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Research

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Green Technology: Transformation of Domestic Bio-Waste into Electricity Energy to Mitigate the Global Energy and Environmental Vulnerability

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Abstract

Background

Green Technology, a sustainable mechanism is being proposed to fulfill the complete need of energy for a building that can be created by the building itself by the transformation process of domestic biowaste into electricity energy *in site*.

Results

The results suggested that the transformation of domestic biowaste including human feces to execute into converting process into an anaerobic tank bioreactor (BR) in the cellar which can form biogas (CH_4) by *methanogenesis* that can be converted into electricity energy to power the entire building. Besides, the discharged waste water in another detention tank *can be* conducted a complete treatment process of primary, secondary, tertiary and UV application to utilize it for gardening.

Conclusions

Implementation of this technology indeed shall be an inventive field of science where a building can form electricity by itself to complete its total energy need without any connection with the utility authorities which is benevolent to environment.

Keywords: Domestic Bio Waste; Bioreactor; In Site Biowaste Treatment Technology; Methanogenesis, Bio Energy; and Environmental Sustainability

Highlights

- Building's biowaste is being proposed to transformation process *in site* Bioreactor instead of passing it into the sewer system
- Bioreactor is being proposed to implement to collect the building biowaste for methanogenesis process to produce bioenergy (CH_4).
- Bioenergy is to be transformed in electricity energy (kW) to meet the total energy demand of a building

Background

Environmental vulnerability correlated much on building sector since 40% of global fossil energy is consumed by building sector throughout the world (8,19,30). In 2018, the net energy consumption globally accounted for 5.59×10^{20} *joules* = 559 EJ, where 2.236x10^{20} EJ energy is alone engulfed by the building sector (15,22). Consequently, building sector triggered to release nearly 8.01x10^{11} ton CO_2 (218 gtC by building sector of worldwide total carbon production of 545 gtC; 1 gtC = 10^9 ton C = 3.67 gt CO_2) into the atmosphere in year 2018. The quickening of fossil fuel consumption by building sector is getting higher and higher and globally and the situation shall remain unchanged until an innovative technology is used to power the building sector globally. At present, the atmospheric CO_2 level is 400 ppm where building sector is the major player for creating this high level of CO2 concentration into the atmosphere and it is accelerating 2.11% per year which is the clear and present danger to survive all living being in this planet near future (1,3,62). Necessarily, the atmospheric CO_2 level must be lowered to a clean breathable level of 300 ppm CO_2. Therefore, a sustainable energy mechanism in building sector is an urgent demand to confirm a clean and green environment on earth.

Though there are some recent interesting study shows that a person can produce feces average 0.4 kg/day that can form the 0.4 m3 biogas/day and this amount of biogas (0.4 m3/day) production which is good enough to cook three meals for a family of four persons in day (2,33,28). However, no one has shown that the mechanism of using cellar of a building as an acting bioreactor to transform biowaste into electricity energy to satisfy the total energy demand of a building.

Therefore, in this research, a net zero carbon release by a building has been proposed by producing bioenergy by the building itself and transform it into electricity energy to meets its net energy need. Simply, the domestic bio waste including human stool and waste water of the building are being chosen to collect it into the sealed separation chamber into the basement. Thereafter, this bio waste is being isolated into (I) waste water, and (ii) sludge and transferred into two separation tanks into the cellar. Then the waste water is being conducted for treatment process *in site* by integrating required all chemical and physical process in order to use for landscaping. Consequently, the solid biowaste has been permitted to undergo for *methanogenesis* process into the bioreactor to form bioenergy and then convert it into electricity energy. Implementation of this innovative mechanism shall indeed would be a promising technology to fulfil the net need for a building which is delivered by the building itself.

Results and Discussion

Since the anaerobic *Co-digestions* of domestic bio waste including human feces is lead into an anaerobic bioreactor, thus, the *methanogenesis* process began to produce biogas into the bioreactor right way. Naturally, the formation of biogas from the biowaste is being is examined by computerized gas chromatograph (21,29,42).

