Energy in Germany: A critical review of current issues and analysis of future potential

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Abstract— **Germany's energy constellation is changing somewhat. The nuclear pull-out is being substituted by biofuels, however, with controversial results. In terms of sustainability, these biofuels cannot contribute as significantly as perhaps anticipated. Government subsidies for biofuels are at very high levels while the carbon footprint is far from being impressive. Soil depletion, erosion, high levels of greenhouse gas (GHG) emissions and resulting rising food prices are the drawbacks of this development. The bulk of German energy production still consists of fossil fuel combustion. As long as this is the case, the energy sector is causing emissions of some very health threatening toxins such as mercury, cadmium, lead and others. Beside the GHG emissions, these emissions cannot be seen as being sustainable in environmental and social terms. However, any strategy must take into account that the economic sustainability of this market is of crucial importance and must be acknowledged accordingly. Change can only take place gradually with all the stakeholders at the negotiating table. Scientifically, energy sources are emerging, which could potentially make a gradual change possible. So called Low Energy Nuclear Reactions (LENRs) may play a significant role in future energy strategies. As briefly demonstrated in this paper, life-cycle assessing a reference building shows the possible impact change comparing LENR to conventional thermal and electrical energy sources. Clearly, LENR is only emerging into the energy market. However, all pillars of sustainability can be addresses by this novel technology. Especially interesting for future markets, are aspects such as high value adding factors and higher tax incomes. By the taxation of decentralised energy production, much higher revenues are possible with potentially nearly zero environmental and social harm. However, to reach this goal, the science must be developed and engineered into a reliable technology. Once this development has taken place and is represented by politics accordingly, LENR can be anticipated to be adopted with much appreciation by the public body.**

Keywords—sustainability; energy; biofuels; coal; LENR; CO_2- emissions, Mercury emissions, energy costs

ENERGY IN GERMANY IN THE 2010s

The energy business represents one of the greatest sectors in the world. In terms of their turnover, nine out of the top twelve companies and corporations of the world are in the energy business making several trillion United States Dollars in annual turnover [1]. In any future energy strategy, this fact must be acknowledged and the stakeholders considered. None of these corporations are German, however, Germany's dependency on some of these companies for energy imports is clearly present. Germany, is among the top six energy consumers in the world and is almost completely dependent on foreign fossil fuels and nuclear resource imports [2]. The demand for fossil fuels is dramatically rising especially in China and India. With the demand growing, price rises can result. The German economy is very dependent and vulnerable on its product exports [3]. With high energy costs and dependencies, products from Germany become more expensive and thus less attractive for foreign importers. Changes in energy production significantly affect the national economy and changes in the German energy production sector have occurred in recent years. Changes towards biofuels and away from nuclear energy have been observed as being most dominant trends in the early 2010s.

SUSTAINABILITY

How sustainable are German biofuels? The strong development of biofuels in Germany is made possible by national and European Union (EU) subsidies. Biofuels come from plants, sometimes referred to as energy crops, grown for purposes of processing fuel out of them. Critical assessment of the energy crops mainly shows them in a negative light due to the issue of Land-Use and Land-Use Change (LULUC), a negative carbon footprint and contribution towards rising food prices. In short, food crops or agricultural food areas are replaced by monoculture energy crops, without a significant environmental advantage, however, with the effect of promoting food import dependency and causing global food price rises. For example, a life-cycle assessment undertaken by [4] shows that maize or corn bioethanol does not have significant potential to lower greenhouse gas (GHG) emissions compared to petrol or gasoline [4]. Also, in [5], a calculation of the future total production costs of biofuels for 2015 shows that biofuel production costs are primarily driven by the price of raw materials, e.g. petrol or diesel (crude oil) [5]. The comparison shows crude oil, estimated at €100/barrel, with the highest energy density and lowest price compared to all biofuels assessed. Biofuels are more expensive than crude oil in this assessment by factors of 1.56 (maize ethanol), 2.25 (wheat ethanol), 2.39 (waste ethanol), 2.0 (biodiesel from rape seed oil, 1.29 (biodiesel from palm oil), 1.05 (biodiesel from waste oil), 3.43 (hydro-treated vegetable oil (HVO) from palm oil) and 13.13 (biomass to liquid (BTL) from wood).

Independent assessment of biofuels has revealed that their carbon footprints were not sustainable and not worth further investigating in the quest of finding potential alternatives for energy in the German economy [6] [7-11]. The unsuitability of biofuels in Germany is further illustrated by scientific committees which withheld their support for the political subsidisation of biofuels of the first generation [12] (as being subsidised today, e.g. maize to methane biogas):

- The scientific advisory council of the Federal Ministry of Food, Agriculture and Consumer Protection of 2007
- The scientific advisory council of the Federal Government Global Environmental Change of 2008
- The German National Academy of Sciences Leopoldina of 2012

These organizations withheld their support because of the significant rising food price impact due to biofuels and the questionable contribution to climate protection due to the indirect effects on global land use [12]. Many sources also demonstrate the importance of food security. Food security is a situation in which the affected people have access to sufficient, non-hazardous and nutrient-rich food to meet their physical needs and food consumption habits which guarantee a healthy and active life. In 2008, 923 million people across the globe did not have this security due to lack of monetary resources. This represented roughly 14 % of global human population in 2008. The problem has increased since then due to rising food prices. Another 100 million people were expected to be affected by this problem if food prices remained at the 2008 level. In the time period between January 2000 and November 2013, food prices dramatically increased. According to data from the World Bank and the International Monetary Fund, prices increased in this time period by factors of 2.9 (hard wheat), 2.1 (maize), 1.8 (rice), 3.2 (sugar), 2.6 (soya beans), 2.0 (coconut oil), 2.8 (rapeseed oil) and 2.7 (sunflower oil) [13]. One of the major causes for these price increases is the promotion of biofuel in the EU and United States of America (USA). Chakravorty et al. [14] state that many studies show that EU and USA biofuel energy mandates have a large (30-60 %) impact on food prices. Germany is the strongest promoter of biofuels in the EU, for example, she accounts for more than 60% of total biogas production in Europe [15].

