

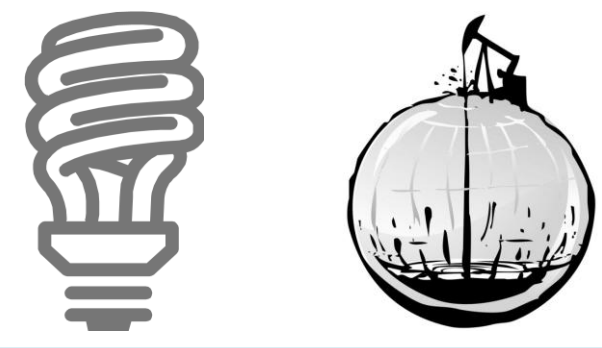
Learner Understanding of Energy Degradation

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Motivation: Teacher Interest in Energy Usefulness

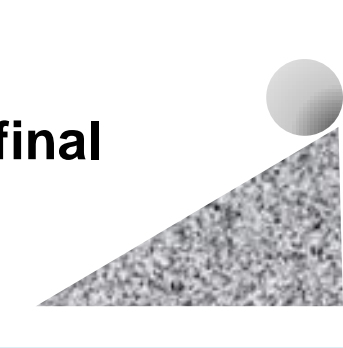
K-12 teachers desire to better understand the **connection** between everyday **sociopolitical energy** and **energy in formal physics** curricula

Sociopolitical Energy



Physics Energy

$$E_{\text{initial}} = E_{\text{final}}$$



Degradation statements and questions from teachers:

The quality of the energy decreases as it dissipates.

Energy's value has decreased.

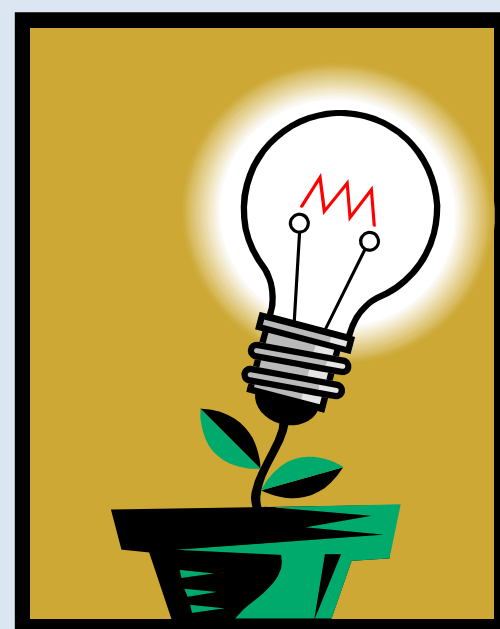
Energy degrades into a less useful form.

Energy is used up and becomes less available.

When is energy useful?

The above align with research on student ideas (Watts, 1983; Solomon, 1992; Duit, 1984).

Theoretical Framework



- Learners' ideas always have some seed of correctness (Hammer & Van Zee, 2006; Duckworth, 2006)
- New knowledge is built out of existing knowledge (Gupta et al., 2010; Hammer, 2000; Smith, diSessa, & Roschelle, 1994)
- Attention to learners' ideas is among the most powerful tools for facilitating growth (Rogers, 1981)
- Learning is growth: ideas mature through experience to become more coherent and consistent with evidence (Piaget & Inhelder, 1969)
- Instruction is gardening: providing favorable conditions for growth (Elby, 2000).

What is Energy Degradation?

$$\text{Energy}_{\text{(total)}} = \text{Free energy}_{\text{(able to do work)}} + \text{Degraded energy}_{\text{(can't do work)}}$$

Energy Degradation...

