Concept Proposal for the Sacramento-San Joaquin Delta Conservancy
Ecosystem Restoration Water Quality Grant Program 2015-2016:

Beneficial Reuse of Harvested Invasive Aquatic Plant Species: Biofuel Demonstration Project

Category 2 Grant Proposal

Submitted to:

State of California

Sacramento-San Joaquin Delta Conservancy

Submitted by:

Port of Stockton, California

ENERCON

Environmental, Government & Public Affairs Department

On Behalf of the Water Hyacinth Ad-Hoc Committee

December 18, 2015

PORT OF STOCKTON

Phone: (209)946-0246 Fax: (209) 464-1251

December 18, 2015

Mr. Campbell Ingram
Sacramento-San Joaquin Delta Conservancy
1450 Halyard Drive, Suite 6
West Sacramento, California 95691

SUBJECT: Letter of Support for the Port of Stockton/Water Hyacinth AD-HOC Committee's Biofuel Demonstration Project Delta Conservancy Ecosystem Restoration and Water Quality Grant Application

Dear Mr. Ingram:

On behalf of Water Hyacinth AD-HOC Committee (Committee), this letter is being submitted in support of the request by the Delta Conservancy (DC) application for grant funding under the Water Quality, Supply and Infrastructure Improvement Act of 2014 (Prop. 1), approved by voters in November 2014.

The control and management of invasive aquatic plant species in the San Joaquin-Sacramento River Delta (Delta) has been a serious challenge for a wide range of Delta stakeholders. In the summer of 2015, the Port of Stockton, California Department of Water Resources and United States Bureau of Reclamation, local marinas and Delta businesses spent over $3,000,000 to harvest and dispose of water hyacinth to keep shipping lanes and marinas open and maintain critical water supply operations. In response to the explosive growth of water hyacinth invasion, in October 2015, the Port of Stockton commissioned a brief study prepared by ENERCON Environmental Consulting, on the potential beneficial uses of harvested water hyacinth in the Delta. The study concluded that harvested aquatic plants could be used for several beneficial purposes including as a feedstock for ethanol or methane production, although to our knowledge this concept has not been done on a small or commercial scale. The Port's report is attached to our application for your review. Based on this initial research, the Port has generated significant interest with Committee stakeholders to support a biofuel demonstration project. The goals of this demonstration project are: (1) to validate prior academic research on the use of various invasive plants for methane production; and (2) to determine whether the current infestation of water hyacinth or any other invasive weeds found in the Delta could be utilized as biofuel feedstock on a commercial scale. Pacific Ethanol, which owns and operates a large scale commercial ethanol refinery at the Port of Stockton, is a vested partner in this intriguing concept. This project has all the right ingredients for a successful project that will provide a durable contribution to the invasive aquatic plants dilemma in the Delta.

The Committee believes that numerous aquatic invasive plants such as water hyacinth, South American Sponge plant and other plant species that have invaded the Delta may be harvested and used for a variety of beneficial purposes, including silage for livestock, soil amendment and for biofuel production. Pacific Ethanol, Inc. will be supplying land area and equipment for the anaerobic digestion project and if this effort is proven successful, there could be significant commercial beneficial use for reduction of invasive species plants biomass.

The proposed biofuel demonstration project is consistent with the goals and objectives of Proposition 1 and the Delta Conservancy to improve water quality and habitat conditions in the Delta and will have numerous benefits including:

- Improving water quality conditions by removing floating biomass that eventually dies and consumes dissolved oxygen in Delta waters (a problem in the lower San Joaquin River);
- Significantly reducing large scale aquatic herbicide spraying by California Department of Boating & Waterways for weed control;
- Reducing invasive species in the Delta and generating a beneficial reuse of a solid waste into a commercially viable enterprise;
- Reducing ecological impacts associated with large floating masses of water hyacinth, including refugia for non-native predators, reduction of primary productivity and food production and decreased dissolved oxygen; and
- Diverting waste biomass from landfills through conversion to methane gas for marketable energy, and reducing methane emissions that are strong contributors to climate change.

The Water Hyacinth AD-HOC committee has tentatively set a goal of $80,000 cost-sharing for the demonstration project to fund some of the key technical studies needed for the project. In addition, the committee membership (including PEI) estimates In-Kind contributions of approximately $120,000 that will support this effort. These initial tasks are described in our application.

The grant proposal request is approximately $300,000 from the DC for the engineering, construction, operation and reporting the results of the demonstration project for a one year period. The goal is to complete the study by the first or second quarter of 2017 when the PEI anaerobic digester will be fully operational and ready to accept Delta biomass as a feedstock to their operations.

The Port of Stockton was selected to be the lead agency for the purposes of this grant, but the undersigned agencies are providing financial assistance and fully support this concept proposal.

Jeff D. Wingfield
Port of Stockton

Paul P. Koehler
Pacific Ethanol, Inc.

Pacific Ethanol, Inc.

Roger K. Patterson
Metropolitan Water District of Southern California

Frances Mizuno
San Luis & Delta-Mendota Water Authority

Paul A. Marshall
California Department of Water Resources

Bill Wells
California Delta Chambers

CALIFORNIA DELTA CHAMBERS & Visitors Bureau

Greg Gibeson
Recreation Boaters of California

RBOC

Concept Proposal Application Form

Submit this document and the required attachments in PDF

Applicant Information

Applicant Name (organization): Port of Stockton on behalf of the Water Hyacinth-AD-HOC Committee

Type of Organization: Public Agency

Address: 2201 W Washington St, Stockton, CA 95203

Contact Name: Jeff Wingfield, Director of Environment, Government & Public Affairs

