Co Applicants:

South Jersey Economic Development District

and

Rowan University

Project Partners:

Atlantic, Cape May, Cumberland and Salem Counties

Cities of Egg Harbor, Millville and Salem

Small Business Development Center at Richard Stockton College of New Jersey

Cumberland Salem Workforce Investment Board

NJ Department of Transportation/Office of Maritime Resources

Cumberland Community College

Atlantic Cape Community College

Salem Community College

Salem County Improvement Authority

Interested Participants:

Public Service Electric & Gas (PSE&G)

Atlantic City Electric

PSE&G Nuclear

South Jersey Gas Co.

Calpine

DCO/Energetics

Mahogany Company

Introduction:

The southern New Jersey i6 Green Challenge Team, comprised of a broad based consortium of public/private universities and community colleges and economic development agencies, has identified Submersible Hydro Powers Systems (SHyPS) technology as an untapped opportunity to produce energy from a renewable source. It is believed that resources devoted to this renewable energy asset will yield optimal results in solutions that will transform the global renewable energy market driven on reliability, scalability and cost effectiveness. For most renewable energy, the early stage research and development through commercialization was subsidized via tax credits and incentives. Today, renewable energy solutions will have to achieve price points that generate profitable sales volumes without subsidies. We believe SHyPS will be a great vehicle toward this purpose. The value proposition of this proposed project will be to achieve a reasonable cost recovery period and to gain market acceptance at profitable price points, all without the benefit of subsidies.

Hydro power has been a traditional source of renewable power, as it is a reliable and predictable source of renewable energy. The cost and environmental impact of large scale hydro projects became far too burdensome with the growth of economy and population. The sites with easily profitable water head have been mostly realized. The low water head places or hard to access areas are not very suitable for traditional hydropower technology using dams and reservoirs. Meanwhile, its large scale value diminished as coal, oil and nuclear came online with a far better return on investment (ROI) although existing hydro facilities still continue to represent a significant contributor to the grid with a comparatively small carbon footprint.

The dynamics of technological advancements have changed the picture. It has been discovered in recent years that moderately sized SHyPS can produce power in a cost effective way. SHyPS, both turbine-based and reciprocal-style systems, particularly the underwater "Kite" technology that is proposed in this project, presents remarkable economical promise as a premier renewable energy source. These systems have experienced limited attention, given government subsidies in wind and solar. This is evidenced by new patent filings of wind and solar outpacing those on hydro technology. On the other hand, the ROI on research and development on solar and wind technologies is largely depending on these government subsidies. Diminishing subsidies may have detrimental effects on levels of both private investment and market demand on wind and solar energy sectors. At the same time, the economical benefits of SHyPS will become more evident.

Our proof of concept will focus on the design and commercialization of new scalable SHyPS product technologies that utilize the existing skilled workforce and production capacity that can achieve profitability without the benefit of ongoing public subsidies. This ambitious goal will be attained by the convergence of five strategies.

1. A Proof of Concept Center will be formed around SHyPS technologies to design and test the efficacy of such technologies on scalable and distributed platforms.

2. The SJEDD will establish the "Innovation, Collaboration and Transformation Consortium", a broadly based network of public/private/university organizations that will focus on market opportunities for technology based solutions within the capabilities of southern New Jersey's regional innovation clusters.
3. All the partners of this proposal will assess existing regionally available resources and identify other essential catalysts that will be organized to accelerate the research and development continuum.
4. We will provide local industries the opportunities to access technologies that can provide market opportunities to fully utilize production capabilities, spur new jobs and private investment within the RIC from the resultant technological advancement.
5. Our approach will put forth a Best Practices model for an economic development strategy that is replicable particularly in rural areas.

