Portable savonius horizontal axis water turbine as renewable energy learning media

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Abstract
The Potential of Utilizing Water Energy as a Renewable Energy Source is Significant. Water turbines are used to convert water energy into electrical energy. Among various types of turbines, the Savonius water turbine is most suitable for low-flow water conditions in Indonesia. This research aims to develop a horizontal axis Savonius water turbine for low-flow water conditions. The turbine utilizes L-shaped blades and a deflector with a 30-degree inclination to enhance power and torque. The developed turbine has an aluminum frame with dimensions of 66 cm x 38 cm x 40 cm, while the turbine blades are made of acrylic with dimensions of 30 cm x 10 cm. Data collection was performed by varying the water velocity in 10 levels (0.4 m/s to 4 m/s) with 10 repetitions for each velocity level. The research results revealed that the maximum power output occurred at a velocity of 4 m/s, generating 0.38 Watt with a shaft rotation of 258.63 rpm. This study highlights the potential of water energy as a renewable energy Learning media and demonstrates the practical application of Savonius water turbines for environmentally friendly water energy utilization.

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1. Introduction

To sustain and reduce dependence on fossil energy sources, the utilization of renewable energy is becoming increasingly important. Renewable energy technologies offer environmentally friendly solutions and have the potential to generate sustainable energy. One of the latest technologies that has captured attention is the Portable Water Turbine (Jacob Riglin, 2016). This turbine harnesses water energy as its primary source to generate electricity. Some sets of this turbine apart can be easily transported and installed in various locations, enabling the utilization of water energy in remote or hard-to-reach areas (Meryeme Azaroual, 2022). With its portable capability, the Portable Water Turbine offers high flexibility and accessibility in harnessing renewable energy (Kheng Wee Tan, 2021). This opens new opportunities for the development of renewable energy projects in various regions, including areas that lack adequate power infrastructure (Herman Jacobus Vermaak, 2014). By continuously developing and improving the Portable Water Turbine technology, we can optimize the utilization of water energy as a potential and sustainable renewable energy source (Jihoon Chung, 2021).

There are several types of water turbines used for harnessing the energy from flowing water. One commonly used type is the Savonius turbine, which is a vertical axis turbine (Wei Yang, 2019). However, in the case of the Portable Savonius Horizontal Axis Water Turbine, as mentioned in the introduction, it utilizes a horizontal axis design. The Savonius turbine is named after its inventor, Finnish engineer Sigurd Johannes Savonius. It consists of two or more curved blades that are shaped like half cylinders or S-shaped cups. These blades are mounted on a central shaft, forming a rotor. When water flows through the turbine, it causes the rotor to rotate, converting the kinetic energy of the water into mechanical energy (A.H. Elbatran Y. M., 2017).

The unique feature of the Portable Savonius Horizontal Axis Water Turbine is its horizontal axis orientation. Unlike the traditional vertical axis Savonius turbine, which rotates around a vertical axis perpendicular to the direction of flow, the horizontal axis turbine rotates around a horizontal axis parallel to the direction of flow. This design variation allows for efficient utilization of water currents in various water environments. The horizontal axis configuration offers several advantages. It allows

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the turbine to capture energy from water currents flowing horizontally, such as in rivers and streams, where the water flow is typically parallel to the ground (Anuj Kumar, 2016). Additionally, the horizontal axis design facilitates easy portability and installation, making it suitable for temporary setups or emergency situations (Xiu Wang, 2023).

The Portable Savonius Horizontal Water Turbine is specifically designed to efficiently convert kinetic energy from water into electrical energy. Its innovative and portable design allows for its use in locations with low water flow. These turbines have distinctive curved angles, which enable them to optimize energy capture from water flow, even at low speeds. One of the key advantages of the Portable Savonius Horizontal Water Turbine is its high mobility. They can be easily moved and installed in locations that require renewable energy sources. This makes them ideal for remote areas, rural communities, or even in emergency situations such as natural disasters (A.H. Elbatran O. Y., 2018). By using these turbines, we can harness the available water energy potential around us to meet our daily energy needs. In addition to its mobility, the Portable Savonius Horizontal Water Turbine also offers advantages in terms of sustainability and cleanliness. They utilize water energy, which is a renewable and environmentally friendly energy source. In operation, these turbines do not emit greenhouse gases or other pollutants, making them a cleaner and more sustainable solution compared to conventional energy sources (Pankaj Kumar Yadav, 2023).

