1. EXECUTIVE SUMMARY

The Ontario Research Chair in Renewable Energy Technologies & Health (ORC-RETH) at the University of Waterloo officially commenced in May 2010. The five-year Chair program, which is highly multi-disciplinary, is addressing the technological, health, and safety issues of renewable energy conversion. In a unique blend of research approaches, technological issues linked to performance, reliability, and affordability are covered in parallel with health and safety aspects of the RETs at their production, operational, and end-of-life stages. By bringing together different expertise, the Chair program engages in in-depth studies, innovative R&D, and aims to provide technological solutions, guidelines, and recommendations. This Chair program is considered timely given today's rapid growth in the manufacturing and deployment of RETs. The RETs covered in this research are Wind, Solar PV, Solar Thermal, Bio, their hybrids and grid connection.

Building up a multi-disciplinary team of faculty members, recruiting graduate students at Master's and PhD levels, and hiring post-doctoral fellows were among the important tasks during the past year. Eight faculty members from two Faculties (Engineering and Applied Health Sciences) representing three academic departments (Electrical & Computer Engineering, Mechanical & Mechatronics Engineering, and Health Studies and Gerontology) are actively taking part in the research. A total of 13 graduate students (7 MASc, 6 PhD) and about 20 part-time undergraduate co-op and summer students (Waterloo and McMaster) have been engaged to work on the ORC-RETH program. There had been significant waiting time to bring the graduate students on board. Furthermore, most of them had to spend time in taking courses in the first year. Two post-doctoral fellows were also hired to work in the program from May 2011 on.

The ORC-RETH program has forged several cross-departmental research activities among the team members. In addition, a number of external collaborations have also been established in the first year as part of the on-going and planned research activities. These collaborations enhance and strengthen the scope of the research program. Notable collaborations that are either ongoing or initialized include: School of Nursing at McMaster University, Ontario Public Health Association- Environmental Health Working Group (OPHA-EHWG), Registered Nurses' Association of Ontario (RNAO), and Halton Region Health Department. Contacts have also been established with Education and Research Centre for Occupational and Environmental Health and Safety at the University of Colorado Denver, and future collaborations are being planned.

A secure web-based tool, SharePoint, has been set up for the research team with the support of the Information, Systems, Technology (IST) administration of the University. The system allows the researchers share and store documents, scientific and health data and provides an effective means of communication with all people having access to it. In addition to numerous informal meetings, theme-based Chair meetings are also taking place on a monthly (at times bi-weekly) basis. A website describing the Chair program (hhtp://www.orc-reth.uwaterloo.ca) was created and went live in May 2011.

In the first year, efforts were put on finalizing the work plans involving experimental and field activities, formation of task-based teams, and identification of infrastructure. While the ORC-RETH program involves technological and health & safety aspects of a range of RETs, the main focus has been on the wind technology and associated health and safety aspects. Team members from the faculties of Applied Health Sciences and Engineering are closely working on these topics. Research themes on technology and safety aspects of solar photovoltaic technologies, grid connection of hybrid renewable technologies, and nanotechnologies have also commenced. Activities on bio energy and solar thermal systems are scheduled to start next year.

As part of the studies on potential health effects of wind turbines working partnerships and collaborations have been established with other professional health associations and community health units. A scoping literature review on the topics has also been completed. Qualitative studies in community health will commence entailing detailed analysis of semi-structured interview transcripts and in a grounded theory method.

Protocols for performing clinical and epidemiological studies are also finalized along the lines of evaluation of clinical measures of health, psychometric evaluation of non-clinical measures of health, and observational epidemiology.

- In the first phase of evaluation of clinical measures of health, student teams were engaged with specific themes to come up with evidence-based recommendations pertaining to health assessment tools and clinical biomarker collection methods. Next, the most appropriate measures and methods of biomarker collection will be determined and the research and field study protocols will be finalized.
- In psychometric evaluation of non-clinical measures of health, a cross-sectional, case study with a possible combination of random and purposeful sampling will be utilized to obtain initial general health assessment information. Subsequent assessments of a random selected group of respondents reporting specific complaints such as, headaches, sleep disturbance, and stress, will be measured using specific survey tools.
- Progress has been made in study design and completing the data collection protocol for observational epidemiology studies pertaining to wind turbines. Epidemiological science and interaction with stakeholders were key considerations in planning the activities. Logistics will be worked out, and sample size computations based on the information gathered and survey studies will be carried out in the next year.

A study on risk communication on wind turbines and health in conventional print media outlets is undertaken as a subset of the ORC-RETH program, focusing on news media that serve communities with existing and proposed wind farms. Work is in progress in the identification of wind farms by province, community newspapers, and community profile characteristics. Quantitative directed content and qualitative thematic analyses will also be carried out on the database information.

Research activities have commenced on the application of geographical information systems (GIS) and spatial analysis technologies for wind turbines. Recording the exact locations, including GPS coordinates, of wind turbines in Ontario, making arrangements to have access to the Canadian Community Health Survey (CCHS) geographically-referenced micro-data from the Statistics Canada Data Research Centre, and preliminary analyses assessment on the use of GIS and CCHS data are some of the ongoing activities.

A noise exposure modelling work has been initiated covering propagation of wind turbine noise, sound power measurements, and evaluation/validation of existing models. The work will complement the activities of on-site noise measurements. Sound power level iso-contours will also be developed as part of this work.

Research on computational modelling of noise generation from wind turbine blades and design criteria for turbine blades has commenced and is in progress. High resolution flow fields are resolved with the development of computational fluid dynamics (CFD) tools, and the results are used in the prediction of trailing edge noise, contributed by dipole noise from solid surface loading and quadruple noise from the vortices. New design criteria are also considered involving trailing edge serrations.

On-site field measurements on wind turbine noise and wind speed are to be carried out. Arrangement is underway to acquire the equipment and instrumentation. Measurement protocols and locations are being worked out. In addition to the outdoor measurements, indoor measurements in the field are also planned.

Smart sensors based on micro-electro-mechanical systems (MEMS) are being developed for structural health and dynamic behaviour monitoring of wind turbines as part of the research work on safety measures for wind turbines. Blade strain, blade loading, wind velocity, gust and turbulence, vibration, blade acceleration, and temperature are the parameters to be studied. Initial work is focused on strain and vibration sensing, and geometries for new capacitive strain sensors and structures to amplify the strain on sensors are developed. An integrated smart sensor system consisting of different sensors, signal conditioning circuits, and data communication is being designed.

