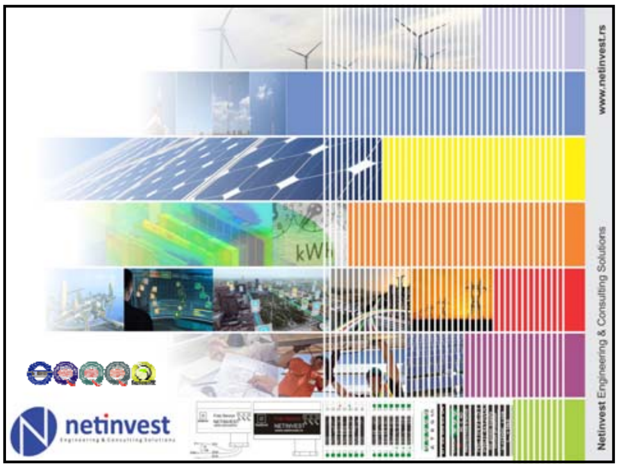
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O NETINVESTU
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Netinvest je kompanija koja preko dve decenije uspešno sprovodi razvoj i implementaciju projekata u inženjerskom sektoru uključujući konsalting i projektni menadžment. Kompanija se sastoji od tima inženjera različitih struka – elektrotehničke, građevinske, mašinske i arhitektonske, uključujući i tim specijalizovanih izvođača radova sposobnih da implementiraju predviđena rešenja.
Svi zaposleni i angažovani u kompaniji poseduju značajno međunarodno iskustvo i aktivnosti kompanije pokrivaju svim aspektima projektovanja i izgradnje – od istražnih studija, idejnih projekata, izrade projektne dokumentacije do izvođenja radova i izrade projekata izvedenih radova. Tim inženjera svaki zadatak posmatra kao zahtev koji treba kreativno, optimalno i racionalno sprovesti u delo.
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Netinvest nudi kompletne sisteme za merenje potencijala vetra visina od 50 do 140m sa kompletnom uslugom preciziranja lokacije, montaže i kontinualnog pribavljanja podataka. U procesu merenja vetra poželjno je da visina merenja bude ista ili bliska visini budućih vetroturibna te se uvek savetuje da se odabere što viši stub za merenje kako bi i merni podaci obezbedili sigurniji proračun proizvodnje vetroparka i bolje uslove za finansiranje.
Netinvest nudi sopstvena rešenja visina do čak 140m i ovlašćeni je zastupnik NRG Systems Ltd. Netinvest nudi kompletan asortiman NRG opreme, a može ponuditi i opremu drugih proizvođača, u skladu sa posebnim zahtevima klijenta.
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VETROELEKTRANE

Razvoj i menadžment projekata vetroparkova predstavlja važno polje u okviru aktivnosti kompanije jer obuhvata objedinjenu materiju legislative, inženjeringa i nauke. Netinvest izrađuje studije vetropotencijala koristeći se kompleksnim softverskim alatima i višegodišnjim iskustvom na polju vetroenergetike.

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Rešenja koja Netinvest nudi mogu značajno skratiti vreme za izgradnju vetroparka i optimizovati resurse tako da projekat vetroelektrane bude perspektivniji i bankabilan, posebno kada je u pitanju izbor opreme, priključenje na elektroenergetsku mrežu i pitanje zaštite prirode.

Vestas Gamesa ALSTOM GE Energy

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SOLARNE ELEKTRANE

Netinvest je projektant i izvođač prvih solarnih elektrana u Srbiji koje se priključuju na elektrodistributivnu mrežu.

Netinvest nudi kompletnu podršku od faze konsaltinga, preko tehno-ekonomskih analiza pa sve do faze zaključenja ugovora o otkupu električne energije, uključujući izradu projektne dokumentacije i izvođenje kompletnih radova.

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ENERGETSKA EFIKASNOST

Kod stambenih, poslovnih i objekata sličnih namena nudimo precizne simulacije energetskog bilansa objekata. Osim garantovanih energetskih ušteda i povećanog komfora takođe izrađujemo tehno-ekonomske analize po ESCO modelu. Osim sigurnosti u povrat investicije ovakve energetske optimizacije nude i tržišni kvalitet koji investitoru može garantovati izuzetnost ponude.

Izrada energetskih pasoša

Netinvest je jedno od prvih preduzeća u Srbiji koje je ispunilo uslove i steklo licencu resornog Ministarstva da kao pravno lice može izrađivati i izdavati sertifikate o energetskim svojstvima objekata visokogradnje, odnosno, kako se popularno nazivaju - energetske pasoše.

Finansiranje

Netinvest je registrovani konsultant kod Evropske banke za rekonstrukciju i razvoj (EBRD) koja nudi refundiranje troškova prilikom povećanja energetske efikasnosti, u okviru BAS programa.

