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500 MW on-shore wind park "NOP" the Netherlands

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Abstract

The NOP wind park will be the largest on shore wind park in the Netherlands. The location of the park is the Noordoostpolder (NOP) which is land acclaimed from the sea in 1942. The wind park consists of four different new parks: three on the land of the Noordoostpolder and one in the lake. This lake, the IJsselmeer, is one of the largest lakes in western Europe and was created in 1932 by closing an inland sea, the Zuiderzee. The four parks will have a total of 86 turbines generating over 500 MW. 51 of these turbines will be Enercon E126 7.5 MW and 35 Siemens SWT 3.6 MW. During the planning of the park the noise regulations of the Netherlands were changed. The old regulation is a wind depending noise level L_{eq} for a representative night. The new regulation is a yearly average L_{den}. This L_{den} is based on the wind statistics at hub height. The royal Netherlands meteorological institute has made a database of the yearly wind statistics for a height of 80 to 120 m of the whole of the Netherlands. In this article the effects of both regulations is discussed using the NOP park as an example. For the planning procedures it was necessary to cumulate the wind turbine sound with other noise sources. Other noise sources are not only the electrical transformers of the parks but also the road traffic noise, agricultural noise and industrial noise. This cumulation was used to asses the impact on residents of the noise of different types of sources.

Figure 1 Location of the Noordoostpolder (Source: Google Earth)

Introduction

The Noordoostpolder (NOP) is located on the west side of the IJsselmeer (IJssel-Lake). This lake has been created with the completion of a large enclosing dam, separating the Zuiderzee (Southern Sea) from the Noordzee (North Sea). The creation of this dam was a response to the flood of 1916. With the completion of the Afsluitdijk (Closing dike) in 1932, the Zuiderzee, and her diurnal tides, became history.

Now, large areas of water could be reclaimed for farming and housing. Polders (reclaimed land) were created. These areas were the Wieringermeer, the Noordoostpolder and the Flevopolder. The total project, called the Zuiderzeeworks, ran from 1919 to 1986. For the NOP the work started in 1936, with the official reclamation in 1942. Several islands (like Urk) were now part of the main land.