Research work has also commenced on hybridization of renewable energy technologies for increased reliability and performance, and also on the safety aspects of grid-connection of renewable energies. In the first phase, multi-input configurations in wind/photovoltaic hybrids combining sources from the DC-end to achieve maximum power are designed. In addressing the power quality issues in grid connection of renewable energies, studies on frequency fluctuation and harmonics distortion are underway. Development of a real-time dc injection measurement technique and advanced reliable anti-islanding methodologies are also in progress.

Experimental studies have commenced on the development of nanotechnologies for future solar systems and protocols are being developed to study the operational safety and reliability of the new materials. The research activities include synthesis and introduction of new nano-structured materials (quantum dots, nanowires) to demonstrate of the feasibility of next generation PV cells with conversion efficiencies higher than even the theoretical limit of conventional p-n junction solar cells, development of new solar cell architectures, and study design for experimental evaluation of material safety issues, particle exposure, and preventive measures in the production environment.

Besides the future technologies, studies are also carried out on the effects of new processes and materials on currently industrial technologies. Occupational health and safety studies have commenced utilizing the solar pilot facility at Waterloo as a test platform. In the first phase the introduction of new adhesive materials and metallic pastes in advanced screen-printing techniques for solar cell metallization are studied. Material development involving metallic additives and characterization is also carried out as part of the research.

The first year of the ORC-RETH program has progressed mostly according the plan. Despite some delays in recruiting graduate students, a multi-disciplinary team of researchers has been formed within the first year forging strong inter-departmental collaborations. Some external collaborations have already been established, with more research partnerships, including international, expected in the next year. Research activities in several wind and solar topics have commenced and a large number of students are being trained. More experimental and field activities are scheduled to take place in the second year. Dissemination of research results, in the form of publications and conference participations is expected to take place from the second year on.

2. MEMBERS OF THE RESEARCH TEAM

The following faculty members, post-doctoral fellows, and graduate students form the ORC-RETH team.

Faculty Members	
Prof. Philip Bigelow	Department of Health Studies and Gerontology (AHS)
Prof. Laurie Hoffman-Goetz	Department of Health Studies and Gerontology (AHS)
Prof. Mehrdad Kazerani	Department of Electrical and Computer Engineering (ENG)
Prof. Jane Law	Department of Health Studies and Gerontology (AHS), and School of Planning (ENV)
Prof. Fue-Sang Lien	Department of Mechanical and Mechatronics Engineering (ENG)
Prof. Stephen McColl	Department of Health Studies and Gerontology (AHS)
Prof. Siva Sivoththaman	Department of Electrical and Computer Engineering (ENG)
Prof. Zhongchao Tan	Department of Mechanical and Mechatronics Engineering (ENG)

Post-Doctoral Fellows	
Dr. Ehsanollah Fathi	Department of Electrical and Computer Engineering (ENG)
Dr. Mahtab Kamali	Department of Health Studies and Gerontology (AHS)

Graduate Students	
MASc Student #1	School of Planning (ENV)
MASc Student #2	Department of Electrical and Computer Engineering (ENG)
MASc Student #3	Department of Health Studies and Gerontology (AHS)
MASc Student #4	Department of Mechanical and Mechatronics Engineering (ENG)
MASc Student #5	Department of Mechanical and Mechatronics Engineering (ENG)
PhD Student #6	Department of Electrical and Computer Engineering (ENG)
PhD Student #7	Department of Electrical and Computer Engineering (ENG)
PhD Student #8	Department of Health Studies and Gerontology (AHS)
PhD Student #9	Department of Electrical and Computer Engineering (ENG)
MASc Student #10	Department of Electrical and Computer Engineering (ENG)
MASc Student #11	Department of Mechanical and Mechatronics Engineering (ENG)
PhD Student #12	Department of Health Studies and Gerontology (AHS)
PhD Student #13	Department of Electrical and Computer Engineering (ENG)

AHS: Faculty of Applied Health Sciences
ENG: Faculty of Engineering
ENV: Faculty of Environment

In addition, about 20 upper year undergraduate students from AHS (Waterloo) and School of Nursing (McMaster) were engaged during the first year on a part-time basis.

3. RESEARCH PROGRESS AND PLAN

The research progress made during the first year, and plans for the immediate future under the various topics in the ORC-RETH program are described below.

3.1 Potential Health Effects of Wind Turbines – Establishing Collaborations

Collaborative activities – McMaster University: A partnership has been established with the School of Nursing at McMaster University to strengthen our research capacity in the clinical sciences. One of our team's researchers has an adjunct appointment at the School of Nursing, and will coordinate a research practicum course that will allow 4th year nursing students to participate in various aspects of the ORC-RETH program. In the winter term of 2011 eight nursing students participated in the activity titled Health Effects of Wind Turbines- Literature Review. At present (spring 2011), six nursing students are collaborating with the team on finalizing field health measurement tools (both clinical and non-clinical measures) as well as a protocol for collection and evaluation of health assessment indicators and biomarkers of exposure/effect. In the fall 2011 term nursing students will participate in the field component of the investigation which will include clinical assessments and the collection of biomarkers. This research collaboration with the School of Nursing greatly expands the team's expertise and capacity in the clinical area. Additionally, it provides visibility and credibility in the community because of the social capital and professional status of the nurse-researchers.

Collaborative activities - OPHA-EHWG: Health researchers in the ORC-RETH team have initiated discussions and established strong interactions with the Ontario Public Health Association- Environmental Health Working Group (OPHA-EHWG). The mission of the OPHA-EHWG is to "To work collaboratively to improve the health of the public as it is impacted by environmental health factors through project participation, research and advocacy to promote healthy public policy". The EHWG is a multidisciplinary group with members being public health professionals with varied backgrounds including epidemiology, environmental health, and risk assessment. All aspects of the ORC-RETH program are of interest to the EHWG and they have agreed to collaborate with us when possible and when specific research interests overlap. Although the EHWG is limited in their capacity to actively participate in the hands-on research, they have agreed to provide expert reviews of products and research protocols. The OPHA-EHWG is a well-respected, professional group that has extensive connections in the field of public health in Ontario and in Canada. Thus, the EHWG is well suited to knowledge translation and exchange and indeed this is one of their key goals as it is integral to public health advocacy. In our discussions with the group their ability in communicating with the public health community was emphasized. We have agreed that we will provide study findings, when appropriate, to the EHWG and they will actively disseminate such information within their network and to their stakeholders. Interactions with the EHWG also will be valuable in our field studies as one of their key stakeholders are public health units across the province. Having EHWG support of our research protocols will aid in gaining participation of local health units and local communities.

