Article

To Develop an Ecofriendly Cold Nuclear Thermal Power Plant by Considering Iron-56 as A Fuel

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Abstract: In this contribution, we make an attempt to write a theoretical proposal for designing an eco friendly thermal power plant which runs with cold nuclear fusion technology at a temperature of (1500 to 2000) deg.C. In our recently published papers, we have proposed a clear cut mechanism for understanding and implementing cold nuclear fusion technique pertaining to fusion of hydrogen with metals of mass numbers starting from 50. In this context, we would like to stress the point that, fusion of hydrogen under controllable temperature and pressure can be understood as a phenomenon of fusing neutron to the nucleus of the base atom. Part of isotopic nuclear binding energy difference of final and base atomic nuclides can be seen in the form of safe thermal energy of the order of (1 to 3) MeV per atom against 200 MeV released in nuclear fission of one Uranium atom. Due to increased heaviness and weak interaction, sometimes fused neutron splits into proton and electron. Proton seems to be retained by the base atom's nuclear core and electron seems to join with the electronic orbits of the base atom. In this way, increased mass of base atomic nuclide helps in eco friendly production of thermal energy in large quantity. For this purpose we consider Iron-56 as a fuel. In a simplified view, under strong nuclear attractive forces, Iron-56 absorbs hydrogen atom as a neutron and by emitting 1MeV equivalent thermal energy transforms to Iron-57. Thus, one gram of Iron-56 can generate 1000MJ of heat with 50% efficiency. In a shortcut approach, by bombarding powder and semi-liquid forms of Iron-56 with direct neutrons coming from neutron source, our proposal can be tried, understood and verified experimentally.

Keywords: Cold nuclear fusion; Iron-56 as a fuel; Eco friendly Thermal energy; Power plant;

1. Introduction

Now-a-days subject of cold nuclear fusion (CNF) is being attracted by many scientists, engineers and research institutes across the globe [1,2,3,4]. Mostly CNF refers to liberation of green thermal energy associated with fusion of any heavy atomic nuclide with one hydrogen atom at low temperatures and moderate pressures for a long time in a sustainable mode. In our recent publications [5,6,7,8], following the actual nuclear binding energies [9] of isotopes and by considering maximum binding energy per nucleon as a reference parameter, we have developed a simple mechanism for understanding the mystery of energy liberation mechanism in CNF. In this paper, we are making an attempt to understand the eco friendly CNF mechanism involved in producing one giga watt electric power. As entire world is facing many hurdles in generating, controlling and burning of fossil fuels, it seems inevitable to work on protecting earth and mankind from polluting gases and developing green energy sources. In this context, we are aiming on using most stable and more abundant Iron-56 atom as a CNF fuel.

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2. On the possibility of occurrence and present status of CNF

Important points to be noted are,

1) Occurrence of CNF is possible because of the mutual attractive nature of heavy atomic nuclide and neutron under strong nuclear attractive forces.
2) Compared to hot nuclear fusion, in CNF, nuclear density is of the order of 10^{22} nucleons per cubic centimeter.
3) CNF is a low energy nuclear reaction (LENR) compared to nuclear fission and hot nuclear fusion. Thermal energy liberated in CNF is of the order of 1 MeV whereas energy liberated in nuclear fission and hot fusion is around 200 MeV and 15 MeV respectively.
4) Our proposed Strong and Electroweak Mass Formula (SEWMF) for estimating nuclear binding energy is very simple and very easy to understand [10,11,12]. With a marginal error, starting form Z= 3 to 118 and $N \geq Z$,

$$BE \cong \left\{ A - \left[1 + \left(0.0008\left(Z^2 + A^2\right)\right)\right] - A^{1/3} - \frac{(A_s - A)^2}{A_s} \right\} (10.1\text{ MeV})$$
$$\text{where} \begin{cases} \text{A=Mass number, Z=Proton number} \\ A_s \cong 2Z + 0.0064Z^2 = \text{Estmated mass number close to stable mass number} \end{cases} \quad (1)$$

