Expert judgement on the underpinning of the maximum calculation distance in project-specific calculations of nitrogen depositions

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Summary

When using a model for a specific (policy) goal, it must first be determined what the scientific application range of a model is. The application range indicates where the model can make reliable statements (given the purpose for which the calculation results are used). If the results are too uncertain (there is a 'false certainty'), then the model is insufficiently reliable (not valid) for use. There is always a limit to a model. In the context of air quality and deposition modelling of individual sources, 25 km is a scientifically accepted limit. Uncertainties in nitrogen deposition calculations increase with increasing distance beyond 25 km from the source. Calculation results at a distance greater than 25 km are scientifically insufficiently reliable for use in decision-making (the model system is then not fit for purpose). Theoretical and empirical considerations, the agreement with other models and peer consensus do not allow room for policy – due to false certainty – to scientifically calculate nitrogen depositions from individual sources beyond that distance at a resolution of 1 ha.

Introduction

I have been asked for an independent expert judgement on the way in which the maximum calculation distance of 25 km has been substantiated in project-specific calculations of nitrogen depositions. First of all, I must state that although my broad scientific background also includes boundary layer meteorology, atmospheric chemistry and (large-scale) dispersion modelling, the requested expertise on my part here is mainly on methodology of science and philosophy of science.[1] Naturally, my background in natural sciences does help with the substantive assessment of the discussion.

What struck me in the exchange of documents in the context of the appeal procedure before the Council of State regarding the Route Decision ViA15 is that the appellants and also the STAB (Foundation of Independent Court Experts in Environmental and Planning Law) are not prepared to recognise the major uncertainties in model calculations of nitrogen deposition at a spatial resolution of 1 ha further than 25 km from an individual source. *For experts on this subject, it is abundantly clear that this uncertainty is large and increases with distance.*[2] I see no reason whatsoever to doubt the judgment of the experts[3] involved on

[1] I have had no involvement in my career with the development of the models under discussion here (mainly because these models are not managed by the PBL Netherlands Environmental Assessment Agency).

[2] This expert judgement, incidentally, has a history of several decades and therefore does not so much concern *new* knowledge.

[3] In the various documents, the experts come from both RIVM (National Institute of Public Health and the Environment) and TNO (Netherlands Organisation for Applied Scientific Research). The independent experts

this point and, given my own scientific expertise, I can also follow what this expert judgment is based on. However, what is taking its toll – and I also encountered this in my evaluation of the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) (see Meyer and Petersen 2010) – is that expert judgements that play an important role at the interface between science and decision-making are often difficult to follow (insufficiently transparent)[4] for decision-makers and other parties involved (including judges) or even for scientists in related fields. This explains the repeated lamentations on the part of the STAB that they cannot follow how the experts arrived at their judgement and the irritated reactions from TNO that the STAB has not understood them properly and does not understand how science works. I hope that my expert opinion contributes to a clearer understanding of what can be responsibly asked of scientific models.

What is important to understand in this dossier is that meteorologists and air quality modellers often draw the line between results that are just reliable and results that are just not reliable for drawing conclusions at a relative uncertainty of a factor of two (i.e., that the modelled value is between –50% and +100% of the actual value).[5] This is evident from the documents of both RIVM and TNO, from documents from experts from the United Kingdom (Derwent et al. 2010) and the European Union (Denby et al. 2011) and from the fact that in scientific literature on air quality regularly a so-called 'FAC2' indicator (the percentage of calculations that are within a factor of two of the observations) is used to assess the reliability of results. A relevant anecdote from my first doctoral research – on which I reflected from the perspective of philosophy of science in my second doctoral research – confirms the value that certain scientific practices attach to an accuracy of a factor of two. It concerns the public defence of my thesis (Petersen 2006, 2–3; 2012, 2–3):

> On June 7, 1999, I publicly defended my doctoral dissertation "Convection and Chemistry in the Atmospheric Boundary Layer." In this dissertation, the main body of which consisted of three journal articles based on computer simulation, I argued that one of the uncertainties in regional and global computer models of air quality was significantly smaller than was previously thought. Formerly, it was not known whether the influence of turbulence on chemical reactions in the atmospheric boundary layer could be neglected. I, together with my colleagues from the Institute for Marine and Atmospheric Research Utrecht (IMAU), using a hierarchy of computer models, had shown that this neglect was allowable. One of the opponents, Professor Frans Nieuwstadt of Delft University of Technology, sternly questioned me about the reliability of my research results until he was satisfied with my final answer that I was confident about my research results only within a factor of two. [*] His main problem with the work was that only simulation models of different complexity had been compared with each other, and no comparison had been made with experimental or observational data. My contention was that the most complex simulations that I had done using the

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who were on the Hordijk Committee (Advisory Committee on Measuring and Calculating Nitrogen) also share this opinion.

