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The effect of the accumulation of noise from heat pumps in neighbourhoods in The Netherlands

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Abstract

For many districts in The Netherlands, an all-electric heat pump has been selected by the municipality as the future mode for heating dwellings. Municipalities want to prevent the transition to individual heat pumps from leading to noise pollution. However, at this time, data on the cumulative noise impact at district levels is lacking.

In this paper and the accompanying report, the research into the cumulative noise impact at the district level, because of the outdoor units of heat pumps will be presented. The research was conducted on behalf of the National Program Local Heat Transition (NPLW) and the Netherlands Enterprise Agency (RVO).

This study provides insight into the noise impact of heat pumps and the circumstances that increase this impact. Acoustic 3D simulation models were used in which common Dutch neighbourhoods were modelled. Within the models, the heat pumps were placed at various positions near the homes (including the front garden, on the facade, on the roof, in the back garden, on top of and behind the shed). The effect of the accumulation of noise within the neighbourhood, as a result of the operation of all heat pumps, was mapped. The results are presented as acoustic heat maps. The effect of acoustic enclosures was also taken into account as was the ambient noise level.

The results show that some installation positions for heat pumps are acoustically more favourable and are preferred, while other positions are possible if additional measures are taken.

In addition to the results presented in this paper, the data and an English translation of the report presented in The Netherlands, will be available on the website of the IEA HPT Annex 63. This allows other researchers, policy officers and professionals to access the information and utilize it for their own studies or policy making.

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Keywords: heat pumps; noise; sound cumulation; residential neighbourhoods.

1. Introduction

The Netherlands is undergoing a significant energy transition, with municipalities and residents increasingly adopting all-electric and hybrid heat pumps as alternatives to traditional gas-based heating. This shift is driven by national climate goals and the need to decarbonize residential heating. All-electric heat pumps have been determined to be the best future heating supply in many regions. Municipalities and residents are concerned about the noise effects of heat pump outdoor units on neighbours and the environment.

Municipalities are tasked with developing heating programs by the end of 2027, as mandated by national policy. One of the key challenges is managing the environmental impact of heat pumps, especially the cumulative noise effects that may arise when multiple units are installed in close proximity. While statutory noise limits exist for individual installations, there is a lack of independent, publicly available information and tools to assess cumulative noise at the district or regional level. This gap complicates decision-making for municipalities and may affect public acceptance of heat pump technology.

This study, commissioned by the NPLW, aims to:

- Provide insight into the potential cumulative noise effects of heat pump outdoor units placed outside homes.
- Identify circumstances that can increase cumulative noise effects.
- Propose mitigation measures and recommendations to reduce heat pump noise at the district level.

The study focuses on four common Dutch district types, with a generally homogeneous architectural style. The findings are intended to support municipalities in responding to residents' concerns and guide the selection of heating solutions.

Acoustic calculation models are used to simulate noise propagation and assess the impact of various heat pump placements. The results are used to calculate the noise for fictitious built areas, visualised as noise heat maps. The fictitious districts were entered into the acoustic calculation model. This model was used to calculate the noise for various heat pump placements per district. The study also took the representative heat pump sound power levels into account for each type of home. Additionally, data from Peutz and public noise maps were used to determine appropriate background noise levels for each district.

2. Legal Framework

Depending on the circumstances, there are various statutory limits applicable in the Netherlands to heat pump operational noise. There are no specific noise limits for the cumulative effects of noise produced by multiple homes' individual heat pumps.

Since April 2021, operational noise from heating or cooling systems located outside buildings is subject to the requirements specified in the Building Environment Decree (Bbl). The decree states that maximum noise level cannot exceed 40 dB(A) at the boundary with a plot for a different residential function. This limit is primarily aimed at protecting outdoor areas (e.g. gardens, balconies) of homes on adjacent plots from noise nuisance in summer. If a unit has a separate setting for a silent mode for the nighttime and evening hours, the daytime noise limit increases to 45 dB(A).

Humans perceive tonal noise as being especially annoying. Tonal noise can be a squealing or whistling noise (high-frequency noise) or a buzz or hum (low-frequency noise). Heat pump compressors can produce a low humming noise. The recorded noise level is adjusted in case of tonal noise, with tonality determined in accordance with ISO 1996-2:2017, Annex J. The tonality correction will be between 0 dB and +6 dB in increments of 1 dB.

3. Typology of Dutch Residential Districts

Heat pumps have been determined to be the best future heating supply in many districts. Municipalities wish to avoid a collective transition to individual heat pumps resulting in noise nuisance in a district. The study therefore concentrates on several common district types. These districts have a generally homogeneous architectural style.

Calculation models were created for four types of districts[1] in order to identify the acoustic effects at district level of the use of a heat pump as a heating supply alternative for ground-based single-family homes.

The typological classification[2] of Dutch districts used in this paper follows the typology used by the national climate effect atlas[3]. This divides the Netherlands into various district types based on characteristics such as year of construction, building height, housing density, percentage of green spaces, etc. The study models four representative district types commonly found in the Netherlands:

- Vinex Districts: Built after 1990, featuring detached and semi-detached homes.
- Cauliflower Districts: Built between 1970 and 1990, characterized by closed blocks and unique cauliflower-shaped layouts.
- Post-war Residential Districts: Residential district built after 1945; two or three storeys; often with front and rear gardens and broader streets; combination of terraced and semi-detached homes.
- Garden City Low-Rise: Built between 1945 and 1960, open blocks with two or three storeys.

See the images in Fig. 1 from the national climate effect atlas for an impression of the various district layouts modeled in this study.

