



Empa

Materials Science and Technology

Aktuelle Laboruntersuchungen an der Empa zur Lästigkeitswirkung von Windturbinenlärm

*Annoyance effects of wind turbine noise:
current laboratory studies at Empa*

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Empa, Abteilung Akustik / Lärminderung



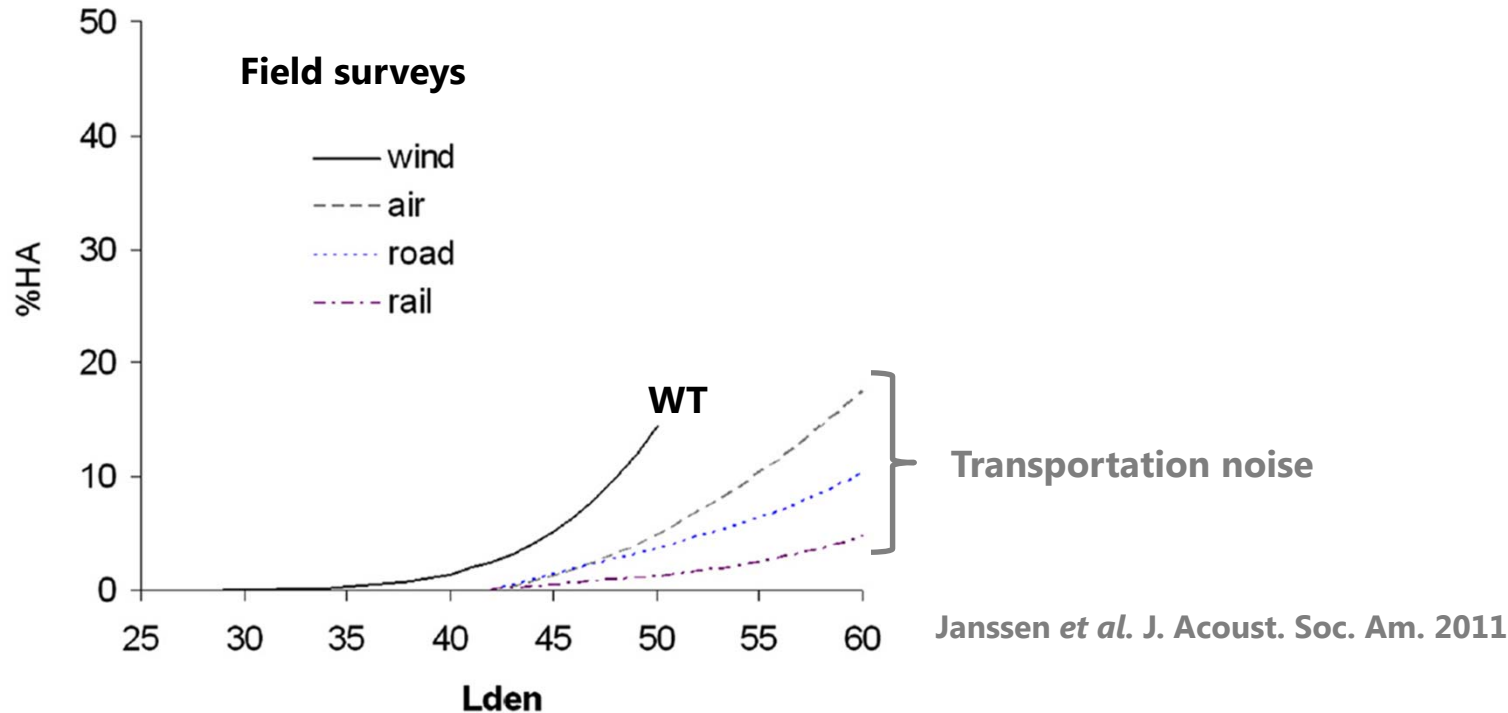
SGA Frühjahrstagung, St. Imier, 24. Mai 2018

Outline

- Background: WT noise annoyance
- VisASim
- Listening experiments – **WT noise annoyance**
 - 1. WT vs. road traffic noise**
 - 2. WT noise – audio-visual effects**
- Conclusions

Wind turbine noise annoyance

- WT noise annoying at low sound levels



- Field: confounders (e.g. visibility of WTs)
- Acoustical characteristics (alone, no confounders)?

