New and Ongoing Wind Power Research in Sweden 2019

A compilation of Swedish research programs and new scientific publications on wind energy

UPPSALA UNIVERSITET

The National Network for Wind Utilization

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Front page: Wind turbines at Näs peninsula in early spring, Southwest Gotland.
Photographer: Ulrika Ridbäck

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www.natverketforvindbruk.se

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Contents

1. Introduction

Uppsala University Campus Gotland annually publishes a compilation of *New and Ongoing Wind Power Research* in Sweden. The compilation is published on the website of the National Network for Wind Utilization, Nätverket för Vindbruk, where both the English and Swedish versions are available.

The aim of this summary is to provide an easily accessible overview of what is happening annually in wind power research for interested parties. This report is the eighth edition in the series.

This compilation consists of two sections, of which the first is a presentation of the research centres and research programmes active in wind power research in Sweden. The research programmes allocate funds to the research projects and in the various research centres the research is carried out.

The second section is a topic-based list of the wind power research published in 2019, where at least one of the authors is active at a Swedish university. Here one also can find doctoral and licentiate theses as well as theses at bachelor and master levels that have been published during the year. All have direct online links to the publications. In this report, compilations of new publications are also included.

For this report, we collect data from various databases and websites, and from direct contact with universities, researchers and representatives of the various programs. We would like to take this opportunity to thank everyone for your contributions and help. To complete this report for the coming year, we will gladly accept more information!

Uppsala University Campus Gotland is the node with responsibility for education and competence development within the National Network for Wind Utilization, which is financed by the Swedish Energy Agency. The 2019 summary of current wind power research is a part of this task.

Previous editions of *New and Ongoing Wind Power Research in Sweden* are published on the website of the National Network for Wind Utilization and at DiVA Portal.

2. Research programs, research institutes and centres

In Sweden, several universities and colleges conduct research in a number of areas linked to wind power both on and offshore. The research is extensive and includes technical development, operational solutions, environmental impacts, acceptance and other issues. This summary describes activities during 2019 at research programmes that grant funding as well as at institutes and centres that collect and conduct research on wind power.

2.1. VindEL

VindEL is the Swedish Energy Agency's research and innovation program for wind power. The program goal is to contribute to wind energy impact targets that the Swedish Energy Agency points out in its wind power strategy. The targets of wind energy impact are:

- Wind power is a significant part of the Swedish electricity supply
- Wind power contributes to climate change mitigation, business development and the stability of the power system
- The installation and operation of wind power takes place with regard to social, economic and ecological sustainability.

During the program period 2017–2024, the Swedish Energy Agency intends to hold an annual announcement. The program's third call for research funding was in April 2019 with the following areas identified in the wind power strategy by the Swedish Energy Agency:

- Resource efficient wind power in Swedish conditions
- Wind power's place in society and the environment
- Integration in the power system
- Knowledge dissemination and competence
- Business development

The next call will be in March 2020. The links below provide more information about the VindEL program, previous calls and grants for the years 2017 and 2018.

- About VindEL
- Swedish Energy Agency strategy for wind power
- The first call from VindEL program 2017
- Granted projects within VindEL 2017
- The second call from VindEL program 2018
- Granted projects within VindEL 2018
- The third call from VindEL program 2019

Granted projects in the research call from VindEL 2019

A hundred percent renewable – how many percent sustainable?
The project investigates how the conversion to a 100 percent renewable electricity system can be carried out in a sustainable and resource efficient way, while also ensuring security of supply and competitiveness. Various scenarios are developed and will be analysed based on environmental, economic and social sustainability. A qualitative sustainability

assessment is initially applied to define critical sustainability goals and target conflicts between them are to be identified. The project runs until 31 December 2023. IVL Swedish Environmental Research Institute, Jenny Gode.

Lean Wind Power to Grid – wind forecasting and dynamic rating
This project intends to study new methods for optimum choice of electric power components when wind power parks are to be connected. For a resource-efficient wind integration, knowledge of wind conditions, dynamic rating and specific design of electric power components are combined. The project runs until 31 December 2023. KTH Royal Institute of Technology, Patrik Hilber.

Increased utilisation of the grid with combined solar- and wind power parks
Sweden's most resource-efficient locations for combined solar and wind farms will be mapped in this project. Further, the project also studies how the degree of utilization and extension in the economy can be improved by the installation of solar cell parks next to a wind farm. The study will also contribute with knowledge of how the electricity grid with components is affected by combined solar and wind farms. The project runs until 31 December 2023. Uppsala University, David Lingfors.

2.2. Vindval

The research program Vindval is a collaboration between the Swedish Energy Agency and the Swedish Environmental Protection Agency with the task of developing and communicating scientifically based facts about the effects of wind power on humans, nature and the environment. The program's reference group is represented by users that apply results from Vindval's projects. The reference group's mission is to carry out analyses on needs, propose initiatives based on needs and to follow Vindval's projects in more detail.

Vindval started in 2005 and is now in its fourth stage (Vindval IV) that continues until the 31st of December 2021. The programme's impact goals are that the research results will contribute to a sustainable expansion of wind power in Sweden and that environmental effects should be placed in relation to the environmental impact of other activities.

The currently running projects were granted funding through the last research call in 2018. This call was aimed at projects in *Wind power and planning*, as well as on *Reindeer and wind power*.

Projects in Vindval IV that were finished in 2019

Insect occurrences and their effects on aerial mammalian and avian predators near wind farms
The purpose is to study the accumulation of insects at wind turbines in different weather conditions and whether the occurrence of insects attracts food-seeking bats and birds, such as European Nightjar (*Caprimulgus europaeus*), Common Swift (*Apus apus*) and swallows . The project is based on new technology where laser-based remote sensing technology registers insects, vertical radar is used to study movements of insect-eating

birds and through GPS logging techniques movements of nesting nightcaps are followed. Lund University, Susanne Åkesson.

Marin MedVind – Basis for Large Scale Sustainable Windpower at Sea - Fundament
The project aims to develop a new planning basis for sustainable offshore wind power in the Baltic Sea. The first part of the project produced an overview of EU and national legislation with an emphasis on the environmental impact of offshore wind power. This includes developing criteria to meet these regulatory requirements and quantifying species and habitat impacts. Interesting areas for new offshore wind power would also be identified through a list of criteria developed in dialogue with the industry. Aquabiota Water Research, Martin Isaeus.

Ongoing projects in Vindval IV that finishes in 2020

WindChoir – Tool for strategic planning by assessing the cumulative environmental impact of wind power
In large-scale wind power expansion, new areas are utilized and the location of new plants is dependent on the landscape's conditions in terms of form and infrastructure. This also involves how other businesses, plans, local residents and the natural environment are affected. The project will develop a tool for assessing and comparing the overall environmental impact on land and at sea for various development scenarios nationally, regionally and from a landscape perspective. Chalmers University of Technology, Sverker Molander.

