TORONTO STAFF REPORT

November 18, 1999

To: Works Committee

From: Barry H. Gutteridge, Commissioner, Works and Emergency Services

Subject: Windmills and Noise Issues in Urban Areas
(All wards)

Purpose:

To address questions regarding the potential of windmills to cause noise and recommend standard separation distances and procedures to be followed in respect to noise issues when siting windmills in Toronto.

Financial Implications and Impact Statement:

There are no financial implications to the City of Toronto resulting from this report.

Recommendations:

It is recommended that:

(1) That City Council adopts as its approved practice to reduce noise impacts, the use of

(a) a 200 metres separation between windmills and residential low-rise dwellings;

(b) a 300 metres separation between windmills and high-rise residential buildings; and

(c) a 50 metres separation between windmills and sensitive natural areas or sensitive park use areas;

unless lesser distances can be demonstrated to be similarly appropriate in keeping with the spirit and assumptions of this report.

(2) That Council require noise impact assessment statements regarding specific siting proposals for windmills on City lands.

(3) That City Council require noise compliance monitoring to be undertaken following the installation of windmills.

Background:

The Works Committee in adopting my report entitled "Approval Process for the Siting of Waterfront Windmills" (September 23, 1999) also requested that I report back to the Committee "on noise levels produced by commonly used wind turbines". This report addresses that request.

The issue is that wind turbines are perceived as being noisy and can not be appropriately located within, or in close proximity to, residential areas, parks or natural areas. This report presents noise levels associated with typically sized wind turbines (660 kW) as have been proposed by Toronto Hydro and TREC for installation on City lands, evaluates the use of commonly employed separation distances around the world, and recommends standards for use within Toronto in respect to residential and park areas (including natural areas).

Comments:

Windmills, also known as wind turbines, generate sounds. Unwanted sound can be defined as noise. Impacts and their perceived significance vary and depend on the level of intensity, frequency, frequency distribution and the pattern of the noise source; ambient or background noise levels; terrain between emitter and receptor; and the nature of the noise receptors.

The effects of noise on people can be classified into three simple categories:

the subjective effects of annoyance, nuisance, dissatisfaction;

the interference with activities such as speech, sleep or learning; and

physiological effects, ie direct health effects, such as anxiety, tinnitus, or hearing loss.

The sound levels associated with environmental noise generally, including wind turbines specifically, produce potential effects that can normally only occur in the first two categories. Workers in industrial plants and around aircraft can experience noise effects in the last category.

The siting of wind turbines is largely a land use and neighbourhood compatibility problem. It is important that the City recognize the potential problem and address it appropriately. The City should ensure that sound levels as may be created by wind turbines are not intrusive at the nearest residential dwellings, or in any nearby sensitive municipal and public spaces, such as sensitive natural areas or sensitive park use areas. The amount of disturbance associated with a noise source depends on a number of factors. These factors include the nature of the sound source, the level and type of ambient noise, and the distance of the recipient from the source.

More specifically, the evaluation of any potentially intrusive sound level involves an assessment of:

noise source levels and type (including frequency, time pattern and intensity);

recipient area ambient noise levels, including location relative to other uses (e.g. roads), land use type (e.g. residential or industrial) and other environmental factors (e.g. topography and wind regime);

noise decay with distance, shielding and attenuation; and

noise channelling with topography and its passage or "bouncing" over large water areas or other hard surfaces.

Specific noise levels are usually "estimated" as an alternative to monitoring which would require a considerable time sequence to capture all the possible permutations among different wind speeds, wind directions, air density, precipitation, air stability, and air temperature. Sound meters can not be operated under very windy conditions. Wind turbines, however, are more likely to be perceived as intrusive under calm rather than stormy conditions.

A noise impact statement, as is generally required by the City of Toronto in the context of a development proposal review, typically addresses the above in respect to particular sources or developments from three perspectives:

what is the impact of the source on the environment?

what is the impact of the environment on the source? and

what is the impact of the source on the source?

