inter.noise
HAMBURG 2016

WINDMILL NOISE ANNOYANCE, VISUAL AESTHETICS, AND ATTITUDES TOWARDS RENEWABLE ENERGY SOURCES

Ronny KLÆBOE[1]; Hanne Beate SUNDFØR[2]
Institute of Transport Economics, Oslo, Norway

ABSTRACT

A small focused socio-acoustic after-study was undertaken in the autumn of 2015 after local health officials demanded a health impact study to look into neighbor noise complaints. The Lista Windmill Park consists of 31 turbines and is located in the South of Norway affecting 179 properties. Simple exposure effect-relationships indicate stronger reactions to windmills and windmill noise than shown internationally, with the caveat that the sample size is small (n=90) and responses are colored by a conflict situation. Pulsating swishing sounds and turbine engine hum are the main causes of noise annoyance. About 60 per cent of those who participated in the survey were of the opinion that windmills degraded the landscape aesthetically, and are not convinced that land- based windmills are desirable as a renewable energy source in Norway. The results suggest that attitudes play an important role in addition to visual aesthetics in determining the acceptance of windmills and resulting noise annoyance.

Keywords: Human reactions, Wind Farms, Noise sensitivity. I-INCE: 63.2,63.4

1. INTRODUCTION

Lista wind farm was put into operation in 2012. It consists of 31 windmill turbines, with 179 properties within a 2 km radius from the closest turbine. Norwegian land areas zoning restrictions are imposed on areas exposed to an evening and night time equivalent noise level (Lden) of 45 dBA and above. The limit for windmill noise is thus 10 dBA stricter than for road traffic noise, which is Lden 55 dBA.

After the establishment of the wind farm, the residents complained about the noise from the wind turbines, and how persistent and bothersome the noise turned out to be. A socio-acoustic study was required by the local health authority to look into possible causes for local noise complaints.

2. METHOD

2.1 Sample

The study population was defined as all residents 18 years or older living closer than 2 km from the nearest wind turbine. The population was extracted by a three stage process. All 179 properties within 2 km were extracted from the national property register. About 40% of the properties are used part of the year, whereas 60% are used the whole year. Information on all 240 identified owners of these properties were thereafter obtained from municipality ownership records. The survey in the autumn of 2015 was voluntary. The response rate was 38 per cent, as expected for this type of survey. Since the population was small, every member of the household were given the opportunity to answer. Only a few respondents made use of this opportunity.

To check whether the respondents closest to the wind mills had a higher response rate than those living more distant, noise calculations were obtained the whole study population. There was a lower response rate from respondents least exposed to wind mill noise, see Figure 1. Simple bar charts and cross-tables not controlling for noise exposure will be affected. Note that not only wind mill noise exposure but demographics and other factors may differ with distance from the wind mill park.

[1] rk@toi.no
[2] hbs@toi.no

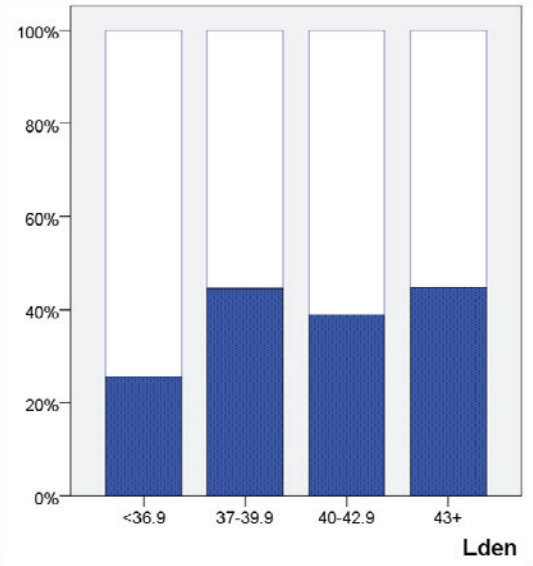

Figure 1 – Response rate (dark) as a function of noise exposure (four intervals). Lista 2015.

.

2.2 Questionnaire

The questionnaire was introduced as a study of the living environment. Given the local conflict and community awareness of a pending survey, the introduction fails to mask the "real" purpose of the survey. However, framing the survey as a general survey of living quality avoids some of the focusing effects of a narrow focus. (Given the scarcity of other significant exposures this rural area, it is possibly less effective than when conducting socio-acoustic surveys in urban areas).