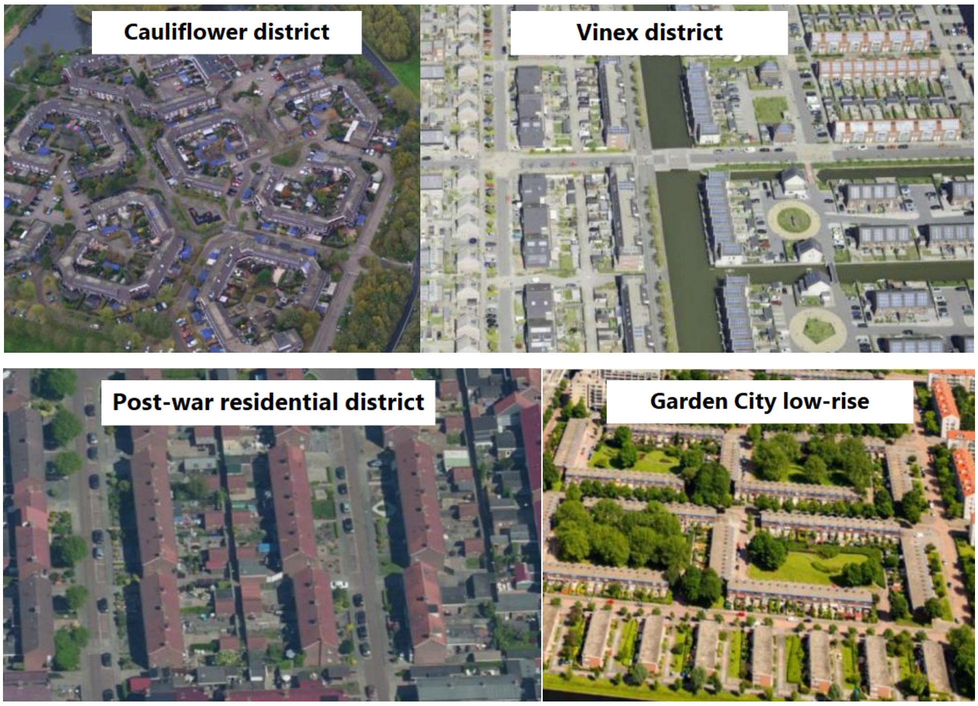


Figure 1. The four types of districts, selected for the study.

4. Acoustic Calculation Model

The districts described were entered into an acoustical 3D calculation model, created with acoustical software Geomilieu version 2024. Geomilieu is one of the standard tools in the Netherlands for calculating, presenting, assessing, and predicting industrial noise. The software uses ray acoustics modeling to calculate sound pressure levels. The calculations are in accordance with the Environment and Planning Act, Annex IVh, ‘Measurement and Calculation Method for Industrial Noise’. Calculations were carried out for octave bands with mid-band frequencies of 63 to 8000 Hz. For the purpose of the calculation model, heat pumps were modelled as point sources radiating in all directions. These point sources radiate sound in all directions equally.

3D BAG is a data set containing 3D building models of the Netherlands. 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.

This model included all houses and associated outbuildings such as sheds. Partially enclosed fences 1.8 m high were used for all plot boundaries in the rear gardens. Paving was taken into account for the side of the homes facing the street in front. The calculation results presented are the expected sound pressure levels at 1.5 m above ground level.

The colour scale and key shown in Fig. 2 displays the heat pump units, fences in rear gardens, roof ridges, paving and buildings. The colour scale in the results ranges from yellow to red, increasing in steps of 5 dB(A). For readability, the legend is shown in Fig. 2 and is not repeated with each figure. The scale is defined in such a way that sound pressure levels equal to or exceeding 40 dB(A) are indicated in red. Noise levels under 40 dB(A) are indicated in shades of yellow or white (inaudible).

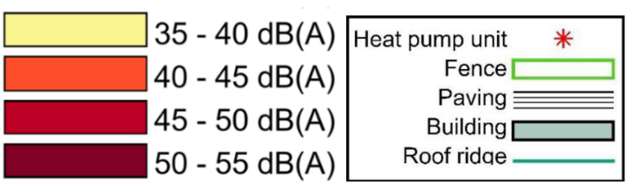


Figure 2. Noise level colour scale (left) and key (right)

Fig. 3 shows part of a Cauliflower district from the model with the associated aerial photograph.

Figure 3. Part of acoustic calculation model of Cauliflower district with aerial photograph of the underlying district.

4.1. Heat pump selection and operation

Two different all-electric outdoor units were used for the heat pumps in the model. An 8 kW variant was used for mid-terrace houses and a 10 kW variant for corner houses, semi-detached and detached houses. The 8 kW heat pump has a sound power level of 58 dB(A), while the 10 kW heat pump's sound power level is 60 dB(A). The thermal capacities are based on the average gas consumption for the relevant homes in the districts studied, converted to the required electrical capacity if these homes stop using gas.

The calculations assume continuous heat pump operation. Sound power levels are based on the most common specifications provided by heat pump suppliers and manufacturers. This information can also be determined from the ErP or Ecodesign label. It is important to compare the correct data. The data used in this study was obtained by measuring heat pump noise in an acoustic laboratory. The outdoor units were placed in an environment of 7 °C and hot water for heating or domestic use produced at a temperature of 55 °C.

In practice, it is unlikely that every single outdoor unit in the entire district will be operating at the same setting simultaneously. However, it is important that the results of different placements can be correctly compared with each other.

4.2. Heat pump placement

In practice, there are certain common placements for heat pump outdoor units. Not every placement is suitable for every home, if there is no shed or extension for example. In such cases, the closest equivalent placement was used instead. Calculations were made per district type for the following heat pump placements:

- By front wall at ground level (height of 0 m)
- By front wall at ground level (height of 0 m) with acoustic enclosure
- Mounted to front wall at height of 3 m
- Mounted to (sloping) roof in front
- In rear garden by rear wall at ground level (height of 0 m)
- Mounted to rear wall at height of 3 m
- In rear garden by plot boundary in back
- On shed or extension roof or behind shed

The following photographs in Fig. 4 show examples of some of these placements.