Municipal Standards:

Wind turbine siting related local land use planning standards attempt to deal with the complexity of noise in specific local situations but commonly do so with cautionary prudence. Such cautionary prudence can be helpful in establishing site selection "rules-of-thumb" to guide rough site selection ground rules, while still allowing for variations on the basis of more complete information. As such, simple rule of thumb criteria are often based on "distance from" criteria whereas more detailed assessment are based on "noise received at" criteria. Evidence suggests that it is noise levels at potentially impacted dwellings rather than distance from wind turbines that should drive final siting and planning decisions.

For example, local government requirements in nine California Counties show a variety of wind turbine related standards that have been adopted in respect to noise. All but one County establishes a maximum permitted dB(A) level. These vary from "not to exceed 65 dB(A)", to "not to exceed 45 dB(A) for more than 5 minutes in any hour or to exceed 50 dB(A) for any

period within 50 feet of a home, school, church, hospital or public library". The ninth county establishes a simple requirement of "not closer than 1000 feet in an upwind direction from any dwelling, nor closer than 300 feet in any other direction".

An equivalently simple, and prudently cautious, guideline of "not-closer-than 300 metres" has been adopted in Great Britain by the British Wind Energy Association in respect to residential dwellings. The standard reflects the normally rural and hilly siting of wind turbines in Britain.

Indeed, most wind turbines have been located in rural areas and siting separation standards reflect this. But, rural areas are typically quieter than urban areas, and the distances may be more cautionary than is necessary. Knowledge of noise transmission, attenuation and channelling characteristics, and logic suggests that simple distance standards may be over cautionary in low-density urban areas of high ambient noise, but under protective in denser urban areas composed of high rise developments. This relates to noise attenuation in low-density urban and suburban areas provided largely by trees and other ground cover, and the bouncing and mixing effect of sound waves from wind turbine hub sources from higher elevations, in high density areas.

Perceptions:

Perceptions are often historically based rather than currently supported. This is seemingly also the case for wind turbines. Early wind turbines in Europe were often promoted as inaudible. They were not. But neither did they create noise levels "equivalent to that of a helicopter at take-off", as was suggested in the European press. However, much of the presently accepted perception of noise levels is based on early installations in Europe.

Those that were built two decades or so ago, as in Wales (U.K.), generated considerable local antagonism that was focused in perceptions of noise impacts. Today, the older technologies have been updated and current state of the art installations generate substantially lower sound levels. Recent direct drive turbine developments are purported to be more efficient and almost inaudible as they do not have gearboxes. However, the noise and vibration associated with standard wind turbines should not be regarded as insignificant and appropriate safeguards need to be taken.

Technical Appendix

The attached appendix provides technical information used directly in support of the conclusions reached in developing this report. It includes discussion of windmills as a source of various sound types, typical ambient sound pressure levels (i.e. noise levels) experienced in residential areas (from quiet suburban to very noisy urban), and sound level decay with distance.

Noise and Windmill Siting in Toronto

Given that the quietest "quiet suburban" residential ambient noise level according to the US-EPA is approximately 45 dB(A) and the quietest experienced (as measured by City staff) residential ambient level in Toronto is typified as approximately 45dB(A), and given that manufacturers

measurements indicate that this is normally achieved at a distance of 200 to 250 metres, a policy of prudent avoidance would suggest 250 metres separation between a wind turbine and a residential dwelling. However, within the wind related waterfront areas indicated under other siting criteria adopted by Toronto Hydro and TREC the ambient noise level in the vicinity of residences is typically higher, and a prudent value of 200 metres would not be inappropriate

In high rise dwelling areas, noise will be less likely to be attenuated in all cases. Wind turbine hub noise could travel directly from point source at 50 metres elevation to apartments at the same elevation with significantly less attenuation. Therefore, a logical and reasonable rule of thumb would be to ensure as part of an initial scoping exercise to separate wind turbines from residential property by a buffer separation of 200 metres for low rise dwellings and by 300 metres for high rise dwellings.