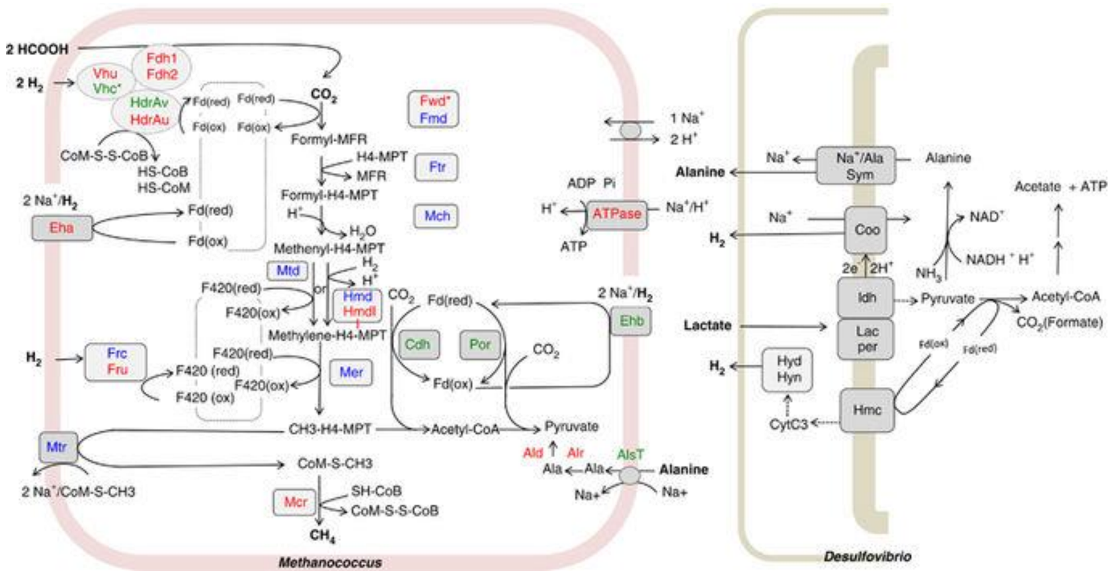
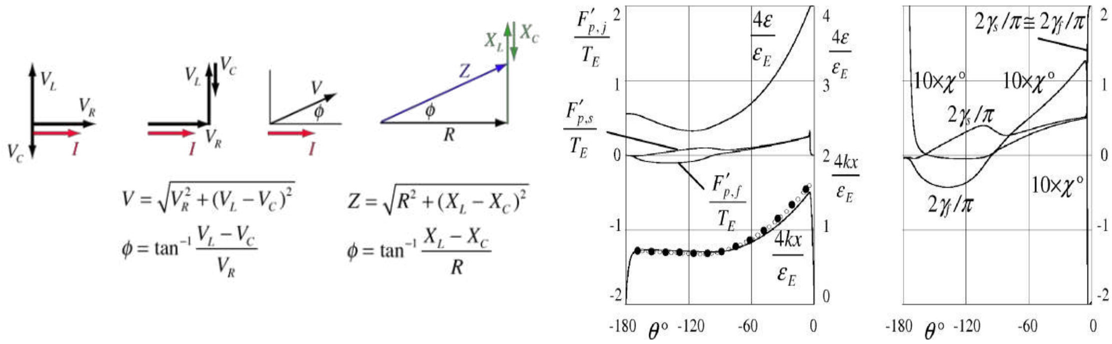
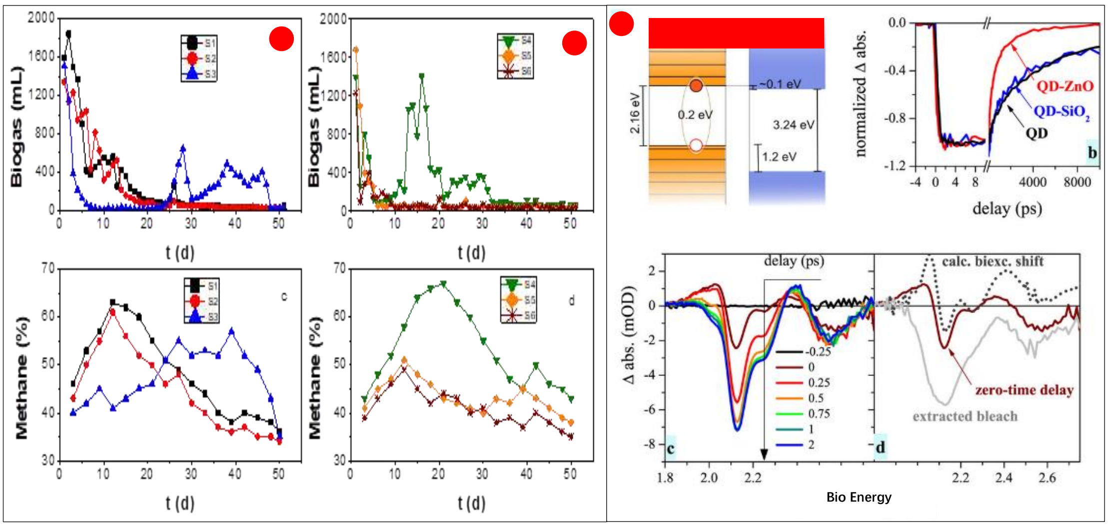


Figure 5. The pathway of the methanogenesis mechanism depicts the biosynthesis of Methanecoccus maripaludis and Desulfovivrrio. vulgaris to conduct bioenergy generation by consuming sludge.



(a)



(b)

Figure 6: (a) The biowaste transformation rate into the bioreactor in different direction and angles, (b) the production rate of biogas and the bio energy considering bioreactor methane content of the biowaste.

Therefore, a model of bioreactor module described the generation of maximum bioenergy from domestic waste considering protective anerobic detention chamber (Figure 5). Naturally, the model of the bioreactor module is being simplified by the determination of accurate form of the current-voltage (*I-V*) curb considering the mode of single diode electricity circuit (30,35,55).

The next step is to calculate the electricity energy generation I_{pv} form biogas production by the calculation from the mode of current flow into the diode panel accounting *I-V-R* relationship and biogas received by the diode to convert to alternating current (AC) for using domestic energy demand (Figure 7).

The below equation represents the electricity energy output from biogas (CH4):

$$P_{pv} = \eta_{pvg}\, A_{pvg}\, G_t \tag{1}$$

Where, η_{pvg} represents the methane -generation efficiency, A_{pvg} represents to the electricity energy generation, and G_t represents the current flow in the circuit cell. Thus, η_{pvg} can be rewritten as follows:

$$\eta_{pvg} = \eta_r \eta_{pc}\left[1 - \beta(T_c - T_{c\,ref})\right] \tag{2}$$