Impact and mitigating measures for wind power within reindeer winter grazing areas
There is a lack of knowledge about how wind turbines and human activities associated with wind power affect reindeers, with emphasis on behaviour and avoidance reactions of reindeer in winter grazing areas. The goal is to gather knowledge about which measures can mitigate and minimize negative effects on visibility, noise and human activity. The University of Oslo, Jonathan E. Colman.

Reindeer and wind power in the winter grazing area
A large proportion of wind power establishments in Sweden occur in reindeer husbandry areas, which requires knowledge of how it affects the reindeer and reindeer herding. This project therefore intends to collect and analyse more data to develop and strengthen the knowledge that has emerged through previous studies on wind power and reindeer. Swedish Agricultural University SLU, Anna Skarin.

The effect of wind turbines on the spatio-temporal behaviour of Capercaillie Tetrao urogallus
The project is an international collaboration with the German Forest Research Institute of Baden-Württemberg as well as the University of Natural Resources and Life Sciences in Austria. The aim is to assess the risks of wind power for the threatened Central European Capercaillie (*Tetrao urogallus*). In Sweden, inventories of Capercaillie is done in contiguous forest landscapes where wind power is relevant. The Swedish part of the study ends in December 2020. SLU Swedish University of Agricultural Sciences, Henrik Andrén.

- *Capercaillie and Wind Energy – an international research project*

Ongoing projects in Vindval IV that finishes in 2021

Land-use synergy, integration or conflict in sustainable land-based wind power
The project will contribute to sustainable expansion of land-based wind power by developing knowledge bases and develop planning conditions and possible scenarios in relation to other national interests on a local, regional and national scale. SLU Swedish University of Agricultural Sciences, Johan Svensson.

Regional wind power planning
In order to find good locations for wind power development, regional planning needs to be developed. The project will develop proposals for how regional wind power planning can be designed to be a good support for municipal planning, strengthen anchoring and sustainable regional growth. KTH Royal Institute of Technology, Ulla Mörtberg.

Research reports published in 2019

Activity of bats and insects at a wind turbine (Johnny De Jong et al. 2019, in Swedish).
The report presents results of research on underlying factors for collision between bats and the wind turbines rotor blades.

Below are links for more information about Vindval's research programs, ongoing research projects and previously published reports.

- Vindval website
- Vindval research programs 2005–2021
- Vindval IV – increased knowledge about wind power's environmental impact

2.3. SamspEL – Research and innovation for the future electricity grid

The research program SamspEL is run by the Swedish Energy Agency since 2016 and supports research, development and innovation in the area of electricity networks. SamspEL aims to contribute to the development of a flexible, resource-efficient and robust electrical system, which includes collaboration within a complete renewable electrical system that includes the socio-technical system, its actors and regulations. SamspEL finances several projects relevant to wind power. The last research call was in April 2019 and also included the programs *El från solen* and *VindEL*.

- The research program SamspEL
- Call for El från solen, VindEL and SamspEL 2019

The Swedish Energy Agency has a support project linked to SamspEL in the form of the interactive knowledge portal *Framtidens elsystem* [Future power systems], which is used for dissemination of results and communication regarding research, development and current seminars, and research calls.
- Framtidenselsystem.se

Granted projects 2019 with relevance for wind power in SamspEL

System integration for sustainable electricity production: organizational drivers and barriers
The project will contribute with knowledge of the energy companies' ability to increase the share of renewable electrical production by balancing the electricity system with system integration. RISE Research Institutes of Sweden, Niklas Fernqvist.

Projects that started 2019 with relevance for wind power in SamspEL

Grid strength metrics and evaluation in converter-dominated grids
The project aims to re-evaluate classical metrics and propose new suitable metrics in order to evaluate the grid voltage and frequency strength of a power system dominated by power electronics. This can contribute to a functioning system and increased understanding for the grid strength. Chalmers University of Technology, Peiyuan Chen.

Modelling and evaluation of different designs of intraday markets
The project evaluates different designs of intraday auctions using theoretical models. This includes analyses of how the power system, variable wind power production and generators' ramp speeds affect the trade, and how traders' virtual bids in the day-before and intraday markets can change. KTH Royal Institute of Technology, Mohammad Reza Hesamzadeh.

Performance evaluation of safe, scalable and renewable organic matter based electrical energy storage systems
The aim of the project is to establish a new type of safe, energy efficient and sustainable energy storage system for locally storing and producing electricity. Through advanced nanotechnology and organic chemistry, industrial scale-up prototypes will be developed based on organic material, water electrolytes and nanostructured electrodes. Uppsala University, Martin Sjödin. Fernqvist.

Projects that continue in 2020 with relevance for wind power in SamspEL

New prediction services to enable resource efficient grids
The project will develop forecasting tools for electricity grid companies of different sizes with emphasis on accuracy, working hours and costs. This means knowledge, method and prototype development in order to create the conditions for efficient use of existing electricity resources, for predicting energy and power demands and weather-dependent electricity production, including wind power. Expektra AB, Niclas Ehn.

Power electronic based dc transformer for off-shore wind energy installations
A new concept for DC/DC converters is investigated for the collection of wind energy from offshore wind turbines. The overall goal of the project is to develop the dc/dc converter to reduce its weight and installation cost and to improve the energy efficiency. Chalmers University of Technology, Torbjörn Thiringer.

Minimizing of curtailments in power systems with high share of wind and solar power
If there is no possibility of storing energy surplus from renewable power production in batteries or through export, it will be an energy loss. The purpose of this project is to develop methods for estimating when disconnection is necessary and that its implementation minimizes the energy loss while maintaining power system stability. Royal Institute of Technology, Lennart Söder.

Efficient control of the power balance in systems with a large share of renewable production
The project aims to improve the efficiency of power balance control in power systems, first and foremost by developing optimal trading strategies on the regulating market. The result is expected to contribute to increased competitiveness in terms of renewable electricity production. Linnaeus University, Magnus Perninge.

Finished projects in 2019 with relevance for wind power in SamspEL

Energy storages for regional and local integration of heat and power systems
The purpose is to study how the integration of renewable and variable electricity production with a changed need for electricity and heat can be optimized through district heating production and thermal energy storage. It includes case studies with simulations and calculations of energy balance in, among other things, solar and wind power production. Uppsala University, Magnus Åberg.

Replacement inertia for a power system dominated by renewable sources
A continuously active synthetic inertia will be developed and demonstrated through this project. This means developing new hardware that can deliver the inertia that corresponds to what is needed in the power system. Uppsala University, Claes Urban Lundin.

2.4. Swedish Wind Power Technology Centre - SWPTC

The Swedish Wind Power Technical Centre - SWPTC is led by Chalmers University of Technology and is run in collaboration with Luleå University of Technology, RISE, Lund University and companies in the wind power industry.

