SDG #7: Affordable and Clean Energy

This module focuses on SDG 7 which aims to "ensure access to affordable, reliable, sustainable and modern energy for all." The stories include an individual who builds a wind turbine in Mali, a Spanish company developing floating wind turbines, and Kenya's expansion of geo-thermal energy. The activities include an introduction to various sustainable energy sources, group discussions, a lab activity, and a field trip.

Link to Subjects	Engineering, Science (Earth/Climate), STEM, Technology		
Link to Indiana High School Core	TBD HS-ESS3-4 GHW.12.3	Link to International Baccalaureate	TBD
Story	Story #1: Moving Windmills: The William Kamkwamba story Story #2: This company is reimagining floating wind Story #3: Kenya straddles a volcanic rift. It's a green-energy geyser		
Activities	Activity #1: Introduction to types of energy	Activity #2: Create a windmill / wind turbine	Activity #3: Renewable energy field trip
Type of Activity	Group Research & Discussion	Lab Experience	Field Trip
Time of Activity	1 class	1 class	1 class

Key Questions & Terms

Key Questions	**Key Terms**
What is the difference between renewable and nonrenewable energy? How does renewable energy relate to energy access? Why are energy storage and distribution important when considering a renewable energy system?	Renewable energy Solar energy Geothermal energy Hydroelectricity Wind energy

Story Summaries

Story #1: Moving Windmills: The William Kamkwamba story

This is the story of the 14-year-old William Kamkwamba of Malawi, who built a wind turbine to power his home and eventually his village. The young William built his first windmill using only a few books from the library, and has inspired youth and innovators around the world. There are both youtube videos, a book, and a film about his story.

Story #2: This company is reimagining floating wind

The Spanish start-up company has developed a new floating wind turbine that can be placed in deeper ocean waters at lower costs to harness more of the earth's wind power. This youtube video discusses the unique design features of this wind turbine.

Story #3: Kenya straddles a volcanic rift. It's a green-energy geyser

Kenya's location along the great rift valley means that it has access to geothermal energy. As of 2018 it was the leading producer of geothermal energy in Africa with a capacity of 650 megawatts, over 40% of the electricity generated in Kenya in that year.

Opening discussion

1. Introduce students to SDG #7 to "Ensure access to affordable, reliable, sustainable and modern energy for all"
    a. You can use this video: https://youtu.be/jlWfQoycRPE or the UN Goals website as resources: https://bit.ly/3RxOXhZ
2. Divide the class into groups, have half of the groups read the Story #1 and the other half read Story #2.
3. Ask students how each story demonstrates issues related to each of the following
    a. Energy affordability
    b. Energy reliability
    c. Energy sustainability
    d. Modern energy

Activity #1: Introduction to types of energy

Students will research basic information about various renewable energy sources and how they might be used in their community.

Activity Learning Objectives

1. Students understand the variety of energy sources that exist
2. Students identify ways in which their community and school use different energy sources

Teacher preparation

1. Ensure that students will be able to conduct research during the activity either via internet access or through handouts. You can create handouts about some of these facts and figures for the United States using the reports from the U.S. Energy Information Administration, see: https://bit.ly/4ccSpa8
2. For the enrichment activity, ask your school administration what types of energy the school uses to determine if asking students to research this would be a useful exercise. Identify different green/renewable energy sources/projects in the community to direct students to if they have difficulty finding them.

Lesson Flow

1. Remind students of the key focus of SDG 7 to "Ensure access to affordable, reliable, sustainable and modern energy for all."
2. Divide the students into four groups, assign each group a different type of energy (solar, wind, geothermal, hydroelectric), and ask each group to use the internet to research the following questions for that energy source. For this activity you can assign a specific state, region, or country to use.
    a. How has the price of that energy changed in the past 20 years?
    b. How has the amount of that energy produced changed over time?
    c. How does the availability of that energy change by location or time of day?
    d. How could this be used in your school or community?
3. Ask each group to share back with the class what they found out
4. Discuss what mix of sources would be ideal for their school and/or community.

Possible Enrichment

Assign the same groups of students to investigate how their school/community uses their assigned type of renewable energy and what the local price is for that type of energy. Based on this research, ask students to create a proposal (written or presentation) for increasing the use of that renewable energy source in their community. Teachers should do some initial research to determine if any of the common sources should be eliminated or replaced in your context.

Activity #2: Create a windmill / wind turbine

Students will work to create a wind turbine (either as a model or as a functioning turbine depending on your resources). This will encourage students to explore how they can make a difference through their own energy consumption and how they might learn more about skills involved in the green energy economy.

Activity Learning Objectives

1. Understand the basic functioning of a wind turbine to generate electricity
2. Build confidence in the skills that are a part of the green energy economy

Teacher preparation

1. Ensure that you have the materials necessary for students to work in groups to create wind turbines.
2. Set up a way to generate wind for the activity (e.g., some fans)
3. Review the potential labs to choose your preferred activity. We suggest the materials from KidWind, and an example activity (and needed materials) are found here: https://bit.ly/4ctID37

Student preparation

1. If necessary, ask students to bring some basic materials (e.g., cardboard, PVC pipe). Be cognizant that some students might not be able to afford to buy/bring materials, and find out if your school can support you via some materials for this activity.