- ...occurs with a quantity's movement toward equilibrium (e.g., temperature, pressure, or concentration)
- ...is defined relative to a specific set of objects

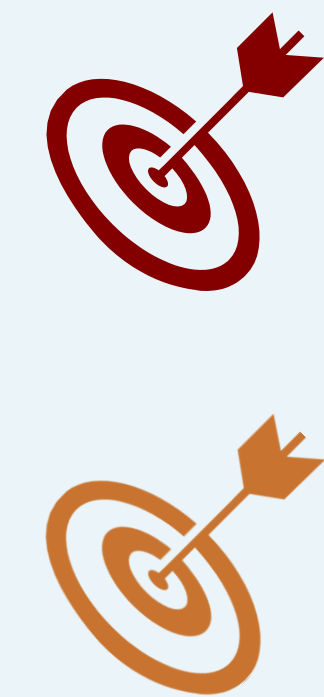
Second Law of Thermodynamics

In real, irreversible processes:

- Energy degrades
- Gradients are reduced
- Energy spreads (within objects, to other objects, through space, by mixing, and in momentum space)
- Entropy increases

This co-occurrence prompts a degradation-oriented statement of the **second law of thermodynamics**: Energy degrades in irreversible processes.

Energy Degradation Learning Goals



Goal 1: Since energy degradation is associated with the movement of some quantity towards equilibrium, learners will be able to show that the identification of energy as "degraded" or "free" depends on the choice of objects in the scenario.



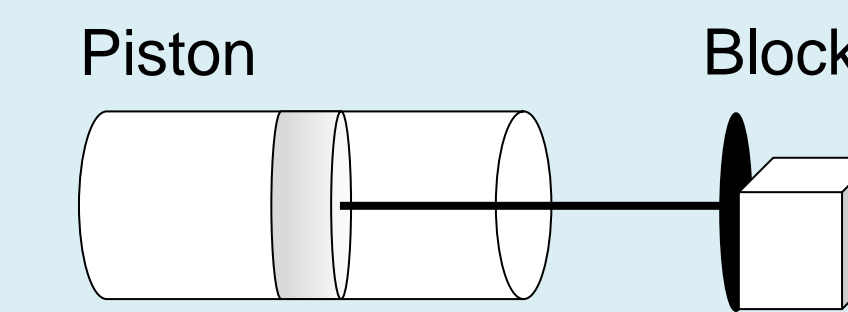
Goal 2: Learners will be able to identify the occurrence of overall energy degradation.

Energy Project K-12 Teacher Professional Development



Teacher discussion: *How is the energy usefulness different at the beginning vs. the end of the scenario?*

Piston Scenario



A compressed piston is released to push a block across the floor.

House Scenario



A wind turbine heats a house and the heat rises to be used in the turbine again.

Teachers' Productive Ideas about Energy Degradation and the Second Law of Thermodynamics

Degraded Energy Can Be Made Useful



- Charlene:** I still don't, I can't wrap my brain around degraded energy.
- Donna:** Can you tell us a little bit, I wasn't able to make it last time.
- Charlene:** Just the idea that people have, who does- how do you know that it's been degraded? I mean how, you can't really measure, **I understand the idea that once you have the energy out, I understand that it's no longer useful in this aspect, [piston scenario] but that, I don't see how that can make it not useful in other areas.**
- John:** I think that is what we were trying to define. We were trying to say, you need to define that. Because it may be degraded in one sense but
- Donna:** but it might be useful somewhere else.
- John:** -not degraded. Yah, because it's not going away, it's just going somewhere else.
- Charlene:** Yah, but that's not the impression that I got from what a lot of people were saying. The impression I got was that it was degraded so **we can't gather it back up again and use it again.** But how do we know we can't gather it back up again? Does it just like hang around and now I'm degraded and I've got to just sit here and
- John:** That's not the impression that I got at all.

Degraded energy in the piston scenario is not useful, BUT it is not useless elsewhere.

- Donna:** With newer technologies, we find better ways to reuse energy, like, in a hybrid car vs. a regular car, **there's a lot of energy that's wasted that goes to braking and heating,**
- Charlene:** Yah, we talked about that too.
- Donna:** Yah, we actually charge the batteries off of braking, **so we are able to channel some of that energy back into something that's useful.** So part of it is a leap of technology too, in terms of what we can do.

Wasted thermal energy can be reused to charge the battery of a car.

