# Connecting Learner Ideas about Energy and Free Energy

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## Why Bridge Energy and Free Energy?

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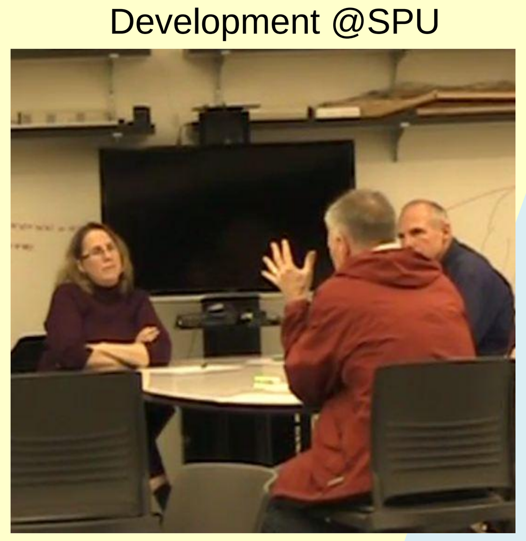

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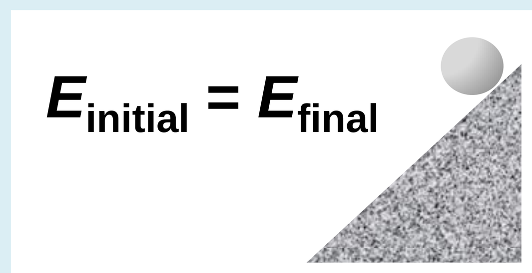
### Energy

Canonical treatment of energy in physics courses focuses on **energy conservation** in the context of idealized systems.

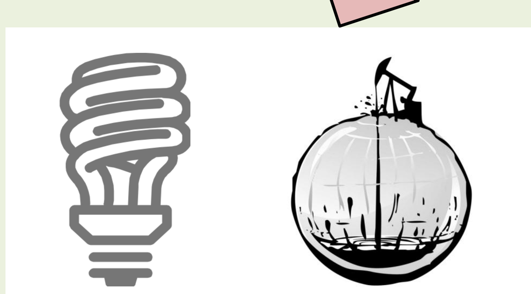


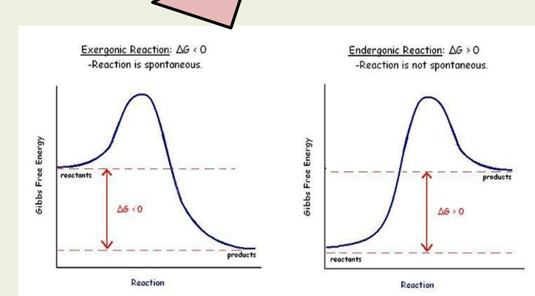

Connecting 'physics energy' to 'free energy' is at the heart of efforts to relate traditional physics instruction to sociopolitical and biochemistry energy.

**Bridging between School and Society**

**Bridging between Science Disciplines**

### Free Energy





**SOCIOPOLITICAL ENERGY**

In everyday discussions of energy conservation, energy is something that can be "wasted," "used up," or "degraded." What's left to do useful work is the **FREE ENERGY**.

**BIOCHEMISTRY ENERGY**

In biology and chemistry courses, **FREE ENERGY** is the central quantity, determining the spontaneity of reactions and the formation of biological structure.

## How are Energy and Free Energy Related?

**Total Energy = Free Energy + Degraded Energy**

$$\Delta H = \Delta G + T\Delta S$$

If one thinks of the *TS* term as "degraded" energy, the total energy can be thought of as the **sum of the free energy and the degraded energy.**

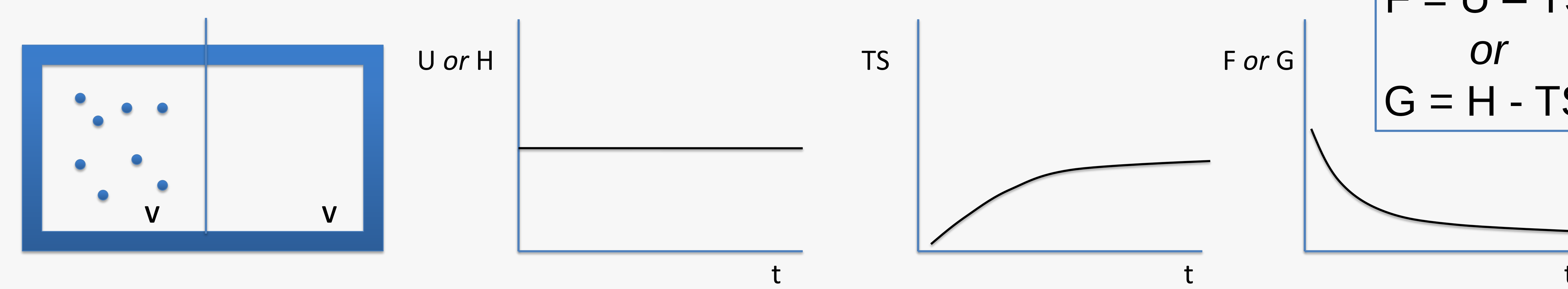
The **1st Law of Thermodynamics** expresses the conservation of ENERGY. On the other hand, FREE ENERGY is not conserved, and the decrease in a system's free energy coincides with an increase in the entropy of the universe.

$$\Delta G = \Delta H - T\Delta S$$

$-T\Delta S_{total}$ $\quad -T\Delta S_{surroundings}$ $\quad T\Delta S_{system}$

The requirement that the system's Gibbs Free Energy must decrease in a spontaneous process is a proxy for the **2nd Law of Thermodynamics**, since $\Delta G_{sys} < 0$ *is* equivalent to $\Delta S_{total} > 0$.

