Energy and Humanity

Energy and Humanity:

An Intertwined Evolution

By

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Dedicated to the memory of Meher Bano

Dedicated to the riders of the next energy platform, the Generation Next.

“Mathematics is only a tool and one should learn to hold the physical ideas in one’s mind without reference to the mathematical form”

P. A. M. Dirac, 1930

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“All that exists in the World, is Energy”

The Axiom of Energy

ACKNOWLEDGEMENTS

There is a long list of acknowledgements, and to begin with I thank God for having enabled me to write this book. He is the one who created energy and caused it to flow in every nook and corner of the universe, which is the topic of this book.

I acknowledge the work of the man who first invented the wheel and the man who first discovered fire and all the unsung and unknown scientists who scratched away in the caves and applied their intellect to stones, twigs, wood, metal, etc. under conditions that we can only imagine. But they were successful, and that is why we have this civilization and that is why we are talking about energy.

Writing a book is not easy as it is a time-intensive effort, and there are competing requirements for your time and effort. You need the cooperation and patience of the people around you. This book would not have been possible without the patience of my children Zaeem and Zaira and that of my wife Nayyara. I dedicate this book to the next generation – to question and to probe – and to the memory of my mother Meher Bano who was alive when I was writing this book and would often ask me – what are you working on, so late? She could not make it until the end of the book and rests in peace now, but she was a source of motivation and inspiration.

The kind support of Alex Monaghan, who helped me in coming up with publishable language in a very short period, is also acknowledged.

PREFACE

An iceberg at -40°C in Antarctica can have enough energy (heat) in it to boil a kettle of water or, depending on its size, it may have more heat than a furnace that melts steel in a factory. A cricket ball travelling at 140 kmph may also have enough energy in it to boil a kettle of water. There is something common between the iceberg and the cricket ball travelling at 140 kmph that can boil water in a kettle. The iceberg and the cricket ball are vastly different in state, size, shape and speed, yet they carry the equivalent of the same thing that causes the water to boil. It is not just a concept but a physical reality.

There must be innumerable books written on energy and, in recent times, about "energy transition". Why then this book, which is also about energy and energy transition? There must be a compelling reason to write yet another book on energy and energy transition. Unless there is a strong rationale, the book might turn out to be a waste of energy – my energy, the publishers' energy, the book distributors' energy, and lastly the reader's energy.

Indeed, there is a compelling reason. While there are innumerable books on energy, there is no book I have come across that tracks the evolution of human society through an energy-time funnel, what we otherwise call the energy transition. The phrase "energy transition" is modern vocabulary, but what is transiting is not energy but the human society in the manner it uses energy.

There are three different aspects of energy, all of which come into play when we talk about the energy transition. One of the aspects is the fundamental philosophical and conceptual aspect of energy such as what "energy" actually is, the second is the physics of energy, and the third is the societal aspect of energy. In this book, we look at all three aspects but with a primary focus on energy transition. Come to think of it, what sets humans apart from other animals, what sets modern humans apart from the ancients, what sets developed countries apart from developing and under-developing countries, and what sets the rich apart from the poor is "energy". The parameter of demarcation is energy – how is it used and how much is used?

Obviously, it would be too much to claim that I have read all the books on energy, but of all the literature or books I have come across on energy over the last thirty years, none project "energy" as a fundamental variable or parameter that defines and correlates with the evolution of human society. While writing this book, I realized that when we discard most of what we know and start looking at things in a very fundamental way, we get an understanding and a story that is somewhat different from what we have been told and what we accepted without questioning.

Many people might question my obsession with energy as a parameter that defines our civilization or, in other words, energy as a driver of human civilization. There are other parameters that make a difference, such as race, culture, religion, politics, climate, geography, food, education, etc. No doubt, these parameters do have an important role in the evolution of human society, however, in my opinion they kick in only when societies or civilizations have mastered the art and science of energy manipulation. Societies or civilizations or countries that have managed supremacy on energy can then start looking at other aspects. The other parameters are subservient to energy; consider one example, that of colonization – the European countries and Japan were able to colonize the rest of the world because they were operating from a higher energy platform.

Looking at the evolution of human society over the last few hundred years, one would have thought that mastering energy manipulation is the key to the supremacy and the wellbeing of any society. In this book, we find that in order to gain supremacy, we do need mastery over energy, but it does not necessarily guarantee us the long-term wellbeing of the human race. We find that it can also be a trap from which we must get out as fast as we can.

