Sources for energy harvesting: benefits and drawbacks

This paper provides a highlight of the benefits and drawbacks for energy harvesting from four renewable energies (**solar**, **thermal**, **kinetic**/vibration and **electromagnetic**/RF). Energy harvesting is a way to obtain through a converter electrical energy already available in the environment in another form.

Perhaps the most famous example of energy harvesting is the use of **solar** energy, where a photovoltaic cell is the energy harvester.

Solar energy harvesting	
PROS	CONS
Found everywhere: Green, renewable, abundant and efficient source in the environment (outside), where most mechanical systems are located.	**Non-uniform:** Sunlight is crucially affected by the region, weather and length of day. Artificial light has little correlation with these factors, but its illumination level is several orders of magnitude lower than that of sunlight.
Control of its conversion: through the photovoltaic technique.	**Inconstant availability:** the direct use of electricity generated by photovoltaic cells or panels leads to low efficiency and inconvenience.
Can be stored: rechargeable batteries can be used to store solar energy for many applications.	**Medium conversion efficiency**: instability, time-variance and regional restriction, inevitably affect the conversion efficiency.
Suitable for outdoor use: it is undeniable that light energy harvesting is a feasible way to power machine condition monitoring systems with low noise.	**Not suitable for indoor use:** only useful as a backup for other energy harvesting technologies for indoor machine condition monitoring.
	High cost: materials and installation for photovoltaic cells and batteries are significantly expensive.

Thermal energy harvesting can be divided in thermoelectric energy harvesting and pyroelectric energy harvesting, relying on the temperature changing over distance and time, respectively. We will focus on thermoelectric energy harvesting.

Thermal energy harvesting	
PROS	CONS
Well suited for widely wearable devices: because the human body is a constant heat source with a temperature difference with the ambient temperature most of the time.	**Low conversion efficiency**: since thermoelectric generator is a heat engine, its conversion efficiency is limited by the Carnot cycle efficiency. The generated power is usually insufficient for the requirements of devices.
No use of battery: contribute to clinical medicine through harvesting energy from the human body to support wearable electronics for health condition monitoring to avoid frequent battery replacement.	**Need a large temperature difference**: the temperature difference found in many machine systems is small, leading to small power gains.
Innovative technology: according to the advancement of the nanotechnology and fabrication techniques, numerous new promising nanomaterials and the optimization of structures and circuits have been investigated to improve the thermoelectric harvesters.	
Well suited for industry: because of the features of safety, reliability and durability, as well as the extensive existence of temperature difference, thermoelectric generators have been widely applied in vehicles, aerospace, ships and other industrial operations.	

Source : https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6308802/

Kinetic energy harvesting is another important technology where a vibration energy harvester is the corresponding transducer. It is not the most available in nature, but it can be a valid alternative to the solar one. Here we will see most specifically Piezoelectric Energy Harvesting. When piezoelectric material is subject to stress from environmental vibrations, it generates an AC voltage proportional to the applied stress.

Kinetic energy harvesting	
PROS	CONS
Adaptability: piezopolymers have been successfully utilized in the field of sensors, especially for biomedical sensors, because they are soft, deformable and lightweight.	**Low efficiency**: their conversion efficiency is relatively poor compared with piezoceramics.
Wide range of use: can harvest energy from ambient kinetic energy, such as water, wind and other mechanical vibrations.	**Complicated process**: the few suitable materials and the complicated fabrication process are the key problems that need to be solved before piezoelectric generators become an efficient commercial product.

RF energy harvesting devices can convert electromagnetic energy into a useful direct current (DC) voltage to power low-power consumer electronics and WSNs.

Electromagnetic energy harvesting	
PROS	CONS
Wide coverage of RF: RF energy harvesting is suitable for powering a larger number of devices distributed in a wide area.	**Limited energy with distance**: the energy carried in the far-field RF waveform is limited.
Suitable for indoor and outdoor applications: electromagnetic energy is usually captured from the ambient RF sources which generate high electromagnetic fields, like TV broadcast stations, radar stations, Wi-Fi routers, Bluetooth, global system for mobile communications (GSM) and other communication networks.	**Non-uniform**: the energy harvesting rate varies significantly depending on the source power and distance.

Source : https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6308802/