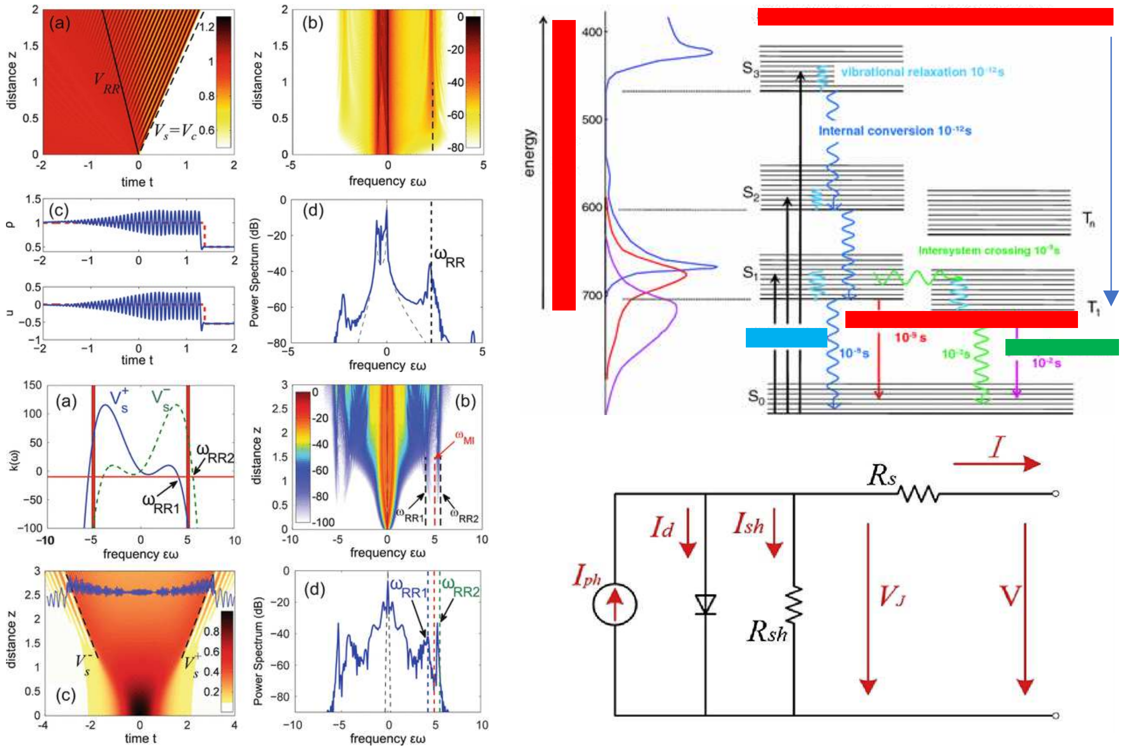
η_{pc} represents the power factor effectiveness once it is equal to 1; β represents the energy cofactor (0.004-0.006 per °C); η_r represents the mode of energy production; and T_{cref} is the cell temperature in °C which can be obtained from the equation follow:

$$T_c = T_a + \left(\frac{NOCT-20}{800}\right)G_t \tag{3}$$

Here, T_a represents the ambient temperature in °C, G_t represents the current flow in a ciccuit cell (W/s), and NOCT represents the standard operating cell temperature in Celsius (°C) degree. The total electricity energy production in the circuit panel is estimated by the following equation:

$$I_t = I_b R_b + I_d R_d + (I_b + I_d) R_r \tag{4}$$

The current flow into the circuit cells which is determined by the functional mode of its P-N junction that is able to produce electricity by conducting the interconnection of series-parallel configuration of the circuit cell (34,47,52).



(A) (B)

Figure 7. (A) MATLAB simulation calculated that the generating of electricity energy from bioenergy shows at various frequencies and the distances of the electric charges into the single-diode circuit cell, (B) shows the conversion mechanism of electricity energy DC into AC for the use of as the prime source of power supply for a building.

Implementation of the standard single diode circuit cell, the function of N_s series and N_p parallel connection in relation to current generation can be expressed as

$$I = N_p \left[I_{ph} - I_{rs} \left[\exp \left(\frac{q(V+IR_s)}{AKTN_s} - 1 \right) \right] \right] \tag{5}$$

where

$$I_{rs} = I_{rr} \left(\frac{T}{T_r}\right)^3 exp \left[\frac{E_G}{AK} \left(\frac{1}{T_r} - \frac{1}{T}\right) \right] \tag{6}$$

Here, the equations 5 and 6, q represents the generation of electron charge (1.6×10^{-19} C), K is the Boltzmann's constant, A represents the cell standard cofactor, and T represents the cell temperature (K). I_{rs} represents the cell reverse current at T, T_r represents the cell referred temperature, I_{rr} represents the reverse current at T_r, and E_G represents the band gap energy flow into the circuit cell. The electric current I_{ph} formation conforming the circuit cell's temperature can be simplify as follows:

$$I_{ph} = \left[I_{SCR} + k_i (T - T_r) \frac{S}{100} \right] \tag{7}$$

I_{SCR} represents the cell short-circuit current and electricity energy generation, k_i represents the short-circuit current temperature coefficient, and S represents the electricity energy (kW). Thus, the *I-V* relationship into the circuit cell can be expressed simply as:

$$I = I_{ph} - I_D \tag{8}$$

$$I = I_{ph} - I_0 \left[\exp \left(\frac{q(V+R_S I)}{AKT} - 1 \right) - \frac{V+R_S I}{R_{sh}} \right] \tag{9}$$

I_{ph} represents the electricity current (A), I_D represents the functional current (A), I_0 represents the inverse current (A), A represents the functional constant, q represents the charge of the electron (1.6×10^{-19} C), K is the Boltzmann's constant, T represents the cell temperature (°C), R_s represents the series resistance (ohm), R_{sh} represents to the shunt resistance (Ohm), I represents the cell current (A), and V represents the circuit cell voltage (V). Thus, the output electricity current into the circuit panel is thus described as follows:

$$I = I_{PV} - I_{D1} - (\frac{V+IR_S}{R_{SH}}) \quad (10)$$

where

$$I_{D1} = I_{01}\left[\exp\left(\frac{V+IR_S}{a_1 V_{T1}}\right) - 1\right] \quad (11)$$

$$I_{D2} = I_{01}\left[\exp\left(\frac{V+IR_S}{a_2 V_{T2}}\right) - 1\right] \quad (12)$$

