**“Downdraught”**

**Downdraught effect**

High rise developments are an inevitable part of an urban areas’ cityscape. They shape the heart of the city and are often landmarks. However, very often they cause strong, accelerated winds in their proximity and at street level.

As cities are building higher buildings, they are becoming increasingly more concerned with this problem as high-rise structures are exposed to higher altitude winds with higher velocity.

This phenomenon, which occurs primarily at the base of skyscrapers, is called the downdraught effect and it may be so strong to cause people to fall over and even knock signs off of the buildings.

In the downdraught effect the wind hits the building and depending on the shape of the building, is either pushed up, down, or towards the sides. The effect can be much stronger   
if the buildings’ orientation and elevation faces oncoming winds. 1, 5

**Tower and the energy production**

In the environment, wind velocity increases exponentially with height. The tower’s design takes advantage of this phenomenon and through its form harnesses stronger winds from higher altitudes and drags them towards the bottom to harvest energy.

The tower is an 85m-high, slender structure, with an orientation set according to the wind rose for St Kilda. The majority of winds in St Kilda come from the north and south, respectively- the northern and southern elevations are wider. The wide elevations face the prevailing winds. The design of the building is intended to push winds downwards, towards the base of the structure and into the wind tunnel.  
In the wind tunnel two types of energy harvesting machines are installed- piezoelectric flags and vertical wind turbines.

Piezoelectric flags are membranes consisting of rows of smaller flags, which cover the base of the building. They have optimal load resistance and in uniform wind conditions regular fluttering frequency happens. Flapping is restricted so that the visual effect of flags movement remains pleasant for pedestrians. The tower design utilizes the concept of inverted piezoelectric flags, which were researched by Hopkins Extreme Materials Institute at Johns Hopkins University in Baltimore, USA. This mechanism works in proper wind conditions and is extremely reliable. 2, 3

The Vertical wind turbines which are underneath the piezoelectric flags are installed horizontally in two rows. Turbines are positioned with a slight shift towards the upper row. This positioning enables each turbine to get direct wind energy.

The upper part of the elevation is equipped with canals which go to the opposite elevation (see section). Part of the wind energy which gets into canals, is lead to the opposite side where another set of energy harvesting machines is activated. In this way, even if the wind comes from one side, two opposite elevations can produce energy.

To achieve a more precise and condensed air flow on the elevation, the facade also has a distinctive structure which is inspired by whale’s skin. The surface of the elevation is covered with longitudinal, vertical stripes through which air is led downwards inside the channels between the stripes.

The elevations are designed to have more predictable wind conditions and minimize turbulence and changes in wind directions. It is necessary for efficient operation of the flags and wind turbines.

**Downdraught tower, promenade, event space**

The Project transforms St Kilda Triangle into a dynamic place for leisure, recreation and promenading. St Kilda’s Triangles’ landscape and topography was adapted and slightly elevated to create a promenade in conjunction with the bridge across Jacka Boulevard to offer direct connection to the beach, uninterrupted by traffic lights.

The new boulevard competes with the current most popular pedestrian connection to the beach which starts on the recreational portion of Acland street, goes through the parking lot on Shakespeare Grove, and crosses the traffic lights on Jacka Boulevard. The newly designed pedestrian route provides better traffic flow and a more comfortable connection to

entertainment areas like Acland Street, Luna Park, Palais Theatre with the beach.

The promenade’s curved shape includes an open event space which creates a comfortable setting for viewing performances. It also offers views of the bay which start at the Palais Theatre and continues to the beach unobstructed. Seating areas are integrated on the promenades’ sides which can be freely used by passers-by and simultaneously used to view cultural events like an amphitheatre.

**Tower**

The most distinctive part of the project is the tower with its aerodynamic shape for harvesting wind energy, and its sculptural design serves as a landmark for St Kilda.

The building is conceived as a mixed-use tower with a more multifaceted atmosphere around it.

