Summary of Strategic Environmental Assessment for Wind Turbine Provisions for the Living Environment

Dutch Ministry of Infrastructure and Water Management

5 April 2023

Contact

FRANS DOTINGA
Senior Specialist

T +31 6 2706 1031

Arcadis Nederland B.V.
P.O. Box 1018
5200 BA 's-Hertogenbosch
The Netherlands

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1 Summary of strategic environmental assessment for wind turbine provisions for the living environment

This is the summary of the Strategic Environmental Assessment for Wind Turbine Provisions for the Living Environment. A Strategic Environmental Assessment (*PlanMER* in Dutch) is an environmental impact report for plans and programmes. Below, the term 'Strategic Environmental Assessment' is used to specifically refer to the Strategic Environmental Assessment for Wind Turbine Provisions for the Living Environment. You will find the complete report on the website of the Participation Platform[1]. In the Strategic Environmental Assessment, the baseline is compared with an alternative and with several variants.

1.1 Strategic Environmental Assessment for Wind Turbine Provisions

Wind turbines can only be installed in the Netherlands if certain rules are adhered to. For example, the installation of the wind turbine in the specific location ('spatial integration') must be both possible and permitted, and certain construction and environmental rules apply as well. This Strategic Environmental Assessment does not concern construction rules. The spatial planning rules and the environmental rules are often interrelated. It can concern national rules (imposed by the central government) or local ones (imposed by municipal or provincial authorities). Before a wind turbine can be installed or a wind farm can be realised, the government will assess whether the applicable rules can be met. A government decision will be issued setting out whether this is the case. If an interested party does not agree with this decision, a court of law will determine whether the government has decided correctly.

Since 2009, the national environmental rules for wind turbines have been set out in the Activities Decree (*Activiteitenbesluit* in Dutch). These rules are also referred to as 'general rules', because they are rules imposed by the central government that apply in the entire country. The environmental rules for wind turbines concern noise nuisance, shadow and light reflection caused by the moving blades (shadow flicker and glare), and the permitted safety risks (also referred to as 'external safety'). When assessing whether a wind turbine or a wind farm is possible, government authorities previously assumed that the nuisance caused by the wind turbines was acceptable if these general rules could be adhered to. In the past, the highest general administrative court in the Netherlands, the Council of State, therefore gave the green light for many wind projects.

However, in 2021 the Council of State concluded that it is not right to assess wind farm decisions based on the general rules from the Activities Decree. The reason for this is that the European Court of Justice, the highest court in the EU, has established that those general rules were created without performing an environmental impact assessment of the possible environmental effects of these general rules. The performance of such an environmental impact assessment was mandatory, however, because the European Strategic Environmental Assessment Directive requires that for such general rules the environmental effects are investigated. As a result, the general environmental rules ceased to be applicable in July 2021.

The Dutch central government would like to see the introduction of new general environmental rules for wind turbines. Without such rules, every wind project needs to be assessed individually with regard to its effects for the environment and the question of whether these effects are acceptable. In the opinion of the central government, this is not a desirable situation. Therefore, a study has been conducted into the environmental effects of possible new general rules. For this study an environmental impact report was drawn up, and because this concerns an environmental impact report for a plan, it is referred to as a strategic environmental assessment.

[1] For all documents relating to the Strategic Environmental Assessment for Wind Turbine Provisions, see: https://www.platformparticipatie.nl/windturbinebepalingen/default.aspx (only in Dutch).

2 Delimitation

2.1 Baseline

In this Strategic Environmental Assessment, the baseline consisting of the current situation and developments expected over the coming years is compared with an alternative and several variants. The baseline is the situation without any new general rules. This is the situation that arose due to the judgment of the Council of State in 2021. To be able to compare the alternatives and the variants with the baseline, three aspects of the baseline have been specified:

1. A description of the current state of the environment, including the expected developments, both for the year 2030 and for the year 2050. A description has been elaborated for the whole of the Netherlands for each topic, used for the assessment of the alternative and the variants (see Table 1).
2. Local standards. This concerns local standards set by municipal or provincial authorities for the assessment of wind turbine projects.
3. 'Reference turbine': two wind turbine sizes which have been used as the standard.

These three elements are described in more detail below.

2.1.1 Baseline 1: Description of the current state of the environment and developments

Health

Health can be linked to serious noise nuisance. People can experience nuisance from noise produced by all kinds of sound sources. To determine the degree of nuisance, noise is expressed as the number of decibels (dB) in a specific spot, such as on the façade of a home. A noise standard may have different limits during the day than during the night. In a noise standard, noise during the night (and evening) is weighed more heavily because it creates more nuisance since it disturbs people's rest or sleep. In 2019, noise from road traffic formed the main source of serious noise nuisance (10.4% of cases), followed by neighbours (8.8%) and air traffic (6,3%). On a national level, wind turbines lead to relatively low serious nuisance scores, i.e. 0.2%. Locally, however, wind turbines add to the total noise nuisance experienced. It is relevant here that at the same noise level, noise produced by wind turbines is experienced as being more bothersome than noise from road and rail traffic or industry. Sometimes, wind turbine sounds have a specific tonal character. This means that the noise includes clearly audible pure tones. If these tones are at a low frequency, they are referred to as humming tones. Low-frequency sounds reach further than higher-frequency sounds. Nuisance can already be caused by small exceedances of the hearing threshold. Future developments which are relevant for noise nuisance are increases in the number of wind turbines, in the number of homes being built, and in the share of quieter and electric vehicles.

Visual intrusion and light pollution

In the Strategic Environmental Assessment, the category of visual intrusion and light pollution is subdivided into three types of nuisance: 'visual intrusion caused by obstacles', 'nuisance caused by shadow flicker' and 'light pollution caused by obstacle lighting'.

Visual intrusion caused by obstacles has an effect on how people experience the landscape. People's experience of landscapes is subjective, but mainly depends on the presence of natural and historic features (which are seen as positive) and on urbanisation level and spoiling of the skyline (which are seen as negative). Research has shown that small-scale landscapes, the coastal zone and hilly areas are valued best. Open landscapes with a high degree of urbanisation and/or agriculture are valued least. In the future, visual intrusion may increase due to the addition of more buildings and extra wind turbines.

