The Future Of Energy

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The Past

Energy is a crucial resource for life. Alongside water, energy is available in relative abundance. Though water can be obtained without much effort, the generation of energy requires more sophisticated methods. The ability to control fire and the invention of hydrodynamic power made huge impacts on human evolution as we will see below. After the discovery of concentrated and easily exploited energy sources like coal or fuel, the dependence on energy in almost every area of life was significantly increased. Although the law of energy conservation, postulated by the German mathematician Gottfried Wilhelm von Leibnitz in the 17th century, states that the total energy of a system cannot change – implying that energy can neither be created nor destroyed – the worldwide demand for primary energy is met by the consumption of fossil and mineral resources (coal, oil, gas, uranium) which has led to a drastic reduction in the availability of these resources and their occurrence. "Essentially, primary energy is the total 'content' of the original resource"([11], p.53).
The worldwide and continually increasing demand for primary energy and the simultaneous decline in mineral resources has led to a seemingly insoluble conflict. Solutions to this problem will be addressed later.

Before analysing the current extent of global energy consumption and its impact on the environment, a retrospective review of human energy consumption appears expedient.
As society evolved, the consumption of energy increased. Consistent demographic growth in past eras may lead to the false conclusion that energy demand rises proportionally to demographic growth. This relationship did apply to our East African ancestors who lived about one million years ago, owing to the fact that their only source of energy consumption, during the period labeled *"Primitive"*, was food. The American Scientist Earl Cook investigated the history of daily human energy consumption at six periods of social development (cf. [1]). In the first period as mentioned above, humans consumed an estimated amount of 2000 kcal of energy in the form of food. The ability to control fire subsequently led to an increased energy demand for food as well as wood. Fire provided light and heat – hence people could utilize it to cook meals, illuminate caves and warm themselves

in colder climates. Cook's energy estimate regarding the *hunting period* related to Europe about 100,000 years ago.
"The *primitive agricultural period* was characterized by the domestication of animals. Humans were able to use animals to help them grow crops and cultivate their fields. The ability to grow more food than they needed became the impetus for creating an agricultural industry"([1], p.3). Cook's energy estimate regarding the primitive agricultural period applied to Mesopotamia around 5000 BC.
During the *advanced agricultural period* people learned to obtain energy from coal, wind and water. Hydrodynamic power was used, for instance, to operate weaving mills and to irrigate cultivated land. In addition, people used wood and coal to generate heat, wind to propel sailing ships and water to drive mills. Cook's energy estimate for this period was for north-western Europe circa 1400 AD.
"The development of the steam engine ushered in the *industrial period*" ([1], p.4). However, other authors claim that Industrial Revolution began before the invention of the steam engine, but for reasons of simplicity, we won't regard this circumstance in more detail. From this time on, energy requirements rose significantly, because steam power gave rise to a systematic transformation of fossil fuels to mechanical energy, which was the key to industrialization. Furthermore, the emergence of transportation in this specific period led to an entire re-evaluation of energy supplies - henceforth humans required energy in form of fossil fuels to propel trains and ships (cf. [1], p.4). Handcraft was successively replaced by automated production. Therefore, production and transportation became a fundamental component of energy consumption. Cook's estimate concerning the industrial period was for England around 1875 AD.
The last phase of Cook's investigation is referred to as the as *technological period*. He associates it with the development of internal combustion engines and applications of electricity. Major energy sources are oil, coal and gas. Domestic markets were transformed into intercontinental commercial relationships between nations and this led to substantially increased use of fuels for mobile purposes. Huge amounts of electrical power were now needed to meet the living standards of industrial nations. Cook's energy estimate was for the United States circa 1970 AD.

Historical Energy consumption					
Daily per capita consumption (1000 kcal)					
Period	**Food**	**H&C[1]**	**I&A[1]**	**Transportation**	**Total**
Primitive	2				2
Hunting	3	2			5
Primitive Agricultural	4	4	4		12
Advanced Agricultural	6	12	7	1	26
Industrial	7	32	24	14	77
Technological	10	66	91	63	230

Source: [3], p.135-144

Cook's investigation illustrates the energy consumption of the world's population throughout history. It is of great importance in analysing how humankind evolved in past eras in terms of energy consumption and establishing a deeper understanding of the direction energy demand will take. As seen in the figure above, energy demand almost doubled between periods until the industrial era, when energy demand rose dramatically. It can therefore be fairly assumed that worldwide energy demand for electricity and fossil fuels will continue to increase. On the other hand, a predicted shortage of fossil fuels, coupled with the geopolitical challenges associated with oil and the growing needs of developing nations, have contributed to the need for a serious reappraisal of the entire energy system.