According to Laborde and Msagi [16], of the International Food Policy Research Institute, many renowned international institutions came together to issue a joint report. The report was to address the issue of biofuels and food prices and called for an end for "distortive" biofuel policies "especially when environmental benefits are not as high as expected". The institutions addressing the problem of food price increases due to biofuels included the following:

- The Food and Agricultural Organization of the United Nations (FAO);
- International Fund for Agricultural Development (IFAD);
- The International Monetary Fund (IMF);
- Organization for Economic Co-operation and Development (OECD);
- The United Nations Conference on Trade And Development (UNCTAD);
- United Nations World Food Programme (WFP);
- The World Bank Group;
- International Food Policy Research Institute (IFPRI); and
- The World Trade Organization (WTO).

Brendel and Traeger de Teran [17], state that even the most efficient source of biomass to energy conversion, namely maize to electricity and heat, is questionable in terms of GHG emission reductions. The assessment of the maize biomass in climate change terms, shows an extremely nitrogen hungry crop which needs to be seen "very critically" when compared to fossil fuels. N_2O emissions are expected in the process of converting maize (and rape seed) into methane. The global warming potential (GWP) of N_2O is 300 times higher than that of CO_2 [18]. Butterbach-Bahl et al. [19], show the carbon footprint assessment dependent on two very significant factors, namely the Land-Use Change (LUC) (using the carbon captured in soil for energy hydrocarbons) and N_2O emissions from nitrogen fertilizers which are needed by bio-energy plants. According to [19] the standard values of 1% N_2O emissions from nitrogen-fertilized soils as promoted by the International plant Protection Convention IPPC are not correct and higher values must be taken into account in a critical GWP impact assessment.

The 2010 publication of the Karlsuher Institute of Technologie (KIT) of the University of the Province of Baden Würtemberg and the National Research Center of the Helmholz-Society states that the assessment of renewable energy crops with high nitrogen requirements, e.g. maize, purely under climate protection aspects must be considered very critically due to the increase of N_2O emissions and that no or perhaps only a slight reduction of GHG emissions can be expected compared to fossil fuel emissions, however, with other negative impacts. The same can be expected with the cultivation of e.g. maize crops on grasslands (LULUC) due to the significant reduction in carbon storage in the soil [19] .

Despite these facts, [17] demonstrate that under certain, yet common, conditions, electricity feed-in tariff (in €/kWh) for biofuel-electricity is much higher than market prices in Germany (subsidies around 28 cents per kWh) [17]. The market value of electricity in Germany is only around 15 cents per kWh for industry [20], and 25 cents per kWh for private households. The subsidy for agricultural maize areas, worth up to 3,000 Euros per hectare, is almost ten times higher than the average subsidy for agricultural areas worth about 339 Euros per hectare [17].

The remaining renewable energy sources in Germany such as hydro power, solar thermal, geothermal energy and others made up a much smaller fraction compared to biofuels, namely together only 10.3 % of all renewables, thus, roughly 1.2 % of total energy production. Renewables including biofuels made up 11.5 % of all total energy. Overall, photovoltaic accounted for only 0.12 % and wind power for 1.2 % of overall German energy production in 2009. The rest of the energy came from fossil fuels (80%) and nuclear fission (8%) [2].

However, in terms of GWP, biomass could be compared with fossil fuel combustion due to e.g. N_2O emissions over 300 times more harmful than CO_2. This would leave around 98 % of the energy production in Germany being of nuclear or fossil fuels origin thus contributing to the controversial energy sources. The mining (extraction) and combustion of fossil fuels bears very heavy impacts and Germany contributes to these greatly.

SOCIAL AND ENVIRONMENTAL IMPACTS OF FOSSIL FUELS

Fossil fuels include hard coal, lignite, oil and gas. These different fossil fuels have common and unique impacts in social and environmental domains. However, this article focusses on hard coal because of the consisting analysis availability concerning issues such as trace metal emissions (e.g. Mercury, Cadmium, and Lead etc.). Coal mining is thriving but at what environmental and social cost? To illustrate the environmental and social impact of hard coal, the authors use the example of one of the leading organisations in coal mining in the world, BHP Billiton Corporation. BHP Billiton Corporation is "(…) committed to zero harm (…)" according to its 2012 Annual Review which also goes on to state that "(…) We believe that Zero Harm to our people, the environment and our communities is achievable through comprehensive systems and processes for safe operations." [21]. Perhaps the word *achievable* is to be understood in the future tense since reports on the Corporation, paint a somewhat different picture as the following paragraphs demonstrate.

A great portion of BHP Billiton Corporation shares are owned by German shareholders such as Deutsche Bank DWS with 200.67 million Euros, Union Investment Group with 88.63 million Euros, Deka Investment with 80.36 million Euros, and the provincial Landesbank Baden-Württemberg with 29.67 million Euros [22], which makes the corporation quite relevant for Germany. In total, German financial institutions are involved with around 482 million Euros in BHP Billiton Corporation alone. BHP Billiton Corporation is the world's largest diversified natural resource company with around 234 billion USD in market capitalization [23] which further justifies choosing it as an example in this article. This fact, BHP Billiton Corporation of course not being the only coal mining company German banks are involved in, clearly demonstrates how Germany's financial sector is a major stakeholder in the energy business at the extraction stage. It is acknowledged that this issue is not limited to Germany or to German Banks. This phenomenon is a global issue; however, the scope of this study is on energy in Germany thus the attempt is made to focus on organizations with high levels of relevance in this context.

