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Research Article

Could LENR Change the World?

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Abstract

World energy consumption is equivalent to 13865 million tons of oil (2018). Eighty one percent of energy is provided by fossil fuels. Energy generation releases 34 Gt of CO_2 into the environment annually, which produces climate change. This paper considers the potential scenario with LENR sources of clean energy. It is based on the supposition that the new energy is generated by Metal Hydrogen Energy (MHE) stationary reactors that deliver heat at different temperature levels (100–200–350°C) as the technology evolves along the years. The potential penetration of LENR energy is analyzed taking into account the different conversion routes between the primary energy sources and the final industrial and domestic u sers. It is assumed that MHE replaces all conventional sources operated at a similar temperature level.

- 100°C-class sources can be used for heating. The corresponding market is 700 Mtoe,
- 200°C-class sources can supply all industrial processes using steam. Market: 500 Mtoe,
- 350°C-class reactors can generate electricity in renewed power stations. Market: 5200 Mtoe.

If cheap electricity is generated by such MHE reactors, there will be no need to increase the temperature of operation further. Hydrogen can be produced via water electrolysis. Future mobile equipment will be fueled by hydrogen. Extraction of CO_2 from the atmosphere combined with hydrogen makes it possible to manufacture synthetic fuels to supply the fleet of vehicles and aircrafts using present technology. According to this scenario LENR combined with renewable energies may ultimately eliminate the need for fossil fuels.
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1. Introduction

Humanity consumes huge amounts of energy and 81% of the total is provided by fossil fuels coal, oil and natural gas [1]. These sources emit CO_2 during combustion.

Figure 1 shows the global emissions between 1870 and 2017 [2]. Energy generation released 34 Gt of CO_2 or 83% of the total of 41 Gt emitted that year. This figure also shows that global emissions increased rapidly over the years.

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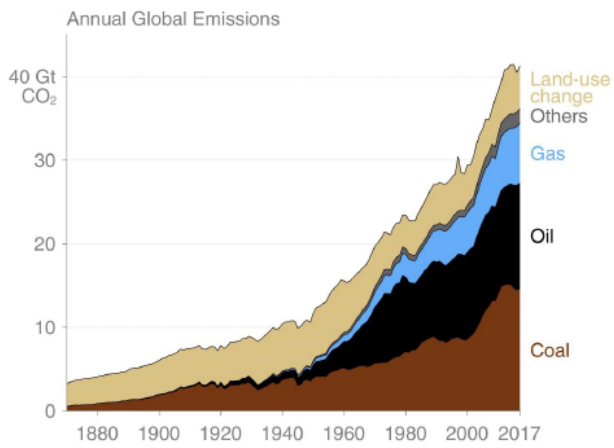

Figure 1. Annual global CO_2 emissions – Others: cement and gas flaring – emissions caused by energy production amounts to 34 Gt CO_2 or 83% of the total – Source [2].

The influence of the greenhouse gases on climate change is now well established [3,4]. Carbon-free energy like wind and solar are presently developed in many countries. Unfortunately, to harness these energies large infrastructures must be deployed in the environment. The resources vary along the day and the year. An electrical grid relying largely on renewable energies must include facilities for energy storage and policies to manage demand by the customers. This is a major change compared to the present situation where the customers can consume in a non-restricted manner with the production following at best it can.

Nuclear energy is also carbon-free but the technology is only accessible to a limited number of countries because of the high safety standards, the management of wastes and the fear of proliferation.

A general problem is that the countries that consume large quantities of energy are different from the countries rich in energy resources. This is true today for oil and gas, but the situation will be similar tomorrow if solar PV becomes a major energy supplier worldwide. This problem generates a large disparity between the different regions and leads to geopolitical tensions and uncertainties [5].

Our modern civilization could not exist without easy access to energy. Any event that affects the cost of energy is a factor toward a recession of the global economy. Our societies are highly dependent on mobility and sensitive on transportation costs (marine, land and air transport). The absence of flexibility in energy costs makes it very difficult to introduce political incentives to control consumption.