Telephone: (209) 946-0246 Email: jwingfield@stocktonport.com

Federal Tax ID#: 94-6001403

Project Information

Project Name: Small Scale Biofuel Demonstration Project

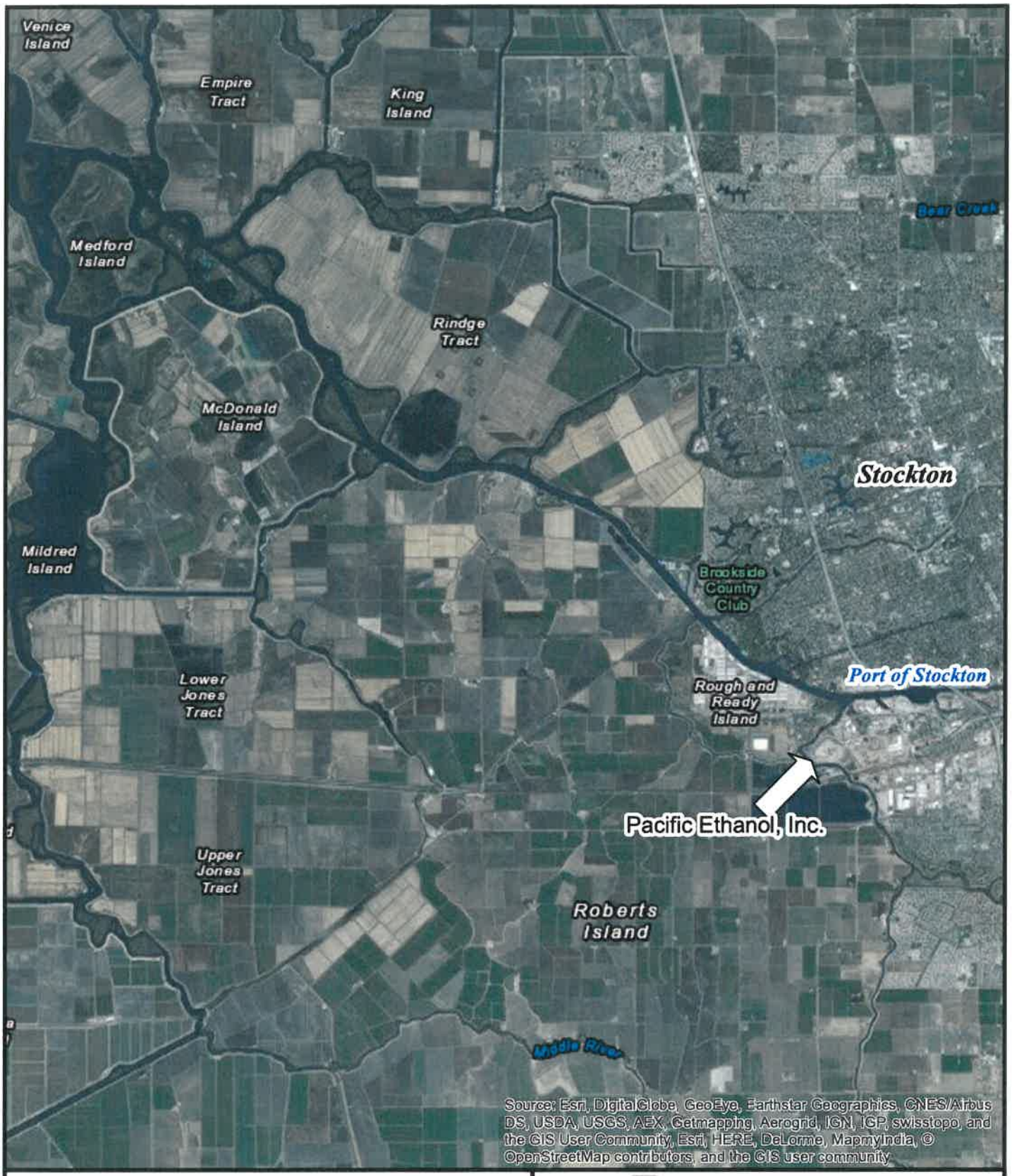
Project Location: Port of Stockton Pacific Ethanol Refinery

County: San Joaquin County City/Community: Stockton Specific Location: see above

Grant Category: Category 2

Funding Priority: Restoration Enhancement and Water Quality Improvement

Proposed Start Date: June/July 2016 Estimated Completion Date: December 2017



Prepared for:
Sacramento-San Joaquin Delta Conservancy

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Prepared by: Keith Imler; December 16, 2015

ENERCON

Figure 1: Location of Pacific Ethanol Inc., Stockton Plant

0 1.25 2.5 5 Miles

Project Description and Organizational Capacity

The proposed Port of Stockton BIOFUEL demonstration project would be located at the Pacific Ethanol, Inc. (PEI) refinery at the Port of Stockton. PEI currently uses corn to produce ethanol at this refinery which is used in gasoline formulations and other uses. PEI is currently planning, designing and building an anaerobic digester at this facility to create methane from ethanol refining byproducts to create methane gas which will be used to power their own power plant. This demonstration project will leverage investments already being made by PEI for their commercial enterprise.

Need for the Project

The proposed project is needed to assist in solving an existing regional invasive species invasion of the South American water hyacinth (WH), a non-native aquatic plant that has invaded the Sacramento-san Joaquin River Delta. In addition, there is a great need to restore recreational boating and navigation and local Delta economic sustainability and water supply reliability.

Goals and Objectives:

The goals and objectives of this BIOFUELBIOFUEL demonstration project include:

- Demonstrating that invasive species plant biomass, such as water hyacinth and others, can be harvested and used either by itself or in combination with other materials including ethanol refining byproducts to generate methane gas and be put to beneficial use at a commercial scale,
- Significantly reduce populations of invasive plant species in the Delta for ecosystem protection and economic well-being of Delta business and residents,
- Provide an alternative source of biomass for PEI's methane production process,
- Improved circulation in the Delta from removal of large floating masses that choke waterbodies

Background

Currently, WH is posing a serious problem to the communities, businesses and water supply operations in the Delta. Substantial academic research can be found in the literature indicating WH could be a potential feedstock for both ethanol and methane production. A recent literature review conducted by the Port of Stockton revealed that water hyacinth (WH) and potentially other invasive aquatic weeds in the Delta (e.g., Brazilian waterweed, South American Spongeplant, Water primrose and others) may be used for other potential beneficial uses including ethanol and methane production, animal feed and soil amendment (Port of Stockton 2015) (Attachment A). Pacific Ethanol Inc. (PEI), operates an ethanol refinery at the Port of Stockton which utilizes corn primarily as a feed stock. Pacific Ethanol, Inc. (PEI) along with the Port of Stockton and the members of the WH Committee are proposing this concept proposal for funding from the Delta Conservancy to demonstrate the feasibility of beneficially using harvested invasive aquatic plants for methane production. The WH Committee has decided to upfront certain costs for tasks in the first phase of this project (lab bench studies and harvesting analysis).

PEI has already started the planning, engineering, and permitting process for constructing a full scale anaerobic digester to digest thin stillage from ethanol refining operations for methane production and currently has a Request for Proposal for turn-key services for a methane digester at their Stockton refinery. The digester would produce methane that would then be used to run a cogeneration power plant. .

