Wind resource assessment in urban areas in Portugal – CFD aplication

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LNEG
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MINISTÉRIO DA ECONOMIA E DA INOVAÇÃO

Wind Energy Sector in Portugal

Wind Energy Sector in Portugal

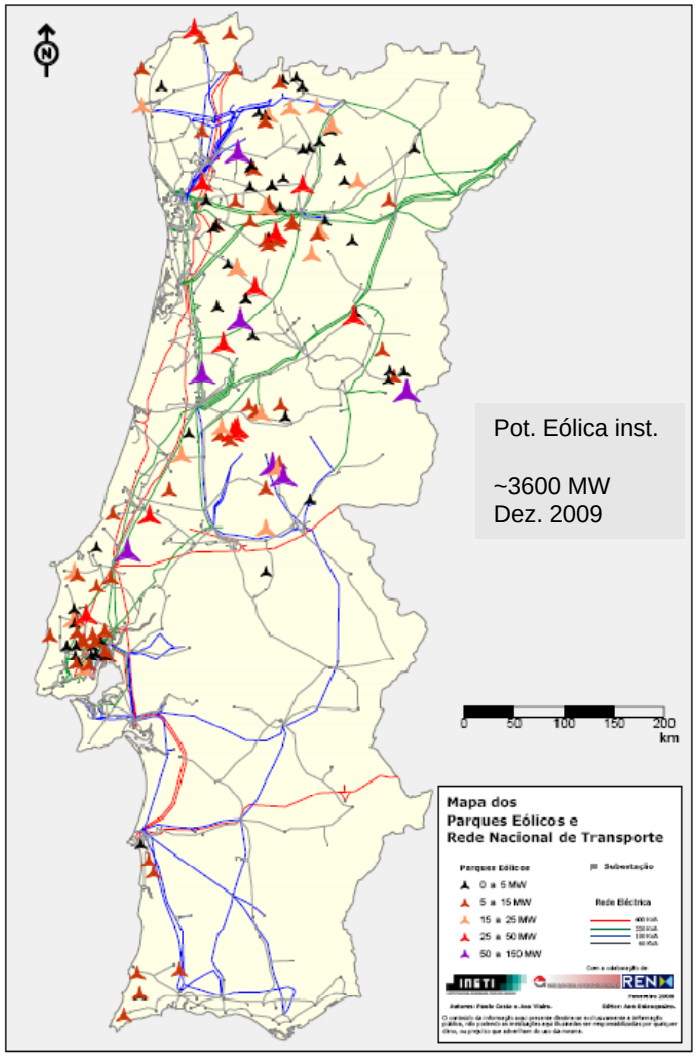
General Data (Dez. 2009)

~3600 MW installed capacity

Wind power plants in project phase: ~280 MW

Sustainable wind potential in Portugal (estimate):

Continent: ~6500 MW.
Madeira and Azores: 150 a 200 MW
Offshore: >3500 MW



Wind Power Plants
December 2009

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Wind Energy Sector in Portugal

- Nevertheless...
  - Sites with good wind potential for WP instalation onshore: almost exhausted...
- Therefore...
  - The wind energy exploitation offers other possibilities:

    - *Offshore* and small wind turbine installation for domestic use in urban and built areas.
  - Microgeneration!!

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Urban wind resource assessment

Urban wind resource assessment

Wind resource must be charaterized, but...

1. Wind flow over urban areas is difficult to characterize :
   A. Strong 3D effects and separation on top and edges of buildings;
   B. Wind speed reduction (> 20%);
   C. High turbulence
   D. and so on...

2. Standard micro scale models can't respond/solve this issues, although they can describe in a simple way the wind flow around obstacles.

Urban wind resource assessment

3. Urban wind resource assessment non-profitable – studies and measurement campaigns are expensive when compared to the swt costs, (sometimes higher).

   - The risk of skipping wind resource assessment is often assumed, or;
   - the idea is abandoned.

