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RENEWABLE ENERGY RESOURCES IN A NUTSHELL: PRESENT AND FUTURE

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ABSTRACT

The Kardashev's scale of civilizations is based on the energy resources for example, a type I which draws its energy from the host planet. A type II civilization harnesses energy from its planet's star and a type III civilization harnesses energy on the galactic scale. A type IV civilization could be added to this scale as well. It is the most sophisticated civilization, it might be able to use energy at an intergalactic scale and may have a know-how to exploit dark energy. Using this scale, our civilization is still a type-zero, it still relies mainly on fossil fuels with a mix of renewable energy sources. In spite of that, we are constantly approaching a turning point and by a century we may move to a type I civilization. Such a transition could not be fulfilled without starting up by exploiting all our planetary resources such as wind, solar, oceans, hurricanes, volcanoes etc. Here, we performed a survey of different renewable energy resources, their economic viability based on the energy returned on energy invested. The basic principal behind these clean types of energy is briefly described. Last but not least, we draw a conclusion on how it is strategic to invest on the environmentally friendly energy and what is beyond this era. An educated guess on the time frame for a full transition from using fossil fuels through renewable energy to energy sources of the future and a changeover to a type I civilization is predicted here with regard to very recent scientific breakthroughs and technological progress.

Keywords: Kardashev's scale, Energy returned on energy invested, Sustainable Energy, Time frame

1. INTRODUCTION

To conquer the universe, cosmologists consider four types of civilizations (Kardashev, 1964). A type I, this civilization is able to harness its planetary resources. A type II, after depletion of its planetary resources, this stellar civilization explores its parent star energy using mega structures such as Dyson's sphere (Dyson, 1960), for instance, a type III or a galactic civilization, capable of harnessing energy from all stars available in the whole visible cosmos and a civilization type IV which could be added to Nikolai Kardashev's classification, it is the most sophisticated civilization. In addition to take advantage of the whole visible universe it has a scientific know-how to unravel and use dark energy and intergalactic energy (Kaku, 2011). On this scale, we are still a very primitive civilization, a type-zero civilization or accurately a 0.7H civilization on Sagan's Kardashev scale (Sagan, 2000), poised somehow for a transition to a type I. We still depend primarily on fossil fuels in the production of our growing need for energy as our population is constantly growing. We expect to reach 11 billion by 2100 (Foster, 2017) (figure 1).

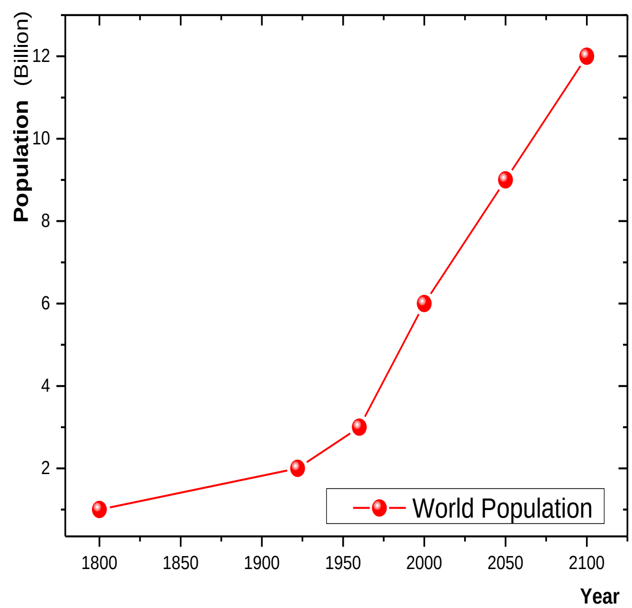

Figure 1 World population estimation from 1800 to 2100 (The United Nations, 2017)

In addition to their harmful impact on the environment, hydrocarbon deposits are likely the essence and among the driving forces for many geopolitical conflicts. Our reserve of fossils is limited and by 2057 we may face a serious crisis.

Not only our fossil fuels are going to run out but also climate change consequences are now more and more tangible in our everyday life. Therefore, investigating renewable energy (RE) resources should be set as a priority.

