# The Basics of Energy

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• Energy is more than just an economic resource. Economics may be the primary motivator for  the primary driver for many landowners, but as natural resource professionals we need to have a broader understanding of energy, how it works in the agricultural ecosystem, and how our use of it affects the environment. We need to understand why our agency cares. To get there we need to start with some basic energy concepts.

# Energy Basics Topics

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- Definitions
- Different kinds of energy
- Units of energy measurement
- First two laws of thermodynamics
- Energy efficiency
- Exercise/Example

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# Some Basic Definitions

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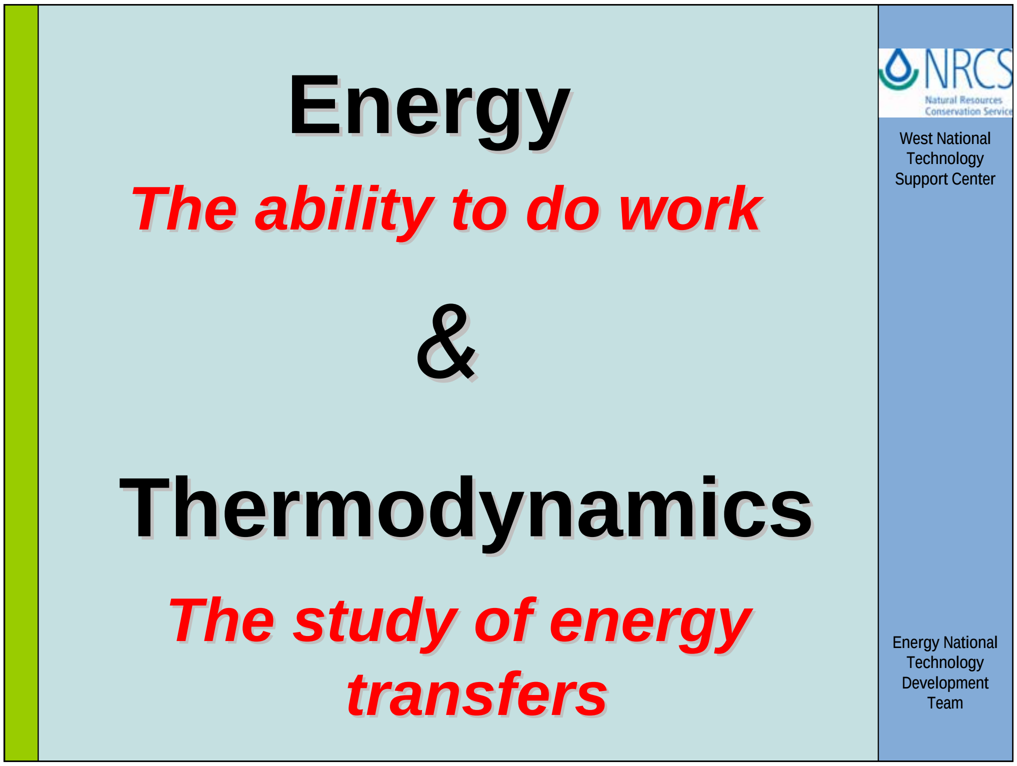


• Energy is that "certain something" inside stuff (or matter to be more precise) that makes everything happen. When something or somebody moves or jumps or falls or explodes or breathes or thinks or dances or does anything, it's because energy is being transformed.

•Nothing can happen in this wondrous world without energy.  Energy is that certain something inside "stuff" that makes things happen.  But it isn't just energy. Energy can sit around doing nothing for a long time, like in a battery or a tank of diesel fuel. Nothing will happen until that "waiting" **potential energy** gets changed into another form of energy.    It's energy moving from one place to another place, or energy being changed from one type of energy into another type of energy, that makes things happen.

•This "energy-changing-making-things-happen" concept is often not clear. Thermodynamics is not so much the study of energy, as it is the study of energy being changed. Energy that is not "happening" is only a concept of what might be. Potential energy for example is really just a mathematical concept describing something that can happen.

•Richard Feynman, one of the best known physicists of the twentieth century said, "It is important to realize that in physics today, we have no knowledge of what energy is or this from David Rose (MIT engineering professor famous for his work in fusion, energy, and nuclear engineering): "Energy is an abstract concept invented by physical scientists in the nineteenth century to describe quantitatively a wide variety of natural phenomena".