European Bank for Reconstruction and Development

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Osnovna delatnost ovog sektora Netinvesta je projektovanje, izgradnja i održavanje objekata različitih funkcija i namena. Višegodišnje iskustvo i posvećenost stvaranju idealnih uslova komfora uz minimalne troškove doveli su do razvoja širokog spektra usluga koje možemo da ponudimo i koje obuhvataju sledeće:

- organizacija gradilišta
- projektovanje i izrada projektne dokumentacije
- izgradnja objekata i izvođenje mašinskih i elektro instalacija
- izrada ugovornih, okvirnih i mesečnih planova izvođenja radova
- kontrola vremena, troškova i kvaliteta izvođenja radova
- puštanje sistema u rad i dokazivanje parametara.

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UPRAVLJANJE PROJEKTIMA

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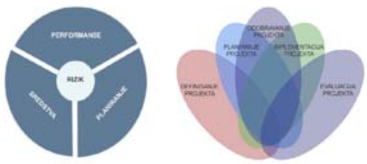
Tokom početnih faza investicija posebnu pažnju obraćamo na ukupne faktore koji mogu ugroziti uspešnu implementaciju. Stručnu ekspertizu i kvalitetan projekt i risk menadžment nudimo u sektoru građevinarstva i energetike, uključujući kompozitne sektore.



Tim stručnjaka različitih struka može sagledati investicionu problematiku i na vreme reagovati kako bi se sprečili neželjeni troškovi i kašnjenje u implementaciji. Poseban fokus u okviru kompanije je na građevinskom sektoru i u obnovljivim izvorima energije kao i specifičnim problemima.

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Osnovna delatnost ovog sektora Netinvesta je primena različitih pametnih rešenja i servisa dostupnih na tržištu i njihovo prilagođenje lokalnim specifičnostima u nastojanju da se promeni svest i odnos prema životnoj sredini i da se ujedno poboljša kvalitet svakodnevnog života građana ali isto tako da se poveća efikasnost, bezbednost i održivost.

Posebna pažnja posvećena je izradi specifikacije zahteva i mapiranju zahteva u potrebne funkcionalne celine rešenja koje se implementira uz izradu studija opravdanosti uvođenja pametnih servisa.

