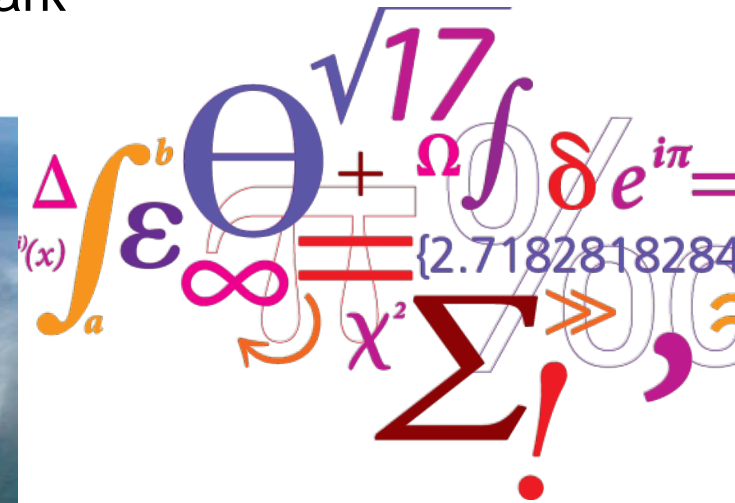


# Projektstatus 2013

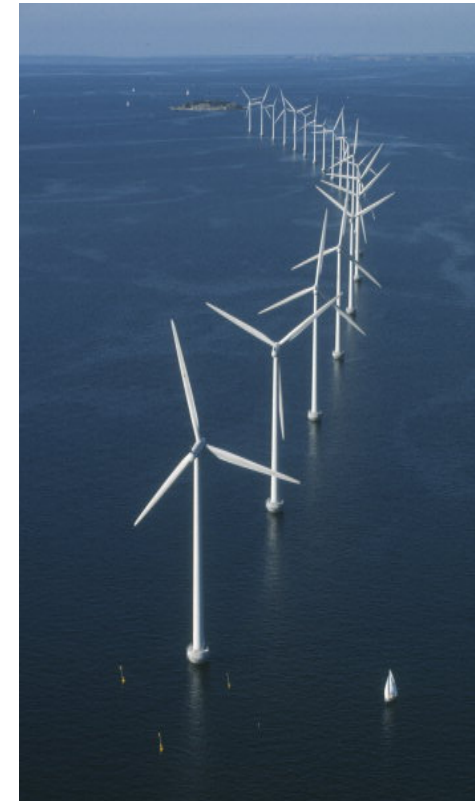
*Jens N. Sørensen, Jakob Mann & Niels N. Sørensen*

Department of Wind Energy  
Technical University of Denmark



## Center for Wind Turbine Aerodynamics and Atmospheric Turbulence

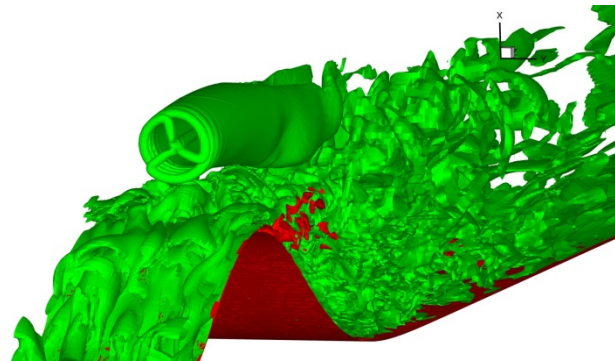
- **DSF-bevilling under Bæredygtig Energi og Miljø**
- **Start: 1. Januar 2010**  
**Slut: 31. December 2016**
- **DSF-bevilling:**  
**Direkte udgifter: 22.246.666 kr.**  
**Overhead/adm: 9.788.533 kr.**  
**I alt: 32.035.199 kr.**
- **In-kind og medfinansiering: 32.000.000 kr.**
- **Forskningspartnere: MEK, VEA-Risø, MET-Risø**
- **Industripartnere: LM, Vestas, Siemens, Vattenfall**



# Oprindeligt og Revideret Budget

## Grand totalregnskab/budget 2010 - 2016:

År	2010	2011	2012	2013	2014	2015	2016
Udbetalingsprofil i bevillingsbrevet	3.036.450 kr	4.736.393 kr	6.874.618 kr	6.617.419 kr	6.301.620 kr	4.468.699 kr	
Revideret udbetalingsprofil				5.132.674 kr	5.409.444 kr	5.238.819 kr	5.383.420 kr
Faktiske udbetalinger	2.289.341 kr	3.764.430 kr	5.274.375 kr				