•Therefore, we can use our knowledge of how energy behaves to build machines and power plants and to better understand the processes of nature, but we really do not know what it is.

# Work

***The transfer of energy***

*Work (W)=F*D*

*F= Force*

*D= Displacement*

# Power

***The rate at which work is done.***

*Power (P) = W/t*

*W= Work*

*T = Time*

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# Two Broad Types of Energy

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# Stored Energy (Potential Energy)

***Any energy source that is available or on stand by***.

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# Working Energy (Kinetic Energy)

*The energy of motion.*

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# Potential or Kinetic?

- Tillage
- $NH_3$ fertilizer
- Diesel fuel
- Electricity
- Irrigation
- Ethanol
- Corn crop

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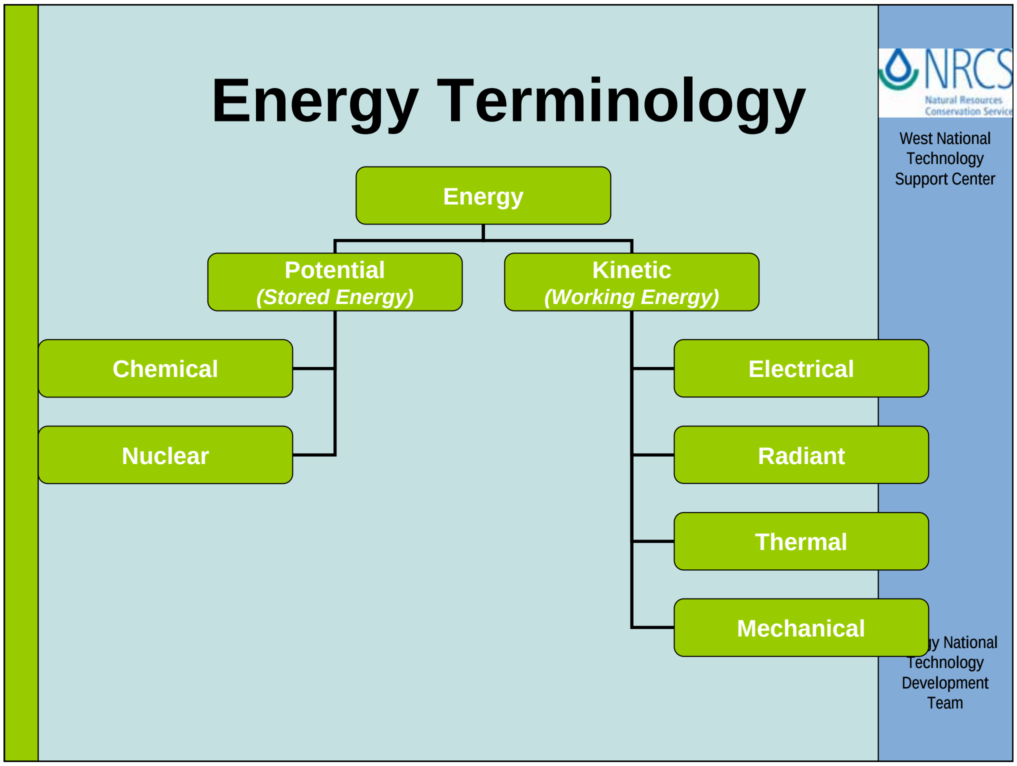


While most science education broadly groups all forms of energy into the two broad categories of kinetic energy and potential energy, **energy exists in many different forms**. **These forms can usually fit under one of the two broad categories, although sometimes** they are a varying mix of both potential and kinetic energy. By clicking on the different types of energy shown on screen you will be able to learn more about each type of energy.

