# DRAFT SOUTH AFRICAN WIND ENERGY TECHNOLOGY PLATFORM: PRELIMINARY WIND ENERGY RESEARCH AND DEVELOPMENT FRAMEWORK

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## ABSTRACT

**The South African Wind Energy Technology Programme (SAWEP) Phase 1 aims to achieve two key strategic outputs that will guide South Africa on wind energy development. One of these outputs is the Wind Atlas for South Africa (WASA) which will play a significant role in providing information for potential investors for wind farms on areas that have opportunities. The other output is the study of the development of a Wind Industrial Strategy for South Africa. This will help determine the possibility of establishing a wind industry in South Africa. The Wind Industrial Strategy project aims to play a strategic role in paving the way for the gradual phasing in of wind energy in South Africa.**

**One of the objectives of the Wind Industrial Strategy project was to also undertake a preliminary investigation into local innovative wind turbine and component research and development.**

**This paper describes the potential high-level opportunities for wind energy research and development. A preliminary Technology Tree and a Draft South African Wind Energy Technology Platform is also discussed.**

## 1. INTRODUCTION

Preliminary results from the Wind Atlas for South Africa (WASA) project are showing that South Africa has good wind resources. As these wind resources become more accurately quantified, the opportunities for exploiting these wind resources become clearer. This results in the application and justification of wind energy technologies becoming clearer.

As yet neither South Africa nor the CSIR has a wind energy research and Development strategy to quantify what are the opportunities and priorities to wind energy innovation.

This paper will attempt to answer the primary research question: “What are the opportunities for wind energy research and development in South Africa?”

A preliminary research and development strategy is discussed in the SAWEP project: “Investigation into the development of a wind energy industrial strategy for South Africa, [1].

The International Energy Agency (IEA), [2], published a global technology roadmap for wind energy. This roadmap aims to identify the primary tasks that must be undertaken in order to reach a vision of 2000 GW of global wind energy capacity by 2050. Governments, industry, research institutions and the wider energy sector will need to work together to achieve this goal. Best technology and policy practise must be identified and exchanged with emerging economy partners, to enable the most cost-effective and beneficial development. The IEA’s primary tasks in this technology roadmap are:

- Wind technology development
- Delivery and system integration
- Policy frameworks
- International collaboration

During the Barcelona European Council in 2002 the European Union (EU) set the goal of increasing the European research effort to 3% of EU’s GDP by 2010, with two-thirds coming from private investment and one-third from the public sector.

To reach this objective, the European Commission proposed six key instruments, one of which is the implementation of Technology Platforms. This instrument was designed to bring together companies, research institutions, the financial world and regulatory authorities at a European level to define a common research agenda. This research agenda aimed to mobilise a critical mass of both national and European public and private resources.

In 2006, the European wind energy sector launched the European Wind Energy Technology Platform (TPWind). TPWind’s ,[3], tasks are to identify and prioritise areas for increased innovation, and new and existing research and development tasks. Its primary objective is to reduce the social, environmental and technological costs of wind energy.

The Strategic Research Agenda (SRA) of TPWind is divided into five thematic priorities for research. These thematic priorities are:

- Wind resources, design wind conditions and forecasting
- Wind turbine technology
- Wind energy integration
- Offshore deployment and operation
- European research infrastructures.

## 2. STATE OF THE ART TECHNOLOGY

Over the past 20 years, average wind turbine capacity ratings have grown continuously with the largest fraction of onshore utility-scale wind turbines installed globally having a rated capacity of 1.5 MW to about 3.6 MW. The main reason for the continual increase in size has been the optimization of the wind turbines. For land-based turbines, however, size growth in the future is expected to be limited due to the logistical constraints of transporting the very large blades, tower, and nacelle components over the highway, and the cost and difficulty in obtaining large cranes to lift the components in place and due to visual effects especially in areas with high populations.

Many turbine designers don't expect land-based turbines to grow to a size much larger than about 3 MW to 5 MW. The largest installed offshore wind turbines are 5 MW. To date offshore turbines are basically onshore designs with some minor modifications and special foundations, The mono-pile foundation is the most common, but this may change as sites with greater water depths are utilized. Also turbines designed specifically for offshore applications will become more prevalent.