SWPTC was established in 2010 with the purpose to strengthen the expertise of wind power technology in Sweden and to meet the demands of the rapidly expanding global wind power industry. The goal for the research is to lead an increased life expectancy of wind power plants by means of better load prediction, optimum operation and preventive maintenance and cost-effective electrical system integration. The research at SWPTC focuses primarily on the individual wind turbine, as it is of the utmost importance, to understand how its individual parts interact to become an optimal converter of wind energy to electrical energy. Today's view, that a group of wind turbines is to equate to an electricity production plant, shows the importance of having good knowledge of the interaction between wind turbines in a wind farm and how these are controlled and linked together in the best way for maximum energy production and best life span.

The research focus is on larger wind turbines and parks for locations in forest, alpine and marine environments. SWPTC identifies a number of areas as important for research development in wind power and stage 3 started in January 2019 to address the following research areas: Bearing structure, Electric drivetrain and DC power grid, Life span and maintenance, De-icing and ice detection, Forest/complex terrain and regulation, Network services from wind turbines.

▸ More about SWPTC (via Chalmers)

Ongoing research projects 2019 at SWPTC:

Site-specific analysis methods for predicting and increasing the service life of wind turbines
The project investigates how the operation of a wind turbine is affected by surrounding terrain and how the life of the turbine components is affected by its geographical location. The goal is to develop a tool to describe the current state of each turbine in a park and evaluate different decisions. An optimal maintenance strategy will also be developed per turbine.

Methods and materials for durable and cost-effective towers and foundations
This project will provide more knowledge about the supporting structure of wind turbines to reduce environmental impact and increase structural sustainability. A generic tool will be developed for foundations with regard to durability, buildability and degradation. The method for controlling bias in tower bolts will also be further developed.

2.5. RISE

RISE, Research Institutes of Sweden, is an independent, state research institute that runs and supports all kinds of business-related research projects and innovation processes for technologies, products and services within many areas, of which wind power is one. RISE has been a research institute since 2016, collaborating internationally with companies, academia and the public sector to contribute to a competitive business community and a sustainable society.

Research and innovation in the field of wind power has grown at RISE for several years. There is a targeted investment in wind power research, which expands in line with the Swedish government's goal of a 100% renewable electricity generation by the year 2040. In 2018, RISE expanded the European research collaboration through a greater involvement in the wind power portion of EERA, European Energy Research Alliance, and similar research networks in order to strengthen Sweden’s role as a knowledge centre in wind power.

In 2019, RISE has continued its work on wind power-related research within designated priority areas. The following areas for the coming years are:

- Testing and verification in cold climate as well as technology and materials for de-icing
- Sea-based wind power in Swedish conditions
- More efficient methods of operation and maintenance for increased technical life span, additional cost reductions and increased durability

- Increased contribution/benefit from wind power for the stability of the electrical system
- Fire technical issues and fire protection for wind turbines and electric power equipment

▸ RISE website

New projects that started in 2019, directed/coordinated by RISE

ReComp – Circular streams from fiberglass composite
This project is funded by Vinnova and examines how fibreglass composite waste from wind power, boat, vehicle and construction industries can be recycled through solvolysis/HTL process. The project starts on January 1, 2019 and extends over three years. Contact person: Cecilia Mattson.

Rekovind – Chemical recycling of glass fibre composites from wind turbine blades
This project is funded by the Swedish Energy Agency and EnergiForsk and investigates the possibility of recycling fiberglass components and chemical building blocks from wind turbine blades on a chemical basis (solvolys/HTL). The idea is to contribute to a circular economy where the recycled materials can be reused in other products (see chapter VindEl 2.1, *Chemical recycling of glass fiber composite from wind turbine blades*). The project started on January 1, 2019. Contact person: Cecilia Mattson.

Active Network Management for All (ANM4L)
The projekt aims to demonstrate how integration of renewable production in electricity distribution networks can increase effectively through innovative solutions with active network management (ANM). It will also show how this can be done even when the networks theoretical design boundaries have been reached. The project includes three different parts and demonstration of results will be carried out in Sweden and Hungary. Contact person: Emil Hillberg.

Ongoing projects in 2019, directed/coordinated by RISE

Floating wind power at sea
The company SeaTwirl strives to become leading in the marine wind power market and their patented wind turbines have already received a lot of attention. To develop a new wind turbine, SeaTwirl collaborates with RISE and Chalmers to calculate how the construction is affected by the wind. The turbine S2, with a power of 1 megawatt, will be ready for use in 2020. Contact person: Gabriel Strängberg.

Cold climate test
The new test centre for wind power under icy conditions was established in 2019 at Uljabuouda in Arjeplog, 780 meters above sea level. RISE led the establishment of the test centre where testing of new wind turbine models will be carried out in an authentic cold climate environment. Collaboration partners include Skellefteå Kraft, Wind Power Center, Vinnova, Swedish Wind Power Technology Center (SWPTC), Vattenfall and the Energy Research Center of the Netherlands (ECN). Contact person: Stefan Ivarsson.

Design of cost effective DC-based collection-network for inland-sea wind-farm using series high-frequency transformers
The project is based on a collaboration between RISE and Chalmers and the goal is to determine what power can be achieved at different frequencies and output voltages. The research object is a special wind farm configuration for inland sea environment with intermediate frequency transformer, with focus on high voltage isolation at medium frequency levels. Thermal properties are also examined to ensure optimal operating temperature. Contact person: Mohammad Kharezy. .

Lasting concretes for energy infrastructure under severe operating conditions (LORCENIS)
The project LORCENIS aims to optimize concrete used in energy infrastructure and to withstand extreme environments. As a foundation for, among others, wind turbines, concrete is required which can be exposed to cold climate, soft water and other harsh conditions. Contact person: Urs Mueller.

Flexible heat and power (FHP)
The challenge with renewable energy sources, including wind power, is that the asset cannot be controlled. The main goal of the FHP project is to increase the share of renewable energy in the power systems. By increasing flexibility for electricity-to-heat solutions, electric louds can be controlled for periods with plenty of renewable electricity in relation to the demand. Contact person: Markus Lindahl.

New projects that start in 2020, directed/coordinated by RISE

System integration for sustainable electricity production: organizational drivers and barriers
The project objective is to contribute with knowledge about the energy companies' prerequisites for increasing the share of renewable electricity production by balancing the electrical system with district heating. Opportunities and barriers to system integration will be identified by studying the companies and how they interact. Contact person: Niklas Fernqvist.

2.6. STandUP for Wind

The research center STandUP for Wind is collaboration between the Royal Institute of Technology KTH, Uppsala University, Luleå Technical University and the Swedish University of Agricultural Sciences SLU.

STandUP for Energy was formed in 2009, following a government decision to allocate funding to universities and colleges for the development of 24 research areas that were considered strategically important. One of these areas was renewable electricity on a larger scale and its integration into the power grid. Research within wind power are gathered in the center STandUP for Wind, where the intention is to facilitate the development towards a larger proportion of electricity from wind power in the grid through interdisciplinary working methods.

