



# Renewable Energy Harvesting for Wireless Sensor Networks in Precision Agriculture

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## Abstract

Wireless sensors are used for smart building monitoring, biomedical applications, intelligent home appliances, urgent disaster management and precision agriculture production. These devices today operate with batteries that are very difficult to change. The major problem hindering the widespread deployment of wireless sensor networks is the need to constantly replace them because their batteries expires. We can see that it is possible to charge them using energy harvested from solar, vibration, thermal or ambient radio frequency sources. we can implement sustainable health surveillance systems, agriculture, mining, environmental protection and national infrastructure, which will improve the quality of life, save money and achieve ecological goals. We realized that it would be wise to specify a field of application for internet of things in order to be able to clarify the identification of the problem of energy consumption and its relation with renewable energies. In addition, one of the most interesting applications for the socio-economic fields in the world in recent years is Smart Farming. In this paper, we reviewed a state of the art on the use of renewable energy harvesting in precision agriculture.

**Keywords** IoT · Smart farming · Renewable energy · Battery · Energy harvesting

## 1 Introduction

Wireless sensor networks (WSN) consists of billions of sensor nodes which are scattered across different areas to collect important data from their surroundings. In fact, it has been used extensively in the Internet of things (IoT), mostly to measure environmental conditions like sound, humidity, temperature, wind and so on. Nowadays, IoT, cloud computing and Big Data are used in precision agriculture and this is a new concept adopted worldwide to allow crops to be

harvested throughout the year regardless of seasonal changes using analytical tools and sensors [1].

The lifetime of the sensor determines the lifetime of the entire system and in order for each system to complete its mission, it requires a massive amount of energy; usually provided by a battery and/or an embedded form of energy harvesting. Energy harvesting is the process of converting the ambient energy, which is present in the environment into electrical energy, and it stores it in units such as batteries. Ambient energy is natural, non-electric in nature, and renewable. In addition, the main advantage of energy harvesting is that it eliminates the need for wires or frequent visits to replace sensor batteries [2].

There are several categories of energy harvesting and each with its own characteristics and its power density: Solar cells with  $15\text{ mW/cm}^3$ , Piezo-electric with  $330\text{ }\mu\text{W/cm}^3$ , Vibration with  $116\text{ }\mu\text{W/cm}^3$ , Thermo-electric with  $40\text{ }\mu\text{W/cm}^3$  and Acoustic noise with  $960\text{ }\mu\text{W/cm}^3$  [3]. As we can clearly see, the solar energy harvesting is the best technique in terms of the amount of output energy.

Thermoelectric power harvesting is based on the production of electrical energy from the difference in temperature. This technique generally consists of the use of thermoelectric generators [4].

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Photovoltaic energy harvesting is the process of converting photons from sources such as sunlight, into electricity. Photovoltaic energy can produce higher levels of electricity than other energy harvesting techniques. This makes these sources suitable for large-scale energy harvesting systems.

However, the power generated and the efficiency of the system are highly dependent on the availability of light and environmental conditions as well as the used materials [5]. The Range of power transportation for underground nodes should be 35 m, however the range of the power transportation in 100 m above ground covers 300 300 m agricultural field [6]. Multilayer and receiver-initiated mac protocol is designed in [7] for precision agriculture based on solar energy harvesting to provide high performance network.

This paper is a survey of most important existing energy harvesting techniques used in the internet of things especially in agricultural fields to extend the lifetime of wireless sensor networks.

We identify the various sources of energy available for harvesting and describe works carried out by researchers. Kinds and methodology of energy harvesting used in wireless sensor networks will be introduced in Sect. 2; detailed discussion is then developed in Sect. 3, to be able to concluded in Sect. 4. In the last section, our future works will be exposed.

## 2 State of the Art

Minimizing batteries and sensors production and waste, preserving the environment, extending the lifetime of sensor networks, making sensors self-powered; are all good reasons to use energy harvesting. It's a very attractive technique which has become of a growing interest in the last few years. That's why we find several types of techniques for energy harvesting based on renewable energies (solar and light, thermal, biological, chemical,...). We focus on techniques that concern the field of smart farming and precision agriculture.

### 2.1 Solar Energy Harvesting

Solar energy harvesting allows conversion of the light into electricity. That's what is called photovoltaic effect. It was discovered since the 19th century that it is possible to product electricity from light, that's why this technique has been largely improved to be so effective and cost less today compared to other techniques.