The average size of installed turbines in 2009 was 1.8MW. Denmark, the UK, Germany and Sweden have the highest average wind turbine size due to an increased number of offshore installations.

Wind turbines typically operate at variable speed using full-span blade pitch control. Blades are typically constructed from glass polyester or glass epoxy. Towers are commonly tubular steel structures that taper from the base to the nacelle at the top. Wind turbines began operating variable speed in the mid 1990's to smooth out the torque fluctuations in the drive train caused by wind turbulence, and to allow more efficient operation in variable and gusty winds.

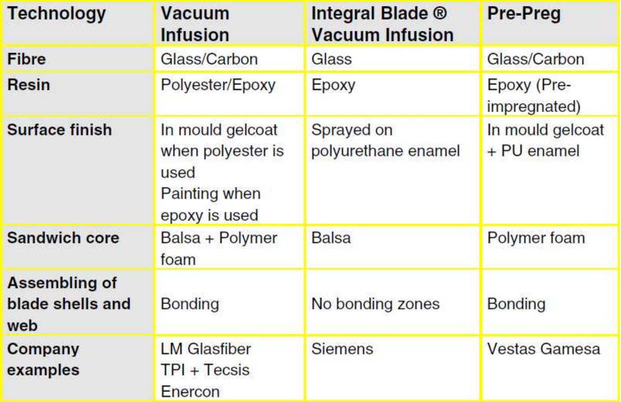
Variable speed operation generated variable frequency alternating current (AC) electricity that then had to be converted constant frequency 50 or 60 hertz for connection to the utility grids depending on the grid operating frequency. Due to the rapidly decreasing cost and increasing capacity of power transistors the cost impact of this power conversion has been minimal, and the loads reduction in the drive train has been significant.

## 3. CURRENT COMPONENT TECHNOLOGIES AND TRENDS

### Blades

The most manufacturing technology is vacuum infusion to impregnate different fibers (Glass/Carbon, Glass) with resin (epoxy, polyester/epoxy). Sandwich cores provide local stiffness. The different approaches are presented in Table 1 with examples of companies using these.

Table 1: Common blade manufacturing technologies (source: BTM)



| Technology | Vacuum Infusion | Integral Blade ® Vacuum Infusion | Pre-Preg |
|---|---|---|---|
| **Fibre** | Glass/Carbon | Glass | Glass/Carbon |
| **Resin** | Polyester/Epoxy | Epoxy | Epoxy (Pre-impregnated) |
| **Surface finish** | In mould gelcoat when polyester is used<br>Painting when epoxy is used | Sprayed on polyurethane enamel | In mould gelcoat + PU enamel |
| **Sandwich core** | Balsa + Polymer foam | Balsa | Polymer foam |
| **Assembling of blade shells and web** | Bonding | No bonding zones | Bonding |
| **Company examples** | LM Glasfiber<br>TPI + Tecsis<br>Enercon | Siemens | Vestas Gamesa |

***R&D trends*:**
The reduction of blade weight with size is one of the main focus points. One approach is better blade design methods coupled with new materials, such as carbon fibre, and advanced manufacturing methods. Another approach to increasing blade length while restraining the weight and cost growth is to reduce the fatigue loading on the blade, through passive or active aerodynamic control. There can be a big payoff in this approach because the approximate rule of thumb for fiberglass blades is that a 10% reduction in cyclic stress can provide about an order of magnitude increase in fatigue life.

Another focus point is the transportation logistics for the very large blades: Concepts such as on-site manufacturing and segmented blades are also being explored to help reduce transportation costs. In a currently running EU funded R&D project, UpWind, one of the elements is to develop a segmented blade. It may finally be possible to segment moulds and move them into temporary buildings close to the site of a major wind installation so that the blades can be made close to or at the wind plant site

### Drive-train/Gearbox, Generators

Most manufacturers use the conventional drive-train concept: low-speed shaft (driven from the rotation of the blades)-gearbox-high speed shaft (connected to the generator). The gearbox is one of the most expensive components and the one that has seen higher failure rates, probably due to under-estimating the loads seen by the gearbox: 1 to 3 major overhauls in the 20 year life-time of the turbine. Thus there is a big focus in increasing reliability of these components with recognised design standards.

