



# Wind Energy Engineering

A Handbook for Onshore and  
Offshore Wind Turbines

Edited by  
Trevor M. Letcher



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# Preface

*Wind Energy Engineering* is an outcome of our earlier book, *Future Energy, improved, sustainable and clean options for our planet, 2nd edition* (Elsevier 2014). It was felt that the wind turbine industry was developing so rapidly that it was now necessary to compile a collection of wind energy related topics into one volume.

The use of renewable energy sources such as wind and sun for electricity generation is becoming commonplace in our society as we move away from fossil fuels to more sustainable forms of energy, free from carbon dioxide production. The move cannot come quickly enough as each month we hear that the previous month was the hottest month since records began and that CO<sub>2</sub> levels are increasing every year and have now passed the 400 ppm level.

Our book gives an all-round view of wind energy with a special focus on technical issues surrounding wind turbines. The 26 chapters are divided into the following seven sections: Introduction; Wind Resource and Wind Energy Worldwide; Wind Turbine Technology; Generation of Electricity; Environmental Impacts of Wind Energy; Financial Modeling/Wind Economics; Investment, Growth Trends, and the Future of Wind Energy. In more detail the book includes chapters on the following areas:

- Scientific aspects (basic theory of wind energy, global potential for producing electricity from wind);
- Wind energy in China and in Germany to give a flavor of developments in two leading wind energy countries;
- The history of wind power;
- Engineering aspects that include the design of different types of wind turbines, basic technologies and problems, and reliability of wind turbines;
- Electricity generation including integration into national grids, small-scale turbines, and the storing of excess electricity;
- Environmental aspects including life cycle investigation, landscape, and safety issues;
- Economics of wind power generation;
- Growth trends and the projected future of wind power.

It is hoped that the book will act as a springboard for new developments and perhaps lead to synergistic advances by linking ideas from different



chapters. Another way that this book can help in expanding and developing the wind industry is through contact between readers and authors and to this effect email addresses of the authors have been included.

This volume is unique in the genre of books of related interests in that each chapter of *Wind Energy Engineering* has been written by an expert scientist or engineer, working in the field. Authors have been chosen for their expertise in their respective fields and come from 12 countries: Australia, Belgium, China, Denmark, Germany, Hong Kong, Finland, India, Russia, South Africa, United Kingdom, and the United States. Most of the authors come from developed countries as most of the research and development in this relatively new field, is based in these countries. However, we look forward to the future when new approaches to wind energy, focusing on local conditions in emerging countries, are developed by scientists and engineers working in those countries. Perhaps this new book will aid in this endeavor.

The chapters in this book can be considered as snapshots, taken in 2016, of the state of this rapidly developing industry. Like *Future Energy*, one can expect an updated version of *Wind Energy Engineering* in a few years' time. *Wind Energy Engineering* goes hand in hand with two other books we have recently published: *Climate Change: Observed Impacts on Planet Earth, 2nd edition*, (Elsevier 2015); and *Storing Energy: with Special Reference to Renewable Energy Sources*, (Elsevier, 2016).

For consistency and to appeal to an international audience, the International System of Units and Quantities is reflected in the book with the use of the *Système International d'Unités* (SI) throughout. Other units such as Imperial units are written in parenthesis. The index notation is used to remove any ambiguities; e.g., billion and trillion are written as  $10^9$  and  $10^{12}$ , respectively. To avoid further ambiguities the concept of the quantity calculus is used. It is based on the equation: physical quantity = number  $\times$  unit. To give an example: power = 200 W and hence:  $200 = \text{power}/\text{W}$ . This is of particular importance in the headings of tables and the labeling of graph axes.

A vital concern related to the development and use of renewable and sustainable forms of energy, such as wind, is the question of what can be done when it appears that politicians misunderstand or ignore, and corporations overlook the realities of climate change and the importance of renewable energy sources. The solution lies in sound scientific data and education. As educators we believe that only a sustained grassroots movement to educate citizens, politicians, and corporate leaders of the world has any hope of success. Our book is part of this aim. It gives an insight into the subject, which we hope readers will consider and discuss. The book is written, not only for students, teachers, professors, and researchers into renewable energy, but politicians, government decision-makers, captains of industry, corporate leaders, journalists, editors, and all other interested people.

I wish to thank all 47 authors and coauthors for their cooperation, help, and especially, for writing their chapters. It has been a pleasure working with each and every one of the authors. I thank my wife, Valerie for all the help she has given me over these long months of putting the book together. I also wish to thank Elsevier for their professionalism and help in producing this well-presented volume. Finally I wish to thank Professor Ron Weir of IUPACs Interdivisional Committee for Terminology, Nomenclature, and Symbols for his help and advice.

**Trevor M. Letcher**  
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December 2016



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