After the success story of saving ozone layer further to the Montreal protocol on substances that deplete the ozone layer held in 1987, by getting rid of ozone-depleting substances such as chlorofluorocarbons (HCFCS), widely used as refrigerants. We still struggle against another serious problem caused by a yearly 35 Giga-tons emission of CO_2 due to the use of fossil fuels (Olivier el al., 2017). This extra dioxide carbon brought by the industrial renaissance could break down our ecosystem. Among other issues, greenhouse effect for example may lead to an increase in the temperature of our planet, if we keep up consuming the unfriendly environmentally sources of energy at the same pace. A small change leads to a huge impact like disappearance of many coastal cities as a result of icebergs melt-off in the polar arctic, not far from Canada. The South Pole which has been reported to be stable for centuries shows very recently signs of icebergs cracks.

Today one of our major challenges is to find out a sustainable supply of energy, so the interest in renewable energy production is increasing (Popescu, 2018). A report on global warming from greenhouse gas emission, fluctuating oil prices and a rising demand for electricity in developing countries clearly shows a need for new solutions. It is of interest to note that even tough, without greenhouse effect the temperature of the Earth would drop by 35 °C and then our blue planet would be simply frozen.

The Paris agreement in which 196 countries were gathered in December 2015 urged to keep the global average temperature rise below 2 °C above the pre-industrial era level by the end of the current century. Hence, the need for accelerating the transition out of fossil fuels era is emergent (Olivier et al., 2017; Palmer, 2018). Depending thoroughly on renewable energy seems to be a good target to hit by the mid-century. Thus far, RE counts for only 18.2% of our global energy consumption. While the remaining 79.5% is covered by oil, gas, coal and about 2.2 of nuclear energy (Irena 2018).

In this work, we first discuss briefly the basic principles of different types of renewable energy resources namely, solar energy, hydropower, wind, geothermal, biomass and energy of the future such as hydrogen storage and nuclear fusion (figure 2). Later, we sketch our vision for the future of energy in our planet. We start up using a mix of RE and non RE before moving to the use of only pure RE, this period will last for few decades. The timeline for a transition to the energy source of future and what is beyond this era i.e., a transition to a civilisation type I, is also studied.

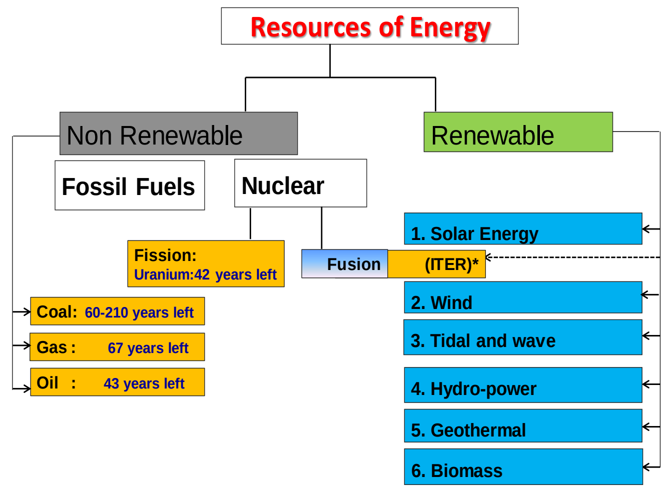

Figure 2 Diagram of different resources of energy

2. DISCUSSION

From an economic point of view, energy returned over energy invested (ERoEI) is a reliable indicator on how viable a source of energy is. Experts are persuaded that ERoEI should exceed 3:1. The breakeven point 1:1 is far from being economically worthwhile. Coal ERoEI for instance is 80:1. It is extremely economical regardless of its harmful impact on the environment. In table 1, we show different ERoEI for different RE compared to coal.

TABLE 1 ERoEI of different energy sources (Hall and Balogh, 2014; King et al., 2018; Palmer, 2018)

			ERoEI
Coal			80 : 1
Biomass	Solid	Wood	25 : 1
	Liquid	Biodiesel	1.3 : 1
		Corn	1.3 : 1
		Sugar canes	8 : 1
Hydropower			100 : 1
Solar	Thermal		1.9 : 1
	Concentrated		9 : 1
	Photovoltaic		6.8 : 1
Tidal / wave			15 : 1
Wind			18 : 1
Geothermal			9 : 1

Apparently, RE has probably a relatively long way to go before being competitive with the non RE.

