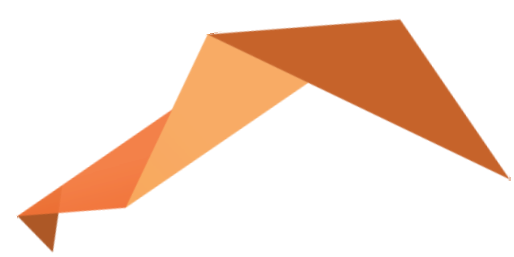


# Impact of various national codes on wind farm design.

Wind Turbine Sound 2016



**EMD International A/S**  
[www.emd.dk](http://www.emd.dk)



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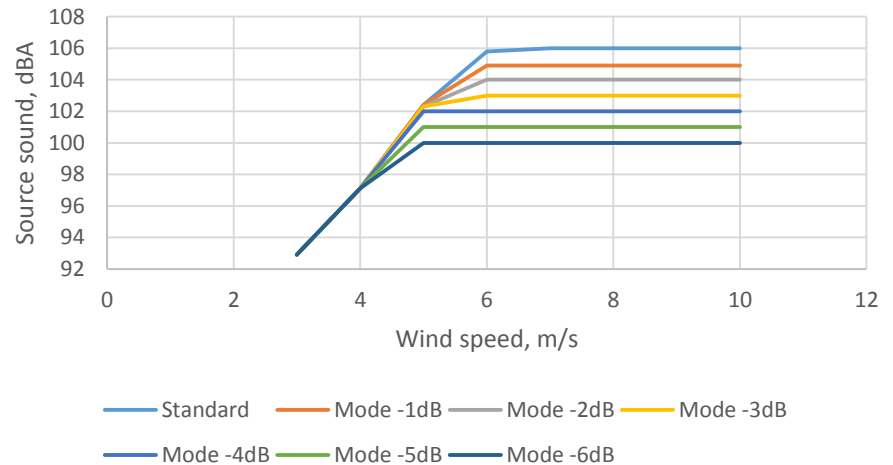


# Sound codes from a developer's perspective

- Get the most possible out of the available area, as many turbines as possible, highest efficiency of output (after all it is a business!)
- Press the sound targets to the limit
- To help us: sound reduced power curves and custom sound reduction

Example turbine supplied by Siemens Wind Power  
The SWT-3.6-130 is representative of modern turbines and can be adapted to regional sound codes with optimized sound curves.  
Figure lists the standard modes.

Operation modes for Siemens SWT-3.6-130





# What is a sound code?

- Distinction between law and guideline
- Defines sound targets
- Often defines a propagation model to be used
- Describes the documentation requirements
- Prescribes verification procedures

Examples of earlier comparisons

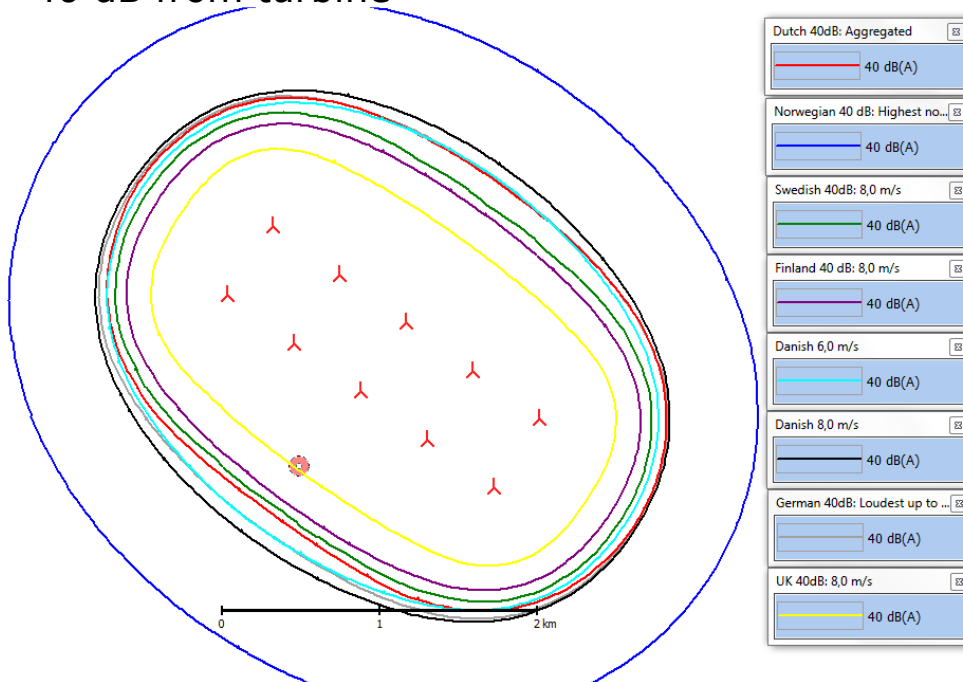
Nieuwenhuizen, E and Köhl, M: "Differences in sound regulations for wind turbines in four European Countries", Eurosound 2015.

Koppen, E and Fowler, K: "International Legislation for Wind Turbines sound", Eurosound 2015.

# What is in a sound target?

It is tempting to aim for specific sound target, but the value only tell part of the story. If we arbitrarily pick 40 dB what does that mean in the different codes?

The figure shows the 40 dB curve in the different codes and the table give the extent of 40 dB from turbine

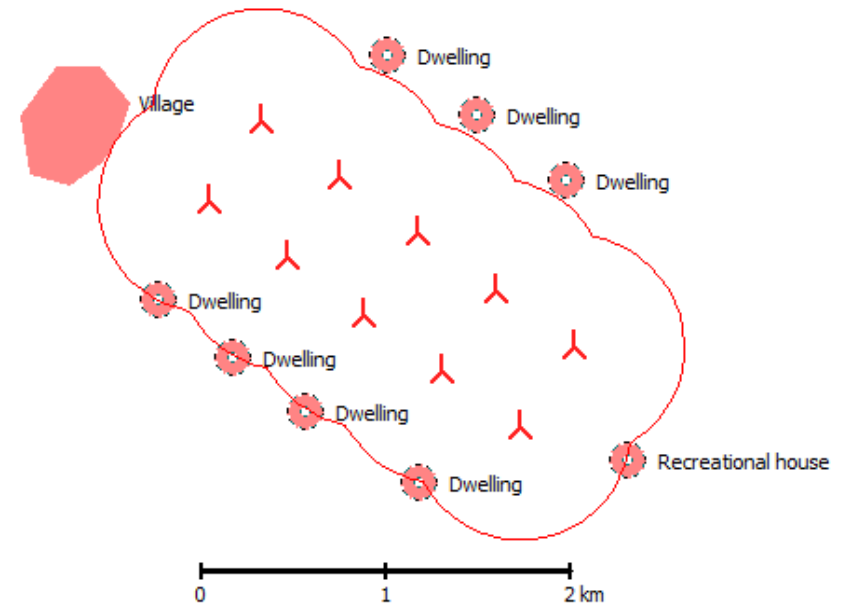


Code	Distance to 40 dB
Dutch	957
Norwegian	1784
Swedish	905
Finnish	848
German	1072
Danish	1160
UK	635