4. There are national and regional maps of the wind potential

   -Ex. Wind potential atlas for mainland Portugal (LNEG/INETI)
   - But... Not adapted to the urban environment/mesh

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Urban wind resource assessment - models

Models for the characterization of the wind potential in urban environment

- CFD – Computational fluid Dynamic, 3D model
  - FLUENT (Ansys) – Solves a large number of equations and can be used for several types of problems involving fluids: Thermal comfort, airfoils, wind energy, among others.
  - UrbaWind (Meteodyn) – Especially adapted for urban wind energy modelling: solves the Reynolds Averaged Navier-Stokes (RANS) equations. Uses the k-epsilon as turbulence closure.

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Urban wind resource assessment - models

- WindSim (WindSim) – Suitable for wind energy assessment: complex and very complex orographies. Uses same methodology as UrbaWind RANS and Turbulence closure – k-epsilon model.
- WindPro (EMD) – Similar to WASP, but can integrate WindSim.

Urban wind resource assessment - models

- Advantages CFD
  - Ability to solve complex sets of equations in geometrical domain divided into small volumes – calculus mesh;
  - Allows to understand the fluid flow without recurring to measurements instruments of the flow variables in the sites of interest;
  - Solves in a reasonable precise way problems involving turbulent flows.

Urban wind resource assessment - models

- Disadvantages CFD
  - Computations are highly time-consuming;
  - Geometry of the domain and mesh generation are usually complex;
  - Model convergence difficulties often generates errors in the results.

Urban wind resource assessment - models

- Physical models – Wind tunnel
  - Perfectly adapted to this kind of models
  - Very few errors in the results
- But...
  - Need wind tunnel...not available to everyone;
  - 3D physical models (physical representation of the environment to be studied) are very expensive;
  - The use of wind tunnels with the ability to simulate stratification of the atmosphere are very expensive.

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Wind resource assessment

- In isolated/punctual cases, the use of these models is not a problem, but for application in large areas, yes.

- The ideal case would be the existence of an Urban Wind Potential Atlas, in a regional or national scale.

- It is necessary to define urban wind resource assessment methodologies to estimate sustainable wind potential in cities and regions in the short-medium term.

Methodology

Wind resource assessment - methodology

LNEG/INETI is developing a methodology for the identification of suitable sites in urban and built areas for the installation of small wind turbines

- Tools:
  - Software: ArcGIS, WAsP/WindPro/(WindSim) e FLUENT/UrbaWind for validation.

-Input data:
  - wind data (measurements, databases, ...); Wind potential atlas for mainland Portugal;
  - Cartography (altimetry, urban planning – geometry and buildings heights).

Wind resource assessment - methodology

- Construction of a surface involving an urban area so that the buildings can be treated as a very complex terrain.

- Surface is generated with the geometry of the buildings in a CAD map, as long as information on the heights of the buildings is available.

- Application of an interpolation method to generate the surface.

- Method saves time in what concerns mesh generation (CFD) and can be used as input in any type of model/method (CFD, tunnel, micro scale).

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Wind resource assessment - validation

Validation :

- Measurements campaign as just started (very few data at this date) in an urban test area.

- CFD application in selected sites of the urban area (distinct typologies and small areas of buildings).

Input data and models:

- Wind data: Potential wind atlas for mainland Portugal – h=10m

- Models: Surface – WASP and WindSim; buildings - UrbanWind

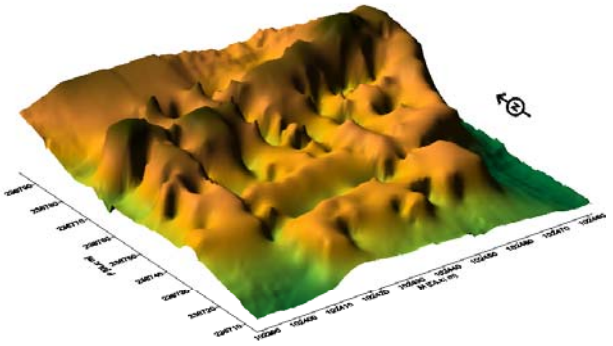
Models Results

Models results

Area under study – natural geometry of the buildings and generated surface

Polygons representing the buildings

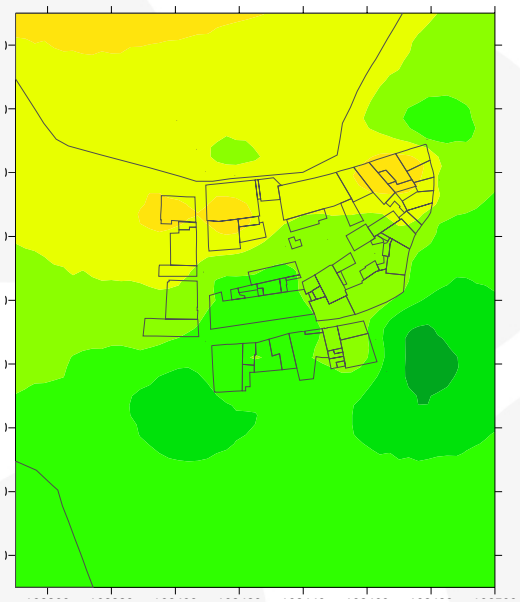
Generated surface



3D representation of the surface over and around the buildings area

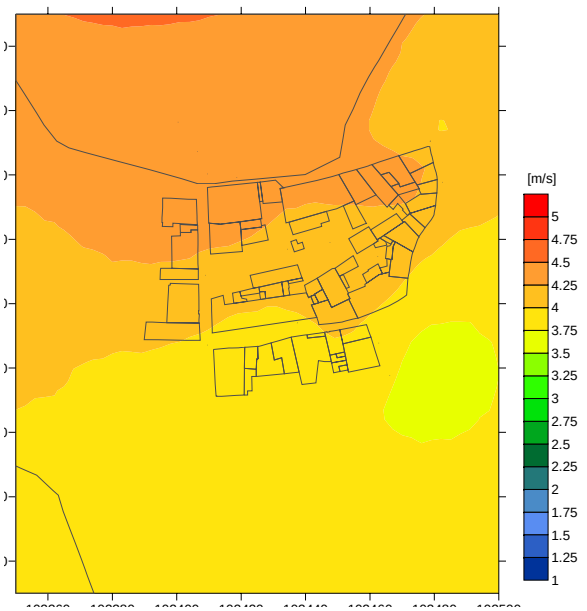
Models results - WASP

WASP results, for h=10, 16 and 20m a.g.l



H=10m

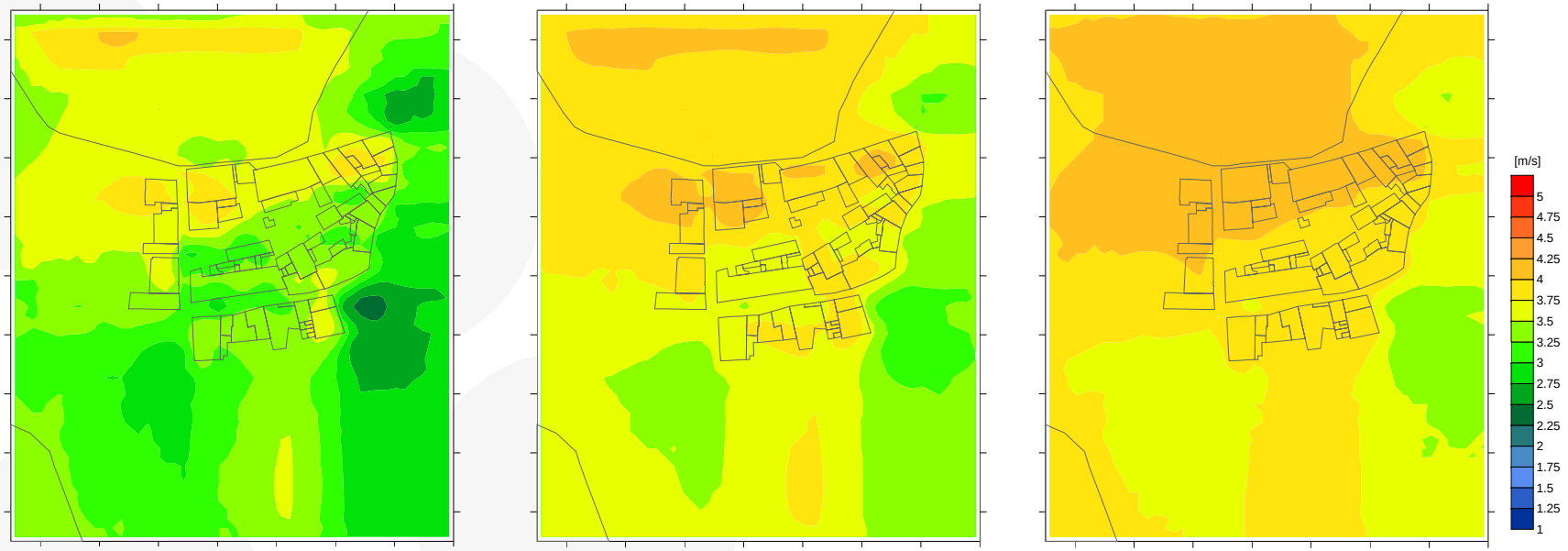
H=16m



H=20m

Models results - WindSim

WindSim results, for h=10, 16 and 20m a.g.l



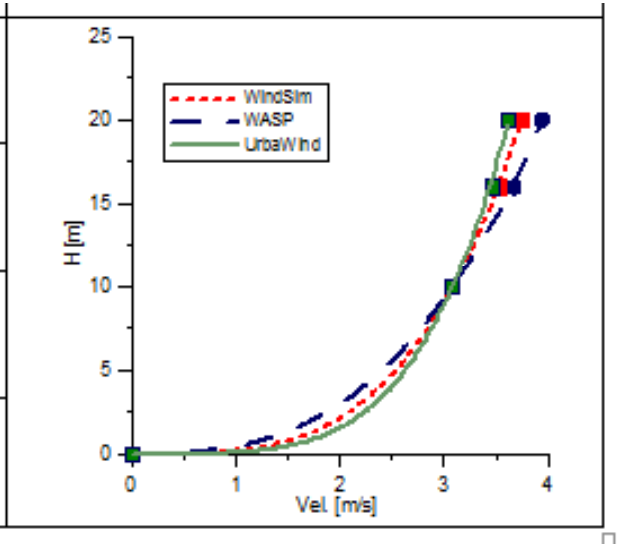
H=10m H=16m H=20m

Models results

Wind speed and turbulence intensity variation

Modelo	Velocidade do vento [m/s]			Intensidade turbulência [%] (sector 0°)		
H [m]	10	16	20	10	16	20
UrbaWind	3.08	3.46	3.61	19 - 25	14 - 21	14 – 16
WindSim	3.08	3.54	3.74	10 - 22	9 - 16	9 – 14
WASP	3.08	3.67	3.98	-	-	-

	UrbaWind	WindSim	WASP
UrbaWind	-	+2.3%	+6%
WindSim	-2.3%	-	+3.6%
WASP	-6%	-3.6%	-



-Final notes

-WASP overestimates wind speed when compared to other two models;

-WindSim results are nearer UrbaWind results, but higher vertical extrapolation coefficients are used leading to higher wind speeds. This was expected due to the use of a surface instead the natural geometry of the buildings.

- Turbulence values for dominant wind sector area higher when using UrbaWind due to the use of natural geometry of the buildings, which was also expected.

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-Final notes

- Methodology under development may be adequate to the purpose in mind, but still needs further validation.
- Data from measurements campaign will be used in a short term to validate model results
- Other areas of the city will also be modeled in order to establish calibration coeficients (if needed). These coeficients may allow a more precise spatial distribution of the wind resource in the area under study.

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...Thank you!!

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