Urban wind, urban legend?

Mark.Runacres@vub.ac.be

Vrije Universiteit Brussel
I N D I
Industriële Ingenieurswetenschappen
Vrije Universiteit Brussel
BRUSSELS RETROFIT XL
INNOVIRIS STRATEGIC PLATFORM
ENVIRONMENT
BruWind
Brussels Wind Energy Research Institute

Overview

- Introduction
- Small and medium-sized wind turbines
- Urban wind energy: case study Brussels
- Summary and conclusions

Introduction

Urban wind energy - introduction

- Wind has the potential to provide 50% of European electricity
- Wind energy has low power per land area: 1-3 W/m^2
  - can be higher for offshore, but 6 W/m^2 is unusual
  - German solar farms reach 5 W/m^2
- Cities have high power use per land area: 20-50 W/m^2 (150 m^2 for Mumbai)
- Urban wind energy will not provide a large fraction of the energy needs of any major city. This will always require large-scale generation

Urban wind energy - introduction

- There is no such thing as centralised generation of renewable energy
- A entirely non-fossil, non-nuclear electricity production of electricity means living around power plants

Urban wind energy - introduction

- Bringing power production closer can create awareness and goodwill
- There is a lot of unused space in cities: rooftops
- If there is wind, this space may be used
- Secondary benefits only count if the energy production is economically viable in the first place

Urban wind energy - introduction

Question of this contribution:

- Can wind energy produce local electricity in an urban area
  - in a economically viable manner
  - safely
  - with limited impact on surroundings ?

- **Feasibility** depends on **viability** and **impact**

Some definitions

Small and medium-sized wind turbines

- **Small wind turbines** (IEC 61400-2 definition)
  - "a system of 200 m^2 rotor swept area or less that converts kinetic energy in the wind into electrical energy"
  - $d \lesssim 16$ m
  - Prated $\lesssim$ 50 kW
- **Medium-sized wind turbines**
  - working definition: 50 -300 kW
  - 16 m $\lesssim d \lesssim$ 35 m

Power and energy

- In good conditions
  - A 1000 kW turbine will produce around 3 500 000 kWh/yr
  - A 100 kW turbine will produce around 350 000 kWh/yr
  - A 5 kW turbine will produce around 13 000 kWh/yr
- The average Belgian household consumes 3500 kWh/yr of electricity

Feasibility of a SMWT project

- **Economic viability**: measured with a metric such as
  - levelised cost of energy (LCOE)
  - payback period
  - internal rate of return (IRR)
  - secondary benefits (e.g. of greening of company image) have tangible monetary value
- **Impact**: safety, shadow flicker, noise, vibrations, biodiversity

Viability of small and medium wind turbines

Small and medium wind turbines

- Challenge of small and medium wind turbines:
  - immature market
  - low-cost
    → low budget for resource assessment and siting
    + limited time for measurements
  - generally complex environment



Rule 1: Know the market

VUB database of small wind turbines

- Turbines < 100 kW
- 762 turbines and counting
  - Most extensive survey to date
  - HAWT
  - VAWT
  - Other concepts

VUB database of small wind turbines

- Typical entry: main characteristics of turbine
  + comments: measured P-curve, cut-in or start, ...

Image	Naam	Bedrijf	Vermogen	Rotor diameter	Cut-in	Cut-out	Jaarlijkse Productie	Prijs	Mogelijkheid met netconnectie	P-curve
	FD6.4-5kW	ReDriven	5000 W	6,4 m	2 m/s start	19 m/s	6184 kWh/jaar (U_{gem} = 4 m/s) Berekend	€ 10660 Excl. mast	Ja	Ja