One approach for improving reliability is to build a direct-drive generator that eliminates the complexity of the gearbox where most of the current reliability problems are occurring. Depending on the design, the generator can be in the range of 4 m to 10 m in diameter (for conventional DC generators taken up by e.g. Enercon) and can be quite heavy.

Some manufacturers that use direct-drive technology are: German Enercon (however, not based on Permanent Magnet Generators), Siemens, Dongfang and Chinese Goldwind. About 85% of wind turbines use 3-phase asynchronous generators.

***Trends:***
The decrease in cost and increase in availability of permanent magnets is expected to significantly affect the size and cost of future permanent-magnet generator designs. Permanent-magnet designs tend to be quite compact and lightweight and reduce electrical losses in the windings. A hybrid of the direct-drive approach that offers promise for future large-scale designs is the single-stage drive using a low- or medium-speed generator. This allows the use of a generator that is significantly smaller and lighter than a comparable direct-drive design. The Multibrid M500 turbine is an example of this improvement approach, [4].

Another approach that offers promise for reduced size, weight, and cost is the distributed drive-train. This concept is based on splitting the drive path from the rotor to drive several parallel generators. Studies have shown that by distributing the rotor torque on the bull gear over a number of parallel secondary pinions, a significant size and weight reduction is achieved. In 2006, Clipper Windpower developed a 2.5-MW prototype, which incorporates this approach [4].

### Power electronics

With the increase in the MW capacity of a single wind-farm, utility system operator's requirements on wind farms to operate more as a conventional power plant are increasing. The most efficient and cost effective way to handle these requirements and be capable of providing ancillary grid services is through full power conversion at the wind turbine. This requires much larger power converters. Power converter technology is rapidly developing with a still decreasing cost to power ratio. Three converter topologies are currently the most attractive in the wind industry: back-to-back converters, multilevel converters and matrix converters, the first being the most used.

The future success of wind turbine integration into the grid system, where large concentrated wind projects are planned, is dependent on a wind turbine's grid compatibility, increasing interest in developing power electronics. The growth in turbine size and the corresponding increased power output is perhaps spurring interest in larger transistors with much higher capacity, such as SiC devices, as well as innovative higher voltage circuit topologies. In the future, it is expected that the turbine generators will go to medium voltage generators and converters, and make use of new circuits and transistors.

## 4. CURRENT TRENDS IN GLOBAL R&D

In the USA and Europe, wind energy research strategies have been developed through government and industry collaborations. The U.S. Department of Energy in conjunction with the American Wind Energy Association, the National Renewable Energy Laboratory, and Black & Veatch undertook a study to explore the possibility of producing 20% of the United States electricity using wind energy. This "20% Wind Energy by 2030", [5], report describes in detail the many important future development needs to achieve 20% wind energy including: turbine technology development; manufacturing, materials and resources; transmission and integration into the U.S. electric system; siting and environmental issues; and wind power markets.

In Europe, "The European Wind Energy Technology Platform" (TPWind), [3], supported by the European Commission and lead by the European Wind Energy Association together with industry and the wind energy research community, envisions that "in 2030, wind energy will be a major modern energy source, reliable and fully cost competitive in terms of cost per kWh." The "European Wind Energy Technology Platform" describes a long series of research and development improvements that will be necessary to make wind the most cost competitive energy source on the global market by 2030.

However, there is no "big technology breakthrough" envisioned for wind technology in the United States or in Europe. The path forward is seen as many evolutionary steps executed through incremental technology advances that cumulatively bring about a 30% to 40% improvement in the cost effectiveness of wind technology over the next two decades, as has been achieved over the past two decades.

While the industry focuses on short-term production, operation, and installation issues, government-sponsored R&D programs promote innovation and long term research and development routes, roles that have been assumed in the past.