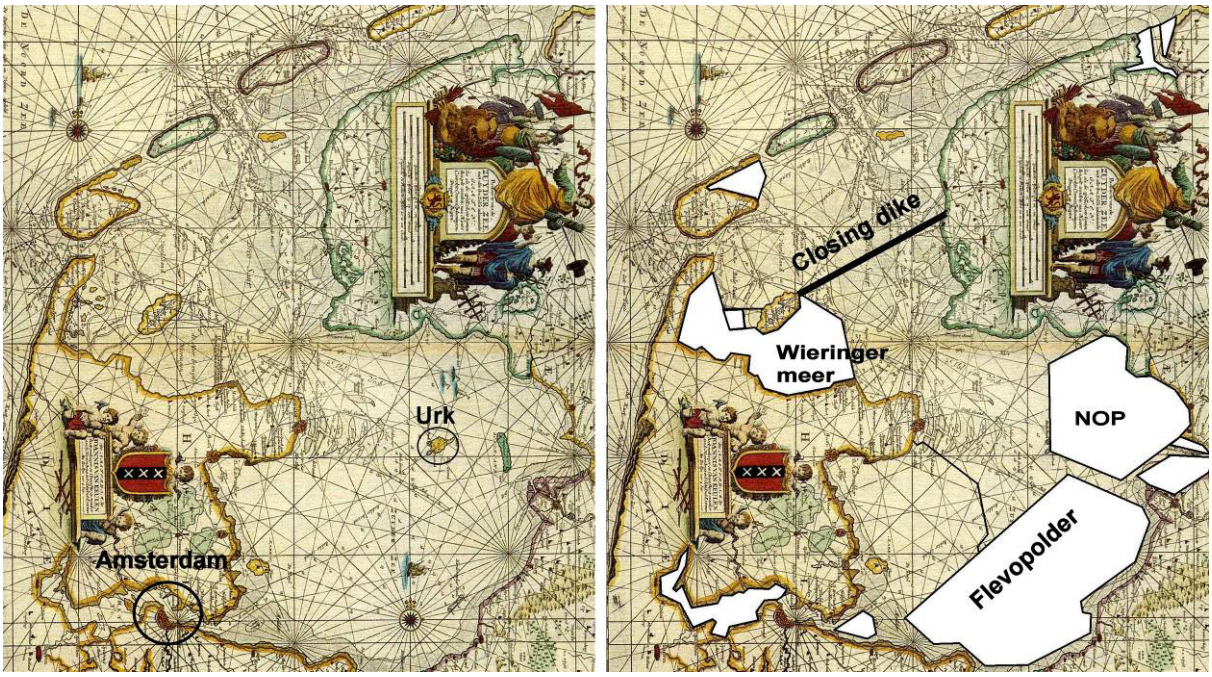

Figure 2 Land reclamation of the last 300 years

Now, approximately 85% of the total land area of the NOP is used for agriculture (data 2008). And, off course, some parts are used for wind turbines and small wind parks. Over 12 years ago the municipality NOP established a policy for less or no new, single on-shore wind turbines. All new turbines had to be concentrated in one big plan. So, over 10 years ago, a group of farmers and entrepreneurs, united in the “Koepel Windenergie Noordoostpolder”, developed a plan for one big new park.

The result of this plan is a wind park containing 86 wind turbines with the possibility of producing a yearly 1.4 billion kWh of energy. Replacing over 50 smaller wind turbines, it will be one of the biggest on-shore wind parks in Europe.

The wind park

The wind park NOP consists of four separate wind parks, listed in table 1 and visualised in figure 2.

Table 1 The NOP wind parks

Wind park	Type	Hub height [m]	Rotor diameter [m]	# Turbines
A - “Creil”	Enercon E126	135	127	13
B - “Westermeerdijk binnendijks”	Enercon E126	135	127	17
C - “Zuidermeerdijk”	Enercon E126	135	127	8
D - “Westermeerwind” (2+1 rows)	Siemens SWT 3.6	95	107	48

Figure 3 The NOP wind parks. All red stars indicate a separate wind turbine (background: Google Earth).

Many different turbine types have been considered. Two different types of wind turbines have finally been selected. First, the Enercon E126 7.5 MW turbine with a hub height of 135 m. The rotor diameter of this turbine is 127 m, resulting in a tip height of nearly 200 m. This turbine is used for the land locations. Second, the Siemens SWT 3.6 MW turbine with a hub height of 95 m and a rotor diameter of 107 m. This turbine is used for the locations in the lake. Originally the lake wind park "Westermeerwind" consisted of more turbines, parallel to the 17 land located turbines of the wind park "Westermeerdijk binnendijks". For a smaller visual impact from the former island of Urk a few turbines at the southern end of the rows are deleted.

All four wind parks are united in the "Koepel Windenergie Noordoostpolder", resulting in a simultaneous planning procedure. LBP|SIGHT acted as environmental adviser, especially on the topic of noise. During the development of the wind parks the noise regulations for wind turbines in the Netherlands were changed. This change took more than a year of discussion and of course delay for the park. The NOP wind park is the first wind park assessed by these new regulations.

Sound level regulations

The old regulation

The old regulation is a wind depending noise level L_{eq} for a representative night, resulting in a curve (Wind norm Curve – "WNC") with a different limiting sound value for each wind speed at 10 metres height.

