DESIGNING A BRIGHTER FUTURE

UNIT 4:

CHANGE IS IN THE WIND

In efforts to be environmentally friendly, some individuals and businesses have begun to invest in off-grid homes and buildings.

This unit will provide students with an opportunity to explore ways to make a home, school or other building self-sufficient using wind energy. Students will also learn about leaders in the wind energy industry and the history of wind energy in Canada.

CURRICULUM CONNECTIONS

This resource is connected to elementary science and technology curricula, particularly in grades 4 to 6 with a link to energy, electricity, forces and the environment. The unit is also linked to the secondary level, most notably in grades 9 and 11, where there is a focus on energy, electricity, magnetism, and climate change.

LEARNING OUTCOMES

- Explain what is considered a self-sufficient building
- Debate the efficiency of wind energy
- Analyze ways to make a building self-sufficient by considering energy requirements, location, climatic conditions, cost and turbine efficiency
- Explain the science behind wind energy
- Create a model of an off-grid building
- Assess the strengths and weaknesses of a prototype

SUGGESTED TIME: 4.5 HOURS

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These resources were created through a collaboration between Ingenium and a University of Ottawa doctoral candidate, Janelle Fournier.

INTRODUCTION AND BACKGROUND INFORMATION

Did you know that in 2016 Canada consumed 8786.4 petajoules of energy[1]?

What is 8786.4 petajoules?

1 petajoule = energy of one thousand trillion joules = 1 000 000 000 000 000 J

Unit conversions

8786.4 petajoules = 8.7864×10^{18} joules = 2.1×10^{15} kilocalories = 2.440667×10^{15} watt hours

Equivalent in barrels of oil

With the single use of oil, we would need approximately 1436.2 million barrels of oil to produce that amount of energy.

This energy is essential for our homes, our businesses and our agriculture. It is imperative that every citizen of the world assesses their energy consumption and preferred energy sources.

Natural Resources Canada informs us that:

> Energy efficiency is hard to see, but we feel the benefits in our homes, neighbourhoods, economy, and wallets. It is the quickest and least costly way of addressing energy-related security, environmental and economic challenges. Canada has a long history of working to improve energy efficiency. However, we can and should go further[2].

In order to save energy, more and more individuals and businesses want their buildings to go green, by either installing solar panels, wind turbines or other devices. Take the example of the Dockside Green community in the city of Victoria, British Columbia. The image below shows a building with three wind turbines. The turbines partially power the bakery on the first floor. The 15-acre community has also implemented other green initiatives, such as a stormwater management system, an integration of bee and bird habitats, and communal green roofs[3].

Dockside Green community

We suggest that students begin this unit by exploring ways to make a building, such as a home or school, self-sufficient.

[1] Natural Resources Canada, 2011
[2] Natural Resources Canada, 2019, p. 6
[3] Crescenzi, 2020

RECOMMENDED PROCESS

1. **Exploring careers in STEM/Case study of Monique Carpentier**
   - In science, technology, engineering and mathematics (STEM), there are many career opportunities. Allow students to explore a variety of websites, such as Let's Talk Science, DiscoverE and Explore Engineering, to discover careers related to the environment and energy.
   - With students, make a list of careers that interest them and discuss the steps they should take to pursue such professions. Ask students why they are interested in these careers and offer other suggestions for future directions.
   - Next, present the case study of Monique Carpentier, an engineer with a talent for science communication (see Appendix 1).
   - Ask students to debrief on the case study. Below are some suggested questions.
     a. What are your impressions of Monique Carpentier's work?
     b. If you ever have the opportunity to meet Monique Carpentier, what questions would you ask?
     c. What does the wind turbine model make you think of?
     d. Monique Carpentier says that dreams are made to be realized. Do you think she is right?
     e. Are you interested in a career similar to Monique Carpentier's? Why?

2. **Exploring the history of wind energy in Canada**
   - Further explore one STEM disicipline – wind energy. Present the History of Wind Energy from Appendix 2.
   - Announce to students that they will need to prepare for a debate that addresses the question: Is wind energy a viable solution to the energy crisis? This debate will prepare students for the project that follows.
   - Divide the students into two groups, one affirmative and one negative.

