Diya

Improving literacy through innovation.

Giving light to improve children's education in rural villages of India without access to consistent electricity.

California State University, Chico

College of Business

College of Engineering, Computer Science, and Construction Management

For submission to Collegiate Wind Competition 2016

May 1, 2016

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Executive Summary

Company

Diya is a United States-based nonprofit organization that works to improve the way of life in rural communities by providing a clean and sustainable energy source independent of existing electrical grids. We offer an off-grid wind turbine that generates environmentally friendly energy to power lights in rural schools where they do not have a readily available source of electricity. Our initial market will focus on schools in northern India, specifically the states of Uttar Pradesh and West Bengal. Our organization believes in being socially responsible and is committed to being pro-sustainability in all of our efforts.

Problem

The inconsistent electricity problem in India is exemplified by this statistic:

36% of the total households receive at least 20 hours of electrical access, 30% receive less than 12 hours, 23% receive less than 8 hours, and 11% have less than 4 hours of supply every day.[1]

The electrical infrastructure in India is currently insufficient at supplying its population with access to electricity. There are 1.3 million schools in India and about 550,000 do not have access to electricity. India is ranked 5th in the world for wind energy capacity.[2] Currently producing 23.4 GW of wind energy, they have the potential to produce 302 GW of wind energy.[3]

Solution

Diya will provide off-grid wind turbines to power lights in the schools of India to help further children's education. The electricity we provide extends study hours, facilitates learning in the classroom, enhances staff retention and training, and increases attendance rates, completion rates and test scores. Additionally, providing electricity to schools can improve the quality of life in the community by improved sanitation, health, gender empowerment, and community resilience. India was chosen for the wind speeds, population, and lack of an effective power grid available. For many rural villages experience inconsistent electricity access; depending on the area, some only have power for two hours out of the day.

Target Market

We will partner with nonprofit organizations, such as Asha for Education, based in the United States and focuses on funding education-related development efforts in India. When we obtain funding for our initial fundraising efforts, Asha has agreed to assist us in fundraising for our wind turbines by soliciting their members. Asha's schools, that are educating underprivileged children in India, will be our beachhead market for our first stage of product launch. Once we have powered Asha's schools, we will then move on to powering nearby villages. We will do this with the help of the non-profit organization

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[1] http://www.vasudha-foundation.org/wp-content/uploads/2)%20Reader%20Friendly%20Paper%20for%20USO_Status%20of%20Rural%20electrification%20status%20in%20India.pdf

[2] http://www.inwea.org/

[3] http://cleantechnica.com/2015/09/07/indias-wind-energy-potential-upgraded-302-gw/

ActionAid, who are located in India. They have agreed to help us with our marketing efforts to reach these rural villages they are currently working to (em)power.

Product

Diya's design is a towered wind turbine that charges a 12-V battery bank with sufficient energy storage for two days of windless output. The DIYA 700 is a 3-bladed, downwind, diffuser-augmented wind turbine (DAWT) designed to exploit low wind regimes in rural and remote areas. The aerodynamically efficient 3-bladed rotor minimizes tower oscillation and blade length. The downwind configuration and lens brim allow the system to yaw passively and eliminates the possibility of tower strike. The wind lens was designed based on research that improves efficiency while reducing tip noise for a given rotor size. This particular low-profile design reduces the added cost and weight issues associated with shrouded designs. The wind lens also allows the turbine to take advantage of low wind speeds, giving rise to lower cut-in wind speeds and relatively low hub height while the direct drive design minimizes the number of moving parts and overall parts count.

Business Model

Diya's competitive advantage and overall business model leverages various strategic partners both in the United States and in India. We will fundraise in the United States with our partner Asha and other nonprofits to fund our turbines. We use manufacturers in India to supply the parts and components needed, then our installation team in India will assemble and install, utilizing our partner Mix Mat's concrete mat mixers. We will coordinate with our nonprofit partners in India, Asha and ActionAid. We will also incorporate our partner KidWind and their curriculum on wind energy into the schools with our turbines.

Table 1: Financial Snapshot

	Year 1	**Year 2**	**Year 3**
Sales	$364,000	$966,00	$1,449,000
COGS	$24,000	$186,000	$279,000
Gross Profit	$339,200	$780,000	$1,170,000
Gross Profit %	93%	81%	81%
Total Operating Expenses	$21,516	$45,494	$55,125
Net Income	$209,522	$595,522	$881,745

Business Plan

Business Overview

General Company Description

The word "diya" is a type of Indian lamp and when the word is translated from Hindi into English, it means "to give." This is exactly our mission: to give light. Our company, Diya, uses wind turbines to provide sustainable electricity to people who do not have access to a power grid. Our primary goal is to provide light that will allow children to improve their education by being able to read and write when they otherwise would not have been able to do so without proper lighting.

India is ranked 5th in the world for wind energy capacity.[4] Currently producing 23.4 GW of wind energy, they have the potential to produce 302 GW of wind energy.[5] We plan to take advantage of this potential with our wind turbines.

Our team is a diverse group committed to finding the best way to make, market, and sell wind turbines for the benefit of our customers. We are social entrepreneurs helping developing countries improve their children's education. Diya's wind turbines have been designed by a team of engineers from CSU, Chico to be effective and efficient in rural off grid communities of India. The turbines will provide adequate amounts of clean and sustainable energy for the lighting of schools.

Strategic Partners

This is the first group of partners that we are working with to provide our turbines to the rural schools of India.

Asha for Education[6]

Asha for Education is a secular organization dedicated to change in India by focusing on basic education in the belief that education is a critical requisite for socio-economic change. The volunteers of Asha are involved with and support projects that are secular and have an education-related component to them. The objectives of this group are:

- To provide education to underprivileged children in India.
- To encourage the formation of various local groups across the world to reach out to larger sections of the population.
- To support and cooperate with persons and groups already engaged in similar activities.
- To raise the required human and other resources to achieve the group objectives.
- To provide opportunities to individuals living outside India who wish to participate in Asha activities in India.
- To address, whenever possible, other issues affecting human life such as health care, environment, socio-economic aspects and women's issues.

Asha is a critical partner for us since they are our initial funding source and the ones providing our initial turbine locations. We will be raising funds through Asha's chapters in America to provide our turbines at the school's they have built in India. This is a great way for us to start our business because it provides our initial funds and it gives us our stepping stone into India. Once we have powered as many of Asha's schools as we can, we will then have the experience needed to move on to other schools or villages in these areas.

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[4] http://www.inwea.org/

[5] http://cleantechnica.com/2015/09/07/indias-wind-energy-potential-upgraded-302-gw/

[6] http://new.ashanet.org/about/

ActionAid[7]

ActionAid focuses on the people that others forget. People in poverty. People who face discrimination. People whose voices are ignored. ActionAid helps people fight for the rights that they are denied. Simple things, like the right to eat. The right to stay on their land. To an education. To have a say in the decisions that shape their lives. ActionAid isn't about giving handouts or telling people what to do, because in the long run they know that doesn't work. Instead, they use their resources, influence and experience to help people find their own solutions. ActionAid listens to what people really want and need, by helping communities take action together to hold their governments to account, and give local organizations support where they need it to make a lasting difference together.

ActionAid is an amazing partner for us to have, especially for when we want to start lighting up villages. Since ActionAid is currently located throughout India, they already know all about our end users. This is critical for us because being all the way over in America makes it hard to understand their needs and wants. Partnering with ActionAid will greatly improve our access to customers and marketing efforts in India.

KidWind[8]

KidWind has been helping students and teachers learn and explore wind energy for 15 years. KidWind is a hands-on and interdisciplinary wind energy curriculum that prepares students for careers in science, technology and engineering.

We will be partnering with KidWind to supply children with wind energy curriculum at the schools we provide wind turbines for. This will be an amazing chance to show the children how their school lights are being powered and to spark their interest at a young age in renewable energies.

Mix Mat[9]

Mix Mat is a concrete mixing tool that has recently partnered with Next Step Ministries and is sending Mix Mats to be used on location at mission sites around the world dedicated to building and rebuilding the communities of those in need and that have been affected by disaster. Their mission is to to provide an affordable yet indispensable tool to the people on the ground trying to help and also have them be left for the locals to continue using so that they may continue to improve and upkeep their infrastructures.

We have Alex Van Dewark, the CEO of Mix Mat on our team. We will be utilizing this resource by partnering with his company to provide a more effortless ease for our turbine installations.

Products and Services

Diya provides light to children who have a right to an education that is not impeded by the lack of basic necessities such as light. The light provided allows children to spend more time studying. Diya turbines harvest 700 W of energy from the wind to charge 12 kW batteries that power the lights of a school.

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[7] http://www.actionaid.org/what-we-do

[8] http://www.kidwind.org/#!about/o3lp1

[9] http://www.vandewarkconstruction.com/mix-mat-news/

The climate in Northeastern India is generally windy and cloudy. This provides optimal condition to store wind energy and can be more efficient than solar panels. Our turbine was designed to provide clean and sustainable energy at the average wind speeds for the area.

We will initially raise money to provide our wind turbines to rural schools without electricity. We will also be incorporating KidWind curriculum at these schools to educate students about wind energy. We plan on working with NGO's to first target these schools and then expand out to provide power to as many people as possible. This will be done by a small marketing and sales team within the region as well as partnerships with local NGOs.

Figure 1: Product Concept

The production of our turbines will be outsourced to Indian manufacturers to save on costs. First, the importation of our wind turbines from the United States would be more costly due to the tariff on imports. Second, the Indian Government provides subsidies and tax incentives for employing Indian workers. The workers will be accompanied by the engineers developing the wind turbines and can provide their expertise for future development and expansion.

Market Opportunity

Overview

An excerpt from the Washington Post about a rural farmer in India that shows the emotional tie to the availability of electricity:

[This Solar lamp] belongs to the family of Satish Paswan, 35, a farmer who sold a bit of his family's land to purchase a solar panel and light a few months ago for about $88. He wanted his five children to be able to do their homework. "We feel very ashamed and bad that other neighboring villages are enjoying power facilities and we don't have it. Whenever a small leader or a big leader belonging to the ruling party comes here, they promise their first priority is to provide electricity to the villages. But they have never fulfilled that promise." [10]

The electricity market in India is currently insufficient in supplying residents with their energy needs. There are 1.3 billion people worldwide who live without electricity and 300 million of them live in India.[11] In the rural villages of Northeast India, electricity is not constant; people only get electricity a few hours out of the day. Our product will provide schools with a dependable source of electricity separate from the power grid. Access to electricity will improve the quality of children's education and lives. The light we provide will allow children more time to learn and be taught which will increase literacy and improve school completion rates.

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[10] https://www.washingtonpost.com/world/asia_pacific/indias-huge-need-for-electricity-is-a-problem-for-the-planet/2015/11/06/a9e004e6-622d-11e5-8475-781cc9851652_story.html

[11] https://www.washingtonpost.com/world/asia_pacific/indias-huge-need-for-electricity-is-a-problem-for-the-planet/2015/11/06/a9e004e6-622d-11e5-8475-781cc9851652_story.html

The region of Northeast India experiences frequent wind that is ideal for our wind turbines. "The main advantage of wind [turbine] is that they can produce electricity day or night as long as there is wind."[12] Since wind turbines are capable of producing energy twenty-four hours a day, they can be more efficient than solar panels that produce energy only in the sunlight.

Manufacturing the wind turbines in India will help lower our production costs and allow us to provide a reliable energy source to our end users at an affordable price. By manufacturing in India we will avoid high tariff costs and will be granted government subsidies for providing jobs to the locals as well as producing renewable energy. We will also partner with nonprofit organizations, like ActionAid and Asha for Education, to be able to better reach and connect with our end users. Our partnerships will be based on our common goals of helping these rural villagers of India.

The Indian government is concentrating on solving the electricity shortage in larger cities by diverting and transmitting electricity from other parts of the country. The cost of tying these rural communities into the power grid exceeds the possible benefit for the Indian government. This is where our off-grid application will come in for a solution to power these remote rural areas in need of electricity.

