ANNUAL REPORT **2012**

Western

WindEEE Research Institute
Engineering, Energy & Environment

welcome to our first year

Preface

The Wind Engineering, Energy and Environment Research Institute (WindEEE RI) was established on July 1st, 2011 as a clear recognition of new opportunities related to the emergence of the novel WindEEE Dome facility and the extensive collaborations this mega-project has generated at Western (among several Faculties) and with Canadian and International partners. We are happy to present to you the first WindEEE Research Institute Annual Report.

At the first Annual Research Meeting (January 2012), two phases have been defined for the WindEEE RI development. Phase 1 was defined for years 0 to 5 and it has as its main objectives to:

i. Validate, Commission and Demonstrate the capacity of the WindEEE Dome;

ii. Establish the Membership, Governing and Fee Structures for the WindEEE Research Institute;

iii. Attract Industry-Academic Collaborations and

iv. Expand the National and International visibility of the Institute.

We are happy to report that all these aspects have been successfully addressed and significant progress has been made. By the end of 2012 a significant part of the CFI/ORF funded Construction Phase of the WindEEE Dome has been accomplished with the fabrication of the test chamber completed and ready for installation in 2013. At this point in time it is expected that the building construction will be finished by April 2013 and the commissioning of the WindEEE Dome will start by June 2013.

Three types of memberships have been created for the WindEEE Institute: Western, Canadian and International. We are happy to say that the membership list is continuously increasing and it counts approximately 20 Western researchers from several Western Engineering Departments (CEE, ECE and MME), the Ivey School of Business and the Faculty of Science. At the same time the Canadian and the International memberships are presently totalling more than 20 researchers. We are extremely happy to acknowledge the awarding of a new Canada Research Chair II in Wind Engineering to Dr. Girma Bitsuamlak, one of our Associate Directors. The Governing Structure of the Institute has been established and memberships for both the Advisory and the Scientific Committees have been discussed. We are happy to report that some high caliber researchers and personalities have already expressed their interest in joining the Institute's Committees. A fee structure is presently under development and it will be structured so that it can accommodate research from capacity demonstrator to industry-driven research and applications.

While the WindEEE Dome is still under final construction, a number of Industry-Academia funding opportunity are presently being secured. These opportunities also create a demonstration base for WindEEE and they presently include industry partners from several sectors: the Hydro Electric sector with interest in wind resilience of transmission line systems, the Insurance Industry sector with interest in tornado risk assessment, the Engineering Manufacture sector with interest in Urban Sustainability, the Automotive sector with interest in vehicle aerodynamics as well as the National Research Council with interest in wind environment studies. At the same time new CFI funding by Dr. Bitsuamlak has been secured, considerably expanding both the physical testing capacity at the WindEEE Dome and the computing capacity of the Institute.

An important effort during 2012 was to expand the National and International visibility of the Institute as part of the Western Internationalization program. Going Global funding has been secured through the Ministry of Foreign Affairs Canada and three European trips have been accomplished. As a result of this initiative, the European High Commission in Brussels has shown interest to qualify WindEEE as a Global Research Infrastructure in the context of the new Horizon 2020 EU Research Strategic Plan. This would ensure the opening of WindEEE to the exceptional researcher base in Europe, securing its future in the global research market.

A first step in obtaining the Global Research Infrastructure status is to obtain a "national" status. The first steps in this direction have been made with WindEEE being declared an Institute of National Importance by the NSERC Wind Energy Strategic Network (WESNet) and by the Wind Energy Institute of Canada (WEICan). In order to fulfill these high level expectations, grass root connections have been initiated and several Memorandums of Understanding have been signed with high profile Institutes in Germany and France

our vision
to be a global leader in wind research and innovation

our mandate
to make global contributions in building resilient and sustainable communities through multidisciplinary wind research, education and innovation

such as: Fraunhofer IWES and E.ON Research Center in Germany, Paris International Energy Institute (PIERI) in France or the DTU-Risoe Wind Energy Institute in Denmark. These efforts are presently complemented with similar initiatives in the Americas with Texas Tech University and University of Notre Dame as the first main collaborators in USA and Universidad Federal de Porto Allegre and Universidad Federal de Rio de Janeiro in Brazil.

I would like to thank Western and all its Departments from the President, Provost and Vice Presidents, to Research Services, Engineering, Financial Services, Facility Management, the Boundary Layer Wind Tunnel Laboratory and the University Machine Shop for their continuous support during the entire 2012 year. I would also like to thank our main contract partners (AIOLOS as the designer, NORR as the architects, ABB, LorDon, Mader as our main equipment providers and TONDA as our general contractor) for all their contributions and dedication to the project and the Institute during 2012.

At the research level I would like to acknowledge that none of these would have happen without the enthusiastic contribution made by our group of dedicated graduate students. Last but not least, I would like to thank to all my colleagues, staff and coworkers for their continuous support to the WindEEE Research Institute.

Horia Hangan

London, March, 2013

Organization

The **Governance Structure** needs to provide direction, innovative input and expert advice to the Institute in order to facilitate its development at Western and towards a National and International Institute.

Two external Committees are thought to provide the necessary inputs to the **Director of the Institute**: the Advisory and the Scientific Committees.

The **Advisory Committee** advises the Director of the Institute on the evolution of the wind engineering, energy and environment sectors, with a global perspective. The Advisory Committee also advises the Director on the general orientation of research and industrial trends in the areas of interest of the Institute; along with providing advice on potential sources of funding for the research, development and innovation program of the Institute. The Advisory Committee normally meets once a year usually at Western.

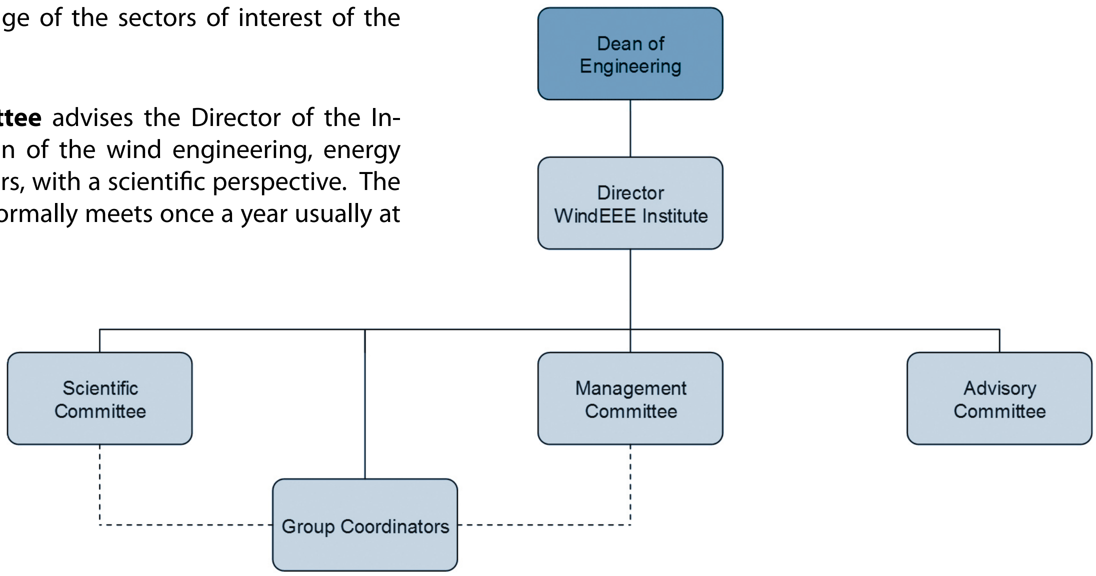
The Members of the Advisory Committee of the WindEEE Research Institute are nominated for two (2) year terms; this mandate can be renewed depending on the evolution of the sector and the expertise of the Members of the Advisory Committee; their contributions rely on their experiences, expertise and knowledge of the sectors of interest of the Institute

The **Scientific Committee** advises the Director of the Institute on the evolution of the wind engineering, energy and environment sectors, with a scientific perspective. The Scientific Committee normally meets once a year usually at Western.

The Members of the Scientific Committee of the WindEEE Research Institute are nominated for two (2) year terms; this mandate can be renewed depending on the evolution of the sector and the expertise of the Members of the Scientific Committee; their contributions rely on their scientific and technical experiences, expertise and knowledge of the sectors of interest of the Institute.

The **Management Committee** advises the Director of the Institute on management issues of the Institute. The Members of the Management Committee are Coordinators of the Wind Resilience and Wind Sustainability Groups as well as the Managers for Operations and IT.