Worth noting that not all renewable energy resources are sustainable. Biomass-wood for instance is renewable but not sustainable. Furthermore, renewable energy resources can be non-sustainable if they are exploited at a high rate to not be able to be regenerated. In this sense, sustainable energy should meet today's demand and the future needs for energy.

2.1 Solar Energy

For over 4.6 billion years, in the core of the Sun at a temperature of about 10 to 15 mega kelvin, 600 million tons of hydrogen nuclei fuse to form helium and then daily release ten yotta Joules (10^{+25} J) of energy. Nevertheless, only 5×10^{-8} percent of this energy reaches the surface of the Earth since it is absorbed through the one astronomical distance of space (about 150 million kilometers) in addition to about 10 km of the atmosphere surrounding the Earth (Montwill and Breslin, 2008; Calkins, 2013). This important energy of the Sun can be used mainly for either:

a. *Passive Solar Energy*

The key for such an approach is based on well engineering the building design in order to harness as much as possible of useful sunlight. A combination of climatology and thermodynamics are the building blocks of such a technology.

b. *Photovoltaic Plants (PV)*

PV devices are capable of converting directly light into electricity. They are mostly fabricated from semiconducting materials namely silicon as depicted in figure 3:

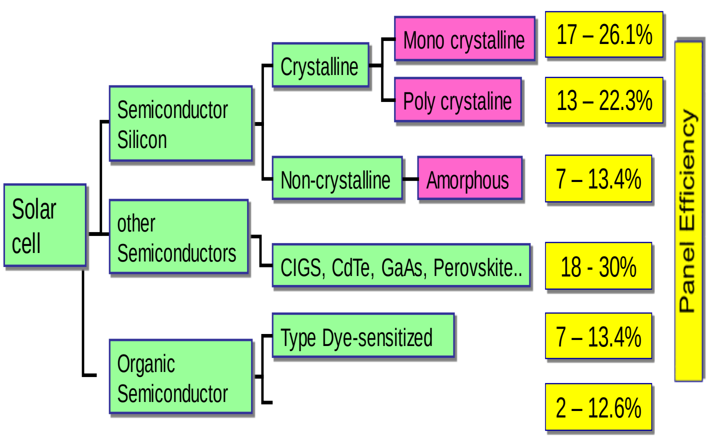

Figure 3 Different solar cell technology

c. Concentrating Solar Heat Plants (CSP)

They serve to generate electrical energy or/and heat when solar radiation is collected and magnified based on greenhouse effect. A specific fluid is heated to subsequently produce steam. The generated heat could be used directly or stored in a special thermal insulating salt as simple heat for buildings or to turn turbines and then to produce electricity according to Faraday's law. The basic principle of CSP is shown below in figure 4.

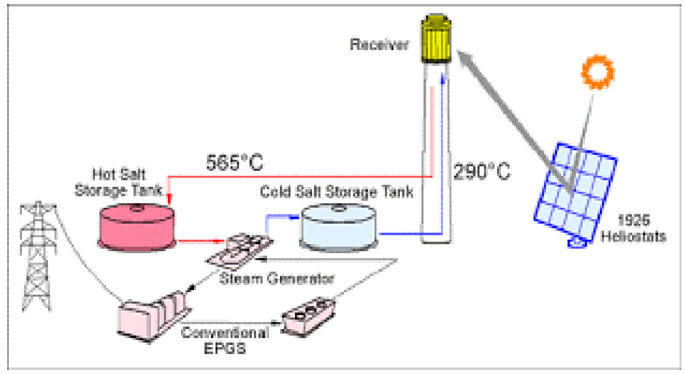

Figure 4 Principle of generating electric current from concentrating solar heat plants (Image credit: Greenterrafirma.com)

2.2 Wind Energy

Compared to other zones on the surface on the Earth, in the vicinity of the equator, the harnessed heat from principally the infra-red region of the solar spectrum is greater. The generated heat gradient drives air to move in the form of wind. This natural phenomenon is exploited by wind machines (turbines). Commonly, we can distinguish two classes: horizontal-axis and vertical-axis turbines. The two turbines when gathered at larger scale, they form wind farms. The wind energy ERoEI is economically viable; it is 18:1 despite of a noise caused by these plants. The power of a turbine can be estimated using this formula:

$$P_{wind} = \frac{1}{2}\rho \times A \times V^3 \qquad \text{equation 1}$$

where A is the area scanned by a rotor: $\pi \times R^2$ (m^2), R is the pale radius, V is wind speed (m/s) and ρ is density of air (1.23 kg/m^3 at 15 °C, 1.0132 bar)

2.3 Hydropower Energy

A flow or fall of water in rivers, lakes or stored in dams carries an important mechanical energy once converted to electricity by turning a grand electromagnet rotor contained within a cylindrical stator itself formed of coils. The water power pushes the blades of the turbines, the rotor spins then according to Faraday's law a variation of a magnetic field flux induces a generation of current.