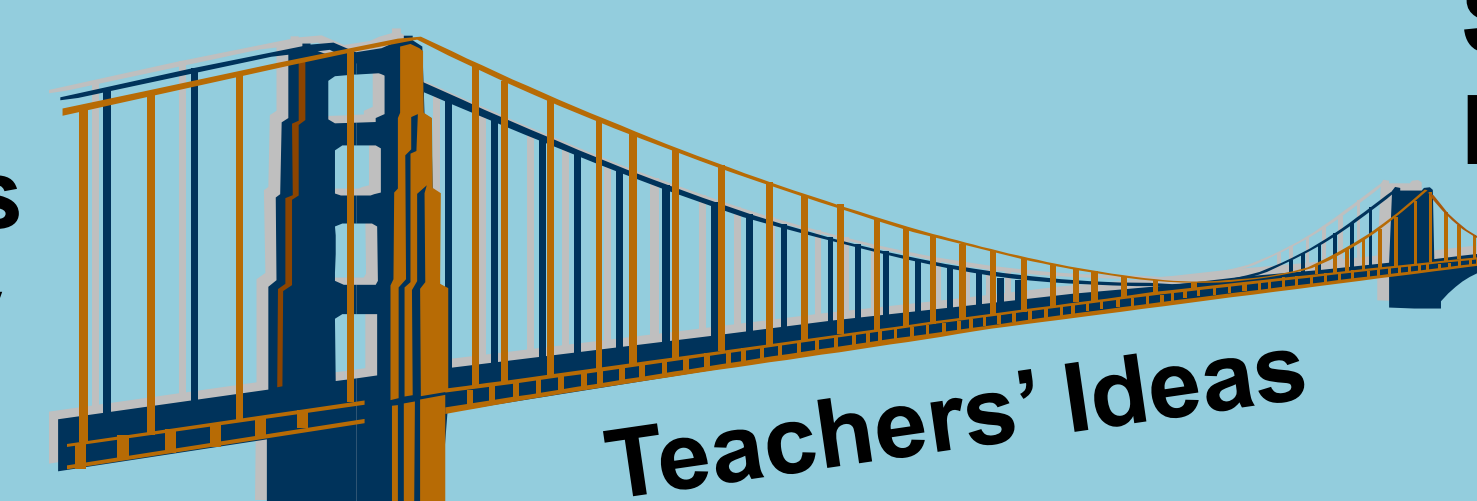
Making Energy Useful Requires Effort



Gathering requires effort make a new gradient
Recycling implies a process that involves preparation for reuse.

Channeling energy back and recapturing imply an intervention to reuse the energy that takes effort to design and achieve.

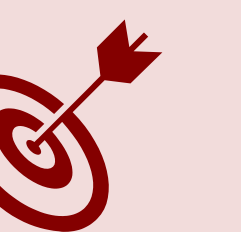
Physics Energy



Sociopolitical Energy

Teachers' Ideas

Making Energy Useful Requires Relocation



- John:** My impression was, it's degraded- remember when we did the house thing, you know with the perpetual motion machine thing. Were you here? Last time we had the scenario of a house that was run off a turbine and the turbine ran an electric-
- Donna:** Oh okay, a generator to power the house?
- John:** Right, and then we thought, why can't that be a closed system? **As far as that system goes, the energy would be eventually being degraded in the sense that that system wouldn't work anymore. But that energy had to go somewhere, and I got the impression that it goes out, it goes somewhere in the universe, or somewhere in the earth, and it will eventually be recycled in to some other useful purpose,** but not that it was degraded in a permanent sense.

Energy becomes useful again when it goes:

- somewhere,
- out,
- somewhere in the earth or universe.

- John:** You mentioned the car idea, the degraded energy and technologies that **recapture some of that** but that's still defined as the energy usefulness within the car. **But if it's outside of the car, what's to say that all that thermal energy doesn't become part of a weather system?**

Degradation occurs in a particular system and energy can be either useful or degraded depending on the choice of objects.