The book makes a strong case as to why we need energy transition and why now. It is a path that takes us out of the trap that we find ourselves in today in the form of global warming and climate change.

While I have attempted an interesting non-fiction work, the main character of which is "energy", I feel the book will also be useful to students to arrive at an understanding of energy and how it interfaces with our society. In fact, one "hidden" purpose of the book is to encourage students and scholars to question facts that are either taken for granted or assumed to be true. Scientific contemplation has again and again shown us that what is assumed to be true is not actually so, and there are either special cases or a

universal case where our laws and understanding fail. Indeed, I think our society would progress very rapidly if we did not take things for granted.

The book is meant for anyone with an interest in energy, environmental science and general science. It can also be a thought-provoking supplementary textbook at Master's level for students pursuing studies in energy, environmental science, society or liberal arts.

Jami Hossain
Author

1.0

ENERGY AND HUMAN CIVILIZATION

1.1 What is energy?

On the morning of 29th May 1953, the New Zealander Edmund Hillary and the Nepali Sherpa Tenzing Norgay struggled against all the odds, unbearably freezing temperatures and chilly winds from below the south summit to make it to the top of Mount Everest, the highest peak on the surface of this planet. Before they knew it, the two had become celebrities. Summiting Mount Everest was an ambition that many a mountaineer carried in their heart, and many also died in the attempt, but Edmund Hillary and Sherpa Tenzing succeeded, recording their names in the history of mankind forever. Come to think of it, their struggle was entirely against or with three elements – temperature, oxygen and gravity. We seldom realize that this epic struggle of two men was all about energy: the energy in the human body to keep the body warm, to keep enough energy in the cells of the body despite the lack of oxygen, and to struggle against the force of "gravity" that was pulling them down all the time.

This little example right at the beginning of our narrative is meant to enlighten the reader to the fact that all our struggles, all the time, are about energy, be it Mount Everest, the man on the moon or an expedition to Antarctica.

Energy, its conversion and its use have been as essential to human civilization as blood is to the human body. It comes into play with every other thing we do and is intertwined with our existence. The kind and the amount of energy we consume also determines our lifestyle and our wellbeing. It can also be assigned different meanings and perceived differently in different contexts. In a scientific context, it has one meaning, and in a socio-political context, another. All these meanings, in totality, have influenced and impacted the evolution of our society.

In this chapter, we examine some of the fundamental concepts and common perceptions of energy, the role of energy in the evolution of human society, and the modern-day issues concerning energy, i.e. climate change, energy access and energy security.

First and foremost is the question – what exactly is "energy"? Normally we assume that we understand the concept of energy very well since we use it all the time in different forms. We could, if we wish, go with the definition of energy from classical physics, as understood by the common man, i.e. the kilowatt-hour or joule or BTU, and straight away launch ourselves into a discussion on energy transition. However, when we are examining the role "energy" has played in the evolution of human society and tracking this evolution over almost 3 million years, it becomes important to also examine how the understanding that humans have had of "energy" has evolved with time. It also becomes equally important to examine the current state of knowledge and understanding with respect to "energy". Have we reached a stage where our knowledge and understanding of "energy" is complete and there is nothing more we can know?

We begin with some common concepts and perceptions. Imagine a man sitting on a sofa and working on his laptop. Is he consuming energy? The common perception would be that a man relaxing and not moving is hardly consuming any energy while a person working out in a gym is consuming a lot of energy. If we scrutinize this sofa-seated man closely, we find that he could be consuming a lot more energy than appears to us at first sight. First, his body consumes energy and then, depending on where he might be seated (home, hotel, office, etc.), that building will be consuming energy to keep the temperature inside the building within the comfort zone. Depending on where on earth this building is located, it could be consuming a lot of energy or relatively little. All devices such as TVs, fans, air-conditioners, mobiles, laptops, etc. consume energy. All our tools and implements consume energy. Our cooking consumes energy and the storage of eatables in a refrigerator consumes energy. If we stay at home, we consume energy, and if we travel, we consume energy. Therefore, it is quite possible that a sofa-seated man on a cold wintery evening in Moscow or Scotland consumes more energy than a man working out vigorously in some park in Singapore.