A Solar energy-harvesting scheme is proposed in [5] for the supply of long term and stable power in wireless sensor networks. The proposed scheme works on the principle of photovoltaic effect. A recharging circuit for batteries in sensor nodes is also designed. It consists of a solar panel,

regulator circuit, triggering circuit and NiMH battery. The solar panel provides the input voltage to the circuit. The regulator TCTL 431 adjusts the input voltage to about 5 Volts and then compared it with the initial feedback voltage. The output is provided to the IC555's triggering point. A positive pulse is generated and navigates the 2 transistors to fullness mode and then the 2 transistors start to transfer the output to the battery. The initial voltage of the NIMH battery is 0,50 volts.

The results show the increase in voltage after recharging to roughly 0,8 volts after 10 min. After 20 min it becomes about 1,2 volt and After 30 min the voltage increases up to 1,8 volts. According to the results, we noticed that the NiMH battery is charged slowly and becomes inefficient if the energy needed immediately. To solve this problem we suggest to use another type of battery which can be charged faster.

Li [8] et al brought forward a novel intelligent solar energy harvesting system for powering WSN sensor nodes in IoT. Those sensor nodes contain ARM-cortex-MO, Zig-Bee module and sensors (dissolved oxygen, PH, Temperature) and consumes about 0.92 Wh every day. The System can provide a power supply with an output voltage of 5V via a standard USB interface. The system components are a solar panel, a control circuit and a lithium polymer battery that is chosen according to its load capacity, which is approximately 4000 mAh after comparing five types of batteries. Hardware, Instead of software is used to control the charging and over-discharging protection. RS triggers are used to implement this. When the battery is totally charged the circuit is disconnected, it will only switch on when the battery voltage drops under the limit. To protect the battery from over discharging, U12(ST2301) switches off the battery power output.

This system takes full advantage of solar energy, if the solar energy is sufficient, it use it directly, otherwise he uses a lithium battery. We think powering the sensor nodes through a standard USB interface has many negative outcomes especially for the underground sensor nodes used in agriculture. It is better to find a way to connect sensor nodes's batteries directly with the energy source, which means that the lithium battery and the USB interface will no longer be necessary.

Recently, the internet of things has been invested in agriculture to increase the productivity all while optimizing resources. When rechargeable batteries are used to power the sensor nodes, energy consumption will be major preoccupation for the proper functioning of the system, so energy harvesting devices and energy optimization can be used to extend the lifetime of nodes.

In Sadowski et al [9] a study was performed between three agricultural monitoring systems with solar energy harvesting capacities that use different wireless technologies: Wifi,

Zigbee and Lorawan. Four experiments were performed in roof research lab at the university of Guelph engineering building to measure the lifetime of sensor nodes per example: soil moisture sensor. The first one does not use energy harvesting to evaluate the performance of nodes's battery alone, the remaining experiments used solar energy and were conducted in different time periods: August 2018, December 2018 and May 2019. The results of experiments showed that the system which uses Lorawan would be the best because its monitoring nodes consume less energy and last longer than the other ones. In addition solar energy harvesting extends the lifetime of the system especially during the month of august when the lifetime of the system which uses Lorawan reaches 228.2h, The Zigbee system was the second best option with 104.8h, followed by the WiFi system with 28.3h.

Sharma et al [10] have proposed framework for smart agriculture monitoring using solar energy harvesting to maximize WSN network lifetime. They studied the problem by analyzing the performance of several data communication network layers, a batch experiment composed of 20 nodes, gateway node and a sensing agent, all used in Netsim network simulator. According to the results the WSN network lifetime increased from 575 to 115,75 days using solar energy harvesting. Thus the network energy consumption increased from 129,600 to 2,673,080 mJ. At the same time the performance of IEEE 802.15.4 standard (Number of packets transmitted) and network throughput has also increased: 31,45 times and 1,6 times respectively. Meanwhile the Number of packets dropped at routing layers decreased from 195,285 to 128,260. This paper shows the important role of solar energy harvesting in the maximization of WSN Network lifetime but at the same time we think that we have the ability to optimize the energy consumption of SEH-WSN nodes which will provide better results.

A study of the use of grid connected photovoltaic system in Algerian dairy farm is carried in [11]. This system is used without any batteries. The grid is used as a storage device of extra photovoltaic electricity that we need in periods where solar energy is not available. Lighting, milking, pumping and cooling of milk are the activities that consume electricity in this farm located in the region of Sebdou south of Tlemcen where the yearly solar irradiation is estimated at 1970 KWh/m<sup>2</sup>. After the use of computational program, artificial lighting and pumping were optimized and the farm became a producer of electricity with a profit of 29633 euro

instead of only consuming; which used to costs roughly 27017 euro; See Table 1.

