobioreactors need to be reduced substantially |
| Estimated Cost | $3-5M |
| Execution Horizon (early, mid, late) | Early – it is an effort to fully determine technical and economic viability of algae-based biofuel feedstock production |
| Schedule/Duration | 2007-2009 |
| Level of Development/ Level of Maturity at completion | Several key components of algae-based biofuel feedstock production systems will be determined and optimized. A large-scale field demonstration will be determined and optimized. A large-scale field demonstration/production facility could be established based upon the efforts made by this project. |

| Research Area 6-9a. Forecasting hydrologic impacts associated with forest and agricultural biomass feedstock production. | |
|---|---|
| Statement of Need | Large scale production of primary biomass feedstock through forest thinning/remediation and energy crop production could alter the regional hydrology (reservoirs capacity and quality and quantity, quality and timing of water flows). Such changes could affect hydropower options in some regions and water quality, quantity and timing of flows in all regions. |
| Research Objective | Develop and apply tools to forecast the potential effects of primary biomass feedstock production on regional hydrology. Such tools must be able to accommodate a variety of primary biomass feedstock production strategies - forest thinning, perennial energy crops, annual crops such as corn grains and novel sources such as micro-organisms. For example, forest remediation in mountain regions can alter snowpack and transpiration and thus stream flow. It can also alter fire behavior that in turn can affect regional hydrology. Likewise the use of irrigation for perennial or annual energy crop production could have negative or positive impacts on local water supplies.<br><br>Additionally, watershed-scale experimental manipulations of proposed practices are needed to improve our understanding and parameterize forecasting models. These experiments would also provide the public real examples of proposed technologies and ecological outcomes to improve public discussion of politically sensitive issues. |
| Impact/Benefits | The positive benefits and potential negatives of primary production of biomass feedstocks on water quality and quantity could be estimated and the public could make better informed decisions. |
| Priority | Very high if the potential forest biomass resources are to be seriously accessed in the future. Also very high for improving the adoption rate of perennial energy crops. |
| Summary Scope of Work | 1. Support for the development of hydrological models that can explicitly account for land use associated with biomass feedstock production. One will probably need at least two efforts – one associated with agriculturally-dominated watershed and one associated with forested watersheds. There are no models that work well with watersheds that are both forested and agricultural.<br>2. To improve these models, there is a need for paired watershed studies involving experimental manipulations at the watershed scale (we would recommend first-order watersheds) in forests and in agricultural settings. Experimental forests and Ag research stations are likely locations for such experiments. |
| Technical Approach | Establish case studies of representative watersheds in agricultural and forested regions. Determine representative management scenarios for differing biomass feedstock sources to be used in experimental cases. Identify models appropriate for improvement through use in experimental settings, and include iterative model development cycles geared toward useable products in other watershed analysis. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Consortiums should lead the projects. This is very important for the findings to be acceptable to the many interest groups. This would most effective if there are regional consortiums – say one funded consortium per region. The funding for these consortiums should be multi-organizational (including public agencies, universities, national labs and key NGOs) and include federal and |

