

Electricity Generation from the Foot Beats of Dancers at Club Centres in Awka, Anambra State

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Abstract The study designed and developed a system of generating electricity through the beats of human feet using piezoelectric materials. The system made use of mechanical deformation occasioned by the foot beats of dancers when stepped on a platform in which piezoelectric materials were installed at dance club centres to cause piezo films to generate electrical density that was stored in a rechargeable lead acid battery for future use. The study shows that human pressure due to human weight when applied in the system could be converted to electrical energy for later use. The study shows that it would require 1802 foot beats for a 50kg dancer to increase a unit voltage in a battery; foot beats for a 60 kg dancer; and 1194 foot beats for an 80kg dancer respectively. The system is suitable where there are high volumes of human traffic such as markets, worship centres, shopping malls, bus stations, and parks. It can also be used in powering small electrical appliances and electronic gadgets such as cell phones, radio stereo, television, fan, and street lights. Based on this, research into this kind of electricity generation should be expanded in large scale and sponsored by the government or corporate organisations. The system should be incorporated in the design and construction of building including new material development as a means of achieving sustainable construction and minimisation of conventional energy consumption in building use.

Keywords Club Centres, Electricity Generation, Foot Beats, Piezoelectric, Renewable Energy, Sustainable Building

1. Introduction

The socio-economic development of any country is

largely dependent on the availability and accessibility of electricity [1-3]. The sustainability and defossilisation of today's energy systems to guard against the impacts of climate change in Nigeria have also been advocated [4,5].

As the population of Nigeria continue to grow, so also the electricity demand and consumption. In Nigeria, there are severe electricity problems due to non-availability, non-accessibility and non-affordability of electricity provision in the country [6,7]. The effects of this are untold, and play a major part in the developmental status of Nigeria [8-10]. The Federal Government report on the Nigerian power sector investment opportunities and guidelines also shows a complex problem where there is huge gap between supply and demand in the Nigeria power system [11]. The Advisory Power Team [12] categorises these challenges into generation, primary energy-gas, transmission and distribution problems.

In Awka the capital of Anambra State, the electricity situation is not better. Studies have shown that lack of steady electricity is the bane of problems of small, medium and large scale industries [13-16]. But the small scale businesses suffer the most. There are many small scale business outfits springing in Awka the capital of Anambra State in recent years. These business outfits include night club centres which are growing in number on daily basis.

Every day and night, there are thousands of people visiting these centres for night clubbing. However, the amount of electricity consumed in the course of running club business in Awka is outrageous compared to the revenue generated from it. This is because the business is usually carried out at night. The activities of night clubbing involve locomotive movements in terms of dancing. As the dancers dance, energy is being wasted in the process. Unfortunately, little or nothing have been done to conserve or convert the energy into useful state,

while the events are being run using electricity generating set to provide electricity or on a very high electricity tariff. This condition brings little or no profit to the business outfit, thereby leading premature closure of most of these businesses.

Interestingly, there are many potential alternative and renewable sources energy in Nigeria [17]. The commonly known sources include: solar, wind, hydro, biomass and geothermal energy. However, the power needs of Nigeria have continued to increase and could not be met by the available energy sources, thus the need for more avenues through which electricity could be generated.

With advancement in technology, and the growing quest for more sustainable sources of energy, research has shown that mechanical energy could be converted to electrical energy for use in buildings and other outdoor and indoor centres through the human foot beats [18-24]. This is in an effort to complement the existing sources of energy. Notwithstanding, Nigeria has not practically delved into robust research in this area which has the potential of ameliorating the electricity problems of our people especially for small scale electricity consumption.

Most unfortunately, human energy that could have been converted into electrical energy for use at least by the small scale business outfits, markets religious centres, event centres, club houses, bus stations and parks, etc., are being wasted on daily basis. The ability to develop this system of generating electricity through the human foot beats as an alternative to conventional electricity supply could go a long way to boosting the economic potential of country. Therefore, this study was aimed at developing a system of generating electricity through the foot beats of dancers for dance clubs in Awka Anambra State.

2. Literature Review

Studies into alternative and renewable source of energy in Nigeria have been robust [9,10,25-32], however, these studies principally focused on the well-known form of energy sources such as solar, hydro, wind, thermal and biomass. Ohimain [8] and Sambo [33] had acknowledged the limiting factors to efficient and effectiveness of these renewable energy sources; thus, the need for efficient, effective, environmentally friendly and sustainable source of electricity generation in Nigeria.