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- Urbanistički projekti
- Generalni projekti
- Idejni projekti
- Glavni projekti
- Projekti izvedenog stanja
Studije
- Studije vetropotencijala i proizvodnosti vetroparkova
- Studije solarnog potencijala i proizvodnosti elektrane
- Prethodne studije opravdanosti
- Studije opravdanosti
- Elaborati energetske efikasnosti
Izvođenje i nabavka opreme
- Montaža metereoloških stubova i opreme
- Montaža solarnih elektrana
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PROJEKTOVANJE VETROPARKOVA I PRORAČUN PROIZVODNJE ENERGIJE
KORIŠĆENJEM NAPREDNIH CFD TEHNOLOGIJA
EP HZHB Mostar
ČETVRTAK, 26. FEBRUAR 2015, 9:00h
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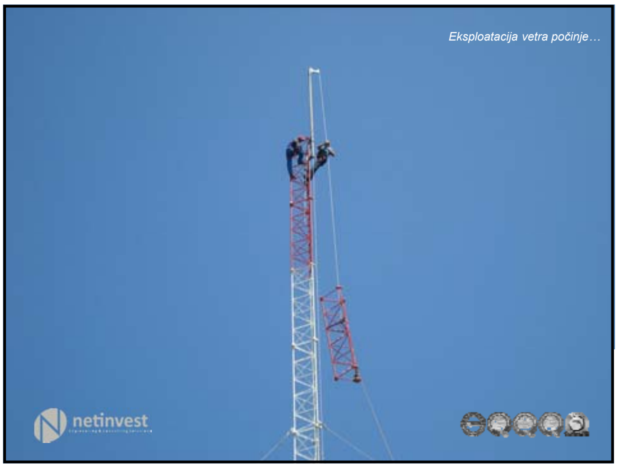
Eksploatacija vetra počinje…
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…podizanjem meteorološkog stuba…
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…nastavlja se mernom kampanjom…
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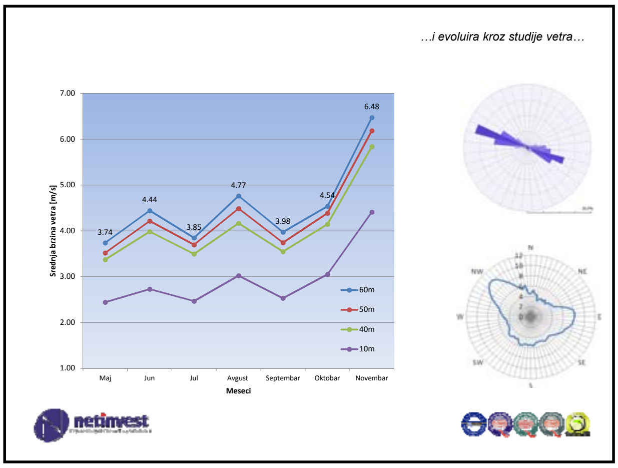
...i evoluira kroz studije vetra...
Srednja brzina vetra [m/s]
7.00
6.00
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Septembar
Oktobar
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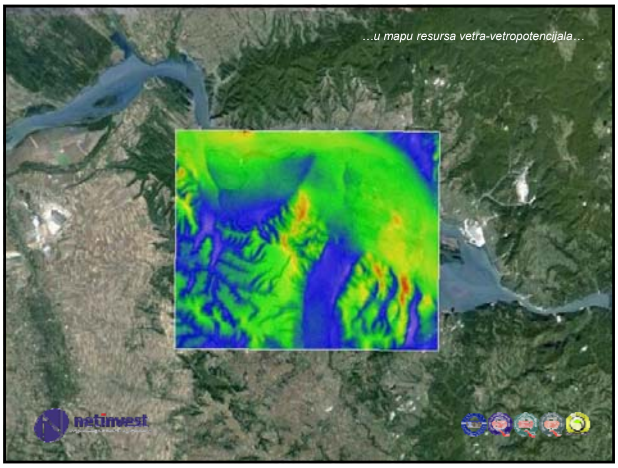
...u mapu resursa vetra-vetropotencijala...
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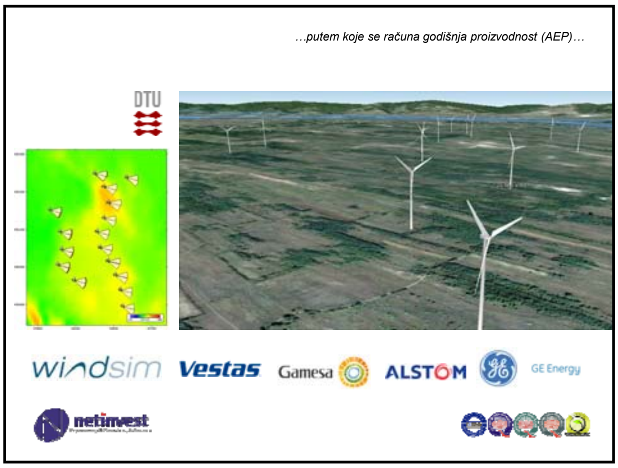
...putem koje se računa godišnja proizvodnost (AEP)...
DTU
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Vestas
Gamesa
ALSTOM
GE Energy
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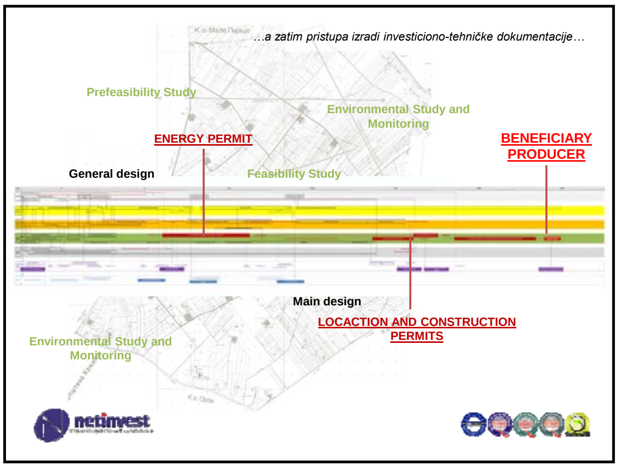
…a zatim pristupa izradi investiciono-tehničke dokumentacije…
Prefeasibility Study
Environmental Study and Monitoring
ENERGY PERMIT
BENEFICIARY PRODUCER
General design
Feasibility Study
Main design
LOCACTION AND CONSTRUCTION PERMITS
Environmental Study and Monitoring
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…koja dovodi do izgradnje!
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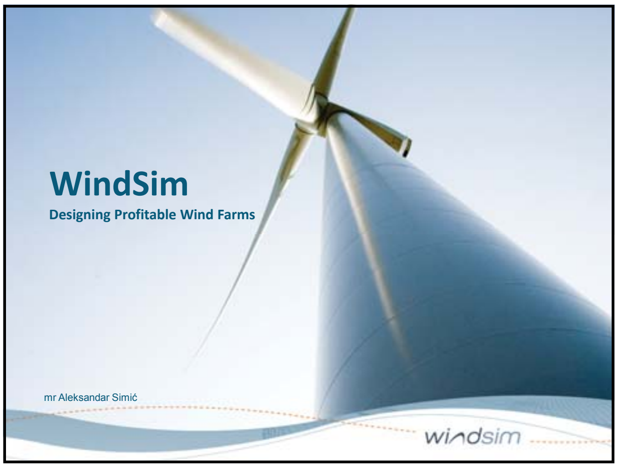