Previous studies of WH in the European Union by Organic Waste Systems (OWS) has shown that WH has greater potential for methane production when compared to ethanol production. PEI plans to have their full scale methane cogeneration plant online by 2017. In the interim, the WH Committee will conduct a small scale demonstration plant at the PEI facility to better understand ethanol and methane production from a WH and other invasive plant species or other sources of biomass for use in their commercial operations.

This concept proposal report involves bench scale testing of various invasive plant species in the Delta and a small scale demonstration project to determine whether Pacific Ethanol or other end users could utilize WH and other invasive weeds in the Delta to blend with corn, sorghum feedstocks to produce ethanol or for methane production. The small scale pilot study would be broken down into 2 phases:

- Phase 1 Invasive Species Biogas Potential Analysis, and
- Phase 2 Small Scale Demonstration Project.

Phase 1. Invasive Aquatic Plant Species BIOGAS Potential Analysis

Task 1-1. Bench Scale Experimentation and Laboratory Analysis

The cost of this task maybe be funded by the WH-AD-HOC Committee and is provided here for Delta Conservancy (DC) staff to understand the technical linkages to our primary DC grant request.

Task 1 of our concept proposal includes several tasks including bench scale testing of invasive species tissue chemistry and methane production of various trials with various anaerobic digestion fermentation techniques and various enzyme formulations, analysis of WH harvesting techniques and delivery techniques to the PEI facility and preparation of Phase 1 technical report. The goals and objectives of Phase 1 are to confirm academic research by conducting independent analyses of methane production in the laboratory using a variety of available invasive plant species currently in the Delta including:

- *Arundo donax* (giant reed),
- *Egeria densa* (Brazilian water weed),
- Eichhorrnia crassipes (water hyacinth),
- Ludwigia hexapetala (water primrose)
- Hydrilla verticillata (hydrilla)
- Limnobium laevigatum (South American spongeplant).

These invasive plant species and others will be used to determine efficacy of various species by themselves and blends for optimum methane production. The testing trial may involve continuous fermentation tests that involve using ½ -1 pound of plant material for a 16 week trial. The results of Phase 1 testing trials will be presented in a Technical Report prepared by the WH AD-HOC Committee to the DC.

Task 1-2 Evaluation of Alternatives to Invasive Species Harvesting, Transportation Techniques and Optimization

Currently WH is removed from the Delta via several techniques such as mechanical harvesting equipment, herbicide spraying applications by CDBW, and aquatic in-situ maceration and disposed of primarily on land by various entities for eventual disposal. . There is significant spatial and temporal variability of where WH and other invasive species are found in the Delta and depends upon many factors such as channel structure, water supply pumping operations, prevailing wind direction, tides and other factors. Given this l variability of WH episodes in the Delta, the costs of harvesting and transporting invasive species including WH to the refinery needs to be researched to determine the most cost effective method to deliver invasive species biomass to the PEI refinery. This task will evaluate alternative harvesting techniques (e.g., boat & boom operations, conveyor systems, other alternatives) and bundling/hauling techniques (e.g., rail, using traditional hay baling equipment, green waste garbage trucks, others) to determine the most cost effective method to deliver invasive species biomass to PEI refinery. We will also estimate relative costs of the various techniques to select the most cost effective method given the spatial and temporal variations in hyacinth production and harvesting in the Delta.

Task 1-3 Develop BIOFUELBIOFUEL Demonstration Project Plan.

The anaerobic digestion of different agricultural feedstocks like corn stillage and WHs has been researched for decades by various academic institutions and industry. PEI has already started the planning process for constructing a full scale anaerobic digester to digest thin stillage from their current ethanol refining operations. In concert with PEI's long term plan to provide cogeneration facilities, a small pilot plant could be constructed at PEI's facility to confirm performance of different combinations of feedstock (corn, sorghum, WH, and other invasive species biomass stocks).

In Phase 1, we will develop the plan and develop pilot project design criteria, process sizing, and budgetary costs for a small pilot anaerobic digester located in small area adjacent to PEI refinery. The digester would include a 10,000 gallon flat bottom stainless steel tank (provided by PEI), a mixer, a heat exchanger, gas flow and analyzing equipment measuring composition of the biogas, and scales to measure extent of conversion of mass to biogas. We will develop a proposed pilot plant, design and operating criteria, research plan, and construction and operating budget in a technical memo so the working group can review the concept prior to project installation.

Phase 2 Small Scale BIOFUEL Demonstration Project

The small scale demonstration project is envisioned to be located within a relatively small area at the existing PEI refinery for receiving harvested invasive species biomass for further processing, a processing/shredding machine to macerate the WH and other species into preferred particle size for fermentation and digestion, installation of several small fermentations tanks and associated piping, vales and other equipment to monitor and assess production levels. The small scale pilot study is envisioned to be operated for about one year to ensure results consistency and to enable sufficient data is collected to provide results for decisions by PEI or others to implement project in the summer of 2017. The results of the small scale demonstration project will be summarized in a report to the DC. This report will form the basis for assisting PEI with making informed business decisions to include plant material biomass into their new anaerobic digestion system which should be operational by 2017.

Task 2-1. Design, Build and Operate Demonstration Project

The POS/WH Committee will select an engineering contractor to assist with the final design, construction and operation of the project for a 12 month period in this task. The demonstration project is intended to be operated for about one year and will utilize various invasive species that are available in the Delta for biogas production. During the one year test, the contractor will utilize harvested WH and other invasive species in feeding the digester and experimenting with various mixtures and blends to optimize BIOFUEL production. PEI may provide technical staff occasionally to assist with monitoring the digester and other required operational issues. The consultants will prepare a final study report that will include discussion of all study phases and recommendations for optimizing full scale commercial operation will be prepared.

Organizational Capacity

The Port of Stockton and members of the WH AD_HOC Committee have experienced several years in dealing with WH and other invasive species in the Delta. The Port of Stockton has implemented several high profile habitat restoration projects in the Delta including the Antioch Dune Restoration Project which beneficially reuses dredged sediment from the Stockton Deepwater Ship Channel to create habitat for the Antioch Dune beetle, and endangered species. The Port has also been instrumental in assisting DWR and CVRWQCB with water quality issues and the dissolved oxygen depression in the lower San Joaquin River DO Total Maximum Daily Load (TMDL) process. During that period, the Port managed several CALFED contracts to operate a jet aeration system research in the ship channel. DWR, USBR and others have demonstrated organization capacity to support and guide the POS on this project from their experience on various water resources projects including Bay Delta Program, CALFED, and others.