Also; the produced milk increased by 8%. This system is considered like a paradigm shift in Algerian agriculture sector because of the increasing need for electricity, but we see the absence of a battery in photovoltaic system decreases the revenues resulting from electricity losses.

Due to significant global water shortages, water is urgently needed in all sectors, water has become urgently needed across all sectors especially for irrigation in agriculture, where provision of water became expensive and energy consuming process, Yang et al [12] elaborated a solar powered smart farm device made up of a container with a movable top cover, timer, motors, tracks, solar panel, control panel and cu-complex synthesized by a liaison feedback between the ethanollamine ligand and CuCl<sub>2</sub>·2H<sub>2</sub>O. The Cu-complex is in charge of harvesting atmospheric moisture during the night when the humidity is higher and during the day time, the solar radiation conducts the automated irrigation process without the need for electricity; See Table 2.

The experimental results showed that the combination of Cu-complex, graphite (G), carbon black (CB) and carbon nanotubes (CNT) improves the light absorption which increases the rate of water release. This smart farm device can help strengthen the urban agriculture like rooftop farming that would decrease the carbon emission and avoid bringing food supplies from remote rural areas.

We think that the only problem with this smart farm is automatic irrigation that might damage some plants, which don't need lots of water, that's why internet of things became an essential need which allows the synchronization process between all devices of the smart farm and irrigation control according to the soil and the need of each plant. Furthermore, the addition of water tank contributes in maintaining the water safety and the irrigation control process.

Saxena et al [13] introduced the efficiency of using the combination of wireless sensor networks (WSN), solar energy harvesting and internet of things (IoT) in

**Table 1** Difference between before and after optimization

	Before optimization	After optimization
Network energy consumption	136Kwh/day	22Kwh/day
Energy consumption from the grid	29,8Mwh/year	9,6Mwh/year
Amount of CO <sub>2</sub> emission	16t/year	5t/year

**Table 2** Cu-complex characteristics

Adsorption capacity	3.0 gg <sup>-1</sup>
Water production rate	2.4 gg <sup>-1</sup> h <sup>-1</sup>
Adsorption energy of one water molecule	-1.21 eV
Light absorption with major peak at 585 nm	0.15

agriculture field for several purposes such as boosting production in Indian agriculture sector, minimizing farmer efforts and maintaining the system functionality by charging sensors batteries with harvested energy. In this paper, the authors chose the solar energy because it's an inexhaustible source of energy, and they show it's power density in outdoors which is 15mW/cm<sup>2</sup> with 1,5 % efficiency, meanwhile the outdoor's power density at a cloudy day is estimated at 0,15 mW/cm<sup>2</sup> however indoor power density is worthless than 10 μW/cm<sup>2</sup>. Fig 1 shows the diagram of the presented work.

A surveillance system used in smart agriculture powered by solar energy harvesting is showcased in [14]. The hardware components of the system are shown in Table 3.

Sadowski et al. compared two prototypes, one of them uses solar energy harvesting to charge the sensor node battery. Figure 2 shows how the prototype works.

The experiments results show that the battery level of solar node and non-solar node decrease with similar levels over time. After 20 h the solar node battery level increases due to the energy provided by the solar panel. After 24 h, the battery level of non-solar node and solar node was 3.57V and 3.65V respectively. After 43 h, the non-solar sensor