Key identified research areas from TPWind, [6], can be summarised as:

- Large turbine development: improved reliability; better understanding of aerodynamics; innovative concepts and integrated design; improved design codes; improved gearbox design; mechanical structures and materials
- Offshore wind in shallow and deep waters (floating structures)
- Power system operation and grid integration: wind power plant capabilities (providing ancillary services, wind farm control); grid planning and operation; energy and power management.
- Wind farm optimization

- Wind conditions: complex terrain; offshore meteorology; wakes; extreme wind speeds; wind profiles at high heights; short-term predictions

## 5. SMALL WIND TURBINES

This section aims to give an overview of activities within the market for small wind turbines that is, turbines smaller than 100kW that are designed for electricity production. (There are, naturally, small wind turbines that are used for other purposes – for example those that pump water – but these will be not covered here).

Small wind turbines are very different to large wind turbines, even though they may look like miniature versions. The Small Wind Energy section of the Canadian Wind Energy Association notes the following comparisons between the two, [6].

- **Purchase decisions.** The decision to install a large wind turbine is largely based on financial considerations such as return on investment and payback. In contrast, the decision to install a small wind turbine can be based on a wide variety of factors including energy independence, energy price stability and a desire to make a personal or corporate contribution to a cleaner environment. These "soft" components do not have a numerical value that enters into typical cost payback calculations.
- **Value of generated electricity.** "Large wind" generates electricity at the wholesale price while small wind systems offset utility supplied electricity at the retail price level. Note that in certain cases, small wind can produce power at less than half the cost of "traditional" electricity sources (e.g. remote communities with diesel electric generators).
- **Technology.** Small wind turbines involve different materials and technologies, including the mechanisms for transferring energy.
- **Installation requirement.** Small wind installations involve different by-laws, tax treatment and local installation requirements than large wind. There are also differences in terms of the requirements for wind studies and environmental assessments.

For this size of wind turbine there are fundamentally two applications:

- Grid connected: turbines that feed directly into the grid, perhaps off-setting the local consumption using net-metering.
- Isolated systems: turbines that are part of a (usually small) grid independent of the main grid perhaps for recharging a battery and maybe in combination with other generation e.g. solar voltaic panels or diesel powered generators.

### *Technology and research efforts*

In order to try to improve the performance, reliability and ultimately the cost of energy of small wind turbines various studies, [7], have identified areas where there is, or should be, research and development effort. These listed below:

- Product reliability,
- Improve designs,
- Focus on “design for manufacturing”,
- Availability of maintenance support:
- Use of performance standards, testing, and ratings,
- Technologies for low-wind regimes,
- Turbine noise,
- Lightning protection,
- Grid interconnection and integration,
- Tower options for larger wind systems and
- Energy storage for remote power systems**.**

## 6. SOUTH AFRICAN WIND ENERGY TECHNOLOGY PLATFORM

In the investigation into the development of a wind energy strategy for South Africa, [1], a preliminary research agenda for South Africa was formulated. A preliminary external macro-environment (big picture) analysis was done of the South African wind energy research, development and demonstration community.

This analysis was done using the Political, Economic, Social, Technological Legal and Environment (PESTLE) analysis technique. This PESTLE analysis is presented in Table 2.

Interpreting the PESTLE analysis as well as analysing the data and information gathered a preliminary Technology Tree was developed.

Table 3 presents the Preliminary Technology Tree. The cross-cutting theme in this technology tree is the proposed South African Wind Energy Technology Platform.

## 7. DISCUSSION

A review was done of global wind energy technology trends as well as trends in global wind energy research and development. As part of an investigation into the development of a wind energy industrial strategy for South Africa a preliminary research and development framework was developed.

Analysis was done using the Political, Economic, Social, Technological Legal and Environment (PESTLE) analysis technique.

Thereafter a preliminary Technology Tree was developed. It is proposed that the preliminary Technology Tree and the associated South African Wind Energy Technology Platform form the basis of identifying a research framework and Action Plan to support the South African wind turbine industry.

