# Wind resource assessment in urban areas in Portugal – CFD aplication

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LNEG
Laboratório Nacional de Energia e Geologia, I. P.

MINISTÉRIO DA ECONOMIA E DA INOVAÇÃO

# Wind Energy Sector in Portugal

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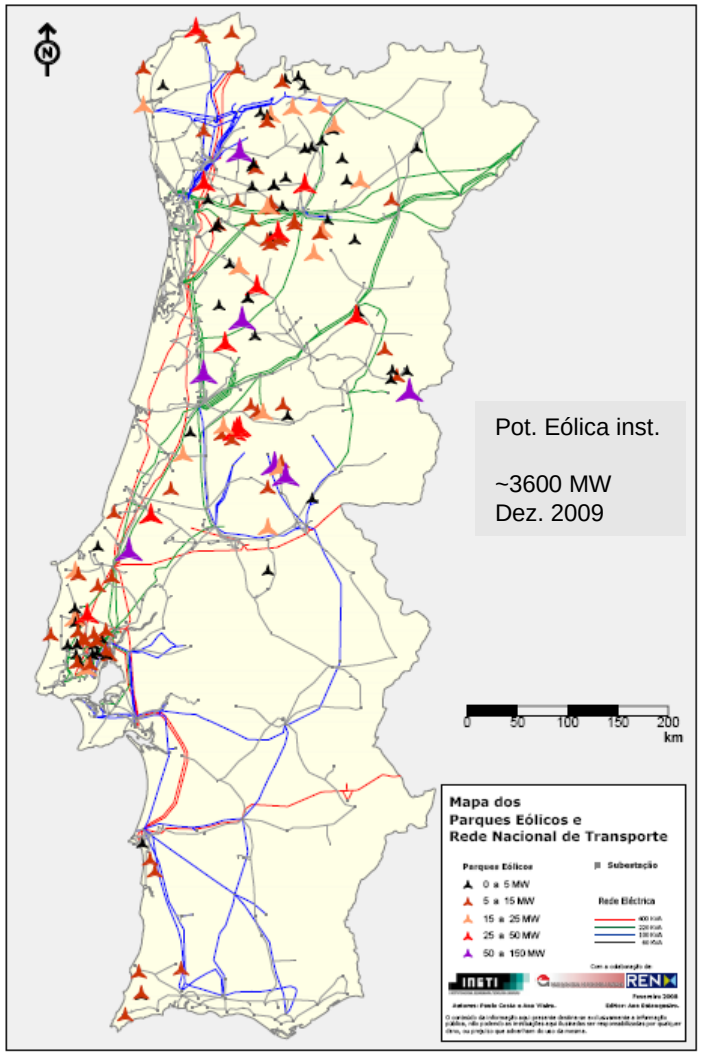
## General Data (Dez. 2009)

**~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

# 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***

# 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.*

# 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:***

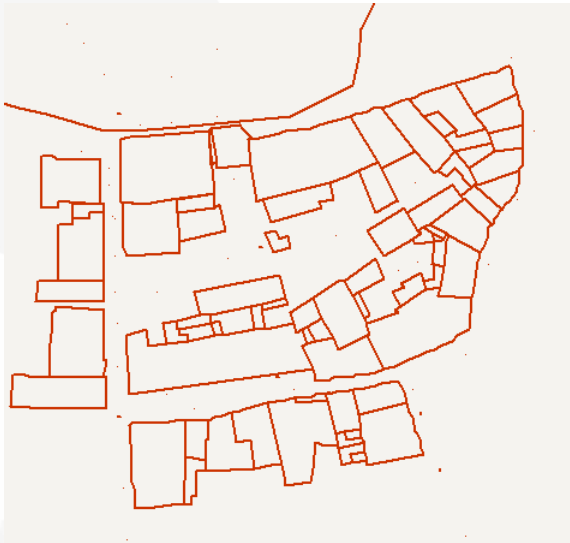
*- Wind data: Potential wind atlas for mainland Portugal – h=10m*