Nuisance caused by shadow flicker from wind turbines may increase in the future because more homes will be built near the turbines and because turbines are becoming bigger. Shadow flicker occurs when the sun is shining and the blades of wind turbines create a moving shadow ('cast shadow'). The occurrence of shadow flicker is mainly relevant on a local level because it depends on the exact position of the sun in relation to the turbine and to the people in the vicinity.

Light pollution is caused by artificial lighting. Think of night lighting from light sources like roads and motorways, residential areas, industrial parks and business districts, horticulture facilities and sports grounds. Wind turbines can cause light pollution as well, due to the use of obstacle lighting. Obstacle lighting is lighting that makes wind turbines visible to air traffic. Light pollution can cause sleep disturbance, unsafe situations on roads, disturbance of animal behaviours and spoiling of the skyline.

The expectation for the future is that the construction of more homes and the expected growth in the number of wind turbines will cause increasing visual intrusion and light pollution. Another possibility, however, is that the degree of light pollution will decrease in the future, for instance thanks to the introduction of light pollution regulations for the horticulture sector.

External safety

For external safety (the safety risks of wind turbines), a distinction is made between risks for vulnerable objects and risks for moderately vulnerable objects. Vulnerable objects are homes and buildings where large numbers of people may be present or buildings that accommodate people who cannot take care of themselves. Examples are schools, hospitals, big office buildings and hotels. In moderately vulnerable buildings, people are present but not in large numbers. Examples are scattered dwellings, service and company housing, restaurants, and smaller office buildings. Risks caused by wind turbines include situations where the nacelle breaks off (nacelle failure), where the entire tower topples over (tower failure) or where a blade falls off. This is illustrated in Figure 1 (upper section). These failure scenarios have a direct effect on the surrounding area. About 15% of wind turbines in the Netherlands are close enough to objects for relevant failure scenarios to occur. In cases where a wind turbine breaks down, indirect risks may also occur, for example if high-risk businesses or pipelines containing hazardous substances in the vicinity are damaged by wind turbine components that come off. This damage will result in an increased risk for the surrounding area due to a knock-on effect. This is shown in Figure 1 (lower section).

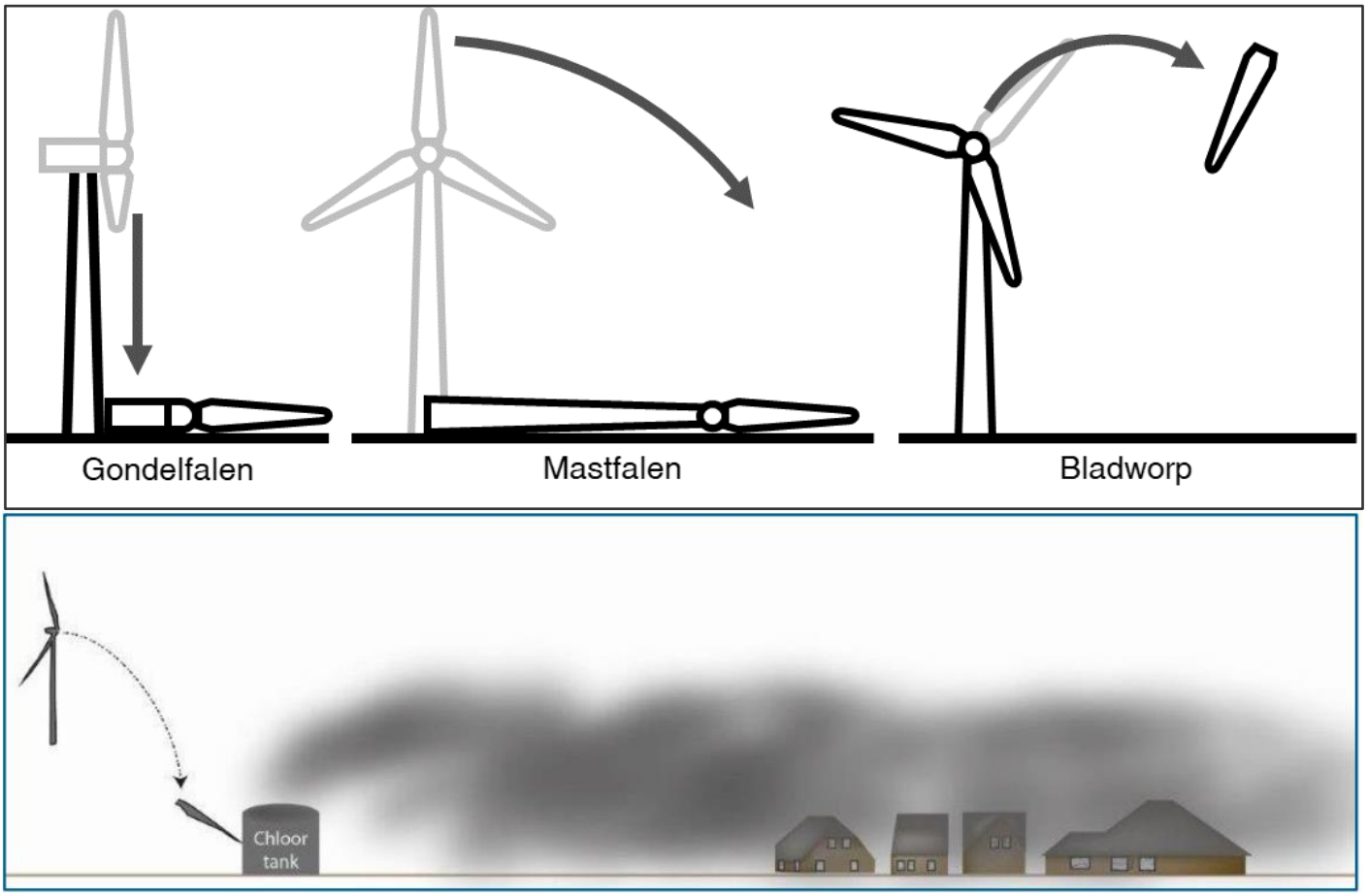

Figure 1 Visualisation of failure scenarios (above) and occurrence of knock-on effect (below) (source: Anteagroup - Wind turbines near high-risk businesses)