Fig. 1 Block diagram of presented work

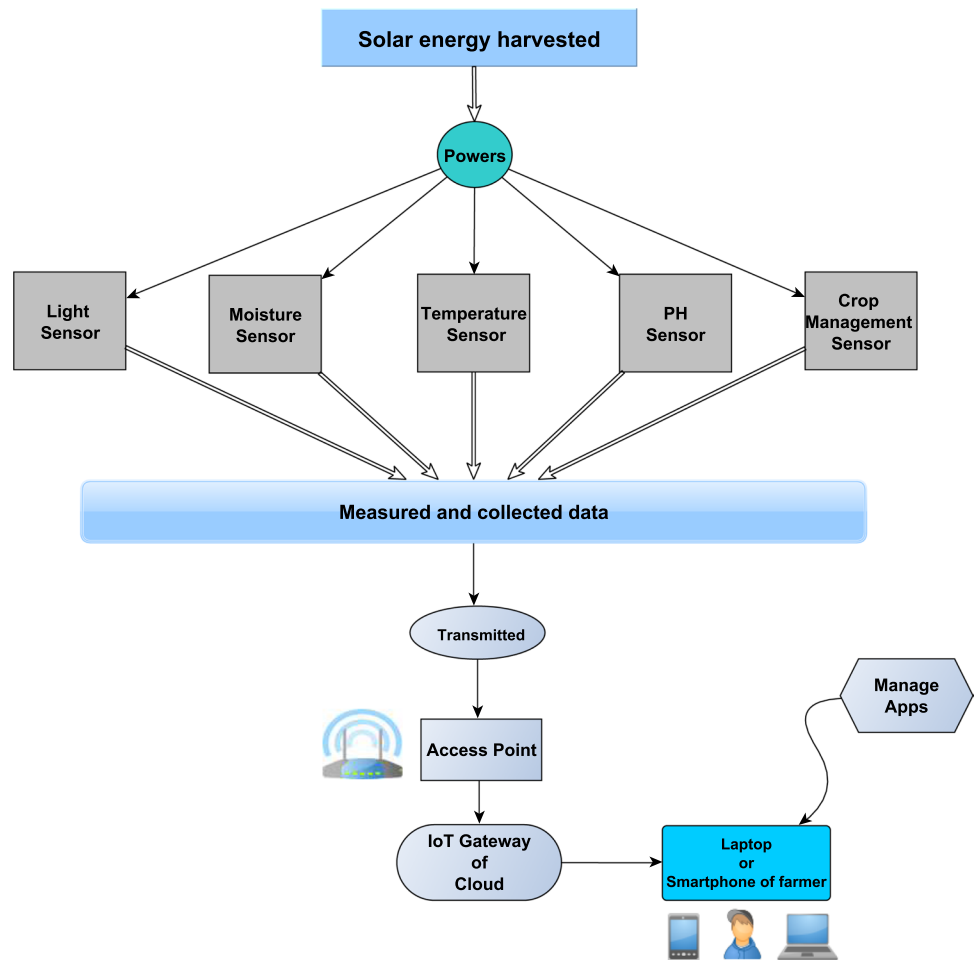
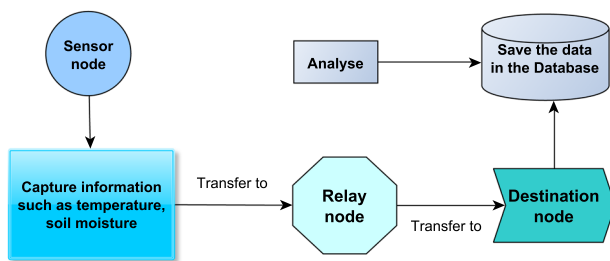


Table 3 The hardware components of the system

The components	Its role
Arduino uno	Connects all devices together
Series 2XBee with 2mW wire antenna	Wireless communications between devices
Soil moisture sensor	Measures the amount of water in the soil
DHT 22 temperature and humidity sensor	Measures temperatures and humidity in environment
Power converter	Responsible of charging the LIPO battery of the sensor node
Solar panel	Powers the system with solar energy harvesting



**Fig. 2** Block diagram showing the functioning of the prototype work

stopped functioning, but the solar sensor still had considerable voltage levels remaining in its battery. This confirms that the solar energy harvesting plays a significant role in extending the lifetime of sensor devices and the whole system, which permits to develop the agriculture applications and improve the agriculture yield.

The exploitation of dual-chip system for single cell photovoltaic energy harvesting was used in agriculture system; it is mentioned in [15]. The purpose of using this chip is to increase the photovoltaic input voltage from 300 to 600 mV by a maximum power point tracking (MPPT) and voltage regulation (VR) algorithms for an efficient use of produced energy by the photovoltaic panel which was imperfect energy source tied with climate change such as temperature and sun radiation. In addition, a dead time driver circuit reduces energy losses and NiMH battery is used as a reservoir device to ensure a steady energy supply to the wireless sensor devices regardless of the climate is. The simulation results show that the maximum power point tracking algorithm increased the tracking efficiency to 96.5 %. the strength conversion efficiency is estimated at 42.8 % from photovoltaic cell to a NiMH rechargeable battery and the conversion efficiency from NiMH battery to wireless sensor module and MCU rose into 97.2 %. This results show that the system has become more robust and sustainable.