# Other Energy Categories

- Radiant

- Electrical

- Mechanical


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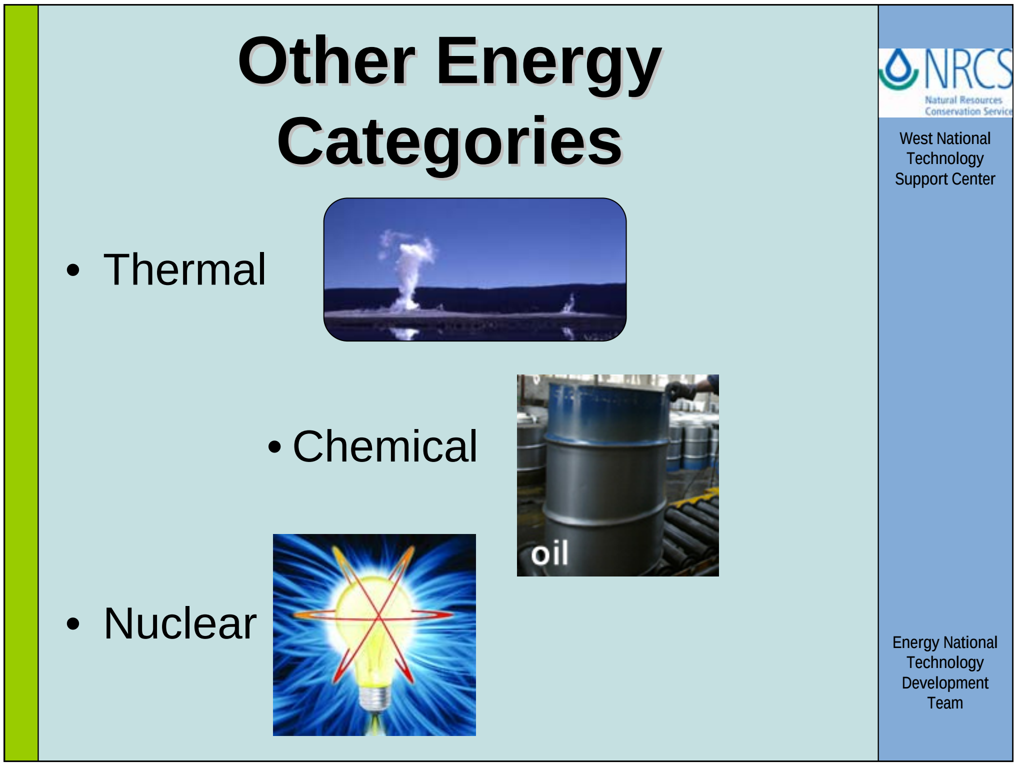
**Radiant energy** is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Light is one type of radiant energy. Solar energy is an example of radiant energy.

**Electrical energy** is the movement of electrical charges. All matter is made up of tiny particles called atoms. Atoms are then made up of electrons, protons, and neutrons. When force is applied, electrons may begin to move. Electricity is the movement of electrical charges through wire. Lightning is another example of electrical energy.

Mechanical energy is the energy which is possessed by an object due to its motion or due to its position. Mechanical energy can be either kinetic energy or potential energy.




**Thermal Energy**, or heat, is the internal energy in substances—the vibration and movement of the atoms and molecules within substances. Geothermal energy is an example of thermal energy.

Chemical Energy is energy stored in the bonds of atoms and molecules. Energy is what holds the particles together. Biomass, petroleum, natural gas, and propane are examples of stored chemical energy.

Nuclear energy is energy which is stored in the nucleus of atom. It is the energy that holds the nucleus together. The energy can be released when the nuclei are combined or split apart. At nuclear power plants, fission is preformed to split the nuclei of uranium atoms. The sun combines the nuclei of hydrogen atoms in a process called fusion.

# How do we measure energy?

- **Kilocalorie**: Heat required to raise the temperature of 1 Liter of water $1^{o}C$.
- **British Thermal Unit**: The heat required to raise the temperature of 1 pound of water $1^{o}F$.
- **Joule**: The force required to move a mass of 1 kg 1 meter.
- **Watt (power)**: One joule per second.

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# Conversion of Energy

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| Energy Conversions to BTU's [1/] | | | |
|---|---|---|---|
| Code | Energy Source | Unit | Conversion factor |
| 1 | # 2 Fuel Oil[2/] | Gallon | 139,000 |
| 2 | Coal | Pound | 10,550 |
| 3 | Diesel | Gallon | 138,694 |
| 4 | Electricity | Kilowatt hour | 3,413 |
| 5 | Ethanol | Gallon | 84,400 |
| 6 | Gasohol. (10% ethanol) | Gallon | 120,900 |
| 7 | Gasoline | Gallon | 125,000 |
| 8 | Kerosene | Gallon | 135,000 |
| 9 | Methanol | Gallon | 62,800 |
| 10 | Natural Gas | Therm | 100,000 |
| 11 | Propane/LPG | Gallon | 95,475 |
| 12 | Residual Fuel Oil | Gallon | 149,690 |
| 13 | Wood | Standard Cord | 21,000,000 |
| | | | |