Figure 4. Different examples of heat pump positions. From left to right: Roof mounted, behind the sheds, on the façade.

The figures in Fig. 5 show how some of the placements are presented in the model.

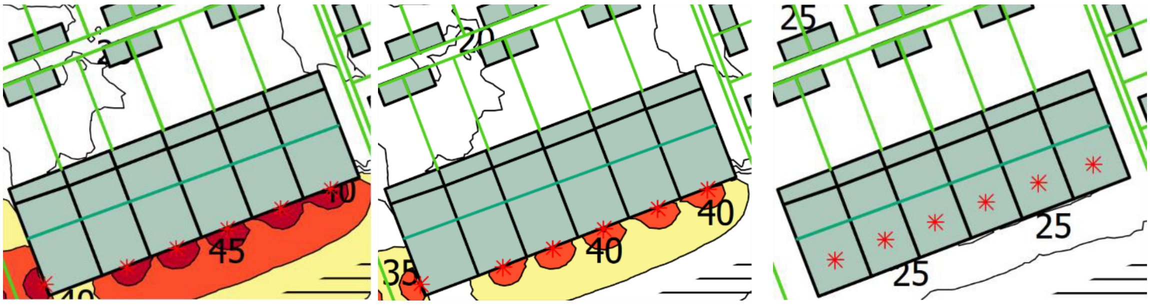


Figure 5. From left to right: Placement on ground by front wall, by front wall with acoustic enclosure and on sloped roof.

4.3. Effects of background noise level

There is always some level of background noise (indicated by BG in the figures); nowhere is truly silent. Background noise is a combination of district traffic, more distant motorways, trains, planes passing overhead, neighbours making noise, wind in the trees, etc. There is generally less noise at night than during the day, and a small town in the country will be quieter than a busy city. It is also usually quieter in the relatively shielded rear gardens than at the front of a home.

The more background noise there is at a specific location, the more this will mask any other noise. If, for example, a district's usual background noise level is 45 dB(A) during the day, noise below approx. 35 dB(A) will be barely noticeable or inaudible depending on the dominant frequencies.

To illustrate this effect at two background noise levels, the model does not display heat pump noise in colour when it is more than 10 dB(A) below the background noise, as such noise would be inaudible. The present study uses two different background noise levels, namely 40 dB(A) and 45 dB(A). In a larger town or city, daytime background noise levels are generally over 45 dB(A), while levels in a small town in the country can be lower than 40 dB(A) during the day.

Any noise levels under 35 dB(A) are not displayed in colour/white if the modelled background noise level is 45 dB(A). This is equivalent to a situation with a background noise level of 45 dB(A), whereby noise levels below 35 dB(A) are not or barely audible. Similarly, noise levels under 30 dB(A) are indicated in white if the modelled background noise level is 40 dB(A). The effect of the difference in background noise level with the same heat pumps is shown in Fig. 6.

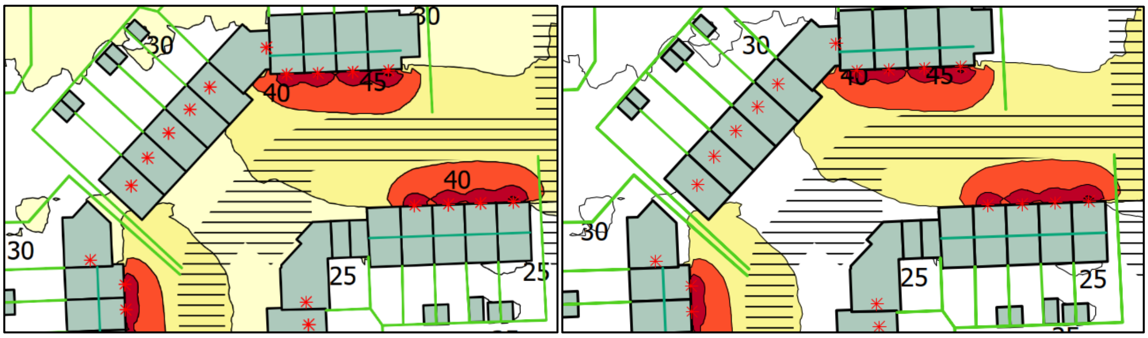


Figure 6. Visual effect of background noise. Left: background level 40 dB(A). Right: 45 dB(A).

5. Results and Discussion

The following describes various general or common effects of cumulative heat pump noise. In cases with a heat pump placed at ground level or mounted to the wall at the front of the home, the noise level from the street is approx. 35–45 dB(A). In the units' immediate vicinity, the noise level is 45–50 dB(A). In the shielded rear gardens, the noise from the heat pumps is quiet enough that it is no longer discernible over the background noise there.

There is no great difference in noise level between heat pumps placed at ground level and those mounted to a wall at 3 m. However, it is apparent that the heat pump noise's reach increases if the unit is mounted to the wall at a height of 3 m. If the outdoor unit is mounted on a home's roof, the acoustic effects are greatest at the front. In that case, the heat pumps will not be audible from the street.

Fig. 7. shows the result of the Cauliflower district. The background level is 45 dB(A). The heat pumps are positioned at the façade, at 3 m height. The key is shown in Fig. 2.

