

# Annual International Conference on Mechanical Engineering

August 7-8, 2025  
Oxford, United Kingdom



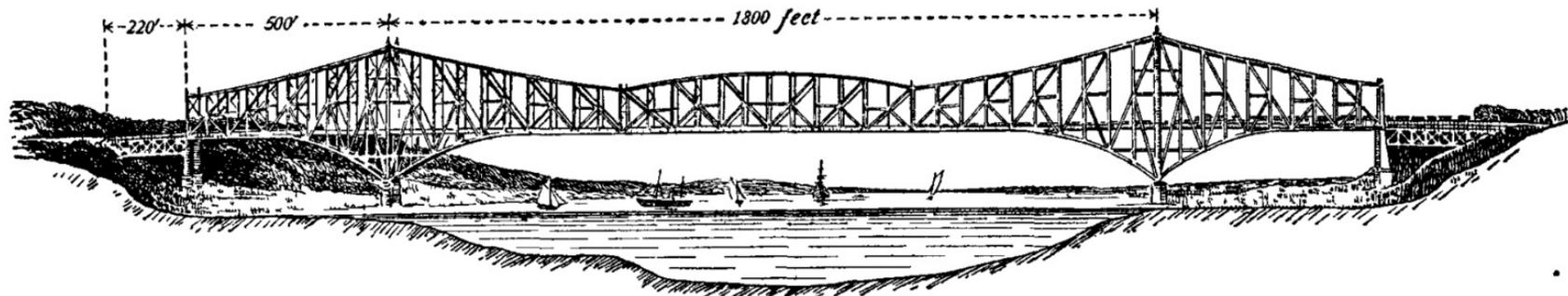
Thanks for attending this presentation – what will we cover

# Thanks for listening

As an engineer,  
you have a special relationship  
with “risk”

There will be time for discussion  
and your questions at the end

## Why do engineers have this special relationship? – A Canadian example



This was what the Quebec bridge was to look like – from design drawing of 1907

It was to be an Engineering wonder – the longest bridge of it's kind in the world – longer even than the Firth of Forth bridge at Edinburgh

## The Quebec bridge – what can happen if we ignore facts of risk.



Sadly – this is what the bridge looked like on August 29, 1907

- Three times, beginning 23 days before, a young engineer had reported structural problems on the construction project, but the Chief Engineer continued the work. 75 of the 86 workers on the bridge died on the day the bridge collapsed.

Then, after clearing the debris, when raising a new centre span on Sept. 11, 1916, the lift failed, and 13 more workers died.



Since 1937 the Ontario Professional Engineers Act has identified the legal obligation of Professional Engineers to protect public safety. The Act notes this responsibility is paramount, even above duties to clients or employers.

Most Canadian Engineers wear an iron ring – as a reminder of the Quebec bridge disaster, and that our work impacts people. We need to deal with errors that can happen – not ignore them.

## The Preamble – “risk” – there are many definitions

*Risk Assessment, Theory, Methods, and Applications*, by Rausand, M, and Haugen, S. (2020) John Wiley & Sons, quotes risk researcher Stan Kaplan, that failing a common definition of “risk” each author should explain the way “risk” will be used.

This presentation follows the approach of Rausand and Haugen, noting “risk” is the combined answer to three questions:

- Q1 – What can go wrong? (identify the accident scenarios)
- Q2 – What is the likelihood of it happening? (consider all accident scenarios)
- Q3 – What are the consequences? (consider protective barriers)

Often, “risk” is simplified as:  $RISK = FREQUENCY \times CONSEQUENCES$

**Q1. What can go wrong? (actually what has gone wrong with Ontario wind turbines)**

| Date    | What went Wrong? / Turbine Type | Turbine age at Failure |
|---------|---------------------------------|------------------------|
| 2007-04 | Blade failure / GE 1.5 sle      | 0.9 years              |
| 2008-01 | Blade failure / GE 1.5 sle      | 2.1 years              |
| 2013-04 | Fire / Vestas V80               | 7 years                |
| 2015-08 | Blade failure / GE 1.62         | 0.5 years              |
| 2017-04 | Blade failure / GE 1.62         | 3 years                |
| 2018-01 | Tower collapse / GE 1.62        | 7 years                |
| 2018-05 | Blade failure / Vestas V80      | 15.4 years             |
| 2019-04 | Blade failure / Senvion MM92    | 1.3 years              |
| 2021-06 | Blade failure / Vestas V100     | 6.9 years              |
| 2021-08 | Tower collapse / GE 1.62        | 6 years                |
| 2024-06 | Fire / Vestas V80               | 18.2 years             |
| 2024-06 | Fire / Siemens Gamesa 2 MW      | 11.4 years             |
| 2025-03 | Hub Collapse / GE 1.5 sle       | 18.8 years             |

| By Year End | Turbines In Service |
|-------------|---------------------|
| 2005        | 10                  |
| 2010        | 808                 |
| 2015        | 2297                |
| 2020        | 2679                |
| 2025        | 2712                |