Coal mines operated by BHP Billiton Corporation forcibly (against the will of the people) cause replacement of complete villages and communities of which indigenous peoples are among as demonstrated at the Cerrejón Mine in Columbia. Van Gelder [24] states: "The mine borders and partly covers reservation land of the indigenous Wayúu people. To expand the mine (…) the community of Tabaco was bulldozed flat. The 700 residents, pushed out by 500 soldiers and 200 police who accompanied the mine operator, didn't even have time to retrieve their personal effects. When the job was complete, the village's school and clinic were also razed and the cemetery desecrated. There was no compensation. "

BHP Billiton Corporation has been "criticized for allegedly using a flawed and corrupt process to secure indigenous peoples' lands" according to Reprisk's special report on *Most Environmentally and Socially Controversial Companies 2009* [25]. In this report, BHP Billiton Corporation was ranked tenth. It is not surprising that seven of the ten companies listed as being the most environmentally and socially controversial companies of the world are involved in the business of fossil fuel extraction, namely, Vedanta Resources, Newmont Mining, Rio Tinto Group, KBR, Exxon Mobil Corporation, BP and BHP Billiton Corporation. Even when agreements of resettlement and reconstruction of villages are made with the villagers, BHP Billiton Corporation often does not even bother to engage in the stipulated reconstruction after the people have left the desired site of mine expansion which drives these people into poverty beside the major health problems caused by neglecting environmental aspects in the operation of the mines. "The world's largest miner produced a net profit of $22.5 billion (…)" as stated by ABC-News [26] referring to BHP Billiton Corporation. However, BHP Billiton does not compensate the thousands losing their home, their reserved lands, their food resources and even their complete cultures. The profits are huge and the hunger for coal is growing rapidly. Germany is currently planning the construction of 20 new coal combustion plants adding to the 139 already running. Ten of the planned plants are already under construction and, as of 2011, Columbia was Germany's main supplier of hard coal [8] and most of the coal is coming from the Cerrejón Mine in La Guariga, Columbia.

The gigantic open pit mine in La Guariga, Columbia is eating away the fertile land, destroying the vegetation, polluting the rivers [8] and simply sweeping away the indispensable necessities of life from the indigenous peoples. This mine occupies an area of 50 kilometers in length [24] and is constantly expanding. The people around the mine are forced to adjust from centuries of cultural freedom on native land to working in hazardous mines for a starvation wage [8]. The conditions in BHP Billiton mines in Columbia led to 26 deaths between 2009 and 2011 [24]. Since more coal has been found under the Rancheria river, it is even planned to divert a 26 km stretch of the river in order to gain access to the coal beneath it.

In other BHP Billiton Corporation mines, such as the Ok Tedi mine in Papua New Guinea, around 80,000 tons of mining wastes have been dumped into the Ok Tedi and Fly rivers and this has been done on a daily basis for the last 20 years. This has harmed the environment and the livelihood of thousands of people living on the river. Around 50,000 affected people live downstream of these rivers and the damage done is simply devastating.

Environmental and social impacts of coal mining are intertwined and so are the environmental and social impacts of burning fossil fuels to generate energy. Mercury emissions are one of the most dangerous forms of air pollution from fossil fuels. Brown et al. (2000) [27] state that coal fired power generation is the largest source of Mercury emissions as a class of industrial activity and that an annual 4,000 tons of Mercury emissions are attributed to anthropogenic activities. It is to be acknowledged that these are figures of the year 2000. Furthermore, main sources of anthropogenic Mercury in our environment are mining and the extraction of fossil fuels [28]: "Stationary combustion of coal, and to a lesser extent other fossil fuels, associated with energy or heat production in major power plants, small industrial or residential heating units or small-scale residential heating appliances as well as various industrial processes, is the largest single source category of anthropogenic Mercury emission to air."

In 2005, the Mercury emissions from stationary combustion of power plants alone amounted to 880.2 tons [28] and most of these emissions came from coal fired plants. Due to the extreme growth rate of fossil fuel extraction and coal in particular, it is estimated that Mercury emissions from coal combustion plants alone will exceed 1,400 tons per year by the year 2020 [28]. Yet, Mercury is the most toxic non-radioactive substance in the world [29]. About Mercury, Zahir [30] states: "With Mercury contaminating rain-, ground- and sea-water no one is safe. Polluted water leads to Mercury laced fish, meat and vegetable. In aquatic environments, inorganic Mercury is microbiologically transformed into lipophilic organic compound 'methyl Mercury' (..). The easy access of the toxicant [Mercury] to man through multiple pathways air, water, food, cosmetic products and even vaccines increase the exposure. (…) Decreased performance in areas of motor function and memory has been reported among children exposed to presumed safe Mercury levels. Similarly, disruption of attention, fine motor function and verbal memory was also found in adults on exposure to low Mercury levels. (…) Mercury has been found to be a causative agent of various sorts of disorders, including neurological, nephrological, immunological, cardiac, motor, reproductive and even genetic. Recently heavy metal mediated toxicity has been linked to diseases like Alzheimer's, Parkinson's, Autism, Lupus, Amyotrophic lateral sclerosis, etc. (…). Therefore, it becomes imperative to spread the information regarding the threat of Mercury exposure amongst the scientists and masses."

Mutter [29] refers to a study reported in 1999 in which Mercury levels of dilated cardiomyopathy (DCM) patients were compared with those of healthy patients. DCM is a condition of a weakened heart which enlarges and loses its ability to pump blood. The level of Mercury in the hearts of the DCM patients averaged 178,400 ng/g. The control group averaged 8 ng/ g [29]. The DCM patients thus had Mercury levels which were around 22,000 times higher compared to the healthy test persons. Many other diseases and disorders such as autism, attention deficit disorder, attention deficit hyperactivity disorder, miscarriage, infertility, oxidative stress, genotoxicity, gene mutation, gene damages, cancer, Alzheimer's disease, antibiotic resistance, multiple sclerosis, autoimmunity, nephrotoxicity, neurophysiological diseases are associated with high Mercury levels [29].