3. **Think-Pair-Share**
   - After the debate, ask students what is the meaning of the term "self-sufficient".
   - Conduct a think-pair-share activity to discuss off-grid buildings, most notably how to make a building self-sufficient.
   - To do this, allow students to think about the question below for 30 seconds, then they can talk about it with a partner for one minute, and finally share their thoughts and knowledge with the class.
   - Question: How can we make a building self-sufficient?

4. **Setting the scene**
   - Now that the students have begun to think about how to make a building self-sustaining, the next step is to present the context to the students. Essentially, they will have to answer the question: How can we use wind energy to make a home, school or building self-sufficient?

- For example: As an educated person, you are concerned about environmental sustainability and decide to make a change to at home, at a school or at a building to make it self-sustainable with the help of wind energy. As a young engineer, you will use the design process to find the best way to make your chosen building self-sufficient with wind energy. You must design a model of your self-sufficient space, while considering aesthetics, cost and efficiency.

- Form heterogeneous groups of 3 to 4 students.

5. **Present the design process**
    - If this is the first time you or the students are using the design process, please take the time to read Appendix 3 and introduce the process to the students.

6. **Begin the design process**
    - As students undertake the steps in the design process to create a model of a self-sufficient building, please provide relevant information. For example, if students choose your school as the building they'd like to make self-sufficient, they will need to know the energy consumption of the school. Please be sure to have this information ready to share with the students.
    - You can also present them with questions to reflect on, such as the ones below:
        - Why is it important to consider what has been done in the past in order to make an effective model?
        - How much energy is consumed in the building each month? How much energy would have to be produced to make it self-sustaining?
        - Are there ways to reduce this consumption?
        - Will the building be able to be self-sufficient solely with the use of wind energy?
        - What type of wind turbine would work best? Why?

7. **Model evaluation**
    - Ask students to provide a written report or make an oral presentation to explain their design choices (e.g., type, number and location of turbines, cost, etc.), calculations of efficiency, successes and failures, and areas for improvement.

ADAPTING TO DIFFERENT GRADE LEVELS

Grades 4 to 8

Depending on their level of understanding, teachers may require students to answer more questions, including:

- How does wind energy become electricity?
- Why did you choose this type of wind turbine?
- Is the model feasible? Why?

Grades 9+

Require high school students to provide more detailed responses by considering the following elements:

- They will have to choose a location for their building, because the location and weather conditions affect the productivity of the wind turbine.
- Explain the type of wind turbine they have chosen and why.
- Describe in detail how electricity is generated by wind and stored.
- Analyze the prototype and determine if it is currently feasible.
- If the project were to be repeated, what renewable energy sources would you utilize? Why would you choose renewable energy sources?

DIG DEEPER

Discussing the need for failure

Once the design process is complete, teachers could lead a discussion on the need for failure in order to continue to develop a growth mindset in students. Here are some suggestions:

- Initiate a discussion with the students by presenting a quote from Dr. Henry Petroski, a mechanical engineer. He says, "Today's successful design is tomorrow's failure"[4]. Ask students: What is meant by Dr. Petroski's quote? Are they right?
- Continue the discussion on failure by presenting the example of the Tacoma Narrows Bridge that collapsed in 1940 due to high-speed winds. Present a report or a video of the bridge, such as this one https://www.youtube.com/watch?v=XggxeuFDaDU, and ask the question: What did we learn from this bridge?

Innovation village

- You may decide to organize an innovation village within the school where students can present their model to others grade levels.
- Otherwise, the project could be a school-wide initiative or it can be undertaken with feeder schools (such as at a science fair), and then presented to parents, staff and community members.

[4] Dean, 2006

ASSESSMENT

Diagnostic
Assess their prior knowledge of wind energy and how to make buildings self-sufficient during class discussions.

Formative
As students begin the design process, teachers can assess their knowledge of self-sufficient buildings and wind energy, either through questioning or written documentation. Question: Why use this type of turbine? How many turbines will be needed to make the building self-sustaining? Will the location of the turbines affect the production of electricity? In addition, students could complete a handout while working through (or after completing) each step of the design process. These documents can be part of the final report or could be useful to ensure student understanding as they work on their prototype. Lastly, the debate could also act as an assessment or evaluation.