Overview of Target Customer

We are targeting the 57% of people in Uttar Pradesh and 41% of people in West Bengal without access to electricity.[13] We have chosen to prove our concept with four targeted schools through our funding partner Asha's current projects. We will be receiving donations from members of Asha to fund our turbines in these school's Asha has built in India to improve education. Our beachhead sites will include: Project- Gramya Sansthan, located in Varanasi District, Uttar Pradesh. Project- Voluntary Association for Rural Upliftment and Networking-VARUN, located in Varanasi District, Uttar Pradesh. Project- Society for Women in Rural Development, located in Medinipur District, West Bengal. Project- Kaorakhali Jana Sevashram, located in South Twenty Four Parganas District, West Bengal. Once we have proved our concept and worked out all the logistics with these four projects, we will then move on to doing the same for other schools throughout the country.

Once we have built a name for ourselves in these areas, we will start marketing to nearby villages that would like to have power in their homes. These states are made up of thousands of villages with around 50-150 families in each village with an average family size of 5 people. Usually the earning member of the family is male and makes the big buying decisions. The females usually make more of the small buying decisions, but they also usually influence the male's decisions. Access to electricity will improve their quality of life immediately, and improving children's education will be exponentially beneficial to their futures.

India has a Castes system that segregates people and is still used in rural areas. The first class is Brahmin, which consists of academics and the Gramini (village leader), which are the people that will actually make decisions for the village. The second class is Kshatryia, which is the military of which 80% of its members come from rural areas and will not likely be in the village. The third class is Vaishya, consisting of farmers, merchants, and landowners, which have some influence on village decisions. The lowest classes are the Sudra and Untouchables, who are servants or outcasts that do the dirty work for villages

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[12] http://gogreeninyourhome.com/how-to-save-electricity/solar-power-vs-wind-power-pros-and-cons/

[13] http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/11/03/000333037_20141103235403/Rendered/PDF/922230PUB0978100Box385358B00PUBLIC0.pdf

and are not respected and will not be targeted because they lack money or village influence.[14] Due to this structure, we will be focusing our marketing strategy around the Brahmin, especially the Gramini, because of their significant influence within the villages.

There are advisors to the Gramini who facilitate 1-2 village meetings per month. This is where they discuss the village issues and solve their problems and can act like a court for small disputes. There are village newspapers, some televisions, and usually weekly village events such as watching a movie together.

There is a person in every village that in charge of the electricity for the village, but because they are the government's people they are not always fair and would not be interested in buying our wind turbine charging station. In order to reach our target customers we need to work with nonprofit organizations also working to help Northeast Indian rural villages. This will increase our chances of success because their goals align with ours. We both want to help better these communities and their knowledge and resources will be helpful in our marketing efforts. ActionAid is a perfect partner for us as they are: "...an international organization, working with over 15 million people in 45 countries for a world free from poverty and injustice."[15]

Business Goals

Our goal is to give light to improve children's literacy rate. In graph below, the relationship between electricity and education. The graph shows that when less than 80% of the population has access to electricity the completion rate of primary school decrease.

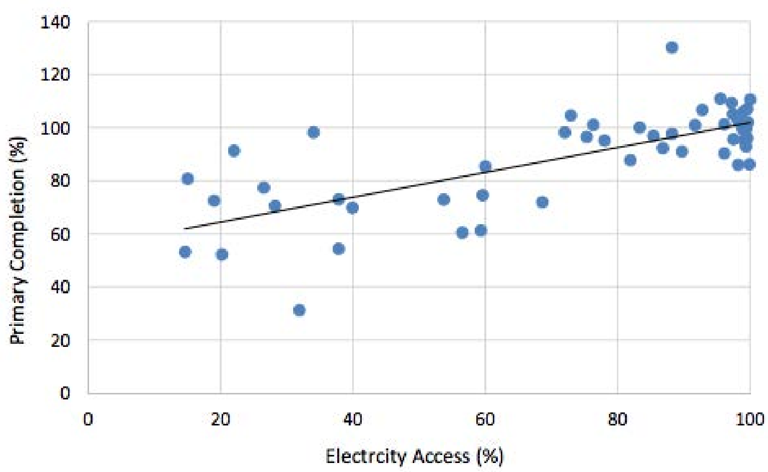

Figure 2: Electrification rate (% of population) and primary school completion rate, total (%) for 56 developing countries, 2012:

In the first year of sales, we will work with Asha to provide 4 of our Indian-made, off-grid wind turbines to schools in the states of Uttar Pradesh and West Bengal. The following year our goal is to sell wind turbines with Asha and ActionAid to power 50 schools across the country. We will also be working towards connecting with at least two new NGOs and nonprofit organizations each year.

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[14] https://i.ytimg.com/vi/Uihw0hFUXho/maxresdefault.jpg

[15] http://www.actionaid.org/who-we-are

Strategies and Tactics

Our marketing strategy is to market towards nonprofits that will in turn connect us with the end user. The Internet is used by nearly 15.1% of India's population, which are primarily those located within the larger cities such as Delhi. This means it would be difficult to reach our audience through the use of digital media. Therefore, the nonprofits are the target because of the lack of resources to reach the villages directly.

We will work with ActionAid, a local non-profit organization in India, in order to reach our customers. Our partnership will allow us to use their resources to design our marketing campaigns as well as gathering information on the region. Due to the high cost of importing, we will be establishing our turbine production in India to give us access to their workforce, reduce production costs, and reduce transportation costs.

Budget

Our marketing budget consists of a paid marketer and materials such as brochures and our website. We will have a paid member that will be paid a yearly salary $36,000, with paid travel expenses, that will connect with nonprofit organizations to fundraise and work with schools to install our turbines. During our first ten months of fundraising, we will be aiming to reach at least two a month of other nonprofit organizations outside of our Asha to expand our funding. A list of the organizations we will initially contact is in the appendices.

Table 2: Year One Marketing Costs

Salary	$36,000
Travel Expenses	$2,400
Brochures	$50
Website	$120
Total	$38,570

Management Team

Diya brings a variety of skill sets to manage our nonprofit business from the United States and India. Our business team will partner with nonprofits located in the United States working to help people in India as a funding source. One of these organizations will be Asha, who focuses on empowerment, education, and environmental improvements for people in India. Asha has supported more than 400 different projects spanning 24 states in India. In terms of project funding, almost $32.3 million has been disbursed to these projects since Asha's inception. Diya will also partner with nonprofits located in India working to help people in India for marketing access. One of these organizations will be ActionAid, who focuses on helping communities in poverty to make a difference. In 2014 ActionAid received $5,986,835 in funding for their projects.

Our technical team will be located in the United States to work on the design of our wind turbine charging stations. Our manufacturing and deployment teams will be located in India to avoid importation fees and to be closer to our targeted rural villages with limited electricity in Uttar Pradesh and West Bengal.

Professional and Advisory Support

Board of Directors

Aditya Joshi- India Research

Aditya has worked in the field of sustainable energy with KPIT Technologies in India. He was the co-founder of AMJ Devs before the company was dissolved in 2013. He is currently on the board of directors of M.J Healthcare Pvt Ltd in India. He has experience in managing projects and has several contacts in India which have proved beneficial for Diya. He holds a Bachelor's degree in Computer Science and is currently pursuing a Master's degree in the same field from CSU, Chico.

PJ Shepard- Wind Industry

PJ Shepard has over 20 years of experience in the medical device industry from the university laboratory setting to project management and product marketing. She has participated in writing grant applications for electric vehicle charging systems as well as geothermal, solar and airborne wind energy projects. On behalf of the Airborne Wind Energy Consortium she continues to share promotion efforts for this new renewable energy sector. She has worked in the public, private and nonprofit sectors focused on human and animal health and quality of life. Ms. Shepard holds a B.S. in Plant Science from UC Davis with Highest Honors, and an A.S. in Electronic Engineering Technology from Heald Engineering College, San Francisco. PJis highly committed to energy innovation, improving health care related outcomes and the health of our planet pertaining to water, food and energy supplies.

Marc Nemanic- Renewable Industry

Marc Nemanic has over 24 years' experience managing economic development organizations and small business financing programs, serves on the board of California Association for Microenterprise Opportunity (statewide micro-business network made up of over 170 organizations, agencies, and individuals) and is President of the California Financing Collaborative (CFC – a multi-agency capital access corporation including 22- Northern California counties). As the Executive Director, Marc guides the overall organizational and program direction, leads strategic and business planning, drives fundraising and capitalization efforts and manages investor relations.

Todd Amdor- Legal

Todd Amdor advises domestic and international business clients on corporate governance issues, mergers, acquisitions, asset sales, start-up financings, and complex commercial transactions under the Texan, Californian and English legal systems. His clients include public and privately held corporate entities, including both emerging companies and Fortune 500 entities in the energy and technology industries.

Executive Director

Karola Grant- Has been Diya's dedicated project manager from the beginning, making sure all aspects of the business are in coordination.

Advisory Board Members

Sandeep Chachra- ActionAid

Executive Director of ActionAid India. Has a Master's degree in Social Anthropology and is actively involved in nonprofit leadership.

Girish Joshi- Asha

Involved in fundraising for Asha. Has a Master's degree in Electrical Engineering and has achieved success in a career of technology and sales.

Faculty Board Members

Colleen Robb- Entrepreneurship

Dr. Colleen Robb is an internationally recognized researcher in the area of strategy and social entrepreneurship, specifically examining how social ventures can maintain advantage in the marketplace. Dr. Robb currently serves as an assistant professor of entrepreneurship for California State University, Chico (CSUC). She has over fifteen years of experience in the nonprofit sector in various roles for organizations such as MedShare International, the University of Cincinnati, and Best Buddies International.Dr. Robb holds a B.F.A. and M.B.A. from Florida International University and a Doctorate of Economics and Business Administration from Abo Akademi University in Finland.

David Alexander- Engineering

Dr. Alexander has 10 years of industry work experience most of which as CEO of IVUS Energy Innovations – a technology start-up company that he and three partners formed around unique fast changing technology. As CEO, he raised over $2 million in equity financing, secured a worldwide license agreement, and managed the commercialization and launch of the industry's first 90-second rechargeable flashlight. In addition he is co-inventor on four U.S. patents and has presented numerous times at advanced energy technology conferences in the areas of business and technology development.

Business Team

Aubrey Connors- Marketing Manager, AA Behavioral and Social Science. Experience with activity coordination and sales.

Thomas Morcate- Technical Design Manager, AA Environmental Studies. Experienced in science, development, and design.

Troy Carter- Human Resource Manager, AA Behavioral and Social Science. Experienced in management Use knowledge and skills to maintain a capable and efficient workforce.

Kyle McDade- Financial Manager, experience in managing lump sums of monetary resources through the process of raw goods to finished products.

Alex Van Dewark- Operations Manager, experience in construction and overseas operations. CEO of our partner Mix Mat.

Technical\Design Team

Angelina Teel Jonson, Henry Sanchez, Jorge Alvarado, Darrell Sinclair, Yahya Al Maqboul

Deployment Team

Devon Burton, Haley Kennedy, Jorge Alvarado, Yuanyuan Ju

Development and Operations

Production

Our turbines will be assembled on-site from outsourced, custom-made parts, initially. As "sales" increase, assembly will be started in a warehouse and completed on-site. We are looking to have our wind turbines produced by a manufacturer near the city of Kanpur, Uttar Pradesh. Kanpur is the commercial capital of Uttar Pradesh and in a strategic location that will allow us to produce and distribute our product to schools located in Northeast India with low shipping and transportation costs.

Location

Year 1: The production of the turbine parts will be outsourced to Indian manufacturing companies and assembled on-site to be able to adapt to worksite changes.

Year 2: We will have a warehouse in India to store our turbine parts in. Operation will be based in the commercial capital Kanpur, Uttar Pradesh to be close to our northeast rural villages.

Cost Estimates:[16]

- 1,07,000 rupees (~$1,600) a month for renting a 12,000 sq ft warehouse in Kanpur[17]
- 15,000 rupees (~$220) a month for maintenance
- 1,00,000 rupees (~$1,500) for the security deposit
- 17,945 rupees (~$270) a month for utilities
- 68,150 rupees (~$1,020) a month for 10 unskilled workers
- 16,794 rupees (~$252) a month for 2 skilled workers

Legal Environment

According to Ebiz.gov:

"Our next step after licensing would be checking the zoning of potential factory locations. Entering into the market from a foreign vantage point would be favorable because the country is pushing for more industry."[18]

Once the business has been established in India, the next step would be establishing a work force and maintaining the legal foundation of our factory.

