**Prior Knowledge and Skills**
- Experience using graphic organizers
- Experience locating information using internet sources
- Experience working in cooperative small groups

**Success Criteria**
- Students clearly express and organize ideas and information from various electronic sources using electronic research tools
- Student research demonstrates understanding of the processes, advantages and disadvantages of fission and fusion as energy sources

**Assessment Strategies**
- Assessment of student graphic organizers
- Observation of group work
- Individual writing assignment (Mini-Position Paper)

**RESOURCES & MATERIALS**
- BLM – Fission vs. Fusion Student Web Links [doc] [pdf] – 1/student
- Large pieces of white paper – 2/group of 4 students
- Electronic device with internet access

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**OVERVIEW**

| Subject Focus: Physics, Science | 21st Century Skills Focus: Critical Thinking, Communication | Suggested Timing: 45-60 minutes plus time outside of class

**Learning Goals**
- Understand the basics of the processes of nuclear fission and fusion
- Discuss the implications of nuclear fission and fusion as potential energy sources
- Evaluate evidence and consider alternative perspectives, ideas, and explanations

**Learning Activities**
In this lesson, students will gather information from various online resources to gain an understanding of the differences between the processes of nuclear fission and fusion and will write a Mini-Position Paper about the scientific and technological pros and cons to be considered when thinking of these two processes as meeting future energy needs.

**Big Idea**
Nuclear fission involves the splitting of a heavy nucleus into lighter nuclei, while nuclear fusion involves the combining of light nuclei into a single heavier nucleus. Both processes produce vast amounts of energy, but each has its own unique set of advantages and disadvantages as an energy source.

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**Lesson Context**
Currently, all of the nuclear reactors in Canada employ the process of nuclear fission to generate electricity. Since the 1950s, physicists and engineers have been attempting (using various techniques) to build fusion reactors for this same purpose. If successful, humanity will have an inexhaustible source of energy, but the technical challenges facing them are great.

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*How would you allocate funding between (1) continuing to build and run fission reactors and (2) research into the development of fusion reactors?*
### MINDS-ON  
**Suggested Timing:** 15 minutes

- To assess what students already know about fission and fusion, each group will create and use a graphic organizer. Have each group print the word “fission” in the middle of one piece of paper and “fusion” in the middle of a second piece of paper. Have the students add their names to both pages.
- The students will then take turns writing on the papers everything that they know, or think they know, about nuclear fission and fusion.

### Implementation Options
- The groups could create KWL, or similar, charts to assess and record knowledge instead of using graphic organizers.
- The graphic organizer may also be done digitally using a concept-mapping program such as Inspiration (www.inspiration.com).

### ACTION  
**Suggesting Timing:** 10 minutes plus time outside of class

- Provide students with the Fission vs. Fusion Research Guide Sheet BLM and the Fission vs. Fusion Student Web Links BLM. These two pages can help the students to focus their research about the processes of nuclear fission and fusion and their technological advantages and disadvantages. Time permitting, the students could also locate information from additional internet sources.
- At the end of their research, have the students write new information on their graphic organizers. Have the group members discuss what they learned during their research to ensure that all members understand the concepts of nuclear fission and fusion and the technological advantages and disadvantages of each.

### Implementation Option
- You may want to have each student use a different colour of pen or pencil to record his/her learnings so that you can monitor his/her progress and understanding of the concepts.

### CONSOLIDATION  
**Suggested Timing:** Outside of class time

- Students will demonstrate their understanding of the science and technology of nuclear fission and fusion by participating in an individual writing assignment. Based on their research as well as their own critical thinking and decision-making skills, each student will communicate his/her recommended allocation of funds towards current nuclear fission reactors and/or towards research for nuclear fusion reaction in a Mini-Position Paper (see the Fission vs. Fusion Mini-Position Paper Assignment and Rubric).
- Each student will be required to construct arguments and defend his/her position on the issue using examples which demonstrate a thorough understanding of the processes of both nuclear fission and fusion, and the technological challenges as well as the implications of their funding decision (what if…?).

### Implementation Options
- Review essay writing strategies with students if necessary.
- Instead of doing a position paper, students could demonstrate their understanding of nuclear fission and fusion by developing a poster campaign to support either fission or fusion as the energy source of the future, by writing an op-ed piece (see the Food Irradiation: What’s the Scoop? lesson for an op-ed assignment) or by writing an article for an online class newsletter.
EXTENSIONS

- Compile the dollar values assigned by the students in favour of nuclear fission and fusion (on chart paper, on a graph, etc.). To which did they allocate the most money? Discuss these results as a class.