The questionnaire contains sections on the living environment, health, annoyances, non-acoustic modifiers such as visual aesthetics, attitudes, and noise sensitivity. Most of the attitudes were measured using a five-point Likert-scales where the respondents signify how strongly the agree or disagree with a given statement.

2.3 Noise annoyance questions and noise sensitivity

We use a slightly modified version of the ISO technical standard for socio-acoustic surveys (1). The modification is that we allow for" *not relevant"* – and distinguish between noise annoyance when right outdoors and right indoors.

"*When thinking about the last 12 months, how annoyed are you by noise from windmills when you are inside your own dwelling?*

"*When thinking about the last 12 months, how annoyed are you by noise from windmills when you are right outside of your own dwelling*?

A five-point response scale was used: "*Extremely annoyed, Very annoyed, Moderately annoyed, Slightly annoyed, Not annoyed. - Not relevant*)". The response category "*Not relevant*" was merged with" Not annoyed" after ensuring that the respondent was part of the survey population

We use a single question on how sensitive the respondents are towards noise. The response categories are *"very", "partly", "not" and "don't know"*. The latter category was merged with not sensitive.

2.4 Noise calculations and measurements

The noise calculations where undertaken using CADNA See http://www.datakustik.com/. In separate project the calculated values were controlled with a measurement regime (2). Since the noise measurements, resulted in estimates that were not significantly different from the calculated values (+/-1 dBA), we used the calculated values.

Daytime is in Norwegian regulations counted as 06:00 to 18:00, the evening period from 18:00-22:00 and night time 22:00 to 06:00. The evening and night weighting adds 6.4 dBA. A windmill turbine noise exposure of $L_{Aeq,1h}$=38.6 each hour of the diurnal cycle, will thus just satisfy the 45 dBA limit.

2.5 Exposure-effect modelling

Ordinal logit models (3-5) were used to estimate exposure-effect relationships between noise exposure (L_{den}) and annoyance responses. They belong to the same class of models as grouped regression models (6). SPSS version 22 was used for the estimation of all models.

To control for noise sensitivity, the indicator was added as an ordinal modifying variable to models for annoyance when outside and inside dwelling as a function of noise exposure. Since there were more noise sensitive persons in the second highest noise exposure interval, we estimated exposure-effect relationships given a homogenous spread of noise sensitivity using the sample distribution. To check for the importance of visual aesthetics (7) a dummy for whether the respondent considered that they were unsightly was constructed. To check the importance of attitudes towards renewables, a dummy variable was constructed signifying respondents who did not agree that Norway should prioritize hydro power.

3. RESULTS

Many respondents are unhappy with the establishment of the wind farm. Nearly 60% think the wind mills are unsightly. Nearly half of the respondents regard the wind mills as a danger to wild life, and about half report that they become irritated from hearing the wind mills, see Figure 2.

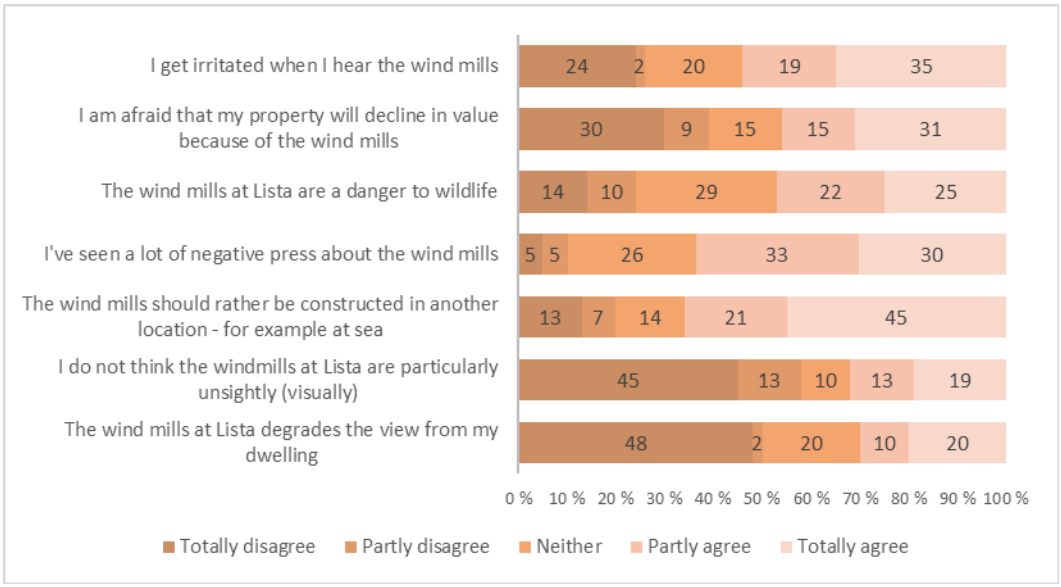

Figure 2 – Respondents who agree or disagree to a set of prepared opinion statements.

