

Foreword by the German Federal Minister for Economic Affairs and Energy



The use of both onshore and offshore wind energy is a key element in Germany's energy transition. Today, onshore wind energy is already the primary source of renewable energy in electricity generation in Germany. The increased expansion of offshore wind turbines still offers a great deal of potential. However, it also requires a lot of innovative solutions to be developed in the areas of construction and operation.

The research undertaken at the first German offshore wind farm Alpha Ventus has played a crucial part in helping to build up knowledge and expertise in what is still a very young sector in energy generation in Germany. It is particularly pleasing that the various research projects could be coordinated with one another so well, and that it has been possible to combine the different interests of researchers, facility operators, and plant manufacturers, whilst also ensuring that expansion work is environmentally sound. The Alpha Ventus wind farm is a pioneering venture which – together with the research initiative 'Research at Alpha Ventus – RAVE' – has laid the foundations for German projects in the area of offshore wind energy. The results of the research are outstanding – something which is also reflected in the level of international interest that has been attracted.

There is, of course, still a great deal of research yet to be carried out on developing the use of wind energy in Germany. We will only be able to use the potential that exists in this field if we continue to reduce the costs of electricity from wind energy and continue to raise grid security. Doing so will enable Germany's wind sector to stay competitive in the long term.

Given this background, the primary aim of the research funding provided by the Federal Ministry for Economic Affairs and Energy is to reduce both the investment and the operating costs for wind-powered installations. The state-of-the-art in German wind-power technology is impressive – with German industry setting international standards based on high-capability wind-powered installations 'Made in Germany'.

When it comes to the expansion of wind power into the future, it will be crucial to ensure that the electricity generated by wind turbines can be reliably integrated into the public grids. Indeed this is one of the priorities that the Federal Ministry for Economic Affairs and Energy has set in the area of energy research. Further research is needed in areas such as optimising

the grid connection of offshore wind farms, load and generation management, wind-energy-specific aspects of storage, and improvements in wind forecasts.

German companies, universities, and research establishments are among world leaders in wind energy thanks to the innovations that are being generated in this field. Research activities are being supported by German manufacturers and service providers, who are developing solutions designed to meet the specific requirements of foreign markets. The Federal Ministry for Economic Affairs and Energy is providing funding for these activities with the aim of ensuring the highest possible value generation in wind energy in Germany and, through this, of making the German wind industry internationally competitive.

I am delighted that an essential overview of the many different research projects being funded by the Federal Government as part of the Energy Research Programme now appears in book form. I wish you interesting reading and hope that this publication will serve as a source of inspiration to you.

Sincerely yours,

Sigmar Gabriel

Federal Minister for Economic Affairs and Energy

Foreword by the Chair of the Offshore Wind Energy Foundation



The construction of the Alpha Ventus test field played a significant role in the development of offshore wind energy in Germany. Within five years of it being commissioned in April 2010 there were wind farms in the German North and Baltic Seas with an output of 3,294 megawatts connected to the grid. And based on the investment decisions and business planning already made, the output will have more than doubled by 2020 – while optimistic predictions reckon that the government-set upper limit of 7.7 gigawatts will be fully utilised. This breakthrough of this new technology, which had no easy task in overcoming many teething troubles, would not have been possible without the extensive research projects and their findings that were part of the RAVE research initiative.

Over 50 universities, research institutions and businesses have been involved in numerous individual projects dealing with the solution of problems that would improve offshore wind turbine technology, making it safer and more profitable while also optimising its compatibility with the marine environment. The entire German offshore wind industry has profited from this.

The foundation would therefore like to thank all the scientists who have been involved in this national offshore wind research project and who have thus helped a new technology to make its breakthrough.

On behalf of this research community the foundation would especially like to thank Project Management Jülich (PtJ) and the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), who supported and coordinated the individual scientific works, and aggregated all the results.

The RAVE research network has made a great contribution to the development of offshore wind energy in Germany.

Jörg Kuhbier

Chairman, Offshore Wind Energy Foundation

CSI Test Field, CSI Offshore

Publisher's Foreword

RAVE: 1) a frolicking crowd, a dancing mass of people, a swarm 2) abbreviation of Research at Alpha Ventus. So ambiguous and yet so applicable, because the installation and investigation of Germany's first offshore wind farm, Alpha Ventus, also proved to be a ride over the North Sea, for everyone involved.

