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Short Term Scientific Mission Report

COST Action:	TUD COST Action TU1304 WINERCOST "Wind energy technology reconsideration to enhance the concept of smart cities"
Reference Number:	COST-STSM-TU1304-32381
STSM Title:	Structural aspects of built-environment wind energy applications
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Host:	Professor Gülay Altay - askarg@boun.edu.tr
Host Institution:	Boğaziçi University, 34342 Bebek, Istanbul, Turkey
Period:	From 12/2/2016 to 21/2/2016

Thessaloniki, 21 March 2016

1. Summary

In the framework of TUD COST Action TU1304 "Wind energy technology reconsideration to enhance the concept of smart cities-WINERCOST", I had the opportunity to carry out a Short Term Scientific Mission at Boğaziçi University in Istanbul, Turkey from 12 February 2016 to 21 February 2016. Boğaziçi University in Istanbul was founded in 1863 as Robert College, the first US college to be established outside of USA. In 1971, it was integrated into the Turkish public university system as Boğaziçi University. Civil Engineering Department was founded in 1912 as a part of Robert College and possesses a prominent role, being one of the oldest departments of the University.

The STSM took place at the facilities of the Department of Civil Engineering and the host was Professor Dr Gülay Altay. In particular, the activity was carried out in two Campuses of the university, namely in South Campus (mainly) and Saritepe Campus. South Campus is the historical campus of Bogazici University, encompassing the oldest buildings of the University and is situated on a hill overlooking the Bosphorous and the fortress Rumeli Hisari, while the Saritepe Campus is 34 km North from South Campus, near Kilyos village, on the Black Sea coast.

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The aim of the research activity is to investigate structural aspects of the built-environment wind applications addressing safety issues of urban wind energy systems. In addition, the short term research activity focused on the creation of the framework for advancement of investigation of design parameters of built environment wind energy application, as well as on the configuration of a cooperation scheme between the two academic units (Institute of Metal Structures-Aristotle University of Thessaloniki and Department of Civil Engineering- Boğaziçi University) to develop further the subject of urban wind energy, addressing also additional aspects (financial, social, education).

A research work has been initiated to develop the aforementioned introductory study and produce results that will correspond directly to WINERCOST WG2B activity and possibly prepare a paper to be published in an international journal (indicatively, “Structural Safety”, “Renewable energy”) and a conference (indicatively, Eurosteel 2017, ICOSSAR 2017), in order to disseminate as broad as possible the particular scientific collaboration. The objective will be focused on building mounted systems, either roof and/or side mounted built environment wind turbines, where optimal siting and connectivity issues possess a significant role in design process. Regarding ground mounted standalone small scale wind turbines, we decided that they will be studied in the next stage. Towards further approach, an inventory of existing built-environment wind turbines (BWTs) is decided to be collected, so that studies can represent more realistically their behavior. This will be based on existing information from the open literature and commercial sources on internet, as well through personal communications with companies.

In view of structural design, dynamic behavior of BWTs and their interactions with buildings were identified as a major design concern and regarding resonance frequencies, studies have been launched on how the building-turbine vibrations are coupled. BWT vibrations will in general be much higher than natural frequencies of buildings and the workplan involves investigation of the linked building-turbine vibrations. Besides whole-building resonance frequencies, individual building components may be excited by urban wind energy systems’ vibrations. At Boğaziçi University in Istanbul, an extensive board of research activity and expertise on the dynamic analysis of structures and the seismic effects on buildings has been registered throughout the years, scientific fields that are important toward a more advanced analysis of urban wind energy systems’ behaviour. Therefore, courses and seminars were primarily conducted by Prof. Altay and other colleagues with respect to advanced seismic engineering analyses procedures, reliability issues and vibration effects on buildings.

Regarding safety issues, on the other hand, lower average wind speeds in the built environment may reduce one aspect of fatigue loads on BWTs. However, increased turbulence intensity and directional variability will increase another aspect of fatigue loads on a turbine, reducing its design life.

In view of related specifications, BWT system designs must comply with building codes, as well as to be integrated with the building's mechanical and electrical systems, so code (building codes in Europe, Turkey and USA) compliance is another issue that has been discussed and agreed to be clarified. Additional design aspects were introduced, such as the architectural integration of BWTs and their financial viability.