A dam can produce a power of:

$$P = \phi \times g \times h \times \eta_{elec} \times \eta_{hyd} \qquad \text{equation 2}$$

where P: power (W), h: fall height (m), ϕ: water flux (m^3/s), g: gravity 9.8 (m/s^2), η_{hyd}: turbine efficiency (0 - 1) and η_{elec}: electrical conversion efficiency (0 - 1)

2.4 Geothermal Energy

This term is derived from Greek words geo that stands for Earth and thermo for heat. As we dig gradually deeper into the Earth, the temperature rises at a rate of 3°C per 100 m.

The steam and heat produced deeper in the Earth could directly be used to heat buildings or to indirectly generate electricity based on the same principal described above.
In the core of the Earth at about 5 000 km depth, the temperature is more than 10 000°C, somehow hotter than the Sun's surface. In effect, rocks composing the Earth are made of radioactive particles, they naturally decay to release this thermal energy.

2.5 Biomass Energy

Organic materials originating from animals and plants are the essence of biomass energy. The most common form of biomass is wood, which is not sustainable, and biofuel such as ethanol and biodiesel.
RE exists relatively perpetually. It is abundant and ready to be harnessed.

2.6 Tidal and wave energy

Water flow in seas and oceans generates mechanical energy capable to spin turbines. Their motion can be converted into electrical energy through electromagnetic induction.
Tide is a periodic rise and fall of the sea water. It originates from a differential force due to the gravitational Sun (30%) and the Moon (70%) to the Earth. On the other hand, oceans and seas waves are derived, however from wind energy which derives in turn from the Sun.

2.7 Fusion energy

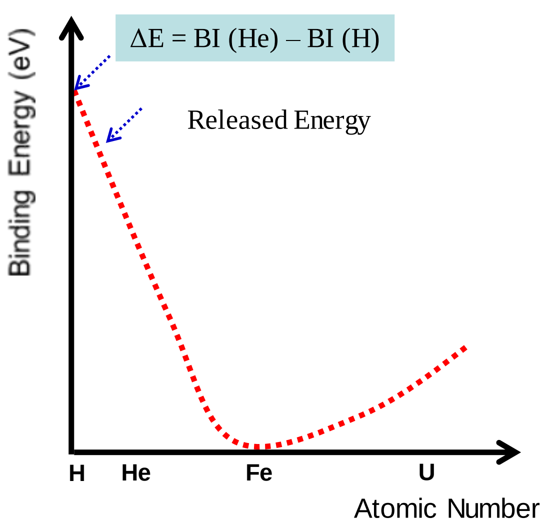

Figure 5 Nuclear binding energy of different nuclei

Unlike fission, nuclear fusion occurs when light nuclei combine to form heavier nuclei. Figure 5 shows the process of fusing hydrogen nuclei into helium, to release energy. The pioneer project International Thermonuclear Experimental Reactor (ITER) (Pioneer Project: International Thermonuclear Experimental Reactor www.iter.org) metaphorically aimed at putting the Sun in a box i.e., reproducing stellar nucleo-synthesis in generating energy by a nuclear fusion of two isotopes of hydrogen; deuterium and tritium into helium nuclei:

$$_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1 + \text{Energy}$$

The fuel for such a reaction is water, cheap and renewable. Actually, deuterium is available in water but tritium is radioactive with a half-life of 12.3 years. Compared to fission radioactive by-products such as plutonium with thousand year's half-life, tritium is much better environmentally and is also reused in the cycle of fusion reaction. Tritium can be produced from bombarding lithium with neutrons released from the above reaction.