Half of the respondents report that the view from their dwelling is degraded by wind mills The local press has contained a number of articles in opposition to the windmills and about 63 agree that there has been a lot of negative media.

3.1 Noise sensitivity and exposure—effect relationships

Noise sensitivity is usually not correlated with noise exposure and is considered a personal trait with genetic components (8). However, given the small sample size, it is not unexpected that the noise sensitivity distribution is not the same in each exposure interval. Aa higher proportion of the respondents are noise sensitive at higher exposure levels See Figure 3. Since noise sensitivity is usually treated as an individual trait, we need to control for noise sensitivity to show how the exposure—effect relationships would look like for a population where the sensitivity distribution is not skewed.

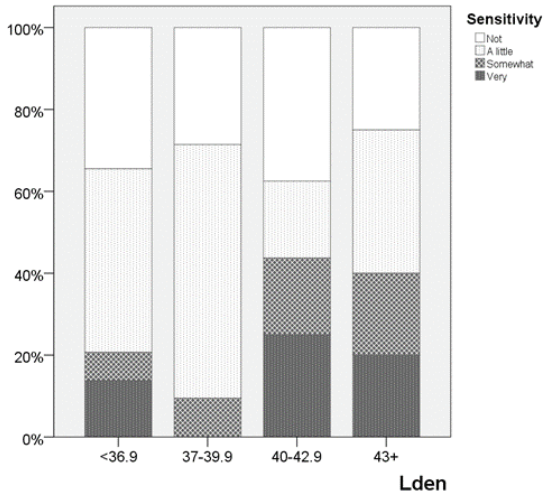

Figure 3 – Noise sensitivity distribution within each exposure interval. Lista 2015

We have consequently estimated exposure effect relationships with and without control for noise sensitivity. Since the sensitivity distribution of the target population is not known, we use the sample sensitivity distribution for estimating the curves.

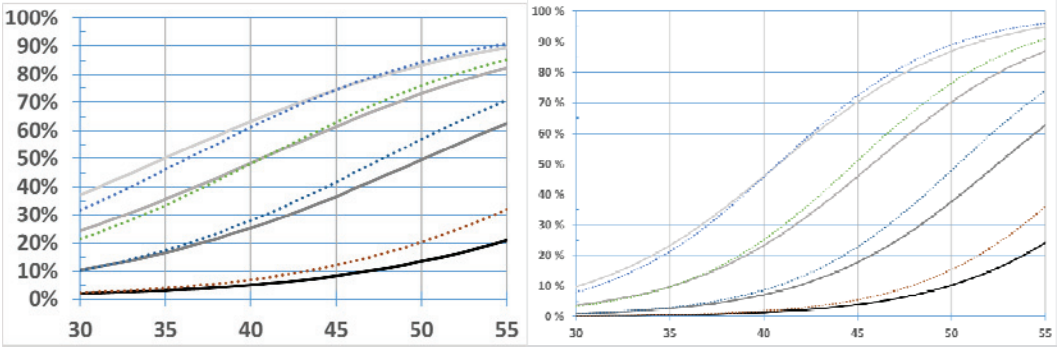

Figure 4 – Exposure—effect relationships for wind mill noise annoyance right outside dwelling, and when indoors. Areas between dividing lines are from the top: *Not-annoyed/Not relevant, slightly, moderately, very and extremely annoyed*. Curves before correction for noise sensitivity are dotted. N=87. Lista 2015

For comparison purposes: About 21 per cent of the population in Norway are extremely and very annoyed by road traffic noise at 55 dBA (9). For wind mill noise it can be seen that this level of annoyance is reached at L_{den} 37 dBA, see Figure 9, Numerically this is 18 dBA lower than for road traffic noise and 8 dB lower than the current zone limit (45 dBA.)

3.2 Aesthetics and attitudes as modifying factors

Respondents who report that they consider windmills a visual blight (in general or at Lista in particular) are significantly more annoyed. The effect is substantial and in size equivalent to 11 dBA (1.548/.136) See table 1. More than half of the respondents are of the opinion that windmills are detrimental to the visual landscape.

