



Survey of Potential Energy Harvesting Solutions for use in the Built Environment

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What Is Energy Harvesting?

- Energy harvesting is the collection of ambient energy from the surrounding environment
- Ambient energy sources could be:
 - A by-product of another energy-using process
 - Energy intended to be used for another purpose
- The ambient energy sources can take a number of forms, dependant upon the local environment
- Energy harvesters are typically designed to operate from one specific form of energy

Why Use Energy Harvesting?

- Can provide an alternative to hard-wired or battery powered wireless sensors
- Potential for a almost perpetual green energy supply
- Can reduce system costs due to:
 - Reduction in installation costs
 - Reduced raw material requirements
 - Negation of need for service visits to replace batteries
- Reduced environmental impact as:
 - Production of hazardous waste by the need to regularly replace batteries is avoided
 - Quantity of materials used, such as copper, are significantly reduced compared to that needed for a fixed wiring installation

Energy Forms Available in the Built Environment

Within the built environment energy may be present in many forms:

- Light, from both natural and artificial sources
- Vibrational, from machinery or equipment
- Thermal, from heat from building elements and the HVAC system
- Air flows, from both natural and artificial sources
- Mechanical movements caused by interaction with the building occupants

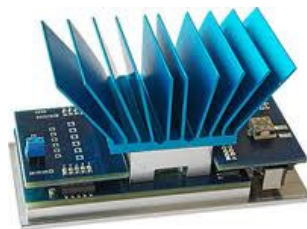
Types of Energy Harvester

For each of the potential energy sources in the ambient environment there are harvester technologies available, some examples are:

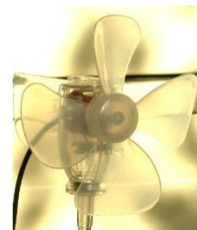
- Light – Solar cells
- Vibrational – Electromagnetic harvesters
- Thermal – Thermoelectric harvesters
- Air Flows – Miniature turbines
- Mechanical – User powered devices



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Solar Energy Harvesting

- Typically accomplished using solar cells, which are a well established technology
- Available as solar modules with a wide range of output characteristics
- Solar modules are available optimised for differing operational conditions
 - Exterior specification modules:
 - High sensitivity to wavelengths present in natural light
 - Designed to operate under higher illumination levels
 - Indoor specification modules:
 - High sensitivity to wavelengths present in fluorescent and incandescent light sources
 - Designed to operate under lower illumination levels than the exterior specification modules

Vibrational Energy Harvesting

- Commercially available harvesters typically use either piezoelectric or electromagnetic energy conversion
- Many harvesters for use in the built environment are based on a resonant structure and are targeted at harmonics of the electricity supply frequency
- The energy harvester needs to be selected to suit the available source vibration, need to consider:
 - Vibration level
 - Primary vibration frequency
 - Frequency spectrum of the vibration



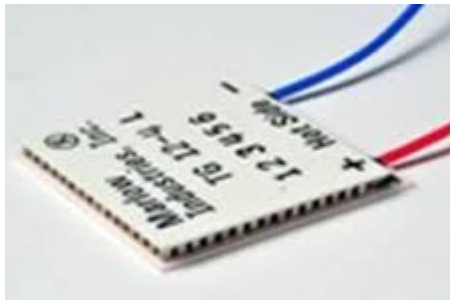
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Thermal Energy Harvesting

- Thermal harvesters are based on thermoelectric materials utilising the Seebeck effect
- Devices are available based on bulk ceramic materials and micro-fabricated silicon
- Operation is achieved by providing a thermal difference between the two sides of the device
- Output power is a function of thermal difference and number of thermopile junctions within the harvester



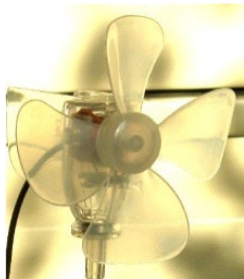
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Wind Energy

- Established technology that is widely available in many sizes
- Achievable through the use of mini- and micro-scale wind turbines in the built environment
- For successful operation the harvesters require a suitable air flow, possible installation locations are:
 - In the vicinity of air intakes or air circulation systems
 - Inside HVAC duct work
 - External mounting
- Can prove problematic to ensure a suitable air flow for the device within a building if not mounted in the HVAC system



Mechanical Energy

- These devices are used to transform energy from mechanical actions performed by a user to electrical energy, and are available in many forms and sizes
- An smaller sized example is the EnOcean switch:
 - Harvests energy from the switch action
 - This energy is used to transmit a radio signal reporting its status
- A larger scale example is the energy harvesting revolving door from Boon Edam:
 - Rotation of the door by the users provides the energy input
 - Harvested energy can be used to light the door and to power information displays



EnOcean



Boon Edam

Ambient Energy Surveys

- When specifying energy harvesting devices for use in a given built environment it is necessary to first survey the typical environment to assess what sources of energy are available
- Typical parameters that may be investigated and measured include:
 - Light levels
 - Temperature of the ambient air and any suitable thermal sources
 - Spectra and levels of vibration sources
 - Speeds and volumes of available air flows
 - Details of any repeated mechanical actions or user interactions

Energy Availability Considerations

As well as identifying the energy sources that are present in a deployment environment there are further considerations that may need to be taken into account to build a fuller picture of the ambient energy:

- The primary use of the space, and the activities performed within it
- The hours of use of the space
- Seasonal variations in the availability of the energy sources
- The environmental conditions preferred by the users or occupants of the space

Site Measurements

Within the TIBUCON project energy harvesting devices are being deployed through a variety of different environments in both residential and commercial buildings

- Prior to the deployments site surveys have been performed with the following environmental parameters recorded where applicable:

- Light levels
- Air and surface temperatures
- Vibration spectra
- Air flows

- Other details recorded are:

- Use of the space being surveyed
- Orientation of any exterior windows

Conclusions

- Energy harvesting can be applied to a range of potential deployment locations within the built environment
- A range of potential ambient energy sources have been identified including light, thermal and vibrational
- Energy harvesters are commercially available to harvest from a range of forms of ambient energy
- Within regularly occupied areas such as domestic living spaces and offices solar energy harvesting has been identified as the most commonly available energy harvesting modality
- Use of more than one form of energy harvesting increases reliability of the energy supply

Sensor



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