Annex 3 to report D3471-2-RA

Cumulative effects of heat pump noise at district level in the Netherlands

1 District selection method

Calculation models were created for four types of districts commonly found in the Netherlands, in order to identify the acoustic effects at district level of the use of an all-electric and hybrid heat solution (heat pump) as a heating supply alternative for ground-based single-family homes.

This document describes the selection of district types and formulation of the calculation models.

1.1 District typology

The classification of Dutch districts follows the typology developed in [1]. This divides districts in the Netherlands into 14 types based on characteristics such as year of construction, building height, housing density, percentage of green spaces, etc. In [2], artificial intelligence was used to create a model dividing the entire country into these 14 district types at the PC6 (postal code) level.

The resulting typological map of the Netherlands is freely available at https://www.klimaateffectatlas.nl/nl/wijktypologie.

This classification was then used to create an overview of the prevalence of the various districts, as shown in the following Figure f 1.

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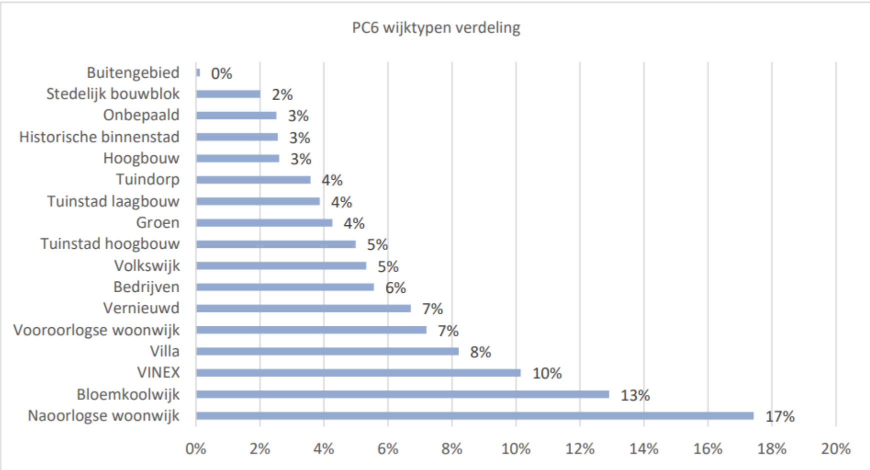


f 1 Prevalence of PC6 districts in percentages (source: [2])

Translation of the above mentioned district types:

Dutch	**English**
PC6 wijktypen verdeling	Postal code 6 level district classification
Buitengebied	Rural area
Stedelijk bouwblok	Urban housing development
Onbepaald	Undefined
Historische binnenstad	Historic city centre
Hoogbouw	High-rise buildings
Tuindorp	Garden City
Tuinstad laagbouw	Garden City low-rise buildings
Groen	Greenery
Tuinstad hoogbouw	Garden City high-rise buildings
Volkswijk	Working-class district
Bedrijven	Businesses
Vernieuwd	Modernised
Vooroorlogse woonwijk	Pre-war residential district
Villa	Detached houses
VINEX	Vinex district
Bloemkoolwijk	Cauliflower district
Naoorlogse woonwijk	Post-war residential district

As prevalence is determined based on a proportional division of the various PC6 postal codes, the total area for each district type also has an effect. There are not actually very many detached houses, for example, but this type is relatively well-represented. Furthermore, as the typology was originally created in the context of urban climatological effects such as heat and flooding due to climate change, not all the typological properties are of equal acoustic relevance. This made it desirable to combine different districts for the purposes of the current study.

Based on this classification and municipalities' indicated preferences, an acoustic calculation model was used to further investigate a selection of four district types:

- Vinex district
- Cauliflower district
- Combined Post-war residential and Garden City low-rise district

The third category contains both Post-war residential districts and Garden City low-rise buildings, which are sufficiently similar acoustically to be combined into one model. The differences between these classifications mainly concern the amount of greenery in a district, which is of lesser relevance acoustically. Statistical analysis shows a very similar prevalence of certain home dimensions (length, width, height, garden size, etc.) and years of construction within and between the two.

Districts/Neigbourhoods included in statistical analysis:

Cauliflower district	**Vinex district**	**Post-war + Garden City low-rise:**	**Other districts analysed**
- Peelo, Assen - Meerenwijk, Leiden - De Gouwen, Almere - De Marken, Almere - De Laar, Arnhem - Aetsveld/Oostelijke Vechtoever, Weesp - Aa-landen, Zwolle - Centrum Oost, Leusden	- Vathorst-Centrum, Amersfoort - Vroonermeer, Alkmaar - Romantische buurt noord, Doetinchem - De Enk, Zutphen - Dalem Zuid II, Tilburg - De Burgt, Barneveld	- Generalenbuurt, Eindhoven - Oude Gracht-Oost, Eindhoven - Orden, Apeldoorn - De Mheen, Apeldoorn - Dieren-West (above railway tracks) - Taag- en Rubicondreef, Utrecht - Voorst - Dubbeldam South - Westermarkt, Tilburg - Verzetstrijdersbuurt, Delft - Rodenburg and surroundings, Leek - Van Tijenbuurt, Amsterdam - Groot Deijleroord and Ter Weer, Wassenaar	- Wippolder, Delft - Vermeerkwartier, Amersfoort - Katwijk aan Zee - Frankendaal, Amsterdam - De Riet, Almelo - Molenberg, Heerlen - Hof van Delft, Delft - Berkum, Zwolle - 't Lansink, Hengelo - Slotermeer, Amsterdam - Pendrecht, Rotterdam - Zichtenburg, The Hague - Orden, Apeldoorn - Dubbeldam, Dordrecht - Badhoevendorp Oost, Badhoevendorp - Wolgadreef, Utrecht - Dieren (Rheden municipality) - Generalenbuurt, Eindhoven

1.2 District properties

Statistical analysis was carried out for each of the three district types based on representative districts. Acoustically relevant properties were collected for houses in these districts, including the width, depth, length of garden, street width, roof height, number of storeys, etc. Additionally, it was recorded whether roofs were flat or sloped and if there were any sheds present. This data was obtained using BAG (Key Register of Addresses and

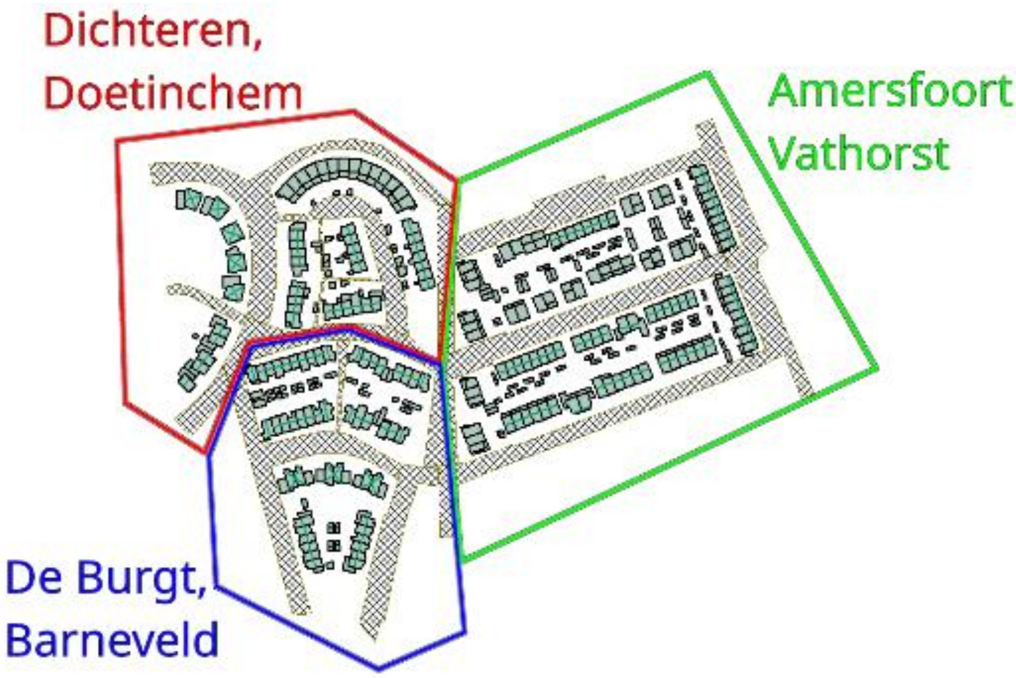
Buildings), 3D BAG and maps in the public domain. Districts were identified using the typological map and lists maintained by Wikipedia.

Based on the statistical distribution of these typological properties, three representative neighbourhoods in different Dutch municipalities were selected for each district type. Per district, parts of these three neighbourhoods were combined to create a fictitious district with the right acoustic properties and variability. The partial neighbourhoods were subsequently copied from 3D BAG.