➔ **Fully controlled laboratory experiments**

VisAsim



Co-workers: R. Pieren, K. Heutschi, K. Eggenschwiler, M. Manyoky, U. Wissen Hayek, A. Grêt-Regamey

Funding: 

- Tools for **Visual-acoustic simulation** of wind farms
- Joint project Empa and ETH, 2011–2014



- Full control of wind turbine sounds and visual sceneries

VisAsim

- Mountain landscape



- Hilly landscape



- Plain landscape



- **Applications:** demonstrator (instrument for communication); tool for spatial planning; assessment of noise control measures; **research** (listening experiments)

WT vs. road traffic noise

Objective: investigate and compare annoyance to WT and road traffic noise without confounding factors

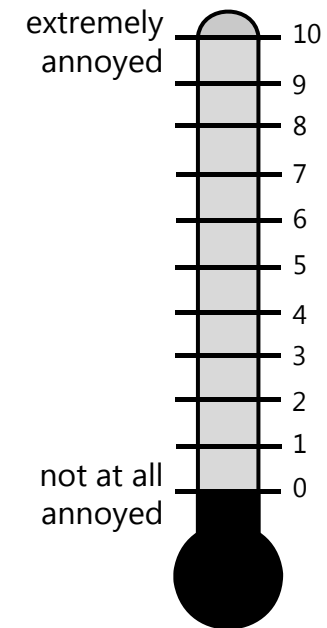
Schäffer *et al.* *J. Acoust. Soc. Am.* 2016
Eggenschwiler *et al.* *Lärmbekämpf.* 2016

Co-workers: B. Schäffer, R. Pieren, K. Heutschi,
S. J. Schlittmeier, M. Brink, J. Hellbrück, R. Graf

Funding:  Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Bundesamt für Umwelt BAFU

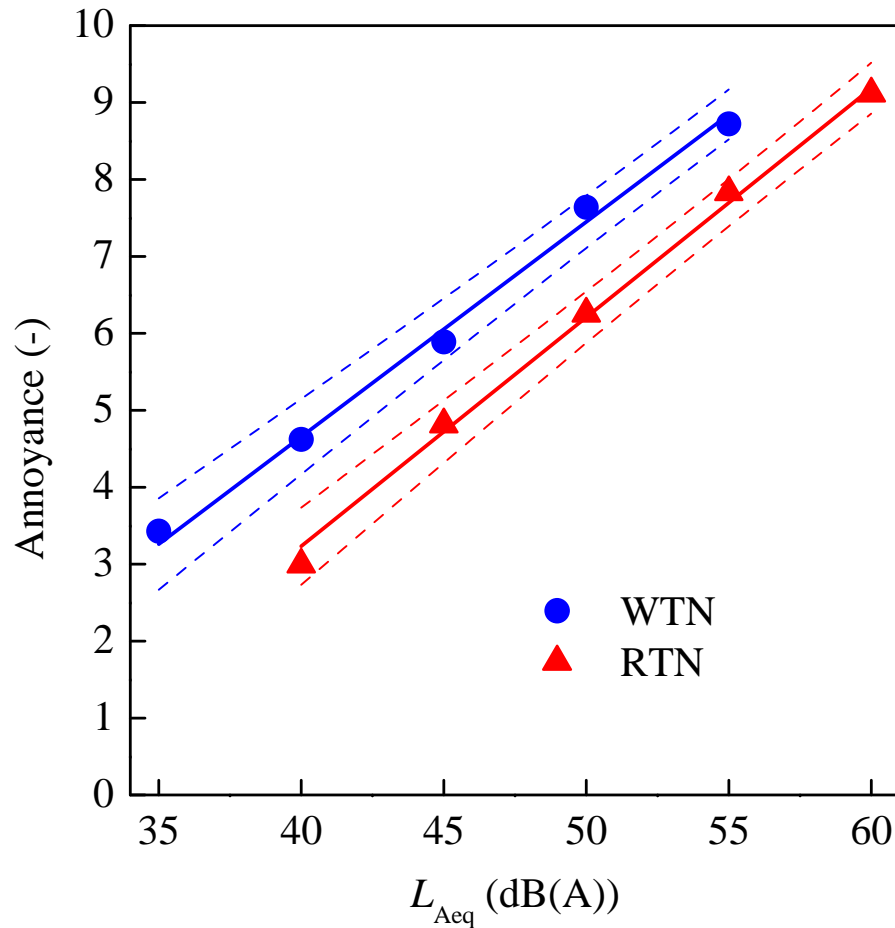
WT vs. road traffic noise

- Experimental setup
 - **Full factorial design:** stimuli systematically varied to represent different sound situations. **3 variables:** L_{Aeq} [35–60 dB], **AM** [no, per., rand.], **source** [WT, road traffic]
 - **Experimental setup:** 3-channel stereo setup in semi-anechoic chamber