Collaborative activities - RNAO: The researchers have also established collaborative interactions with the Registered Nurses' Association of Ontario (RNAO). RNAO is the professional association of Registered Nurses throughout the province and has over 31,000 members. The RNAO is well-respected by both the general public and by health policy leaders. RNAO through primary research activities or by careful review

of available evidence advocates for healthy public policy on a wide variety of topics relating to social determinants of health. Affiliation with this association has demonstrated the ability to lend additional credibility and trust that will facilitate planned field studies, community participation, and collaboration.

Collaborative activities – other community health units: Public health units across Ontario are aware of the ORC-RETH program as we often are contacted for information. A large proportion of questions is related to wind turbines and health. Through these queries we are actively engaged with a number of health units including those in the Grey Bruce, Halton, and Haldimand-Norfolk regions. At Grey Bruce we are close to finalizing arrangements to have an ORC-RETH student conduct a document analysis of complaints associated with wind turbines. Our interactions with personnel at the health units highlight the practical issues that public and environmental health specialists face in dealing with wind farm issues. These professionals are looking to the ORC-RETH program for unique approaches as well as good practices in resolving health-related and health communication issues.

3.2 Potential Health Effects of Wind Turbines – Literature Review

A scoping review of the published literature pertaining to wind turbines and health effects/concerns has recently been completed. As the literature was diverse, a thematic analytic approach was used to identify and quantify the reporting of wind turbine related health concerns. Findings from primary research studies were evaluated using the Bradford Hill criteria which is a common theoretical framework in epidemiology for assessing causality. The information from this review provided useful information regarding the nature of complaints, state of the scientific evidence for causation, and the advantages and limitations of exposure and health assessment tools used in past investigations. Key themes from the review are:

- Evidence is conflicting for health impacts related to wind turbines
- Overall the quality of the studies is low
- Investigations rarely measure exposures to audible or low frequency noise
- Studies are predominately qualitative
- Annoyance is cited with greater frequency than adverse physiological health impacts
- Commonly reported health complaints reported were sleep disturbance, headache, visceral vibratory vestibular disturbance, dizziness (vertigo, unsteadiness), tinnitus, ear pressure or pain, memory and concentration deficits, irritability, and fatigue.
- Based on a few methodologically weak studies reporting associations, there is limited evidence to support an association of exposure to wind turbines and adverse health effects in humans

3.3 Qualitative Studies in Community Health

Wind farms have the potential to impact the communities in which they are located and these impacts can have potential health implications at the individual and population levels. The community impacts are often first observed when decisions are made to site wind turbines in a location where community members feel they will be affected. In the fall of 2011 field work will begin on an investigation that will explore the processes by which communities deal with what may be seen as an intrusion: namely the siting, public consultation, and operation of commercial wind turbines in rural settings. The research questions will include:

- How does community structure change as a result?
- What are the processes whereby communities and individuals deal with this issue?

- Is there a dominant discourse present on either side of the debate that functions in the context and role of power relations?
- How do these power structures change and shift as the process continues?

Using qualitative methodology, an interpretivist frame and specifically taking a postmodern grounded theory approach, the study will explore the connections and disconnections that make up community processes surrounding these decisions. This will entail detailed analysis of semi-structured interview transcripts. By following a grounded theory method, investigators will attempt to tease out categories and concepts that are directly grounded in the data, then processually connect the overarching themes in order to reassemble them into a working theory of community action and reaction, engagement and disengagement; all in a context conscious of the power structures that shape and guide community functioning.

In order to gain an understanding of the overarching issues that face communities prior to the data collection in the community, an analysis of narratives on an anti-wind advocacy group website was completed. This component of the study explored elements of thematic organization in online narratives presented by Wind Concerns Ontario (WCO) and examined how they related to community resistance and activism. The WCO is an umbrella organization representing 57 smaller activist groups across Ontario whose stated mandate is to protect citizens' quality of life as it relates to the development and installation of wind turbines. Detailed findings from the analysis of the WCO narratives are contained in a manuscript that is in preparation titled: "Wind Energy Blows! An Analysis of Anti-Wind Activism Narratives" thus only a brief summary is presented here. Three dominant functions of the WCO narrative that emerged were the evocation of feelings of disruption, doubt, and injustice. The themes that were identified seemed to interact in various ways with the actor focus of each piece to solidify their meanings to the audience. Practical implications of this research include the potential use of narratives on websites as framing devices for the anti-wind movement. Further understanding of the ways in which narratives are used, disseminated, and understood by anti-wind groups and other social movements may give insight into the social processes through which we understand collective and participatory action.

3.4 Wind Turbine Exposures: Clinical and Epidemiological Studies

The ORC-RETH team has made significant advances focused specifically on Clinical and Epidemiological Studies of Wind Turbine Exposures. The health researchers in the team, in a broad and inclusive approach, have come up with study designs that will allow examination of multiple exposures from wind turbines (e.g., flicker, visual impacts). These initiatives include;

- Evaluation of clinical measures of heath
- Psychometric evaluation of non-clinical measures of health, and
- Observational epidemiology – Study design and data collection protocol

3.4.1 Wind Turbine Exposures: Evaluation of Clinical Measures of Health

The nursing students from McMaster were divided into small research teams and were assigned a specific theme previously identified within the literature review to study and provide evidenced-based recommendations pertaining to health assessment tools and clinical biomarker collection methods and measures. The research teams are in process of completing a literature search of environmental health data bases such as, Cinhal, Medline, Ovid, Proquest, Pub-Med, Web of Science, and Ebsco Host. Each team has searched specifically for information regarding biomarkers according to the following sub-categories and keywords:

- Chronic stress/ psychological stress/ sleep disturbances/ headaches/ annoyance/ anxiety/ depression
- Environmental noise/ chronic stress/ psychological stress/ sleep disturbances/ annoyance/ anxiety/ depression/ headaches
- Noise/ chronic stress/ sleep disturbances/ anxiety/depression

The third category did not produce many results; however, over thirty articles were obtained and are subsequently being reviewed. A detailed description of the review process, references, research binders and presentations is being prepared. As a next step, the research team will determine most appropriate measures and methods of biomarker collection and finalize research and field study protocol.

Preliminary analysis of the literature indicate that venous cytokine measures and urine cortisol levels are valid and reliable measures of inflammatory process and chronic stress and would be a clinically appropriate measure in context of potential health effects of wind turbines.