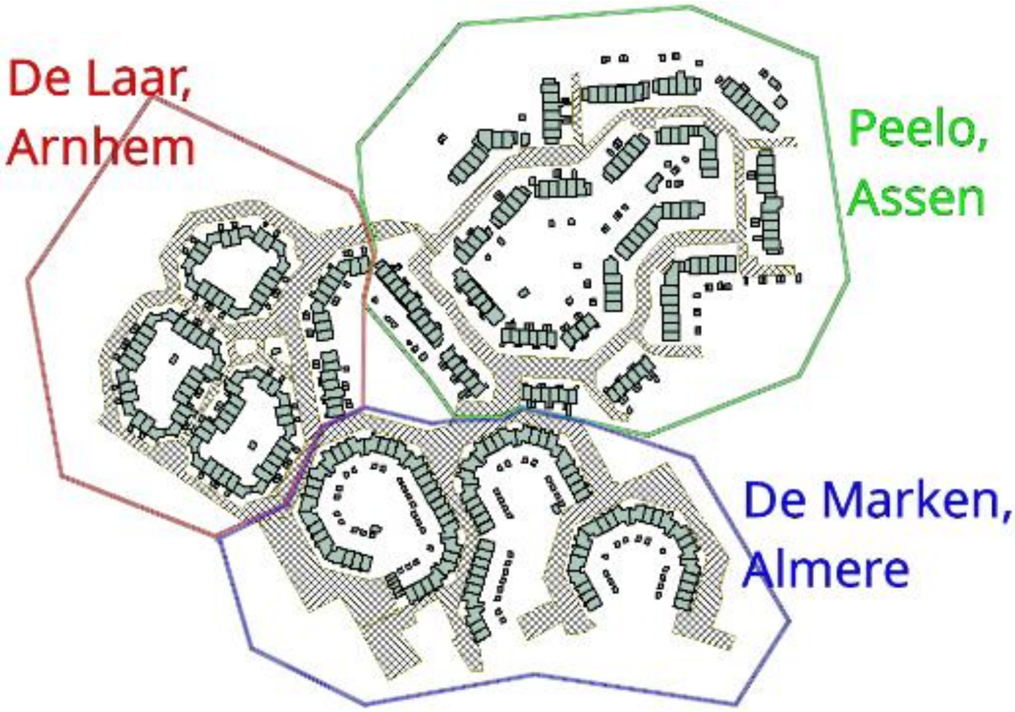
The following Figures f 2, f 3 and f 4 show which districts were used to create the calculation models. In the case of Vinex and cauliflower districts the entire district is often classified as the relevant district type, while for Post-war residential neighbourhoods and garden city low-rise often only smaller sub-neighbourhoods or sections are classified as a consistent district type. The latter districts tend to be older and also contain sections with other classifications, such as Garden City high-rise buildings, Garden City, Working-class and Modernised districts.

For Vinex and Cauliflower districs parts of the district with a suitable arrangement were thus selected for the ficticious districs, while the Post-war and Garden City low-rise district is composed of parts of neighbourhoods that corresponded to the relevant district type.

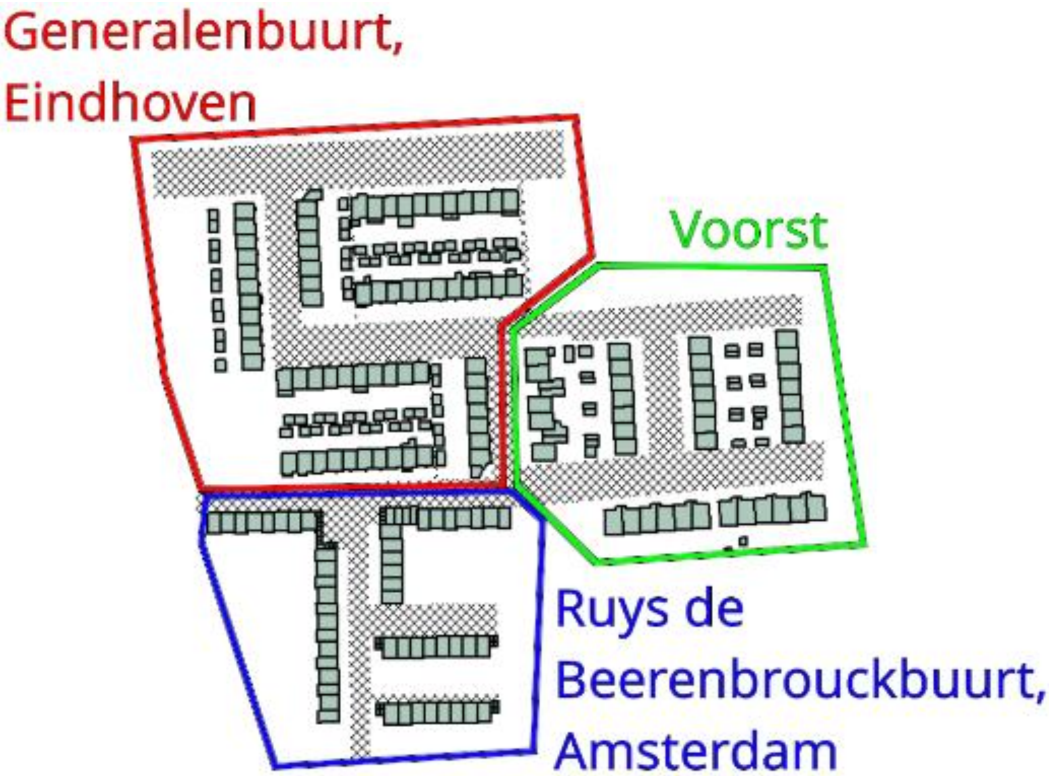
Small town centres in particular often consist of diverse historic buildings interspersed with newer bits and pieces. Many of these later additions also correspond to the characterisation of Post-war residential district, such as one section of the town of Voorst included in the calculation model.