For open spaces and park spaces a buffer separation would also seem prudent but there is no precedent for this either in respect of human or ecological functions. A range of functions is fulfilled within parks. These vary from the active sports activities (e.g. as on soccer pitches or baseball diamonds) that may be more tolerant of noise, to the more sensitive use areas in parks that provide solitude (e.g. as in ornamental gardens or along nature trails), where noise is more likely to be an issue of concern.

Urban park areas that offer "quiet solitude" are not noise free. The same ambient urban noise level ranges will be measurable in such spaces as in residential areas even though the perception may be that such space is noise free. No standard sound level or separation distance has been identified in respect to sensitive natural areas or sensitive park use areas and noise sources.

As a surrogate standard the Province of Ontario's standards regarding noise in "Outdoor Living Areas" [as provided in "Noise Assessment in Land Use Planning: Requirements, Procedures and Implementation" (MOE, May 1997)] can be examined. In simple terms, the standard suggests that for road noise sources no control measures are required if the day time sound level is less than or equal to 55dB(A), and for rail noise sources no control measures are needed if day time sound levels (outside bedroom windows) are less than or equal to 60 dB(A). If sensitive park use areas and outdoor living places are equated as equal to "outdoor living areas" the standard of 55dB(A) can be recommended. For wind turbines this translates to a separation distance "rule-of-thumb", based on a normalized wind speed of 28.8 km/h (8m/s) at 10 metres above the ground surface, for turbines equivalent to the Tacke TW 600, of 53dB(A) at 50 metres, and of 56 dB(A) at 25 metres. To best ensure prudent compliance with the outdoor living standard of 55dB(A) a distance of 50 metres separation between sensitive natural park areas and sensitive park use areas and the siting of a wind turbine appears sufficient.

Noise Impact Statements

Prior to final site selection and approval, the wind turbine proponents should undertake a noise impact statement, subject to the satisfaction of City Council, if the selected site is within 250 metres of a low-rise dwelling or within 350 metres of a high rise dwelling. The noise impact statement need not address the impact on the environment on the wind turbine, or the effect of

the wind turbine on itself, as no office or dwelling space is to be included (this would not hold true if a wind turbine were to be sited on top of a building), and need only address the impact of the wind turbine on the environment external to the wind turbine. Further, the noise impact statement should also address the site specifics of impacts on nearby park uses within 50 metres distance.

Post-Installation Monitoring and Compliance

Wherever a wind turbine is installed, it would be prudent at that time to ensure its compliance with noise standards through appropriate monitoring and analysis. This could be made a condition of a lease arrangement should a wind turbine be sited on City land. Any subsequent complaint resulting from mechanical deterioration or blade damage, that renders the wind turbine noisier than at the time of installation, should be investigated under the City's Noise By-law and appropriate action enforced where necessary.

Conclusions:

Though seldom established in dense urban areas, there is no apparent reason to exclude modern wind turbines, based on noise issues provided that reasonable separation distances are adhered to or amended on a site-specific basis.

A separation of 200 metres from low rise residential and 300 metres from high rise residential buildings appears to be prudently adequate. A separation of 50 metres from sensitive park use areas also seems prudent.

Any final site selection should provide a Noise Impact Statement to the satisfaction of the Commissioner of Works and Emergency Services prior to final site approval in keeping with the spirit of this report. Further, post construction monitoring should establish a base line of actual on site noise data from source to nearest receptors to confirm compliance with the Noise Impact Statement and to offer a benchmark against any future adverse change of the sound level caused by equipment deterioration.

Staff representing the Commissioners of the Economic Development Tourism and Culture Services Department and the Urban Planning and Development Services Department were consulted in preparing this report.

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List of Attachments:

Technical Appendix

CM/cm

TECHNICAL APPENDIX

Sound Source Levels:

Sounds created by wind turbines come from several sources which result in several sound types including: broadband noise from the blades; tonal noises from fans, generators, pumps and gearboxes; infrasonic noise due to tower shadow; and impulsive noises from brake clamping/release, limit stops and general creaks. Wind turbines create noise from within the outer casing, or nacelle, that houses the turbine generator and the bearings that link to the rotating blades. The noise levels immediately outside the nacelle are considerably less than the levels inside. These are seldom measured. The point source noise level measurements are typically provided as a manufacturer's specification derived from factory floor testing within 1 metre of the equipment rather than noise levels on the outside of the nacelle casing.