Metropolitan Water District of Southern California (MWDSC) has over 3 decades of experience in actively participating in efforts to preserve and enhance natural habitat and to improve watershed and restoration. Examples of past projects include the Southwestern Riverside Reserve and the Santa Rosa Plateau Reserve. Each of these projects includes the monitoring and protection of special status flora and fauna on critical habitat. Similarly, DWR also contributes extensive involvement and oversight for habitat restoration projects. DWR is working on the Yolo Bypass Habitat Restoration Project along with the Fish Passage Improvement Program to implement restoration of juvenile winter-run and spring-run Chinook salmon and Central Valley Steelhead rearing habitat in the lower Sacramento River Basin. The POS role will be to enter into the contract with the Delta Conservancy for implementation for the project and project management duties including issuing subcontracts, invoices and other project management duties. The Port of Stockton (POS) consultants, ENERCON Consulting, will be responsible for working with PEI staff and implementing the demonstration project on PEI property. Mr. Doug Brewer, with over 30 years of experience in California environmental industry, will serve as the overall Program Manager for the BIOFUEL Demonstration Project. Mr. Dan Rich, P.E., will serve as lead engineer and work closely with Mr. Russ Ryan, P.E. From MWD and Mr. Pat McKenzie, Chief Engineer from PEI serve in project design and implementation. Staff from both NEXGEN Engineering and ENERCON will assist with the final design and operations of the anaerobic digester for the 12 month period.

State Priorities /Tangible Project Benefits

California Water Action Plan

The proposed demonstration project is consistent with the restoration goals of the California Water Action Plan. It provides multiple tangible results and benefits including the reduction of herbicide use by CDBW the subsequent biological oxygen demand in Delta waters from decomposing vegetation. WH and other invasive species create dead spots in the Delta from blocking out sunlight in vast areas, creating refugee for predators to special-status species such as Delta smelt and having negative impacts on biological productivity. Harvesting of invasive species will contribute to the improvement of water quality, ecosystem restoration, and biodiversity. These benefits will result in a healthier ecosystem for fish and wildlife that will support sustainability and habitat. Multiple aspects of the project will help to combat the effect of climate change on the Delta by reducing the amount of WH and other invasive weeds that have grown exponentially from higher temperatures and less precipitation in the Delta. The project will also take biomass waste and will promote an economically sustainable model to create clean and renewable energy. The transition to sources of clean energy will reduce emission impacts and help to combat climate change.

Delta Conservancy Strategic Plan:

This project is in compliance with multiple goals for the Delta Conservancy. The project will promote the harvesting of invasive aquatic weeds and the protection and biodiversity of sensitive native species that have been harmed by the dominance of invasive plants in the ecosystem and changes in Delta food webs and primary production. Another tangible benefit from the project is keeping Delta waterways open for recreational boaters that have been severely impacts by WH invasion in the last few years. WH interrupts the use of radar navigation impeding commercial vessels from entering the port at night resulting in delays and a finical burden for shipping into the Port of Stockton. There are several Delta marinas that have been overtaken by WH prohibiting recreational boaters and fisherman from utilizing the Delta and impacting the regional economy. This project will help the mission of the Delta Conservancy to protect and enhance the ecosystem and promote the local Delta economy.

Bay Delta Conservation Plan:

This project will protect and enhance water storage and conveyance in the Delta. Removing invasive aquatic weeds will prevent water pumps to fail from excessive vegetation intake. The Delta is an essential point of water diversion for California so protecting these pumps will significantly improve the

water reliability of California. Additionally, removal of invasive weeds will promote the enhancement of habitat in various areas of the Delta including identified locations in the Bay Delta Conservation Plan.

Section 5. Readiness

This is a Category 2 grant proposal that will plan, design, build and operate a BIOFUEL demonstration project. The proposed project is ripe for implementation based on numerous positive events and factors that all come together for a win-win solution to this perplexing regional problem. The alignment of various important ingredients make the project ready for implementation include:

- Ethanol refinery/methane generator and power plant located in the heart of the Delta;
- Leverages work being done by USDA ARS and others on WH distribution;
- Broad support from a wide range of Delta stakeholders that are being impacted; and
- Leverages existing BIOFUEL research done by the POS, academia and potentially moves the concept to the next level of a commercial scale project.

The combination of having an ethanol/methane refinery geographically situated within the Delta proper along with the state and federal water project operators and multiple parties impacted by the WH invasion in the Delta combine to make self-evident the need for the project. Port of Stockton invested and conducted significant research on potential beneficial reuse of harvested WH in order to inform the WH-AD-HOC Committee and to stimulate discussion with local industry about potential funding sources about this project. The addition of Delta Conservancy grant funding to assist funding the demonstration project will be essential for demonstrating the feasibility of beneficially reusing invasive species for commercial scale methane production and power generation. The project has direct and indirect benefits to reducing greenhouse gases such as carbon dioxide and methane that cause climate change.

This proposal is for a Category 2 DC grant application. The POS along with PEI have already engaged in foundation level planning and research to support implementation of a t specific BIOFUEL demonstration project. Implementation of the project will require limited planning to insure that all the different aspects of the project (harvesting, transporting, and energy producing) are performed efficiently and to the benefit of the delta and parties involved. Execution of this project will involve the evaluation of the various harvesting and transportation methods currently being performed by the Port of Stockton and CDBW. Implementing a project level study will allow for critical research on the use of WH and other invasive Delta plants for the production of biogas through anaerobic digestion. Even at the study level this project will still serve to focus efforts on weed removal. There are limitations on the amount of available information for commercial scale methane production with WH using an anaerobic digester. This study will serve to bridge the current data gaps and determine the best methods for performing each part of the study. This project includes a timeline for necessary phases of the project.

Pacific Ethanol, Inc. is currently engaged in the process of acquiring full scale anaerobic digestion for methane generation at their Stockton Refinery. Having access to this type of technology would ideally allow for efficient and inexpensive access to unload collected invasive vegetation. This project will help to see that opportunity will be taken full advantage of and help turn a current burden into an advantage. PEI has offered their participation in research and consultation, including use of their facility and sub-contracting companies, in the process for the project team.

Implementation of a small scale demonstration project at the PEI refinery is consistent with existing land use and zoning at the POS and the project per se is not anticipated to trigger discretionary actions subject to CEQA environmental review. Based on the current project description, the phases of the project should not require California Environmental Quality Act (CEQA) review. The study will be completed on a small scale and be limited to an expansion of current facilities at Pacific Ethanol, Inc. For this reason the project should be able to be started quickly and completed efficiently with minimal permitting. We will verify these assumptions if a full proposal is warranted by the DC.