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2. Background and technological aspects

Introduction

As defined in the technical report-roadmap prepared by Smith et al. in 2012 for the US National Renewable Energy Laboratory (NREL), built environment wind turbines (BWTs) represent the wind energy production systems located in an urban or suburban environment. Most of these applications are also classified as small wind turbines (SWTs), therefore a more generic description would be "the application of small wind turbines within a built environment framework" (Smith et al. 2012).

As the industry is developing and the cost of small wind turbines is reduced, built-environment applications are becoming more attractive and approachable (James et al. 2010). In pursuit of energy independence and driven by environmental awareness, more and more people want renewable energy to enhance power for their homes or businesses have nowadays easier access to this technology. Many people are motivated by a desire to be environmentally responsible, and they want clean, renewable energy to help power their homes or businesses.

The field of urban wind energy may be still at primary stage, but gradually it exhibits significant growth rhythm and great potentials for wider utilization. Current data from industry as well recent research projects demonstrate that there are promising opportunities to integrate wind energy in the built environment in effectively. Indicatively, The United Kingdom, the Netherlands, and France participated in a large multi-country activity called Wind Energy Integration in the Urban Environment- WINEUR, where most of this work was completed in 2006 and 2007 (Wineur 2005). This program began by configuring the European Cities Urban Wind Network, a network of cities in which turbines were installed in the urban environment (http://www.urbanwind.net).

A remarkable growth in built-environment wind turbine unit sales has been registered in recent years. Indicatively, 1,074 roof-top units were installed in US market in 2010, representing an increase of 430% related to 2009 (AWEA 2011). At global scale, according to the 2015 small wind world report summary, the recorded small wind capacity installed worldwide has reached more than 755 MW as of the end of 2013. This represents a growth of more than 12% compared with 2012, when 678 MW were registered (WWEA 2015). The acknowledged easier consumer access to small wind turbines resulted in boosting sales and accelerating applications.

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Despite the ongoing technological and scientific progress, there are still a lot of issues to be addressed. Some of the key parameters to be clarified are the unique wind resources at urban terrain and their effect on energy yield, along with social acceptance and financial aspects. But the main concern and actually a prerequisite in order to produce a viable renewable system is safety, referring to structural aspects of turbine applications' design and their interaction with buildings. The present activity aims to enrich the knowledge basis on safety issues of urban wind energy applications, to investigate thoroughly the structural design aspects of such systems as well as their interaction effects with buildings. It intends to identify and highlight the parameters that a design process shall take into account, attempting thus to address in depth the respective structural issues.

BWTs: Wind turbines, installations and special characteristics

Built-environment wind turbines are small wind turbines (SWTs) with capacity of 100 kilowatts (kW) or less. The most common sizes are between 1 and 3 kW of rated output, which correspond to a rotor diameter of approximately 2 to 4 m for horizontal-axis wind turbines (Gagliano et al. 2012).

There are two types, namely the horizontal axis wind turbines (HAWTs) and the vertical axis wind turbines (VAWTs). HAWTs constitute the major type in use today for large turbines and have received a lot of attention from research and commercial sectors. This is mainly because VAWTs are less efficient than HAWTs and major problems may arise to handle the static and dynamic loads for large-size applications. HAWTs have a high efficiency and demand a small amount of material. They are normally located at homogenous sites with high wind speeds and operate with a tip speed that is several times faster than the prevailing wind speed. The HAWT is designed to operate with the axis of rotation turned into the mean wind direction, otherwise it loses much of its efficiency. This design is therefore not very convenient in complex environments with gusty winds and rapid wind direction changes.