WindSim

Designing Profitable Wind Farms

mr Aleksandar Simić

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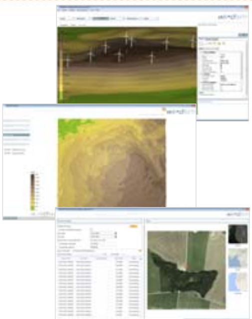
WindSim AS: Software Suite

Software:

- WindSim
- WindSim Evaluation
- WindSim Express/WindSim Express Cloud
- WindSim Park Optimizer
- WindSim Power Forecasting

Tools:

- WindSim Terrain Editor
- WindSim Reanalysis Data Downloader
- WindSim RSCT (Remote Sensing Correction Tool)
- MCU (Multiple Core Utilization)



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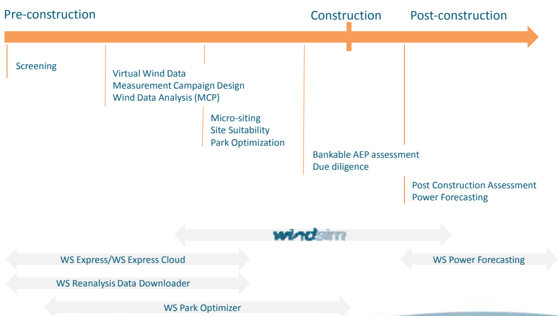
WindSim AS: Software Suite – Wind project time span



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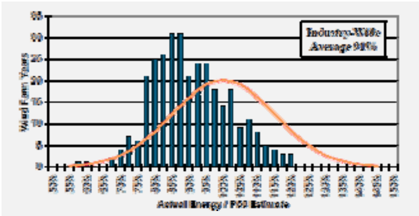
White paper – Wind Power Project Underperformance of 9%



Actual Energy versus P50 Estimates based on 60 projects with in total 317 wind farm years for the period 2000 to 2010. The AEP underperformance is 9%

Source: DNV Doc. No.: IEWP0101, Version B, "*Wind Power Project Underperformance*", 20 May 2011

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Designing profitable wind farms – The financiers perspectives

- Proper wind characterization is required for designing profitable wind farms
- How does accurate wind characterization increase the value of your wind project?
  - Increased Annual Energy Production, AEP
  - Reduced maintenance costs
  - Better financing

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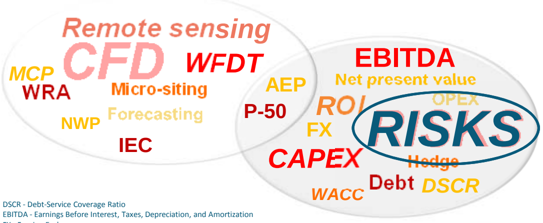
Vocabulary: Engineer – Financier

- Which language do you speak?
- How large is the vocabulary overlap?
- How large is the overlap in understanding?



DSCR - Debt-Service Coverage Ratio
EBITDA - Earnings Before Interest, Taxes, Depreciation, and Amortization
FX - Foreign Exchange
WACC - Weighted Average Cost of Capital

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Case: 120 MW wind farm

What are the investment, development and operational costs for a 120 MW Norwegian wind farm?

Key assumptions:

Number of turbines	40
MW per turbine	3
Installed capacity (MW)	120
Price per MW (MEUR)	1,05
AEP base case:	
P50- Energy production (MWh)	330 000
P50- Energy production (hours)	2 750
WACC (weighted average cost of capital)	6,00 %
Re-investment	6,00 %
Tax	28,00 %

Source: Cost model developed by Norwegian Wind Energy Association, NORWEA

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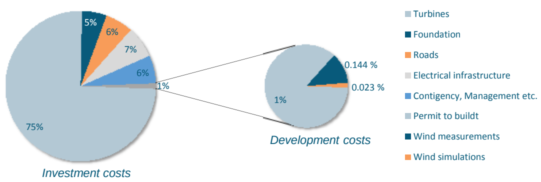
Investment costs versus development costs – 120 MW wind farm

Investment costs (MEUR)	176
Development costs (MEUR)	2
Wind measurement costs (MEUR)	0,27
Wind simulations costs (MEUR)	0,05



Source: Cost model developed by Norwegian Wind Energy Association, NORWEA

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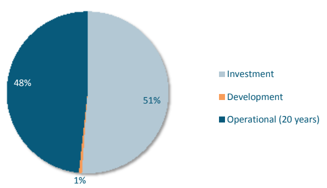
Investment costs versus operational costs – 120 MW wind farm

The average annual operational costs is 7,7 MEUR. During the lifetime of the wind farm the operational costs are in the same order of magnitude as the investment costs.