The **Group Coordinators** act as a catalyst to expand the research and innovation programs of their Group, to assure that the research and innovation programs are well integrated within the Group



Team

Core Research Team

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Professor and Director WindEEE Research Institute,
Faculty of Engineering, Western University

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Associate Professor and Tier-2 CRC in Wind Engineering, Associate Director WindEEE Research Institute,
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Department of Mechanical and Materials Engineering, Western University

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Associate Professor, Department of Civil and Environmental Engineering, University of Windsor

Curran Crawford
Assistant Professor, Department of Mechanical Engineering, University of Victoria

Hanping Hong
Professor, Department of Civil and Environmental Engineering, Western University

Gregory Kopp
Professor, Department of Civil and Environmental Engineering, Western University

Christian Masson
Professor - CRC Tier 2 in Wind Turbine Aerodynamics, Département de génie mécanique,
Université du Québec - École de technologie supérieure

Stephen Mitchell
Associate Professor, Department of Forest Sciences, The University of British Columbia

Rajnikant Patel
Distinguished University Professor and Tier-1 Canada Research Chair, Department of Electrical and Computer Engineering,
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Andrew Pollard
Professor and Queen's Research Chair, Department of Mechanical and Materials Engineering, Queen's University

Affiliated Researchers

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Ashraf El Damatty
Professor and Chair, Department of Civil and Environmental Engineering, Western University

Hesham El Naggar
Professor and Dean Research, Western Engineering, Western University

Yves Gagnon
Professor and KC Irving Chair in Sustainable Development, Universite de Moncton

Mark Glauser
Professor, and Dean Research, Department of Mechanical Engineering, Syracuse University

Guy Holburn
Associate Professor, Suncor Chair in Energy Policy and Director of Energy Policy and Management Centre, Richard Ivey School of Business, Western University

Panagiota Karava
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Rajiv Varma
Professor and Hydro One Chair in Power Systems Engineering,
Department of Electrical and Computer Engineering, Western University

Ernest Yanful
Professor, Department of Civil and Environmental Engineering, Western University

Mair Zamir
Professor Emeritus, Apllied Mathematics, Western University

Operations Team

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Project Manager, WindEEE Research Institute, Western University

Andrew Mathers
Project Engineer, WindEEE Research Institute, Western University

Adrian Costache
Sr. Systems Specialist, WindEEE Research Institute, Western University

Visiting Scholars, Postdoctoral Fellows and Graduate Students

Prof. Xu Feng Sun - Visiting professor, Yangzhou University, China;
Research on Membrane loading

Dr. Aly Mousaad Aly Sayed Ahmed - Postdoctoral fellow, supervisor Dr. Bitsuamlak
Research on Wind load on green and energy infrastructures

Dr. Aly Gadallah - Postdoctoral fellow, supervisor Dr. K. Siddiqui
Design improvement of gas injectors in two-phase flows

Dr. Taravat Kadivi – Postdoctoral fellow, supervisor Dr. H. Hangan
Research on Aerodynamic optimization of vehicles

Dr. Arash Naghib Lahouti – Postdoctoral fellow, supervisor Dr. P. Lavoie, co-supervisor Dr. H. Hangan
Research on Active control on blunt trailling edge airfoils with application to wind turbine blades

Maryam Refan – Ph.D. candidate, supervisor Dr. H. Hangan
Research on Physical simulation of tornadic flows

Pooyan Hashemi-Tari - Ph.D. candidate, supervisor Dr. H. Hangan, co-supervisor Dr. K. Siddiqui
Research on Wind turbine wake aerodynamics

Jubayer Chowdry – Ph.D. candidate, supervisor Dr. H. Hangan, co-supervisor Dr. G. Bitsuamlak
Research on Wind loading and heat transfer for ground mounted solar panels

Ziad Boutanios – Ph.D. candidate, supervisor Dr. H. Hangan
Research on Wind driven snow drifting

Djordje Romanic – Ph.D. candidate, supervisor Dr. H. Hangan
Research on Urban wind energy assessment

Daniel S. Abdi - Ph.D. candidate, supervisor Dr. G. Bitsuamlak
Research on Assessing urban surface and topography effects on wind load

Zoheb Nasir - Ph.D. candidate, supervisor Dr. G. Bitsuamlak
Research on Evaluation of tornadic load on transmission line structures

Ahmed Abd El Kadir - Ph.D. candidate, supervisor Dr. H. El Naggar, co-supervisor Dr. G. Bitsuamlak
Research on Effective foundation for offshore wind turbines

Ahmed Elatar-PhD candidate, supervisor Dr. K. Siddiqui
Thermofluid investigation in low Reynolds number flows

Mona Hassanzadeh Jobehdar - PhD candidate, supervisor Dr. K. Siddiqui
Investigation of two-phase flow in effervescent injectors

Muhammad Bashar - PhD candidate, supervisor Dr. K. Siddiqui
Heat transfer process in PCM thermal storage

Dan Parvu – M.Sc. candidate, supervisor Dr. H. Hangan, co-supervisor Dr. Yves Gagnon
Research on Effects of topography and canopy on wind farms

Ayo Abiola – M.Sc. candidate, supervisor Dr. K. Siddiqui, co-supervisor Dr. H. Hangan
Research on Wind loading and flow field for ground mounted solar panels

Abdel Ramadan - MESc candidate, supervisor Dr. K. Siddiqui, co-supervisor Dr. H. El Naggar
Ground loop optimization for geothermal systems

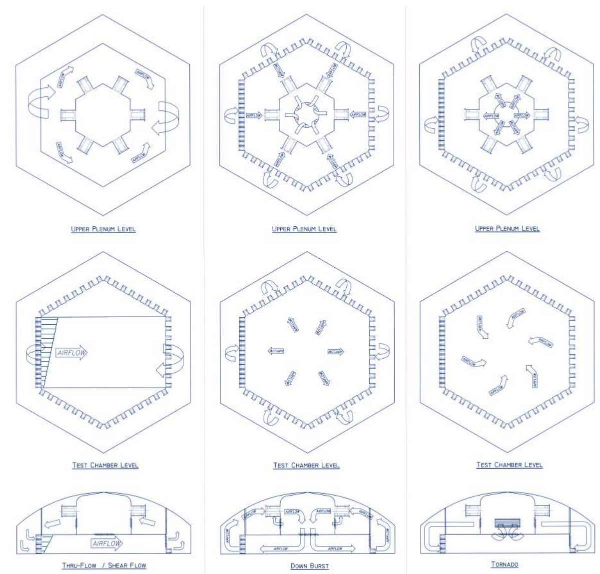
Aditi Jog - M.Sc. student, supervisor Dr. Bitsuamlak
Research on Hurricane, tornadic and downburst wind load comparisons

Facilities

WindEEE Dome

The Wind Engineering, Energy and Environment (WindEEE) Dome is the world's first 3D wind chamber, consisting of a hexagonal test area 25 m in diameter and an outer return dome 40 m in diameter. The extremely large size of the WindEEE Dome test area allows for wind simulations at larger scales and over extended areas of the order of 20 km^2.

Mounted on the peripheral walls and at the top of the dome test area are a total of 106 individually controlled fans and 195 louver systems. These fans and louvers are connected via a sophisticated control system which allows manipulation of the flow to produce almost any wind type including time-dependent, straight, sheared or swirl winds of variable directionality.



The fan system has a maximum power draw of 1.8 MW and can produce flow rates over 1,000,000 CFM. A cooling system with heat exchangers on all 6 sides is used to extract the heat produced by the fan system and maintain stable wind tunnel temperatures. These capabilities allow for the physical simulation of a large variety of naturally occurring wind fields and storm systems such as boundary layers, tornados, downbursts, low level currents, gust fronts or portions of hurricanes in a laboratory environment.

In the case of the tornado and downburst flows, the WindEEE Dome also has a unique hydraulically driven system which provides the capability to translate these local storm systems at high speed (up to 2 m/s) across the test area.

All types of test objects can be accommodated in the 3.8 m tall test area, including model buildings and bridges, solar arrays, vehicles and wind turbines. The WindEEE Dome is also able to operate in an Open Loop mode which allows for testing of large full scale test objects on an outdoor test platform. This outdoor platform also allows for wind driven rain and sediment testing. An active boundary layer generation system and CNC router provide the capability to generate a wide diversity of surface topographies and represent areas in the order of 20 km^2 at a practical scale. At the centre of the WindEEE Dome test area is a 5 m diameter turntable which is used to rotate test objects and test for all angles of wind exposure.

Model WindEEE Dome (MWD)

The Model WindEEE Dome (MWD) is a 1:11 scale version of the WindEEE Dome. The MWD was originally used as part of the design validation for the full scale facility and underwent significant flow studies. The MWD has many of the same features as the full scale WindEEE Dome and is able to produce the same flow scenarios. The model is located on the main Western University campus at the Boundary Layer Wind Tunnel Laboratory. Because of its inexpensive operation and maintenance costs, the MWD will continue to serve as a tool for preliminary test validation/set-up, fundamental tornado research and demonstrations.

Research

Research will be conducted in (but not restricted to) the following main areas, namely:

1. Physical modeling of non-synoptic wind systems and their impact on buildings and structures

- Physical modelling of Tornadoes
- Physical Modelling of Downbursts and Microbursts
- Physical modelling of other wind systems
- The impact of non-synoptic wind systems on buildings and structures

2. Modeling of near surface wind environment

- Physical modeling of flow over rough surfaces, urban canopies and complex topographic terrain
- Interface with meso-scale and micro-scale (CFD) models
- Interface with full-scale measurements
- Atmospheric dispersion of pollutants
- Wind-driven rain and snow
- Forestry related research
- Re-suspension of mine tailings in ponds in realistic terrain
- Wind debris

3. Wind Energy research

- Siting of wind turbines in complex terrain
- Array effects
- Forecasting
- Wind turbine scaling
- Blade and turbine aerodynamics

4. Risk, Economic Analysis, Policy and Decision making

- Risk models
- Grid operation
- Economic models
- Risk Analysis
- Decision making strategies
- Policy definition and implementation
- Insurance aspects

Reproducing Tornadoes in Laboratory Using Model WindEEE Dome

National Oceanic and Atmospheric Administration (2012) has reported that in 2011 tornadoes have killed 550 people in the United States (compare to 564 deaths in US during the prior 10 years combined) with approximated damage of $10 billion. These catastrophes have led researchers to investigate the characteristics of this phenomenon in more depth. Limited full scale and significant experimental and numerical research has been carried out on tornadic flows. Full scale measurements using Doppler radar are limited due to dangerous environment and unpredictable path of tornadoes.