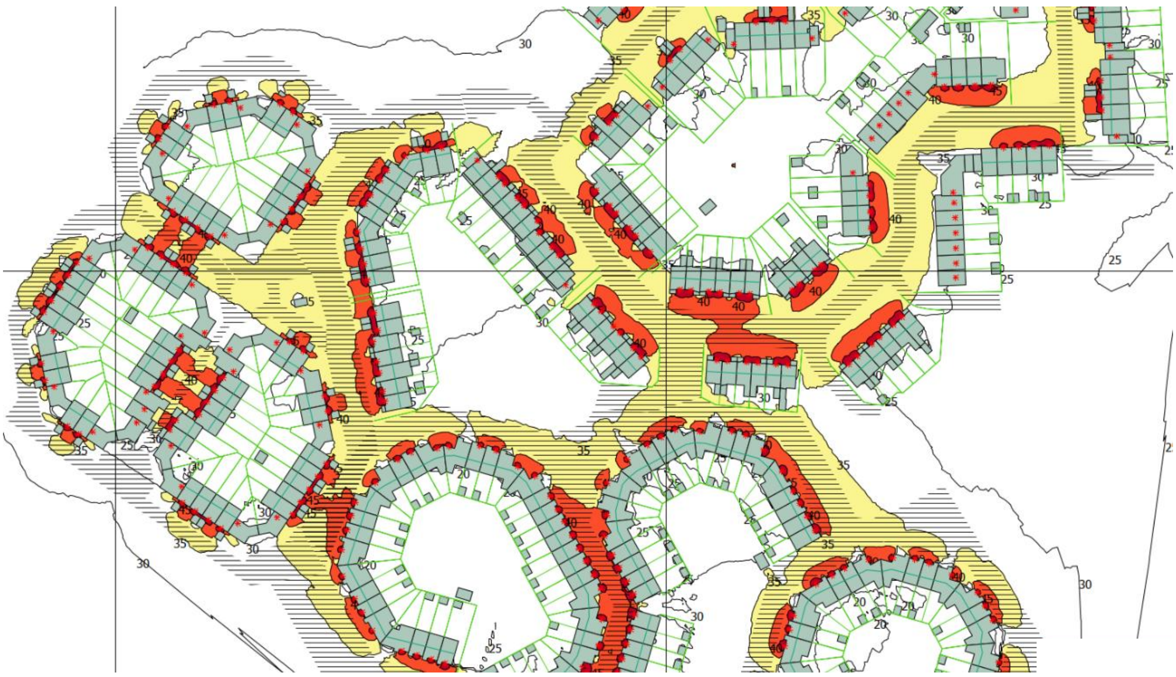


Figure 7. Cauliflower district, BG: 45 dB(A), heat pumps at façade, 3 m height

5.1. Heat pump placement

5.1.1. Heat pumps in front of homes

In cases with a heat pump placed at ground level or mounted to the wall at the front of the home, the noise level from the street is approx. 35–45 dB(A); see Fig. 8. In the units' immediate vicinity, the noise level is 45–50 dB(A). In the (shielded) rear gardens, the noise from the heat pumps is quiet enough that it is no longer discernible over the background noise there.

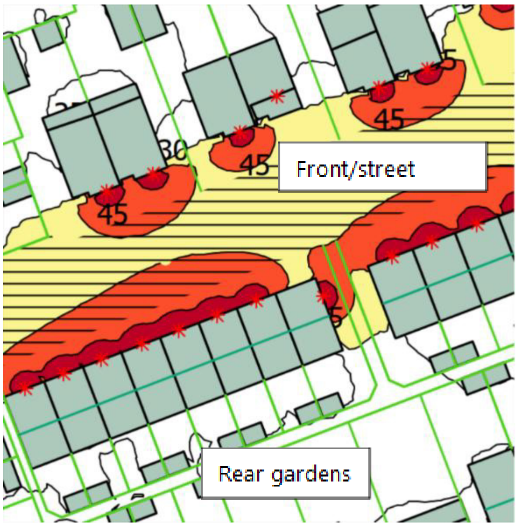


Figure 8. Noise level due to heat pump units in front; rear garden is well-shielded

There is no great difference in noise level between heat pumps placed at ground level (0 m height) and those mounted to a wall at 3 m. However, it is apparent that the heat pump noise's reach increases if the unit is mounted to the wall at a height of 3 m. If the outdoor unit is mounted on a home's roof, the acoustic effects are greatest at the front. In that case, the heat pumps will not be audible from the street. The results are shown in Fig. 5.

5.1.2. Heat pumps near, on or behind sheds

Fig. 9 shows the effects of sheds in rear gardens and various heat pump placements around the sheds.

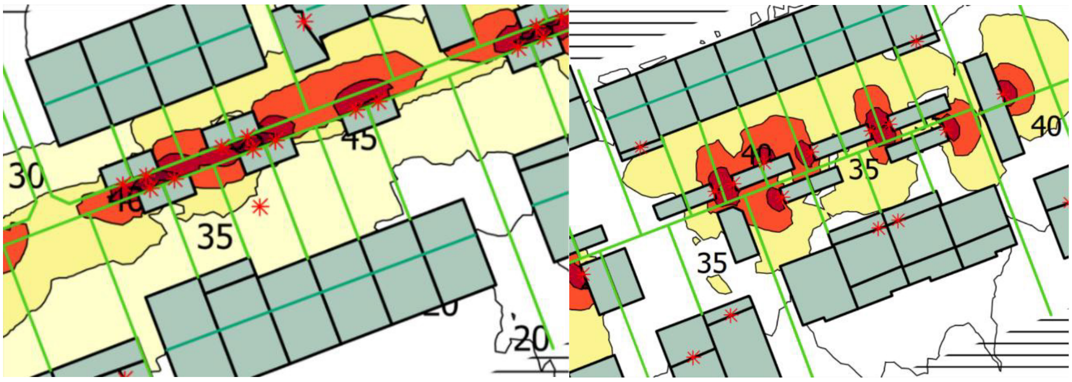


Figure 9. Effects of sheds – Vinex district, BG: 40 dB(A) - Left: Behind shed. Right: Next to shed.