- STandUP for Wind
- Ongoing research projects 2019

Ongoing research 2019 within STandUP for Wind's research areas:

Wind surveying and cold climates

- Meteorological effects on wind resource calculations over an enclosed sea - forecasting and climatology. Uppsala University, Erik Sahlée et al.

Fluid dynamics for wind turbines in parks and forests

- Boundary layer over wind farms. Royal Institute of Technology, Antonio Segalini.
- Interaction between wind turbines investigated by spectral-element methods. Royal Institute of Technology, Vitor Gabriel Kleine et al.
- Linearised simulation of wind-farm flows. Royal Institute of Technology, Antonio Segalini.
- NEWA - New European Wind Atlas. Uppsala University, Stefan Ivanell.
- Prediction of transition to turbulence in wind turbines. Royal Institute of Technology, Thales Coelho Leite Fava et al.
- Vortex methods for wind turbine simulations. Uppsala University, Anders Goude.
- Wind power in Swedish conditions - optimization of loads and production. Uppsala University, Karl Nilsson.
- Wind power in Swedish forest conditions. Uppsala University, Stefan Ivanell.

Electrical systems

- Advanced modular multilevel converters for wind power integration with HVDC grids. Royal Institute of Technology, Stefanie Heinig.
- Efficient hydro power modelling in presence of volatile wind power. Royal Institute of Technology, Evelin Blom.
- Minimizing curtailments in power systems with high share of wind and solar generation. Royal Institute of Technology, Elis Nycander.
- Multi-area power system generation adequacy. Royal Institute of Technology, Egill Tomasson.
- New market design impact on hydro power operation in presence of large scale wind power. Royal Institute of Technology, Abolfazl Khodadadi.
- Protection for multi-terminal HVDC grids to connect large scale wind power. Royal Institute of Technology, Ilka Jahn.
- Real time estimation of power system inertia. Royal Institute of Technology, Dimitrios Zografos.
- Reduced vulnerability and risk mitigation in the power grid. Uppsala University, Mikael Bergkvist.
- The role of flexible consumers in the future renewable based power system. Royal Institute of Technology, Lars Herre.

Sound

- Noise reduction of vertical axis wind turbines. Uppsala University, Aya Aihara.

Vertical axis wind turbine development

- Aerodynamics of vertical axis wind turbines. Uppsala University, Victor Mendoza.
- Experimental research on a 200 kW vertical axis wind turbine. Uppsala University, Hans Bernhoff.
- SAVANT: SAVonius turbine for ANTarktis. Uppsala University, Hans Bernhoff.
- The Marsta vertical axis test site. Uppsala University, Hans Bernhoff.

Generators and control systems

- Analysis of sub-synchronous oscillations in wind power plants. Royal Institute of Technology, Muhammad Taha Ali.
- Design of a permanent magnet synchronous generator with alnico magnets. Uppsala University, Fausto Lopez m. fl.
- Modelling novel nonlinear permanent magnet materials for energy applications. Uppsala University, Sandra Eriksson.
- SiC-based converter cells for HVDC connection of wind power. Royal Institute of Technology, Keijo Jacobs.
- Volatile project - Voltage control on the transmission grid using power at other voltage levels. Royal Institute of Technology, Stefan Stanković.
- Weekly planning of hydropower in systems with large volumes varying power generation. Royal Institute of Technology, Charlotta Ahlfors.
- Wireless control of autonomous submodules in modular multilevel converters for wind power integration. Royal Institute of Technology, Baris Ciftci.

Landscape and participatory planning

- Deltagandeprocesser vid etablering av vindkraft. Uppsala University, Sanna Mels et al.

Operation and maintenance

- Asset management for wind power. Royal Institute of Technology, Yi Cui et al.
- Efficient trading for wind power integration. Royal Institute of Technology, Priyanka Shinde.

Example of research projects within EU's Horizon 2020 programme

The four-year research project REACT - Renewable Energy for Self-Sustainable Island Communities is financed by EU's program Horizon 2020. The project was initiated in 2019 and is a collaboration between NUI Galway, Austrian Institute of Technology, IK4-Tekniker Research Alliance, Uppsala University, Teesside University, University of the Aegean, Université de la Réunion and several companies established in Europe. The goal is that islands will achieve energy independency through renewable sources, including wind power. The project will develop a technical and business model that demonstrates how these technologies can provide important economic benefits, contribute to reduced use of carbon in local energy systems, reduce greenhouse gas emissions and improve air quality.

- REACT

2.7. Summary

The various research programs and research centres presented here provide a picture of what is happening in wind power research in Sweden. The Swedish Energy Agency is a main financier for VindEL, Vindval and SamspEL.

In 2019, the Swedish Energy Agency has gathered support for wind power research within the programs VindEL, Vindval and SamspEL. Projects financed by VindEL and Vindval are directly aimed at research on wind power, whereas SamspEL is categorized within the framework of solar and wind power and electricity grids that contribute to a sustainable climate conversion.

VindEL is the Swedish Energy Agency's program for research and innovation in wind power with the goal of contributing to the transition towards a sustainable and renewable energy system in Sweden.

Vindval is a collaboration between the Swedish Energy Agency and the Swedish Environmental Protection Agency, with focus on the impact of wind power on humans, nature and the environment.

SamspEL is run by the Swedish Energy Agency and supports research, development and innovation in the power system, with particular emphasis on a complete renewable electricity system, which also includes wind power.

The Swedish Wind Power Technical Centre - SWPTC is run by Chalmers in collaboration with Luleå University of Technology. At SWPTC, expertise in wind power technology strengthens to meet demands of the rapidly growing global wind power industry. The focus is on development of wind turbine construction which optimizes the cost of manufacturing and maintenance.

The research institute RISE work with research and innovation in the wind power area. The research activities have grown over several years, mainly focusing on testing and certification services.

The research centre STandUP for Wind is a collaboration between the Royal Institute of Technology KTH, Uppsala University, Luleå University of Technology and the Swedish University of Agricultural Sciences SLU. Here, research is gathered on how the wind is generated and how it is integrated into the Swedish electrical system, with research on design and planning of wind power as well.

The research project REACT was launched in 2019 and

In addition to the above research programs and centres, there are also international collaboration projects for wind power. One example is REACT (See chapter 2.6 under STandUP for Wind) which is a collaboration between several European universities, including Uppsala University, and several companies in Europe. With the goal that islands should achieve energy independency through renewable sources, the project develops a technical and business model to demonstrate how these technologies can provide important benefits for the local economy and environment.

3. Published scientific articles and reports

In this chapter, scientific articles are listed according to the subject. This also includes book chapters and articles that have been published during or in connection with conferences. At least one of the authors of each publication is active at a Swedish university.

Some of the links below require login into Scopus. When you open the link, you are free to open and read the document.