3.4.2 Wind Turbine Exposures: Psychometric evaluation of non-clinical measures of health

A cross-sectional, case study with a possible combination of random and purposeful sampling will be utilized to obtain initial general health assessment information. Subsequent assessments of a random selected group of respondents reporting specific complaints such as, headaches, sleep disturbance, and stress, will be measured using specific survey tools. Each reported heath complaint and/or health theme identified within the literature goes through a process of review, analysis, evaluation measures and validity.

General Health Assessment Tool: A comprehensive literature review has been completed on valid and reliable health assessment survey tools that would be appropriate and applicable to wind turbines' reported symptoms. Upon review of available assessment tools and over twenty journal articles, the conclusion was to use the SF36v.2 health assessment tool. The SF 36 tool is valid and reliable and has been used throughout the world in a number of research contexts. The survey can be administered in a variety of methods including on-line, phone or paper formats. The SF 36 includes general information regarding psychosocial, physical and functional aspects of health. A further recommendation was to consider utilizing the Canadian Health Care Survey (CHCS) as a means of obtaining baseline measures of health from which to compare responses from those exposed to wind turbines. Questions are being reviewed in context of requirements of a complete health assessment of reported complaints by those exposed to wind turbines with the purpose of creating a hybrid health assessment survey tool. In addition to this health survey document, qualitative questions will be formulated that would provide additional health assessment measures not included within closed ended quantitative survey tools. The revision of the hybrid assessment tool and questions is expected to be complete by mid-fall 2011 before pilot testing. Considering health effects and any correlation to reported health effects in a holistic, rather than separate health complaint is important for these types of health complaints and measures. Literature indicates that reported complaints are often interconnected, therefore, determining if a dose response, pre-existing medical conditions existed and conducted sequential and repeated health assessments will improve the ability of the research team to identify if any causal relationship exists between wind turbine and reported health complaints.

Headache Assessment: Headaches are a commonly reported complaint among those living near a wind turbine. Headaches are a symptom rather than an illness or disease. It is the result of any abnormality occurring in the organs of the body such as the cardiovascular, endocrine, or gastrointestinal. (Smeltzer & Bare, 2001). There is much debate regarding the high quantity of reports of headaches in relation to wind turbines. This is because headaches are subjective symptoms and there are no objective measures available to explain the cause of the reported headaches. Because annoyance is a common report in relation to

headaches, it is important to explore this further. The annoyance is a result of the mechanical noise. For those who live near wind turbines, their headaches most often occur in the summer season and during times when they are outdoors (Pedersen & Peerson, 2004). In terms of the infrasound, there is detection; however people are unable to distinguish whether the pain is from actual sound or infrasound. "The lower the infrasound, or frequency of waves, the higher the energy. Therefore, there is higher energy entering the ear creating resonant vibrations on objects, the house, body (e.g. chest cavity). Detection raises the possibility of subjective reactions such as, annoyance, and annoyance may contribute in complex ways to other biological and psychological effects of the signal," (Berglund & Hassmen, 1996). This may explain why people report other physiological health complaints related to headaches and annoyance. One very significant variable is the interpretation of the attitude and sensitivity to wind turbines.
It is therefore imperative to explore the aetiology and pathophysiology of headaches to further understand and identify the origin of these headaches. The headache tool –HIT 6 – has been chosen after completing a critical appraisal of each available assessment tool.

Sleep Assessment: Poor sleep can increase stress levels, thus increasing incidence of headaches. Coincidentally, these are all found in reports of health effects from wind turbines. When people report having a negative belief about wind turbines, they are more likely to report health symptoms, than those who have a positive insight (Pedersen & Peerson, 2004). As people age, they are more sensitive to noise, whether it is infrasound or not.
A review of literature regarding preferred sleep assessment measures has been completed. Sleep assessment recommendations have been incorporated into research design and planned field studies. The director of a sleep lab in the Kitchener-Waterloo area has expressed an interested in the research. This collaboration with a credentialed sleep lab will allow for field and lab polysomnography testing and using participants as their own control enabling dose response effects of wind turbines and sleep. Other methods of measuring sleep, including design and use of a sleep diary, will also be considered.

Vestibular Function and Noise Processing: The bulk of available literature pertaining to wind turbines is in the area of noise, especially infrasound. Within a multidisciplinary team of predominantly non-clinical researchers, there was an identified need to have working knowledge of how noise is received and processed. Many reported wind turbine symptoms included complaints whose aetiology could be connected to the vestibular system.
As part of this approach, a review of the human vestibular system, mechanics and sound processes has been completed in context of wind turbines. A review of sound waves and their effect to middle and inner ear and potential to cause symptoms of nausea, dizziness, headaches and even vision effects helped shape additional noise assessment field work plan.

3.4.3 Wind Turbine Exposures: Observational epidemiology – Study design and data collection protocol

The success of a major epidemiologic field study of the type to be conducted is largely related to pre study planning and preparation. Considerable effort has gone into planning activities both in terms of the epidemiologic science as well as interactions with stakeholders. Through our discussions with stakeholders, sample size considerations, as well as logistical issues (e.g., travel time of researchers) we have selected three communities with existing wind farms that are under consideration for selection of one that will be the location of data collection in 2011-2012. One of Grey Bruce, Ripley or Piston will be selected for inclusion in Phase 1 of the epidemiologic study. A community similar in size and demographics will be identified once the "exposed" community is identified and issues of recruitment are resolved (e.g., buy in by community groups and local government). Preference for a control community will be given to one that has a high probability that a wind energy installation will be installed in the future but no public announcement has been made.

The overall study design will be prospective with opportunity for a nest case-control arm. The prospective component will be panel study with participants providing information at multiple intervals of time. The cohort will be enumerated based on stratified random sampling of respondents to a census baseline survey conducted in the two communities. Thus the design incorporates a cross-sectional aspect which allows for the determination of prevalence of symptoms in the study communities (Hudson et al 2005). A stratification variable for enrolment in the cohort will be distance from the nearest wind turbine in the exposed community to ensure sufficient variation of this variable in the dataset. To reduce respondent burden, not all scales and health measurements will be administered to all study participants. Only selected individuals in the cohort will be requested to participate in the longitudinal aspect (repeated measures component) and will be administered all study scales and health measures.