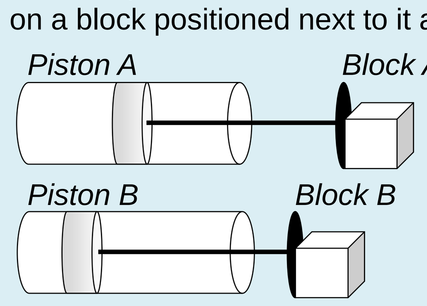
### Example: Isothermal Expansion of an Ideal Gas




F = U – TS
*or*
G = H - TS

## Piston Task: Learner Engagement with Free Energy

Consider two pistons each containing an *equal amount of a monatomic ideal gas* and each in *thermal equilibrium with the same environment*. The gas in Piston A is compressed to a volume *V*/2, and the gas in Piston B is compressed to a volume *V*/4. The pistons are *held in place until the moment of release*, at which point each is allowed to push on a block positioned next to it as shown:



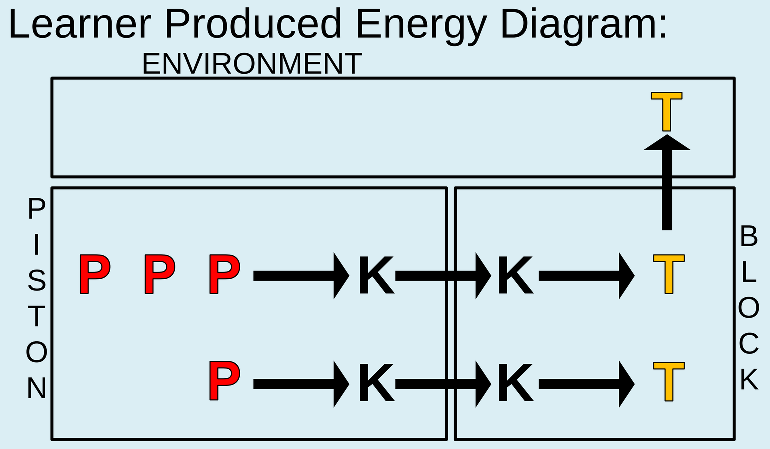

Forms of Energy Identified

**T** = Thermal Energy

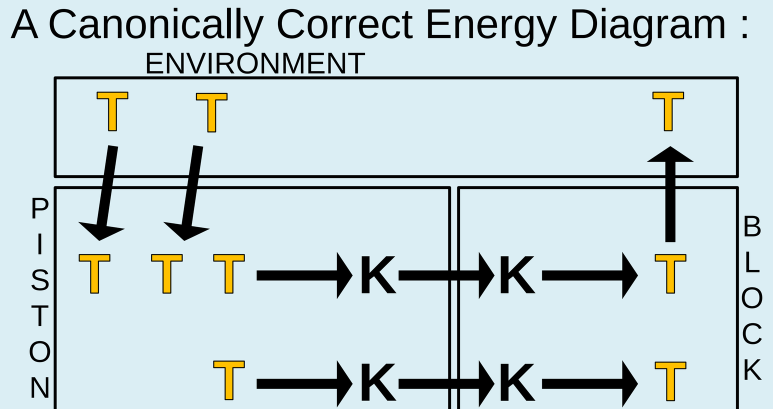
**K** = Kinetic Energy

**P** = "Pressure Energy" [defined by learners]

Learner Produced Energy Diagram:




A Canonically Correct Energy Diagram :

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Owen: What exactly is the energy in there?
Dustin: Whether its kinetic or potential and that's why I'm calling it **pressure energy**.
Owen: What really is causing it, why does it want to expand?
Dustin: Let's call it **captured pressure energy** and then I can erase whichever letter I need to.
Kate: How about **spring energy**?
Dustin: That's what I thought.
Owen: What's spring energy?
Kate: : I think, everything, when it comes down to it, is a spring.

### Free energy is "hidden."

Free energy is not a "form" of energy such as potential or kinetic energy. We found learners search for the location of free energy within a system. Learners devised new types of energy that might account for differences observed between two systems having different amounts of free energy (like pistons A and B in this task).

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"The [extra energy in the compressed piston] is '**compression energy**'."
- Tammy

### What does "free" mean?

Learners grapple with what it means for energy to be "free," and what it means for energy not to be free.

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"The [energy that isn't free] is '**bound up**,' like in the bonds" - Elena

"The [energy that isn't free] is '**expensive**'… it costs a lot to use it." - Elena

## CONCLUSION

Learners in K-12 professional development and university Physics for Biologists courses have prior knowledge about energy, either from their everyday experiences with conserving energy and/or their previous biology and chemistry instruction.

Instructors can create opportunities for students to bridge this prior knowledge to concepts of energy as found inside physics courses.

**Discussions of FREE ENERGY and its connection to ENERGY are ingredients with which to make these ideas relevant.**

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