**Experiencing the building**

The building wakes up curiosity in people and calls them to come closer.

Piezoelectric flags produce sound and movement with regular, periodic frequencies, imitating wind motion and provides for a more sensual experience.

Guests visiting the Palais Theatre can continue an evening by spending some time around the tower, observing the ocean, taking in the view, enjoying drinks and if they are lucky, see another performance on the stage opposite the tower. Everybody is welcomed around the tower- those dressed elegantly, the casually clothed and even those engaging in recreational activities. Some visitors are standing and the majority occupy the stairs.

It’s a dynamic mélange of different kinds of people, everybody is included.

The tower has a soft, organic shape, the base of the elevation is raised to reveal its inside, while, welcoming visitors. In the evenings stronger light is emitted from the entrance area which also attracts attention. Inside, a big atrium is conveniently arranged for guests to relax, meet new people, or see an exhibition. The environment enables social interaction and connectivity. If someone is tired they can enter the parking space located directly underneath the development and depart.

This design unifies nature with urban space and delivers harmonious scenery for differentiated creative initiatives. It aspires is to be memorable through its authentic and unique aura.

**Dimensions and list of the primary materials used in the design**

|  |  |
| --- | --- |
| Tensile roof structure over the promenade | Cable-supported tensile steel construction with attached PV modules;  length approx.=115m  width approx.= 5m - 22m |
| Piezoelectric flag | Membrane out of flexible piezoelectric polymer- PVDF;  total area =1695m² |
| Tower construction | [Reinforced concrete](http://www.madehow.com/knowledge/Reinforced_concrete.html), glass;  tower´s height= 85m (measured from the main entrance level)  tower´s width= 12m -14m\*  tower´s length= 18m - 20m\*  \*this does not include the base with piezoelectric flags |
| PV Modules | PV modules with translucent structure, transparency 50%;  total area = 2380m² |

**Technology used in the design**

Piezoelectric flags and vertical wind turbines arranged horizontally- to harvest wind from downdraught effect, additionally- PV modules

**Estimate of the annual kWh generated by the design**

**Simplified energy calculation**

In the project energy will be harvested from wind and sun in three ways:

1. from wind using piezoelectric flags
2. from wind using vertical wind turbines (in project arranged horizontally)
3. from sun using PV-modules
4. **Wind energy: piezoelectric flags**

Based on the work “Harvesting ambient wind energy with an inverted piezoelectric ﬂag” from Johns Hopkins University in Baltimore, USA, a speed of 10 m/s (~36 km/hr) will produce

~5 mW/cm^3 of power. 3

The calculations were done using the formula:

**volume x power x hours= annual energy generated by flag**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Flag’s  position | Flag´s area (m²) | Flag´s volume (m³)\* | Annual wind amount  hitting the building’s elevation (%) | Produced energy (MWh/year)\*\* |
| North | 426 | 8,5 | 32,74 | 121,68 |
| South | 631 | 12,5 | 33,21 | 181,81 |
| East | 247 | 5,5 | 11,7 | 27.9 |
| West | 401 | 8 | 22,2 | 77,8 |
| Sum: | | | | 409,2 |
| energy production doubled: wind hitting one elevation is additionally lead to the opposite elevation | | | | **~818,4** |

\*Assumed flag´s thickness=0,02m  
\*\*Assumed average wind speed within the tower´s wind canal =10m/s

1. **Wind energy: vertical wind turbines** (e.g manufacturer Windside4 / type WS-4, 18 items)

|  |  |  |  |
| --- | --- | --- | --- |
| Wind turbine’s position | Amount of wind turbines | Annual wind amounts hitting the building’s elevation (%) | Produced energy (MWh/year)\* |
| North | 6 | 32,74 | 21,805 |
| South | 6 | 33,21 | 22,118 |
| East | 3 | 11,7 | 3,896 |
| West | 3 | 22,2 | 7,393 |
| Sum: | | | 55,212 |
| energy production doubled: wind hitting one elevation is additionally lead to the opposite elevation | | | **~110** |

