NATUUR-INBOUW

optimising building details for building-dependent animals



EINDHOVEN UNIVERSITY OF TECHNOLOGY
Stan Ackermans Institute

SMART BUILDINGS & CITIES

NATUUR-INBOUW: OPTIMISING BUILDING DETAILS FOR BUILDING DEPENDING ANIMALS

By

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A thesis submitted in partial fulfillment of the requirements for the degree of: **Engineering Doctorate (EngD)**

The design described in this thesis has been carried out in accordance with the TU/e Code of Scientific Conduct

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PUBLIC SUMMARY

Nature in cities and villages is under pressure. New construction and climate-resilient buildings offer less and less space for animals. With the project “Natuur-inbouw” new living space is being created in and on buildings for birds, bats, and insects that depend on these structures.

To counteract the loss of biodiversity, the nature and construction sectors are joining forces to support building-dependent species in urban environments by providing nesting and breeding sites. This knowledge is applied in Flemish and Dutch homes, buildings, and infrastructure. The project contributes to promoting nature-inclusive building practices and sharing expertise.

Within this research project, two pillars are essential: innovation and policy. Innovation focuses on how Flanders and the Netherlands can learn from each other through knowledge exchange during multiple meetings. The project does not only examine built-in nesting and breeding boxes, but also entire building structures to identify and make use of unused spaces.

In terms of policy, the project explores different ways nature-inclusive construction can be implemented within legal frameworks. The challenges surrounding building-dependent animals are highlighted, and the goal is to work towards a future in which every building incorporates fauna provisions. Finally, practical methods and recommendations are offered to various target groups and policymakers.

This document focuses primarily on how construction details can be optimized so that they can be more easily integrated into building practice in the future. Various possibilities within residential construction are identified. For each option, construction detail principles are presented that make nesting and breeding sites for animals possible. The document discusses which species, such as building-dependent bats or birds, may benefit. Attention is also given to the materials and shapes of nesting and breeding sites, which are important design factors.

The details are assessed based on three principles: social design, constructability, and participation. By incorporating these principles into the design process, citizens can more easily implement them while also increasing awareness.

Finally, the document aims to serve as a source of inspiration for professionals in the construction industry, such as architects and contractors. With more creative freedom and time, designs can better and more beautifully accommodate both animals and humans.

FOREWORD

During the two years that I have spend on my EngD, a lot was learned and experienced. The biggest learning for me was to understand detailing better, coming from an architectural master. The ecologist side of the research was a pleasant surprise. Where I thought I knew a lot of ecosystems and nature, I was proven wrong. My understanding has grown so much, about the animals living and how it eventually also affects us.

To make sure that all was guided properly, I got the opportunity to become the coordinator of the work package I was doing my research in. This led to steering the project as well, where eventually a good result came forward from.

Next to the research and design process that was done, a side track was created. Within the project, education was also an important factor to take into account. This gave me the possibility to practice the field of education. To go more into depth on this topic, I followed the UTQ learning track, next to my research and courses. With obtaining the UTQ, I know am able to implement the notion of nature inclusive better in the education.

All these extra but relevant experiences, which has deepen my personal and professional sides, were not possible without a few people. Firstly, a very big 'merci' to Anke Haex, project coordinator. She always was open for discussion and guiding me where needed. Thanks for the trust. Faas Moonen is also some one who not only was my supervisor during this project, but also became a valuable colleague and in a way, mentor for more than just the project.

Also big thanks to my friends and family who have supported me during the last two years. Sometimes, these ambitions and several side quests led to a busy life, but I always got through it.

Lastly, a big thanks to my office family, who were there for me every day if I needed to vent, run around or just make noises. Floor and Vincent, thanks for letting me be the tiny brother. And Monique, major thanks for always allowing me to storm inside to talk.

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1.INTRODUCTION







RELEVANCE
why it is important to research

Across the world, a wide variety of climates, habitats, biomes and ecological niches can be found. When these elements come together, they form what is known as a biotope: a spatial environment defined by both its living (biotic) and non-living (abiotic) conditions. Traditionally, seven major biotopes are distinguished: tropical rainforest, desert, savanna, tundra, forest, freshwater, and saltwater environments *(Wikipedia-bijdragers, 2025)*.

Each of these biotopes functions as part of a larger ecological system. The abiotic components, such as temperature, water, soil, and light, form the foundation upon which life can exist *(De Niche, Habitat, Biotoop En Het Ecosysteem - Mr. Chadd Academy, n.d.)*. When these conditions are disrupted, the ecosystem as a whole is affected. Changes in a biotope can lead to the loss of habitats, shifts in temperature, and a decline in vegetation. These effects rarely remain isolated; instead, they cascade through the system, influencing both animal and plant life.

Because ecosystems are inherently interconnected, it becomes clear that something is missing from the traditional list of biotopes. The city, where more and more of the world's population now lives, is not considered a biotope in this classification. However, this omission has been questioned. In 2002, planner and academic Helga Fassbinder introduced the concept of the "Biotope City," proposing that dense urban environments should be understood as ecological systems in their own right. Her idea suggests that cities are not separate from nature, but rather places where ecological processes continue to take place in new and often unexpected ways *(Helga Fassbinder Personal, n.d.)*.

Some urban developments already demonstrate how the concept of the city as a biotope can be translated into design. A well-known example is the Zuidas in Amsterdam, where parts of the development have been approached as if they form a mountain landscape. This design strategy creates conditions that resemble natural habitats, attracting bird species that typically inhabit mountainous environments.

At the same time, elements of the city center of Amsterdam can also be understood as functioning biotopes. The canal system, for instance, forms a unique ecological network in which plants and animals live, interact, and adapt over time. Within these water-based structures, species are not only able to survive, but also to develop and evolve in response to the specific urban conditions.

This perspective is reinforced by more recent observations of urban nature. As described by Menno Schilthuizen, species living in cities do not simply survive, they adapt and even evolve in response to urban conditions. Animals and plants in urban environments can develop differently from their rural counterparts, showing that the city is not just a passive setting but an active ecological context *(Studio Schilthuizen, n.d.)*.

If we accept the city as a biotope, then the way we design it becomes crucial. Urbanisation has already altered many natural systems, often reducing the availability of suitable habitats. A clear example is the decline of species such as the house sparrow, which has been linked to changes in construction methods that no longer provide appropriate nesting opportunities. Similar challenges affect bats, which play an important role within ecosystems. As indicator species, their presence often reflects the overall health of an environment, when bat populations decline, other species are likely to follow.

The importance of these species extends beyond ecology alone. A striking example can be found in the United States, where a fungal disease led to a large-scale decline in bat populations. As bats disappeared, insect populations increased, forcing farmers to use significantly more pesticides. This increase had direct consequences for human health, including a measurable rise in infant mortality. The absence of bats disrupted a natural balance, demonstrating how closely human well-being is tied to ecological systems *(Frank, 2024)*. Therefor, given that it is less known what bats prefer, the focus will be more on how to design for bats.

This example illustrates why it is essential to reconsider the role of nature in and around our buildings. Supporting populations of birds and bats is not simply a matter of conservation, but part of a broader responsibility to design environments that function ecologically as well as socially. However, achieving this is not straightforward. It requires a shift in thinking, from buildings as isolated objects to buildings as active components within larger ecological networks. Designing with nature in mind therefore means more than adding greenery as an afterthought. It calls for integrated solutions that address multiple challenges at once, including climate adaptation, water management, circularity, and biodiversity. In this context, nature-inclusive design becomes a key approach, enabling buildings to contribute to their surroundings rather than simply occupy them.

Within this research, the focus is placed on this nature-inclusive approach at the scale of the building detail. More specifically, it explores how architectural elements can be designed to provide suitable living spaces for birds and bats. By working at this smaller scale, the aim is to demonstrate how targeted interventions can contribute to a larger ecological system, bridging the gap between architecture and the urban biotope.

Therefor, the major research question for this thesis will be:

"To what extent can building details optimized to make a valuable and suitable habitat for building-dependent animals, with a focus on bats?"



image 1.0: The Barbican in London, good example of how architecture and nature are intertwined

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INDICATORS
focus for the research

Within the research project three types of construction methods were examined: new construction, timber frame construction, and the integration or renovation of existing buildings. Because construction practices and commonly used materials differ between Flanders and the Netherlands, the selection of options distinguishes between general applicability in the Netherlands and/or Flanders.

Since bats and birds have different needs, it is important to consider options for both, but only when this is practically feasible. Birds such as the house sparrow require less space than, for example, the greater horseshoe bat.

When roosting sites are integrated into a home, it is most logical to consider this from the design phase. The study will explore whether the possible options can be applied in new construction. With the future in mind, however, there are also two more sustainable construction methods: renovation and timber frame construction. Therefore these methods will also be explored within the construction of new homes.

The difference in construction methods between Flanders and the Netherlands is striking. The Netherlands builds much more efficiently than Flanders. On average, the Netherlands constructs 65 square meters per home, while in Flanders this is as much as 148 square meters. For this reason it is important to investigate whether certain construction techniques from the Netherlands can also be applied in Flanders.


for bats


for birds


new buildings


timber skeleton


renovation


for Flanders


for Netherlands

HIDE-OUTS
bats and birds

The illustration on the right shows a schematic overview of where bats and birds can stay in and around houses. Because of their small size, bats can position themselves in many small openings and hidden spots.

Common places where bats like to stay include the cavity wall (11), under the roof (6), and close to a chimney (2). This is because these areas often have heat loss from the house. One of the main reasons they prefer these locations is that they can easily move between different spots. This will be explained in more detail later.

There are also many small gaps and spaces where bats can settle. Think for example of a roofed terrace (5) or a small but suitable opening near a gutter (4). Almost every dated house has its cavities and other free spots that are attractive to bats.

More traditional house construction also offers plenty of space for bats. A suitable place can be created, sometimes unintentionally, behind the wooden cladding (16) of a house. Because wood is a material that often has natural irregularities and is never completely even, this can create roosting opportunities for bats.

There are also many other places where bats may stay briefly but will not use as a resting place for the night. Some species can hang under an eave (1) during the summer. They may also make use of a roof fold (10), because the fold creates a kind of narrow gap where they can hide. The same applies to a stone facade (15), where the irregularities in the structure offer shelter.

All in all, there are many places in and around a house where bats can hide, stay, or reproduce.

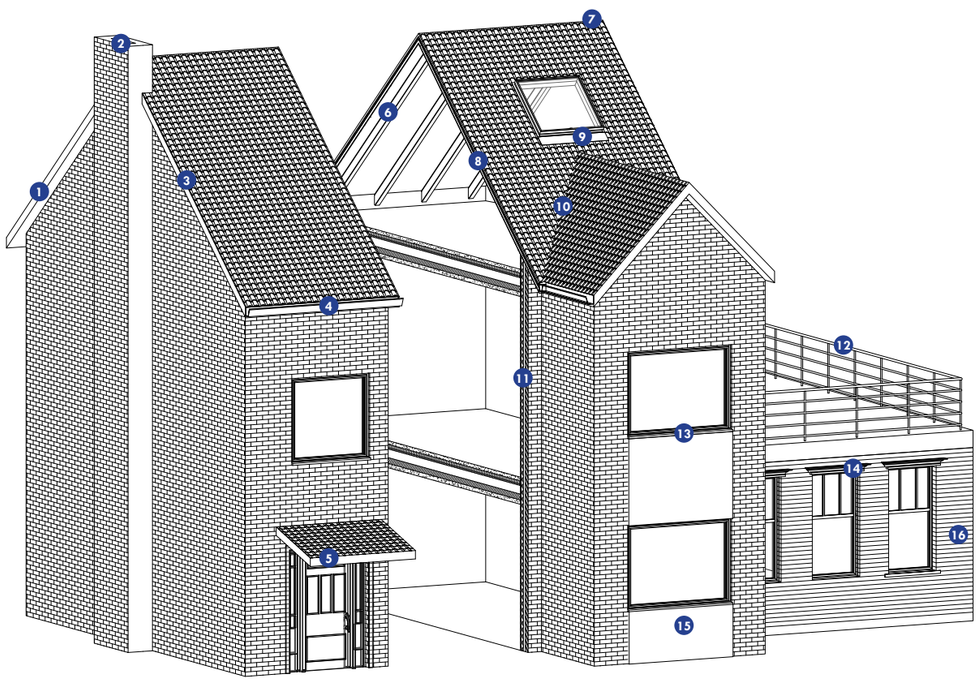


image 1.1: indication of possible shelters for bats and birds

UNUSED SPACES

how to optimize for building depending animals

Following the possible locations where bats and birds can stay, an examination was also made of the spaces inside a house that are not used by people. Next to this text there is a schematic representation of a section and a floor plan of a standard home in Flanders and the Netherlands. The areas shown in dark blue indicate where there are possibilities for an improvement of nest and roosting places. Both images will be used in the following chapters to show where these improvements are located within the house.

Because of traditional house construction, there are unused spaces in certain parts of a home that may be suitable for bats or birds. It can be seen that both the ridge of the roof, at the very top, and the roof to floor connections often contain spaces that are unused or inconvenient for people.

These spaces, although built, are unused but paid for. So why not include them in the building process and make them accessible for animals as well. The next chapters will explore this further.

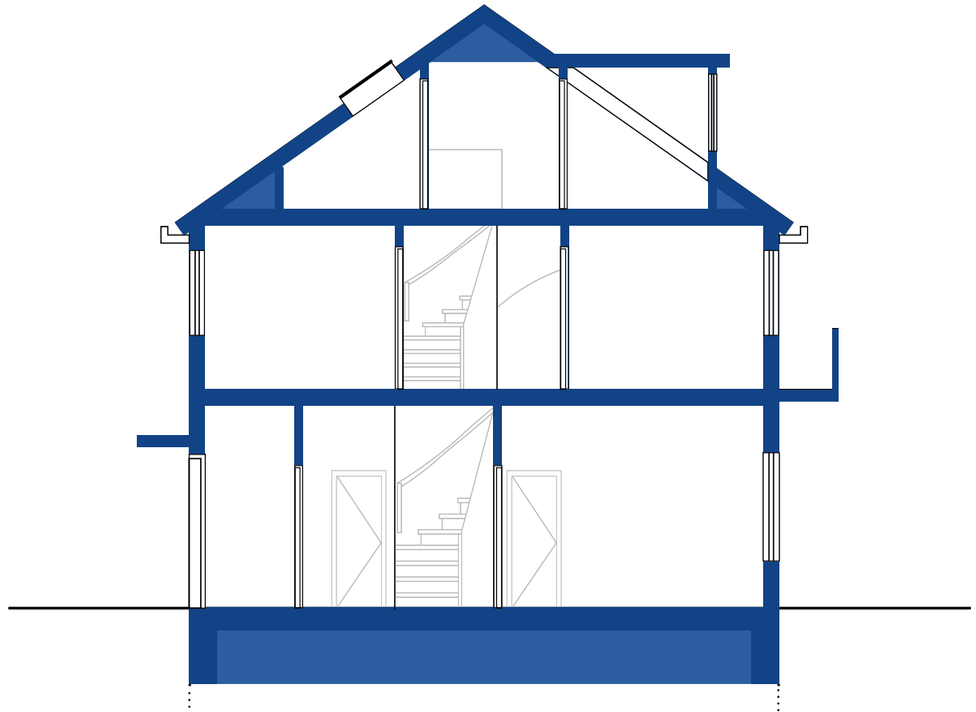


image 1.2: section of a house, showcasing the unused areas in yellow

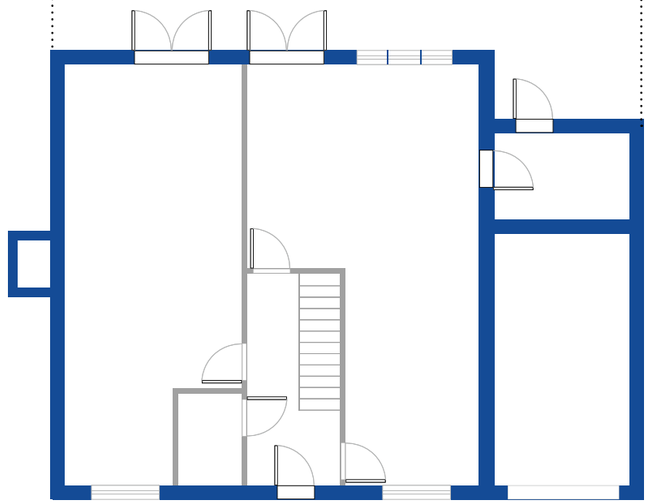


image 1.3: section of a house, showcasing the unused areas in yellow

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BIRDS
how to design for them

Birds have different needs compared to bats. Birds benefit from various types of nesting spaces, depending on the species. There is a wide variation in the height, width, and length of a bird house, as well as the shape and size of the entrance opening that is suitable for each specific bird.

In this chapter the different requirements of the birds are presented and illustrated. For each species the optimal nest box size is shown along with the preferred mounting height. Attention is also given to the side of the house on which the nest box should be placed. This relates to wind direction, exposure to rain, and sunlight. *(Vogelbescherming Nederland, n d c)*

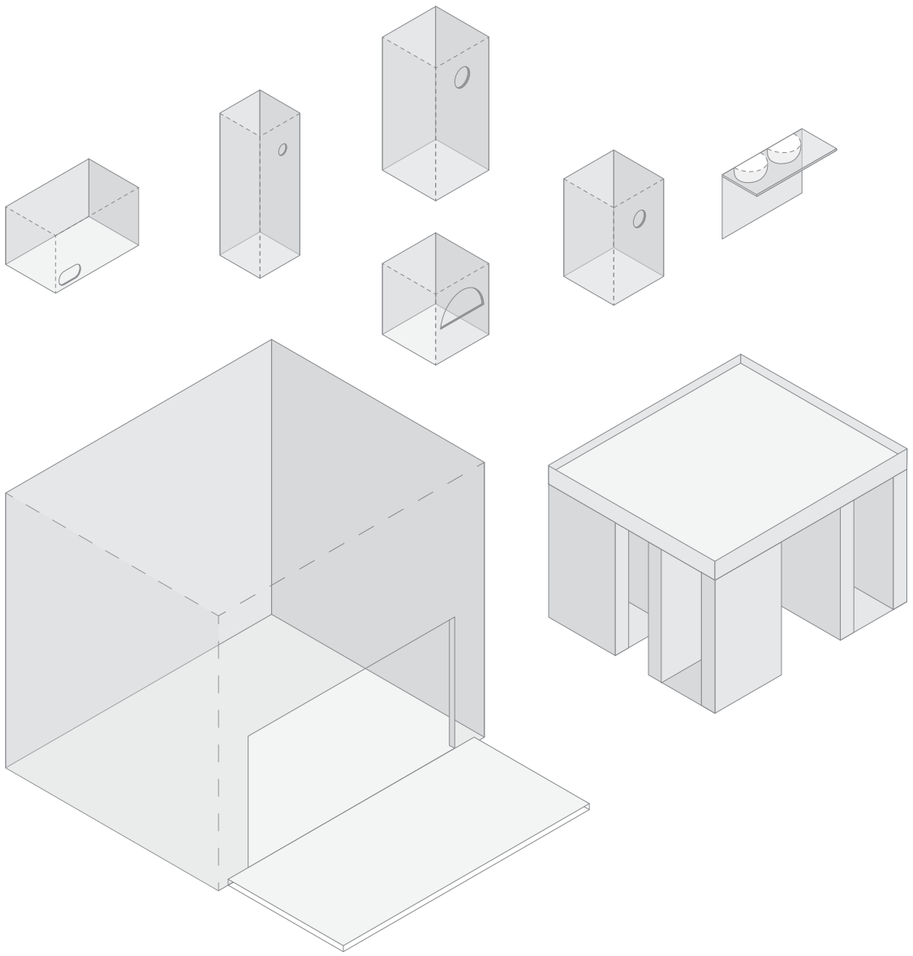
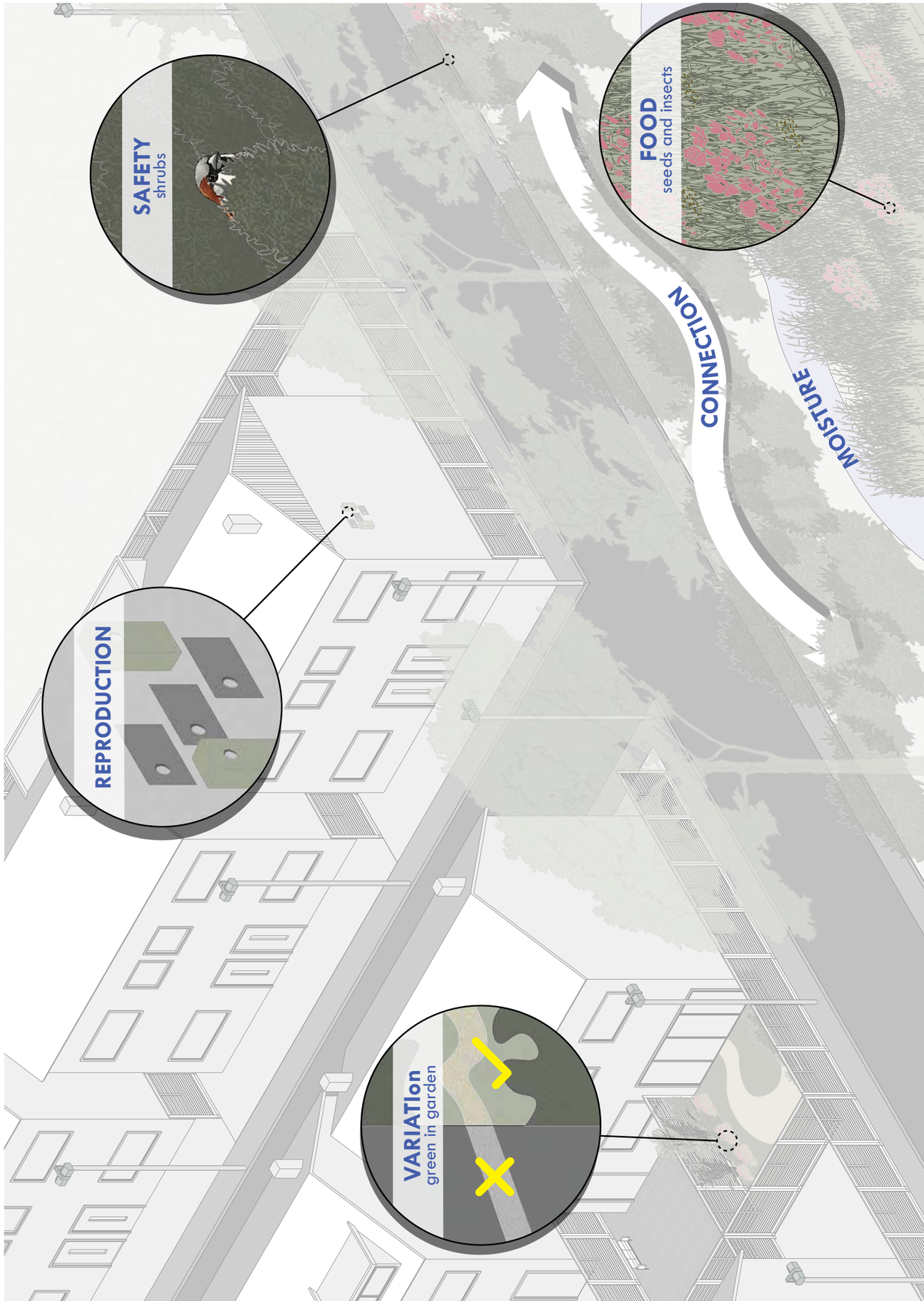


image 1.4: options per species

Several species are shown, with their preferences of height, orientation and the dimensions of the shelter in the work document that is published within the research project.

On the image on the right side, the five criteria are shown that are important for birds to thrive in an urban context.



BATS
dangers for bats

Because bats live in the cavity wall due to the warmth, it is important to take into account activities such as additional insulation. Although insulation is necessary, an approach that is not well considered can cause bats to lose their roosting place. Bats are protected under the Environmental Act *(Omgevingswet en Vleermuizen, n d)*. This means that measures must be taken to prevent the loss of these roosting places and to ensure that bats do not become trapped in the insulation. For this reason it is essential that in fauna inclusive construction and renovation, both goals, insulation and the protection of animals, are combined in a thoughtful way.

In addition to this, lighting is an important factor in bat behavior. Most bats avoid light, mainly because it increases their vulnerability to predators. Artificial night lighting, such as Ember light, can have a negative effect on bats. This is because they are unable to see properly in bright light and therefore may not notice, for example, an approaching owl. Only a few species, such as the common pipistrelle and the noctule, tolerate some degree of light in their hunting area, usually because it attracts large numbers of insects around street lamps. However, for the rest of the species, a completely dark hunting area is preferred. This also applies to their roosting places, which may be avoided if light shines outward from windows.

Although wood is a natural product and very suitable for bats, timber used in construction is chemically treated. Because of this treatment, it is dangerous and harmful for bats to come into contact with it. These treatments are only necessary on the exterior of a house. Inside a house, untreated natural wood can be used, which is suitable for bats. On the exterior, natural wood can also be used, such as tropical hardwood like azobe or modified timber.

Another risk for bats is the loss of suitable roosting places as a result of renovation and new construction. Buildings are becoming increasingly well sealed, which leaves fewer accessible spaces for bats. Additionally, certain spaces are intentionally or unintentionally closed off. This occurs for example when weep hole grids are used, which make cavity walls inaccessible for bats.

Finally, predators form a threat to bats. Although martens, owls, and even rodents are known as occasional predators of bats, the free roaming domestic cat is the greatest enemy. If a cat can access the exit point of a bat colony, it can cause significant harm. It is therefore important to take this into account when protecting bats and their habitat.

BATS
misconception

A common misunderstanding is that bats gather in large numbers in open spaces and occupy these areas with hundreds at a time. In the Netherlands and Flanders, however, bats often live in a solitary manner and prefer individual roosting places within buildings. This preference highlights the need to create multiple enclosed spaces in order to house bats effectively.

Despite this, residents often have concerns about bats living in buildings. It is sometimes believed that bats make squeaking sounds or scratch surfaces with their claws, especially in cavity walls or attics. This is not the case. Bats are very quiet animals and fly out only at night. In addition, they do not scratch anything; they only hold on. The droppings of bats are small and do not cause much nuisance. The droppings, called guano, are in fact a good fertilizer for the garden. When a maternity colony is present in a building, there may be slightly more droppings.

Homeowners often fear that bats can cause structural damage to their house, but these concerns are largely unfounded. Bats are very small, which allows them to move easily through spaces in the wall without damaging anything. They do not gnaw, scratch, or break any part of the structure when they are inside a wall. This is mainly because they do not have a beak or limbs that could be used for such damage.

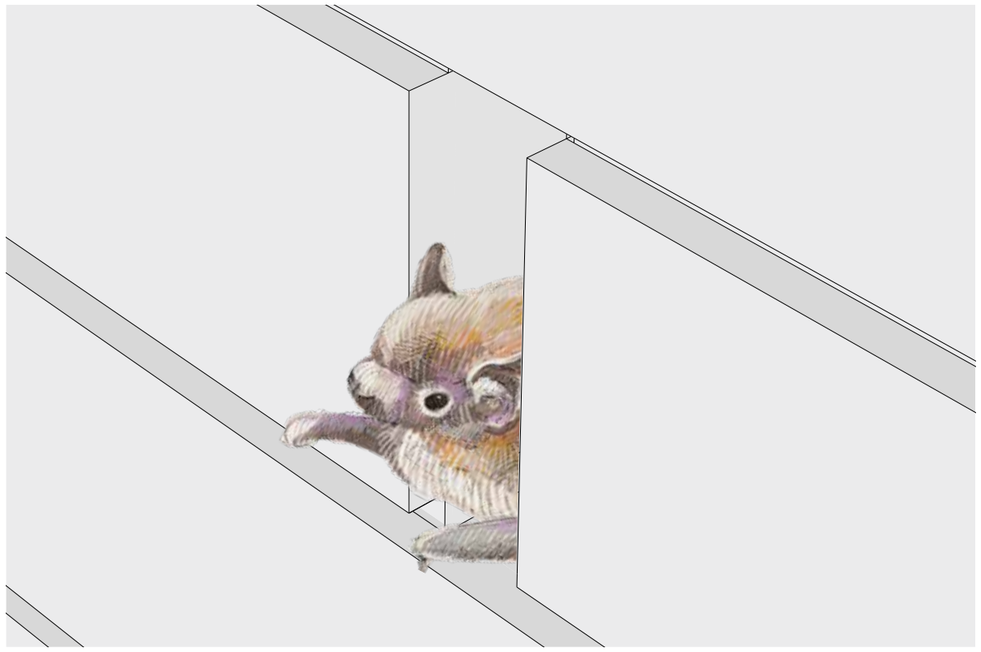


image 1.5: how a bat fits in an opening of the wall

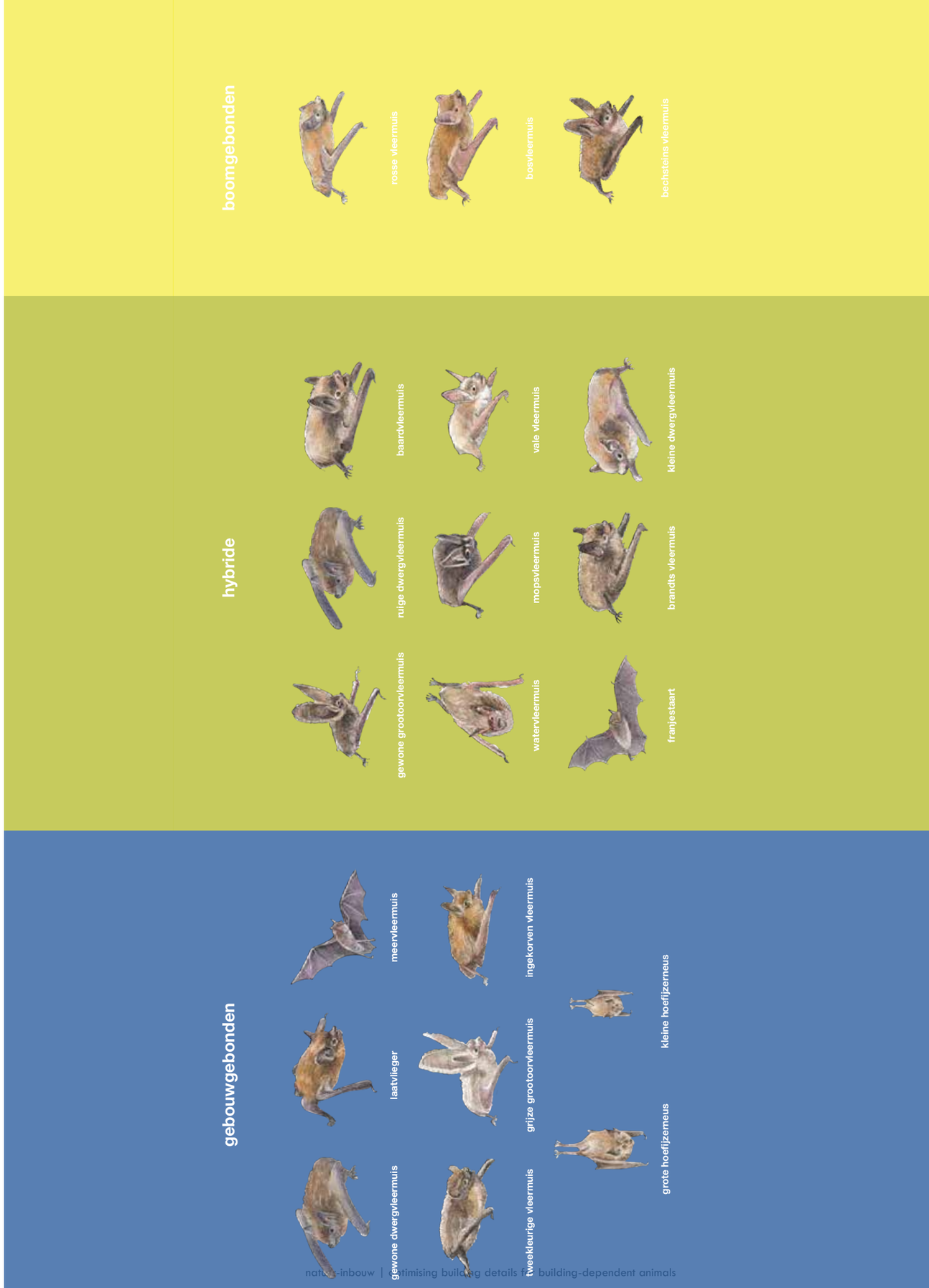
BATS
the species and their spots

Bats have become highly adapted to flight through evolution, as their hands and arms have grown together to form wings. Because of this, bats cannot make their own hollows or create gaps in which to live. They are therefore completely dependent on the surrounding environment to find shelter and a suitable roosting place. Over time bats have increasingly settled in buildings, because these provide many spaces that are comfortable for them. However, different species have different habits. For this reason bats are generally classified into three categories: tree dependent, building dependent, and a hybrid form of both.

Tree dependent bats make use of hollows in trees, often abandoned woodpecker nests. Whether they use the tree throughout the entire year or only during certain seasons depends on the species. The pond bat, the parti coloured bat, and the noctule for example have a strong preference for trees. Pond bats, however, often seek refuge in marl caves, bunkers, or forts for their winter hibernation.

Building dependent bats often occupy small spaces in the cavity walls of buildings. Many species, such as the whiskered bat, the noctule, and the common pipistrelle, fall into this category. Larger bat species, such as the lesser mouse eared bat, the grey long eared bat, and the brown long eared bat, prefer large open spaces where they can fly freely, such as church towers and attics.
(Verblijfplaatsen, n d)

image 1.6: different species of bats and their preferred habitat *(M, Bolsakova)*



BATS
the species and their spots

Why do certain bat species choose to live in houses? Just like humans, bats look for clean and comfortable shelters that protect them from predators. There is an important difference, however. While people usually stay in one place, bats change their roost depending on the season. It is therefore possible that a bat lives in four different places within a single year. This depends on several factors.