- **Annoyance rating:** ICBEN 11-point scale

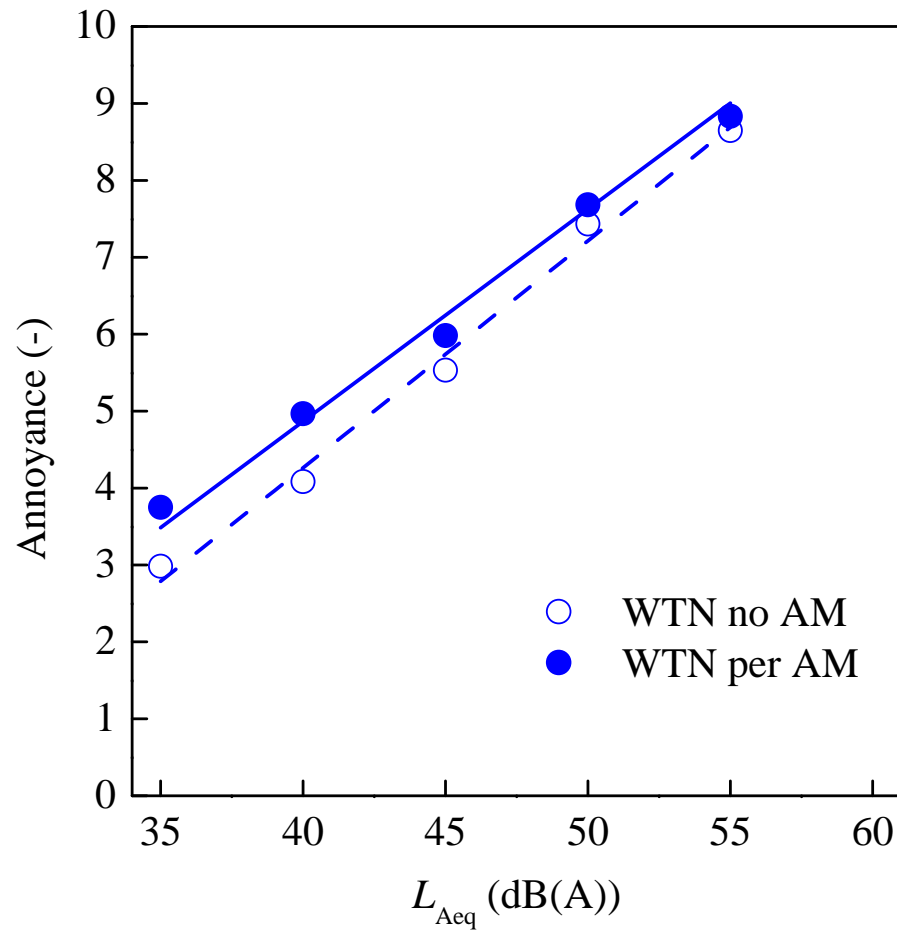
WT vs. road traffic noise



- Linear increase with L_{Aeq}
- WT more annoying than road traffic at same L_{Aeq}
- Difference: acoustical characteristics (spectral shape, periodic & random AM)

WT noise: effect of periodic AM?

WT vs. road traffic noise



■ Distinct effect of AM

WT noise – audio-visual effects

Objective: quantify contribution of acoustic characteristics and visibility of WTs to annoyance

- Partner:  **PLUS**
PLANNING OF
LANDSCAPE AND
URBAN SYSTEMS 

(in preparation) Co-workers: B. Schäffer, R. Pieren,
U. Wissen Hayek, N. Biver, A. Grêt-Regamey

Funding:   **Empa**
Materials Science and Technology

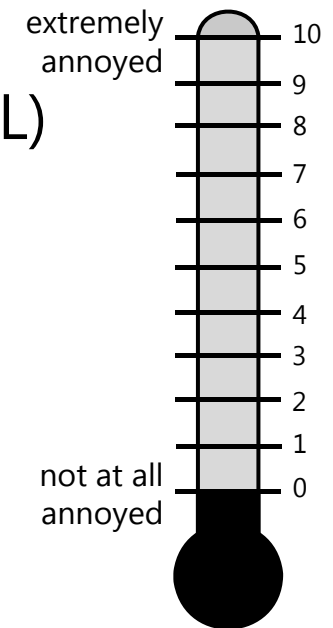
WT noise – audio-visual effects

- Experimental setup
 - **Full factorial design:** stimuli systematically varied to represent different sound situations. **3 variables:** L_{Aeq} [35–50 dB], **periodic AM** [no, yes], **image** [none (gray), landscape, landscape + WT]