Lesson Flow

1. Ask students if they think they could make a wind turbine if they needed to? Ask them why or why not.
2. If students have not already done so, ask them to read/watch the story of William creating a windmill in rural Malawi. Discuss the story and how it might change their answer to the opening question.
3. Explain that today students are going to work in groups to create model wind turbines. Unless you choose another approach/set of materials, we propose this approach: https://bit.ly/4ctID37
4. Hand out the material and instructions for the activity to each group of students.
5. After they complete the activity ask them to reflect on the following questions
    a. What was technically difficult?
    b. What materials do they think would be hardest to acquire at a large scale?
    c. How does the experience of doing this lab change their view of what William did?

Possible Enrichment

Explore with your school and local authority if there would be a possibility to install a small wind turbine or a solar array at the school to provide power to the school (or for a small laboratory setting). Students should be given substantial responsibility to carry this out. This would be an ideal activity to engage with TVET courses at your school.

Activity #3: Renewable energy field trip

Students will have the opportunity to visit a company that produces/distributes renewable energy and learn more about the process and the jobs associated with that type of energy production. This might be a wind turbine farm, a solar farm, a geothermal power plant, or a hydroelectric dam.

Activity Learning Objectives

1. Understand more about a particular type of renewable energy produced in their area
2. Engage with experts about the broad range of skills needed to engage in green energy
3. Connect abstract ideas and goals of “sustainable energy” with local practice

Teacher preparation

1. Identify the nearest company producing renewable energy (e.g., geothermal, wind, solar, hydroelectric)
2. Get permissions from the organization, the school, and students’ families for a field trip to the site.
3. Alternatively, you can arrange a ‘remote’ field trip in which someone gives a tour of the site using a video conferencing platform which students access from school.
4. Identify one speaker from the company/organization to speak to and answer questions from the students.

Student preparation

1. Ask students to come with two questions they want to ask / learn more about. One question about the technical process and one question about job prospects/skills needed to work in that sort of environment.

Lesson Flow

1. Organize an introduction to the site by someone working for the company/organization
2. Have students ask them some questions
3. Conduct the in-person/virtual visit of the site
4. Have an opportunity for students to ask additional questions

Full Story Text

Story #1: Moving Windmills: The William Kamkwamba story

Original story: https://youtu.be/arD374MFk4w; Movie adaptation (trailer): https://youtu.be/nPkr9HmglG0; Book version: https://bit.ly/3zfDmOv

Transcript of first video generated by Youtube Transcript Generator

In late 2006, a Malawian newspaper first wrote about a remarkable young man from a remote rural village north of the capital.

My name is William Kamkwamba and I'm from Malawi. The economy of Malawi, most of them, we depend on farming, we depend on Tobacco. I'm 20 years old now. My Village has 60 families here and in my family we are about 20. I dropped out of school because my parents had no money to pay school fees. The school fees are about $80.

We have enough wind in Malawi and I was thinking: what can I do to use that wind so that we can have something. That is why I decided to read some books about the windmills.

The first time I saw a windmill in the book, they just came up with the pictures. But they didn't say anything about what you can do to build that windmill so that you can generate electricity or you can pump water.

Journalist: “You figured that out on your own?”

Yeah I figured that out on my own. If this windmill is in this book, then if I can try, then maybe I can make one so that I can have electricity in my home. The time I was set to build a windmill I was 14 years old. It took me about two months to build the first windmill. They couldn't believe that I made something to generate electricity. What makes people to start realizing that this thing is useful was when it powered a radio.

Journalist: “Was it music that was on the radio?”

It was a local Malawian reggae music. And most of the people didn't know what I'm doing. They thought that maybe I'm going mad and maybe I'm crazy. I didn't see much support the first time. But after I've built a little windmill is when some people started to realize that, ‘Oh maybe this is a useful thing, maybe we should help him.’

I went to the library to return the books. And the librarian asked me, ‘Oh you built the windmill using the knowledge from this book.’ And I said ‘Yes.’ [And the librarian said], ‘Oh okay I'll come to your home so that I can see.’ And the guys came with some journalists and wrote an article about the windmill.

As a result of his efforts, William was invited to visit the United States for the first time.

Journalist: “So you have a machine that's like this?”

William: “I took a tractor fan.”

Journalist: “Well first off, when you see these enormous windmills what are your first impressions?”

Radio host: “From a photograph in a textbook William built a windmill. This is a story that should be shouted from the rooftops.”

William: “My dream is to finish my education and in the future to start my own company about the windmills. Most of the people, they want technology, about the internet technology, but they cannot use the internet technology without electricity. That's what I'm planning to do, is to come up with reliable electricity. Yeah that's what I'm planning to do.”

Over the last nine months, William has added a second windmill, solar panels, bright lighting, and a deep water well to his family compound. For the first time, his family can work, study, and read at night, and irrigate crops by day. In September 2008, William will join the inaugural class of the African Leadership Academy in Johannesburg, the first pan-African preparatory school.