# PhD Students:

- **Tilman Koblitz (Start: July, 2010)**  
**‘CFD Modelling of non-Neutral ABL Conditions’**
- **Jesper Grønnegaard Pedersen (Start: July, 2010)**  
**Numerical modelling of the boundary-layer wind profile**
- **Søren Juhl Andersen (start: July, 2010)**  
**‘Simulation and prediction of wakes and wake interaction in wind farms’**
- **Hamid Sarlak (Start: January, 2011)**  
**‘Simulation and prediction of wakes in offshore wind farms subject to turbulent and stratified atmospheric boundary layers’**
- **Dmitry Kolmogorov (Start: January, 2011)**  
**‘Navier-Stokes simulations of flow past wind turbines’**
- **Ewan Machefaux (Start: November 2011)**  
**‘Measurements and LES simulations of multiple turbine wakes’**
- **Paul Maarten van der Laan (Start. 2011)**  
**‘Development of efficient turbulence models for CFD wake simulations’**
- **Emmanuel Simon Pierre Branlard (Start: 2012)**  
**‘Wind turbine aerodynamics and aeroelasticity using vortex based methods’**
- **Julie Lange (Start: March, 2013)**  
**‘Atmospheric turbulence’**



# Publikationer

Publikationer	2010	2011	2012
Peer-reviewed	19	23	20
Conf. Proc.	24	25	28



# Konferencer og kurser



## 2011

- **Wake topical workshop, 25. Maj, Risø DTU**
- **PhD Course: ‘LES in Hydrodynamics and Offshore Wind Energy’  
15. -26. August, DTU & Oslo Universitet**
- **PhD Seminar, 7. November , Risø DTU**
- **Centermøde, 13. December 13, Risø DTU**
- **Wake Konference, 8.-9. Juni, Visby, Gotland**

## 2012

- **PhD study circle in Atmospheric Turbulence**
- **Center seminar, March 6**

## 2013

- **PhD Course: ‘Marine Hydrodynamics and Aerodynamics  
of Offshore Wind Energy’. 14. -21. August, DTU & Oslo Universitet**
- **PhD Seminar, 4. Juni , Risø Campus, DTU**
- **ICOWES2013, DTU**
- **WindInspire, DTU (with Johns Hopkins University)**

## 2014

- **Torque 2014, 18. – 20. Juni, DTU**
- **European Fluid Mechanics Conference, 14. – 18. September, DTU**

## 2015

- **European Academy of Wind Energy – PhD conference**

# Gæsteprogram

## 2010

- **Charles Meneveau (Johns Hopkins Univ.): DCAMM Annual Speaker**
- **Dan Henningson (KTH): Fluid-DTU lecture**
- **Michael Sherry (PhD student, Monash University)**
- **Thomas Leweke (IRPHE/CNRS, Marseille)**

## 2011

- **Prof. John Grue, Oslo Universitet, Norway**
- **Prof. Dan Henningson, KTH, Sweden**
- **Ass. Prof. Mehmet Özgün Korukçu, Uludag University, Turkey**
- **Assoc. Prof. Stefan Ivanell; Lektor, KTH/HG, Sweden**
- **Prof. Jim Brasseur, Penn State University, USA**

## 2012

- **Prof. Victor Kozlov, Russian Academy of Sciences, Novosibirsk**
- **Prof. Dan Henningson, KTH, Sweden**
- **Ass. Prof. Johan Meyers, KU Leuven, Belgium**
- **Assoc. Prof. Stefan Ivanell, KTH/HG, Sweden**
- **Prof. Horia Hangan, Univ. Western Ontario, Canada**
- **5 PhD students from different partner universities**

## 2013

- **Prof. Charles Meneveau, John Hopkins University, USA**
- **Prof. Hugh Blackburn, Monash University, Australia**
- **Prof. Rebecca Barthelmie, Univeristy of Indiana**

# Internationalt samarbejde

- **Monash University (Australia):**  
Vortex structures in wind turbine wakes and their modification
- **KTH, Univ. of Gotland (Sweden):**  
Nordic consortium for optimization and control of wind parks
- **Johns Hopkins University (USA):**  
PIRE: USA/Europe Partnership for Integrated Research and Education in Wind Energy
- **IRPHE/CNRS (France):**  
HELICE: Helical Vortex Wakes
- **IEA Wakebench network:**  
Collaboration between various European and American partners
- **NREL Collaboration (USA)**