Proof of Concept Center:

In this proposal, we will develop different types SHyPS to suit different power needs, from a sub-kW level pico-hydro turbine along a river for household application to a MW level power farm in a tidal bay for commercial power generation. Specifically, we are going to develop three different types of SHyPS: Horizontal and vertical axes waterwheel type, underwater windturbine type, and dynamic underwater "kite" type. In contrast to the high-speed jet turbines used in traditional hydro-power, we will use low speed impact water turbines. These SHyPS can be installed along the rivers or in the entrance of bay areas without building expensive dams or other water constraining infrastructures.

In this proposed research, we will:

1) Optimize the design of various types of hydro turbines for high efficiency and low manufacturing and maintenance cost.
2) Survey the Salem river and find the optimal locations of installation.
3) Prepare for commercialization:
    a. Select the best materials and components for ease of fabrication and repair and take advantage of existing capacity of the private sector;
    b. Develop modular household grade hydro turbines;
    c. Develop manufacturing process;
    d. Develop custom built hydro farm for commercial power generation.
4) Develop a standardized procedure to install the hydro turbines including
    a. To determine the proper power needs;
    b. To locate the ideal site of installation;
    c. To select the proper hydro turbine type to suite the budget and maintenance constraints;
    d. To streamline the permit or license procedure;
    e. To prepare a complete handbook with multimedia web supplements.
5) Explore the marketability of the SHyPS.

Concept of the technology:

The kinetic energy of a moving object is $KE=\frac{1}{2}mv^2$, then the power (the energy per unit time) of flowing fluid can be calculated as $P=\frac{1}{2}\rho Av^3$, where ρ is the fluid density, A is the cross-section area or the area swept by the blades of a turbine, v is the flow speed. In general, the water density is about 1000kg/m^3 in rivers or 1025kg/m^3 in sea. The speed of a river or tidal stream is generally between 1m/s

(2 knots or 2.2 miles/hr) to 2m/s depending on the season and location. Correspondingly, the potential power density is between 0.5kW/m^2 and 4kW/m^2. Potentially, this number can reach much higher after rains or at the locations where the river or bay narrows or the elevation drops. Although the water speed is generally slower than that of wind, the much higher density (ρ_{water}≈1000kg/m^3 v.s. ρ_{air}≈1.25kg/m^3) will make the difference. For example, in some selected but not rare ideal locations where the water speed reaches 3m/s, the power density is equivalent to the wind speed at nearly 27m/s, or 63mile/hr, which is not practical or sustainable in the most areas of the world.

After considering the energy loss and the speed variation of the water, we can still expect the hydro turbine to be able to extract water energy at the level of anywhere between 100W/m^2 and 1kW/m^2. Meanwhile, the fundamental technologies (blade material and fabrication, pressure seal, generator, controller, inverter, etc.) are relatively mature and most of them can be obtained off-the-shelf and there are abundant diverse untapped water resources in the proposed region including rivers, bays and shore areas.

Technology development:

In this proposal, we will develop several SHyPS technologies. Some are relatively mature (such as the waterwheel based hydroturbines) and only need a small amount of effort to improve the design and make them suitable for production. Some other technologies (such as underwater "kite" style generator) are still in their infancy and need longer time to fledge. This tiered approach will help us to expedite the process of commercialization and help the private partners to engage the process as early as possible. It also helps to diversify the risk and provide a steady pipeline of technology so the manufactures will be able to push new and improved products to meet the market demand.

a. Horizontal and vertical axis waterwheel:

A horizontal axis hydro-turbine is similar to the design of a waterwheel that is traditionally used to power the ancient agriculture and the early stage industrial revolution. It is suitable for shallow water, small scale (kW grade) hydro-power. In this proposal, we will try to revive the concept with two approaches. As seen in the figure, a water wheel with multiple blades is supported by two buoys, which are in turn secured at the floor of the river or the bay via an anchored tether. The shaft of the wheel is connected to a gearbox and a generator assembly. To maximize the power and simplify the maintenance, the shaft of the water wheel will be raised above the water surface. In the vertical axis approach, the entire wheel will be submersed into the water while the generator will be raised above the water surface and supported by a buoy. Again, the entire system is fixed to the bottom via an anchored tether.