But as we continue to dissipate energy in our daily activities including during our leisure time while walking, running or dancing, the energy could be converted to a more useful form of electrical energy. Available studies showed that this form of energy system have only been identified and developed in the developed and Asian countries. For example, Kamlesh et al. [34] developed a system through which power could be produced through human footsteps as a source of renewable energy that can be obtained while walking or standing on a certain

arrangement like footpaths, stairs, plate forms and can be install specially in the more populated areas. Al-Qadhi et al. [35], Sabarish and Kumar [36] and Upadhyaya and Upadhyaya [37] equally designed a crankshaft mechanism as a mechanical arrangement installed on the stair case to convert the foot power applied on stairs, as a rotary motion into electrical energy, stored in a battery used for activating the connected loads.

Ang et al. [19] experimented the conversion from kinetic energy to electricity energy by placing a mechanical footstep power generator on the hind foot region using 45 individuals and compared the experiment results with the theoretical results. The result showed that generated power increased proportionally with the mass of an individual and that the actual power generated from experiments were higher than the theoretical results.

Babu et al. [20] developed a power generating slab using mechanical parts consisting of top plane, Rack and Pinion arrangement, Gear mechanism, springs, Shaft and Freewheeling bearing with dynamo fed into electrical system consisting of Converter, battery and Inverter units which can be used for emergency backup power, charging purpose and to run small electrical equipments during load shedding conditions.

Abhishek and Shivasharana [38], Bhosale et al. [39], Kotadiya and Parmar [40], Munaswamy et al. [41] and Sahoo et al. [42] also designed a footsteps system that generated electricity with the help of rack and pinion arrangement along with alternator and chain drive mechanism connected to a battery for storage.

Saeed et al. [23] employed ansys17.0 software to show in a simulation how about 10.925kw power could be produced in one hour using a footstep power generation mechanism that produces electricity by moving the human on a moving plates in which rack and pinion gear are used to convert the physical energy into mechanical energy and further into electric energy using a dynamo.

In their study, Aman et al. [43] developed a model that can generate 1 megawatt of power with a 100 floor on just twelve footsteps and it is capable of generating 10000w power for just 120 footsteps. This system can be installed on road side footpath, parks and jogging tracks and many other public place, airport etc. Similar model had also been developed by Shiraz and Farrukh [24].

On the other hands, Chavan et al. [44], Dhimar et al. [45] and Madhu et al. [46] designed a foot step power generation platform using piezoelectric sensors that generates electricity using the pressure due to weight of the person walking on the platform and stored using batteries. Marshiana et al. [47] proposed a novel technique for the creation of power utilising piezoelectric sensors kept along the footpaths which can charge the battery and supply the force at whatever time of our prerequisite. A similar technique that is capable of generating 40V of electricity was devised by Anooj et al. [48], while Gopinath et al. [49] proposed a power generation

technique through piezo sense and treadmill stride control generator framework that uses the piezoelectric sensors to produce control through strides as a wellspring of sustainable power source that can be gotten while strolling on a specific course of action like venturing foot on piezo tiles. The same technique was also designed by Naresh et al. [50], but together with microcontroller.

The forgoing studies demonstrated the different means through which electricity could be generated through the human foot beats. However, Hofstede [51] argued that the applicability of western cultures and technologies across countries due to cultural differences makes them implausible. In addition, since the amount of voltage, current and power generated through piezoelectric material is dependent on the pressure and weight of person [24], it is argued that more pressure would be exerted on the piezoelectric platform when one is dancing or jumping as it's the case of clubbers than walking. It is against this background that this study seeks to generate electricity through the beats of human feet as a renewable and sustainable alternative to other forms of electricity generation source for dance clubs in Awka Anambra State.

3. Methodology

Foot step power generation can be done through various techniques and methods like piezoelectric sensors, mechanical arrangement like fly wheel, gear wheel, rack & pinion and chain sprocket arrangement, pedal and springs type arrangement, and staircase energy generating system by rotating the generator. In this study, piezoelectric system was used to develop a technique of generating energy from the foot beats of dancers in a dance club.