5) Based on the above formula, it can be shown that, for Nickel and Palladium, Coulombic energy shares are around 1.03% and 1.6% of their volume energies respectively [13].
6) Following the concept of CNF, we have tried to develop theoretical concepts for preparing Gold like costly elements [6], converting high level nuclear radioactive waste and preparing medical isotopes [7,8].
7) NASA team is seriously working on Lattice Confinement Technique associated with Erbium atoms turning into Thulium atoms at ambient temperatures [14,15].
8) Russian scientists experimentally [16] confirmed the energy emission mechanism proposed by Andrea Rossi's Energy Catalyzer (E-Cat) [17,18].
9) All collaborative long run experiments conducted by Japanese scientists [19] pertaining to CNF experiments associated with specially-prepared palladium-nickel-zirconium and copper-nickel-zirconium verified the continuous generation of excess heat. It has been confirmed that, total amounts of energies released per atom were larger per atom by a factor of two to several hundreds.
10) United States and European countries are planning to run most advanced CNF experiments with million dollar funding.

3. Hidden energy mechanism of CNF – a short review

In our recently published papers, we proposed that [5-8],

1) At 1000 to 2000 deg. C, one hydrogen atom combines with one heavy atomic nuclide (HAN).

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2) Fusion of hydrogen atom can be considered as a case of a fusion of one neutron with one heavy atomic nuclide.
3) During CNF, neutron gives a minimum 8.8 MeV to HAN. Maximum energy that can be given by any neutron depends on its kinetic energy.
4) By absorbing neutron, HAN becomes its next stage isotope.
5) HAN can be called as base isotope and its next stage nuclide of HAN can be called as HAN's next stage isotope.
6) 8.8 MeV is distributed among all the nucleons of HAN's isotopes in two modes.
7) First mode can be seen as an increase in internal kinetic energy of nucleons of isotopes of HAN.
8) Second mode can be seen as liberation of thermal energy = 8.8 MeV - Difference in isotopic binding energy of any isotope of HAN and its previous isotope.
9) Increased kinetic energy of neutron helps in increasing possibility of isotopic transformation of HAN and increased liberation of thermal energy.
10) Keeping on absorbing neutrons, HAN becomes heavy and transforms to its next stage periodic element via isobar formation.

4. To establish thermal energy liberation mechanism for designing a power plant based on Cold nuclear fusion with Iron-56

Based on the above described mechanism, it seems possible to design a thermal power plant with the following technical data. See the following Table 1 for the main isotopes of Iron and their binding energy details [9].

Table-1: Isotopes of Iron and their general properties

S.No	Mass Number	Abundance%	Life time	Decay product	Nuclear binding energy (MeV)
1	54	5.85	Stable	No decay	471.76
2	55	2.73	Synthetic	^{55}Manganese	481.06
3	56	91.75	Stable	No decay	492.26
4	57	2.12	Stable	No decay	499.91
5	58	0.28	Stable	No decay	509.95
6	59	Synthetic	44.6 days	^{59}Cobalt	516.53
7	60	Trace	2.6×10^{6}	^{60}Cobalt	525.35

1) Considering the data presented in Table 1, one can expect thermal energy liberation in the following way. See Table-2.

Table-2: Possible Thermal energy liberation in Fe isotopic conversion

Energy liberation mode	Energy liberation status

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$^{54}Fe \rightarrow ^{55}Fe$ $\Rightarrow 8.8-(481.06-471.76)=-0.5$ MeV	No energy liberation
$^{55}Fe \rightarrow ^{56}Fe$ $\Rightarrow 8.8-(492.26-481.06)=-2.4$ MeV	No energy liberation
$^{56}Fe \rightarrow ^{57}Fe$ $\Rightarrow 8.8-(499.91-492.26)=1.15$ MeV	**Possible energy liberation**
$^{57}Fe \rightarrow ^{58}Fe$ $\Rightarrow 8.8-(509.95-499.91)=-1.24$ MeV	No energy liberation
$^{59}Fe \rightarrow ^{60}Fe$ $\Rightarrow 8.8-(516.53-509.95)=2.22$ MeV	**Possible energy liberation**