- **Experimental setup:** mobile visual-acoustic lab (MVAL)

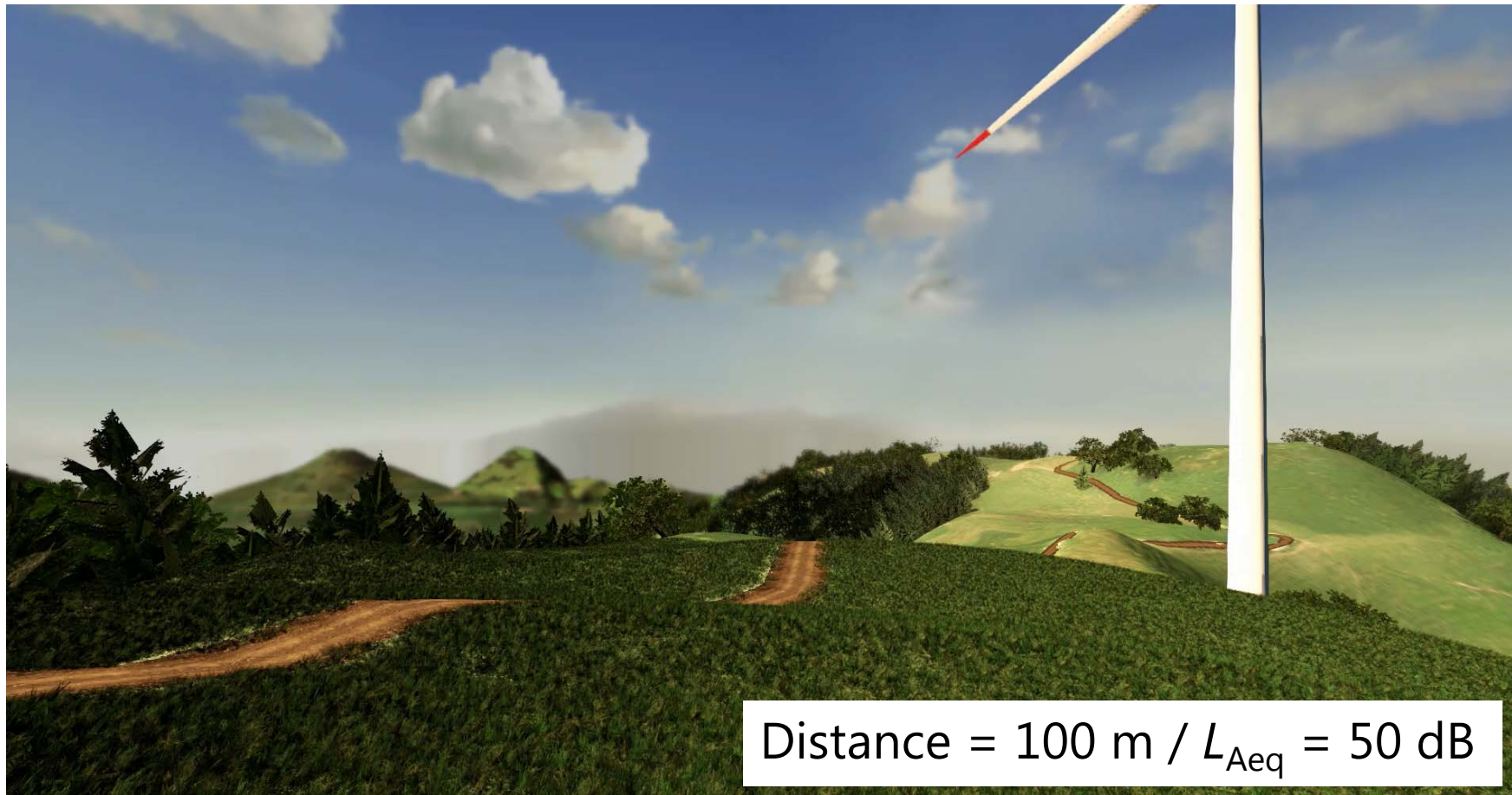


(see Manyoky *et al.* Landsc. Urban Plan. 2016)



