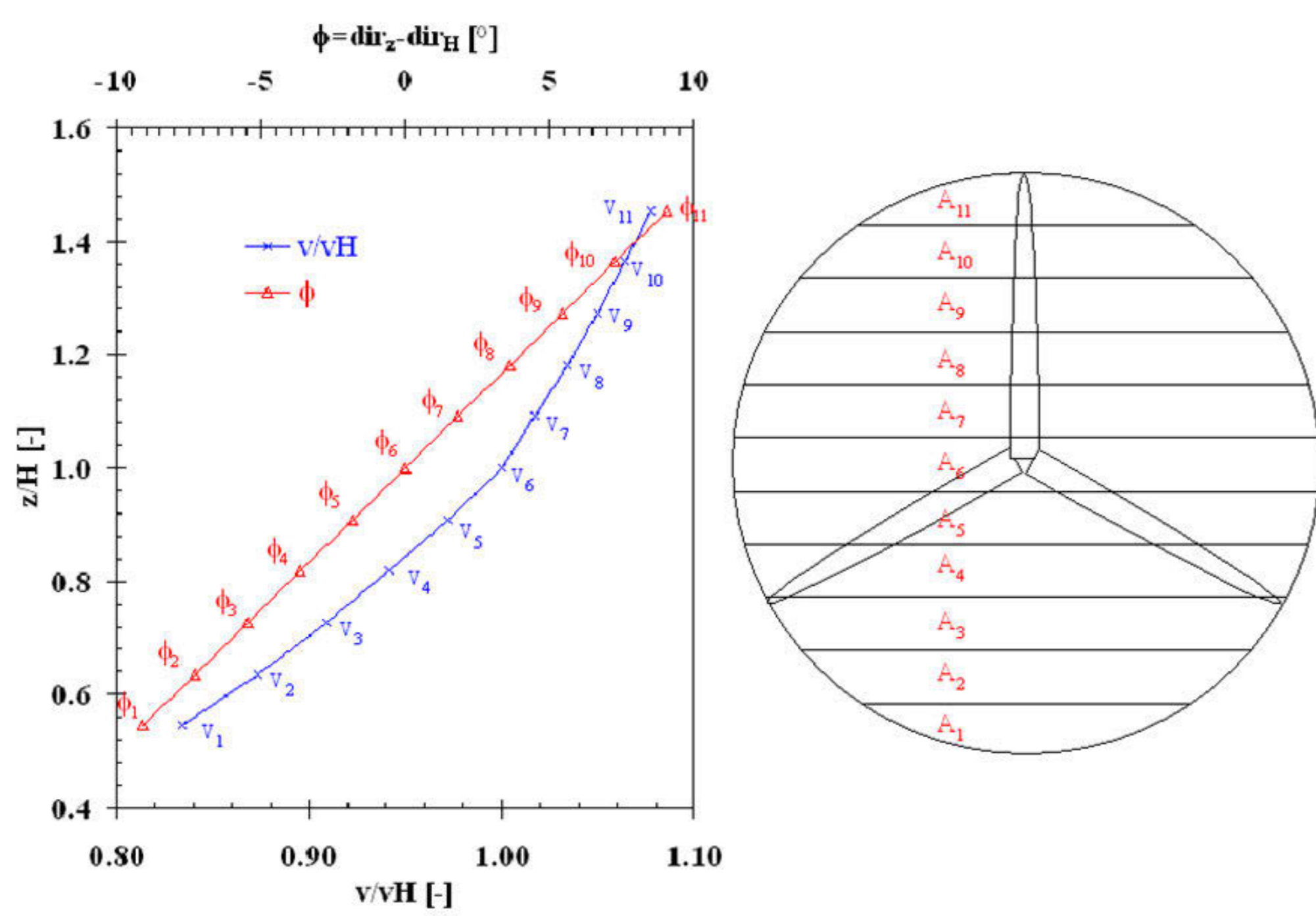


Abstract

Rotor Equivalent Wind Speed (REWS) is the wind speed corresponding to the kinetic energy flux through the total swept area of a wind turbine. It considers change of wind speed and wind direction over the substantial height of modern day multi-megawatt turbines. Introduced by the upcoming revision of the IEC 61400-12-1 [1], this wind speed definition aims at deriving power curves representative for a wider range of environmental conditions than current state of the art power curves based on hub height wind speed (HHWS). In this work, the challenge of handling measurement uncertainties of this innovative measurement method is addressed.