[4] In the PBL evaluation of the relevant IPCC report, we defined an expert assessment as insufficiently transparent 'when we could not trace the reasoning behind a statement [in the summary] from underlying texts or literature references given' (Meyer and Petersen 2010, 15). Incidentally, in that evaluation, with the help of the original IPCC authors, we succeeded in providing sufficiently transparent underpinning for all expert judgements that were initially found to be insufficiently transparent.

[5] This can be formulated even more precisely. For example, Derwent et al. (2010, 15) state that if at a certain distance the majority of results deviate from reality by more than a factor of two, the model is not valid beyond that distance.

national supercomputer of the Netherlands were more reliable for answering my research questions than were any of the sparse experimental or observational results reported in the literature. This was judged by Professor Nieuwstadt to be a 'medieval position'. I disagreed since the large-eddy simulation (LES) model that I had used had been rigorously compared with experimental and observational data. † The only thing I had done, I claimed, was to apply this model to a somewhat different problem, which was extremely difficult to approach experimentally or observationally. After this minor public controversy, the episode ended well since the doctorate was awarded by the committee without any objections. ‡

* This accuracy was high enough for drawing the conclusions that I wanted to draw.
† On this, Professor Nieuwstadt had to agree. Although I did not bring this into the discussion, I knew that Nieuwstadt was well aware of this fact since the LES model was his.
‡ For those unfamiliar with the Dutch university system, as in many other countries, PhD students are admitted to defend their dissertation only after an assessment committee has approved it. Nieuwstadt, who was an external member of this committee, had already approved it.

Only when I indicated that my results were reliable within a factor of two was it scientifically regarded as ‘reliable enough’ for the research purpose at hand.

In my expert judgement on the underpinning on of the maximum calculation distance in project-specific calculations of nitrogen depositions, I will, as transparently as possible:

1. Reflect on the importance of delineating the application range of scientific models, especially when they are used in decision-making. I place this in the context of dealing responsibly with uncertainties as codified in the Guidance for Uncertainty Assessment and Communication.
2. Judge on the underpinning of using a maximum calculation distance of 25 km in project-specific calculations of nitrogen depositions.
3. Respond (briefly) to the main points raised by the STAB, in the light of 1 and 2.

1. Guidance for Uncertainty Assessment and Communication: Scope of application of scientific models

A good starting point for the discussion on how to deal with uncertainty at the interface between science and decision-making (in the context of policy-making or licensing – and with a focus on the scope of application of scientific models) can be found in the *Guidance for Uncertainty Assessment and Communication*, originally published in 2003 (Petersen et al. 2003; Janssen et al. 2003; Petersen et al. 2013) and in the report *Dealing with Uncertainty in Policymaking* (Mathijssen et al. [2007] 2008). These documents represent the state-of-the-art in dealing with uncertainties in science and policy. The Guidance for Uncertainty Assessment and Communication has been developed for use by scientists in the environmental domain,[6] in the Netherlands and abroad.[7] The Group of Chief Scientific Advisors of the European Commission’s Scientific Advice Mechanism has explicitly

[6] The Guidance for Uncertainty Assessment and Communication can be applied more broadly than just in the environmental domain.
[7] The first phase of development took place at the RIVM and further development took place later at the PBL.

recommended the Guidance approach for wide use in decision-making based on scientific input (European Commission 2019, 46–49).

The scientist-focused Guidance for Uncertainty Assessment and Communication pays particular attention to the following six key points:

1. How is the problem framed; which contextual factors are included/excluded?
2. What are the main parties (stakeholders/ actors) involved; what are their views, roles, stakes and involvement with respect to the problem, and what would be the added value of involving certain stakeholders in the study?
3. What are the main indicators/visualisations used in this study and how do these relate to the problem definition?
4. How adequate is the knowledge base that is available for the study?
5. What are the uncertainties relevant to this problem and what is their nature and location?
6. How is uncertainty information communicated?