# Andet

- Jakob Mann modtog European Academy of Wind Energy's videnskabelige pris for 2013
- De to mest citerede artikler fra 2012 i *J. Wind Energy* kommer fra flowcentret:
  - Bingol, F.; Mann, J.; Larsen, G.C.: Light detection and ranging measurements of wake dynamics. Part I: One-dimensional Scanning.
  - Troldborg, N.; Sørensen, J. N.; Mikkelsen, R.: Numerical simulations of wake characteristics of a wind turbine in uniform inflow.
- Et af de mest downloadede papers i *J. Wind Energy* kommer også fra flowcentret:
  - Hansen, K. S., Barthelmie, R. J., Jensen, L. E. and Sommer, A.: The impact of turbulence intensity and atmospheric stability on power deficits due to wind turbine wakes at Horns Rev wind farm.

# **Overview of tasks:**

**Task 1. Rotor/ABL Aerodynamics (NNS)**

**Task 2. Wind Turbine Wakes and Clusters (JNS)**

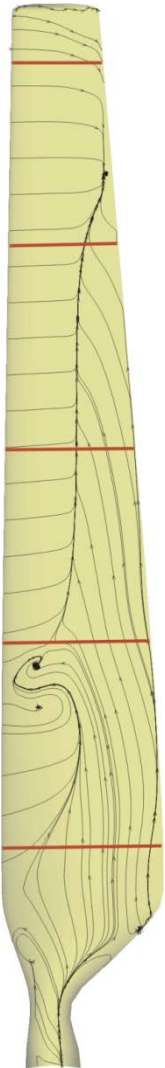
**Task 3. Wind Farms (JNS)**

**Task 4. Siting in Forested and Complex Terrain (JM)**

**Task 5. Atmospheric Boundary Layers (JM)**

# Task 1. Rotor/ABL Aerodynamics

Comparison of state of the art turbulence models with multi-scale aerodynamic data. Development of phenomenological ‘engineering’ models describing dynamic stall and yaw

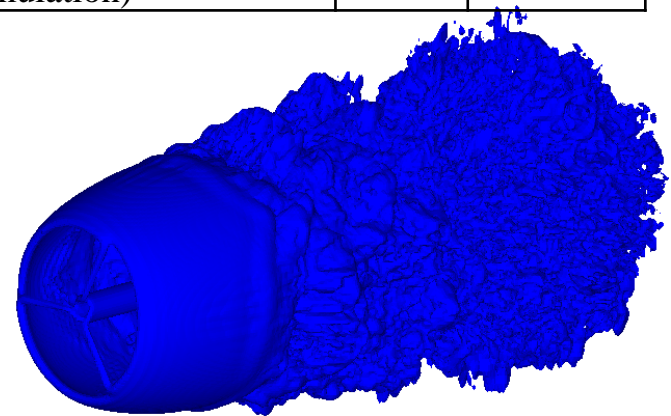
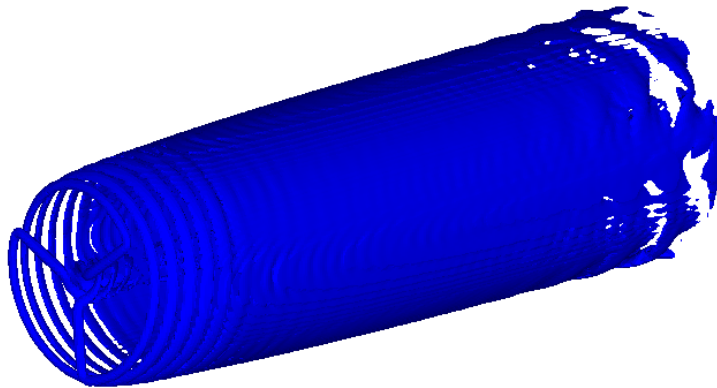


Task	Milestone	Description of Milestone	Month	Status
1	M1	Parametric study of RANS/DES computations of two modern turbines (NM80, Siemens 2.3MW) in atmospheric shear compared to experiment. (Using resolved rotor geometry and laminar/turbulent transition.)	12	Done
1	M2	Evaluation of the importance of cross flow instabilities for modern wind turbine rotors.	24	In progress
1	M3	Parametric study of two modern turbines (NM80, Siemens 2.3 MW) turbine in yaw compared to experimental results. (Using resolved rotor geometry and laminar/turbulent transition)	24	In progress
1	M4	Development of refined ‘engineering’ yaw model	36	In Progress
1	M5	Evaluation of dynamic stall models and airfoil characteristics with respect to dynamic inflow and inflow turbulence	48	In Progress
1	M6	Simulation of various unsteady inflow conditions for the NM80. (Using resolved rotor geometry and laminar/turbulent transition)	36	In Progress