The Portable Horizontal Savonius Turbine is also highly suitable as a learning tool in the field of renewable energy. Due to its simple and portable design, this turbine allows students to easily understand the basic concepts of converting the kinetic energy of water into electrical energy. Its use in hands-on experiments can help reinforce understanding of the working principles of water turbines, energy efficiency, and the environmental impact of eco-friendly technologies. Additionally, this turbine can be applied in various environments, including small rivers or water channels around schools, enabling students to practically learn about this technology in real-world contexts. By integrating the Portable Horizontal Savonius Water Turbine into the curriculum, educators can foster students' interest in science, technology, engineering, and mathematics (STEM) while raising awareness of the importance of renewable energy in maintaining environmental sustainability.

This article provides a more detailed discussion on the design, working principles, and benefits of the Portable Savonius Horizontal Water Turbine. It also describes the development of horizontal axis Savonius water turbines for low-flow water conditions. The potential applications in various environments, such as individual use, community use, or even small-scale industrial use, are outlined. Additionally, we will present the latest research findings that evaluate the performance and efficiency of these turbines under field conditions. With its efficient and portable ability to harness water energy, the Portable Savonius Horizontal Water Turbine offers an intriguing solution to meet sustainable energy needs. In an era where environmental protection and energy sustainability are increasingly urgent issues, this article will provide in-depth insights into the potential and benefits of this portable water turbine in maintaining our energy sustainability.

2. Method

The research started with the design of the turbine, fabrication of the turbine, and data collection for output measurement. The locations for data collection were the Sugutamu River in Sukmajaya, Depok, West Java, and the Microteaching-Mechanic workshop Laboratory at Jakarta State University. The experimental method was employed in this study, which involved creating a water turbine device with a Savonius L-type rotor. The developed turbine had a frame with dimensions of 66 cm in length, 38 cm in width, and 40 cm in height, and the rotor had dimensions of 30 cm in length and 10 cm in width. The research measured the rotational speed and power output generated by the turbine. The data collection technique used in this research was observation. The research was conducted with input variables of water flow velocity (m/s) and output variables of generator shaft rotation speed (rpm), output voltage (volt), and electric current strength (ampere). Data processing and calculations were performed to obtain power values (watt), torque coefficient, power coefficient, and Tip Speed Ratio (TSR). The data analysis technique employed was quantitative analysis. Quantitative analysis was chosen because the data obtained in this research were numerical data, allowing for the analysis of the power values generated by the designed turbine. The data to be analyzed in this research included the efficiency comparison of turbine outputs for each data collection based on the variation of water flow velocities from 0.4 m/s to 4 m/s.

The process of creating and testing The Portable Horizontal Savonius Turbine as a learning media for renewable energy involves several steps. First, the turbine design is planned by selecting lightweight and waterproof materials, such as plastic or aluminum, to craft the turbine blades in a half-cylinder shape. Once the materials are cut and shaped, the blades are mounted onto a strong yet lightweight horizontal shaft. The next step is assembling other components, such as a small generator to convert mechanical energy into electricity, and a support system to easily install the turbine in various locations. After assembly is complete, the turbine is tested in a lab or real water flow, such as a small river or water channel. This testing includes observing the turbine's rotation speed, the electricity generated, and performance efficiency at different water flow speeds. The data obtained is then analyzed to evaluate the turbine's performance, and the results can be used for discussions to enhance students' understanding of renewable energy.

3. Results and Discussion

3.1. Portable Horizontal Axis Savonius Water Turbine

The designed turbine has 3 blades made of acrylic material, with a blade spacing of 120 degrees as shown in the following illustration Figure 1.