In summary, this section has shown the heavy environmental and social burden coming from fossil fuels. The environmental and social cost in this *dash for* fossil fuels is extremely high. Settlements of hundreds are literally bulldozed flat without compensation by companies making more than 20 billion USA Dollars in net profits a year. This profit is garnered while extracting the dirty energy and completely neglecting any environmental aspects and poisoning the surrounding ground water, rivers as well as the animal and plant life. Furthermore, this energy source is also responsible for the highest emissions of the most toxic non-radioactive substance in the world, namely, Mercury. Once the Mercury vapors come into contact with the biosphere, a reaction to methyl Mercury (MeHg) takes place. MeHg finds its way to the food chain and is efficiently absorbed by food (>90%) and readily crosses the blood-brain and placental barriers [31] and contributes to various disorders and diseases among humans. It is, at this point, argued that further promotion of coal combustion is not suitable for a long term scenario in Germany. The status quo, however, tells a different story. The reason for this may be the amounts of investments which can be attributed to coal mining and the gigantic profits that come with this branch of investment banking. The four energy giants in Germany, Eon, RWE, ENBW and Vattenfall control the energy market. In late 2013, Chancellor Merkel granted the highest single government subsidy in Germany, namely three billion Euros to the coal industry [32]. The energy economy in Germany needs to change to meet the demands and expectations of a civilized and fair society of the 21st century. The following section presents a suggestion as to what form this change can take.

HOW CAN THE IMPACTS IN THE ENERGY ECONOMY BE ADDRESSED?

One of the key considerations, in addressing the question above, is: what alternative sources of energy are available now? The main alternatives to fossil fuels as a source of energy in the German economy currently are nuclear fission, biofuels, solar, hydroelectricity and wind energy. Nuclear fission energy bears great risks of radioactive contamination and wastes with thousands of years of radioactive gamma-decay. The recent catastrophe at Fukushima has reminded Germany how dangerous this energy source in fact is – and led to a programme of withdrawal from this energy source. Biofuels such as methane produced from maize for electricity generation (the most efficient of all biofuels), show no or very insignificant positive impacts economically, environmentally and in terms of social sustainability (food prices and food import dependencies). Due to the geography and meteorology of Germany, other alternatives such as solar, hydroelectricity and wind energy simply do not have the potential to produce energy in the magnitudes necessary.

The other key consideration is energy loss. Energy generation can broadly be classified as either centralized or decentralized. Centralised energy generation is characterized by high levels of energy loss. In Germany, it is estimated that centralized power plants operate with losses of around 73% in the form of heat during transportation and conversion (from high to low voltage). Decentralized energy production, e.g. for dwellings or commercial buildings, has a major advantage compared to central power plants since it minimises transport and conversion losses. Decentralized Combined Heat and Power (CHP) units enable the use of combustion heat losses for heating and hot water purposes while producing electricity (without power grid losses) and keeping considerable losses within the thermal shell of the particular building.

From the above, the authors contend that one way of addressing the environmental and social impacts of the current energy economy in Germany is to explore alternative technologies, especially those that promote decentralized energy generation. One such technology is the so called Low Energy Nuclear Reaction (LENR). The following sections explain the basics of LENR and how it can be used in a new energy economy and how the impacts can be understood.

THE BACKGROUND OF LENR

On March 23rd 1989, Stanley Pons and Martin Fleischmann, two renowned scientists in the field of chemistry, gave a press conference at the University of Utah. They announced to have found an unusual effect of heat production while conducting experiments with Deuterium and Palladium. Biberian, [33] describes the reaction in Pons and Fleischmann's reaction as "The equivalent of a nuclear reaction in a test tube!" With this announcement, Pons and Fleischmann introduced a whole new field (LENR) of science [34] since this reaction between Deuterium and Palladium was releasing such high amounts of thermal energy that could not be accounted for by any physical or chemical reaction known at the time.

Today, 25 years later, it is becoming increasingly difficult to ignore the advantages of potential LENR applications over conventional energy sources. In recent years, there has been an increasing interest in the *disruptive* LENR technology. Disruptive technologies offer "another set of attributes" [35] compared to mainstream technologies - attributes, which have the potential to threaten current markets. In its 2009 Defense Analysis Report, the United States Defense Intelligence Agency "assesses with high confidence that if LENR can produce nuclear-origin energy at room temperatures, this *disruptive* technology could revolutionize energy production and storage, since nuclear reactions release millions of times more energy per unit mass than do any known chemical fuel." [36]. While a variety of names for this technology such as the Fleischmann-Pons Effect (FPE), Chemical Aided Nuclear Reactions (CANR), Heat Energy from Nuclei Interaction (HENI), Anomalous Heat Effect (AHE) and more have been suggested, LENR is adopted in this article and represents the particular name used in various publications in the field of Condensed Matter Nuclear Science (CMNS). The resources used for these reactions are metals such as Palladium and Nickel and a variety of isotopes of hydrogen. Isotopes are described depending on the varying number of neutrons and a consistent number of protons. Common Hydrogen with only one neutron and one proton is represented as 1H1. Hydrogen has two more isotopes which are usually given names on their own, namely Deuterium (D), with two neutrons and represented as 2H1 and Tritium (T), with three neutrons and represented as 3H1. The quantity of metal needed in LENR is extremely small and not at all comparable with common fuels.

The word "low" in LENR describes the low amounts of electrical input energy, e.g. UV-LED or laser excitation, which goes into the reaction of e.g. Nickel and Hydrogen (NiH), Palladium and Hydrogen (PdH) or Palladium and Deuterium (PdD). The name LENR may be somewhat misleading. It does, however, differentiate LENR from the conventional high energy nuclear fission and suggests decentralized small scale applications. A differentiation is also made in terms of high energy binding energy (e.g. nuclear fission) and nuclear weak forces. As a definition of LENR, McuKbre and Tanzella [37] show: “The Fleischmann–Pons Effect is defined as the production of nuclear level heat from the electrochemical stimulation of the D2O–Pd. This effect has been observed by hundreds of people in dozens of laboratories around the world, and published in (…) thousands of papers as recently reviewed.”