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| | state involvement and each consortium should be overseen by a n advisory/oversee body. There should be regional advisory/oversight groups for each consortium, and a national oversight body. We would recommend an annual meeting of representative from each consortium and the national oversight group.<br><br>We also recommend establishing formal linkages between regional consortia and ongoing large-scale biomass conversion enterprises, particularly those adapting new technologies for cellulosic biofuels production. |
| Potential Collaborative Govt. Agencies | USDA, USFS, Academia, Nat. Labs and NGOs. It is very important that NGO's be engaged such that the findings will be transmitted to the environmental communities. DOE should be involved to ensure relevancy in the modeled biomass production strategies and to link hydrological studies to hydropower. |
| Leverage Opportunities with Existing Programs | Long-term Ecological Research (LTERs, supported by NSF); various USDA Forest Service Experiment Stations and Experimental Forests; State Experimental Forests and Ag Research and Experiment Stations (e.g., Cooperative Extension); FERC relicensing studies, particularly those initiated under the Federal Power Act section 4e authorities). Sun Grant Consortia. |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Forest thinning activities especially in the west for reduction of fuel loadings (reducing the risk of catastrophic fires) and production of biomass feedstock touch many public concerns- air quality, esthetics, wildlife, recreation, jobs, etc. finding solutions which effectively balance all these concerns is politically very challenging and existing regulations and policies may create barriers to finding optimal solutions. |
| Estimated Cost | $5-10 million per case study (paired watershed study) |
| Execution Horizon (early, mid, late) | The modeling could be effective near term. The experimental watershed work should be established immediately but will require long term support if it is to be truly effective) 10+ years. Establishment of consortia should begin immediately. |
| Schedule/Duration | 2007-2017 |
| Level of Development/Level of Maturity at completion | Building block for ensuring access to future biomass resources. Midlevel maturity of watershed characterization techniques; High level of maturity for hydrologic models used in the studies. |
| Additional comments | We can't emphasize the importance of DOE's engagement on these issues. The obvious connection for DOE is through hydropower and protection of hydrologic integrity in watersheds. However, if DOE expects to foster sustained and continued access to biomass resources, it must ensure that land use and complex watershed-scale interactions are addressed to the public's satisfaction. |

| Research Area 6-10. Improve reactor/digester design, monitoring systems, and microorganisms to increase production of biogas and other valuable by-products from conventional waste streams. | |
|---|---|
| Statement of Need | Increasing biogas productivity and other value-added products from a broader variety of conventional waste stream feedstocks in microbial reactors/digesters will enable greater productive use of water by increasing the production of valuable byproducts from waste streams. Applies to conventional waste stream feedstocks with up to 12% solid content. |
| Research Objective | Increase the biogas and other value-added byproduct productivity through improved digester design and optimized operation. |
| Impact/Benefits | In US have need for at least 5000 digesters compared d with current use of only a hundred just with ag animal industries (feedlots, dairies, pigs and poultry). 98% of municipal water treatment plants could be generating energy but are not… could potentially be energy self-sufficient. Also could be using biosolids from waste water treatment and organic content from solid municipal wastes. Huge market potential and potential for energy production and reduced water use. Also potential impact of reduced material going to landfills for waste disposal. GHG emissions reduction potential also. |
| Priority | Medium |
| Summary Scope of Work | Investigate and better understand the processes by modeling, monitoring, and control optimization for broader range of feedstocks: ag waste, biosolids, organic municipal waste, etc… Optimize co-product production and maximize co-product value. Look for ways to better control ammonia production with high nitrogen content feedstocks. |
| Technical Approach | Fundamental R&D on improving performance and effectiveness of microbes on range of feedstocks. Better understanding of anaerobic microbial genetics and microbial ecology. Develop mathematical models for systems research, design, and optimization. R&D on feedstock pretreatment, deployment, biomass and microbial mixing and retention in the bioreactor system (type of carrier, etc.). Work on operational optimization with mechanical and microbial issues. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Collaboration of university, industry, and national labs… also with end users, and waste producers / investors |
| Potential Collaborative Govt. Agencies | EPA?, USDA |
| Leverage Opportunities with Existing Programs | USDA bioenergy program… focused more on producers. |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Lack of funding for basic and applied research in this area. Lack or difficulty of access of industry to national labs capabilities. Difficulties and impediments with two-way net metering for power production and sales (market price). Carbon credit trading system. Lack of incentives to implement technologies. |
| Estimated Cost | $10-15M |
| Execution Horizon (early, mid, late) | Early |
| Schedule/Duration | 3-5 years |
| Level of Development/Level of Maturity at completion | Industrial / Commercial applications |
| Additional comments | Longer term R&D could look at possible reduction of $CO_2$ vs methane production optimization for given feedstock characteristics. |