To build nuclear fusion reactors there is two main strategies: inertial confinement and magnetic confinement:
The former strategy has been developed at Lawrence Livermore laboratory through two stages. The first generation named Shiva laser. It was built in 1978 by combining 20 nano-second pulsed laser beams (neodymium glass gas mixture) to focus onto a tiny deuterium-tritium target chamber. The second generation Nova laser was more sophisticated and ten times more powerful. In December 1993, Nova reached the Lawson's criterion (Lawson J. D., 1957). To overcome deuterium-tritium inertia, it is possible to use steam of particles instead of laser.

The latter strategy is based on confining and controlling plasma in an elliptical-like shape by applying two magnetic fields to subsequently avoid any contact with chamber walls. In 1990, Tokamak Fusion Test Reaction (TFTR) at Princeton produced 5.6 megawatts in a controlled fusion. Regardless of the fact that it was less than the breakeven point, it demonstrated the feasibility of the magnetic confinement strategy. Joint European Torus in England produced 1.7 megawatts in 1991, as well.

An additional challenge is to provide enough energy to break down the strong nuclear force binding protons together, of about MeV/nucleon. This energy comes in the form of heat and 1 MeV converted to heat is fairly equivalent to about ten Giga kelvins. This could not be achieved without a new progress fulfilled in Laser technology enabling the production of instantly hot plasma. On the other hand a new challenge arises: how to find out a material capable of bearing such extreme temperatures.

Tokamak shown in figure 6 was the first machine designed from carbon and later from less contaminant elements such as beryllium and tungsten, to meet this criterion alongside a technologically trick enabling the confinement of a hot plasma (150 Mega kelvins) generated in a free space. In effect, a magnet filed is applied to confine the hot plasma and to keep it far from the chamber walls directed towards the inner of the vacuum chamber.

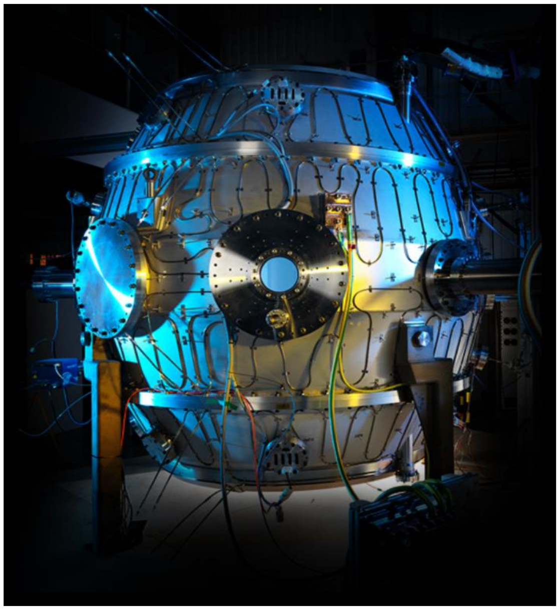

Figure 6 Photo of a Tokamak (Image credit: Tokamakenergy.co.uk)

The energy produced is relatively clean exempt of long life-time radioactive waste and renewable (World Commission on Environment and development, 1987). Hydrogen can be safely used to turn turbines and to produce low cost electrical energy. In addition, hydrogen isotopes are abundantly available in oceans and seas. The only hurdle left is enhancing the ERoEI. So far, energy to fuse hydrogen into helium is higher than the released energy. The ITER perspective was set to provide ten-fold the input energy in most likely two decades.

2.8 Fuel cell

It is basically based on generating electricity from chemical combinations of atoms of hydrogen and oxygen to cogenerate water and current.

$$H_2 + O_2 \rightarrow H_2O \quad + \text{heat}$$

This reaction is followed by expelling heat. This thermal energy can be directly used or converted to other forms of energy. An essential issue that hampers this technology from flourishing is the production of water during this process and how to handle it. In conclusion, it is noteworthy how the contribution of renewable energy is shaping our world lifestyle. The production of renewable energy increased by 8.3% to reach 2.179 Giga watts by the beginning of 2018. The major contribution comes from hydropower followed by solar and wind energy sources as depicted in figure 7 (Irena 2018).