Story #2: This company is reimagining floating wind

Original video: https://youtu.be/j4AL8seRwSc

This is the x30 wind turbine prototype by Spanish company X1 wind. It's a floating platform, has a traditional three-blade design, and it hopes to take offshore wind to a whole new level. This map shows the potential for harnessing wind energy across the world. As you would expect some countries are windier than others. Britain looks as miserable as ever.

But across the entire map there is one consistent trend: most of the world's wind resource is offshore, not onshore. And according to the energy sector management assistance program just one percent of the global offshore wind potential could generate enough energy to meet the current Global demand.

As it currently stands though, offshore wind power as opposed to onshore wind, makes up just 7.1 percent of the total installed wind capacity worldwide. Which on greater reflection isn't surprising, given the challenge of installing operating and maintaining turbines far out at sea. Not only that but according to the World Bank, over 70% of the world's wind energy resource is found in deeper waters unsuitable for fixed turbines.

It is this that in recent years has led to the rapid development of floating wind turbines.

Few designs however have been able to achieve the cost competitiveness scalability and flexibility that X1 wind's project aims to achieve. With the tagline, 'disrupting offshore wind,' X1 wind hopes their turbines will be able to achieve cost competitiveness not only with fixed offshore turbines but even onshore arrays.

How will they do this you ask? Well, it all comes down to some very clever design considerations. The concept proposed uses a single point mooring system configured to point downstream. This essentially turns the turbine into a massive weathervane allowing it to passively self-orientate improving overall efficiency.

Traditionally; however, wind turbines point in an upwind direction. And there is a reason why this is favored: by having the blade upwind of the tower you reduce the disturbance or shadowing by the tower of the airflow onto the turbine blades. There is also evidence that downwind turbines are noisier due to this disturbed airflow and can experience greater blade loads compared to upwind turbines.

So why opt for a downwind design then? One of the main drawbacks of upwind turbines is that the tolerance for flexing of the turbine blades is very small in order to prevent the blade striking the tower under high loading. This means that the blades need to be stiffer, often calling for more complex, heavier designs, with higher material and manufacture costs which quickly add up when considering a commercial scale project.

In a downstream design such as the one used by X1 wind, the blades flex away from the supporting tower or structure this means engineers are less constrained by measures to prevent tower strike and the blades can be made longer, lighter, and crucially, at a lower cost. The use of a passive, as opposed to active, orientation system, also means less can go wrong in the way of maintenance.

Perhaps the jewel in the turbine's crown though is X1 winds trademarks pivot buoy connection system. Contrary to other floating wind designs, using semi-submersible or spar boy systems, pivot buoy uses what is known as a tension leg platform, or TLP. Instead of using a heavy ballast to stabilize the wind turbine, TLP mooring works by connecting a platform with excess buoyancy to the seabed by taught cables, restraining the vertical motion of the platform. X1 wind’s smaller x30 prototype, which has already been tested, is the first fully functioning floating wind platform to successfully use this kind of mooring.

Whilst the use of these cables and the tension does increase the risk of fatigue and requires more expensive anchoring systems at the seabed, TLP does come with a number of very attractive advantages. Not only does it reduce the overall mooring footprint and weight of the turbine, but the clever design of the pivot buoy also allows for easier installation. In the case of X1 wind, the pivot buoys are pre-installed with the mooring system, allowing the actual turbine to be assembled onshore and then towed to the site. This simultaneously opens up advantages when it comes to servicing, as the platform can be easily disconnected and towed away for maintenance.

In part due to its downward design, X1 wind have completely redesigned the structure of the wind turbine as we would imagine it, using a tripod design instead of a single tower. This eliminates the high bending moments and stresses of tower-based designs and instead distributes the loads in tension and compression. This kind of tripod-based design is becoming increasingly more competitive in large rotor turbines, even more so in floating systems where large moments create difficult design challenges.

X1 wind states that this makes the structure more scalable. And whilst the structure above the surface may have a larger footprint, the single point mooring system ensures a small footprint below the surface, where it arguably has a larger impact on marine systems. As for the size of the final product, X1 wind hopes to have their 14 to 16 megawatt commercial scale x150 platform in use by the end of the decade, using a whopping 240 meter diameter blades. For context then, the current largest wind turbine in the world has a blade diameter of 260 meters and a capacity of 18 megawatts whilst most of today's new offshore wind power projects have capacities in the range of 8 to 12 megawatts. What is perhaps so striking about this design though, is not its performance or efficiency, nor is it its scale. It's about using clever designs and systems together in a package that makes it perfectly suited to the application, finding sensitive trade-offs between economic, environmental, and practical factors

If there was one word to describe what this design offers, it's adaptability. Adaptability in scale; adaptability to location and conditions. And in an industry where change is happening so rapidly, adaptability is what you need.

Story #3: Kenya straddles a volcanic rift: It's a green geyser

Rosen, J.W. (2018). Kenya straddles a volcanic rift: It's a green geyser. Retrieved from: https://on.natgeo.com/3VwVNWp