Reducing Fossil Fuel Dependency of Syrian Irrigation Systems

TAMU PHASE

21 October 2024

1. Partnering

Yes, partnering is of interest to the group as if multiple partners have similar solutions then it is possible to come together and design an improved implementation that takes the best parts of each individual submission to create a design that can effectively solve the problem. Usually with more people you have a more diverse set of skills that can benefit large projects like this.

2. Participation Type

Student Organization: PHASE

3. Solution Level

At a 3 right now. We could sit down as a team to advance this to 4 modeling the system in SolidWorks and doing mechanical verification in SolidWorks simulation/ ANSYS Mechanical and a wind simulation in ANSYS Fluent.

4. Problem & Opportunity

Our innovative solution focuses on utilizing the region's consistently high wind speeds, averaging over 10.7 miles per hour, to generate energy for irrigation systems. This approach sets itself apart from conventional methods that predominantly rely on solar power or fossil fuels which have their own flaws in reliability and cost that allows us to create a distinct opportunity to address the problem of energy scarcity and high operational costs for farmers.

Point of Difference

Our solution employs a wind-powered irrigation system that leverages local wind resources to generate clean energy. For example Ar Raqqah, Syria has historical wind speeds from January-July of 10.0 mph, a number 35% over the global mean. January through July represent the months from mid-season through harvest after the wheat is sowed. By integrating small, efficient vertical wind turbines, we can convert kinetic energy from the wind into mechanical power for irrigation pumps. This wind-based system not only minimizes the reliance on diesel but also reduces operational costs for farmers in the long term as shown in section 9 as well as having low maintenance with the benefits given by a vertical wind turbine that allows for wind from all directions and speeds to be utilized efficiently.

Advantages and Benefits

1. **Cost-Effectiveness**: By using wind energy, farmers can significantly lower their energy expenses. The initial investment in wind turbines can be offset by the savings on diesel, which has been rapidly increasing due to the ongoing conflict and supply chain disruptions as well as not always being readily available. Additionally, the low maintenance requirements of vertical wind turbines further enhance their cost-effectiveness, making them an attractive option.
2. **Scalability**: The modular design of vertical wind turbines allows for easy scaling based on the specific needs of different farms. Vertical wind turbines are additionally incredibly efficient in use in a modular array, with new research even showing the low-maintenance option to be even more efficient than the traditional wind turbine. This adaptability ensures that all requirements for differing farms can be met while simultaneously meeting the requirements of the challenge.
3. **Integration with Existing Systems**: Our solution is designed to complement and enhance existing irrigation infrastructure. As shown in the solution overview in section 5, the design allows for the already existing systems to be complimented with the wind turbine and offer an option for the wind to be used when necessary along with the diesel operated pumps, creating a smooth integration into the irrigation system. Farmers can easily integrate wind energy into their current operations without significant changes, ensuring a low cost and low maintenance effective option. When maintenance is inevitably required, only simple tools and no advanced knowledge will be needed due to the simple mechanics of the chosen wind turbine.

In summary, our innovative approach harnesses the natural wind resources in northeast Syria to create a cost-effective and scalable solution for powering irrigation systems. This unique strategy not only alleviates the dependency on fossil fuels but also empowers farmers to enhance their productivity and resilience amidst challenging circumstances.

5. Solution Overview

Address: how it reduces reliance on fossil fuels, adds energy, it is self sustainable, matches or exceeds performance of existing solutions, suited for drawing water from depths of 80-100m, able to operate uninterrupted

A vertical axis wind turbine (VAWT) that provides mechanical power can offset the reliance on fossil fuels, mainly diesel, while minimizing both upfront and maintenance costs. A simple VAWT would take wind energy and drive it down through a gearbox to a torque needed to efficiently drive a water pump already owned. A chain or belt would connect the output of this gearbox directly to the pump. In this solution a farmer could have the passive windpump running until they choose to swap to the active diesel engine. Optionally, a differential can be used to allow for both the wind turbine and the diesel engine to provide power to the pump, this would be more expensive but would save the farmer time. When the fields are properly irrigated the VAWT will continuously pump water into a water reservoir, essentially storing energy in the raised water. The turbine is fully self sustainable excluding general maintenance costs: see price breakdown in section 9. With the bypass of electrical energy we can save on high cost inverters and electrical energy storage solutions. Bypassing electrical energy also avoids the energy loss associated with turning mechanical energy to electricity and then back to mechanical via an expensive motor.