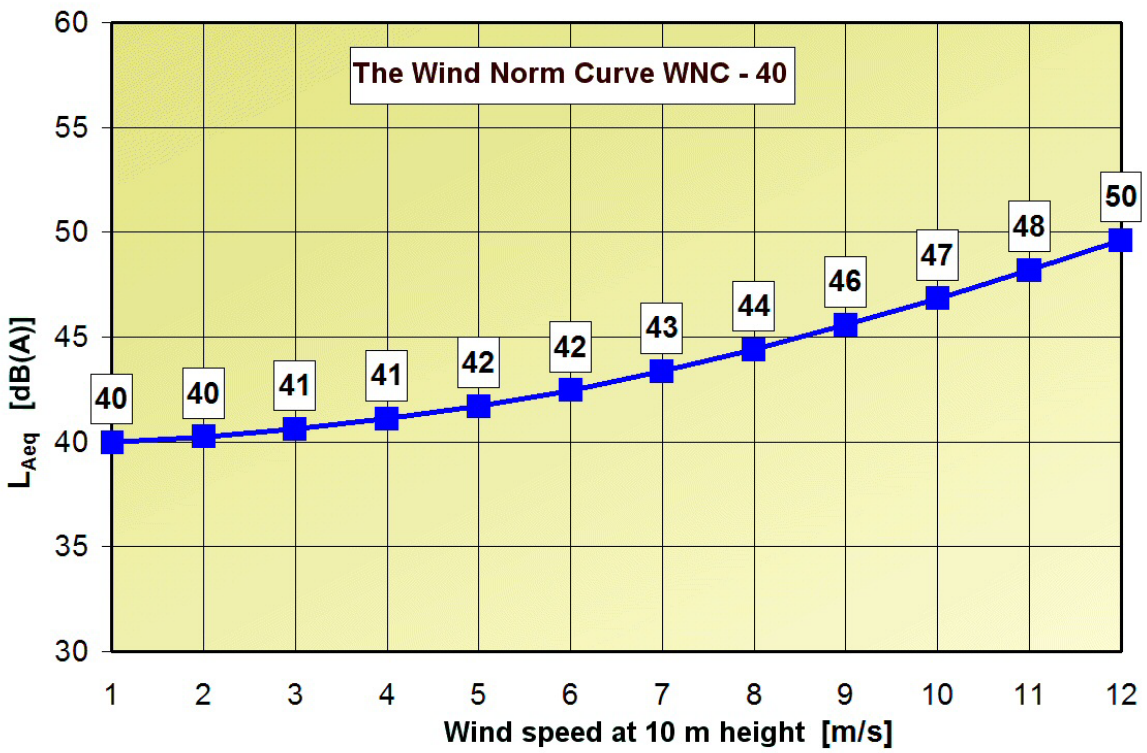

Figure 4 The old regulation, WNC-curve.

When assessing the sound levels for each wind speed, corrected for wind velocity at 10 metres height according to table 2, the resulting level should be 40 dB(A) at most at dwellings during the night (an eight hour equivalent). The correction can be applied on the resulting noise level at dwellings or, it can be applied on the sound power level. When it is applied on the sound power level the resulting level can be compared to sound power levels of other turbines.

Table 2 Correction of sound level according to the WNC

V_{10} [m/s]	3	4	5	6	7	8	9	10	11	12
Correction [dB]	-1	-1	-2	-2	-3	-4	-6	-7	-8	-10

The dependency of the wind speed at 10 metres height results in a practical problem when the wind profile is different from the neutral wind profile. The sound power level of a turbine is measured with a neutral wind profile. With a wind profile at stable atmospheric conditions, the sound power level is higher then expected according to the wind speed at 10 meters height. The difference is expected to be 1 or 2 dB higher for a representative night of the year. The new regulation is not related to the wind speed at 10 metres height.

New regulations

The new regulation (operative since the first of January 2011) states a maximum yearly average of 47 dB L_{den} and of 41 dB L_{night}. The L_{den} is calculated by adding 0, 5 and 10 dB to respectively L_{day}, $L_{evening}$ and L_{night} and subsequently averaging the levels time-weighted. In a formula:

$$L_{den} = 10\lg\frac{1}{24}\left(12*10^{\frac{L_{day}}{10}} + 4*10^{\frac{L_{evening}+5}{10}} + 8*10^{\frac{L_{night}+10}{10}}\right)$$

The L_{day}, $L_{evening}$ and L_{night} are the equivalent levels during the periods 7.00 to 19.00, 19.00 to 23.00 and 23.00 to 7.00 hours. The L_{den} is chosen because of the European Directive 2002/49/EG for the assessment of environmental noise. The value of 47 dB is based on the research by the Dutch institute TNO. At this level 9 % of the population is highly annoyed. For other noise sources a similar percentage is obtained at the by the Dutch law allowed noise level of these sources.

Although the NOP park consists of four legally different parks the L_{den} value of 47 dB has to be met by the cumulation of noise levels of the four parks.