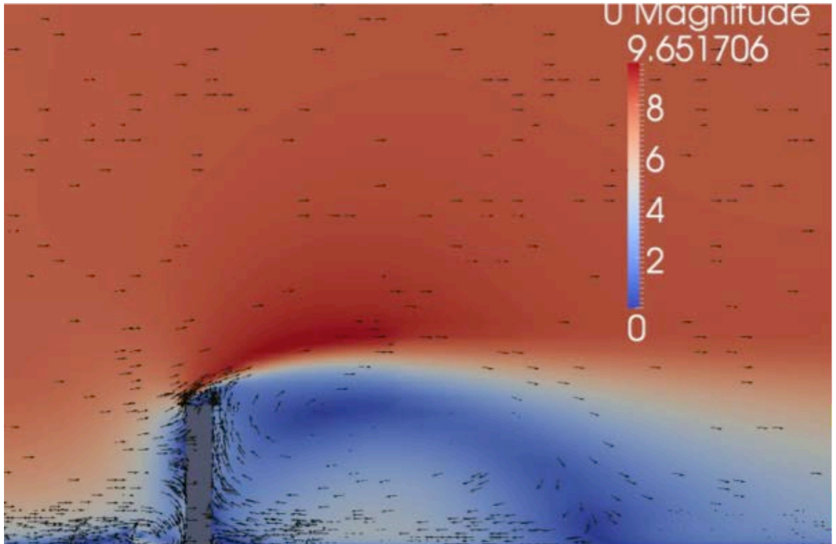
- Basis for comparison between small turbines, with estimate of annual production
- Select turbines for test fields
- Help clients select small turbines

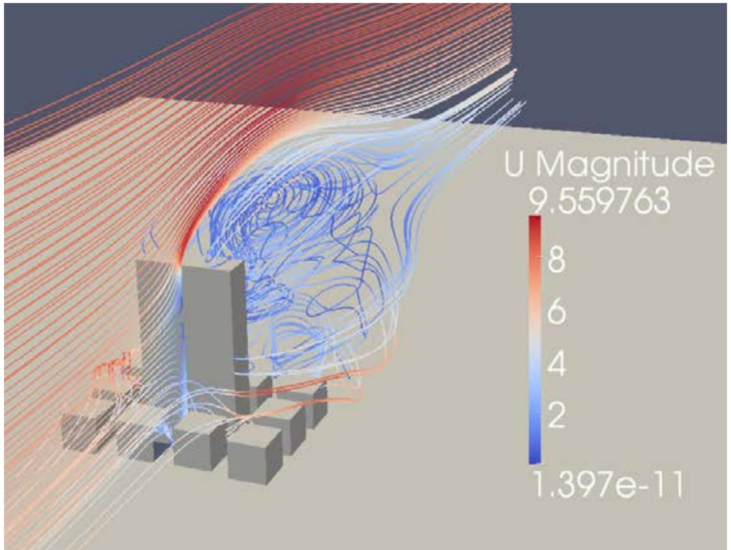
Rule 2: know the wind resource

- Estimate the available wind resource
  with the aim of predicting the energy production for an appropriate wind turbine
- This is in practice not always easy to do cheaply and reliably

Rule 3: proper micrositing

- Optimal location and height of the turbine
  - 3-D model of the site or building
  - Combined with computational fluid dynamics ('virtual wind tunnel')





Small and medium wind turbines: resource assessment + siting

- Feasibility
  - Turbine choice
  - Resource assessment
  - Turbine siting
  - Technical feasibility and impact
- Use measurements and numerical simulations
  - Resource assessment: measurements
  - Micro-siting: numerical simulations