Investment costs (MEUR)	176
Development costs (MEUR)	2
Operational costs (MEUR) (20 years)	153



Source: Cost model developed by Norwegian Wind Energy Association, NORWEA

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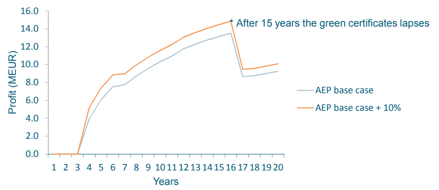
Increased AEP and profit – 120 MW wind farm

• The accumulated profit for the "AEP base case" with 2750 full-load hours is 164 MEUR, whereas for a case with a 10% increased AEP the accumulated profit is 184 MEUR

• The increased profit is 20 MEUR. Remember: Wind simulation cost was only 0,05 MEUR



Source: Cost model developed by Norwegian Wind Energy Association, NORWEA

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Reduced maintenance costs

• The operational costs are of the same order of magnitude as the investment costs
  • Approximately 50% of the costs is the turbine service agreement

• How much would a proper site suitability lower the operational costs?

• The extreme case!
  Relocation of wind turbines placed in high shear and high turbulence regions

• The typical case?
  Higher frequency of the repair/replacement of rotor blades and mechanical components like the gear and yaw system

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Added resources for wind characterization pays off

Apparently limited resources are spend on wind characterization – Why?

• Wind characterization is performed at an early stage of the project
  • Often with insufficient funding during the development stage

• Layout changes can be difficult at a later stage after completion of the permit process

• There is no incentives for improving the AEP
  • Support regimes which doesn't favor increasing AEP

• Financiers handles a complex risk picture, and a proper wind characterization doesn't get the attention it deserves. The added value brought to the project is not well understood

How to improve:

• Make consultants, developers, financiers and authorities aware of the importance of a proper wind characterization. It will increase AEP profit, lower operational costs and give a better financing of wind farm projects – It pays off

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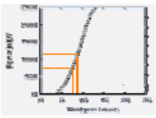
Designing profitable wind farms – The engineers perspectives

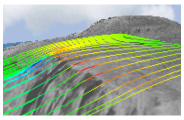
- Why is accurate wind characterization important for the wind energy industry?
  - The energy is proportional with the wind speed in third cube
  - A 10% increase of the wind speed gives 30% more energy

$$E = \frac{1}{2} \rho U^3$$

Energy content in wind field



Power versus wind speed



Wind speed variability

- The wind speed is the single most important condition for establishing profitable wind farms, due to its extreme power output sensitivity and large variability

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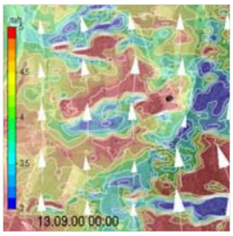
WindSim AS: Value proposition

- To increase the power production from wind turbines through optimal placement and operation by means of wind modeling



Local wind fields calculated with CFD, Computational Fluid Dynamics; Area:1 km²

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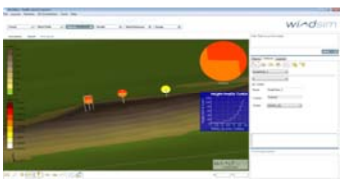
Micro-siting today

- Simulations based on advanced numerical methods
  - Tightly coupled with remote sensing - blending measured and simulated results
  - Sound physical models
- All flow parameters like speed, shear, inflow angle and turbulence will be determined over the swept turbine area, as this is what affect production and lifetime



All flow parameters are determined over the swept area

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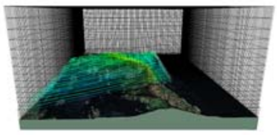
Wind characterization – Measurement & Simulation

- Knowledge about the wind conditions can be obtained by measurements and simulations
- Measurements are divided in two groups; point measurements and remote sensing
- Simulations are undertaken by a range of methods with varying sophistication levels

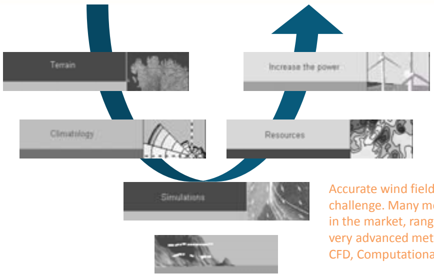
Cup Anemometer, point sensor

LIDAR (Light Detection And Ranging), remote sensing



Computational Fluid Dynamics, CFD

Micro-siting procedure – Where to position the turbines



Accurate wind field simulations is a great challenge. Many methods are available in the market, ranging from simple to very advanced methods – we will look at CFD, Computational Fluid Dynamics