One of the most important factors is temperature. During the summer bats prefer warm roosts, while in winter they prefer cold ones, which is the opposite of human preferences. Bats usually give birth to only one young per year, which they raise in the summer. During this period the females gather with their young in a maternity roost, where the temperature can rise to thirty or even forty degrees. This temperature preference varies between species. Some species are so selective that an increase of only one and a half degrees can already cause discomfort. The males live in separate, smaller roosts that are cooler than those of the females. Because of these varying preferences it is important to offer bats different roosting options so they can find the right place.

In winter bats prefer cold conditions. This is because bats in Flanders and the Netherlands feed on insects, which become scarce in winter. They therefore enter a state of hibernation and adjust their body temperature to the surrounding environment. Bats prefer an ambient temperature between five and ten degrees, with a high level of humidity.

The orientation of roosts is often linked to the season. Maternity roosts in the Netherlands and Flanders are usually oriented toward the south and the west, because these sides receive the most sun. Male roosts and winter roosts are often oriented toward the north, because there is the least amount of sun exposure.
(Trust, n d)

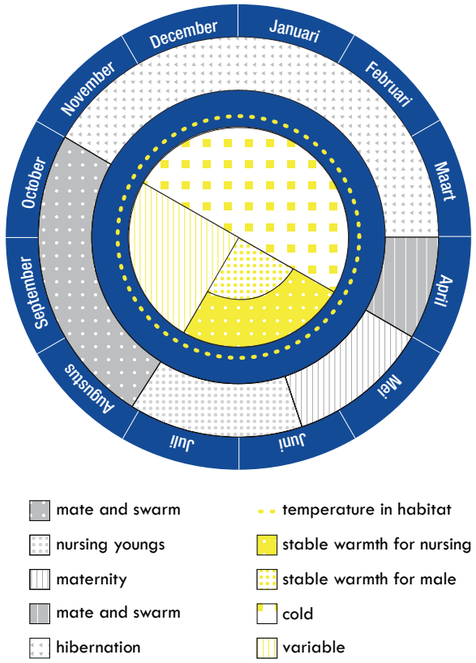


image 1.7: cycle of the bats

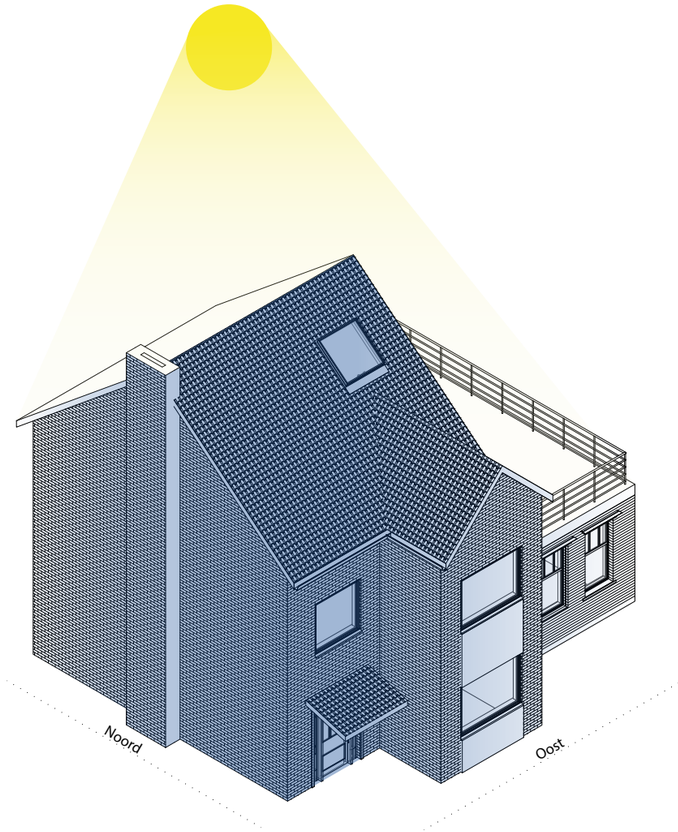


image 1.8: illustration of house with sun

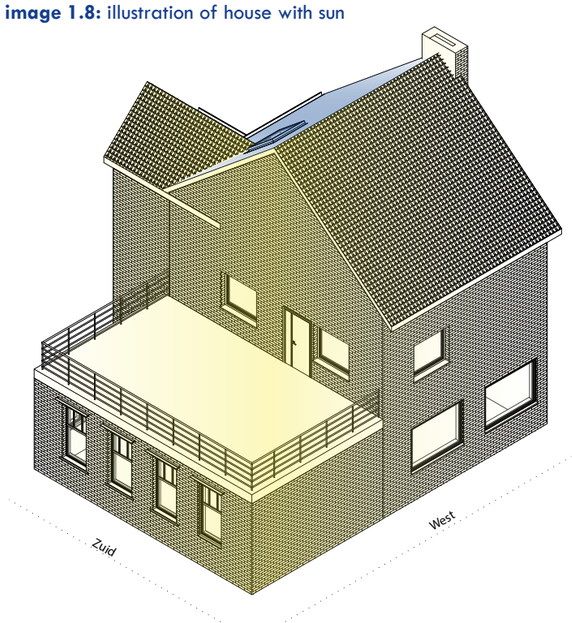


image 1.9: illustration of house with sun

BATS
the species and their spots

Although not much is known about the very specific roosting preferences of bats, there are some general sizes and guidelines for housing bats in new construction or existing buildings, as mentioned earlier. There are four classifications for bats that live in houses: crevice dwelling species, roof dwelling species, free flying species, and horseshoe bats. Each type has specific requirements for the entrance of their roost.

Crevice dwelling bats crawl through small gaps to enter their roost. These gaps must be between fifteen and twenty millimeters high and twenty to fifty millimeters wide. The ideal height of this entrance is between two and seven meters above the ground.

Roof dwelling bats usually occupy open spaces in or under roofs. They have the same entrance requirements as crevice dwelling species, but in addition they need a wooden beam or roof beam to hold on to. Here as well the entrance is located between two and seven meters above the ground.

Free flying bats also require an opening that is fifteen to twenty millimeters high and twenty to fifty millimeters wide. Their roosting space must have a height of about two point eight meters and a width and depth of five meters. It must be a large open space without divisions into compartments. The entrance is located more than two meters above the ground.

Horseshoe bats differ from the other three classifications because they fly straight inside instead of crawling through gaps. The lesser horseshoe bat requires an opening of three hundred millimeters in width and two hundred millimeters in height, while the larger species requires a width of four hundred millimeters and a height of three hundred millimeters. Other than this, their roosting requirements are similar to those of free flying bats.

When looking at bat species that use houses as roosts, the focus is mainly on crevice dwelling and roof dwelling species. These are the most common types found in residential buildings. Large open spaces are much less common because such spaces are usually not practical for human living.
(Trust, n d)

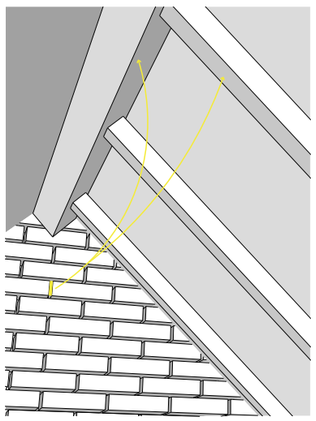


image 1.10: roof-living bats

brown long eared bat
grey long eared bat
lesser mouse eared bat
noctule
whiskered bat

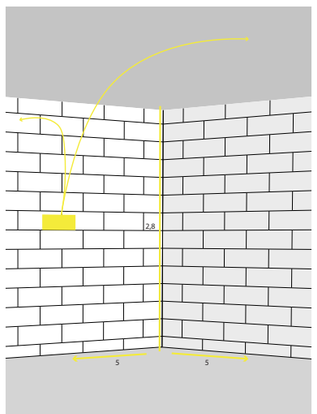


image 1.11: swarming

common pipistrelle
pond bat
noctule
whiskered bat

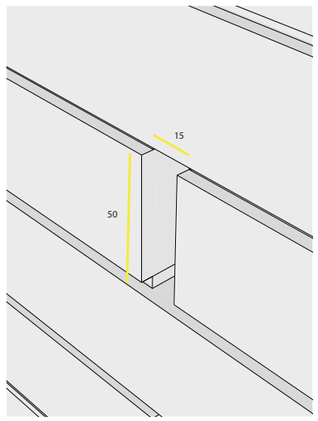


image 1.12: cavity-living bats

common pipistrelle
pond bat
noctule
whiskered bat

BATS
height and warmth gradient

It is well known that bats like to move through the cavity wall of a house. The reason they do this is because they are very selective. As discussed earlier, bats require a specific temperature range in order to thrive. To find the perfect location, there are two crucial factors: a height gradient and a warmth gradient within their roost.

The height gradient is important because it allows bats to move freely and find a new hiding place if needed. Think of a space with different levels and side spaces. This creates many options within the same area. In the illustration next to this text an exaggerated example is shown.

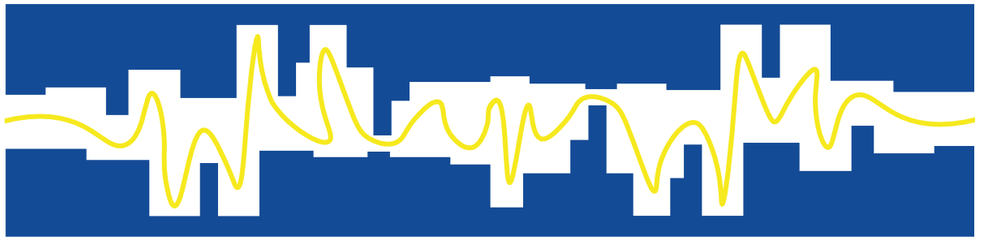


image 1.13: height gradient illustration

These different heights work together with the warmth. Because bats are so selective, they quickly move to another spot that feels more comfortable. Height helps with this. A pocket of warm air can form in the higher parts, or there may be a cooler place lower down where they can go. This is essential for providing the best thermal comfort for the bat.

The insulation of the cavity wall also plays a role. A well insulated wall can help to keep the temperature stable, which attracts bats. But the presence of small openings or gaps can also draw bats into the space. It is important to understand that bats are protected animals and that their presence in houses often indicates a healthy ecosystem around the home.



image 1.14: warmth gradient illustration

BATS
positioning of shelters

When installing built in boxes and mitigation boxes, several aspects must be taken into account. The height of a roost is crucial for bats, because they need to drop downward to gain speed when taking off. It must also be impossible for predators to reach them. A minimum height of four meters is necessary for this downward dive and to avoid predators. For this reason roosts at a height of four meters are considered acceptable. However, roosts and built in boxes placed higher than five meters are ideal for bats when flying in and out.

Trees and shrubs in urban areas are essential for bats to navigate, but they can also act as obstacles. Trees and shrubs must not block the entrance or exit of the roost. It is recommended to maintain at least two meters of distance between vegetation and the building. There are also obstacles within the building itself. Boxes and roosts should not be placed close to windows that are frequently used. This is important for two reasons. First, the light from the rooms can disturb the bat when entering the roost and can cause noise disturbance. Second, it may create discomfort for residents due to an accumulation of droppings on the windowsill.

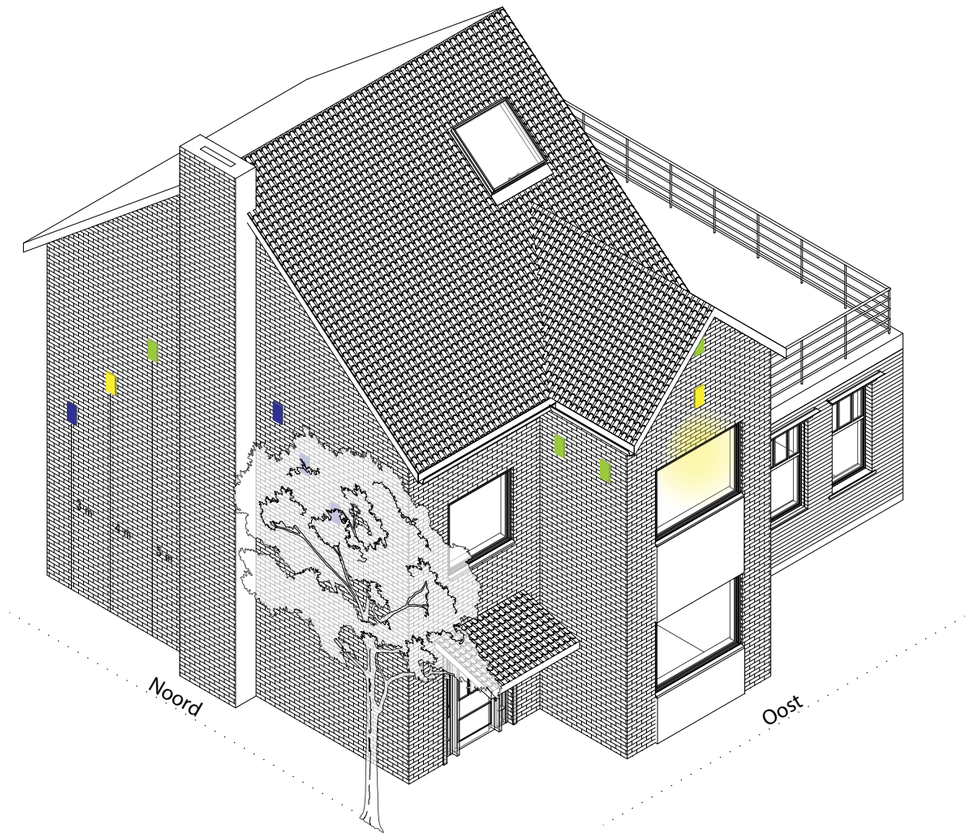


image 1.15: illustration of positioning of the boxes

good optional bad

A roost can also be placed above an extension or above a garage. In this case the height at which the box is installed is essential. A minimum height of two meters is preferred to deter predators such as cats and to provide the minimum drop height needed for the bat to take off. Ideally, the boxes should be installed at a height of three meters.

Bats avoid light sources, such as lamps mounted on buildings that shine in multiple directions. For this reason, boxes should not be installed directly above or next to a light source unless the beam of light has been adjusted, for example by narrowing the illuminated area.

For maternity boxes the location is also important. Maternity roosts should not be placed above openings such as doors or windows that are regularly open, to prevent animals from accidentally flying into the building or droppings from falling inside. A standard roost generally causes less disturbance from droppings. For maternity boxes, side walls or gable walls with few or no windows are most suitable. The best location is at the very top of the ridge of the roof.

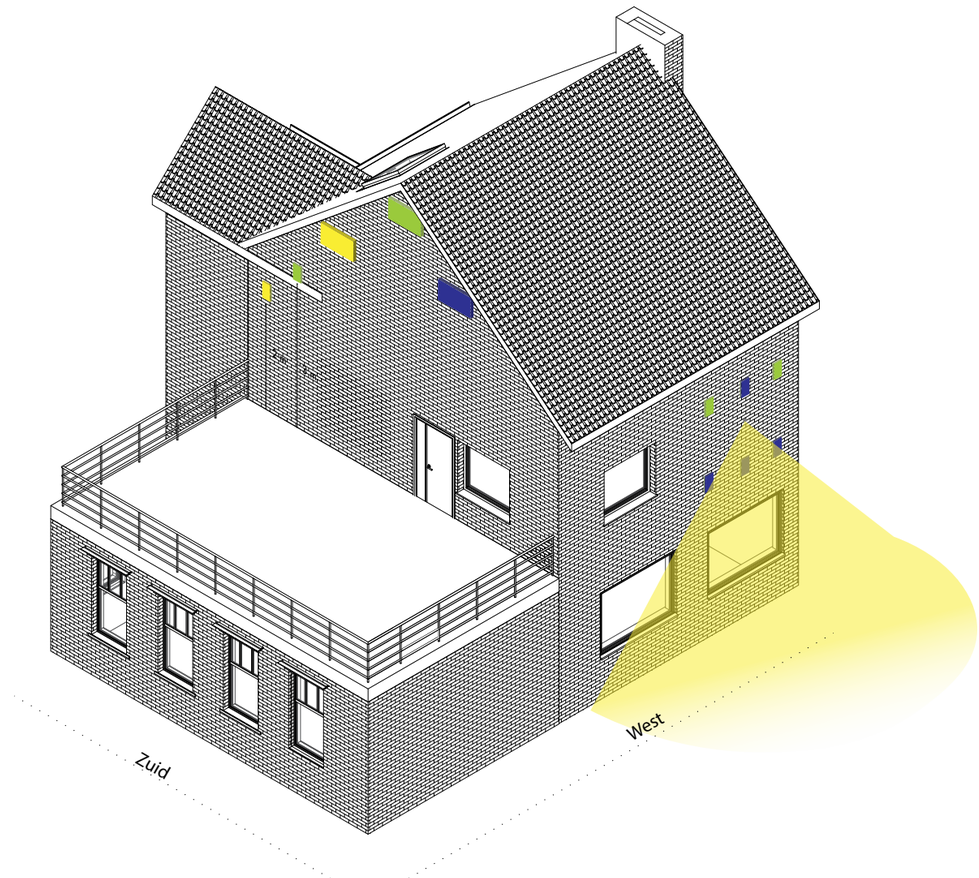


image 1.16: illustration of positioning of the boxes

good optional bad
good optional bad

BATS
environment

The material of the roosts is also very important. It must be made of rough and untreated natural material, such as Douglas wood. It must also not corrode or crumble, because this could harm the bats. Foils or fabric like materials can be dangerous, as bats can become entangled in them.

The roost must also be made of a material that can maintain the correct temperature conditions. The temperature variation within a time span of twenty four hours must remain minimal in order to create a stable environment. For summer roosts the material must help the temperature rise.

Regarding the exterior of the roost, lighting and the surrounding landscape also play an important role. Bats are nocturnal and can fly very well with little or no light. However, due to the modern world, light pollution has become an increasing problem, which can confuse bats. It is therefore important that the flight routes are never illuminated. If lighting is necessary, the illuminated areas must be shielded or specifically directed.

The environment must also provide enough options and places where the bats can hunt. The landscape must attract insects through plants that are beneficial for insect life. Dark hedges, rows of trees, and water features help bats move easily through the area. These linear structures, shown in the illustration, are used by bats to navigate from their roost to open areas where they can hunt. This vegetation not only offers shelter from predators and rain, but also functions as an echo wall for their acoustic orientation.

By designing an environment with many insect rich areas, where trees and water create linear connections and where it remains dark enough to keep it safe, bats will be able to reproduce successfully in a building that offers sufficient variety.
(Trust, n d)

The image on the right, shows in Dutch, the five criteria a surrounding needs to be fulfilling of.

Veiligheid = safety
Variatie = variation
Voorplanting = reproduction
Verbinding = connection
Voedsel = food

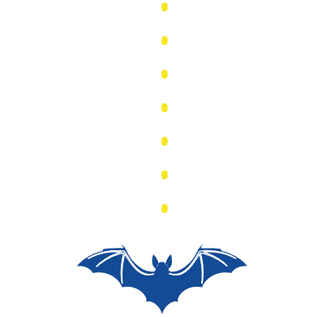
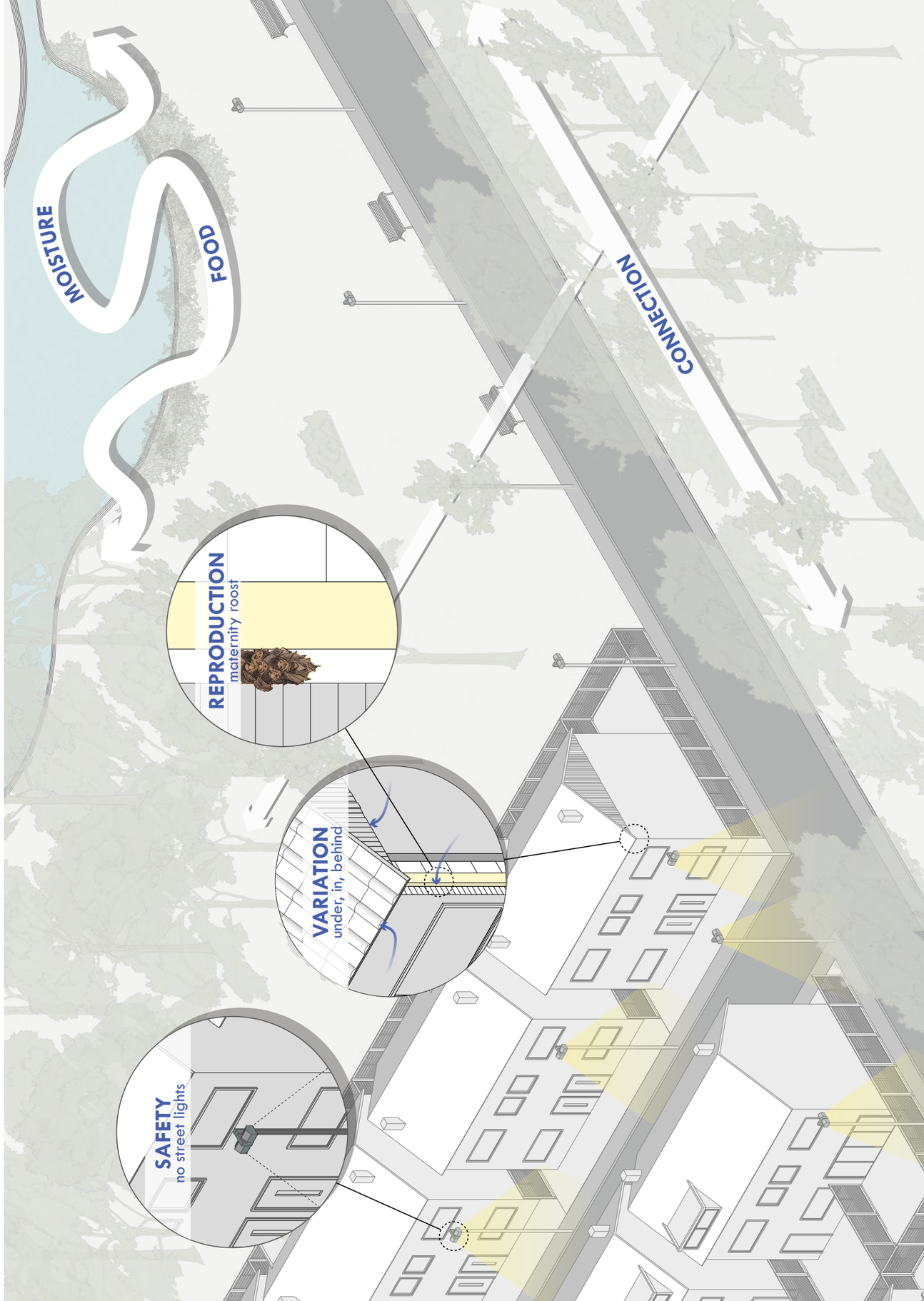


image 1.17: illustration of bat dodging a light source



PREDATORS
danger for bats and birds

Despite many accusations, the bat is an innocent animal within the food chain. Apart from humans, who threaten the animal by causing suitable roosting places to disappear, there are also other animals that actively prey on bats.

Bats often fall prey to birds and rodents. Birds of prey catch bats in the air, while rodents more often enter the roost to attack them there.

For bats the situation is already unsafe at dusk. Around this time the kestrel is still flying and can spot the bat and catch it from the air. But even during the night there are birds of prey with night vision, such as the tawny owl and the barn owl. Because many bats are the size of an ordinary mouse, rodents such as mice can also easily enter their roost. This also applies to rats and stone martens. A bat needs twenty to thirty minutes to awaken fully from hibernation. As a result there is a risk of being eaten alive.

Bats also suffer from parasites that attach themselves to their bodies. Mites, fleas, and ticks feed on the blood of the bat. It does not help that bats are good hosts for these parasites because they can live a long time, they often live in large groups, and they have a relatively large surface area for parasites to sit on.

(De parasiet van de parasiet: Vleermuizen, vleermuisvliegen en schimmels, n d) (Bedreigingen voor vleermuizen, n d)



image 1.18: Tawny owl



image 1.19: Kestrel



image 1.20: Barn owl



image 1.21: Stone marten



image 1.22: Mouse



image 1.23: Rat



image 1.24: Tick



image 1.25: Flea



image 1.26: Mite

NOTICES
where to look into when designing

When designing a roost for bats within a building, careful consideration must be given to preventing predators from gaining access. This challenge must be examined for each construction detail, and solutions should be developed where necessary.

However, the bat roost can also pose a risk to other animal species. Sometimes animals are able to enter the roost but, unlike bats, are unable to fly out again and become trapped inside. This can happen, for example, when an entrance to the roost is placed at ground level, allowing frogs and toads to fall into the space.

For this reason it is essential to ensure that only bats can access the roost. This can be examined in detail, and a suitable solution can be found for each specific situation. Many bat roosts are positioned at greater heights and are therefore accessible only to bats that can fly to them. When the roost is located at a lower height, solutions such as a so called mouse tooth, shown in the illustration next to this text, can be used.



2.RESEARCH

RESULTS
methodology

This research was conducted within the framework of an Interreg subsidy project, which aimed to develop construction details that can be easily integrated into building envelopes while providing suitable habitats for bats and birds. The overall goal was to design feasible, scalable building details that meet ecological, thermal, and construction-related requirements.

Within the Interreg subsidy, a structured methodology was defined to guide the process from exploration to implementation. The first step involved collecting a broad range of construction details that could potentially function as habitats for fauna while minimizing disturbance to occupants. In total, fourteen details were identified based on three main criteria:

- Suitability for bats and birds
- Minimal negative impact on houses
- Practical and efficient integration into the construction process.

To improve clarity, the collected details were categorized into four groups: external elements (e.g. chimneys or crawl spaces), walls, floors, and roofs.

Each of the fourteen details were evaluated using SWOT analyses, which allowed for a critical assessment of the strengths, weaknesses, opportunities, and threats of each option. This systematic evaluation helped identify the most promising solutions and set aside details that did not sufficiently meet the project criteria. On a level from 1, worst, to 10, best, the details were classified and gave an overview which ones were not good to use.

Based on this analysis, the fourteen details were narrowed down to eight: crawl space, concrete floor, roof edge, additional façade, roof pitch, green wall, chimney, and roof-related elements. These eight details were further refined to six after evaluating feasibility, ecological value, and technical performance.

Presentation at EmBuild Inspiration Day

The shortlisted details were first presented at the EmBuild Inspiration Day, where professionals from the construction sector provided feedback. These discussions were instrumental in reflecting on construction feasibility, integration within existing building practices, and potential limitations. The feedback supported further refinement of the selected details.

To assess the thermal performance of the selected details, COMSOL Multiphysics was used to simulate heat transfer behavior. Thermal stability is essential for both indoor comfort and animal habitats, making this step critical for evaluating feasibility.

The simulations focused on thermodynamics, using heat flux calculations to analyze temperature behavior within the building skin. The following boundary conditions were applied consistently across all simulations:

Inside: convective heat flux
heat transfer coefficient of **8 W/m²K**
temperature of **20 °C**

Outside: convective heat flux
heat transfer coefficient of **20 W/m²K**
temperature of **0 °C**

These values represent common indoor and outdoor conditions and are suitable for assessing building-envelope performance. As COMSOL relies entirely on input data, the simulations are indicative rather than absolute; however, they provide a reliable basis for comparative evaluation. Details that did not maintain a stable internal climate or failed ecological or construction criteria were excluded.

The refined results and simulated details were subsequently presented during the Inverde Education Day, where participants from the ecological sector provided in-depth feedback. These discussions contributed valuable insights into species-specific requirements and highlighted potential ecological risks or improvements that had not been previously identified. This interdisciplinary feedback was essential in validating the ecological relevance of the designs.

Following simulation results and expert feedback, the process concluded with the selection and further development of six construction details:

- Roof edge
- Additional façade
- Roof corner
- Roof ridge
- Chimney
- Crawl space

The six remaining details were further evaluated through discussions on their real-life implementation and the ecological requirements of bats. This process took place within the project consortium and involved iterative exchanges between experts from the ecology sector and the built environment. By continuously aligning these perspectives, the feasibility and ecological suitability of each detail were critically assessed.

Throughout this phase, the details were designed from three interconnected perspectives: social design, participation, and makeability. As the project addressed multiple stakeholder groups, social design played a key role. An important objective was to increase public understanding of bats and their positive impact on the ecosystem, which positioned participation as a central design criterion. In addition, the details were developed with practical constraints in mind, ensuring that materials, construction methods, and costs were accessible and manageable for both private individuals and professional construction parties.

Based on these considerations, the selection was narrowed down to four final details: the crawl space, chimney, additional façade, and a combined roof detail. The roof corner and roof ridge were merged into a single solution in the form of a dormer. This choice was made because dormers are commonly prefabricated in the Netherlands, allowing for efficient installation and on-site feasibility. Furthermore, dormers offer considerable flexibility in design and integration, increasing their potential ecological and architectural value.

These four final details were presented at the midterm event of Natuur-Inbouw, attended by stakeholders from the ecology sector, the built environment, as well as representatives from legislation and municipalities. The multidisciplinary nature of the audience resulted in extensive feedback, which was carefully reviewed and incorporated into the further development of the details.

In the final phase, ecologists provided a last round of targeted feedback on ecological suitability, identifying limitations and opportunities for optimization. This ensured that the details were designed to best support bats and birds while remaining technically and practically feasible.

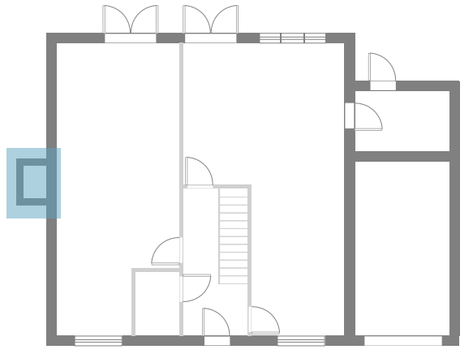
To verify that the digital designs could be successfully implemented in practice, the four details were constructed as 1:1 scale sketch models. These physical models revealed several opportunities for refinement and led to further adjustments to the designs. To bridge the gap between digital design, physical modeling, and real-world application, material renders were produced. These renders served as a clear communication tool, illustrating how each detail functions within a realistic construction context.

The upcoming pages will discuss the results and the process on how the four details were selected.

natuur-inbouw | optimising building details for building-dependent animals

RESULTS
(fake) chimney - external

Chimneys offer many spaces where animals can roost and build nests, especially in homes where the chimney is no longer in use. A false chimney can also serve as a habitat for animals. As the name suggests, a false chimney looks like a functional chimney, but it's actually a decorative addition to a house. However, it also provides places for animals to roost and breed.



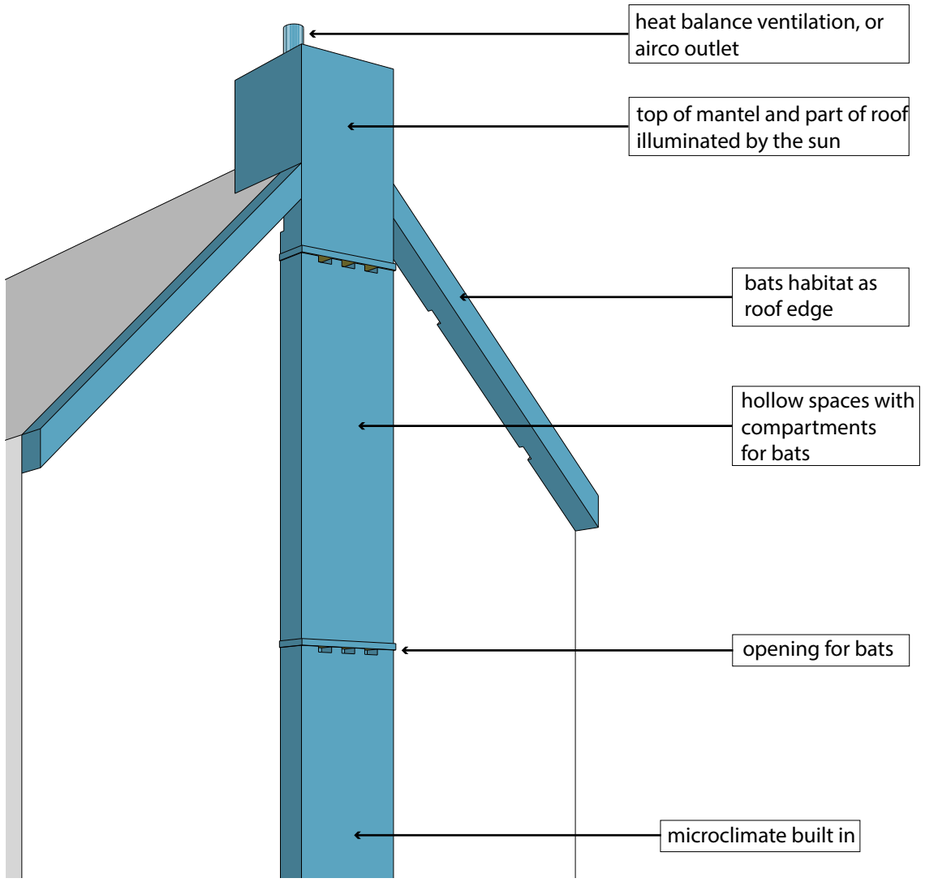


image 2.1: illustration of the possibilities within and around a chimney

SWOT analysis

strength

- Chimneys are used less and less, making them a perfect empty space for conversion into a bat roost.
- Preserving chimneys preserves the character and streetscape of houses, as they are a traditional feature.

weakness

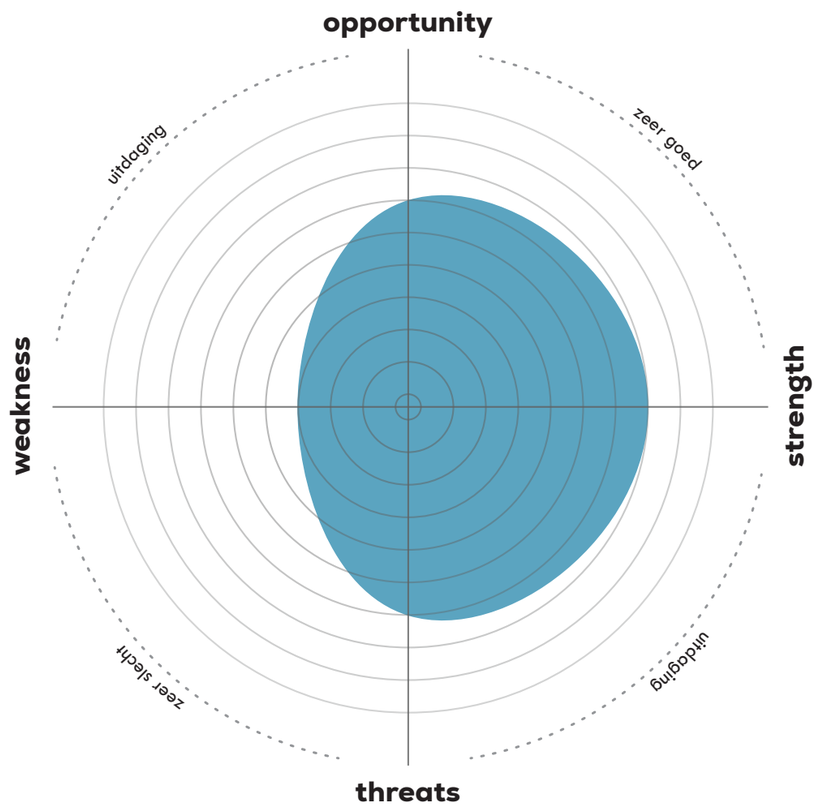
- Chimneys can be problematic due to the difficulty of accessing the enclosed space, which can lead to deterioration of the building.
- This problem is especially prevalent over the long term, for example, over a period of 30 years.

opportunity

- In new construction, a false chimney can be implemented, preserving the streetscape and ensuring better integration of bat roosts.
- False chimneys can help preserve the character of older neighborhoods when new construction takes place.

threat

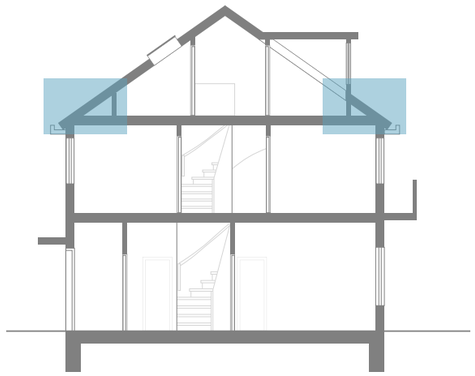
- The disappearance of traditional houses with chimneys due to the rise of high-rise or multifunctional buildings, which changes the streetscape.
- Unnecessary construction costs that make this less likely to happen.