Gondelfalen	Nacelle failure
Mastfalen	Tower failure
Bladworp	Falling blade

Landscape & cultural history

Wind turbines affect the landscape and cultural history. The degree to which this happens can vary enormously depending on the location. In the Strategic Environmental Assessment, UNESCO World Heritage Sites and valuable landscapes have been examined. UNESCO World Heritage Sites are of outstanding universal value for humanity. In the Netherlands, the following World Heritage Sites are important for the effects of wind turbines: the Dutch Water Defence Lines, the Colonies of Benevolence, the Beemster Polder and Schokland. In addition, some landscapes are so valuable for the Netherlands that they deserve extra protection. Examples are the Green Heart, the Wadden Sea, the Southwest Delta, the Veluwe region, the IJsselmeer region and the national parks. Various developments, including the addition of new wind turbines, may have a negative effect on the valuable landscapes.

Nature

The state of Dutch nature has deteriorated over the past few decades. The biodiversity in protected natural areas is no longer decreasing, but is lower than it should be. The biodiversity in agricultural landscapes is still showing a downward trend. Therefore, nature conservation measures have been taken. The most severe nature conservation measure applies to Natura 2000 areas, which cover about 5700 square kilometres of land and waterways in the Netherlands, or about 15% of the country. Moreover, there are natural areas which are protected within the National Ecological Network of the Netherlands (‘NEN’ in short), which partly overlap with Natura 2000 areas but are also additional to them. The conservation status of protected species and habitats is key in the assessment of how Natura 2000 areas are doing. This is not yet going as it should, and there are several scenarios for how it will develop in the future.

For the effects of wind turbines, birds and bats are relevant. Birds and bats may die as a result of collisions with wind turbines, their lives may be disturbed, or larger wind turbine structures may form a barrier to them. Birds are protected under the European Birds Directive. The Netherlands is monitoring the development of 271 bird species. Half of these bird species are developing in a stable or positive way, while for the other half the trend is uncertain, unknown or deteriorating. Birds are under pressure from expanding cities, water management, infrastructure and agriculture. In the future, additional pressure will be caused by climate change, wind farms and solar farms. All bats are protected under the European Habitats Directive. They can be found in the whole of the Netherlands, in buildings, caves and forests and near large waterways. The number of bats is rising, and three quarters of the eleven bat species which are being monitored have been doing well since the mid-20th century, while three other species are showing a downward trend. The increase in the number of bats is thanks to better water quality, better protection and the increasing maturity of forests.

An important negative factor for nature quality is nitrogen deposition from the air. This causes eutrophication and acidification of the soil. As a result, some plant species are proliferating and are outcompeting other species, which has a negative effect on the biodiversity. The Strategic Environmental Assessment charts the level of nitrogen caused by the construction of wind turbines as well as the nitrogen reduction caused by the transition to fossil-free energy production.

Use of space

Eighty percent of the Dutch surface area is covered by so-called green and blue functions, like agriculture, waterways and nature. The other twenty percent is used for red functions (built-up areas and infrastructure). The ratio between green/blue functions and red functions varies greatly between provinces. Multi-purpose use of space is where a combination of activities take place in a certain location. When combined, the activities jointly take up less space than where they exist separately, adjacent to one another. If we think about multi-purpose use of space, wind energy can be combined with several other activities. This is a way to reduce the increasing pressure put on space.

Energy yield

In connection with the United Nations Paris Agreement, the Climate Act (*Klimaatwet* in Dutch) was adopted in the Netherlands. This Act is aimed at limiting global heating. Its goal is to significantly reduce carbon emissions. Wind energy plays an important role here. For wind energy, several objectives have been agreed on, like the realisation of a Dutch capacity of 6,000 MW in 2020. In addition, it was laid down in the Climate Agreement that in 2030, 35 TWh of energy will be generated through renewable electricity (large-scale onshore solar and wind farms).

The transition to sustainable energy generation using non-fossil fuels is continuing. This also means that more onshore wind turbines are expected to be installed. As a result of technological advances, these wind turbines are expected to have a better yield in the future, and to be safer and bigger. The growing number of wind turbines may conflict with other interests. For instance, it may lead to nuisance and risks for local residents, and to birds and bats colliding or experiencing disturbance. The production and installation of wind turbines cause nitrogen emissions, but the wind turbines subsequently eliminate nitrogen emissions that would otherwise have been caused by fossil power plants, for example.

2.1.2 Baseline 2: Local standards

For the determination of the local standards, use has been made of five practical situations where the competent authority has set standards without being able to use the original general rules. The way in which local authorities have dealt with standards for noise, external safety and shadow flicker for these wind farms gives an idea of the situation that will arise if the central government does not adopt any new wind turbine provisions. The general picture is as follows:

- The standards for noise, external safety and glare set by municipal and provincial authorities are the same as the general environmental rules which previously applied:
  - For noise: average annual noise for homes can amount to up to 47 dB L_{den}[2].
  - For external safety: A risk of one in a million for vulnerable objects and of one in 100,000 for moderately vulnerable objects.
  - For glare: Prevention of glare by fitting out wind turbines with non-reflective materials and coatings.
- Rotating blades can cause disruptive shadow flicker on sunny days. For shadow flicker, pausing operation of the wind turbine is required as of certain transgression levels, according to local rules. The interpretation by government authorities of which objects are affected by shadow flicker varies; some only consider homes, and others include offices as well. In addition, different limit values have been used for shadow flicker nuisance, ranging from up to 0 hours per year (i.e. never allowing shadow flicker nuisance) to up to 6 hours per year. In other words, there is a bandwidth in the standard. For the baseline, up to 6 hours of shadow flicker nuisance has been assumed in the Strategic Environmental Assessment.
- The general rules which were previously applicable did not include a distance standard. The five practical situations do not include any distance standards either.