The micro-siting procedure consists of five steps; Terrain, Climatology, Simulation, Resources and AEP

CFD: Solving the Navier-Stokes equations – a nonlinear problem

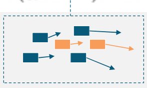
- The Navier–Stokes equations, named after Claude-Louis Navier (1785–1836) and George Gabriel Stokes (1819–1903), describe the motion of fluids, that is substances which can flow
- These equations arise from applying Newton's second law to fluid motion, together with the assumption that the fluid stress is the sum of a diffusing viscous term plus a pressure term

$$\mathbf{F}_{\text{net}} = \frac{d(m\mathbf{v})}{dt}$$

Forces = Mass x Acceleration (Newton's second law)

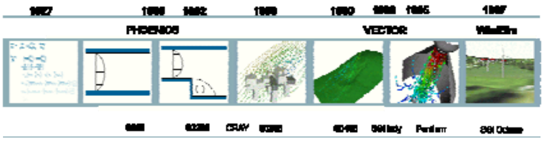
$$\rho\left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v}\cdot\nabla\mathbf{v}\right) = -\nabla p + \nabla\cdot\mathbb{T} + \mathbf{f},$$

Navier–Stokes equations



The convective acceleration is nonlinear.
It describes the effect of time independent acceleration of a fluid with respect to space.

CFD: We have the computing power



CFD development – A personal view

1980 - PHOENICS, first commercial available CFD software

1982 - Stanford, backward facing step, prediction of the size of the recirculation zone

1986 - CRAY XMP 28, 28 MB RAM, Cost 10 Million EURO (First super computer in Norway)

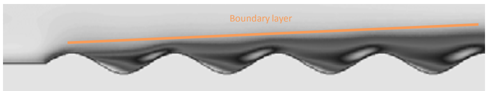
1988 - Troll platform with 100 000 cells, presented as a “monster” model at the CRAY UM

2003 - WindSim 100 000 cells on ordinary PC

2013 - WindSim 10 000 000 cells on ordinary PC

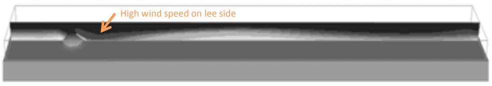
CFD: Adding more physics

• Turbulence, adding new transport equations



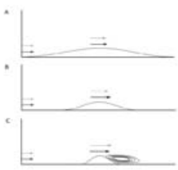
Transport of the turbulent kinetic energy in an idealized 2D sinusoidal terrain, illustrating the development of a turbulent boundary layer.

• Stratification, adding new transport equation, coupling with momentum and turbulence

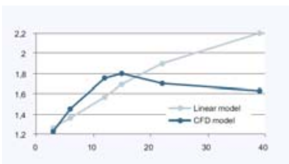


Gravity waves over obstacle in a stable atmosphere, a clear wave structure is present, involving high wind speeds in the lee side of the obstruction, length of computational domain is 15 km (Luke Norris 2011)

Linear versus non-linear (CFD) methods



Upstream speed-up, (Speed hill top/speed inlet). Average inclination angle (degrees) A) 5.7 B) 11.3 C) 21.8



Differences in simulated speed-up for different inclination angle (degrees)

Source: Ishihara T., Yamaguchi A. and Fujino Y. *“A Nonlinear model for predictions of turbulent flow over steep terrain”,* The World Wind Energy Conference and Exhibition, Berlin, 2002.

Validation – The Bolund experiment, 2010

• The Bolund experiment was a field campaign for validating numerical models of flow in complex terrain and was the basis for a unique blind comparison of flow models. WindSim participated in the Bolund experiment conducted as an anonymous blind test

• 50 results was handed in and grouped in 4 categories; Linearized, LES (Large Eddy Simulations) and 1 and 2 equations RANS (Reynolds Averaged Navier-Stokes)

Bolund

Linearized	35%
LES (CFD)	26%
RANS 1 eqn. (CFD)	25%
RANS 2 eqn. (CFD)	20%

Average wind speed errors based on all measurement points, WindSim is a RANS 2 eqn. model

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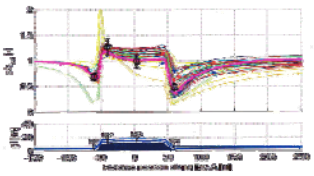
Validation – The Bolund experiment, 2010

• The CFD methods – including WindSim as the best commercial software in the test – showed the lowest errors among the various methods



Normalized wind speed at 5 meters height, measurements are given by black boxes, solid pink line is the WindSim results, while the other lines are results from other methods