Figure 5.1. *A typical very low cost, DIY, Savonius VAWT [1]*

Due to the highly customizable nature of our chosen system, individual farmers can choose their VAWT configuration to best fit their considering both cost and power requirements. For larger scale operations a farmer could choose a <20kW VAWT [6,8] or possibly a small scale could choose something closer to 6-10 kW.

Figure 5.2. *A variety of different VAWT configurations and power ratings.*

We chose a VAWT rather than the popular horizontal axis wind turbine due to the high initial costs and required substructures of the HAWTs. VAWTs not only require less support structures, but have much lower costs, but at the expense of efficiency. Because Syria often has shifting winds, a VAWT can capture wind energy omnidirectionally unlike its HAWT counterpart. VAWTs are also more efficient at lower speeds seen in Syria [2,3,11].

This system will work uninterrupted as long as there is wind. When wind use is consistent and outperforms the farmer's power requirements of the motor, the pump can store water in a tank allowing the farmer to use it at a later time. Because relying on solely a renewable energy source like wind poses a large risk this system would most likely be used in conjunction with the existing solution and act as an aid to diesel engines.

A direct next step would be to form a few different power configurations; low, medium, and high, and fully working out system designs and procurement plans.

6. Solution Feasibility

Using wind power to pump water has historically been the way that rural American farmers and ranchers have collected and stored water in the US. The self-governing windmill was introduced in the 1850's where the idea quickly spread through the rural areas of the US [7]. Later, the steel windmill was introduced in the 1870's and this made the windmill much cheaper, easier to install, and more reliable. Furthermore, the additions of curved blades, back gearing, and self lubrication in the early 1900's lead to huge improvements in terms of efficiency and water output, allowing windmills to operate in much calmer wind conditions. Current commercial windmills are able to comfortably pump 640 gallons (2.42 m^3) at a depth of 310 ft (94.5 m) at 15-20 mph wind speeds [5] (priced at ~$3,000 for the structure alone). Typically, HAWT turbines are used due to their high efficiency. However, for the purposes of pumping water by way of interfacing with an external pump, VAWT has been shown to have a higher real efficiency. Although VAWTs have less theoretical power efficiency, their vertical work output allows for extremely smooth mechanical integration with an external gearbox and pump system. This significantly reduces the cost while simplifying the system, thus eliminating potential sources of failure and reducing maintenance costs. VAWTs also have the advantage of higher operating efficiency at low wind speeds and are less affected by turbulence [9]. This concept was tested by the US Department of Agriculture Research Service in 1981 where they had three different turbines each consistently output above 8kW (>10hp) at wind speeds between 5-11 mph (less than the mean ~10mph over the two year testing window [10]. Modern advancements in aerofoil manufacturing and CFD/ FEA simulation software have increased the efficiency of these devices since the 1980's. Advancements in material science and manufacturing have produced significantly cheaper airfoils using carbon fiber and modern manufacturing techniques have both increased efficiency and reduced capital expenditures. A VAWT turbine that mechanically drives pre-existing pumps is the most economically efficient option in reducing energy costs in pumping, storing, and irrigating water. In addition, the purely mechanical structure will avoid all of the reliability issues caused by electric components and inefficiencies in power conversion. The mechanical issues it does have will likely be repairable on the field by the farmers.