A concept of wireless sensor network monitoring system that measures the temperature in greenhouses was introduced in [16], this system can save more energy compared to other systems because in addition to using the solar energy harvesting to power the wireless sensor network batteries, it also uses several equipments to reduce the energy consumption of the system. This system used MSP430F149 as microcontroller unit made by TI Company and used serial flash-AT45DB041B as data memory chip. In addition, a URF24L01 chip was used for wireless communications, its interval frequency band is between 2.4 and 2.5GHZ. ADS18B20 is a temperature humidity sensor used in this system, its interval temperature band is between  $-55^{\circ}$  and  $+125^{\circ}$ . All of those equipments are very carefully selected because they achieve the same objective, which is reducing system's energy consumption. In addition, the solar energy

harvested is used reasonably through the combination of energy management and energy transfer.

In [17] a new distributed CDS algorithm that extends the lifetime of wireless sensor network in precision agriculture was presented.

The SDSSEHA algorithm was compared with the APRCDS algorithm mentioned in [18] and with traditional flooding methods. The simulation results show that the FLD application with 30 nodes is expected to run for 21.969 min, the FLDH-30 has an estimated lifetime of 22.2253 min, APRCDS-30 and CDSSEHA-30 should function for 63.145 min, 151.032 min respectively. In addition, the comparison between those applications with 50 nodes show that the FLD-50 is capable of running for 23.686 min, meanwhile the FLDH-50 stopped after 24.093 min. The APRCDS functioned for 64.034 min and CDSSEHA-50 was able to last 117,014 min. On the other hand the energy consumption rate of FLD-30 and FLD-50 was 1001301,461 and 665528,611 mj/min respectively. The consumption rate of APRCDS-30 and APRCDS-50 is 139562,193 and 132718,010 mj/min respectively. CDSSEHA-30 and CDSSEHA-50 have the lowest energy consumption rate only at 71012,934 and 53813,839 mj/min respectively. From analysing, we conclude that the CDSSEHA is the optimal algorithm in term of increasing the lifetime of agriculture applications and decreasing the energy consumption rate.

## 2.2 Vibration Energy Harvesting

Mechanical energy can be found almost everywhere, making the conversion of mechanical energy from ambient vibration into electrical energy an interesting approach to powering wireless sensors. Mechanical energy harvesting means the conversion of mechanical energy into electricity using vibrations.

In [19] experiments are conducted to measure the vibration energy harvesting from a center pivot irrigation and a 4 wheeler in an agriculture test field in Nebraska, whose purpose is to extend the lifetime of wireless underground sensor networks (WUSNs). After theoretical study, the maximum harvestable piezoelectric power can be determined by the formula stated in Eq(1).

$$P_{max} = \frac{\omega^4(m^2)}{8c} \times \frac{|F_0|^2}{(K - \omega^2M)^2 + (\omega C)^2} e^{\beta\omega(-dh)} \quad (1)$$

Function generator, Power amplifier carver pm-600, vibration excited Bruel 4809 & Kjaer and 3 DLP-TILT-G sensors are used in the experiments. The First DLP-TILT-G is planted 20 cm deep, the second one at 40 cm and the third at a distance of 2 m from the first and planted at the same depth as the first one. The results of the experiments proved

that the 4 wheeler is better than center pivot irrigation as a source of vibration.

On the other hand the closest sensor to the vibration source captures the biggest amount of piezoelectric energy. We see that this study provides positive step in WUSN lifetime but it suffers from attenuation problems, which are found in the soil that decreases the frequency of output power.

### 2.3 Thermoelectric Energy Harvesting

Thermoelectric materials are capable of transforming a heat stream directly into electricity or vice versa.

A battery-less thermoelectric energy harvesting interface circuit was developed by Ramadass et al. [20] in order to extract electrical energy from the heat of the human body, Fig. 3 illustrates how it works.

The proper selection of thermoelectric sensor and conductor allows a maximum power transfer to happen instead of using a more complex power tracking loop, which is the advantage of this circuit but the negative part is that the thermoelectric harvester produces only 50 to 75 mV open circuit voltage, Therefore it's not possible to supply the CMOS circuit in the absence of a battery. So the use of a startup circuit with thermoelectric generator can solve the problem. This technique is an option to avoid the difficulties of replacing devices's batteries in emerging applications like wireless microsensors networks.