Top 10 ListID	Turb.model	Error 5m [%]
ID0053	RANS k-epsilon	6
ID0037	RANS k-epsilon	4
ID0000	RANS k-epsilon	5
ID0036	RANS k-epsilon	5
ID0016	RANS k-epsilon	5
ID0015	RANS k-epsilon	5
ID0077	RANS k-epsilon	5
ID0010	RANS k-epsilon	7
ID0009	RANS k-epsilon	5
ID0034	RANS 1 eqn.	7
ID0068	RANS k-epsilon	10
ID0006	RANS k-epsilon	6

Best results are obtained with RANS k-epsilon models. The errors at 5 meters height are in the order of 5-6% for the best models

Source: Meissner C., Gravdahl A.R., Weir D., "CFD Validation – A Simple Approach", European Wind Energy Conference, Brussels, 2011

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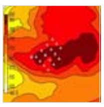
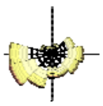
CFD: Validation – Added value in a simple terrain site

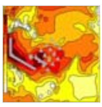
• Even in a simple site there is no direct coincidence between high wind speed areas and high elevation areas. Simulations shows that areas west of the below wind farm display the highest wind speeds. This area has terrain gradients perpendicular to the main wind directions, giving significant speed-ups



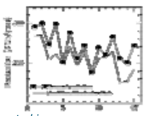
Elevation



Climatology



Wind Resources



AEP per turbine

• The wind resource map reveals a significant wind speed variability within the wind farm area

• An alternative layout increased the AEP with 10% – Highlighting the value added by CFD

Source: Gravdahl A.R., Rorgemoen S., Thogersen M., "*Power prediction and siting - When the terrain gets rough*", The World Wind Energy Conference and Exhibition, Berlin, 2002.

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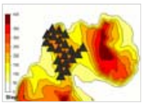
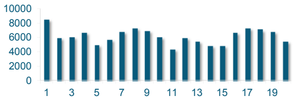
CFD: Added value in a complex terrain site

- In a complex site with height variations in the order of 100 meters within the wind farm area the wind speed variability can become very large
- The simulated AEP varies between 8468 and 4356 MWh/y
- The AEP variability is in the order of 100% – Highlighting the modelling optimization potential



Elevation



AEP per turbine based on simulations (MWh/y)

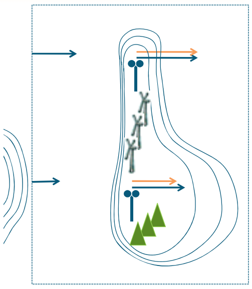
Maximize production – Chosing position for a real case

Given a site with two measurement masts, with a large difference in the mean wind speed. The turbines will be placed in between the measurement masts

The discrepancies could be due to several sources:

- Cliff
- Forest
- Large scale, inlet condition

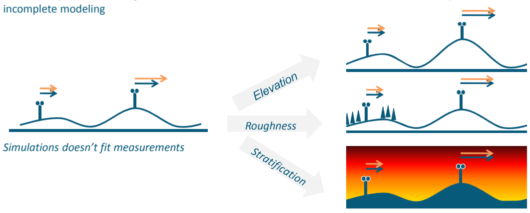
With limited information from the site it is hard to determine which of the sources that are responsible for the discrepancies?



simulation → *measurement* →

Tuning – "Right for the wrong reasons"

- What do to when the simulations → doesn't fit the measurements → ?
- Historically elevation, roughness, stratification and other variables have been tuned to compensate for incomplete modeling

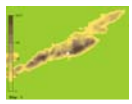


Simulations doesn't fit measurements

Adjustments to fit measurements

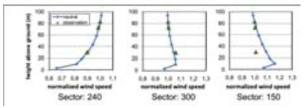
- It is important to establish proper models capable of reproducing reality, in order to improve our understanding of the flow behavior. Tuning could mean: "Right for the wrong reasons"

Including thermal effects in CFD simulations

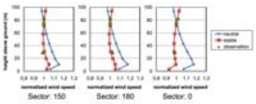


Sector (°)	Stability
0	s
30	s
60	s
90	s
120	s
150	s
180	s
210	n
240	n
270	n
300	n
330	s

left: Hundhammerfjellet area. The met mast is marked by a grey dot . Right: wind sectors with neutral (n) and stable (s) stratification



Simulations without consideration of thermal effects (blue) and measurements (green) for sectors with neutral (left, middle) and stable (right) stratification



Simulations with (red) and without (blue) consideration of thermal effects and observations (green) for sectors with stable stratification

3D WindSim simulation of horizontal wind speed for neutral (left) and stable (right) conditions

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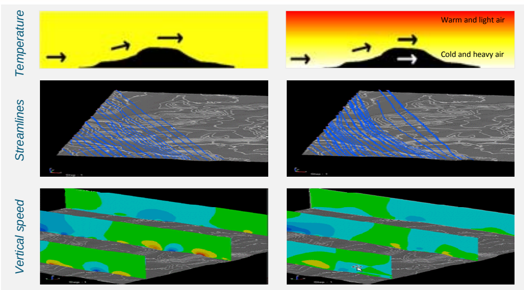
CFD: Stability modeling