Definition REWS



$$REWS = \left(\sum_{i=1}^n (v_i \cos(\phi_i))^3 \frac{A_i}{A} \right)^{\frac{1}{3}}$$

REWS Rotor Equivalent Wind Speed

v_i Wind speed in i -th area element A_i

ϕ_i Wind direction in i -th area element A_i relative to hub height wind direction

A total rotor area ($\sum A_i = A$)

Wind Speed Definitions (WSD)

Simultaneous measurements with both a hub height met mast and a Leosphere Windcube LiDAR allow for the following wind speed definitions (WSD):

HHWS,M HHWS measured by met mast (current practice)

HHWS,L HHWS measured with LiDAR

REWS,L REWS measured by LiDAR

REWS,M+L HHWS,M corrected by the ratio REWS,L / HHWS,L

Uncertainty Cumulation

Combined uncertainty of REWS measurement need to consider the correlation of individual uncertainty components between different heights. Correlation between LiDAR uncertainties reduces the overall budget if relative LiDAR measurements (WSD D) are used. Cumulation of uncertainties should be performed in the following order:

1. Over heights
2. Over wind speed bins (for AEP calculation)
3. Over independent components

New Uncertainty Components

The Draft IEC 61400-12-1, Ed. 2 [1] requires the consideration of several uncertainty components previously not covered in the uncertainty budget. Especially the range for This includes the following:

- Usage of REWS or if HHWS used, an estimation of the impact of the lack of knowledge about wind shear or veer
- Normalization of power with regard to turbulence intensity or if not used, an uncertainty for not using this method.
- Uncertainty of the method of air density normalization.

Especially the gross uncertainties to be included if some method is not used lead to a difference in uncertainties to the current standard.