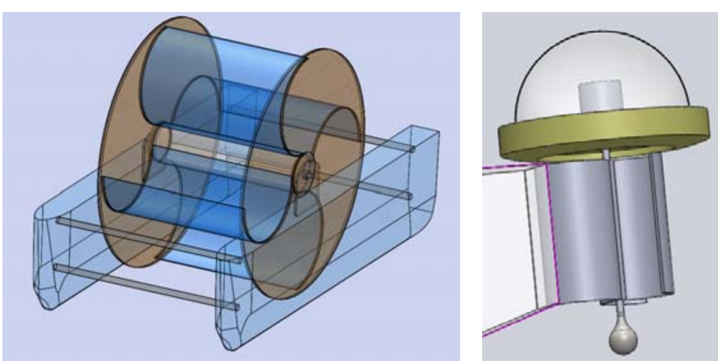
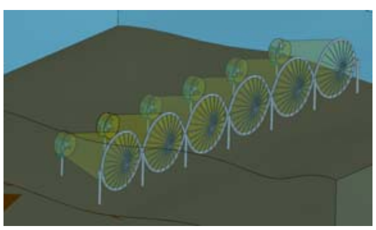


Figure 1: Horizontal axis and vertical axis waterwheel-style hydro-turbines.

b. Horizontal axis fan style hydro-turbine

For the deep water and large scale power generation, a fan-style horizontal axis hydro-turbine will be more suitable. The larger size will increase the tip speed of the blades and significantly increase the power density. We will develop and test experimental (1m diameter) and small (5m diameter) size turbines. They will be used to accumulate experiences on building larger (>20m diameter) commercial scale turbines.

Since all the components of the turbines are submersed in water, this technology requires higher quality on seal and posts more challenge on installation and maintenance. However, the view of the surface will not be disrupted except a few buoys to mark the existence of the underwater equipment. The large sizes will also mean the greater power output since the area is proportional to the square of the diameter. We expect to market this technology to commercial power companies so they can deploy them as an underwater hydroturbine farm for base-line electricity.



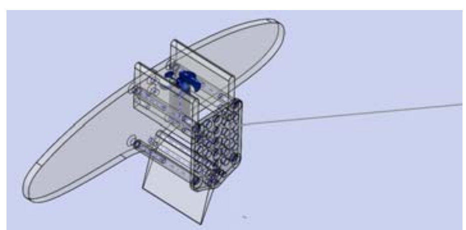


Figure 2: Horizontal axis fan style hydro turbine farm and underwater kite style dynamic hydro-turbine.

c. Underwater Kite-style hydro-turbine

As we mentioned earlier, the power of water can be calculated as $P=\frac{1}{2}\rho A v^3$. In order to get greater power, the only method of the above two approaches of hydropower is to increase A, the area where the water passes through. The density of the water will only be slightly larger in sea and the speed of the water is beyond control without the help of expensive water constraining infrastructure. However, inspired by a kite flying in cross-wind, we propose to develop an underwater kite-style device to only increase the speed of the water that is passing through the hydro-turbine.

As seen in Figure 2, a turbine is attached to the top of a sting-ray shaped gliding board. The board is attached to an anchored tether. A rudder is installed on the tail of the board. When the water current is flowing through the board that is maintaining an attack angle relative to the current direction, the pressure difference will generate force to push up the board like a kite in the wind while the tether will keep the board within a fixed distance. Meanwhile, the force on the rudder will control the board to change directions. The combined actions of the water flow, tether, and rudder will push the board circling in the water with a speed that is much faster than the speed of the flow itself. Since the power is increasing with the cubic of velocity, we can obtain a relatively high power level with a small size turbine and generator. In our preliminary computer simulation, the speed of the underwater kite can reach as high as 10 times the water speed. That is, the power density of this technology will potentially reach 1000 times higher than the previous two technologies. Meanwhile, the higher corresponding angular velocity of the turbine will simplify the gear reducing system that is generally required between the slow turning turbine shafts and the fast running generator.