RESULTS
roof-floor connection - external

The upper floors of homes with pitched roofs often contain empty spaces that are rarely, if ever, used. This is because these spaces are difficult to access or inconveniently sized, leaving them unused. Furthermore, a large portion of this space may be filled with insulation, which in some cases can be reduced to create space for nesting and breeding sites.

For example, by adding a small amount of cladding at the eaves or ridge, the attic space can be kept clean more easily. If the empty space is then properly insulated, there is no risk of thermal bridges. This empty space can be accessed either through the tiled roof or the gable end.



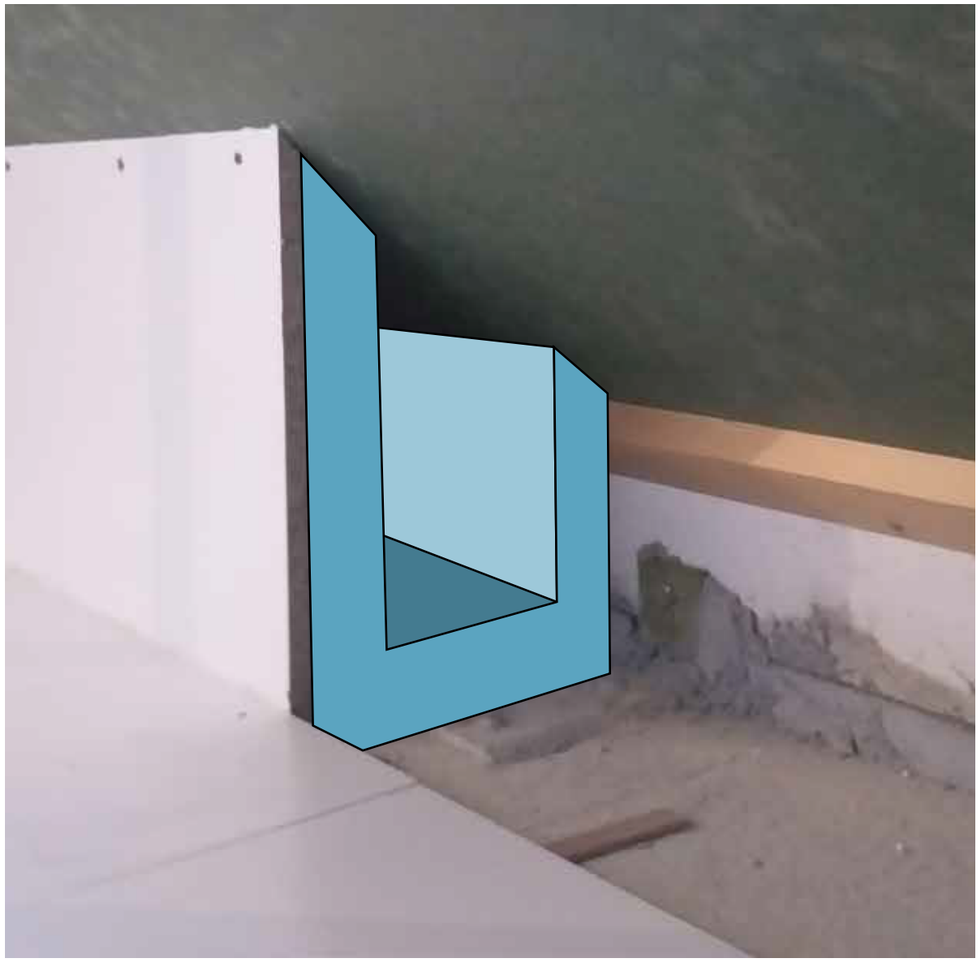


image 2.2: illustration of the possibilities at the roof and floor connection

SWOT analysis

strength

- The space can easily be adapted for bats, making effective use of unused areas.

weakness

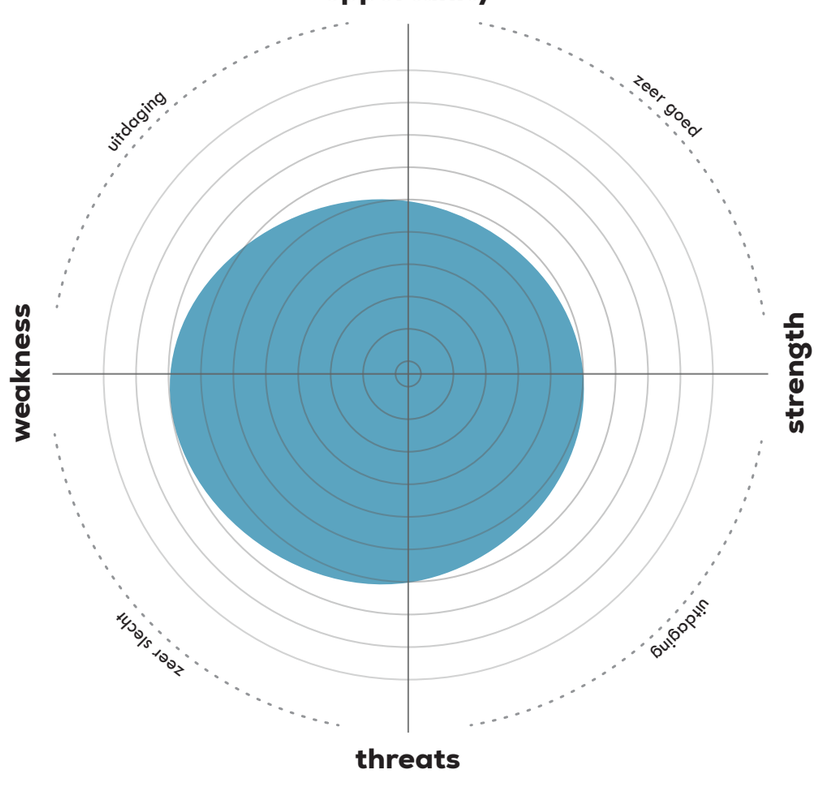
- Horizontal orientation can cause nuisance to residents due to the accumulation of bat droppings.
- Suitable only for single-family homes; terraced houses lack sufficient space, unless a long-stay residence is being created, making them more difficult to clean.

opportunity

- A good option for detached houses with pitched roofs or sheds, provided they are installed short.
- A sloped surface can be used to drain waste, preventing buildup in the space.

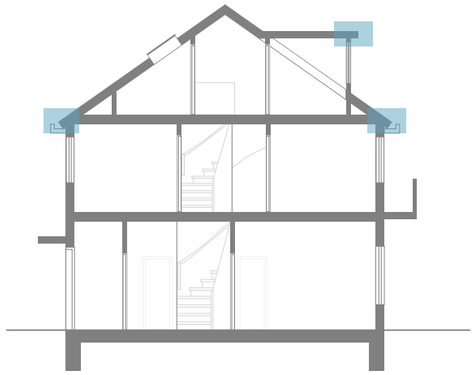
threat

- Potentially inconvenient opening on the side of the house, visible as a bat box.
- Restricted length may conflict with the needs and preferences of bats.



RESULTS
roof edge - external

The roof often extends slightly beyond the wall. This often protects the facade from precipitation and reduces overheating from direct sunlight. Under and within this overhanging eaves, there are also excellent opportunities to create nesting, roosting, and breeding sites for animals. These can easily be housed under the eaves. This is already practiced by and for swallows. In older homes, this nesting spot was always popular with house sparrows. By learning from nature, this knowledge can be translated into optimized building details.



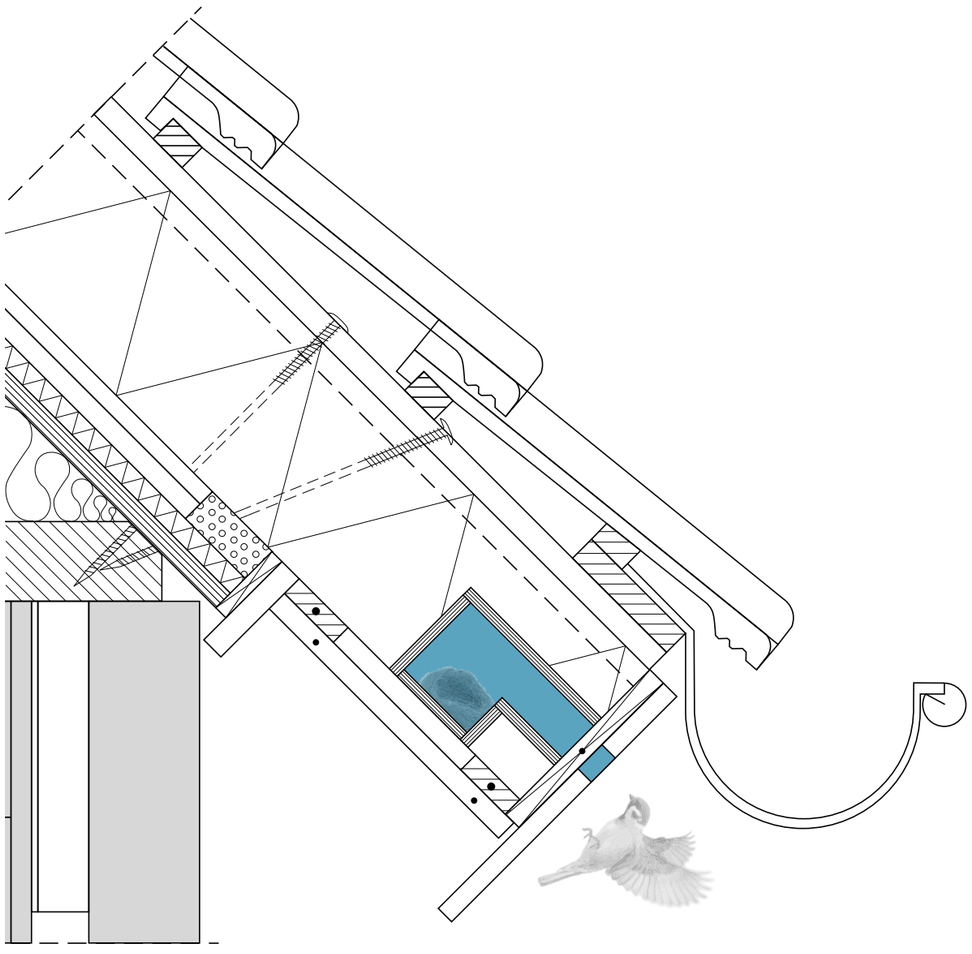


image 2.3: illustration of the possibilities of the roof edge

SWOT analysis

strength

- The eaves can be made suitable for both bats and birds.
- It's an area rarely used, except for rain protection.
- The eaves offer a long space, ideal for creating different climate zones, allowing bats to move around and find the right spot.

weakness

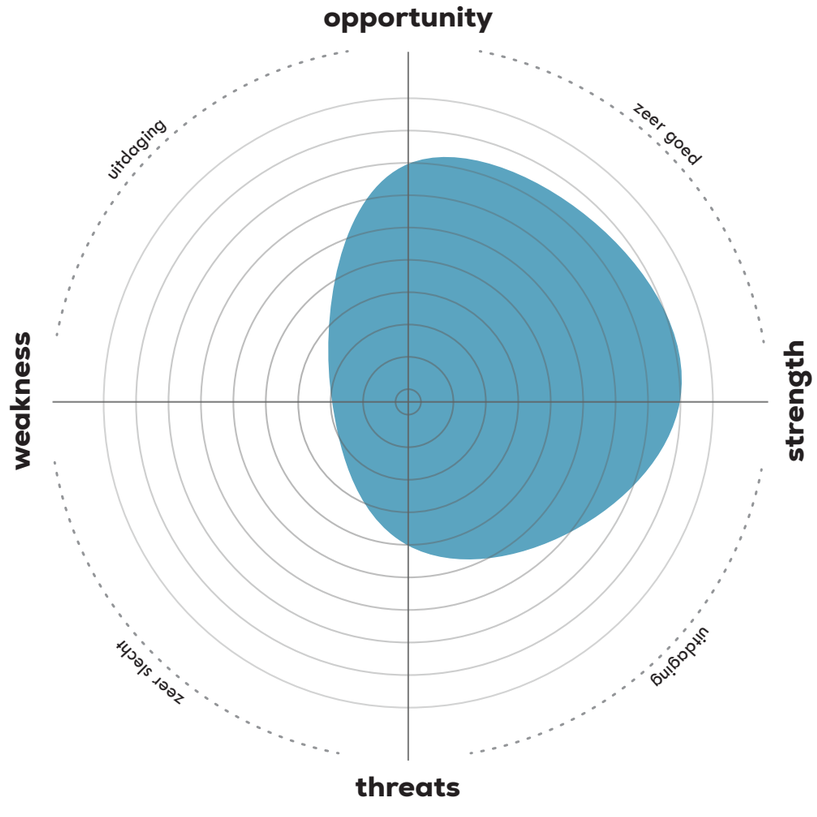
- There is a chance that birds of prey could sit on the roof edge and grab the bats as prey.

opportunity

- The eaves offer an opportunity to create a bat roost in unused spaces.
- The sloping roof allows droppings to fall easily without accumulating, contributing to a cleaner roost.

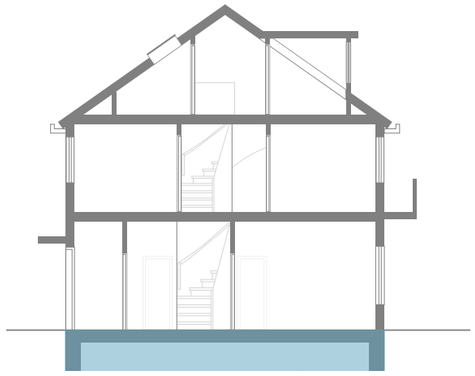
threat

- Bat droppings on the ground may cause some nuisance, but this is minimal.
- The long horizontal space could potentially cause inconvenience to residents.



RESULTS
crawl space - external

Especially in the Netherlands, in areas where the soil's load-bearing capacity is only found at greater depths and where piles are required as foundations, homes have crawl spaces beneath the ground floor. Because humidity in the crawl space can be quite high during wet (winter) periods, crawl spaces are generally well sealed off from the living space above. The ground beneath the home maintains a fairly constant temperature of around 10 degrees Celsius year-round, even during the winter months. This makes the crawl space a suitable place for bats, butterflies, and insects to hibernate.



A crawl space is typically approximately 80 cm high. Sometimes, a 60 cm opening is created under beams and other obstacles, allowing the entire surface of the home to be accessible from below during maintenance.

Access to the crawl space is usually a hatch, often located directly behind the front or back door and covered with a doormat. Almost all crawl spaces have ventilation to remove moist air. These ventilation openings are often equipped with grilles with narrow blades (and sometimes even insect screens) to prevent pest infestation.

However, crawl spaces are usually not sufficiently accessible from outside. If they were, predators also could access them, which makes it in current stage not suited for a bat s in hibernation. In existing homes, this can be optimized with limited resources and at a low cost. For new-build homes, this can be implemented during the design phase, without additional costs.

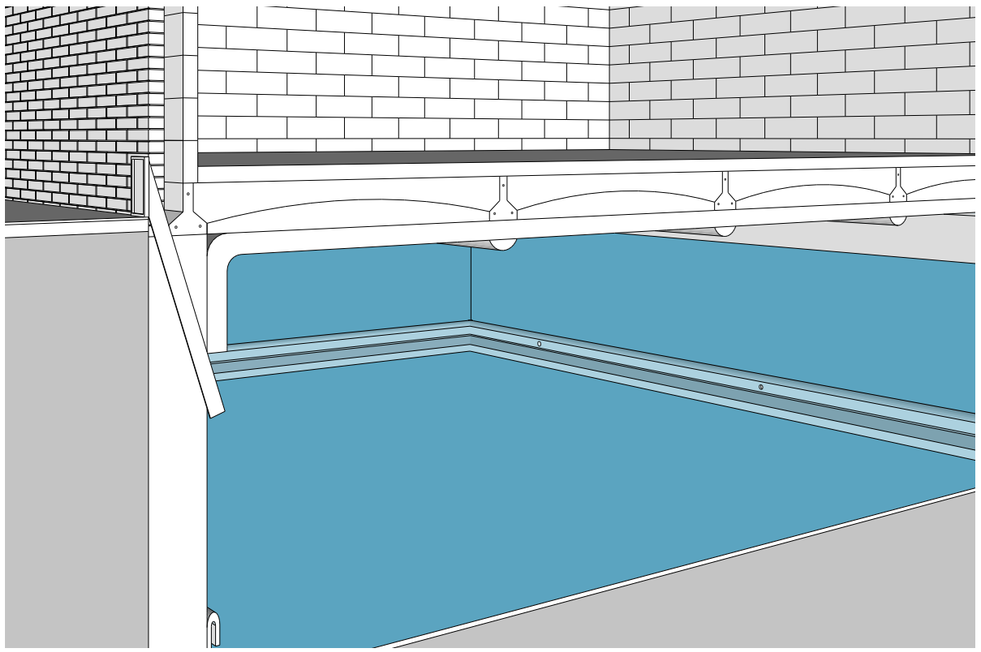


image 2.4: illustration of the possibilities of crawl space

SWOT analysis

strength

- The crawl space has a large, virtually empty surface beneath the house, ideal for a potential bat roost.
- Because it's underground, the space maintains a constant heat.

weakness

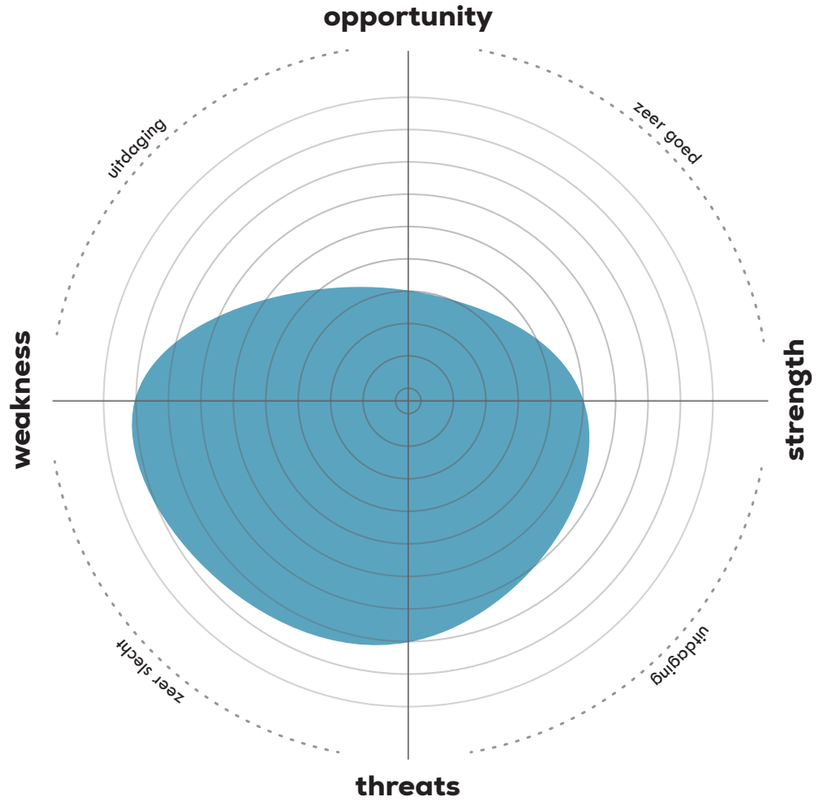
- Bats prefer a higher entrance; the crawl space has a maximum opening of 20 cm.
- A bat colony should not be disturbed, as this can hinder maintenance, such as leak repairs.

opportunity

- There is the possibility to create multiple climate areas for the bats in the crawl space.

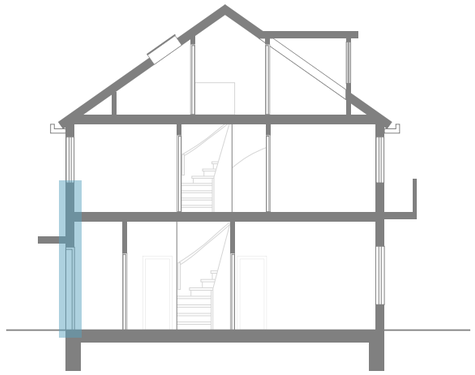
threat

- The low opening creates a dangerous trap for other animals, such as frogs and toads, which can't escape.
- Bats can have difficulty safely flying out at low altitudes because of predators.



RESULTS
cavity - wall

Bats can be found roosting in the cavity wall, including the brick structure, open air space, insulation, and supporting stones. This space is often accessible and easy to reach. The insulation in the cavity wall is often not completely heat-sealed, causing heat leakage. This makes it ideal for bats to roost around. The graphs show that a thin layer of insulation and plaster can quickly alter the temperature.



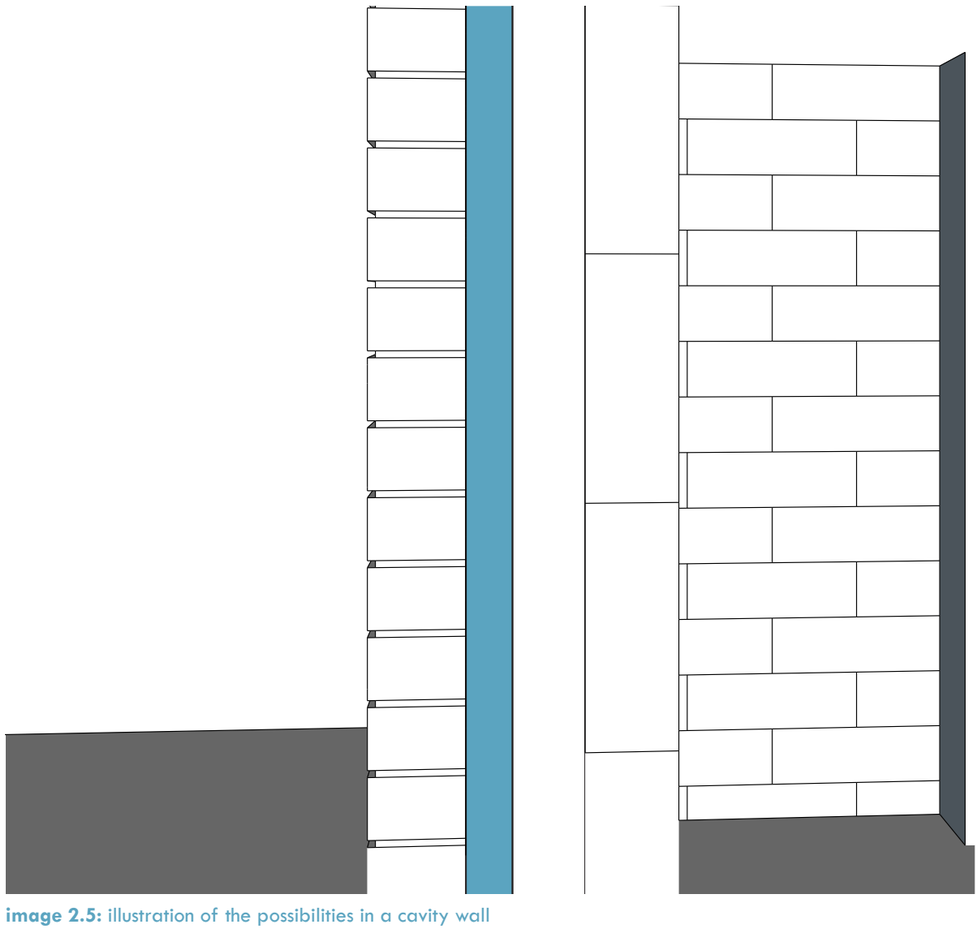


image 2.5: illustration of the possibilities in a cavity wall

SWOT analysis

strength

- It provides a large surface area for bats to move behind the walls, especially vertically.
- The connection to the roof makes it a much more attractive roosting area for the animals.

weakness

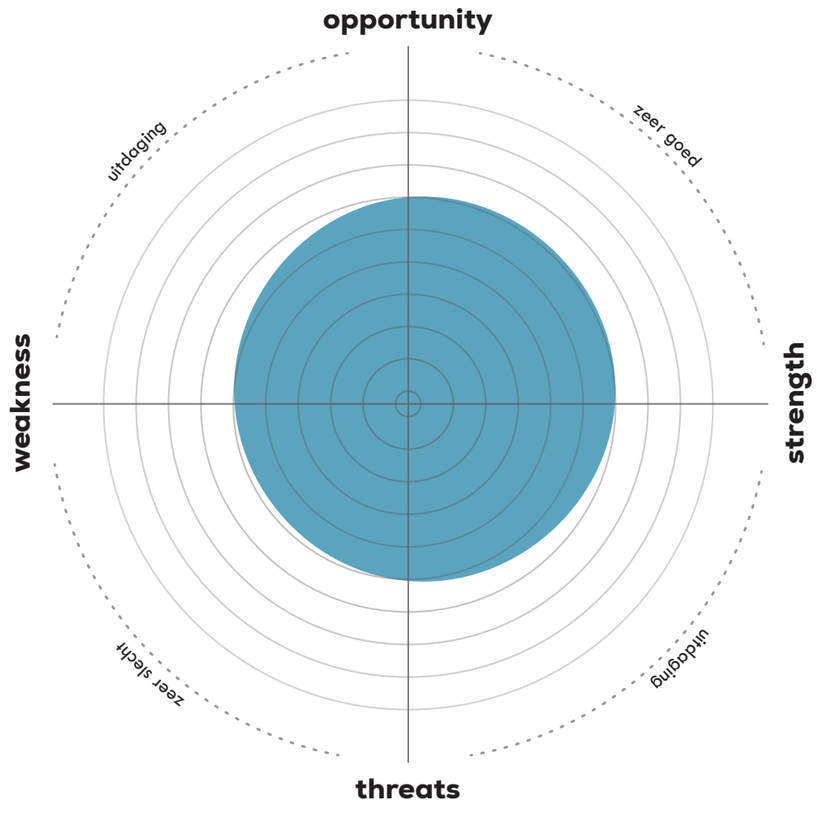
- Because the cavity walls of existing homes no longer meet the insulation requirements, they are being insulated. This is achieved by filling them with insulation material injected into them.

opportunity

- There are options that ensure that the cavity wall warms up even more or creates a better climate for the animals.

threat

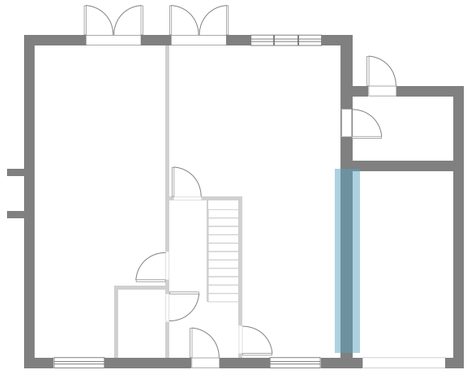
- In the future, with climate change, the current cavity wall may no longer be able to meet its requirements. This poses a new threat to bats.



RESULTS
cavity in between - wall

A wall separating two houses often consists of two separate shells to minimize noise pollution between them. The cavity between these shells provides an ideal roost for bats, both during the winter months and during the breeding season. The bricks of the dividing wall maintain the temperature inside the houses year-round. Making this space accessible to bats will not cause any nuisance inside the houses, as the construction of both shells must already be sealed to prevent sound vibrations.

Currently, the cavity is inaccessible to bats. However, with a few simple (and virtually cost-free) adjustments, a suitable roost can be created, especially if the cavity is designed to be a few centimeters wider.



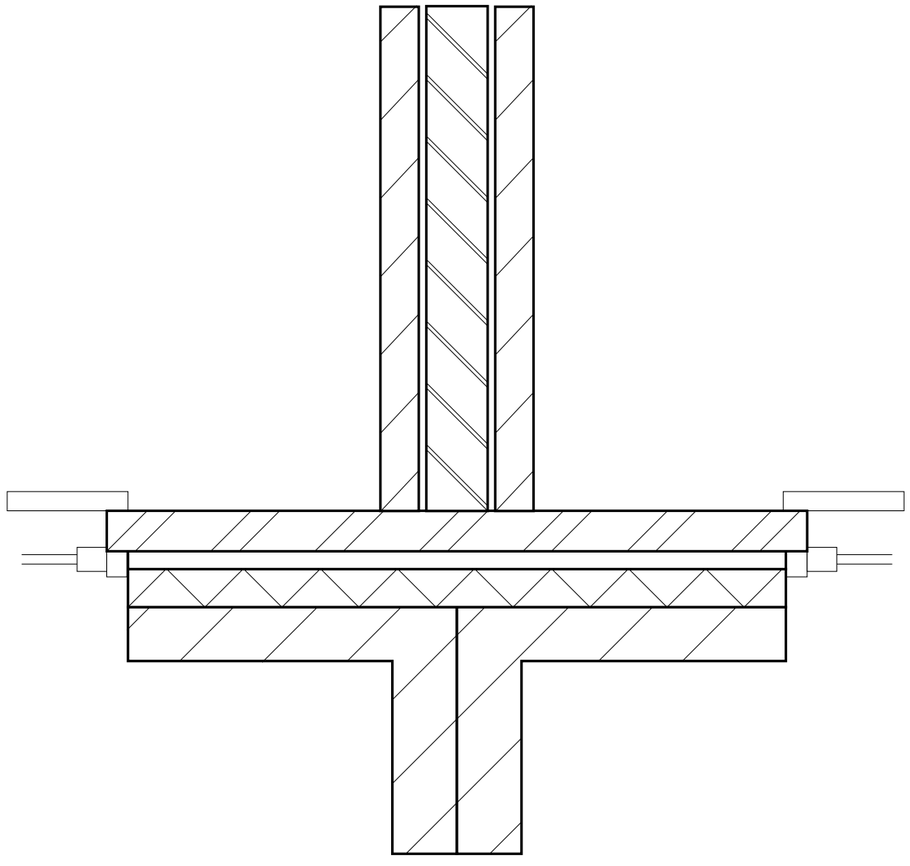


image 2.6: illustration of the possibilities in a cavity wall between two walls

SWOT analysis

strength

- The implementation takes place within an existing structure, requiring minimal intervention.
- This also creates a large space where bats can move freely.
- Heat from the houses is drawn through the dividing wall. These temperatures are often suitable for bats, providing them with a thermal gradient.

weakness

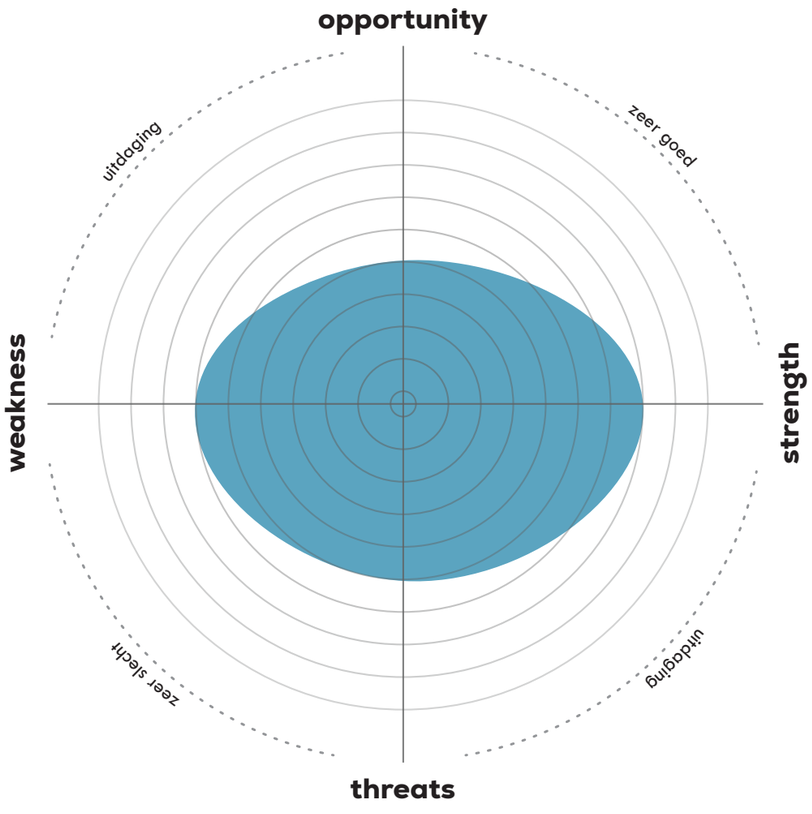
- The wall will be opened up, potentially creating a draft in the dividing wall. This draft is unsuitable for bats.
- There may be insulation in the space between the walls that could be harmful to bats.

opportunity

- Placing mesh in the dividing wall makes it easy for bats to move around and grab onto.
- Creating an opening on the facade makes it easy for bats to enter.