Fig. 10 and Fig. 11 show the variety of heat pump placements by and behind sheds in rear gardens in the Vinex and Cauliflower districts respectively. On some plots, there is enough space to install a heat pump behind the shed.

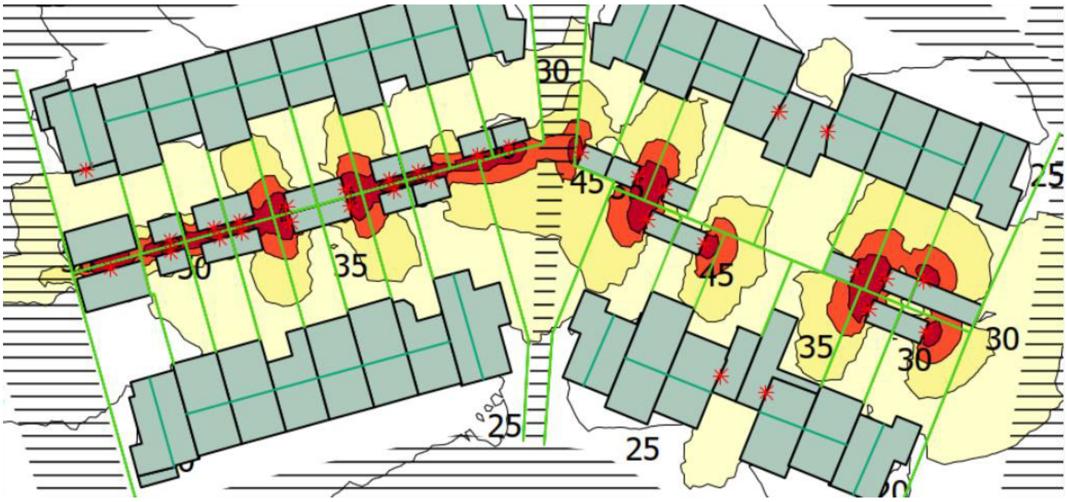


Figure 10. Variation in sheds in rear gardens – Vinex suburb, BG: 40 dB(A)

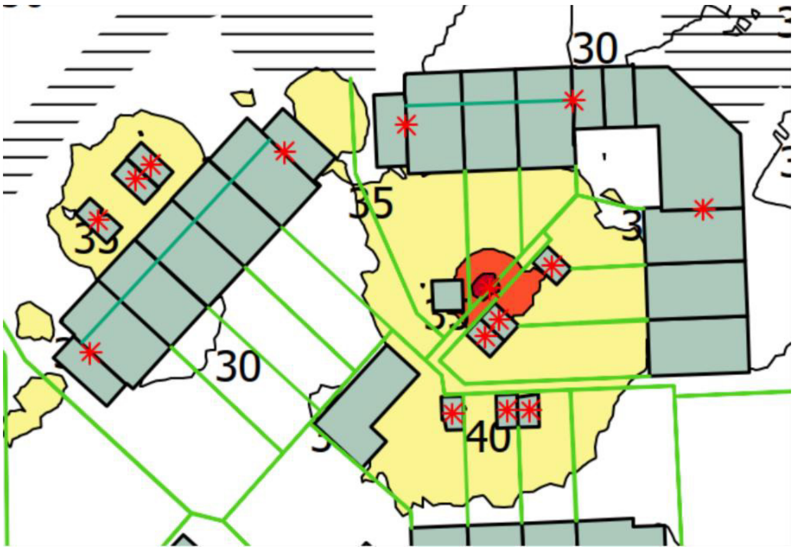


Figure 11. Effects of heat pumps on sheds and garages, various placements – Cauliflower district, BG: 45 dB(A)

The following Fig. 12 show the effects of heat pump units placed at the back of a relatively small rear garden (approx. 5–6 m wide by 10–13 m deep) in the Post-war residential district, with and without sheds.

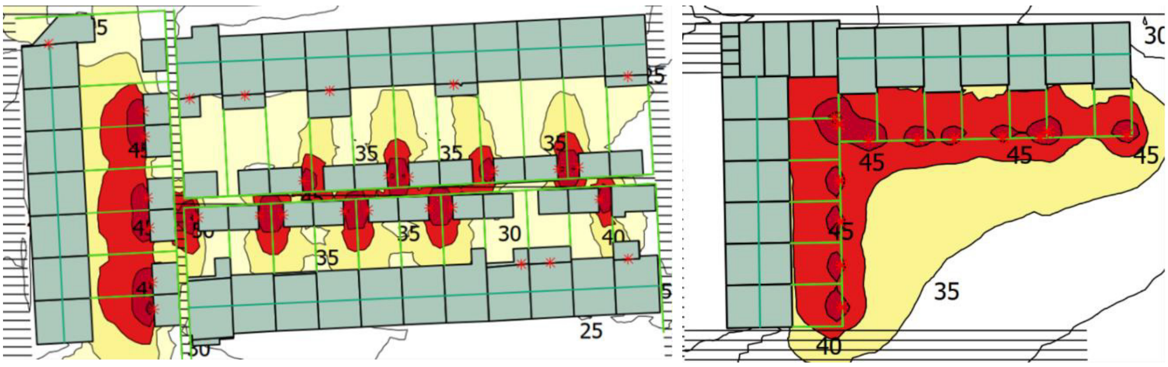


Figure 12. Effects of heat pumps in small garden with and without shed – Post-war residential district, BG: 45 dB(A)

5.1.3. Detached house

Fig. 13 shows the effects of a heat pump outdoor unit for a home on a relatively large plot in the Vinex district. The surrounding detached homes have garages, to which the outdoor units are mounted.

