**Energy and ethics, a personal perspective.**

Thomas Roser, December 14, 2015

I am a physicist working at Brookhaven National Laboratory out east on the Island. I work with the Relativistic Heavy Ion Collider or RHIC - the atom smasher that explores the beginning of our universe and discovered the "Quark Gluon Plasma", a substance that is 250,000 times hotter than the center of our sun. I have a longtime interest in these very high energies but also in questions of energy production and consumption in everyday life. I am particularly interested in the connection of energy and human civilization and society.

When we think of energy we think of warm sunlight, a power snack, a tank of gas, or a speeding car. These are all different forms of energy. Energy can be both doing work such as lifting a heavy load or running on a treadmill, and it can also be the possibility of doing work in the future such as the electric charge in a battery, the food we eat, the chemical energy in a tank of gas, the explosive energy in a stick of dynamite or the nuclear energy in Uranium. These latter examples are forms of stored energy and it is stored energy that can be extracted, accumulated and also bought and sold.

However, if we talk about energy today we mainly talk about fossil energy, which is the energy stored in the organic material of plants and animals that lived hundreds of millions of years ago. Fossil energy, which is mainly coal, oil and natural gas, and its availability has been very much in the news. Wars are being fought about access to fossil energy, mainly in the Middle East. The fortunes of whole countries rise and fall depending on whether they have it themselves or whether they have to import it. Its extraction is endangering the environment and its

use is responsible for changing the climate of the world possibly in a catastrophic way.

But, today's energy problems are often only expressed in terms of the high price of oil. However, the real cost of energy is difficult to determine. It typically only covers the cost of extracting or collecting the energy and then transporting it to the consumer. As we can see from the wild fluctuations in the price of oil, we don't pay for the energy content of oil but mostly for its trading value including speculation. Probably the closest that one can get to the real cost of energy is to pay for somebody else's work.

All of us have lived our lives in this age of fossil energy and, understandably, have difficulties imagining what life would be like without the ready availability of fossil energy. Nevertheless, we are using up the available fossil energy at an immense rate as if there was no tomorrow. We started to use fossil energy about 200 years ago and we will have used it all in about another 200 years in the future – that is, in about 400 years we literally will have burnt up the remains of hundreds of millions of years of life on earth.

Another and more immediate consequence of burning all this ancient material is the release of all the stored carbon into the atmosphere in the form of carbon dioxide, a potent greenhouse gas. This sudden release is unprecedented in the history of the earth and will drastically change the global climate and could have dire consequence for the survival of the human race.

Now, if we want to understand the importance of energy to the human society, instead of following the money, we need to follow the flow of

energy from its origin, mainly from the sun, to powering our activities here on earth. Even though we often refer to energy consumption, energy, in fact, cannot be used up nor can it be created. It can, however, be converted from one form of energy to another. The flow of energy, from one high quality form to another low quality form of energy, is the foundation of the evolution of our universe and also of the evolution of life on earth.

High quality energy is concentrated, directed, and is characterized by differences.

Low quality energy is diffuse, spread out, and is characterized by uniformity.

The stars evolved by converting high quality fusion energy, which is extremely concentrated, to low quality heat. Life and living organisms developed by using high quality directed sun light to create complex structures such as DNA, carbohydrates, and proteins and radiate lower quality energy in the form of waste heat. The carbohydrates and proteins also are a form of concentrated high quality energy.

All life continuously needs this high quality energy to maintain its structure against the constant assault of decay and also to create new structure.

For plants this means using the directed light from the sun to assemble carbohydrates from carbon dioxide and water and releasing oxygen. This is a very complicated process and involves a delicate balance of investing just enough energy to grow tall enough to collect a sufficient amount of sunlight. Only in favorable conditions can plants succeed in

this and survive.

Animals get all their energy from plants in the form of carbohydrates or from other animals in the form of proteins. To collect this energy by either eating grass or hunting prey they have to first expend energy. Survival for animals means that they can extract more energy from the grass or the hunted animal than will be expended during the chewing and digestion of the plant material or during the hunt.