Personnel

In the first year we are employing 5 people as Production Team Members and 1 person as a Turbine Technician. We're adding a new team each year to keep up with production. The manufacturing labor will be make up our general workforce that will produce the turbines. Our managers will supervise production as well as maintaining the workforce. The technicians will be trained in installation and calibration of the turbines in the rural communities as well as be able to service the turbines upon request.

All employees will be compensated by the industry standard with the ability of earning performance-based wage increases.[19] Production Team Members will earn Rs 6,815 per month performing unskilled labor. Production Managers will be compensated Rs 7,496 for their semi-skilled work. Turbine Technicians will be compensated Rs 8,397 for their skilled work.

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[16] http://www.coned.com/customercentral/calculators/EC_bus_Calc.html

[17] http://www.magicbricks.com/property-for-rent/commercial-real-estate?proptype=Commercial-Shop,Commercial-Showroom,Warehouse-Godown,Industrial-Building&cityName=Kanpur&Keyword=uttar%20pradesh,india&price=Y

[18] https://www.ebiz.gov.in/industriallicense

[19] http://www.paycheck.in/main/salary/minimumwages/uttar-pradesh/minimum-wage-in-uttar-pradesh-with-effect-from-october-1-2015

Inventory

We will need to carry raw materials such as metals and electrical components for our wind turbine business. The main component of our turbine would be steel due to its strength and weight. We will also need turbine blades, a shroud, and battery. After purchasing the material, we will store it in our warehouse for manufacturing our turbines. We will also need concrete to be mixed on site with our Mix Mat's.

Suppliers

We will source out some of the components of our product to keep start up and manufacturing costs as low as possible. With over 30 manufacturers who supply wind turbines and components in India, there is potential for multiple supplier relationships.[20] DREDO (Digitech Renewable Energy Development Organisation) is located in Mysore, Kamataka India and concentrates on manufacturing renewable energy equipment and technologies. They produce micro wind turbines, wind inverters, and wind generators in sizes from 100 watts to 10,000 watts. Luminous Renewable Energy Solutions is located in Pune, Maharashtra India and produces micro turbines that generate from 1 to 4.5 kW. Both of these manufacturers in the country supply components that would be useful for outsourcing in the production and assembly of our wind turbines.

Sales Policies

One of the challenges we face is the lack of disposable income in our target market. The per capita monthly income for Uttar Pradesh is around 3,360 Indian rupees or 50 U.S. dollars.[21] Electricity costs 4.99 rs/kWh in Uttar Pradesh.[22] The average electricity consumption in India is 200 to 300 kWh a month. At 250 kWhs this costs the consumer US$18.71 per month in Uttar Pradesh. This is why we chose to be a nonprofit organization. We plan on raising funds in the Unites States to provide our product to the end users.

Financial Analysis

Startup Expenses

We have listed the initial startup costs that we will need to start operations on day one. This includes everything we need for the marketing manager to travel to the chapters of the partner organizations for fundraising the installation of the turbines. This also includes the accounting and legal services we will be needing to launch our nonprofit.

Table 3: Startup Expenses

Marketing

Marketing Manager	$36,000
Website	$120

20 http://energy.sourceguides.com/businesses/byGeo/byC/India/byP/wRP/swindturbine/byB/manufacturers/manufacturers.shtml

21 http://pib.nic.in/newsite/PrintRelease.aspx?relid=123563

22 http://www.indianpowermarket.com/2012/10/short-term-power-market-prices-and.html

Brochures	$50
Travel Expenses	$2,400
Total	= $38,570

Professional Services (Located in India)

Accounting	$5,996[23]
Legal	$3,372
Total	= $9,368

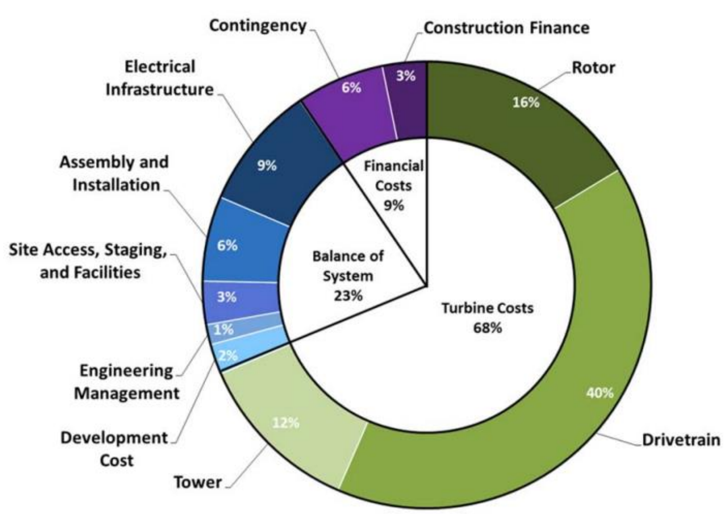
Total Startup Expenses **= $47,938**

Financial Assumptions

- Secure contract with Asha by end of 2016
- Secure contract with ActionAid by end of 2016
- Secure contract with manufacturers in India by end of 2016
- Secure contracts with two to three NGOs in U.S. yearly
- Secure 4 schools by the end of first year
- Secure 30 schools by the end of second year
- Secure 45 schools by the end of third year
- Raise $100,000 in the first year

Expense Assumptions

- Raise salaries 2% annually, Health benefits 10%, and Payroll tax 8%
- Increase repairs & maintenance by 5%
- Printing/postage increase 15%
- Office rent increase by 5%
- Bank Service charges increase by 12% per year



[23] http://www.payscale.com/research/IN/Job=Chartered_Accountant/Salary

Figure 3: Capital Expenditures for the Land-Based Wind Plan Reference Project

Appendices

Income Statements

Table 4: Income Statement Year 1

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Annual Totals
Revenue													
Turbines	-	-	-	-	-	-	-	-	-	-	14,000	14,000	**$ 28,000**
Donations	21,000	21,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	35,000	35,000	**$ 336,000**
Total Revenue	**$ 21,000**	**$ 21,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 49,000**	**$ 49,000**	**$ 364,000**
Cost of Goods Sold													
Turbines	-	-	-	-	-	-	-	-	-	-	12,400	12,400	**$ 24,800**
Donations	-	-	-	-	-	-	-	-	-	-	-	-	**$ -**
Total Cost of Goods Sold	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 12,400**	**$ 12,400**	**$ 24,800**
Gross Margin	**$ 21,000**	**$ 21,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 36,600**	**$ 36,600**	**$ 339,200**
Payroll	**$ 7,540**	**$ 7,540**	**$ 7,540**	**$ 7,540**	**$ 7,540**	**$ 7,540**	**$ 7,540**	**$ 7,540**	**$ 7,540**	**$ 7,540**	**$ 8,267**	**$ 8,267**	**$ 91,931**
Operating Expenses													
Car and Truck Expenses	-	-	-	-	-	-	-	-	-	-	3,148	-	**$ 3,148**
Legal and Professional Services	9,368	-	-	-	-	-	-	-	-	-	-	-	**$ 9,368**
Rent or Lease -- Other Business Property	-	-	-	-	-	-	-	-	-	-	1,600	1,600	**$ 3,200**
Travel, Meals and Entertainment	400	400	400	400	400	400	400	400	400	400	400	400	**$ 4,800**
Utilities	-	-	-	-	-	-	-	-	-	-	500	500	**$ 1,000**
Total Operating Expenses	**$ 9,768**	**$ 400**	**$ 400**	**$ 400**	**$ 400**	**$ 400**	**$ 400**	**$ 400**	**$ 400**	**$ 400**	**$ 5,648**	**$ 2,500**	**$ 21,516**
Income (Before Other Expenses)	**$ 3,692**	**$ 13,060**	**$ 20,060**	**$ 20,060**	**$ 20,060**	**$ 20,060**	**$ 20,060**	**$ 20,060**	**$ 20,060**	**$ 20,060**	**$ 22,685**	**$ 25,833**	**$ 225,753**
Other Expenses													
Amortized Start-up Expenses	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	**$ 15,979**
Depreciation	-	-	-	-	-	-	-	-	-	-	116	135	**$ 251**
Total Other Expenses	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,448	1,467	**$ 16,231**
Net Income Before Income Tax	**$ 2,361**	**$ 11,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 21,237**	**$ 24,366**	**$ 209,522**
Income Tax	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	**$ -**
Net Profit/Loss	**$ 2,361**	**$ 11,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 18,729**	**$ 21,237**	**$ 24,366**	**$ 209,522**

Table 5: Income Statement Years 1-3

Revenue	First Year		Second Year		Third Year	
Turbines	28,000		210,000		315,000	
Donations	336,000		756,000		1,134,000	
Total Revenue	**$ 364,000**	**100%**	**$ 966,000**	**100%**	**$ 1,449,000**	**100%**
Cost of Goods Sold						
Turbines	24,800		186,000		279,000	
Donations	-		-		-	
Total Cost of Goods Sold	**24,800**	**7%**	**186,000**	**19%**	**279,000**	**19%**
Gross Margin	339,200	**93%**	780,000	**81%**	1,170,000	**81%**
Payroll	91,931		119,911		210,670	
Operating Expenses						
Car and Truck Expenses	3,148		6,296		6,296	
Legal and Professional Services	9,368		9,368		9,368	
Rent or Lease -- Other Business Property	3,200		19,200		19,200	
Travel, Meals and Entertainment	4,800		9,600		19,200	
Utilities	1,000		1,030		1,061	
Total Operating Expenses	**$ 21,516**	**6%**	**$ 45,494**	**5%**	**$ 55,125**	**4%**
Income (Before Other Expenses)	**$ 225,753**	**62%**	**$ 614,595**	**64%**	**$ 904,206**	**62%**
Other Expenses						
Amortized Start-up Expenses	15,979		15,979		15,979	
Depreciation	251		3,450		6,481	
Total Other Expenses	**$ 16,231**	**4%**	**$ 19,429**	**2%**	**$ 22,461**	**2%**
Net Income Before Income Tax	**$ 209,522**		**$ 595,166**		**$ 881,745**	
Income Tax	$ -		$ -		$ -	
Net Income/Loss	**$ 209,522**	**58%**	**$ 595,166**	**62%**	**$ 881,745**	**61%**

Cash Flow Statement

Table 6: Cash Flow Forecast Year 1

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Totals
Beginning Balance	$ 6,430	$ 10,122	$ 23,182	$ 43,243	$ 63,303	$ 83,363	$ 103,423	$ 123,484	$ 143,544	$ 163,604	$ 183,664	$ 210,537	
Cash Inflows													
Cash Sales	21,000	21,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	28,000	49,000	49,000	$ 364,000
Accounts Receivable	-	-	-	-	-	-	-	-	-	-	-	-	$ -
Total Cash Inflows	$ 21,000	$ 21,000	$ 28,000	$ 28,000	$ 28,000	$ 28,000	$ 28,000	$ 28,000	$ 28,000	$ 28,000	$ 49,000	$ 49,000	$ 364,000
Cash Outflows													
Investing Activities													
New Fixed Asset Purchases	-	-	-	-	-	-	-	-	-	-	8,213	1,600	$ 9,813
Cost of Goods Sold	-	-	-	-	-	-	-	-	-	-	-	12,400	$ 12,400
Operating Activities													
Operating Expenses	9,768	400	400	400	400	400	400	400	400	400	5,648	2,500	$ 21,516
Payroll	7,540	7,540	7,540	7,540	7,540	7,540	7,540	7,540	7,540	7,540	8,267	8,267	$ 91,931
Total Cash Outflows	$ 17,308	$ 7,940	$ 7,940	$ 7,940	$ 7,940	$ 7,940	$ 7,940	$ 7,940	$ 7,940	$ 7,940	$ 22,128	$ 24,767	$ 135,660
Net Cash Flows	$ 3,692	$ 13,060	$ 20,060	$ 20,060	$ 20,060	$ 20,060	$ 20,060	$ 20,060	$ 20,060	$ 20,060	$ 26,872	$ 24,233	$ 228,340
Operating Cash Balance	$ 10,122	$ 23,182	$ 43,243	$ 63,303	$ 83,363	$ 103,423	$ 123,484	$ 143,544	$ 163,604	$ 183,664	$ 210,537	$ 234,770	
Ending Cash Balance	$ 10,122	$ 23,182	$ 43,243	$ 63,303	$ 83,363	$ 103,423	$ 123,484	$ 143,544	$ 163,604	$ 183,664	$ 210,537	$ 234,770	