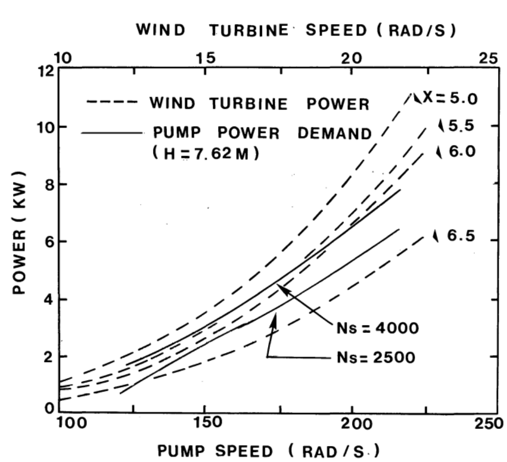

Figure 6.1. Power output of VAWT according to US Department of Agriculture [10]

7. Experience and Background

As a team we would love to volunteer and help the IRC with this project or future projects. We all have a deeply technical background ranging from mechanical engineering to computer science. The following is a more in depth description of each team member:

Marco Martinez - Chemical engineering student with a passion for finance. Marco will be completing a Masters in Finance at Texas A&M and will be doing an internship with Opportune, an energy consulting company. Marco has a passion for solving hard problems, competing in various hackathons and engineering design competitions. Interested in realizing our prototype solution.

Nick Robertson - Mechanical engineering honors sophomore at Texas A&M University, nine months of design engineering experience at Tesla, three years of aerodynamic engineering at Texas A&M Solar Car Racing Team, and four years of design and leadership experience in high highschool robotics (FRC, team 418). Experienced with CNC lathe, mill, welding, FDM, SLS, other fabrication techniques. Interested in realizing a prototype solution.

Davis Palmer - Mechanical engineering and applied math junior at Texas A&M University minoring in computer science; past experience includes a hardware engineering intern: controls, structures, and verification; currently conducting thermal engineering and packaging research with Samsung Semiconductor; past events include Aggies Invent for the Planet and various hackathons. Fab skills: welding, mill, general woodshop, laser cutters, etc. I would love to take our idea and make it into a working prototype.

Harry Wu - Junior Mechanical Engineer at Texas A&M, Power Distribution team lead teaching design of efficient electrical systems, implementing electric drivetrain, and mechanical design for Texas A&M Solar Car Racing Team. I am very interested in realizing our prototype solution.

Quinn Hamilton - Junior Industrial Engineering also pursuing a Masters of Science in Finance at Texas A&M. Past experience at Maas energy works designing P&IDs and 3D piping models for complex methane capture systems; background in solar energy installation and an upcoming internship with ExxonMobil in Low Carbon Solutions. Interested in realizing our prototype solution.

Owen Brown - Senior Computer Science Student at Texas A&M. Owen has a passion for machine learning and has six months of experience as software engineer with SpyCloud. Interested in realizing our prototype solution and assisting in procurement plans and analysis of wind data.

8. Solution Risks

There are several potential risks associated with the wind turbine solution, including damage from environmental factors such as strong winds or lightning and insufficient wind speeds to consistently power the system. Extreme weather, such as thunderstorms, could harm the turbine, but this risk is minimized due to the turbine's design for high wind tolerance. However, in severe storms, the possibility of damage from lightning or high winds remains. To address this, the turbine's modular, lightweight, and removable design allows it to be easily removed or lowered during extreme weather conditions, thereby preventing damage and reducing maintenance costs for the farmer.

Another challenge is the potential for low wind conditions, which would reduce the turbine's effectiveness in powering the irrigation system. To mitigate this, the turbine mechanically drives the pump, removing the energy loss in converting to electrical. Building upon the pre-existing system, the turbine will turn the input pulley using a belt, transferring energy the same way the diesel engine. Not only does this reduce energy loss due to energy conversion, but it also allows the diesel engine and turbine to be easily swapped for different wind conditions. This hybrid design ensures the system remains functional even during periods of low wind, giving farmers flexibility in energy use and reducing the risk of downtime in water extraction. The only risk then is when there are low winds as well as supply chain and price issues with diesel.

Importing turbine parts into the region could present logistical issues, such as delays in customs or difficulties due to local regulations. However, these are challenges that apply to any agricultural equipment. Although the US has sanctions on exporting to Syria, Eport Waivers are provided for "reconstruction related equipment" that is decided on a case by case basis by the Department of Commerce [] This project has a very strong case of being accepted as it contains no potentially dangerous components and is only able to be used for irrigation restoration. Similarly, assembling and installing the turbines will provide its own set of challenges. Due to the inexpensive and purely mechanical design, there won't be any electrical or coding issues. All issues will be mechanical and will be resolvable without the need of expensive equipment or spares for smoother installation. Overall, while the solution has potential risks, they are mitigated through thoughtful and simplistic design, which allows farmers to adapt to varying weather conditions while maintaining operational flexibility.