The potential for wind energy in Brussels

Wind potential in Brussels: global wind conditions

- Wind maps based on terrain information and meteo data

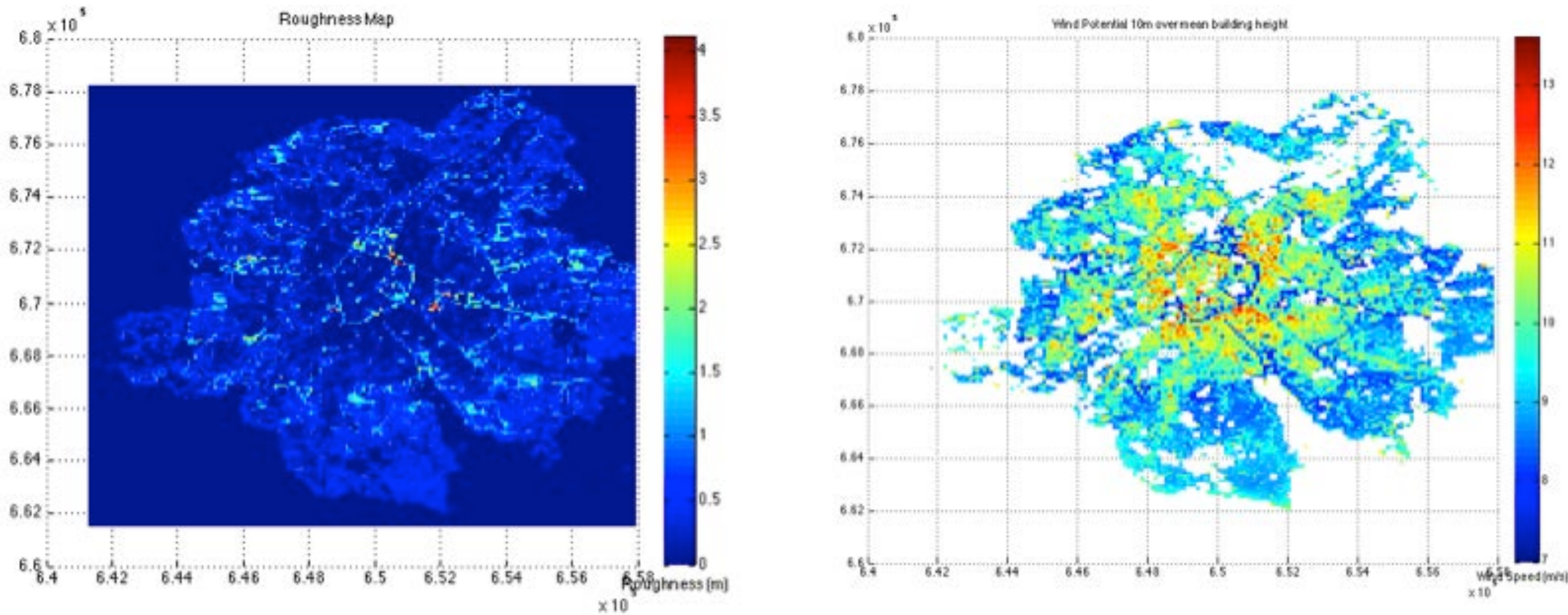
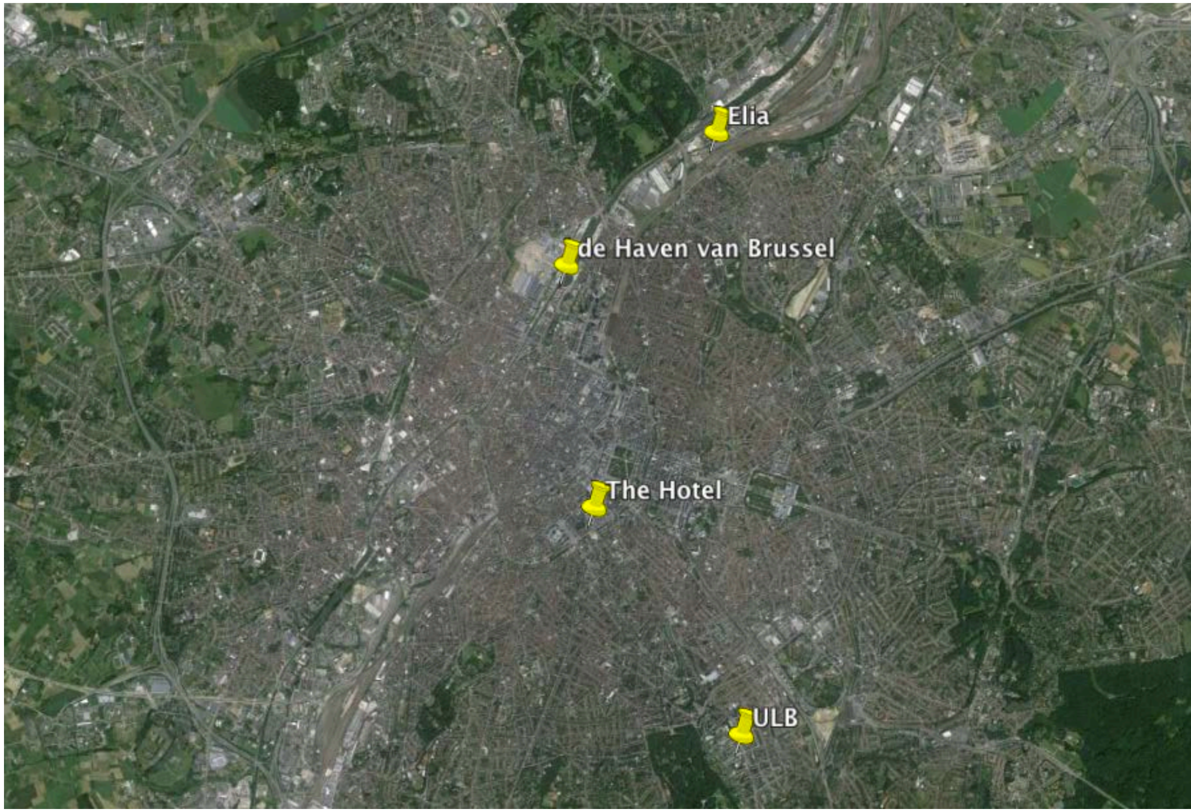


Figure 1: Roughness map (left) and wind speed at 10 m above mean building height (right) for the Brussels Region.