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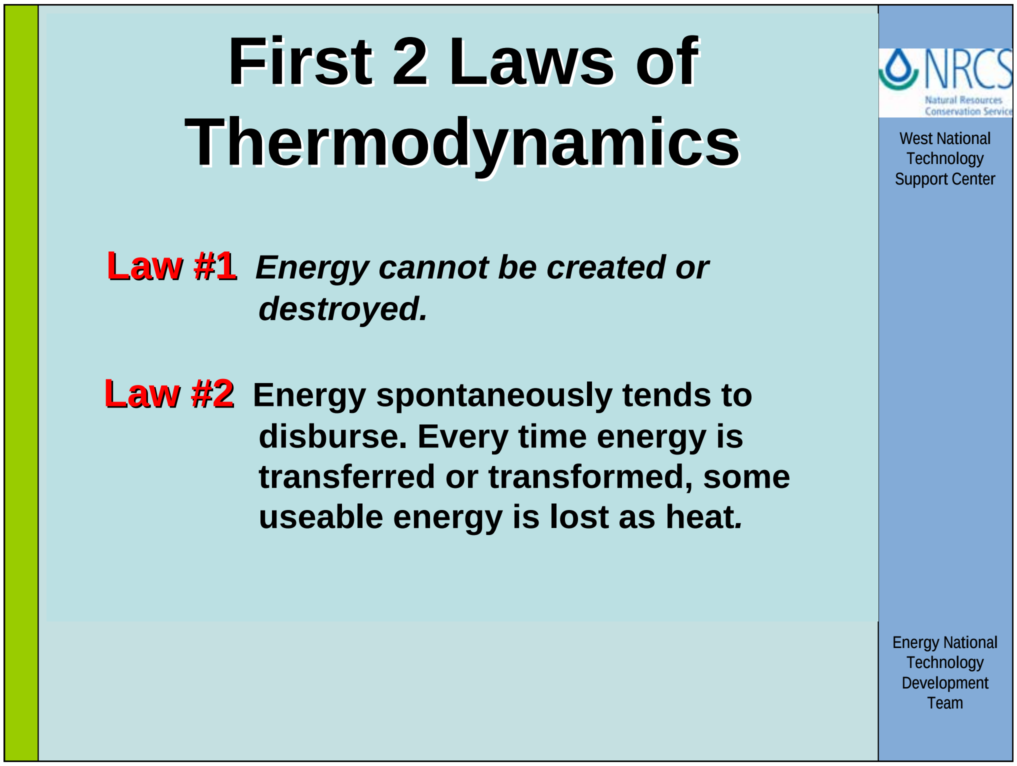
**http://www.eia.doe.gov/kids/energyfacts/science/energy_calculator.html#oilcalc**




LAW #1: The total amount of energy in a closed system doesn't change, i.e., "Energy in" equals "energy stored" plus "energy out.“ if no energy is stored, then "Energy in" equals "Energy out".

LAW #2: Energy spontaneously tends to flow from being concentrated to becoming dispersed and spread out.  Each time energy gets transferred or transformed, some of it gets dispersed and diluted and becomes unusable.

LAW #3: As a system approaches a temperature of absolute zero all processes cease. It is impossible to obtain absolute zero.

# Energy Efficiency

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***The ratio of energy output to energy input***

$$\text{Efficiency } (\eta) = \frac{\text{power output}}{\text{power input}}$$

**Can output divided by input = 100%?**

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Not according to 2nd Law of thermodynamics.

It says, there can never be a perpetual motion machine, there is noo such thing as 100% efficiency.