- **Annoyance rating:** ICBEN 11-point scale

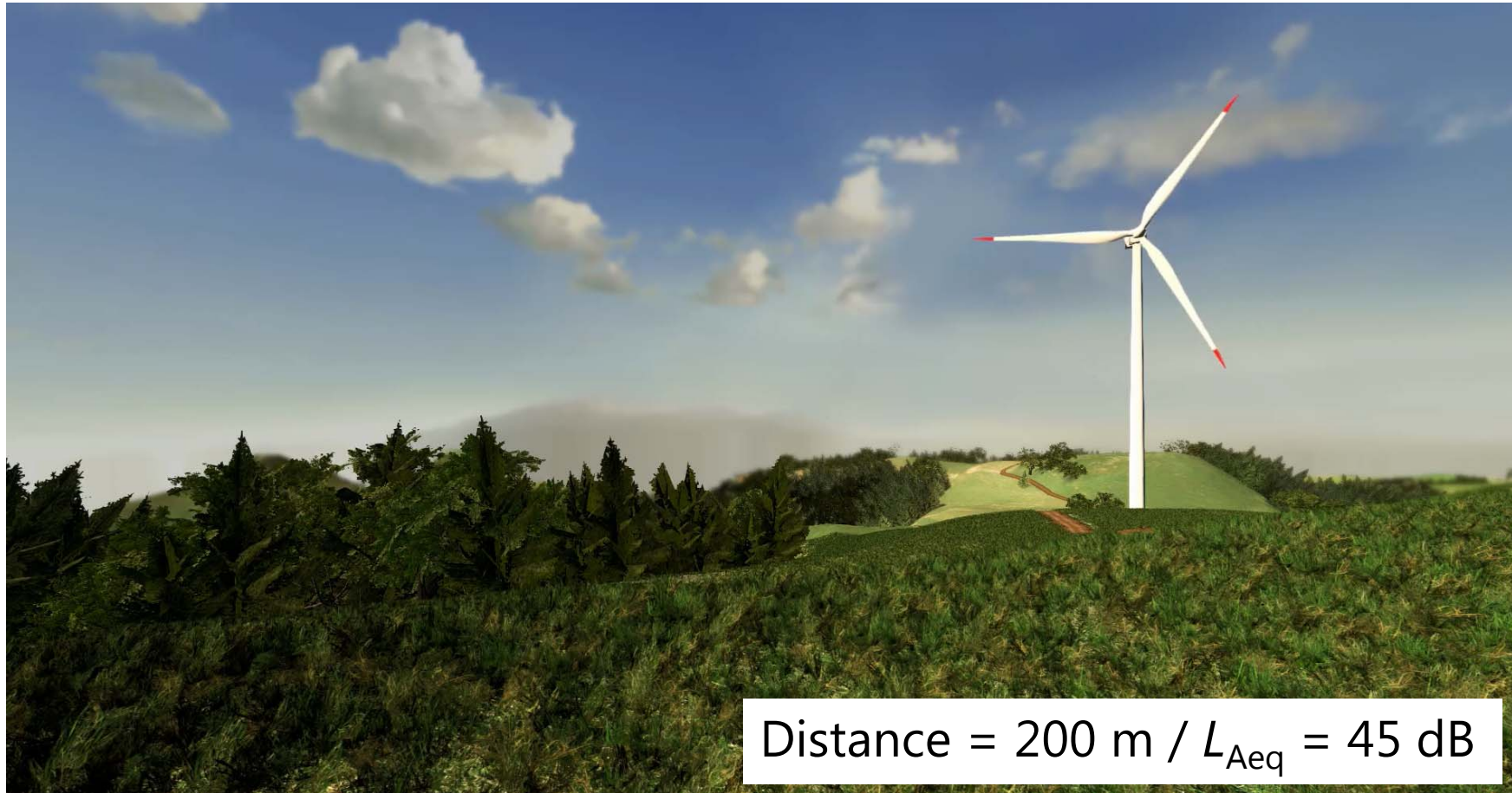
WT noise – audio-visual effects



100m_sWT.mp4

- Screenshots (movie)