### 2.4 Piezoelectric Energy Harvesting

Piezoelectric materials can be used to convert oscillatory mechanical energy or ambient vibrations into electrical energy. This technology can generate electricity with minimal cost or effort from different renewable sources.

Piezoelectric sensors for energy regeneration installed on the wheels of an efficycle is reported in [21], mechanical stress is produced when the tire touches the ground, then the piezoelectric plate or sensors made from two metal plates and a lead zircoante titanate develop free electrons that are converted by a transducer to electricity that can be stored in the battery. Size and type of piezoelectric material (Quartz,PMN,PT,PZT) control the amount of current voltage and wattage. Those devices have a major role in energy harvesting applications when battery power is not available.

Scorciono et al. [22] have presented a wireless sensing system composed of a tractor and a farm implemented to improve safety in agriculture and to reduce accidents such as tractor overturns. They placed a Master device (MD) on a tractor and an End device(ED) on a farm implement,

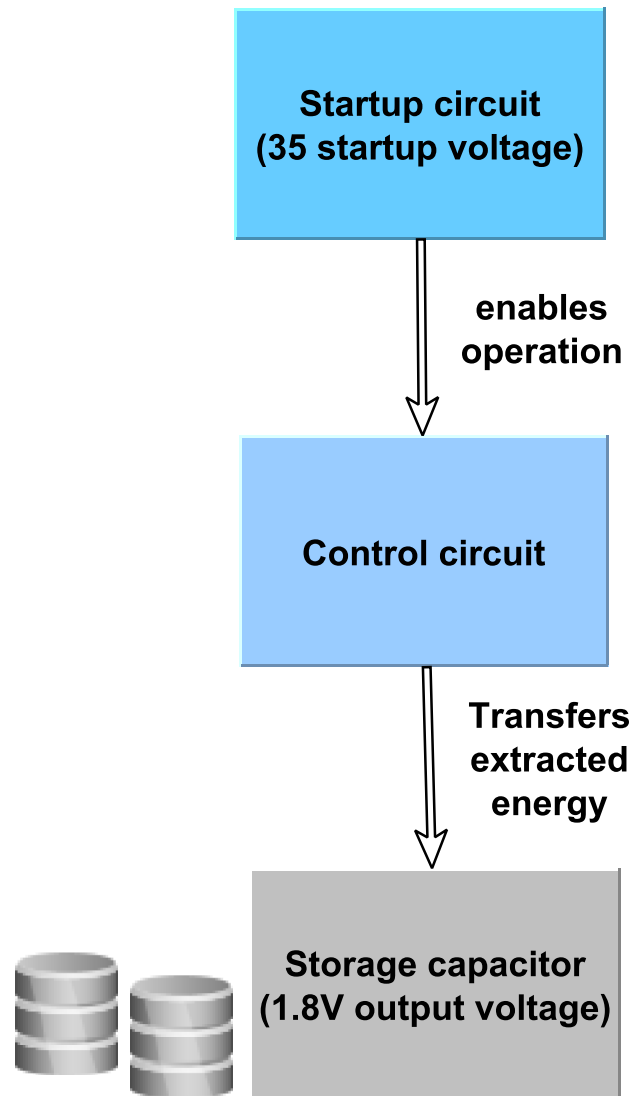
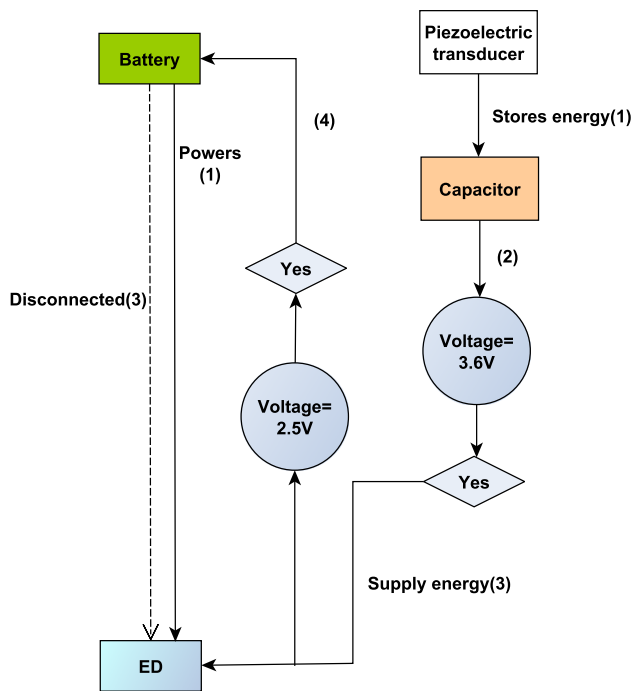


Fig. 3 Block diagram regeneration using thermoelectric energy harvesting interface circuit

both devices are responsible of the communications. The ED uses the vibrational energy harvester which allows charging an energy reservoir and extending the lifetime of the system. See Fig. 4.