2) From Table-2, considering the isotopic conversion of ^{56}Fe to ^{57}Fe and ^{59}Fe to ^{60}Fe, one can expect thermal energy liberation in a significant level.
3) As the abundance of ^{56}Fe is very high, selecting one gram of ^{56}Fe and considering a suitable catalyst, there is a scope for generating thermal energy.
4) Expected number of atoms in one gram of ^{56}Fe seems to be around 1.08×10^{22}.
5) Corresponding thermal energy liberation seems to be around $1.0\times10^{22}\times1.15\text{ MeV}\cong1.98\times10^{9}\text{ joule}\cong2000\text{ MJ}.$
6) Considering an efficiency of 50%, for one gram of ^{56}Fe, $1\times10^{9}\text{ joule}\cong1000\text{ MJ}$ of thermal energy can be generated.
7) By considering a single big nuclear reactor or 4 to 5 number of small reactors that can convert 1.08×10^{22} number of ^{56}Fe into ^{57}Fe per second, there is a possibility for getting 1000 MW or 1 GW of equivalent electric power.
8) It needs a review at basic level and after a successful review, one can proceed for designing a cold nuclear thermal power plant accordingly.

In this way, we are showing the possible thermal energy liberation mechanism in terms of CNF by considering the most abundant Iron as a (nuclear) fuel. Scientists and designers can work on other elements also.

5. A detailed analysis on Coulombic term

It's very important to note that, mainstream nuclear scientists do not believe in CNF. The main reason is that, currently believed hot nuclear fusion is being carried out in between Deuterium and Tritium ions at high temperatures, high pressures and super magnetic fields. Hot nuclear fusion point of view, maintaining high temperatures for a long time and generating Tritium needs lot of attention. As Deuterium ions and Tritium ions are having a positive charge, it seems natural to have Coulombic repulsion and to overcome the Coulombic effect, energy is needed. In case of CNF, under controllable temperature and pressure conditions, hydrogen atom combines with any heavy atomic nuclide in the form of neutron under strong nuclear attractive forces. Clearly speaking, compared

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to hot nuclear fusion, CNF is a simple technique in fusing one heavy atom and one light atom. The question of Coulombic repulsion or Coulombic barrier will not come into picture. Following the same concept, recently we have developed a very simple formula [10-12] for understanding and estimating nuclear binding energy of isotopes in terms of strong interaction [20] and electroweak interaction [21]. It is almost 99% accurate. Starting from Z=3 to 118, and for $N \geq Z$, it can be expressed as,

$$BE \cong \left\{ A - \left[1 + \left(0.0016\left(\frac{Z^2 + A^2}{2} \right) \right) \right] - A^{1/3} - \frac{(A_s - A)^2}{A_s} \right\} (10.1\ \text{MeV}) \quad (2)$$

$$\text{where} \begin{cases} \text{A=Mass number, Z=Proton number} \\ A_s \cong 2Z + 0.0016(2Z)^2 \cong 2Z + 0.0064Z^2 \\ = \text{Estmated mass number close to stable mass number} \\ B_0 \cong \frac{1}{2}\left[\left(2m_u c^2 + m_d c^2 \right) + \left(m_u c^2 + 2m_d c^2 \right) \right] \cong 10.1\ \text{MeV} \\ \text{where } (m_u, m_d) \text{ reprsent Up and Down quark masses} \end{cases}$$

Here,

1) First term is associated with nuclear volume.
2) Second term is assocaited with electroweak interaction.
3) Third terrm is associated with nuclear radius.
4) Fourth term is associated with asymmetry about mean stable mass number.
5) Very important point to be noted is that, second term can be considered as a representation of number of free nucleons and minimum number of free nucleons is equal to 1.