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

# Models Results

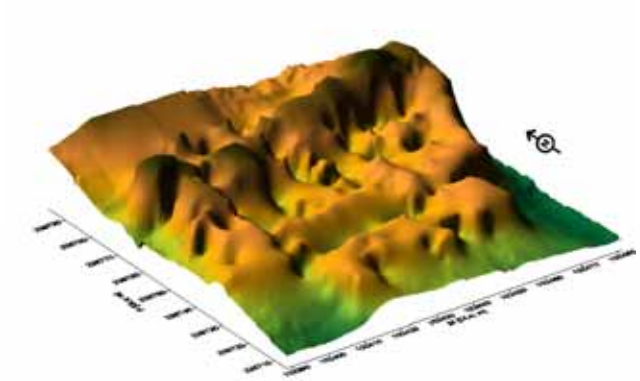
# Models results

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



*Polygons representing the buildings*

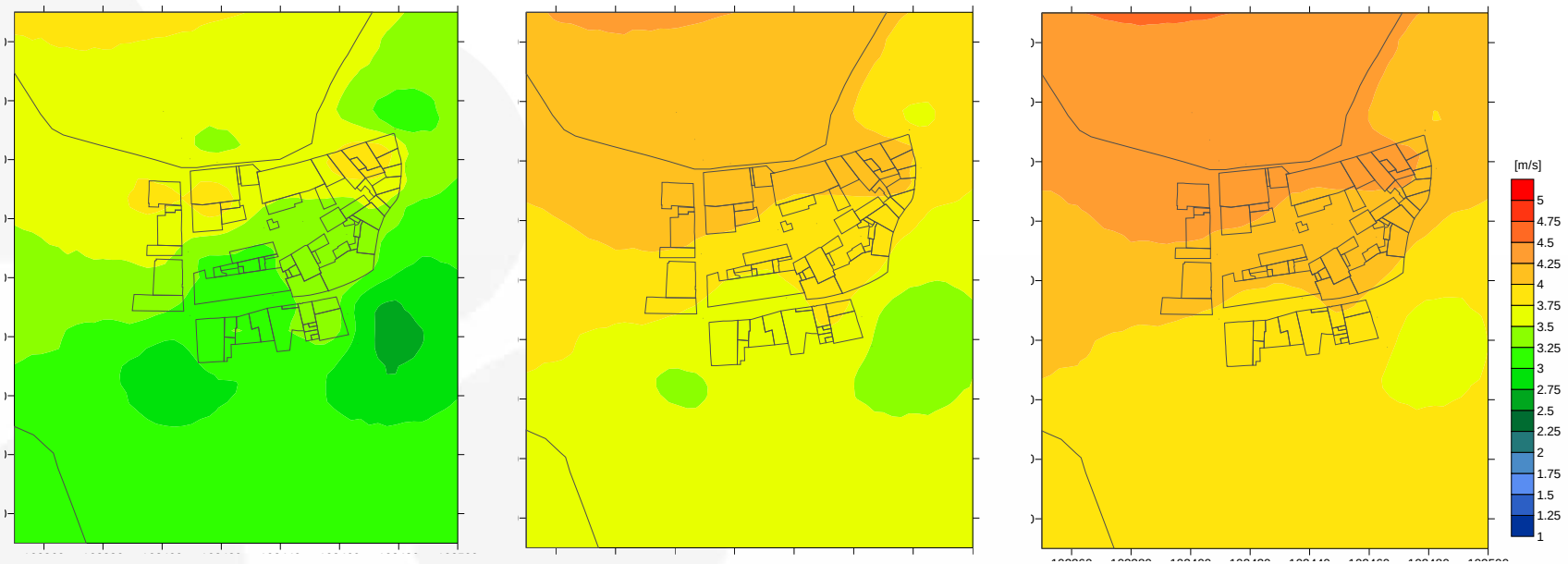
*Generated surface*



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

# Models results - WASP

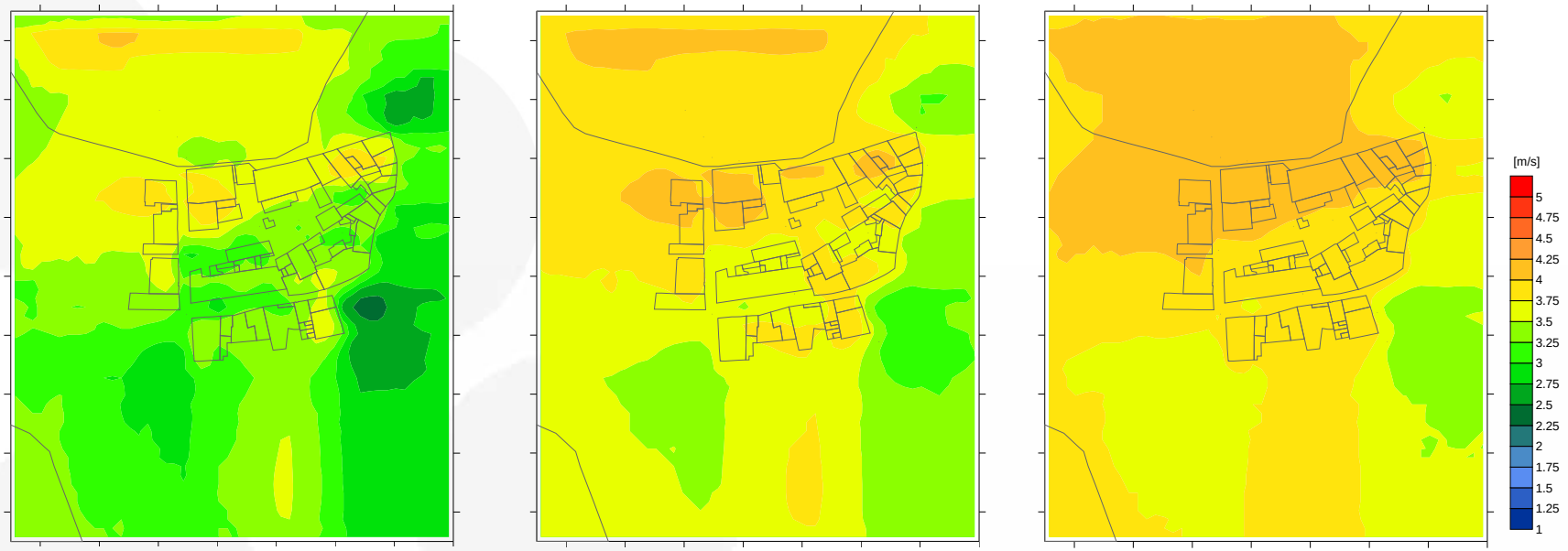