Table 2: Political, Economic, Social, Technological, Legal and Environmental (PESTLE) analysis

| | | |
|---|---|---|
| **Political**<br>• REFIT for wind energy in place<br>• DST's Energy Grand Plan<br>• DoE's white paper on renewable energy<br>• DTI's Industrial Policy and Action Plan encourages localisation<br>• SA has strong international relations<br>• Potential for international RD&D collaboration<br>• SA research funding for wind energy non-existent<br>• Research themes to be influenced by high value, high intellectual property content items | **Economic**<br>• Need to grow SA's energy sector to meet demand<br>• Concerns on decline in manufacturing<br>• Wind energy part of overall SA energy mix<br>• Favourable SA government support measures for wind industry<br>• Funding programmes for innovation need to be strengthened<br>• South African/African supply and value chain issues will influence innovative design concepts | **Social**<br>• Job creation opportunities through localisation of wind energy<br>• Increase in quality of life through universal access to electricity<br>• Capacity development (career) opportunities at all levels as wind energy sector grows<br>• Curricula at all levels(artisan to post doctorates) needs to be enhanced as wind energy sector grows |
| **Technological**<br>• Globally, reduction of blade weight is a main focus point<br>• Reduction in fatigue loading on the blade<br>• Increasing reliability of gearboxes<br>• Increasing reliability of wind turbines by direct-drive permanent-magnet generators<br>• Wind turbine integration into the grid has increased interest in developing power electronics.<br>• Increasing quality and quantity of wind resource data<br>• Improving certification and testing<br>• Locally, South African industry has propensity to innovate. | **Legal**<br>• National Treasury's mandatory local content for government investments in wind energy being developed<br>• SA regulatory body, NERSA, in place but processes yet to be fully operationalised<br>• The DTI's Enterprise Investment Programme needs to be made more clear on possible support for the wind energy sector<br>• Customs duties for wind energy is not clear<br>• Policies are in place for export credit assistance, but is not clear if wind is included<br>• Quality certification needs to be finalised | **Environmental**<br>• Growth in wind energy influenced by need to reduce green house gas emissions<br>• Wind resource for South Africa not fully quantified<br>• Unfriendly/complex business environment in South Africa<br>• Restrictive international trade barriers |

Table 3: Preliminary Technology Tree

<table>
<tr><th><b>Needs</b></th><th colspan="2"><b>Innovative wind turbine system designs</b></th><th colspan="2"><b>Local manufacture of components</b></th><th colspan="2"><b>Job creation</b></th><th colspan="2"><b>Energy security</b></th></tr>
<tr><td><b>Key Solutions</b></td><td colspan="4">• Wind resource assessment and maps<br>• Advanced designs for next generation wind turbines<br>• Advanced materials selection and development<br>• Advanced and cost effective manufacturing techniques</td><td colspan="4">• High quality manufactured components<br>• Certification and testing procedures<br>• Advanced techniques for wind turbine/grid integration<br>• Human capacity development</td></tr>
<tr><td><b>Platform</b></td><td colspan="8"><b>South African Wind Energy Technology Platform</b></td></tr>
<tr><td><b>Applied technology</b></td><td><b>Life cycle evaluation and prediction</b></td><td colspan="2"><b>Component design and manufacturing</b></td><td colspan="2"><b>Wind farm design optimisation</b></td><td colspan="2"><b>Condition monitoring and fault prediction</b></td><td><b>Policy development and decision support</b></td></tr>
<tr><td><b>Base technology</b></td><td>• Constitutive equations<br>• Materials characterisation<br>• Aero-elasticity methodologies<br>• Numerical failure identification methods<br>• Non-destructive evaluation</td><td colspan="2">• Database of new materials<br>• New design standards<br>• Power electronics<br>• Manufacturing processes<br>• Quality assurance</td><td colspan="2">• Increased accuracy of wind resource database<br>• Wind turbine emulation system<br>• Extreme wind condition evaluation techniques<br>• Complex terrain & offshore evaluation techniques</td><td colspan="2">• Monitoring & evaluation<br>• Supervisory Control & Data Acquisition (SCADA) systems<br>• Smart grid technologies</td><td>• Data and information evaluation techniques</td></tr>
<tr><td><b>Infrastructure</b></td><td colspan="4">• Wind measurement equipment<br>• Computational fluid dynamics<br>• Finite element methods<br>• Dedicated wind tunnels<br>• Blade test facilities<br>• Generator test facilities<br>• Drive train test facilities</td><td colspan="4">• Natural resource databases<br>• Geographic Information Systems<br>• Quantitative methods<br>• Science and Engineering know-how<br>• Supply chain linkages<br>• Indigenous knowledge</td></tr>
</table>

## 8. REFERENCES

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**Presenter:**

The paper is presented by Stefan Szewczuk.