Calculation method

Yearly wind data is necessary to calculate a yearly noise level. For the Netherlands, the royal Netherlands meteorological institute (KNMI) has more than hundred years of data available. The problem is that the wind velocity in this data is at 10 metres height. Using this data, the problem of wind shear in stable atmospheric conditions would emerge again. Therefore the KNMI has made a database of the wind statistics for a height of 80 to 120 metres of the whole of the Netherlands. This database gives a frequency distribution of the different wind velocities during day, evening and night time for any given coordinate in the Netherlands and a given height between 80 and

120 metres. With this distribution a yearly sound power level can be calculated. In table 3 this calculation is given for an Enercon 126 in the NOP project.

Table 3. Yearly sound power level according to KNMI wind statistic

Enercon E126							
Wind speed		Hub height 139 m				Lw+cb	
hubheight m/s	Lw max	Day	Evening	Night	Day	Evening	Night
0	0.0	0.0	0.0	0.0			
1	0.0	1.7	1.1	1.1			
2	0.0	3.4	2.8	2.2			
3	88.5	5.1	4.3	3.4	75.6	74.9	73.8
4	92.1	7.2	6.8	5.7	80.7	80.4	79.6
5	95.3	9.5	9.0	8.0	85.1	84.9	84.4
6	98.2	10.4	10.9	10.3	88.4	88.6	88.4
7	100.8	10.8	11.7	12.3	91.2	91.5	91.7
8	103.1	10.6	11.3	13.1	93.4	93.6	94.3
9	105.1	9.3	10.4	11.6	94.7	95.2	95.7
10	106.7	7.7	8.5	8.2	95.6	96.0	95.8
11	108.0	6.3	6.4	6.2	96.0	96.1	95.9
12	109.0	5.1	4.6	4.9	96.0	95.6	95.9
13	109.6	3.7	3.2	3.8	95.3	94.6	95.5
14	109.9	2.7	2.6	2.7	94.2	94.1	94.3
15	109.9	1.8	2.0	1.9	92.4	93.0	92.7
16	109.9	1.3	1.5	1.5	90.9	91.7	91.6
17	109.9	1.0	0.9	1.0	89.9	89.6	89.9
18	109.9	0.6	0.6	0.7	88.0	87.8	88.1
19	109.9	0.4	0.4	0.4	86.5	85.5	86.4
20	109.9	0.3	0.2	0.2	84.4	82.4	83.6
21	109.9	0.1	0.1	0.1	81.3	78.6	79.0
22	109.9	0.1	0.0	0.0	78.5	72.6	72.4
23	109.9	0.0	0.0	0.1	76.8	65.2	77.3
24	109.9	0.0	0.0	0.0	76.3		76.3
25	109.9	0.0	0.0	0.0	76.8	74.2	
				sum	104.9	104.9	105.1
				Lden	**111.5**	dB	

From this sound power level a sound pressure level can be calculated according to the required method. This method is similar to the ISO9613-2 method. Ground attenuation and air absorption is used. The directivity of the noise source can be taken into account but so far not enough data on the directivity is available. The wind direction is not used extensively in the calculation. The propagation method is valid for the usual wind direction from source to receiver and the KNMI wind statistics do not give any information about direction. The Dutch method gives a formula for a wind direction depended meteorological correction (C_{meteo}) which takes the prevailing south west direction into account:

$$C_{meteo} = 5\left[1 - 10\left(\frac{h_b + h_0}{r}\right)\right]\left[1 - \frac{1}{2}\cos(\beta - 45°)\right]$$

However the C_{meteo} is mostly zero for dwellings within a relevant distance.

Calculation results

Noise calculations for the NOP parks already started under the old WNC regulations. During the planning the L_{den} 47 was introduced but the KNMI wind statistics were not yet available. The calculations were then made with statistics from a local measuring

mast of 115 m height. Finally the calculations have been made with the KNMI statistics. The KNMI statistics are valid for a long term average of several years whereas with the local measuring mast consistent values were only obtained for a part of one year. Both (wind mast and KNMI wind statistics) sound power levels are listed in table 4. Also the WNC corrected sound power level is given. The sound power levels are compared with the noise limit.

Table 4 The sound power levels of both turbine types used in calculations.

Wind park	WNC Lw [dB] 10 metres data	Lden Lw [dB] Wind mast Enercon	Lden Lw [dB] Wind statistics KNMI
Enercon E126 7.5 MW	104.3	112.2	111.0 - 111.5*
Siemens SWT 3.6”MW	102.3	109.6	109.3 - 109.4*
Noise limit at dwellings	40	47	47

*The sound power levels are slightly different using the KNMI statistics due to different wind distributions of each separate wind park.