On the other hand, 850 million people around the world have no access to electricity [5]. In the future the developing countries will sharply increase their energy consumption.

The overall result is that it will be very difficult to limit the emissions of greenhouse gases if the world energy system does not undergo a profound mutation.

LENR may help modify the situation in a very positive way [6,7]. The purpose of this paper is to discuss how the development of the breakthrough sources of LENR energy could influence the global energy production, conversion and use.

Table 1. CO_2 emissions of various combustibles [12].

Combustible	Emissions of CO_2 (kg CO_2 / toe)
Lignite (Rhineland)	4773
Wood	4589
Coal	3950
Oil	3069
Gas	2349

2. World Energy Consumption Today

The global consumption of energy in 2018 was 580×10^{18} J [1]. It is difficult to apprehend such a large number. Therefore, it is a custom to account for the energy as the quantity of oil that would be required to obtain the same amount of energy by combustion. This quantity is measured in metric tons of oil equivalent (1 toe = 41.87 GJ). This practical unit is used in this paper. The 2018 world consumption corresponds to $13\ 865 \times 10^6$ toe or 13 865 Mtoe. Because all of this energy is extracted from the Nature in diverse forms (from oil and coal, to uranium fission, to wind and sun light) this is designated primary energy [11].

The different fuels release different quantities of CO_2 as shown in Table 1 [12].

In general, the primary energies cannot be used directly. It must be transformed into secondary energy types, which are easier to handle. For example, coal is processed in power plants to generate electricity. After transportation and distribution to the final consumers, the usable forms of energy are called final energies. The conversion introduces some losses, so that the quantity of final energy available for consumers is less than primary energy. Figure 2 exhibits the situation in 2018. The global final energy consumption was 9700 Mtoe.

For the purpose of this paper this figure introduces the conversion processes that allow the transformation of the primary energies into secondary ones. For example, coal is used to produce electricity via steam turbines, and refineries

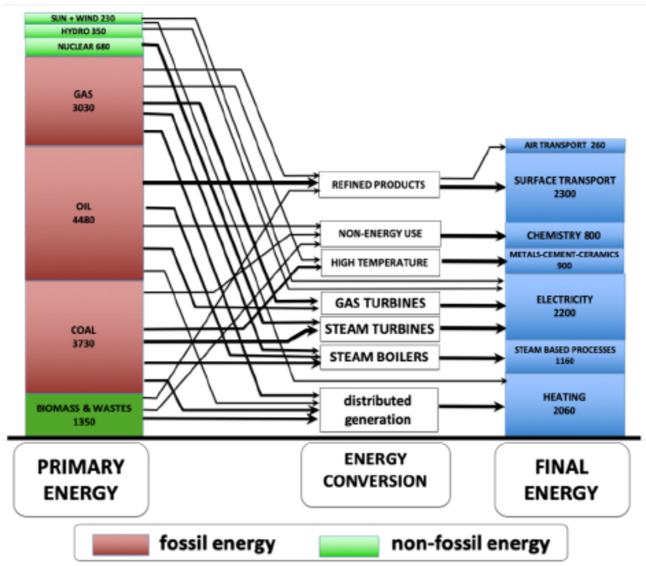

Figure 2. Present global energy flowchart showing main conversion routes between primary and secondary energies.

transform crude oil into fuels suitable for cars or aircraft. The arrows indicate the main process routes to transform primary energies into specific usable forms.

3. Introduction of LENR (MHE) as a Commercial Energy Source

3.1. LENR energy sources

LENR offers the theoretical possibility to provide unprecedented energy sources:

- Sources can be built in any size including small devices,
- large power units can be obtained by clustering many independent reactors,
- the consumables are very small, so a reactor can run for a long time with a single load of active materials,
- no radiation is emitted, so the reactors are inherently safe,
- no green-house gases are produced,
- scrapped units can be easily recycled because they do not contain radioactive wastes.

