1

Types of Energy Sources and Energy Production and Use

Introduction

In order to differentiate the forms of alternative energy sources, it is important to understand the various definitions of energy. Energy, as treated in physics, chemistry, and nature, occurs in numerous forms, all of which involve the ability to perform work. In these sciences, energy is a scalar quantity that is a property of objects and systems, and is conserved by nature.

Several different forms of energy, including kinetic energy, potential energy, thermal energy, gravitational energy, electromagnetic-radiation energy, chemical energy, and nuclear energy, have been defined to explain all known natural phenomena.

Conservation of Energy

Energy can be transformed from one form to another, but it is never created or destroyed. This principle, the law of conservation of energy, was first postulated in the early nineteenth century and applies to any isolated system. The total energy of a system does not change over time, but its value may depend on the frame of reference. For example, a seated passenger in a moving vehicle has zero kinetic energy relative to the vehicle, but does indeed have kinetic energy relative to the earth.

Understanding Energy Production and Use: A Historical Background

Upon establishment of agricultural societies and throughout millennia, some civilizations have established managerial rules in defense, economics, and education that have allowed them to survive and prosper, making their mark in the history. But other societies have dissolved in the annals of history.

Civilizations that established their mark were always led by leaders who maintained superiority in strategizing survival skills, which have constantly evolved as human knowledge progresses. Likewise, the downfall of major civilizations may have resulted from maintaining status quo strategies, which had once promoted their survival but later failed to meet new challenges.

What is significant is that progress in human knowledge develops from constant change and improvements in our understanding of the universal laws of nature, which follow dynamics of natural forces, energies, and events.

The anthropologist Max Gluckman remarked once that "a science is any discipline in which the fool of this generation can go beyond the point reached by the genius of the last generation." Since strategizing is essentially information-based knowledge, and since information is always evolving at an ever-faster pace, every organizational activity must constantly keep pace with the information expansion simply to survive.

When making reference to any organizational activity, we must consider the extended boundaries of its context. In short, organizational activity encompasses all endeavors, whether educational, industrial, economic, or governmental, as well as any human activity that defines the fabric of a community, organization, or a nation.

To keep up in the marathon of the current and future information age, organizational leaders must constantly strive to devise strategies that will promote means and ways to adapt to today's and tomorrow's information pace.

In order to keep pace with constant evolutionary changes, organizational leaders must first and foremost understand the universal laws of nature. Leaders must constantly be aware that the survival of communities, organizations, and governments requires an understanding of the fundamental principles of the first and second laws of thermodynamics, also known as the laws of universal conservation of energy, the laws of entropy, the Keynesian laws of natural capitalism and the pro-evolutionary laws of existence within the universal context.

At first, such fundamental laws of nature may appear to deal only with scientific or philosophical matters. But understanding these subjects, even though they are empirical in nature, will illuminate the universal relationships of all human activities and reveal the meaning of the flow and development of natural events, which affect all human related strategic management. Before we proceed further, it is worthwhile to review the principal features of these fundamental laws.

First and Second Laws of Thermodynamics

The first law of thermodynamics (as we have learned in introductory physics courses) simply states that energy is neither created nor destroyed, and that it can only be changed from one form to another. For instance, electrical energy can be transformed into mechanical energy and vice versa. During the transformation, any residual energy that cannot be fully transformed to mechanical energy is transformed into heat, or any other form of energy; however, this residual energy can never be destroyed. This same principal of energy transformation applies to all forms of energy.

The second law of thermodynamics states that higher energy levels always dissipate their energy and pass it on to bodies of energy that is in lower energy states. For instance, putting a warm water of glass into a container that already has cold water in it will cause the heat from the hot water to flow into the cold water, but not in the reverse direction. The energy flow from higher levels to lower levels is termed entropy.