All these points are important for scientists who develop models in the context of policy-making or licensing and make calculations with their models in order to reach reliable statements based on these models.[8] There is no general 'guidance' available for policy-makers and other decision-makers, although there is a need for one:

> Policymakers are faced with a dilemma: on the one hand, they are expected to base their decisions on clear, measurable facts, while, on the other hand, they are confronted with developments that give rise to uncertainties as a result of variable and unpredictable processes. (Mathijssen et al. [2007] 2008, 9)
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> The exchange of experiences and best practices [in the conference 'Dealing with Uncertainty in Policymaking' of 16 and 17 May 2006] was expected to provide some guidance for dealing with uncertainty in policymaking. It turned out that we were aiming too high, because of the complexity of the issues involved and the great diversity in policy environments, policy questions, types of uncertainty and experiences. (Don [2007] 2008, 5)

Of course, the complexity of decision-making does not absolve decision-makers and other parties involved from the duty to ascertain, in particular, the scope of application of the models used. They should encourage scientists to deal responsibly with uncertainty in the context of decision-making. One of those responsibilities is not basing decisions or having them based on results that are too uncertain according to the scientists involved (where that limit lies is exactly what the discussion is about, see the next section).

There are several examples of scientists and consultants who have contributed to dealing irresponsibly with uncertainties, for example by offering quasi-certainties ('false certainties'), quantifying non-quantifiable uncertainties, providing point estimates instead of ranges, believing in their own models and analyses and applying knowledge outside the

[8] 'Reliability' has three dimensions: (1) statistical reliability ('confidence intervals'), (2) methodological reliability, and (3) public reliability (Smith and Petersen 2014, 142–47). Each of these three dimensions plays a role in public discussions about 'the' reliability of models for policy-making or licensing. I will discuss methodological reliability in more detail below.

range of phenomena for which it has been validated (Petersen and Van Asselt [2007] 2008, 64). From a scientific point of view, this needs to change.

UNCERTAINTY MATRIX			Level of uncertainty *(from determinism, through probability and possibility, to ignorance)*			Nature of uncertainty		Qualification of knowledge base (backing)			Value-ladenness of choices		
Location ↓			Statistical uncertainty (range+ chance)	Scenario uncertainty (range as 'what-if' option)	Recognized ignorance	Knowledge-related uncertainty	Variability-related uncertainty	Weak –	Fair 0	Strong +	Small –	Medium 0	Large +
Context		Ecological, technological, economic, social and political representation											
Expert judgement		Narratives; storylines; advices											
Model	Model structure	Relations											
Model	Technical model	Software & hardware implementation											
Model	Model parameters												
Model	Model inputs	Input data; driving forces; input scenarios											
Data (in general sense)		Measurements; monitoring data; survey data											
Outputs		Indicators; statements											

Table 1. Uncertainty matrix (Janssen et al. 2003, 16; Petersen [2007] 2008, 17; Petersen et al. 2013, 27). See Petersen et al. (2013, 29–32) for a concise explanation of all dimensions in the uncertainty matrix and Petersen ([2006] 2012) for a philosophical discussion.

The Guidance for Uncertainty Assessment and Communication is intended as an 'antidote' to this tendency of many scientists (which, incidentally, they mainly give in to under pressure from decision-makers)[9] and thus forms the basis for carefully dealing with uncertainties in decision-oriented scientific research (Petersen et al. 2013, 6). It is not only important for scientific research itself to know where uncertainties are located (in model studies, for example, in the 'model structure', the 'model parameters', the 'model inputs' or the 'technical model', see table 1). At the interface between science and decision-making, this then mainly concerns assessing the impact of uncertainties on specific model results and conclusions based thereon (including on the scope of application of the models in the specific decision-making context). And that is why it is important to have an idea of the reliability of a model *for a certain purpose* (see also Smith and Petersen 2014, 137). And even before that: 'When building the model, it is important when selecting model components to take into account the policy-related requirements and the circumstances of the specific policy problem' (Hordijk [2007] 2008, 54).