Table 7: Cash Flow Forecast Years 1-3

	Year 1 Totals	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Year 2 Totals
Beginning Balance		$ 234,770	$ 267,974	$ 301,178	$ 350,132	$ 406,086	$ 455,840	$ 505,593	$ 555,347	$ 605,101	$ 654,855	$ 697,609	$ 762,313	
Cash Inflows														
Cash Sales	**$ 364,000**	61,250	61,250	77,000	84,000	84,000	84,000	84,000	84,000	84,000	77,000	92,750	92,750	**$ 966,000**
Total Cash Inflows	**$ 364,000**	$ 61,250	$ 61,250	$ 77,000	$ 84,000	$ 84,000	$ 84,000	$ 84,000	$ 84,000	$ 84,000	$ 77,000	$ 92,750	$ 92,750	**$ 966,000**
Cash Outflows														
Investing Activities														
New Fixed Asset Purchases	**$ 9,813**	1,862	1,862	1,862	1,862	1,862	1,862	1,862	1,862	1,862	1,862	1,862	1,862	**$ 22,348**
Cost of Goods Sold	**$ 12,400**	12,400	12,400	12,400	12,400	18,600	18,600	18,600	18,600	18,600	18,600	12,400	12,400	**$ 186,000**
Operating Activities														
Operating Expenses	**$ 21,516**	3,791	3,791	3,791	3,791	3,791	3,791	3,791	3,791	3,791	3,791	3,791	3,791	**$ 45,494**
Payroll	**$ 91,931**	9,993	9,993	9,993	9,993	9,993	9,993	9,993	9,993	9,993	9,993	9,993	9,993	**$ 119,911**
Total Cash Outflows	**$ 135,660**	$ 28,046	$ 28,046	$ 28,046	$ 28,046	$ 34,246	$ 34,246	$ 34,246	$ 34,246	$ 34,246	$ 34,246	$ 28,046	$ 28,046	**$ 373,753**
Net Cash Flows	**$ 228,340**	$ 33,204	$ 33,204	$ 48,954	$ 55,954	$ 49,754	$ 49,754	$ 49,754	$ 49,754	$ 49,754	$ 42,754	$ 64,704	$ 64,704	**$ 592,247**
Operating Cash Balance		$ 267,974	$ 301,178	$ 350,132	$ 406,086	$ 455,840	$ 505,593	$ 555,347	$ 605,101	$ 654,855	$ 697,609	$ 762,313	$ 827,017	
Ending Cash Balance		$ 267,974	$ 301,178	$ 350,132	$ 406,086	$ 455,840	$ 505,593	$ 555,347	$ 605,101	$ 654,855	$ 697,609	$ 762,313	$ 827,017	

	Year 2 Totals	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Year 3 Totals
Beginning Balance		$ 827,017	$ 882,743	$ 932,268	$ 1,005,418	$ 1,089,069	$ 1,163,419	$ 1,237,770	$ 1,312,120	$ 1,386,471	$ 1,460,821	$ 1,524,672	$ 1,621,447	
Cash Inflows														
Cash Sales	**$ 966,000**	91,875	91,875	115,500	126,000	126,000	126,000	126,000	126,000	126,000	115,500	139,125	139,125	**$ 1,449,000**
Total Cash Inflows	**$ 966,000**	91,875	91,875	115,500	126,000	126,000	126,000	126,000	126,000	126,000	115,500	139,125	139,125	**$ 1,449,000**
Cash Outflows														
Investing Activities														
New Fixed Asset Purchases	**$ 22,348**	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	**$ 19,200**
Cost of Goods Sold	**$ 186,000**	12,400	18,600	18,600	18,600	27,900	27,900	27,900	27,900	27,900	27,900	18,600	18,600	**$ 272,800**
Operating Activities														
Operating Expenses	**$ 45,494**	4,594	4,594	4,594	4,594	4,594	4,594	4,594	4,594	4,594	4,594	4,594	4,594	**$ 55,125**
Payroll	**$ 119,911**	17,556	17,556	17,556	17,556	17,556	17,556	17,556	17,556	17,556	17,556	17,556	17,556	**$ 210,670**
Total Cash Outflows	**$ 373,753**	$ 36,150	$ 42,350	$ 42,350	$ 42,350	$ 51,650	$ 51,650	$ 51,650	$ 51,650	$ 51,650	$ 51,650	$ 42,350	$ 42,350	**$ 557,794**
Net Cash Flows	**$ 592,247**	$ 55,725	$ 49,525	$ 73,150	$ 83,650	$ 74,350	$ 74,350	$ 74,350	$ 74,350	$ 74,350	$ 63,850	$ 96,775	$ 96,775	**$ 891,206**
Operating Cash Balance		$ 882,743	$ 932,268	$ 1,005,418	$ 1,089,069	$ 1,163,419	$ 1,237,770	$ 1,312,120	$ 1,386,471	$ 1,460,821	$ 1,524,672	$ 1,621,447	$ 1,718,223	
Ending Cash Balance		$ 882,743	$ 932,268	$ 1,005,418	$ 1,089,069	$ 1,163,419	$ 1,237,770	$ 1,312,120	$ 1,386,471	$ 1,460,821	$ 1,524,672	$ 1,621,447	$ 1,718,223	

Balance Sheets

Table 8: Balance Sheets Years 1-3

ASSETS	First Year	Second Year	Third Year
Current Assets			
Cash	234,770	827,017	1,718,223
Prepaid Expenses	31,959	15,979	-
Other Initial Costs	-	-	-
Total Current Assets	**$ 266,728**	**$ 842,996**	**$ 1,718,223**
Fixed Assets			
Leasehold Improvements	3,200	22,400	41,600
Equipment	2,742	2,742	2,742
Furniture and Fixtures	723	723	723
Vehicles	3,148	6,296	6,296
Total Fixed Assets	**$ 9,813**	**$ 32,161**	**$ 51,361**
(Less Accumulated Depreciation)	$ 251	$ 3,701	$ 10,182
Total Assets	$ 276,289	$ 871,456	$ 1,759,401
LIABILITIES & EQUITY			
Liabilities			
Accounts Payable	12,400	12,400	18,600
Total Liabilities	**$ 12,400**	**$ 12,400**	**$ 18,600**
Equity			
Common Stock	54,368	54,368	54,368
Retained Earnings	209,522	804,688	1,686,433
Total Equity	**$ 263,890**	**$ 859,056**	**$ 1,740,801**
Total Liabilities and Equity	$ 276,289	$ 871,456	$ 1,759,401

Plans to Contact Other Non-profit Organizations

- American Indian Foundation
- The Asia Foundation
- Give2Asia
- Indians for Collective Action
- UniversalGiving
- Arpan Foundation
- Association for India's Development
- Child Rights and You

- Forgotten Children
- Give Foundation
- ICICI Communities
- Katha
- Mukti
- Parivaar
- SERUDS
- Team for Educational Activities in Motherland
- Bay Area Action Center of Vibha
- Kerala Associations
- Gujarati Associations
- Telugu Associations

Technical Design Report

Design Overview

The DIYA 700 is designed to power LED lighting for off-grid schools in rural areas. The business plan also calls for funding from NPO's in the early stages of development. These constraints call for a design that is not only low cost and durable but easy to manufacture, ship, and assemble on site.

The resulting design is a towered wind turbine that charges a 12-V battery bank with sufficient energy storage for two days of windless output. The DIYA 700 is a 3-bladed, downwind, diffuser-augmented wind turbine (DAWT) designed to exploit low wind regimes in rural and remote areas. The aerodynamically efficient 3-bladed rotor minimizes tower oscillation and blade length. The downwind configuration and lens brim allow the system to yaw passively and eliminates the possibility of tower strike. The wind lens was designed based on research[24] that improves efficiency while reducing tip noise for a given rotor size. This particular low-profile design reduces the added cost and weight issues associated with shrouded designs. The wind lens also allows the turbine to take advantage of low wind speeds, giving rise to lower cut-in wind speeds and relatively low hub height while the direct drive design minimizes the number of moving parts and overall parts count. The size was constrained by: 1) ease of manufacturability, 2) affordability and 2) ability to deploy in areas with limited infrastructure, while still providing adequate power to customers in areas with low wind regimes.

Table 9: DIYA 700 Turbine Design Specifications

Turbine	
Configuration	Shrouded, Three Blade, Horizontal Axis, Downwind
Rated Power (W)	700
Rated Wind Speed (m/s)	9
Rotor Speed (rpm)	600
Survival Wind Speed (m/s)	60
Cut-out Wind Speed (m/s)	25
Cut-in Wind Speed (m/s)	2.5
Overall Weight (kg)	50
Application	Off-grid, Battery Charging Network
Rotor	
Rotor Diameter (m)	2
Swept Area (m^2)	3.14
Blade Length (m)	0.867

[24] Y. Ohya and . T. Karasudani, "A Shrouded Wind Turbine Generating High Output Power with Wind-lens Technology," *Energies,* vol. 2010, no. 3, pp. 634-649, 2010.

Blade Material	Fiberglass Composite
Power Regulation	Stall Control
Generator	
Generator Type	Permanent Magnet Alternator
Configuration	3-phase AC, 60Hz
Brake and Safety Systems	
Main Brake System	Electrical Stall, Generator Terminal Short Circuit
Secondary System	Stall Regulated
Safety Shutdown Triggered by	Safety Switch, High Wind Speeds, Electrical Disconnection, Over rpm
Controls	
Type	Speed Control, Parallel Conversion Load
Turbine MCU	ARM Cortex STM32F103C6.
System User Interface	Programmable Remote Interface
Tower	
Available Hub Heights (m)	9.58
Tower	Monopole Guy Wire Support

Design Development: DIYA 700

Power Production

The DIYA 700 is designed to bring LED lighting to off-grid schools. To develop an appropriate system, the design team calculated the amount of power needed for light and the amount of locally available wind power. Wind density was calculated using a Weibull distribution of wind speeds based on India Meteorological Data (see Deployment Plan). This was used to determine a cutoff rotor size for producing the necessary amount of power for DIYA's initial deployments. To move forward with design a modest coefficient of performance was assumed, Cp = 0.3. This number was later adjusted according to preliminary wind tunnel testing results. The DIYA 700 was designed to capture a wide range of wind speeds with a rated wind speed of 9 m/s while also providing adequate performance in areas with 5.0 m/s wind speed.

Aerodynamic Design

The aerodynamic design consists primarily of the rotor and wind lens. The nacelle was designed to support the aerodynamic performance of these two elements.

Blade Design

DIYA's turbine utilizes the SG6040 and SG6043 airfoils developed by Michael Selig and Phillipe Giguère for use in small wind turbines (1 – 5kW)[25]. The SG6040 is a root airfoil and the SG6043 is a primary airfoil. Both have been wind tunnel tested and exhibit low laminar separation characteristics for low Reynolds numbers. Their recommended design Reynold's numbers were used in the blade optimization analysis. The SG6040 provides a larger thickness to chord ratio for, which lends desirable structure to the root. The SG6043 has high lift to drag characteristics desirable for primary and tip sections.

[25] M. Selig and P. Giguere, "New Airfoils for Small Horizontal Axis Wind Turbines," *Journal of Solar Energy Engineering,* vol. 120, no. 2, pp. 108-114, 1998.