Local Support In 2014, MWD initiated the formation of the Water Hyacinth AD-HOC Committee which is comprised of the following organizations: MWD, Port of Stockton, CDWR, San Luis Delta-Mendota Water Authority, USDA, CDFA, Recreational Boaters of California, California Delta Chamber of Commerce and others.

All of the current members of the WH-AD-HOC Committee are supportive of this project either financially or through In-kind contributions. The partnerships created here leverage the strengths of multiple organizations with special districts (POD), government (CDWR/USBR) and private industry. The goal of this project is to create a sustainable method of WH control that will benefit commerce, water supply, habitat restoration, and restore recreational boating use of the Delta.

This project offers a solution to a problem that impacts various agencies including: Department of Boating and Waterways; California Department of Fish and Wildlife; as well as fisherman and recreational boaters. We believe public support for this project would be very high because it attacks a serious invasive plant issue, restores important habitat, and is beneficial for recreational and commercial use of the Delta.

Scientific Merit and Performance Measures

ENERCON prepared a report on behalf of the Port of Stockton to explore the feasibility of using WH primarily as a feedstock for ethanol. The research concluded there has been various academic level experiments testing the ability of WH to be used as the source material for ethanol, biogas/methane, composting material, and animal feed. The report laid the framework in developing this concept and showed the potential for further exploration. The project is based on best available science performed by numerous renewable energy researchers at U.C Davis, U.C Riverside and other academic institutions in California and abroad.

Through a laboratory assessment of WH completed by PEI, it was concluded the optimal use of WH would be for the production of biogas/methane from WH that has been put through the anaerobic digestion process.

There are currently 11,000 acres of water hyacinth in the Delta. This project will have several benefits to greenhouse gas emissions and relevance to climate change including:

- Incremental decrease in greenhouse gas emissions,
- Incremental decreases in carbon footprint from water hyacinth coverage in the Delta,
- Potentially decrease rail deliveries of feedstock corn from the Midwest,
- Potential reduction in GHG emissions due to PEI becoming energy independent and less reliance on outside power sources,
- Potential reduction in GHG emissions from inefficient harvesting practices and improved regional management and centralized harvesting techniques,

Water Quality conditions in the Delta have changed due to the current drought. In addition, climate change in the Delta has caused the increase of temperatures and reduced precipitation rates. Combined with nutrient loading from the areas agricultural activity, the result has been the explosion of invasive weeds we currently see in the delta. If left untreated, or all treated with herbicide in the current manner, the delta faces the risk of increased dissolved oxygen in the water and released CO2 in the air resulting from decomposition. WH is a seasonally fluctuating plant that peaks in the warmer months. Because of the extended hot and dry seasons resulting from climate change the pressure to find a sustainable method of weed control is even greater.

Project Assessment

In order to measure and report project effectiveness, the amount of WH collected from the delta will be recorded and analyzed. The analysis will be focused on two different criteria including pre-project and

post project levels. We will be leveraging the work of many other researchers in the Delta including the recently funded USDA Agricultural Research Service Area wide Weed Control Project.

Pre-Project Report: The baseline level of WH acreage in the delta will utilize data and mapping information gathered by NASA-Ames Research Center as part of the USDA Areawide Study. There will be studies using satellite imagery to estimate the approximate coverage of WH in the Delta. The current estimate of WH is over 11,000 acres.

Post-Project Report: Will be based on the results of the study and the ability of the parties involved to effectively harvest and produce biogas from WH and other invasive vegetation at a volume that will provide an effective and commercially sustainable solution. The Post-Project report will summarize the findings of the study and will demonstrate the most viable choice for harvesting.

Other techniques that will be considered for project assessment may include: documenting tonnages of water hyacinth used in the digester, measurements of the total volume of methane created during the pilot project and potential power it would create, set the baseline to estimate the amount of plant biomass that could be harvested in a daily basis and used for power production, record the amount of acreage harvested on a daily basis for the project.

In addition, the team intends to utilize the existing BayDeltaLive.com, an open source data management resource this provides an open and transparent process for public dissemination of project information and results. Real-time information for data analysis and visualization. All reports will be provided to stakeholders, including participating state and local agencies in the Water Hyacinth Ad Hoc Committee (including the Division of Boating and Waterways), the USDA Agricultural Research Service Areawide Weed Control Project, and the Delta Conservancy.

Adaptive Management

Adaptive management, as it is traditionally used in the context of habitat restoration, is not relevant to this project. However, design of the demonstration project and recommendations for optimizing commercialization at scale will both reflect best industry practices and incorporate adaptive management practices to ensure cost-effectiveness and maximum benefit to various stakeholders. Uncertainties that will need to be considered and adaptively managed will include temporal and spatial distribution and abundance of Water Hyacinth; available modes of transport and their relative costs; fluctuations in demand for methane as an energy source; ability to coordinate Water Hyacinth harvesting/control efforts with the Port of Stockton and the Division of Boating and Waterways, and others; and various feedstock mixes.

Funding: Cost Share and Leveraging

In general, this concept proposal is requesting a grand total of $ 300,000. Significant in-kind investment ($25 K) has already been made by the POS in studying the beneficial reuse concept and generating the initial energy and momentum for support by other members of the Delta community. The WH-Committee is directly funding the cost of specific anaerobic digester laboratory studies on invasive species, harvesting options study and preparing the demonstration project plans. This cost sharing contribution totals approximately $120,000. The funds requested from the DC will cover the engineering design, construction, operation and maintenance of the demonstration project for one year. During the course of the operations various experiments with different invasive species will be conducted to optimize the operation and may include some laboratory tests etc. PEI is contributing in-kind labor and equipment needed for the demonstration project.

Concept Proposal Budget Template

BUDGET CATEGORY	TOTAL COST	
	Conservancy	Cost Share (Please note if in-kind)
Personnel	$113,000	$40,000 (in-kind)
Fringe Benefits		
Travel	$10,000	$10,000 (in-kind)
Equipment	$50,000	$50,000 (in-kind)
Supplies	$20,000	
Contractual		$10,000 (in-kind)
Construction	$50,000	
Monitoring Costs*	$30,000	
Performance Measure Reporting	$12,000	
Administrative**	$15,000	$10,000 (in-kind)
Planning		$60,000
Other		$20,000
TOTAL	**$300,000**	**$200,000**

*Category 2 grants may not exceed ten (10) percent overall for planning and monitoring costs.