On the other hand, numerical methods are not capable of simulating a large domain to accommodate a tornado vortex while resolving near surface flow structure. Although laboratory simulations have the advantage of controllable condition and repeatability, they are limited in terms of the number of available simulators.

Tornadoes in nature are characterized by (Enhanced) Fujita scale while laboratory/numerical simulated tornadoes are governed by Swirl ratio (S) which is essentially the ratio between tangential velocity and radial velocity. Experimentally simulated tornadoes and their effects on low-rise buildings have been attempted but without investigating the scaling ratio and without defining a relation between Swirl ratio and the extensively used (Enhanced) Fujita scale.

In this study, tornado-like vortices are investigated experimentally using Model WindEEE Dome (MWD) simulator. The main focus of this work is to understand the flow field characteristics, identify main parameters responsible for destruction and establish a relation between field tornadoes and laboratory simulated tornadoes.

Flow visualization, surface static pressure measurement and Particle Image Velocimetry (PIV) were performed to characterize the flow in MWD. Attached images show snapshots of the flow visualized using dry ice and helium-filled bubbles. Quantitative and qualitative data obtained in MWD were compared with previous results reported for classical Tornado Vortex Chambers (TVCs). It is observed that the flow pattern is in good qualitative agreement with previous experimental works and MWD is capable of producing various tornado-like structures. In the next step, correlations between flow patterns and swirl ratios will be constructed.

In the next step, Doppler radar field measurements of real tornadoes will be compared with experimental results obtained from MWD simulations in order to establish a relation between simulated and field tornadoes.

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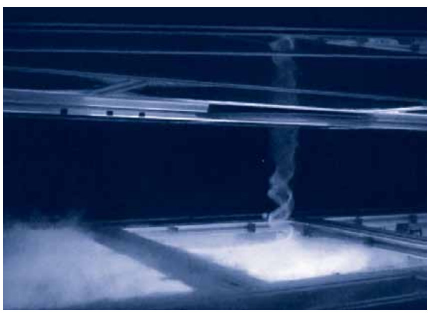
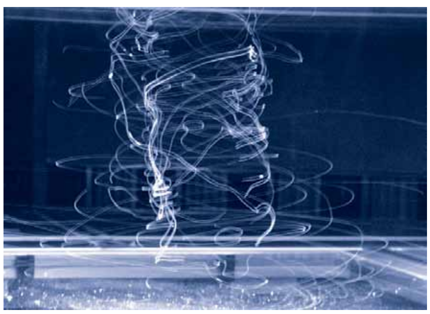
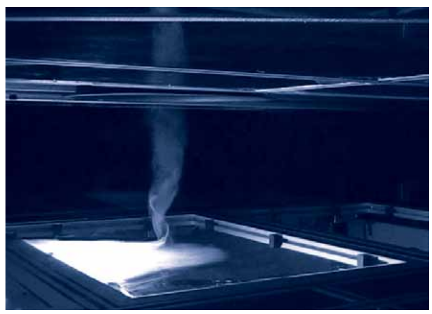
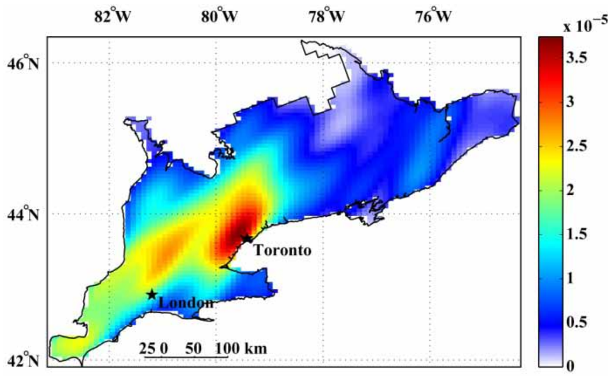




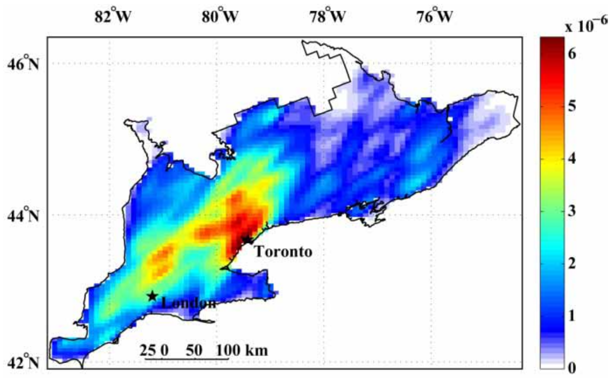


Tornado-like vortex simulated in MWD and visualized using dry ice and helium bubbles

Tornado Hazard and Risk Assessment



Spatial distribution of the tornado occurrence intensity.



Exceedance probability considering the maximum tornado (3-s gust) wind speed equal to 337 (km/h).

Tornados occur randomly in time and space, and affect structures and infrastructure system that are vital for safe living. Our studies are focused on the combined application of the stochastic and spatially varying tornado occurrences and probabilistic tornado wind field model in estimating the tornado hazard by using the Monte Carlo technique.

For the hazard estimation, it is considered that the footprints of the structures or infrastructure system of interest can be represented by points, areas or lines; and that the tornado hazard at a site can be expressed in terms of probability distribution of maximum gust wind speed. It is noted that by assuming the tornado occurrence is spatially homogeneous, the estimation of tornado hazard for a region is simplified. However, such an assumption could lead to over- and under- estimate tornado hazard for regions with lower and higher tornadic activity.

To investigate the degree of over and under-estimation, the tornado hazard is estimated for different regions in Canada by considering spatial inhomogeneity of tornado occurrence.

The results show that the spatial inhomogeneity of tornado occurrence influence the spatial tornado hazard, that the return period values of tornado wind speed vary significantly over the considered region, and that the inhomogeneity must be considered in developing probabilistic quantitative tornado hazard maps. Also, in general at the wind speed corresponding to the design wind speed implemented in the National Building Code of Canada, the annual exceedance probability for tornadic winds is much smaller than that for synoptic winds. The hazard for line infrastructure system such as transmission lines of hundreds to thousands of kilometers can be several order of magnitude of that for a point.

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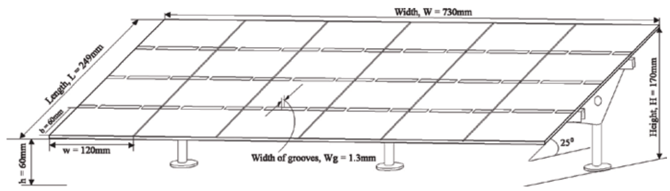
Wind Loading on Solar Panels

Pressure and flow measurements were conducted in the wind tunnel as part of on-going efforts to codify the wind loading on solar panels for various geometries. These tests were performed by using a model of a solar panel whose geometry is similar to a flat plate with grooves mounted on a three-legged support at 25° inclination to the horizontal.



Model of solar panel with grooves, tested in the wind tunnel inclined at 25°

The pressure measurements were conducted using local pressure taps at 128 locations on both surfaces of the panel. The results of the pressure measurements showed that the wind load induced on the panel increased if the inclination angle of the panel were increased. Also, the critical load on the panel occurred when the wind approached head-on (at 0° and 180°).

The wind flow was visualized and measured using the particle image velocimetry (PIV) approach by acquiring images of the flow across the panel at very small time intervals. The PIV images were analyzed and show that when the wind approaches the panel head-on, it impinges at its leading edge, remain attached on the upper surface, but separates from the lower surface.

The results indicates that the wind load on the inclined panel was primarily due to the differential pressures induced on both surfaces rather than the flow dynamics at the interface of the fluid and surface of the panel. Also, the flow over the panel's upper surface flowed through the grooves on the panel to its bottom surface to alter the wind loading patterns at the wind angle and panel's inclination.

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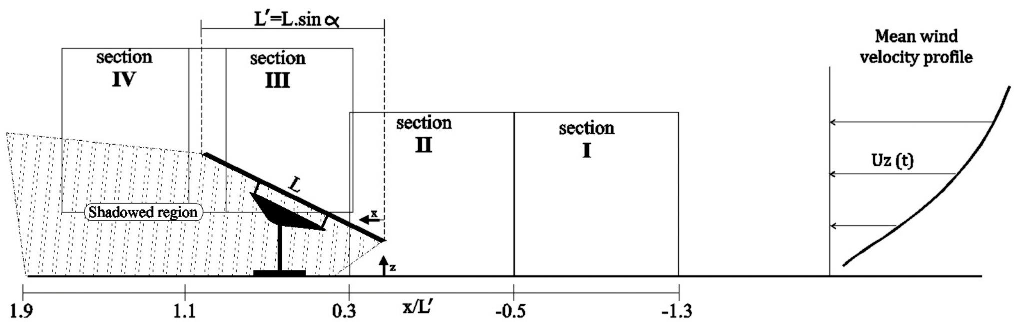


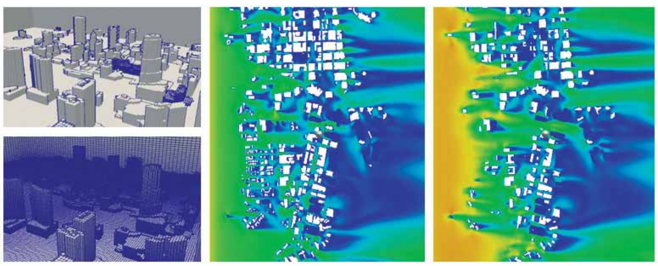
The four sectional planes of image capture across the solar panel model during PIV measurement in the wind tunnel. The approaching flow is shown on the right.