Q1: What can go wrong? Fire - 2024-06 Vestas V80 Turbine - Kingsbridge Array

Photos courtesy Scott Miller, CTV News



**Q1: Another example - What can go wrong? Collapse - GE 1.62 turbine - Bow Lake Array**



Tower collapse – 2021-08

Photo courtesy  
Saultonline.com

50 ton nacelle ~ 80m from  
tower base

**Q1: Again - What can go wrong? - Blade failure.**

**Huron Wind Vestas V80  
Wind Turbine Blade Failure  
May 4, 2018**

Estimated environmental conditions at time of failure - from Environment Canada  
Warton Airport Monitoring Site

Wind speed at 10m above ground 14 to 15 m/s, gusting to 17 to 24 m/s



Debris at 560m from tower - 1 m x 0.15m



Debris photography and placement on Google Map of site by William Palmer, P. Eng.

Note - debris positioning as accurate as possible, but size is not to scale due to limitations of graphics program - refer to photographs for actual debris dimensions.



Debris at 150m from tower - 1.2m x 3.6m  
- Note Binoculars placed on debris for Scale



Debris at 170m from tower - 1m x 3.6m



Debris at 210m from tower - 1.2m x 3.0m

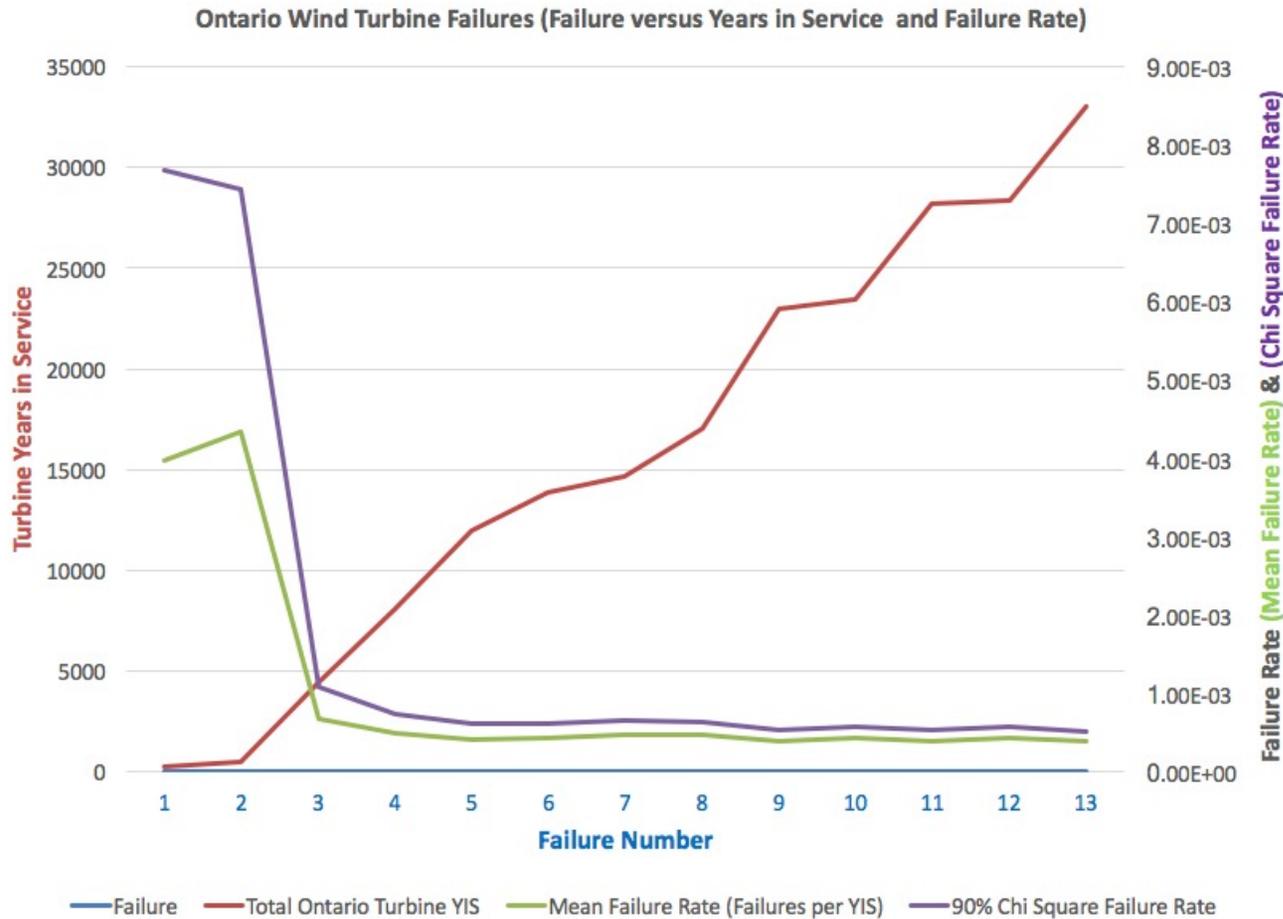


Debris at 280m from tower - 1.2m x 3.0 m  
- Note Boot at bottom left corner for Scale



