



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

P. Dymarski, N. Grabham, S. Beeby, M. Tudor

# 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

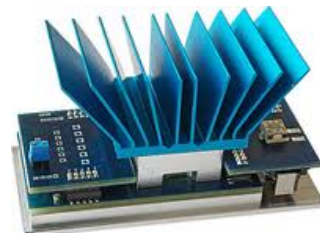
# Types of Energy Harvester

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

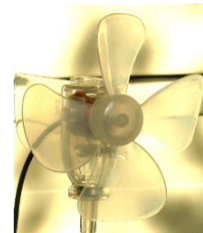
- Light – Solar cells
- Vibrational – Electromagnetic harvesters
- Thermal – Thermoelectric harvesters
- Air Flows – Miniature turbines
- Mechanical – User powered devices



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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



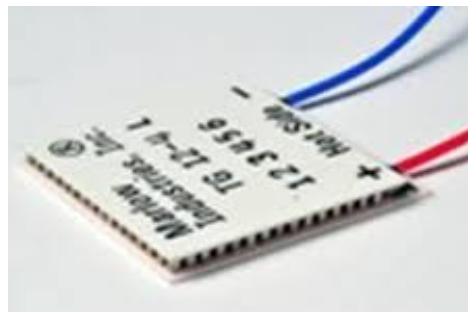
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# Thermal Energy Harvesting

- 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



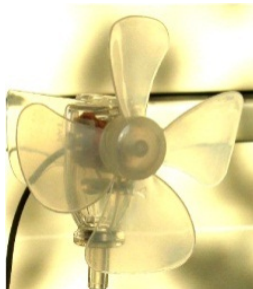
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# Wind Energy

- 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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