Much historical developments of wind turbine technology have focused on HAWTs, although VAWT machines may be more appropriate to the urban context (Walker 2011). VAWT technology has some distinctive features that could make it attractive for smaller size applications, especially when complex flow patterns occur, like at a rooftop or for building-integrated solutions. VAWTs do not require any yaw mechanism, pitch regulation or gearbox; they have few movable parts and, therefore, lower maintenance costs. Recent applications of VAWTs provide even better results than horizontal ones, as they use all the different directions of wind flow and are quieter in operation. The type designs include Savonius, Darrieus and Hrotor. In general, VAWTs can produce electrical energy in separate units or they can be used as an integrated system for connecting with an electrical network. Although VAWTs have shown to have advantages over HAWTs, their installation heights are limited and their blades are prone to cyclic fatigue. For large-scale turbines, the market has converged on the three-bladed horizontal axis turbine as the right way forward for multi-megawatt turbines. Furthermore, the main manufacturers now only produce these types and so there is little option for most to opt for large scale VAWTs. One interesting advantage of VAWTs is that blades can have a constant shape along their length and, unlike HAWTs, there is no need in twisting the blade as every section of the blade is subjected to the same wind speed. This allows an easier design, fabrication and replication of the blade which can influence in a cost reduction and is one of the main reasons to design the wind turbine with this rotor configuration. Moreover, there are two ways of extracting the energy from the wind depending on the main aerodynamic forces used. The drag type takes less energy from the wind but has a higher torque and is used for mechanical applications as pumping water. The most representative model of drag-type VAWTs is the Savonius. The lift type uses an aerodynamic airfoil to create a lift force, they can move quicker than the wind flow and the most representative model of a lift-type VAWT is the Darrieus turbine.

Figure. 1. VAWT-HAWT

Vertical axis wind turbines (VAWTs) consist of curved or straight rotor blades which rotate around a central column that is mounted to the ground. The rotor diameter is measured as the horizontal distance between the blades. All mechanical and electrical components are placed on the ground, which makes maintenance more convenient. No tower is needed, which has economic benefits but with the disadvantage that it is therefore operating closer to the ground where wind speeds are lower and the shear in the vertical wind profile is larger.

The blades of the wind turbines are preferably made of a light but strong material with a low rotational inertia and thus a quick acceleration so that the tip speed ratio3 can be maintained nearly constant, even in gusty conditions. The larger the blades, the more important it is to keep the blade weight under control. All wind turbines are a source of noise emissions of different character and intensity and at different frequencies that is spread in the nearby area. The rotation of the blades through the air gives rise to a sweeping sound and in some constructions the cogwheels in the gearbox emits a humming noise that is amplified through the tower of the wind turbine. The noise level decreases with distance due to geometrical spreading, weather effects and dampening effects by vegetation or buildings as well as the atmosphere itself. The effect of the latter on sound propagation is dependent on atmospheric stability and wind direction. But the noises can also be minimized by installing damping systems that produce counter vibrations. One problem is that modern wind turbines change their rotational speed depending on the wind speed, producing noise at varying frequencies. Older versions of the damping systems only produce certain counter frequencies but modifications of these damping systems are under development. The new versions detect the varying frequencies of the sound and produces negative, dampening vibrations at those frequencies (Fraunhofer-Gesellschaft, 2008).

In the research work by Pagnini et al. an experimental analysis of two small size wind turbines with the same rated power, placed in the same urban environment and realized with vertical and horizontal axis, respectively, Fig. 2 (Pagnini et al. 2015). The HAWT was a three-bladed turbine with an up-wind 10 m diameter rotor and the VAWT, is an H-rotor turbine having 8 m diameter and 5.8 m height. The rated power was 20 kW for the turbines and according to the manufacturers the power curves supplied by the manufacturers. The analysis showed that the overall energy production of the HAWT is higher than that of the VAWT.

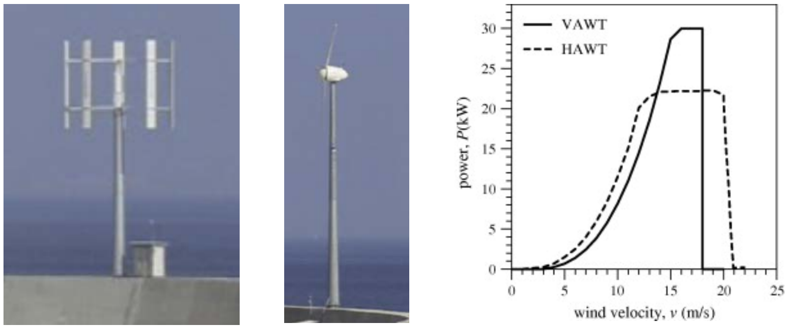

Figure. 2. Examined wind turbines- Manufacturer’s power curves (Pagnini et al. 2015)