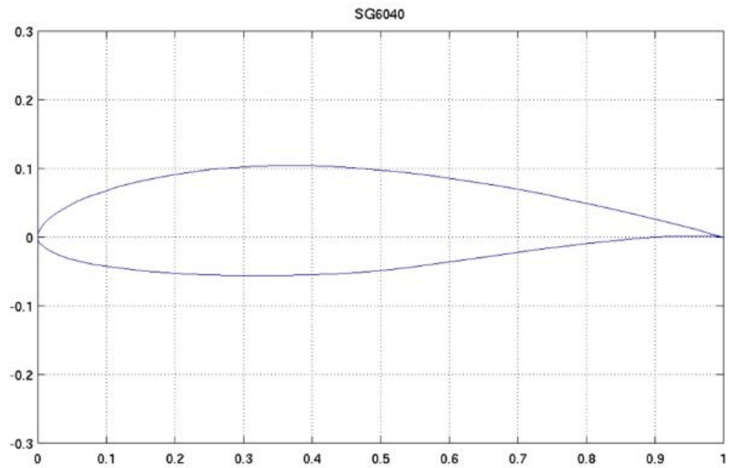


Figure 4: SG6043 Primary and Tip Airfoil

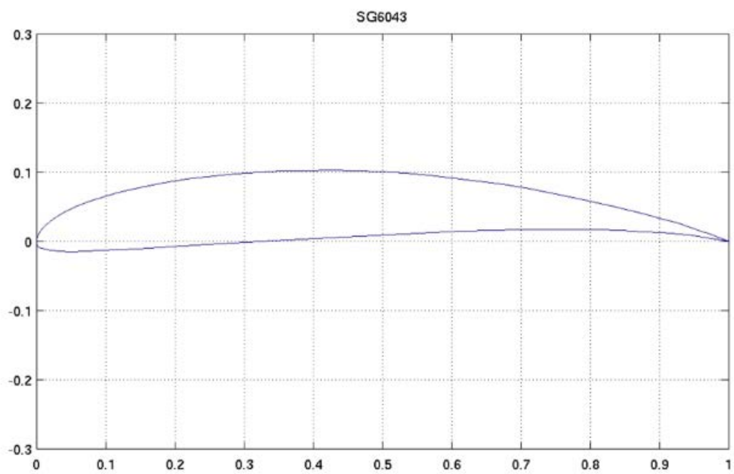


Figure 5: SG6040 Root Airfoil

The blade was designed using QBlade, which iterates section twist and chord length to produce optimum lift to drag ratio given a designed rotor diameter and TSR. See Table 10 below for blade geometry.

Table 10: DIYA 700 Turbine Blade Geometry

Position (m)	Chord (m)	Twist (deg)	Foil
0.125	0.148	26.13	SG6040
0.225	0.128	10.78	SG6040
0.325	0.103	3.37	SG6040
0.525	0.061	1.95	SG6043
0.625	0.052	0.08	SG6043
0.725	0.046	-1.29	SG6043
0.825	0.040	-2.33	SG6043
0.9	0.037	-2.96	SG6043
0.95	0.035	-3.33	SG6043
0.975	0.03	-3.50	SG6043

0.9875	0.025	-3.58	SG6043
1.00	0.025	-3.66	SG6043

Wind Lens

The wind lens features a hybrid nozzle-diffuser design. The expanded inlet exploits the conservation of mass principle, accelerating a control volume of air through the throat of the lens. The expanded outlet and brim feature create vortices that give rise to a low pressure zone behind the turbine. The moving air is thus accelerated from the throat of the lens to the back of the turbine as it moves from a high to low pressure zone. In addition to power augmentation the brim on the lens enables passive yaw.

Table 11: Wind Lens Dimensions

Component	Dimension (m)
D	2.040
D_r	2.000
s	0.020
D_h/D	0.130
D_h	0.265
h	0.204
Lt/D	0.137
Lt	0.279
D_{brim}	2.636

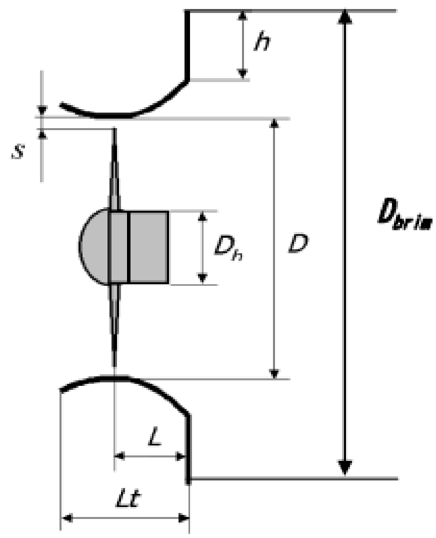


Figure 6: Wind Lens Components

The complex surface is an equation-driven cycloid curve based on a design developed by researchers Yuji Ohya and Takashi Karasudani at the Research Institute for Applied Mechanics at Kyushu University in Kasuga, Japan[26]. Of their experimental designs, the C_i shape was selected due to the balance it strikes between compactness and performance, which is essential to minimizing the size, cost, and complexity of the system, while increasing its power production performance in low wind speed regimes. Kyushu wind tunnel testing results showed on the order of 75% increase in C_p.

Nacelle Design

The nacelle is designed to support the aerodynamics of the rotor and wind lens. Due to its position upwind of the rotor, the aerodynamics are more critical. The diameter was constrained to prevent it from tripping the boundary layer and the length was constrained to reduce boundary layer development

[26] Y. Ohya and . T. Karasudani, "A Shrouded Wind Turbine Generating High Output Power with Wind-lens Technology," *Energies,* vol. 2010, no. 3, pp. 634-649, 2010.

in front of the blades. It is made from cast aluminum, so it is lightweight and durable. It is not load-bearing and mounts to the DIYA tower kit.

Generator Selection

For low point of entry into the market, the design team focused on off-the-shelf components for the first generation DIYA 700. In this case the Windtura 750 permanent magnet alternator (PMA) was selected as the basis for the aerodynamic design. The alternator is more efficient than a similar DC motor and does not contain brushes, which are subject to fatigue and higher maintenance requirements. The alternator produces 3-phase AC electricity and has a rated power output and rotational speed of 700 W and 600 rpm, respectively. The 12 V battery charging cut in voltage correlates to a rotational speed of 150 rpm. Its maximum ratings are 500 rpm with a maximum power output of 1kW. Its maximum dimension (7 in) and weight (25 lb) correspond to the size constraints for the nacelle design and the rated tower load.

Electronics

A 3-phase bridge rectifier was selected to convert the voltage from AC to DC for battery charging. The ARM Cortex STM32F103C6 microcontroller will monitor and control the turbine. The nacelle will house several sensors that drive control feedback and turbine operation. These include industrial sized current sensors, a tachometer, and accelerometers to measure wind direction. In addition, the nacelle will store a small battery to enable user interface (UI) when there is no power in the system.

A diversion controller will control current flow between the batteries and the diversion load. The diversion load automatically initiates a 3-stage battery charging cycle. Bulk, Absorption, and Float modes are used to ensure that voltage and current settings accurately match the batteries' actual state of charge. The diversion load will be rated for 1200 W.

Turbine Control

The control strategy centers on shaft speed regulation. The diversion controller varies the load based on the number of batteries being charged and their state of charge. The diversion controller will compensate for the changes in wind speed by controlling current flow through the diversion load. This ensures safe operating speed of the wind turbine at all times. A wind speed profile will be downloaded into the MCU memory during full-scale testing of the turbine, which will serve as a set point for optimum operating rotational speeds for each given wind speed.

Turbine Shutdown

Multiple parameters will be internally monitored in order to ensure safe operation of the wind turbine under a range of conditions. The turbine will initiate shutdown if any of the following parameters are true:

- Turbine to Load disconnection
- Manual Switch is activated
- Shutdown command through UI
- Shaft rotational speed > 1000 rpm

Braking of the turbine will be achieved by electrically stalling the generator.

Load

The DIYA 700 will charge three battery banks, one per classroom. Each bank consists of 4 12VDC 80Ah lead acid batteries, in which each battery supplies 480 Whr at maximum recommended depth of discharge, 50%. Each battery bank will have two batteries connected in series and another two connected in parallel, providing 3.84 kWh of storage. Each battery requires approximately 12 hours to charge above 90%, at a 0.1C rate, or 8 amps. At this rate 96W is delivered each hour for 48 hours, which meets the power specification.

Tower

To achieve DIYA's immediate goal of delivering electricity to rural schools in India it is imperative that the turbines are structurally sturdy and weather resistant. To this end a Tilt-up Tower was designed.

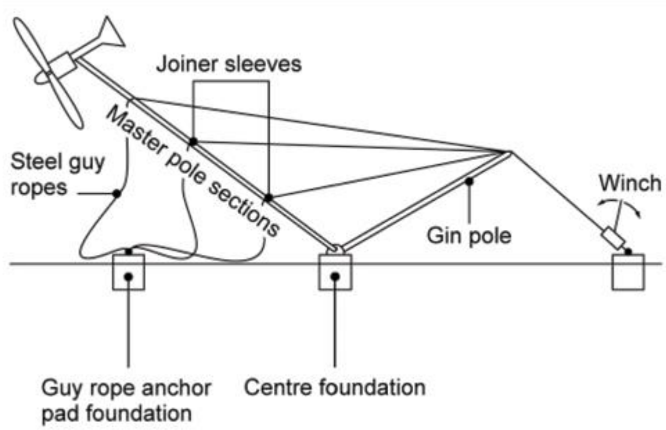


Figure 7: DIYA 700 Tower and Winch Design

The Tilt-Up Tower must withstand primary forces of extreme wind loads and gravitational loads from the overall weight of the turbine. The tower is steel piping with a radius of 0.1016 m (4 in) OD and a 0.011 m (0.45 in) thickness, made of ASTM-A36 structural steel with a modulus of elasticity of 200 GPA. The critical load for buckling of the tower was calculated to be 10804 N (2430 lb).

The tower itself will be made of three different sections; the bottom portion 3.93m long (13 ft), the middle portion 5.15 m long (17 ft), and the last portion on which the turbine is attached to is 0.5m long (1.15 ft). The total design length of the tower is 9.58m (31.4 ft), which allows for ease of installation and maintenance while also placing the wind turbine at a height for desirable wind speeds.

Each of the tower sections will be secured by three threaded joiner sleeves. The sleeves are attached to steel guy wires on four sides to counteract the overturning moment of high wind speed forces. Given the guy wire radius of 10 m, angles, are 21.45°, 42.24°and 43.77°, respectively. Guy wires are secured to a concrete pier 0.5 m x 0.5 m with a depth of 1.2 m. The concrete piers are designed to withstand winds up to 70 m/s with a factor of safety of 2.3. The tower will be lowered at winds that over 28m/s to avoid potential damage from extreme cyclic loading.

In addition, the main tower section will be secured at its base, although in order to acquire the tilt up motion a rotation is needed. Rotation is achieved by using 20.3 mm (8 in) OD pipes welded to C beams which are also welded down to the steel plate metal on top of the concrete pier. Inside the 20.3mm (8in) OD pipe are 19.8mm (7.8in) OD pipes welded to the tower base pipe.

The steel base plate is secured into its concrete foundation by 0.30m (1 ft) J bolts on four sides. The concrete pier for the base of the tower is 0.5 m x 0.5 m (1.64 ft x 1.64 ft) and has a depth of 1 m (3.28 ft), although this will be adjusted depending on the soil profile of the target area. Welded to the bottom to the main tower is a 2.44 m-long (8 ft) gin pole. This pole is the main component of the tower base allowing for the tilt-up motion. Before the tower is erected the pole must be secured to both the main tower and winch. To ensure maximum safety the winch must also be anchored in a concrete pier to the same dimensions of the guy wire connections.

Lighting Solution

To determine the required electrical load, the lighting requirements for the schools were calculated. LED lights were selected for their exceptional efficiency and long life over incandescent and fluorescent bulbs. Lighting efficiency and fixture types were based upon existing LED light solutions by Charlston Lights, an Indian LED lighting company. Their solutions boast up to 130 lm/W and have been tested for Indian environments, in temperatures up to 45 °C (113 °F)[27]. Analysis took into account room size, ceiling height, illumination intensity, wall color, and fixture placement with respect to the center of the ceiling. The following values were used to calculate the number of lumens needed to light one classroom.

Table 12: Lumens/Watt Calculation Parameters

Room Width	20 ft
Room Length	20 ft
Ceiling Height	10 ft
Illumination Intensity	Medium
Wall Color	Light
Light Placement	Center
Required Lumens	9291 Lumens

The best lighting solution that meets the calculated requirements of 9,291 lumens at 92 Watts is the Halo 12W shown in Figure 8 and Figure 10 below.