# Our test case

- 2x5 turbine layout
- Large turbine type (Siemens SWT-3.6-130), hub height 85m, total height 150 m
- Spacing 4 x 4 rotor diameter as minimum
- Receptors:
  - 4 dwellings ca 600 m distance
  - 3 dwellings ca 700 m distance
  - A village (urban area) ca 600 m distance
  - A recreational house ca 600 m distance
- Location: flat (the Netherlands), realistic





# Dutch sound code

## **Code**

Guideline: Reken- en meetvoorschrift windturbines, 2010

## **Propagation model**

A variation on ISO 9613-2

## **Sound parameter**

Lden, using the actual average sound through a wind distribution

## **Sound targets**

All dwellings

- 47 dB Lden
- 41 dB Lnight

## **Minimum setback**

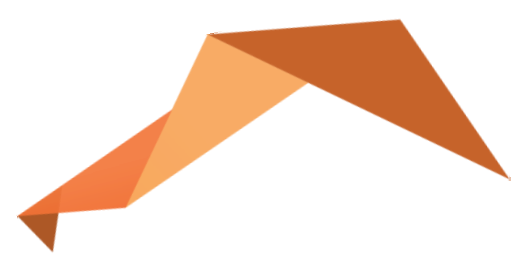
None

## **Verification**

?

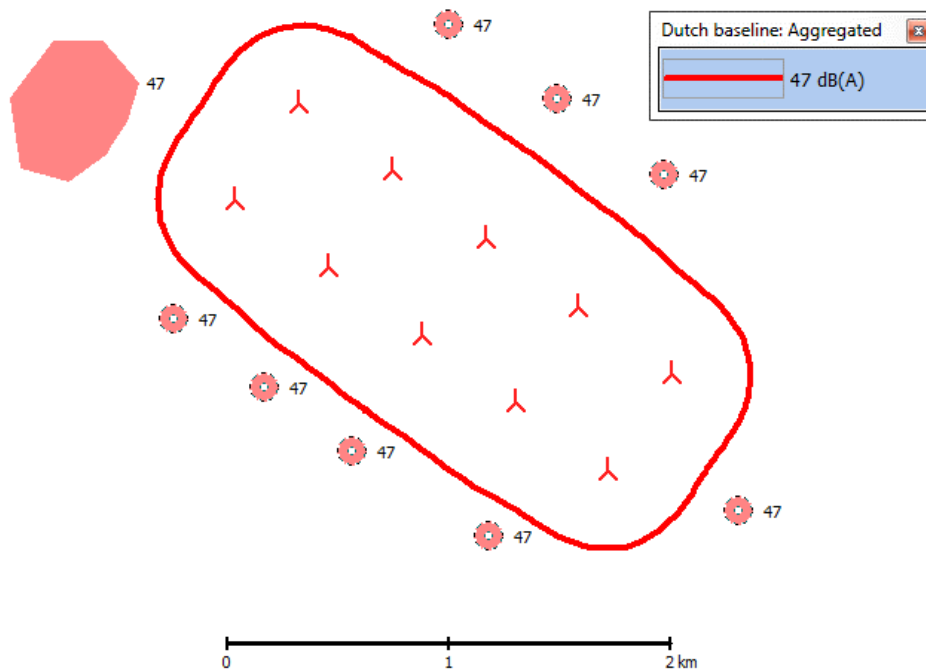


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# Dutch baseline

Lden well within limits

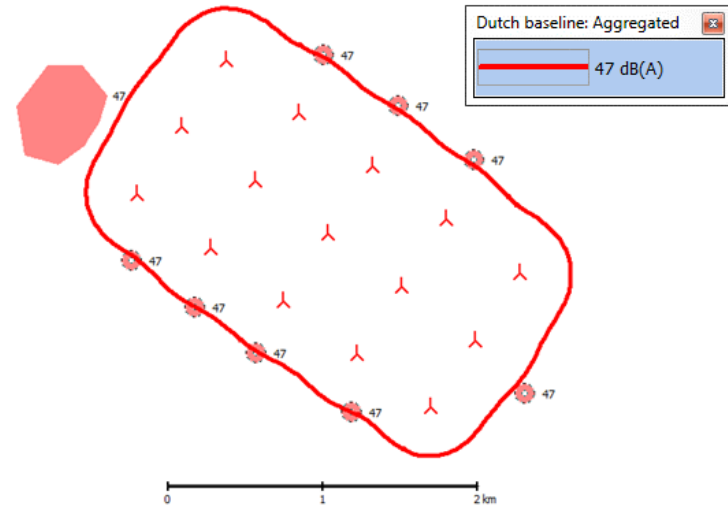




# Dutch layout

Layout 1: Increase spacing to 8 x 4.5 RD without sound reduction (closest dwelling 405 m). **104,1%**

Layout 2: Add 5 turbines with minor sound reduction night and evening (closest dwelling 375 m). **144,5%**





# Norwegian sound code

## **Code**

Guideline: Veileder til retningslinje for behandling av støy i arealplanlegging (T-1442)

## **Propagation model**

Logarithmic model with ground attenuation and atmospheric attenuation (octave band distributed). Similar to Swedish model

## **Sound parameter**

Lden, based on maximum sound

## **Sound targets**

Red Zone: 55 dB Lden

Yellow zone: 45 dB Lden

## **Minimum setback**

None (?)