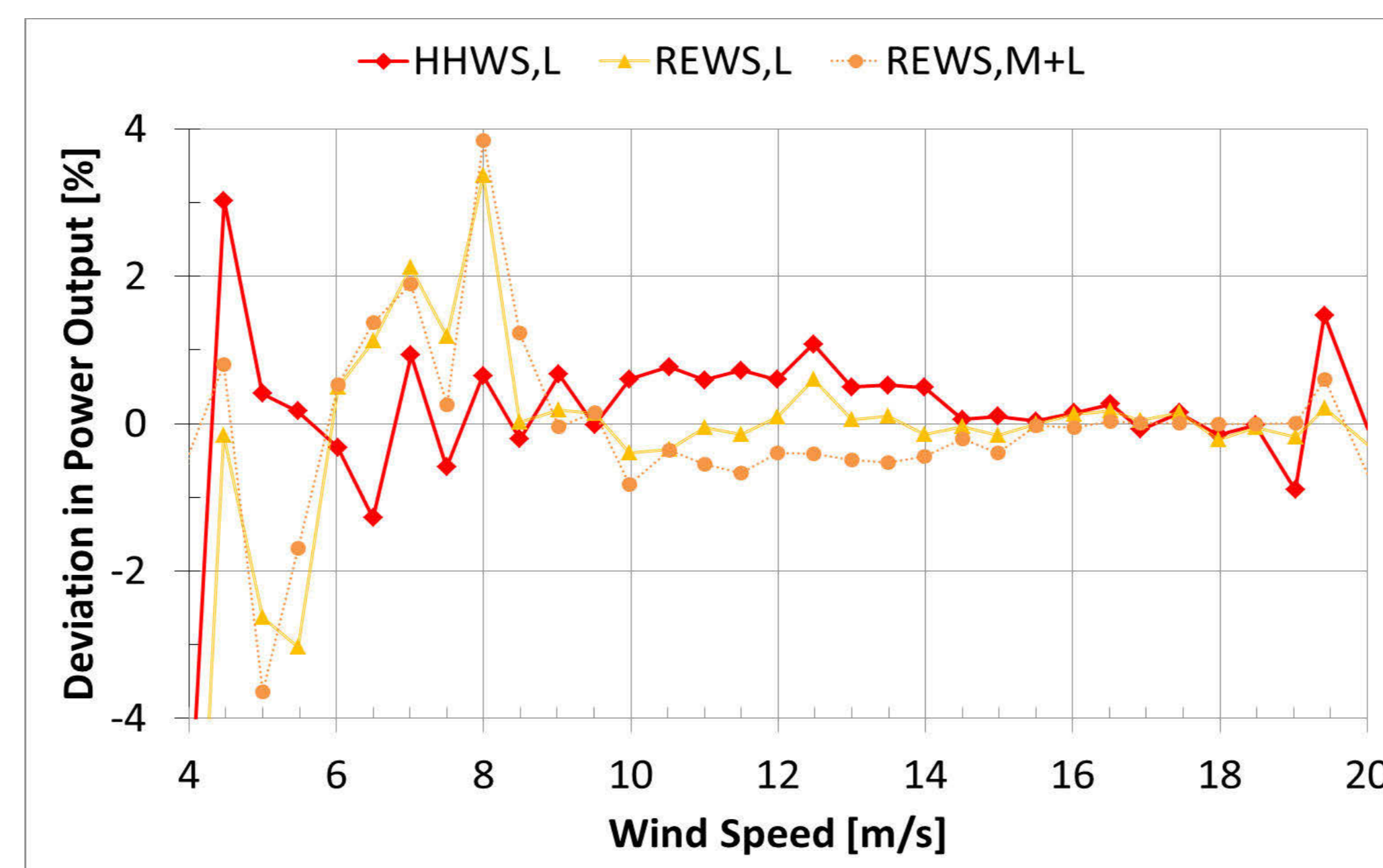


Fig. 1: Deviations in bin averaged power for different WSDs. Results are given relative to the power curve with HHWS,M.

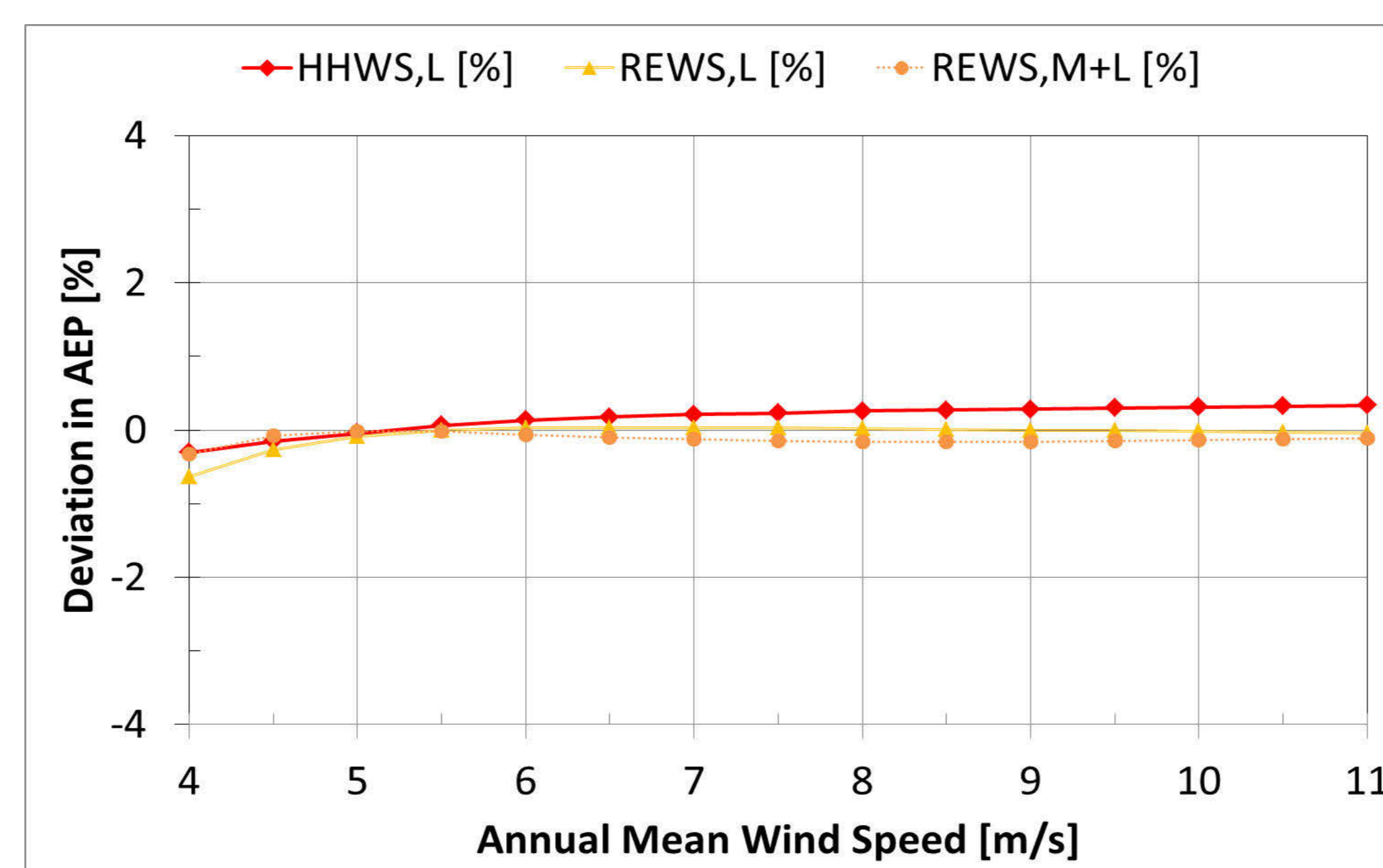


Fig. 2: Deviations in AEP measured for different WSDs. Results are given relative to the power curve with HHWS,M.