Emergency road closure Conc 4 due to hazard  
May 4, 2018 - ongoing - looking westerly

## Q2. Likelihood of a known accident happening?



Mean failure rate for  
Components > 1  
metre in size landing  
outside protected  
area of blade length  
+ 10 metres

~ 0.5 x 10E-03  
failures per turbine  
YIS

### Q3: What are the consequences if an accident occurs? (are they limited by protective barriers?)

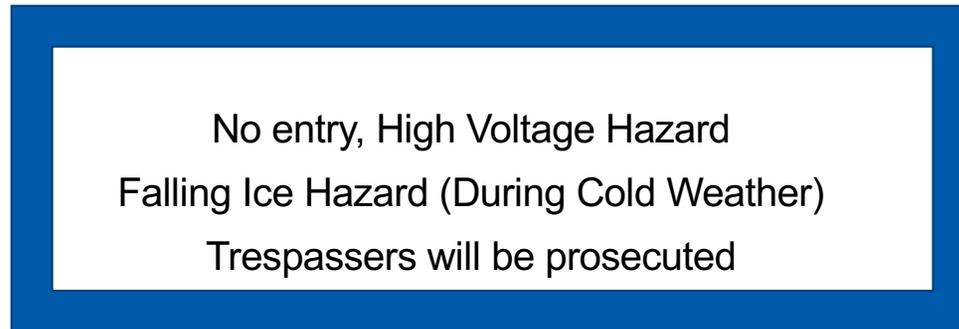
Regulators of other energy systems possibly impacting public safety (e.g. Canadian Nuclear Safety Commission or U.S. Nuclear Regulatory Commission) require both:

- Deterministic safety analysis
  - Demonstrate defence in depth limits consequences to public (and workers) in the event of failure
  - Show effective safety barriers exist to protect against all known accidents
  - (e.g.) For a wind turbine blade failure, is there a sufficient barrier (such as distance) to protect the public from adverse consequences?
- Probabilistic safety assessment
  - Demonstrate no initiating event or contributor to failure consequences causes a disproportionately large or significantly uncertain contribution to safety
  - (e.g.) For wind turbines, does lack of fire suppression make contribution to safety uncertain?
  - (or e.g.) Does height restrict fire suppression, or safe exit of staff from fire?

### Q3: Are the protective regulations for known wind turbine accidents effective to limit consequences?

Ontario regulations “protect” the public from wind turbine accidents by an exclusion zone equal to blade length plus 10 metres (the “protective” fence line seen on the Huron Wind failure slide)

Turbine that failed 2018-05 shown previously has 1.2 metre high fence 52 metres from turbine with sign



Yet, following 2018-05 blade failure, blade segments were found and photographed:

- 1.2m x 3.6m, 150m from tower
- 1.0m x 3.6m, 170m from tower
- 1.2m x 3.0m, 210m from tower
- 1.2m x 3.0m, 280m from tower
- 1.0m x 0.15m, 560m from tower

### Q3: Are consequences limited by regulations (continuing)

Photos of the 2021-08 tower collapse at Bow Lake show the 50 ton nacelle on the ground,  
> blade length + 10 metres from the base

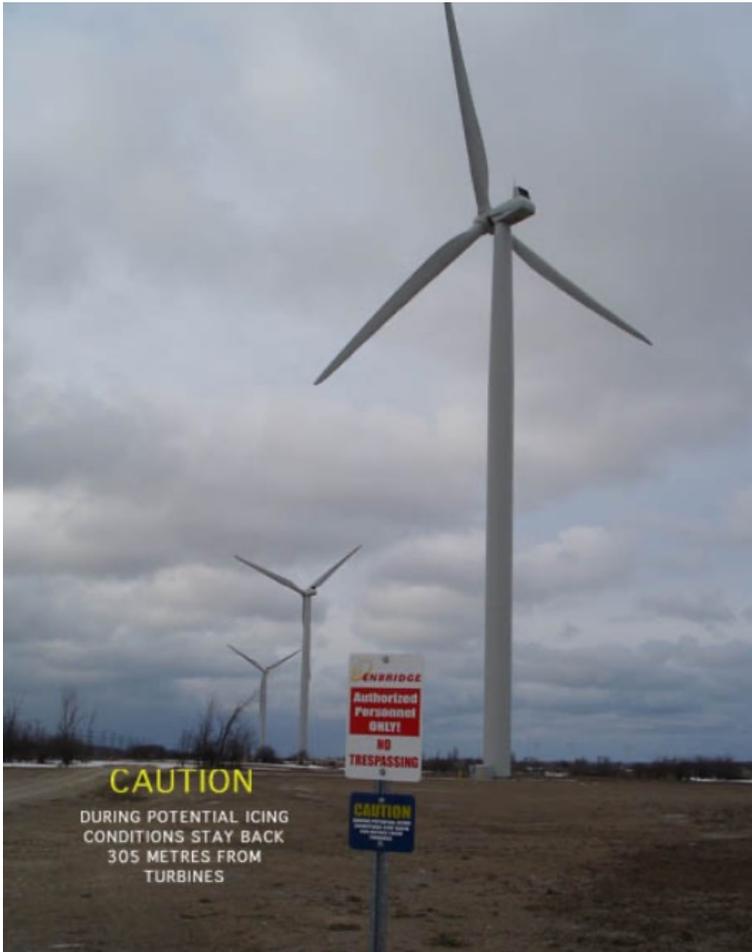
After the 2013-04 wind turbine fire at the Kingsbridge array, wind facility staff reported burning debris hit ground 200 m from tower