3.1. Financing, electricity market, cost accounting

Transition towards 100% renewable power and heat supply for energy intensive eeconomies and severe continental climate conditions: Case for Kazakhstan
Bogdanov, Dmitrii, et al., Applied Energy, vol. 253, 113606, 2019

Auctions for all? Reviewing the German wind power auctions in 2017
Lundberg, Liv, Energy Policy, vol. 128, pp. 449-458, 2019

3.2. Wind resources, energy calculations

Wind resource assessment and economic analysis for electricity generation in three locations of the Republic of Djibouti
Assowe Dabar, Omar, et al., Energy, vol. 185, pp. 884-894, 2019

A statistical model for wake meandering behind wind turbines
Braunbehrens, Robert; Segalini, Antonio, Journal of Wind Engineering & Industrial Aerodynamics, vol. 193, 103954, 2019

The potential of wind power-supported geothermal district heating systems-model results for a location in Warsaw (Poland)
Ciapala, Bartlomiej, et al., Energies, vol. 12, 3706, 2019

Measurements and reanalysis data on wind speed and solar irradiation from energy generation perspectives at several locations in Poland
Piasecki, Adam, et al., SN Applied Sciences, vol. 1, UNSP 865, 2019

Characterization of wind resource in China from a new perspective
Ren, Guorui, et al., Energy, vol. 167, pp. 994-1010, 2019

Minute-scale forecasting of wind power –– Results from the collaborative workshop of IEA wind task 32 and 36
Würth, Ines, et al., Energies, vol. 12, Issue 4, Article 712, 2019

Advantage of variable-speed pumped storage plants for mitigating wind power variations: Integrated modelling and performance assessment
Yang, Weijia; Yang, Jiandong, Applied Energy, vol. 237, pp. 720-732, 2019

A reversal in global terrestrial stilling and its implications for wind energy production
Zeng, Zhenzhong, et al., Nature Climate Change, vol. 9, pp. 979-985, 2019

3.3. Technical development, wind turbine design and loads

Numerical investigation of the aeroelastic behavior of a wind turbine with iced blades
Gantasala, Sudhakar et al., Energies, vol. 12, 2422, 2019

Design and CFD study of a hybrid vertical-axis wind turbine by employing acombined Bach-type and H-Darrieus rotor systems
Hosseini, Arian; Goudarzi, Navid, Energy Conversion and Management, vol. 189, pp. 49-59, 2019

A reference model for airborne wind energy systems for optimization and control
Malz, Elena C., et al., Renewable Energy, vol. 140, pp. 1004-1011, 2019

The use of uncertainty quantification for the empirical modeling of wind turbine icing
Molinder, Jennie, et al., Journal of Applied Meteorology and Climatology, vol. 58, pp. 2019-2032, 2019

Wind turbines from the Swedish wind energy program and the subsequent commercialization attempts –– A historical review
Möllerström, Erik, Energies, vol. 12, Issue 4, Article 690, 2019

Direct finite element simulation of the turbulent flow past a vertical axis wind turbine
Nguyen, Van-Dang, et al., Renewable Energy, vol. 135, pp. 238-247, 2019

Machine learning-based prediction of icing-related wind power production loss
Scher, Sebastian; Molinder, Jennie, IEEE ACCESS, vol. 7, pp. 129421-129429, 2019

Structural analysis and optimal design of steel lattice wind turbine towers
Stavridou, Nafsika, et al., Proceedings of the Institution of Civil Engineers - Structures and Buildings, vol. 172, pp. 564-579, 2019

Uncertainty quantification of aerodynamic icing losses in wind turbine with polynomial chaos expansion
Tabatabaei, Narges, et al., Journal of Energy Resources Technology, vol. 141, pp. 051210 (11 sidor), 2019

Dynamic regulation characteristics of pumped-storage plants with two generating units sharing common conduits and busbar for balancing variable renewable energy
Tang, Renbo, et al., Renewable Energy, vol. 135, pp. 1064-1077, 2019

Grand challenges in the science of wind energy
Veers, Paul, et al., Science, vol. 366, Issue 6464, pp. 443-451, 2019

Adaptive structural control of floating wind turbine with application of MR Damper
Wang, Lei, et al., Energy Procedia, vol. 158, pp. 254-259, 2019

3.3.1. Conference proceedings

The actuator line model in Lattice Boltzmann Frameworks: Numerical sensitivity and computational performance
Asmuth, Henrik, et al., Journal of Physics: Conference Series, vol. 1256, 2019 (22-24 maj), Wake Conference 2019

CFD analysis of a cross-flow turbine for wind and hydrokinetic applications
Hosseini, Arian, Goudarzi, Navid, Proceedings of the ASME International Mechanical Engineering Congress and Exposition, vol. 6B, 2018 (9-15 november), ISBN: 9780791852088

3.4. Manufacturing, operation and maintenance

Detection and identification of windmill bearing faults using a one-class support vector machine (SVM)
Saari, Juhamatti, et al., Measurement, vol. 137, pp. 287-301, 2019

3.5. Electrical grids, electrical grid integration, electrical power and power systems

Identification of resonance interactions in offshore-wind farms connected to the main grid by MMC-based HVDC system
Beza, Mebtu; Bongiorno, Massimo, Electrical Power and Energy Systems, vol. 111, pp. 101-113, 2019

Synthetic inertia control based on fuzzy adaptive differential evolution
Chamorro, Harold R., et al., Electrical Power and Energy Systems, vol. 105, pp. 803-813, 2019

Investigation of subsynchronous control interaction in DFIG-based windfarms connected to a series compensated transmission line
Chernet, Selam, et al., Electrical Power and Energy Systems, vol. 105, pp. 765-774, 2019

Power electronic converter configurations integration with hybrid energy sources - a comprehensive review for state-of the-art in research
Krishnamurthy, Kumar, et al., Electric Power Components and Systems, vol. 47, pp. 1623-1650, 2019

Dynamic modeling, stability, and control of power systems with distributed energy resources
Sadamoto, Tomonori, et al., IEEE Control Systems Magazine, vol. 39, pp. 34-65, 2019

Day-ahead dispatch optimization with dynamic thermal rating of transformers and overhead lines
Viafora, Nicola, et al., Electric Power Systems Research, vol. 171, pp. 194-208, 2019

Reliability considerations and economic benefits of dynamic transformer rating for wind energy integration
Zarei, Tahereh, et al., Electrical Power and Energy Systems, vol. 106, pp. 598-606, 2019

3.5.1. Conference proceedings

Zero emission super-yacht
Eastlack, Edward, et al., 2019 Fourteenth International Conference on Ecological Vehicles and Renewable Energies (EVER), 8 sidor, 2019 (8-10 maj), ISBN: 9781728137032

Evaluation of the system-aggregated potentials of inertial support capabilities from wind turbines
Imgart, Paul; Chen, Peiyuan, 2019 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe), pp. 1-5, 2019 (29 september – 2 oktober), ISBN: 9781538682197

3.6. Resource management of renewable energy sources

Optimal placement and sizing of heat pumps and heat only boilers in a coupled electricity and heating networks
Ayele, Getnet Tadesse, et al., Energy, vol. 182, pp. 122-134, 2019