I_{01} and I_{02} represents the reverse currents of cell, respectively, and V_{T1} and V_{T2} represents the thermal voltages of the respective cell. The cell idealist constants are denoted as a_1 and a_2. Then the simplified equation the cell mode is described as:

$$v_{oc} = \frac{V_{oc}}{cK\,T/q} \quad (13)$$

$$P_{max} = \frac{\frac{V_{oc}}{cK\,T/q} - \ln\left(\frac{V_{oc}}{cK\,T/q}+0.72\right)}{\left(1+\frac{V_{oc}}{K\,T/q}\right)}(1 - \frac{V_{oc}}{\frac{V_{oc}}{I_{SC}}})(\frac{V_{oc0}}{1+\beta\ln\frac{G_0}{G}})(\frac{T_o}{T})^{\gamma} I_{sc0}(\frac{G}{G_o})^{\alpha} \quad (14)$$

where v_{oc} represents the normal value of the open-circuit voltage V_{oc} represents the thermal voltage $V_t = nkT/q$, c represents constant current flow, K is the Boltzmann's constant, T represents to the temperature in Kelvin, α represents the non-linear cofactor, q represents the electron charge, γ represents the factor representing all the non-linear temperature-voltage function, while β represents the cell module coefficient. Since the equation (14) depicted the tip energy generation by the circuit cell therefore, the equation of total power output for an array with N_s cells connected in series and N_p cells connected in parallel with power P_M for each mode can be expressed as

$$P_{array} = N_s N_p P_M \quad (15)$$

Conversely, the derivative of the power with respect to current will equate to peak electricity energy production

$$\left.\frac{dP}{dI}\right|_{mpp} = \left.\frac{d(VI)}{dI}\right|_{mpp} = V_{mpp} + I_{mpp}\left.\frac{dV}{dI}\right|_{mpp} \quad (17)$$

And

$$V = V_{oc,n} + V_{T,n} \ln\left(1 - \frac{I}{\mathrm{I_{ph,n}}}\right) - R_s I \qquad (18)$$

Thus, the net electricity energy production volt (V) from biogas is finally computed as, $V = V_{oc,n} + V_{T,n} \ln\left(1 - \frac{I}{\mathrm{I_{ph,n}}}\right) - R_s I$, where the total amount of power has been determined using the equation $P_{max} = \frac{\frac{V_{oc}}{cK\,T/q} - \ln\left(\frac{V_{oc}}{cK\,T/q} + 0.72\right)}{\left(1 + \frac{V_{oc}}{K\,T/q}\right)} (1 - \frac{\frac{V_{oc}}{V_{oc}}}{I_{SC}}) (\frac{V_{oc0}}{1 + \beta \ln\frac{G_0}{G}}) (\frac{T_o}{T})^y I_{sc0} (\frac{G}{G_o})^a$ (equation ss) considering the paraperter of $P_{array} = N_s N_p P_M$ (Equation s). The electricity energy production is therefore accomplished per mole biogas production which is equvlanent to 1.4 eV/moles. Since the 0.4 kg biowaste can produce 81 mole biogass thus, the total electricity generation from 0.4kg biowaste equivalent to 1.4x81=113.4 eV (cc). Since the 1.4eV is equal to 27.77 kWT, thus, the total electricity energy production would be (27.77 kW x 81) = 2249.37 kW · eV per day [36,38,56]. If a commercial building and an office consumption is roughly 2,200 kWh/day for a building with a 20 m x 20 m footprint and height of 20 meter, 0.4kg/day biowaste is sufficient enough to meet the total energy demand for this building which is environmentally friendly.

Conclusion

The advancement of building construction in both urban and sub-urban regions around the globe are quickening tremendously for the past fifty years. Thus, environmental change is expanding quickly because of the traditional utilization of fossil fuel by building sector throughout the world. Likewise, conventional domestic waste and wastewater treatment process are causing/executing the serious ecological contamination, making harm to human wellbeing, hampering the animals and plants kingdom. Here, the "Green Technology", an inventive technology could be the front-line science to mitigate the complete energy need for a building without using any utility service connection. Because this innovation "Green Technology" could deliver sustainable energy by utilizing building’s cellar as the acting bioreactor to create biogas from the household biowaste and then convert it into electricity energy to meet the total indispensable energy need for a building which is environmentally friendly.

Materials and Methods

For the conversion of domestic biowaste into bioenergy, structurally sound long-lasting bioreactor (BR) needs to be designed. Thus, load resistant factor design (LRFD) bioreactor must be constructed for a structurally sound bioreactor to operate regularly under high water velocity pressure considering the mathematical calculation of water velocity (379 mile/hour), water density (1.2 kg/m^3), and the friction loss cofactor 1.00/m^2 respectively (27,28,46). As the water dynamic force is 0.5 of half of the density of the water, thus, the equation for water force into the bioreactor can be expressed as $p_w = 0.5\rho C_p v_r^2$;where p_w represent the water force (Pa), ρ considers water density (kg/m3), C_p denoted as water force gradient which is 1, and v_r^2 is the water velocity (m/s) into the bioreactor. Thus, the net resultant force of P_w = 0.5 x 1.2 kg/m3 x 379^2 m/s is 86,185 Pa is the water pressure resistance capacity of the bioreactor. It can be simplify as force of F = area X drag coefficient (constant=1.00) X water dynamic force by following equation $F = 1m^2 \; x \; 1.0 \; x \; 86{,}185 = 86{,}185 \; N \; (8{,}788 \; kgf) = 19{,}375 \; ibf$ to confirm that the bioreactor is structurally sound which flows the water velocity must be less than 19,000 *ibf* to operate bioreactor normally throughout the year.