~ 4 x (blade length + 10m)

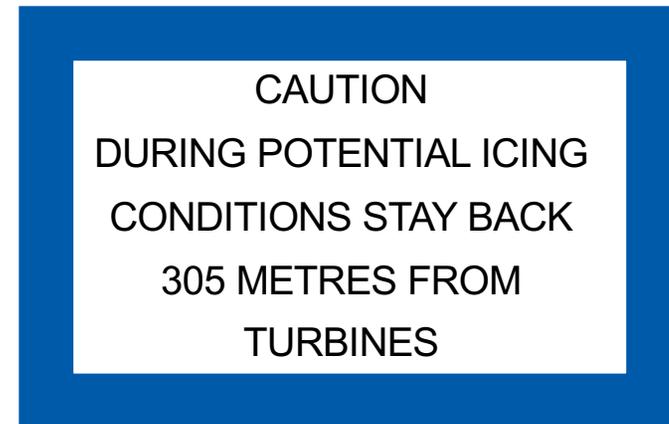
**It appears that blade length + 10 metre separation from neighbouring property may NOT be adequate to limit consequences from the acute wind turbine failures already observed in Ontario with a frequency of  $0.5 \times 10^{-3}$  events per turbine year.**

Ice falling from wind turbines, was not included in the analysis of acute wind turbine failures. Ice fall occurs frequently enough (e.g. often several times per year per turbine in Canada) to be considered as chronic, rather than acute.

**Q3: Are industry safeguards and cautions effective to limit consequences? Consider this case.**



- 20 cm x 25 cm sign at the edge of Provincial highway 21 reads



- While that sounds reasonable, is it effective to limit consequences?
- The sign is too small to be read from the road
- 7050 vehicles/day pass this point
- How do vehicles comply to stay 305 metres away from turbines, when the roadway right of way is 121 metres from the turbine?

### Q3: Consider consequences if they are not limited



Melancthon Wind Turbine Array – Jan. 19 case - credit Mr. Michael Pobjoy for photos of these GE 1.5 turbines  
Wind Turbines in Cold Climate report, and GE Wind suggest setback of  $1.5 \times (\text{Hub Height} + \text{Rotor Diameter})$

### Q3: Equivalency of falling ice from turbine = same as dropping 18 kg concrete block from 8<sup>th</sup> floor

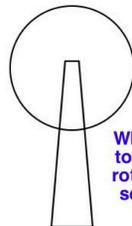
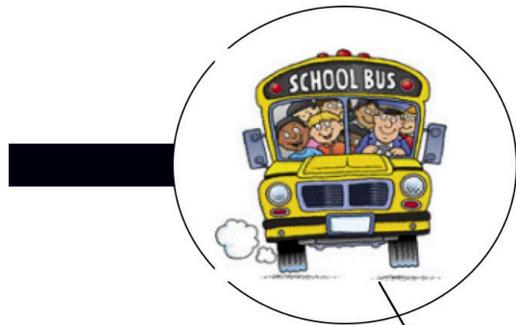
Simple drop energy calculations for distance:  
 $S = V_0t + \frac{1}{2}at^2$

and energy:  
 $K = \frac{1}{2}mv^2$

Shows ice 30 cm x 30 cm x 2 cm falling from turbine blades has same energy as dropping 18 kg concrete block from 8<sup>th</sup> floor