Estimation of aerodynamic roughness of the built-environment using CFD

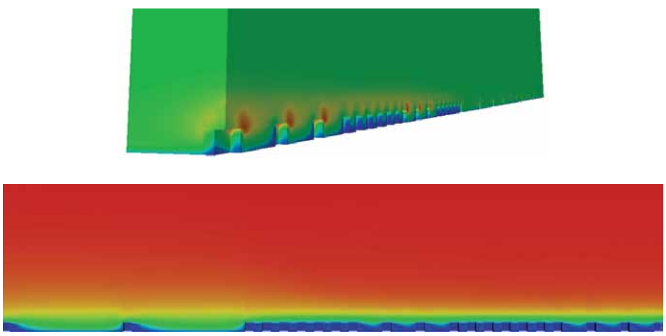
Boundary layer velocity profiles close to the ground are significantly affected by the size, shape and spacing of obstacles consisting of buildings, bridges, crops, forests etc. Proper estimation of roughness parameters, aerodynamic roughness length (z_0) and displacement height (d), is important for evaluation of design wind loads.

This work focuses on estimation of roughness parameters using CFD methodology on simplified homogeneous and inhomogeneous modes and verification on real world complex urban environment.

The ground surface roughness lengths are usually estimated by examining aerial or Google Earth (www.googleearth.com) photographs subjectively for each wind direction. These estimated values will be used in the logarithmic wind velocity profiles at a particular study site.



Urban city center model, grid and sample velocity contour plots.



CFD simulation results on four roughness changes.

For inhomogeneous upwind terrain condition and city centers this task is even more complicated. CFD simulations with appropriate turbulence models can be a rational alternative to estimate roughness parameters.

This CFD study investigates roughness parameters for:

i. homogenous regular and staggered array of different shape obstacles and compares with empirical methods,
ii. inhomogeneous roughness within the pertinent fetch and
iii. urban city centers.

Such large-scale simulations are scarce in literature due to flow complexity, large computational requirement and lack of validation data. WindEEE is expected to provide the much needed validation data. In house developed CFD programs are used for the present study.

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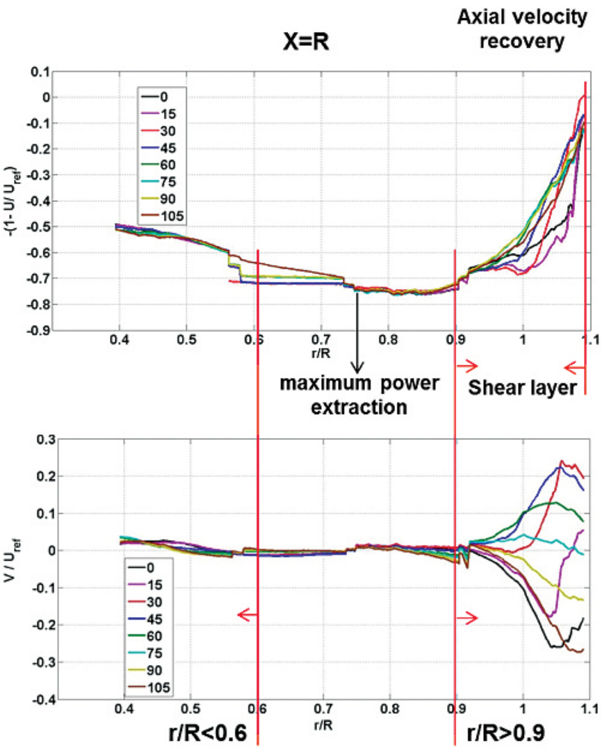
Characterization of the Mean and Turbulent wind turbine wake

One of the most important features of a wind farm is the structure of the wake behind a wind turbine. By knowing this flow structure one can optimize wind farms both in terms of power output and resilience.

Experiments have been conducted in a large wind tunnel set-up in order to study the flow structures within the near-wake region of a horizontal axis wind turbine. Particle Image Velocimetry (PIV) has been employed to quantify the mean and turbulent components of the flow field. The phase locked measurements have been performed in multiple adjacent horizontal planes in order to cover the area behind the rotor in a large radial interval, at several locations downstream of the rotor.



The results demonstrate the successful implementation of the PIV technique and the associated post-processing to accurately construct the flow field in the near-wake of a HAWT in a large wind tunnel setup.

The mean velocity and turbulence characteristics clearly correlate with the near-wake vortex dynamics and in particular with the helical structure of the flow, formed shortly behind the turbine rotor. Close to the rotor and close to the blade tip and root regions the mean and turbulent characteristics of the flow are highly dependent on the azimuth angle of blade due to the tip and root vortices. Further from the rotor, the characteristics of the flow become phase independent. This can be attributed to the breakdown of the vortical structure of the flow, resulting from the turbulent diffusion.

These findings point out that in the far wake region, the turbulent characteristics are independent of azimuth angle of the blade, which suggests the possibility of generating simple and robust wind turbine wake models for wind farm analysis.

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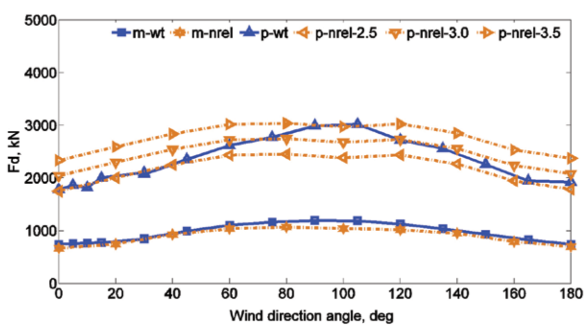
Evaluation of Design Wind Loads for Wind Turbine Foundations

In the past two decades, wind farms have been enjoying renewed interest as means for clean and renewable energy. Larger and higher power offshore and onshore wind turbines are used for harvesting clean energy generated by the wind.

The larger wind turbines are relatively new and there is no sufficient wind load information or clear guidance for calculating wind loads that can be used for their foundation design, especially for offshore installations.

Wind tunnel testing of 1:150 NREL 5 MW scaled model



Wind tunnel results vs. average FAST results
m:mean, p:peak, nrel: NREL FAST results,
p-nrel-2.5:peak with 2.5 peak factor

In this paper, a boundary layer wind tunnel study was carried out to estimate the wind-induced loads for the foundation of a 5 MW NREL offshore wind turbine. An experimental aerodynamic study was carried out by using the force balance technique at the boundary layer wind tunnel of Western University on a scaled 1:150 model. While the aerodynamic effects were assessed experimentally, the aeroelastic effects (e.g. resonance) were estimated analytically and augmented to the aerodynamic forces to provide the overall design wind loads. Part of the results was compared with limited NREL results, which were achieved by FAST (Fatigue, Aerodynamics, Structures, and Turbulence) program. The agreements in the comparison between the numerical and the boundary layer wind tunnel test results give creditability for the proposed approach and the data presented to be used in offshore and onshore wind turbines foundations' design. Although the present study could be applied to onshore turbines directly, it did not include the wave effect for a typical offshore wind turbine system and that the foundation was completely restrained (rigid foundation). A current study combining these loads with soil-structure interaction is in progress where the correction for wave loading will be applied analytically.

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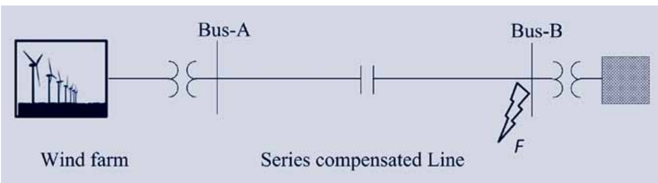
Towards Experimental Modeling of a Wind Farm

Large-scale integration of wind farms in the transmission and distribution networks has led to several challenges. Substantial upgrades of grid transmission infrastructure including construction of very expensive new transmission lines may be needed to accommodate increased flow of wind power.

Series compensation is known to be an effective and cost-effective means of enhancing the power transfer capability of existing transmission lines. Hence, series compensation of transmission networks is being increasingly considered, worldwide, for integration of large wind farms to transfer bulk power to the electric power grid. For instance, Stateline wind farm in USA is connected to a series and shunt compensated network in BPA transmission network. Series compensation of transmission lines is also being planned in Alberta and Texas for integrating large wind farms.

Series compensated transmission lines connected to steam turbine driven synchronous generators, are known to cause subsynchronous resonance (SSR) problems which can lead to turbine-generator shaft failures, although extensive research has provided techniques to mitigate such problems.



Study system.

Shaft damage has also recently been reported in wind turbine generators connected to series compensated transmission lines in Texas due to SSR. The mechanical drive train of wind turbine generator (WTG) system may be prone to torsional vibrations which can be excited by both wind fluctuations and electrical disturbances.

The proposed research in WINDEEE Dome will investigate the potential of shaft damage in wind turbines connected to series compensated lines due to wind fluctuations and electrical disturbances, and develop measures to mitigate such damage.

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Public Policy for Private Investment in Wind Energy

A challenge for wind energy firms when considering new investments is to balance expected financial gains against potential risks. Investment opportunities in different jurisdictions are often relatively straightforward to identify, but the regulatory risks for investors in a young industry can be more difficult to accurately ascertain. In my research I develop a conceptual framework for how firms can assess regulatory risk that focuses on the institutional processes governing policy-making.