3.1. Materials

Materials used in this study include: 300mm x 300mm x 25mm thick wooden board, 3mm thick plywood of the same dimension, 150mm x 150mm electric unit box, human weight of different kilogrammes, electric panel, foam spring, Lead Zirconate Titanate (PZT) piezoelectric sensors, rectifier (diodes), capacitors, resistors, 6V4AH Lead acid rechargeable battery, multimeter, AC nipple neutraliser, current controllers (switches), electric strand wire, LED and USB output.

3.2. General Arrangement, Procedure and Working Principle

A sheet of plywood measuring 300mm x 300mm x 3mm thick was placed on a hard wooden board of 300mm x 300mm x 25mm thick. On this board, twelve piezoelectric sensors were placed because the power output from one piezo film was found to be very low.

However, the PZT-5 sensors were used because of their high piezoelectric properties [52-54]. The physical characteristics and electrical specifications of the PZT sensors are presented in Table 1, while the arrangement of piezo sensors and connections in the system are shown in Figure 1.

Table 1. Specifications of piezoelectric sensor discs

S/N	Properties	Symbol	Value
A. Physical Properties			
1.	Diameter (mm)		10
2.	Thickness (mm)		1
3.	Hardness		Hard
4.	Density(g/cm ³)	ρ	7.5
5.	Curie Temperature (°C)	T _c	225
6.	Mechanical Quality Factor	Q _{m,p}	70
B. Dielectric Properties			
1.	Dielectric Constant at 1 KHz	K _{3t}	2600
2.	Dissipation factor at 1 KHz	tan δ	0.02
3.	Resistivity	Ω -cm	10-12
C. Electro-Mechanical Data			
1.	Planer coupling co-efficient	K _p	0.62
2.	Transverse coupling co-efficient	K ₃₁	0.37
3.	Longitudinal coupling co-efficient	K ₃₃	0.72
4.	Piezoelectric Charge constant (C/Nx10 ⁻¹²)	-d ₃₁	195
		d ₃₃	460
5.	Piezoelectric Voltage constant (10 ⁻³ volts-meter/ Newton)	-g ₃₁	13
		g ₃₃	27



Figure 1. The Arrangement of Piezo Sensors and Connections in the System

Subsequently, series connections were done because the parallel association failed to show important increase within the voltage output. The series connection was used for manufacturing voltage output with high current density. Between the plywood and hard board, a foam spring area unit was placed at the corners and nails area unit placed on the second board such as the sensors at the middle of board in 3 x 4 arrangement. Subsequently, the piezoelectric platform was prepared for stepping.

When the dancers step on the platform (plywood) of the system, the plywood will dip down slightly due to the weight of the dancers. The downward movement of the plywood results in generation of electrical power after which the top plywood reverts back to its original position due to negating spring action of the foam provided in the device as in this case.

Usually, the output voltage from a single piezo-sensor was extremely low, therefore combination of 12 piezoelectric is used. Since the output of the piezoelectric material is not a regulated one, variable to linear voltage converter circuit rectifier was used. In this case, AC ripple neutralizer was the circuit used to reduce the ripples from the piezoelectric output. The AC ripple neutralizer consists of rectifier and ripple filter. AC ripples were filtered out using ripple filter and it was used to filter out

any further variations in the output and then it can be pass through regulator in order to regulate, and it is constant until the load and mains voltage is kept constant.

Again, the output of the voltage regulator is given to the unidirectional current controller which allows flow of current in only one direction. In this system, diode was used as a unidirectional current controller which main function was to allow the flow of current in only one direction while blocking current in the reverse direction.

Thereafter, a battery was connected to the system to store energy for future use. In this case, a LED display was shown using this foot power. The block diagram of footsteps electricity generation is shown in Figure 2.

As the gadget was placed under the dancing floor, electricity was generated from the pressure from the foot beats of dancers. The electricity generated charged the battery which could be used to energise electrical appliances when the pressure was withdrawn. Multimeter was used to determine the amount of energy generated in the system. as varying forces (foot beats) were applied on the Piezo material, different voltage readings corresponding to the force was displayed. For each such voltage reading across the force sensor, various voltage and current readings of the Piezo material were recorded.