- Students could debate the issue of funding nuclear fission vs. fusion reactors by role-playing fission advocates (e.g., owners of nuclear reactors, energy association members, etc.) and fusion advocates (e.g., physics researchers, etc.).

- Students could individually, or in groups, research current fusion experimentation. The students could report about how the fusion was produced (including what is being fused), the controls used in the experiment, the status of the experiment and, if possible, the expectations of viability for sustained fusion. This project is best suited for upper grade science or physics students or as an enrichment project. Students could choose one of the following methods of nuclear fusion:
  
  - Muon-catalyzed Fusion, Pyroelectric Fusion, Laser-driven Fusion, Cold Fusion (Pons & Fleishman), ICF (Inertial Confinement Fusion), Farnsworth-Hirsch Fusor, Magnetic Confinement: Tokamak, Stellarator, Reversed Field Pinch, Spheromak, JET (Joint European Torus), ITER (International Thermonuclear Experimental) – an international Tokamak

ADDITIONAL RESOURCES — Canadian Nuclear Association

TeachNuclear Web pages
- Isotopes
- Nuclear Fission
- Nuclear Fusion
- Types of Reactors
- Nuclear Energy

- How Nuclear Reactors Work

Related TeachNuclear Lesson Plans
- Atomic Theory Jeopardy Lesson Plan
- Radioactive Half-Life: The Whole Story Lesson Plan
- Understanding Isotopes Lesson Plan

ADDITIONAL RESOURCES — CurioCity by Let’s Talk Science

Videos
- Taylor Wilson: My radical plan for small nuclear fission reactors
- The Power Plant of the Future

- Nuclear Chemistry Part 2 – Fission and Fusion (Crash Course)
- Fission vs. Fusion (Instant Egghead)

BACKGROUND/ADDITIONAL INFORMATION

Fusion:
- EFDA-JET (Retrieved Dec.2, 2014)
  JET (Joint European Torus), the world’s largest fusion experiment, is located near Oxford, England. On their web site you can learn more about fusion in general and more specifically about Tokamak (a machine producing a toroidal magnetic field for confining plasma).

  The Fusion at a Glance section has modules on how fusion works and the history of fusion research.

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http://teachnuclear.ca/
European Commission – Fusion at Work (Retrieved Dec. 2, 2014)
The Fusion at Work section has more information about ITER - a large-scale scientific experiment that aims to demonstrate that it is possible to produce commercial energy from fusion.

The FusEdWeb web site has introductory educational materials on fusion energy and the physics of plasmas. This online fusion course was created by the Fusion and Plasmas Group of the Contemporary Physics Education Project (CPEP). CPEP is a non-profit organization of teachers, educators and physicists, with substantial student involvement. CPEP creates educational materials on contemporary physics topics for use in introductory physics classes.

General Atomics - Fusion Education (Retrieved Dec. 2, 2014)
This web site from General Atomics has teacher resources including educational materials, Fusion Science slide shows and links to other fusion sites.

This web site has information about nuclear fusion reactors and how they work.

This page from the Interactive Plasma Physics Education Experience has information about what fusion is, how fusion works and the challenges of fusion.

Here you can find information about fusion research, including fusion facilities and institutions in the United States and around the world which are participating in fusion research.

Fission:

This web site has information, including graphics, about the process of nuclear fission.

The Fission at a Glance section has modules on how fission works and the history of fission research.

This web site has information about nuclear fission and nuclear power plants.

This web site has information about nuclear fission, including the fission process, fission reactors, the fuel cycle, new reactor technology and more.

Comparing Fission vs. Fusion:

This short article from 2009 (also available as a podcast) describes some of the promise as well as problems involved with harnessing nuclear fusion.

University of Virginia Physics Department - Nuclear Reactions—A Physical Science Activity (Retrieved Dec. 2, 2014)
In this activity, students visualize the processes of fission and fusion using breakfast cereal.

Nuclear Energy:

The ABC’s of Nuclear Science (Retrieved Dec. 2, 2014)
The ABC's of Nuclear Science is a brief introduction to Nuclear Science produced by the Nuclear Science Division of the Lawrence Berkeley National Laboratory. It includes information, experiments and a glossary. You will also find ordering information for an excellent wall chart on Nuclear Science (there is also a Teacher Guide for the wall chart).

This list was compiled and answered by John McCarthy, a professor emeritus of Computer Science from Stanford University.