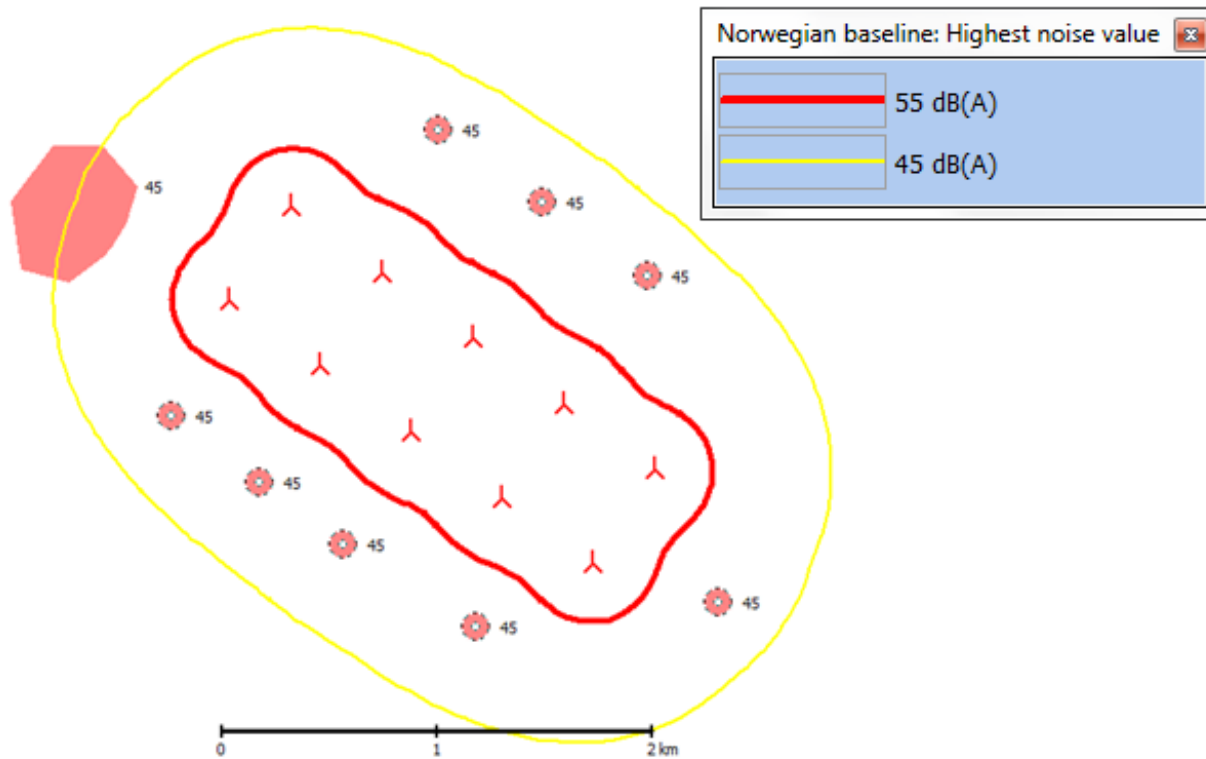
## **Verification**

Unlikely

**Special:** Alternative models (NORD2000) can be used

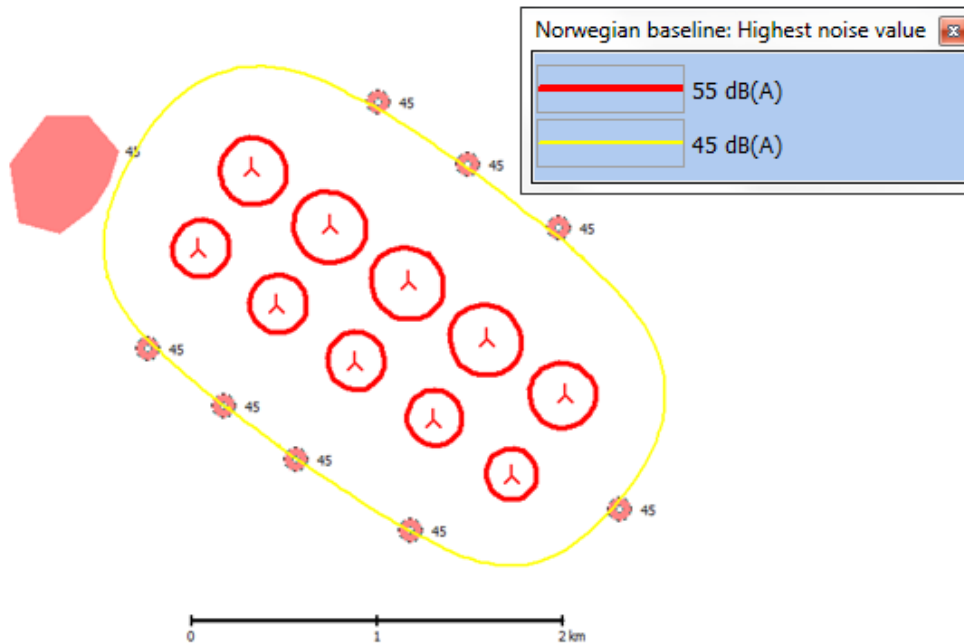
# Norwegian baseline

Sound well outside target



# Norwegian layout

Massive use of sound reduced modes. **94,2%**



Operation mode strategy

Turbine	Day	Evening	Night
1	0	0	-6
2	0	0	-6
3	0	0	-6
4	0	0	-6
5	0	0	-6
6	0	-6	-6
7	-2	-6	-6
8	-2	-6	-6
9	-3	-6	-6
10	-3	-6	-6



# Swedish sound code

## **Code**

Guidelines: Ljud från Vindkraftverk, rapport 6241, april 2010  
Mätning och beräkning av ljud från vindkraft, vägledning, 2013-06-10

## **Propagation model**

Logarithmic model with ground attenuation and atmospheric attenuation (octave band distributed).

## **Sound parameter**

Standard LA at 8 m/s at 10 m/s (relating to hub height wind speed with IEC profile)

## **Sound targets**

Guideline sound targets usually decided by municipalities

Dwellings: 40 dB, Recreational areas and dwellings: 35 dB

Recommendation to confirm that difference between A weighted and C weighted low frequency sound does not exceed 20 dB

Supposed to be indoor LF sound, but no propagation model is recommended, nor sound insulation values.

## **Minimum setback**

None

## **Verification**

Verification measurement of source sound and sound at dwellings can be made

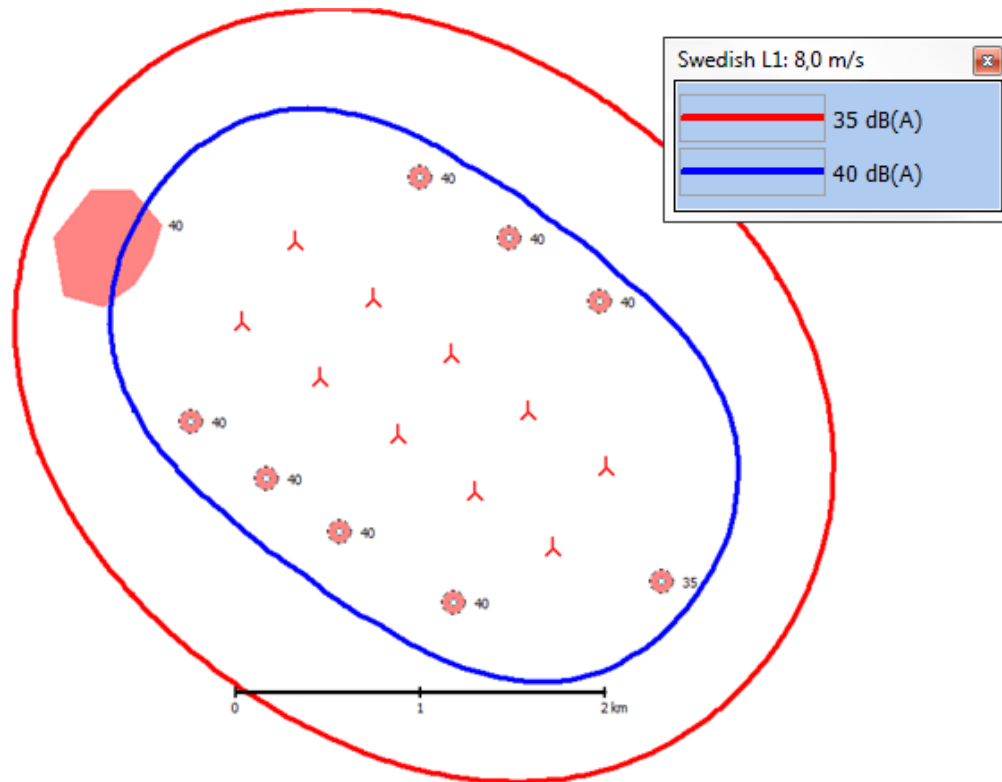
**Special:** Alternative models (NORD2000) can be used