The start signal for RAVE was given just eight years ago and it is already hard to visualise what it was like back then. Nobody had ever had any experience of erecting wind turbines so far out at sea, over 40 kilometres from the nearest piece of dry land. Nor did anyone have any experience of building wind turbine foundations in water 30 metres deep. The foreseen five-megawatt wind turbine generation was also new and had never been tested out at sea. But we are in a very different position today; nobody asks the question "Is that at all possible?" any more. Five-megawatt turbines are now old hat. Today around 800 offshore wind turbines are operating in German waters, and over 3,200 in Europe. That is also thanks to Alpha Ventus and RAVE.

Both of them are success stories. With around 4,500 full load hours of wind power a year, Alpha Ventus is very impressive. This is especially so compared with other European offshore wind farms – even though Alpha Ventus is a test field. The experiences made and the operating results of Alpha Ventus have significantly contributed to building trust in the technology, which is a prerequisite for further expansion. And this indeed came to pass; in 2015 there was a record 2,282 megawatts of new offshore installations in Germany. There are now offshore wind farms with a total of around 3,300 megawatts on grid. The government goal of achieving its short-range target of 6,500 megawatts of offshore wind power by 2020 appears feasible. Based on current information, around 80 % of the projects planned to date have the financing in place.

RAVE is also a success story. Never in the history of wind power has there been such a large coordinated research initiative, in which the industry and research institutions have acted so in concert. And with success, because within just a few years not only have the manufacturers involved been able to develop their wind turbines further, but based on the research findings they have also been able to develop new guidelines that are now applied across the entire industry. Last but not least, the project has also provided new fundamental knowledge, ranging from the behaviour of porpoises to loads caused by breaking waves. Within just a few years, German offshore wind energy research has made it to the top of the international league – as proven by the many publications and conference contributions.

RAVE has been a joint effort. Despite, or perhaps because of, all the obstacles that had to be overcome. "We were all bitten by the offshore bug." Us, all the researchers involved in Alpha Ventus, Germany's first North Sea wind farm. We are proud that this test field came to fruition – and that we scientists were able to research in the field. Also very important was the financial support that first enabled this research work, for which we must thank the Project Management Jülich PtJ and the Federal Ministry of Economics and Energy. Over 50 universities, research institutes and businesses have been involved in the RAVE research. Their results help to further develop offshore wind energy use.

An incredible amount has been achieved in the past ten years. Our knowledge has increased enormously. But as we all know, miracles take a bit longer, and that is something we should bear in mind when all that is discussed nowadays is how quickly we can expand offshore wind power and how quickly the costs can be reduced. Despite the massive advances made, the offshore wind industry is still a very young industry, which still needs a long time – which it must also be allowed – in order to complete its knowledge, optimise its technology and gather operational experience. Offshore wind farms are built for an operational life of at least 20 years and even the first German offshore wind farm, Alpha Ventus, is not even half way there yet.

Research can make a contribution, and wants to. The long-term behaviour of materials and components in the harsh offshore conditions has to be investigated and understood. Deeper knowledge enables innovations that can reduce the cost of power generated offshore. New approaches in planning, production, construction and operation of offshore wind farms have to be conceived, developed and tested. In ten years' time wind farms will look very different, and also cost less than today.

One last question remains to be asked. Who is this book really aimed at? Everyone interested in offshore wind power, and everyone who wants to understand what research issues had and have to be solved if they are to become reality. In other words, it is for everyone who wants to know more about the work and (interim) results from Germany's first offshore test field. And it is for those who do not want to first study engineering or physics if they are to understand it. This book is an attempt to express the scientific findings of RAVE in a way that is generally understandable. If anyone wishes to have more detailed information we recommend that they read the final reports of the respective research projects, look at the Internet presentations or speak to those involved in the projects.

Offshore wind power in Germany is only just getting started. Research into it continues, and hopefully the success story will also. We researchers want to make our contribution and look forward to doing so.

Foreword to the English edition

After more than half a decade of research involving over 50 universities, research institutes and businesses, Alpha Ventus is the world's most thoroughly investigated offshore wind farm. This translation of the German book "Meer – Wind – Strom" will also give a wider international readership the opportunity to share in the results of the RAVE research project.

Michael Durstewitz



Dr. Bernhard Lange



Sea – Wind – Power

Research at the first German offshore wind farm Alpha
Ventus

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