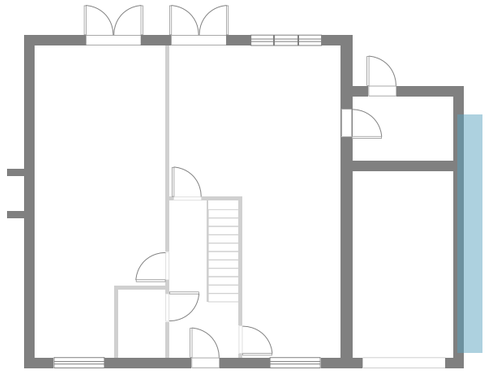
threat

- The animal's droppings can accumulate in the dividing wall. After some time, this can cause unpleasant odors and moisture.



RESULTS
façade panel - wall

With the curtain wall, a structure is mounted against the existing facade. This facade provides better insulation and can reduce noise pollution. The hollow spaces behind the curtain wall offer many opportunities for animals to create or integrate nesting, roosting, and breeding sites. Not only the curtain wall itself, but also the conditions within the wall behind it are significantly improved for animals such as bats.



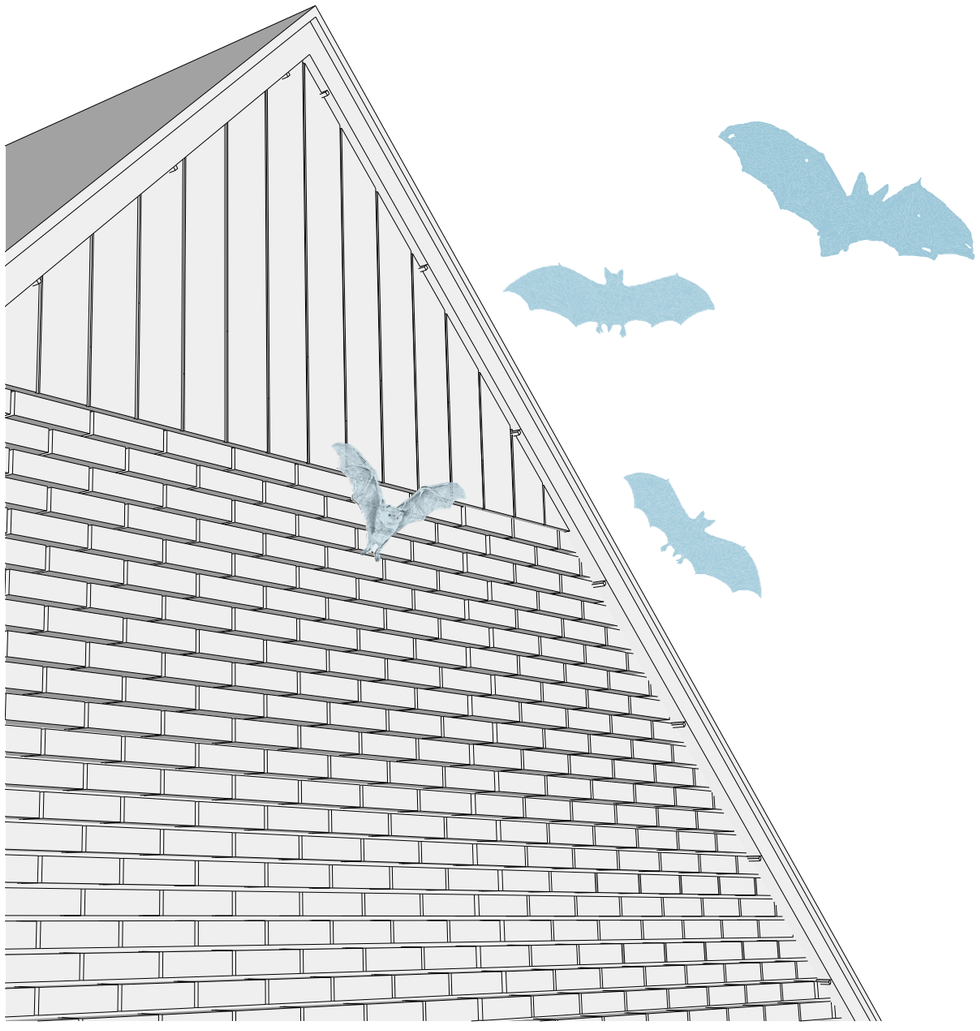


image 2.7: illustration of the possibilities of an additional façade element

SWOT analysis

strength

- A perfect option not only for new construction, but also suitable for renovations or timber-framed buildings.
- It provides additional sound insulation.
- Using only the top half of the roof provides protection against climbing rats and mice.

weakness

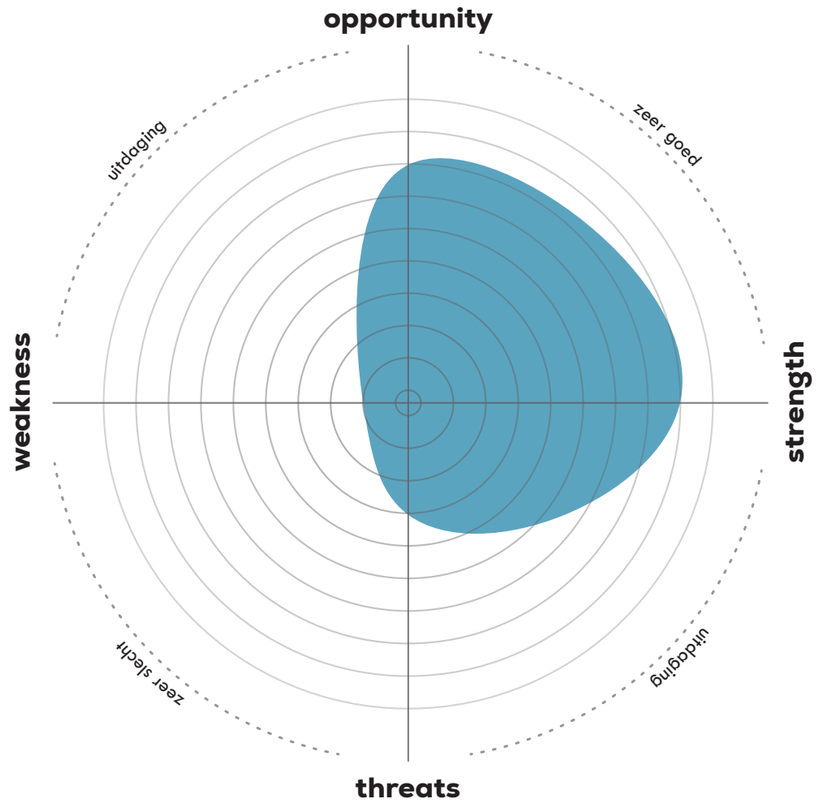
- Feces can build up on the ground along the side of the house.

opportunity

- Can serve as a winter roost for bats, especially if placed near a summer roost.
- A flowerbed placed under the cladding can collect droppings and fertilize them at the same time.

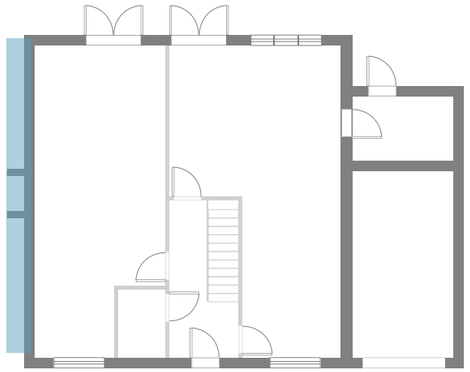
threat

- A fairly thick construction may be required to achieve the correct insulation value for bats.



RESULTS
green panels - wall

Green facades are becoming increasingly common as a means of combating heat in cities and promoting biodiversity. A green facade attracts many insects, which in turn is attractive to bats and birds, provided it is well-designed with the right plants. Often, behind these green facades, there is empty space that can be optimally utilized for nesting, roosting, and breeding sites. This is achieved by creating various roosting areas behind the structure.



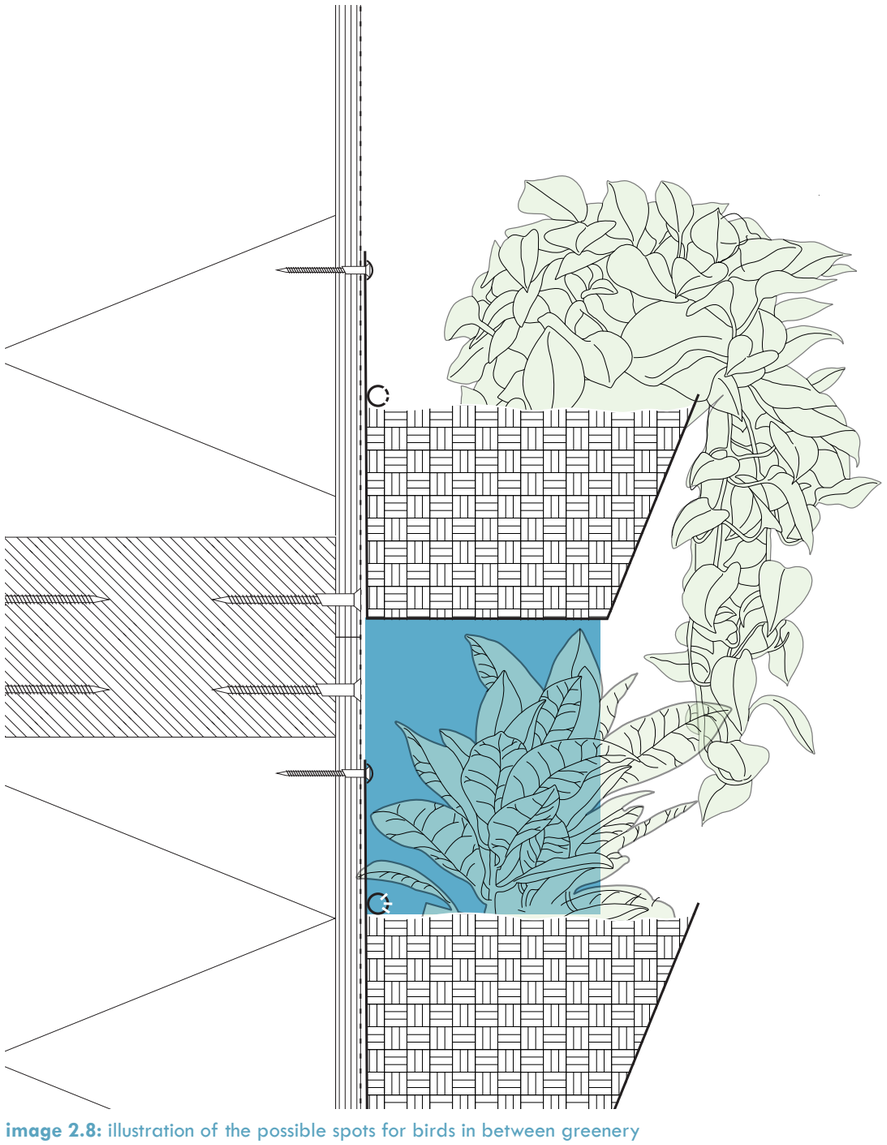


image 2.8: illustration of the possible spots for birds in between greenery

SWOT analysis

strength

- It can be integrated into the growing desire for more green space in the city.
- It reduces CO2 emissions by absorbing them.

weakness

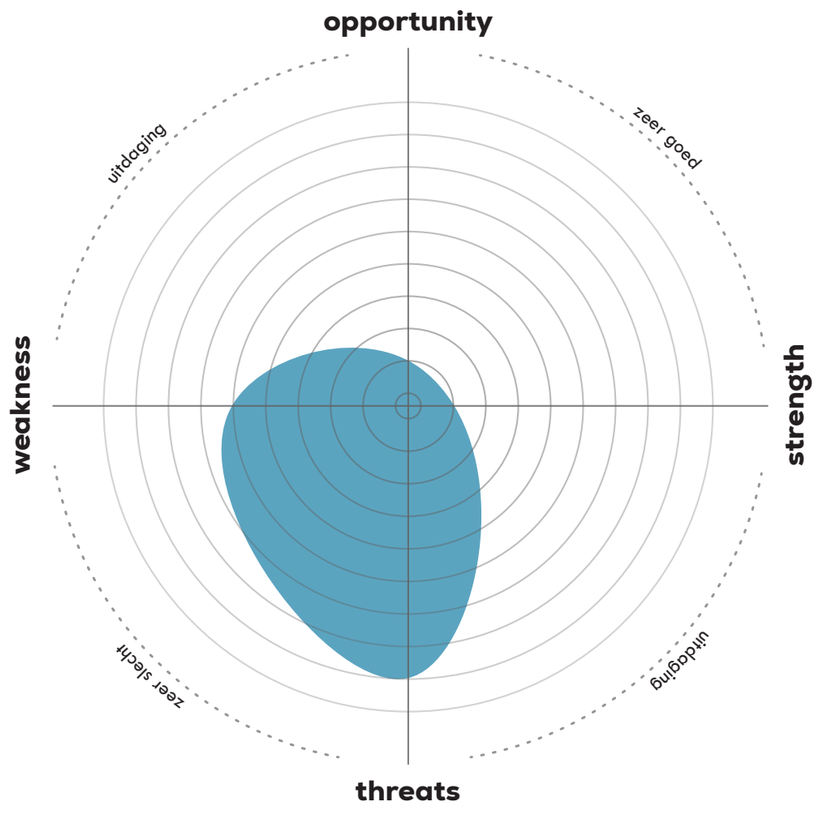
- Many buildings require additional materials to build, as their construction isn't suitable.
- Without an irrigation system, it's difficult to water this facade.

opportunity

- In new construction, it's possible to implement a green facade.
- It offers plenty of hiding places for birds like the house sparrow.

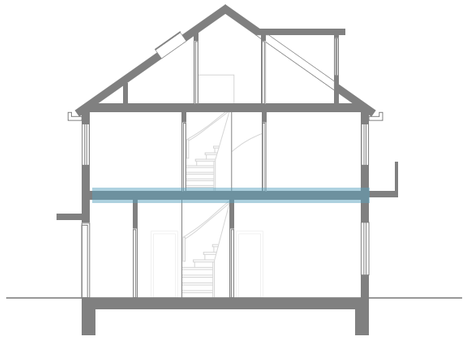
threat

- Predators like mice and rats can easily climb through the vegetation and enter the bat roost.
- A roost behind or between the roosts can be difficult when plants grow in front of the entrance, as bats cannot build their own burrows.



RESULTS
hollow-core slab - floor

Hollow-core slab floors are particularly popular in the Netherlands for residential use due to their fast and economical construction. In Flanders and the Netherlands, hollow-core slabs are also frequently used in offices and apartments. These floors are hollow throughout the entire length of the concrete slab. The hollow ducts are completely separated from the upper and lower floors, providing ample roosting opportunities for bats and birds without causing any nuisance.



Current construction practices typically seal hollow ducts with tightly fitting plastic covers to prevent airflow from one facade to the other within the cavity. Airflow prevention is also achieved by placing a cap on one side of the floor, allowing the other side to become a potential entry point for bats or birds.

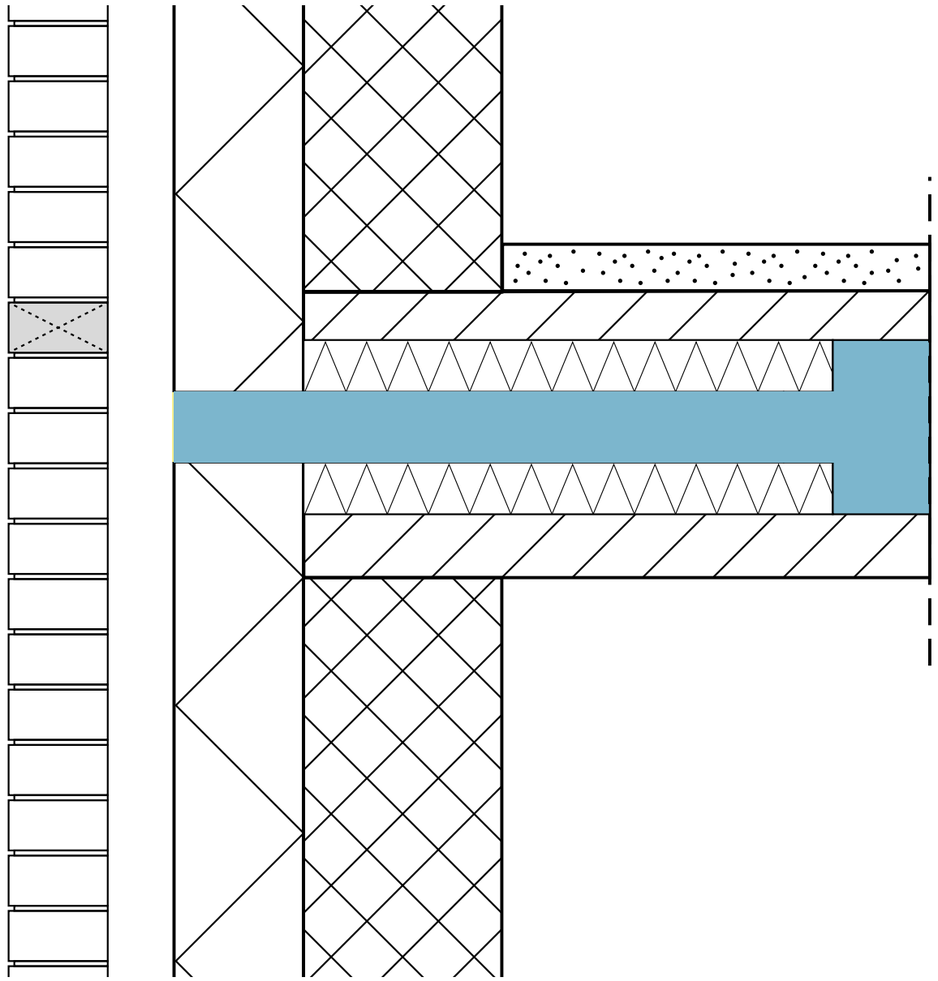


image 2.9: illustration of the possible spots for animals to shelter

SWOT analysis

strength

- These floors contain many long, empty spaces that can serve as potential roosts, especially in larger buildings like schools or office buildings.
- The multi-height floors offer bats a variety of landing and roosting opportunities.

weakness

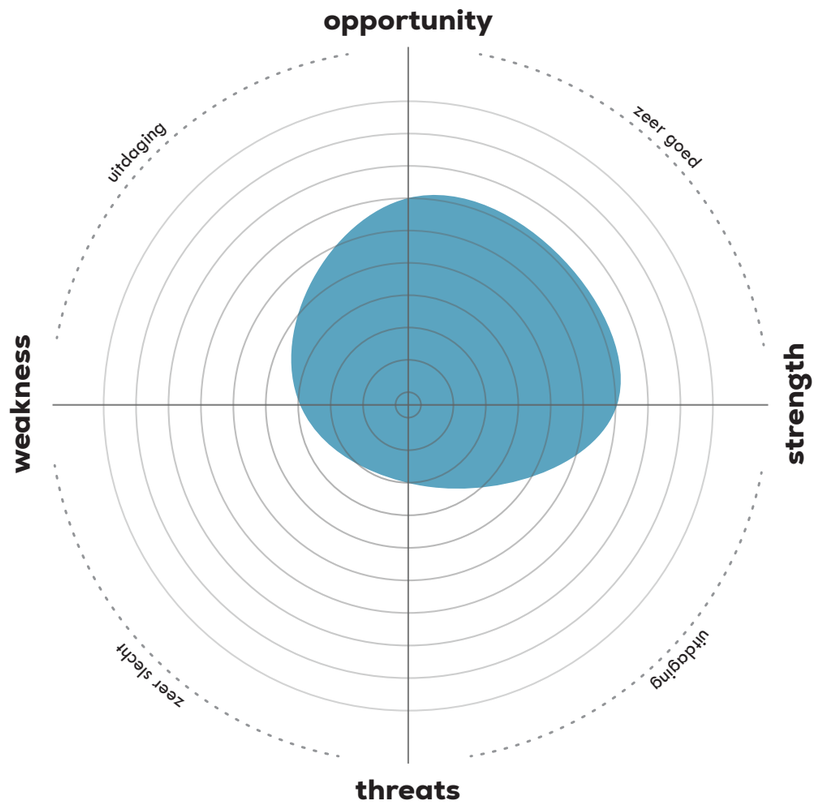
- Long space that is difficult to keep clean in view of feces.

opportunity

- Because of its length, it will be less likely to become soiled in a specific spot.
- Under normal conditions, the droppings are not very heavy.
- The temperature shifting from the inside to the outside will create an ideal environment for males during the spring and fall months.

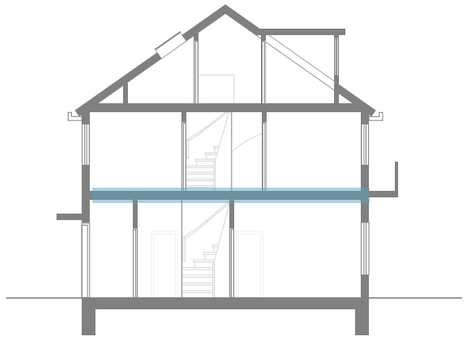
threat

- If a maternity colony is present, this can cause potential nuisance.



RESULTS
timber hollow-core - floor

Just like channel plate floors, hollow-core wooden floors are also suitable for creating living spaces, thanks to the hollow spaces within the floor.



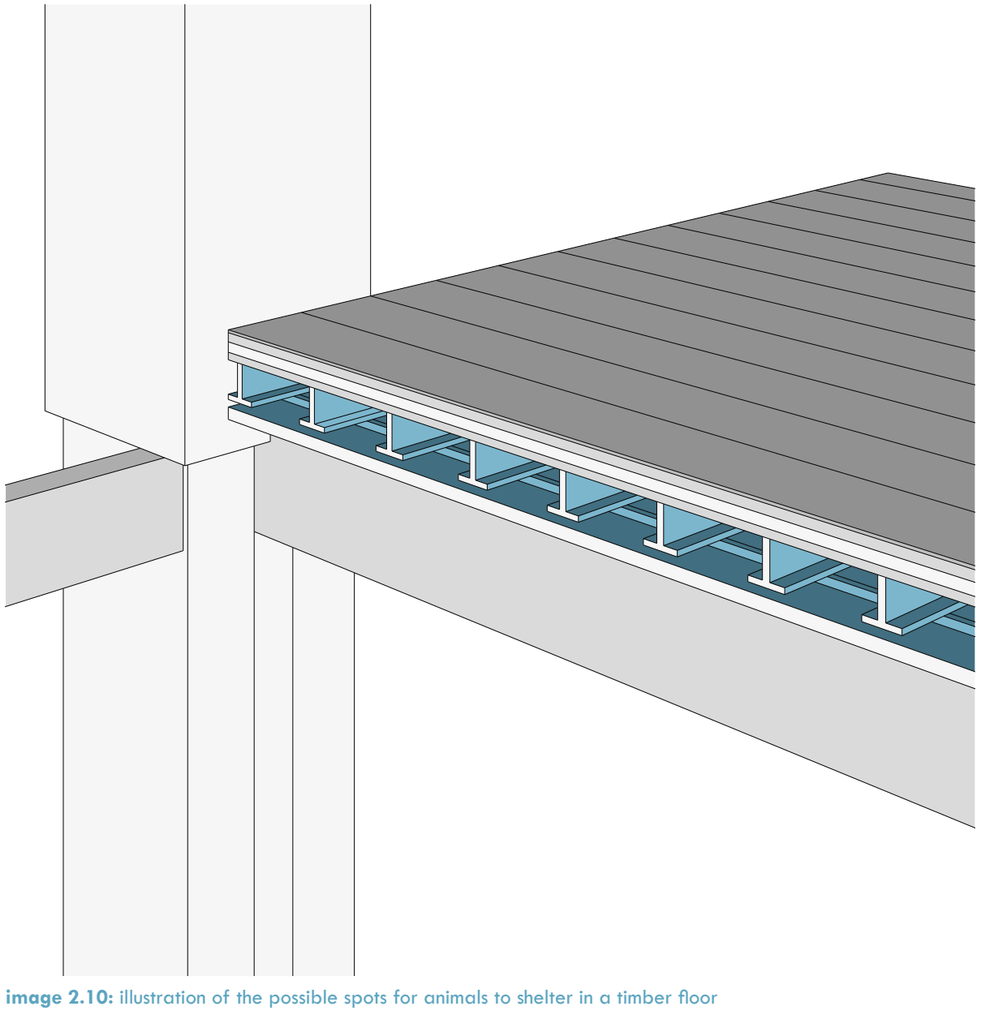


image 2.10: illustration of the possible spots for animals to shelter in a timber floor

SWOT analysis

strength

- These floors contain many long, empty spaces that can serve as potential roosts, especially in larger buildings like schools or office buildings.
- The multi-height floors offer bats a variety of landing and roosting opportunities.

weakness

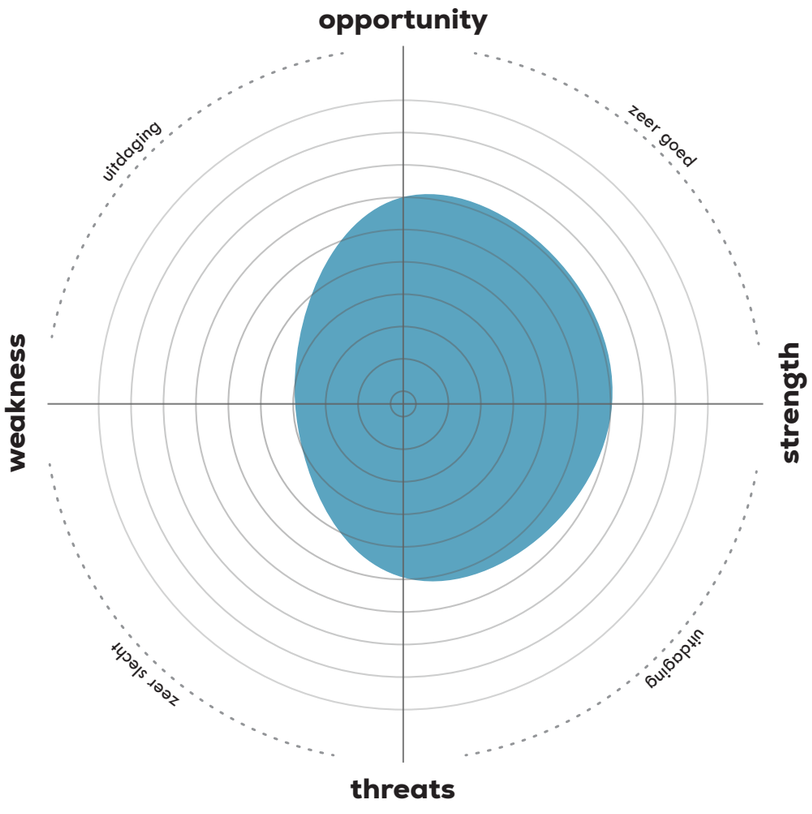
- Long space that is difficult to keep clean in view of feces.

opportunity

- Because of its length, it will be less likely to become soiled in a specific spot.
- Under normal conditions, the droppings are not very heavy.
- The temperature shifting from the inside to the outside will create an ideal environment for males during the spring and fall months.

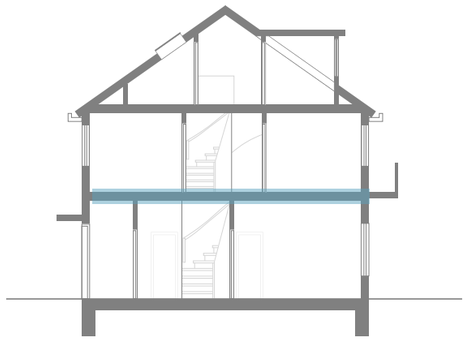
threat

- If a maternity colony is present, this can cause potential nuisance.
- The materials are natural and can therefore wear out due to bat use and their droppings.



RESULTS
ceramic hollow-core - floor

Hollow-core ceramic floors are less common in modern construction. They were once widely used in construction. However, they still offer possibilities, especially with developments in 3D concrete printing. This technology could also allow these types of floors to be printed, opening up new opportunities for innovative construction methods.



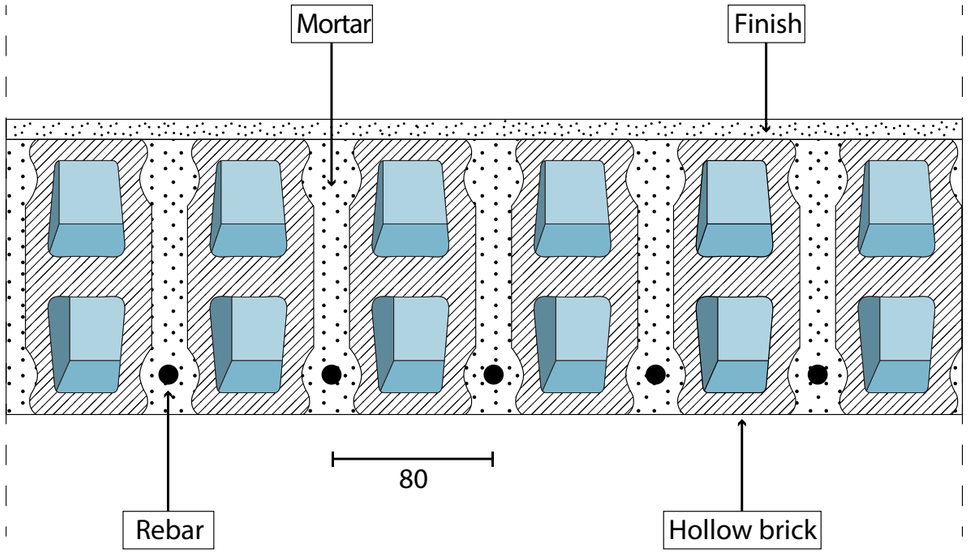


image 2.11: illustration of the possible spots for animals to shelter in a ceramic floor

SWOT analysis

strength

- These floors contain many long, empty spaces that can serve as potential roosts, especially in larger buildings like schools or office buildings.
- The multi-height floors offer bats a variety of landing and roosting opportunities.

weakness

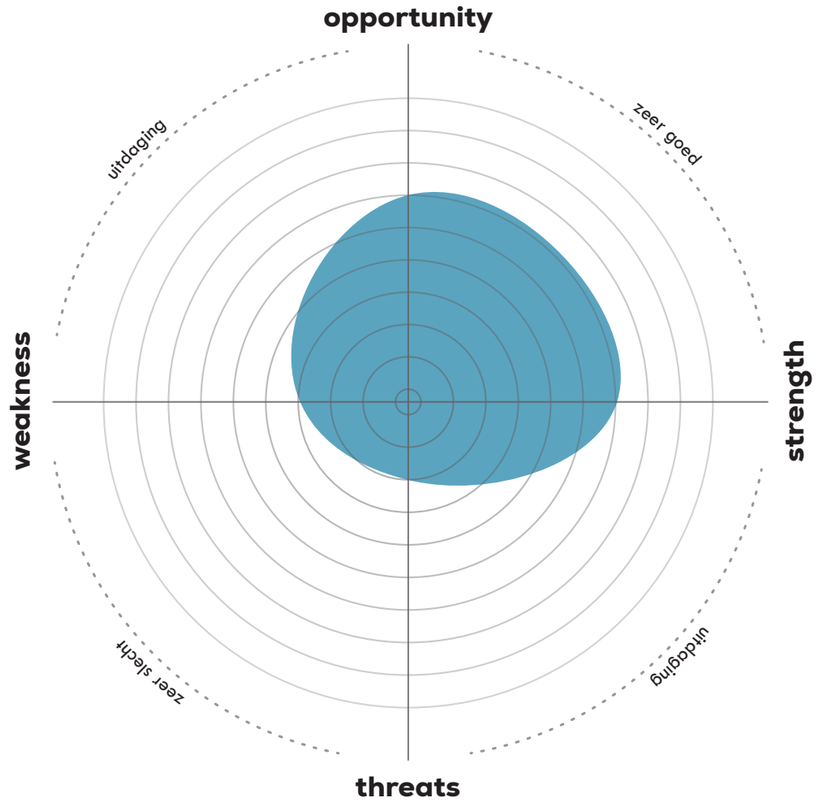
- A long space that is difficult to keep clean due to feces.
- It's not a common technology used in modern construction.

opportunity

- Because of its length, it will be less likely to become soiled in a specific spot.
- Under normal conditions, the droppings are not very heavy.
- The temperature shifting from the inside to the outside will create an ideal environment for males during the spring and fall months.