# Energy Efficiency

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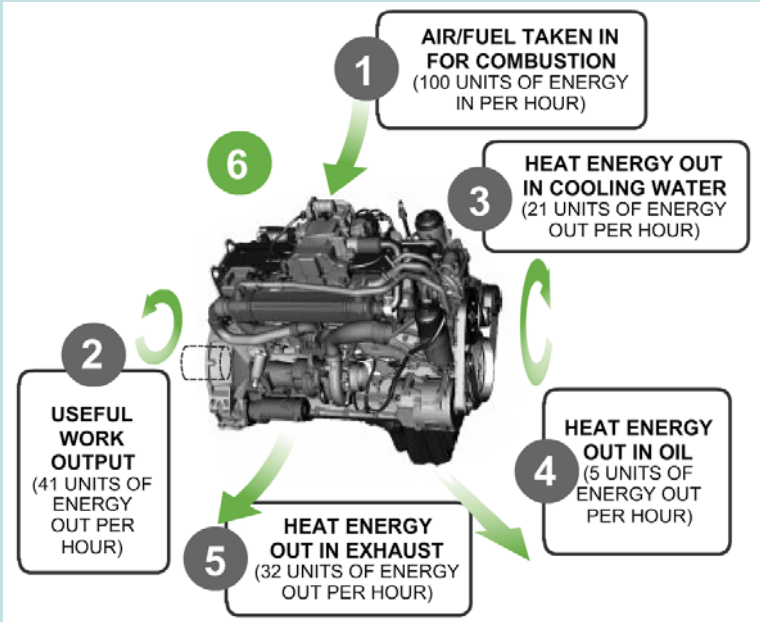


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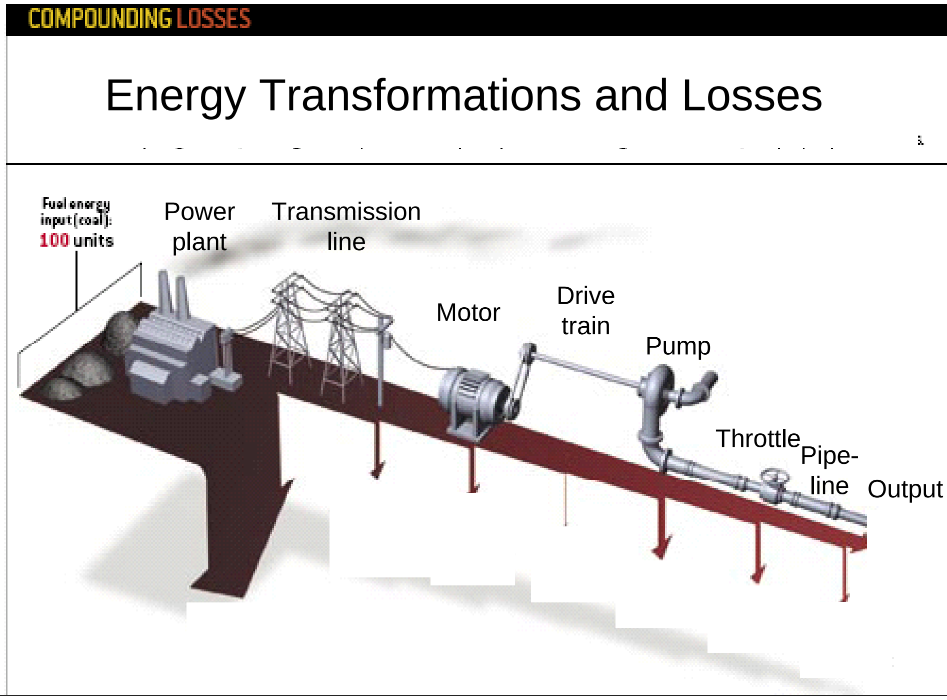
# Energy Transformations and Losses



## Direct vs. Indirect Energy

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- In the previous examples, the energy in, the energy lost , the energy stored, and the useful work produced at the end are termed *direct energy.*

- However, there is also *indirect energy*. For all man-made materials and equipment it also takes energy to make, to keep in service, to transport, and ultimately to dispose of and recycle the parts after serving a purpose.

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There is also *indirect energy* to consider.

In the previous example, we saw that for energy going in, and useful work out. This energy is *direct energy.*

It takes additional energy to make the engine, to keep it in service, and then ultimately to dispose of and recycle some of the parts. Each of these processes has its own energy inputs – known collectively as *indirect energy*.