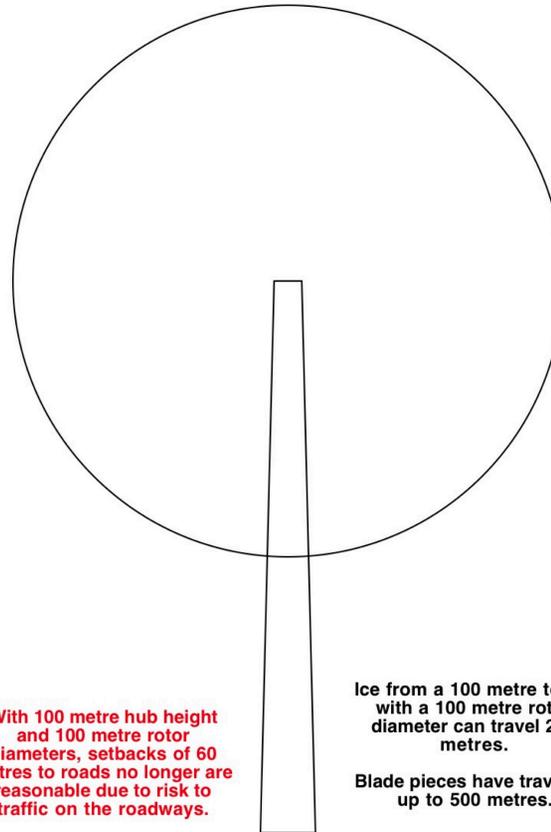
#### Let's Consider Risk from Wind Turbines to Ontario Roads (to scale)

Even magnified 10 times this School Bus is no match to a 100 metre turbine tower with a 100 metre rotor diameter.



When turbines had 30 m towers and 22 m rotor diameters in 1990, setbacks of 50 metres to roads were set

With 100 metre hub height and 100 metre rotor diameters, setbacks of 60 metres to roads no longer are reasonable due to risk to traffic on the roadways.



Ice from a 100 metre tower with a 100 metre rotor diameter can travel 225 metres.

Blade pieces have travelled up to 500 metres.

Scale sized School Bus on an Ontario highway at the approved highway setback of 60 m (blade length + 10 m)

Wind Turbine in Cold Climate report suggests setback of 1.5 x (Hub Height + Rotor Diameter) = 300 metre setback

5 x blade length + 10 metres

### Q3: Consider consequence of wind turbine accidents – from accident boundary cases

Upper boundary case: Turbine collapse placed 50 ton nacelle on ground at distance > blade length + 10 metres

- Even without medical assessment, a 50 ton nacelle falling from 80 metres hitting a human, would appear to have fatal consequences

Lower boundary case: Ice Drop – travels beyond blade length + 10 metres

- Falling ice of 30cm x 30cm x 2cm (~3 kg) from turbine blade , is equivalent to dropping 18 kg concrete block from 8<sup>th</sup> floor
- Again, even without medical assessment, would appear to have fatal consequences
- Heated blades do not mean no ice, only that ice falls off in bigger bits

At Right:  
Heated blades can  
shed even larger  
ice pieces >> 3 kg



## Back to Q1: What can go wrong – consider chronic scenarios associated with acoustic conditions

A presentation to the Grey Bruce Medical Officer of Health, and the Municipality of Kincardine (2012) by Crawford, C. documented “Health Impacts in Two Local Wind Projects” for 20 families. This presentation was referred at the Acoustical Society of America 165<sup>th</sup> Meeting (International Conference on Acoustics). Palmer, W., Wind turbine sound prediction - the consequence of getting it wrong, Proceedings of Meetings on Acoustics, Vol. 19, 040066 (2013), DOI: 10.1121/1.4800422.

A “Freedom of Information” request filed with the Ontario regulator by a citizens’ group, “Wind Concerns Ontario” showed that 5832 complaints about wind turbine “noise, vibration, and sound pressure” were filed with the Ontario regulator from 2006 to 2018. 595 complaints were filed in 2018 alone, indicating that the frequency of complaints was not diminishing appreciably, even with the installation of newer “quieter” wind turbine types.

Peer reviewed papers have been written documenting the cases of 67 families living in the vicinity of wind turbines. Krogh, C.M., McMurtry, R.Y., Johnson, Punch, J.L., Dumbrille, A., Alvez-Pereira, M., Hughes, D., Rogers, L., Rand, R., Gillis, L., (2024), Wind turbines: Vacated/abandoned homes study – Exploring research participants’ descriptions of observed effects on their pets, animals, and well water, *Environmental Disease* [9\(1\):p 1-12, Jan–Mar 2024](#). | DOI: 10.4103/ed.ed\_2\_23.

Over 100 citizens have met face to face with the author, each expressing words such as, “*Since the wind turbines were installed in the vicinity of our home, we just cannot stand it. Please, can’t you do something?*”

This presentation summarizes data gathered to understand these issues.

## Chronic scenarios – Step 1– Noise inside versus outside homes

Some reports were initially hard to comprehend.