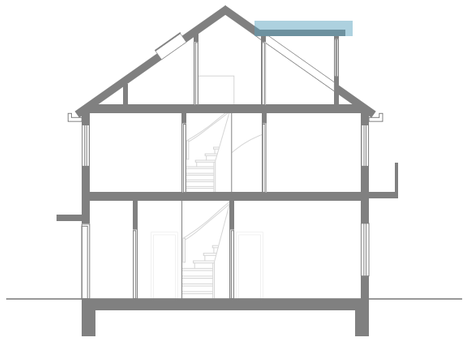
threat

- If a maternity colony is present, this can cause potential nuisance.



RESULTS
timber flat - roof

Unlike traditional roofs, flat roofs can be more efficient in terms of the materials used. For example, there are no empty spaces such as with a ridge or foot. A flat roof, like a hollow floor, can be constructed of wood. The structure then consists of a few beams, with smaller beams supporting planks perpendicular to them. When this space is closed off with panels, it can be very suitable as a roost for bats.



Furthermore, a flat roof can be finished in various ways, with brown or green roofs being among the better ecological options. These finishes not only offer ecological benefits but also contribute to the sustainability of the roof structure.

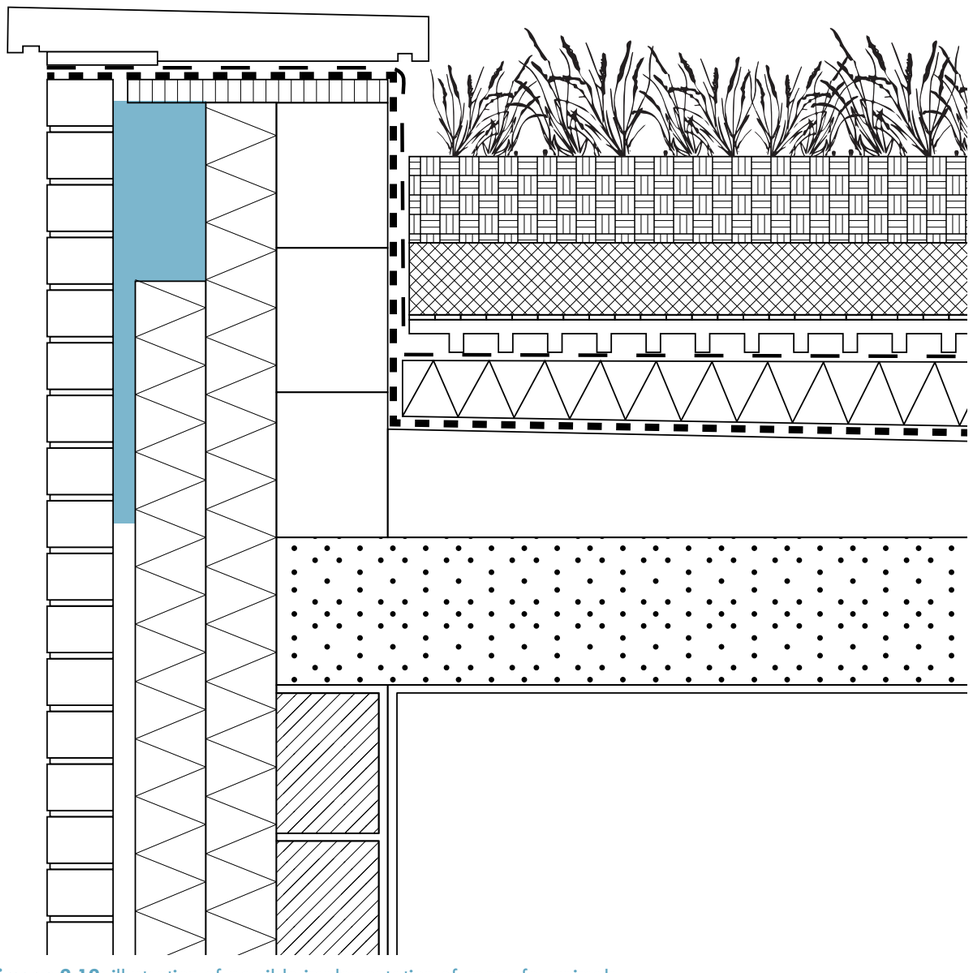


image 2.12: illustration of possible implementation of space for animals

SWOT analysis

strength

- These floors contain many long, empty spaces that can serve as potential roosts, especially in larger buildings like schools or office buildings.
- The multi-height floors offer bats a variety of landing and roosting opportunities.

weakness

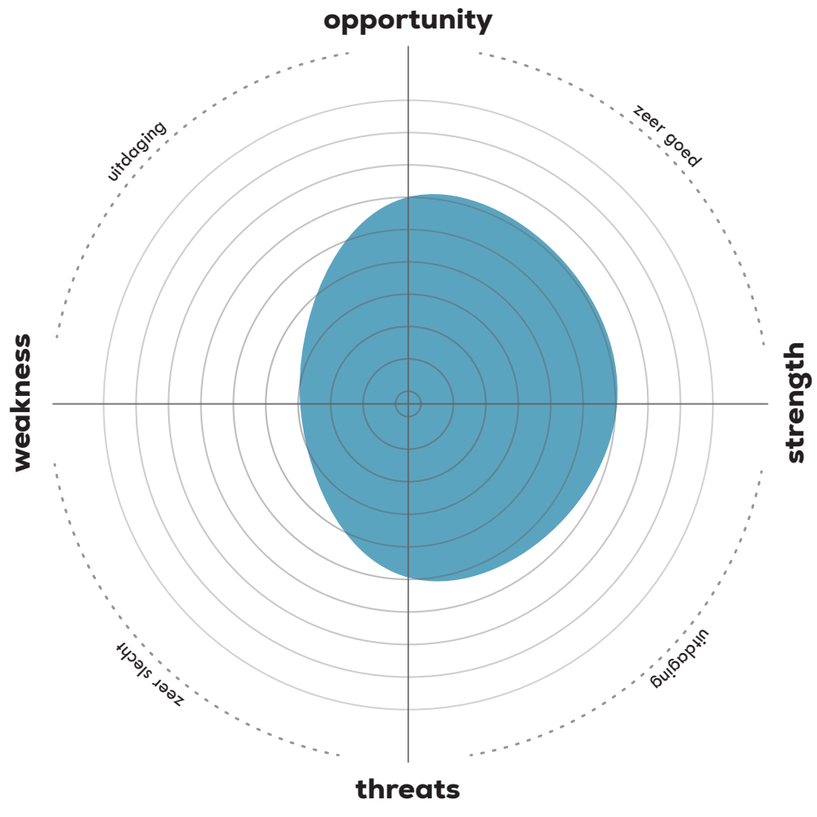
- Long space that is difficult to keep clean in view of feces.

opportunity

- Because of its length, it will be less likely to become soiled in a specific spot.
- Under normal conditions, the droppings are not very heavy.
- The temperature shifting from the inside to the outside will create an ideal environment for males during the spring and fall months.

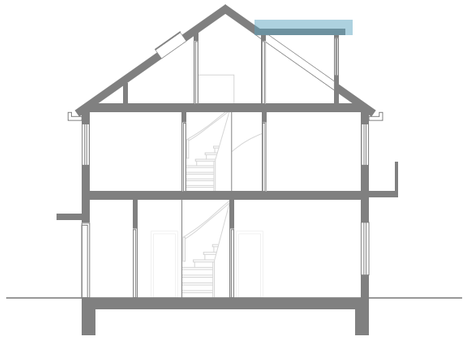
threat

- If a maternity colony is present, this can cause potential nuisance.
- The materials are natural and can therefore wear out due to bat use and their droppings.



RESULTS
brown - roof

Bitumen or EPDM roofing is often used on flat roofs. These materials are usually dark (black), which can cause the surface temperature to rise significantly on a sunny day, even up to 70 degrees Celsius. By covering the waterproof layer with, for example, a layer of soil (a “brown roof”), the surface temperature is significantly reduced and UV damage is prevented. This extends the lifespan of the roofing and makes it suitable as a breeding ground for birds and a habitat for insects.



By excavating the top layer of the building area and using it for roofing, an excellent habitat can be created for birds such as the oystercatcher, common tern, and black redstart. In addition, bird species such as the linnet, goldfinch, and white wagtail can find food on roofs finished in this way. By creating slight variations in the depth of the soil layer, more diversity of plants and soil life develops. This type of roof, especially with its height gradients, also provides an excellent habitat for various bee species.

The bird species that typically nest on flat roofs are precocial, with the young immediately after hatching already roaming around and searching for food. Therefore, it’s important to cover open downspouts and gutters and to provide a slightly raised roof edge. A successful roof nesting site also benefits from a simple shelter from the heat and predators.

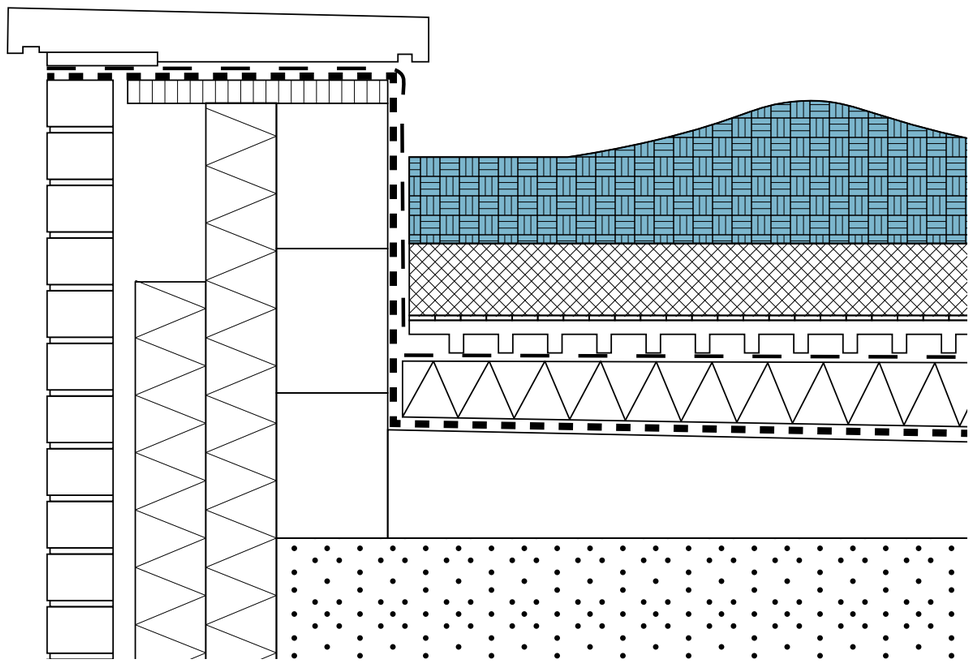


image 2.13: illustration of possible implementation of space for animals

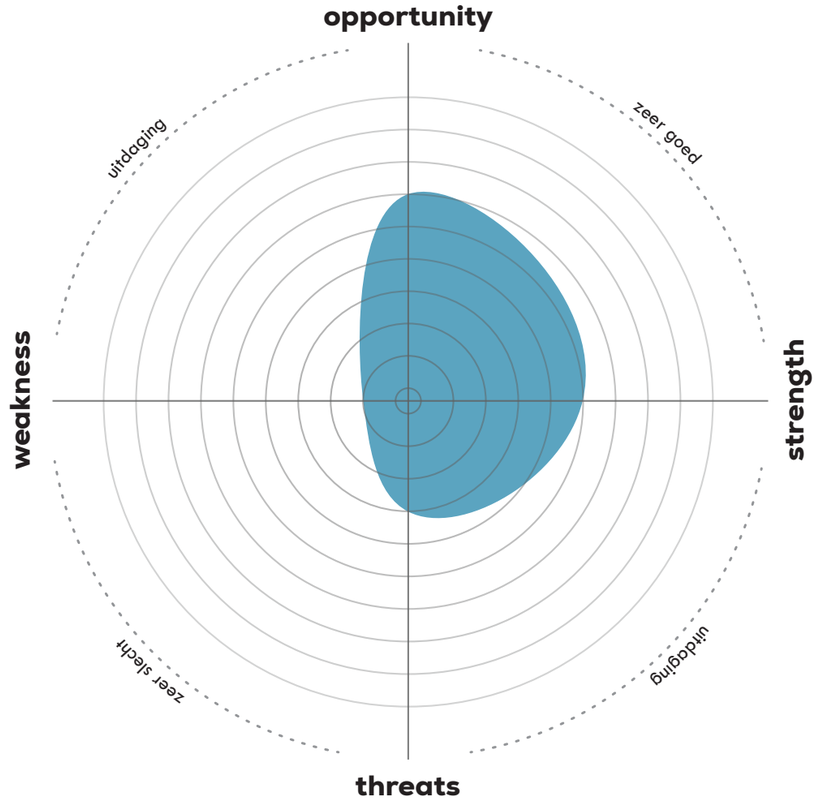
SWOT analysis

strength
- Maintaining an existing ecosystem by implementing it on the flat roof so that it functions as a raised lawn.
- Reducing temperature.
- Providing ample nesting sites for birds such as gulls and oystercatchers.

weakness
- Some maintenance for the roof to keep it from becoming an overgrown area.

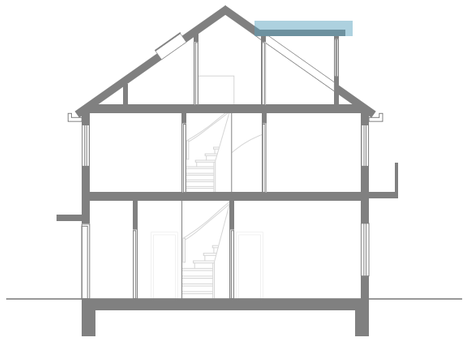
opportunity
- This could be applied to virtually any flat roof in the city.
- It also attracts other animals such as butterflies, bees, or small birds.

threat
- A raised edge is mandatory to prevent chicks from falling over the edge.



RESULTS
green - roof

The lifespan of roof coverings is significantly improved by the use of green roofs. These roofs lower the surface temperature of the roof covering, which not only reduces the heating of the living space under the roof but also extends the roof's lifespan. Like green facades, green roofs attract many insects and can serve as extensions of green spaces used by animals, such as potential breeding grounds. Provided the plants are natural and native.



Not only flat roofs can be greened; sloped roofs also offer opportunities for a lightweight green roof with (native) sedum. This sedum is available in the form of vegetated rolls or cassettes. For (slightly) sloped roofs, ready-made cassettes are a convenient way to create a green roof. Green roofs offer significant potential for increasing green space for birds and insects.

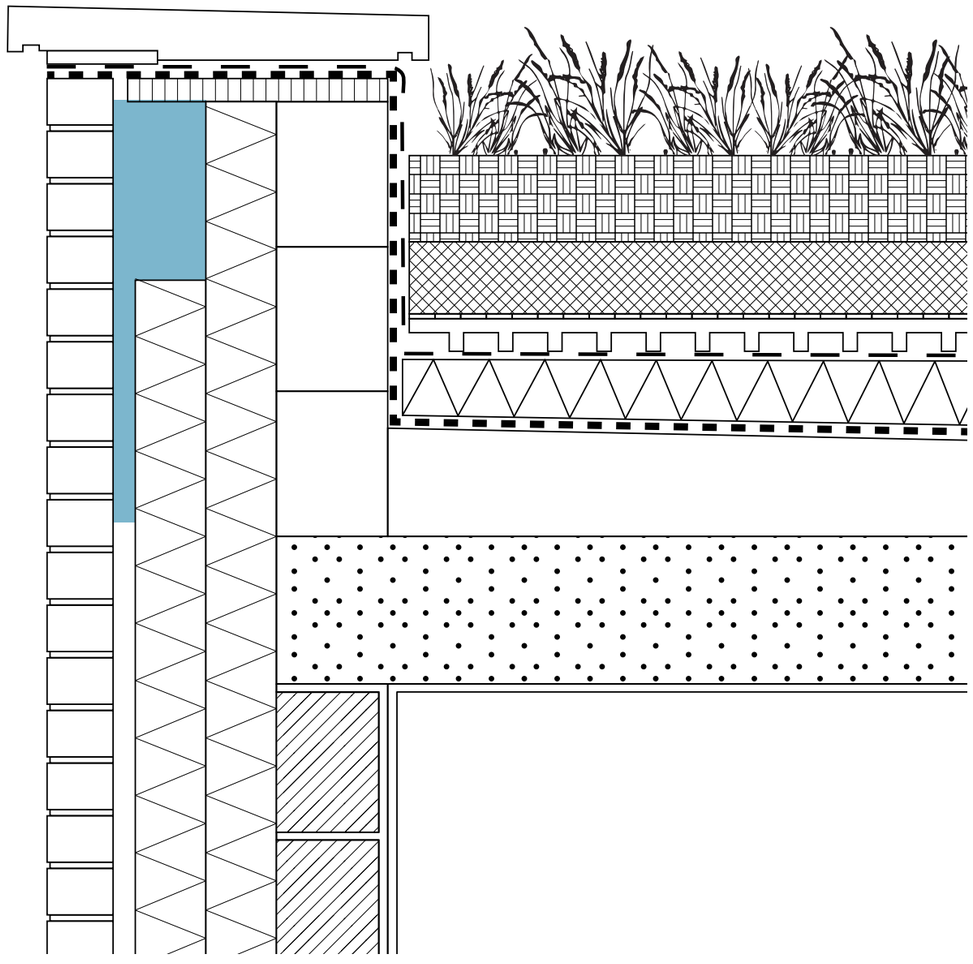


image 2.14: illustration of possible implementation of space for animals

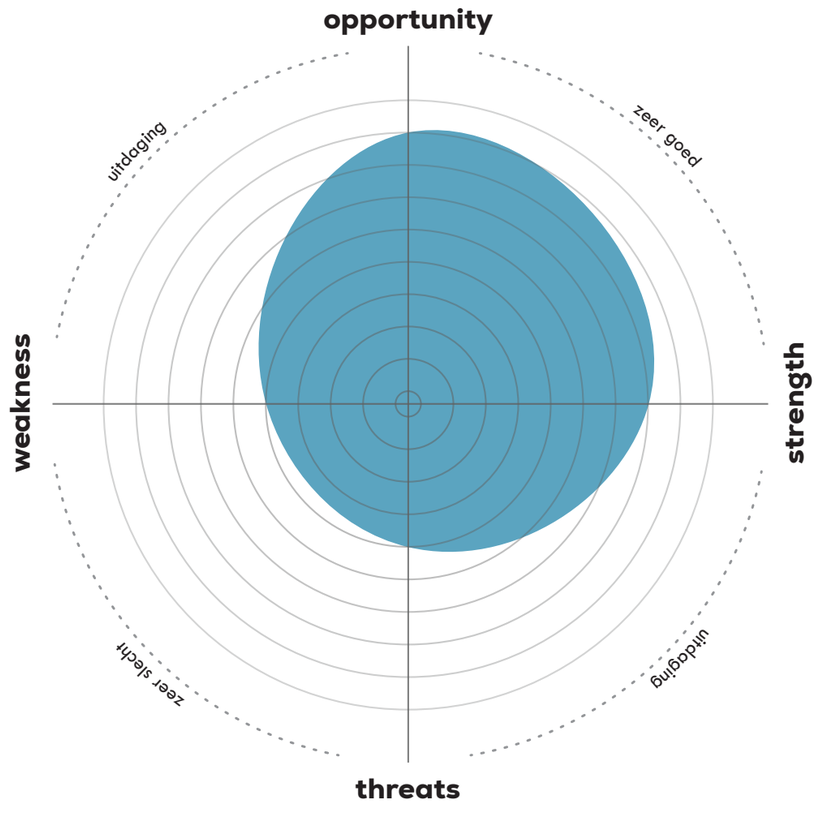
SWOT analysis

strength
- The roof temperature is kept lower by the greenery, which absorbs heat and reduces moisture.
- The greenery attracts many insects, providing food for bats and birds.
- This roof is suitable for both new construction and renovation projects.

weakness
- Some maintenance for the roof to keep it from becoming an overgrown area.

opportunity
- It can be applied to both sloped and flat roofs.
- There are developments to combine this with solar panels.

threat
- In extreme drought this could be a fire hazard, but this has almost never happened.



RESULTS
SWOT analysis

To determine which details will be most suitable, including heat optimization for bats, a top option must first be selected for further investigation. The top five are as follows:

Diagram 1 shows that this option has almost no threats or shortcomings. Its strengths and potential are, however, high.

The second-place is the roof overhang. This is also a good option due to its versatility and the SWOT score it achieved. While it may face slightly more threats, this is easily remedied, as discussed earlier.

The third-place is the green roof. This one came in third because, despite its many possibilities and strengths, it still has some threats and weaknesses that require attention when designing for it.

In fourth and last place we find the wooden hollow floor, or in this case a flat roof. Since there are some challenges, but mainly a lot of opportunities.

Last spot is for the chimney. There are opportunities but also threats. Luckily the strength is bigger than that of the weakness

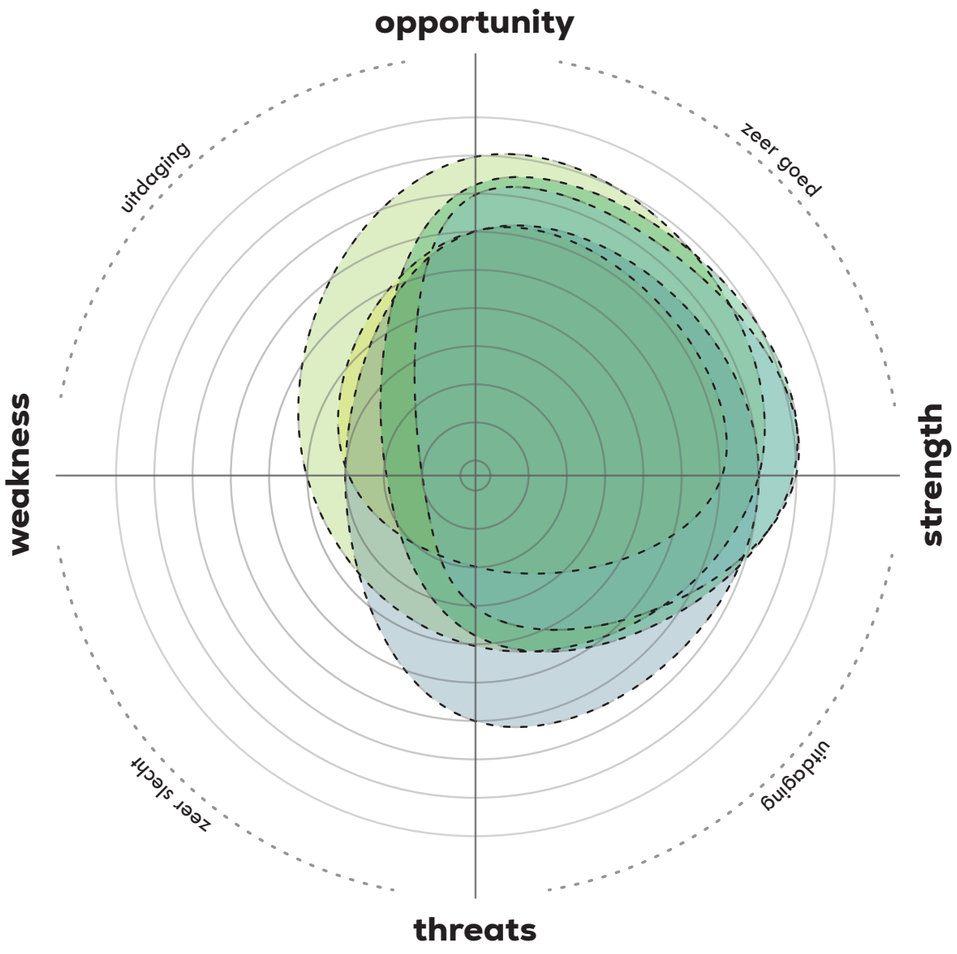


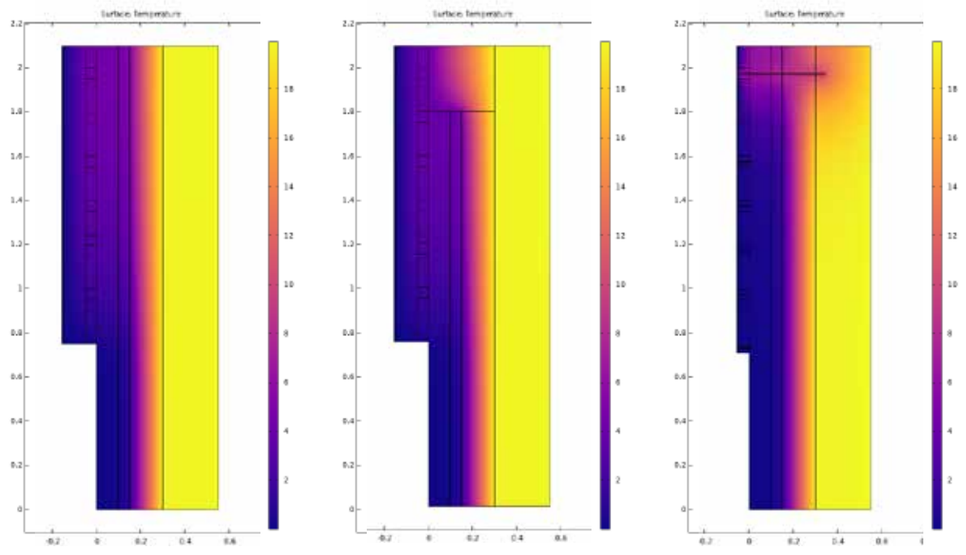
image 2.15: collected possible SWOT analyses of the top five

RESULTS
façade panel - COMSOL

The first image on this page illustrates a facade that shows the current situation without any heat source within the structure. This depicts a situation that retains little to no heat for the bat. This could be a potential hibernation location for bats. The advantage of this structure is that it is high enough to prevent mice and rats from climbing up.

The other two images show two experiments. The first shows the same situation, but with a thermal bridge that can transfer heat from the interior insulation to the exterior. This creates a warmer environment for the bat to roost. This option can be further explored with other insulation materials that transfer more heat. A disadvantage is the heat loss from the house.

The other experiment is very experimental. It involves placing iron pins in the interior wall, piercing the insulation, cavity wall, and bricks. These pins conduct a amount of heat and energy outside, which can then be captured in the bat roosts. This solution also has a drawback regarding heat loss. Moreover, the roost can become too warm at some spots, but can then find their own desired spot concerning the heat.



RESULTS
roof edge - COMSOL

A 3D axonometric view of part of the potential experiment is shown alongside. By deliberately creating a thermal bridge, a warmer spot is created for bats in the facade. The image shows that this temperature will be around 5 degrees Celsius. This ensures that on a very cold night that drops below freezing, the bats don't have to move.

As mentioned, a thermal bridge is created. However, if this pin is placed at the highest point, little heat will escape because the heat rises upward. The pin is also needed to attach the structure to the facade.

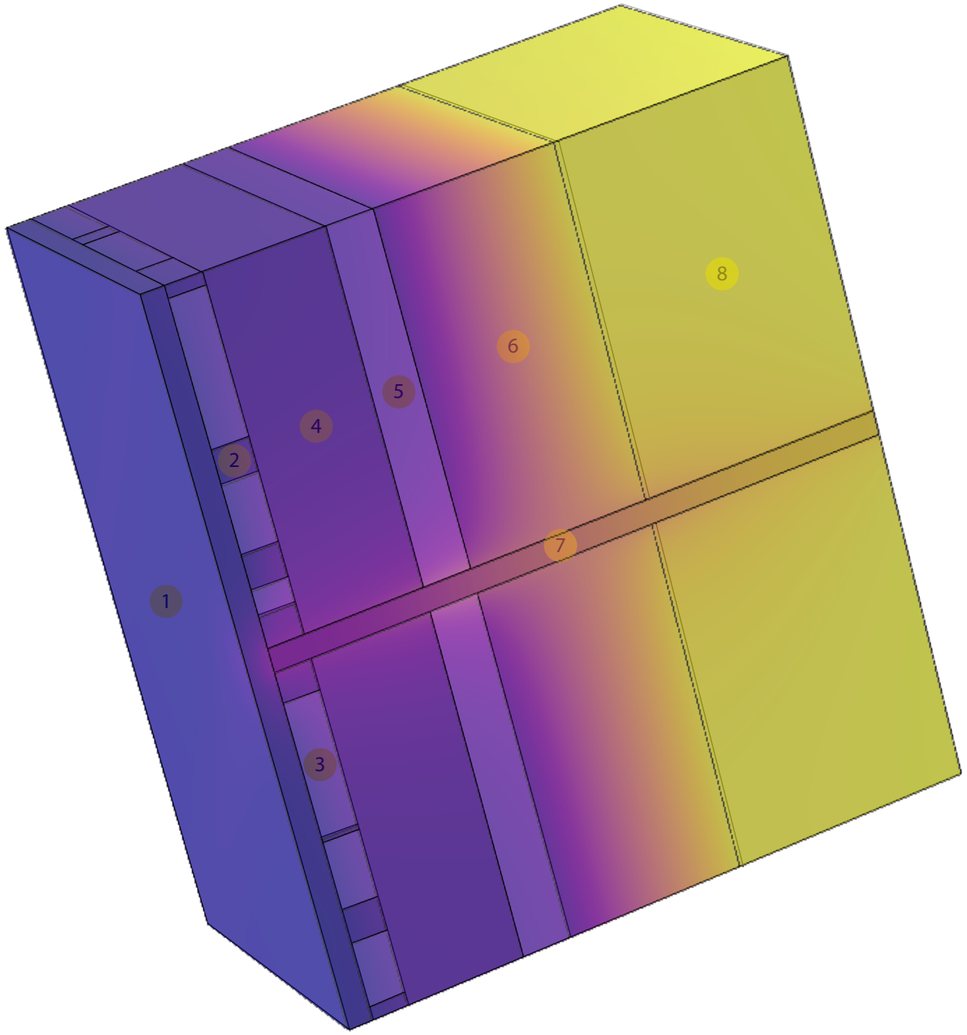


image 2.17: COMSOL simulation part of experiment

The first image shows the standard situation with a roof overhang that blocks heat. It shows that the hollow space has the same temperature as outside and offers little to no warmth for the bat to roost in. Therefore, closer attention should be paid to spaces near warmer areas, such as insulation.

The first experiment attempts to create a space within the existing roof structure. By creating a hollow, insulated space within the roof, it could be suitable as a roosting area. However, the simulation shows that there is little heat in this space. This could make it a suitable option for wintering bats.

The second experiment focuses more on the interior to generate more heat for the bats. Part of the roof insulation is hollowed out and several small spaces are created, suitable for bats to roost in. This creates both warmer and colder areas.

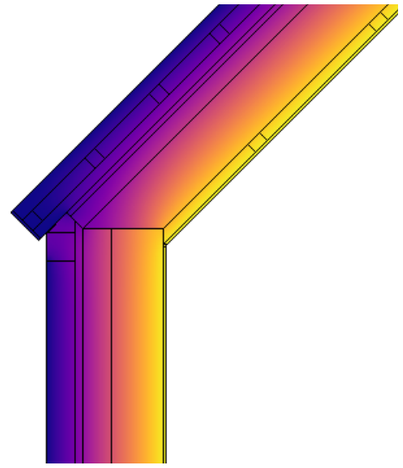


image 2.18: normal situation

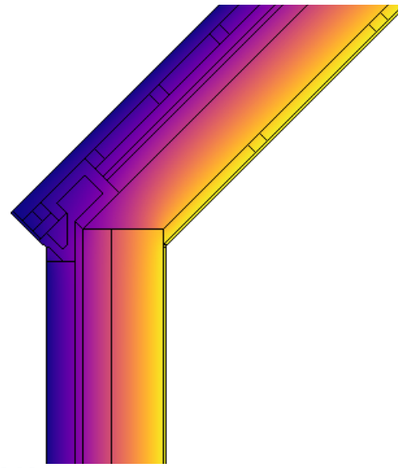


image 2.19: experiment one

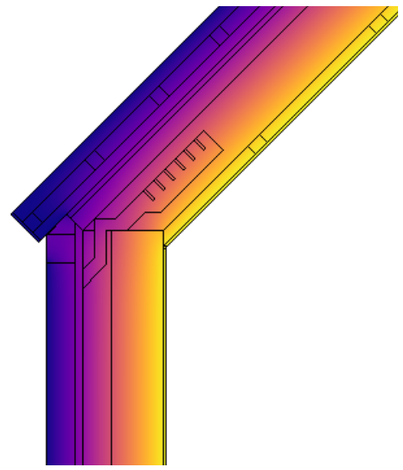


image 2.20: experiment two

RESULTS
concrete floor - COMSOL

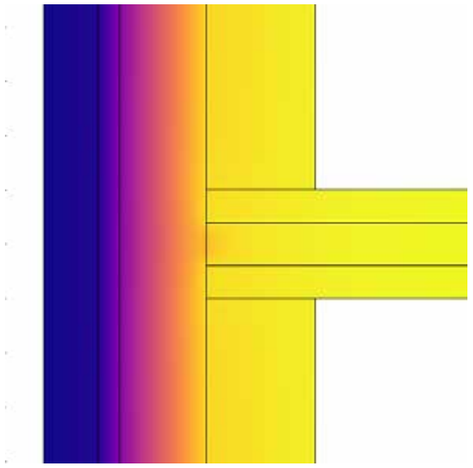


image 2.21: normal situation

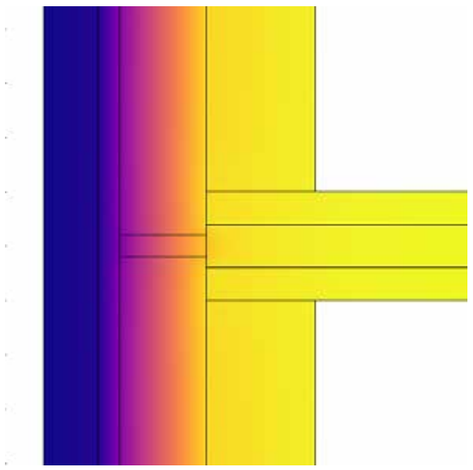


image 2.22: experiment one

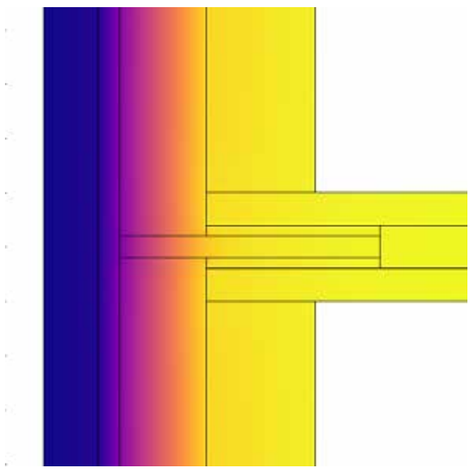


image 2.23: experiment two

Hollow-core concrete floors are used in terraced houses, apartments, and office buildings. The hollow spaces in the floors allow them to span long distances without becoming too heavy. These openings are usually completely sealed with caps on both sides to prevent pests such as rats from entering.