[1]H&C = Home and Commerce / I&A = Industry and Agriculture

The Present

The previous section reveals that there is no doubt that humans are having to deal with an exacerbated scarcity of fossil fuels owing to rising energy consumption worldwide. However the shortage of raw materials is not the sole challenge future generations have to face – environmental pollution, climate change as well as the globally rising energy demand are major issues which have to be addressed. To understand why our energy supply needs to be fundamentally reconsidered, it is useful to examine how the demand for energy may increase in the future. The "Human Development Report" published for the United Nations by UNDP[2] offers an annual report which "looks at the evolving geopolitics of our times, examining emerging issues and trends and also the new actors which are shaping the development landscape"([4]).

The Human Development Index (HDI) measures achievements in education, GDP, health and income dimensions. It seems reasonable that social achievements correlate with an increasing consumption of energy. Furthermore, "a relationship between energy consumption and quality of life has been reported in the literature"([1]). The Human Development Report 2013 concludes that the world is witnessing a profound shift in global dynamics. China is lifting hundreds of millions of people out of poverty, Brazil is raising its living standard, India is investing heavily in entrepreneurial concepts and developing countries such as Indonesia, Mexico, South Africa, Thailand and Turkey are becoming leading players on the world stage. In addition, 40 developing countries have progressed better than expected (cf. [4]). That said, humanity has to face profound changes in many respects. A growing living standard in the majority of countries, as observed by the UNDP, is usually accompanied by a higher life expectancy – hence, humanity has to deal with an increasing world population, higher energy consumption (shown in Figure 1) and diminishing natural resources.

Figure 1 suggests that the world's energy demand will continue to rise. Consumption is measured in MTOE. The prefix mega (M) multiplies the unit OE by 10^6. Oil equivalent (OE) is used to compare different sources of energy, where the energy of one tonne of crude oil is the yardstick for other energy sources – one tonne OE corresponds to $\approx 11,700\,kWh$.

[2]United Nations Development Programme

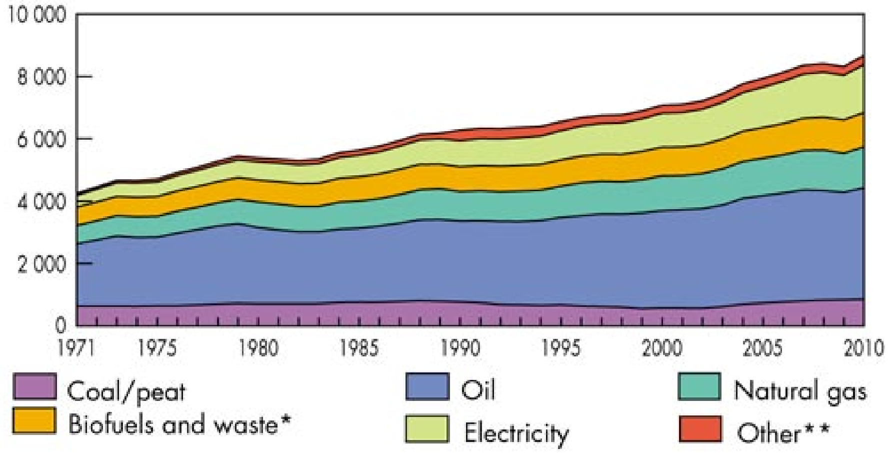

Figure 1: World total consumption from 1971 to 2010 by fuel (Mtoe) [5]

In addition to the consumption of coal, oil and gas, one has to consider "that all fossil fuels produce carbon dioxide when burnt and contribute to increase the greenhouse effect which causes climate change"([2], p.21). Carbon dioxide emissions of different energy sources can be compared in the table below.

Carbon dioxide emissions[3]	
Method of production	**Emissions (g/kWh)**
Coal	860-1290
Oil	700-800
Gas	480-780
Nuclear	4-18
Wind	11-75
Solar photovoltaic	30-280
Biomass	0-116

The complete production chain is taken into account and not simply emissions during operation. Source: [2], p.21.