Summative
Evaluate the final report or oral presentation of the prototype of a self-sufficient building. Ask students to include calculations of energy consumption and production, their choice of turbines, cost, etc. They should also highlight their successes and failures and explain how they would improve their design.

APPENDIX 1 – AN ENGINEER WITH A UNIQUE TALENT

Monique Carpentier

- Graduate of Laval University
- Bachelor of Engineering Physics
- Professional engineer
- Policy researcher
- First woman in Canada to manage the government’s wind energy research program
- Founding member of the Canadian Wind Energy Association
- Recipient of the R.J. Templin award

“Anything is possible. If you want to do it, you do it. Put what you need in place to make it happen. A dream is meant to be realized. So dream and then work to make your dream come true.”

Originally from Québec, Monique Carpentier is an engineer and policy researcher. In 1982, she received her Bachelor's degree in Engineering Physics from Laval University, with a specialization in energy and mechanical engineering. Her degree led her to a career with Natural Resources Canada working on wind energy research. She was one of the first women in Canada to participate in wind energy research that was in its infancy, and one of the first women in the world to work on it (M. Carpentier, personal communication, January 9, 2020).

As a recent graduate, she collaborated with the team of Raj Rangi, Peter South, Jack Templin and others working on wind energy (M. Carpentier, personal communication, January 9, 2020). You may recognize the names Rangi and South, as they have gained worldwide recognition for the rediscovery of the Darrieus-type vertical axis wind turbines (wind turbines that were patented by French engineer Georges Darrieus) (Tudor, 2010).

While Monique Carpentier was working with this team, Darrieus wind turbines were the main area of research at the National Research Council Canada (M. Carpentier, personal communication, January 9, 2020). An image of a small scale model of a vertical axis wind turbine can be found on the following page and more details about this artifact can be found on Ingenium's website - https://ingeniumcanada.org/ingenium/collection-research/collection-item.php?id=2009.0101.001.

Looking back on her career and what she enjoyed the most, Monique Carpentier explains: "The drive, spirit and ability to dream of people who were in wind energy” [translation]. At the time, there weren't many people working in wind energy, but those involved were dedicated. For Monique Carpentier, it was a motivating factor because the team worked with a desire to change the world, and they were not working just for a salary. Having worked in wind energy for just over 5 years, Monique Carpentier acknowledges that progress in this field is due to the many people who have dedicated their careers to it (Mr. Carpentier, personal communication, January 9, 2020).

While working on wind energy, Monique Carpentier recognized that she had a unique talent. She realized that she could easily do something that challenged many scientists and engineers – science communication. She decided to pursue that path and her career blossomed. In 1990, she turned her attention to

Darrieus turbine model
Artifact # 2009.0101.001
Ingenium National Collection

the development of science policy, in which one of her tasks was to be a liaison between politicians and science groups. She explains: "I built trust with the researcher(s) and with politicians, providing answers that they could understand and be used afterwards. I was able to make a good connection between the two" [translation] (M. Carpentier, personal communication, January 9, 2020).

Prior to her retirement, she became the Director of the Earth Sciences Policy and Coordination Sector at Natural Resources Canada. Monique Carpentier has had a successful career in wind energy and science policy development, but is grateful for her humble beginnings (M. Carpentier, personal communication, January 9, 2020).

Family upbringing

Her mother was a teacher and later a housewife, and her father was a farmer. She had 7 brothers and sisters who all had to work on the farm and do the dishes in the house. Both her parents understood the value of education and the 8 children were encouraged to pursue university studies (M. Carpentier, personal communication, January 9, 2020).

Her parents encouraged her to follow her dreams. They told her that she could realize them and that nothing could stop her. Passionate about science, she decided to pursue her studies in engineering physics. Thanks to grants and loans, she was able to attend Laval University. In fact, she became the second woman from that university to earn a degree in engineering physics (M. Carpentier, personal communication, January 9, 2020).

Success in the field of STEM

Monique Carpentier attributes her professional success to her education, a supportive spouse and a personal investment on her part. She expresses that she has had some success because of her commitment and the many hours she has devoted to the cause. When asked what she is proud of, the very humble Monique Carpentier explains, "What makes me happy today is to see that wind energy continues and thrives. I think […] I may have played a small role at one time that kept it going" [translation] (M. Carpentier, personal communication, January 9, 2020).