The first graph shows a simulation of the tube operating under heat. It shows that the building functions normally without thermal bridges. However, a slight coldness is visible at the opening of the hollow-core floor.

The second graph shows the situation if the floor were opened up for bats, but without insulation.

The last graph shows the operation of the floor with an insulating tube inserted. This tube is approximately 30 centimeters long to sufficiently block the cold. The opening for bats is kept small enough for them to enter, but makes it more difficult for pests to enter. A mouse tooth can also be installed if necessary. It also helps that this is only implemented at higher elevations, where it is harder for rats to reach. This approach comes with a caution to prevent cold bridges within the structure.

RESULTS
timber roof - COMSOL

Flat wooden roofs use beams and battens for their construction, creating hollow spaces. Insulation can be placed in these spaces, providing comfortable shelter for both people and bats.

The first graph shows the current roof construction with battens and beams. This demonstrates little to no heat loss and a high level of finish.

The second graph shows a side opening, which creates an entrance for bats. A disadvantage of this is that it creates a thermal bridge due to temperature fluctuations inside and outside.

The last graph shows a similar option, but here a louvered construction has been applied within the eaves. This allows for the creation of climate-controlled spaces.

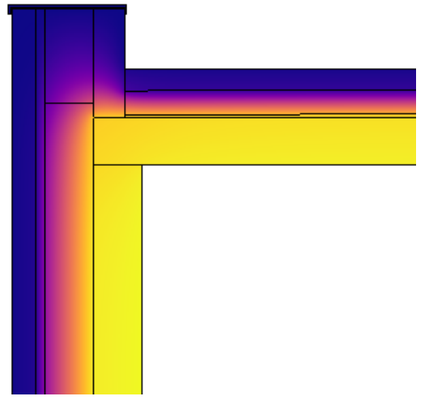


image 2.24: normal situation

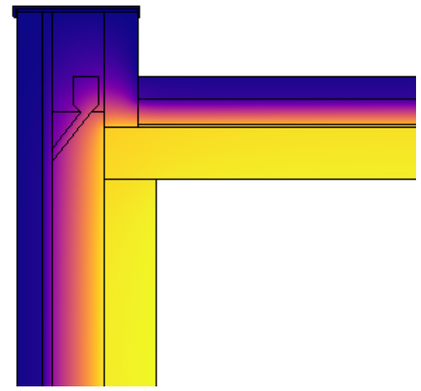


image 2.25: experiment one

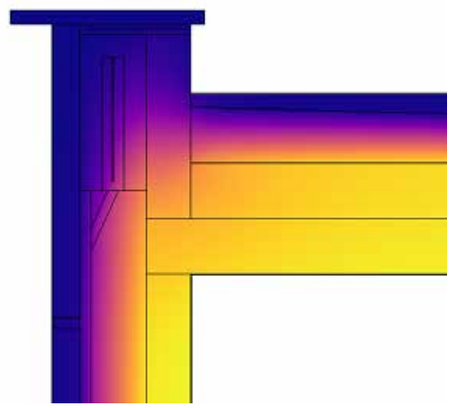


image 2.26: experiment two

RESULTS
roof ridge - COMSOL

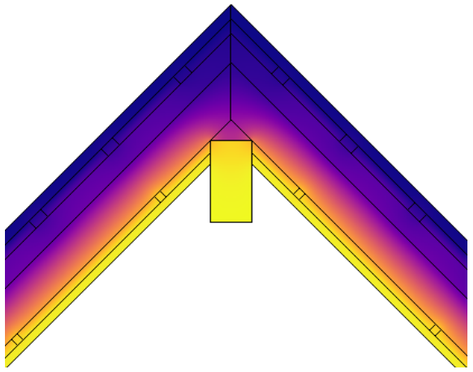


image 2.27: normal situation

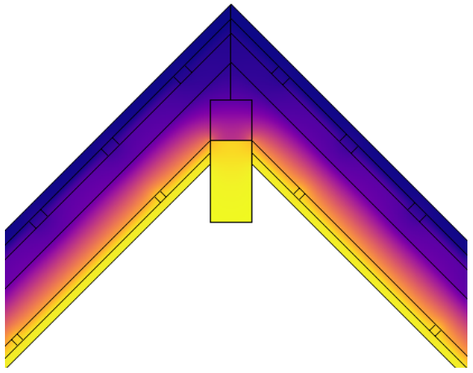


image 2.28: experiment one

There are many different ways a roof can provide a nest for bats. For example, the ridge of a roof is abundantly insulated. By either removing or opening up a portion of the insulation, it can provide a suitable roosting area for bats.

The first illustration shows the current functioning of a roof ridge. It shows that a considerable amount of heat is transferred through the insulation, including in the ridge. This offers potential.

The second illustration shows a space created above the roof beam that supports the structure. It shows that the heat differences compared to the original situation have hardly changed, despite the opening.

A second experiment could involve implementing a slatted structure within the empty space above the beam. This would not only retain more heat but also create different climates, which could be beneficial for bats.

RESULTS
crawl space - possibility

The crawl space offers a lot of space because of its large area, which is rarely used by residents, except for insulation improvements. The space also mimics a cave or fort, a nesting site for many bats. This construction detail generated considerable discussion within the panel. People saw many drawbacks and problems, but over time, these were also positively evaluated. A few issues were considered most important and recurrent: moisture and ventilation, construction, safety, and accessibility. These will be discussed individually.

To prevent the space from becoming too humid, passive ventilation, also known as draft ventilation, is used. However, this draft is less suitable for maintaining a constant, stable temperature for bats to roost in. If the basement is unventilated, the crawl space can develop mold due to the moisture in the soil. To solve this, a separate compartment or wall can be installed to stabilize the air. To make houses more sustainable, insulation can be applied under the floors to reduce the amount of cold air that rises from the crawl space into the living area. However, this can cause problems for bats. Either the animal can become entangled in the foil covering the insulation, or the finishing material is too smooth for bats to cling to.

This could be solved by using a simple construction of wooden planks for the insulation, allowing the bat to cling to it. Furthermore, several small spaces can be created in the crawl space where crevice-dwelling animals can settle.

Because a connection between the outside and inside is being created, there is also a significant risk of water infiltration. This means that the water barrier must be considered. This is not only dangerous for the bat, which can drown, but also for the residents, as it must be secure to prevent the house from sinking. The panel recommended a T-shaped tube that would allow water to drain away but prevent the area from flooding.

First, considering the bat, it can be concluded that the access tube should not be made of PVC or a similar material. This would prevent the animal from having a grip on the material, making it more difficult to crawl out. Therefore, a rough inside in the tube or shaft should be developed for the bat to enter. To prevent other unwanted animals from entering, various options could be explored.

To deter mice and rats, a raised edge could be installed to prevent the mouse from crawling in, while the bat could. Furthermore, the opening for the bat should not be larger than 3 centimeters, as above 3 centimeters the stone marten already has enough space to crawl in. Furthermore, it should not become an ecological trap for amphibians or insects. For this purpose, the opening is placed a little higher.

The crawl space offers many nesting opportunities for bats, as long as appropriate measures are taken. The participation and awareness-raising process also recommended that the entrance be clearly visible from the outside. This means a prominent opening on the exterior wall will be installed to indicate that this is a bat roost.

RESULTS
concrete hollow-core - possibility

Looking at a concrete hollow-core slab, as the name suggests, it offers many open spaces where bats can roost. These spaces don't cause any nuisance to residents, as they are located between the slabs. However, several points were discussed that influence this approach. These considerations include moisture and ventilation, construction, and safety.

Within hollow-core slabs, there is a static airflow. This is because one end is closed and the other open. This allows bats to enter without creating drafts, which bats dislike. However, the temperature can be a bit too cold for bats during the summer months. Around 20 degrees Celsius is a dangerous temperature for a maternity colony. There is also little temperature variation, which is desirable for bats to roost.

During the discussion, it was mentioned that the construction was not feasible due to a different method used in Flanders. Placing an open butt joint at such a height would also be unusual and unnecessary.

The floor height provides a safe distance from the ground for bats to roost in and avoid being attacked by mice or rats. However, the accumulation of droppings can make the space difficult to inhabit and therefore unsafe for bats.

As already discussed, this option is not really suitable for bats because the temperatures are not suitable for a maternity colony, they are too cold. During hibernation season, the temperatures here are too cold. The droppings also pose a significant problem within the structure. However, it does offer a possibility for implementation within parking garages, but this falls outside the scope of this research.

RESULTS
roof edge - possibility

Looking at the roof overhang, it offers ample space for birds and possibly bats. However, this has been done many times before, so much is already known about it. It presents an opportunity because the overhang is an unused, yet insulated, space. One conclusion from the discussion was that a roof overhang isn't really common in the construction sector in Flanders. This made it difficult to develop this design.

The sketch shows an entrance at the front of the roof overhang. However, the discussion revealed that this entrance could also be located at the bottom or even on the side. A side entrance can be very suitable for the black redstart, and a crescent-shaped opening can be used. Various orientations can also be created to suit different species.

Overheating can occur if this is not properly managed. This can cause wildlife to die under these conditions, making it an ecological trap. This problem can be solved by placing the entrance under the roof tiles and the underlayment.

For the bats, a slatted structure could be installed to allow them to seek out different temperatures. However, this requires a somewhat more complex structure within the roof.

This has been done before and can therefore be implemented, as long as the orientation is taken into account and the climate within the roost meets the animals' needs. Another point that emerged from the discussion is that dormer windows could be considered, particularly in the Netherlands. There, they are prefabricated and easy to install, unlike what is done in Flanders. A roost can then be created in the dormer roof on flat roofs, for example, for bats to crawl into or for small sparrows. The dormer walls were also considered a potential solution.

RESULTS
façade panel - possibility

An analysis of potential curtain walls revealed that these walls don't really serve a purpose. Therefore, it's all the better to give them a function, such as for bats or birds. Bats don't need much space to pass through; 2 centimeters is sufficient. The construction is also relatively easy to implement for existing buildings, as it can easily be installed on the side. This was discussed during the meeting, and it's possible to tailor the curtain wall to the desired size for the side. This ensures that anyone can make and create something themselves. The following points emerged from the discussion, focusing on construction, comfort, and application.

The curtain wall, as illustrated, should have a slatted structure behind the wooden planks so that the wood on the back can breathe and prevent mold growth. The spacing and orientation of the internal baffles can also be better placed in different ways and at different lengths. This creates different climate zones behind the wall. Larger open spaces can also be considered to accommodate potential maternity colonies. Diagonal beams are fixed into the wall to provide further structural support. The panel can also be made modular and prefabricated. For this, a single unit is attached to the wall, which also creates the opportunity for bats to grab onto and climb into rough walls.

To create different climate zones within the curtain wall, varying the thickness of the insulation board can be considered. This ensures stable air circulation in the cavities. Varying thicknesses can also result in slightly higher or lower temperatures. The exterior materials can also vary in color and thermal resistance. For example, some areas may have heat-absorbing materials and colors, while others are more heat-repellent.

As discussed earlier, the panel can be prefabricated. This can be a ready-made box that is simply hung on the side of the facade. Furthermore, a parametric and modular construction offers the flexibility to adjust the panels to the angle and height of the available space on the facade. This approach allows the panels to be optimized for various situations without extensive custom solutions. Prefabricated panels are a versatile solution that can be tailored to the specific needs of each project.

All in all, the curtain wall could be a good candidate for further research within this project. It is a simple and labor-friendly intervention for humans to install against the facade, and the bats also benefit from this. Before making any adjustments, the panel's construction and how it can be made modular and adjustable must be considered.

RESULTS
roof-floor connection - possibility

Considering the roof and its connection to the wall, there are opportunities for bats and birds to roost. The awkward angle created in the attic makes it difficult for people to convert it into a usable space. Returning this unused space to nature presents a great opportunity.

This space can be created by installing a wall between the roof and the attic floor. A space above the roof beam can also be created by making an opening in the insulation, as shown here. This ensures a stable airflow. By installing slats and small baffles, this construction can be optimal for bats to find different nesting spots.

Because the separation between the exterior and interior of the spaces does not cause any nuisance to people or bats, it is also oriented at a height that makes it difficult for predators to reach. To prevent other birds from entering the hole, a raised edge can be added that bats can climb. However, a space for birds can be created by creating compartments. No research has yet been conducted on birds and bats living together, but generally, they don't interfere. In this case, it can be a matter of "just let things be."

Because there is only one opening in the space, allowing for only one airflow, this creates no drafts, which is pleasant for the animals. Furthermore, the insulation ensures little to no heat loss to the outside compared to the interior.
This option offers many possibilities, considering the long space can be transformed into several smaller bat roosts. By varying the partitions and cavities, just as with the curtain wall, there's always a place for bats to nest.

RESULTS
green wall - possibility

A great idea to enrich a green and sustainable wall with biodiversity. However, this option is not practical for bats. Research has shown that mice and other predators can easily climb up this green structure. This means the bats' safety is compromised.

Bats, when hibernating, need about 20 to 30 minutes to wake up. This means that the animal only becomes aware of being gnawed on by a mouse or rat after 30 minutes. This makes bats particularly vulnerable to predator attacks during hibernation.

A green wall is also not a good option for birds, as they too are prey for rodents. Birds that nest in the green wall run the risk of being attacked by mice and rats, which endangers their safety.

While a green wall and a wildlife habitat can be combined, these two elements should not be directly connected. The plants and any flowers attract insects such as bees, mosquitoes, butterflies, and other animals that both birds and bats feed on. This can positively contribute to biodiversity, provided the animals' safety is guaranteed.

Combining a green wall with a wildlife enclosure is a good idea, but it poses too many risks for the animals to stay there. It does, however, provide shelter for birds. It's important to consider the safety of both bats and birds when designing such structures.

RESULTS
fake chimney - possibility

With the energy transition, more and more people are choosing electric heat pumps, making central heating boilers and fireplaces redundant. This leads to unused chimneys. New construction sometimes omits chimneys, which changes the streetscape. Therefore, attention is being paid to these structures and how they can accommodate bats and birds, seeking to combine two criteria.

A chimney is often located on the exterior of the house, on the ground floor. By creating openings for bats and birds, this space can be easily accessed from outside. During renovations, a built-in cupboard can be installed at the desired height. In new construction, the argument can be made that the chimney should be preserved for the streetscape and the connection to other neighborhoods. These chimneys can be installed as prefabricated elements.

Because the structure is located on the exterior, it is primarily suitable as a winter shelter. Insulation can be added to ensure a comfortable temperature for bats. The discussion revealed that, just like with roof overhangs, this concept has already been applied and is available on the market. It's important to explore how this can be further improved by collaborating with various stakeholders and experts.

CONCLUSION
possibility

Following this discussion, two details were eliminated for further development, but a new concept was also introduced. For example, the hollow space in a concrete floor will no longer be considered for housing bats, primarily because it is unsuitable for maternity colonies. While this concept could potentially be applied to parking garages, it falls outside the scope of Interreg and will therefore not be explored further.

Furthermore, the green facade will not be further developed as an animal habitat due to the associated risk factors. However, it remains possible to combine a green facade with built-in amenities.

However, a detail has been changed from just a flat timber roof to something that could potentially also be beneficial for bats and birds: the dormer can accommodate animal amenities on the roof, in the roof, and on the side of the dormer window.

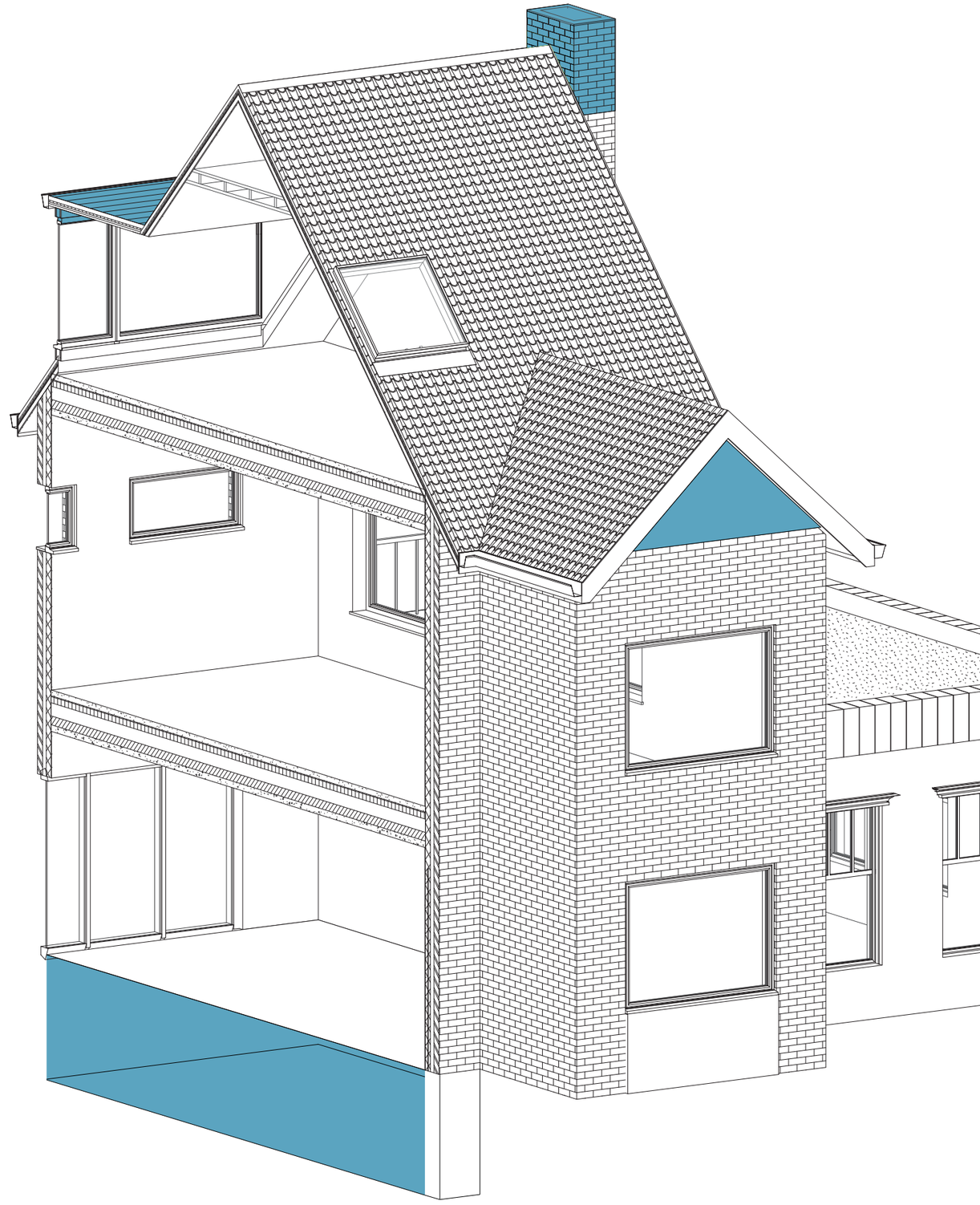
The coming chapters will thoroughly evaluate the key points that need to be addressed to further optimize the details. This includes improving the structures and ensuring the safety and comfort of the animals. In addition, there will be more intensive consultations with experts, such as the bat group, to hear their opinions on the six new ideas. This consultation is essential to ensure that the solutions are not only theoretically feasible, but also practically effective and sustainable.

During a conference of Interreg with partners and demo project owners, the question of the construction costs of the proposed solutions was repeatedly raised. These financial aspects will be addressed at a later stage, once the details have been finalized. For now, the focus is primarily on the needs and welfare of the animals. It is crucial that the proposed solutions actually contribute to their protection and habitat improvement before considering the financial aspects.

The final four details in which more research will be done are the following ones:

- Voorzet
- Fake chimney
- Dormer
- Crawl space

In the following chapter, these four details will be showed and explained how the design came to be.



3.DESIGN

DESIGN KEY VALUES
introduction

The research phase has identified several essential principles that must be taken into account when transitioning into the design phase. These design values are crucial to ensure that the resulting structure effectively supports both human needs and building-dependent animal species. In particular, three core elements require careful consideration to optimize the design for bats: **entrance, spatial configuration, and material choice**.

Entrances play a critical role in creating suitable habitats. Research indicates that bat roost entrances should be positioned at least five meters above ground level, or a minimum of three meters above an extension. Additionally, the entrance surface must be rough enough to allow bats to land securely, grip with their claws, and crawl into the roost.

When considering interior spaces, several design aspects are equally important. First, the space should incorporate variation in height as well as opportunities for movement. This involves ensuring an effective relationship between depth, width, and height, enabling the creation of multiple micro-spaces within the roost. Such spatial diversity supports the formation of thermal gradients, often referred to as “warmth bubbles”, which allow bats to select microclimates suited to their needs. These thermal variations can be enhanced through strategic placement of thin insulation layers, as well as the use of materials or colors that absorb and release heat, such as dark or metallic surfaces with higher thermal conductivity than the primary construction material.

Finally, material selection must also align with the needs of bat species. Materials should be as natural and untreated as possible, providing rough surfaces that allow bats to grip with their claws. Certain adhesives, such as tile glue or wood glue, can be safely used to improve surface texture or structural performance, as they are non-toxic to bats.

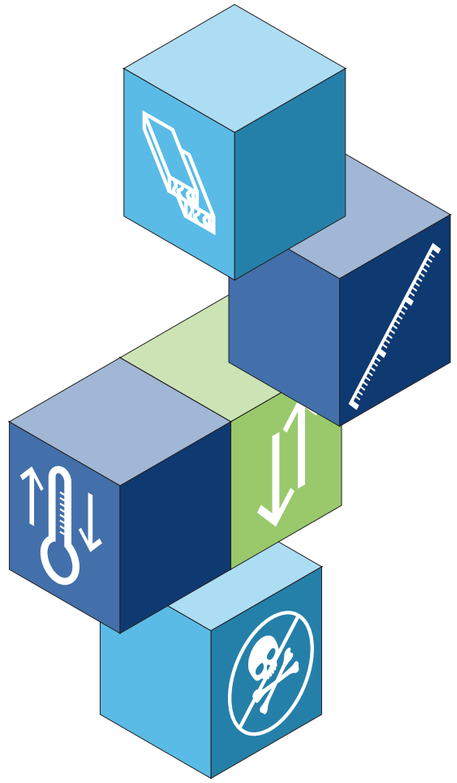


image 2.1: design key values of own experience

The previous discussed criteria that came from experience and discussion with ecologists and experts for designing, are being supported by the book ‘stadsnatuur bouwen’. It focuses on discussing the implementation of nature-inclusive designing, regarding plants and animals in the skin of a building. In the final chapter, they focus on 10 criteria that should be considered when designing for animals and greenery. For the design and research within this thesis, the six most relevant criteria are discussed and used within the design process.

1. Design a process
Mainly focus on starting a process of nature development, and maintain this. We as humans can not decide where nature will come and grow, therefore a place needs to be incorporated in the plan.

2. Design inclusive and integral
Always incorporate the opportunity to improve and/or incorporate nature developments within the city context. Think not only from a human perspective, but also wonder what benefits humans can give to the nature.

3. Keep it simple
Try to create gradients, as also mentioned in the own stated research, and incorporate a divers habitat for the animals. Enlarge the diversity of the different species. Do not forget empty and dry areas, these biotopes are also needed for species.

4. Design collective
Make sure that there is more than just a nesting box. The surrounding with the 5 V’s (veiligheid, voortplanting, verbinding, voedsel, en variatie) are important to incorporate. This can also be translated to points (habitats), lines (routes), and surfaces (nature areas).

5. Design ‘with’ nature
There are already a lot of species of animals and plants present in the surrounding. Try to incorporate them as much as possible. It does not make sense to design for non-present species. This should become part of the design process, see which species are present.

6. Design maintainance, and vice versa
Not only should the maintainer of the building be taken into the process, but also a plan should be made to maintain the designed building and that it keeps doing the intention.

After the design has been concluded, there will be looked into a reflection on these 6 points and how well these can be incorporated within the design process, but also the downsides are discusses, if there are any.

DESIGN PRINCIPLES
introduction



image 3.2: illustration of social design

7.1 Social design

Given the large number of stakeholders involved in the design of the details, social design provides an appropriate conceptual framework. Social design, as discussed in the literature, considers not only human desires and needs but also the roles of nonhuman actors. This broader perspective aligns closely with the research and design processes conducted for this project. Nold (2022) presents twelve "potluck principles" of social design, eight of which are directly relevant to the current study:

- working through and with things;
- addressing human and technical problems collectively;
- altering existing ways of knowing, being, and doing;
- adopting interdisciplinary approaches;
- engaging in discussions about needs, purposes, and values;
- fostering new democratic relations between places, living beings, and things;
- acknowledging inequalities, absences, and exclusions;
- mitigating unintended or harmful outcomes of design.

Several of these principles are closely interconnected. For example, the principle of working "through and with things" is especially applicable, as the "things" in this project include the animals that form part of the design process. This perspective is consistent with the broader field of more-than-human design, which explicitly recognizes nonhuman actors as meaningful participants.

The principle addressing "inequalities, absence, and exclusion" is equally significant. Animals cannot articulate their needs or advocate for their interests, which often results in their exclusion from conventional design processes. Recognizing this structural inequality necessitates a reconsideration of how democratic relations are constructed within environments shared by humans, animals, and other entities. In turn, this calls for a shift in how designers conceptualize agency, responsibility, and representation.

These social design principles resonate strongly with the theory of more-than-human design. Allen (2010) defines more-than-human design as an approach that includes not only all humans, such as nonwhite, Indigenous, or disabled communities, but also nonhuman beings, including plants, animals, and even nonliving entities such as rocks or atmospheric conditions. Transitioning away from anthropocentric modes of thinking requires fundamental changes in design practices. It demands new methods, new forms of collaboration, and a reorientation toward ecological and multispecies forms of coexistence. Embracing these shifts is essential for moving toward an era in which nature and nonhuman life are genuinely integrated into design processes rather than treated as passive background elements.

But how do we design with more-than-human for this project? In the works of Wakkary (2025) and Tarcan (2022), several design principles are being discussed and explained. Eventually, they will guide the design process further into the final designs.

Decentering the human

The human should not be taken as a centralized being, but rather a rejection of human exceptionalism needs to happen. The human does not make the final decision but is seen as a stakeholder within a pool of many more stakeholders which are part of ecological, material, and social systems. Therefor, humans are seen as relational and interdependent. Decentering does not mean that the human is not responsible anymore, the contrary, we as humans should be the speaking subjects within these systems. But decentralizing, is not a one time trick. It needs to be made sure that this keeps on going. By constantly asking whose needs should be prioritized, who is left behind, and who is too much represented. This reached by iterative making, reflection and observation. It could be said that the perspective of the humans needs to shift from egological to ecological, from self-centered to decentered being.

Designing with, not just for

As mentioned within the social design principles, the design process should not be designing just for some, but rather see what the behaviors, temporalities, resistances, decay, growth, and responses to interventions are. Therefor, conditions need to be made, in with nonhumans can visibly influence the design process. Some examples are materials aging, plants growing, and animals taking habitat in a structure.

Relationality

The design is not only focused on the individual, but needs to be taken into the whole picture, how does it behave in the systems and with other participants. Humans and nonhumans have always been entangled as mentioned within indigenous knowledge. Therefor, controlling or optimizing nonhuman behavior is something that needs to be transformed into design alongside. Sometimes this means that the design is not adopted or altered to the desires of the nonhumans.

Time as duration and intensity

Nonhuman temporalities are something that should be kept in mind, such as seasonal cycles, growth and decay, nesting, hibernation and moments of intensity that can disrupt human plans. Therefor, the outcomes of a design can never be fully to satisfaction. Partial knowledge is thus encouraged, rather than problem solving and embracing uncertainties. This not-knowing creates an opportunity to learn from unexpected failures and interactions.

Liminality

A lot of the more-than-human design takes place in liminal spaces, thresholds between inside, built, domestic, and outside, natural, ecological. These spaces make sure that design can be done with safe encounters, but remaining accountable for the actions. Therefor, the designer should reflect the harm, care, inclusion, and exclusion. Eventually the goal is ethical cohabitation rather than domination or extraction.

Knowledge beyond the rational

The value of traditional, indigenous, and experimental knowledge is important to take within the design process. Humans are seen as not separated from nature but understand environments as living relational entities. This, together with the rational and technical approach, help with the designing with more-than-human. Therefor, affective and sensory attentiveness is cultivated. Through proximity, care, and repeated engagement, the knowledge of designing is influenced, both emotionally as well as physically. This is more experimental rather than analytical.

natuur-inbouw | optimising building details for building-dependent animals

DESIGN PRINCIPLES
introduction

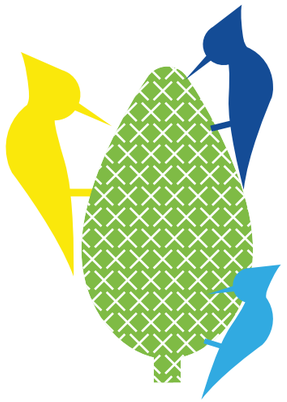


image 3.3: illustration of participation

7.2 Participation

At present, most people have little awareness of birds and other species that depend on buildings for nesting or roosting. Bats, in particular, are often associated with negative imagery, such as disease, misfortune, or folklore references, resulting in widespread misunderstanding. In line with the social design principle of altering existing ways of knowing, being, and doing, as discussed by Nold (2022), it becomes essential to challenge these misconceptions through accessible forms of education and engagement.

To support this shift in understanding, the building-dependent animal details developed in this project have been transformed into construction kits that users can assemble themselves. Each kit includes an instructional booklet that:

- explains the reasoning behind the design and its functional requirements;
- provides accessible information about the animals and their ecological roles;
- contributes to reducing stigma, especially surrounding bats, by offering factual and relatable insights.

The booklet draws on a visual language similar to well-known IKEA manuals. However, to align with social design principles, additional illustrated speech bubbles are incorporated. These coloured annotations highlight the design rationale, biological facts, and broader ecological significance embedded in each step of the construction process. By combining straightforward instructions with moments of learning, the kit not only guides users through the building process but also actively reshapes how they perceive bats, birds, and other species that rely on built environments.

The kits can also be implemented within educational settings. When ordered by schools, they can serve as the basis for classroom projects in which students learn to assemble the details while also receiving supplementary informational material. This approach strengthens collective learning and follows Nold's (2022) call for socially engaged design practices that foster reflection, participation, and new forms of environmental understanding.

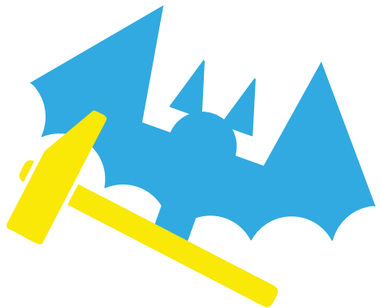


image 3.4: illustration of participation

7.3 Feasibility

To ensure that individuals who order the construction kit can successfully assemble the detail, particular attention must be given to the design of the connections and the overall assembly process. Similar to the approach used in IKEA packaging, the joints must be intuitive and straightforward so that users can complete the construction without specialized tools or prior experience. This accessibility can be achieved through simple yet robust joining techniques, such as:

- Tongue-and-groove joints, which provide stability through interlocking surfaces.

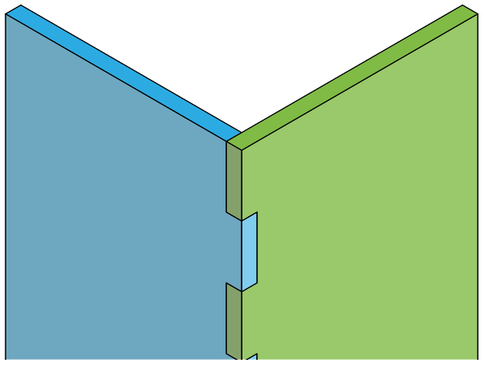


image 3.5: tongue and groove joints

- Slot-and-tooth systems, where components slide into predetermined openings, allowing multiple parts to lock together into a coherent structure.