# Direct vs. Indirect Energy – Corn Production

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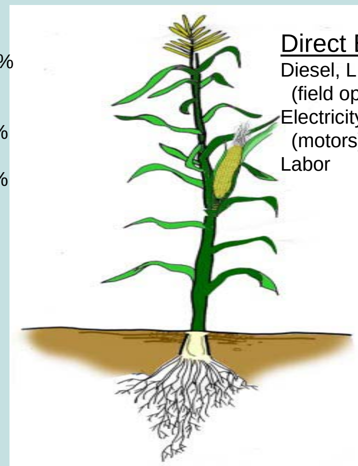
Indirect Energy Inputs

| | |
|---|---|
| Nitrogen Fertilizer | 26.5% |
| Phosphorus, Potash & Lime | 5.8% |
| Pesticides | 10.7% |
| Seeds | 5.3% |
| Machinery | 11.8% |



Direct Energy Inputs

| | |
|---|---|
| Diesel, LP gas, gasoline (field ops, grain drying, irrig.) | 38.1% |
| Electricity (motors) | 1.1% |
| Labor | 0.1% |

*Pimentel, 1984*

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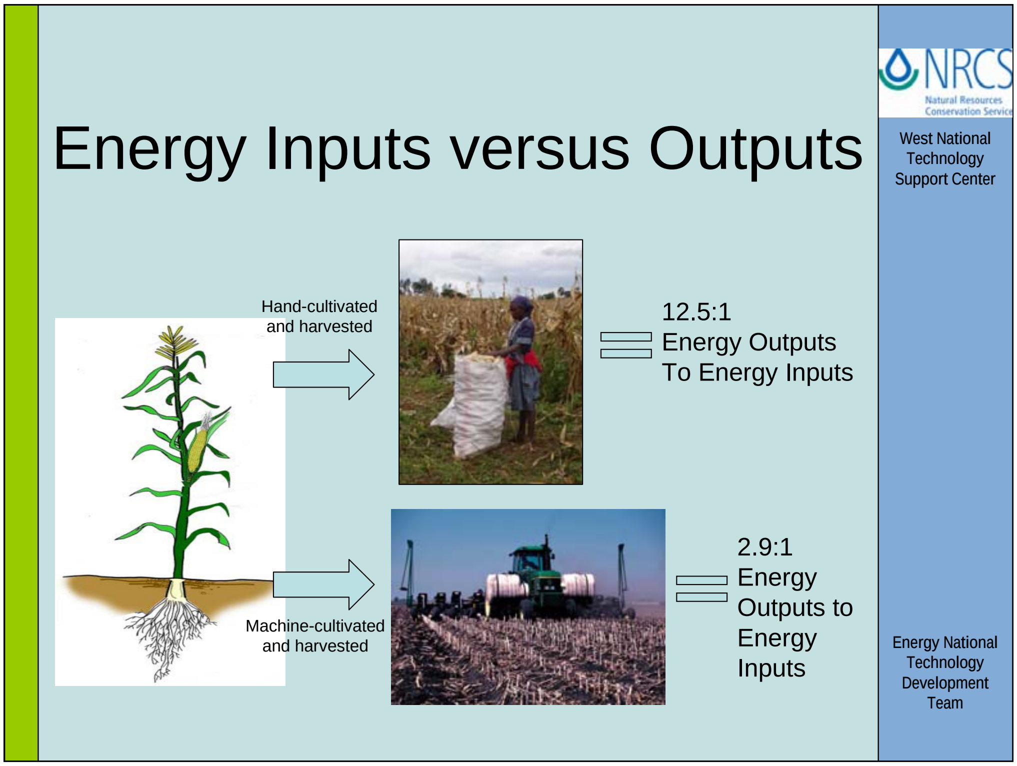
Although all the energy in the food we consume comes from the sun, additional energy is needed to produce the food. This additional energy comes in the form of human labor, animal labor, and the work done by machines. Energy is also required to produce the machines, tools, seed, and fertilizer, to provide irrigation, to process the food, and to transport it to market. We must examine all these energy inputs to understand the energy costs of agriculture and to develop a basis for a more sustainable use of energy.

Here is an example of the energy inputs for corn production **somewhere** in the United States. Most of inputs, both direct and indirect, come from industrial sources manufactured or made outside the farm. A significant portion of the inputs is embedded in the fertilizers and pesticides.