Once the sophisticated water force resistance two chambers bioreactor has been constructed, then the bioreactor is to be connected into bio waste chamber in order to collect the biowaste into the shut separation chamber into the basement. The other chamber is to be connected with the separated waste water for the process of treatment of primary, secondary, and tertiary mechanism and then implemented into UV application to disinfect the waste water. The UV application and filtration constitutes the simplest way of treating waste water involving *Disinfection* (DIS) system in which one fills a detention chamber with water and exposes it to full UV light for a few hours. Once the waste water temperature hits 50 °C due to the subject of UV light of approximately 320 nm, it functions immediately to kill all bacteria, viruses, molds and disinfect the water completely thorough bacteriological disinfection process (Figure 1).

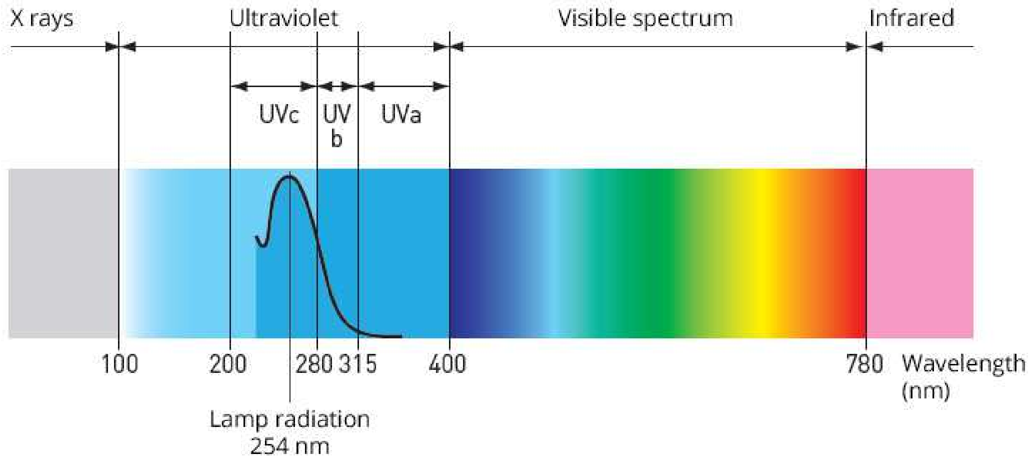


Figure 1: The application of photo-physics radiation in purifying water that illustrates that once one applies UV light of 320 nm into the waste water, it begins to kill the microorganisms once the temperature momentum hits at 50^0C.

This treatment mechanism removes nearly 100% microorganism and other contaminants from the waste water effluent which could be used for local gardening.

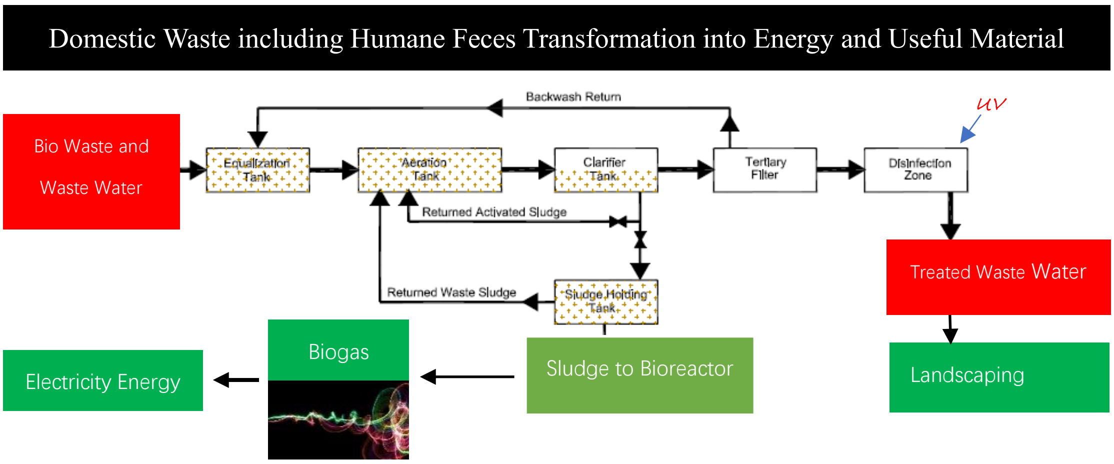
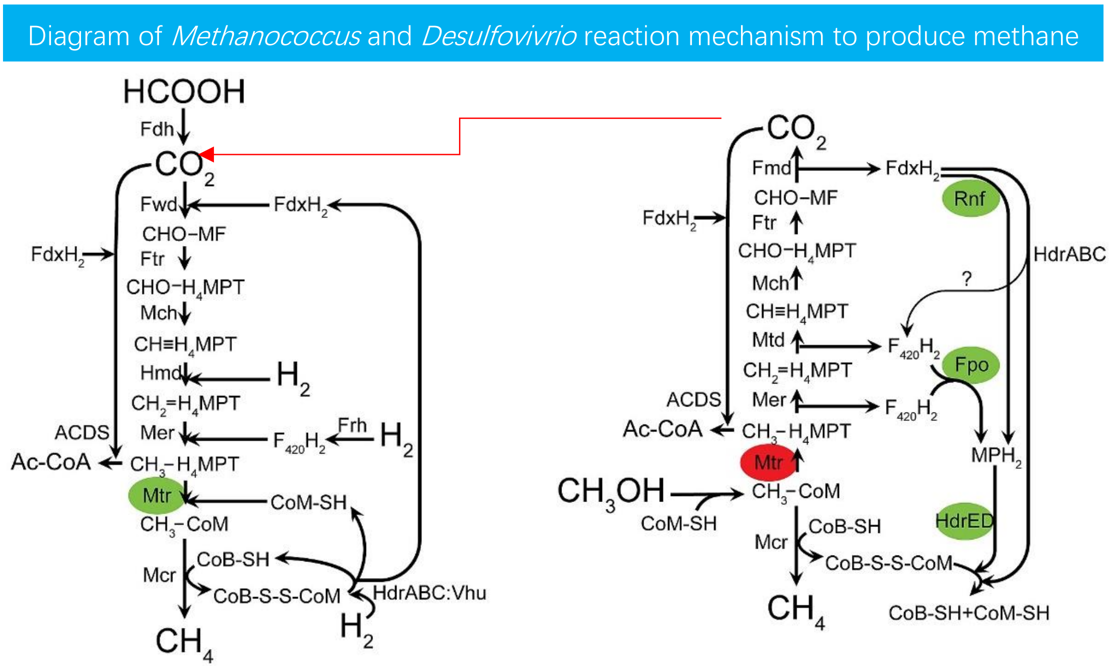
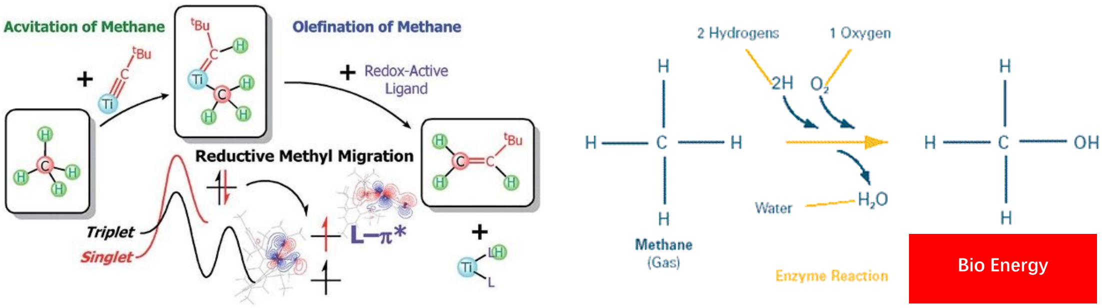