In figure 5 the L_{den} 47 dB contour is depicted using the KNMI wind statistics. The dwellings in the NOP are mostly found in the former island Urk. In the newly acclaimed land (the ‘polder’) farms were evenly distributed over the land along straight lines. The 47 dB contour line runs along such a line of farms. Several turbines in wind B (“Westermeerdijk binnendijks”) has to be switched to reduced modes to meet the 47 dB limit.

The L_{night} 41 dB contour does not add useful information, since all calculated noise levels meet L_{den} minus L_{night} >6.

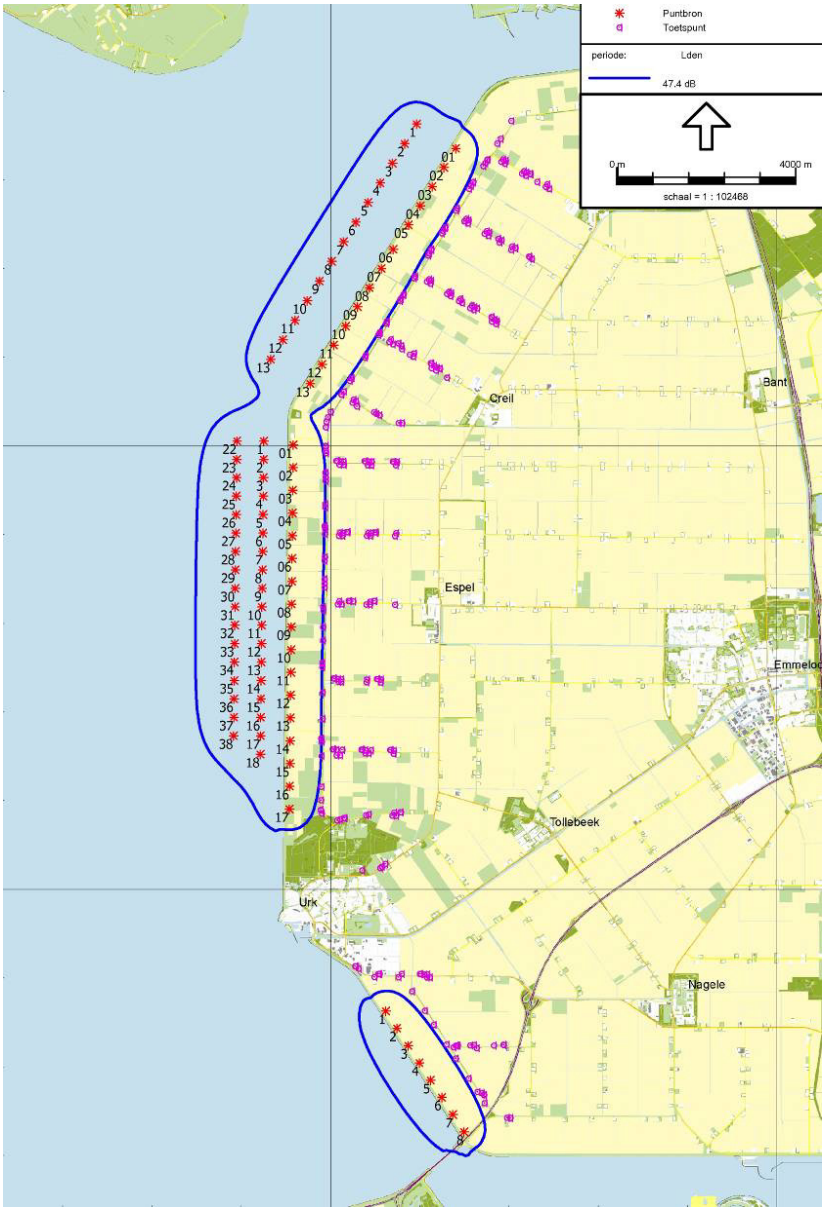

Figure 5 L_{den} 47 dB contour (The turbines are given as red stars and all surrounding dwellings as purple icons).