In Guidance terminology, the assessment of the methodological reliability of a scientific model involves giving a 'qualification of the knowledge base (backing)' (see table 1). This concerns 'the degree of underpinning of the established results and statements' (Petersen et al. 2013, 31). If the qualitative classification 'weak' is given, then this is an indication 'that

[9] Fear of being held responsible for something can also play a role. However, scientists have a social responsibility to monitor what is done with their results, to advise on this and to warn against misuse.

the statement of concern is surrounded by much (knowledge-related) uncertainty, and deserves further attention' (Petersen et al. 2013, 31).[10] To determine the qualification of the knowledge base, '[c]riteria such as empirical, theoretical or methodological underpinning, and acceptance/support within and outside the peer community may be used' (Petersen et al. 2014, 32). A so-called 'pedigree analysis' can be used for this:

> Pedigree analysis is an analysis that evaluates the 'strength' or scientific status of a figure [number, ap]. Pedigree literally means 'genealogy', 'origin' or 'background': how did the figure originate and does it have a good background? Two aspects are considered here: how does a figure (in a conclusion) come about and what is its scientific status, and how is it substantiated?
>
> Criteria that may be used in the pedigree analysis for evaluating a model include 'proxy' (degree of directness of the indicator applied), 'quality and quantity of empirical basis', 'theoretical basis', 'representation of the system's underlying causal mechanisms', 'plausibility' and 'degree of consensus'. (van der Sluijs [2007] 2008, 25–26)

Pragmatic choices also play a role in determining whether a model is 'good enough' for a particular purpose (for example, the budget and time available must be used efficiently). In terms of the 'uncertainty matrix' this can be seen as one of the dimensions of the value-ladenness of choices regarding the model.[11]

To give an example of problematic use of models in a domain other than nitrogen deposition (this example deals with false certainties and the use of climate models outside their scope of application): in 2009 the United Kingdom published very high-resolution probability predictions of various variables from climate change to the end of the 21st century at the postcode level (the United Kingdom Climate Projections 2009–UKCP09), and actors in policy-making and licensing were subsequently required to use these overly detailed and completely uncertain probability predictions (far beyond the scope of what climate models can calculate reliably). This misuse of models has been strongly criticised by several scientists and philosophers of science (including myself) (e.g., Smith and Petersen 2014; Frigg et al. 2015; Thompson et al. 2016). While scientists who understand the models know that the models are not valid and can also conclude this from the background report, this does not automatically apply to the users:

> A scientist reading through the report will find what appears to be clear evidence that the UKCP09 probabilities should not be taken at face value as probability statements about the real world; red flags to a scientist might not be so obvious to non-scientists. (Smith and Petersen 2014, 151)

A false sense of certainty also quickly arises in the case of model calculations of nitrogen deposition resulting from individual projects. In the remainder of this expert judgement, I will focus on the main question at hand, namely whether the calculation of high-resolution

[10] The Guidance emphasises that the qualification of the knowledge base is always given in the context of the purpose of using the knowledge and therefore never about a model detached from the context.
[11] The following dimensions of 'value-ladenness of choices' can be distinguished: general epistemic values, discipline-bound epistemic values, sociopolitical values and practical values (Petersen 2006, 50; 2012, 51).

nitrogen deposition beyond a maximum calculation distance in the context of granting licenses for individual projects leads to false certainty and is not fit for purpose.

2. Judgement on the underpinning of using a maximum calculation distance of 25 km for project-specific calculations of nitrogen depositions

The Hordijk Committee (the Advisory Committee on Measuring and Calculating Nitrogen) published its first report on 5 March 2020 (*Not Pulled from the Air*). It concluded in the summary:

> The OPS model is suitable for modelling nitrogen dispersion on a local scale. On a regional and national scale, the influence of other processes (chemical conversion, long-range transport, meteorology) is increasing, and with it the uncertainty. (Advisory Committee on Measuring and Calculating Nitrogen 2020a, 5)

The uncertainties in calculations with the OPS model are not easy to determine (either quantitatively or qualitatively) and where in the context of national nitrogen policy errors can be averaged out and a calibration can be applied due to the difference between measurements and model results (which reduces the uncertainties) this is not the case in the context of project-specific calculations. Where exactly the suitability of the model ends (what distance corresponds to 'local scale'?) depends of course on the application. It has been established on scientific grounds that this distance becomes smaller as fewer emission sources are modelled, because there is then less averaging of errors (for an illustration, see TNO 2022b, 21–22). However, the Hordijk Committee finds that 'too little structural research is being done into uncertainties' in this dossier (Advisory Committee on Measuring and Calculating Nitrogen 2020a, 21) – this makes it difficult for the experts involved to make their assessment of uncertainties more transparent (see my introduction). Nevertheless, experts can (and should!) make judgements about the degree of reliability of models in different application ranges.