Through trial and error evolution has found, over hundreds of millions of years, ways to make the net energy to be positive for the surviving species. But the balance is always a fragile one and small changes to the environment can make survival difficult. This delicate balance of expended energy and collected energy is also true for we humans.

About 2000 Calories of food energy per day are needed for our survival. For subsistence living, where this energy has to provide for survival, including shelter, for finding food for the next day and also for reproduction and child rearing, the daily energy need is actually significantly higher.

Thus, early humans had to spend most of the day foraging for food or hunting animals. In a favorable environment the human body can find the daily amount of two to three thousand calories – in fact, we would not have survived otherwise. Finding access to this minimum amount of energy and going beyond it has driven human development and also human civilization.

The close connection between energy and human development is illustrated by the fact that we started to cook food. Only humans do

this, but why? By cooking food, which is a process of predigesting it, we can extract about 30% more energy from the food. This doesn't seem like much, especially if one subtracts the extra energy we had to expend to gather wood and make a fire. However, at the same time we started to cook our food, our brains also increased in size. This might be a coincidence but it could also be that the extra energy from cooking food allowed our brains to get bigger. The brain uses a lot of energy: our three-pound brain, about 2% of the body weight, uses about 20% of all the energy. This example shows the close connection between energy flow and development. It also shows how technology can help us with gathering more energy although the increase was actually quite modest for such a major breakthrough in technology development, that is, the control of fire.

Similar modest advances in energy collection were achieved through farming with its far reaching consequences for human civilization. We also started to use domesticated animals as well as other humans as slaves to do our work. In fact slaves have been, throughout human history, essential to allow some humans to escape from subsistence living. Much of what we today know as the culture of societies, before the discovery and use of fossil fuels, was created on the backs of slaves. This was the case for the ancient societies but also for the medieval kingdoms up to the recent use of serfs in Russia and the use of slaves by the British Empire and here in America.

But, today, fossil fuels are providing us with enormous amounts of high quality energy for very little work on our part. In a dramatic change in human history, starting about 200 years ago, humans had abundant energy available without spending much time and energy collecting it. This has changed human society in profound ways!

In today's world every person, on average, uses a total energy of about 40,000 calories every day, twenty times more than the minimum amount of 2,000 food calories! And this is an average over the whole world population! Energy consumption for every person in the US is about 200,000 calories per day or about 100 times the energy a person consumes as food per day. All this additional energy consumption supports our modern lifestyle of climate controlled living with many conveniences, individual transportation, consumer products, etc. – all the amenities and more, that used to be reserved for aristocrats with many servants. So, in a very real way fossil energy has given everybody his or her own 100 servants.

So, we truly live in a historically unique time. Never before has any life form on earth had access to almost unlimited energy without investing much energy first. More than anything else, more than technology, more than large scale wars, population explosion or even democracy and human rights, this is probably the defining feature of our times. In fact, I think that all of these hallmarks of modernity that I listed are a result of having access to large amounts of fossil energy. We could not have started to think about the equality of people with fundamental human rights if it wasn't for all this energy available to provide comfortable living conditions to everybody instead of having to exploit the lower classes or use slaves to provide it only to a few. It is not a coincidence that the French and the American revolutions occurred and slavery was abolished just when the age of fossil energy got underway.

In just a short 200 years we have become fully dependent on an easily accessible source of energy, not just for bigger and bigger vehicles, but

also for the structure of our society and for how we treat our fellow human beings.

We now urgently need to start the transition away from fossil energy. But how can we do that?

First, we need to reduce the use of energy on a global, local and also personal level. This should not be too difficult here in the US as we use so much more than the rest of the world. But we have to be mindful of the fact that every device designed to save energy itself requires energy to produce it. This does not come natural to us anymore as it did before the advent of fossil energy, when everything had to be produced with our own energy.
But reducing energy use has its limits. Short of returning to subsistence living we will need a new source of energy. And even at the subsistence level the world could not support today's population because ever since the "green revolution" that started in the 1960's food production with its reliance in synthetic fertilizers has also been largely based on fossil fuels.