[3]per electrical kWh produced by different sources of energy

Considering the present situation of world energy supply, one has to take into account that fossil fuel reserves have been drastically reduced in the past three centuries. Mineral resources, stored by nature for millions of years, were burnt in only a fraction of that time and yet humans do not have a valid alternative to meet their energy needs. "By 1997, rather more then 110 billion tonnes (Gt) of oil had already been extracted from underground"([2], p.22). Although scientists at the British company BP mention proved oil reserves of 235.8 Gt crude oil worldwide in their *Statistical Review of World Energy 2013*(see [6]), it is nonetheless apparent that these oil reserves will be utterly exhausted in the foreseeable future.
However one should regard "deadlines" concerning the depletion of oil reserves with suspicion, both because other fossil fuels such as gas and coal can be used as *substitute goods* for oil and because technological progress in exploration and extraction has taken place. Indeed the exploitation of a finite resource can be mathematically described as the scientist Marion King Hubbert did in 1956. His theory predicted that the uncontrolled extraction of a finite resource follows a bell-shaped curve that reaches its peak value when half the resource has been exhausted. Scientists adopted Hubbert's model for different countries and recognized in the early 70's that his theory was fairly accurate (cf.[2], p.23). Though many resources had not even been discovered at this time, Hubbert's theory can be adapted to future scenarios and can therefore assist in demonstrating radical changes in fossil fuel production once natural resources are nearly depleted.
Given these facts, it is obvious that humanity has to modify its energy needs and, moreover, has to switch to alternative sources of energy. Yet the greatest challenge for future generations is not to maintain the achieved living standard that modern societies offer their citizens, but rather to behave in a appropriate way and be prepared to negotiate when natural resources are almost depleted. Conflicts between nations and ethnic groups should be avoided and humans should cooperate rather than pursue their vested interests. The key challenge for coming generations is to aspire to cooperation between disputing parties, rather than relapsing into obsolete habits in which the survival of the fittest prevails.

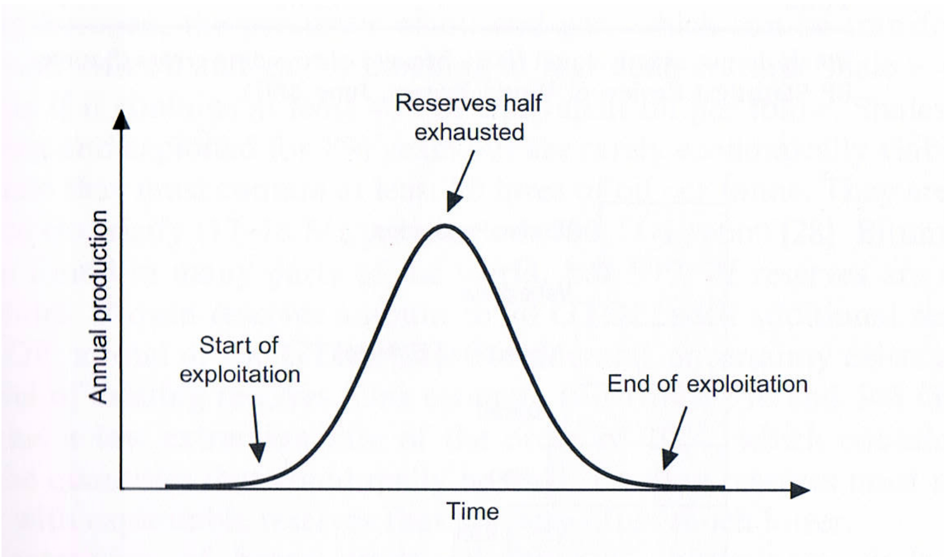

Figure 2: The Hubbert theory of the exploitation of a finite resource ([2], p.23)

The Future

To counter the inevitable rise in future conflicts regarding the distribution of mineral resources, nations have to design sustainable plans for a far-reaching reorganisation of the world's energy sector. As previous sections of this article illustrate, current behavioural patterns in energy consumption need to be urgently rethought. Humans have to face two major challenges in order to facilitate a turnaround in energy policy. Firstly, comprehensive approaches in the political sphere need to be discussed; secondly, technological solutions have to be addressed in a complete restructuring of current energy generation. It is essential that both these aspects are addressed in order to shape the future of energy.
The modern conception of a nation state arose in Europe in the seventeenth century. The gradual transition of monarchies towards nation states with fundamental rights, democratic values and a functioning law system led to unprecedented economic prosperity. However, the rapid technological advances in the industrial period gave rise to a progressively globalised economy. This particular development involves global issues which not only affect nations, but entire economic regions. For example in the past, people experienced these issues during the economic