*WASP results, for h=10, 16 and 20m a.g.l*




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

# Models results - WindSim

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



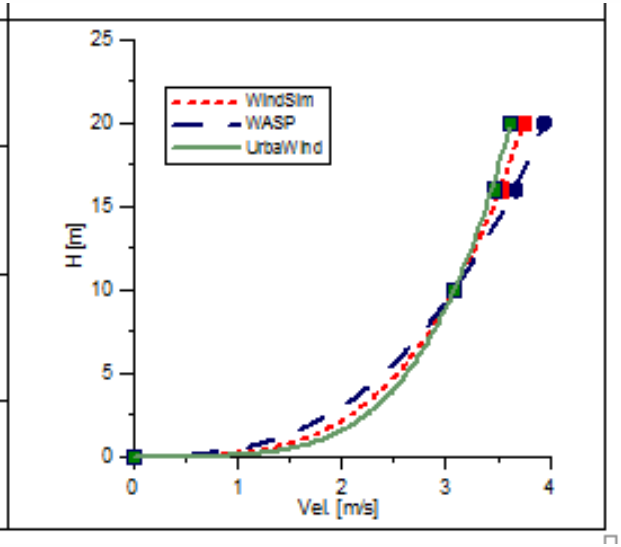

*H=10m* *H=16m* *H=20m*

# 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.*

# ...Thank you!!

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