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# Swedish baseline

Sound well outside target

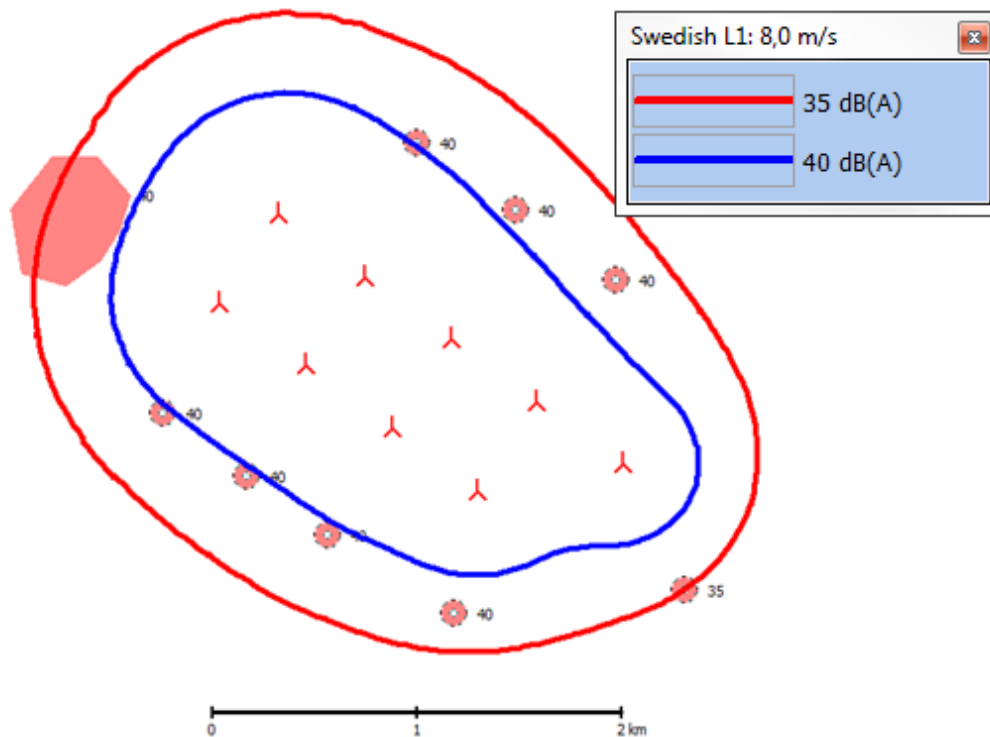


# Swedish layout

1 turbine removed

Sound mode strategy needed. **82,3%**

Custom sound curves can be used (reduction only needed up to just above 8 m/s).  
**84.6%**



Operation mode strategy

Turbine	Day and night
1	-1
2	-2
3	-4
4	-6
5	-6
6	-3
7	-5
8	-4
9	-6



# Danish sound code

## **Code**

Law: Bekendtgørelse nr 1736 af 21/12/2015 from the Danish Environmental Agency  
Guideline: Støj fra vindmøller, Vejledning fra Miljøstyrelsen nr.1, 2012

## **Propagation model**

Logarithmic model with ground attenuation and atmospheric attenuation (octave band distributed).

Separate model for low frequency sound

## **Sound parameter**

Standard LA at 8 m/s at 10 m/s. Low frequency frequencies: 10 to 160Hz

## **Sound targets**

Dwellings, 15 m from building: 6 m/s 42 dB, 8 m/s 44 dB

Areas with particular sensitive use (villages and recreational areas): 6 m/s 37 dB, 8 m/s 39 dB

Low frequency target, all dwellings and areas: 6 m/s 20 dB, 8 m/s 20 dB

## **Minimum setback**

4 x total height (in example 600 m)

## **Verification**

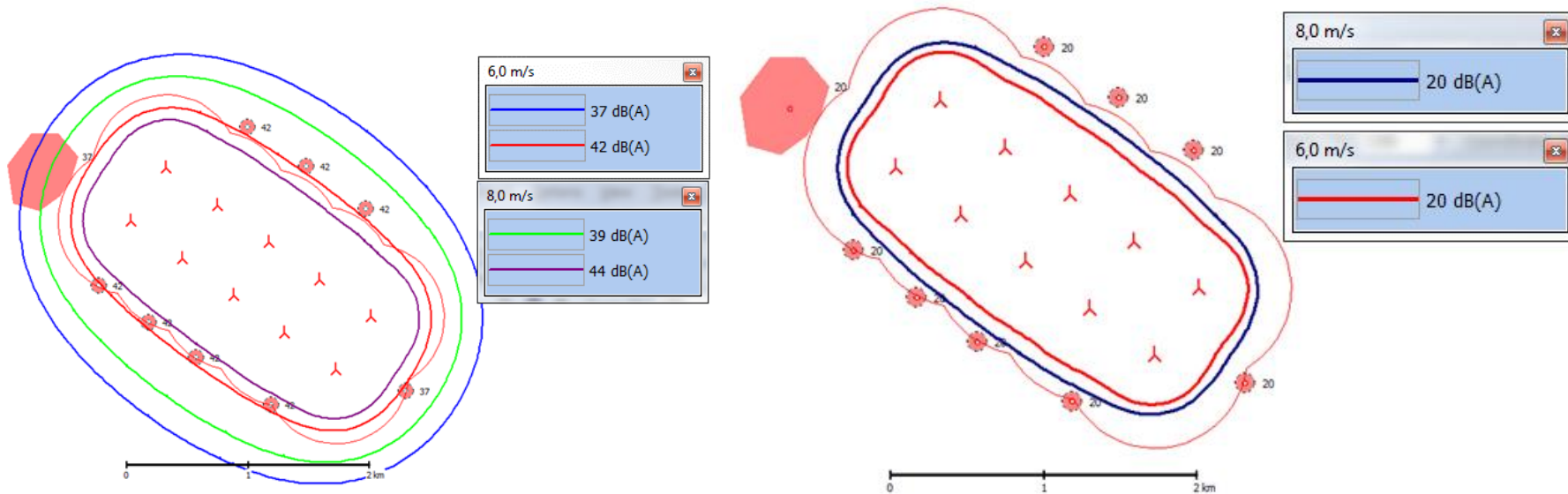
Verification measurement of source sound can be made