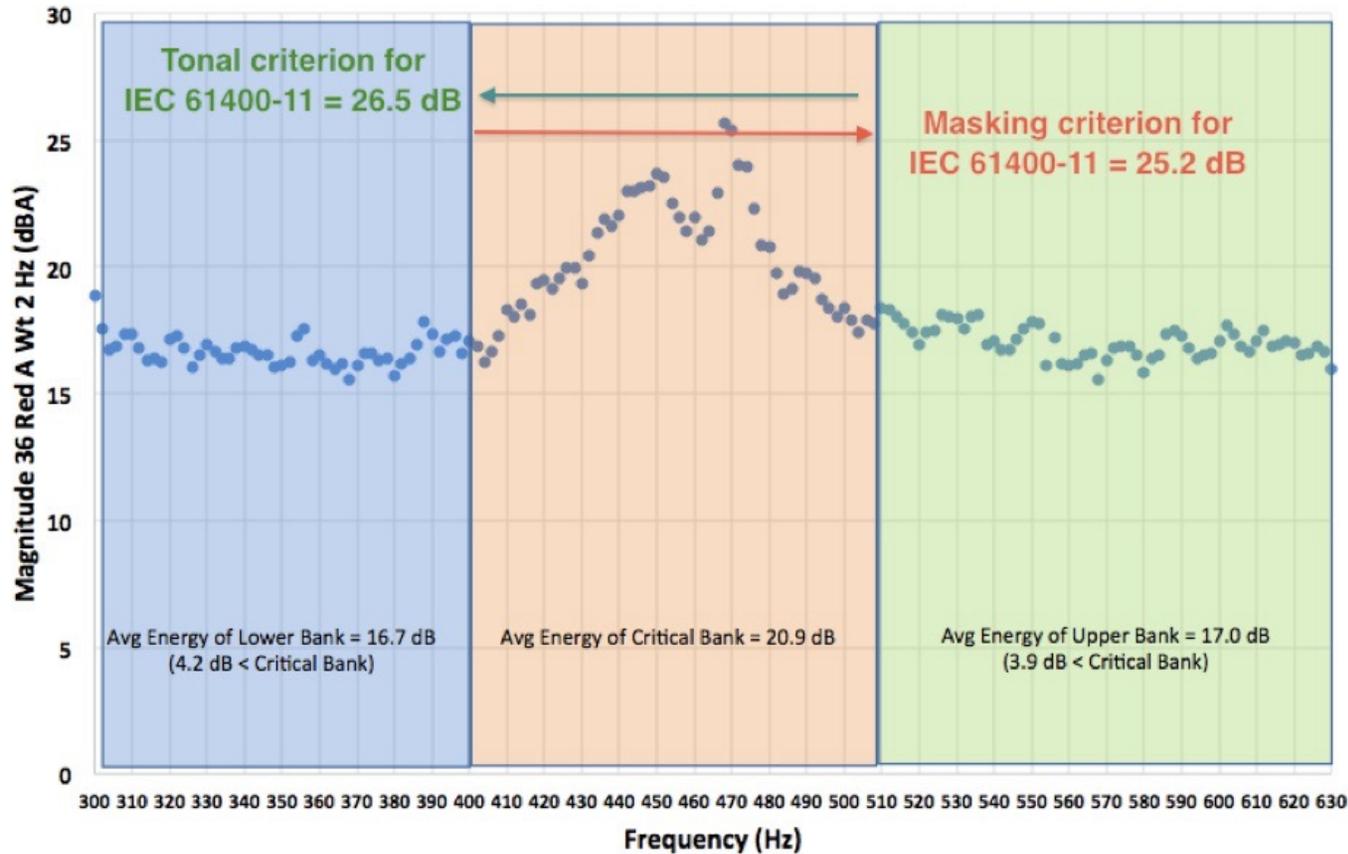
- One family reported that when noise within their home was untenable, they found some relief by sleeping in a tent, outside.
- This challenged the expectation that the home structure would attenuate sound more than a tent.
- Another resident reported that when unable to sleep due to noise from wind turbines, they found some relief by reversing sleeping position, with their head at the foot of the bed. Again, puzzling.
- To understand the reports data was gathered at various locations inside the second home, for many hours, with windows open or closed.
- The results were reported at the 168<sup>th</sup> meeting of the Acoustical Society of America, and subsequently documented, Palmer, W.K.G., *Why wind turbine sounds are annoying and why it matters*, *Global Environment, Health and Safety*, (2017), Vol. 1:2, p1-17.
- The investigation found that “room conditions” result in different acoustic conditions across a room. The centre of a room, near the foot of the bed, was lower in sound level than at the head of the bed, in the room corner. Inside the home, where mid and higher frequency sound is attenuated, the cyclical variation of low frequency became predominant.

## Chronic scenarios – Step 2 – tonal sound conditions from wind turbines

Extended monitoring campaign conducted in parallel with audit performed for regulator.

- Field visits by regulatory staff had confirmed that they could hear “tonality,” but the audit report submitted to the regulator for the wind farm operator stated the facility was not tonal.
- The data collection confirmed that “tonal-like” sound exists, meeting the ECMA 74/418 criterion for tonality which compares energy in a “critical bark” surrounding the tone, to the energy in the “upper” and “lower” bark.
- However, the data collection showed the sound usually met neither the International Electrotechnical Commission (IEC) technical standard 61400-11, nor the International Standards Organization / Publicly Available Specification (ISO/PAS) technical standard 20065 methods for determining tonality. They focus on the highest narrow band energy, relegating energy around that to background.
- Psychoacoustics – Facts and Models, (2<sup>nd</sup> Ed), Zwicker, E., Fastl, H., Springer (1999) (Now in 3<sup>rd</sup> Edition) identified that humans identify sounds falling in grouped energy bands together when assessing tonality. The “critical bark” for these turbines from about 400 Hz to 510 Hz would be assessed together as tonal.