The source-noise pressure level inside a turbine nacelle of a 600 kW wind turbine, varies with the wind speed at hub height and blade rotation speed but is typically between 95 dB(A) and 100 dB(A) for wind speeds in their normal operating range between 14.4 km/h (4 m/s) and 36 km/h (10 m/s). A 600 kW Tacke wind turbine has been installed by Ontario Power Generation at Tiverton near the Bruce Nuclear Power Station and is similar in size to those being considered for use in Toronto by TREC and Toronto Hydro. The Tacke 600 installation has a technical noise-source specification of 98.6 dB(A). Wind speed varies naturally but blade rotation speed is artificially held constant, as on the Tacke 600 at either 18 rpm or 27 rpm through breaking devices that create different noise levels in consequence of different breaking requirements. Changes of rotation speed, including the extremes of starting and stopping, typically create additional noise.

There is also noise created by the rotation of the blades themselves. The noise varies with the speed of rotation and blade design. The leading edge of the blade is of considerable importance. Current leading edge technology is attempting to duplicate the design of the leading edge of an owl's feathered wing (owls as hunters benefit from their "silent wings") on the leading edge of a turbine blade. However, the noise of the blades alone is typically a barely audible "swoosh" (as detected at 50 metres from turbine base) as a blade passes in front of the tower. This obviously varies as the nacelle and blades are designed to operate in upwind or downwind directions.

Noise levels also vary with the number of wind turbines installed. Obviously, "wind farms" comprised of many wind turbine units are noisier than single turbine installations**.**

Ambient Noise Levels:

Ambient, or background, noise levels vary by land use in general and by other specific site factors in particular. Residential and rural areas are more sensitive to noise intrusions because of their relatively low ambient noise level.

The US Environmental Protection Agency and other sources have developed dB(A) ranges for a variety of common noise sources and typical residential locations.

RESIDENTIAL DESCRIPTION	TYPICAL SOUND PRESSURE LEVEL dB(A)
Quiet Suburban	45 – 52
Normal Suburban	53 – 57
Urban	58 – 62
Noisy Urban	63 – 67
Very Noisy Urban	68 – 72

Experience has shown that typical residential values in Toronto run the gamut from quiet suburban equivalent to very noisy urban equivalent and vary from 45dB(A) to 75dB(A).

A further complication is that quantitative sound pressure level measurements may not reflect everyone's qualitative assessment. For example, one person's "deafening" may be another's "silence" (For example, "deafening" complaints, when field investigated by City staff some times, don't even register on the City's sound meters.)

Distance Decay:

In essence, sound pressure levels diminish with distance from a point source at a rate of approximately 3 dB(A) for every doubling of the distance from the point source. The accuracy of the first distance and noise measurement is critical if this assumption is going to be relied upon to predict noise decay from a point source. As noted above, manufacturers' specifications are typically equivalent to levels inside the nacelle not immediately outside or beyond. Certain inherent dangers are associated with taking measurements one or two metres beyond the nacelle at operating height except under the calmest of conditions, but that is when the turbine does not normally operate as wind speed is too low (i.e. less than 4 m/s). Consequently, few (if any) point source measurements external to the nacelle are available.

However, manufacture's measurements of ground level noise levels, averaged for different wind speeds and taken in downwind directions, as for installations of a Vestas V47 turbine and a Tacke 600 turbine reveal some interesting similarities and implications. The data has been normalized for a wind speed of 8 m/s (28.8 km/hr) and a height of 10 metres above ground (weather station wind anemometer readings are normally taken at this height).

DISTANCE FROM TURBINE	VESTAS V47 (660 kW) – NOISE LEVELS dB(A)	TACKE TW 600 (600 kW) – NOISE LEVELS dB(A)
@ 100 m		49.9
@ 200 m	46.5	44.3
@ 250 m	44.4	
@ 300 m	42.7	39.0
@ 400 m		35.6
@ 500 m	37.4	

Cm/cm