Phase 1 of the study is essentially a pilot to work out the logistics and gather information required for sample size computations. In the winter of 2012, the baseline census surveys will be completed and recruiting in both communities for the cohort will be conducted until 20 subjects in each agree are enrolled. These 20 subjects in each community will be asked to keep diaries, wear activity monitors during the evening, and re-administered the measurement instruments at specific intervals. The first follow-up interval will be 7-days.

3.5 Studies in Risk Communication

Mass media has an important role in the framing of health risk messages and the setting of key public agendas about risk. Most members of the public obtain health risk information from the media; media influences public opinion and public opinion can, in turn, affect policy. Therefore, a study on risk communication on wind turbines and health in conventional print media outlets is undertaken as a subset of the ORC-RETH program, focusing on news media that serve communities with existing and proposed wind farms.

Progress and Study Plan: Newspapers that serve Alberta, Ontario and PEI communities with existing large and small wind farms will be identified using a variety of online databases and provincial /federal documents. Newspapers will be searched in online databases for articles, editorials, opinion pieces, and letters to the editor on wind turbines and health from 2000-2011. Included articles will be analyzed for information about wind turbines and health using a mixed methods approach:

- Quantitative Directed Content Analysis, and
- Qualitative Thematic Analysis.

To date, the following have been identified:

- The 3 largest and 3 smallest wind turbine farms by province
- Community newspapers which serve the areas where the wind turbines are installed, and,
- Community profile characteristics.

The next steps entail identification of those newspapers available through Lexus/Nexus and Factiva online databases, those newspapers available only through manual access, generation of search terms for article retrieval and generation of inclusion/exclusion criteria for articles.

Web-based media is specific form of mass media and a study is underway to analyze the ways wind turbines are portrayed on the internet in terms of their health risks. This study will also examine how these depicted health risks have changed over time. So far approximately 250 items have been collected and are being analyzed. Initial findings have shown risks related to wind turbines are portrayed in a variety of ways and the in the past few years the number of hits for health concerns have increased substantially. Services that track internet search volumes by keyword will be used to document internet media trends related to wind

turbines and health. Further information will also be collected on issues that are not health specific such as concerns on property values that occur with more frequency.

3.6 Geographical Information Systems (GIS) and Spatial Analysis Technologies for Wind Turbine Studies

Study on the application of GIS and spatial analysis for wind turbines has commenced. Efforts are under way to record the exact locations, including GPS coordinates, of wind turbines in Ontario. Also, arrangement is underway to have access to the Canadian Community Health Survey (CCHS) geographically-referenced micro-data from the Statistics Canada Data Research Centre. Together with the data regarding wind turbine locations preliminary analyses will be carried out to assess the use of CCHS data for the study.

Progress and Study Plan: About 36 wind farms, totalling approximately 817 wind turbines have been found in the province of Ontario. Geo-coding their locations using GIS will take place in the future. As initial steps, the analysis will focus on one or a few wind turbines in Ontario. Since the CCHS collects health data as well as respondents' addresses, a search of postal codes within the CCHS database can be done, and using Statistics Canada's postal code conversion file the specific location of a respondent's house can be geo-coded. This allows for the creation of a database with both geo-coded wind turbine locations and locations of CCHS respondent's homes. This enables searching surveyed citizens by location. Possible ways of analysis are being developed. Protocols for sensitivity analysis and selection of control groups are also being developed.

3.7 Wind Turbine Noise Exposure Modelling and Evaluation

The study started with the purpose of development of a model and metrics that represent sound power measurement with acceptable accuracy, and to complement other activities of health studies and on-site noise measurements.

Activities and Work Plan: A thorough literature survey on noise propagation models and wind turbine noise perception and annoyance in different communities was done. A draft for evaluation of "noise iso-contours" using ISO standard and different noise propagation models is prepared.

- A noise propagation model for wind turbine noise that presents corresponding field measurements will be developed and validated. The measurements at different locations in different meteorological conditions will be employed to figure out a robust model that accurately presents the noise exposure level.
- Sound power level iso-contours on Google map around different Ontario wind farms based on the variety of noise propagation models will be drawn. These contours will indicate the intensity of the noise at dwellings around wind farms. These contours, along with existing meteorological data (from Environment Canada), can also be used to predict the maximum noise that each receptor in the area of a wind turbine is exposed to with respect to different climate conditions.

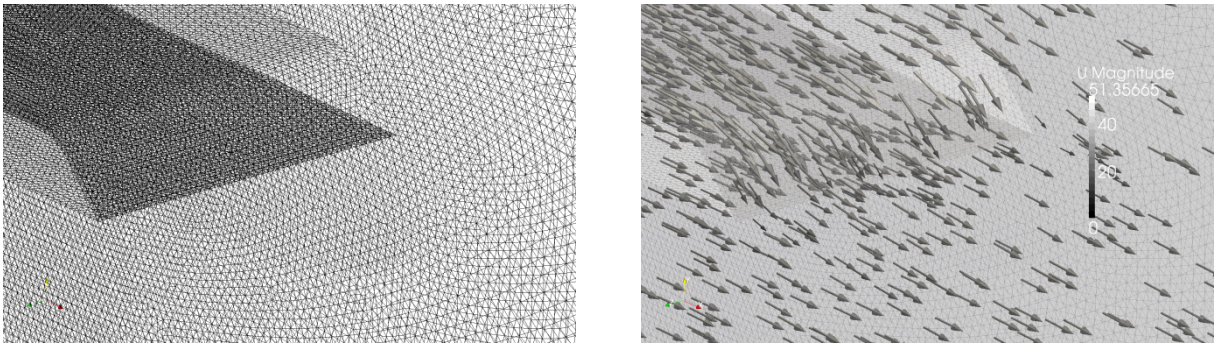
3.8 Modelling of Noise Generation in Wind Turbines and Design Criteria

This research activity has commenced with the initial focus on the aerodynamic noise generated at the trailing edge of the wind turbine blade due to vortex shedding. Dipole noise from the loading of the solid surface and quadruple noise from the vortices contribute to the trailing edge noise. With the development of computational fluid dynamics (CFD) tool, a very high resolution flow field can be resolved with reasonable computational resources and the flow results can be used in trailing edge noise prediction. In all the CFD

methods available, Large Eddy Simulation (LES) with a sufficiently fine grid has been proved to be able to generate a highly detailed flow field with the computational power available today. In addition to be used as an input to aero-acoustics computation, the detailed flow field can provide insight in terms of the mechanism of the turbulence that generates noise.