| Research Area 6-11. Develop/Improve microbial reactors/digesters for high-solid waste feedstocks. | |
|---|---|
| Statement of Need | Developing microbial reactors/digesters for high-solid content waste steams (solid content above 15%) for the production of biogas will enable greater productive use of water (reduce water needed) by increasing the production of a valuable byproduct from more concentrated (higher solid content) waste streams. Expanding the feedstock category to include high-solid organic materials from municipal solid wastes and animal manure streams demands new digester designs and processes. |
| Research Objective | The technology required to deal with high-solid waste streams is less mature and more challenging than working with conventional waste streams. The objective is to develop microbial reactors/digesters that can cost-effectively and efficiently deal with high-solid waste streams. |
| Impact/Benefits | More efficient use of wastes requiring less water. Reduce costs associated with waste water treatment and disposal/reuse. Enhanced energy production from waste streams. Less landfill impacts. Reduced GHG emissions. Less air quality problems in addition to GHGs. |
| Priority | Medium - High |
| Summary Scope of Work | Conduct microbiological research on bugs to facilitate their ability to deal with higher concentrations of inhibiting substances like ammonia, sulfur, etc. Determine how to enhance the microbial distribution and efficiency in the higher solid content wastes. Modeling of system. Pilot testing and demonstration. |
| Technical Approach | Fundamental R&D on improving performance and effectiveness of microbes on high-solid content feedstocks. Better understanding of anaerobic microbial genetics and microbial ecology. Develop mathematical models for systems research, design, and optimization. R& D on high-solid feedstock pretreatment, deployment, biomass and microbial mixing and retention in the bioreactor system (type of carrier, etc.). Work on operational optimization with mechanical and microbial issues. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Collaboration of university, industry, and national labs… also with end users, and waste producers / investors |
| Potential Collaborative Govt. Agencies | USDA, EPA? |
| Leverage Opportunities with Existing Programs | AwwaRF, USDA bioenergy program… focused more on producers. State and municipalities. Producer organizations and cooperatives with private funding |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Educate stakeholders of higher values derived from this technology compared with composting. Lack of cost incentives. Technical challenges. |
| Estimated Cost | $2-3M |
| Execution Horizon (early, mid, late) | Early |
| Schedule/Duration | 3-5 years |
| Level of Development/Level of Maturity at completion | Pre-commercial demonstration of cost and performance. |
| Additional comments | |

| **Research Area 6-12. Develop improved dewatering/separation technologies for use with biogas production processes (before and after digestion stage).** | |
|---|---|
| Statement of Need | Develop improved dewatering / separation (of undigestable materials) technologies for use with biogas production processes (before and after the digestion stage). |
| Research Objective | Develop reliable, low-cost, high-efficiency pre- and post- digestion technologies for dewatering / separation of undigestable materials and nutrient recovery. |
| Impact/Benefits | Reclamation of water, more efficient energy production process, value-added byproducts, more economic system, nutrient removal |
| Priority | High |
| Summary Scope of Work | ID, improve, and adopt technologies for dewatering / separation. Develop new processes for nutrient recovery. Bench scale testing. |
| Technical Approach | Survey literature and other industry applications for best available technologies and practices. Modification and adoption for this application. Conduct laboratory and pilot testing. |
| Lead Investigators (academia, natl. lab, industry, international, partnership) | Collaboration with universities, national labs, industry. Producer organizations. |
| Potential Collaborative Govt. Agencies | EPA?, USDA |
| Leverage Opportunities with Existing Programs | AwwaRF, USDA bioenergy program… focused more on producers. Producer organizations and cooperatives with private funding |
| Constraints/Challenges (Policy, regulatory, technical, sequencing?) | Lack of funding. Lack of awareness of gains that could be made… lack of education of stakeholders. |
| Estimated Cost | $1-2M |
| Execution Horizon (early, mid, late) | Early |
| Schedule/Duration | 2-3 years |
| Level of Development/Level of Maturity at completion | Commercialization of dewatering and material separation. Pilot scale test and demonstration of nutrient separation. |
| Additional comments | |