## THE MASDAR PIEZO OASIS

In a barren landscape springs a cluster of trees, leaves and fronds swaying in the wind. Oases are a source of life-giving resources, places of shade and respite, opportunities for calm and contemplation.

This oasis in Masdar converts a site in Masdar into an oasis that provides energy. Shaded by the branches and leaves, the ground plane echoes traditional gardens while overhead piezo harvesters gather energy from the movement of air. This is a piezo oasis, translating the natural form into an urban experience with the aid of piezo technology.

The installation consists of 207 trees, each square section branches on which leaves are on all four sides. Each leaf is composed of three piezoceramic harvesters that oscillate in the wind, generating energy. The design has been tested as a proof of concept and shown to deliver adequate outputs. The technology and the details of the design are presented below.

## ENERGY HARVESTING

Energy harvesting technology has the ability to capture ambient energy from the surrounding environment, providing a renewable source of power, such as photovoltaic panels, thermoelectric and kinetics. They bring electricity generation within urbanised areas close to the place of consumption and have challenged the way spaces are designed and experienced by providing new scales at which power has been generated, distributed and consumed, reducing the environmental impact and enhancing access.

Whereas some of the energy harvesting technologies introduced in cities, such as photovoltaic panels and wind turbines, are usually considered to have a broader urban scale of impact, for instance capable of providing household power; the energy harvested by sensor technology coming from kinetics can be measured at a smaller scale, ranging between mill-watt to many watt levels of power, depending on the system.

The micro scale implementation of energy harvesting sensor technology has been well researched and evaluated in recent years as low-powered devices (LED lights, mobile phones, laptops etc.) have grown in use. This project demonstrates an implementation in urban space, challenging the level of interaction of the individual with the infrastructure in place.

## PIEZOELECTRIC SENSOR TECHNOLOGY

Piezoelectric technology generates voltage when deformed; specifically, piezoelectricity is the electric polarization in a substance resulting from the application of mechanical stress. Piezoelectric energy harvesting makes use of the direct piezoelectric effect when a deformation of the piezoceramic component is used for generating energy. In this application, the wind deforms the harvesting panel (as used in the leaf of the tree) and energy is generated. The variation in wind and the flow of air over the deforming surface create a flutter, as you observe in leaves of natural trees.

Advancements in piezoelectric technology has focussed on piezoelectric materials and sensors. All piezoelectric sensors for applications in the electronics industry require two phases of design: operational principle and optimal operation, and stability of the operation device against environmental effects, such as temperature changes. There are over two hundred piezoelectric materials that could be used for energy harvesting sensors, with the appropriate ones being selected for each application. Therefore, for our installation we suggest using piezoceramics because of environmental conditions and high temperatures experienced in this site.

## PROOF OF CONCEPT

Before proposing this technology, we have built a proof-of-concept installation. The piezoceramic harvester and actuator was obtained from a leading manufacturer and installed with their engineering assistance. It was pinned to a piece of soft wood (pine), sandwiched between two layers of acrylic. The sensor was clamped evenly, holding it in place without putting any stress on the electrical connections. An oscilloscope was used to initially measure the voltage output. From preliminary tests, it was clear that there was no need to actuate the sensor directly to generate power output, but vibrations from the surrounding environment were enough to deliver energy. We experimented with different circuits in order to maximize energy output. With an improved new circuit, the oscillation needed to provide energy to an LED was only 2 mm. This experimental configuration satisfied as a proof of concept from which we could scale up.

## THE TREE

The installation consists of trees with branches and leaves that sway in the wind. The tree and its branches are constructed of laminate timber. The main trunk is a 440mm x 440mm column standing 19.2m tall. From this spring branches with a square section of 220mm, ranging from 10m to 18m long. Leaves consisting of three piezo harvesters each are attached along these branches; the actuators and wiring are housed within.

## THE OASIS

The oasis is a grove of 207 trees arrayed across the site, aligned on the diagonal to the prevailing wind directions. A mosaic tile ground plane is configured with geometries and a water course provides evaporative cooling. With the rustling leaves and flow of water the oasis will be a place of calm.

## MASDAR WIND AND PIEZOCERAMIC ENERGY

The next step in our investigation was to look at wind patterns around Masdar and see if there was enough wind to help them vibrate and if there were any problems with too much wind in order to make sure that the damage to the installation will be minimal. Our piezoceramics has been located on all four sides of the column in order to make sure that the wind from any direction is cached. If piezoceramics are activated on one side they will create a breeze which will allow piezoceramics on other sides of the column to be activated as well, therefore intensify possible energy production.

From the National Weather Station of Abu Dhabi, we find out that there are only few days in the year without a breeze or wind (wind charts below). Most of the year the average wind speed is between 10 to 15 mph with only stronger winds, not exceeding 25mph, in a few days of the year (March and April). Our calculation is therefore based on the piezo harvesters being active 80% of the year.

## ENERGY OUTPUT

The manufacturer of the piezoceramic harvesters informs us that 3,000 harvesters would be necessary to create 1Ws if moving together. The installation will consist of 8,525,004 harvesters, configured in sets of three to make one leaf. From these data, we estimate that the harvesters will comprise a nameplate power production of 1,400 kWh annually and expected to have a production of 1,100 kWh.

## THE COST

The proposed project will cost in the order of US$36 million.

## ENVIRONMENTAL IMPACT

The project will have positive impacts in creating shaded urban space, providing a calming environment and improving mental health. The materials in this project are largely timber, ceramic floor tiles and concrete in addition to the materials used in the electronics, including the piezo production and associated circuitry. The largest volume is laminated timber, is replenishable and recyclable, if sourced appropriately. Likewise, ceramic floor tiles can be sourced from low impact production processes and of recycled materials. The production of piezoceramics is challenging as performance still relies on toxic materials but when sourced from leading manufacturers the supply chain and production processes can be appropriately managed to minimise and mitigate harm. A project of this profile and scale is also an appropriate platform for research in novel and less harmful materials.