There are three basic types of built-environment installations:

- Building mounted wind turbines (roof, side)
- Ground mounted wind turbines - Standalone small scale wind turbines
- Building integrated (or Building augmented) wind turbines

The majority of built-environment wind applications are roof-mounted small wind turbines with a rated power of 10 kW or less, see Figure 3a. In case of a conventional horizontal axis wind turbine (HAWT), the rotor diameter is less than approximately 7m. Besides HAWTs, several horizontal axis wind turbines (VAWTs) have gained public interest, and some manufacturers market their VAWTs for urban and suburban installations. Small wind turbines can be safe and reliable. Installing them on towers tall enough to place them well above any nearby obstacles, increases production and reduces turbulence-induced loads. However, according to Stankovic et al. and their research on urban wind energy, home-mounted wind turbines require a relatively high level of knowledge and investment in time in order to avoid unnecessary complications and poor energy yields (Stankovic et al. 2009). This includes understanding key issues such as predicting available wind resources, avoiding turbulence, mitigating environmental impacts, preventing structural damage and understanding the economic aspects. It will also often involve applying for grants, obtaining planning permission, dealing with the production of the electricity (e.g. selling to the grid) as well as maintenance issues.

Another option is the erection of a standalone wind energy unit within the urban environment, see Figure 3b. A free-standing urban wind turbine can be a relatively simple option as it can be procured in an ‘off-the-shelf’ manner suitable for developers, investors, energy service companies and community schemes. If the impacts of installing wind energy are demonstrably low and local wind resources demonstrably high, a stand-alone wind turbine offers a very real means of addressing concerns such as energy security, pollution, and of course cli-mate change while producing an attractive source of income. In addition, ground-mounted turbines require consideration for installing and raising the turbine as well as decreased production due to the poor wind resource found in the urban environment.

One of the approaches being used, and investigated more frequently, is the incorporation of wind turbines into the design of the building (Figure 3c). Wind turbines located at the high wind speed zones in buildings are called Building Integrated Wind Turbines or Building Augmented Wind Turbines (BAWTs), and the wind turbine makes use of buildings as a concentrator of wind. For retrofit applications can only be positioned to invest any augmentation afforded by the existing building (Megahed 2013). Based on air naturally flows from areas of high pressure to areas of low pressure, the most effective locations for wind turbines will be either in the accelerated shear layers around the edge and top of the building, or in specially developed passages linking the areas of positive and negative pressure.

Building-integrated turbines are limited to new developments in relatively windy areas and will have natural constraints in the size of turbines they can accommodate. The vision behind integrating a turbine into a building, in some cases, is perhaps less a practical solution to be widely adopted than an architectural and cultural statement. The role of the architect is very significant in configuring the building in an aerodynamic, while the value of the possible cultural benefits should not be underestimated as architecture simultaneously reflects and influences culture and cultural changes. Having these powerful dynamic symbols integrated directly into the heart of urban communities could have positive effects in terms of environmental action (e.g. homeowners improving energy efficiency or engaging directly in renewable energy). Despite their limitations that influence their wider applicability, these types of built-environment applications are still at primary stage and efforts are ongoing in order to become viable.

a) Roof mounted wind turbines b) Ground mounted wind turbines c) Building integrated wind turbines

Figure 3. Types of built-environment wind applications

Safety issues- Design parameters- Structural aspects

BWTs are installed on or in close proximity to buildings, people, and other property, so a catastrophic failure could damage property, injure people, and tarnish the wind industry's image, This can cause uncertainty and negativity referring to urban wind energy, therefore the need to address safety issues is imperative and from structural point of view, built-environment wind turbines have not yet been thoroughly investigated.

Small wind turbines are often sited in more complex environments than the open terrain sites assumed in relevant installation guidelines or in the international small wind turbine design standard IEC61400-2. The built environment is an example of such a complex environment and most small wind turbines are not designed for a roof, built environment, or urban setting because anything blocking the wind in the dominant wind direction creates high turbulence—the most difficult wind condition for all wind turbines of all sizes.