Figure 2. The schematic diagram of waste water treatment mechanism where treated water could be utilized for landscaping and the sludge is to be used for transforming process to produce the energy.

Then, the other product sludge (humane feces including domestic waste) in another chamber of the bioreactor is being conducted for disinfection process *in site* into an anaerobic chamber. This is the conversion mechanism performed by electrochemical filters of activated carbon nanotubes (CNT), which has the capability to electrolyze and oxidize pollutant in the anode actively from the sludge (23,41,45). It is an advanced mechanism of biowaste disinfection mechanism in combing both electrolyze and oxidation process into the anode of carbon nanotubes and catalyzed by the process of oxidation by H_2O_2 into the cathode of carbon nanotubes. The function here accelerate the rate of sludge treatment, and its active oxidation process into the tank are being calculated and demonstrated a pathway that H_2O_2 flow is very much effective to disinfect the biowaste by the electrode and the cathode potential in order to achieve the content of biowaste pH, flow rate, and oxygen dissolved into a normal clean biomaterial form (37,39,50). Hence, the maximum flow of H_2O_2 is being accounted for 1.38 mol L^{-1} m^{-2} C by achieving CNT L^{-1} m^{-2} with the Implementation of cathode potential V -0.4 (vs. Ag / AgCl), a pH of 6.46, with the flowing rate of 1.5 ml min-1 and the dissolved oxygen (DO) content of 1.95 mol L^{-1} m^{-2}. Additionally, phenol (C_6H_5OH) is being induced as an aromatic element for addressing the removal efficiency by clarifying the oxidation rate directed to the H_2O_2 flow (4,31,32). Consequently, the electro-chemical carbon nanotube filters activated the H_2O_2 generation tremendously in order to carbon nanotubes can work most effectively to remove the organic contaminants from the biowaste nearly 100%.



(a)