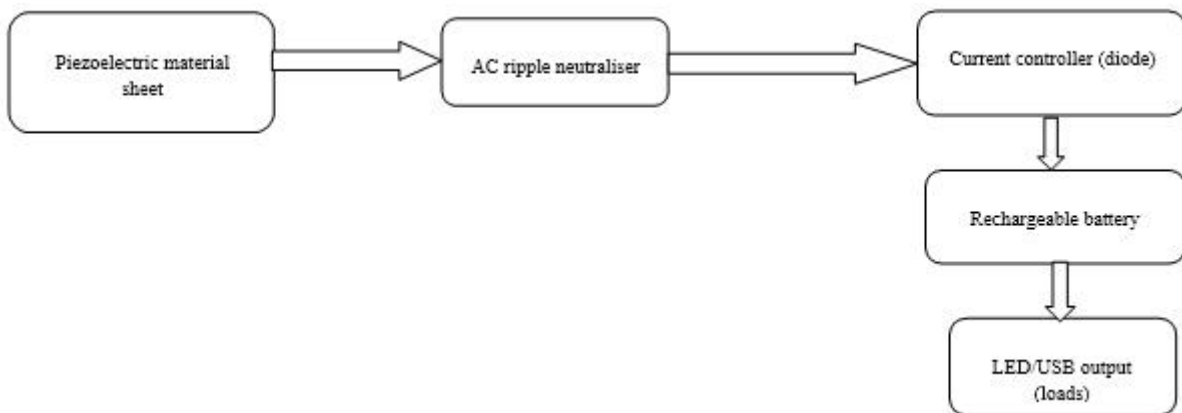


Figure 2. Block Diagram of Footsteps Electricity Generation

4. Results and Discussion

The piezoelectric sensor outputs are presented in Tables 2, 4 and 6. In the design, 12 Piezo electric sensors per one square foot were used. As piezo sensors power generating varies with different foot beats and weights of persons. The gadget was placed under the dancing floor to determine the readings as the number of foot beats increases. Multimeter was connected across for measuring voltages and current. As varying forces were applied on the Piezo material, different voltage readings corresponding to the force were displayed. For each voltage reading across the force sensor, various voltage and current readings of the Piezo material were recorded as presented in Tables 3, 5, and 7.

Table 2. Piezo sensor readings for an average of 50kg weight

Piezo sensor	Voltage (mV)	Current (mA)	Power (mW)
1	0.520	0.064	0.033
2	0.612	0.063	0.039
3	0.560	0.064	0.036
4	0.540	0.065	0.035
5	0.560	0.065	0.036
6	0.600	0.062	0.037
7	0.582	0.060	0.035
8	0.546	0.062	0.034
9	0.522	0.061	0.032
10	0.510	0.062	0.032
11	0.558	0.065	0.036
12	0.552	0.061	0.034
Average	0.555	0.063	0.035

Table 2 showed that one foot beat of an average 50kg dancer produced an average Voltage, Current and Power of 0.555mV, 0.063mA and 0.035mW respectively. The power generation of piezo sensor varies with different beats which was as a result of the pressure of the foot beat and the weight of the dancer.

If an average of 0.555 microvolts is produced per foot beat, it would take about 1802 foot beats from the pressure of an average of 50Kg weight dancer to increase 1 V charge in battery.

So, to increase 6 V in a battery as it is in this case, the total number of foot beats needed would be $6 \times 1802 = 10812$ foot beats. Since this would be implemented in a dance hall where foot beats as source of weight were available, it then took an average of 2 foot beats in 1 second.

Extrapolating from Table 2, the average Voltage, Current and Power per beat were 0.555mV, 0.063mA and 0.035mW respectively. However, an increase in the number of beats increased the amount of voltage, current and power generated as shown in Table 3. There was an upward increment in the amount of voltage added to the battery through charging until the battery was fully

charged to its maximum voltage after which the voltage remained stable regardless of any further increase in the number of foot beats.

