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Energy in Its Material and Social

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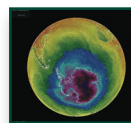
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Energy in Its Material and Social Context: Power Plants

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One way for science teaching to have significance beyond the classroom is for science education to be in the service of community organizing and ethical decision-making.¹⁻³ Power plants have tremendous social significance both locally and globally. In what follows, we will consider the energy dynamics of two electrical power production facilities: (1) the largest coal-fired electrical power production facility in the United States and (2) one of the facilities that provides significant electrical power to the authors. Rather than analyzing power plants apart from their material and social context, we suggest an analysis that includes the relationships between the power plant and the surrounding human, plant, and animal communities, as well as lands, waters, and air. Our intent is to model an approach to energy learning that begins to prepare students to engage in ethical decision-making about energy resources.

A large coal-fired power plant

While leading an online summer professional development workshop for secondary physics teachers with participants from all over the country,⁴ I (author R.E.S.) selected a nationally and globally significant power plant for analysis. The largest coal-fired electrical power production facility in North America is Plant Scherer, located near Macon, Georgia (Fig. 1). As a first instructional step, I had learners analyze the energy dynamics of the power plant using an "energy tracking diagram," in which learners track the transfers and transformations of energy among objects and systems.^{5,6} Teachers in the summer workshop created an energy tracking diagram for Plant Scherer based on the diagram in Fig. 2, taking the boiler, turbogenerator, cooling system, and electrical grid as the primary objects of interest.

Two different learning teams' sample energy tracking diagrams are shown in Fig. 3. Both show chemical energy (in the coal) transforming to thermal energy by burning, then to kinetic energy (in the steam), which is transferred from the boiler to the turbogenerator. In the turbogenerator, some of the kinetic energy is transformed into electrical energy through electromagnetic induction, which is then transferred out to the electrical grid. Other kinetic energy is transferred to the cooling system and transformed into thermal energy that heats the surrounding environment.⁷

The above analysis is relatively decontextualized: it treats



Fig. 1. Aerial view of the Scherer power plant.

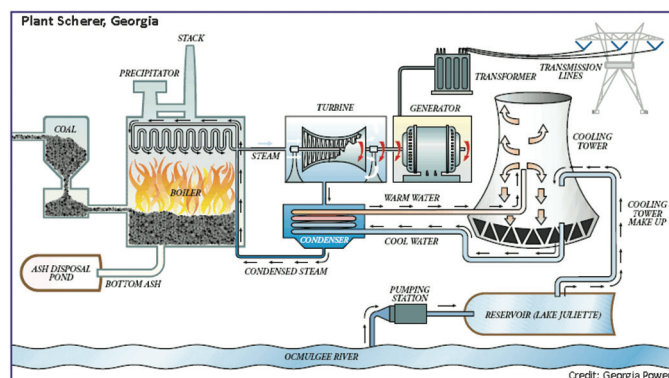


Fig. 2. Operational diagram of Plant Scherer. Credit: Georgia Power.

the power plant as if it were separate from the world around it. Community decision-making, however, takes place in the context of relationships between the power plant and the surrounding lands, waters, air, human communities, and plant and animal communities. To build learners' awareness of these relationships, we pose questions such as, What if you extended your energy tracking diagram "back" further—where does the energy ultimately come from? What materials are associated with those sources of energy? What if you extended your energy tracking diagram "forward" further: what forms of energy are emitted from the power plant? Where does the energy go—to what locations, or into what objects? Learners (whether teachers or students) are often able to answer these questions on their own through internet research, and supporting them to do so teaches processes that they can use to research other matters of scientific and community interest.

In the case of Plant Scherer, the source of power is chemical energy stored in coal, which comes from the land (and