Research on LENR has increased in recent years and the technology has gained acceptance worldwide. Today, LENR can take place at room temperature and at standard ambient pressure. Although LENR can emit high amounts of nuclear energy and produce nuclear products, they can take place without the harmful radioactive materials and wastes and without harmful amounts of radioactive radiation. In the following paragraphs, a variety of examples of LENR researchers, some of their statements towards LENR and their credentials are shown. These examples make the point very clear, that reputable researchers at renowned institutions have demonstrated the functioning of LENR worldwide.

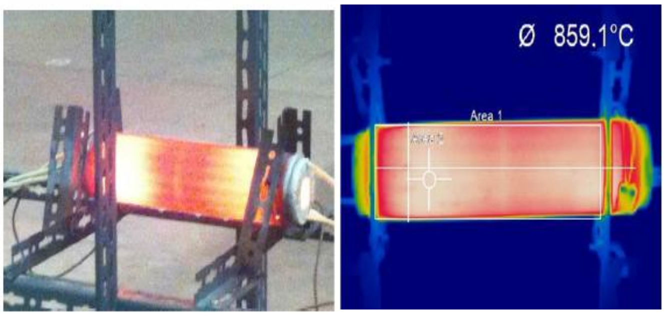
The first of the leading LENR researchers named here is Dr McKubre of the Stanford Research Institute (SRI) at Stanford University. Dr McKubre is an electrochemist and former Director of the Energy Research Center at SRI International. He is “recognized internationally in this field as an expert in the areas of PdH and PdD electrochemistry and calorimetry.” [38]. Dr McKubre has been an active member of the Electrochemistry Society and the Royal Society of Chemistry (…) He has received various awards from these three societies [not all mentioned here]. In 1993 Dr McKubre was co-Chair of the 4th International Conference on Cold Fusion (ICCF4) and in 2005 was awarded the Preparata Medal for conspicuous contributions in the field of Condensed Matter Nuclear Science.” Referring to LENR, Dr McKubre wrote “The Fleischmann-Pons-Effect (FPE) produces real and useful energy. In Energetics experiment L64, in a single burst, twenty five times more heat was produced than entered the cell as electric power. This heat was produced at temperatures sufficient to boil water. Such an effect has practical value.” [39].

The second of the leading LENR researchers is Professor Dr Sergio Focardi formerly of the Department of Physics and Astronomy at the University of Bologna. He was also Head of the Italian National Institute for Nuclear Physics, Head of the Faculty of Mathematical, Physical and Natural Sciences at the University of Bologna. He was also member of the Presidents Board of the Italian Physical Society. From the early 1990s to his death in June 2013, Professor Focardi worked in the field of nickel-hydrogen reactors. As early as 1998, Professor Focardi, while at the Italian Society of Physics, co-authored the paper: *Evidence of a large heat excess produced in NiH systems* [40]. In the experiment reported in this paper, two reactors, cell A and cell B, were used. The cylindrical stainless steel reactors had 22 mm and 34 mm inner diameters and a length of 150 mm. Although relatively small, the reactors were able to produce remarkable amounts of energy. In the 1998 publication (ibid), makes it clear that these anomalous quantities of energy could not be accounted for by any chemical reaction. The electric input energy was around 150 W for cell A and around 70 W for cell B. The anomalous heat produced, in cell A was 900 MJ (250 kWh) and in cell B was 600 MJ (167 kWh). Both cells were able to maintain the reaction for several months, cell A for 278 days and cell B for 319 days. Before the shut-down of Cell A, it was working with an input power of 94.3 W and sample temperature T_{PT} of 429.7 K above T_0 (ibid).

The third of the renowned researcher in the field of LENR is Professor Dr Jean-Paul Biberian. He is a retired professor at the Faculty of Physics at the University of Marseille, France. He is a member of the Advisory Committee of the International Conference on Condensed Matter Nuclear Science, Chief Editor of the Journal of Condensed Matter Nuclear Science and Advising Member of the Scientific Board of the Fluvio Frizone Foundation. He holds advanced qualifications in mechanical engineering, crystallography and physics. He is the author of the technical book: *Fusion in all its forms: Cold fusion, ITER, Alchemy, Biological Transmutation*. Biberian and Armamet conclude that after 18 years in the field of Condensed Matter Nuclear Science (CMNS), there is more evidence of the reality of LENR, production of anomalous heat and the detection of nuclear products showing that the phenomenon is probably of nuclear origin [33].

The photo on the left shows a LENR reactor in a demonstration test carried out by the Leonardo Corporation. The thermal energy from this reactor can be utilized by applying a heat exchanger system (e.g. spiral pipe with liquid medium flowing along the outside of the reactor. Due to the high temperatures LENR can produce, many technologies can be used to convert thermal energy into electricity.

Energy input: E_I = 360 W Reactor temperature: ca. 860 °C
Energy output: E_o = 1609 W
COP = EI/ EO COP = 4.47
Reactor temperature: ca. 860 °C



The Leonardo Corporation has arranged third party validation tests at several academic institutions. "Swedish researchers have tested Rossi's energy catalyzer – E-cat Researchers from Uppsala University and KTH Stockholm has conducted measurements of the produced heat energy from a device called the E-cat. It is known as the energy catalyzer invented by the Italian scientist Andrea Rossi. The measurements show that the catalyzer produces significantly more energy than can be explained by ordinary chemical reactions. The results are very remarkable (E-CAT.com, 2013).

Figure 1 An example of LENR reactors (Levi et al., 2013)

The fourth researcher is Steven B. Krivit. In the introduction of a peer-reviewed chapter, in the American Chemical Society's *Low-Energy Nuclear Reactions and New Energy Technologies Sourcebook Volume 2*, Krivit [34] states: "The evidence for a new class of inexpensive nuclear energy research topics is now unambiguous, though its road to recognition has been a bit slow, bumpy and, at times, treacherous for its intrepid explorers". Krivit introduces one of the significant government supported LENR projects of the Bhabha Atomic Research Center (BARC) in India. In another peer-reviewed chapter of this publication, Krivit remarks the status of publication on LENR: "Three thousand papers exist on the subject, a third of them in peer-reviewed journals. Together, they represent many thousands of experiments." [34]. Krivit has managed to publish in renowned mainstream journals such as the Reference Module in Chemistry, Molecular Sciences and Chemical Engineering in 2013 and some more.