Table 3. Power generated per foot beat for an average weight of 50kg dancer

No of Beats	Voltage (mV)	Current (mA)	Power (mW)
100	55.50	6.30	0.35
200	111.00	12.60	1.40
300	166.50	18.90	3.15
400	222.00	25.20	5.59
500	277.50	31.50	8.74
600	333.00	37.80	12.59
700	388.50	44.10	17.13
800	444.00	50.40	22.38
900	499.50	56.70	28.32
1000	555.00	63.00	34.97

Table 3 principally showed that as the number of foot beats exerting pressure on the gadget increases, there were corresponding increase in the amount of voltage charge in the battery, current and power. However, the increase is not indefinite but up to the maximum voltage of the battery and in this case, 6Volts. The voltage charge in the battery is expected to remains steady regardless of any further increase in the number of foot beats or additional pressure from the foot beats. This is in line with the Ohms law which implies that an increase in the mechanical energy will increase other corresponding parameters such as voltage, current and power as far as the resistance is constant.

Table 4. Piezor sensor readings for an average of 60kg weight

Piezor sensor	Voltage (mV)	Current (mA)	Power (mW)
1	0.680	0.080	0.054
2	0.650	0.080	0.052
3	0.680	0.083	0.056
4	0.645	0.080	0.052
5	0.680	0.083	0.056
6	0.654	0.083	0.054
7	0.650	0.080	0.052
8	0.684	0.080	0.055
9	0.684	0.082	0.056
10	0.645	0.080	0.052
11	0.680	0.083	0.056
12	0.680	0.083	0.056
Average	0.668	0.081	0.054

Table 4 showed that one foot beat of an average 60kg dancer produced an average Voltage, Current and Power of 0.668mV, 0.081mA and 0.054mW respectively. The power generation of piezo sensor varies with different beats which was as a result of the pressure of the foot beat and the weight of the dancer.

Likewise, if an average of 0.668 microvolt was produced per foot beat. it would take about 1498 foot

beats from the pressure of an average of 60Kg weight dancer to increase 1 V charge in battery. So, to increase 6 V in a battery as in this case, the total number of foot beats needed would be $6 \times 1498 = 8988$ foot beats.

Extrapolating from Table 4, the average voltage (0.668mV), current (0.081mA) and power (0.054mW) respectively, the corresponding increase, current and power due increase in the number of beats were shown in Table 5.

As usual, there was an upward increment in the amount of voltage added to the battery through charging until the battery was fully charged after which the voltage remained stable despite further increase in the number of foot beats. But there was a lesser number of foot beats required to increase 1 unit volt in a battery due to an increase in weight.

Table 5. Power generated per beats for an average weight of 60kg

No of Beats	Voltage (mV)	Current (mA)	Power (mW)
100	66.80	8.10	0.54
200	133.60	16.20	2.16
300	200.40	24.30	4.87
400	267.20	32.40	8.66
500	334.00	40.50	13.53
600	400.80	48.60	19.48
700	467.60	56.70	26.51
800	534.40	64.80	34.63
900	601.20	72.90	43.83
1000	668.00	81.00	54.12

Table 5 showed that as the number of foot beats exerting pressure on the gadget increases, there were corresponding increment in the amount of voltage charge in the battery, current and power. This was in line with the Ohms law which implies that an increase in the mechanical energy will increase other corresponding parameters such as voltage, current and power as far as the resistance is constant. However, in this case, there was lesser number of foot beats and the amount of time required to increase a unit voltage in the battery due to increase in weight.

Table 6. Piezor sensor readings for an average of 80kg weight

Piezor sensor	Voltage (mV)	Current (mA)	Power (mW)
1	0.820	0.088	0.072
2	0.860	0.085	0.073
3	0.840	0.088	0.074
4	0.770	0.092	0.071
5	0.860	0.086	0.074
6	0.840	0.089	0.075
7	0.864	0.082	0.071
8	0.804	0.088	0.071
9	0.866	0.090	0.078
10	0.850	0.086	0.073
11	0.842	0.090	0.076
12	0.840	0.083	0.074
Average	0.838	0.087	0.073

Table 6 showed that one foot beat of an average 80kg dancer produced an average voltage, current and power of 0.838mV, 0.087mA and 0.073mW respectively. The power generation of piezo sensor varies with different beats which is as a result of the pressure of the foot beat and the weight of the dancer.

Therefore, if average of 0.838 microvolts was produced per foot beat, it then took about 1194 foot beats from the pressure of an average of 80Kg weight dancer to increase 1 V charge in battery. So, to increase 6 V in a battery as in this case, the total number of foot beats needed would be $6 \times 1194 = 7164$ foot beats.