Figure 8: Halo 12W Side View

Figure 9: Installed Halo 12W

The Halo saves 8,000 rupees (Rs) over its life as compared to compact fluorescent lighting. The halo requires 14 W at 1500 lumens per unit and will require 8 units for each installation. Eight units at 14 W creates a 112 W instantaneous need per room at 12,000 lumens. The LED life span is 50,000 hours at its rated performance; the size is 185 mm diameter x 50 mm height and weighs 580 g. To create a feature-rich experience as well as maximize energy efficiency, the lights will be installed with two switches that enables a user to isolate light to the front or back half of the room if not all lights are needed. Additionally, a master dimmer knob will control light intensity.

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[27] "Charlston," [Online]. Available: http://www.charlstonlights.com/.

Design Validation

Prototype Design Description

A small scale model of the DIYA 700 was designed, fabricated and tested to estimate performance, shroud augmentation, and controls optimization.

Table 13: Technical Specifications DIYA 700 Prototype

Turbine	
Configuration	Shrouded, three blade, horizontal axis
Rated Power (W)	17.5
Rated Wind Speed (m/s)	11
Rotor Speed (rpm)	3000
Survival Wind Speed (m/s)	30
Cut-out Wind Speed (m/s)	19
Cut-in Wind Speed (m/s)	3
Overall Weight (kg)	2
Application	Testing, Proof of Concept
Rotor	
Rotor Diameter (m)	0.33
Swept Area (m^2)	0.0855
Blade Length (m)	0.143
Blade Material	SLS
Power Regulation	
Generator	
Generator Type	Brushed DC Motor
Configuration	Graphite Commutator
Brake and Safety Systems	
Main Brake System	Electrical Stall, Generator Terminal Short Circuit
Safety Shutdown Triggered by	Safety Switch, High Wind Speeds, Electrical Disconnection, Over rpm
Controls	
Type	Speed Control, Parallel Conversion Load
Turbine MCU	Arduino Uno
System User Interface	Programmable Python GUI
Tower	
Available Hub Heights (m)	0.5
Tower	4130 Chromoly

Aerodynamic Rotor Design

The blade design process was nearly identical for the prototype. The primary difference is that the prototype features only one airfoil instead of two. It was significantly different that lower Reynolds number (<100,000), the rotor characteristics vary compared to that of the DIYA 700 for blade optimization. The airfoil was selected based upon its ability to perform at a low Reynolds number. Blade element theory was used in order to achieve blade optimization. The lift and drag coefficients of the airfoil were used to calculate the forces on the blade elements.

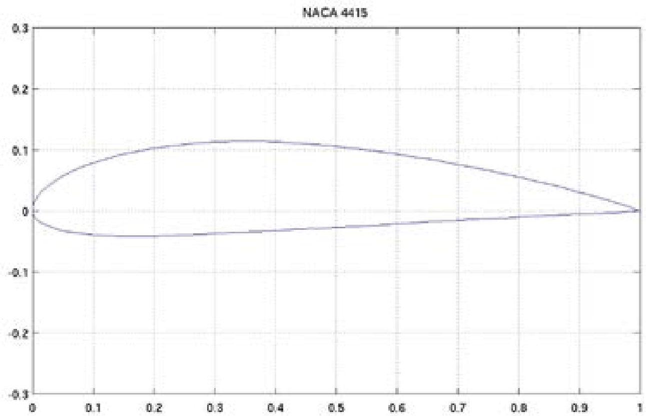

Figure 10: NACA 4415 Airfoil

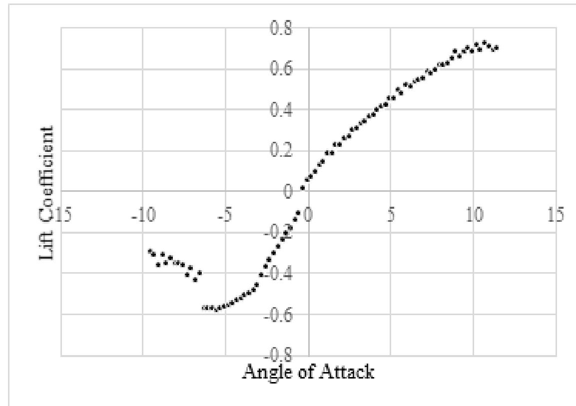

Figure 11: Prototype Lift Coefficient vs. Angle of Attack

Both hand calculations and FEA simulation were used to estimate blade deflection. The pressure force on a single blade can be approximated by a cantilever beam with a uniformly distributed load. This assumes that the wind force is applied normal to the face of the blade. Average blade dimensions were used to calculate deflection, including average chord length (0.0171 m) and the average thickness (0.0025 m). A single blade was analyzed using SolidWorks static analysis software with a calculated applied max pressure and a fixed boundary condition at the root. The maximum deflection at the tip is 4.165 mm.

Table 6: Turbine Blade Geometry

Node (cm)	Chord (cm)	Twist (deg)
1.596	2.382	27.095
3.192	2.415	19.559
4.789	2.271	14.075
6.385	2.016	10.436
7.981	1.769	8.009
9.577	1.557	6.310
11.173	1.380	5.073
12.770	1.234	4.141
14.366	1.112	3.418
15.962	1.009	2.846

Generator

The generator selected for the wind turbine prototype is the M3272 CR Micromotor, a brushed DC motor manufactured by Faulhaber. It provides a very low friction torque and has an overall motor efficiency of 87%. As a result, the motor enables a low cut in wind speed, adequate direct drive power while remaining compact.

The turbine motor can reach speeds of up to 6,000 rpm with a max power output of 65 W, has a speed constant of 230 rpm/V, and has a torque constant of 41.6 mN-m/A. Based on these parameters and a desired TSR of roughly 5 with a rotor diameter of 33 cm, an expected rpm of 3100 is to be expected at 11 m/s. Using these values and the expected Cp value of 0.5 from the shroud, a calculated voltage of 12.5 V and a current of 2.1 A can be expected at the rated wind speed.

Electronics

Electronic design for the prototype turbine was similar to the DIYA 700. The primary difference is the hardware solutions. An Arduino Uno MCU replaced the STM32 controller and an incremental encoder was mounted to the generator shaft to measure shaft rotational speed. In lieu of a power supply a DC-DC converter with an input range of 2.3 - 18 VDC and an output of 5VDC powered up the microcontroller once the generator began producing power. An SPDT latching relay switched between shutdown and power generation operations. It kept the turbine in shutdown mode even if the microcontroller was turned off then retriggered when the load was reconnected to the turbine. See Figure 10 below for electrical connection.

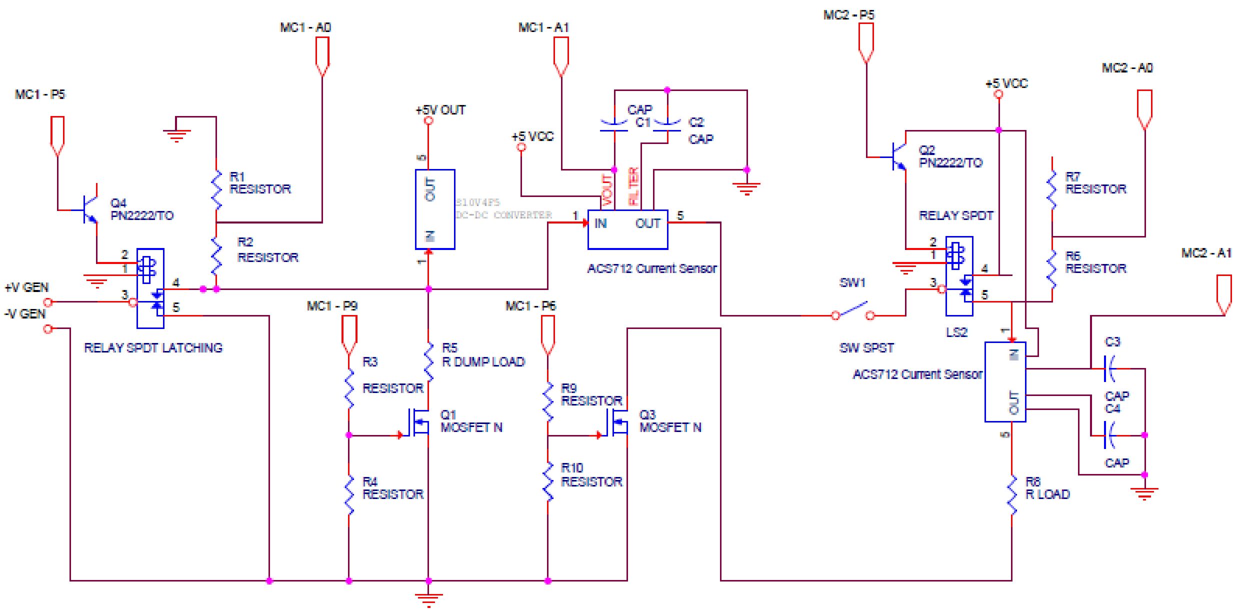

Figure 12: Electrical One-Line Diagram of Turbine System Connected to Load System

Controls

The prototype turbine is designed to optimize power output at varying wind speeds by adjusting the voltage across a set load resistance. The microcontroller takes inputs from the turbine sensors that monitor circuit voltage, current, and generator rpm, calculates the error between the desired and measured rpm, and adjusts the adjusts the PWM signal to the n-channel MOSFET on the turbine side.

Rated power output and shaft rotational speed, is experimentally determined and written into the code. If the sensing value exceeds the set point, a second PWM connected to a diversion load absorbs the extra power being produced and the rated shaft rpm is maintained. Both PWM signals are always active to maintain rated power and rated rpm.

Turbine Shutdown

Shutdown method and conditions are identical to those outlined in Section 2.4.2 except that the prototype shuts down at speeds over 5000 rpm instead of 1000 rpm.

Load System

The prototype load system consists of a second Arduino Uno microcontroller, a Raspberry Pi 2, a 7” touch screen, a 2 Ω 100 W resistor and their supplemental components. The second microcontroller communicates with the microcontroller located in the turbine, signaling the state of the turbine and measured rpm. The Raspberry Pi interfaces with both the Arduino and the touch screen to graphically represent important characteristics of the wind turbine performance and display important numerical values such as power, voltage, and rpm. It also allows the user to interface with the microcontroller to adjust the wind turbine settings. Another important function of this Arduino controller is to reset the turbine after the brake has been applied. It directs momentary power to the turbine controller so it can register the queued operation command to trigger the relay and disengage the electrical brake. I2C protocol and a bi-directional optocoupler ensure that no power is transmitted via the communication lines between the load and turbine control. The Arduino and Raspberry Pi interface via a type A/B USB cable.

Wind Tunnel Test Results

Initial testing focused on the aerodynamic performance of the rotor and controls optimization. In every case, even with 3D printed lower quality ABS rotors, the blade tip deflections of the blades were acceptable and never in danger of tower strike. Results of power performance testing indicated that varying the voltage across a set load resistance can be effectively used for power optimization of an off-grid system and speed control was shown to be a valid power regulation method.

Aerodynamic Test Results

The data acquisition system was comprised of an Arduino microcontroller and sensors that measured current, voltage, and rotational speed of the shaft. Each sensor was calibrated and tested to ensure that measurements read by the microcontroller were consistent with external instruments. To characterize the performance of the rotor, wind turbine test data was captured and analyzed using C++ in the Arduino IDE and Python v.2.7.

After initial rotor design comparisons and debugging the power optimization code and other controls, testing focus turned to validating and quantifying the performance augmentation of the wind lens. Initially, an off-the-shelf RC plane rotor was used to demonstrate proof of concept. The rotor was tested with and without the wind lens and the results compared. These results showed an increase in C_p of up to 70% at 7 m/s and a 56% at 10 m/s associated with the wind lens. While the relative change was enough to validate the lens, the max rotor C_p was only 1.4, far too low to infer similar augmentation results for the full scale design. Hence, after aerodynamic testing and redesign, a 3D printed version of the actual rotor was tested (see Figure 13).