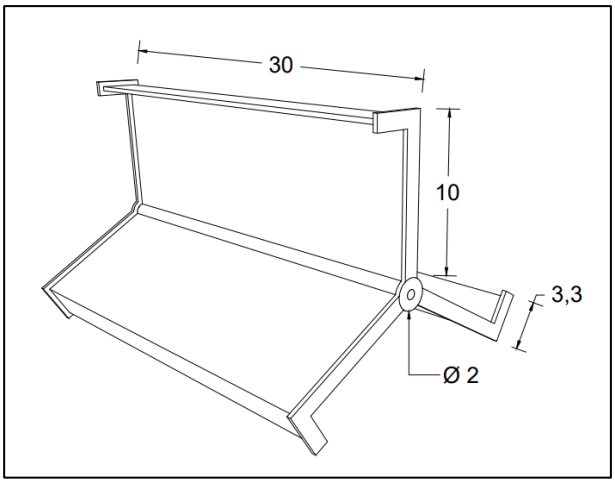

Figure 1. Design of Savonius Horizontal Axis Turbine Blades

The turbine blades will be placed on an aluminum profile turbine frame using bearings with acrylic mounting. The frame also includes a section for placing a deflector with a 30-degree inclination. The pulley on the shaft, along with the generator positioned at the top of the turbine, is connected by a belt as shown in Figure 2.

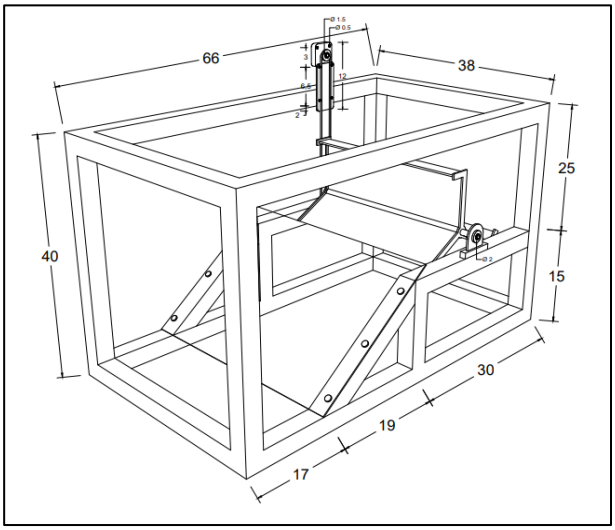

Figure 2. Design of Portable Savonius Horizontal Axis Water Turbine

The turbine frame has dimensions of 66 cm in length, 38 cm in width, and 40 cm in height, while the turbine blades have a length of 30 cm and a width of 10 cm. The turbine blades have elbows with a width of 3.3 cm, and there is a hole for the shaft in the middle with an outer diameter of 2 cm and an inner diameter of 0.8 cm. The turbine blades are made of acrylic material, while the blade shaft is made of solid stainless steel. The turbine frame is constructed using aluminum profiles, joined together with L-type SS304 M4 Full Thread bolts, M4 T-nuts, and brackets. At the rear of the blade assembly, an aluminum timing pulley with an 8 mm width is placed. The pulley serves as a connection to transfer the rotational motion received from the blades through a R610mm timing belt to the generator. The generator used is a 12V DC Stepper Motor, Nema17 17HS4401 type, with a maximum output current of 1.7A, which is repurposed as a generator due to its lightweight rotation. The final product is shown in Figure 3.

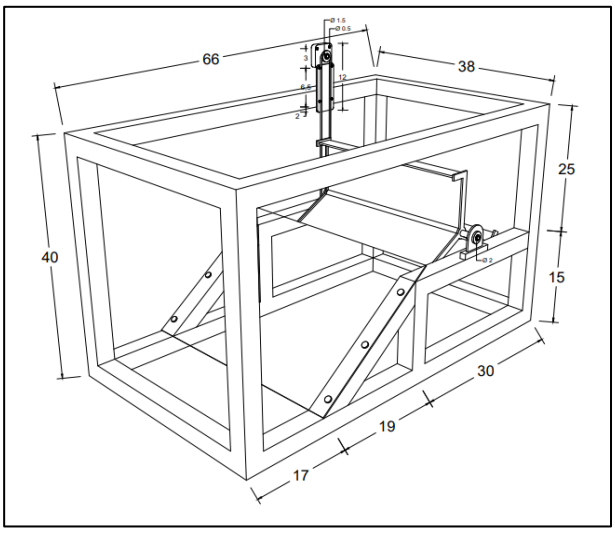

Figure 3. Portable Savonius Horizontal Axis Water Turbine

3.2. Testing of the Portable Savonius Horizontal Axis Water Turbine

The testing was conducted at Sugutamu River located in Sukmajaya, Depok, West Java. The turbine was attached to the river flow as shown in Figure 4.