In essence, entropy is loss of energy that can never be recovered, or a total loss of usable energy. Since energy is also defined as a phenomenon that creates work, or the capability to do work, and since entropy is a flow of universal unrecoverable energy, then entropy is a loss of capability to perform work.

From physics, we know that energy is the source of all matter and that substances are, in fact, condensed forms of energy. This is elegantly expressed by Einstein's relativity equation $\mathbf{E = mc^2}$; simply stated **E**, energy, equals **m**, mass times $\mathbf{c^2}$, the square of the speed of light, which means that all matter in the universe if accelerated to the speed of light would become energy. However, since entropy is dissipation of unrecoverable energy, this implies that all universal energy forms transition from higher to lower levels, resulting in energy decay. The principal of universal entropy is the fundamental principle of cosmic expansion and energy decay.

The principle of entropy means that all life on our globe is formed by the interaction of various molecules and energy absorbed from the sun. From the entropy perspective, any and all life developed on the earth results in entropy or loss of energy that has emanated the sun and been absorbed by the earth. In fact, the growth of a single blade of grass contributes toward universal entropy. In effect, the total energy content of the universe is constant, and the total entropy is continually increasing.

Earth is an enclosed physical body consisting of a ferrous core, mineral elements, and water that form animal and plant life by combination and recombination of various molecules through absorption of solar energy. Once again, development of life on earth causes entropy, which means that, without total loss of energy potential or entropy, life could not have developed on the earth. In other words normal development of life results in entropy.

In addition to plant and animal life, universal energy has created numerous forms of substances that are listed in the periodic table. Furthermore, through the evolutionary progress of entropy, solar energy has created numerous forms of consumable energy resources in the form of hydrocarbons and a wide variety of other types of molecules, which humankind has used to sustain its existence on earth.

When forming combination of molecules from various substances, such as $H_2 + O = H_2O$ (water), or $C + O = CO_2$ (carbon dioxide) and so on, the energy absorbed by various substances causes the combination of various elements. Part of the energy absorbed when forming molecular bonds is retained within molecules, which can be released when the bonds are broken by absorption of various types of external energy. This process releases the sequestered bonding energy. Upon separation from bonding, elements revert to their original form and release their bonding energy, which is commonly referred to as enthalpy.

In the process of releasing bonding energy, when considering the energy used to separate the molecular structure, the net energy produced is lower than the sum of energy input and energy output resulting from the energy transaction; therefore, the process of molecular disintegration results in entropy. It should be noted that every time energy is transformed from one state to another a certain penalty results. The penalty is a loss in the amount of available energy that can perform work. It could also be said that entropy is a measure of the amount of energy that is no longer capable of conversion into work. In addition, work can only occur when energy moves from a higher level of concentration to a lower level. If we think of entropy as unavailable energy, it must be considered as wasted or dissipated energy. The second law of thermodynamics also implies that entropy always tends toward a maximum.

Since the earth is an isolated celestial body, with a closed and limited resource boundary, the development of life, which necessitates consumption of earth's native sequestered energy resources, results in the expansion of entropy. Consequently, the increase of animal or plant life results in the exhaustion of more and more unrecoverable resources. This means that the expansion all plant, animal, and human life, and the associated advancements in technologies that are essential to the promotion of life and human existence, directly contribute to the exhaustion of earth's energy resources, Consequently, technology advancement, which requires the use of natural materials and sequestered energy resources, accelerates entropy, which diminishes life-sustaining elements for human, animal, and plant species.

Human population growth, energy demand, and the material requirements for advancement of technologies, constantly accelerate entropy at an ever-faster pace, which eventually will result in the exhaustion of useful energy resources and the demise of plant, animal, and human life.

The survival of mankind has always been based upon short-term strategic planning, without concern for the natural laws of conservation. If humankind continues its technological expansion, it will inevitably face the ultimate boundaries of the second law of thermodynamics. As a life form, human beings are simply conglomerations of large molecules, which will ultimately be subjected to the mandates of the universal laws of physics and in the not too distant future will perish in the same manner as prehistoric life forms.