# Danish baseline

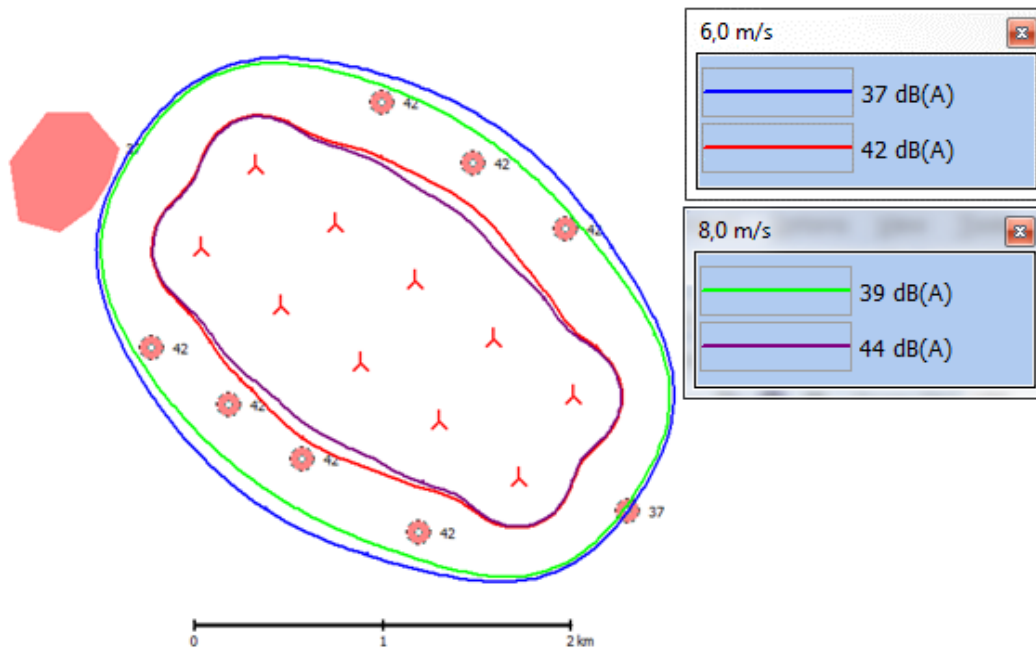
Normal spectrum sound well outside targets  
Low frequency sound well within targets



# Danish layout

Sound mode strategy needed. **91,1%**

Custom sound curves can be used (reduction only needed up to just above 8 m/s and a 2 dB difference from 6 to 8 m/s is ensured). **93,2%**

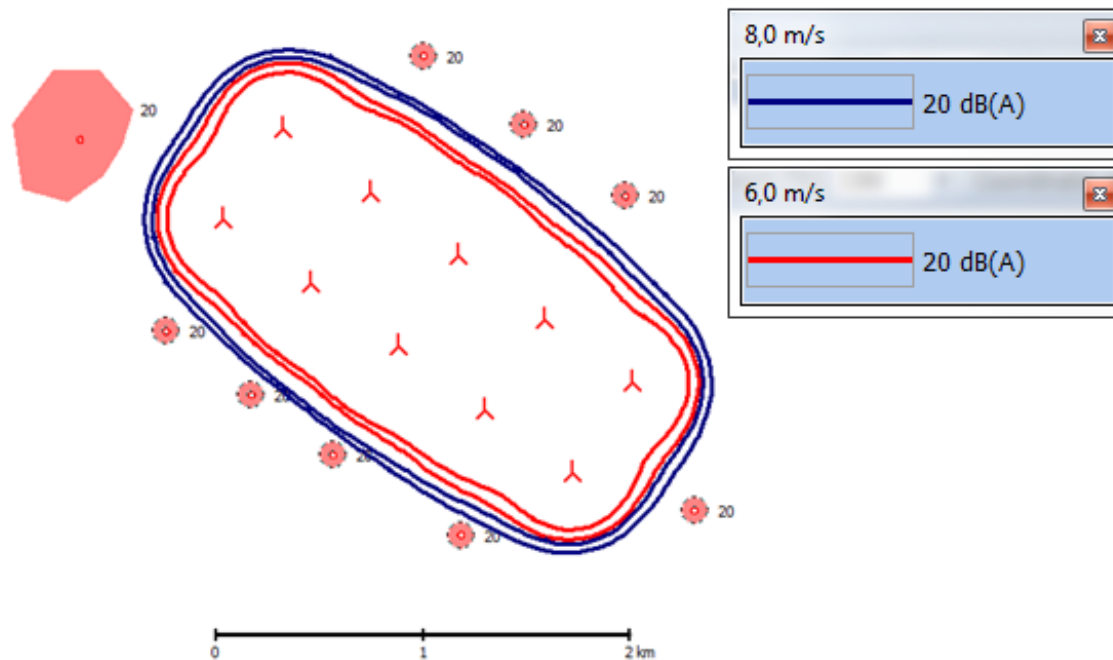


Operation mode strategy

Turbine	Custom curves	Standard curves
1	-4	-6
2	-1	-2
3	0	0
4	-3	-5
5	-4	-6
6	-4	-6
7	-1	-2
8	0	0
9	-3	-6
10	-4	-6

# Danish low frequency result

Sound reduction has only little effect on low frequency sound





# Finnish sound code

## **Code**

Law: Statsrådets förordning om riktvärden för buller från vindkraftverk, 2014  
Guideline: Ympäristöhallinnon ohjeita 2, 2014, Ministry of the Environment of Finland

## **Propagation model**

For initial study: Iso 9613-2, ground attenuation 0,4

For final study: NORD2000

Separate model for low frequency sound. Guideline is for indoor LF sound, but no guideline concerning insulation values. In practice Danish 60% values are used.

## **Sound parameter**

Standard LA at 8 m/s at 10 m/s. Low frequency frequencies: 20 to 200Hz

## **Sound targets**

Dwellings and recreational areas, day: 45 dB, night: 40 dB

Low frequency spectrum must stay beneath health guideline curve for day and night

**Minimum setback:** None

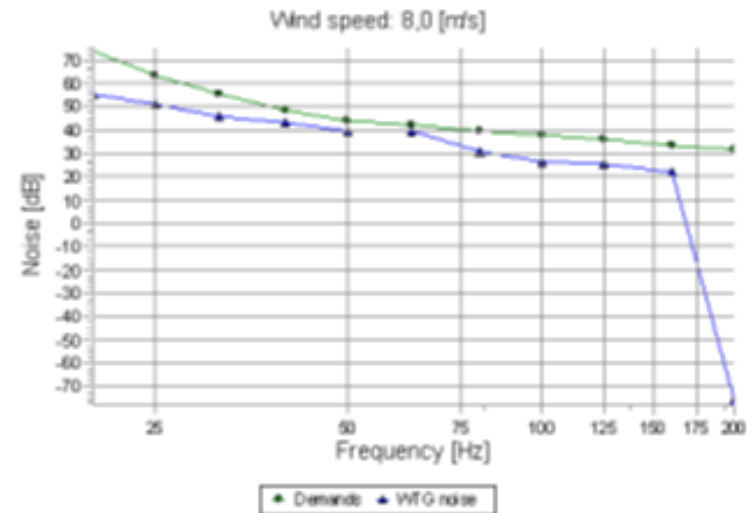
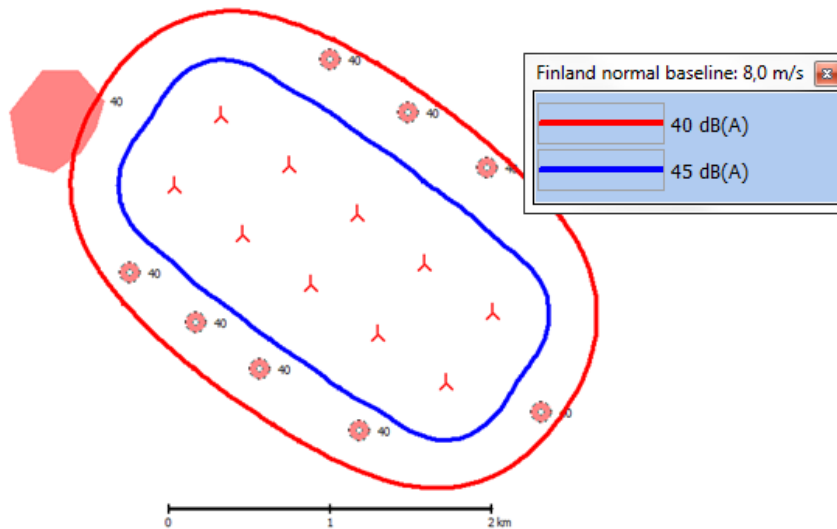
## **Verification**