Here, very interesting point to be noted is that, the number 0.0016 can be understood as a ratio of the mean mass of pions to the mean mass of electroweak bosons [22]. It can be expreessed as,

$$\left(\frac{\sqrt{(m_\pi c^2)^0 (m_\pi c^2)^\pm}}{\sqrt{(m_z c^2)^0 (m_w c^2)^\pm}} \right) \cong \left(\frac{\sqrt{134.98 \times 139.57}\ \text{MeV}}{\sqrt{80379.0 \times 91187.6}\ \text{MeV}} \right) \cong 0.0016032 \quad (3)$$

It may be noted that, relations (2) and (3) are completely new for the mainstream physics and it needs further study. The most famous and most advanced SEMF [23] that follows isospin concept can be expressed as,

$$BE \cong \left\{ \left[1 + \left(\frac{4k_v}{A^2} \right) |T_z| \left(|T_z| + 1 \right) \right] a_v * A \right\} + \left\{ \left[1 + \left(\frac{4k_s}{A^2} \right) |T_z| \left(|T_z| + 1 \right) \right] a_s * A^{\frac{2}{3}} \right\} + \left\{ a_c * \left(\frac{Z^2}{A^{1/3}} \right) \right\} + \left\{ f_p * \frac{Z^2}{A} \right\} + E_p \quad (4)$$

where, $T_z \cong \text{3rd component of isospin} = \frac{1}{2}(Z - N)$

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$$\left\{\begin{array}{l} a_v = -15.4963 \text{ MeV}, a_s = 17.7937 \text{ MeV} \\ k_v = -1.8232 \text{ MeV}, k_s = -2.2593 \text{ MeV} \\ a_c = 0.7093 \text{ MeV}, f_p = -1.2739 \text{ MeV} \\ d_n = 4.6919 \text{ MeV}, d_p = 4.7230 \text{ MeV} \\ d_{np} = -6.4920 \text{ MeV} \end{array}\right\} \text{ and } \left\{\begin{array}{l} \text{for } (Z, N) \text{ Odd, } E_p \cong \frac{d_n}{N^{1/3}} + \frac{d_p}{Z^{1/3}} + \frac{d_{np}}{A^{2/3}} \\ \text{for } (\text{Odd } Z, \text{ Even } N), E_p \cong \frac{d_p}{Z^{1/3}} \\ \text{for } (\text{Even } Z, \text{ Odd } N), E_p \cong \frac{d_n}{N^{1/3}} \\ \text{for } (\text{Even } Z, \text{ Even } N), E_p \cong 0 \end{array}\right\}$$

It may be noted that, in SEMF, stable nucleon mass number is an output whereas in SEWMF, stable nucleon mass number is an input. In SEWMF, stable mass number plays a vital role in estimating the binding energy of other isotopes. See Fig. 1 for the estimated binding energy close to stable mass numbers of Z. Blue curve represents nuclear binding energy estimated with SEMF and Red curve represents nuclear binding energy estimated with SEWMF. One can see an excellent fit in a broad view.

$$BE \cong \left\{A_s - \left[1 + \left(0.0008\left(Z^2 + A_s^2\right)\right)\right] - A_s^{1/3}\right\}(10.1 \text{ MeV}) \tag{5}$$

where $A_s \cong 2Z + 0.0064Z^2$ and $\frac{(A_s - A)^2}{A_s} \cong 0$

$$BE \cong \left\{\left[1 + \left(\frac{4k_v}{A_s^2}\right)|T_z|\left(|T_z|+1\right)\right]a_v * A_s\right\} + \left\{\left[1 + \left(\frac{4k_s}{A_s^2}\right)|T_z|\left(|T_z|+1\right)\right]a_s * A_s^{\frac{2}{3}}\right\} + \left\{a_c * \left(\frac{Z^2}{A_s^{1/3}}\right)\right\} + \left\{f_p * \frac{Z^2}{A_s}\right\} + E_p \tag{6}$$