2.1.3 Baseline 3: Reference turbines

For the determination of some effects, the size of the wind turbine matters. For this purpose, two reference turbines of different sizes have been used. The development of wind turbines is progressing rapidly. They are becoming more advanced and higher, and their capacity is increasing as well. This means that there is great variation in the axis height, rotor diameter and capacity of wind turbines. The growth in the size of onshore wind turbines is still limited at the moment, however, because it must be possible to transport the components by road. In the Strategic Environmental Assessment, the following two reference turbines have been used:

- A relatively small wind turbine with an axis height of 150 m, a rotor diameter of 170 m (85-m radius) and a tip height of 235 m. The tip height is the greatest distance from the ground reached by the blade.
- A relatively big wind turbine with an axis height of 180 m, a rotor diameter of 200 m (100-m radius) and a tip height of 280 m.

[2] L_{den} is a value for the annual average in which the noise level during the evening and the night is weighed more heavily due to the application of a 'supplement' of 5 dB and 10 dB, respectively. In practice, the actual annual average noise level is approximately 6 dB lower than the L_{den} value.

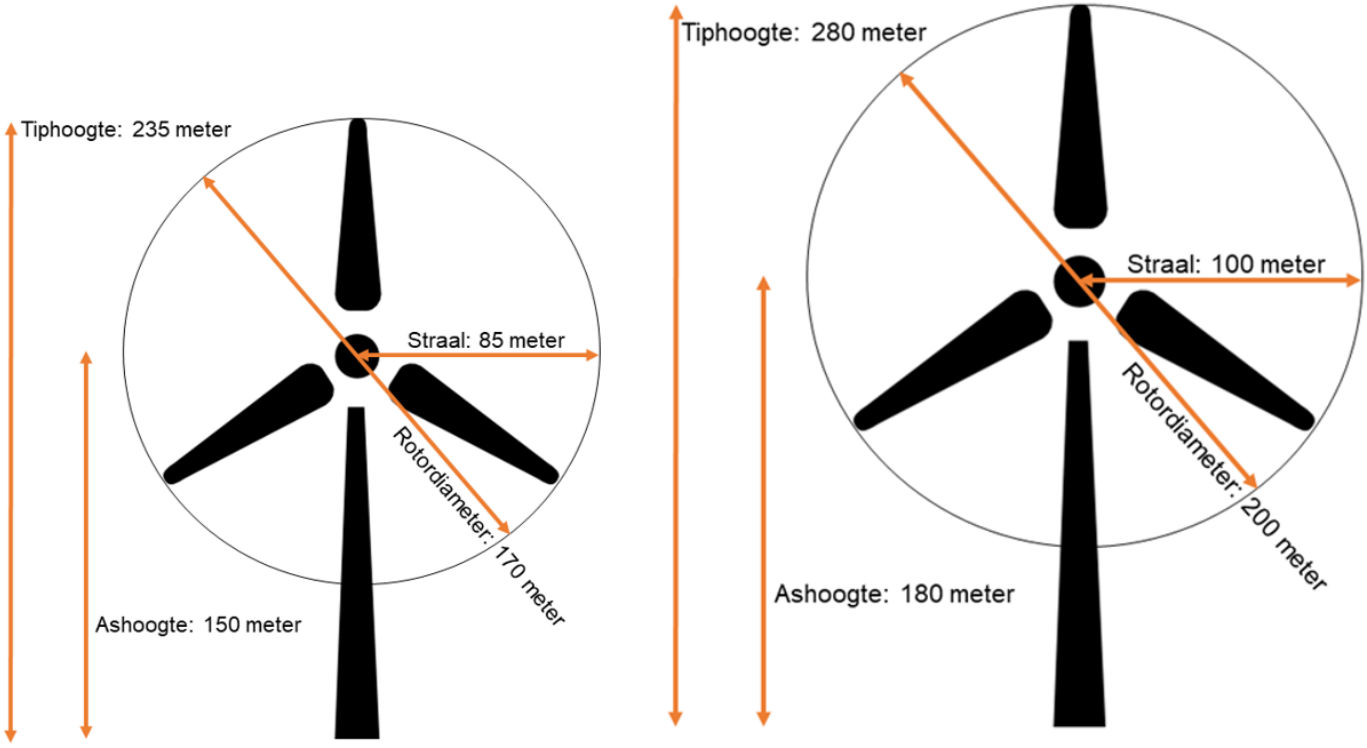

Figure 2 Reference turbines - small (left) and big (right)

Tiphoogte: 235 meter / 280 meter	Tip height: 235 meters / 280 meters
Ashoogte: 150 meter / 180 meter	Axis height: 150 meters / 180 meters
Straal: 85 meter / 100 meter	Radius: 85 meters / 100 meters
Rotordiameter: 170 meter / 200 meter	Rotor diameter: 170 meters / 200 meters

2.2 Alternatives and variants

In the Strategic Environmental Assessment it has been investigated whether the general rules for wind turbines should be different from the original rules of the Activities Decree. In addition to the general rules that applied previously, the Dutch central government also wanted to investigate distance standards in the Strategic Environmental Assessment, as was agreed in the Coalition Agreement from 15 December 2021, entitled *Looking out for each other, looking ahead to the future*[3]. The possibilities for a different definition of the general rules have been elaborated into alternatives and variants.

The Strategic Environmental Assessment serves as a substantiation of the new general rules. It needs to contain sufficient information to be able to take the environmental interest into account in the considerations for the new general rules. For this a clear delimitation is needed: what environmental effects and variants for standards should be investigated? This is what is referred to as ‘scope and level of detail’. Through public consultation, anyone could respond to the policy document on the proposed scope and level of detail. This resulted in 329 consultation responses and an advice from the Netherlands Commission for Environmental Assessment for the Strategic Environmental Assessment[4]. A great number of ideas were provided for the contents of the Strategic Environmental Assessment. The Dutch central government responded to these in a response memorandum (see footnote 1).