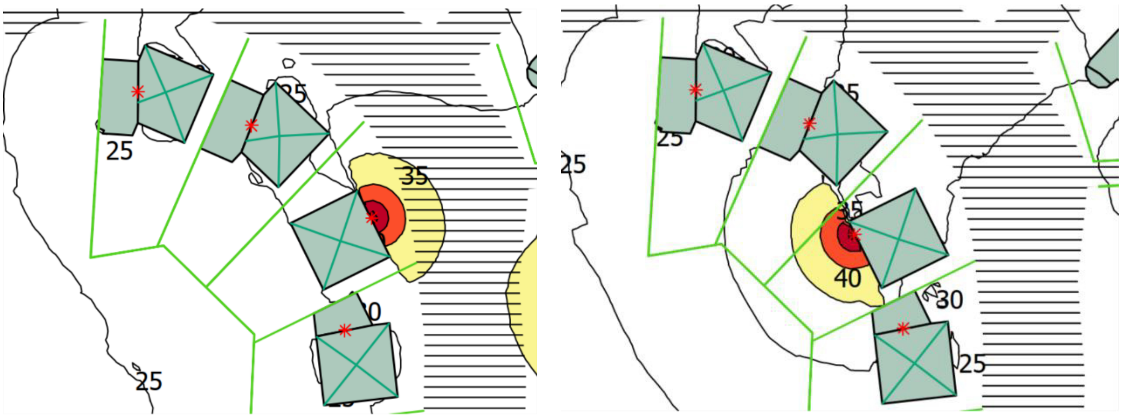


Figure 13. Detached homes – Vinex district, BG: 45 dB(A)

5.1.4. Narrow streets

Fig. 14 shows the cumulative heat pump noise for e.g. a Cauliflower district's relatively narrow street (approx. 7.5–10 m distance between walls) without vehicle access.

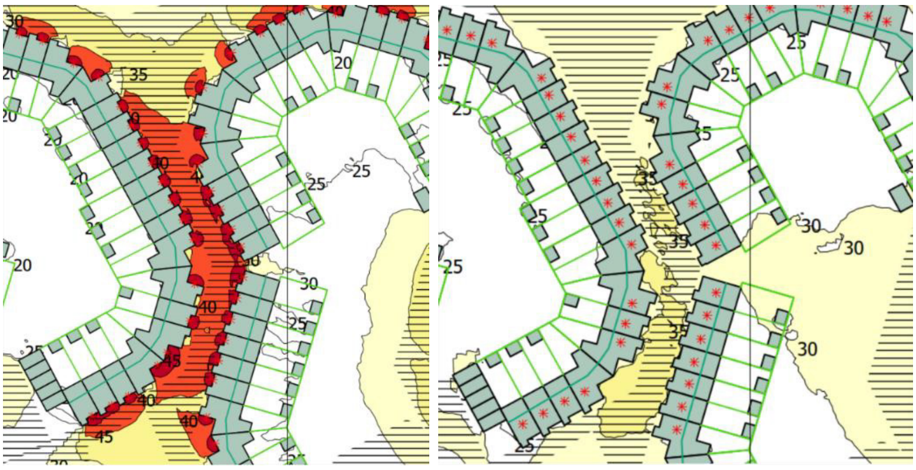
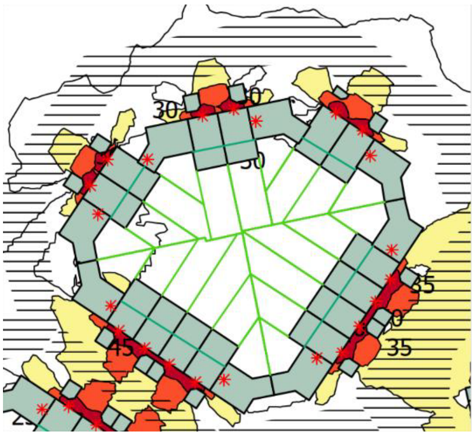


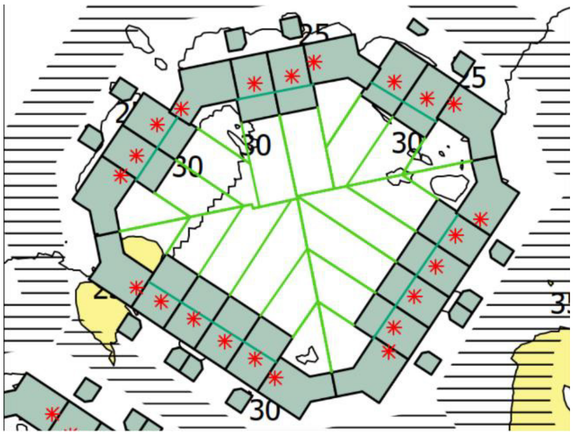
Figure 14. Effects on a narrow street – Cauliflower district, BG: 40 dB(A). Left: heat pump in front at 0 m. Right: on front roof

5.1.5. Fully enclosed courtyards

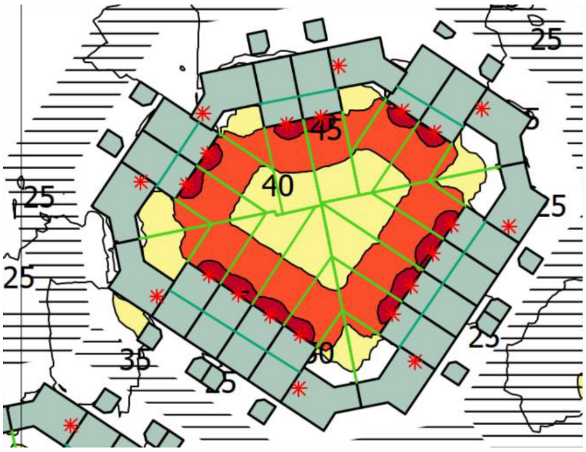
Fig. 15 shows a layout typical of Cauliflower districts. Rear gardens are separated entirely from the street by the homes, creating enclosed courtyard gardens. If there is a flat roof, the heat pump is mounted to the roof; for the other homes the placement varies.