where $A_s \cong 2Z + 0.0064Z^2$

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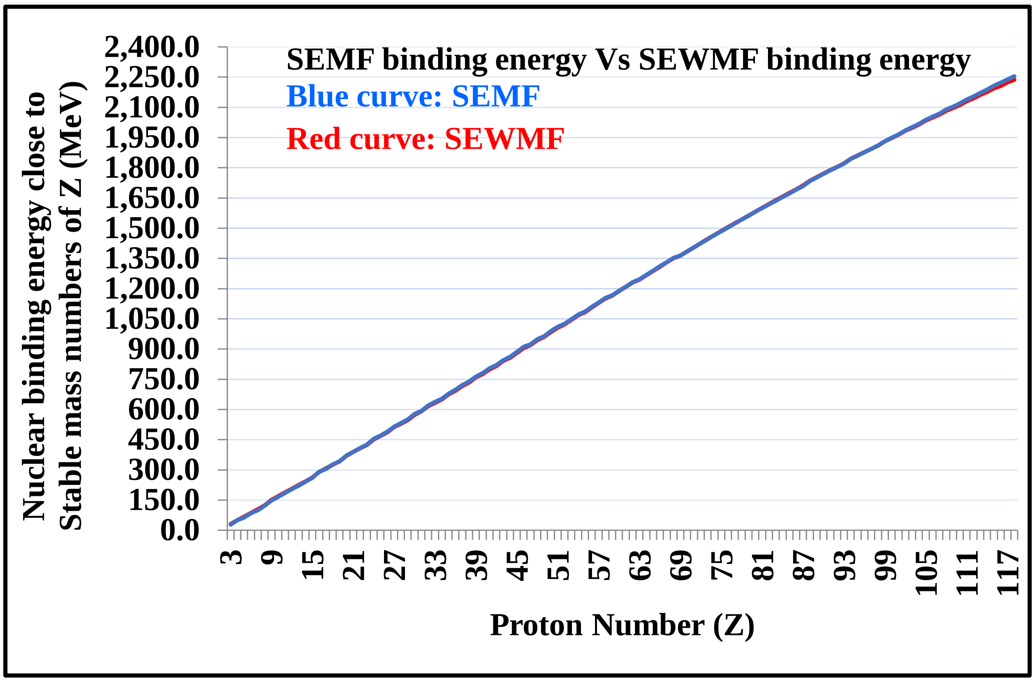

Figure 1: Estimated nuclear binding energy

Our aim is to compare the second term of relation (2) with third term of relation (4). Clearly speaking, Second term of relation (2) is,

$$\left[1+\left(0.0008\left(Z^2+A^2\right)\right)\right]\times 10.1\text{ MeV} \tag{7}$$

Third term of relation (4) is,

$$a_c*\left(\frac{Z^2}{A^{1/3}}\right)\cong 0.7093*\left(\frac{Z^2}{A^{1/3}}\right)\text{ MeV} \tag{8}$$

It may be noted that, relation (7) can be expanded into two terms for Protons and Total Nucleons as,

$$\left[1+\left(0.0008Z^2\right)+\left(0.0008A^2\right)\right]\times 10.1\text{ MeV} \tag{9}$$

Since coefficient is common for $\left(0.0008Z^2\right)$ and $\left(0.0008A^2\right)$, we appeal the science community to consider $\left[1+\left(0.0008\left(Z^2+A^2\right)\right)\right]\times 10.1\text{ MeV}$ as a new term associated with electroweak interaction. Attributing the Coulombic effect to $\left(0.0008Z^2\right)$ and leaving the nucleon term $\left(0.0008A^2\right)$, it seems possible to study in a logical way. We wish to make a comparative study in the following way.