The wind resource in the built environment is characterized by large differences existing among sites with small vertical or horizontal separation. Better understanding of the urban wind resource is critical to define the wind actions imposed on the urban wind systems. Besides average wind speed, turbulence and directional variability are also important. Because of the surrounding structures, the built environment has higher turbulence and directional variability than rural environments. Unfortunately, only rough estimates exist for turbulence intensity, and even fewer exist for directional variability. With respect to the loading framework, higher turbulence causes higher stresses on the systems that can lead to potentially inadequate design and eventually reduced performance. Issues arise regarding the accuracy of the loads provided by manufacturers so far and whether the appropriate load combination for design is considered during design stage and if loads distribution to the support points is achieved.

Flows around buildings are inherently complex, see Figure 4. At first the topology of the terrain in the oncoming direction of the wind determines the local wind structure in terms of average wind speed; vertical gradient and turbulence intensity. Secondly the topology of the building itself and of adjacent buildings will determine the local structure. The optimal position of a wind turbine on a roof of a building is to be placed it above the turbulence layer. The wind turbine must be placed as closer as to the edge of the roof for the prevailing wind. The height plays important role as a lower height is a major advantage for a WT placed near the roof's edge and also from the prospective of height restrictions and costs.Proximity to people and property may create additional zoning and permitting issues. If these policies are crafted well, they will reduce hazards to personnel installing and servicing BWTs and will facilitate BWT installations. However, poorly informed zoning and permitting policies will create a barrier for BWTs.

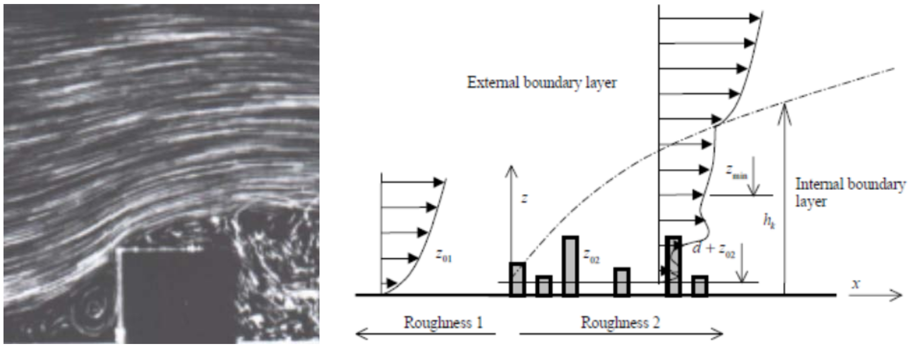

Figure 4. Wind flow within urban environment

When designing a wind turbine, careful consideration needs to be taken on safety and quality in order to reach operational reliability and durability. For that task, the IEC standards provide valuable guidance to the wind turbine designer of how these requirements are fulfilled. One critical requirement for small wind turbines is to be able to withstand a variety of external wind conditions, including turbulence, which will add both transient and fatigue loading on the construction. In the IEC International standard 61400-2 (from 2006), four different standard SWT classes (I-IV) are defined to describe the external conditions of various types of sites. The standard SWT classes include information about reference wind speed, annual average wind speed and turbulence intensity, as given by Table 1.

	Small Wind Turbine Classes				
	I	II	III	IV	S
V_{ref} (m/s)	50	42.5	37.5	30	Values specified by the designer
V_{ave} (m/s)	10	8.5	7.5	6	
I_{15}	0.18	0.18	0.18	0.18	
a	2	2	2	2	

Table 1. 61400-2 SWT classes

These classes are in many ways similar to the classes defined for large wind turbines in IEC 61400-1 (IEC, 2005). Note that for special conditions, such as urban environments, it is possible for the wind turbine designer to define a class S with relevant parameters and models for that environment. External conditions primary refers to wind conditions, which can be divided into normal or extreme wind conditions, and will be presented below. Apart from these basic parameters, several other important parameters need to be specified, for example environmental conditions like temperature, lightning, icing and electrical load conditions like voltage and frequency deviations.