As eloquently stated by Herman Daily, "The terrestrial stock consists of two kinds of resources: those renewable on a human time scale, and those renewable only on geological time scale and which, for human purposes, must be treated as nonrenewable. Both resources, the terrestrial and the solar, are limited. Terrestrial nonrenewable energy resources are limited in total amount. If the available energy stock resources are exploited to exhaustion, they cannot be renewed. The solar source even though considered unlimited in total amount, however, it is strictly limited in its rate and pattern of arrival to earth."

As discussed earlier in the chapter, work or life can exist only through the expansion of entropy: that is, the flow of energy from higher to lower states. By the same token, energy flow will stop only when energy levels become equal or are brought into equilibrium, which means the end of life, or death.

Life and Entropy

In order to exist, living things absorb free energy from the sun, the ultimate source of energy, and from their surrounding environment, in what can be described as a process that is counter to entropy. In the process of living, all living organisms constantly consume and transform surrounding energies and in turn dissipate energy with their physical activity or motion. It should also be noted that any human cerebral activity or thinking process requires consumption of glucose in the brain, hence, dissipating heat in the process.

From the perspective of thermodynamics, living systems are considered to be open systems, because they exchange matter and energy with the outside world. While organisms are alive, the process of exchange of energy takes place until they reach a level of energy equilibrium at death, when they can no longer exchange energy with their environment. Therefore, all living organisms have a natural tendency to move toward an eventual equilibrium. In other words, in order to prevent reaching equilibrium, living organisms require a constant flow-through of energy from their surroundings.

In his celebrated book *Entropy A New World View*, Jeffrey Rifkin remarks, “In this process of energy scavenging, every living thing on this planet dissipates energy as that energy flows through its system, making at least part of it unavailable for future use.” Therefore, organisms survive by accumulating negative entropy, or energy from their environment.

Advancements in Technology and Entropy

Ever since the dawn of civilization, humankind has constantly endeavored to invent tools and technologies, which have been used to promote the survival of the species. From the perspective of thermodynamics, all advancements in technology have been devised to improve the intake and processing of usable energy from the environment, transforming, exchanging, and discarding it in the form of unusable energy, or entropy. Figure 1.1 represents the earth as a closed thermodynamic system.

Energy has and always will be the foundation of human culture. Cultures that have succeeded in developing tools and technologies for greater consumption of terrestrial and solar energy have historically enjoyed greater chances of survival and have maintained economic dominance over cultures and civilizations that did not advance in technology and science. In anthropology, tools and technologies are termed *Exosomatic instruments* or *human extra corporal instruments* for harvesting larger amounts of energy. Such tools are principal factors in shaping various cultures. The following section provides an overview and summary of the fundamental laws of nature.

Fundamental Laws of the Universe: Conservation of Energy

- The first law of thermodynamics: Energy cannot be created or destroyed. Energy can only be transformed from one form to another.

Figure 1.1. Earth is a closed thermodynamic system.

- The second law of thermodynamics: Energy only flows or dissipates from higher to lower levels.

The Thermodynamic Laws of Entropy
(Rudolf Clausius 1868)

- Every time energy is transformed from one level to another, there is an irreversible loss of usable energy.
- Entropy is a measure of the amount of energy that can no longer be converted to work.
- Work occurs when energy moves from a higher level of concentration to a lower level.
- Bertrand Russell wrote that whenever there is a great deal of energy in one region and very little in a neighboring region, energy tends to travel from the one region to the other, until equality is established. This whole process may be described as tendency toward democracy.
- Sadi Carnot: Discovery of flow of energy from hot to cold.
- States of energy are defined as

   a) the available or free-energy state;
   b) the unavailable or bound-energy state.
- Unavailable energy is *pollution.*
- *Pollution* is the sum total of all energy that has been transformed into unavailable energy.
- In a closed system, the difference in energy levels always tends to even out.