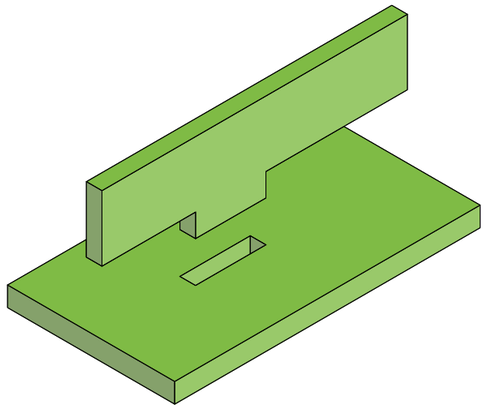
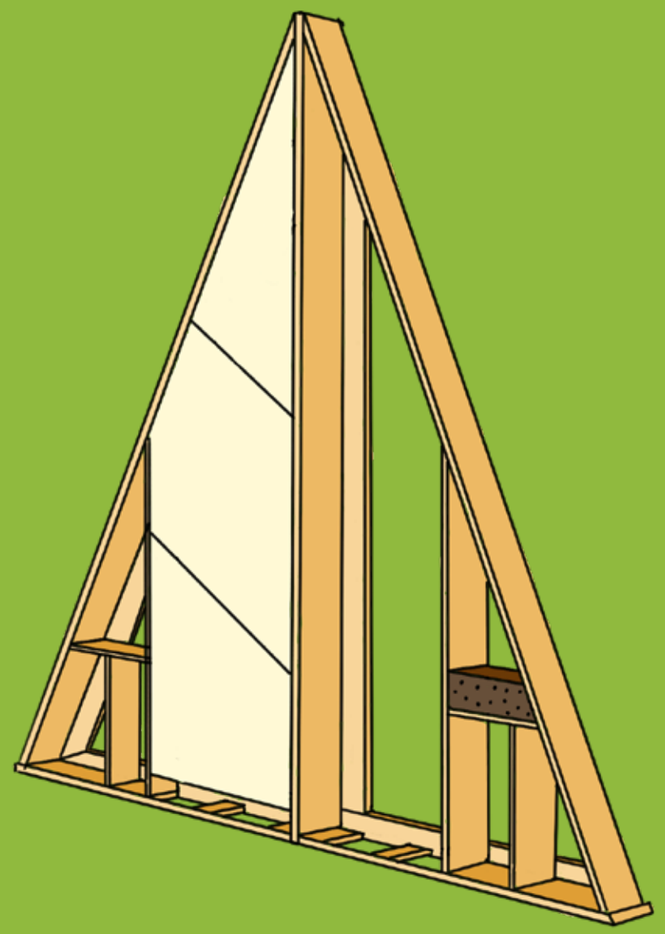


image 3.6: slot and tooth system

These construction strategies make the assembly process effortless for users while maintaining the structural integrity required for the detail to function effectively. As a result, the kits become not only practical and easy to use but also engaging, encouraging users to install the finished detail in or around their homes. This enhances both the educational and ecological impact of the design, as users interact directly with the product.



VOORZET

external addition for bats and birds

De voorzet, has in Dutch two definitions:

1. a push or pass in the sports to help make a goal. This ‘goal’ can be referred to as a successful detail that helps the animals
2. to put something in front of something else. In this case, an addition to the wall on the outside.

Therefore this came from the ‘voorzetgevel paneel’ (put-in-front-of-your-facade-panel), which became ‘voorzet’. With these elements, people can easily add possibilities for bats and birds on the outside of their house. To give them a little push.

For the first detail, the focus is on further developing and improving the façade element integrated into the roof ridge. This principle is already recognizable within the streetscape, ensuring that the intervention blends naturally into its context.

An analysis of different roof types showed that a single standard solution is not feasible, mainly because roof pitches vary between buildings. Through a step-by-step study of various roof geometries, it became clear that the most effective approach is to work with two standardized modules. Each module consists of two elements, allowing for flexibility when dealing with differing roof slopes.

The gaps between the modules and the roof edge can function as buffer zones, offering bats additional sheltered spaces. This is particularly relevant, as observations indicate that bats often occupy irregular and unpredictable locations. The first module is designed for steeper roof pitches, while the second is better suited for more shallow slopes. In addition, the cavity within the element provides space not only for bats, but also for birds and insects. By integrating nesting boxes and other ecological features, the system can support multiple species within a single architectural intervention.

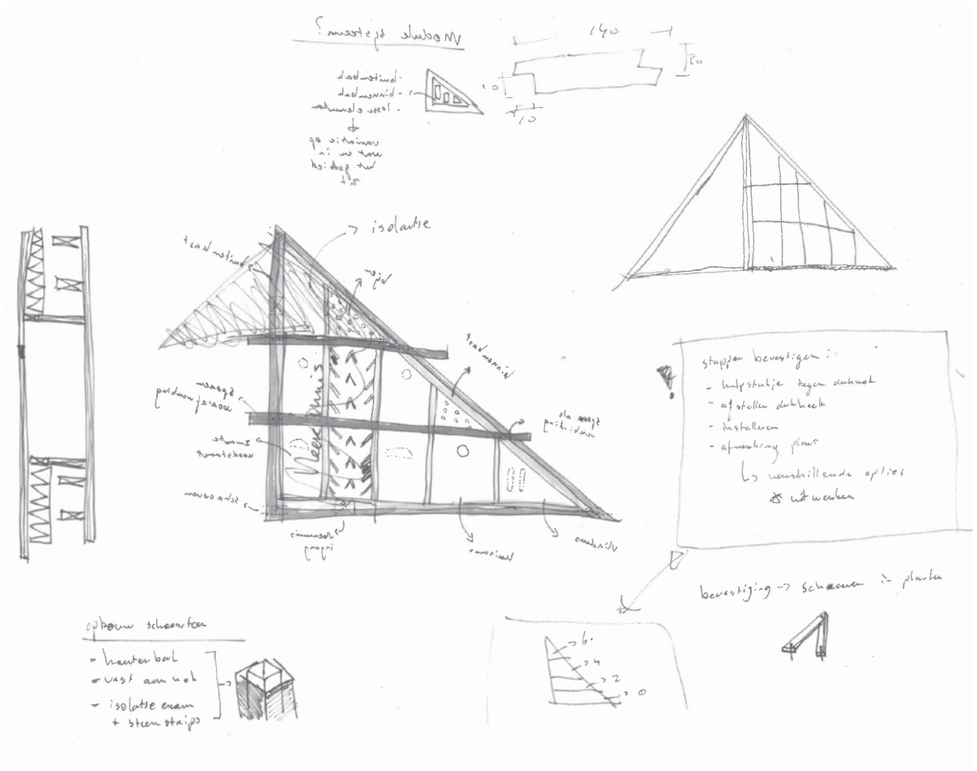


image 3.7: sketch of possibilities

DESIGN
voorzet

After the sketch phase, combined with several feedback sessions, led to a promising concept, the technical development phase followed. The first step focused on the internal configuration: how can the element be designed to accommodate bats, birds, and insects?

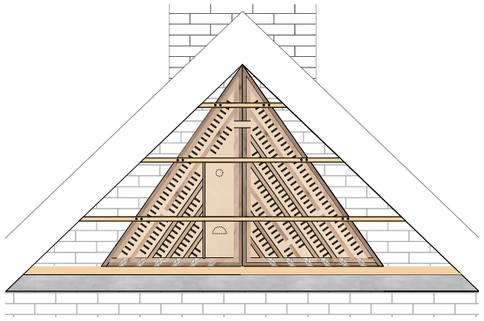


image 3.8: first variant

Following the development of the drawings, attention shifted to the realization of the element, including segmentation, connections, and material choices. The second design variant proved too complex to manufacture. As a result, the design was simplified by reducing complex connections and eliminating unnecessary structural elements.

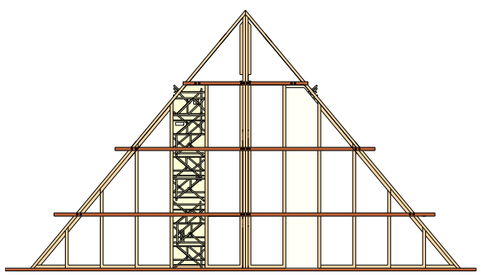


image 3.9: second variant

The final variant was selected as a prototype and prepared for testing at a suitable location. To simplify installation, the system was divided into two parts. This approach makes the element lighter, easier to handle, and allows for variation in configuration. An opening between the two modules enables bats to move from one compartment to the other. Once the outer shell is installed, the inner components can be attached separately, avoiding the need to mount a single large and heavy structure.

Beneath the insulation panels, a dedicated module is designed specifically for bats. The integrated lamella structure creates a stable and comfortable internal temperature gradient. Additionally, three compartments with varying insulation thicknesses further enhance this gradient. Alongside the bat habitats, two compartments are designed for birds, primarily suited for species such as house sparrows and swifts. Above these, a wooden block with drilled holes provides nesting space for solitary bees, while a separate cavity is included to offer shelter for butterflies.

The element is finished with a customizable outer panel, which includes two openings for birds and several smaller openings for butterflies. During construction, it became clear that the initial dimensions were not efficient, as they were not based on standardized sizing. This led to complications during the building process.

The chosen angles of the modules, based on average roof pitches, were implemented in the first prototype, which resulted in further challenges during fabrication. An improved version was therefore developed. This version includes a module suitable for roofs with lower pitches, offering more space for birds and insects. While the overall concept remains similar, adjustments are still required in the digital drawings to better align with standardized construction dimensions.

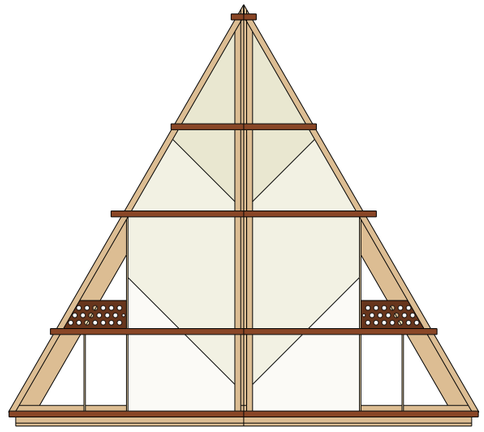


image 3.10: third variant/first prototype

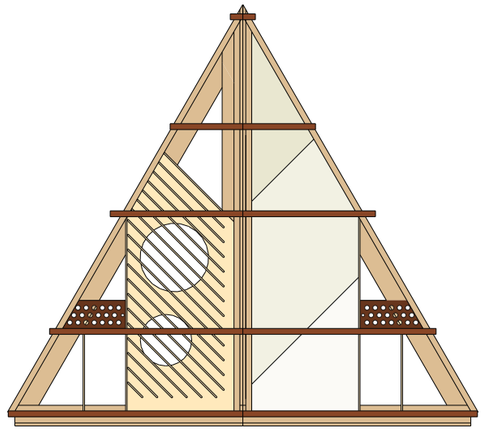


image 3.11: inside of first prototype

image 3.12: exploded view of the first prototype

Figure 3.13 shows a typical wall construction with an open cavity vent. The temperature inside the cavity is very low for bats, around 2°C. To ensure that the animals can maintain sufficient warmth during hibernation, additional measures are required—either within the cavity or as an added element in front of it.

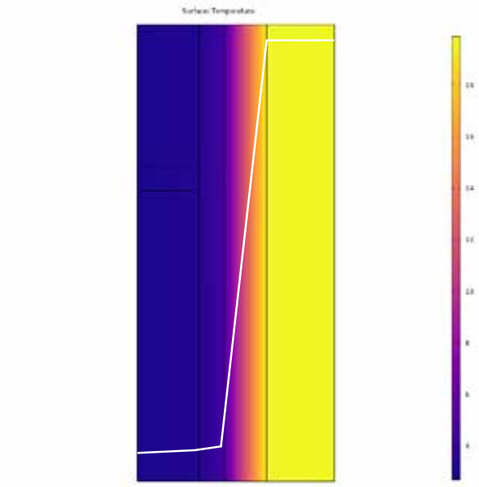


image 3.13: COMSOL simulation wall without voorzet

Figure 3.14 illustrates the section of a façade system designed to address this issue. From left to right, a wooden outer cladding is applied, followed by a ventilated air gap to allow the timber to breathe. Behind this, a sealed timber enclosure prevents drafts and creates a stable thermal pocket suitable for bats.

The diagram shows that when the outdoor winter temperature drops to 0°C, the temperature inside the façade system can reach a more comfortable 6°C. This improvement is partly due to heat transfer from the interior of the building. If the façade is intended for maternity colonies, higher and more stable temperatures between 25–30°C are required during the summer. This can be achieved by varying insulation thicknesses and incorporating heat-absorbing materials within the internal lining.

The most effective way to test a detail in practice is by constructing it at a 1:1

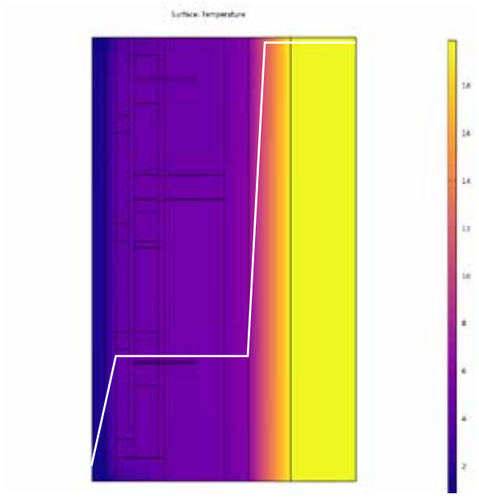


image 3.14: COMSOL simulation of wall with voorzet

scale. This was done based on the digital models. As mentioned earlier, the lack of standardized dimensions caused significant challenges during fabrication. Despite these difficulties, the process also led to valuable insights. Due to an accidental duplication of elements, an overlap was created between two modules, resulting in a well-aligned connection where the ridges fit neatly into each other.



image 3.15: prototype with lamellae

The lamellae in this prototype were laser-cut. However, the carbon residues left on the wood are harmful to bats. This can be resolved by milling the lamellae instead. By adding small notches to the lamellae and corresponding grooves in the panels, the elements can be easily clicked into place, allowing for faster and simpler assembly.

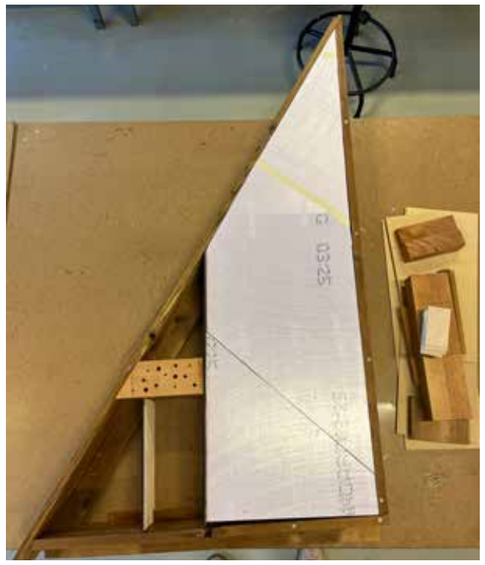


image 3.16: prototype with lamellae covered up

Looking at the façade system, two approaches are possible. The first is to construct the façade entirely on-site, but this is both complex and costly. The second option is to develop a prefabricated element, which is more efficient. The prefab panel consists of an insulation layer attached to the wall, a backing panel, a timber structural frame, lamellae positioned in between, and a front panel. This is finished with a secondary timber cladding, including an air gap to allow for ventilation and moisture control.

To improve connectivity, an opening in the masonry joint (open cavity vent) can be linked to the cavity behind the façade. This provides bats with access to a larger network of spaces. It should be noted that this scenario is based on single-unit production. If the system is further developed as a prefab product, production can be optimized, leading to reduced costs.

In table 3.1, the costs are being presented that were made when making the first prototype. This was a prototype, in the future the MDF will be replaced by a more robust and hard natural wood, such as Douglas or something that is rough in texture.

Soort	Houten plank	MDF plaat	Houten balk	Houtvezel	Schroeven
Lengte	300,00 cm	244,00 cm	30,00 cm	140,00 cm	/
Breedte	9,00 cm	122,00 cm	2,00 cm	25,00 cm	/
Hoogte	2,00 cm	0,60 cm	8,00 cm	4,00 cm	/
Prijs	€ 0,02/cm	€ 3,60 /stuk	€ 0,40 /stuk	€ 0,0018 /cm2	€ 0,05 /stuk
Hoeveelheid	2 stuks	3 stuks	1 stuks	1 stuks	28 stuks
Totaal	€ 12,00	€ 10,80	€ 0,40	€ 6,30	€ 1,40
Specificatie	Geacetyleerd	Lasercut	/	Isolatie	/
Totale bouwkosten					€ 30,90

table 3.1: costs for the first prototype

DESIGN
voorzet

The first prototype was presented during the midterm event of Natuur-inbouw. It was showcased in a session focused on inspiring construction details, and additionally exhibited in the foyer, where visitors were invited to provide feedback.

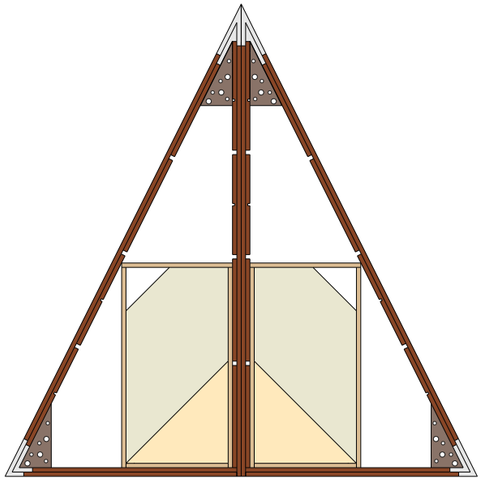


image 3.17: second prototype design

The following feedback was collected:

- Add tile adhesive to the wood surface to improve grip for animals
- Ensure the design is suitable for different climates, such as coastal environments
- Lamella spacing should vary between 15 and 30 mm
- Consider using wood fibre insulation
- The dimensions were impractical

To enable faster production, the design was refined by standardizing key dimensions across the different module types. The short side was set to 50 cm and the long side to 100 cm. Two custom connector elements were developed to link the sloped side with the long and short sides. These use finger joints, allowing the panels to be securely connected. This system enables flexibility, accommodating both sharp and obtuse triangular forms, as well as rectangular configurations.

Additionally, each unit contains a smaller internal box that houses the lamellae for bats. This contributes to a modular system, improving flexibility and ease of assembly. Prototype evaluation and improvements The first prototype revealed several issues, including unnecessary assembly steps, awkward angles, and poorly considered connections. To address these, the design was refined by:

Reducing the overall size, making the unit lighter and easier to install by a single person Improving the lamella connections; using laser-cut notches allows them to slot together more securely and efficiently Simplifying the board connections, eliminating the need for complex angled cuts Optimizing material use to reduce waste and improve production efficiency.

Although 3D-printed components were initially explored, they proved less effective in practice, though not entirely dismissed for future iterations. Adjustments based on ecological expertise Following a discussion with an ecologist from Natuurpunt, several improvements were made to enhance the ecological performance of the design. The second prototype served as a useful discussion model.

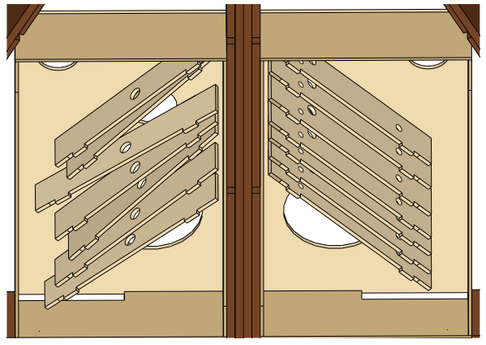


image 3.18: alteration of the degrees of the lamellae

In image 3.19, an exploded view is shown on how the structure is made and functions. Within the triangular shape, a rectangular box is placed, with lamellae and over that insulation layer is added. This makes sure that the bats have that desired climate for their existing.

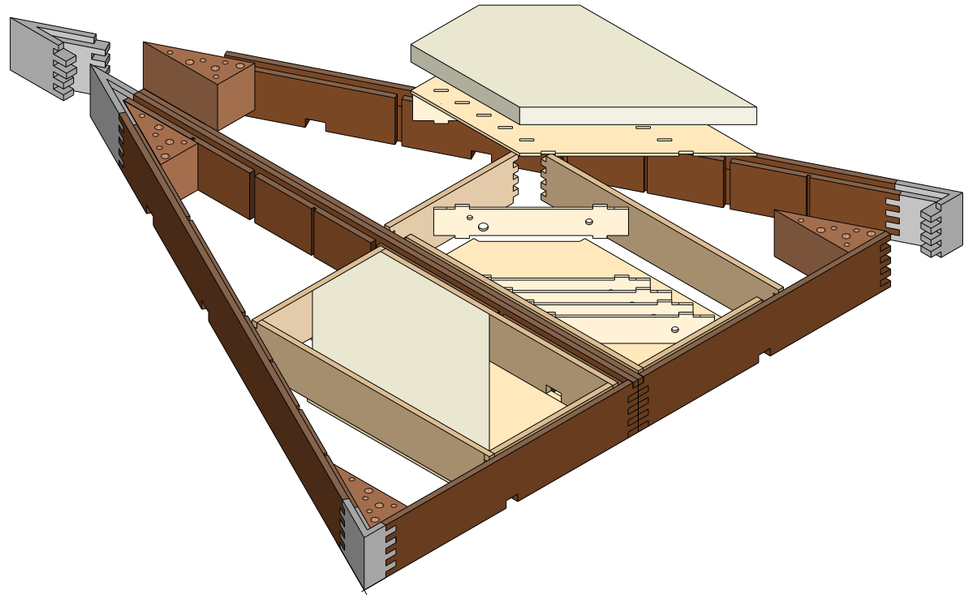


image 3.19: exploded view of the second prototype

DESIGN
voorzet

By reducing the size of the panel, material use is minimized. In addition, the connections were simplified by introducing laser-cut slots, allowing the lamellae to be easily inserted. The number of connections were also reduced, resulting in a simpler and more efficient production process.



image 3.20: second prototype

DESIGN
voorzet

During the midterm event and a meeting with Kamp C, it became clear that there is also a need for a rectangular unit that can be mounted directly onto a façade with a flat roof. A new variant was therefore developed, which can be produced with minimal adjustments. This rectangular unit can also be combined with the existing triangular modules, maintaining a modular system.

The unit is divided into two compartments. One side is designed for bats and includes lamellae similar to the other models. The other side provides space for birds and insects, making the element multifunctional. To simplify production, the rectangular unit uses the same components as the triangular version. The lamellae are identical to those used in the triangular modules and the chimney element, and the mounting method to the wall remains the same. This consistency improves both efficiency and ease of assembly.

By minimizing the number of connections, the production process becomes faster and less complex, reducing both time and costs. As with the updated triangular module, the panel size has been reduced to limit material use. In addition, the connections have been simplified by introducing laser-cut slots, allowing the lamellae to be easily inserted. This further reduces the number of connections and contributes to a more efficient production process.

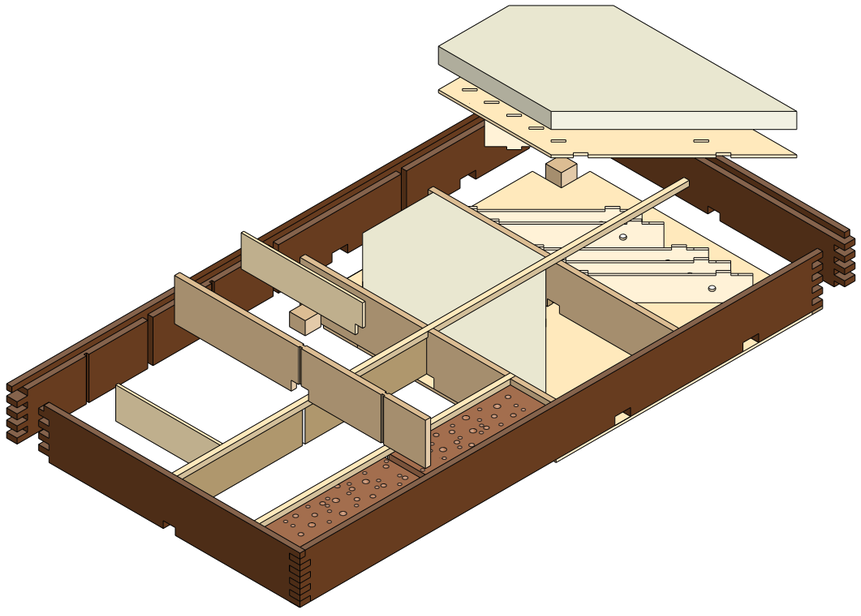


image 3.21: exploded view of rectangular version



image 3.22: construction of rectangular prototype



image 3.23: impression of materials used for real

DESIGN
voorzet

After optimizing the first prototype, several areas for improvement were identified, mainly through self-reflection. The following adjustments are proposed:

- The panels that hold the lamellae should allow for more variation in placement, creating a wider range of spatial conditions.
- The connection between the unit and the wall can be improved for easier installation and better stability.
- Applying tile adhesive to the wooden surfaces could increase grip for the animals.
- Increasing participation in the production and installation process. This was explored through the development of an IKEA-style assembly manual, with a visualization illustrating how such a guide could function.



image 3.24: impression on how booklet would work

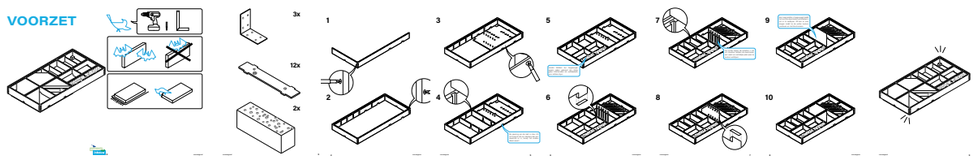


image 3.25: booklet impression, added in appendix

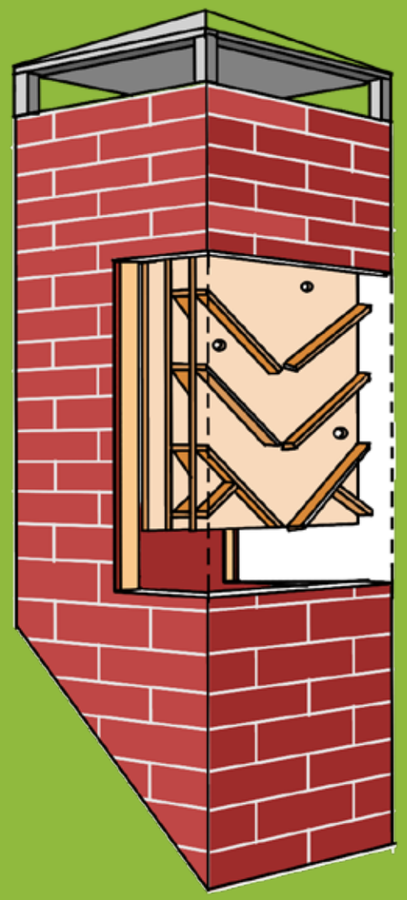
conclusion

Looking at the design process of the façade element, several key steps contributed to the final outcome. A thorough analysis of Dutch and Flemish roof pitches revealed that a single standardized dimension can be applied to the majority of buildings. By dividing the triangular variant into two parts, the module became easier to handle and install. The unfilled space around the unit functions as a buffer zone, providing additional shelter opportunities for bats.

Throughout the design process, not only bats were considered, but also birds and insects. These species were positioned around the bat habitats, as their spatial preferences and requirements are well understood. Constructing the detail at a 1:1 scale provided valuable insights that could not be identified digitally. This led to several optimizations, including a reduction in size for easier installation and a decrease in unnecessary material use. Furthermore, the internal lamella system was standardized, enabling scalability and improving both cost and material efficiency.

Due to the simplicity of the components, the system is suitable for mass production. It can be distributed as a kit, accompanied by an IKEA-style assembly manual, allowing users to easily assemble and install the unit themselves. Placement near an open cavity vent is recommended, as this creates a connection to the existing wall cavity and expands the available habitat for bats.

In conclusion, the combination of ecological feedback, iterative design, prototyping, and optimization has resulted in a robust yet lightweight system. Its modular nature allows it to be adapted to different environments, roof types, and species. At the same time, standardization ensures that the product can be produced efficiently and scaled for wider application. While it may appear as an unconventional building detail, it represents an important and architecturally relevant step towards integrating ecological function into the built environment



FAKE CHIMNEY

external addition for bats and birds

The mean reason for looking into a chimney had two reasons. Firstly, the implementations of chimneys in the streetscape is becoming less and less. Therefor giving it back with a different function can be useful for people who would like to still have the expression of a chimney on their home.

Second reason is that often chimneys are not used anymore and therefor destroyed. But looking at an add-in for the chimney, a nice new structure can be made which can house birds and bats inside.

Currently, chimneys are becoming less common in new buildings, mainly because they are no longer necessary due to advances in technology. As a result, the traditional chimney is gradually disappearing from the streetscape. To maintain a sense of architectural continuity, a “false chimney” can be introduced. This offers new opportunities to integrate habitats for bats and birds within a familiar architectural element.

During the initial design explorations, limited variation was found, largely due to the linear and standardized nature of chimney forms. However, differences between the Netherlands and Flanders revealed important considerations. These regions differ not only in general construction practices and regulations, but also in specific requirements for chimneys, including legislation, placement, and construction methods.

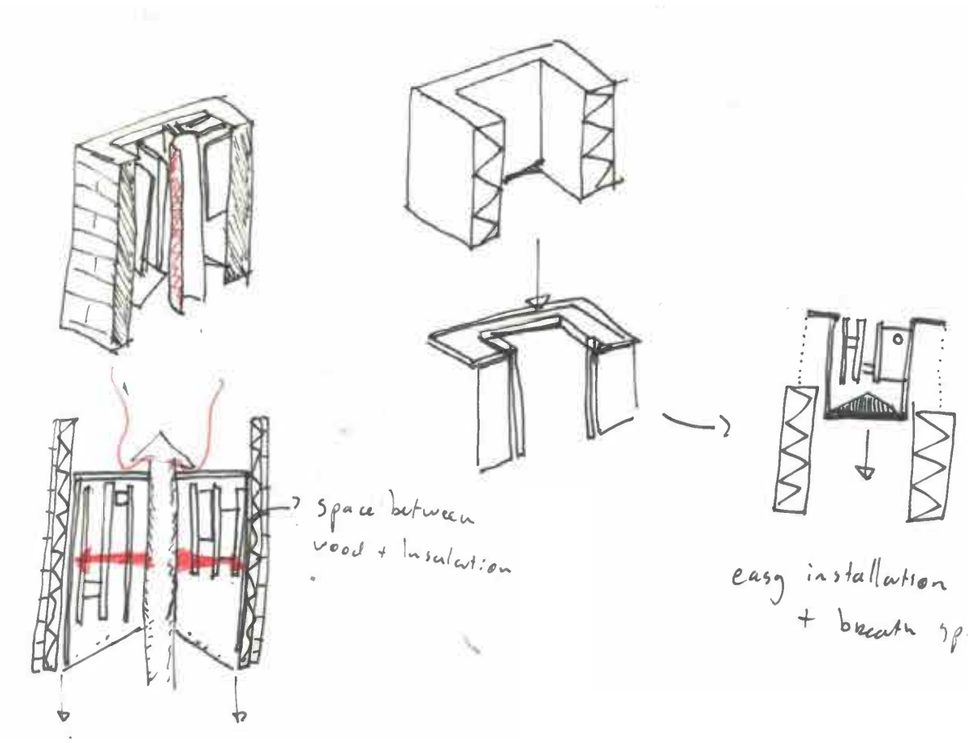


image 3.26: sketch of possibilities

DESIGN
fake chimney

The most notable difference concerns chimney height on flat roofs. In the Netherlands, regulations require a chimney to extend at least 0.5 meters above the roof surface, while in Flanders a minimum height of 2.0 meters is prescribed (NEN 2757; NBN B61-002).

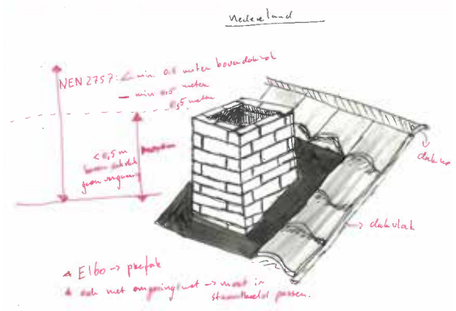


image 3.27: Dutch legislation

There are also differences in regulatory frameworks. In the Netherlands, chimney construction is governed by national legislation, primarily through the Building Decree (Bbl) and supplemented by NEN standards. In many cases, chimney installations do not require a permit, provided they do not involve structural modifications and remain within height limits.

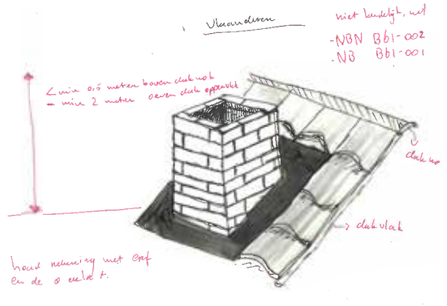


image 3.28: Flanders legislation

In contrast, Flanders applies a more detailed and technically oriented system, combining regional regulations with European standards (such as EN 1443 and EN 13384). These focus strongly on safety, emissions, and the correct calculation of draft and dimensions.

Construction requirements also vary. In the Netherlands, emphasis is placed on fire safety and airtightness, while in Flanders stricter demands are made regarding CE certification, double insulation, and computational validation of flue systems.

In summary, Dutch regulations rely on a more uniform national framework, while Flemish regulations adopt a more detailed, technical approach. Within the internal configuration of chimneys, variation is relatively limited. Most differences are found in dimensions and the type of roof on which the chimney is placed. However, one variable is whether the chimney includes a cap, which depends on functional requirements such as the need for ventilation outlet systems.

Finally, chimneys can be positioned in several ways: on a flat roof, along the side of a pitched roof, or at the ridge of a pitched roof.

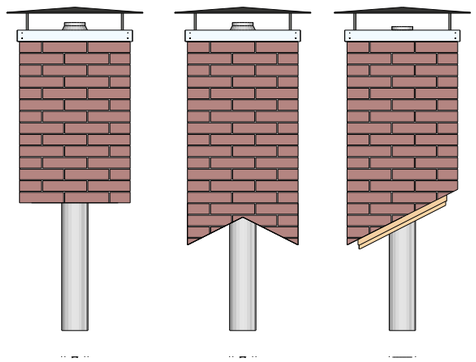


image 3.29: different pitched roofs

In modern construction, natural ventilations are increasingly being replaced by systems such as balanced ventilation with heat recovery. These systems supply fresh air while extracting warm indoor air, transferring heat between the two air streams without mixing them. During winter, this results in incoming air being preheated, while the outgoing air retains a moderate temperature. This residual heat can serve as a valuable energy source within the chimney, improving winter conditions for bats seeking shelter.

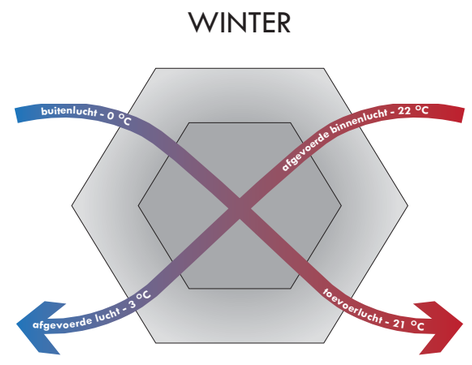


image 3.30: working of a balance ventilation system

In summer, the same system contributes to a more stable indoor climate. Warm outdoor air is tempered by passing along cooler extracted air, helping to moderate temperatures inside the building.