Stratified local wind field, neutral (left) and stable (right), presented with courtesy from juwi

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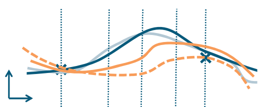
Wish for the future; Validated models – no more tuning



The "reality"

Measurements

Poorly validated model

Poorly validated model tuned – "Right for the wrong reasons"

Validated model – no tuning

- We solve a non-linear problem
- Tuning a simple model can give worse results
- Validated models based on proper physics is the way forward
- Share your data with the wind community for validation purposes

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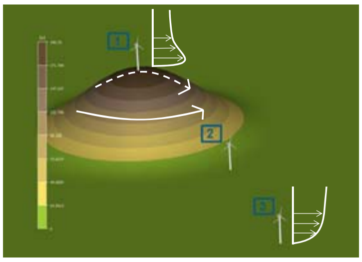
Exame: Chosing position for maximum production

Which turbine position 1, 2 or 3 will give the maximum AEP?



The well exposed position 1 at the hill top is the best for most wind climates, but ….

Terrain effects could impose a negative shear at the hill top making position 3 the best, but ….

Stratification could restrict the flow from passing over the hill top, cold and heavy air will instead pass around, making position 2 the best

The obvious choice wasn't too obvious after all, but ……

Good news: Flow modeling based on Computational Fluid Dynamics, CFD, captures all the above effects

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Park Optimizer

- Drawn wind farm area
- Check IEC constraints
- Optimize layout according to:
  - Annual Energy Production
  - Net present value

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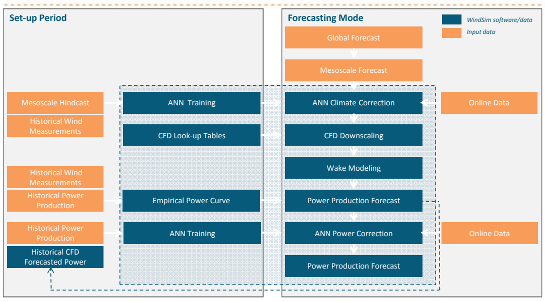
Short-term Power Production Forecast



Short-term Forecasting using Mesoscale Simulations, Artificial Neural Networks (ANN) and CFD

Webinar: https://www.youtube.com/watch?v=oafLxYfOYA4

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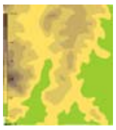
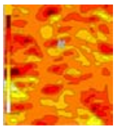
Remote Sensing Correction Tool – Validation

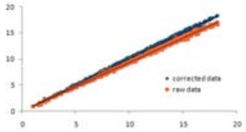
- Mast – 54 m, 76 m, 100 m
- WindSim model – 10 m resolution, 9 nodes < 100 m
- Location – CRES Lavrion Test Facility, Greece
- LIDAR Hardware – Leosphere WINDCUBE™



Elevation



Vertical Wind Speed



Source: Meissner C., Boquet M., “Correction of Lidar Remote Sensing Measurements by CFD Simulations”, European Wind Energy Conference, Brussels, 2011

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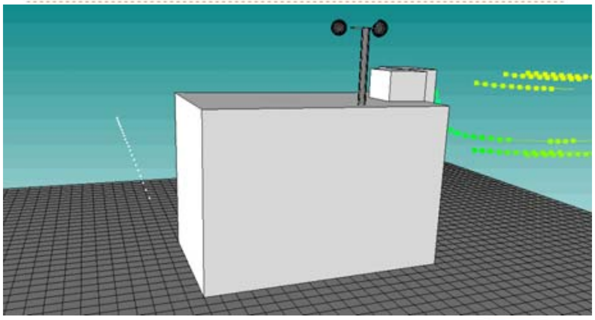
3D visualisations



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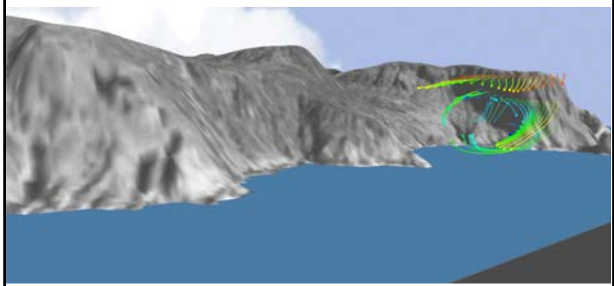
3D visualisations



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Conclusion

- Accurate wind characterization by means of numerical modeling has been and is still a great challenge
- Today advanced CFD based methods have increased the accuracy of the wind field simulation, even at sites with complex terrain and complex climate conditions
- Proper wind characterization is required for designing profitable wind farms

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