f 2 Overview of Vinex district model sources



f 3 Overview of Cauliflower district model sources



f 4 Overview of Post-war residential/Garden City low-rise district model sources

1.3 Heat pump capacity

To be able to determine the heat pump capacities and thus their sound power levels, gas consumption was reviewed for all the districts/neighbourhoods studied. Each year Statistics Netherlands (CBS) publishes its Key Figures for Districts and Neighbourhoods, which includes data on the gas consumption for different types of housing, such as mid-terrace, end-of-terrace, semi-detached and detached houses. The data also notes the proportions of various types of housing within a district and which parts of the district are supplied by a district heating system. A limited data set is available for consultation at https://allecijfers.nl. The gas consumption data available is not fully current, dating from before 2023. Due to the COVID-19 pandemic and 2020–2022 gas crisis, it was determined that these years could not be considered representative and data from 2019 was used. This gas consumption data was collected for all the districts/neighbourhoods studied and averages calculated for those districts/neighbourhoods without a district heating system. The resulting figures were then used to calculate the required thermal capacity of a heat pump for each type of housing and district.

1.4 Housing type

Only terraced houses were assessed for the Post-war residential/Garden City low-rise and Cauliflower districts. The majority of ground-based homes in these districts are terraced houses (81% for Post-war residential/Garden City low-rise districts and 89% for Cauliflower districts). Additionally, terraced houses are more acoustically critical due to the proximity of neighbouring homes. For an acoustic assessment of detached and semi-detached houses, see the Vinex model. The modelled homes include mostly sloping roofs, but also some flat roofs, and a combination of houses with and without sheds or extensions. The terraces selected also have a range of garden designs, with courtyards and different layouts.

1.5 Geomilieu

Calculations were carried out according to the Environment and Planning Act, Annex IVh, ‘Measurement and Calculation Method for Industrial Noise’. The acoustic calculation model was designed in Geomilieu, version 2024.

The calculations for this study followed the methodology described in Annex IVh under

- 3.2. Method II.8: Transfer model.

Calculations were carried out for octave bands with mid-band frequencies of 63 to 8000 Hz. Considering the relatively large A-weighting for the 31 Hz octave band and the heat pump noise levels in this octave band, noise contributions near this band are not relevant. The calculations do not include the 31 Hz octave band for this reason.

For the purpose of the calculation model, noise sources are represented as point sources. These point sources radiate sound in all directions equally. The calculations use a calculation height of 1.5 metres. Noise levels are calculated and displayed at this height.

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The calculation models were created using Geomilieu v2024 software. Houses were imported from 3D BAG as .shp files and then the heights were adjusted to be identical per row of terraced housing and to correspond to 3D BAG. Sloping roofs were modelled as absorbent screens at the height of the ridge. Fences around homes were modelled as landscaping with a height of 1.8 m and an insertion loss comparable to common partially enclosed fencing (not a fully enclosed screen).

Heat pumps were modelled as point sources radiating in all directions, placed either at a distance of 10 cm from objects such as walls or in the open. These point sources are located at a height of 30 cm above any underlying items such as the ground or roof. For heat pumps mounted to a wall at a height of 3 m, the modelled point source has a height of 3.3 m.

The following Table t 1.1 provides an overview of the source sound power levels used.

t 1.1 Calculated source sound power levels in dB per octave band in Hz.

	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**dB(A)**
Heat pump 8 kW	46	46	48	55	51	48	43	34	58
Heat pump 10 kW	48	48	50	57	53	50	45	36	60

The following table shows the insertion loss used for the fencing.

t 1.2 Insertion loss used for partially enclosed fencing in dB per octave band in Hz.

	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Fencing insertion loss	1	1	2	3	5	5	10	10

Streets were modelled as ground types with ground factor 0 (= reflective). Noise contours were determined using a grid at a height of 1.5 m, with grid points at 1 m intervals along the x and y axes. Ground level is always at a height of 0 m.

2 Bibliography

- [1]: Kleerekoper, L. (TU Delft, 2016). Urban climate design: Improving thermal comfort in Dutch neighbourhoods. *A+ BE| Architecture and the Built Environment*, (11), 1-424, https://doi.org/10.7480/abe.2016.11.1359
- [2]: *Kluck, J., Erwin, S., Corpel, L., Bons, P., Arif, Z., Geisler, L., ... & Koekoek, A. (HvA, 2023). Computer leert wijktypen bepalen voor heel Nederland*