Figure 4. Testing of Portable Savonius Horizontal Axis Water Turbine

The data was collected at various water flow velocities, namely 0.4 m/s, 0.8 m/s, and 1.6 m/s. Each velocity variation resulted in 20 data points, allowing us to obtain the average rotational speed of the blades at different water flow velocities as follows. The relationship between blade rotation and river water velocity is depicted in Figure 5.

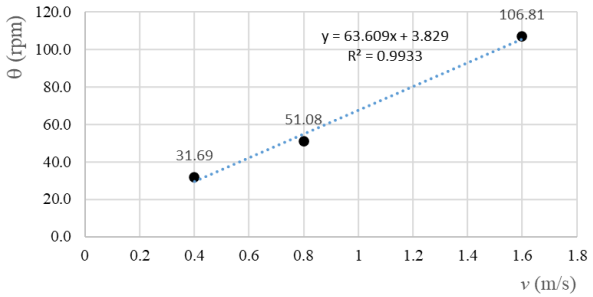

Figure 5. Graph of Shaft Rotation against Water Velocity

By using regression equations, simulations were conducted for a wider range of velocity variations. The relationship between water velocity and the corresponding output voltage is shown in Figure 6.

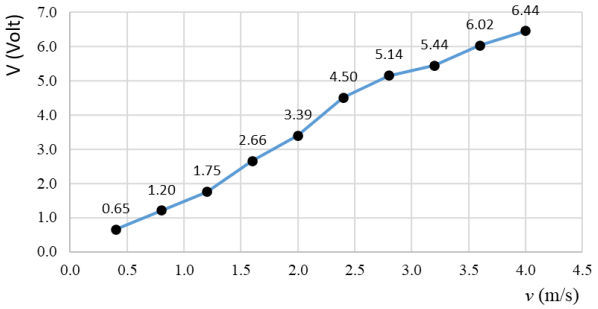

Figure 6. Graph of Output Voltage against Water Velocity

The turbine produces a peak voltage of 6.44 volts when the water velocity reaches 4 m/s. There is a significant increase in turbine output between velocities of 2.4 m/s and 2.8 m/s. The largest increase occurs at a water velocity of 2.4 m/s, where the voltage reaches 4.45 volts, representing an increase of 1.11 volts from the previous water velocity. On the other hand, the lowest increase occurs at an average wind speed of 4 m/s, with a turbine voltage of 6.44 volts, increasing by 0.42 volts from the previous water velocity.

3.3. The Potential of Portable Savonius Horizontal Axis Water Turbine as a Renewable Energy Learning media

The Portable Savonius Horizontal Axis Water Turbine offers an intriguing potential as a learning media in the context of renewable energy. With its innovative and portable design, this turbine can serve as an effective tool for introducing the concept of renewable energy to students, university students, or the public. The discussion on the potential of this turbine as a renewable energy Learning media will cover several relevant aspects. First and foremost, this portable water turbine enables direct hands-on experience in learning about the concept of water energy and its transformation into electrical energy. By installing the turbine in a water flow, students can observe how the flow of water moves the turbine blades and generates electricity. This provides them with an opportunity to understand the basic principles of energy conversion and how renewable energy can be practically utilized. Additionally, the Savonius horizontal axis water turbine provides an opportunity to learn about turbine design principles and optimization. The discussion can focus on the curved angle of the turbine blades, the use of a deflector, and their influence on power and torque generation. Students can learn about the aerodynamic principles involved in the design of this turbine and how to maximize energy efficiency. By utilizing the Portable Savonius Horizontal Axis Water Turbine as a Learning media, students can engage in interactive and experiential learning, gaining a deeper understanding of renewable energy concepts, and fostering an appreciation for the potential of sustainable energy sources. This turbine serves as a tangible and practical example that showcases the applications and benefits of renewable energy in a hands-on manner.

The integration of renewable energy education into academic curricula has become increasingly important to prepare students for the future challenges of sustainable development. One innovative

and promising learning media that can be utilized is the Portable Savonius Water Turbine. This discussion explores the potential benefits and opportunities of using this portable turbine as a learning tool for renewable energy education.