How much energy we consume determines the ease and comfort we have. Therefore, a poor man living with hardly any devices to cool or heat his dwelling may have to put up with rather harsh living conditions, while a

rich man living in a mansion with all the amenities such as central heating, air conditioning, wi-fi, piped gas and running water – all of which consume energy – has far better living conditions and far less discomfort.

Energy has seemingly different meanings for different people. What is "energy"? If you pose this question to a common man, he will probably start thinking about how "energetic" he feels. The same question addressed to a schoolteacher will, in all likelihood, incite a response based on classical physics and the "FORCE over DISTANCE" laws of Newton. An average literate person may talk about gas and electricity, a politician about energy security and an economist about energy poverty or oil prices. Ask a physicist and he would probably be less confident and vaguer. He might mumble something about matter and energy and a famous equation of Einstein. It is interesting that the more knowledgeable a person is about the physics of energy, the less sure he is of the question "what is energy"? It then turns out that what the common man thought was a simple and straightforward answer is not actually so. Come to think of it, the term "energy" is quite an enigma. People may have thought that they understood it rather well until the end of the 19th century with steam, coal and the beginning of the era of electricity. One could have a sound understanding of the concept based on Newtonian physics, the FS (Force X Distance) relationship or the concepts of thermodynamics. However, with Einstein establishing Mass–Energy equivalence, the advent of quantum mechanics, the discovery of a large family of fundamental particles, modern cosmology, the concepts of dark matter and dark energy (NASA, n.d.-a), etc., the term "energy" has become more and more intriguing.

At the same time, as we track the role "energy" has played in the evolution of human society, we find that it is the most crucial thing, stuff or "*whatever*" in the entirety of human history, including in our lives today. Thus, it becomes essential for us to arrive at a deeper understanding of "energy" or at least have the realization that, to fully grasp its meaning, we need more scientific and investigative work.

It is not a substance, though it exists in substances, and it is not a material, but it exists in matter. It is neither light, nor radiation, nor heat, but manifests itself in all of these. It is all around us – in clouds, rain, trees, waves, food, transmission poles, etc. The sound we hear is energy transfer by means of a wave in a medium, what we see is energy transfer by radiation, what we smell is energy transfer by molecules and what we sense as hot or cold is also energy. It thus transpires that all that we sense

is manifestations of energy. The movies we see are energy and the music we hear is energy. It is in any conceivable thing, whether material or non-material.

Without energy, we may not be able to live, even for a fraction of a second, and we also know that had it not been for the energy riding the solar radiations, there would be no life on earth. Without energy, there can be no intelligence either. In fact, physicists and cosmologists will tell us that without energy, there can be no world. *Whatever* it is, energy is inseparable from us, our world and our existence.

In arriving at a clear understanding of what "energy" is and what its physical reality is, we find that we have constraints of language and concepts. It is the only entity that transforms itself from different and seemingly unrelated forms such as electricity, gushing waters and light, yet remains conserved. It is necessary to make distinctions between the commonly held concepts about the meaning of "energy" and the deeper concepts and understanding that we are trying to arrive at.

In Figure 1-1, we present a map of dark matter and dark energy, developed by NASA, of the massive galaxy cluster Abell 1689, located 2.2 billion light years away, using a Hubble telescope to observe gravitational lensing in the cluster. Scientists believe that 95% of all that exists is either dark matter or dark energy, which cannot be directly observed by us. In the next chapter, we will also challenge the commonly held concepts and perceptions on energy and, relatedly, those on mass and force.