** Eligible administrative costs must be directly related to the project and may not exceed five percent of the project implementation cost. To determine the amount of eligible administrative costs, the applicant must first determine the cost of implementing the project, not including any administrative costs. Once the project implementation cost has been determined, the applicant may calculate administrative costs and include them in the total grant request.

NOTE: Category 1, planning proposals, may use one 100 percent of awarded funds for planning activities, however, these funds would apply to a future Category 2 proposal for the same project and may not exceed 10 percent of the total project funds (Category 1 and Category 2 combined) requested from the Conservancy.

ATTACHMENT A

PORT OF STOCKTON STUDY

Potential Beneficial Uses of Water Hyacinth in the Sacramento-San Joaquin River Delta

POTENTIAL BENEFICIAL USES FOR HARVESTED WATER HYACINTH IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA

BRIEF REPORT

Prepared for:

Port of Stockton

Contact: Mr. Jeff Wingfield, *Director*

2201 West Washington Street
Stockton , CA 95201

October 7, 2015

Prepared by:

Enercon Services, Inc., *Environmental Services Group*
Contact: Douglas Brewer, *Project Manager*
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EXECUTIVE SUMMARY

Invasive aquatic weeds and other plants have cost the Port of Stockton (Port), federal, and state government agencies millions of dollars in recent years. Expansive growths of floating mats of water hyacinth is causing significant operational and environmental issues for the Port, California Department of Water Resources (state agency responsible for State Water Project operations), United States Bureau of Reclamation (Central Valley Project operations) and numerous private marinas in the Sacramento-San Joaquin River Delta (Delta). Water hyacinth, a floating aquatic weed from South America, is one of the main contributors to blocked shipping channels, radar interference, creating favorable conditions for mosquito populations, and native habitat degradation. In 2015, more than $2.5 million was spent on harvesting and disposing of water hyacinth in the Delta by these agencies, and it was clear that a solution is urgently needed to address the invasion. One concept is to evaluate whether there are beneficial uses of harvested water hyacinth, such as a potential feedstock for ethanol or methane production, soil amendment, and or fertilizer. The Port has numerous industrial tenants, including Pacific Ethanol, Inc. The City of Stockton's municipal wastewater plant, also located nearby, possibly could use water hyacinth in their industrial processes. Water hyacinth could also be used to make methane and used at a local power plant such as the new landfill gas-to-energy power plant recently built by San Joaquin County at the Foothill Linden landfill.

By utilizing new technology and a growing alternative energy market, it may be possible to significantly reduce the aquatic weed issue in a profitable and beneficial manner. The weed problem has grown exponentially as a result of warmer weather and drought conditions throughout the Delta. The California Department of Boating and Waterways (CDBW) is the primary state agency responsible for addressing the aquatic weed issue in California. CDBW has teamed with the U.S. Department of Agriculture (USDA) Agricultural Research Service and other government agencies to focus on research and control. Water hyacinth has been studied in recent years by various entities as a potential feedstock for ethanol production and, after technological advancements in refining ethanol, it is now believed that water hyacinth could be a sustainable and cost effective feedstock for ethanol production—one that doesn't compete with food and land resources. Ethanol is used primarily as a relatively low-cost and clean burning alternative to gasoline.

The Port is situated at the heart of the water hyacinth problem and has a Port tenant (Pacific Ethanol, Inc. [PEI]) that could potentially be a part of the solution. Using harvested water hyacinth in the Delta as feedstock for ethanol production could potentially be a cost effective means to solve solid waste disposal issues, beneficially reuse the biomass to produce ethanol, and/or use it as a soil supplement in nearby farms or livestock silage. We recommend that the Port and/or a consortium of agencies initiate discussions with PEI, the City of Stockton, and other relevant agencies on this beneficial reuse concept. More detailed planning and technical studies may be needed to further evaluate this concept's feasibility.

INTRODUCTION AND BACKGROUND

The issue of invasive aquatic plants in the Delta has resulted in millions of dollars in cleanup and control efforts. In 2015, it is estimated the Port, the California Department of Water Resources via the State Water Project, and local marinas spent nearly $3 million in harvesting water hyacinth to keep their operations from being impacted. The Delta currently supports more than 4 million acres of irrigated agriculture with a $25 billion value in California and is a critical component of the water supply to 25 million people, according to the USDA- Agricultural Research Service (ARS) Areawide Management of Aquatic Weeds in San Joaquin County program (Aquatic Weed Program) (USDA 2015). Invasive weeds have caused the inability of commercial and recreational boat passage in various areas of the Delta, a degradation of environmental quality, increase in the mosquito populations, and millions of dollars in economic damages. The main culprit has been identified as water hyacinth; a floating nonnative plant from South America that spreads rapidly and covers the water surface. In response to this regional problem, San Joaquin County Board of Supervisor Larry Ruthstaller, along with support from Senator Galgiani, was able to secure funding for $1.1 million to USDA ARS to study the water hyacinth issue and recommend solutions.

The Aquatic Weed Program focuses on the assessment and control of invasive weeds in the Delta. Approximately 50 percent of project funding has been put toward developing new tools to perform weed mapping of the current status of water hyacinth and to predict the spread of plant populations using satellite imagery provided by the NASA-Ames Research Center, including the potential use of unmanned aerial vehicles (UAVs) and airplane mounted imaging systems. The remaining budget has been allocated for the control of various aquatic weeds, water hyacinth given top priority, mainly through the use of herbicides. The practice of using herbicide has been shown to be moderately effective in short term prevention of spread but is still being studied to determine the impacts on fish and other delta wildlife species. CDBW, USDA, and state and federal agencies are working together to perform mechanical aquatic weed control in areas determined to be "nursery sites" for water hyacinth in the fall and winter of 2015 to 2016. A University of California (UC) Davis bioeconomist -has created a model for the project that determined the total damages to the marinas and supporting businesses of the Delta, in terms of loss of revenue, will exceed $8 million per year until this problem is dramatically reduced.

CDBW spent more than $7 million towards the Aquatic Weed Program in 2013 to 2014. They have already allocated roughly $9 million to combat the spread of water hyacinth in the 2014 to 2015 fiscal year. According to their website the CDBW believes that eradication is impossible and efforts and budgeting should continue to go toward control and reduction of water hyacinth population. Funding for the removal of water hyacinth by CDBW comes directly from the Harbors and Watercraft Revolving Fund. This Fund is created from the revenue received by boater registration fees and gas taxes.