According to the measurement results of the ED powered by the vibrational harvester, the charging time of the capacitor from 0V to 3,6 V when vibration strength is equal to 0.5, 1 and 2 is 2980 s, 426 s and 75 s respectively and the average power provided by the harvester module takes in order, the following values  $2.17 \neq w$ ,  $15.21 \neq w$ ,  $86.40 \neq w$ . The use of capacitor prevents the frequent charge and discharge of the battery but we see that the use of the battery after a long period of inactivity forms the loss of energy.



**Fig. 4** The process of charging the energy reservoir (capacitor and backup battery)

## 2.5 Chemical Energy Harvesting

Chemical energy harvesting is the process of converting oxygen and endogenous substances into electricity through electrochemical reactions.

Weiland [23] presented the operation of biogas production from biomass and energy crops in agriculture in Germany. Germany is the European country which is numerically estimated to have the largest amount of agricultural biogas plants such as maize silage, cereal residues and grass silage. Producing sustainable energy from organic wastes is an advanced method and an attractive investment in agriculture field. There are two methods in biogas production, the first one is wet fermentation which is a continuous operation and applicable for liquid, solid and pasty substrates, it also uses the vertical completely stirred tank fermenter. The second method is a discontinuous operation applicable only for solid substrates.

The generated biogas is used for in producing electricity that can power agricultural equipments such as sensors or can be used as a vehicle fuel for all sorts of machines like tractors. To use The biogas as a vehicle fuel the water content must be  $<32 \text{ mg/Nm}^3$ , the oxygen reach  $<0,5 \text{ vol } \%$ , the carbon dioxide  $<3 \text{ vol } \%$  and methane  $>96 \text{ vol } \%$ . The digestibility of biomass allows us to profit from ephemeral substances, thereby contributing significantly in energy saving for agriculture field.

**Table 4** PV module specification

Solar PV panel	ADL 100-12V
Standard testing condition(STC)	1000 W/m <sup>2</sup>
Current (A)	6:00 AM
Voltage (V)	22.5 V
Power (W)	100 W

## 2.6 Hybrid Energy Harvesting

As we have seen in the previous sections, there are several sources of energy harvesting for sensors, but in order to maximize the amount of the generated energy, it's more efficient to use hybrid harvesting because each technique has its weak points and hybridization will optimize the overall energy harvest.

Roh et al. [24] proposed a new ultrathin unified rain, wind and solar energy harvesting module that can be implemented in the applications of the internet of things to extend their lifetime. The UHM is composed of:

- Rain TENG: made of two indium tin oxide (ITO) under one fluorinated ethylene propylene (FEP).
- Wind TENG: made of PTFE film placed between two aluminum electrode plates with neodymium magnets.
- A Solar cellule with amorphous silicon.

This hybridization enhances energy production compared to solar energy harvesting used alone especially at night or cloudy weather and produces high frequency electricity, which is proven by the example that the use of solar cell only enables to turn on 2 green LEDs, meanwhile 8 LEDs are turned on using Rain TENG and 48 are turned on when using Wind TENG, but using all previous three (UHM) takes the number up to 62 LEDs. The UHM can be used as self-powered weather monitoring sensor in a smart farm, its advantage is self-cleaning made by rain TENG that eliminates the problem of pollution of solar cell, which decreases the electricity output, but the absence of storage equipment can cause many problems.

Shatar et al. [25] investigated in the efficiency of photovoltaic thermoelectric generator (PV-TEG) hybrid system to power LED lighting system for precision agriculture. This study shows the difference between using only the photovoltaic panel and the combination of PV and TEG. Table 4 shows the PV module output after a simulation.

The components of PV-TEG of this work are shown in Fig. 5.