Figure 13: Prototype Wind Tunnel Testing

Test results are shown in Figure 14: Cp vs. TSR – Without Wind Lens Figure 15 below. The max C_p value increased by 69% at 7 m/s and 45% at 11 m/s. Figure 16 compares the power output between the shrouded and non-shrouded. Not only is there an observable increase in power output for each wind speeds, but the cut in wind speed is lowered significantly. This goes a long way toward validating the inclusion of a shroud in areas with low wind speed regimes. Note that the testing wind tunnel idles at roughly 5 m/s so it data below this wind speed is unavailable. It is important to note that the though the rise in effective wind speed has a cubic effect on performance, it has no effect on the TSR behavior of the rotor.

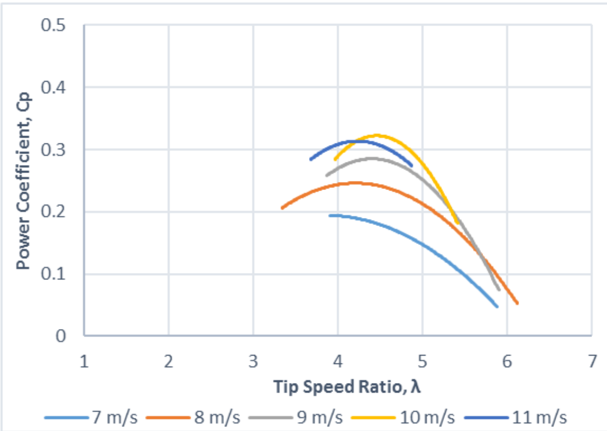

Figure 14: C_p vs. TSR – Without Wind Lens

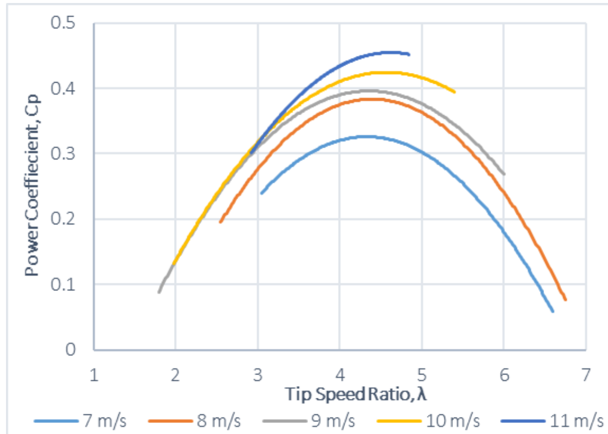

Figure 15: C_p vs. TSR - Wind Lens Added

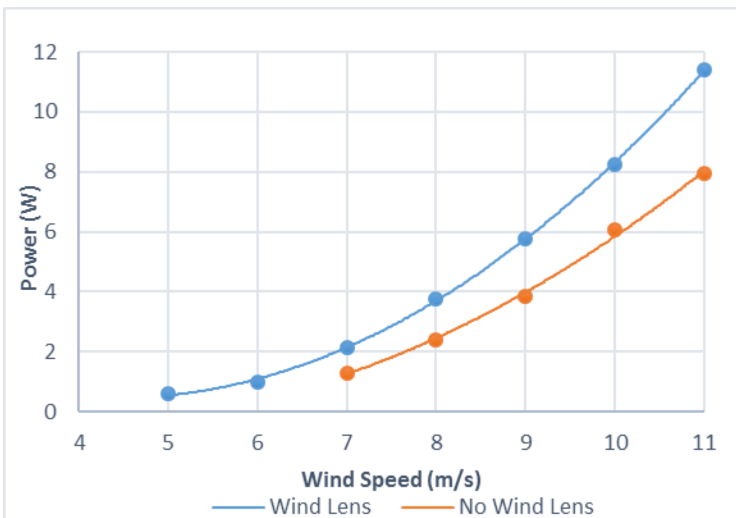

Figure 16: Power Performance Comparison

These results validate and help quantify the anticipated efficiency augmentation of the wind lens for a particular HAWT rotor and indicate the potential for implementing a wind lens in the full-scale design. While the baseline C_p profiles for this rotor are still relatively conservative for a modern HAWT[28], they are more comparable to what might be expected at full-scale. Directly applying these results creates a conservative estimate for the augmented performance of the full-scale system.

[28] K. E. Johnson, "Adaptive Torque Control of Variable Speed Wind Turbines," National Renewable Energy Laboratory, Golden, CO, 2004.

Control System Test Results

The controls strategy is based on regulating the rotational speed of the shaft as the system is subjected to varying wind speeds. The desired RPM was set at 2800 RPM and was tested under wind speeds ranging from 6 – 18 m/s. The results, shown in Figure 17 demonstrate successful rpm control up to 18m/s.

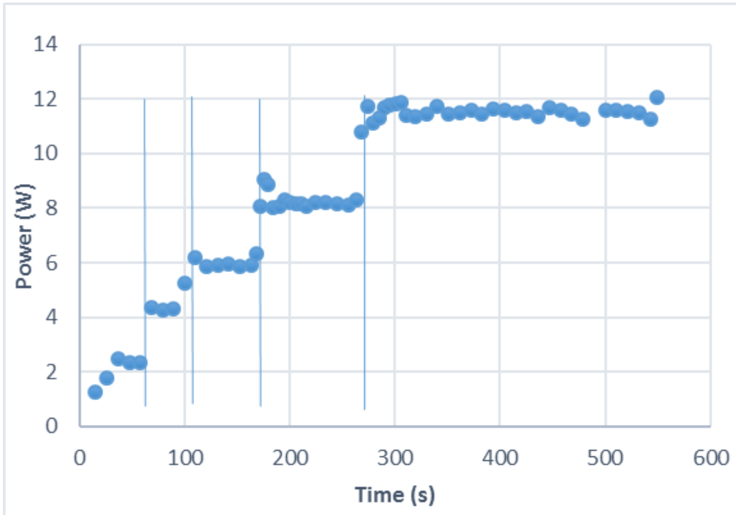

Figure 17: Prototype Control System Response

Finally, system shutdown procedure via electrical stalling was tested successfully at integer wind speeds 5-18 m/s. The turbine achieves shutdown status[29] in under 2 seconds when activated by either load disconnection from the turbine electronics or on command by a manual switch. There has been no observable degradation to the turbine's electrical or aerodynamic components. This method of braking is known to work on systems of comparable scale to the DIYA 700 but should be life cycle tested on a full-scale model before it is deployed. If it the electrical stall proves damaging or unsafe during full-scale testing, an electromechanical brake design will be considered.

Conclusions

This report documents the development of DIYA's 2 m 700 W DAWT, the DIYA 700. This turbine addresses the market needs described in the DIYA business plan and responds to the geographical context and challenges outlined in the DIYA deployment plan. A small scale prototype was developed for proof of concept and preliminary testing. The aerodynamics, controls, and load system have undergone multiple iterations and debugging and are supported with structural analysis and wind tunnel test data. The prototype demonstrates the market potential of the full-scale design and while the prototype has been tested safely, the DIYA 700 will require full-scale life cycle testing and potential design updates to for improved safety, manufacturability, procurement cost, and compact shipping.

Deployment Strategy

Figure 18 outlines the following criteria for evaluating a given site for deployment and installation:

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[29] United States Department of Energy, "U.S. Department of Energy Collegiate Wind Competition 2016: RULES AND REQUIREMENTS Revision 3," Updated February 8, 2016.

- Deployment Timeline and Project Lifecycle
- Siting and Evaluation
- Reliability and Risk Management
- Stakeholders and Communication
- Installation and Maintenance
- Wind Survey of Case Study Village

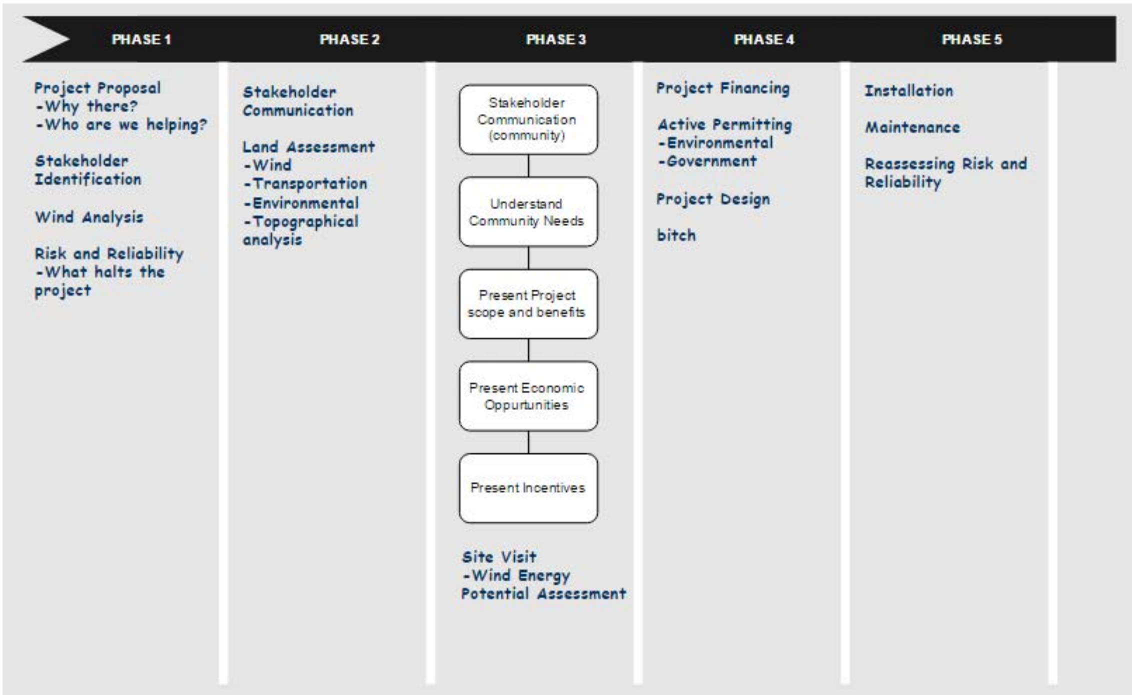

Figure 18: Phased Deployment Strategy

Phase 1: Prospecting and Identifying Projects

DIYA, with the help of Asha, has identified four target schools without constant sources of power that require installation of wind turbine units. Of the four schools, two reside in the state of Uttar Pradesh while the other two are located in West Bengal. Diya will focus on the Voluntary Association for Rural Upliftment and Networking and Gramya Sansthan schools, both are located within the Varanasi district of Uttar Pradesh. Following those projects Diya will install wind turbines at the Society for Women in Rural Development School, located in the Medinpur District of West Bengal. The other planned turbine installation will be at the Kaorakhali Sana Sevashram School, located in the South Twenty Four Parganas District of West Bengal. Basic wind speed data analysis for these locations has already been conducted verifying the wind regimes. Asha's connections with these target schools have allowed for relative ease of stakeholder communication for these sites, although during the later stages of the deployment process Diya will be very much involved in the stakeholder communication and outreach. After initial projects are completed, Diya will have sufficient experience and connections to move from the guidance of a larger organization such as Asha and begin to have a strong enough network and supply chain to manage their own projects.

Phase 2: Early Development

Stakeholder Communication: Government

Diya has already confirmed approval with the main stakeholders for these project sites. Organizations willing to aid our non-profit are groups such as Action Aid and Kid Wind. Action Aid is an international non-governmental organization whose primary aim is to work against poverty and injustice worldwide. They have been working in India since 1972 in order to fight poverty and have established many connections on a local and national scale. Action Aid will provide assistance to Diya in order to communicate projects and scope to local and national governments. KidWind will assist Diya to gain approval from schools and local villages. Both of these groups are integral to Diya in providing the necessary outreach and communication for preliminary development.

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of government for all matters relating to new and renewable energy. The goal of the Ministry is to develop and deploy new and renewable energy projects for supplementing the energy needs of the country. The current Memorandum of Understanding between the United States and India recognizes the partnership between both countries to advance clean energy, which is a clean energy and deployment initiative. The Ministry also offers many support programs that aid in the development of renewable energy education and interest.