Terrestrial Stock of Energy

- The terrestrial stock consists of two kinds of resources:
  1. Renewable resources on the human time scale and
  2. Renewable resources on the geological time scale (on the human time scale these resources are considered nonrenewable).
- Classification of terrestrial low-entropy stocks:
  a) Energy and
  b) Material.
- Both terrestrial and the solar energy resources are limited.
- Terrestrial nonrenewable stocks are limited in total amount available, and if exploited to exhaustion cannot be renewed.
- Solar energy is practically unlimited (on the human time scale) in its total amount, but is strictly limited in its rate and pattern of arrival to earth.
- Every natural process undergoing change depletes available free energy, therefore increasing entropy: for instance, walking, talking, the growth of a blade of grass, the lighting of a cigarette, the manufacturing of any article and so on.
- Recycling of any material cannot achieve 100% efficiency. The average recycling efficiency of man-made materials is at best 30%, since recycling processes require considerable amounts of energy. Therefore, any recycling requires the expenditure of additional energy, which increases the overall entropy.
- The entropy of the universe is continually increasing and will ultimately reach its maximum.
- In reference to the universe, the earth is a closed system; as such, its energy stock is depleting continuously.
- For life to develop, the sun must interact with the closed system of matter, minerals, and metals on the planet earth, converting these materials into life and the utilities of life. This interaction dissipates the fixed amount of terrestrial material resources, giving rise to entropy growth.
- When energy becomes unavailable, the technical term is *energy death.*
- The minimum entropy state, where concentration of energy is highest and where available energy is at a maximum, is also the most ordered state. In contrast, the maximum entropy state, where available energy has been totally dissipated and diffused, is also the most disordered state. This law applies to all aspects of life and existence.

Fundamental Conclusion and Final Analysis

Solar energy is the most viable energy form. When considering the limited terrestrial energy resources, the development and deployment of solar power technology, as well as research and development, are of paramount importance to the survival of humankind. The promotion of alternative and solar power studies by higher learning institutions worldwide must be an academic priority.

Consequences of Accelerated Entropy

Humankind has inherited close to 3.8 billion years of stored natural capital, in the form of hydrocarbon energy and minerals. As a result of advancements in science and medicine, we have considerably reduced infant mortality and prolonged life spans; as a result, population growth has accelerated. At the present rate of population growth, our inherited natural resources are being consumed and degraded at such an accelerated rate that there will be little or no natural capital left to sustain modern lifestyles. As a result of the continued pace of consumption, there will be little or no meaningful natural capital left to sustain life on the planet. Meaningful and long-lasting solutions must be developed for the future generations.

The Concept of Energy in Various Scientific Fields

- In chemistry, the energy differences between chemical substances determine whether, and to what extent, they can be converted into, or react with, other substances.
- In biology, chemical bonds are often broken and made during metabolism. Energy is often stored by the body in the form of carbohydrates and lipids, both of which release energy when reacting with oxygen.
- In earth sciences, continental drift, volcanic activity, and earthquakes are phenomena that can be explained in terms of energy transformations in the earth's interior. Meteorological phenomena like wind, rain, hail, snow, lightning, tornadoes, and hurricanes are all a result of energy transformations brought about by solar energy.

Energy transformations in the universe are characterized by various kinds of potential energy that have been available since the Big Bang and later "released" to be transformed into more active types of energy.

Nuclear Decay

Examples of such processes include those in which energy that was originally "stored" in heavy isotopes such as uranium and thorium is released by nuclear-synthesis. In this process, gravitational potential energy, released from the gravitational collapse of supernovae, is used to store energy in the creation of these heavy elements before their incorporation into the solar system and earth. This energy is triggered and released in nuclear fission bombs.