crisis of 1929. Today, governments and intergovernmental organisations, such as the OECD, the International Monetary Fund and the United Nations, attempt to regulate global issues. Yet the continued existence of national government action makes it increasingly difficult to address global problems such as a deregulated financial sector. Nations act in their own interests and could potentially be disadvantageously affected by trying to solve global issues on their own. This matter concerns not only the financial, military or legal sector, but above all the world's energy sector. If Germany, for example, imposes environmental restrictions on its domestic economy, it has a profound competitive disadvantage when compared to those nations which stick to traditional production methods and, for example, exclude water purification in the manufacturing process
Or, to give another example, the International Maritime Organization (IMO) declared the North and Baltic Seas as an "emission-control-zone" in which the total sulphur in fuels cannot exceed a threshold of 0.1%. As a result, cargo ships are forced to burn liquefied natural gas (LNG) instead of heavy oil. This regulation certainly leads to higher transportation costs and that means a competitive disadvantage for neighbouring countries along the North and Baltic Sea compared to the rest of the world (see [7]). This example illustrates that global problems cannot be resolved on a national level since this automatically leads to inequality. To remedy this problem, nations must become more conscious of the notion that global energy issues can only be solved through an international institution, which has the power to impose sanctions if participants break agreed law. Furthermore, such an organisation should establish stricter rules regarding CO_2 emissions and enforce legislation and investment plans for the development of renewable energy sources. Consequently, national governments could no longer argue that standards of development among countries differed and give them the excuse to violate international law. Since the use of energy sources would be fairly regulated, countries would have an equal chance to develop their national economies in a competitive but regulated environment. In addition, all members of this supranational institution would have to delegate national responsibilities and declare that an infringement of generally accepted laws and ecological directives would lead to a complex of punitive measures. Only these radical steps can enhance cooperation between nations in the shifting process of global fossil fuel consumption and furthermore create structures for a renewable energy production.

In addition to this factor, European nations have to move from seeing their future in terms of a patchwork of regional and national interests towards developing a conglomerate of cooperating countries, in a "United States of Europe". If in the future raw material acquisition becomes more difficult due to an increase in prices, Europe's member states will have to deal with powerful countries like China, India, Brazil, Russia and the United States of America (see [8], p.9). Although, the last mentioned maintains good diplomatic relations with almost every member of the European Union, other nations exceed these European countries' population size and have reliable access to the majority of natural resources. Thus, Europe's nations must increasingly focus on the expansion of renewable energy sources and the development of sustainable technologies and infrastructures. Most renewable energy sources, however, fluctuate in terms of their exploitation and hence require an intelligent and connected grid. In this respect – as in so many others – European nations have to cooperate and compensate for fluctuations in energy generation, which could be achieved by establishing a Europe-wide 'energy institution'. Such an institution would have to coordinate the production, storage and transportation of sustainable energy. Regardless of whether the sun shines in the south, or the wind blows in the north, an autonomously controlled grid would have to distribute electricity in order to balance regional accessibility to energy. A potential means of transporting electricity over long distances could be a new electrical high-power network operating with direct current thus eliminating most power losses during transportation. At the generation stage, electricity meters could be installed to measure the total amount, and such meters could be placed on national borders to record the influx and efflux of electrical current. This would enable precise cost accounting so that countries which produce more electricity than they consume are not disadvantaged.

In 2005, the European Union introduced regulatory procedures in order to cut pollutant emissions of production sites. Since then, "emissions trading" has aimed at a cost-effective method to reduce carbon dioxide emissions. While taxation was seen as being harmful to the economy, it was assumed that "emissions trading" might encourage members of Europe's economy to reduce their CO_2 emissions at production level. The price for emitting one ton of carbon dioxide amounts to 13 euros ([10]). Therefore, this liberal instrument of regulation should assist in improving CO_2 emissions owing to self-regulation and austerity measures of companies, which consistently aim to reduce their costs. According to the essential economic principle that “the price determines the demand”, one assumed that increased prices for products with an above-average “CO_2-product-allocation” lead to decreased demand. This relationship was supposed to enforce the economic change in production. However, studies related to the effectiveness of “emissions trading” within the European region regarding total CO_2 emissions cannot yet significantly confirm the impacts of this particular measure on the reduction of pollutant emissions.