[3] For the Coalition Agreement, see: https://www.government.nl/documents/publications/2022/01/10/2021-2025-coalition-agreement
[4] For the advice from the Netherlands Commission for Environmental Assessment, see: https://www.commissiemer.nl/docs/mer/p36/p3615/a3615rd.pdf

In the Strategic Environmental Assessment the following alternatives and variants have been examined:

a. The **baseline**, where no new general rules are introduced. This is the situation that arose due to the judgment of the Council of State of 2021. Based on a number of practical situations it has been investigated what standards government authorities have used since the judgment of the Council of State, without being able to use the original general rules.
b. **Alternative with unchanged rules**, where the original general rules are reintroduced. These are:
    - A standard for the annual average noise for homes of up to 47 dB L_{den} and 41 dB L_{night}[5].
    - A standard for external safety with a location-based risk (the annual chance of one person dying due to an accident) of one in a million for vulnerable objects and one in 100,000 for moderately vulnerable objects.
    - Up to 17 days per year with more than 20 minutes of shadow flicker on vulnerable objects (homes).
    - No glare.
c. **Variants for noise**: Five different standards for the annual average noise for homes. The strictest standard is 37 dB L_{den} and the most lenient standard is 50 dB L_{den}. The Strategic Environmental Assessment has also investigated the added value of the use of an additional standard for low-frequency noise and tonal sounds (sounds with pure tones), an additional standard for the level of noise within homes (interior noise value), and the possibility for local deviations from a noise standard. These are called 'sub-variants' in the Strategic Environmental Assessment.
d. **Variants for external safety**: Two standards for external safety, i.e.:
    - The same standard for protection of vulnerable and moderately vulnerable objects of one in a million.
    - Consideration for knock-on effects caused by high-risk businesses or pipelines being hit in case of wind turbine accidents.
e. **Variants for shadow flicker**: Three variants, i.e. 0 hours, up to 6 hours and up to 16 hours of shadow flicker per year.
f. **Variants with distance standards**: There were no distance standards in the general rules. Three variants have been formulated, i.e. the distance from a wind turbine to a noise-sensitive object of 2, 3 and 4 times the tip height of the wind turbine. The tip height is the greatest distance from the ground reached by the blade.
g. **Variant for obstacle lighting**: To prevent disruptive lighting, a variant prescribing approach detection has been examined. If there is approach detection, the obstacle lighting will not come on unless an aircraft approaches the wind turbine.

2.3 Assessment: criteria, existing knowledge, by experts

To determine the effects of the alternative with unchanged rules (see under b above) and of the different variants (c to g), the assessment criteria from Table 1 have been used.

Table 1 Assessment framework

Topic	Assessment criterion	Assessment method
Health	Noise nuisance	Nuisance from noise, based on the increase or reduction in the statistical chance of serious nuisance.
Visual intrusion and light pollution	Nuisance due to obstacles	Visual intrusion caused by obstacles
	Nuisance due to shadow flicker	Nuisance caused by shadow flicker, based on the increase or reduction in the number of hours of shadow flicker per year.
	Light pollution	Light pollution caused by obstacle lighting based on the expected increase or reduction.
External safety	Vulnerable objects	Risk for vulnerable objects, based on an increase or reduction in the risk for a small or large number of vulnerable objects.
	Moderately vulnerable objects	Risk for moderately vulnerable objects, based on an increase or reduction in the risk for a small or large number of moderately vulnerable objects.
Landscape & cultural history	UNESCO World Heritage Sites	Impact on World Heritage, based on the increased or reduced chance of negative effects on World Heritage.
	Valuable landscapes	Impact on valuable landscapes (landscapes of national importance), based on the increased or reduced chance of negative effects on valuable landscapes.

[5] L_{night} concerns the annual average noise level during the night time.

Topic	Assessment criterion	Assessment method
Nature	Natura 2000 areas	Impact on Natura 2000 areas (European network of protected natural areas), based on the increased or reduced chance of negative effects on Natura 2000 areas.
	National Ecological Network of the Netherlands (NEN)	Impact on NEN (network of interconnected natural areas in the Netherlands), based on the increased or reduced chance of negative effects on NEN areas.
	Birds	Impact on birds, based on the increased or reduced chance of negative effects on bird populations.
	Bats	Impact on bats, based on the increased or reduced chance of negative effects on bat populations.
	Nitrogen emissions	Impact on nitrogen emissions during the production and installation phases and the usage phase, based on key figures for nitrogen emissions caused or avoided.
Use of space	Multi-purpose use of space	Impact on multi-purpose use of space (combination of spatial functions with wind turbines), based on the increase or reduction in opportunities for multi-purpose use of space.
Energy yield	Placement potential	The impact on the energy yield as a consequence of an increase or reduction in the placement potential of wind turbines on land.

The assessment was based on existing sources of information, i.e. an analysis of the available literature. Based on this information, experts determined or estimated the effect for every alternative/variant and compared this to the baseline (see under a above). If quantitative data were available (numbers, percentages, distance, etc.), these were used to substantiate the qualitative assessment. The effects were awarded a score on a scale of (+++) to (- - -).

It was not necessary to take every criterion into account for all variants. For each variant a selection of relevant assessment criteria was made. These criteria are set out in the overview below. Moreover, it was assessed whether an alternative or variant may have effects in other countries. Finally, the Strategic Environmental Assessment looks ahead at environmental effects that will occur in 2050 if the developments expected for that period do indeed take place.

Table 2 Variants matrix

Topic →		Health		Visual intrusion and light pollution			External safety		Landscape & cultural history		Nature					Use of space	Energy yield
Assessment criterion →		Percentage experiencing serious nuisance	Added value sub-variants noise	Visual intrusion caused by obstacles	Nuisance caused by shadow flicker	Light pollution	Vulnerable objects	Moderately vulnerable objects	UNESCO World Heritage Sites	Valuable landscapes	Natura 2000	NEN areas	Birds	Bats	Nitrogen emissions	Multi-purpose use of space	Placement potential
	Alternative with unchanged rules																
Topic																	
Noise	47 dB Lden / 41 dB Lnight	X							X	X	X	X	X	X	X	X	X
External safety	PR 10-6 for vulnerable objects / PR 10-5 for moderately vulnerable objects						X	X								X	X
Shadow flicker	< 17 days/year for up to 20 mins.				X											X	X
Glare	No glare																
	Variants in Strategic Environmental Assessment																
Topic	**Variant**																
Noise	37, 40, 43, 45, 50 dB Lden	X	X						X	X	X	X	X	X	X	X	X
External safety	Standard value PR10-6 for moderately vulnerable objects						X	X								X	X
External safety	Avoidance of knock-on effects						X	X								X	X
Shadow flicker	0, 6, 16 hours per year				X											X	X
Distance standard	2, 3, 4 times tip height	X		X	X		X	X	X	X	X	X	X	X		X	X
Obstacle lighting	Approach detection					X								X			

3 Assessment Scores

3.1 Alternative with unchanged rules

As an alternative, the Strategic Environmental Assessment includes the situation where the general rules will apply without any changes, as they were before the judgment of the Council of State. This is referred to as the 'alternative with unchanged rules'. The alternative with unchanged rules only differs from the baseline where it concerns shadow flicker. It is based on the original standard, which means that more than 20 minutes of nuisance due to shadow flicker may occur on up to 17 days per year.