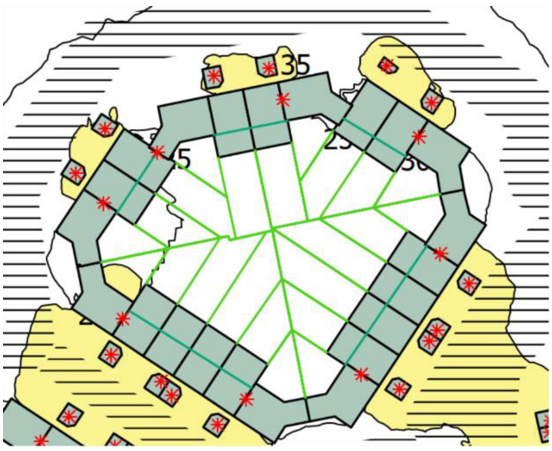
Courtyard, heat pump in front at 0 m



Courtyard, heat pump on roof in front



Courtyard, heat pump by rear wall at 0 m



Courtyard, heat pump on shed (if present) in front

Figure 15. Effects in a courtyard – Cauliflower district, BG: 45 dB(A)

5.1.6. Mirrored and non-mirrored streets

The following Fig 16 shows the difference between streets in a Post-war residential district with mirrored rear gardens versus a layout with front gardens facing the next street's rear gardens, with the outdoor unit located at the front in both cases.

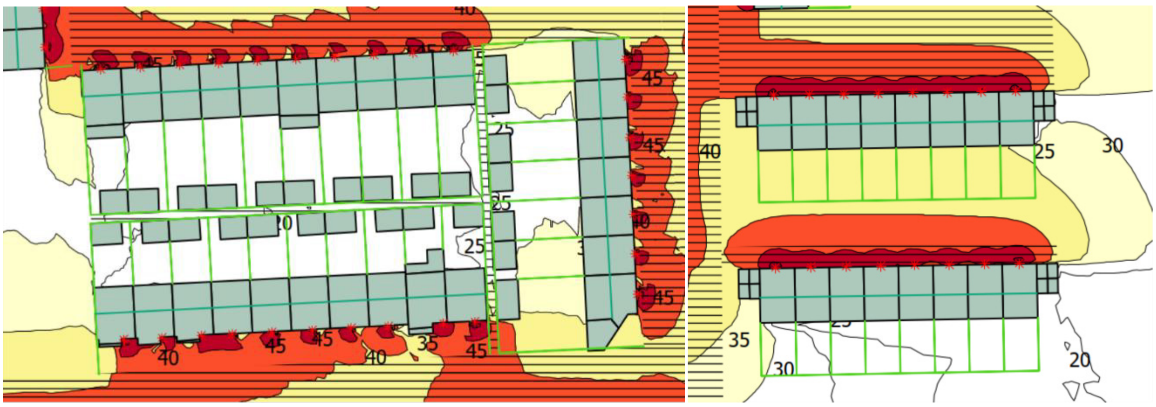


Figure 16. Non-mirrored and mirrored gardens – Post-war residential district, BG: 40 dB(A)

6. Conclusion

The results of the calculation model show that certain placements are consistently better acoustically with regard to cumulative noise. Additionally, under specific (architectural) circumstances, certain placements are preferable. Generally speaking, the differences between districts are small enough that the following recommendations can be applied to all of the districts researched:

- Semi-detached homes with a flat-roofed garage are more common in Vinex districts.
- Sheds at the front of the home are found in some Cauliflower districts.
- Rear gardens or courtyards fully or partially surrounded by homes are common in Cauliflower districts.
- Front gardens facing the next street's rear gardens can be found on certain residential Post-war district streets.
- Narrow, car-free streets with front walls that are closer together are found in Cauliflower districts, and possibly also in Vinex districts.

6.1. Preferred placement

6.1.1. On the roof

To reduce noise at the front of homes, a rooftop placement is strongly preferred. In that case, the heat pump units will be barely noticeable or inaudible at both the front and rear due to the roof's shielding effect and the greater distance. The same applies to heat pump units mounted on an adjoining garage. However, this also affects maintenance access. There are various solutions available to provide easier access to the outdoor unit in such cases, e.g. roof access hatches.

6.1.2. Inside or behind shed

If there is a shed present, installing the heat pump inside it is preferred. The shielding provided by the shed greatly reduces cumulative noise. If the heat pump unit cannot be placed inside the shed itself, it can be an option to mount it to the shed roof instead. With this placement, cumulative noise levels in the rear gardens will be approx. 30–40 dB(A), which is acceptably low.

If the heat pump units are placed behind the sheds, this will result in cumulative noise in the alley or to the back of the houses. Depending on the distance and shielding of the rear gardens, placing heat pump units behind the sheds may result in cumulative noise levels of approx. 40–45 dB(A) in the gardens.

In most cases, placing a heat pump unit to the side of a shed will produce too much noise in the home's own rear garden.

6.1.3. Larger plots

Without additional measures, installing an all-electric heat pump in the rear garden at ground level (or on the wall) is only viable on larger plots. The plot must have a width of at least 10 m. This ensures sufficient distance to neighbouring plots to comply with statutory noise limits without further measures and reduces cumulative noise. Of course, the outdoor unit will still need to be located far enough away from the plot boundaries.

6.2. Placement with additional measures

6.2.1. On the ground in front

If the heat pump cannot be mounted to the roof, inside or behind a shed, placement inside an acoustic enclosure at the front is an acceptable alternative. This is estimated to result in cumulative noise levels of approx. 40–45 dB(A) near homes' front walls.