Although in 2005 the European Union took an important step in the right direction regarding climate protection, the matter became too urgent to be tackled merely with a liberal-market measure like “emissions trading”. As a matter of fact, the anthropogenic – that is, human-induced – greenhouse effect has long been questioned by scientists and journalists; however, it is now widely regarded as causing climate change. Taking the world’s anthropogenic climate change into consideration, it is of great importance to discuss whether Europe’s nations are making enough progress in climate protection or whether their commitment and actions are insufficient. To appreciate how the greenhouse effect causes a rise in temperature, a brief explanation seems expedient: “The greenhouse effect in its natural form has existed on the planet for hundreds of million of years and is essential in maintaining the Earth’s surface at a temperature suitable for life” ([11], p.14). Without an atmosphere, the earth’s surface temperature would be approximately minus 18°C. “However our atmosphere, whilst largely transparent to incoming solar radiation in the visible part of the spectrum, is partially opaque to outgoing infra-red radiation. It behaves in this way because, in addition to its main constituents, nitrogen and oxygen, it also contains very small quantities of ‘greenhouse gases’. Put simply, these enable the atmosphere to act like the panes of glass in a greenhouse, allowing the sun to enter but inhibiting the outflow of heat, so keeping the earth’s surface considerably warmer than it would otherwise be”([11], p.14,15). Therefore, ‘greenhouse gases’ are identified as substantial chemical compounds which provoke anthropogenic climate change. The principal ‘greenhouse gases’ are methane (CH_4) and carbon dioxide. Since the industrial revolution, humans have been adding substantial quantities of CO_2 to our atmosphere by burning fossil fuels such as coal, oil and gas. These amounts of

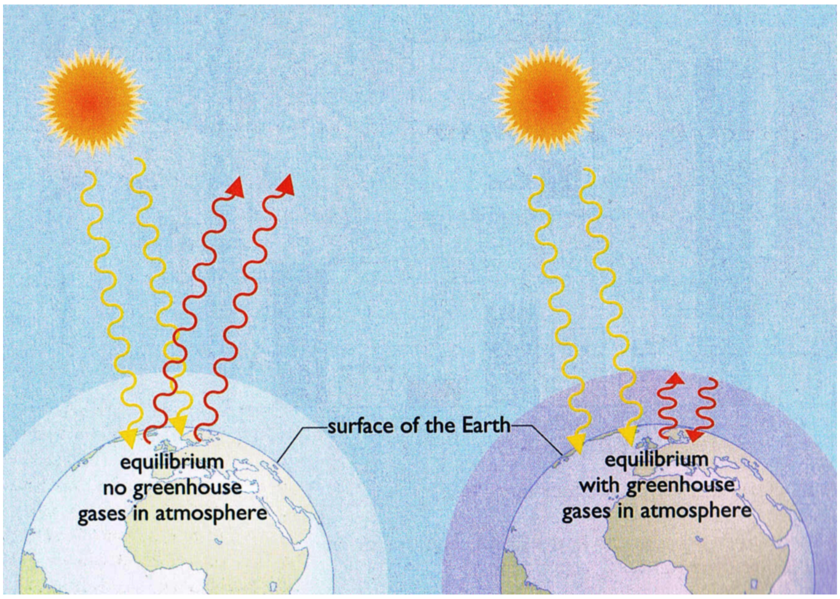

Figure 3: A simplified depiction of how the greenhouse effect raises the earth's temperature ([11], p.14)

CO_2 emissions were combined with the natural carbon cycle and therefore likely to cause an increase in temperature. In pre-industrial times, the concentration of CO_2 in our atmosphere was around 280 parts per million by volume (ppmv). However, from this time onwards CO_2 concentration has steadily risen and, according to NASA, is now reaching 396.72 ppmv (see [12]). This significant increase in 'greenhouse gases' in our atmosphere, especially when taken together with an unprecedented rise in surface temperature of between 1.4 and 5.8°C by the end of the century (see [11], p.16), calls for a radical reorientation of climate policy not just in Europe but all over the world. In addition to "emissions trading", other approaches should be considered – one of which could be a tax on consumer goods. Equal taxation of goods in the European Union would ensure that everyone makes their contribution to ensuring renewable energy production at a European level. Individuals would have to pay a small amount for every product consumed, entrepreneurs would buy capital goods and intermediates, which would be charged with a tax, and companies would have to pay taxes for raw materials and other production items. This particular tax could not be passed on to the consumer and