Measurement Example

Deutsch WindGuard (DWG) performed several power curve measurements, where both a hub height met mast and a Leosphere Windcube LiDAR have simultaneously measured wind parameters during a power curve measurement. For one example the differences between the different WSDs are shown relative to the HHWS,M in Fig. 1 and 2.

For these examples the uncertainty budget was calculated according to both Edition 1 [2] and the upcoming Edition 2 [1]. Comparisons of the resulting uncertainties are shown in Fig. 3 and Fig. 4.

References

1. Draft CDV IEC 61400-12-1, Ed. 2, July 2015
2. IEC 61400-12-1, Ed.1, December 2005

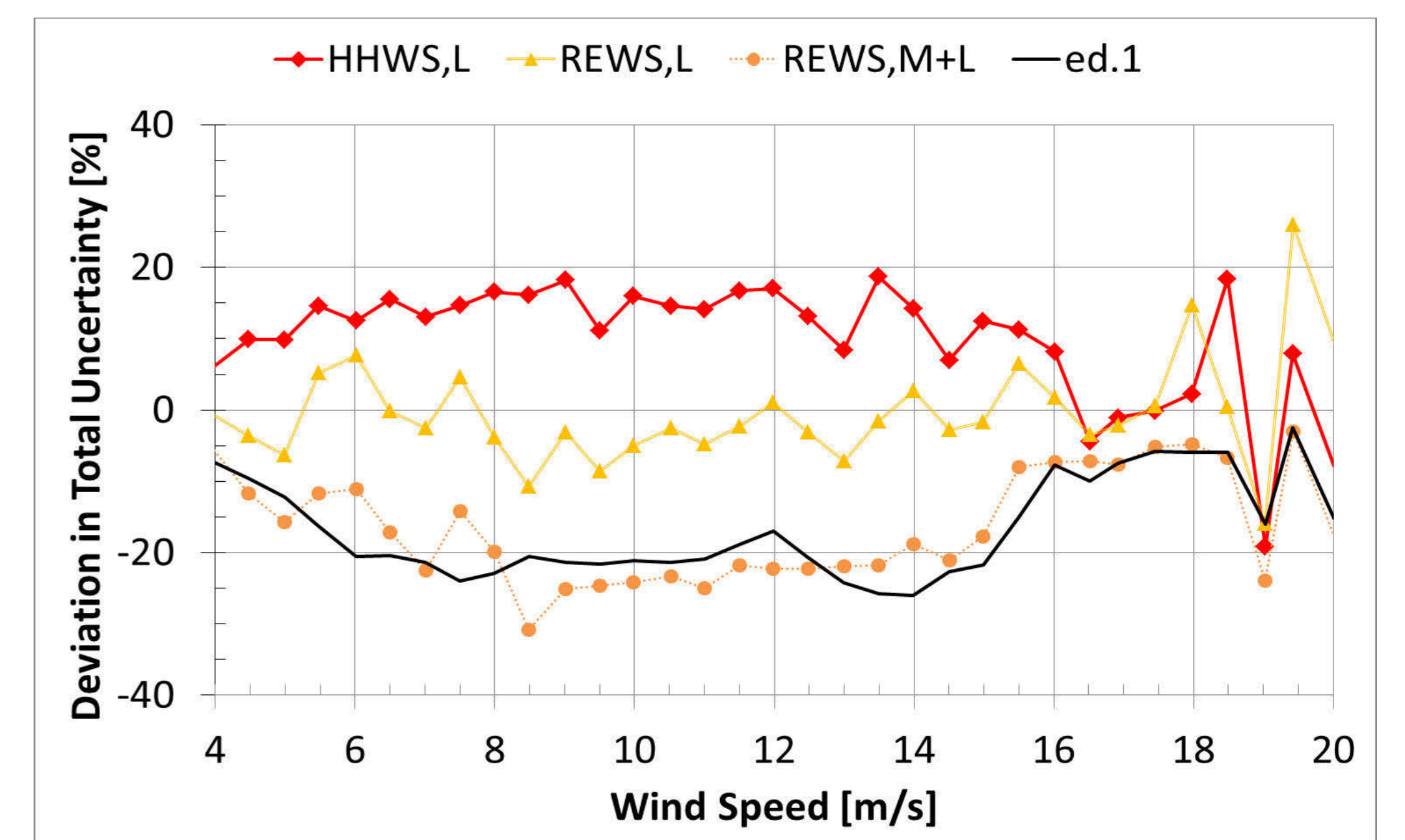


Fig. 3: Deviations in total power curve uncertainty for different WSDs. Results are given relative to the uncertainty with HHWS,M according to the upcoming standard [1].