Optimization and assessment of floating and floating-tracking PV systems integrated in on- and off-grid hybrid energy systems
Campana, Pietro Elia, et al., Solar Energy, vol. 177, pp. 782-795, 2019

Optimal hybrid pumped hydro-battery storage scheme for off-grid renewable energy systems
Guezgouz, Mohammed, et al., Energy Conversion and Management, vol. 199, 112046, 2019

The role of intelligent generation control algorithms in optimizing battery energy storage systems size in microgrids: A case study from Western Australia
Mahmoud, Thair Shakir, et al., Energy Conversion and Management, vol. 196, pp. 1335-1352, 2019

Machine learning methods to assist energy system optimization
Perera, A. T. Dasun, et al., Applied Energy, vol. 243, pp. 191-205, 2019

Redefining energy system flexibility for distributed energy system design
Perera, A. T. Dasun, et al., Applied Energy, vol. 253, 113572, 2019

Biomass in the electricity system: A complement to variable renewables or a source of negative emissions?
Johansson, Viktor, et al., Energy, vol. 168, pp. 532-541, 2019

Investigation of an Ordovician carbonate mound beneath Gotland, Sweden, using 3D seismic and well data
Levendal, Tegan, et al., Journal of Applied Geophysics, vol. 162, pp. 22-34, 2019

3.7. Planning and Policy

Landscape and wind energy : a literature study
Butler, Andrew; Wärnbäck, Antoienette, Urban and rural reports 2019:4, SLU Swedish University of Agricultural Sciences, pp. 1-49, 2019

International experiences with opposition to wind energy siting decisions: lessons for environmental and social appraisal
Cashmore, Matthew, et al., Journal of Environmental Planning and Management, vol. 62, pp. 1109-1132, 2019

3.8. Summary of published articles and conference proceedings

According to the summary in Table 1 below, the number of scientific articles in wind power research in Sweden 2019 has had a slight decrease compared to 2018. Articles mainly dominate in technical development, wind turbine design and loads as well as electricity grid, electric grid integration and electric systems.

For 2019, there are no publications in the categories of regional development, public benefits, acceptance, impact on animals, climate and environmental impact as well as sound, noise and vibrations. The reduction in these categories may depend on the fact that research calls for funding from Vindval (see Chapter 2.2, p. 6) now prioritize planning issues in wind power. In previous years, the research calls have been focusing on animal and environmental impacts and social acceptance.

Table 1. The number of scientific articles published in 2018 compared to previous years.

Category	2015	2016	2017	2018	2019
Financing, electricity market, cost accounting	5	4	10	1	2
Wind resources, energy calculations	5	5	28	14	8
Technical development, wind turbine design and loads	4	9	8	9	14
Manufacturing, operation and maintenance	4	11	16	5	1
Electricity grid, electrical grid integration, electric power	7	14	27	13	9
Resource management of renewable energy sources	2	-	6	-	8
Planning and policy	2	3	9	4	2
Regional development, public benefits	5	4	5	-	-
Acceptance	1	1	-	-	-
Impact on animals	1	-	2	2	-
Climate and environmental impact	3	3	1	-	-
Sound, noise and vibrations of wind turbines	1	-	2	1	-
Risk assessments, lightning damages	-	-	-	1	-
Others	-	7	8	-	-
Reviews	2	3	1	-	-
Total	**42**	**64**	**123**	**50**	**44**

This summary is based on this report and *New and ongoing wind power research 2015, 2016, 2017 and 2018.*

4. Academic dissertations and theses

The scope of various types of theses depend on the level of the education programme. Master theses of 30/60 credits is included in an education of 4.5 to 5 academic years (270–300 credits), while master theses of 15 credits is part of an education that lasts at least four academic years (240 credits). A thesis for a professional degree of 30 credits is part of an education equivalent to 4.5 academic years (270 credits). We have placed the professional degree as a sub-category in master theses of 30/60 credits because they are in the same advanced level of education. Bachelor theses comprise 15 credits as part of three academic years (180 credits).

4.1. Doctoral dissertations

Adaptation of wave power plants to regions with high tides
including a net load variability study for a highly or a fully renewable Nordic power system with four different intermittent renewable energy (IRE) sources: solar PV, wind, tidal power, and wave
Ayob, Mohd Nasir, Uppsala University, Department of Engineering Sciences, Electricity, 2019

Large-scale graphene production for environmentally friendly and low-cost energy storage: Production, coating, and applications
Blomquist, Nicklas, Mid Sweden University, Faculty of Science, Technology and Media, Physics, 2019

Wind turbine sound in cold climates
Conrady, Kristina, Uppsala University, Department of Earth Sciences, LUVL, 2019

Numerical computations of wakes behind wind farms : A tool to study farm to farm interaction
Eriksson, Ola, Uppsala University, Department of Earth Sciences, Wind Energy, 2019

Detection of blade icing and its influence on wind turbine vibrations
Gantasala, Sudhakar, Luleå University of Technology, Computer Aided Design, 2019

Electricity markets operation planning with risk-averse agents: stochastic decomposition and equilibrium
Jovanović, Nenad, KTH Royal Institute of Technology, Electrical Engineering and Computer Science, 2019

Wind-turbine wakes – Effects of yaw, shear and turbine interaction
Kleusberg, Elektra, KTH Royal Institute of Technology, Department of Mechanics, 2019

Ride the wind: Symbiotic business model innovation for the Chinese wind power industry
Liu, Lihua, Halmstad University, School of Business, Engineering and Science, 2019

High performance finite element methods with application to simulation of vertical axis wind turbines and diffusion MRI
Nguyen, Van-Dang, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

Nanomechanics – Quantum size effects, contacts, and triboelectricity
Olsen, Martin, Mid Sweden University, Department of Natural Sciences, 2019

Assessment of energy storage systems for power system applications based on equivalent circuit modeling
Pham, Cond-Toan, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

Development and test of an imaging instrument for measurement of water droplets in icing conditions
Rydblom, Stefani Alita Leona, Mid Sweden University, Department of Electronics Design, 2019

On transfer functions for power quality studies in wind power and solar PV plants
Schwanz, Daphne, Luleå University of Technology, Department of Engineering Sciences and Mathematics, Electrical Power Engineering, 2019

Techno-economic assessment of wind energy for renewable hydrogen production in Sweden
Siyal, Shahid Hussain, KTH Royal Institute of Technology, Department of Energy Technology, Energy and Environmental Systems, 2019

Planning and operation of demand-side flexibility
Song, Meng, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

The "Dark side" of marine spatial planning: A study of domination, empowerment and freedom through theories of discourse and power
Tafon, Ralph, Södertörn University, School of Natural Sciences, Technology and Environmental Studies, Environmental Science, 2019

Electrification of road transportation - Implications for the electricity system
Taljegård, Maria, Chalmers University of Technology, Department of Space, Earth and Environment, Division of Energy Technology, 2019