In the final report of the Hordijk Committee (*Measure More, Calculate More Robustly*, 15 June 2020), the summary discusses the reliability of high-resolution deposition modelling in more detail and the committee indicates

> that the calculation tool AERIUS Calculator is not fit for purpose. There are two reasons for this: 1. the imbalance between the detail required by policy and the degree of scientific uncertainty in calculating the deposition on a small area and 2. the unequal treatment of different sectors due to the use of different models (SRM- 2, OPS) when granting a license. (Advisory Committee on Measuring and Calculating Nitrogen 2020b, 4)

This is further specified in the conclusions of the report:

> Two considerations play a role in the assessment of AERIUS calculations for licensing. In the first place, the reliability of the prediction is insufficient due to the use of a very low assessment threshold, and this approach leads to false certainty. AERIUS Calculator (hereinafter referred to as AERIUS for short) calculates small contributions to concentrations and deposition based on emissions from a project. The uncertainty of this extra deposition

> on Natura 2000 areas is many times higher than the assessment threshold at the spatial scale used (hexagons the size of one hectare). Science cannot provide what policy demands here.
>
> A second consideration is that it is indefensible that a different calculation system (SRM-2) is used in AERIUS when granting licenses for the construction of a road than for the construction of a stable (OPS), whereby also the deposition of nitrogen oxides at more than five km from the source is not included. (Advisory Committee on Measuring and Calculating Nitrogen 2020b, 9)

Since the scientific uncertainty in calculating the deposition increases with distance from the source, the problem of displaying results at the level of hectare-sized hexagons is all the more pressing at a greater distance from the source. One way that the Hordijk Committee advised to make the models more suitable for the granting of licenses, namely to calculate the deposition not on a hexagon but on a cluster of hexagons, classified according to habitat type – which would reduce the false certainty in deposition calculations at a great distance from the source – has not been followed by the government. However, the government has opted for a different method in 2021 – using a uniform maximum calculation distance (of 25 km, i.e., five times greater than the 5 km previously used for road traffic) – to make the models more fit for purpose use by not using unreliable calculations based on hexagon level beyond that calculation distance.[12] Using a maximum calculation distance, while still calculating at the hexagon level within 25 km, solves part of the problem of false certainty. I have not separately assessed the extent to which other improvements in the system are necessary to make the instrument even more fit for purpose – that question falls outside the scope of this expert judgement. Scientifically, however, there is no doubt that using a maximum calculation distance increases the reliability of the model results. Furthermore, on the basis of the documents before me, I see no reason to conclude that the current system is not fit for purpose.

Below, I will discuss in more detail the justification provided by TNO for delineating the application range of the model used for project-specific calculations (in the light of what is said in science about methodological reliability and what has been crystallised about this in the Guidance for Uncertainty Assessment and Communication). But first the possible deliberate use of false certainty in the context of the precautionary principle must be considered, which is scientifically undesirable. The Hordijk Committee sheds light on this issue for the choice of the assessment threshold (‘threshold value’) of 0.005 mol/ha/yr:[13]

> For the time being, the precautionary principle calls for a strict threshold value when granting licenses. An ambitious source policy with established national objectives has the advantage that the threshold values could be increased when granting licenses, so that the uncertainties in the calculations for the licenses become less critical and false certainty becomes less prominent. (Advisory Committee on Measuring and Calculating Nitrogen 2020b, 10)

A tension in the quote above is that limiting false certainties – in the example mentioned by the Hordijk Committee by increasing the threshold value, but this also applies to the use of a

[12] Both ways of making the models more fit for purpose are not mutually exclusive and can be combined (i.e., calculations with clusters of hexagons within the maximum calculation distance).

[13] This concerns a choice made by experts for an arithmetic lower limit.

maximum calculation distance – is scientifically preferred by far. The fact that this limitation, which is necessary from a scientific point of view, does not always happen (and that calculations are still based on false certainties) has to do, among other things, with the value-laden nature of the choices made by the experts.[14] Modellers can choose to accept false certainties based on an assumption (which is not always factually correct in terms of the effect)[15] that this is necessary because of a 'precautionary principle'. Here, however, epistemic and non-epistemic values mix in a non-transparent manner in the systematics of the model and from a scientific point of view it is preferable to let epistemic values prevail in the assessment of models' fitness for purpose.