The potential of this approach is great. A large (6 meter wingspan with 1 meter propeller diameter) underwater kite can easily generate 1MW power at 2m/s flow given the assumptions and calculations we have above. It is large by itself, but miniature compared to the same power grade windturbines and hydroturbines. However, the technology is not mature and only at its early stage. The power transmission from the running glider (following either a circle or a figure 8) without water and power leakage posts a significant challenge. Meanwhile, monitoring and controlling fast moving underwater equipment is also a research topic we need to face in this proposal. We expect to finish a small-scale (1kw) prototype during the two-year period of this proposal and use the technology to attract investment of power companies for commercial application.

Implementation, schedule and management:

Due to the different maturity level of the technology, we will divide the development of the SHyPS into two tracks. One track is to develop household grade 1kW level vertical and horizontal hydro turbines. The technology is relatively simple and the work is mostly focused on mechanical design, seal and material selection, and overall electro-mechanical integration.

The other track is the underwater kite development. Since the motion needs to be constantly monitored and the rudder might need to be adjusted to maintain the linear speed of the board in changing current speed, more work will be conducted on automatic control system. Underwater generator and high-pressure water seal technologies are available in industries. However, we need to obtain and test them and select the most proper one.

The proposed work will be conducted by a partnership of faculty members, technicians, graduate students, undergraduate students, government agencies, and industrial partners.

We will recruit two graduate students per year to conduct fundamental research and development in this proposal. Each graduate student will take the lead of each track under the close advice of the co-PIs of this proposal.

In the summer time, two undergraduate students will be hired to work full time with the graduate students. During the academic year, each track will be performed by a team consisting of 4 undergraduate students and 1 graduate student. This format will take advantage of our time-proven junior/senior Engineering Clinics. The engineering clinics courses are a hands-on series in Rowan University. The students work on well-defined projects in freshman and sophomore years and obtain systematic training on problem solving and project management skills. In junior and senior years, they are mixed and divided into small (mostly four-person) groups and work on open-ended real-world research or industrial projects. All groups are under direct advice of faculty members while some also work closely with graduate students or external experts.

After the two-year period of the project, many student participants will be graduated from the school. We will also try to work with the industrial partners and recruit some of them to join the companies that will continue the commercialization of the products. The students (who are mostly from the targeted counties, since we are a regional university) will save significant efforts on job hunting and work on a project they are familiar with. The company will also save a lot of time and energy to find and train the qualified employees.

Besides the traditional marketing effort, a Wiki style website will be set up to collect all the information, such as the references, design details, calculations, simulations, and discussions. A blog will be updated regularly to check against all the milestones. Partners of the project, local government agencies (such as EPA and DOT offices), and any other related third parties will be consulted to obtain their support. We will set up a database of potential locations within the proposed area and guidelines of setting up kilowatt grade hydro turbines. Due to the complex legal and financial issues of a commercial grade hydro turbine farm, it needs the expertise beyond the applicants of this proposal.

Initial Commercialization Approach:

a. Product development

The applicants and partners of this proposal will work together to design a technology transfer strategy at the entire process from proof-of-concept to commercial products. For example, one of our industrial partners is a boat manufacturer using mostly wood and fiberglass as the main materials. In all designs mentioned earlier, unless the data proves otherwise, the blades and gliders will be fabricated from steel strengthened fiberglass and the buoys will also be foams encapsulated with fiberglass skin.

b. Site surveillance

Rowan University staff will survey the water speed of the Salem River and of selected bays of the targeted region and therefore can locate and recommend the ideal sites for SHyPS which would form the basis of broader target market analysis.

c. Energy analysis

Rowan University staff will prepare a checklist for the potential customers. The checklist will help them to understand their power needs, the renewable energy resources they have in their area and the worthiness of using our proposed hydro-turbine technology. A web-based calculator will be developed to help them calculate the return of investment, the energy production, and the potential pollution prevention.

d. Product Manuals

Multimedia material will be prepared to both the DIY customers and contractors. These step-by-step selection, installation and maintenance instructions will be available online as 24/7 reference and by person in training sessions.