PEI is the leading producer and marketer of low-carbon renewable fuels in the Western United States and has an operating facility in the Port. In 2014, PEI was awarded a $3 million matching grant from the California Energy Commission to develop a sorghum feedstock program

collaboratively with Chromatin, Inc., California State University's (CSU) Fresno's Center for Irrigation Technology, and the Kearney Agricultural Research and Extension Center. The main purpose of the grant is to develop sorghum as a lasting and low-carbon feedstock for ethanol production. The intention of the research to develop a more sustainable feedstock for ethanol potentially could open up PEI to do research involving the use of water hyacinth, a crop that could be sourced in high volumes locally and already has funding for harvest and removal.

PURPOSE AND OBJECTIVES

The primary purpose and objectives of this brief report include:

1. Assess feasibility of water hyacinth as a potential feedstock by itself or blended with corn and/or other feedstocks for ethanol production of biodiesel;
2. Determine other potential beneficial uses of water hyacinth (e.g., fertilizer, soil amendment, silage feed);
3. Provide a basis for initiating discussions with other impacted agencies (e.g., PEI, City of Stockton), and other relevant regional partners.

GENERAL OVERVIEW OF ETHANOL PRODUCTION

There are two main categories of ethanol production: "advanced" ethanol production and "cellulosic" ethanol refining. These two categories are separated by the parts of the plant used for feedstock during production (Renewable Fuels Association [RFA] 2015). The first category is the more traditional method called "advanced" ethanol production, which occurs when the source material is composed of sugars and starches from non-cellulosic feedstock, such as corn. This source material is converted to ethanol in traditional refineries. The second method, started in 2014, is called "cellulosic" ethanol refining. This method has experienced a push towards commercial production as -dozens of companies try to develop greater technology to maximize the profits and potential of cellulosic ethanol refining. This method utilizes parts and types of plants formerly considered waste (leaves, stalks, etc.) by breaking down the cellulose in the cell walls into sugars, which then can be turned into ethanol. This method of production includes the use of grasses, wood, and inedible parts of plants (RFA 2015).

Ethanol can be produced through wet or dry milling. In wet milling the vegetation is first soaked in a dilute acid formula to further breakdown the compounds in the plant. Wet milling is the method most commonly used in the trial studies using water hyacinth for cellulosic ethanol production. After "steeping" in the acid solution, the ethanol is ground to smaller pieces and fermented in large vats using heat and time along with yeast. Eventually, the alcohol produced can be filtered and denatured by adding enough gasoline to make the solution undrinkable (RFA 2015).

AVAILABLE LITERATURE ON USING WATER HYACINTH AS A BIOFUEL FEEDSTOCK

ENERCON environmental specialists conducted a literature search on water hyacinth and its potential use in ethanol production. The literature was primarily academic in nature and has not been evaluated on an industry or commercial scale. A total of eight studies were found that evaluated using water hyacinth as a potential feedstock for ethanol production. Table 1 provides a summary of the studies and their conclusions.

Table 1. Brief Summary of Studies on Water Hyacinth and Ethanol Production

Study	Authors	Date	Conclusions
Bioethanol Production From Aquatic Weed Water Hyacinth (*Eichhornia crassipes*) by Yeast Fermentation	A. Manivannan and R. T. Narendhirakannan	January 2015	Bioethanol production from biomass has high potential to substitute fossil fuels. This study represents the suitability of biologically delignified water hyacinth as a feedstock for fuel ethanol production.
Coastal Plants For Biofuel Production and Coastal Preservation	Charles Malveaux	August 2013	Water hyacinth has shown potential for both biofuel production and coastal preservation. With a measured sugar concentration of 20 to 50 percent by dry weight, water hyacinth can be readily converted into ethanol.
Water Hyacinth as a Potential Biofuel Crop	Anjanabha Bhattacharya and Pawan Kumar	2010	As the search for alternatives to fossil fuel intensifies in this age of modernization and industrialization, fueled by increasing energy costs, water hyacinth holds a strong promise in the 21st century biofuel industry.
Combination of Biological Pretreatment with Mild Acid Pretreatment for Enzymatic Hydrolysis and Ethanol Production from Water Hyacinth	Fuying Ma, Na Yang, Chunyan Xu, Hongbo Yu, Jianguo Wu, Xiaoyu Zhang	2010	This suggested that the combination of biological and mild acid pretreatment is a promising method to improve enzymatic hydrolysis and ethanol production from water hyacinth with low lignin content.
Bio-ethanol from Water Hyacinth Biomass: An Evaluation of Enzymatic Saccharification Strategy	U.S. Aswathy, Rajeev K. Sukumaran, G. Lalitha Devi, K.P. Rajasree, Reeta Rani Singhania, and Ashok Pandey	August 2009	Testing of acid and alkali pretreatment methods indicated that alkali pretreatment was more efficient in making the sample susceptible to enzyme hydrolysis. A crude trial on fermentation of the enzymatic hydrolysate using the common baker's yeast *Saccharomyces cerevisiae* yielded an ethanol concentration of 4.4 grams per liter (g/L).
Ethanol Production from the Water Hyacinth *Eichhornia*	Ogawa Masami, Ishida, Yukinari Usui, and Naoto Urano	December 2007	This study concluded that water hyacinth is a promising plant for the production of bioethanol. One strain tested produced 22.4

Table 1. Brief Summary of Studies on Water Hyacinth and Ethanol Production			
Study	**Authors**	**Date**	**Conclusions**
crassipes by Yeast Isolated from Various Hydrospheres			milliliters (ml) of ethanol per kilogram (kg) of dried water hyacinth, which suggests that it may be an efficient producer of bioethanol.
Features Of Promising Technologies for Pretreatment of Lignocellulosic Biomass	N. Mosier, C. Wyman, B. Dale, R. Elander, Y.Y. Lee, M. Holtzapple, and, M. Ladisch	April 2005	Cellulosic plant material represents an as-of-yet untapped source of fermentable sugars for significant industrial use
Bioconversion of Water-Hyacinth (Eichhornia crassipes) Hemicellulose Acid Hydrolysate to Motor Fuel Ethanol by Xylose–Fermenting Yeast	J.N. Nigam	January 2002	The fermentation was very effective at an aeration rate of 0.02 v/v/m (volumes of air per volume of liquid per minute), temperature 30±0.2 degrees Celsius (°C) and pH 6.0±0.2. However, the volumetric productivity (Qp) was still considerably less than observed in a simulated synthetic hydrolysate medium with a sugar composition similar to the hemicellulose acid hydrolysate

Water hyacinth is an attractive fuel source because of its nature to grow exponentially under the right environmental conditions. Research has shown that water hyacinth is a promising plant to use for a low cost method production for ethanol (Masami et al. 2007). The technology for cellulosic ethanol advanced exponentially in the last couple years and now, if put toward water hyacinth as a feedstock, could potentially generate a profitable source of ethanol and significantly improve the Delta ecosystem. From the studies evaluated, it was common practice to treat the water hyacinth in a mild acid solution before beginning the fermentation process in order to accelerate the breakdown of the starch in the plant. One study considered water hyacinth to have a low lignin content, which could result in low productivity of biogas, but determined that when combining the vegetation with a mild acid pretreatment and biological influence using different white and brown rot fungus, it significantly improved the outcome to promising levels (Ma et al. 2010).