Of those who are amenable to the visual aesthetics, the exposure effect relationships are similar (after correcting for number of scale points) to Janssen et al. (10) summarizing Swedish and Dutch exposure—effect relationship. In Norway 60% of the energy is from renewables, mainly hydro power. Persons who did not agree to the statement that Norway should prioritize hydro power, are less affected – comparable to a 10 dBA noise reduction.

Table 1 Parameter estimates for windmill noise as a function of Lden and whether windmills are unsightly (visually degrade the landscape) (Left panel) and whether the respondent agrees that Norway should prioritize Hydro Power (right panel)

Parameter Estimates

		Estimate	Std. Error	Wald	df	S
Threshold	[wmno = 1]	4.457	1.382	10.398	1	
	[wmno = 2]	5.049	1.405	12.914	1	
	[wmno = 3]	6.020	1.444	17.380	1	
	[wmno = 4]	7.759	1.523	25.943	1	
Location	lden	.136	.036	14.245	1	
	[vis_degrading=0]	-1.548	.494	9.820	1	
	[vis_degrading=1]	0[a]	.	.	0	

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.
Threshold	[wmno = 1]	4.907	1.419	11.961	1	.001
	[wmno = 2]	5.487	1.443	14.462	1	.000
	[wmno = 3]	6.437	1.483	18.842	1	.000
	[wmno = 4]	8.168	1.563	27.321	1	.000
Location	lden	.145	.037	15.264	1	.000
	[ProH=,00]	-1.445	.512	7.975	1	.005
	[ProH=1,00]	0[a]	.	.	0	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

4. CONCLUSIONS

Noise from will mills at Lista 2015 is considered 17-18 dBA worse than road traffic noise - if we take the results at face value and disregard the large impact on annoyance from non-acoustic factors. This is within the range of 11-26 reported by Michaud & al. (11).

Our results clearly show that noise annoyance in the Lista study depends strongly on non-acoustic factors. Visual aesthetic factors play a large role as well as attitudes towards wind mill as an alternative to hydro power. Such factors may be relatively more important when noise exposure is low. To compare different studies and extract the partial impacts of noise exposures it could be advantageous to also standardize questions on non-acoustic factors.

ACKNOWLEDGEMENTS

REFERENCES

1. ISO. Acoustics-Assessment of noise annoyance by means of social and socio-acoustic surveys. ISO/TS 15666:2003(E). Geneva, Switzerland: ISO; 2003.
2. Nord R, Szilvay P. Lista Vindkraftverk i Farsund kommune - Støymålinger. Sweco, 2014.
3. Klaeboe R, Turunen-Rise IH, Harvik L, Madshus C. Vibration in dwellings from road and rail traffic - Part II: exposure-effect relationships based on ordinal logit and logistic regression models. Appl Acoust. 2003;64(1):89-109.
4. Agresti A. Categorical Data Analysis. New York: John Wiley & Sons; 1990.
5. McCullagh P, Nelder JA. Generalized Linear Models. Monographs on Statistics and Applied Probability, 2edn, Chapman and Hall, London. 1989;37.
6. Miedema HME, Oudshoorn CGM. Annoyance from transportation noise: Relationships with exposure metrics DNL and DENL and their confidence intervals. Environ Health Perspect. 2001;109(4):409-16.
7. Pedersen E, Larsman P. The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines. J Environ Psychol. 2008;28(4):379-89.
8. Heinonen-Guzejev M, Vuorinen HS, Mussalo-Rauhamaa H, Heikkila K, Koskenvuo M, Kaprio J. Genetic component of noise sensitivity. Twin Research and Human Genetics. 2005;8(3):245-9.
9. Amundsen AH, Aasvang GM, Klaeboe R. Long-term effects of façade sound insulation on noise annoyance and sleep disturbances In: Patrício J, Pérez-López A, editors. 39th International Congress on Noise Control Engineering -- Internoise 2010; June 13 -16, 2010; Lisbon. Lisbon, Portugal: Portuguese and Spanish Acoustical Societies; 2010. p. Paper 672.
10. Janssen SA, Vos H, Eisses AR, Pedersen E. A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources. The Journal of the Acoustical Society of America. 2011;130(6):3746-53.
11. Michaud DS, Keith SE, Feder K, Voicescu SA, Marro L, Than J, et al. Personal and situational variables associated with wind turbine noise annoyance. The Journal of the Acoustical Society of America. 2016;139(3):1455-66.