3.3.1. Experiential Learning

The Portable Savonius Water Turbine offers a hands-on and experiential learning approach. By providing students with the opportunity to assemble, install, and operate the turbine, they can gain practical knowledge of renewable energy generation from flowing water. This direct engagement with the turbine fosters a deeper understanding of the principles behind energy conversion, fluid dynamics, and mechanical engineering (Victória Figueiredo Motta, 2023).

3.3.2. Interdisciplinary Learning

The use of the Portable Savonius Water Turbine promotes interdisciplinary learning. It encourages collaboration between students from various disciplines, such as engineering, environmental science, and physics. Through teamwork, students can analyze and solve real-world challenges associated with turbine deployment, efficiency optimization, and environmental impacts. This interdisciplinary approach enhances critical thinking, problem-solving skills, and encourages a holistic understanding of renewable energy systems (Ji Shen, 2023).

3.3.3. Environmental Awareness

By using the Portable Savonius Water Turbine as a learning tool, students can develop a strong sense of environmental awareness. They can explore the environmental benefits of utilizing renewable energy sources and the impact of fossil fuel dependency on climate change. This awareness encourages students to become responsible citizens and advocates for sustainable practices in their communities (Almulhim, 2022).

3.3.4. Technological Literacy

Engaging with the Portable Savonius Water Turbine helps students develop technological literacy. They learn about the design, construction, and operation of turbines, as well as the principles of renewable energy systems. This knowledge empowers them to comprehend and evaluate the potential of various renewable energy technologies, fostering a technologically literate society that can make informed decisions about energy usage (Aiman A. Alawin, 2016).

3.3.5. Practical Application

The Portable Savonius Water Turbine provides a practical application of theoretical concepts learned in the classroom. Students can apply their knowledge of physics, mathematics, and engineering principles to optimize the turbine's performance and understand the factors influencing its efficiency. This practical experience bridges the gap between theory and practice, enhancing students' problem-solving abilities and preparing them for future careers in the renewable energy sector (Jen Chun Wang, 2023).

The Portable Savonius Water Turbine holds immense potential as a learning media for renewable energy education. Its hands-on nature, interdisciplinary approach, environmental awareness, technological literacy, and practical application make it a valuable tool for engaging students in the study of renewable energy. By integrating this portable turbine into educational programs, we can inspire the next generation to embrace sustainable practices, contribute to renewable energy innovation, and build a greener future. Discussions about the potential of this portable water turbine can also involve environmental and sustainability aspects. Students can be encouraged to consider the benefits of using renewable energy in reducing greenhouse gas emissions and negative impacts on the environment (Serkan Buldur, 2020). They can learn why the Savonius horizontal axis water turbine is a more environmentally friendly alternative compared to conventional energy sources. In addition to being a Learning media in the classroom, this portable water turbine can also serve as a subject of study in student research projects. They can conduct experiments to test the turbine's performance under varying water velocities or make design improvements to enhance turbine efficiency. This can involve scientific aspects and engineering skills, allowing students to develop a deeper understanding of renewable energy (Friman, 2017). By incorporating discussions on environmental aspects and encouraging research and experimentation, students can broaden their knowledge and foster a greater appreciation for the importance of

renewable energy in achieving sustainability. The portable water turbine serves as a practical application and a catalyst for engaging students in critical thinking and problem-solving related to renewable energy and its environmental benefits.

4. Conclusion

The Savonius water turbine, particularly in horizontal axis form, is a suitable choice for harnessing low water flows in Indonesia. The use of L-shaped blades and a deflector with a 30-degree inclination in the turbine can enhance the power and torque generated. The turbine developed with an aluminum frame and acrylic blades demonstrates good performance. Data collected by varying water velocities in 10 levels yield maximum power output at a velocity of 4 m/s. The portable Savonius horizontal axis water turbine holds great potential as a renewable energy Learning media. Through hands-on experience, students can learn about the concept of water energy, turbine design principles, and the environmental impact of utilizing renewable energy. With a practical and interactive approach, this turbine can enhance students' understanding and awareness of the importance of sustainable energy utilization.

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All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

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References

A.H. Elbatran, O. Y. (2018). Numerical and experimental investigations on efficient design and performance of hydrokinetic Banki cross flow turbine for rural areas. *Ocean Engineering*, 159, pp. 437-456. https://doi.org/10.1016/j.oceaneng.2018.04.042.