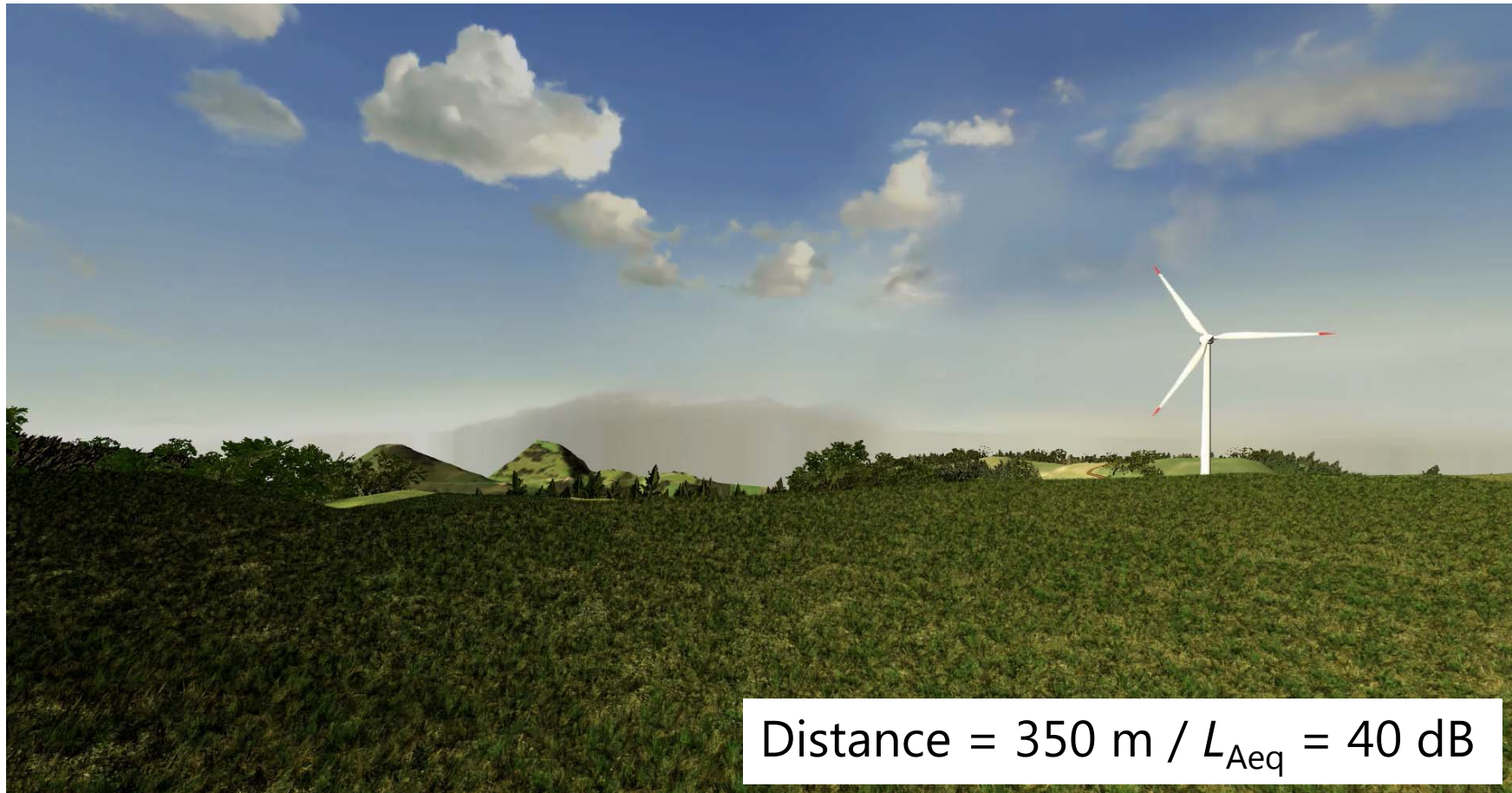
WT noise – audio-visual effects



200m_sWT.mp4

- Screenshots (movie)