The consequence for the alternative with unchanged rules is that more shadow flicker nuisance is permitted than in the baseline, because it turns out based on five recent wind projects that the competent authorities deviate from those original general rules on this aspect. They apply standards of 0 hours or, in the worst case, of up to 6 hours of shadow flicker per year. Of course it depends strongly on the local situation, but we can conceive of situations for the alternative with unchanged rules where 16 to 20 hours of shadow flicker occur each year. For this reason, the alternative with unchanged rules scores highly negatively (- - -) for nuisance from shadow flicker. When the standard for shadow flicker is exceeded, wind turbines must be taken out of operation. This leads to loss of production. Wind turbines are shut down less often in the scenario of the alternative with unchanged rules than in the baseline, because the baseline permits less shadow flicker. Based on shadow flicker studies for ten wind farms, it has been examined what the possible loss of production amounts to. This has shown that the energy yield compared to the baseline may be 0.1 to 0.4 percent higher. Therefore, the alternative with unchanged rules scores slightly positively (+) for energy yield.

For all other criteria there is no difference with the baseline. In other words, the other environmental effects of the alternative with unchanged rules are neutral (0) compared to the baseline.

3.2 Noise variants

The noise standards may become more lenient (noisier) or stricter (quieter) than the standard for the annual average of the baseline (47 dB L_{den}). Four stricter noise standards and one more lenient noise standard for homes have been examined. The strictest standard is an annual average of 37 dB L_{den} and the most lenient standard is an annual average of 50 dB L_{den}. In addition to the TNO study from 2008 into the relation between wind turbine noise and nuisance, a more recent study by Health Canada from 2016 has also been used to determine the impact. Besides the data from the TNO study, this study includes more local residents of multiple wind farms. Up to an annual average noise level of 40 dB L_{den}, the results of the two studies are similar. As of an annual average noise level of over 40 dB, however, the study from 2016 shows slightly less nuisance on average than the TNO study from 2008, although the difference does fall within the margins of uncertainty of the studies. An American study from 2019 shows the same result as the Canada Health study from 2016. On the other hand, a recent study by the Dutch National Institute for Public Health and the Environment (RIVM) from 2022 seems to point to similar nuisance or slightly more nuisance than in the TNO study from 2008.

At a noise level for the home that is equal to the strictest standard for annual average noise examined of 37 dB, the statistical chance of serious nuisance within the home and outside it decreases by approximately 90% compared to the baseline. This results in a highly positive score (+++). If the noise burden is equal to the most lenient standard for annual average noise examined of 50 dB, the chance of serious nuisance increases by approximately 80% for within the home, and for outside the home it increases by approximately 40% (Health Canada study from 2016) to 60% (TNO study from 2008), so the score is highly negative (- - -).

For the aim of reducing noise nuisance, a stricter noise standard is therefore favourable. However, this does not apply to a number of other assessment criteria. The stricter the noise standard becomes, the more limited the placement potential for wind turbines will be. This leads to a greater risk in case of installation near UNESCO World Heritage sites and valuable landscapes, fewer opportunities for multi-purpose use of space, and a lower energy yield. Therefore, the scores for these criteria are opposite to those for the statistical chance of serious noise nuisance caused to residents. Stricter noise standards also cause higher risks for Natura 2000 areas, for birds and for bats. But because greater statutory protection applies to nature, this can never have more than a slightly negative effect (-).

It has also been investigated whether the imposition of additional noise standards may offer added value.

- Low-frequency noise. An additional standard for low-frequency noise has been assessed as having a slight added value in case of a noise standard of 43 dB L_{den} or louder. This is because the effect of low-frequency noise has already been taken into account in the 'regular' noise and the corresponding links with nuisance, but a standard for low-frequency noise will offer assurance against a possible shift in the noise spectrum towards lower frequencies. It will also ensure that for the turbine selection, the share of low-frequency noise will be taken into account more.
- Tonal sounds. A 'supplement' for wind turbine sounds which are tonal in nature offers extra protection in all noise variants and helps avoid problematic situations. Tonal sounds cause more disturbance than regular sounds. By applying a 'supplement', account is taken of this by attaching more weight to tonal sounds.
- Interior value. In addition to the façade standard, it has been investigated whether standard setting for noise within the home offers added value. If a limit value of 50 dB is used for the average annual noise, this offers a great added value, and if the limit value is 47 dB, it offers a slight added value. In case of an annual average limit value of 45 dB or less, a standard for interior noise will not offer any added value, not even for poorly insulated homes.
- Differentiated standards. Finally, it has been examined what the added value is of having a standard for noise depend on situations, such as population density of the area or the existing ambient noise. This does not provide a uniform picture. By means of custom solutions, local authorities may make their own assessment based on a specific situation.

3.3 Variants for external safety

Two standards for external safety have been examined. The first standard involves equal protection of vulnerable and moderately vulnerable objects of one in a million. The second standard takes account of knock-on effects that arise when high-risk businesses or pipelines are hit in case of a wind turbine accident.

The first standard involves equal protection of vulnerable and moderately vulnerable objects of one in a million. For moderately vulnerable objects this is in the form of a standard value, which means that authorities may deviate from the standard or apply it less strictly. This variant scores slightly positively (+) for moderately vulnerable objects. The second variant, where knock-on effects are avoided, offers extra protection for vulnerable objects compared to the baseline. This results in a slightly positive score (+).