Two features are especially salient: first, the degree of independence that regulatory agencies have from elected political institutions affects the level of regulatory risk since more autonomous regulators are more likely to resist political pressures. Second, the nature of policy-making processes through which renewable energy policies are formulated and implemented additionally affects the subsequent risk of change: policies that are 'hard-wired' in legislation are more difficult to modify than policies that are set by agency or ministerial orders.

The contrasting development patterns of renewable energy policies in Ontario and Texas offer support for the framework. Each jurisdiction was an early mover in its country to adopt major commitments to build new renewable energy power generation capacity: in 1999 Texas enacted a Renewable Portfolio Standard (RPS) that led to a target of 5880 MW of capacity by 2015, and in 2003 the Ontario government announced a target of 2700 MW by 2010. However, while by 2010 renewable investment in Texas had far surpassed the 2015 goal, investment levels in Ontario had barely reached 50% of the initial target set in 2003.

What accounts for such divergent investment trajectories? One contributing factor is the higher level of regulatory risk in Ontario: regulatory risks in the province are exacerbated by a regulatory agency that is tightly controlled by the Minister of Energy; and in a single chamber parliamentary system the Minister has considerable ability to determine, and revise, renewable energy policy.

The government also relied on Ministerial directives to agencies rather than legislation to establish renewable energy capacity targets and tariff policies, which enabled successive Ministers to repeatedly change the direction and pace of policy after 2003.

Major aspects of renewable policy exhibited significant instability and unpredictability since inception. My surveys of renewable energy firms have found that policy instability is a major factor that accounts for why investment levels in Ontario have fallen short of targets.

In Texas, by contrast, the institutional structure of the Public Utilities Commission insulates it from political exigencies; and the hard-wiring of the RPS standard in legislation has led to considerable regulatory stability (despite more than 25 proposed bills in the legislature that have attempted – but failed – to modify or repeal the standard since 1999). Both factors reduce the risks for renewable energy firms in Texas, thereby encouraging investment in long-lived, sunk renewable energy assets.

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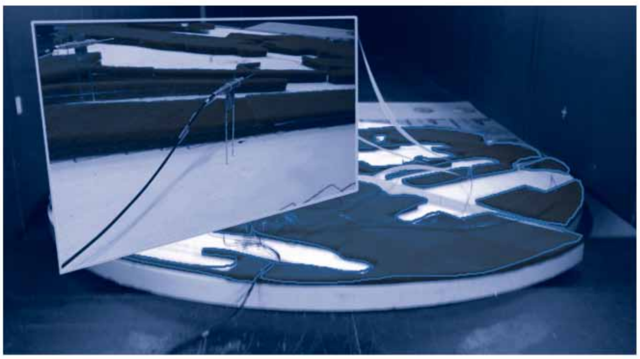
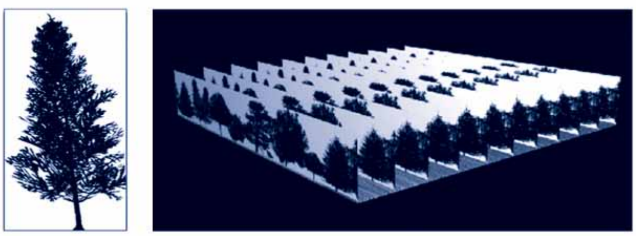
Towards Experimental Modeling of a Wind Farm

Wind energy is an important renewable energy resource in Canada; it offers a way to diversify the energy portfolio from traditional reliance on fossil fuel burning power plants. In this context, it is important that wind farm siting can rely on effective methodologies for the wind resource assessment on the location of projected wind farms. Applying wind tunnel measurements, as well as computer models to generate wind resource predictions, can be a complementary approach to wind resource assessment for the design of wind farms.

This work focuses on an existing wind farm, located at East Point, Prince Edward Island: the Eastern Kings wind farm. The objective of the work is to improve wind tunnel simulations of topography and canopy flows. It will also compare data measured at the site with the results from wind tunnel experiments and computational models.



Wind tunnel experiment: topography and canopy model and cobra probe setup.



Porosity expressed as ratio between empty space (left) and tree-occupied space and proposed forest model based on porosity of strips of trees (right).

Another objective is to make observations on how wind tunnel measurements can be used to improve the design of wind farms.

To this end, a wind tunnel experiment was conceived. The experiment consists of a series of wind speed measurements over a portion of the topographical elements present at the wind farm location. A procedure involving Geographic Information System (GIS) and traditional Computer Aided Design (CAD) was developed in order to create a digital map model of nearby surroundings of the wind farm, and recreate it as a wind tunnel model using Computer Numerical Control (CNC) milling.

On the computational part, the same topographical model as the wind tunnel experiment is used in a computer simulation. Using the WAsP model, which uses the wind speed data collected on site at the wind farm and topographical information, wind prediction maps are generated using linearized Navier-Stokes equations.

A detailed analysis of the real time in-situ data, wind tunnel measurements and computer modeling is performed in order to reach the proposed objective of the work.

After an assessment of the results, it was determined that the forest canopy has a larger effect on the flow than topography has. This is partly due to the mildness of the terrain on PEI's East Point, but also due to the scale of the model, which stretches the capabilities of a conventional wind tunnel. In order to study canopy effects, a good experimental model is required. Literature has shown that wind tunnel models of forest canopies are made on an empirical basis. An attempt is made in this work to represent a forest based on porosity, and a model is proposed.

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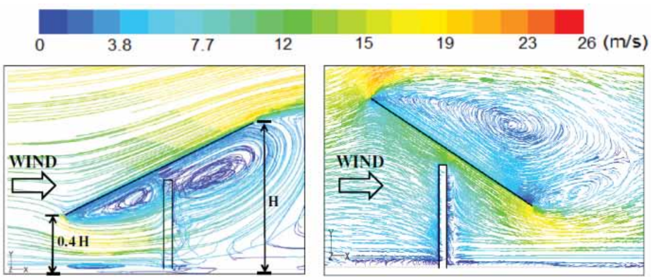
Wind Loading and Flow Characteristics for Ground-mounted Solar Panels

Photovoltaic (PV) panels are the most common and widely acceptable technology to convert solar energy to electrical energy. PV panels are gaining popularity as the process of generating electricity is quiet, does not require any complicated system in order to be used, can be used at almost any scale, from wrist watches to supplying electricity to an entire city and above all, is increasingly supported by the government.

From 2009 to 2010, total existing solar PV capacity of the world grew 72%.The increasing number of PV solar farms around the world is responsible for this growth. PV solar farms consist of arrays of flat plate PV panels and supply power to the electricity grid. These solar farms are usually developed in an open terrain to get unobstructed sunshine, due to which PV panels in the farm experience higher wind loads and more potential damage. On the contrary, the existing codes for estimating wind loads on buildings/structures (NBC 2010, ASCE 7-10) do not provide sufficient information to predict wind loads on the ground mounted arrays of solar PV panels.



CFD design simulation at 0° wind direction (left) and 180° wind direction (right).

Both numerical and experimental approaches are undertaken to investigate the effect of wind on the ground mounted PV panels by analyzing the wind loads and the wind flow field around the panels. Numerical approach consists of 3D unsteady Reynolds Averaged Navier-Stokes (RANS) simulation as well as more sophisticated model such as Large Eddy Simulation (LES).

On the other hand, the experimental approach comprise of wind tunnel pressure measurement to predict wind load and the Particle Image Velocimetry (PIV) measurements to investigate wind flow field around the panel. Both of these experiments are performed in the Boundary Layer Wind Tunnel I at Western University. For both the numerical and experimental approaches, atmospheric boundary layer for open country terrain with aerodynamics roughness length of 0.03 m is employed and the wind directions are varied from 0° to 180° at 45° intervals.

Preliminary results show that the wind tunnel pressure measurements matches well with results obtained from the numerical simulations using 3D unsteady RANS approach. The overall contribution of this study will contribute towards not only the better understanding of the wind flow field around the PV panel by analyzing the velocity streamlines, shedding of vortices, spanwise vorticities and wake characteristics but also finding the critical wind directions in terms of drag, lift and overturning moment of the panel.

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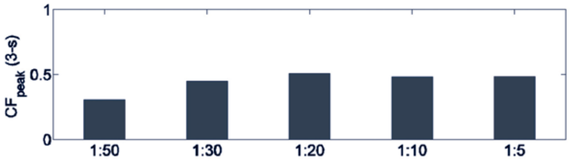
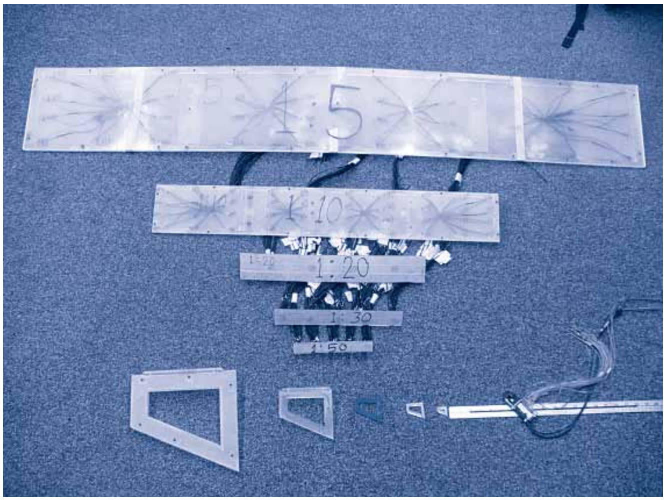
Aerodynamics of Ground-mounted Solar Panels: Test Model Scale Effects

Most standard boundary-layer wind tunnels (BLWTs) were built for testing models of large civil engineering structures that have geometric scales ranging from 1:500 to 1:100. However, producing typical aerodynamic models of the solar panel modules at such scales makes the panels too small, resulting in at least two technical problems: first, the resolution of pressure data on such small-scale models becomes low, and second, the test model may be placed in the bottom portion of the boundary-layer that might not be a true representative of the real world scenario due to high uncertainty in the wind velocity.