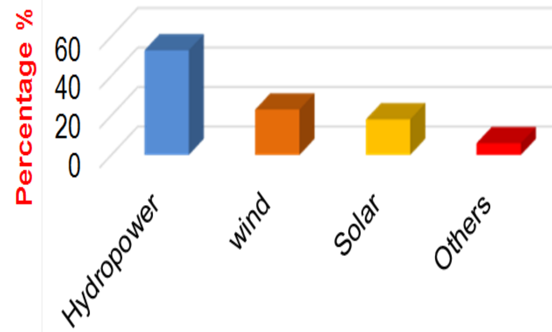

Figure 7 World renewable energy contribution by energy type (Irena 2018)

3 FUTURE VISION AND FRAME TIME

We have succinctly described the major challenges confronting the world today to move towards clean energy resources. An educated guess leads us to believe that before RE to displace fossil fuels first a mix of RE and non RE is now observed but as the fossil fuels cost is steadily increasing in the meantime RE cost is going to fall down (Markard, 2018- IEA 2018b), at a certain moment their curves intersect and at that time we can talk about the economical jump up of the pure RE (figure 8).

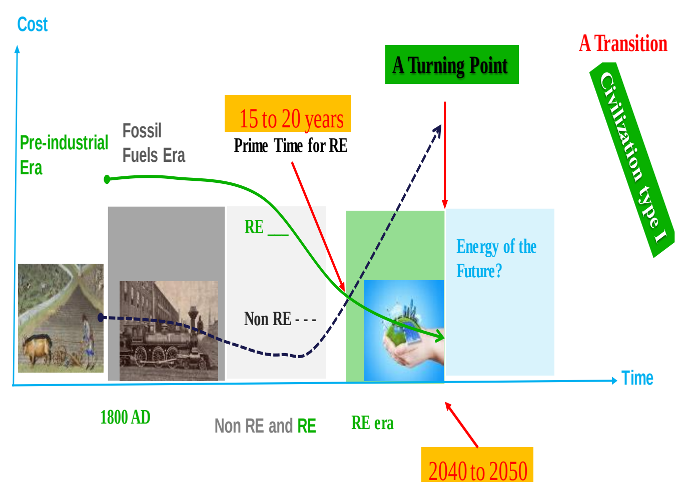

Figure 8 Possible scenario for our civilization frame-time progress

We think this could be reached in about 20 to 30 years and beyond this era; a new age of fusion energy is going to take over alongside hydrogen fuel cell. Both are clean and safe. This turning point is expected to occur by 2040 to 2050. Hydrogen stock is available for more than 4.6 billion years and oceans water is abundant and recycles periodically. Hydrogen counts for about 75% of the conventional matter in the whole observable cosmos. Afterward, a transition to a civilization type I is going to take place few centuries later (figure. 8).

The physical American society firmly stated that proofs for an ongoing global warming are incontrovertible, thus serious actions should be taken before the point of no return is reached. On the other hand and aiming at being objective, we have to evoke the contradictory view point as well. The physicist Ivar Giaever, a Nobel laureate in 1973 (Giaever, 2015) thoroughly rejected all these climate change claims and stated that from 1880 to 2015, the temperature rise is of only 0.3% and there is no need to worry about the climate change. It is a natural process of the universe.

Impartially, we have to look at the big picture, small change leads to a big impact. For every one-meter vertical rise of sea level we lose about 100 meters vertically of the coastal cities. Now, and after the 5th extinction cycle, 65 million years ago, when an asteroid hit the Earth and wiped out dinosaurs, we are likely facing the 6th cycle, this time, it is rather the Homo sapiens who is going to fuel his very own self-destruction.

Our own free will derived from the Copenhagen interpretation of quantum theory suggests to be either indifferent vis-à-vis the global warming. Such a denial state is constantly defended by the global warming denials, or on the other hand, rise concerns about climate change. By the end, a good aspect of an altruistic Homo sapiens trying every effort to preserve his planet for future generations should prevail.

4 CONCLUSION

Through this work, after making a brief review of different sources of renewable energy and explaining the basic principles behind each source, we discussed and estimate how long does it take for a full transition from the era of combined fossil and renewable energy to the era of pure renewable energy. Later fusion energy is going to take over before a turning point to a full transition to a civilization type I that harvest its energy from the whole planet using mega structures such as Dyson's spheres to collect the whole solar radiation and other sources.

Our whole universe is smoothly interconnected; everything is related to everything as could be inferred from a broad generalization of the Pauli Exclusion Principle. To make a clear decision, it is high time to get out of the Plato's cave, indeed!

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