Verification measurement of source sound and sound at dwellings can be made



# Finnish baseline

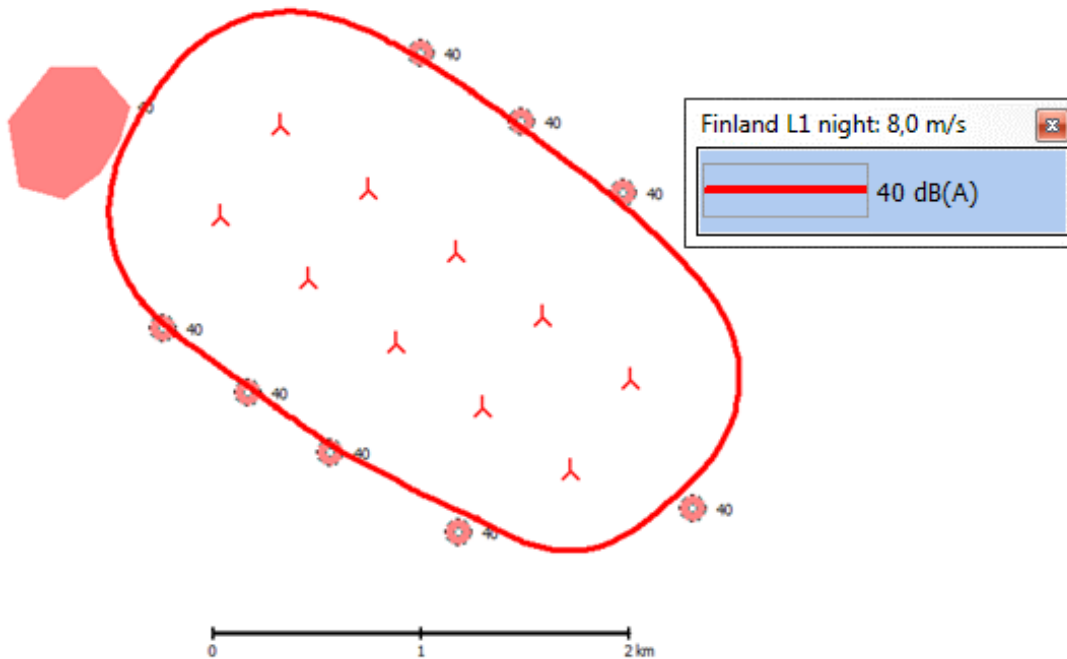
Normal spectrum sound well outside night targets and well inside day targets  
Low frequency sound below night target sound spectrum at most exposed dwelling



# Finnish layout

Sound mode strategy needed at night. **97,4%**

Custom sound curves can be used (reduction only needed up to just above 8 m/s).  
**97,9%**



Operation mode strategy

Turbine	Night
1	-1
2	-1
3	-2
4	-1
5	-1
6	-1
7	-5
8	-3
9	-6
10	-6





# German sound code

## **Code**

Guideline: TA-Lärm, Hinweise zum Schallimmissionsschutz bei Windenergieanlagen

## **Propagation model**

A variation on the ISO 9613-2, alternative model for ground attenuation

## **Sound parameter**

Loudest sound up to wind speed of 10m/s in 10m height or 95% of rated power

## **Sound targets**

Night time: Un-zoned countryside houses, mixed area (village): 45 dB

Daytime: Un-zoned countryside houses, mixed area (village): 60 dB

sound impact is rounded to closest integer

**Minimum setback:** None

## **Verification**

If calculation + unc. < target: usually no verification. If calculation < target but calculation + unc. > target: verification

## **Uncertainty:**

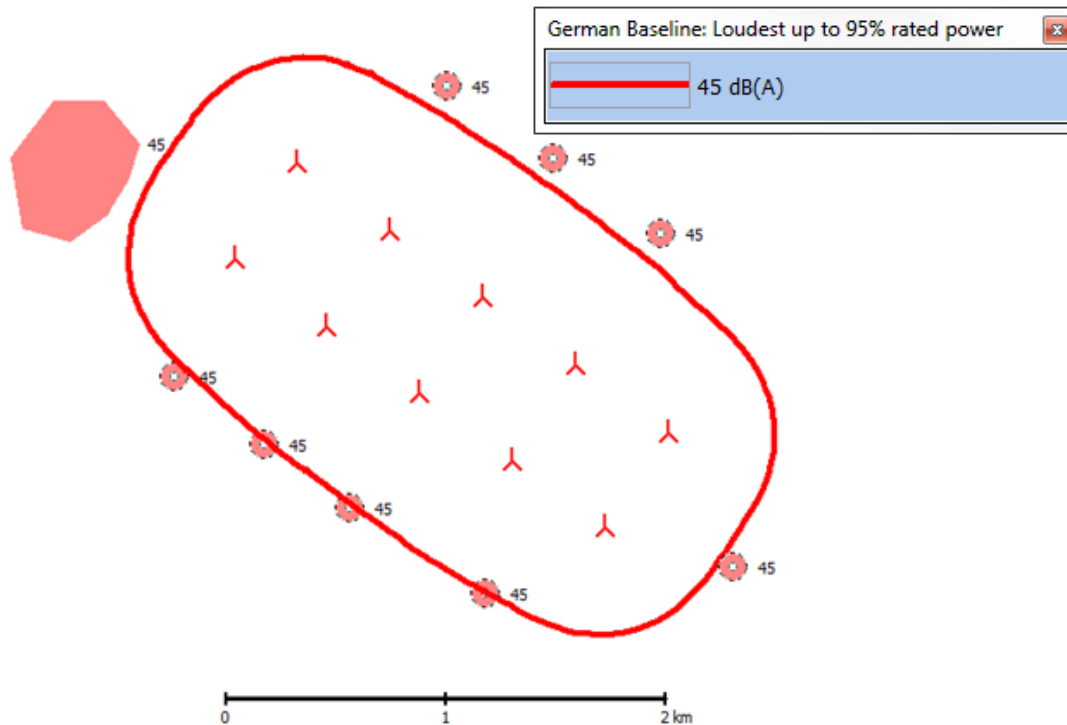
Complex addition of uncertainty (a) measurement uncertainty [default: 0,5 dB] (b) serial distribution [default: 1,2 dB] (c) model uncertainty [default: 1,5 dB]. If emission uncertainty is included in source sound data up to 1,4 dB may be added