Resistance of cold-formed high strength steel sections: Effect of cold-formed angle
Tran, Anh Tuan, Luleå University of Technology, Department of Civil, Environmental and Natural Resources Engineering, Steel Structures, 2019

Power system inertia estimation and frequency response assessment
Zografos, Dimitrios, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

4.2. Licentiate dissertations

The raison d'être of diffusion intermediaries in solar and wind power in Sweden
Aspeteg, Joakim, Chalmers University of Technology, Department of Technology Management and Economics, 2019

Medium voltage generation system with five-level NPC converters for kite tidal power
Mademlis, Georgios, Chalmers University of Technology, Department of Electrical Engineering, 2019

Sustainability-, buildability- and performance-driven structural design
Mathern, Alexandre, Chalmers University of Technology, Department of Architecture and Civil Engineering, 2019

Aqueous organic redox flow batteries: Electrochemical studies of quinonoid compounds
Wiberg, Cedrik, Chalmers University of Technology, Department of Chemistry and Chemical Engineering, 2019

4.3. Master theses (30/60 credits)

Aero and vibroacoustical prediction of the noise generated by turbulent boundary layers
Alonso Pinar, Alberto, KTH Royal Institute of Technology, Department of Vehicle Engineering, 2019

Dynamic transformers rating for expansion of existing wind farms
Ariza Rocha, Oscar David, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

Evaluating the impact of altered electricity systems: Constructing a model for assessment of the GHG impacts of altered electricity system configurations in Northern Europe
Bangay, Carolin, Lund University, Department of Technology and Society, Environmental and Energy Systems Studies, 2019

Nonlinear approximative explicit model predictive control through neural networks
Bolin, Thomas, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

Multi-stakeholder collaboration in wind power planning
Bwimba, Emmy, SLU Swedish University of Agricultural Sciences, Department of Forest Economics, 2019

Forest Simulation with Industrial CFD Codes
Cedell, Petter, KTH Royal Institute of Technology, School of Engineering Sciences, 2019

The impact of voltage dip characteristics on low voltage ride through of DFIG-based wind turbines
Chen, Cheng, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

Oops! They build it again: A suitability analysis for future wind farm location in Sweden
Christofel, Aditya Billy, Umeå University, Department of Geography, 2019

Power system protection modelling with IEC 61850 and IEC 61499
De Lima, Francisco, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

Increased utility of existing energy storage
Eklund, Victor, Umeå University, Department of Applied Physics and Electronics, 2019

Life cycle analysis for a DC-microgrid energy system in Fjärås
Farzad, Tabassom, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

Sound propagation modelling with applications to wind turbines
Fritzell, Julius, KTH Royal Institute of Technology, School of Engineering Sciences, 2019

Modeling, simulation and optimization of a submerged renewable storage system integrated to a floating wind farm: A feasibility case study on the Swedish side of the Baltic sea, based on the geographical and wind conditions
Honnanayakanahalli Ramakrishna, Prajwal, Mälardalen University, School of Business, Society and Engineering, 2019

Analysis of electricity grid for limiting of reactive power
Hudji, Muadh, Uppsala University, Department of Engineering Sciences, 2019

Evaluation tool for large scale onshore wind power projects
Jalkenäs, Frida, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

Value as a motivating factor for collaboration: The case of a collaborative network for wind asset owners for potential big data sharing
Kenjangada Kariappa, Ganapathy; Bjersér, Marcus, Halmstad University, School of Business, Engineering and Science, 2019

Consequences for hydrogen production for vehicle: Climate influence and energy efficiency for different hydrogen production pathways compared with biogas and electricity from windmills produced by an energy company in Östergötland
Lilja, Dennis, Linköping University, Department of Management and Engineering, 2019

An economic feasibility study of hydrogen production by electrolysis in relation to offshore wind energy at Oxelösund
Lindblad, Karl, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

Techno-economic analysis of integrating renewable electricity and electricity storage in Åland by 2030
Nikzad, Dario, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

Nanogrid for renewable off-grid system
Onyia, Chukwuebuka Louis, Uppsala University, Department of Information Technology, 2019

Project evaluation in the energy sector: The case of wind farm development
Rahm Juhlin, Johanna; Åkerström, Sandra, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

Environmental and economic assessment of the combination of desalination powered by renewable energies in Morocco
Rechreche, Jonas, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

Deep autoencoder for condition monitoring of wind turbines - Detecting and diagnosing anomalies
Renman, Johanna, Chalmers University of Technology, Department of Physics, Complex Adaptive Systems, 2019

Power plant operation optimization economic dispatch of combined cycle power plants
Rosso, Stefano, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

Techno-economic analysis of mobile battery storage systems to utilize curtailed wind energy in Germany for off-grid applications
Siddique, Muhammad Bilal, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

An analysis of geospatial factors in medium voltage grid distribution network routing
Tendolkar, Chaitanya, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

Impact of wind farm control technologies on wind turbine reliability
Walgern, Julia, Uppsala University, Department of Engineering Sciences, 2019

Future scenarios for energy security and sustainable desalination in Jordan
Weinstein, Miles, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

End-Of-Life wind turbines in the EU: An estimation of the NdFeB-magnets and containing rare earth elements in the anthropogenic stock of Germany and Denmark
Welzel, Lisa, Uppsala University, Department of Earth Sciences, 2019

On the profitability of largescale PV plants in Sweden
Westén, Annelie, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

LCA of microgrid system: a case study at 'North-five Islands' of Changshan archipelago, China
Yuning, Jiang, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

Outlier detection on sparse-encoded vibration signals from rolling element bearings
Al-Kahwati, Kammal, Luleå University of Technology, Department of Computer Science, Electrical and Space Engineering, 2019

Resilience-enhancement through renewable energy microgrid systems in rural El Salvador
Alarcón, Mathias; Landau, Robin, Uppsala University, Department of Engineering Sciences, 2019

Technical evaluation of existing and potential technologies for automatic frequency control in the Swedish power system
Appelstål, Sophia, Uppsala University, Department of Engineering Sciences, 2019

Experimental investigation of a de-icing system for wind turbine blades based on infrared radiation
Pettersson, Jennifer; Sollén, Sofia, Luleå University of Technology, Department of Engineering Sciences and Mathematics, 2019

Evaluation of systems for deicing wind turbines
Strandler, Erik, Uppsala University, Department of Engineering Sciences, 2019

Ten years with a municipal veto in the Swedish administrative procedure for wind energy –– Is it time for a change?
Ståhl, Jenni, Stockholm University, Department of Law, 2019

4.4. Master theses (15 credits)

Analysis of simris hybrid energy system design and working and checking the effect of using high capacity factor wind turbine
Akthar, Naem, Halmstad University, School of Business, Engineering and Science, 2019

Techno-economic analysis of repowering potential in North Rhine-Westphalia Germany
Baak, Werner, Uppsala University, Department of Earth Sciences, 2019