It is difficult to find a new source of energy that provides a lot of energy for little energy investment. An instructive example is solar energy collected with solar cells. To collect enough energy to power a home it takes many large panels of highly sophisticated solar cells. This can be compared to about 100 barrels of oil that contain enough energy to power the home for the typically 20-year lifetime of solar panels. Whereas it takes little energy to extract the 100 barrels of oil out of the ground the production, transportation and installation of solar panels can take a substantial fraction, if not all, of the energy that the solar panels collect during their lifetime. Note that the recent price drop of

solar panels is partially just the result of using cheap coal for the production of the solar panels in China.

A similar situation exists for wind energy. Both wind and solar energy are low-density energy sources and need complex installations and a lot of energy investment to collect this energy. In some ways by relying on only solar and wind we would return to the time before fossil fuels when, always, substantial energy had to be invested to collect energy. It is highly questionable whether our lifestyle or the world population could be sustained using only solar and wind energy.

Most of the development of renewable energy, such as solar and wind energy, has focused on bringing down the cost. Often this meant moving production to low cost countries, to automate production, and using cheap fossil fuel for the production. None of this actually reduces the energy invested in the production and sometimes might even increase it. To make renewable energy a viable future energy source that can replace fossil fuels, research will have to focus on drastically reducing the energy used in the production of solar panels and windmills because eventually we will need to be able to build solar panels and windmills with the energy collected by existing solar panels and windmills.

Finally a few words on nuclear energy: The energy released by breaking up or fission uranium nuclei is highly concentrated and is therefore of very high quality. The energy was stored in these heavy nuclei during the supernova explosions of massive stars billions of years ago. When our solar system formed uranium was part of the material that made up the planet earth and now the slow decay of uranium in the core of the earth is responsible for the hot center of our

planet. The abundance of uranium, the high quality of nuclear energy and the lack of any greenhouse gas emission would make it the ideal and maybe only energy source that can replace fossil energy.

The huge amount of energy stored inside a uranium nucleus is also the source of the horrifically destructive power of the nuclear bomb. It is in this way, that nuclear energy entered human consciousness for the first time. It is therefore not surprising at all that the use of nuclear energy was always overshadowed by a deep fear especially since radiation from nuclear decay is invisible to us but, if intense enough, can harm us or even kill us. But nuclear radiation is nothing new. As mentioned before radiation from nuclear decay heats the inside of our planet and on the surface we were always exposed to nuclear radiation since the beginning of life on earth. Even though we can't see it, radiation is an important and likely essential part of our environment.

The present generation of nuclear reactors cannot explode but, in rare cases, can develop an uncontrolled nuclear chain reaction. All reactors in the US have now containments that prevent any leaks of radioactive material in such an event, but this has come at a great cost. New reactor designs that are inherently safe, where an uncontrolled nuclear chain reaction is not possible, in fact, exist but the nuclear industry has been very slow in adopting anything new.

Today's reactors also use only about 1% of the energy contained in the Uranium fuel. This wasteful use of the fuel also is the reason why the used fuel elements are so highly radioactive for a very long time, tens of thousands of years. It would be much better to use 100% of the energy stored in Uranium, which then leaves waste with quickly decaying radioactivity. Technologies to do this were first developed

here in the US but the development was stopped in the 1990s. In recent years intense work on these types of reactors was restarted in China, India, Japan, and Europe, but not yet in the US.

To address the energy and climate challenge and also to build a more humane society requires that we become aware and confront our deep dependence on the easy availability of fossil energy. The present mindset of taking cheap energy for granted is hampering the development of more energy efficiently produced wind and solar energy collectors and has led to dismissing nuclear energy as a viable new source of energy that could solve the world's energy and climate crisis. It is urgent that we change this mindset and start addressing the world's energy problem more effectively.

Thank you for your attention.