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# German baseline

Sound within nighttime targets

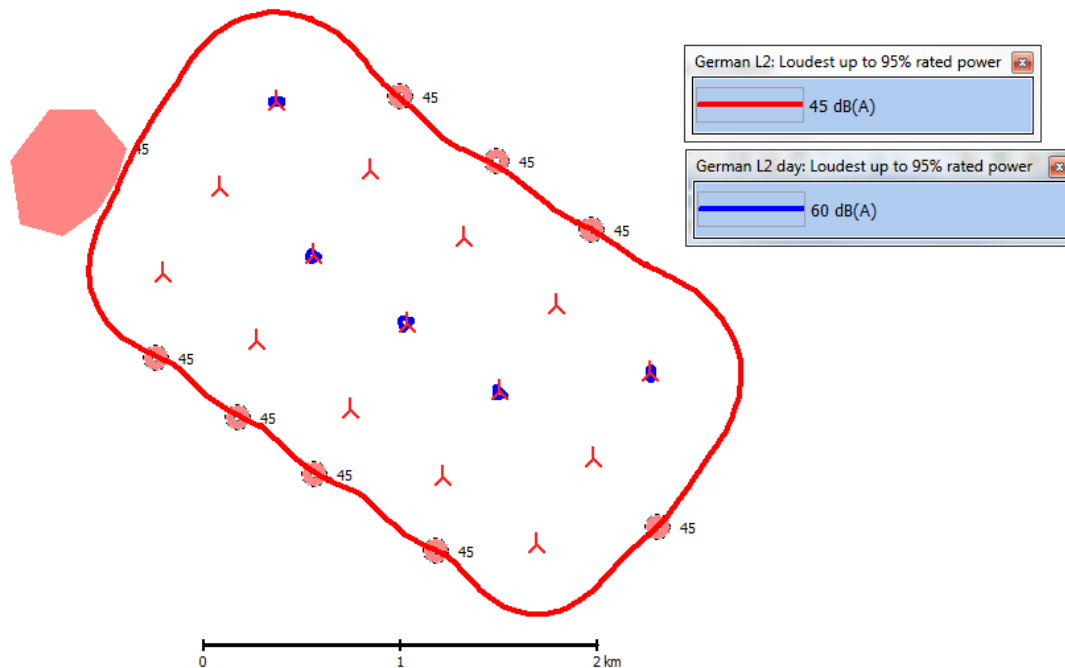




# German layout 2

Layout 1: Increase spacing to 5,9 x 4.5 RD without sound reduction (closest dwelling 470 m). **103,1%**

Layout 2: Add 5 turbines with sound reduction at night (closest dwelling 375 m). **142,2%**



Operation mode strategy

Turbine	Night
1	0
2	-6
3	-4
4	-4
5	0
6	-1
7	0
8	0
9	0
10	-1
11	-3
12	-5
13	-5
14	-6
15	-4



# UK sound code

## **Code**

Guideline: ETSU-R-97, 1996, IoA Best Practice Guidelines, 2014

## **Propagation model**

A variation on the ISO 9613-2. Ground attenuation = 0.5, valley effect and topographic screening

## **Sound parameter**

LA90 at 4-12m/s at 10m

## **Sound targets**

Quiet daytime Dwellings and recreational areas: 35dB or 5dB above background (evenings and most of weekends)

Nighttime Dwellings and recreational areas: 38dB or 5dB above background

**Minimum setback:** None

## **Verification**

Verification of sound at dwellings

## **Background sound**

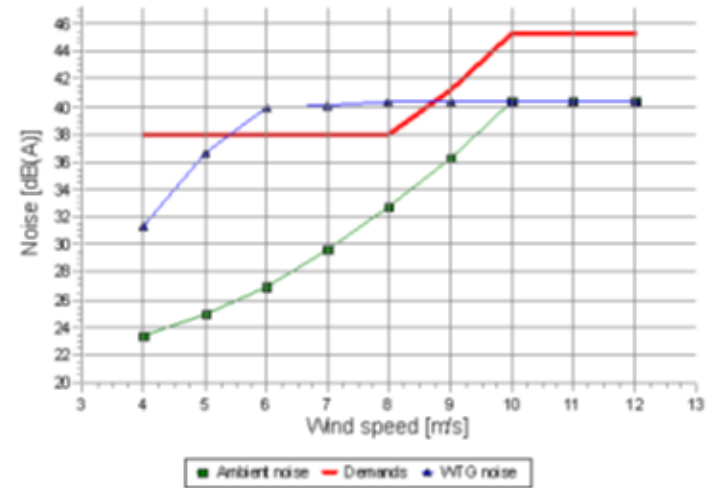
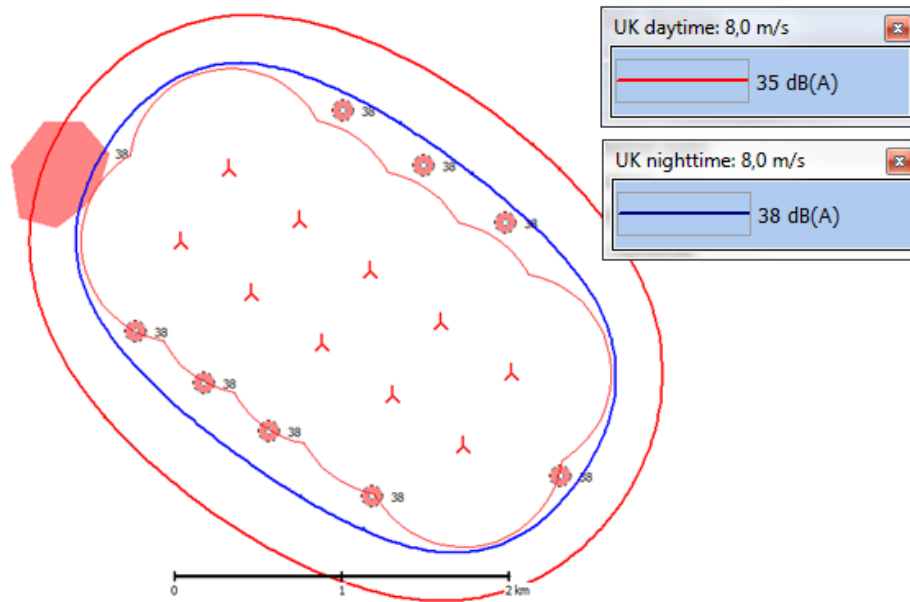
Background sound curve required (Example from rural Aberdeenshire)



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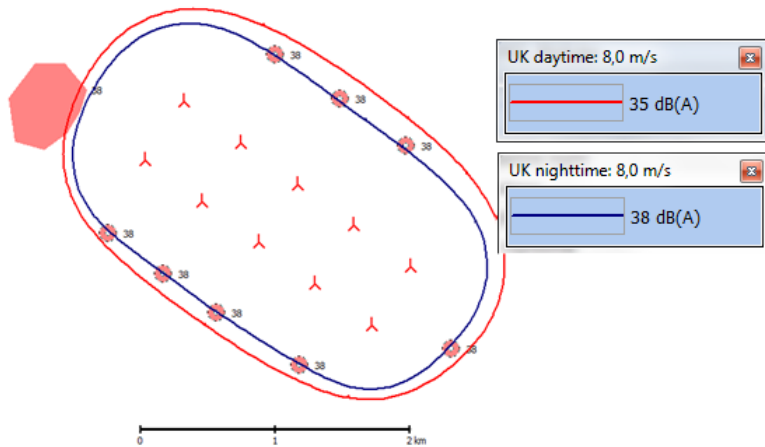
# UK baseline