**\***Assumed average wind speed within the tower´s wind canal =10m/s

1. **Sun energy: PV-modules with 50% translucency**

The calculations were done using the formula6:

**E = A \* r \* H \* PR**

E = Energy

A = Total solar panel Area

r = solar panel yield

H = Annual average irradiation on tilted panels

PR = Performance ratio, coefficient for losses

|  |  |
| --- | --- |
| Assumed solar cell output efficiency | 10 % |
| Total solar panel area | 2380m² |
| Total power of the system | 238kWp |
| Energy produced | **267,59 MWh/year** |

**All systems together:**

|  |  |
| --- | --- |
| System | MWh/year |
| Piezoelectric flags | 818 |
| Wind turbines | 110 |
| PV-modules | 268 |
| = | **1196** |

**Total energy produced by the system= 1196 MWh/year**

**Environmental impact summary**

Design revitalizes the area and generates solar and wind energy.

The proposed 85-m high tower is the highest building in the surrounding area. Although the tower is tall, it has a slender construction that does not interfere with rest of the urban landscape, while still serving as a landmark for St Kilda. Furthermore, it also demonstrates an important point for the emerging pedestrian link connecting two sides of Jacka Blvd.

To maintain free views over Port Phillip Bay and to provide spaciousness of the area the tower has a relatively low footprint.

Topography of the terrain was adopted and slightly elevated to create a bridge connection to the beach. Existing slopes were converted into sitting steps and the parking area is hidden underneath the development.

The tower is an eco-friendly and energy-efficient building.

A large portion of energy used for heating, cooling, and lighting comes from renewable energies. Due to its height and form it can reach stronger winds to use them for energy production. The surroundings are favourable for catching winds because they consist of medium height buildings which do not interfere with wind circulation around the tower.

The average wind speed for St Kilda in 2018 was 20km/h. This was measured at the height of 6.4m (St Kilda Harbour Station- Number 86220). According to regular wind profiles for areas with mid-rise buildings and seas, at heights of 70-80m, the expected wind speed

is 25-35km/h. The building utilizes this power to create energy.

PV modules above the promenade harvest sun energy and protect pedestrians from the sun.

The tower´s primary energy production accounts for 1196 MWh/year which means that this mixed-use tower with a height of 85m would cut CO2 emissions by up to 70% in comparison to traditional high rise buildings.

Sources:

* + - 1. Baker, K., McLelland E., “Windy City! How down-draught from London's 'walkie talkie' skyscraper is blowing workers over and knocking signs off buildings in the Square Mile“, *MailOnline*, 22 July 2015, <http://www.dailymail.co.uk/news/article-3170313/Down-draught-walkie-talkie-skyscraper-blowing-workers-over.html#ixzz5C4jx6JZl> (accessed 1 March 2018).
      2. Orrego, S.*, Harvesting wind energy via piezoelectric flags*, [website],2018, <https://www.sorrego.com/energy-harvesting> (accessed 2 March 2018).
      3. Orrego, S. et al., “Harvesting ambient wind energy with an inverted piezoelectric ﬂag”, [*Applied Energy*](https://www.sciencedirect.com/science/journal/03062619)*,* [Volume 194](https://www.sciencedirect.com/science/journal/03062619/194/supp/C), 15 May 2017, p. 212-222.
      4. Oy Windside Production Ltd*,* [website],2018, <http://www.windside.com/products>, (accessed 2 April 2018).
      5. Parkinson, J., “The problem with the skyscraper wind effect”, *BBC News Magazine,* 9 July 2015, <http://www.bbc.com/news/magazine-33426889> (accessed 1 March 2018).
      6. [Photovoltaic-software.com](http://photovoltaic-software.com/), [website],2013-2018, http://photovoltaic-software.com/PV-solar-energy-calculation.php, (accessed 2 April 2018).