Another study found the ethanol output of water lettuce and water hyacinth was comparable to other more common agricultural wastes after standard acid treatment (Masami 2007), while yet another concluded that the cost of the cellulose enzyme needed to break down water hyacinth would be too high compared to the rate of productivity from the plant in terms of ethanol production (Sukumaran et al. 2008). As a result of advancements made in the last few years the efficiency of using cellulose has grown significantly, suggesting that the cost of the cellulose enzyme shouldn't be a limiting factor for ethanol from water hyacinth to move from the academic to commercial levels.

AVAILABLE LITERATURE ON OTHER POTENTIAL BENEFICIAL USES OF WATER HYACINTH

This section presents information on other potential beneficial uses of water hyacinth that could be considered for implementation, such as methane production and as a fertilizer. A total of fivestudies were found that evaluated these possibilities. Table 2 provides a summary of the studies and their conclusions.

Table 2. Brief Summary of Studies Evaluating Other Beneficial Uses of Water Hyacinth

Study	Authors	Date	Conclusions
Sustainability Assessment of Water Hyacinth Fast Pyrolysis in the Upper Paraguay River Basin, Brazil	Luz Selene Buller, Enrique Ortega, Ivan Bergier, Juan Miguel Mesa-Pérez, Suzana Maria Salis, and Carlos Alberto Luengo	November 2015	The results obtained in this study could be used as the maximum and minimum thresholds to subsidize regulatory policies for new economic activities in tropical wetlands involving natural resources exploitation and bio-industrial systems.
Converting Water Hyacinth to Briquettes: A Beach Community Based Approach	Anthony J Rodriguesa, Martin Omondi Oderob, Patrick O Hayombec, Walter Akunod, Daniel Keriche, and Isaiah Maobe	2014	This study explored water hyacinth briquettes as alternative to the local wood fuels through a pilot briquette production process by appropriate levels of technology mediation. The commonly used biomasses, reasons for community's preference of one species to another were also sought.
Water Hyacinths as a Resource in Agriculture and Energy Production	Gunnarsson CC and Peterson CM	2007	Based on the labor need and the limited access to technology, using dried water hyacinths, as green manure is a feasible alternative in many developing countries.
Production of Biogas from Water Hyacinth (Eichhornia Crassipes) (Mart) (Solms) in a Two-Stage Bioreactor	A.K. Kivaisi and M. Mtila	January 1997	A two-stage rumen-derived anaerobic digestion process was tested for the conversion of water hyacinth shoots and a mixture of the shoots with cowdung (7:3) into biogas. The average methane gas yield was 0.44lg−1 VS digested.
An Economic Assessment of Fuelgas from Water Hyacinths	R.P., Lecuyer and J.H. Marten	1976	An economic study is presented to produce 200 million standard cubic feet (scf)/day of methane using water hyacinths as a feedstock. The results of the analysis indicate that the process is ecologically sound, technically feasible, and economically near-viable in an increasing natural gas cost economy, but possibly questionable from a public acceptance standpoint because of the large land area required.

One study showed that the use of water hyacinth can produce 200 million standard cubic feet (scf)/day of methane (Lecuyer and Marten 1976). The water hyacinth for this study was grown

in a controlled environment and later harvested and fed into an aerobic digester. The study states, "The results of the analysis indicate that the process is ecologically sound, technically feasible, and economically near-viable in an increasing natural gas cost economy, but possibly questionable from a public acceptance standpoint because of the large land area required" (Lecuyer and Marten 1976). Most research in this area combines the use of wastewater and/or animal manure to stimulate methane production in an anaerobic digester. Water hyacinth is considered a potentially strong candidate for use in methane production because of its accessibility and ability to produce biogas.

A 2007 waste management study found that water hyacinth made a good fertilizer due to its ability to quickly absorb and retain nutrients. The plant is believed to have a high nitrogen content, which is often a limiting factor in soils. Water hyacinth has been shown to improve the health of crops and is believed to be a feasible alternative as a green fertilizer in underdeveloped countries (Gunnarsson and Peterson 2007). More recently in 2014, researchers in Africa near Lake Victoria evaluated using harvested water hyacinth as an alternative fuel for indigenous people who rely on wood for fires. In this area of Africa one of the leading causes of environmental degradation is deforestation as a result of harvesting firewood. Water hyacinth was collected from the lake and converted into briquettes, which are now used as a supplement to wood for cooking and eating (Rodriguesa et al. 2014).

CONCLUSIONS

The invasion of water hyacinth in the Delta region is demanding action from government agencies because of its rapid spreading and damage to business activities. It is also a concern affecting the Delta ecosystem and human health in the area. The State has been allocating substantial funding to help control and stop the rate and spread of hyacinth in the Delta.

The academic research provided shows that water hyacinth can be utilized to produce ethanol and that it is feasible for commercial production. However, ENERCON was unable to find any evidence that water hyacinth has been tested on a commercial level by the renewable fuels industry. It does require a dilute acid treatment similar to other sources of cellulosic ethanol. Some research suggests that water hyacinth has a low ethanol output, but other studies suggest recent advancements in technology and production methods have significantly improved the expected output of ethanol from water hyacinth.

The location of PEI in the Port provides an opportunity to capitalize on an alternative ethanol feedstock that helps move away from dependence on corn. Water hyacinth also comes with the advantage of not relying on agricultural land and food resources. Beneficial reuse of harvested water hyacinth would significantly improve the health of the ecosystem and commerce in the Delta, potentially paving the way to manage a major aquatic weed problem for multiple agencies, reduce the need for waste disposal areas, and make a profit in production of ethanol. ENERCON recommends that the Port initiate discussions with PEI or other refiners on this intriguing concept.

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