There is absence of guidelines for installing wind turbines in the built environment. International Energy Agency (IEA) with its Task 27 has started to develop recommended guidelines for wind turbine installation in built environments. The main goal of Task 27 is to offer the opportunity to share technical experience on measuring and modelling urban and per-urban wind resources and gain practical experiences with built-environment wind turbines. New issues found in this urban and periurban environment and its effect on wind resource assessment methodology and trends of impacted turbine performance. In this framework, a "Recommended Practice" guidance that provides information on micro-siting of small turbines in highly turbulent sites (urban/peri-urban settings, rooftops, forested areas, etc.) is getting prepared, while a preliminary vertical-axis wind turbine simplified load methodology, which should be validated and used in consideration of the fourth edition of IEC 61400-2 is being developed.

There is a lack of understanding regarding how the built-environment inflow conditions impact the fatigue life of BWTs. Lower average wind speeds in the built environment may reduce one aspect of fatigue loads on BWTs. However, increased turbulence intensity and directional variability will increase another aspect of fatigue loads on a turbine, reducing its design life. A better understanding of the fatigue issues in the built environment is required to remedy safety concerns.

Many BWTs are mounted to buildings, so interactions with buildings are a major design concern. Furthermore, whether they are attached to or detached from the building structure, BWT systems have electrical integration considerations. The barriers regarding building interactions are further complicated by the multitude of building types and locations. Concerns include also mounting the BWT on buildings. Dutton et al. (Dutton et al. 2005) describe building mounted wind turbines as physically linked to buildings where the building acts as a vertical post for positioning the wind turbine to exploit the desirable wind flow augmentation caused by the building.

In addition to its requirement to structurally support the wind turbine, the building should provide reduction in vibrations. All structures have a natural frequency of vibration, which can potentially control the design for tall buildings, long bridges, or structures subjected to dynamic loading, for example earthquakes or mechanical vibrations. In the case of wind turbines, it is important that the natural frequency of the structure is different from the rotor and blade-passing frequencies to avoid resonance and potential failure of the blades or structure due to large amplitude vibrations. The wind turbine natural frequency is dependent on the efficiency of the assumed support at the foundation level (DNV 2002). DNV states if the model used for analysis or calculations uses a fixed base, then the error in the natural frequency of the tower may be as large as 20%.

BWTs are dynamic systems that introduce vibrations into the structure on which they are mounted which in general are much higher than natural frequencies of buildings. Vibration and resonance remain an important consideration even if a wind turbine is dynamically balanced to such a balance specification that make them vibration free. Roof tops create turbulence that interferes with normal wind turbine operation. Even if sophisticated vibration dampening systems are added to the turbine to isolate it from the structure these will not be able to affect the turbulence that reduces the power production, as well as cause damage to the turbine. To avoid this, wind turbines would have to be installed on towers high above the roof, which practically has negative effects on costs and add to the installation complexity, reducing at the same time its safety. Moreover, blade shedding, turbine collapse are additional possible hazards. R/c roofs may be able to absorb part of the loads created be the wind turbine and its support structure (tower), but this is not valid in case of most wooden or metallic roofs. A concrete roof does not pose problems since its resonance frequency is low and is mass high. A resonance, when occurring, will not be noticeable. An unoccupied structure may bear the dynamic loads and vibrations but an occupied structure would be a significant disadvantage. Besides whole-building resonance frequencies, individual building components may be excited by BWT vibrations.

Concerns remain regarding excitation of resonance frequencies for buildings of different construction types and heights. Small wind turbines have rotational frequencies of several Hz. Resonance of the total building is thus only likely for low building heights. Fortunately, this seems no big problem since low buildings are not so interesting for integration of wind turbine and building as the average wind speed is small close to the earth’s surface. The eigenfrequencies of parts of the building are more likely to give problems. The eigenfrequencies of floors, walls, windows, etc., are considerable higher and small wind turbines induce frequencies that are able to cause resonance in parts of the building. Such resonance should be avoided by choosing very stiff support structures for the small wind turbines so that the eigenfrequency of the support structure is well above the induced frequencies by the small wind turbine. Conversely, there is interest in the effect of building vibrations on a BWT and its tower. An increased understanding of linked building-turbine vibrations is needed to remove this barrier.