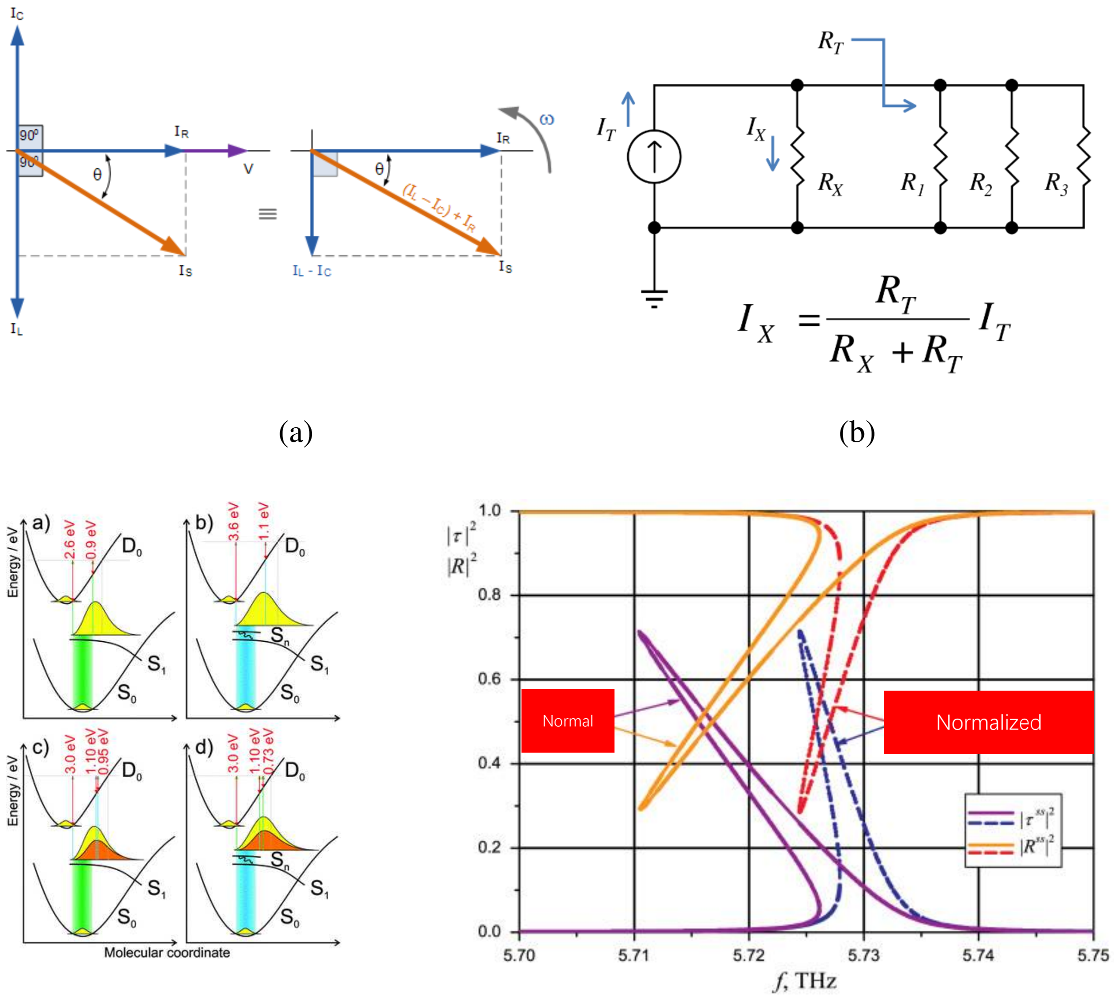


(b)

Figure 3. (a) Biosynthesis mechanism of methanogenesis where shows the conduction of chain reaction to form methane from sludge where two bacteria of Methanococcus and Desulfovivrio are the primary inhibitor to conduct this reaction, (b) the process showing the transformation of methane into bioenergy.

Once the sludge is disinfected, then the product is being placed into the closed bioreactor tank to allow for anaerobic co-digestion process (5,7,61). Thereafter, the product is being heated for 95^{O}F for 15 days which will stimulate the growth of anaerobic bacteria of *Desulfovivrio, Methanecoccus,* which engulf organic material of the sludge and to produce biogas through biosynthesis process (Figure 3).

Then the biogas is to be conducted for transforming process to generate electricity energy through the semi-conductor diodes of the circuit panel. Hence, the electricity production from biogas into the circuit panel is being examined by detailed mathematical computations [22,24,40].



(c)

(d)

Figure 4. The conversation of mechanism of bioenergy into electricity energy, (a) mode of electricity production dynamics with respect power factor (pf), (b) flow of electricity current generation, (c) net electric energy production (eV) rate at molecular rate, (d) the rate of electricity energy generation at normal and normalized circuit parameters respectively.

Hence, to achieve a successful conversion of biogas into electricity energy, the first order perturbation theory has been implemented considering the production of biogas [37,38,39]. The first order mechanism of the transformation of the biogas into the electricity energy needs the adequate surface into the bioreactor to separate the electrons into the semiconductor to produce the electric charge by the given term below [12,13,60]:

$$I = I_{ph} - I_{ph}\left[exp\left(\frac{V + R_s I}{V_r}\right) - 1\right] - \frac{V + R_s I}{R_p} \quad (1)$$

here I is the current and V is the voltage into the circuit panel. I_{ph} (=$N_p I_{ph,\ cell}$) is the electricity energy-created current running inside the circuit module which consists of N_p cells that are connected in parallel. I_0 (=$N_{pI0,\ cell}$) is called the reverse current passing through N_p cells that are connected in parallel, wherein the reverse saturation current $I_{0,\ cell}$ passes through each cell. Subsequently, V_T (=$aN_s \cdot kT/q$) is represented as a matrix of thermal stress of N_S cells that are connected in series where (~1.5=1.0) keeping in mind the diode ideality factor, k (=1.38e^{-23} J/K) is a constant, q (=1.602e^{-19}C) is the charge on an electron and T is the temperature in kelvin. Here R_P is the equivalent resistance in parallel while R_S is the equivalent resistance in series for circuit generator. Depending on the operational point, the cuircit device, in practice, operates as a mixed performance of the current source or the voltage source (49,53). Practically, for the cercuit panel, the effect of R_P parallel resistance will be greater in the operating area having a current source, while the R_S series resistance has a bigger effect on the functioning of the photovoltaic modules when the device works in the area having a voltage source [8,20,59]. Based on studies of various researchers, it can be concluded that for simplifying the model, the value of R_P can be ignored as it is very high [14,25,48]. Likewise, the value of R_S being very low, can be neglected too [9,10,44], thus the temperature of the circuit panel can be shown as follows [18,19,43].