**A case not meeting IEC 61400-11 (nor ISO/PAS 20065) for tonality but meeting ECMA 74 criteria  
(critical bark energy > upper or lower bark) by difference of ~ 4 dB)**

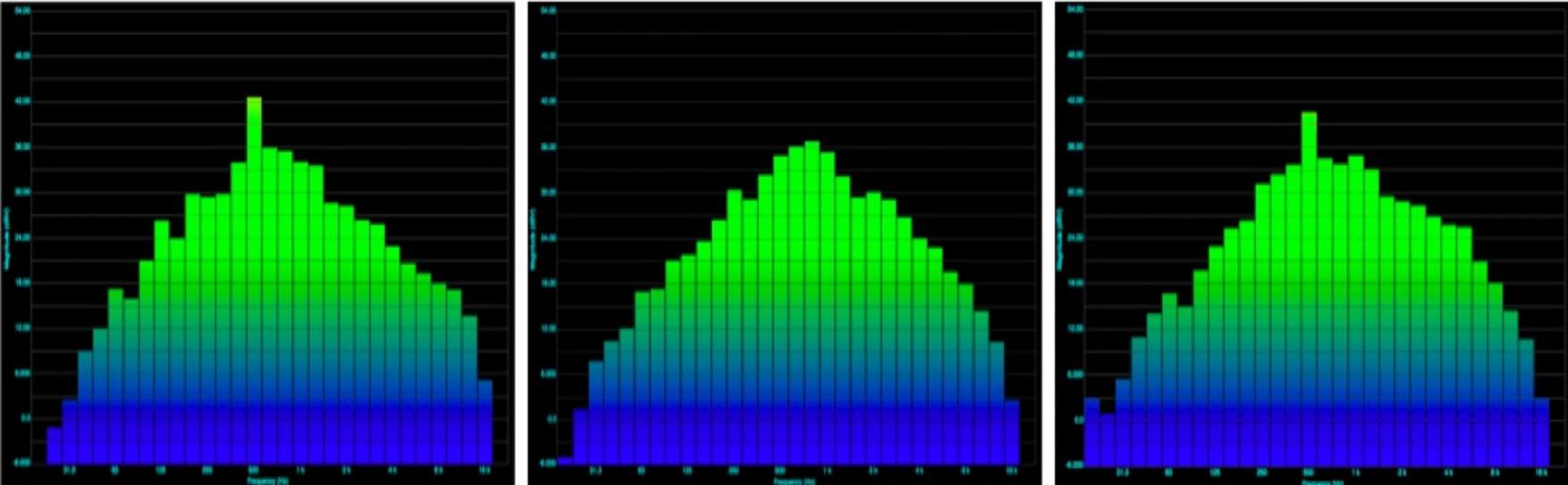


Zwicker & Fastl showed humans tend to group all energy in a “bark” together

Note dual frequency peaks, both in critical bark – and how energy in critical bark is > upper or lower barks

The critical bark is perceived as “tonal-like”

Example of variation in one-third octave – three plots separated by 1 second in time each



Test 63 - Red - 2018-03-16 13-30-13    Test 63 - Red - 2018-03-16 13-30-14    Test 63 - Red - 2018-03-16 13-30-15

Peaks varying ~ 6 dB in amplitude, and in frequency of peak, over short period, heighten perception

## What Step 2 – tonal investigation revealed

- There was high correlation between resident complaints of tonality, and “tonal-like” property of the sound. (as identified by Zwicker & Fastl)
- IEC or ISO/PAS methods to determine “tonality” miss this property of the sound.
- The “tonal-like” property actually increased when remedial action to reduce the output on these Siemens pitch regulated turbines was implemented.
- The “tonal-like” property was observed and recorded on a second wind power development a distance away, using the same turbine model.

### Step 3 – Ongoing investigation of chronic annoyance at a different wind power development

- Monitored at a home 537 m from nearest wind turbine, with 19 within 3 km – residents annoyed
- Amplitude modulation (AM) – (variation of sound up and down in amplitude) is widely considered to be indicative of annoyance
- The investigation looked for difference between L90 (low sound pressure level present 90% of the time - commonly considered background) and L10 (the higher sound level present less than 10% of the time) as an indication of amplitude modulation
- Sound was continuously recorded and analyzed for the times identified by residents as annoying
- Found high correlation between resident assessment as annoying and the condition **(LZ10-LZ90) ≥ 6 dBZ while (LA10-LA90) was ≤ 3 dBA**
- Tested criterion in two more phases
  - Analysed sound just before turbines shut down, just after shutdown, and just after restart
  - testing by simultaneous monitoring near turbines, and farther from them.