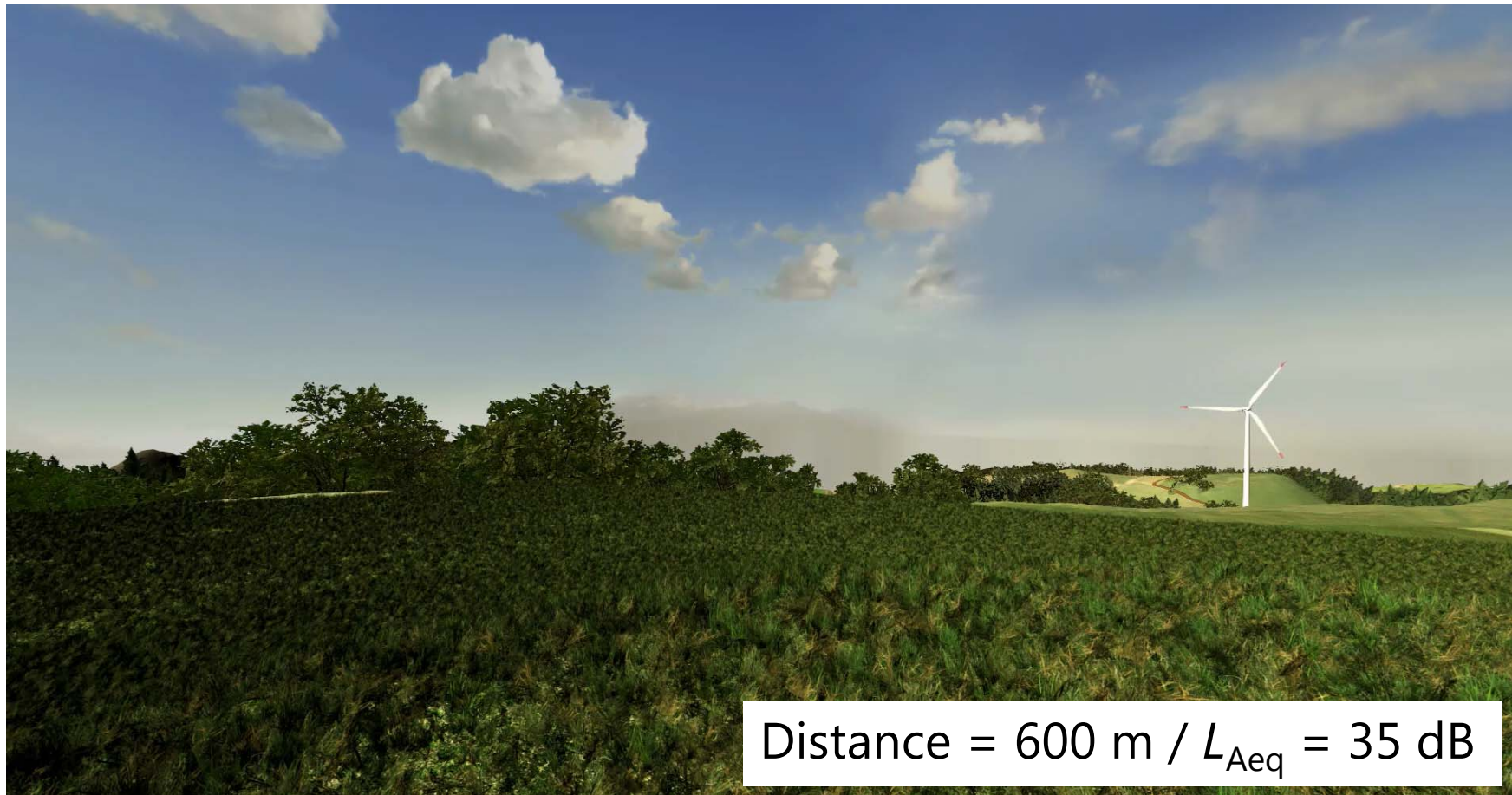
WT noise – audio-visual effects



350m_sWT.mp4

- Screenshots (movie)