For the moment, LENR energy sources cannot be put on the market because it is still not possible to initiate the reaction in a controlled manner. The precise features required to make the materials active are not yet understood and mastered. Recent progress has been made, which indicates that complete success is reachable [8]. Therefore, it is now time to start to think about the possible applications of these new energy sources.

In the following we consider a particular type of LENR reactor that is activated by simple heating. The corresponding reactors are called MHE for Metal–Hydrogen Energy [8]. The reaction occurs with specially prepared nanoparticles containing several metals (e.g., Ni + Cu or Ni + Pd) exposed to an atmosphere of hydrogen isotopes at high temperature. Once the reactor is hot, it starts to generate heat, and is able to do so continuously for several weeks or months. An earlier paper describes how to operate and control such reactors [9].

3.2. Analysis hypotheses

Any prospective study must rely on some assumptions. In this paper, we consider the following set of hypotheses:

(1) The MHE reactors produce only heat,
(2) the heat quality is characterized by its temperature level (temperature class),
(3) MHE production is only made in stationary installations,
(4) the deployment is progressive as the technology evolves,
(5) when the technology is improved the temperature of the heat production increases,
(6) three progressive levels are taken as hypotheses:
    (a) 100°C,
    (b) 200°C,
    (c) 350°C.

This last level is sufficient to convert MHE heat into electricity with acceptable Carnot efficiency. By way of comparison, nuclear reactors also operate at 350°C [10].

Other hypotheses could have been considered, involving, for example, mobile energy sources or reactors able to operate at much higher temperatures. These would have resulted in other scenarios quite different from the one discussed here.

It is further assumed that the cost of MHE energy will be cheaper than conventional energy so that all market segments technically accessible by a given class will adopt the new type of energy. However, an exception is made for renewable energy sources that will continue to grow. In some specific cases renewable energy will be the easiest and cheapest solution (e.g., solar water heating in regions with a high solar insolation). Renewable energy will also continue to receive some support for political reasons.

The advent of MHE energy may have a profound impact on the global energy market. The revolution will evolve progressively. It is supposed that the applications will come stepwise, following the temperature class of the heat delivered by the MHE reactors.

An analysis of the conversion processes to transform primary energy into final energy shows which domains of the industry will be progressively impacted as the MHE reactors reach the supposed temperature levels.

To simplify the analysis, it is supposed that the total energy consumption remains unchanged in the different scenarios. This is a static analysis. It is an oversimplification, because the introduction of MHE in the industry will take several years and during this time the global consumption will continue to increase.

It must be emphasized that this study does not pretend to be exhaustive, and that all quantities mentioned in the following only have an indicative value. Our objective is to demonstrate the boldness of the change.

3.3. Direct utilization of MHE heat source in the industry

In a first intermediate scenario, MHE is introduced as a heat source only in the processes that make a direct use of heat. Further utilization of MHE energy, for instance via the electricity produced, is not considered here, but is discussed below.

3.3.1. *100°C Class MHE*

This temperature is relatively low. It can be used for space heating and some process heat. Small MHE heaters can be installed in houses and buildings, with large ones for district heating. Presently, such heating systems rely heavily on the combustion of coal, oil, gas, and to a limited extent wood. Incineration of wastes supplies district heating facilities and will remain, and solar systems will expand.

It is assumed that the overall heat produced by MHE will be 700 Mtoe, displacing 300 Mtoe coal, 300 Mtoe gas and 100 Mtoe oil.

3.3.2. *200°C Class MHE*

This temperature level is sufficient to power the boilers that produce steam for many process industries like paper mills, food processing, chemical industries, and other process heat, also for steam turbines for mechanical power in some industries. It is assumed that 1200 Mtoe MHE will be introduced for steam generation displacing 500 Mtoe coal, 500 Mtoe gas and 200 Mtoe oil.

3.3.3. *350°C Class MHE*

We make the optimistic assumption that all electricity that is produced by fossil-fuels power stations will be generated by MHE steam turbines. If this hypothesis comes true, all fission-nuclear power stations and gas turbines are phased out. Generation of electricity represents a large share of the global energy consumption. It is assumed that 5200 Mtoe MHE will be introduced displacing 2030 Mtoe coal, 1370 Mtoe gas and 780 Mtoe oil.