The results show that the power produced from solar PV is available from 08 to 20 o'clock which is the time where the solar energy is available in the field of experimentations (Malaysia, with average daily solar irradiation from 4.21 to

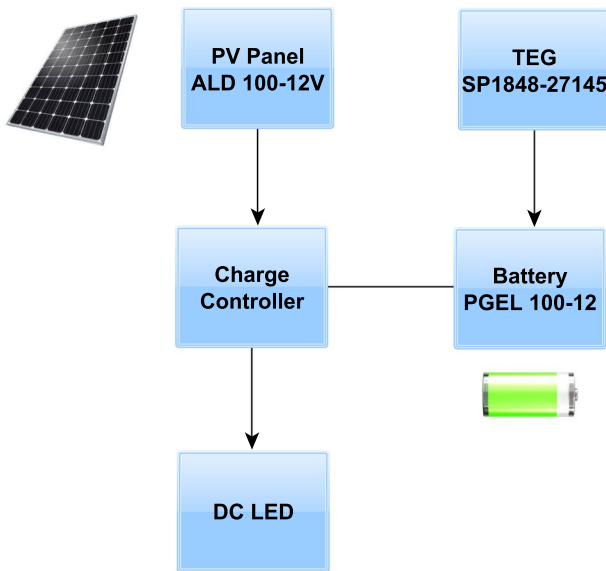


Fig. 5 Diagram of PV-TEG system

Table 5 Power amount of PV and hybrid system

System	Produced power
PV	37.6 Whr/24 h
PV-TEG	1110.88 Whr/24 h

5.56KWh/m<sup>2</sup>). On the contrary, the hybrid system generates constant energy for 24 h, where a battery bank is used during cloudy weather and night time. The results proved that the hybrid system (PV-TEG) increases the power production with 3.4 %, compared to only PV system, See Table 5.

### 3 Discussion

Wireless sensor networks energy preservation and lifetime remains a major obstacle in preserving the proper functioning of agricultural monitoring systems. The use of energy harvesting such as solar energy, thermoelectric energy, wind energy, vibration energy and piezoelectric energy contributed significantly to alleviate the issue by extending the lifetime of the systems.

The harvested Energy is used by the sensors either directly or through a battery, the difference between the two is that the battery works as an energy reservoir, that can be used at time where we suffer from a lack of energy.

We conclude from the researches mentioned in this survey that using a battery is better because it extends the lifetime of the sensors. All these elements contribute to ensure a better system sustainability. In addition, the energy harvested contributes in disposing the periodic replacement of the sensors batteries. After the examination of all the researches,

which we have mentioned, we noticed that the solar energy harvesting is more common and suitable technique compared to the others in agriculture field.

Solar energy is considered as an inexhaustible source of energy because it is available every day, the cost of solar energy panels installation and maintenance is decreasing day by day thanks to its high public support and low carbon emission. Besides, the solar cell systems have a long life span of about 25 years. We noticed that the internet of things (IOT) contributes in developing the agriculture field significantly, it facilitates the farmers job by allowing them to monitor their farms and products in real-time remotely like irrigation, fertilization and avoiding some problems through advance prediction IoT optimizes the amount of water, energy, pesticides and fertilizer used in traditional agriculture.

Also, renewable energy reduces power expenses and environmental pollution that was being caused by the excessive use of fuel. In conclusion, combining renewable energy with IOT forms a massive transition in the field of agriculture which takes it into an entirely other level. This section can provide recommendations to help researches in future works.

### 4 Conclusion

Precision agriculture has gained impetus in recent years because of the benefits it provides to the farmers such as improving working comfort, improving crop management and optimizing yield and production cost. This field suffers from power supply, which can be resolved by using energy harvesting techniques that increase the efficiency, reduce the cost and increase profitability. That immediately motivated us to get involved in this field.

In this paper, various sources of energy harvesting for wireless sensor network applications in agriculture field are collected and discussed and it took us time and effort to construct it in this form. We had to investigate and consult several papers because the subject is quite new. Also in our work we have gathered several aspects such as energy harvesting, precision agriculture, renewable energies to be able to draw up this paper which constitutes an interesting source of data to the researchers of the mentioned fields, but also in other fields.

### 5 Future Works

We are working on the optimization of the use of energy harvested by wireless sensor networks in agriculture field by using weather forecasting. The data collected allows us to minimise the energy consumption especially in days where renewable energy is not available, it also enables us to



maximize the wireless sensor network even more, improve the field farther and value the energy harvested.

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## Declarations

**Conflict of interest** The authors declare that they have no competing interests.

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**Consent to participate** Not applicable.

**Consent for publication** Not applicable.

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