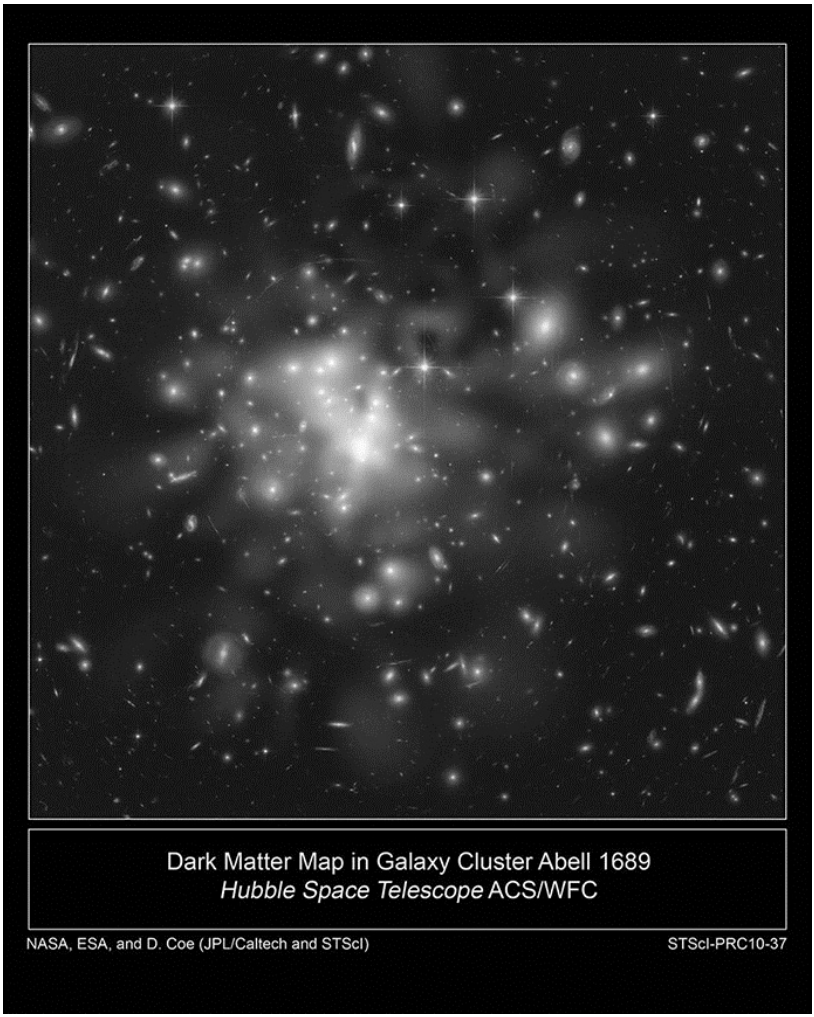

Figure 1-1: Dark matter map prepared by NASA using gravitational lensing concept.
(Source: https://www.nasa.gov/mission_pages/hubble/science/dark-matter-map.html)

1.2 Early encounters

We turn to the earliest encounters of humans with this "*whatever*" that we call "energy". When we talk about human encounters or interactions with "energy", we are essentially talking about an energy source other than that available to us through the biochemical processes within our body. The internal energy source within the biological body is used by all life forms from fish to tigers; what sets humans apart is the ability to use, manipulate and control external sources of energy.

1.2.1 The conquest of fire

A form of energy conversion that humans seem to have learned or mastered in the earliest known times of existence, even when they lived in caves, is "fire" – the combustion of wood, twigs, leaves, etc. It seems that even before *Homo sapien*s, the earlier *Homo erectus* had also learned to light fire. The discovery of controlling fire and the ability to light fire may have happened some 3 million years ago (Cohen, 2018).

Technically speaking, combustion, or "fire", as it is known in layman's terms, is an exothermic chemical reaction in which chemical energy stored in a combustible substance is converted to heat. Chemically, it is a process in which the carbon and hydrogen in the fuel react with oxygen to form carbon dioxide and water through a series of free radical reactions (Wilson and Fristrom, 1963), resulting in the liberation of heat.

Biomass or wood can be represented as $C_xH_yO_z$, and the combustion reaction can be written as:

$$C_xH_yO_z + (x + 0.25y - 0.5z)\ O_2 \rightarrow xCO_2 + (0.5y).H_2O$$

The lit hot gases radiating heat and light are what we see as "fire". The gases rise upwards because they are hot and less dense than air. That is why flames are always rising upwards. If we were to light a fire in a gravity-free zone, the flames may not rise upwards. In nature, a fire would only occur in forest fires, dry grass or volcanic eruptions, but natural fire is uncontrolled and can engulf everything combustible around it – in other words, as long as there are enough combustible substances and a supply of oxygen, the chemical reaction will continue to grow. Animals caught in fires can also come to an end as their bodies are also combustible and, in any case, heat from the fire is painful to those who come in direct contact with it. Thus, all animals fear fire.

For *Homo erectus,* about 3 million years ago, the challenge was to get over the fear of fire and control it. This can be seen as a great act of bravery and a massive victory for humans over what we call the "forces of nature". It must have been a slow and gradual process for early man to figure out that if a little bit of combustible material is isolated from all other combustible materials, it can burn without causing harm and, depending upon the type of substance (biomass), the fire could either be sustained for a long time or would die out soon. For example, dry grass would burn quickly, and wood from trees would burn for longer.