therefore everyone would pay to restructure Europe's economy and change habits in energy consumption. The 'energy institution' already mentioned would raise the tax and steer the process of restructuring the energy sector. It is important to mention that this institution would certainly be autonomous for a legislative period but still be part of Europe's democratic principles. Citizens could vote in favour of comprehensive concepts and approaches concerning construction measures and the development of Europe's renewable energy production sites. Thus, the 'energy institution' would facilitate the development of a power grid, the construction of solar and wind farms and would furthermore direct Europe's energy production and distribution on the principle of sustainability.
If the above mentioned approaches for a prospective renewable energy sector could be adapted, several issues regarding Europe's current energy consumption could certainly be addressed. The dependence on fossil fuels as well as on the global financial market and its fluctuating price levels for fossil fuels could be reduced. Furthermore, if Europe successfully transformed its energy sector towards a renewable and independent energy production, experiences and concepts could be "exported" to facilitate the turnaround in energy policy both in Europe and in other countries. Firstly, the EU could play a progressive role in climate protection and sustainable economic activity and secondly, Europe would attract progressive thinkers and entrepreneurs of state-of-the-art technologies, who would find the infrastructure and political environment to develop and test their technical applications.

In order to facilitate a turnaround in energy consumption and climate protection, technological potential and prospects are also of great importance. Substantial sustainable technologies such as solar, wind and hydrodynamic energy production have gradually been improved. The efficiency of a wind-energy plant, for example, has reached the point where large scale production is becoming profitable. However, as already discussed, all forms of renewable energies are subject to fluctuations and volatility. Their accessibility is hard to predict and therefore it is not always easy to harness renewable energy sources. A major problem besides the availability of these energy forms is their storage. Consumption patterns of private households and the industry demand a reliable power supply of electricity. However, since coal-fired power stations and atomic power plants are well placed to react flexibly to peak consumption times, they are superior to alternative production forms in terms of their price performance ratio. "With still inadequate storage facilities for electricity generated from renewable power stations not available area-wide, new power generation capacities will be needed for mentioned peak consumption times" ([13], p.18). At present, pumped-storage hydro-power plants are used to store electricity in the form of potential energy. During off-peak times, water is pumped to a higher located tank and can be utilized to produce electricity through a turbine. Admittedly, a lot of effort is needed in order to attain a difference in altitude. This effort is more of a challenge in flat areas, whereas mountainous regions and countries provide natural conditions for implementing storage capacities in the form of pumped-storage hydro-power plants. In 2010, the German engineer Dr. Matthias Popp introduced a concept of a hydro-storage system, which can be implemented in flat regions (see Figure 4 on page 15). His idea of a ring wall storage is one of many possible approaches to enhance the accessibility of sustainable energy sources. With a diameter of 11.4 kilometres and a ring wall of 215 meters in height, solar, wind and hydrodynamic energy production could be combined with sufficient storage capacities. The upper reservoir with a diameter of six kilometres could be used for floating solar modules, as could the hillside of the inner ring wall and the tops of buildings in the vicinity. Furthermore, 2000 wind power stations would be installed on higher levels. This construction would have a peak power output of 3.2 gigawatts and an average power output of two gigawatts.

This combination of renewable and sustainable energy production coupled with a storage facility to balance peaks in electricity demand could be installed in regions where lignite mining has destroyed the landscape. One ring wall storage could replace two nuclear power plants. Though humans would have to interfere with the natural environment and build complex infrastructures, a ring wall can blend with the environment and furthermore be used for other purposes. Moreover, such energy production would not burden humans and nature with atomic waste and could gradually replace lignite mining in these regions. Research and development of conventional and unconventional technical concepts must be pushed forward owing to the dramatic changes in our energy production without neglecting the crucial importance of continuing to alter our behavioural patterns regarding consumption.

Figure 4: Dr. Matthias Popps conception of a ring wall storage ([14])

In conclusion, it is the urgency of these issues which needs to be underlined. Everybody talks about climate change, nobody lacks an opinion and yet progress towards the kinds of solutions mentioned in this article is painfully slow. One does not have to be a revolutionary to recognize or develop such solutions and – in this article only some of a long list of possibilities and options have been addressed – there is nothing fundamentally new about them. What is needed more than ever is affirmative action on climate change, which for us humans is nothing less than a matter of life and death. Scarcities of natural resources, dramatic climate change, conflicts regarding water supply and fossil fuels as well as a chronic pollution of our planet are the key issues. We have all the options in our hands to shape the future of energy but change must happen now.

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