The fifth of the LENR researchers is Dr Guiseppe Levi. Dr Levi is an Assistant Professor at the University of Bologna and has also worked with the Leonardo Corporation. Dr Levi has carried verification tests on Leonardo Corporations' E-cat LENR reactor. Figure 1 shows the details of one such test [41] performed at the University of Bologna, Italy.

The above are five of many LENR researchers. LENRproof.com [42] (lists over 50 individuals from UK, USA, France, Italy, Sweden, Japan and Ukraine (including two Physics Nobel laureates) who have contributed to our understanding of LENR over the years. Many scientific and academic institutions are involved worldwide. The scientific body of knowledge in support of LENR is established and growing and so is the realisation of the potential of LENR in decentralised energy generation. It is suggested, that funding and research for LENR be promoted in order to reach the goal of finding truly environmental friendly energy sources, without the social impacts currently existing. A development to such technologies can be achieved without negative impacts to society and the current infrastructure.

The fact that the EU- European Commission for Research and Innovation, has found LENR to be suitable for future energy technologies as stated in the 2012 Materials for Emerging Energy Technologies report (Directorate-General for Research and Innovation 2012 Industrial Technologies Material Unit) [43], shows that this potential has been acknowledged. Although the report is no longer up to date scientifically, the commission recommended thus to: "Include LENR in FP7 calls [Seventh Framework Funding Programme] as research on materials as it [LENR] has unlimited and sustainable future energy technology potential."

A POSSIBLE THEORY OF LENR

One of the most accepted LENR theories may be the Widom-Larsen theory. The Widom-Larsen theory explains LENRs as reactions in the surface plasmon, a film of interactive electrons on metal surfaces. In the surface plasmon of e.g. Nickel or Palladium, tiny droplets form with the size of about 30 microns. In these droplets, protons which weigh a lot more than the electrons, grab the latter and "shake" them to create ultra-cold energy neutrons [44], These ultra-cold neutrons are relatively large in size. Due to the large size, the neutron can easily be captured by the metal proton. Srivastava et al., [45] describe these ultra-cold neutrons as having "extraordinarily large nuclear absorption cross-sections" which gives them a high probability of producing nuclear transmutations [45]. At the same time, this attribute gives the neutrons an extremely low probability of escaping beyond micron scale and smaller surface region which explains the very low levels of harmful radiations.

It is the neutron production in the LENR reaction which is necessary and uses input energy. A neutron is a quite unstable particle. Outside of a nucleus, the neutron decays into a proton, an electron and an antineutrino as illustrated in equation 1;

$$\mathrm{n} \rightarrow \mathrm{p} + \mathrm{e}^{-} + \bar{\nu}_e \qquad (1)$$

This process also occurs in certain unstable nuclei such as the Nickel isotope ^{63}Ni. The decay from ^{63}Ni to ^{63}Cu can take place along with the creation of an electron and an antineutrino. A neutron from the nucleus decays under ß-radiation to a proton. The mass number does not change through the reaction, however, the number of protons changes and the source element transmutes into another element as illustrated in equation 2;

$$^{63}_{28}\mathrm{Ni} \rightarrow ^{63}_{29}\mathrm{Cu} + \mathrm{e}^- + \bar{\nu}_\mathrm{e} \quad (2)$$

An inverse ß-decay, the so-called Ɛ-decay, is also possible. A proton captures an electron and produces a neutron and a neutrino as illustrated in equation 3. This process of electron capture, or Ɛ-decay, does however require energy. The rest mass energies are not sufficient to enable the LENR reaction;

$$\mathrm{p} + \mathrm{e}^- \rightarrow \mathrm{n} + \nu_\mathrm{e} \quad (3)$$

However, since the rest mass of an electron (0.510 MeV/c²) is much smaller than the rest mass of a neutron (939.5 MeV/c²) and a proton (938.2 MeV/c²), the electron is much more active. For an electron to undergo a weak interaction with a proton to create a neutron, a MeV range of energy is needed since the neutron is heavier by about 1.3 MeV. This energy threshold must be overcome [45]. The electron must be *accelerated* in the MeV range in order to undergo a weak interaction in the condensed matter system. The Widom-Larsen theory states that collective processes are capable of this electron acceleration. In metallic hydride surfaces, in this case compounds with hydrogen bounded to metals, plasma oscillations exist on the surface which contribute to the energy needed for the electron acceleration [45]. Limitations to this effect are expressed in [46] which suggests “only little room” for this effect. However, heavy electrons are common in physics. A Princeton University-led team of scientists has shown that electrons moving through certain solids can behave as though they were a thousand times more massive than free electrons (Aynajian et al., 2012). These electrons have been found to be both massive and speedy at the same time. Aynajian et al., [47] reported solids in which electrons lead to the development of low-energy (fermionic) excitations with heavy effective masses [47]. Although Aynajian et al. refer to the phenomenon of heavy electrons in actinides and lanthanides, at high temperatures, heavy-electron metals behave “as if f-electrons were localized on their atomic sites as in conventional rare-earth and actinide compounds (…).” The heavy-electron metals investigated in [48] include a variety of compounds with parts of e.g. Aluminum, Copper and Zinc. The same phenomenon occurs to Nickel or Palladium according to Widom and Larsen [45].

LENRs occur through the excitation of metal surface electron plasma causing surface proton oscillations. Heavy electrons absorbed by protons or deuterons produce ultra-low momentum neutrons and neutrinos. The required energy (mass renormalization by heavy electrons) is provided by the interaction of surface electron plasma oscillations and surface proton oscillations. The resulting neutron initiated LENR emits gamma radiation. However, the same heavy electrons which initiated the neutron emission also promptly absorb the gamma radiation, re-mitting soft photons e.g. in form of infrared radiation (thermal energy). Nuclear hard photon radiation is therefore strongly suppressed outside of the reactor [44].