Table 2 summarizes the results these predicted scenarios. The reductions of CO_2 are higher than the energy reductions because coal is the first fuel removed from the energy mix.

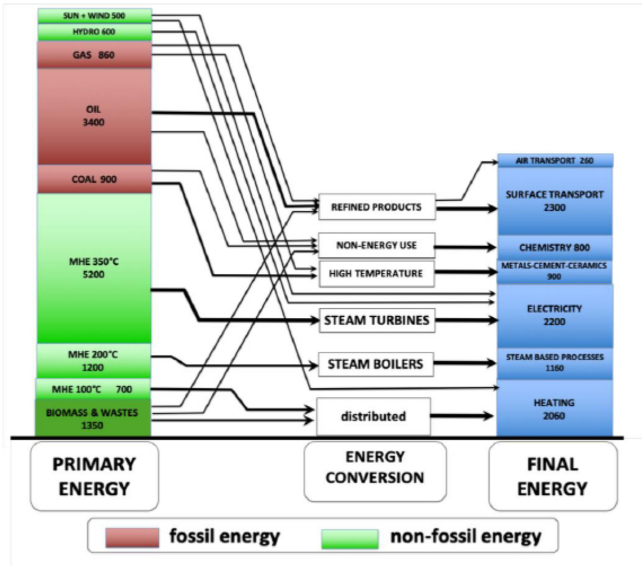

Figure 3. Intermediate scenario with introduction of 7100 Mtoe of MHE as heat source.

Figure 3 shows the global energy flowchart after the introduction of 7100 Mtoe MHE. Fossil fuels share of primary energy falls to 6750 Mtoe or 35% of the Global consumption. Their use is limited to high temperature combustion processes, chemistry, surface and air transport.

Besides combustion, some oil, as well as some biomass, are used as feedstock in chemical plants for the manufacture of plastics, pharmaceutical and food products, etc. We assumed that these uses will not be affected by MHE.

We suppose that renewables will also progress as a result of the trend to foster carbon-free energies.

3.4. Use of MHE for a complete conversion of the global energy flowchart

If we follow the hypothesis of low cost of MHE, a further development is possible with electricity used to generate hydrogen via water electrolysis. Hydrogen can be used as an energy vector for transportation and for long-term storage

Table 2. Introduction of MHE as heat source in the industry.

MHE heat class (°C)	Main market segments	Cumulative MHE primary energy (Mtoe)	Fossil fuels primary energy (Mtoe)	Energy CO_2 emissions (Gt)
Reference	–	0	13 865	34
100	Building heating District heating	700	13 150 (–5%)	31.9 (–6%)
200	Boilers, steam driven processes, paper mills, food processing, etc.	1900	11 950 (–13%)	28.3 (–16.8%)
350	Electricity generation	7100	6750 (–51%)	15.2 (–55.3%)

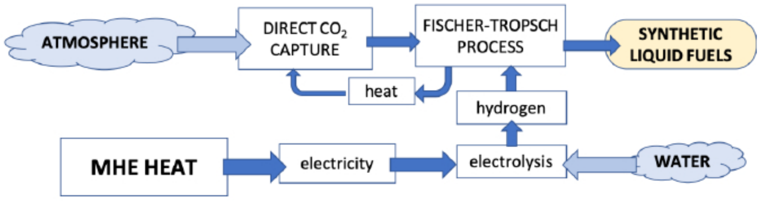

Figure 4. Schematic process of fuel synthesis from water and atmospheric CO_2.

of energy [13].

Synthetic fuels can be manufactured by reacting H_2 with CO_2 extracted from the atmosphere as shown in Fig. 4. These gases are transformed into liquid or gaseous fuels via a series of chemical reaction and the Fischer–Tropsch process [14]. Although this technology is not justified under the prevailing economic conditions today, it is already been studied and developed in niche applications [15,16].