Work Plan and Progress: After the accurate modelling of the trailing edge noise, the method to reduce the noise will be studied. Using CFD and acoustic models, the air foil blade with and without trailing edge serration will also be compared and validated for noise reduction. A beam forming method will be used to create an acoustic image at different location to help accurately locate the source of noise at different frequencies. A comparison will be made with the flow structure and in order to establish a relationship between the two. Further improvement to the blade design can then be made and validated.

- A comprehensive literature review has been conducted to set the path and goal of the research.
- A test case (low Mach number flow over a flat plate with and without trailing edge serration) has already been simulated in the OpenFOAM environment using Reynolds Averaged Navier Stoke (RANS) with k-ε model, in order to validate the use of the CFD software to generate flow field results.



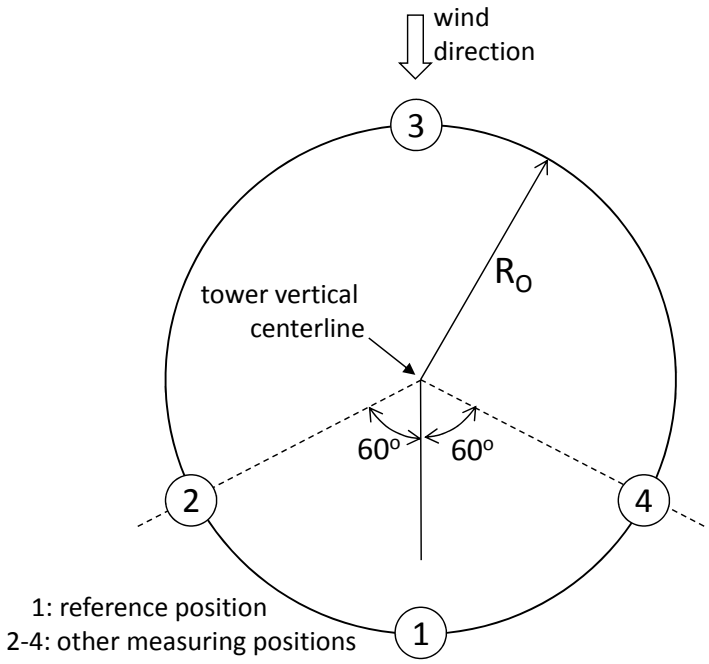
Mesh (left) and Flow Field (right) of non-serrated flat plate trailing edge

3.9 Wind Turbine Noise Measurements

Field measurements on wind turbine noise and wind speed are to be carried out. Planning is underway to either acquire or rent the equipment and instrumentation for the measurements. Key components include multi-channel SoundBook, Sensors, Anemometers, and Wind direction transducers. Noise data to be measured include: A-weighted sound pressure level, one-third octave band measurements, and narrow-band measurements. Also, other measurements of infrasound, low-frequency noise, low-frequency, modulation of broadband noise, impulses or unusual sounds (whine, hiss, screech or hum) are also planned.

The noise measurement data will normally include:

- Measured position of each microphone for each measurement series
- $L_{WA,k}$ (apparent sound power level, where k=6,7,8,9,10) at each integer wind speed from 6 to 10 m/s along with background corrected normalized values.
- Measured data pairs at measuring positions of the wind turbine sound and background noise
- Sound pressure spectrum in third octaves for each integer wind speed from 6 to 10 m/s.



Typical microphone positions for the noise measurements (after ICE 61400-11: 2002)

In the measurement activity, the following will also be considered:

- Simultaneous measurements to be made from at wind turbines and homes to determine the transfer path and relationships to structures.
- Synchronous measurements and processing including Order Analysis and Order Tracking.

The feasibility of indoor measurements will also be studied to involve absolute pressure measurements to capture the periodic components of with turbines by the use of spectral signal averaging techniques.

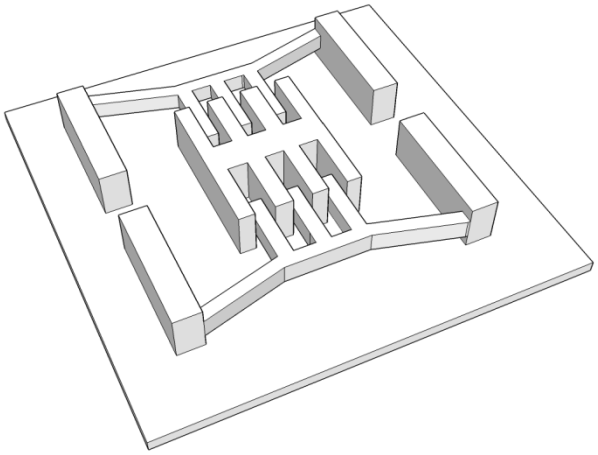
3.10 Structural Health and Dynamic Behaviour Monitoring of Wind Turbines Using MEMS Smart Sensors

Monitoring of structural health and dynamic behaviour in wind turbine systems is an important safety measure, as structural damages can be catastrophic. Different types of stress, fatigue, wind gusts, and moisture are the main causes of wind turbine structural damage. Risk of damage can be minimized by developing successful health monitoring methods with advanced sensing technology and appropriate signal interpretation.

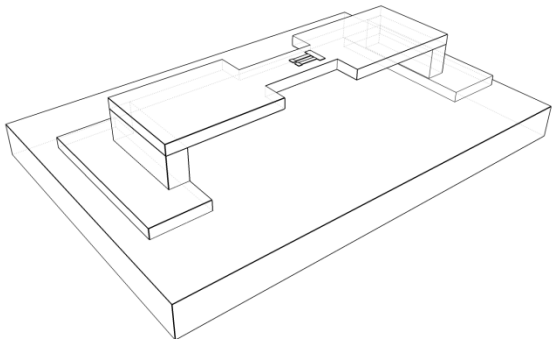
Sensing and control mechanisms deploying devices based on microelectromechanical systems (MEMS) receive serious consideration due to their fast response, high accuracy, stability, and minimum size and weight. They can provide successful operation of condition monitoring systems and therefore better energy capture efficiency of the turbines. At same time low cost sensing possibility of MEMS sensors and its compatibility for integration with CMOS technology for data analysis are the key factors to obtain wind turbine reliability goals. Important sensing parameters for wind turbines are: (a) blade strain, (b) blade loading, (c) wind velocity, gust, and turbulence, (d) vibration, (e) blade acceleration, and (f) temperature.