The possibilities for multi-purpose use of space are slightly under pressure with the assessed variants for external safety, because the placement potential near businesses may be reduced (0/-). In addition, the energy yield may be reduced slightly or very slightly in case of the variant with equal protection of vulnerable and moderately vulnerable objects of one in a million (0/-).

3.4 Variants for shadow flicker

Three variants have been examined, i.e. 0 hours, up to 6 hours and up to 16 hours of shadow flicker per year.

The judgment of the Council of State has not resulted in a uniform baseline for shadow flicker. Different municipal and provincial authorities use different standards for shadow flicker, varying from 0 hours to 6 hours of shadow flicker per year. The decision has been made to assess the effects compared to the upper limit of the bandwidth of the baseline, i.e. compared to a shadow flicker duration of 6 hours per year.

For nuisance due to shadow flicker, the variant of 0 hours per year scores highly positively (+++). The variant of 6 hours per year has been given a neutral score (0), because it is the same as in the baseline. The variant with the greatest amount of shadow flicker, i.e. 16 hours, scores highly negatively (- - -). The variants do not affect the opportunities for multi-purpose use of space, because any shadow flicker nuisance can be resolved by means of a shut-down provision, which is why it has been assessed as being neutral (0).

Shadow flicker standards may affect the energy yield if the turbine is shut down as a consequence of the occurrence of shadow flicker. Based on shadow flicker studies for ten wind farms, it has been examined what the possible loss of production amounts to. For the limit value variant of 0 hours per year, the loss of production is 0.1 to 0.6% higher than in the baseline. For this reason, this variant scores slightly negatively (-). The limit value variant of 6 hours per year is equal to the baseline and is therefore assessed as being neutral (0). A standard of 16 hours per year results in a lower loss of production of 0.1 to 0.3% compared to the baseline. For this reason, the standard of 16 hours per year scores slightly positively (+).

3.5 Variants for distance standards

Distance standards did not exist in the general rules that applied before the judgment of the Council of State. Three variants have been formulated, i.e. the distance from a wind turbine to noise-sensitive objects of 2, 3 and 4 times the tip height of the wind turbine. When the two reference turbines are used, this results in the following bandwidths for absolute distances: 2 times the tip height (= 470-560 m), 3 times the tip height (= 705-840 m) and 4 times the tip height (= 940-1120 m).

The link between visual intrusion caused by wind turbines and distance to wind turbines is not clear-cut. The reason for this is that several factors, which are interrelated, are relevant for visual intrusion. Based on the existing literature, it is not possible to form a clear-cut picture of when the effects of visual intrusion are greater or smaller.

For noise nuisance, the introduction of a distance standard alone will not offer the same level of protection for all local residents, unlike a noise standard. Depending on the situation, the introduction of a distance standard alone may lead to more nuisance or rather to less. Therefore, the score consists of a broad bandwidth for 2 times the tip height (- - - to +), 3 times the tip height (- to +++) and 4 times the tip height (++ to +++).

The assessment of shadow flicker demonstrates that for 2, 3 and 4 times the tip height, the maximum amount of shadow flicker to occur will be 72, 47 and 35 hours, respectively. The maximum here means the shadow flicker duration in the location with the least favourable orientation in relation to the wind turbines. For the aforementioned reasons, all variants for distance standards score highly negatively (- - -).

For the assessment of external safety, the introduction of distance standards may result in positive effects for vulnerable objects and moderately vulnerable objects. With all variants, the use of a distance standard results in a negligibly small risk for vulnerable objects (positive score of ++) and for moderately vulnerable objects (highly positive score of +++). However, it should be noted here that distance standards have been assessed in comparison to vulnerable objects and moderately vulnerable objects and not to noise-sensitive objects (as is the case for the other assessment criteria).

Distance standards reduce the placement potential for wind turbines. This means that the chance of negative effects on UNESCO World Heritage Sites and valuable landscapes in the remaining areas increases in case of 3 times the tip height (slightly negative score of -) and 4 times the tip height (highly negative score of - - -). The opportunities for multi-purpose use of space are reduced, which results in a negative score (- -) in case of 3 times the tip height and a highly negative score (- - -) in case of 4 times the tip height. Nature is affected negatively as well in case of 3 and 4 times the tip height. This effect is slightly negative (-) at most, due to the applicable legal requirement to protect nature. For the energy yield, a reduction in the placement potential for 3 times the tip height leads to a negative effect (- -) and for 4 times the tip height it leads to a highly negative effect (- - -).

3.6 Variant for approach detection

Approach detection makes it possible to switch on the obstacle lighting only when an aircraft is approaching. Tests at three wind farms (Flevoland, Windpark Fryslân and Krammer) have shown that the obstacle lighting can remain off for about 95% of the time.

For light pollution (for people), the variant with approach detection therefore scores highly positively (+++) compared to the baseline where the obstacle lighting stays on the whole time. Some bat species are sensitive to light disturbance. These species are expected to experience less nuisance from obstacle lighting in case of approach detection. (A lot is as yet unclear about light effects for bats.) This variant scores slightly positively (+) compared to the baseline.

3.7 Mitigating measures

If any negative effects have been observed, it is customary in strategic environmental assessments to try and find measures to reduce those effects. These are so-called mitigating measures. In the search for mitigating measures, it should concern other measures than those which are already covered by a variant in the Strategic Environmental Assessment.

A possible mitigating measure is to involve local residents at an early stage of the development of wind farms, to inform them about the noise to be expected and its possible effects. Measures to be taken to reduce nuisance from noise (and other sources) for local residents should be addressed here as well. Another possible mitigating measure with regard to bird migration is the use of shut-down provisions. This means that wind turbines are taken out of operation in periods when there is a high risk of collision victims, like the autumn migration period.

3.8 Cross-border environmental consequences

The wind turbine provisions may have environmental consequences in Belgium or Germany. For some criteria it has been determined that such effects may occur:

- Noise nuisance may occur at homes along the border.
- Cross-border shadow flicker from wind turbines on Dutch soil may occur in case of low sun.
- Vulnerable objects across the border may be at risk in relation to external safety.
- Landscapes of high cultural/historic significance near the border may be affected negatively.
- Certain qualities of nature may be affected. This mainly concerns flight behaviour of birds and bats.