In my opinion, the RIVM report from 2021 does not sufficiently address the problem of false certainties. The summary clearly shows that the uncertainty in the calculation of local deposition from a source is 'a factor of 2' and 'that uncertainties further away from the source are larger than a factor of 2' (RIVM 2021, 9). RIVM does not address to choice of how large the uncertainty (or false certainty) may be to carry out deposition calculations for individual projects and does not go further than offering scientific starting points for choosing a distance limit. This wrongly suggests that determining the boundary between (scientifically sufficient) certainty and false certainty is a policy choice. In view of the above, however, science leaves no room for a possible policy choice to deliberately carry out calculations with false certainty, because false certainty should be limited as much as possible. To systematically limit false certainty, an estimate is needed of the distance within which the results of model calculations are still reliable.

TNO gives this estimate, partly based on the RIVM report: 25 km. TNO (2021) rightly states that even though the OPS model is used at distances greater than 25 km to calculate *total* deposition, the accuracy determined thereby is not a measure of the accuracy of the calculated contributions from *individual* sources: 'This accuracy is expected to be considerably lower' (TNO 2021, 2), i.e.: the uncertainty is greater than a factor of two (as also stated by RIVM). TNO (2022a) discusses the statement in an Apollon report submitted to the proceedings that 'it has not been sufficiently substantiated that the uncertainty in the calculated deposition contribution of an individual source increases with distance and outside a distance of 25 km is greater than a factor 2' (TNO 2022a, 4). However, it turns out to be difficult for the experts involved (as mentioned in my introduction) to explain to a wide audience what that judgement is based on, however true it may be (it is not just an 'assumption'). This requires further analysis in terms of the Guidance for Uncertainty Assessment and Communication.

In scientific practice there are standards for determining the reliability of knowledge. In the Guidance for Uncertainty Assessment and Communication, these standards have been crystallised into the various dimensions that are (in parallel) important in determining the qualification of the knowledge base (see the previous section). The dimensions of methodological reliability can be grouped as follows: (i) the theoretical basis, (ii) the empirical basis, iii) the agreement between different models and (iv) peer consensus (Petersen 2006, 57–62; 2012, 58–62). The substantiation provided by TNO for the limit of 25

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[14] See the uncertainty matrix (in table 1) and footnote 11.

[15] Decisions made on the basis of false certainties need not have the (negative or positive) effect that is modelled.

km (TNO 2021; 2022a; 2022b; 2022c) can be briefly summarised along these four dimensions:

- *Theoretical basis:* The theory behind the OPS model for individual source calculations is that of the 'Gaussian plume model'.[16] This theory is valid as long as the meteorology (all parameters, including boundary layer height and wind direction) can be considered constant. A rule of thumb for the Netherlands is that this amounts to approximately 25 km. Atmospheric chemical reactions also lead to increasing differences between model and reality further from the source. On mathematical and scientific grounds, it can be argued that uncertainties of the OPS model beyond 25 km always increase with distance from the source (and do not stay the same or decrease). It can also be argued theoretically that the uncertainty in the averaging of the deposition of several sources is always smaller than the uncertainty of the deposition of one source.
- *Empirical basis:* The AERIUS models have not been validated for individual sources beyond 20 km. Thus, there is no empirical support for this use of the models outside this range. Insofar as uncertainties have been looked at *within* this validation domain (and that has only been done sparingly), it appears that the results are generally accurate to a factor of two.
- *Agreement between different models:* The application range of the New National Model (NNM) for air quality has also been set at 25 km on scientific grounds. Foreign models have a comparable distance limit for granting permits (see TNO 2021, among others).
- *Peer consensus:* The distance limit for the NNM is the result of consensus among scientists from TNO, KEMA, KNMI and RIVM, among others. Foreign experts also share the opinion about the need for a distance limit and that this is about 25 km (see TNO 2021; 2022b, among others).

Given the limited information available about uncertainties in deposition modelling, I consider the underpinning of the 25 km limit by TNO sufficient. In my opinion, the model instrument using the maximum calculation distance is fit for purpose.

3. Response to STAB report of 8 July 2022 on the Route Decision ViA15

In light of the above, I provide a brief response to the most relevant points from the STAB report (STAB 2022).

- *STAB:* There are no new insights from environmental science that require a limitation.