### Step 3 - Phase 1 - Testing the hypothesis – turbine shutdown and restart – a typical case on 2021-03-25

Before wind turbine shutdown, (LZ10-LZ90) = 11.3 dBZ, (LA10-LA90) = 3.0 dBA

- MET CRITERION for ANNOYANCE

Also {LA90 = 40.8 dBA}

20 minutes later, just after wind turbine shutdown, (LZ10-LZ90) = 3.2 dBZ, (LA10-LA90) = 6.2 dBA

- DID NOT MEET CRITERION FOR ANNOYANCE

Also {LA90 = 33.2 dBA}

In next hour, just after wind turbine restart, (LZ10-LZ90) = 9.3 dB, (LA10-LA90) = 1.6 dB

- MET CRITERION for ANNOYANCE

Also {LA90 = 36.6 dBA} – while still at low power

***Criterion Tested***  
***IF (LA10 – LA90) ≤ 3 dBA AND IF (LZ10 – LZ90) ≥ 6 dBZ***  
***Annoyance Can be Predicted***

## Phase 2 - Testing the hypothesis – simultaneous results near turbines and distant from turbines

- Second monitoring site chosen, (> 6 km from nearest turbine) but from which turbines at first site (537 metres from nearest turbine) were still visually seen – even though 10 km away.
- Both sites of similar environment, except for proximity of turbines.
  - Very similar terrain
  - Similar proximity to vegetation, roads
  - Similar wind speed and direction
- Simultaneous monitoring at both sites revealed:
  - Times identified by residents at first site correlated to annoyance criterion
  - No correlation to annoyance criterion at second site
- Confirmed that meeting annoyance criterion was NOT related to wind speed, but to proximity of wind turbines

### What Step 3 – What investigation of resident reported chronic annoyance revealed

- Found high correlation between resident reporting of annoyance and the criterion
  - $(LZ10-LZ90) \geq 6 \text{ dB}$  while  $(LZ10-LA90) \leq 3 \text{ dB}$
- Testing with nearest wind turbines “ON” / “OFF” / “ON” over short time interval showed criterion met with turbines “ON” but not met with turbines “OFF”
- Testing at site near wind turbines showed annoyance criterion met when reported by resident as annoying, and for 7 of 10 days in sampling period, for periods from 2 to > 12 hours per day. Chronic.
- Simultaneous testing at site distant from wind turbines showed annoyance criterion NOT met, even though wind speed, direction, and environmental conditions very similar.
- Turbines, not the wind, cause the annoyance criterion to be met.

## Conclusions: What this means to engineers

We must do better. Quebec bridge failure reminds us of the consequences of ignoring risk.

- Risk Criterion #1. Have known accidents or impact on health occurred?
  - Accidents have happened that could impact public safety.
  - Noise causing Annoyance exists.
- Risk Criterion #2. Is Frequency known of accidents or noise annoyance?
  - Accidents have happened, and continue to happen. Frequency of  $0.5 \times 10E-03$  seen, and continues.
  - Noise causing annoyance seen in 7 of 10 days of test period, from 2 to 12 hours per day. That is Chronic.
- Risk Criterion #3. Is protection provided by known barriers?
  - Fatalities could occur outside protective barriers
  - Annoyance is not ameliorated by standards
    - Tonal-like is known to be annoying but not found by standard used for regulation
    - Cyclical annoyance is not addressed by limitation of A-weighted noise

## Conclusion: A Path Forward – what needs to be done?

To fulfil engineering legal responsibility to protect public welfare from physical accidents:

- Physical accidents need boundaries to limit consequences
  - Deterministic analysis suggests needed barriers to protect from known events
    - Propose 280 metres for turbines up to 120 to 150 metres in height to avoid fatal consequences (Taller turbines will require greater distance separation)
    - Protection should apply to the most impacted individual, and population
  - Probabilistic assessment needed to identify significant contributors (e.g. fire)

To fulfil engineering legal responsibility to protect public from the acoustic properties of wind turbines that are known to cause annoyance (health impact):

- Need to avoid “tonal-like” conditions meeting ECMA 74/418 conditions of critical “bark” more than 4 dB above upper or lower “barks”
- Need to avoid significant cyclical variation detected by criterion (LZ10-LZ90)  $\geq 6$  dBZ, while (LA10-LA90)  $\leq 3$  dBA

Thanks for your attention

I invite your discussion  
and questions

William Palmer ([trileaem@bmts.com](mailto:trileaem@bmts.com))



**Mechanical Engineering**  
Annual International Conference

28 Speedwell St, Oxford OX1, UK  
Tel: +44 7824 523604  
[www.mechrtc.com](http://www.mechrtc.com)  
[info@mechrtc.com](mailto:info@mechrtc.com)