For the following criteria, it has been concluded based on key figures and available data that cross-border environmental effects are not expected to occur:

- Safety effects for moderately vulnerable objects.
- UNESCO World Heritage Sites are not at risk, because installation near such sites across national borders will not take place for reasons of nature conservation.

Moreover, nitrogen emissions, multi-purpose use of space and energy yield have been evaluated in the Strategic Environmental Assessment only for Dutch territory.

4 Conclusions

4.1 Overview of scores

The overview of all scores can be found in Table 3.

Table 4 shows whether and, if so, when the addition of a standard for low-frequency noise, tonal sounds or an interior noise value offers added value in terms of protection. Low-frequency sounds penetrate homes more easily than other sounds. As a result the interior noise value is largely determined by low-frequency noise. An interior noise value standard therefore also has a positive effect on the management of low-frequency noise. Similarly, a standard for tonal sounds also positively affects the management of low-frequency noise. After all, complaints about low-frequency noise generally concern tonal low-frequency sounds. This cross-fertilisation, as it were, has not been taken into account in the assessment.

Table 3 Scores for alternative with unchanged rules and several variants for wind turbine provisions

Topic →		Health	Visual intrusion and			External safety		Landscape & cultural history		Nature					Use of space	Energy yield
Assessment criterion →		Percentage experiencing serious nuisance	Visual intrusion caused by obstacles	Nuisance caused by shadow flicker	Light pollution	Vulnerable objects	Moderately vulnerable objects	UNESCO World Heritage Sites	Valuable landscapes	Natura 2000	NEN areas	Birds	Bats	Nitrogen emissions	Multi-purpose use of space	Placement potential
	Alternative with unchanged rules															
Topic																
Noise	47 dB Lden / 41 dB Lnight	0						0	0	0	0	0	0	0	0	0
External safety	PR 10-6 for vulnerable objects / PR 10-5 for moderately vulnerable objects					0	0								0	0
Shadow flicker	< 17 days/year for up to 20 mins.			---											0	+
Glare	No glare															
	Variants in Strategic Environmental Assessment															
Topic	**Variant**															
Noise	37 dB Lden	+++						---	---	-	-	-	0	0	---	---
Noise	40 dB Lden	+++						---	---	-	-	-	0	0	---	---
Noise	43 dB Lden	++						--	--	-	-	-	0	0	--	--
Noise	45 dB Lden	++						-	-	-	-	-	0	0	-	--
Noise	50 dB Lden	---						+	+	+	+	+	0	0	+	++
External safety	Standard value PR10-6 for moderately vulnerable objects					0	+								0/-	0/-
External safety	Avoidance of knock-on effects					+	0								0	0
Shadow flicker	0 hours per year			+++											0	-
Shadow flicker	6 hours per year			0											0	0
Shadow flicker	16 hours per year			---											0	+
Distance standard	2 times tip height	+/---	n.a.	---		++	+++	+	+	0	0	0	0		0	0
Distance standard	3 times tip height	+++/-	n.a.	---		++	+++	-	-	-	-	-	0		--	---
Distance standard	4 times tip height	+++/++	n.a.	---		++	+++	---	---	-	-	-	0		---	---
Obstacle lighting	Approach detection				+++								+			

Table 4 Added value assessment for sub-variants for low-frequency noise, tonal sounds and interior noise value

Limit value	Standard for low-frequency noise	Standard for tonal noise	Standard for interior noise value
37 dB L_{den}	No added value	Slight added value	No added value
40 dB L_{den}	No added value	Strong added value	No added value
43 dB L_{den}	Slight added value	Strong added value	No added value
45 dB L_{den}	Slight added value	Strong added value	No added value
47 dB L_{den}	Slight added value	Strong added value	Slight added value
50 dB L_{den}	Slight added value	Strong added value	Strong added value

4.2 Knowledge gaps

For the Strategic Environmental Assessment, use has been made of information that is needed for the determination of national wind turbine provisions. Detailed information on a local level has not been incorporated into the Strategic Environmental Assessment. Such information is suitable for impact assessments on a local (or project) level.

In the Strategic Environmental Assessment it has been assessed whether there are any knowledge gaps that have consequences for decision-making on a national scale. The conclusion is that sufficient information is available to make a decision on the wind turbine provisions.

4.3 Evaluation and monitoring

The system of policy evaluations and policy reviews based on them will help verify later on whether the wind turbine provisions have achieved their goals. More information can be found on the website https://www.rijksfinancien.nl/beleidsevaluatie (only in Dutch).

It is important to monitor the emergence of new insights. These insights may lead to re-evaluation and possible amendment of the standards later on. The following topics are addressed in the Strategic Environmental Assessment for the Monitoring of Wind Turbine Provisions for the Living Environment:

- The periodic performance of nuisance studies by RIVM.
- The periodic determination of wind distribution in the Netherlands by RIVM.
  The growth in the size of wind turbines affects external safety, so that it may be necessary to monitor this and to amend the external safety standard in the future where necessary.

4.4 Next steps

draft wind turbine provisions. Anyone can provide an opinion on both the Strategic Environmental Assessment and the draft provisions. For this, see: National Wind Turbine Provisions For The Living Environment - Participation Platform (only in Dutch). The Netherlands Commission for Environmental Assessment is also reviewing the Strategic Environmental Assessment for its quality and completeness.

The Strategic Environmental Assessment does not determine which choices should be made. After the new wind turbine provisions have been discussed by the Dutch Parliament and after the Council of State has issued its advice, the Dutch government will adopt them.

Colophon

SUMMARY OF STRATEGIC ENVIRONMENTAL ASSESSMENT FOR WIND TURBINE PROVISIONS FOR THE LIVING ENVIRONMENT

CLIENT
Dutch Ministry of Infrastructure and Water Management

AUTHOR
Frans Dotinga

PROJECT NUMBER
30104033

OUR REFERENCE
75A7XHNEZ3QT-893184518-32:1.0

DATE
5 April 2023

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www.arcadis.com

Arcadis Nederland B.V.

P.O. Box 1018
5200 BA 's-Hertogenbosch
The Netherlands

T +31 (0)88 4261 261

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