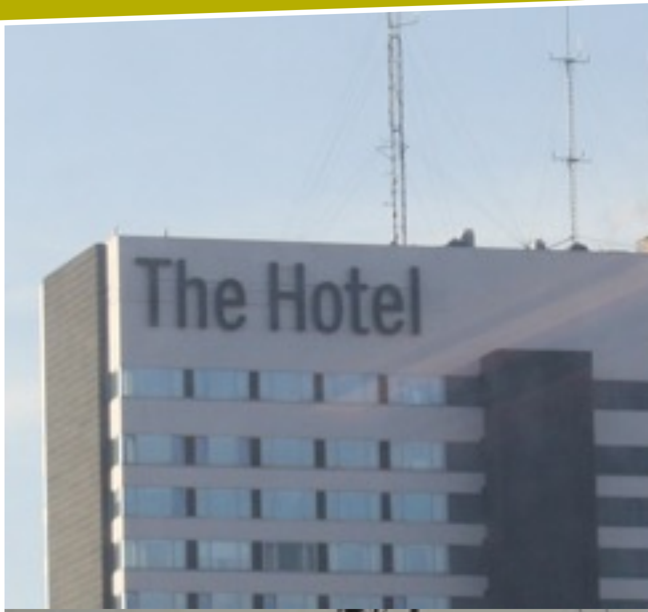
Wind measurements: site selection

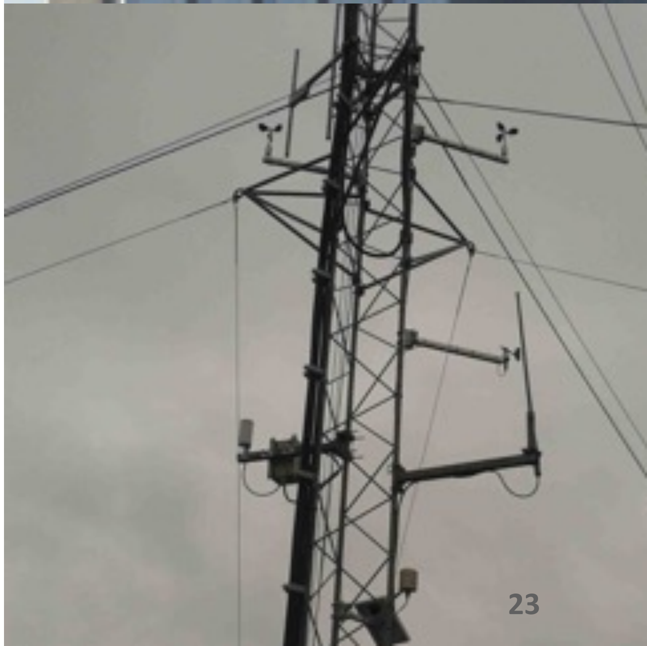
- **Result**
  - 4 sites were selected:
    - » Hilton
    - » ULB Campus Solbosch
    - » Elia
    - » Port of Brussels



Wind measurements: results

- The Hotel:
  - building height 94 m
  - close to porte de Namur
  - Over 1 yr of measurements
  - Average wind speed:
    5.8 m/s
  - This is comparable to the wind at the Belgian coast
    (at normal hub height)





Wat would a wind turbine on The Hotel produce?