Using friction, he also learnt how to ignite or light a fire. The first level of energy conversion takes place when the muscular or biological energy is used to generate friction and, through friction, heat that ignites the combustible material. After the fire is lit, it does not require any further muscular energy to keep it going.

With the ability to light a fire, humans could survive in dark caves, see in the night, frighten wild animals, cook food and have warmth. They may have used the light for creative and productive purposes as well, such as making stone implements and tools, cave paintings, sculptures, etc. Imagine how it would have been if humans had not been able to get over the fear of fire. Had this been the case, apart from the fact that most of humanity would still be living in dark caves, the gateway of energy – including the light, heat and electricity that opened up for humanity with the conquest of fire – would have never happened. There would have been no ovens, no cooked food, no steam engines, no hot water, etc.

The ability to light a fire sets humans apart from all other life forms on this planet and on a path that has resulted in today's modern civilization. Light extended their working or creative hours beyond the day time and must have also led to the process of socialization wherein everyone gathered around the fire for light, food, warmth and security.

Today, we know that the rate at which we supply fuel and air to a combustion device determines the rate of combustion. However, the early man, without knowing science, must have learned to put combustion to good use by trial and error. Fire also helped humans in forging metal and developing metallic tools. Until today, combustion has remained the most important way of sustaining modern civilization. "*Controlled combustion*" is an intelligent use of external energy; some examples are the fires lit by early humans, lamps, wicks, stoves, combustion engines, etc.

Figure 1-2: An artist's impression of the conquest of fire: early man lighting a fire (Source: Shutterstock.com)

1.2.2 Animal energy

There are many ways other than just fire in which humans manipulate and use energy beyond what is available to them in their natural bodily form. Therefore, riding a horse or a camel or an ox is also a manipulation that enabled humans to harness energy from other animals for the purposes of travel or for transporting goods. For a long time, until the 18th century, horses, camels, elephants, donkeys, bullocks, and dogs were used to transport materials and people over distances of hundreds of kilometres. All that is now being achieved through automotives driven by engines was earlier achieved by animal power. Even today, in developing or under-developed countries, animals are being used to transport goods, materials and passengers. However, their use is much diminished now.

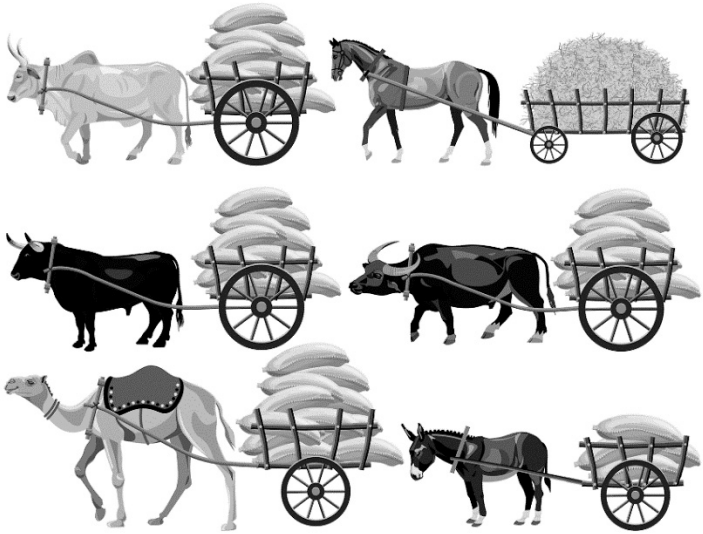

Figure 1-3 (a): Animals met many energy needs of humans before the Industrial Revolution

Figure 1-3 (b): Horse-driven chariots were a symbol of power (Source: Shutterstock.com)

1.2.3 Stone tools

Can we call a stone tool an energy device? Stone tools do not seem to convert energy but, nevertheless, they are tools that enabled humans to carry out many tasks with greater ease, such as cutting chunks of flesh from animals or cutting wood and trees, etc. Imagine the effort required in cutting chunks of flesh from a hunted animal with your bare hands compared to using a stone tool. Stone tools – or, for that matter, any tool meant for cutting, piercing, chipping or penetrating – enable humans to apply a large force at a point or a highly localized area, which cannot be achieved by using one's bare hands. In Chapter 2, we discuss the close relationship between "energy" and "force". Whenever force is applied, there is an energy flow.