Cost comparison of repowering alternatives for offshore wind farms
Bergvall, Daniel, Uppsala University, Department of Earth Sciences, 2019

Using CHP plant to regulate wind power
Elzubair, Arwa, Halmstad University, School of Business, Engineering and Science, 2019

Feasibility of converting a Science Park in a cold climate into an "off-grid" facility using renewable energies and seasonal storage systems
Estaña, Guillermo; Ruiz, Iñigo, Gävle University College, Department of Building Engineering, Energy Systems and Sustainability Science, 2019

Assessment of the offshore wind potential in the Caribbean to satisfy the demand of electricity in Latin America and the Caribbean region
Gómez Sará, José Orlando, Uppsala University, Department of Earth Sciences, *2019*

Analysis of fault ride through disturbances in wind energy
Kumar Mishra, Navin, Halmstad University, School of Business, Engineering and Science, 2019

What are the uncertainties and potential impacts of "Brexit"/the EU referendum result on the UK wind energy sector?
Lawrence Mummery, Robert Andrew, Uppsala University, Department of Earth Sciences, 2019

It's an ill wind: An analysis of justice perceptions around wind power
Niebel Stier, Lucas; Wallimann, Marco, Uppsala University, Department of Business Studies, 2019

Wind power prediction model based on publicity available data: Sensitivity analysis on roughness and production trend
Sakthi, Gireesh, Uppsala University, Department of Earth Sciences, 2019

The potential of grid energy storage: a case study of the Nordic countries and Germany
Schweitz, Anders, Gävle University College, Faculty of Engineering and Sustainable Development, Department of Building Engineering, Energy Systems and Sustainability Science, 2019

Renewable energy policy: A comparative case study of Latvia and Sweden
Timoseva, Anastasija, Uppsala University, Department of Earth Sciences, 2019

Using airborne laser scans to model roughness length and forecast energy production of wind farms
Valee, Joris, Uppsala University, Department of Earth Sciences, Campus Gotland, 2019

4.5. Bachelor theses

Manufacturing of rotor blades for small wind turbines in accordance with Piggott's design
Ahmad, Ammar; Abbas, Rand, Halmstad University, School of Business, Engineering and Science, 2019

Optimal configuration for a bio-solar-wind polygeneration system in Klintehamn
Algarp, Caroline; Svanfeldt, Astrid, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

Electric Roads - Energy distribution systems and energy harvesting systems
Algotsson, Josef; Lundgren, Eric, Örebro University, School of Science and Technology, 2019

Voltage regulation for an electrical grid
Alzubaidi, Jaafar; Antonsson, Rasmus, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

Savonius wind turbine innovation integrated in a constructed nano grid system
Andersson, Oskar, Uppsala University, Department of Electrical Engineering, 2019

Offshore and land based wind power: National interests of varying establishment potential
Bluj, Jakub; Wallentinsson, Måns, Uppsala University, Department of Social and Economic Geography, 2019

Streamlining the work wind load calculations
Bonnevier, Björn; Karlsson, Robin, Linköping University, Department of Science and Technology, 2019

Wind power policy and planning - a comparative study of Sweden and the Netherlands
Brokking, Christoffer, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

Off-grid wind power systems: Planning and decision making
El Zein, Musadag, Uppsala University, Department of Earth Sciences, 2019

Investigation of frequency containment reserves with inertial response and batteries
Ghasemi, Hashem; Melki, Jakob, KTH Royal Institute of Technology, School of Electrical Engineering and Computer Science, 2019

The electricity demand and supply in El Espino: Alternatives for diversification of renewable technologies
Grankvist, Jessica; Gao Lily, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

Batteries in the power system: A study of the potential of batteries as energy storage to support intermittent energy sources in the national power system
Gustafsson, Amelie; Wiklund, Hannes, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

Design of the bearing solution for a TFM generator for wind power
Hedberg, Joakim; Rundström, Per, KTH Royal Institute of Technology, School of Industrial Engineering and Management, 2019

A study in compiling energy plans to highlight power needs in 2030: An explorative and formative study
Kortenius, Jacob; Wallhed, Niklas, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

The electricity certificate system: An overall analysis
Lindberg, Maria, Umeå University, School of Business, Economics and Statistics, 2019

Hydropower planning in combination with wind power and batteries
Lundquist, Frida; Selsmark, Dan, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

Initial evaluation of a wind power installation
Mellquist, Morgan, University of Borås, Department of Textiles, Technology and Economics, 2019

Prospects of Renewable Energy for the New City of El Alamein, Egypt: An Energy System Model using OSeMOSYS to obtain the most cost-efficient electricity production mix
Miletic, Marko; Färegård, Simon; Von Schultz, Erik, KTH Royal Institute of Technology, School of Architecture and the Built Environment, 2019

4.6. Summary of academic dissertations and theses

Table 2 below presents the number of academic dissertations and theses on wind power and wind power related topics in the years 2015–2019. Doctoral theses have had an increase in 2019, while the proportion of licentiate theses remains at a low number as in previous years.

In the case of master's theses (30/60 credits), this is a marked increase compared to 2018 and shows a good distribution between different universities (Table 3). Since 2015, there has been great variation from year to year for how many master's theses that have been published.

Master's theses (15 credits) remain largely the same number as in previous years, while the proportion of bachelor theses has doubled and tops the high number published in 2017.

In table 3 we can see totally sixteen universities have published dissertations and theses in 2019. This shows that wind power as a subject has a large spread, even where there are no courses or education programs specifically within wind power. The Royal Institute of Technology KTH and Uppsala University are currently in the top when it comes to publish master's theses in wind power.

Table 2. Number of doctoral and licentiate dissertations and theses 2015–2019.

Nivå	2015	2016	2017	2018	2019
Doctoral theses	11	13	12	12	19
Licentiate theses	3	4	3	4	4
Master theses (30/60 credits)	17	22	46	17	37
Master theses (15 credits)	16	11	16	13	13
Bachelor theses	10	10	17	8	18
Total	**57**	**60**	**94**	**54**	**90**

The summary is based on this report and *New and ongoing wind power research in Sweden* 2015, 2016, 2017 and 2018.

Table 3. Number of dissertations and theses published per university in 2019.

University	Doctoral	Licentiate	Master[1]	Master[2]	Bachelor
Chalmers University of Technology	1	4	1		
University of Borås					1
Gävle University College				2	
Halmstad University	1		1	3	1
KTH Royal Institute of Technology	7		19		10
Linköpings University			1		1
Luleå University of Technology	3		2		
Lund University			1		
Mid Sweden University	3				
Mälardalen University			1		
Stockholm University			1		
SLU Swedish University of Agricultural Sciences			1		
Södertörn University	1				
Umeå University			2		1
Uppsala University	3		7	8	3
Örebro University					1
Totalt	**19**	**4**	**37**	**13**	**18**

This summary is based on this report.

[1] *30/60 credits*

[2] *15 credits*