6.2.2. Mounted to a wall

Regarding cumulative noise at the front, there is little difference between a heat pump at ground level or one mounted to the front wall at a height of 3 m. Without additional measures, this is estimated to result in cumulative noise levels of approx. 45–50 dB(A) near homes' front walls, which can be considered relatively high and also violates statutory noise limits.

6.2.3. On the ground in back

If there is no shed and the heat pump unit must be placed in the rear garden, additional shielding may be achieved by means of a fully enclosed boundary partition, an acoustic enclosure or a combination of these solutions.

Situations where the rear gardens are fully (courtyard garden) or partially surrounded (U or L-shaped design) by homes should be considered highly unfavourable.

7. Recommendations

The following are general recommendations for improvement in the event of a desired situation or placement that violates statutory noise limits or if additional measures are indicated to avoid noise nuisance and reduce cumulative noise.

For all the situations and measures listed here, the proposed measures do not guarantee compliance with Dutch statutory noise limits. Even if there is no violation of statutory noise limits, noise nuisance and sleep disturbance may still result. In particular, poor adjustment, improper installation or maintenance and aging systems can produce increased noise levels. In critical situations, engaging an acoustics consultant is always recommended.

7.1. Selection of heat pump with low sound power level or use of Silent Mode

Heat pump manufacturers and suppliers often have a range of outdoor units with different sound power levels available. There can also be an even greater variety in the specified sound power levels for different heat pump models. The variation in specified sound power levels between heat pumps with the same thermal capacity can exceed 10 dB(A).

By selecting the right heat pumps in advance (e.g. at the start of a collective purchasing process), possibly in combination with noise calculations for worst-case placements, insight can be gained into which sound power levels are still acceptable to ensure compliance with noise regulations and reduce cumulative noise.

Involving acoustic and installation consultants in this process, either initially or throughout, can be an option. The process could also include a comparison of various heat pump models from reputable manufacturers. For an accurate comparison, the specified sound power levels must have been determined under equivalent conditions, such as an A+7/W55 operating point.

Another option is the selection of a heat pump with a silent mode. Care should be taken to actually activate silent mode during the evenings and at night. The noise reduction achieved in silent mode varies depending on the manufacturer and model. Generally speaking, a reduction of approx. 5 dB(A) is realistic. The unit will be less efficient when operating in silent mode, reducing the capacity.

7.1.1. Tonality

It is important to avoid heat pumps that produce audible tonal noise. As audible tonality is experienced as particularly unpleasant, its presence results in a penalty of up to 6 dB on top of the measured noise level. However, it is not always easy to select for an absence of tonal noise. Tonality is rarely included in unit specifications. Heat pumps from more reputable manufacturers tend not to produce tonal noise, or not as much, but this is not guaranteed. To gain more certainty, options include engaging an acoustic consultant or carrying out a noise assessment of the relevant unit to check for tonality specifically.

7.2. Increased distance to plot boundary

Placing a heat pump at a sufficient distance from neighbouring plots reduces the risk of noise nuisance or a violation of noise regulations. Without additional measures, the distance will need to be relatively large. A suitable distance could easily be as much as 3–4 m for free-standing heat pumps located at least 2 m away from any walls or 4–5 m for units by a wall or shed. The exact distance will depend on the heat pump's sound power level and the specific situation.

7.3. Solid boundary partition

If a heat pump unit in a rear garden is located near or on the plot boundary, the likelihood of exceeding noise limits or creating a nuisance is high. In that case, one possible solution is the installation of a fully enclosed boundary partition with a surface mass of at least 10 kg/m^2. The solid boundary partition must be at least 1.8 m tall. The boundary partition or fence may consist of a masonry wall, ‘closeboard’ wooden fencing or, for example, coconut matting with an acoustic core panel.

7.4. Acoustic enclosure

If the distances to adjacent plots are relatively small and there is no placement option with better shielding available, another solution is to place the heat pump outdoor unit inside an acoustic enclosure. This can achieve a reduction in noise level of approx. 5 dB(A), depending on factors such as the manufacturer and model. The actual noise reduction is also determined by the heat pump’s sound power level and the enclosure’s effectiveness at reducing noise across octave bands. Noise calculations can be used to estimate the achievable reduction in advance.

An enclosure does take up more space, and higher costs are also a consideration. Furthermore, the enclosure may reduce the unit’s efficiency by restricting the flow of air. In that case, the heat pump will switch to a higher setting in compensation, producing more noise and partially negating the enclosure’s acoustic benefit.

Also check that the enclosure is actually designed for noise reduction. The enclosure’s specifications should indicate its effectiveness at reducing noise, preferably for different octave bands. There are also non-acoustic enclosures available which are only intended to conceal the heat pump from view.

7.5. Storage shed

If there is a shed present, placing the heat pump inside it can enable the implementation of additional acoustic measures. Examples include soundproof vents and/or the use of sound-absorbing materials inside the shed. Even without such measures, depending on the vent placement, a shed will provide better shielding toward neighbouring plots. If there is an alley or similar behind the sheds at the back and there is enough room, it can be an option to place the heat pump behind the shed. This takes advantage of the shed’s ability to shield the gardens.

7.6. Full Report

Additional scenarios have been modeled with simultaneous operation of all heat pumps at 100%, 70% and 50% operation. The use of acoustic enclosures, the use of hybrid heat pumps and the effect of different types of fences are also modeled. All results are presented in the full report.

The complete report including all 44 results can be found at:

- https://heatpumpingtechnologies.org/project63/articles/cumulative-effects-of-heat-pump-noise-at-districtlevel-in-the-netherlands/

The original Dutch report can be found at:

- https://www.nplw.nl/warmte-en-ruimte/cumulatief-geluid-warmtepompen

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