Fusion

In a similar chain of transformations at the dawn of the universe, the nuclear fusion of hydrogen in the sun released another store of potential energy that was created at the time of the Big Bang. Space expanded, and the universe cooled too rapidly for hydrogen to completely fuse into heavier elements. Hydrogen thus represents a store of potential energy that can be released by nuclear fusion.

Sunlight Energy Storage

Light from our sun may again be stored as gravitational potential energy after it strikes the earth. Sunlight causes oceanic water evaporation forming clouds, when cooled result in snow or rain, forming rivers which are collected and stored in hydro dams. After water is released at a hydroelectric dam, water can be used to drive turbines and generators to produce electricity. Sunlight also drives all weather phenomena, including such events as hurricanes, in which large unstable areas of warm ocean, heated over months, suddenly give up some of their thermal energy to power intense air movements.

Kinetic vs. Potential Energy

An important distinction should be made between potential and energy kinetic. Potential energy is the energy of matter due to its position or arrangement. This stored energy can be found in any lifted objects, which have the force of gravity bringing them down to their original positions. Kinetic energy is the energy that an object possesses due to its motion. An example of this is a ball that falls under the influence of gravity. As it accelerates downward, its potential energy is converted into kinetic energy. When it hits the ground and deforms, the kinetic energy converts into elastic potential energy. Upon bouncing back up, this potential energy once again becomes kinetic energy. The two forms, though seemingly very different, play important roles in complementing each other.

Gravitational Potential Energy

The gravitational force near the earth's surface is equal to the mass, m, multiplied by the gravitational acceleration, $g = 9.81$ m/s^2.

Temperature

On the macroscopic scale, temperature is the unique physical property that determines the direction of heat flow between two objects placed in thermal contact.

If no heat flow occurs, the two objects have the same temperature, because heat flows from the hotter object to the colder one. These two basic principles are stated in the zeroth law of thermodynamics and the second law of thermodynamics, respectively. For a solid, these microscopic motions are principally the vibrations of its atoms about their sites in the solid.

In most of the world (except for the United States, Jamaica, and a few other countries), the Celsius scale is used for most temperature measuring purposes. The global scientific community, with the United States included, measures temperature using the Celsius scale and thermodynamic temperature using the Kelvin scale, in which 0 K= −273.15 °C, or absolute zero.

The United States is the last major country in which the Fahrenheit, is popularly used in everyday life. In the field of engineering in the United States, the Kelvin scale is relied upon when working in thermodynamic-related subjects.

Specific Heat Capacity

Specific heat capacity, also known as specific heat, is a measure of the energy that is needed to raise the temperature of a quantity of a substance by a certain temperature.

Chemical Energy

Chemical energy is defined as the work done by electric forces during the rearrangement of electric charges, electrons, and protons in the process of aggregation.

If the chemical energy of a system decreases during a chemical reaction, it is transferred to the surroundings in some form of energy (often heat). In contrast, if the chemical energy of a system increases as a result of a chemical reaction, this is the result of conversion of another form of energy from its surroundings.

Moles are the typical units used to describe change in chemical energy, and values can range from tens to hundreds of kJ/mol.

Radiant Energy

Radiant energy is the energy of electromagnetic waves, or sometimes of other forms of radiation. Like all forms of energy, irradiant energy has its own unit of measurement, the joule. The term is used especially when radiation is emitted by a source into the surrounding environment.

As electromagnetic (EM) radiation can be conceptualized as a stream of photons, radiant energy can be seen as the energy carried by these photons. EM radiation can also be seen as an electromagnetic wave that carries energy in its oscillating electric and magnetic fields. Quantum field theory reconciles these two views.

EM radiation can have a range of frequencies. From the viewpoint of photons, the energy carried by each photon is proportional to its frequency. From the wave viewpoint, the energy of a monochromatic wave is proportional to its intensity. Thus, it can be inferred that if two EM waves have the same intensity, but different frequencies, the wave with the higher frequency contains fewer photons.