Cumulation with other noise sources

To asses the impact on residents of the noise of different types of sources another calculation was made. In this calculation the noise level of different noise sources are cumulated. These noise sources are the electrical transformers of the parks, road traffic noise, agricultural noise, shipping noise and industrial noise were cumulated. Noise levels of each source are first converted to a level with the same hindrance as road traffic. The resulting cumulative level can be assessed as road traffic noise. Below the formula is given. LL = air traffic, IL = industrial noise, VL = road noise, WT = wind turbine noise.

$L^*_{LL} = 0{,}98\ L_{LL} + 7{,}03$

$L^*_{IL} = 1{,}00\ L_{IL} + 1{,}00$

$L^*_{VL} = 1{,}00\ L_{VL} + 0{,}00$

$L^*_{WT} = 1{,}65\ Lwt - 20{,}05$

$$L_{CUM} = 10\lg\left(\sum_{n=1}^{N} 10^{L_n^* /10})\right)$$

Striking in these formula is the factor used for wind turbine noise. In figure 6 the cumulated contours of all sources are given, with and without the parks.

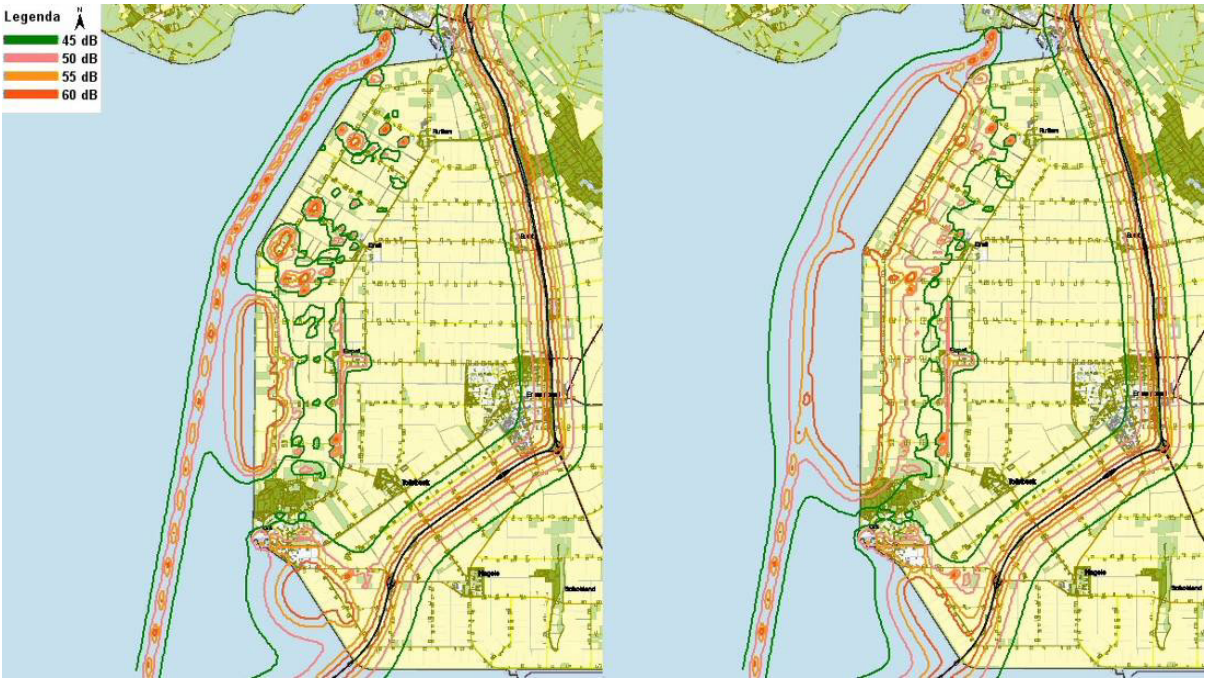

Figure 6 Cumulation of all sound sources NOP. Left without and right with wind park NOP.

Conclusions

The old and new Dutch regulation for wind turbine noise both result in roughly the same restrictions for the NOP wind park. The new regulation avoids the uncertain factor of the wind shear at stable atmospheric conditions. The new regulation introduces a new uncertain factor consisting of the KNMI wind statistics for high altitudes. These values are valid for a long term average whereas the L_{den} of the wind park will differ from year to year. It is expected that this effect is 1 dB or less.

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