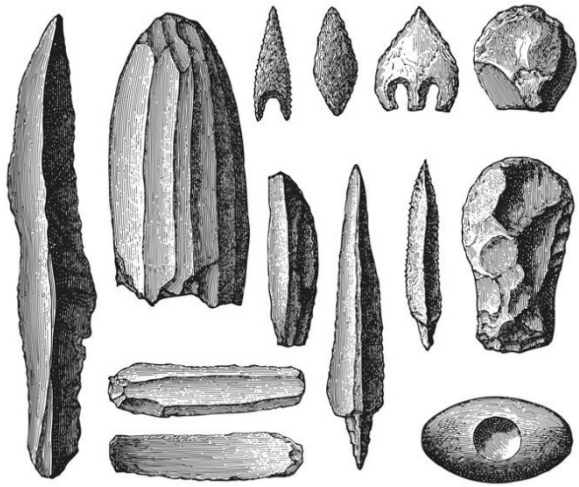

Figure 1-4 (a): Stone tools acted as force multipliers (Source: Shutterstock.com)

Humans have the capacity to run, to use their hands in deploying force, for example, to break a branch of a tree or to lift a stone and to throw it. All this requires energy, which comes from our muscles and the biochemical processes in our body. It is the energy of the muscle that derives from the biochemical process that is deployed while using stone tools or a knife to deliver piercing, cutting and penetrating force. The conversion is from biochemical to mechanical energy, which can be described by force, mass, momentum, torque, displacement, etc. as in classical physics. Since these

devices have to do with force manipulation and since energy is force integrated over distance, these were devices that used energy to amplify force or pressure at the point of application.

The recommended maximum force for a human hand in accordance with human ergonomics is of the order of 45 Newtons (MEADinfo, 2009).

With their bare hands, a human will typically apply this force over an area that corresponds to the size of the hand. This could be around 10 cm X 10 cm, transforming into penetrating or tearing pressure of 0.45 N/cm^2. On the other hand, the same force can be applied over an area of 0.1 cm X 0.1 cm by using a knife, resulting in a pressure of 4500 N/cm^2. Thus, there is a massive pressure multiplier of the order of a million times that can tear through and penetrate wood, flesh, soil or other stones.

The early humans, by trial and error, and intelligent observation, were able to make tools and devices that amplified force or its intensity or pressure.

They neither had any knowledge of physics nor any understanding of the underlying laws that governed all these devices and manipulations. Thus, they made stone tools, knives and spears that either created a higher intensity of force at the point of application (knife-like tools) or executed force at a distance (arrows), or both (spears). These tools enabled a more efficient flow of biochemical energy in human muscles for the intended purpose and can thus be termed as energy devices.

The Stone Age tools that perhaps emerged around the same time as “fire” can be categorized into Early Stone Age, Middle Stone Age and Late Stone Age tools. The earliest stone tools discovered so far are from the Turkana area of Kenya and date back 3.3 million years (Harmand et al., 2015). Similar tools dating to a later period were discovered by archaeologists in Olduvai Gorge in Tanzania (Leakey et al., 1964) and are roughly 2.6 million years old (Palaeolithic Age) (Smithsonian, n.d.-a). These are hammerstones, choppers and hand axes. Interestingly, there does not appear to be much difference between the Olduvai and Turkana stone tools that seem to have existed at either end of a gap of 700,000 years in time. These stone tools or the rudimentary energy technology of early humans or hominids evolved very slowly, unlike what happens in current times, when a smartphone formed by complex technology becomes as common as a cup of tea in a matter of 10 years.

However, a transition did happen somewhere, somehow. The Middle Stone Age (Mesolithic) tools from between 400,000 and 200,000 years ago show some evolution, with sharper and pointed tools (Smithsonian, n.d.-b) that could be fixed on a spear. The Late Stone Age or Neolithic tools were first manufactured around 50,000 years ago and continued to be used around until 3,000 years ago.

The earliest human remains were found in Ethiopia and are about 2.8 million years old (Powell, 2015). These are the remains of *Homo erectus*, the ancestors of the present-day *Homo sapiens* (modern humans), who seem to have been around until 200,000 years ago. Modern humans emerged around 300,000 years ago (Tobias and Rightmire, 2017).