The co-PIs and the partners will study the river and population data of a number of other regions and identify a list of initial test markets.

To summarize the above management plan, we propose a schedule as shown in Table 1:

Year	2011	2012						2013						2014
Month	Before	1	3	5	7	9	11	1	3	5	7	9	11	Beyond
Preliminary work														
Concept generation														
Site investigation														
Modeling														
Simulation														
Small scale test														
Development														
Waterwheel														
Hydroturbine														
1kW kite-style														
Documentation														
Commercilization														
Market analysis														
Cost analysis														
Facility analysis														
Design modification														
Marketing														
Dissemination														
Pre-sale feedback														
Further work														

Table 1: Gantt chart of the project management. At the time of proposal, we are conducting preliminary research on several fronts using the existing resources and infrastructures, albeit at a very limited scale.

Innovation, Collaboration, Transformation Consortium "ICTC":

Concurrently with the creation of the Proof of Concept Center, the South Jersey Economic Development District will undertake the establishment of the Innovation Collaboration and Transformation Consortium (ICTC). The ICTC will be designed in such a way as to easily fit within the context of the EPA Research and Development to Commercialization Continuum model. We will also be engaging the private sector early in the process to avoid downstream issues that have adverse implications on market acceptance and/or production line efficiencies.

Within the consortium we will focus on team building and encourage an entrepreneurial culture. The entrepreneurial spirit and skill sets are fostered by a network of like individuals. This culture is just beginning to emerge in southern New Jersey. The convergence of electrical and computer sciences, and modeling and simulation expertise found at the William J. Hughes FAA Technical Center, the Federal Homeland Security Lab, The Next Generation Aviation Research Park and the Rowan University South Jersey Tech Park have spurred a knowledge based sector driving new technologies and scientific discovery. The entrepreneurial culture can continue to grow and prosper with the advent of the ICTC. Formalizing this network will attract venture capitals and other resource entities that will facilitate the commercialization process. Over the past year, the SJEDD has reached out to other agencies, including the International Trade Administration and the US Patent Office, to garner available business expansion resources.

To tap the resources and capabilities of the entire region, particularly the private sector, the Proof of Concept Center will embrace a distributive approach with the Center being located in the City of Salem. This location offers the closest location to the Salem River Test Bed and equidistance from Rowan University and the SJEDD. To fully engage the Maritime industry, particularly the boat builders/ fiberglass fabricators, satellite offices will be established in Millville and Egg Harbor City. It is the intent of this proposal to establish this consortium as a best practices model within a rural setting.

Research & Development Continuum (RDC):

Southern New Jersey excels in the understanding of complex marine issues, including reliability and product capabilities. The EPA continuum model (Research and proof-of-concept -> Development -> Demonstration -> Verification -> Commercialization -> Utilization) has morphed slightly for our purposes to engage private sector expertise early to assure the soundness of the design and efficiency in production. That is, we will engage the private partner starting from the beginning with the research and proof-of-concept and continue with each step. This will ensure that products achieve the price points necessary to produce sales at volumes that achieve profitably without subsidies. For example, we will choose the material that is already commonly used in our industrial partners, select components that are familiar to the workers of the plants, and develop the manufacturing process that will utilize the existing machinery. Although southern New Jersey has had only a decade in the evolutionary process of a university based innovation process, the pace has accelerated in recent years. Rowan University along with the Aviation and Homeland Security Federal Laboratories have brought national attention to our technical capabilities. Just outside the immediate location are Drexel, Princeton and NJIT Universities. All of these institutions have research and development premier scientific acumen to tackle the most difficult obstacles we currently face.