**Reference: *Agroecology* by Glisan**




Life cycle energy analysis (LCEA) is an approach in which all energy inputs to a product supplied by humans are accounted for, not only direct energy inputs during manufacture, but also all indirect energy inputs needed to produce components, materials and services needed for the manufacturing process. It is important because it shows the degree of energy efficiency for which a particular product is made or grown.

Hand-cultivated corn production is significantly more energy efficient than industrialized corn production because there are less inputs, less transformations, and less wasted useful energy. Furthermore, most of the energy in hand cultivated crops comes from humans which is renewable.

Most of the industrial energy inputs, both direct and indirect, come from fossil fuels. This presents its own unique set of problems.

Of course, the reason we industrialize corn production and many other crops as well is that we can significantly increase yields per unit area and we can grow the crops on larger areas using less labor.

# Not all Energy is the Same

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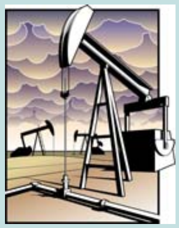
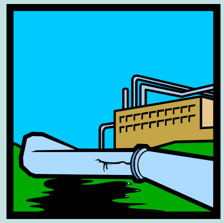


Drilling



Transport

Refining

**Gasoline from Oil**

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# Not all Energy is the Same

Mining

Transportation

Burning

**Electricity from Coal**

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# Not all Energy is the Same

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Indirect Energy

Wind harvesting

**Electricity from Wind**

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# Summary: Energy Concepts

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1. Energy efficiency can be improved by:
   - Reducing the number of transformations necessary
   - Reusing the heat released during transformations
   - Sizing equipment to the task at hand
   - Smart building design
2. Saving energy is good, but not all energy is the same. Where the energy comes from is also important.
3. Lifecycle analysis can help us make smart energy decisions.

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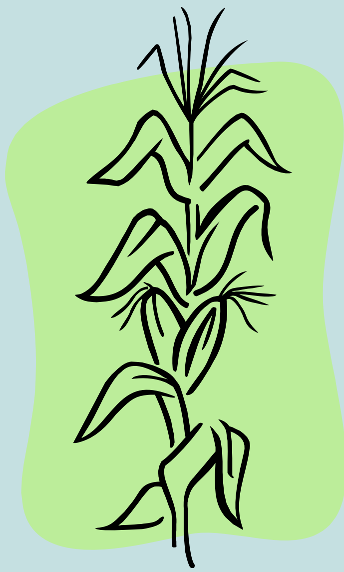
# Energy Efficiency Example