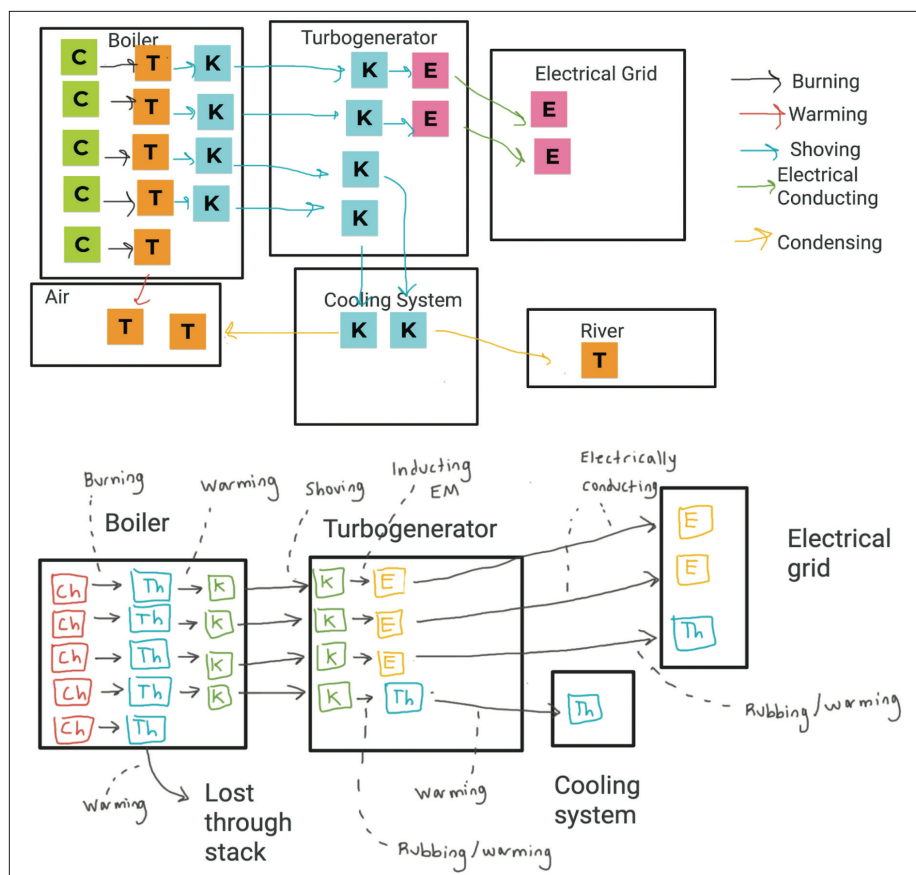


Fig. 3. Two energy tracking diagrams⁵⁻⁷ for Plant Scherer produced by teachers in a summer professional development workshop.

before that, the Sun). The coal itself comes primarily from the Powder River Basin in Wyoming: 40% of the coal used in the United States is from that area, which is the traditional land of the Cheyenne, Crow, Métis, and Mandan people.⁸ In the operations of the power plant, chemical energy is transformed into electrical energy (about 33%) and thermal energy (about 67%).⁹ The original material, coal, is transformed into ash and exhaust gases. In other words, the energy emissions from the plant are electrical and thermal energy, and the material emissions from the plant are ash and gases. Water for the cooling system is drawn from and returned to the Ocmulgee River and Lake Juliette Reservoir nearby.¹⁰ The ash goes into an ash pond on the premises; the exhaust gas goes into the atmosphere; the electrical energy is transferred to the power grid; and the thermal energy is transferred to the land, water, and air around Plant Scherer, which sits on the ancestral lands of the Muscogee people.

With information from their research at hand, learners are in a position to consider the impacts of the power plant on the world around it. This is a space of great complexity. In our professional development course for secondary physics teachers, we invited teachers to research this question openly and briefly, providing them with a few resources to get started.¹¹⁻¹³ In about 20 minutes of class time, teachers identified impacts such as the following:

“Plant Scherer impacts the human communities connected to its power grid in a positive way by providing electricity, but the pollution from the ash pond has a negative local impact on those who rely on nearby water sources for drinking water and agriculture. Water discharged back to the river also contains thermal (heat) energy, which is a form of pollution. Heavy metals and chlorine have a negative effect on river life. Emitted gasses include carbon dioxide, sulfur dioxide, and ozone, which are greenhouse gasses and/or harmful to human health.”

“Power plants are massive industrial complexes, with buildings, stacks, and other structures on a scale that often dwarfs everything nearby. Because of this, power plants can be seen from far away, and they can irreparably harm viewsheds that are highly valued by human society. Nearby homes and sites of historic significance are devalued because of the plant’s inappropriate size, use, and architecture.”