Wind tunnel models at five different scale (above) and corresponding force coefficient. The result indicate 1:50 is too small for typical wind tunnel.

To alleviate these problems, standardized testing protocol that accounts for different time and geometric scales is important to design appropriate wind tunnel experiments that can allow reasonably accurate assessment of the wind loads on the solar panels.

The current project investigates systematically the sensitivity of testing ground-mounted solar panels, both experimentally (BLWT) and numerically through computational fluid dynamics (CFD), at different geometric scales, with the objective to produce a recommendation on the most practical approach to test these types of small structures.

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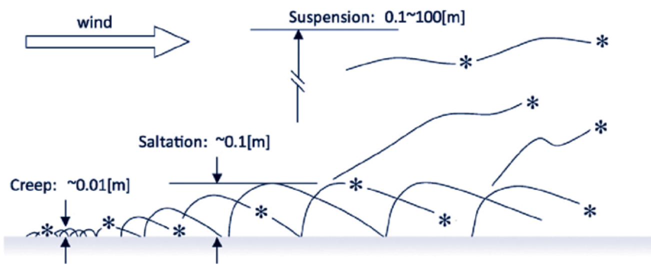
Simulation of Drifting Snow

Drifting snow is an aeolian transport phenomenon that occurs whenever the shear stress from the wind flow at the snow layer outer surface exceeds a threshold value that depends on the snow layer properties and snow particle characteristics. Snow motion under these conditions is classified as either one of creep, saltation or suspension, depending on the distance travelled by a snow particle under the effect of the wind.



Most of the transport happens in the saltation layer where the volume concentration of the snow phase is so high that it acts as a momentum sink for the air phase and both phases affect each other's motion, the so-called two-way coupling mode. In contrast, the volume concentration of the snow phase in the suspension layer is so low that it has no effect on the air phase which dictates its motion, the so-called one-way coupling mode. An accurate prediction of drifting snow transport is of critical importance for determining varying snow loads on rooftops due to the presence of miscellaneous structures. This area is believed to be poorly addressed by building codes nowadays due to the large diversity in modern building types and lack of experimental data which makes it a good candidate for CFD simulations.

Most drifting snow CFD models in existence today avoid computing the saltation layer due to its high computational cost and resort to empirical equilibrium formulations to provide the snow flux boundary conditions at the ground. The snow layer is then approximated using one-way coupled Eulerian continuum formulations of mixture transport equations, similar to the Eulerian continuum approach used for computing the airflow. Two-way coupling is sometimes taken into account through more empirical formulations which have shown limited success. Such empirical approaches are limited to specific airflow regimes and snow types and cannot be extended to non-equilibrium regimes, such as around buildings and rooftop structures, and other snow types without the corresponding snow flux empirical formulations. In many cases these non-equilibrium formulations do not exist due to the experimental difficulties involved. A couple of approaches compute the saltation layer using two-way coupling with Lagrangian particle tracking formulations, which are very expensive due to the extremely high number of snow particles to compute. Lagrangian formulations have been used since the continuum properties of the snow phase are not well understood and this approach has shown some success while being extremely expensive for realistic applications.

In this research a two-way coupled fully Eulerian approach is used for both phases. In doing so the accuracy of the Lagrangian two-way coupling is recovered at the much lower computational cost of the Eulerian continuum formulation. The continuum properties of the snow phase are derived from first principles, providing adequate parameters for each snow type. Moreover, since equilibrium empirical transport formulations are not used the model is universally applicable to all types of flow regimes, especially the non-equilibrium type around buildings and rooftop structures. Initial results have clearly shown the viability of the present approach, and validation and calibration work is underway based on experimental results obtained first-hand from other snow research groups. A drifting snow profile computed around a cubic building model is shown in Figure 2 as an example.

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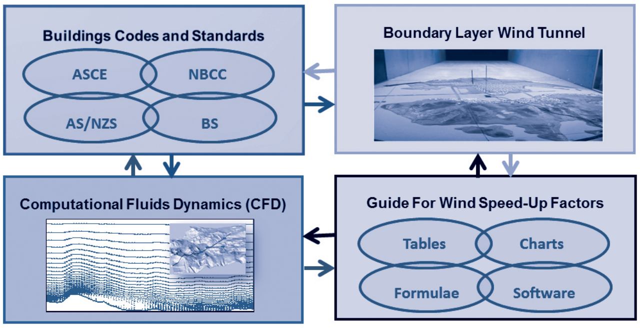
Application Guide for Wind Speed-Up Factors

Assessing the effects of topography on wind characteristics is critical to accurately evaluate design wind loads for transmission lines and towers erected in complex topography. The modifications in wind flow are usually reported in a factor called "speed-up", which represents the relative increase/ decrease in wind speed (mean) in comparison with the incoming wind speed (mean) that is not affected by the terrain, measured at a similar height from the ground.



Methodology adopted.

There are several parameters that affect speed-up including geometric parameters, such as, slope, height, distance from the crest (or bottom), three or two dimensionality, number of hills/valleys, and ground roughness (usually presented as roughness length (z_0)). Wind flows over hills, for example, are significantly accelerated even when the maximum slopes are quite small as shear in the approaching wind amplifies the wind speed. For example, a 20% hill slope could result in a 1.5 speed-up.

The current project presents:

i. literature review mainly focussing on speed-up evaluations presented in four international codes namely: the National Building Code of Canada (NBCC); the American Wind Loading Standard (ASCE-7); the Australian/New Zealand Standard (AS/NZS 1170.2); and the European Standard (Eurocode 1) and

ii. computational fluid dynamics (CFD) based speed-up evaluation for topographic cases that are not covered in the wind code provisions with the objective of generating new speed-up data; and for cases that are covered by these codes for comparison purposes.

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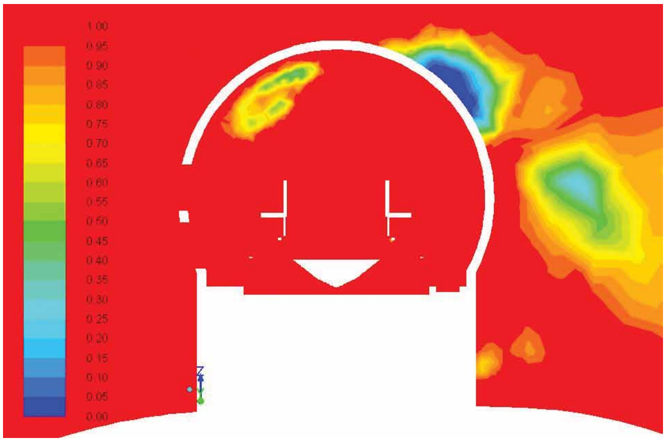
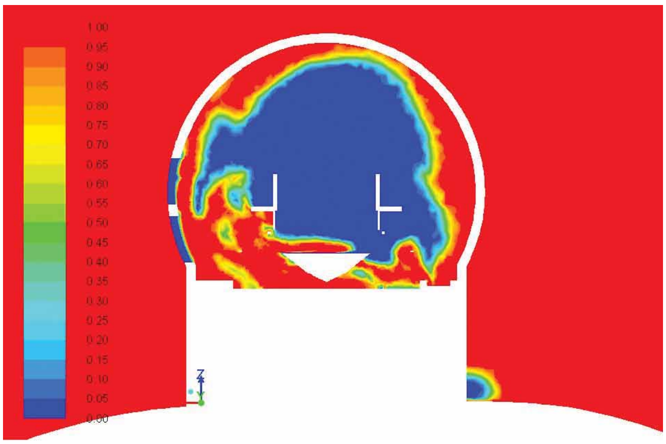
Wind Environment Study for the Next Generation Canada France Hawaii Telescope (ngCFHT)





A large telescope is an astronomical observatory featuring telescope with usually an aperture of more than 3 m. Manufacturing of large telescopes is highly sophisticated and expensive. Therefore, much care should be given to the overall design and placement of these telescopes before the actual fabrication. Environment inside the telescope enclosure is one of the critical elements that can be responsible for the poor image quality produced by the telescope.

The environment inside a very large telescope (30 m aperture) enclosure, namely the Next Generation Canada France Hawaii Telescope (ngCFHT), is studied here using Computation Fluid Dynamics (CFD) approach. ngCFHT is a concept to replace the current Canada France Hawaii Telescope on summit of Mauna Kea on the Big Island of Hawaii at an altitude of 4,204 m. In this study, attention is given to the air exchange time and temperature distribution inside the enclosure as well as the turbulence of air close to the mirror and in the optical path.

Air quality, temperature distribution and the turbulence inside the enclosure can lead to the degradation of the image by the telescope. Two different venting systems, one with 26 window like vents (the advanced venting system) and the other with a well at the floor of the enclosure (the conventional venting system) are studied. For the conventional venting system two different flow rates (90,000 CFM and 180,000 CFM) are employed. In every case, approaching wind is in East-West direction with the camera facing South and with 30° zenith angle.