Thus, one can conclude that Stone Age tools were known not only to humans but also to humans' ancestors, i.e. *Homo erectus* and the *Neanderthals* (Trinkaus et al., 2019), and that, therefore, these tools were known to *Homo sapiens* almost from the very beginning.

These tools existed from the Early Stone Age (Palaeolithic Age) until the Neolithic, or the most recent Stone Age, until around 5000 BC. We are used to fast-paced changes in today's environment, but from 3.3 million years ago until very recent times, evolution in Stone Age devices, as mentioned above, seems to have progressed at a slow and grinding pace.

1.2.4 Energy manipulation methods

There were many practices in the day to day living of early humans where we find intelligent management or manipulation of energy. We find this not only in tools but also in clothing and dwellings. A coat or tent made out of bearskin or the skin of any other animal with fur provides insulation that keeps a person warm. This too, in a sense, is management of energy (in this case, heat!).

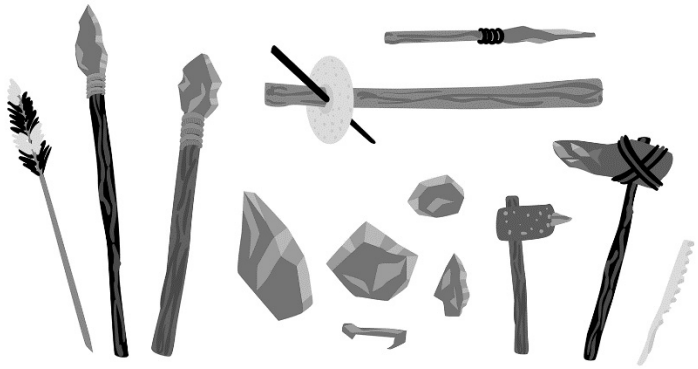

Figure 1-4 (b): Stone tools acted as force multipliers (Source: Shutterstock.com)

Similarly, dwellings made with a mix of mud and agricultural waste or biomass such as rice, straw, etc. not only act as insulation but also allow a flow of air through the perforations. Such dwellings are common even today in the rural areas in developing countries, but must have originated a few thousand years ago.

In the Neolithic Age, dwellings were made by digging into caves in the mountains (Sun, 2013). The mass of the mountain created a thermal buffer that protected the inhabitants from direct exposure to ambient conditions. This may not have been by design but rather a convenient way found through trial and error. There are also dwelling types in China where the house is constructed below ground level instead of as a structure on top of it. These dwellings also protected the inhabitants from the harsh extremes of the ambient climate (Tong and Chen, 2012).

Thus we see the "energy" aspect exists not only in fire, tools and mobility, but also in dwellings and clothing.

1.3 The Wheel

Humans, while moving heavy things around such as fallen trees or large stones, might have found that it was easier to roll an object rather than to drag it. Round objects can be rolled more easily and this may have given birth to the wheel in its rudimentary form, perhaps as a log of wood. The wheel is another revolutionary find of the early humans. It placed human civilization on a higher platform. What has the wheel got to do with

energy? Well, imagine pulling or pushing a cart without any wheels, flat on its belly. The friction will make it nearly impossible to pull it over a large distance. It finally boils down to energy and, in terms of a device, the wheel was perhaps one of the first energy devices.

A wheel is a simple machine that combines mechanical advantage with force manipulation. The forces are those of friction and gravity. The wheel of a cart turns because of the force of friction. In the absence of friction, it will just slip on a surface. The force of friction is also related to the force of gravity (weight), and there is always an energy input in pulling or pushing the wheel and energy output in the form of the distance covered by the wheel, as well as the law of the conservation of energy, which means:

Input = Output + losses

In the case of a wheel rolling downwards on a slope, it amounts to the conversion of potential energy to kinetic energy.

The losses are frictional losses. When it comes to a manual effort or an effort by an animal, more losses means more labour. Even the earliest human who used a stone tool or a wheel was basically finding ways of minimizing efforts or the loss of energy.

Wheels were also used for the purposes of grinding and, in manually operated grinding wheels, the handle to rotate the wheel or the point of application of the force is located near the circumference, thus providing a mechanical advantage in turning the wheel. These are the primary uses of the wheel. In modern machinery it has many other uses, like as a pulley, a gear, for steering, etc.