Blade Strain Sensing: Initial work is focused on blade strain sensing. Most force and torque measurement devices utilize the long and well established resistance strain gauge technology. Unfortunately, the metallic resistance strain gauge is relatively insensitive, their range and overloading capabilities are seriously restricted, and consumes relatively high electrical power. Today's measurement instrumentation needs smaller sensing devices with lower power consumption, enhanced capabilities, and greater compatibility with digital microelectronics. Noncontact, wireless, and battery-less capability is also desirable. A thorough survey has been carried out for candidate technologies including MEMS piezoresistive strain sensors, embedded optical fibres, and semiconductor MEMS-based devices.

Work Plan and Progress: Geometries for new capacitive strain sensors and structures to amplify the strain on sensors are developed. Simulation and evaluation using COMSOL Multiphysics software and MEMS Module are underway.



The proposed MEMS-based capacitive strain sensor

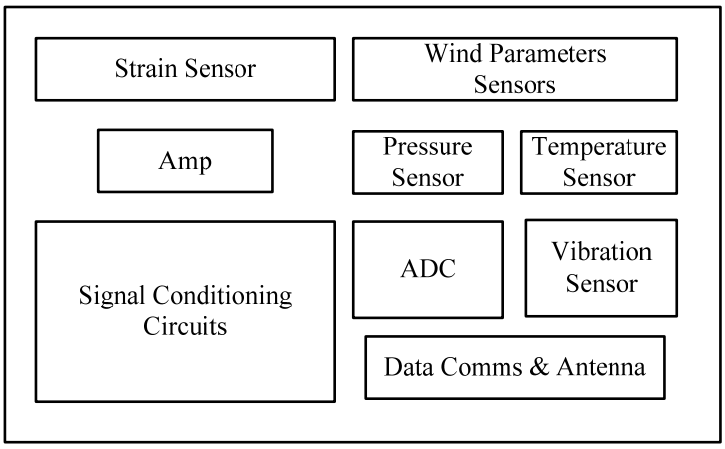


Proposed design for gauge factor amplification

The MEMS capacitive strain sensor is designed to convert the input strain to a capacitive change with high sensitivity. By carefully designing different parameters such as the buckling angle of the beams, number of fingers, and dimensions, the device sensitivity will be improved. The final design will be modified using Finite Element Method (FEM) simulation. Laboratory fabrication of the structures will follow.

Vibration sensor can be fabricated using either strain sensors concept or accelerometers with some slight modifications in structure and data interpretation. Data interpretation and analysis will play an important role in sensing the detrimental vibration. Moreover, wind turbulence and gust may cause rotor imbalance and hence rapid changes of the pitch angle of the blades are necessary. They may also generate large dynamic fatigue loads and significant increase in bending moments acting on the blades. Another dimension to ensure efficient and safe operation of the turbines necessitates detection and prediction of wind turbulence and gusts.

Given the recent advances in the field of MEMS technology and the fabrication of integrated chips, realizing a MEMS-based chip consisting chiefly of microsensors, microactuator, communication, and signal processing components will lead to the monolithic integration of sensors for wind turbines. The wireless capability relieves the burden of cabling issues. A proposed integrated smart sensor for wind turbine blades is shown below.

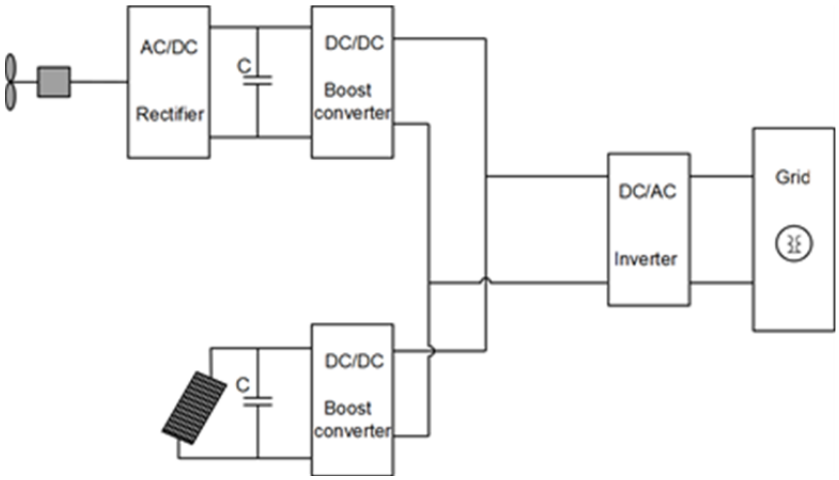


Proposed integrated smart sensor for wind turbine blades

3.11 Hybridization of renewable energy sources and grid connection

This study is focussed on enhancing the (a) performance, and (b) reliability of renewable energy systems via hybridization, and, (c) ensuring safety in their connection to utility grid. Initial phase of the study is centered on the wind/photovoltaic (PV) hybrid systems. Development of hybrid designs is underway for higher performance and reliability. Activities in progress are described below.

Hybrid Design: While several wind-PV hybrid power systems have been proposed in the literature, most of them use separate dc/dc boost converters. These systems can be simplified by using multi-input structures that combine the sources from the DC-end while still achieving maximum power point tracking for each renewable source. Fusion of the buck and buck-boost or the Cuk and SEPIC converters are being studied.



Schematic diagram for the hybrid PV-Wind system

Studies on Frequency Fluctuation and Harmonics Distortion: Power quality problems mostly arise from the contamination of the voltage or frequency characteristics of electric power. In such cases, the system exhibits different issues such as voltage sag, harmonic contamination, and voltage regulation problems. While some of these power quality problems are due to the intermittent nature of wind and solar energy resources, the majority of these issues come from the low quality power electronic components. In

PV/wind hybrid systems, low quality semiconductor components (dc/dc and dc/ac converters) lose their ideal performance by time and result in fluctuations in the output power characteristics. These fluctuations are observed in the form of a distorted sinusoidal waveform output and causes problems such as harmonic contamination and poor voltage regulation. According to the IEEE standards, a maximum of 3 to 4% total harmonic distortion may be allowed from inverter outputs. However, many inverter outputs have much more harmonic distortion than is allowed. The resulted harmonic and voltage sag issues can potentially impose many safety issues when these hybrid systems connected to a grid carrying perfect sinusoidal waveforms. Studies are in progress on the safety (and possibly health) complications that could result from mixing these distorted waveforms by considering the sensitivity of the grid waveform characteristic on the different output waveform fluctuations of the hybrid systems.