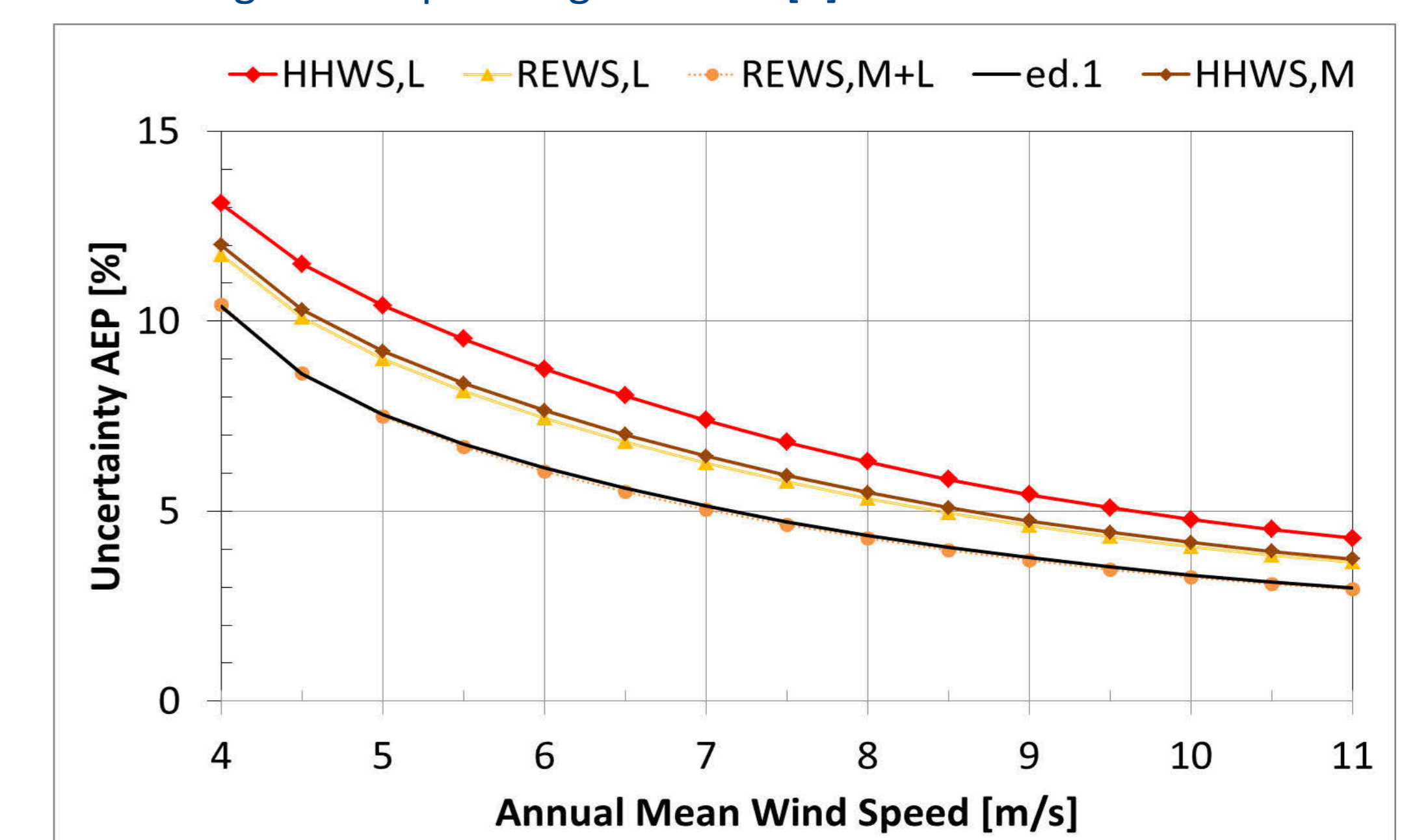


Fig. 4: Relative uncertainty in AEP for different WSDs. Results are given relative to corresponding AEP-measured.

Conclusions

Comprehensive uncertainty analysis according to the upcoming revision of the EC 61400-12-1 [1] were performed. Due to a more sophisticated analysis with the new standard higher uncertainties can be expected for hub height met mast power curves. However, in a combination with a LiDAR assessing the vertical profile, uncertainties at a level as currently applied can be achieved.