- The Hotel:
  - Yearly production
    - Sonkyo Windspot : 14200 kWh/yr
    - Ennera: 8170 kWh/yr
  - Dynamic payback time
    - KMO: Sonkyo Windspot & Ennera : 7 jr
      (10-12 yr without support)
  - IRR:
    - Sonkyo Windspot: 17.2 %
    - Ennera: 15.1 %

Wind measurements: results

- Other high-rises (Manhattan-tower): comparable results
- Lower buildings (40 m): conditions much less favourable
- Unclear: potential for medium-sized turbines in semi-open terrain
- 12 m above ground
  (typical hub height < 15 m):
  - mean wind speed 3.7 m/s
  - comparable to Schoondijke (Zeeland)

Impact of rooftop-mounted wind turbines

Building-mounted small wind turbines

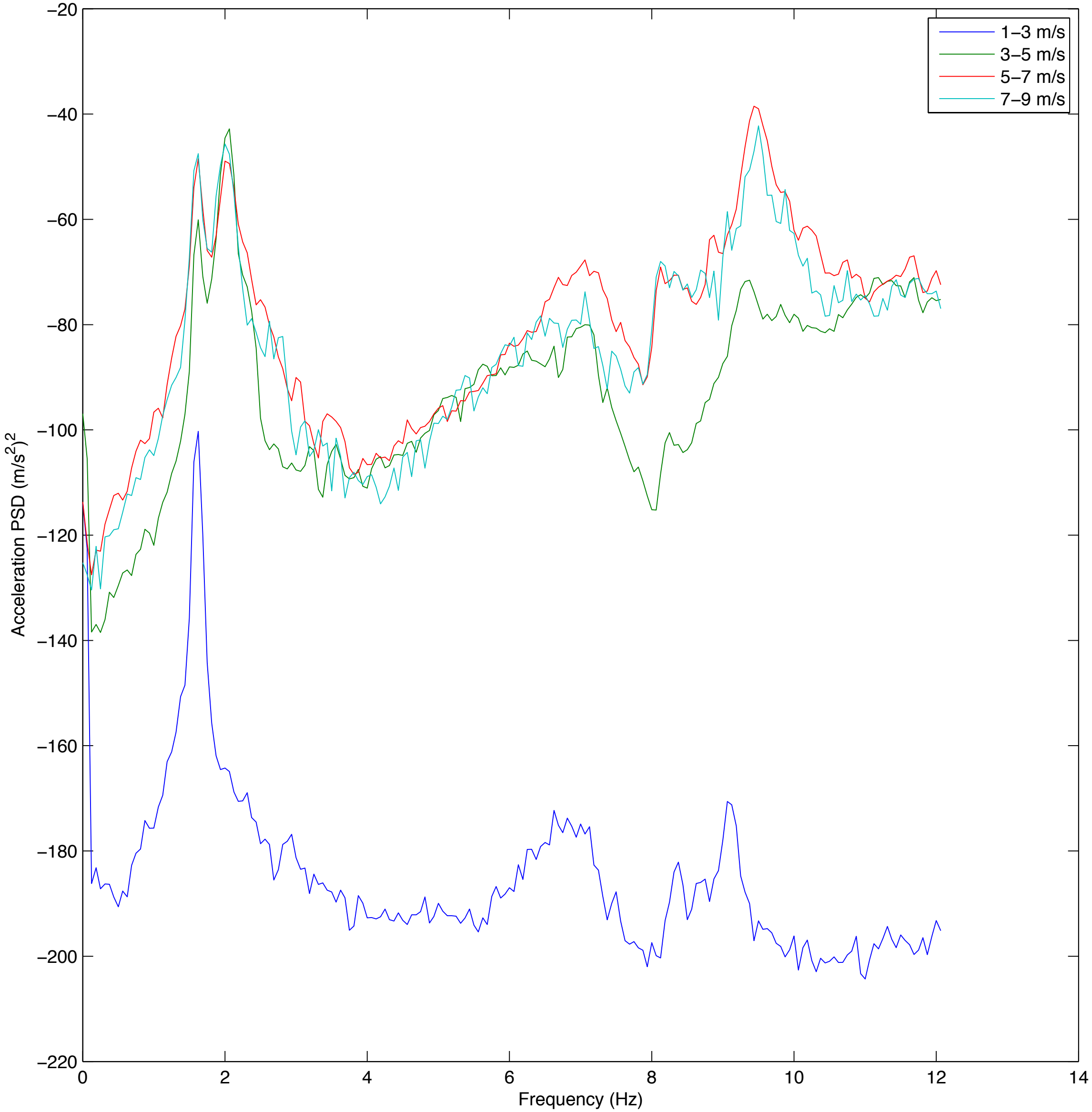
- Turbine should not affect structural health of building
- Impact on occupants and surrounding should be negligible
- Impact on air traffic should be negligible
- Impact on biodiversity should be negligible

Portland, Oregon (2009)

Results: characterisation of vibrations

- This is not in the public domain, so we needed to measure, no data available, so this is really necessary to prepare a rooftop mounting
- We measure on the ground (three turbines of our own turbines on different locations)
- The vibration data of these turbines are then combined with wind measurements on rooftops and with building models (subcontractor Greisch, Liège)

Results: characterisation of vibrations



- Vibration spectrum only weakly dependent on wind speed.
- Some increased damping at higher wind speeds (aero damping, fore-aft in particular).