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$$\left[\left(0.0008Z^2\right)\times 10.1\text{ MeV}\right] \text{ Vs } \left[\left(\frac{Z^2}{A^{1/3}}\right)\times 0.7093\text{ MeV}\right] \tag{10}$$

It may also be noted that, except for the first term, conceptually, relations (2) and (4) are totally different in their understanding. As per relation (10), SEWMF, Coulombic term is free from nucleon number.

We consider the following procedure for comparison. From relation (2) we consider,

$$\frac{\left[\left(0.0008Z^2\right)\times 10.1\text{ MeV}\right]}{A\times 10.1\text{ MeV}} \cong \frac{\left[0.0008Z^2\right]}{A} \cong X \tag{11}$$

We wish to call $\left[\left(0.0008Z^2\right)\times 10.1\text{ MeV}\right]$ as the electroweak coulombic term. From relation (4) we consider,

$$\left[a_c * \left(\frac{Z^2}{A^{1/3}}\right)\right] \div \left\{\left[1+\left(\frac{4k_v}{A^2}\right)|T_z|\left(|T_z|+1\right)\right]a_v * A\right\} \cong Y \tag{12}$$

As most of the cold nuclear fusion experiments are being carried out on stable elements, we consider the mass numbers close to stability line. Approximate mass numbers close to stable line can be estimated with the following relation.

$$A_s \cong 2Z + 0.0016\left(2Z\right)^2 \cong 2Z + 0.0064Z^2 \tag{13}$$

Considering stable mass numbers of Z, relations (11) and (12) can be re-expressed as,

$$\frac{\left[\left(0.0008Z^2\right)\times 10.1\text{ MeV}\right]}{A_s\times 10.1\text{ MeV}} \cong \frac{0.0008Z^2}{A_s} \cong X_s \tag{14}$$

$$\left[a_c * \left(\frac{Z^2}{A_s^{1/3}}\right)\right] \div \left\{\left[1+\left(\frac{4k_v}{A_s^2}\right)|T_z|\left(|T_z|+1\right)\right]a_v * A_s\right\} \cong Y_s \tag{15}$$

Following this kind of procedure we have prepared Fig. 2.

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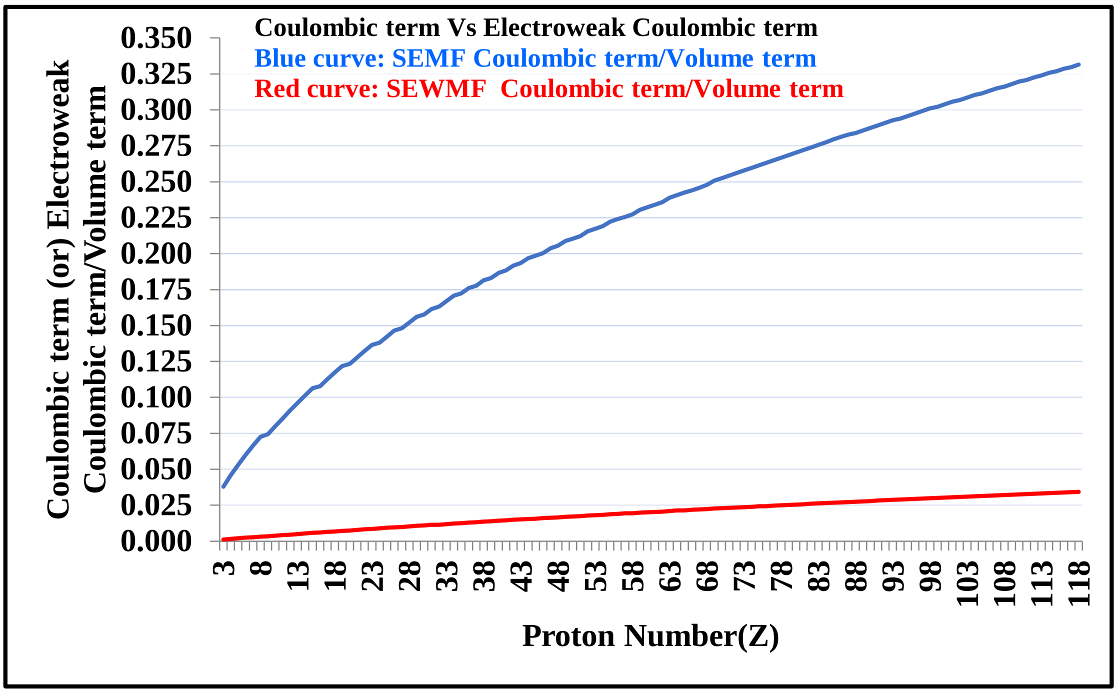