Extrapolating from Table 6 the average voltage (0.838mV), current (0.087mA) and power (0.073mW) respectively, the corresponding increase, current and power due increase in the number of beats were shown in Table 7.

As usual, there was an upward increment in the amount of voltage added to the battery through charging until the battery was fully charged after which the voltage remained stable despite further increase in the number of foot beats. But there was a further lesser number of foot beats required to increase 1 unit volt in a battery due to an increase in weight.

Table 7. Power generated per beats for an average weight of 80kg

No of Beats	Voltage (mV)	Current (mA)	Power (mW)
100	83.80	8.70	0.73
200	167.60	17.40	2.92
300	251.40	26.10	6.56
400	335.20	34.80	11.66
500	419.00	43.50	18.23
600	502.80	52.20	26.25
700	586.60	60.90	35.72
800	670.40	69.60	46.66
900	754.20	78.30	59.05
1000	838.00	87.00	72.91

Table 7 also showed that as the number of foot beats exerting pressure on the gadget increases, there were corresponding increment in the amount of voltage charge in the battery, current and power. Similarly, this was in line with the Ohms law which implies that an increase in the mechanical energy would increase other corresponding parameters such as voltage, current and power as far as the resistance is constant. However, in this case, the number of foot beats and the amount of time required to increase a unit voltage in the battery were much lesser than those of 50kg and 60kg weights due to increase in weight.

The result of this study depicts that the piezo sensors generate different amount of electricity per number of foot beat as the weight of the dancers varies. The amount of foot beats required to increase a unit voltage in battery

also varies as the weight of the dancers varies. For example, it would require and 1802 foot beats for a 50kg dancer to increase a unit voltage in a battery. Likewise, it would require 1498 foot beats, and 1194 foot beats for 60 kg and 80kg dancers respectively to do the same.

This implies that the voltage, current and power would continue to increase with increase in weight (body mass) of dancers or as a result of addition of dancers on the dancing floor until it reaches a point when the parameters would remain constant even when more weight or pressure is added. At that point, the battery is assumed to have been fully charged.

This scenario is in line with the general principles of Ohms law which states that electrical current (I) flowing in a circuit is proportional to the Voltage (V) and inversely proportional to the resistance (R), i.e as the voltage increased, the current increased provided the resistance of the circuit remain constant. Implicitly, the results indicate that the body mass (weight) of the dancers is a determining factor in the generation of electricity through the foot beats despite the number of foot beats or the amount of time.

The result of this study strongly shares the same view with Chavan et al. [44], Dhimar et al. [45], and Marshiana et al. [47], but slightly differs from Madhu, et al. [46] who used parallel connections.

5. Conclusions

One of the objects of establishing any business venture is to make profit in an environment devoid of any dangers. However, business outfits such as night clubbing that are usually night events are being run with generating sets to provide electricity due to epileptic condition of electricity generation, distribution and supply in Nigeria. Since night clubbing involves locomotion through dances a lot of human energies that could be converted into useful form are being wasted. In view of this, the study has designed and developed a system generating electricity through the beats of human feet that is environmentally, socially and economically sustainable. The system shows that the potential energy in human can be converted into electrical energy through piezoelectric materials.

This system is most suitable where there is high volume of human traffic and especially for small business outfits like club houses, markets, and worship centres, shopping malls, bus stations, parks, etc, could generate the own electricity in the course of running the business. The system is also capable of being used in powering small electrical appliances and electronic gadgets such as cell phones, radio stereo, television, fan, and even powering street lights on the highways through a system whereby vehicles run on the laid piezoelectric materials on the road.

This system of electricity generation is green and does

not have any negative environmental consequence, therefore it has added to the search towards sustainable alternative source of energy and electricity generation in Nigeria. It has provided some useful insights into another area of research in Nigeria gearing towards solving the perennial electricity problems in the country especially for small scale electricity consumers. However, a major drawback in this kind of system is the quantity of energy it generates which is usually very small.

On this strength, research into this kind of system of electricity generation should be expanded in large scale and supported by the government or corporate organisations. As new technology in building and construction industry evolves, this system should also be incorporated in the design and construction of building as a means of achieving sustainable construction.

Likewise, effort towards sustainable building in Nigeria should also involve the specification and use of sustainable building materials such as piezoelectric floor tiles as being done in India and other developed countries; this will minimise the amount conventional energy consumption in the building use.

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