To acquire the harmonic data of a hybrid system, we use PSCAD®/EMTDC™ power system simulator. This simulation tool provides a fully modular and visual power systems simulation environment giving the user online control of input data, and the ability to record and display the output data. Using this software, different types of inverters can be implemented for a PV/Wind hybrid system. Here we use a twelve pulse type inverter. This inverter and the control circuit models are both standard models in the PSCAD/EMTDC software package. These kinds of simulations enables us to improve the hybrid power system performance and reliability in terms of power quality, power electronic and control system design and optimization.

Development of a real-time dc injection measurement technique: dc injection suppression is crucial for the PV systems. IEEE Standard 929-2000 specifies that the PV systems shall not inject the DC current greater than 0.5% of the full rated output current to the grid. Usually DC injection measurement is performed to evaluate a transformerless PV system and also to find the opposite dc values that should be injected to the line via a proper control unit. However, in transformerless PV systems, in the presence of high AC currents, it is difficult to extract the very low-level (0.5% I_{rated}) DC currents. In order to overcome this limitation, an effective real-time dc injection measurement technique is being carried out in this project.

Advanced and Reliable Anti-islanding Methodologies: One of the main parts of this research includes the development of an advanced and reliable anti-islanding functionality for grid-interactive inverters used in PV/Wind systems. Most inverters detect the islanding condition by looking for a combination of the sudden change in system frequency, voltage magnitude and the reactive output power. Studies have commenced on this subject. The provisions for safety functions, including the response of the inverters to abnormal utility conditions, by IEEE 1547, “Standard for Distributed Resources Interconnected with Electric Power Systems” are also considered.

3.12 Nanotechnologies for future solar systems and safety considerations

The research work on developing nanotechnologies for photovoltaic devices has commenced. While the nanotechnologies for PV are at an early stage of R&D worldwide, there is agreement that they will play in important role in future PV manufacturing. In this project the ongoing nano-PV work is carried out along the following lines:

- Demonstrate the application of nanotechnologies on conventional PV device platforms in order improve the performance of the latter.
- Introduce and allow the use of inexpensive materials and low production costs while boosting energy conversion efficiency.
- Demonstrate the feasibility of next generation nano-PV devices with conversion efficiencies higher than the theoretical limit of conventional p-n junction solar cells.
- Use the development work as a test platform to study the operational safety, precautionary measures, and manufacturability of the new materials at this early stage.

Work in progress – Technology Development:

- Incorporation of hydrophobically ligated cadmium selenide/zinc sulfide CdSe/ZnS quantum dots (QDs) in transparent matrices by formation of CdSe/ZnS/SiO_2 core/shell/shell structure using a micro-emulsion synthesis method. The optical properties of the QDs over-coated with a chemically grown oxide layer have been studied. The QD/silica films will be used for photon down shifting and multiple exciton generation for PV devices.

- A process has been developed to form arrays of zinc oxide (ZnO) nanowires in a low pressure chemical vapour deposition system. Two types of material growth methods have been established to obtain tangled and aligned nanowire structures for applications as anti-reflection coating and as electrically active components in quantum-dot sensitized NW solar cells respectively.

- Formation of metallic (silver) nanoparticles as plasmonic structures has been demonstrated as a first step to enhance the photovoltaic performance of thin film solar cell structures. The structures are to be used as, (a) metallic nano-particles acting as sub-wavelength scattering objects at the absorber surface, (b) propagating waveguide modes inside the thin film absorber, and (c) thin film layer creating high near-field intensities associated with surface plasmon polaritons.

- Preliminary studies have commenced at the design level to use quantum dot arrays to create intermediate bands in the semiconductor structure. The purpose is to use those structures for the experimental demonstration of demonstration of intermediate bandgap (IB) solar cells. In addition to device design, candidate materials for the QD and the host, as well as the desired structural properties are investigated.

Work in progress – Health and Safety Aspects of the Technologies:

- The existing experimental facilities for nanomaterial synthesis and device fabrication are to be used as test-platforms to study to safety measures. Glove boxes, exhausts, chemical wastes, and cold-traps are put in place in line with the University safety regulations.

- Plan is underway to secure funding (through an NSERC-RTI proposal, Oct 2011) to acquire a Scanning Mobility Particle Sizer Spectrometer which is capable of measuring particles in the 2.5nm – 1000nm range, offering a continuous, fast-scanning measuring capability. The system, designed for long-term environmental monitoring without operator intervention, will enhance our capability in particle emission testing, indoor air quality measurement, inhalation research involving health effects of ultrafine particles.

- Contact has been established with a Research Specialist in Environmental Health of the Halton Region Health Department. A first meeting has taken place (June 2011) and plans for collaboration in nano material safety research is underway.

3.13 Advanced solar manufacturing and safety considerations

The new pilot processing facility for solar technology at the University “simulates” the manufacturing environment of current industrial technologies. The pilot facility, which is now partly operational, provides an ideal study environment for studying lab-developed improvements in current manufacturing techniques as well as the operational and material safety aspects.

Work Plan and Progress: As a first step in developing new manufacturing techniques, metallization process is taken up. To address the drawbacks in current screen-printing technology that requires high firing temperatures there by deprive the devices from having the “theoretically-optimal” shallow junctions to avoid shunting, research has commenced in developing new types of highly conductive and printable pastes that can support shallow junction devices, through lower required heat treatment, to be manufactured with high performance. Ongoing and planned activities are:

- Analyzing the current available metallic pastes in the screen printed solar cells: finding the chemical composition of metallic pastes, investigating material properties and electronic behaviour of deferent ingredients and additives (in progress)
- Investigating the current conductive adhesive materials using in electronic devices (in progress)
- Developing proper metal additives required for; improving the conductivity of available conductive pastes, and controlling the contact formation by thermochemical analysis (in progress)
- Exploring the chemical stability of the additives (in progress)
- Investigating the manufacturability of the new additives
- Inspecting the health and safety issues of the new additives
- Process development for printable paste formation
- Evaluation of the new pastes printed on solar cells; paste wetting and etching, paste transfer process and contact formation during heat treatment, phase transformation during heat treatment
- Analyzing Chemical, Mechanical and thermal stability of the new pastes; corrosion behaviour of the paste in reaction with oxidants, erosion behaviour due to transport by wind, water, or ice, stability, adhesion tests under extreme temperature conditions, humidity and thermal shock tests.
- Evaluating the health and safety issues of the new developed pastes during manufacturing, based on the chemical composition of the conductive adhesive material and curing agent, additives, and any new phases that for during the heat treatment.

The necessary chemical processing facilities and experimental set-up for screen-printing and heat treatment steps are already in place.