Figure 2: Coulombic term Vs Electroweak term

6. Discussion

1) Developed countries are publicly and secretly spending million dollars on CNF experiments.
2) NASA reports and publications [14,15] are directly and indirectly supporting cold fusion like nuclear energy emission mechanisms with possible transmutation of atomic nuclides at ambient temperatures.
3) As the whole world is searching for eco friendly energy resources, our proposal can be given a chance. Readers are encouraged to visit: https://arpa-e.energy.gov/sites/default/files/2021LENR_workshop_Nagel.pdf
4) A preliminary survey on cold fusion conducted by Luciano Ondir Freire, Delvonei Alves de Andrade, suggests that, cold nuclear fusion is not a pathological science and may require revision of nuclear theory [1].
5) According to USA's senior most scientist, Edmund Storms [24]: The most obvious and convenient measurement involves production of energy having no clear relationship to any conventional source, both in magnitude and compared to known possible reactions. Although this energy has been measured hundreds of times when using a variety of calorimeter designs, real and imagined error have distracted from the importance of these studies. Nevertheless, this commonly observed extra energy is consistent only with a novel nuclear process because the amount of energy frequently far exceeds any known chemical source as well as the expected error in its measurement.
6) Lugano report on E-Cat [17] is vehemently suggesting that,
    a) CNF is strongly associated with liberation of excess heat.
    b) Origin of excess heat is somehow connected with nuclear reactions.
7) In 2017, Russian scientists Parkhomov et al [16] successfully developed Andrea Rossi's E-Cat and

confirmed excess heat generation. Even though, E-Cat and its current progress is having many negative remarks in science society, in 2019, Japan scientists [19] confirmed the experimental results given by Andrea Rossi.

8) Senior most scientist Michael C.H.McKubre has positively commented on the experimental results of Andrea Rossi' E-Cat and Alexander Parkhomov's E-Cat like device. For more information, readers are encouraged to visit the URL: http://www.infinite-energy.com/iemagazine/issue118/analysis.html.
9) CNF is a low energy nuclear reaction associated with formation of isotopes and isobars. Based on this point, we would like to emphasize the point that compared to all other models of CNF [1], our proposed concept is very simple and workable.
10) In a shortcut approach, by bombarding powder or semi-liquid form of Iron-56 with direct neutrons coming from neutron source, our proposal can be tried, understood and verified experimentally.
11) Advantage of our proposal is that, both Iron-56 and Iron-57 are stable isotopes and there seems no chance to have harmful beta radiation. Study is required on selecting suitable catalysts and appropriate experimental designs.
12) Compared to the risk involved in hot nuclear fusion technology, it seems better to work on CNF related technical issues in future. By any chance, if CNF comes into mainstream, certainly, things can be improved.

7. Conclusion

Considering the E-Cat test run experimental results reported in arXiv web site and other cold nuclear fusion experimental results reported by Japanese and Russian scientists, in this paper, we make an attempt to develop an eco-friendly thermal energy source that is required for designing a power plant. Interesting point to be noted is that, we consider Iron-56 as a fuel. It needs further review based on suitable catalysts, new experimental set ups and field experts' valuable suggestions.

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Authors' short biography

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