9. Timeline, capability and costs

The solution saves costs by utilizing off the shelf turbine blades and gearboxes. Raw material will be needed to manufacture the few custom components. A local fabrication shop will be needed to outsource the manufacturing if the team is unable to meet the production demands. Long lead times will be necessary due to the international shipping and assembly. Due to the highly modular nature of the solution, different parts will be able to be transported to each individual farm where they will be assembled. Given good GD&T from standard component suppliers and local manufactures, the simple assembly should be easy on site with simple tools. The upfront capital expenditure is estimated to be $12,548 with a yearly operating cost of $1,265, but these numbers are likely huge over exaggerations as the upfront capital expenditure includes ~$5000 accounting for unknown costs (that are in addition to the 10% overapproximation) and the yearly operating costs assumes a worst case scenario of all four turbine blades needing replacement and an additional $500 in maintenance (in addition to the 10% overapproximation).

https://docs.google.com/spreadsheets/d/1uiZ7jefFzSoNKUB7vLcn7pW_PJHXdDF0xQCZR6zK250/edit?usp=sharing

A rough timeline would consist of the following:

1. **Detailed design and procurement plan (1 month)**
    a. The team would sit down and work out 3 VAWT configurations (low, medium, and high power requirements), validating both the power output and an efficiency curve.
    b. An indepth procedure and plan to construct the VAWT from the parts provided.
2. **Small-scale Prototype (1 month)**
    a. A smaller scale <1kW VAWT could be procured and constructed locally to test flaws and validate our power and loss calculations.
    b. In this stage, flaws in our initial system would be pointed out and a number of design iterations would occur.
3. **Final Prototype and Field Testing (2 - 3 months)**
    a. A prototype in Syria would be procured and constructed testing the system in its final environment
4. **Mass funding and shipment (4+ months)**
    a. After finalizing the fully fledged design we would move onto building full-scale VAWTs in Syria and hopefully lighten the reliance on fossil fuels and have a more reliable energy source for the farmers.

10. Online References

1. https://www.journal-aprie.com/article_113965.html
   Low cost Savonius VAWT

2. https://ipad.fas.usda.gov/rssiws/al/crop_calendar/metu.aspx
   Weather in Syria pt 1.

3. https://weatherspark.com/y/101180/Average-Weather-in-Ar-Raqqah-Syria-Year-Round#:~:text=The%20windiest%20month%20of%20the,of%206.9%20miles%20per%20hour.
   Weather in Syria pt 2.

4. https://tesup.com/us/products/tesup-vertical-wind-turbines-for-homes
   Retail consumer baseline

5. https://aermotorwindmill.com/pages/windmill-pumping-capacities
   Modern commercial windmill pumping data

6. https://www.sciencedirect.com/science/article/pii/S1364032118308153
   Past VAWTs and VAWT data

7. https://web.archive.org/web/20111007162315/http://www.windmillersgazette.com/history.html
   History of windmills in the rural US

8. https://www.scirp.org/journal/paperinformation?paperid=92117
   Darrieus VAWT overview

9. https://windcycle.energy/vertical-axis-wind-turbines-2/#:~:text=VAWTs%20have%20a%20different%20design,and%20less%20scalable%20than%20HAWTs.
   Comparison of different turbine types

10. https://www.osti.gov/servlets/purl/7101869
    Research done by the US Department of Agriculture

11. https://www.britannica.com/place/Syria/The-winds
    Weather in Syria pt. 3

12. https://www.state.gov/syria-sanctions/#:~:text=Executive%20Order%2013582%2C%20signed%20on,U.S.%20persons%2C%20prohibits%20the%20importation
    US regulations regarding Syrian exportation sanctions and rules

13. https://www.joace.org/index.php?m=content&c=index&a=show&catid=39&id=155
Wind turbine mechanics

11. How did you find this Challenge?

We found this challenge on the HeroX platform.