It is then theoretically possible to describe a final scenario without any need of fossil fuels.

The synthetic fuels can be directly used by the existing vehicles and aircraft engines without any new technology. The distribution infrastructure of the fuels would also be kept. This is a distinct advantage compared to hydrogen, which is difficult to store onboard vehicles.

Figure 5 shows the flowchart corresponding to the final scenario. The manufacture of hydrogen and synthetic fuels is only possible with a loss of energy. The amount of MHE primary energy must cover the losses, so that the global primary energy consumption is increased to 23 250 Mtoe, including 19 900 Mtoe of MHE plus 2000 Mtoe of solar and wind.

The energy transition will involve direct use of electricity for vehicles and electricity-driven industrial processes.

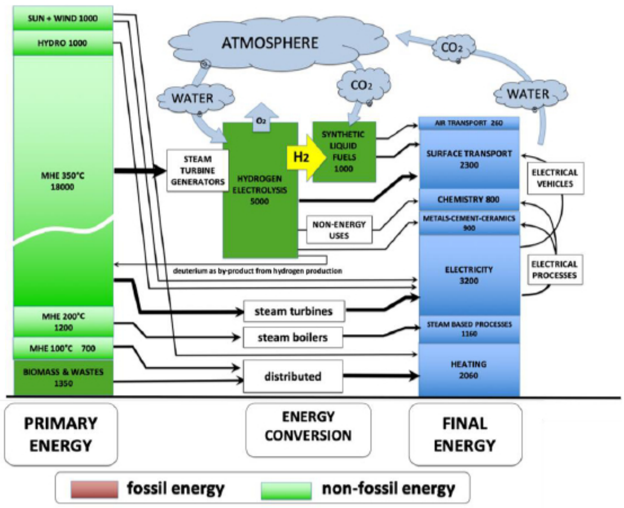

Figure 5. Final scenario global energy flowchart with 100% MHE and renewable energies.

Some hydrogen will be used directly for chemical and metallurgical processes, as well as fuel for a fraction of the fleet of vehicles.

4. Conclusions

The potential benefits of MHE energy are unsurpassable. It would be a compact source of energy available anywhere, at any time, with a positive influence on climate change.

Assuming MHE reaction involves the transmutation of hydrogen into helium, the annual theoretical consumption of hydrogen to cover all the primary energy consumed by humanity would be about 100 tons obtained via the electrolysis of 900 tons of water if normal hydrogen is the feedstock. If deuterium is required, it could be extracted as a by-product of hydrogen production by water electrolysis. The resource has virtually no limit.

The penetration of this new energy in the industrial sector will take some time, the limiting factor being the manufacture of the reactors and modification of infrastructures. The likely development route will probably be similar to all breakthrough technologies:

- First applications will take place in prime market segments, where the new energy will bring a distinct added value.
- The technology will improve as the overall installed power increases. New reactors will be engineered.
- The operation temperature will increase giving access to new markets.

In the power business, experience shows that each time you double the cumulative installed power of a given technology, the cost new installation is reduced by 20%. Figure 6 shows the learning curves for several types of energy [17]. It is likely that the development of MHE sources will obey a similar law.

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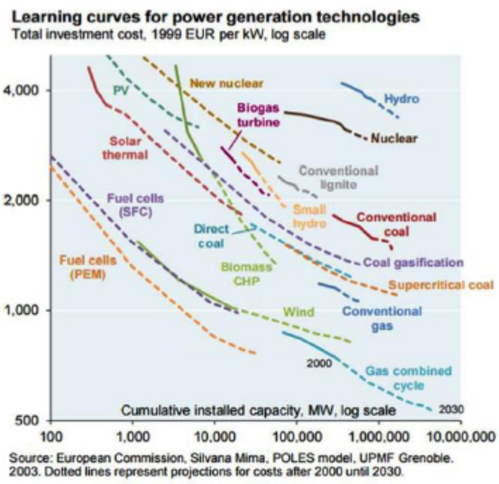

Figure 6. The learning curves for several types of energy generation technologies.

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