Results: characterisation of vibrations

- What about different turbines?
  Dominant modes are from the mast, which has roughly standard dimensions and usually similar stiffness (steel) so dominant frequencies vary little over different types of HAWT.
- So vibrations are quite generic
  (independent of wind speed and turbine type)

Results: structural impact of vibrations

- Structural impact negligible if wind turbine is mounted on the supporting structure of the building
- Local reinforcements may be necessary when turbine mounted away from supporting column
- Damping methods will mainly address possible acoustic issues, rather than structural (vibrations above ~ 50 Hz).

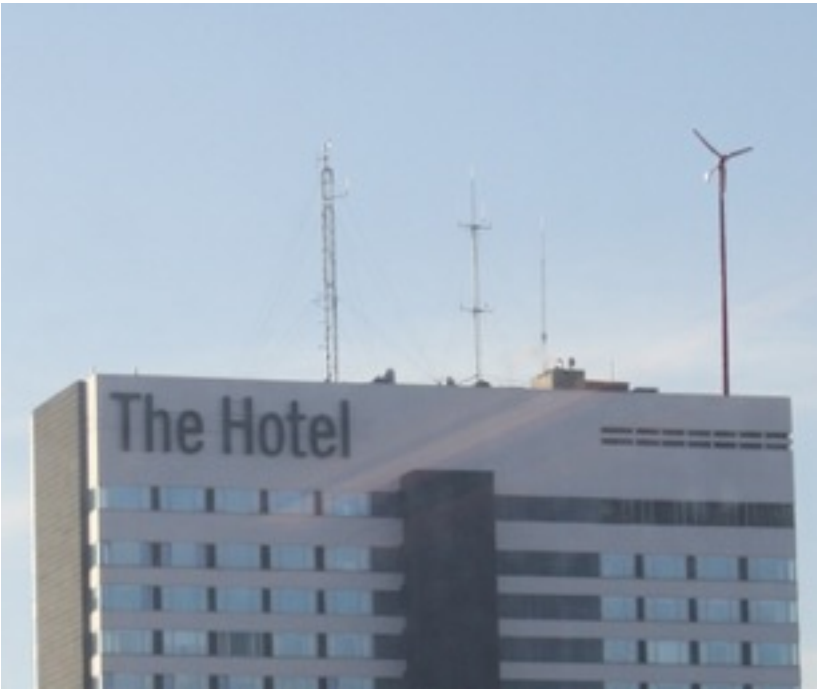
Dallas, Texas (2011)

Shadow flicker

- Guideline
  - *d* = 2 times height
  - max 30 h/yr
  - max 30 min/day
- The Hotel
  - Shadow moves fast enough

Impact of rooftop-mounted wind turbines

- Structural effect of vibrations: very limited
- Visual impact



- Noise:
  - direct: inaudible
  - through vibrations: investigation ongoing
- Biodiversity: very little impact
- No risk for air traffic

Pilot projects

- We are preparing full feasibility reports to prepare building permit requests in Brussels
- We plan to finish end 2015

Wind situation in Brussels

- Wind conditions on high-rises comparable to conditions at the Belgian coast
  - Payback times < 10 yr
  - IRR > 15 %
  - This is very good for distributed generation
- BUT: only true for good wind turbines, in a good location, properly installed
- Semi-open terrain not measured
- Impact very limited. Detailed feasibility study always required

Economic impact — long term

- In the long term, and providing the problem of rooftop crowding can be managed, there is the potential for roughly 50 sites for rooftop-mounted wind turbines in Brussels, resulting in a power production of the order of 1.5 GWh/yr

Summary

- There is a potential for wind energy in the BCR
- Projects can be economically viable with low impact
- Brussels has the technological assets required
- Now is the time for pilot projects

Thank you

Mark.Runacres@vub.ac.be