Sound well outside target floor and above sound curve margin



# UK layout

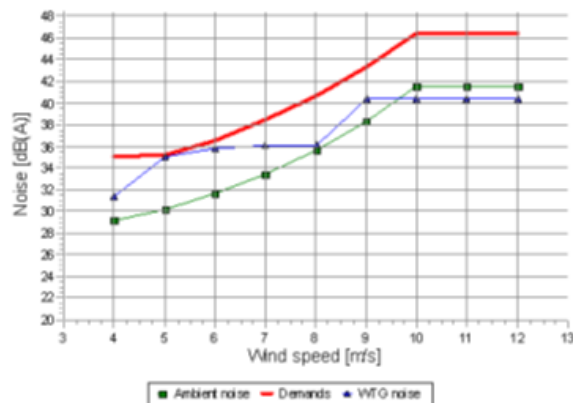
Sound reduction strategy (**95,4%**) with custom curves (**96,8%**) quiet day and night



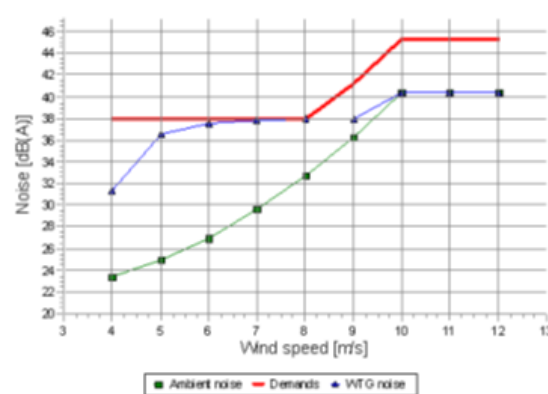
Operation mode strategy

Turbine	Day	Night
1	-2	0
2	-2	-1
3	-3	-2
4	-2	-1
5	-1	0
6	-4	-1
7	-6	-4
8	-6	-3
9	-6	-4
10	-6	-3

Day time most exposed dwelling



Night time most exposed dwelling

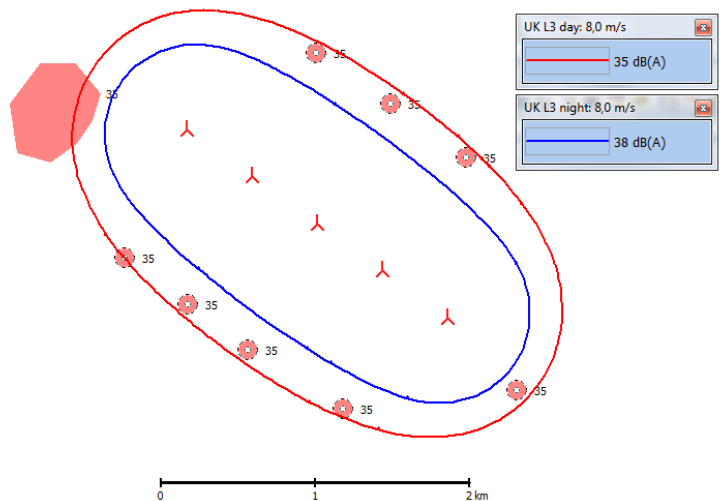


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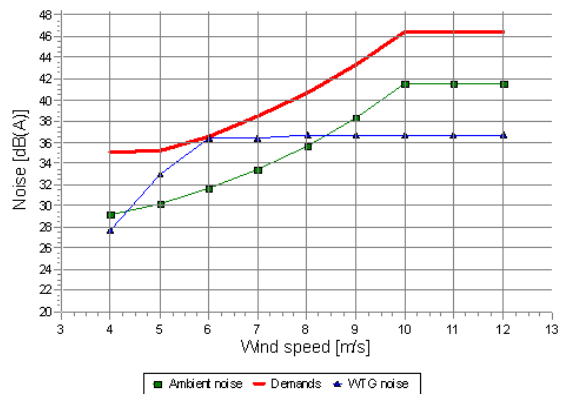


# UK layout, no sound reduction

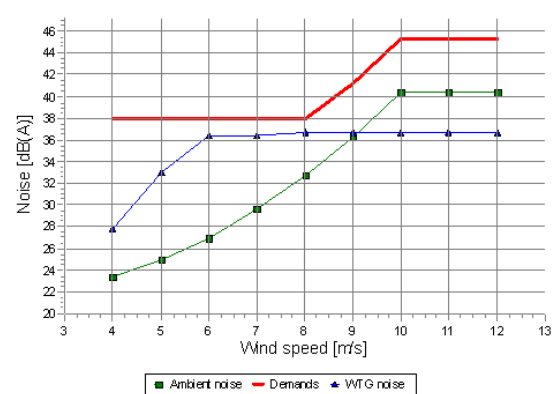
Without sound reduction this site only leaves room for one row of five turbines. **54,1%**



Day time most exposed dwelling



Night time most exposed dwelling



# How much do the codes cost?

Use of sound reduced operation mode costs production

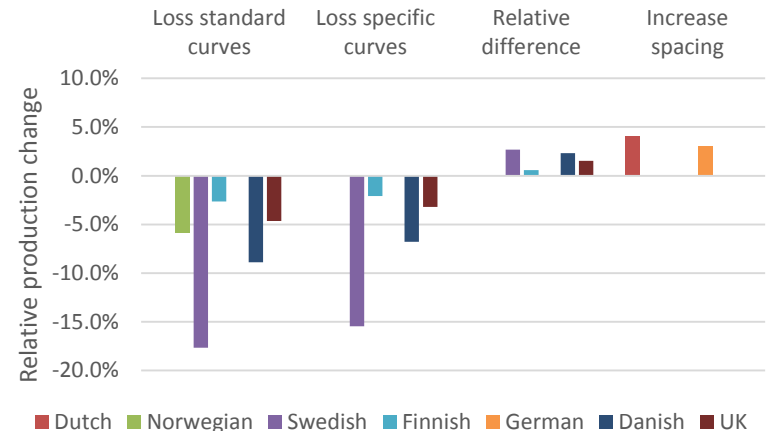
If only applied in a limited period the cost is reduced

Use of custom operation modes reduces cost even further

Codes can also be costly in consultancy hours and time

Some codes are less restrictive than others

Production loss compared to baseline



Code	Loss standard curves	Loss specific curves	Relative difference	Increase spacing	Add turbine	Result
Dutch	0,0%			4,1%	44,5%	<b>145%</b>
German	0,0%			3,1%	42,2%	<b>142%</b>
Finnish	-2,6%	-2,1%	0,6%			<b>98%</b>
Norwegian	-5,8%					<b>94%</b>
Danish	-8,9%	-6,8%	2,3%			<b>93%</b>
Swedish	-17,7%	-15,4%	2,7%			<b>85%</b>
UK	-4,6%	-3,2%	1,5%		-45,9%	<b>54%</b>





# Conclusion

- Each sound code has its unique challenges
- The sound targets may be incomparable across sound codes
- A developer of course prefer as much space as possible
- But even more important is practical, unambiguous codes so the available land can be exploited optimally
- Sound reduced operation modes is a strong tool to optimize the wind farm and customizing them makes them even more powerful
- Does it make sense to consider sound codes as a reflection of real sound?