However, as our scientific assets begin to fully develop, we understand and recognize that there are areas such as venture capital that must be identified and actively engaged to realize our true potential in the "tech sector". Our focus on the catalysts of the continuum and their strategic importance to the success of this initiative will be carefully assessed and will be an early priority in the ICTC process. As an initial step in supporting our entrepreneurs and innovators, the SJEDD has engaged the Small Business Development Center of Stockton College to provide technical support. The SJEDD Board of Directors has also authorized modification to its Revolving Loan Fund Program to allow financial support for start-up businesses that will encourage entrepreneurial activity and innovation. Our central location within the northeast corridor will further enhance our ability to capture these key resources.

Finally, well established processes and experienced professionals that understand and respect an Intellectual Property (IP) framework is essential. Rowan University has an established IP agreement. In addition, we have discussed and are prepared to engage the Rutgers EDA affiliated University Center to coordinate "Alliances" that allows for the licensing of IP to accelerate the commercialization component of the RDC.

Private Investment / Job Creation:

The strategy adopted by the co-applicants and their partners in this proposal is to move the most efficient and effective technology to the marketplace quickly at the lowest possible price. Far too often useful technologies take too long to get to the market place and production issues and pricing strategies are not carefully considered at the early stage. This proposal thoughtfully considers these issues from the onset. A critical path is designed to assure that the continuum moves forward expeditiously. While the marketplace is subject to change, the longer the time within the continuum the greater the risk that production, pricing or promotion will not achieve alignment with the market. This proposal is designed to limit that risk by focusing on research, assuring the production and workforce readiness capabilities and developing a pricing strategy that is a compelling value. The most effective method to achieve this is to engage the private sector early in the process and allow them to deploy their capital in an efficient way.

Additional metrics to benchmark progress will include the growth in membership of the ICTC, new business start-up, technology oriented jobs in renewable energy, application for SBIR funding, patent application, new product introduction, and university and college enrollment in STEM disciplines. SJEDD seed loans issued will provide the metric to measure program success as well.

Implementation Schedule:

The strategy of this project is intended to be executed over a two year period with a thoughtfully prepared budget designed to meet the economic objectives of the region.

The SJEDD strategic approach and long term growth plan for this effort establishes several key milestones:

Years 1-2: Complete Proof of Concept process, field test and verification (Refer to Gantt Chart depicted in **Table 1**).

Year 3: Marketing, Value proposition to potential users through the publication of performance data, initial utilization of existing production capacity.

Year 4: Broader market outreach, full utilization of regional production capacity.

Year 5: Global marketing outreach, executions of technology IP licensing agreements, new production capacity brought online and additional capacity being planned.

Years 1-5: ICTC grows in membership, expands research capabilities, mobilizes and coordinates existing resources and captures new resources including early stage venture capital and global channels of distribution.

Best Practices:

The merits of this proposal are not just the effectiveness to commercialize new technologies, reinvent an industry, or create new jobs and private investment, but the opportunity to apply this model across a wide spectrum of industries and technologies with similar success. The boat building and composite material industry in the southern New Jersey region alone has lost well over 1200 jobs in the last economic downturn. It is believed that by funding this proof of concept we can regain the jobs and surpass the peak employment level in this industry, significantly add to our renewable energy capabilities and reduce our carbon footprint. We also believe that this model can be deployed in similar situations with corresponding positive outcomes.

Experience:

Rowan University and the South Jersey Economic Development District have joined together on a number of projects that build economic strength and diversification through innovation. Each organization brings unique talents to the project. Rowan University excels with its multidisciplinary electrical, mechanical and civil engineering acumen and the South Jersey Economic Development District's expertise in planning and implementing economic development strategies to spur new private investment and create new highly skilled well paying jobs. In addition, each of these organizations has and continues to operate within a research environment. Rowan at its University Research Park in Glassboro, New Jersey and the SJEDD innovation and collaboration efforts at the Next Generation Aviation Research Park in Pomona, New Jersey.