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SUMMARY

This report gives the results of the EU financed study WINDFARMpertception on how residents perceive a wind farm in their living environment as far as sound and sight are concerned. The study includes a postal survey among Dutch residents (n = 725, response rate: 37%) and an assessment of their aural and visual exposure due to wind farms in their vicinity.

Respondents in the survey and calculated exposures
The study group was selected from all residents in the Netherlands within 2.5 km from a wind turbine. As the study aimed to study modern wind farms, wind turbines were selected with an electric capacity of 500 kW or more and one or more turbines within 500 m from the first. Excluded were wind turbines that were erected or replaced in the year preceding the survey. Residents lived in the countryside with or without a busy road close to the turbine(s), or in built-up areas (villages, towns). Excluded were residents in mixed and industrial areas.

The sound level at the residents' dwellings was calculated according to the international ISO standard for sound propagation, the almost identical Dutch legal model and a simple (non spectral) calculation model. The indicative sound level used was the sound level when the wind turbines operate at 8 m/s in daytime -that is: at high, but not maximum power. The size of the turbines was calculated as the viewing angle between the lowest and highest part of the biggest turbine, and also as the fraction of space above the horizon occupied by all wind turbines, both from the perspective of residents' dwellings.

Respondents were exposed to levels of wind turbine sound between 24 and 54 dBA and wind turbines at distances from 17 m to 2.1 km. The (angular) height of the biggest wind turbine ranged from 2 degrees to 79 degrees, with an average value of 10 degrees (the height of a CD box, looking at the front at arm's length). The wind turbines occupied on average 2% of the space above the horizon.

Attitude and economic involvement of respondents
Almost all respondents (92%) were satisfied with their living environment, though many reported changes for the better and changes for the worst. One in two respondents were (very) positive towards wind turbines in general, but only one in five were (very) positive towards their impact on the landscape scenery.

Fourteen percent of the repondents had economic benefits from wind turbines by owning them or having shares in wind turbines or otherwise. They usually lived closer to the wind turbines, were higher educated, less old and hence healthier compared to the other respondents, and they relatively often worked at home. Respondents with economical benefits were less negative to wind turbines in general and their influence on the landscape scenery.

Response to wind turbine sound
The percentage of respondents noticing the sound of wind turbines increased with increasing sound level, ranging from 25% at low sound levels (less than 30 dBA) to 80% and more at higher sound levels (above 35 dBA). Percentages were the same for those who had benefits and the other respondents.
The percentage of respondents that were annoyed by the sound also increased with sound level up to 40 to 45 dBA and then decreased. Respondents with economic benefits reported almost no annoyance. This in part explains the decrease in annoyance at high sound levels: above 45 dBA, *i.e.* close to wind turbines, the majority of respondents have economical benefits. The percentage of respondents without economic benefits that were rather or very annoyed when outdoors increased from 2% at low levels of wind turbine sound (less than 30 dBA) up to 25% at levels of 40 to 45 dBA.

In general respondents perceived wind turbines as being louder in wind blowing from the turbine to their dwelling (and less loud the other way round), in stronger wind and at night. The majority (75%) of respondents that could hear wind turbines think that swishing or lashing is a correct characterization of the sound. The second most typical characterization was rustling (for 25% of the respondents). Other characterizations were chosen by less than 10% of the respondents.

Respondents were more likely to be annoyed by sound from wind turbines when they noted changes for the worse in their living environment and when they had a more negative view on wind turbines in general or their impact on the landscape scenery.

Health effects
There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45 dBA) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or *vice versa* or whether both are related to another factor.

Response to other aspects of wind turbines
Respondents were also annoyed by wind turbines in other ways than by sound: between 4% and 13% were rather or very annoyed by vibrations or the movement of rotor blades or their shadows in- or outdoors.

One out of three respondents could not see a wind turbine from their dwelling, especially when living in a built-up area or further away from the turbines. The visibility of wind turbines strongly affected the probability of being annoyed by their sound: when turbines were visible, respondents were far more likely to be annoyed. An unexpected result was that respondents living in a rural area with a main road within 500 m from the wind turbine(s) were less annoyed than respondents living in a built-up area, though the background sound levels from road traffic are on average the same in both area types and one would expect that wind turbines are more readily visible in a rural area.

Recommendations
In this survey sound was the most annoying aspect of wind turbines. From this and previous studies it appears that sound from wind turbines is relatively annoying: at the same sound level it causes more annoyance than sound from air or road traffic. A swishing character is observed by three out of four respondents that can hear the sound and could be one of the factors explaining the annoyance. Sound is therefore an important and negative feature of wind farms and we recommend that, in the planning of wind farms, the negative impact of the sound and sound reduction should be given more attention.

Nevertheless, people that have economical benefits from wind turbines are much less or not at all annoyed, even though they often live closer to wind farms and are exposed to higher sound levels. This lack of annoyance may be the result of several factors: *e.g.* the 'benefitters' have a more positive view on wind farms, they have an actual benefit and they have a measure of control on the turbines. These characteristics may show the way to more acceptance and less annoyance with other residents: residents may be given some benefits and a sense of control too. Discussion of the different views on the landscape, instead of opposition to other views, may help in reaching consensus.

Visibility of wind turbines enhances their potential to cause noise annoyance. When wind turbines are invisible, they cause less annoyance. Perhaps less visibility can also be the result of reducing the visual contrast between turbines and landscape. The possibilities to do this will depend on the landscape type.

The capability of busy road traffic to mask the sound of wind turbines is apparently not straightforward: a higher level of background sound from road traffic indeed reduces the probability of noticing the sound of wind turbines, but it does not have an effect on annoyance from the wind turbines. This may be due to differences between both sounds in pitch, in character (swishing) and in diurnal variation. This issue needs further investigation.