## Task 2. Wind Turbine Wakes and Clusters

**Objectives: New insight into turbulent wake structures, including wake to wake interaction. Development of dynamic wake and parabolised Navier-Stokes models**

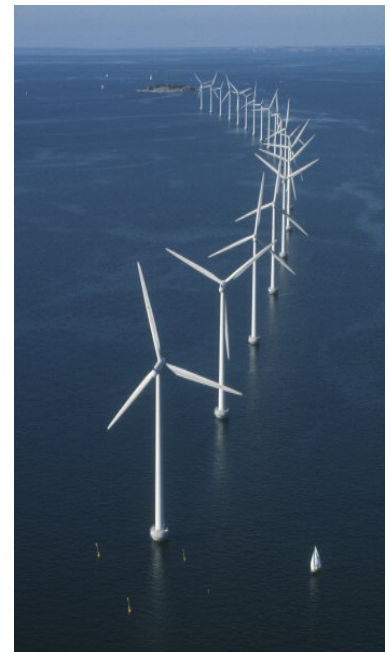
Task	Milestone	Description of Milestone	Month	Status
2	M7	Study of far wakes behind single turbine, comparison with experiments and results from Task-1. (Actuator Disk/Line)	24	Done
2	M8	Refined model for the far wake	24	Done
2	M9	Parabolized stand-alone N-S park model	14	Done
2	M10	Parametric study of the wake stability for varying inflow turbulence, and comparison with M-1.3A (Actuator Disk/Line formulation)	38	Done
2	M11	Refined modeling in the framework of Dynamic Wake Modeling, using input from M-2.1A and M-2.2A.	48	In Progress
2	M12	Parametric study of the wake/wake interaction between two or more turbines, compared to experiments. (Resolved geometry, and Actuator Disk/Line formulation)	36	Done



## Task 3. Wind Farms

**Development of cost effective models for park to park effects, including optimized numerical methods and influence of stratification**

Task	Milestone	Description of Milestone	Month	Status
3	M13	Computations and validation of neutral ABL RANS simulations of wind farms, compared to experimental results from Horns Rev. (Using Actuator Disk)	38	Done
3	M14	Computation and validation of LES simulation of wind farms, using experimental results from Horns Rev and Lillgrund. (Using Actuator Disk/Line)	24	Done
3	M15	Development of low-dimensional turbulence model for wind farms.	36	Done
3	M16	Parametric study of the influence of the stratification of the ABL on wind farm performance.	48	In Progress
3	M17	Evaluation of the mutual interaction of two wind farms located in close proximity. (Using Actuator Disk/Line and LES)	60	In Progress



## Task 4. Siting in Forested and Complex Terrain

**Objectives: New insight about the interference between turbines and terrain, and more reliable predictions of wind energy production and wind turbine loads in complex terrain**

Task	Milestone	Description of Milestone	Month	Status
4	M18	Validation of complex terrain flow models using data from the Bolund and the Vestas India site	6	Done
4	M19	Beta version of terrain flow solver available to industry partner Vestas.	7	Done
4	M20	Beta version of forest model available to industry partner Vestas.	12	Done
4	M21	Forest model Version-1.0 using parametrization from SCADIS	24	Done
4	M22	Terrain flow model that includes atmospheric stratification	40	In Progress
4	M23	Parametric study of the mutual turbine/terrain influence. (Using Actuator Disk/Line, both with RANS and LES)	44	In Progress



## Task 5. Atmospheric Boundary Layers

**Models of the atmospheric flow over terrain that take into account stability effects and boundary layer height. A model of the three-dimensional structure of turbulence affected by atmospheric stability and suited for inflow turbulence simulation**

Task	Milestone	Description of Milestone	Month	Status
5	M24	Implementation and validation of stability and boundary layer temperature inversion in EllipSys3D	44	In Progress
5	M25	Development and verification of a model of the spatial structure of atmospheric turbulence under influence of stratification	48	Almost Done
5	M26	Parametric study of stratified boundary layer from Horns Rev. and Høvsøre.	60	In Progress
5	M27	Assessment of stratification impacts on rotor performance	70	In Progress