A.H. Elbatran, Y. M. (2017). Performance study of ducted nozzle Savonius water turbine, comparison with conventional Savonius turbine. *Energy*, 134, pp. 566-584. https://doi.org/10.1016/j.energy.2017.06.041.

Aiman A. Alawin, T. A. (2016). Renewable energy education in engineering schools in Jordan: Existing courses and level of awareness of senior students. *Renewable and Sustainable Energy Reviews*, 65, pp. 308-318. https://doi.org/10.1016/j.rser.2016.07.003.

Almulhim, A. I. (2022). Understanding public awareness and attitudes toward renewable energy resources in Saudi Arabia. *Renewable Energy*, 192, pp. 572-582. https://doi.org/10.1016/j.renene.2022.04.122. .

Anuj Kumar, R. S. (2016). Performance parameters of Savonius type hydrokinetic turbine – A Review. *Renewable and Sustainable Energy Reviews*, 64, pp. 289-310. https://doi.org/10.1016/j.rser.2016.06.005.

Friman, H. (2017). New Trends in the Higher Education: Renewable Energy at the Faculty of Electrical Engineering. *Energy Procedia*, 115, pp. 18-28. https://doi.org/10.1016/j.egypro.2017.05.003.

Herman Jacobus Vermaak, K. K. (2014). Status of micro-hydrokinetic river technology in rural applications: A review of literature. *Renewable and Sustainable Energy Reviews*, 29, pp. 625-633. https://doi.org/10.1016/j.rser.2013.08.066.

Jacob Riglin, F. C. (2016). Experimental and numerical characterization of a full-scale portable hydrokinetic turbine prototype for river applications. *Renewable Energy*, 99, pp. 772-783. https://doi.org/10.1016/j.renene.2016.07.065.

Jen Chun Wang, T. H. (2023). Learning effectiveness of energy education in junior high schools: Implementation of action research and the predict–observe–explain model to STEM course. *Heliyon*, 9 (3), e14058. https://doi.org/10.1016/j.heliyon.2023.e14058.

Ji Shen, C. W. (2023). Interdisciplinary science learning. *International Encyclopedia of Education (Fourth Edition)*, pp. 1-9. https://doi.org/10.1016/B978-0-12-818630-5.13030-1.

Jihoon Chung, D. H.-H. (2021). A portable device for water-sloshing-based electricity generation based on charge separation and accumulation. *iScience*, 24 (5), 102442. https://doi.org/10.1016/j.isci.2021.102442.

Kheng Wee Tan, B. K. (2021). Small-scale hydrokinetic turbines for remote community electrification. *Energy for Sustainable Development*, 63, pp. 41-50. https://doi.org/10.1016/j.esd.2021.05.005.

Meryeme Azaroual, S. S. (2022). Optimal control application in a hydrokinetic-battery power generation on seasonal river for energy-enabler for remote rural communities: Case of Zambia. *Renewable Energy Focus*, 41, pp. 69-79. https://doi.org/10.1016/j.ref.2022.02.004.

Pankaj Kumar Yadav, A. K. (2023). A critical review of technologies for harnessing the power from flowing water using a hydrokinetic turbine to fulfill the energy need. *Energy Reports*, 9, pp. 2102-2117. https://doi.org/10.1016/j.egyr.2023.01.033.

Serkan Buldur, M. B. (2020). The impact of an outdoor education project on middle school students' perceptions and awareness of the renewable energy. *Renewable and Sustainable Energy Reviews*, 134, 110364. https://doi.org/10.1016/j.rser.2020.110364.

Victória Figueiredo Motta, S. V. (2023). Experiential learning in entrepreneurship education: A systematic literature review. *Teaching and Teacher Eduation*, 121, 103919. https://doi.org/10.1016/j.tate.2022.103919.

Wei Yang, Y. H. (2019). Lift-type and drag-type hydro turbine with vertical axis for power generation from water pipelines. *Energy*, 188, 116070. https://doi.org/10.1016/j.energy.2019.116070.

Xiu Wang, Y. Y.-Q.-P. (2023). Evaluating energy loss with the entropy production theory: A case study of a micro horizontal axis river ducted turbine. *Energy Conversion and Management*, 276, 116553. https://doi.org/10.1016/j.enconman.2022.116553.