Dr Joseph Zawodny, a NASA senior research scientist at the Langley Research Center, is researching LENR with a unique method which enables the comparison of many materials per test run. In the online video, Zawodny refers to LENR technology as being very scalable. Zawodny mentions the Widom-Larsen theory in his work and explains how he came across the theory, and how this theory explains the utilisation of weak forces to produce nuclear power in a completely different way. In this statement, Zawodny [49] refers to LENR and the potential technologies as follows: “When you fully grasp what this represents, [you find] a very inexpensive clean form of power. If we were to have such a (…) [technology], it would be the sort of technology that would fuel our future growth and expansion and have the ability to raise the standard of living of the entire world.” (the word “thing” was replaced by “technology”).

In other statements, Zawodny describes a “method of enhancement for surface plasmon polaritons to initiate and sustain LENR” [50]. With this method, elements obtain a sufficient number of neutrons, which slightly change the atomic mass of the particular element. These neutrons spontaneously decay into something of the same mass, however, into a different element. This transmutation process is an indication of a reaction of nuclear origin. The elements used, such as Nickel, can transmute into a variety of different elements e.g. Copper. Dr Zawodny states that LENR has “demonstrated the ability to produce excess amounts of energy, cleanly, without hazardous ionizing radiation, [and] without producing nasty waste”. Zawodny goes on to say that the easiest implementation of this energy source would be the dwelling. LENR can be used to heat water and convert the produced heat into electrical energy.

THE POTENTIAL OF LENR: REFERENCE BUILDING

A Life-Cycle Assessment (LCA) of a building is an appropriate method of assessing the impact in terms of resource consumptions, GHG emissions, operational costs and trace metal emissions. In this study, a simulation process is used to assess the difference between a conventional and an LENR scenario in a typical German dwelling unit.

DESCRIPTION OF THE REFERENCE BUILDING

The dwelling which represents the statistical mean, is a building most probably built before 1979 and therefore before the first heat insulation ordinance in Germany. The assessment of energy consumption defines the living area and technical areas. Here, the following areas add up to represent a reference dwelling very close to the statistical mean: living area roughly 100 m² and technical area roughly 35 m². In order to obtain a design, which represents the statistical mean, many factors are taken into account. The German Energy Agency (DENA) and the Federal Environmental Office (FEO), (Bundesumweltamt) maintain and publish the necessary statistics which allow the design process of a reference dwelling suitable for this study. The fact that households consume 27% of the total energy in Germany [51] justifies the approach of investigating this portion of energy consumption in more detail. However, the statistical bottom-up approach is not possible since too many variables, such as the number of inhabitants, the weather, the coefficient of performance of the heating source, the type and energy efficiency of the building, room temperatures and the features and efficiencies of domestic appliances being used would need to be considered. These attributes are constantly changing and can only be recorded with great efforts and costs. For these reasons, reasonable assumptions are made. In terms of energy consumption, three main household consumptions (heating, hot water and electricity) are determined and will be assumed using the statistical proportions supplied by FEO [51]. Electricity is calculated with 0.25 € / kWh [20]. Household heating makes up the greatest proportion of energy consumption (75 % of total energy use). For the calculation of the heating energy consumption of a building or apartment, two major attributes are of importance, namely the living area in square meters and primary energy coefficient (PEC) in kWh/ (m²a). The PEC relates to the living area. In this article, a detached building with two dwelling units is assumed. This assumption is justified on the grounds that of the total 18 million dwelling buildings in Germany, around 83 % are detached buildings with one to two dwelling units [52]. Furthermore, of all dwellings, 71 % were built before 1979 and therewith before the initial Heat Insulation Ordinance (HIO) (ibid). Comparing the figures according to the number of buildings with those referring to the number of dwelling units shows similar results. Of the total 40.2 million dwelling units, around 74 % were built before 1979 and therewith before the first HIO. In terms of the living area, 3.4 billion square meters (the average living area per dwelling unit can therewith be calculated to 85 square meters) account for the total living area with 70 % of these established before 1979 [52]. It is important to realize, that buildings built before 1979 account for 75 % of all heating energy in Germany. Household heating requires energy which is represented by the PEC. 50 % of the dwelling units in Germany consume more than 190 kWh/ (m²a) in respect to the living area and 25 % consume more than 250 kWh/ (m²a) [52]. The mean is around 180 kWh/ (m²a), however, 200 kWh/ (m²a) will be assumed for the average dwelling unit in this article. It can be estimated, that around 75 % to 85 % of the total heating energy is obtained by fossil fuels. The highest ranked in proportion is heating oil. Therefore, heating oil will be assumed in the reference building assessed here. Heating oil has colorific value of around 10 kWh/ Liter and currently costs about 1.00 €/ Liter. The averages in Coefficients of Performance (COP) of fuel combustion units are given by the FEO [50]. Here, 70 % are around 0.85 and a mere 12 % are very efficient at 0.98. In this article, a COP 0f 0.75 will be used. The statistical representative number of occupants in the reference household is taken as two persons. The conventional energy consists of heating oil for room and hot water heating and grid electricity. The LENR scenarios use grid electricity to power a LENR - Combined Heat and Power (CHP) system thus providing thermal and electrical energy. Since the electricity production of the LENR CHP unit is assumed at a COP of 0.3, it can be argued that excess heat production leads to heat emissions when no thermal energy is needed. However, in central power stations, the same is the case along with additional grid losses. In addition, thermal electric modules development suggests more potential in small and micro applications.