We also conducted research of our own and shared this with participating teachers, focusing on global impact. Plant Scherer is one of the nation’s top emitters of global warming pollution with average annual emissions of about 16 million tons of carbon dioxide over the past decade.¹⁴ According to a

Instructional sequence for power plants

- What is the name of the power plant? What kind of power plant is it? Where is it located? Find it on a map. Have you been there?
- Track the energy transfers and transformations that occur in the power plant. What is the initial form of energy? What transfers and transformations does the energy undergo?
- What is the source of power for the plant? Consider matter and energy sources. Where does the matter or energy come from (what location)?
- How are the matter and energy sources changed by being used?
- What is emitted? Consider matter and energy emissions. Where do the emissions go?
- What are the impacts of the power plant on the world around it?
 - Consider ancestral and modern human communities, plants and animals, and lands and waters.
 - Consider the power plant’s sources, emissions, and power output.
 - Consider both positive and negative impacts.
 - Consider both local and global impacts.
- What community decisions are being made about this power plant? What are some of the issues that need to be addressed?

Fig. 4. Instructional sequence for power plants.

recent analysis of the “mortality cost of carbon,” each metric ton of carbon dioxide emitted in 2020 is projected to result in 0.000226 excess deaths between 2020 and 2100 due to effects of ambient heat, atmospheric changes, disease patterns, flooding, and effects on food supply.¹⁵ In 2020, Plant Scherer emitted 6.9 million tons of carbon dioxide, which is a relatively low annual amount for this facility. Nevertheless, according to the estimate cited above of the mortality of carbon, 6.9 million tons emitted in 2020 will cause an estimated 1560 excess deaths worldwide between 2020 and 2100.

The instructional sequence described above is represented in Fig. 4.

A power plant near us

In an introductory calculus-based university physics class, the first author (R.E.S.) supported students to learn about electricity generation and associated sociopolitical concerns in their local area, near Seattle, Washington. After students built and explained the operation of a simple electromagnetic motor, students were able to explain that most power plants operate by using a flowing substance to turn a turbine. They identified at least one power plant in the state of Washington that is powered by (1) wind, (2) water, (3) combustion gas, (4) steam heated by burning coal, and (5) steam heated by nuclear fission. They used materials published by utility companies to learn that in the Seattle metropolitan area, 86% of electricity is provided by hydroelectric power plants.¹⁶ About 20% of the hydroelectric power for the Seattle metropolitan area comes from the three dams in the Skagit River Hydroelectric Project (Fig. 5).¹⁷ Students were assigned to learn the names of these three dams, locate them on a map, and identify the Indigenous people who were the original inhabitants of the land now occupied by the dams.⁸ Students were invited to share whether they had ever visited the dams, which are located in a beautiful recreational area in the North Cascades mountain range.¹⁸

Because the U.S. Department of Energy and local utility companies are eager for consumers to understand the benefits of hydroelectric power, students were easily able to research benefits, including renewability, cleanliness, and flexible power output.¹⁹ Of course, all sources of power have downsides as well: dams in the Pacific Northwest drastically change the landscape and rivers they are built on, raise water temperatures, and block salmon migration. Due to these concerns, hydropower has the highest number of citizen protests of all types of energy projects; Indigenous land protectors who lead such resistance efforts experience disproportionate repression and violence.²⁰ The Seattle electric utility company is in the process of relicensing the Skagit River Hydroelectric Project, which means it is reviewing the safety, cost, environmental, and cultural impacts of the continued operation of the project. By searching on terms such as “Skagit hydroelectric project relicensing,” students each located at least two different sources of information about the relicensing, and identified issues that should be addressed during the relicensing process. Some



Fig. 5. One of the dams in the Skagit River Hydroelectric Project.

of these issues include ensuring that decision-making engages all partners fairly, including Indigenous tribes as well as federal, state, and local agencies; contributing to salmon recovery by studying the engineering feasibility and biological impacts of moving salmon from the lower to the upper river; and supporting Skagit River estuary restoration, including projects led by the Swinomish Indian Tribal Community. Students in the Seattle area may even have the opportunity to visit the site of a dam removal and river restoration project, offering a recent example of local decision-making that resulted in decommissioning an energy production facility.²¹ In order to make strategic and equitable energy choices, students should consider alternatives to unlimited ecological extraction for the purpose of continual economic growth.^{22,23}

Significance

Physics concepts such as energy are often taught in the abstract, without reference to lands and people. Electrical power facilities provide an excellent context to prepare students to understand and participate in decision-making about sustainable and just use of energy resources in their own communities. Energy projects are not only matters of science and technology, but are frequent sites of community decision-making and social resistance,²⁰ and must be integrated with “civics, history, economics, sociology, psychology, and politics”²⁴ to address modern energy problems such as fossil fuel supply and climate change. We hope that communities will find ways to take such impacts into account when engaging in decision-making about energy production. In sum, placing the scientific concept of energy in its material and social context can help move physics instruction toward equitable and culturally responsive science education.²⁵

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