- A healthy corn crop has a maximum energy efficiency of about 5%

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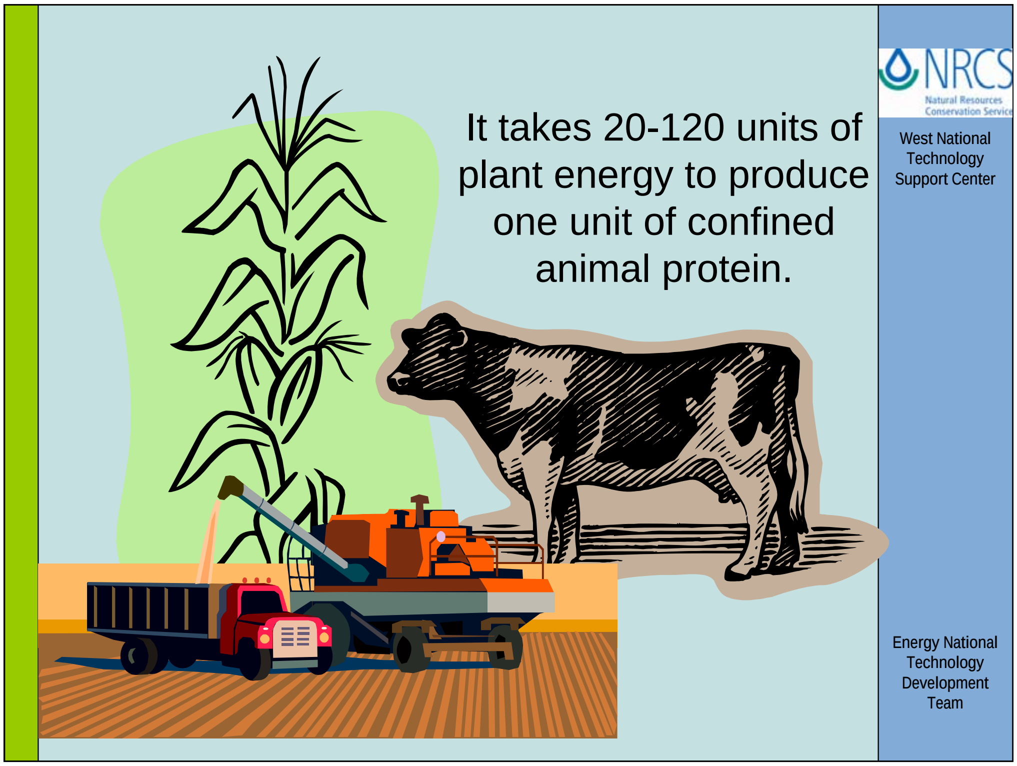
It takes 20-120 units of plant energy to produce one unit of confined animal protein.
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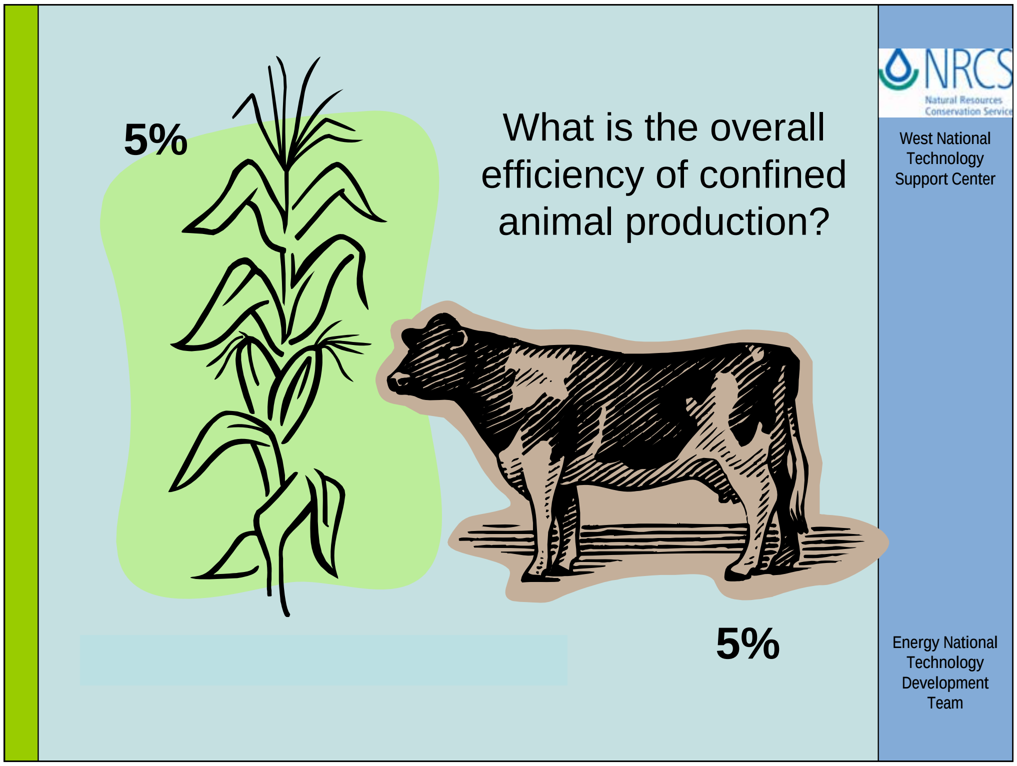
What is the overall efficiency of confined animal production?
5%
5%
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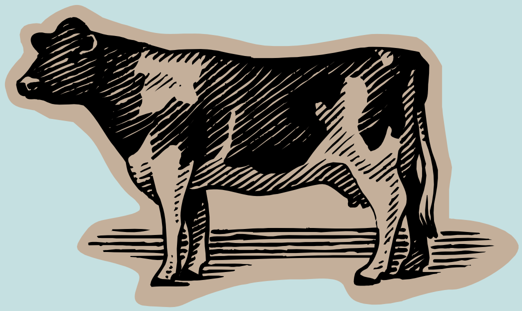
What factors contribute to energy losses in animal systems?



Where do energy transfers occur?

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How do these losses compare to losses in an open grazing system?

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