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3. Parallel activity

Within the framework of the STSM, a visit to Boğaziçi University Kilyos Sarıtepe Campus was organised by Professor Altay and Professor Emre Otay (http://www.ce.boun.edu.tr/en/emreotay). Sarıtepe Campus is situated on the shores of the Black Sea with its 1.000.000 square meter land and has been given to Bogazici University by the Ministry of National Education in 1985 (Fig.5). The important aspect of this campus is that a wind turbine was installed as part of the Bogaziçi University Wind Power Plant (BÜRES) project (Fig. 6). It started to generate electricity on Dec. 27, 2014, making it the only campus in the world that meets the whole of its electricity demands from its own wind power plant. It is expected to save 1.5 million kilowatt-hours of energy generating 40 percent more than its annual electricity consumption and preventing 900 tons of carbon emissions thanks to its 1-MW wind turbine.

As the coordinator of the Sarıtepe Campus, Prof. Otay and his co-workers, his research team organised a presentation of the activities (completed and ongoing), where all research projects and results were thoroughly analysed. During this meeting, I also exchanged my knowledge on the wind energy field and I also introduced WINERCOST activities to this 15 member audience. Towards a more eco-friendly, sustainable and green campus, Prof. Otay stressed that in addition to renewable energy resources such as wind, solar, wave, biogas and geothermal energy, academic studies were also being conducted on energy storage and on the energy efficiency of the buildings of the Sarıtepe Campus.

Figure 5. Boğaziçi University Kilyos Sarıtepe Campus

Figure 6. Structure of 1-MW wind turbine

Furthermore, a meeting with Professor Altay and the Chair of the Department of Civil Engineering, Professor Hilmi Luş (http://www.ce.boun.edu.tr/en/hilmilus) was realized. We discussed on the opportunities to collaborate in terms of research activities that may result in joint publications or H2020 research proposals submissions. During this meeting, I had the chance to inform Prof. Luş about WINERCOST scientific work, the goals set and the outcomes so far. We exchanged useful information on the reliability analysis of wind energy structures and the special parameters of the respective urban applications.

In addition, in the framework of the STSM, another meeting with Professor Cem Avci (http://www.ce.boun.edu.tr/en/cemavci) and Prof. Zafer Öztürk from the Department of Industrial Engineering of Bogazici University was held. I had the chance to present the WINERCOST objectives, as well as to introduce them to built-environment wind energy applications. On the basis of the paper that I had submitted to WINERCOST 2016 Conference along with my co-authors Dr Efstathiades and Dr Cöcen, we discussed on the "Feasibility analysis" of such applications and set the foundation for addressing the issue adopting an integrating approach covering financial and social aspects, aside to technical parameters.

In parallel, a meeting with Istanbul International Centre for Energy and Climate (IICEC) was conducted. IICEC is a future-oriented independent research and policy center designed to conduct objective, high-quality economic and policy studies in energy and climate and I had the chance to inform them on WINERCOST activities and disseminate our results.

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As a conclusion, it is noteworthy to mention that the current Short Term Scientific Mission at the Boğaziçi University of Istanbul was successful since it provided me with knowledge on the analysis procedures and design parameters of urban wind energy systems, while defined the next steps of our collaborative work with Prof. Altay within the framework of WINERCOST WG2B activity. Furthermore, the STSM gave me the opportunity to make new valuable contacts and establish a communication-cooperation network aiming to adopt an integrated approach of built-environment wind applications, thus contributing efficiently also to WINERCOST WG3 objectives.

I would like to express my gratitude to Prof. Altay for accepting to host me at the Department of Civil Engineering of Boğaziçi University. I totally appreciate the valuable time and effort for configuring an holistic program on the investigation of the scientific objective, as well for her guidance and organization of the following stages of our joint research.

In addition, I would like to thank COST Association, TU1304 WINERCOST Core Group and Management Committee for providing me this unique opportunity to carry out the aforementioned STSM that not only enhanced my scientific background, but also assisted significantly the work process towards achieving the goals of the Action as they are described in the Memorandum of Understanding.

Sincerely yours,

Dr Evangelos Efthymiou