Assessing the performance of small wind turbines in urban areas

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Introduction

- Increased interest in microgeneration
  - Microgeneration strategy (2006)
  - Feed-in tariff (2010)

- Significant growth in number of small wind turbine
  - Installed capacity increased from 6 MW to greater than 50 MW between 2006 and 2010.
  - Increased proportion of building mounted turbines in urban areas

- Urban wind turbines are generally performing poorly
  - Warwick wind trials (2009): Average capacity factor: 0.85%
  - Energy saving trust (2009): Highest capacity factor: 3%
Why are small wind turbines located in urban areas performing poorly?

Technology

- Urban wind characteristics affect the performance of the turbines
- HAWTs do not reproduce their manufacturer’s power curves

(Encraft, 2009)
Site Assessment

Current site assessment tools do not accurately predict the wind speed at an urban site.

- DECC wind speed database
  - Mass consistent flow model (NOABL)
  - Mean error in annual mean wind speed: 42%

- Carbon Trust tool (2009)
  - Based on model developed by UK Met Office
  - Mean error in annual mean wind speed: 17%

Logarithmic wind profile

\[ U(z) = \frac{u^*}{k} \ln \left( \frac{z}{z_0} \right) \]

- \( U \) = mean wind speed
- \( z \) = height
- \( U^* \) = friction velocity
- \( k \) = von Karman constant
- \( z_0 \) = roughness length
Internal boundary layer method

Mertens (2003) and Heath et al. (2007)

- IBL wind profile adjusts a reference rural wind speed, $U_{\text{ref}}$ at a height, $z_{\text{ref}}$ to a downwind urban value, $U$ at height $z$.

$$U(z) = \frac{\ln \left[ \frac{z - d}{z_{02}} \right]}{\ln \left[ \frac{\delta}{z_{01}} \right]} \ln \left[ \frac{\delta}{z_{01}} \right] U_{\text{ref}} \left( z_{\text{ref}} \right)$$

Greater London
Urban morphology database

- LUCID project derived dimensions of buildings in Greater London.
- Plan area ratio, $\lambda_p = \frac{A_p}{A_T}$
- Frontal area ratio, $\lambda_F = \frac{A_F}{A_T}$
- Macdonald et al. (1998) expressions

\[
\frac{z_0}{h} = \left(1 - \frac{d}{h}\right) \exp \left(-\left(0.5 \beta \frac{C_D}{\kappa^2} \left(1 - \frac{d}{h}\right) \lambda_f\right)^{-0.5}\right)
\]

\[
\frac{d}{h} = 1 + A^{-\lambda_P} (\lambda_P - 1)
\]

Annual mean wind speed
Small wind turbines

Mean capacity factor
Conclusions

• Current site assessment tools are inaccurate, particularly in urban areas.
  – DECC mean error of U: 42%
  – CT mean error of U: 17%

• Improved representation of urban surface using building morphology data

• Wind map provides best resource for assessing performance of small wind turbines in the region.

• There is a range in the performance of small wind turbines in urban areas. This can only be identified by having improved method.
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