$$T = 3.12 + 0.25\frac{S}{S_n} + 0.899T_a - 1.3v_a + 273 \quad (2)$$

here S and S_n (=1000 W/m^2) are the electricity energy available in working condition, respectively, and T_a is the surrounding temperature and v_a is the surrounding energy flow. The I-V features of photovoltaic panel are based on the internal qualities of the device, i.e. R_S and R_P; consequently, electricity energy as well as surrounding temperature affect outer features. The electricity energy that is responsible for producing the electric current is linked linearly to the electricity energy and temperature and can be stated as follows [6,11,57]:

$$I_{ph} = \left(I_{ph,n} + \alpha_I \Delta T\right)\frac{S}{S_n} \tag{3}$$

here I_{ph} is the current that is produced because of biogass at STC and $\Delta T = T - T_n$, T is the temperature of the circuit panel because of the electricity energy whereas T_n is the supposed temperature. For preventing any problems faced by the electricity energy current in deciding the series resistance (very low) as well as the parallel resistance (very high), it has been presumed that $I_{sc} \approx I_{ph}$ so that an explanation can be given for the complex circuit modelling and the open circuit voltage that is dependent on the temperature can be confirmed [17,20,51]. This can be shown by: (Fig. 1)

$$V_{oc} = V_{oc,n}(1 + \alpha_v \Delta T) + V_T \ln\left(\frac{S}{S_n}\right) \tag{4}$$

here $V_{oc,n}$ is the open circuit voltage that is calculated at the given conditions and α_v is the voltage-temperature coefficient. The electrical and thermal features of the electricity energy panels can be achieved from these characteristics which are integrated to achieve the I-V curve to produce much electricity energy Eq. (1). The characteristics of the suggested electricity energy panel should consist of the following: the short-circuit current/temperature coefficient(α_I), the open-circuit voltage/temperature coefficient(α_v), the experimental peak power(P_{max}), the insignificant short-circuit current($I_{sc,n}$), the Maximum Power Point (MPP) voltage(V_{mp}), the MPP current(I_{mpp}), and the insignificant open- circuit voltage($V_{oc,n}$), to calculate at the supposed conditions or standard test conditions(STC) of temperature T = 298 K and electricity energy of S = 1000 W (53,54). The simple equation at STC can be expressed as follows

$$I = I_{ph,n} - I_{0,n}\left[exp\left(\frac{V + R_s I}{V_{T,n}}\right) - 1\right] - \frac{V + R_s I}{R_p} \qquad (5)$$

here 'n' is evaluated at STC and the values are expected to show that the resistance in series and thr resistance in parallel are not dependent on each other. Hence, the modelling in Eq. (5) can be simplified as below

$$I = I_{ph,n} - I_{0,n}\left[exp\left(\frac{V + R_s I}{V_{T,n}}\right) - 1\right] \qquad (6)$$

There are three significant points on the I-V curve of electricity energy: maximum power point (V_{mp}, I_{mpp}), open circuit (V_{oc}, 0) and short circuit (0, I_{sc}) that can be shown as:

$$I_{sc,n} = I_{ph,n} - I_{0,n}\left[exp\left(\frac{R_s I_{sc,n}}{V_{T,n}}\right) - 1\right] \qquad (7)$$

$$0 = I_{ph,n} - I_{0,n}\left[exp\left(\frac{V_{oc,n}}{V_{T,n}}\right) - 1\right] \qquad (8)$$

$$I_{mpp,n} = I_{ph,n} - I_{0,n}\left[exp\left(\frac{V_{mpp,n} + R_s I_{mpp,n}}{V_{T,n}}\right) - 1\right] \qquad (9)$$

The diode saturation current can thus be shown by its dependence on the temperature of the bioreactor [12],

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)^3 exp\left[\frac{qE_G}{ak}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \qquad (10)$$

here EG represents the band-gap energy of the electricity energy. Eq. (8) shows that the diode saturation current at the STC and the photo-current at STC are linked,

$$I_{0,n} = \frac{I_{ph,n}}{\left[exp\left(\frac{V_{oc,n}}{V_{T,n}}\right) - 1\right]} \qquad (11)$$

The electricity generation model can be further enhanced if Eq. 8 is substituted by

$$I_0 = \frac{I_{sc,n} + \alpha_I \Delta T}{exp\left(\frac{V_{oc,n+\alpha_v \Delta T}}{V_T}\right) - 1} \qquad (12)$$

By assuming $V_{oc,\,n}/V_{T,\,n} \gg 1$, $I_{0,n}$ can be shown as:

$$I_{0,n} = I_{ph,n} exp\left(-\frac{V_{oc,n}}{V_{T,n}}\right) \qquad (13)$$

Using Eq. (13) and Eq. (6), it can be shown that

$$V = V_{oc,n} + V_{T,n} \ln\left(1 + \frac{\mathrm{I_{ph,n}}^{-I}}{I_{0,n}}\right) - R_s I \qquad (14)$$

Thus, Eq. (14) is considered as modest electricity energy generation model that is transformed from the biogas from bioreactor and it can be explained as simply as following equations.

$$V = V_{oc,n} + V_{T,n} \ln\left(1 + \frac{I}{\mathrm{I_{ph,n}}}\right) - R_s I \qquad (15)$$

Declarations

Ethics approval and consent to participate

Yes, all ethics has been maintained properly and I have no reservation to publish this paper is a suitable paper

Consent for publication

Yes

Availability of data and material

NA

Competing interests

None

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Authors' contributions

Md. Faruque Hossain is the 100% contributing author for this paper.

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List of Abbreviations

CH_4	Methane
BR	Bioreactor
UV	UltraViolet
CO_2	Carbon Di Oxide
EJ	Exajoules
gtC	Gega Ton Carbon
Kg	Kilogram
Ibf	Pound fornce
Pa	Pascal
CNT	Carbon nanotubes
H_2O_2	Hydrogen Peroxide
C_6H_5OH	Phenol
DO	Disovled Oxygen
AC	Alternatic Current
DC	Direct Current
STC	Standard test conditions
MPP	Maximum Power Point
kW	Kilowatt
kWT	Kilowatt Time

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