In conclusion, she offers a piece of advice to students: "Anything is possible. If you want to do it, you do it. [...] Put what you need in place to make it happen [...]. A dream is meant to be realized. So dream and then work to make your dream come true" [translation] (M. Carpentier, personal communication, January 9, 2020).

We would like to express our deepest appreciation to Monique Carpentier for her invaluable contribution to this case study.

APPENDIX 2 –HISTORY OF WIND ENERGY IN CANADA

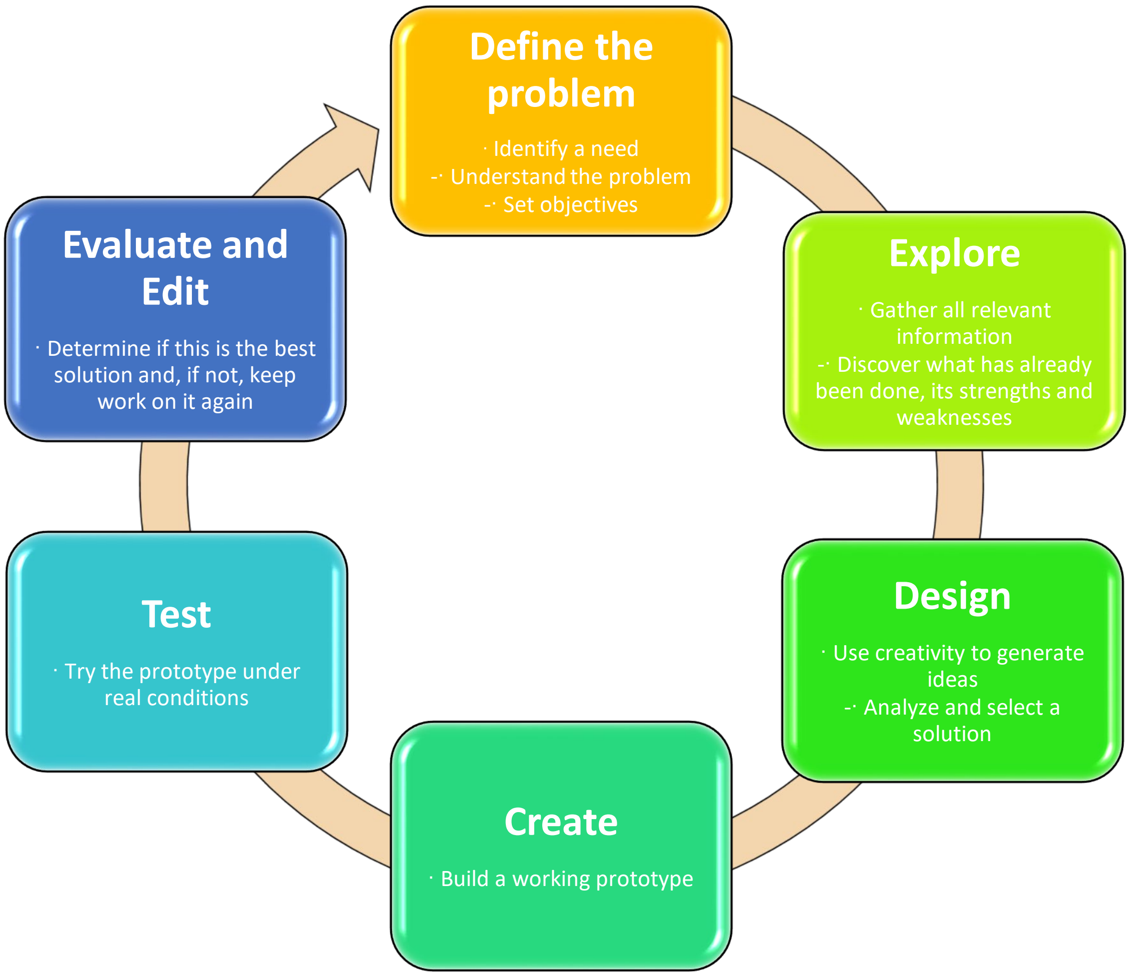
1881	William Thompson was the first to suggest that wind could generate electricity.
Winter 1887-88	Charles F. Brush develops the first wind turbine, called "Wind Dynamo", capable of generating 12 kW of power to charge batteries for crystal radio receivers.
1920s	Modification of wind turbines; inspiration taken from airplane propellers and monoplanes wings (single main wing plane in aeronautics).
1930s	Hundreds of small wind turbines, with the capacity to generate 1 to 3 kW, are being built in rural areas of Western Canada. They are used, among other things, to light farms and later to power electrical appliances.
1931	The French engineer Georges Darrieus obtains a patent for the first vertical axis wind turbine.
1940s	After the Second World War there was less interest in wind energy in North America because the price of fossil fuels was very low. However, wind energy research continues worldwide.
1941	The first wind turbine capable of producing megawatts of energy is designed in Vermont. The turbine is named "Putnam Wind Turbine". It produced 1.25 MW and ran for 1,100 hours before a blade broke. Thus, the need to design lighter materials for wind turbines. The Putnam Wind Turbine was the largest wind turbine built until 1979.
1950s	Johannes Juul from Denmark develops the first wind turbines that can produce alternating current.
Early 1960s	In Canada, there is a renewed interest in wind energy. The Brace Research Institute at McGill University has begun research on wind turbines and their ability to generate electricity for developing countries and rural areas.
1966	Raj Rangi and Peter South at the National Research Council Canada begin their research on vertical axis turbines, including two- and three-blade arc-shaped models. They are credited with the rediscovery and popularization of the Darrieus-type wind turbine.
1973	With the oil crisis, wind power and renewable energy production are becoming a priority.
1975	Hydro-Québec's Research Institute commissioned a vertical-axis turbine called the eggbeater because of its shape. It can generate 40 kW.