Preliminary results have showed that the advance venting system requires much less air exchange time than the conventional venting system. However, both venting systems have met the acceptable requirement for the temperature distribution and the air turbulence inside the enclosure.

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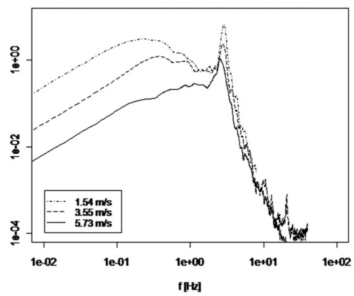
Wind-Trees Interactions

The interaction of a tree with the wind is a complex dynamic problem, which is influenced by the adaption of the tree to its physical surroundings and local wind effects through long term acclimative growth, and a variety of short term responses to wind loads. These long and short term responses are necessary to the survival of the tree as they mitigate the risk of failure from windthrow or stem breakage.

To better understand the various mechanisms forming the short term responses to wind loading a boundary layer wind tunnel is used to provide a controlled wind environment in which instrumented Norway spruce saplings are tested under various sub-failure and windthrow conditions. The experimental setup allows for the measurement of the tree response at various positions within both the tree crown and root system, in combination with the external flow conditions.

The resulting analysis shows that under sub-failure wind loading the natural frequency and damping of the tested trees are mean wind speed dependent. Spectra of the turbulent velocity fluctuations, and the upper and lower stem response show a filtering of frequencies as the loads are transmitted through the various sections of the tree. The lag associated with the transmission of the mean wind loading through the tree is evaluated by the use of cross-correlations and is also found to be dependent upon the mean wind speed. Lastly, by identifying peak wind gusts, the lag and response of the crown-stem-root system associated with peak wind loading is compared to the mean wind loading.



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Aerodynamic optimization of a road vehicle

Due to environmental and economical concerns, fuel efficiency of road vehicles is one of the key factors customers are looking for. Therefore, achieving the fuel efficiency through drag reduction is an essential goal for automotive designers and manufacturers.

In the process of the developing the vehicle from the initial conceptual design through to the production stage, various approaches, including optimization of surfaces and body appendages, are implemented for achieving better aerodynamic performance.

Considering the time and cost of full size vehicle wind tunnel testing, Computational Fluid Dynamics (CFD) simulations are used as a faster and cost efficient flow analysis and visualization tool. The significance of this method is more pronounced in aerodynamic development process and investigations of vehicle proportions and features, where numerous configurations are examined to drive important early design decisions.

WindEEE Research Institute provides the expertise and facilities for carrying out experimental tests and CFD simulations required in automotive projects. Currently, an automotive aerodynamic analysis and optimization project involving an industrial partner is underway at the WindEEE Research Institute. The project, which forms the framework for long term partnership with leading design and manufacturing companies in the automotive sector, consists of the following stages:

i. Comprehensive CFD simulations of a road vehicle to study the effects of appendages on aerodynamics characteristics such as drag and noise

ii. Geometry modeling and grid generation for CFD simulationsv

iii. Wind tunnel testing of selected vehicle configurations to complement the CFD simulations and generate benchmark data

iv. Validating the CFD simulations results against the wind tunnel testing results, to determine the most adequate CFD methodologies

v. Providing an aerodynamic database for design and optimization of aerodynamic configurations, to the industrial partner

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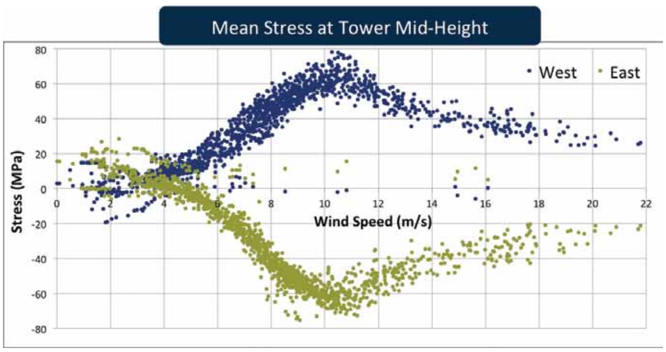
Atmospheric Effects on Wind Turbine Tower Loading

Onshore wind turbines are subjected to a wide variety of environmental conditions. Full-scale physical data can contribute to improving the reliability of turbine service life estimates and provide insight into decommissioning and repowering options.

At a commercial wind farm in Southwestern Ontario, the cylindrical steel supporting tower of a 2.3 MW turbine is analyzed to determine the effects of atmospheric stability and wind characteristics on its structural loading.



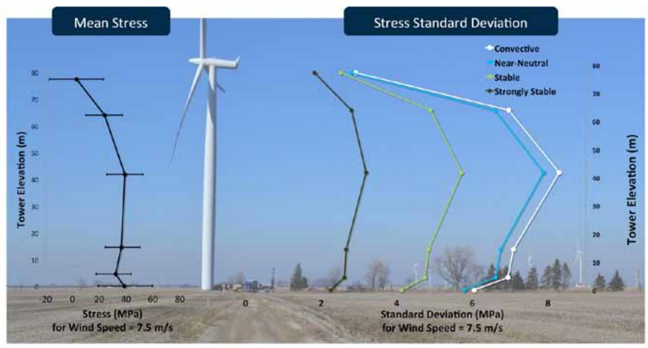
The turbine tower has been instrumented with a strain gauge array measuring longitudinal deformation at six elevations. Recorded loading values are not absolute, but a deviation from a baseline established when the turbine is non-operational. A met mast located 150 m away is equipped with a vertical array of anemometers, allowing stability classifications to be made on the basis of wind shear and turbulence intensity. Data is collected from September 2011 through February 2012, and ten-minute averages of loading and wind data are correlated. Westerly winds (270° ± 15°) are considered for analysis.

Axial rotor thrust serves as a primary loading input on the tower, subsequently, stress magnitudes tend to increase with wind speeds until rated speeds are reached; at which point rotor blade pitch is adjusted to decrease angle of attack; causing rotor thrust to be reduced.

Using values for average on-site wind speed (7.5 m/s ± 0.5 m/s), mean stress varies along the tower elevation, reaching its largest values at base and mid-height. Stress standard deviation values are highest for Convective and Near-Neutral winds, and minimum for Strongly Stable winds.

Strongly Convective winds were not present for the studied wind speed.

The highest stress levels are observed as wind speeds approach levels necessary to make full power. The maximum stresses are located at tower mid-height. Stress deviations along tower elevation are a function of distance away from the rotor and the non-linearly varying wall thickness of the hollow steel tower. A conclusive relationship between atmospheric stability and stress intensity was not found.



The more turbulent Near-Neutral and Convective stability classes coincide with increased stress level variance, which suggests the potential for increased cyclical loading under such conditions. Given that the design of wind turbine towers is typically fatigue-controlled; future work will incorporate these loading cycles as part of the analysis.

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Publications

Peer Reviewed Journal Publications

"Micro-Scale CFD Simulation for Wind Mapping over Complex Topographic Terrains"
Rasouli, A.*, Hangan, H., accepted - Journal of Solar (and Wind) Energy Engineering, January 2013

"Large eddy simulations of translation and surface roughness effects on tornado-like vortices"
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"Aerodynamic performance of a small Horizontal Axis Wind Turbine"
Refan, M.*, Hangan, H., Journal of Solar (and Wind) Energy Engineering, Vol. 134 (2012) 0210131-7

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"Aerodynamic mitigation of roof and wall corner suctions by using simple architectural elements"
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"The May 2012 Tornados"
Refan, M., Hangan H., AAWE12 Workshop, Hayanis, MA, USA, August, 2012

"Numerical simulation of wind loading on photovoltaic panels"
Jubayer, C. M. and Hangan, H., 43rd Structures Congress, Chicago, Illinois, USA, March 29-31, 2012

"Wind effects of photovoltaic (PV) panels - A CFD approach"
Jubayer, C. M. and Hangan, H.,1000 Islands Fluid Dynamics Meeting, Gananoque, Ontario, Canada, April 27-29., 2012

"Aerodynamics of ground mounted solar panels: Test model scale effects"
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"Evaluation of wind loads on residential roof mounted solar panels"
Aly, A.M, Bitsuamlak, G.T., The 2012 Intl Conf. on Adv. in Wind and Structures (AWAS12), 26-29 August, COEX, Seoul, Korea.

"Gutter aerodynamics and their effect on near eave roof pressure"
Warsido, W.P. and Bitsuamlak, G.T., 3rd AAWE workshop, August 12-14, 2012, Hyannis, MA, USA (ID 32)

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"Full Scale and Wind Tunnel Testing of a Photovoltaic Panel Mounted on Residential Roofs"
Erwin, James, Girma Bitsuamlak, Gan Chowdhury, A., Stephen Barkaszi, Scott Gamble., SEI Adv. in Hurricane Eng (2012).

"Wind Load on Ridge and Field Tiles on a Residential Building: a full scale study"
Tecle, A., Bitsuamlak, G.T., Gan Chowdhury, A., Advances in Hurricane Engineering : Learning from Our Past, ASCE, 2013

"A Parametric Representation of Wind-Driven Rain in Experimental Setups"
Baheru, T., Gan Chowdhury, A., Bitsuamlak, G.T., Ali Tokay, Advances in Hurricane Engineering : Learning from Our Past, ASCE, 2013.

"Development of Computational Tools for Large Scale Wind Simulations"
Abdi, D., and Bitsuamlak, G.T., Advances in Hurricane Engineering : Learning from Our Past, pp. 1006-1016. ASCE, 2013.

