Responsible Citizenship in a Technological Democracy

Note 5: Energy

Let's start right off with a concept for you to remember:

> **Concept**: "Energy" is the ability to do work.

Have you every jumped out of bed after a good night's sleep, and stretching, said "I feel great, full of energy, so let's get to work!". If so, a physicist would have been proud – you made a technically correct statement, at least if by "work" you meant physical exertion.

> **Concept:** Energy comes in one of several forms: heat, kinetic, potential, electrical, chemical, and nuclear among others**.**

This will take a bit more explaining. But let's start with just some examples:

- Heat can be used to boil water to make steam which can then be used in a steam engine to do work.
- Kinetic energy is the energy in a moving object. If you have ever been hit by a well thrown baseball you have experienced kinetic energy; the harder the ball was thrown the more kinetic energy it had (and the bigger your bruise).
- Potential energy is what a book on the top shelf or a tightly coiled spring has. Knock the book off the shelf and the potential energy turns into kinetic energy.
- Electrical energy is you get from the outlets on the wall – and it is obviously can do work such as running the vacuum cleaner or hair dryer.
- There are a lot of examples of chemical energy in your everyday life. When anything burns, the chemical energy in the fuel is turned into heat energy. A battery is also an example of using chemical energy. Turn on your flashlight and the chemical energy in the battery is converted into electrical energy that lights the bulb.
- Nuclear energy is the energy that binds the nucleus of an atom together. It's what is released in a nuclear reactor or an atomic bomb.

OK, don't get concerned, but the next two concepts are what are known by physicists and engineers as the "1st and 2nd laws of thermodynamics". They are actually pretty simple, and they have a lot of relevance to being a responsible citizen. The 1st law is:

> **Concept**: Energy can be converted from one form to another, and is "conserved" in the process**.**

Some of the examples given just above involve such conversions – burning fuel turns chemical energy into heat, for example. What is slightly surprising is that, if you add up all the energy after conversion it is exactly the same amount as before the conversion – which is what we mean by it being "conserved".

Hold that thought a minute because the conservation of energy during conversion is a bit more subtle than it sounds. But to explain that we need the 2nd law of thermodynamics. There are lots of ways to state the 2nd law, but for our purposes the one I want you to remember is:

Concept: Nothing works perfectly! Nothing**!**

Specifically, energy conversions don't work perfectly. But isn't that in conflict with the statement about energy being conserved? If the amount of energy in the output is exactly the same as the amount in the input, isn't that a perfect process? Well, no. You see, not all of the energy in the input gets converted to the *kind* of energy you *want*.

Consider the engine in your car, for example. It's a device for converting the chemical energy in gasoline to kinetic energy of the moving car. It turns out that only about 30-35% of the chemical energy in the gasoline gets turned into kinetic energy of the car. Where does the rest go? Into heat!

Don't touch your engine after it's been running a while – you'll get a nasty burn. You have a radiator at the front of the engine to take away that heat, but if the radiator stops working, or it's an especially hot summer day, your whole engine will "overheat" and stop working. That's because 65-70% of the chemical energy in gasoline is turned into heat.

Or consider the battery charger for your digital camera or MP3 player. The charger is a device for converting electrical energy into chemical energy in the battery. Pick up the charger sometime after it's been running a while and you'll notice that it's warm. That's because the difference between the chemical energy you put in the battery and the input electrical energy is given off as heat.

Just to say it again in a slightly different form, the bottom line of the 1st and 2nd laws is that energy can be converted from one form to another, but that conversion is never perfect and the difference between the amount of energy you input and the amount that is output in the form you want is given off as heat.

Policy Relevance

We'll see lots of examples of public policy questions where the key to thinking about it in a useful way involves the second law of thermodynamics. We'll take this up in a lot more detail later, and the following is not the whole story, but it's a quick example of this point.

Recall the example of hydrogen powered vehicles in the previous note on systems. The first thing to do is to identify the larger system of which the vehicle is a part – the manufacture, distribution, storage, etc. The second thing is to recognize that none of the components of that system will work perfectly! Maybe, just maybe, the compound efficiency of two or more conversions is worse than just using gasoline. If we use electricity to make hydrogen by the electrolysis of water, for example, we will

- Use the chemical energy in coal to create heat energy to make steam
- Use the heat energy in the steam to turn a generator to make electrical energy

- Use the electrical energy to perform the electrolysis to make the chemical energy in hydrogen.

So we have three sequential conversions, none of which is perfect. We'll have to do more analysis to know which is more efficient, burning gasoline or hydrogen when all these conversions are included. But it's a question that needs to be answered, *and you need to know to ask it*.

Indeed, the last sentence is the premise of this whole course. To be a responsible citizen you don't need to know the answers to a lot of technical questions, but you do need to know what questions to ask!

I have observed a lot of really dumb public policy positions advocated because the advocate didn't understand the 2nd law – so this is one of the few things that I want you to memorize.

Nothing works perfectly. Nothing!

Aside #1:

We often want to know just how well an energy conversion process works, so we talk about its *efficiency*. That is simply the percentage of the input energy that is converted into the kind of energy we want. These numbers can vary a lot but just to give you a ballpark feel for the efficiency of some things:

- I mentioned before that automobile engines are 30-35% efficient.
- Battery chargers are about 70% efficient.
- It depends on the kind of battery, but discharging a battery is also about 70% efficient.
- Current solar panels are 10-12% efficient.
- Wind turbines are 20-30% efficient.
- The efficiency of electric motors varies a lot, but the kind you are likely to encounter in your daily lives are about 40-50% efficient.

It's a bit sobering to realize that most things you use everyday are less than 50% efficient, so most of the energy we generate does no useful work; it's turned into "waste heat". Moreover, for reasons that are a bit beyond this course, we can't just make things more efficient – they are already close to their theoretically maximum efficiency. Bummer!

Aside #2:

"Everybody knows" that perpetual motion machines[1] are impossible. Now, however, you know *why* perpetual motion is impossible – *nothing works perfectly!*

At the heart of every proposal for a perpetual motion machine is the notion that one part of the machine is supplying energy to another part which is, in turn, supplying energy back to the first

[1] Just in case you aren't one of "Everybody", a perpetual motion machine is one that runs forever without any external source of energy.

part – and that all this perfectly balances out. The problem, of course, is that neither part works perfectly. Some part of the energy received by each part is turned into heat and hence that part cannot return as much energy as it received. Inevitably the process must run down.

By the way, proposals for perpetual motion machines come in two flavors. One flavor is one in which, if you built it, it simply wouldn't work. Surprisingly, the second flavor is one in which, if you built it, it *would* work. Count on it, however – in the second case there is some sneaky external source of energy to supplement that lost due to the 2nd law!