Land Assessment

It is crucial to establish the target location for installing wind turbines. The area must be close to the school to allow for effective transmission of power from turbine to battery storage. Keeping in mind however, it remains important that the wind turbines are installed in locations that will not impact the safety of individuals in the area. This stage in preliminary analysis will require dispatch of a team to survey the target site and decide where to develop based on risk/reliability and practicality for the user. Risks to be considered consist of possible failure of the unit that would result in harm to users or the destruction of property, replacement of damaged or stolen components of the wind turbine, and continuous power output from the turbines. Diya will not be liable for failure of wind turbines or towers used in conditions outside of the recommended specifications. In an effort to minimalize the risk of failure, Diya has designed its wind turbine towers to have the capabilities to lower and raise with relative ease during unfavorable weather conditions.

In order to be approved for land acquisition of the project various tasks must be completed before gaining clearance for the project. First of which is approval from the State Pollution Control Board (SPCB) for the project area. For wind turbine projects the SPCB is in charge of maintaining noise pollution, although there are no sector specific guidelines for the amount of noise produced by wind turbines, the scope of our project must be communicated to the agency. Diya will base our wind turbine's noise limit to laws stated by the Ministry of Environment and Forest. The noise limit set by law is to be 55 dB(A) during the day and 45 dB(A) at night. Turbines of comparable size produce noise of about 30dB(A) at most suggesting that our turbines are within these conditions. In addition to continue our project we must obtain no-objection certificates from the district collector, energy department and the local panchayat.

Environmental concerns

In addition to land assessment, Diya will be in contact with the Ministry of Environment, Forest and Climate Change in order to assess how and if our wind turbines will be affecting the local environment in any way. Currently within India there are no laws indicating that an Environmental Impact Assessment

(EIA) needs to be conducted for wind power projects irrespective of size and location. Even if land is diverted for projects, an EIA is not needed, although the MNEF does not have guidelines which are to be followed for large turbine installations[30]. Large turbine installation consists of a tower height of 50m and a rotor diameter length of 3m. Diya's turbines are well below these bounds having a tower height of 9.58 m and 2-m rotor diameter. While there currently are no EIA regulations barring small scale wind turbine projects in India, Diya will consider many important environmental issues when moving forward with the project. These issues include verifying that the proposed installation will not interfere with bird migration, diversion of natural waterways, and land clearance.

Transportation

Basing small turbine projects in rural areas of India presents transportation and logistical problems. The turbines Diya is set to install at the selected schools are permanent sources of renewable energy that can provide a source of lighting based on Diya's minimum goal of 20-year life span. Diya's design and installation strategy is to use, whenever possible, common off-the-shelf parts and in modular sizes. This strategy will solve many challenges with transportation. The tower and turbine unit are modular and can be completely installed on site during a 3-day installation period. The largest component of the tower and turbine is the 5.18 m section of the tower.

We estimate that an installation team of two technicians and two unskilled laborers will be able to both deliver and set up Diya's wind turbine units. Three standard work trucks comparable to medium duty class 4 (4536 kg and 2.4 m length bed) will be needed to transport the complete turbine, batteries, electrical wiring and tower components.

India's road infrastructure is unpredictable in rural areas; therefore, a small installation team will allow for flexibility when traveling to rural locations. Many of the issues when attempting to install renewable wind resources of this caliber in rural areas arise from lack of accessibility for large semi-trucks to these destinations. In an effort to leave the smallest carbon footprint possible, Diya will take pride in the using technician trucks as opposed to large transportation vehicles.

Phase 3: Intermediate Development

Once Phase 1 and 2 are successful, the intermediate development step will be initiated. This will consist of sending a small team to the desired site to conduct wind research and analysis of the area at different altitudes. Other tasks will be to develop and train a workforce close to the installation for ease of maintenance. Environmental experts will be brought to the site to evaluate and assess the site. Other tasks will be to initiate communication with the MNRE and MNEF.

Careful review of the roads and transportation will be required to account for any unforeseen obstructions or dangers not documented as will the electrical power networks that may exist in order to safely integrate the turbine to battery networks and lighting into the buildings.

Wind Energy Potential Assessment

On site visits are crucial to verifying that the wind turbines will be placed in an area that will ensure efficient energy capture from the wind and longevity of the products.

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[30] http://re.indiaenvironmentportal.org.in/files/file/Green%20Norms%20for%20wind%20power%20full.pdf

The dispatch group will utilize aerial photography for topographical analysis. By researching the area before on site visits anemometer installation locations at different elevations will be identified. Topographical research will also be important in identifying obstructions and terrain of the surrounding area in order to help locate the best place to install the turbine.

In order to capture wind speed data, the dispatch group will set up various anemometers around the target site at different elevations at which wind data will be sampled and updated every hour. Data collection will continue from anemometer locations for a 1-year cycle according to requirements of the MNRE. Along with anemometers, rain gauges will also be installed at all locations. Understanding rainfall patterns in these locations will allow for an assessment of weather fatigue on the turbine units. In addition, Diya will continue to monitor weather patterns to account for severe weather conditions. Once the wind speeds are verified and justify the initial site analysis, the next phases will proceed.

The wind data captured from the anemometers will be made into a histogram to generate a population density function or Weibull distribution curve which will provide the probability of how often wind speeds occur. From the Weibull distribution curve the power probability density will be calculated for the specified areas. Integrating the wind power probability density curve by the distribution of all captured wind speeds and multiplying by the swept area of the rotor, gives the annual average power of the wind. Multiplying by an overall efficiency of the conversion of wind energy to mechanical energy, which will include the Betz limit and an estimate of the drivetrain efficiency, the final mechanical shaft power and ultimately, the electrical power produced from the generator can be determined. Utilizing the Weibull distribution curve and taking into account all of the wind speeds that occur, will provide the technical team a realistic estimate of how much power the wind turbine will produce. Based on the analysis of the power probability density curve, the market turbine rated power and rated wind speed was determined.

Stakeholder Communication: Community

The villagers are important stakeholders in the project because of the environmental and economic impact it can have in their community. In order to deem any location appropriate for further development, the local audience must be accepting and understanding of the technology and what it can offer in order to offset some of the costs, keep maintenance costs local by developing new jobs in the area, and facilitate the integration of the wind turbine installation.

Developing a simple survey of what the public values and what they understand about wind energy can help develop a general census of the public attitude. This can be coordinated with help from the KidWind curriculum. These surveys will be distributed to schools, homes, and farmers. Other activities will be geared at educating the younger audience by showing small wind turbine prototypes, offering internships with regional universities and sponsoring individuals interested in wind turbine training and certification. Many of these goals and activities can be achieved with the aid of the programs offered by the Ministry which offers to offset costs associated with spreading information and public awareness and the Human Resources Development Program whose objective is to educate and train in order to cater to the requirement of qualified and trained workers, by offering internships and short term training programs.

Phase 4: Advanced Development

Currently Asha is working with Diya to identify and choose the target areas and schools in which they would like to operate. It is important to note that Asha and Diya will work together in order to finalize land deals with landowners, complete resource and financial modeling efforts, and finalizing documentation with all permits, agreements, contracts, and certification credentials needed.

Active Permitting

Each state government is represented by a State Nodal Agency (SNA), which looks after sanctioning of renewable energy projects. The Uttar Pradesh New and Renewable Energy Development Agency is the SNA for Uttar Pradesh and West Bengal State Load Dispatch Centre is the SNA for West Bengal. All SNAs are implementing the programs of the MNRE. SNAs will:

1. Facilitate project development from resource assessment to the final commissioning.
2. Undertake wind resource assessment studies and gets the sites approved from Centre for Wind Energy Technology (C-WET).
3. Verifies legal statutory clearances for the identified site.

State Nodal Agencies will facilitate the clearances for the fire department as well as the No Objection Certification.

After wind data for the site has been collected, a financial pro forma must be completed and submitted to the MNRE.

Phase 5: Project Implementation and Construction

Installation and Maintenance

The first steps that need to be taken for installation of the wind turbine and tower is assessment of the soil profiles in the target area. Design of the concrete footings will be based off of the type of soil along with the local water table within the area. Soil profiles must be assessed in order to analyze the heaving properties of the soil and determine the potential effects of expansive soils decreasing the integrity of the concrete footings.

Centre for Wind Energy Technology (C-WET) is an autonomous institution of the MNRE that organizes international and national training programs to cover installation, maintenance, foundations, operations, and wind resource assessments. Diya will provide all workers for the installation of the turbines. After completion of the training programs, and the knowledge is acquired local workers will take over the turbines, Diya will subsequently employ individuals for maintenance. Maintenance should be conducted every six months on the turbines as well as routine inspections after large storms. Diya's turbines are designed to last and be effective for 20 years with proper care.

Case Study: Varanasi, Uttar Pradesh

Project School

Phase 1 schools in which Diya targeted for the installation of wind turbine units are located in Varanasi, Uttar Pradesh. According to a consensus in 2011 conducted by the Government of India and presented by the Vasudha Foundation[31], data shows that there is a total number of 301,485 households in the district. Of those households 180,489 are without reliable sources of electricity, suggesting that 60% of the community is in need of power. Within these areas Diya is focusing on two schools: 1) Voluntary Association for Rural Upliftment and Networking (VARUN) and 2) Gramya Sasthan.

The National Institute of Wind Energy estimates that the state of Uttar Pradesh has an estimated power potential of 137 MW at a hub height of 50 meters. This estimate is based on a conservative estimate of

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[31] http://www.vasudha-foundation.org/wp-content/uploads/8)

the land available in the state to be 2%. This data is based on 79 operational wind monitoring installations located across the country with three of those being in Uttar Pradesh.

Varanasi's wind power potential was analyzed using Weibull distribution curve for the area must be calculated to understand the locations power potential. An online weather tool, WeatherSpark.com[32], was utilized to conduct further analysis of these wind regimes on a daily basis to determine the times during the day that these wind speeds would be the most favorable for power production. The WeatherSpark Beta team compiles wind speed data collected from anemometers located at and around airports. Analyzing the data indicates that wind speeds are best, approximately, between 10am - 4pm, with wind speeds commonly ranging between 2.2 - 4.9 m/s (5 - 11 mph). Often large gusts occur when the heat spikes. Wind gust intensity ranges from 12 – 16 m/s. These averages were then compared using SynergyEnviron.com[33] which verified that these wind data regimes were appropriate and reliable. From the data we calculated a Weibull Distribution Plot.

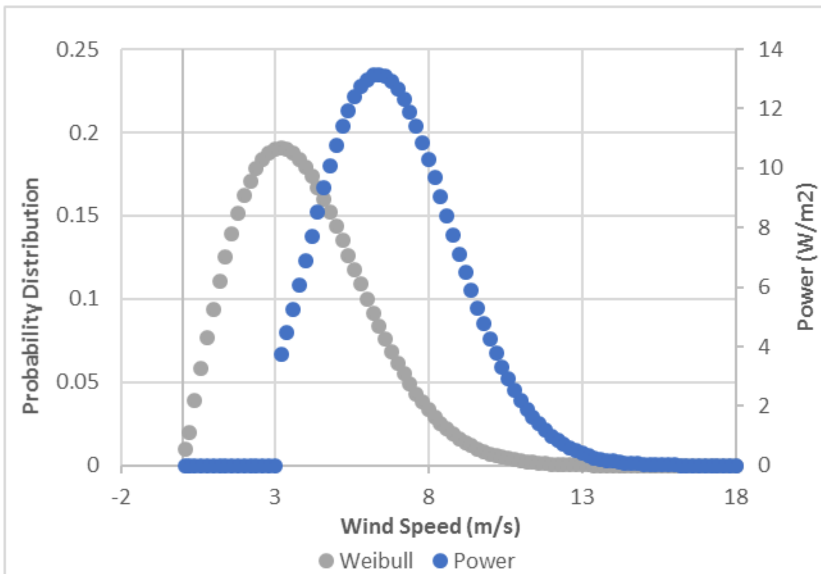

Figure 19: Weibull Distribution of Wind Speeds

Average annual power in which our turbine will be producing is calculated to be 66.2 Watts. While the case study may not reflect optimal power output in which Diya has designed our wind turbines, there is still enough wind potential in the area to allow our turbines to operate in a manner beneficial to target schools.

Initial calculations and estimates indicate that this region is suitable for the development of a small scale wind turbine that will operate under the given wind regimes and meet the power need of these local schools.

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[32] https://weatherspark.com/#!graphs;ws=33932

[33] http://www.synergyenviron.com/tools/wind_data.asp?loc=Varanasi%2CUttar%20Pradesh%2CIndia