"Full Scale and Wind Tunnel Testing of Rooftop Equipment on a Flat Roof"
Erwin, J., Gan Chowdhury, A., Bitsuamlak, G.T., Advances in Hurricane Engineering : Learning from Our Past, ASCE, 2013

"Large eddy simulation for wind-induced responses of a tall building located in a city center"
Dagnew, A. and Bitsuamlak, G.T., 2012 Joint Conference of the Engineering Mechanics Institute and 11th ASCE Joint Specialty Conference on Probabilistic Mechanics and Structural Reliability (EMI/PMC 2012), June 17-20 2012, Notre Dame, IN.

"Estimating peak wind-induced responses of tall buildings"
Warsido, W. and Bitsuamlak, G.T., 2012 Joint Conference of the Engineering Mechanics Institute and 11th ASCE Joint Specialty Conference on Probabilistic Mechanics and Structural Reliability (EMI/PMC 2012), June 17-20 2012, Notre Dame, IN.

"Assessing the effect of roughness boundary conditions on simulating atmospheric boundary flow"
Abdi D. and Bitsuamlak, G.T., 2012 Joint Conference of the Engineering Mechanics Institute and 11th ASCE Joint Specialty Conference on Probabilistic Mechanics and Structural Reliability (EMI/PMC 2012), June 17-20 2012, Notre Dame, IN.

"Wind-driven natural ventilation in a low-rise building: A numerical and experimental study"
Bitsuamlak, G.T. and Rasouli, A., SimBuild 2012 5th National Conference of IBPSA-USA, August 1 - 3, 2012 – Madison, WI.

"The effect of nozzle shape and configuration on bubble formation in a liquid cross flow"
Jobehdar, M.H., Gadallah, A.H., Siddiqui, K., and Chishty, W.A., ASME 2012 Fluids Engineering Summer Conference, Rio Grande, Puerto Rico, July 8-12, 2012

"Effect of low Reynolds number mixed convection on channel flow structure"
Elatar, A. and Siddiqui, K., ASME 2012 Fluids Engineering Summer Conference, Rio Grande, Puerto Rico, July 8-12, 2012

"Investigation of the turbulent flow behaviour in a transpired air collector"
Greig, D., Siddiqui, K., and Karava, P., ASME Fluids Engineering Summer Conference, Rio Grande, Puerto Rico, July 8-12, 2012

"Wall heating effects in low Reynolds number channel flows"
Elatar, A. and Siddiqui, K., CSME International Congress, Winnipeg, June 4-6, 2012

Seminars

"Wind Resilience and Sustainability"
Hangan, H., Northeastern University, Boston, MA, September, 2012

"Urban Wind: Sustainability and Resilience"
Hangan H., Department of Urban Studies and Planning, Massachusetts Institute of Technology (MIT), August, 2012

"Resiliency of energy infrastructure for extreme wind"
Bitsuamlak G., Wind Farms' Underperformance & Partnerships: Building Partnerships To Meet the 2030 Grand Challenge, Texas Tech University, March 28-29, 2012

"Multi-scale computational wind engineering"
Bitsuamlak G., Department of Mechanical and Materials Engineering, Western Engineering, April 16, 2012

"Recent advances in experimental and computational wind engineering"
Bitsuamlak G., Department of Civil and Envirometal Engineering, Western Engineering, February 28, 2012

Grants

Grant Funding 2012

Hydro One, OCE, NSERC / $ 874,296 / 2012
Development of Software for Analysis of Transmission Line Structures Under the Action of High Intensity Wind Loads
El Damatty (PI), Bitsuamlak, Savory, Hangan

NSERC / $500,000 / 2012
Wind engineering for resilient & sustainable built environment of the 21st century
Bitsuamlak (PI, Canada Research Chair)

Canada Foundation for Innovation - Leaders Opportunity Fund for Research Infrastructure / $624,506 / 2012
Large-scale Experimental and Computational Infrastructure for Assessing Wind Effects on the Built Environment

CEATI (Center for Energy Advan. through Technological Inno.) WISMIG / $40,000 / 2012
Application Guide for Wind Speed-up Factors,
Bitsuamlak (PI), Savory, El Damatty, Aly

Hydro One / $20,000 / 2013
Feasibility study for an Adiabatic (or near-adiabatic) Compressed Air Energy Storage
Schainker (PI), Siddiqui, Zadeh

Hydro One / $40,000 / 2012
Prefeasibility/Technical Study - MW Scale Liquid Air Energy Storage Technology
Siddiqui (PI), Zadeh, Dincer, Farooqi

Federal Economic Development Agency (FedDev) / $100,000 / 2012-2013
Optimization of Concentrated Solar Power Components and System
Siddiqui

Western Innovation Fund / $48,850 / 2012-2013
Smart and cost-effective dual-axis solar tracking and load compensator
Siddiqui

Ontario Centers of Excellence / $93,000 / 2012-2013
Universal Solar Tracker
Hassan (PI), Siddiqui

C4 iPOP / $10,000 / 2012-2013
Novel solar thermal receiver
Siddiqui

Federal Economic Development Agency (FedDev) / $50,000 / 2011-2012
Development of a hybrid solar energy system
Siddiqui

Ontario Centers of Excellence / $29,970 / 2011-2012
Solar Assisted Geo-exchange System
Siddiqui

National Research Council / $10,000 / 2011-2012
Development of Effervescent Atomization Fuel Injector for Enhanced Gas Turbine Performance
Siddiqui

Going Global / $28,700 / 2012
WindEEE Research Institute Delegation to European Union
Hangan

Grant Applications

NSERC Strategic / $ 510,400 / 2013-2015
Resource Assessment and Integration of Renewable Energy for Urban Environment
Hangan (PI), Bitsuamlak, Siddiqui, Horvat

4C-NSERC Research Network
Changing Climates of Canadian Cities
Voogt (PI), Mailhat, Kaminski, Christen, Hangan

Patents

Hassan, H. and Siddiqui, K., "Solar Tracker" PCT International Patent Application, serial number PCT/CA2012/050664, 2012.

Hangan, H., "Method and System for Generating Any Type of Wind Fields", EFS ID : 614 436 46, 2011

Chronicle

2011.07

WindEEE Research Institute officially established

2011.08

800 mm Dome fan performance test performed in Pulaski

2011.09

The General Contractor and Fabricator of the WindEEE Dome were awarded contracts

2011.10

The earth moving equipment broke ground

Fabrication of wind tunnel steel components begun at LorDon

Honeycomb system contract awarded to Darchem

2011.11

Lift and turntable contract awarded to Dymech Engineering

2011.12

The 4-fan prototype was tested

First concrete poured at site

2012.01

First annual Institute research meeting to define the Vision, the Mandate and the Governing Structure of the WindEEE Research Institute

2012.02

Dr. H. Hangan and the WindEEE Research Institute receive the Going Global funding by the Ministry of Foreign Affairs Canada to travel and present WindEEE to European potential partners

2012.03

Dr. G. Bitsuamlak presents: "Resiliency of energy infrastructure for extreme wind", Wind Farms' Underperformance & Partnerships: Building Partnerships To Meet the 2030 Grand Challenge, Texas Tech University

2012.04

Visit #1 of Going Global to Germany and the Europoean Commission in Brussels. Participants Dean Andt Hrymak, Prof. Yves Gagnon (Irving Chair U. Moncton) and Horia Hangan. Collaborations are started with Siemens, E.ON Research Center U. Aachen, Fraunhofer Institute.

WindEEE displayed as part of the Engineering research at the London Convention Centre

2012.05

Grad student Maryam Refan participated in the ROTATE2012 project with a group of 30 researchers, grad students and engineers from various universities at Boulder, Colorado collecting data from live tornados

Visit #2 of Going Global to France. Participants are Associate Dean Hesham El Naggar, , Prof. Yves Gagnon (Irving Chair U. Moncton) and Horia Hangan. Collaborations are started with ONERA, Institute de Mecanique des Fluides and Meteo France (Toulouse) and with Paris International Energy Research Institute (PIERI).

Dr. G.Bitsuamlak receives the CRC grant for: "Wind engineering for resilient & sustainable built environment of the 21st century"

2012.06

Concrete pouring completed at the WindEEE site

Horia Hangan starts a 3 month collaborative sabbatical leave working with FM Global in Boston, US to define a new program in tornado damage assessment between FM Global and WindEEE RI

Dr. G. Bitsuamlak receives the Canada Foundation for Innovation, Leaders Opportunity Fund - Funding for research infrastructure : "Large-scale Experimental and Computational Infrastructure for Assessing Wind Effects on the Built Environment"

2012.07

LorDon begins install at dome site

Dome roof steel trusses delivered and erected

2m fans delivered

First 800 mm fans delivered

2012.08

Guillotine factory tested and approved

First layer of roof decking

H. Hangan delivers two seminars at the Massachusets Institute of Technology (MIT) and Northwestern University

2012.09

H. Hangan invited guest speaker and panelist at the ICWE in Shanghai, China

Upper plenum assembly hoisted into place

2012.10

DTU presentation by Dr. Jakob on "Laser scanning of a recirculation zone on the Bolund escarpment".

Visit #3 of Going Global. H. Hangan visits the Calatrava Architects Group in Zurich, Switzerland

OEM control system factory tested.

Test chamber ceiling installation begins

Guillotine installation begins

2012.11

CFI tours the WindEEE site

ABB installation begins

2012.12

Heat exchangers installed

Test chamber steel floor installation begins

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