WT noise – audio-visual effects

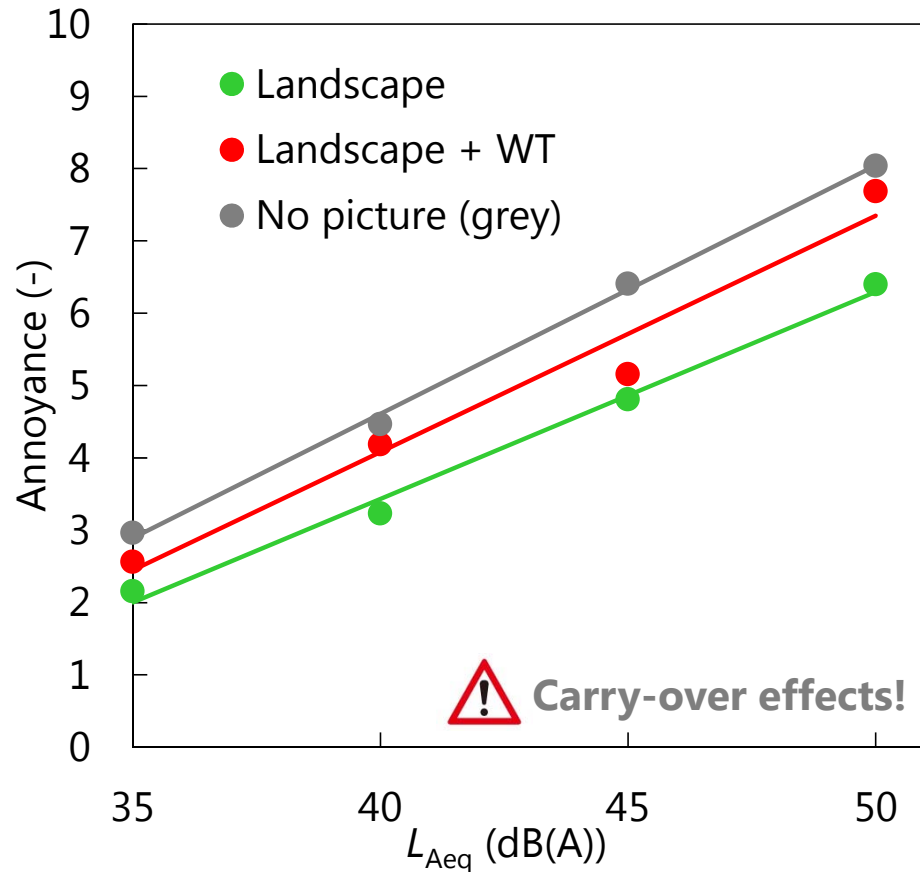


600m_sWT.mp4

- Screenshots (movie)

WT noise – audio-visual effects

- **Acoustics:** distinct effect of per. AM and L_{Aeq} (as before)



(preliminary results)

- **Image:** Distinct effect of visual information:
No image > LS + WT > LS

- Experimental design with image: challenging

➔ **Effects:** visibility of WT increases annoyance

➔ **Experiments:** challenge

➔ **Demonstrator:** image essential

WT noise annoyance ...

- Field: WT noise annoying at low sound levels, but with confounders (e.g. visibility of WTs)
- VisAsim: full control on acoustics and image
- ➔ **Fully controlled laboratory experiments:**
 - **Acoustics**
 - WT more annoying than road traffic noise
 - WT with periodic AM more annoying than without
 - **Visual**
 - Visibility of WTs increases annoyance
 - Visual information decreases annoyance

Literature

Overview

- K. Eggenschwiler, K. Heutschi, B. Schäffer, R. Pieren, H. Bögli, M. Bärlocher 2016: *Wirkung und Beurteilung des Lärms von Windenergieanlagen – Aktuelle Beiträge aus der Schweiz*. *Lärmbekämpfung* 11, 159-167.

VisAsim

- M. Manyoky, U. Wissen Hayek, K. Heutschi, R. Pieren, A. Grêt-Regamey 2014: *Developing a GIS-based visual-acoustic 3D simulation for wind farm assessment*. *ISPRS Int. J. of Geo-Inf.* 3, 29-48.
- R. Pieren, K. Heutschi, M. Müller, M. Manyoky, K. Eggenschwiler 2014: *Auralization of wind turbine noise: emission synthesis*. *Acta Acust. Acust.* 100, 25-33.
- K. Heutschi, R. Pieren, M. Müller, M. Manyoky, U. Wissen Hayek, K. Eggenschwiler 2014: *Auralization of wind turbine noise: propagation filtering and vegetation noise synthesis*. *Acta Acust. Acust.* 100, 13-24.

Listening experiments

- B. Schäffer, S. J. Schlittmeier, R. Pieren, K. Heutschi, M. Brink, R. Graf, J. Hellbrück 2016: *Short-term annoyance reactions to stationary and time-varying wind turbine and road traffic noise: a laboratory study*. *J. Acoust. Soc. Am.* 139, 2949–2963.
- B. Schäffer, S. J. Schlittmeier, R. Pieren, M. Brink 2018: *Effects of different spectral shapes and amplitude modulation of broadband noise on annoyance reactions in a controlled listening experiment*. *Int. J. Env. Res. Public Health* 15, Paper 1029, 1-17.



(AuraLab, Empa)

Thank you. Questions?