1977	A 230-kW vertical axis wind turbine is developed in the Magdalen Islands in Québec thanks to Hydro-Québec's Research Institute and the National Research Council of Canada. The turbine is no longer in operation, but remained on site until 2019. To watch its demolition, please refer to this video - https://www.facebook.com/watch/?v=673253899869170.
Early 1980s	DAF Indal started the commercial production of wind turbines for California.
Mid-1980s	With the end of the oil crisis, oil production increased. As a result, the federal government stopped supporting renewable sources of energy.
1986	Horizontal axis wind turbines have begun to gain popularity because of their higher efficiency as compared to vertical axis turbines. That same year, Hydro-Québec built a 65 kW horizontal axis wind turbine in Kuujjuaq, a village in the Northern Québec region.
1990s	The culture has changed again to prioritize wind energy.
1994	Canada's first commercial park, called Cowley Ridge, was built near Pincher Creek, Alberta.
2006	Progress continues and 3 MW wind turbines are in operation.
2008	Canada's wind energy industry employed over 200,000 people and all provinces had adopted wind power. Also in 2008, British Columbia began construction of its first wind farm.
2009	Some wind turbines now have a capacity of 6 MW and designs continue for onshore and offshore wind turbines that have a capacity of up to 8 MW.
2018	"Wind energy met about 6% of the country's electricity demand. In some provinces, the percentage is higher: 28% in Prince Edward Island, 12% in Nova Scotia, 8% in Ontario, and 7% in Alberta and New Brunswick" [translation] (Canadian Wind Energy Association, n.d., para. 5).
Present	Today, wind energy produces enough energy for more than three million homes in Canada. There are 301 wind farms with more than 6,000 turbines in the country where more than 13,413 MW of energy is produced. There is an increasing demand for wind energy systems that can be used domestically.

Taken from: Canadian Copper & Brass Development Association (2020); Canadian Geographic (n.d.); Canadian Wind Energy Association (n.d.-b, n.d.-a); Danish Wind Industry Association (2003); Hydro-Québec (n.d.); Sager (2016); Tudor (2010)

APPENDIX 3 – DESIGN PROCESS

The design process, used by engineers, can be used when a person tries to solve a problem that has multiple solutions. There are six steps to the design process.



Adapted from Khandani (2005); The Works Museum (2016)

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