  Response: Except for the short period 2015–2019 (and then only for emissions other

[16] The entire discussion in the documents about the transition from OPS to a coarse kind of trajectory model is irrelevant to answering the question whether the uncertainties beyond 25 km are greater than a factor of two (this is also agreed by the RIVM). The uncertainties therefore increase slightly less quickly beyond 25 km than if calculations were made with only the Gaussian plume model (this is already clear *a priori*, despite the fact that the trajectory model has not been validated – the latter unreliability falls under the dimension 'empirical basis', see the next point).

than those from roads), a maximum calculation distance has always been used for project-specific calculations of nitrogen depositions.[17] The use of a maximum calculation distance of 25 km has scientific grounds (see previous section). This expert judgement has a history of several decades. So, no new insight from environmental science is needed to argue the need for a limitation.

- *STAB:* It has not been found that meteorological conditions changing with distance, of which the mixing layer height in particular is considered important, give rise to a limit at 25 km (because the mixing layer height does not change substantially after 25 km).

  Response: The general statement that the boundary layer height (mixing layer height) *does not* change substantially after 25 km is scientifically incorrect. The rule of thumb given in the previous section under 'theory' that in the Netherlands for Gaussian plume models the meteorology (i.e., the combination of all relevant parameters) may be assumed to be constant over approximately 25 km is an expert opinion, but it proves difficult to transparently explain this in the context of this procedure.

- *STAB:* The validation studies based on calculated concentrations are too limited (in number and representativeness) to give rise to limitations.

  Response: I wholeheartedly agree with TNO's response to this point: 'That is the world turned upside down. Without validation, not a single test has been made to determine whether a model is able to describe reality in any way. Validation is essential. But because validation on model results is very complex, expensive and quite often impossible, any degree of validation is already very valuable. The NNM and OPS have been validated for individual source contributions up to 20 km at the concentration level and the associated deposition process in special (international) measurement campaigns.' (TNO 2022c, 16)

- *STAB:* Uncertainties are inherent in model calculations and uncertainties have not been found to be associated with predicting contributions beyond 25 km from the source.

  Response: This point completely ignores the basic fact that uncertainties increase with increasing distance beyond 25 km from the source and results hence lose their scientific validity. Theoretical and empirical considerations, the agreement with other models and peer consensus do not allow room for policy – because of the risk of false certainty – to scientifically calculate nitrogen depositions from individual sources beyond that distance at a resolution of 1 ha.

[17] In the context of the PAS (Programmatic Approach to Nitrogen), no individual licensing decisions for projects were taken based on project-specific modelling of absolute deposition contribution. The models that then calculated without maximum calculation distance were in fact used *for a different purpose*, namely for the comparison of the required and available deposition space, so that part of the uncertainties was cancelled out.

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Arthur Petersen (1970) studied physics (VU Amsterdam, 1993) and philosophy (VU Amsterdam, 1995) and obtained his doctorates in atmospheric physics and chemistry (Utrecht University, 1999), science studies and philosophy of science (VU Amsterdam, 2006) and science and religion/philosophy of culture (Oxford, 2022). In 2001 he joined RIVM's Netherlands Environmental Assessment Agency (one of the predecessors of the PBL Netherlands Environmental Assessment Agency) and in 2003 became project leader of the Guidance for Uncertainty Assessment and Communication, which had been in development since 2001 (1st edition: RIVM/MNP 2003; 2nd edition: PBL 2013). From 2003–2014 he was Programme Leader Methodology and Modelling and from 2011–2014 he was PBL's first Chief Scientist; in the latter role he was a member of the Executive Board and responsible for scientific quality assurance. He was Professor (by special appointment) of Science and Environmental Public Policy at the VU (appointed by the PBL) from 2011–2016. In 2014 he switched to a full-time Professorship: he became Professor of Science, Technology and Public Policy at University College London (UCL). Since 2000 he has been involved in the Intergovernmental Panel on Climate Change (IPCC) – until 2014 from the Dutch delegation, then from the UCL delegation (an 'observer organization'). In 2019 he was elected a member *of Academia Europaea, the European Academy of Sciences. He regularly carries out independent research, advice and evaluation assignments for governments and knowledge institutions (in the past year, among others for the Netherlands Delta Commissioner and the Netherlands Scientific Council for Government Policy). He lives in The Hague. For more information and publications see here (university's personal web page).*