With known levels of Coefficients of Performance (COP), it can be reasonably assumed that future LENR applications will have electrical to thermal COPs of 4.0 and more. Even today, this may be seen as reasonable according to Dr. Michael McKubre of the Stanford Research Institute. In a 2014 Interview, Dr. McKubre states that 400% is what the Brillouin Energy Corporation "has got" referring to one of the *pre-market* LENR corporations [53]. A number of technologies can produce electricity from heat. In this article, no particular technology is chosen, however, a thermo-electric COP of 0.3 is already easily possible with today's technology. Since temperatures of 350 °C can reasonably be assumed in future applications, a liquid medium is used in the thermal electric process and then travels to a heat exchanger to exchange energy for hot water and heating purposes. To simplify calculations for this article, electricity from coal burning power plants is used. Overall statistics of the COPs of German power plants, including grid losses, electricity consumption for the energy sector, as published in [54], are used. The energy input / output ratio is taken as 0.3 (4875178 TJ input / 1505662 TJ output). In other words, around 3.24 times the amount of energy input is necessary to produce electricity per unit. An example presented in [55] shows GHG emissions from a German power plant in Duisburg. The assessment in [55] implies coal from the Cerrejon mine in Columbia, coal transportation to the train connection, coal transport by train to a Columbian harbor, transport by ship to the Rotterdam harbor, transport by ship to the Duisburg harbor, transport by truck to the Stadtwerke Duisburg AG power plant. CO_2 emissions from coal (hard coal and lignite) burning power plants vary considerably from 750 to 1200 g/kWh [56]. Here, 800 gCO_2/ kWh for electricity production from coal power plants will be assumed. For the oil furnace, 300 gCO_2/ kWh thermal heat is used. Mercury vapor emissions from coal burning power plants are calculated as 0.90 x 0.300 ppm = 0.270 ppm. Mercury from oil combustion is taken as 0.150 ppm. Energy density in Coal is averaged at 8.00 kWh/ kg (ibid). Given all the figures considered above, the alternative LENR system to provide the energy in the reference dwelling can be specified as shown below:

- Electricity input: 2,000 W
- Thermal output: 8,000 W
- COP: 0.75 (assumed) (thermal energy conversion)
- Output Water temperature: 350 °C

- Electrical power production: 2,400 W (assumed COP=0.30)
- Output temperature after electricity production: 200 °C
- Water temperature after heat exchanger: 55 °C

A quantitative comparison of the conventional and LENR energy systems in the reference dwelling was undertaken on the basis of cost, CO2 emissions and Mercury Vapour emissions.

LIMITATIONS

The comparison of costs, CO2 emissions and Hg emissions are representatives for a large number of other GHG and trace metal emissions. It is acknowledged that emission values, calorific values, COPs and other are partially simplified. Yet taking into account that publications show very large numbers of different ranges to each specific topic, e.g. CO2 emissions from coal burning plants, Hg emissions from oil burning plants etc., realistic assumptions are justified. Also justified is the choice of energy source for electricity production. Although Germany's energy mix may vary and be different to the chosen assumptions, comparing the same (coal fired electricity production) for the LENR system shows a realistic impact potential.

RESULTS AND DISCUSSION

Table 1 one shows the results of the comparison in the LCA. Significant reductions in energy costs, CO2 emissions and mercury vapor emissions are assessed.

Reference building	conventional	LENR
energy costs	4022	622
Co_2 emissions	16.93	6.45
mercury vapor	.777	.272

Table 1 – Comparison of conventional energy system to LENR energy source: energy costs [€/a]; CO2 emissions: [tons / a]; mercury vapour emissions [g/a]

The comparison clearly shows some advantages of the LENR system over conventional system even though only costs, one GHG and one trace metal is shown. Since other stages such as construction, maintenance and demolition of the LCA do not vary significantly from system to system, only the operational aspects were considered. The results show that annual energy costs can be significantly decreased from 4022 € to 622 € for heating, hot water and electricity. CO2 emissions can also be lowered from 16.93 tons to 6.45 tons per year. The Mercury vapor emissions from fossil fuels combustion can be reduced from 0.777 g/a to 0.272 g/a in the reference dwelling. The emissions are still quite high, since the approach is conservative in terms of the future LENR-COP. Also, since the same harmful electricity sources for the simulated LENR input is being used.

Pirrone et al. (2013) refer to safe daily doses of Mercury (MeHg) intakes. 0.1 microgram per kg body weight is referred to as being safe [31]. In the scenarios assessed here and assuming two persons with 100 kg each, a safe daily doses would be 0.0073 g/a. Although the LENR system only emits around 35 % of Mercury vapor (only because of the assumption of a relatively low LENR COP and the use of electricity from coal fired power stations) compared to the conventional system, the 0.272 g/a of emission still adds up to around 37 times the amount of Mercury emission being considered safe by the U.S. EPA [31]. In short, this dwelling would still emit more Mercury in the operational stage than the occupants could safely take.

CONCLUSIONS

Germany's strong reliance on biofuels and biomass leads to negative impacts such as soil depletion, food price impacts and food import dependencies due to agricultural areas being used for energy crops with negative environmental, social and economic impacts. The combustion of all fossil fuels, biomass and biogases causes GHG - as well as very harmful Mercury and other (e.g. Cadmium, Lead, Arsenic, Aluminum) emissions and exposures. All of these fuels make Germany more dependent on imports and thus vulnerable in a global market. However, high potential energies sources have emerged in science. These are energy sources, which hold one million times more energy than any of the chemical reactions currently being used for energy production in the German infrastructure, namely Low Energy Nuclear Reactions (LENR). The resources needed for these reactions, e.g. nano nickel particles, are used in such small quantities, that the emerging technology could be called *quasi resource free* in comparison to today's technologies.

It is strongly suggested, that funding and research for LENR be promoted. The results in the comparison within the reference building are very moderate compared to the full potential of LENR. Once the engineering improves and LENR-COP increase further to the anticipated levels, the technology can function in a closed loop regarding the electricity input. At this point, the GHG emissions as well as any trace metals or other emissions and exposures can be brought to very close to zero. The technology will then be not only quasi resource-free but moreover also non-polluting. This is a goal worthwhile achieving in all mentioned terms of sustainability. Energy producers can gradually shift to LENR technologies in their central power production and private (de-centralised) power producers can be taxed according to the power production to meet the financial challenges the economy would face in such a shift. Environmental impacts of mining and combustion of fossil fuels can be nearly eliminated thus stopping not only emissions causing global warming but also emissions impacting the health of all species thus addressing social sustainability.

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