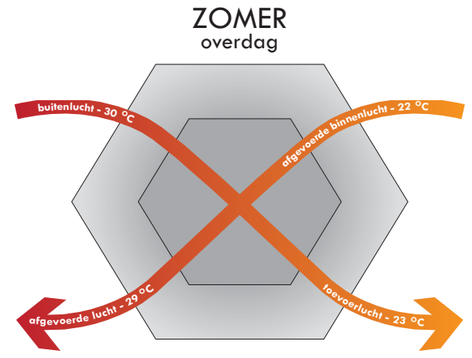


image 3.31: working of a balance ventilation system

An additional opportunity arises during summer nights, when exhaust air temperatures can remain higher than outdoor air. This creates favorable conditions for maternity colonies, which require warmer and more stable environments during this period.

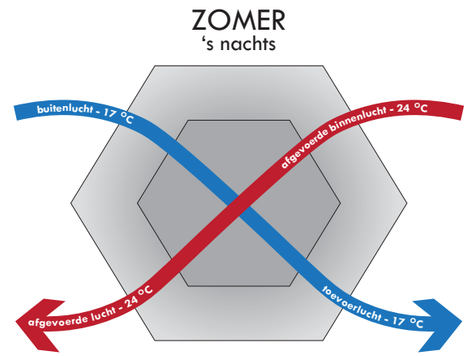


image 3.32: working of a balance ventilation system

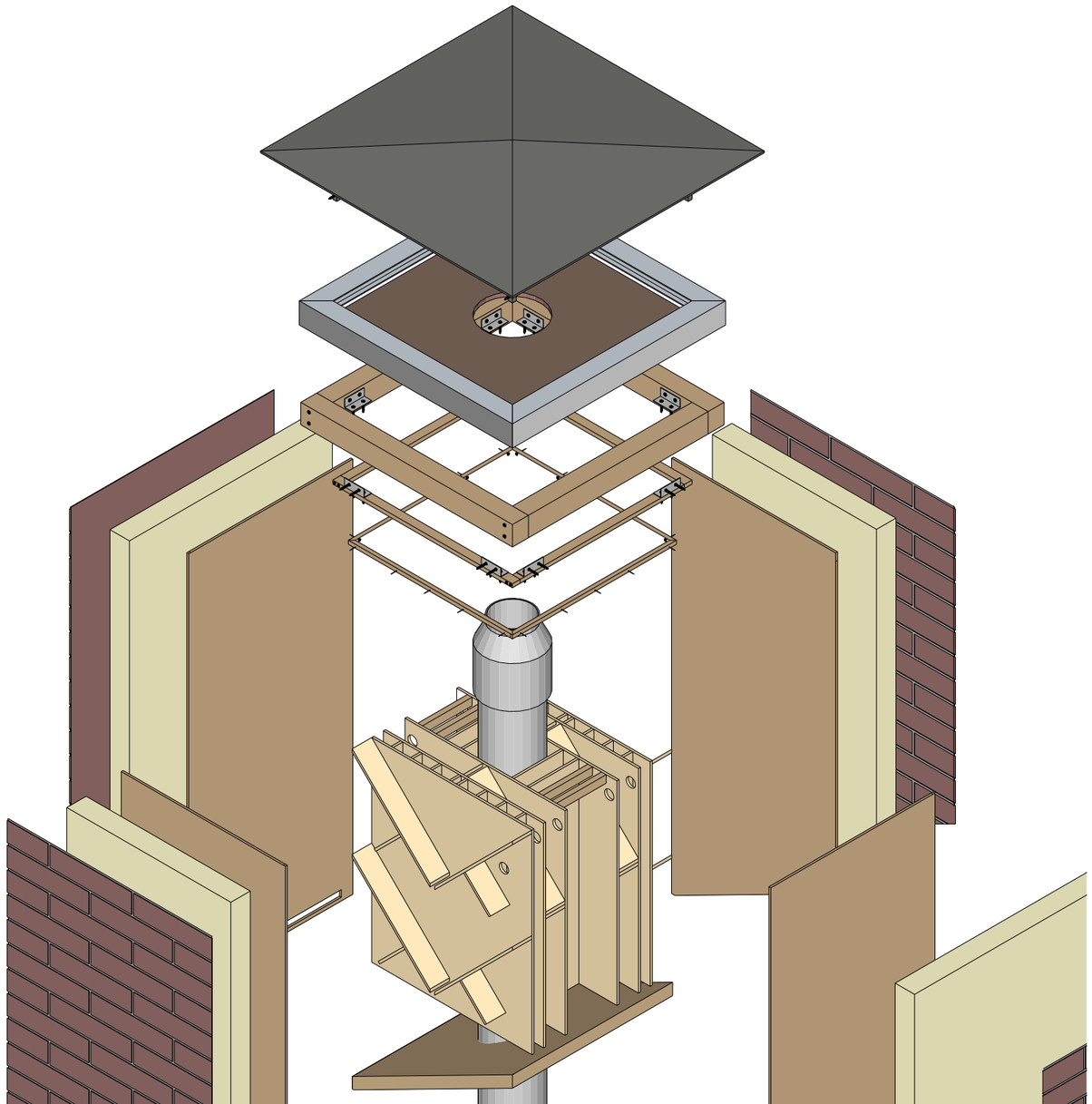
Inside the chimney, different cavities are created using wooden partitions, which are positioned so they do not come into direct contact with the heat source. By varying both height and material conditions, a range of microclimates emerges, ensuring that suitable spaces are available for different needs and seasonal changes. Additionally, two sloped base plates (approximately 10 degrees) are integrated to guide bat droppings downward. These are directed beneath the roof tiles and into the gutter, preventing accumulation within the structure.

DESIGN
fake chimney

The chimney is composed of multiple layers. From the outside to the inside, it starts with a layer of brick slips, which helps to reduce the overall weight. This is followed by an insulation layer, which also functions as a buffer zone to create a more stable and comfortable internal climate. A wooden structural panel is then added, protecting bats from direct contact with the insulation materials.

Inside the chimney, several compartments are created that allow bats to move and occupy different positions. These spaces are formed by integrating sloped or vertical wooden panels within the structure.

image 3.33: exploded view of prototype 1



A simulation was conducted in COMSOL to assess the thermal feasibility of this chimney concept. The first image illustrates the false chimney configuration. Due to the natural behavior of heat rising, a significant amount of warmth accumulates near the top of the structure. The internal partitions and lamellae help retain this heat, creating a more stable internal climate.

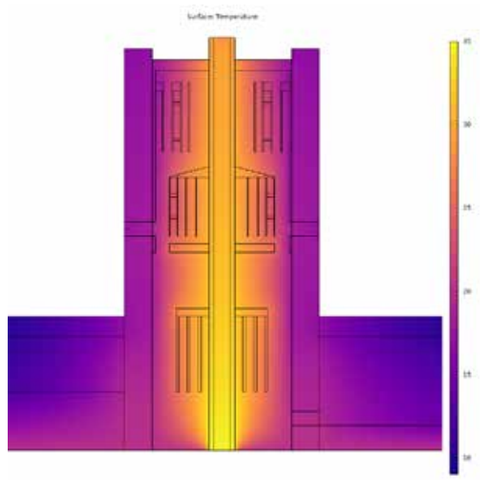


image 3.34: heat in chimney with balance ventilation

As height increases within the chimney, temperatures gradually decrease. This variation creates a vertical temperature gradient, allowing bats to select the most suitable microclimate within the structure. The second simulation presents a design variant in which the exhaust pipe of a boiler runs through the chimney. In this case, the temperature range is higher than 20°C, as reflected in the adjusted color scale. This configuration offers strong potential for creating a range of habitats that meet different ecological requirements.

The chimney was relatively straightforward to construct. First, the diagonal elements were assembled and fixed in place. Then, the panels were attached to create a stable structure. The outer shell was added by fixing wooden boards around the frame, followed by insulation and a layer of brick slips for finishing. The chimney concept can be applied in both prefab construction and renovation scenarios. In renovation projects, a prefabricated module can be inserted into an unused chimney cavity, allowing for efficient adaptation of existing structures. When the chimney is combined with systems that release residual heat, such as boiler exhausts, a prefabricated solution is preferred. This ensures proper sealing and prevents animals from coming into direct contact with the exhaust pipe.

Different beam and panel dimensions are used to create varied spatial conditions within the chimney, allowing bats to hang or move between compartments. Lamellae are integrated at multiple positions, providing additional resting and roosting opportunities. As an additional variation, prefabricated bird nesting boxes can be incorporated into the outer shell. This allows birds to benefit from the structure as well, further enhancing its ecological value.



image 3.35: construction of first prototype

DESIGN
fake chimney

The false chimney was also presented during the midterm event. During this session, several remarks and suggestions were made to further improve the prototype. There were few comments regarding the internal configuration. The use of a standardized lamella structure was considered a strong aspect of the design, as it enables efficient mass production.

Additionally, the variable diameter of the ventilation pipe allows for adjustments in the internal width of the chimney. This ensures sufficient space to properly position the pipe within the structure.

Apply tile adhesive to the wooden surfaces to improve grip for animals. Ensure the design is suitable for different climates, such as coastal environments. Lamella spacing should vary between 15 and 30 mm. Consider using wood fibre insulation. The dimensions were considered impractical. The exploded view illustrates the internal composition of the chimney. The interior consists of two layers: diagonal lamellae, similar to those used in the façade module, and a second layer of thinner, vertical lamellae that create narrower cavities.

The panels are produced using CNC milling or laser cutting, allowing for standardized and efficient production. The use of finger joints enables the outer shell to be assembled quickly and precisely. On the exterior, insulation material is applied, followed by a layer of brick slips to achieve a realistic architectural appearance.

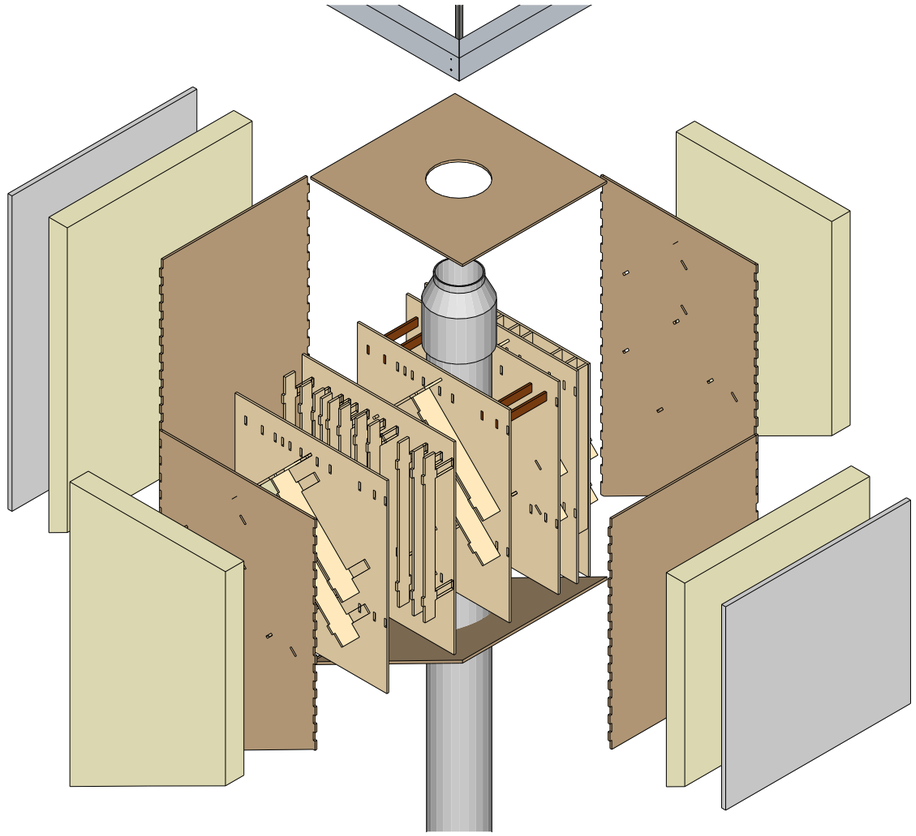


image 3.36: exploded view of alteration

Because roof pitches vary, the chimney must be designed so it can be installed on different roof types. This is achieved by first fixing a base plate to the roof battens. This plate includes an opening for the ventilation pipe, as well as a steel L-profile. During installation, the L-profile temporarily supports the chimney. The chimney is initially placed on its side on the roof, resting on the profile. It is then connected to a hinge system by inserting two pins. To adjust the chimney to the correct angle, two adjustable legs are integrated at the back. These legs are guided through brackets and can be extended to the desired height.

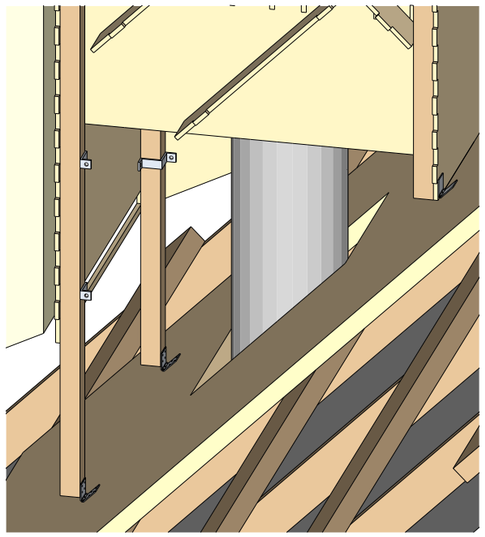


image 3.37: connection on the roof

Once positioned correctly, they are fixed to the base plate, creating a stable structure. Thanks to this system, the chimney can be installed relatively easily, making it accessible for installation in a wide range of residential contexts. The assembly sequence is illustrated alongside. First, a plate is mounted onto the existing roof batten structure. This plate includes a stop that positions the chimney correctly. Once the chimney is placed and secured with hinge pins, it is leveled. To achieve this, the adjustable legs are folded down and fixed to the plate. Because these legs are also hinged, the system can adapt to different roof pitches. After the chimney is properly secured, it is finished with lead flashing or another suitable waterproofing material. The final step is to reinstall the roof tiles.

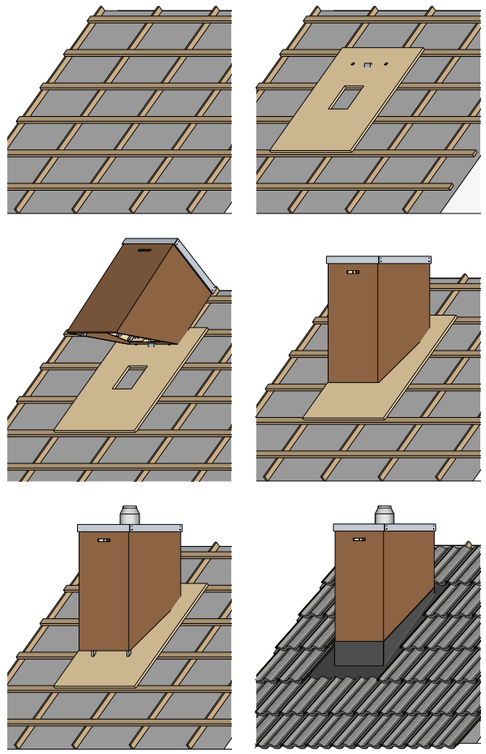


image 3.38: placement of chimney on roof

DESIGN
fake chimney

Because the chimney has limited self-weight and is not anchored to a larger structural system beneath the roof, it is necessary to verify whether the connections comply with Eurocode standards. To ensure safety, calculations were based on the most extreme scenario: the highest wind loads in the most exposed region of the Netherlands. First, the wind load was determined by calculating both the compressive force (Fd) and the tensile force (Ft) acting on the chimney. Together, these forces define the total wind load (Fw,tot). Based on this, the resulting tensile and compressive forces in the connections could be established.

Next, the bending moment of the chimney was calculated. This moment was used to determine the forces acting at the fixing points. Additionally, an upward force caused by the chimney cap was considered; this force is added to the tensile load and subtracted from the compressive load. The resulting tensile and compressive forces were then divided over the four fixing points, resulting in forces per connection. The calculations show that the two connections subjected to compression each carry a load of 0.445 kN, while the two connections under tension each carry 0.435 kN. Based on these values, an M8 bolt provides sufficient strength, meaning a relatively small and efficient fastening solution is adequate for this application.

Windlast

$$F_{w,tot} = F_d + F_t = 0,84 + 0,25 = 1,09\ kN$$

$$F_d = c_{pe,1} \times q_{pz} \times A_2 \times \gamma_q = 1,35 \times 0,4 \times 1,55 \times 1,0 = 0,84\ kN$$

$\gamma_q = 1,35\ G_q$
$A_2 = d \times h_1 = 0,4 \times 1 = 0,4\ m^2$
$q_{pz} = 1,55\ kN/m^2$
$c_{pe,1} = 1,0$

$$F_t = c_{pe,1} \times q_{pz} \times A_3 \times \gamma_q = 1,35 \times 0,24 \times 1,55 \times 0,5 = 0,25\ kN$$

$\gamma_q = 1,35\ G_q$
$A_3 = d \times h_2 = 0,4 \times 0,6 = 0,24\ m^2$
$q_{pz} = 1,55\ kN/m^2$
$c_{pe,1} = 0,5$

Puntlast

$$M = F_{w,tot} \times z = 1,09 \times 0,5 = 0,55\ kN$$

$F_{w,tot} = 1,09\ kN$
$z = 0,5\ m$

$$F_{w,t} = c_{pe,1} \times q_{pz} \times A_1 \times \gamma_q = 1,0 \times 1,55 \times 0,2 \times 1,35 = 0,42\ kN \rightarrow delen\ door\ 2 \rightarrow 0,21\ kN$$

$\gamma_q = 1,35\ G_q$
$A_1 = d \times b = 0,4 \times 0,5 = 0,2\ m^2$
$q_{pz} = 1,55\ kN/m^2$
$c_{pe,1} = 1,0$

$$R_{F,d} = R_d - F_{w,t} = 1,1 - 0,21 = 0,89\ kN$$

$$R_d = h_1 \times \frac{\frac{0,5 \times M}{y}}{0,25} = 1 \times \frac{\frac{0,5 \times 0,55}{0,25}}{0,25} = 1,10\ kN$$

$h_1 = 1,0\ m$
$y = 0,25\ m$

$$R_{F,t} = R_t + F_{w,t} = 0,66 + 0,21 = 0,87\ kN$$

$$R_t = h_2 \times \frac{\frac{0,5 \times M}{y}}{0,25} = 0,6 \times \frac{\frac{0,5 \times 0,55}{0,25}}{0,25} = 0,66\ kN$$

$h_2 = 0,6\ m$
$y = 0,25\ m$

Bevestigingslast

$$R_{F,d} = 2 \times R_{F,d1+2}$$

$$R_{F,d1+2} = \frac{R_{F,d}}{2} = \frac{0,89}{2} = 0,445\ kN$$

$$R_{F,t} = 2 \times R_{F,t1+2}$$

$$R_{F,t1+2} = \frac{R_{F,t}}{2} = \frac{0,87}{2} = 0,435\ kN$$

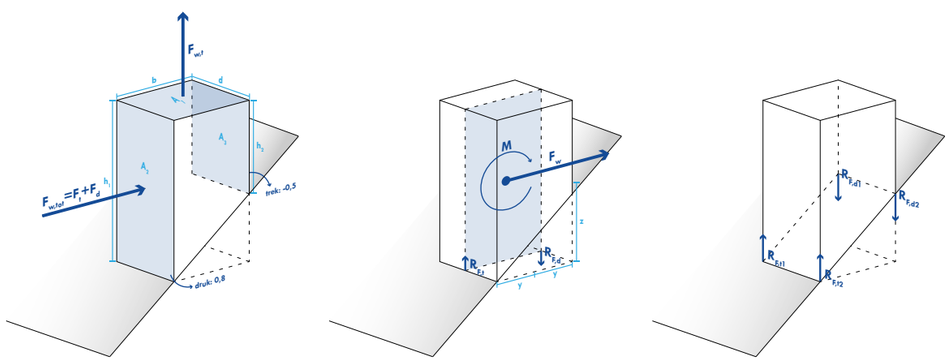


image 3.39: schemes of the forces

Because the chimney consists of pre-cut elements, such as panels and lamellae, it was relatively easy to assemble. This is an important aspect, especially if the product is to be distributed as a kit that users can assemble themselves. Technically, the chimney is composed of three main components:

- Panels with integrated grooves
- Diagonal lamellae
- Vertical lamellae

The outer shell is identical to that of the first variant, ensuring good insulation and a realistic architectural appearance. During construction, an additional element was introduced to improve structural stability. At the points where the outer panels connect through finger joints, extra support was required. During assembly, the glued connections proved insufficient, causing parts to come loose. As a result, timber battens were added at the corners to reinforce the structure.



image 3.40: second prototype

Adjustments based on ecological feedback
Following a discussion with an ecologist from Natuurpunt, several improvements were proposed to enhance the suitability of the chimney for bats. The second prototype served as a working model for this evaluation. The key adjustments are as follows:

The spacing between lamellae has been reduced to create more enclosed and sheltered niches. In the current design, bats have sufficient space to move, but fewer opportunities to occupy tight, protected corners. Additional lamellae have been introduced, some positioned at varying angles, to create a richer range of microclimates.

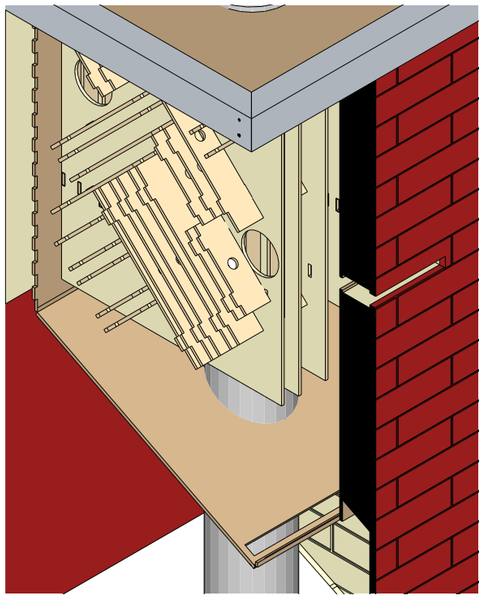


image 3.41: alteration after second prototype

An entrance opening was missing in the initial design. It is now proposed to position this opening centrally on the sloping side of the roof. This placement allows bats to exit more easily. The opening should not be placed too high, to prevent excessive heat loss. The recommended dimensions are approximately 2 cm in height and between 3 and 20 cm in width. A more effective solution for guano drainage is required. This is addressed by incorporating a small channel or cut into the internal panels, allowing droppings to move beneath the roof tiles and into the gutter.

DESIGN
fake chimney

To ensure ease of assembly for users, much of the preparation is done in advance. Grooves are laser-cut into the MDF panels, indicating where diagonal and vertical lamellae should be placed. The outer panels are fitted with finger joints, allowing them to be easily assembled. The lamellae themselves are also laser-cut. Their design allows the diagonal elements to be positioned in four different orientations, creating variation in both spatial conditions and temperature distribution inside the structure. To retain heat, the outer shell is finished with insulation and lightweight foam-based brick slips. This combination reduces heat loss and improves the internal climate, making the structure more suitable for bats and other species.

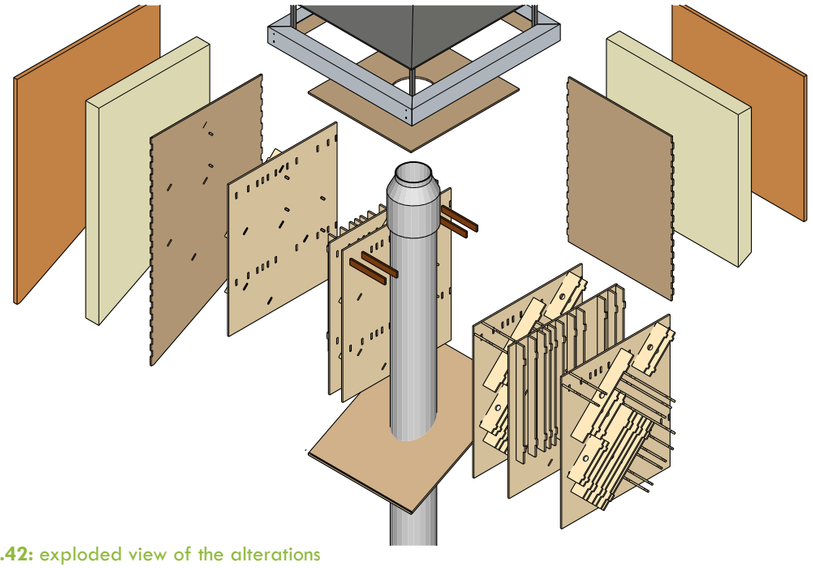


image 3.42: exploded view of the alterations

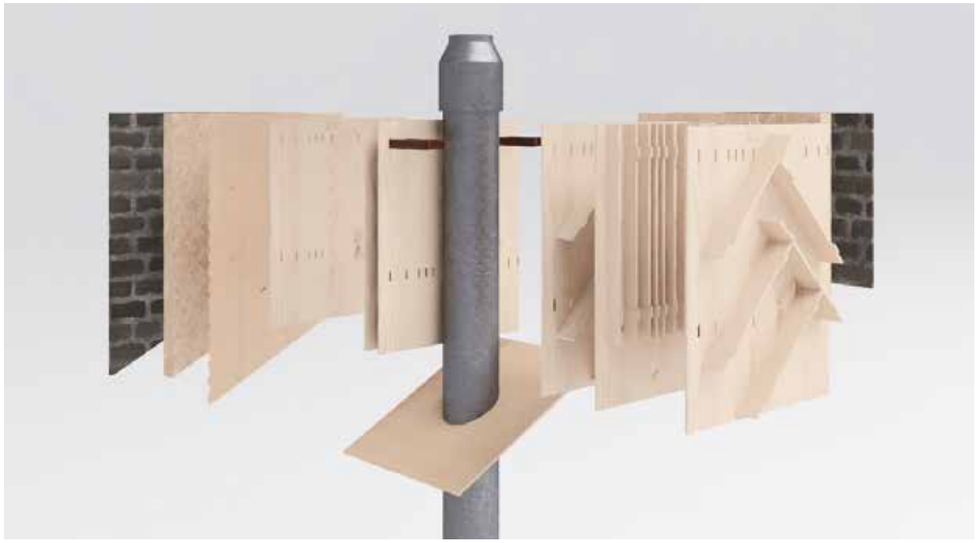


image 3.43: render of implied materials

DESIGN
fake chimney

To ensure that the chimney can be implemented in a wide range of existing structures, a parametric model was developed. This allows key parameters to be adjusted, enabling the design to fit within different chimney dimensions. The diagram alongside illustrates the structure of the script. By looping variable values through the model, different geometries can be generated based on the selected parameters.

The second image shows the Grasshopper model used for this process. With this model, the intervention can be adapted to fit inside an existing, unused chimney. By adjusting the internal dimensions through the script, the module can be precisely scaled to slide into the available cavity.

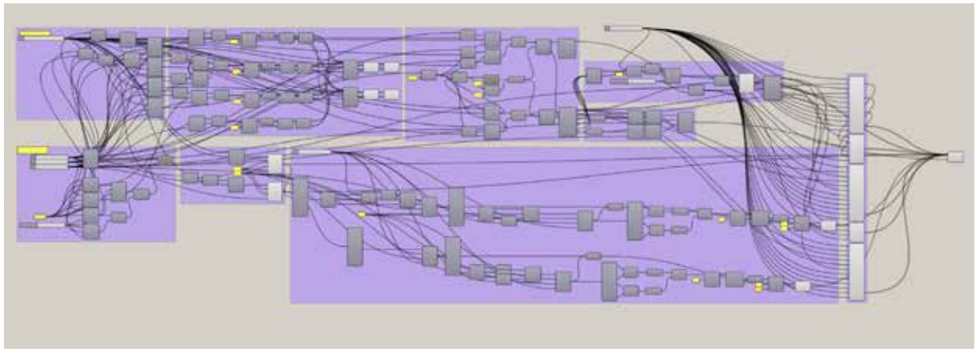


image 3.44: script of the parametric model

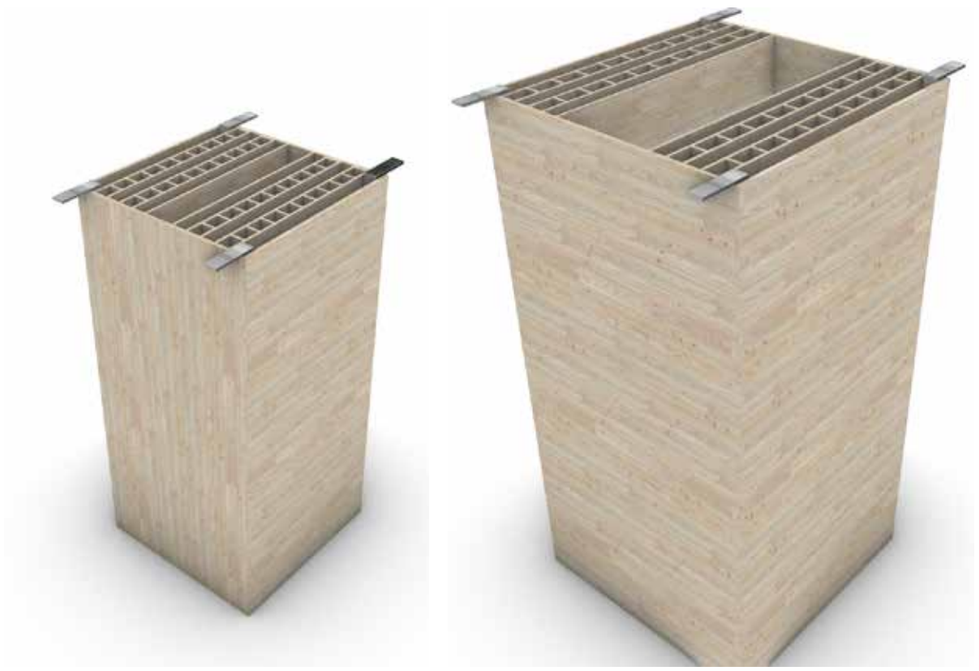


image 3.45: result of the parametric model

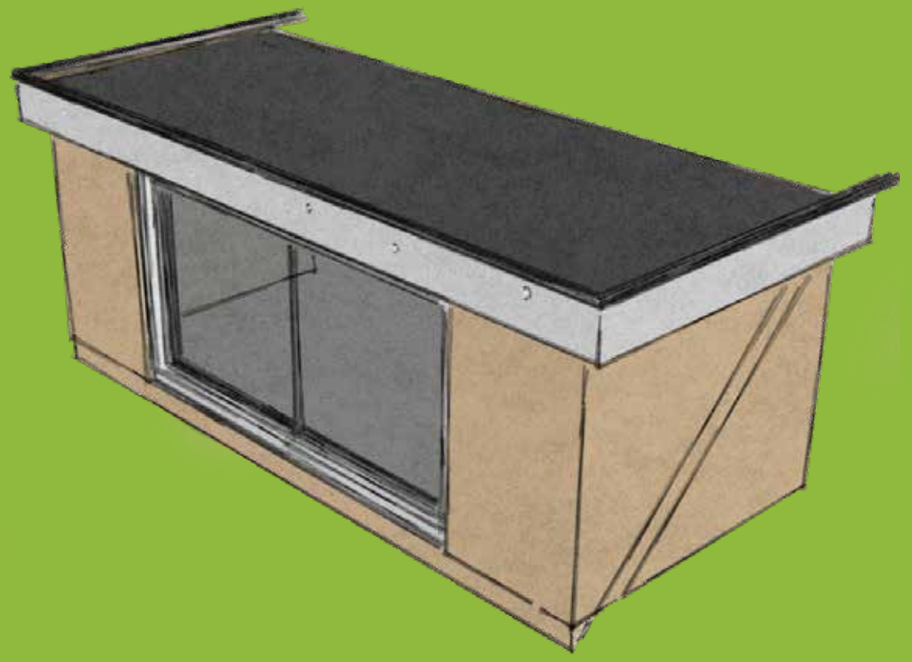
conclusion

At one point, I spoke with an acquaintance about contemporary housing construction. He mentioned that chimneys are still often included in new residential designs, even though they have largely lost their functional purpose due to systems such as balanced ventilation. Despite this, many people still value the visual presence of a chimney on a roof. As a result, non-functional “false chimneys” are sometimes added, often consisting of lightweight materials finished with brick slips to mimic the traditional appearance.

Since these elements currently serve no real function, they present an opportunity to be repurposed as habitats for bats. Chimney regulations differ significantly between the Netherlands and Flanders. The Netherlands follows a more uniform national framework, while Flanders operates with regional guidelines and European standards. Despite these differences, the concept of a chimney-based intervention remains applicable in both contexts. By combining modern ventilation systems with the familiar form of a chimney, an interesting ecological solution emerges.

The exhaust air from balanced ventilation gradually releases heat, creating a suitable microclimate within the chimney. This makes it possible to introduce a lamella structure that generates a range of temperature zones, supporting bats throughout the year. The chimney is designed as a prefabricated system composed of standardized components, such as lamellae. Although the structure is relatively lightweight, installation requires two people; therefore, a mounting system has been developed that can be adjusted to different roof pitches.

Structural calculations were carried out to determine the forces acting on the chimney and the loads on the connections. These results confirm that the connections are sufficiently strong to withstand the expected conditions. By combining contemporary technology with a familiar architectural element, this design creates a detail that is both functional and visually integrated. It provides a safe habitat for bats while preserving the recognizable character of the streetscape.



DORMER

roof addition for bats and birds

In the Netherlands, dormers are prefabricated and are easily placed on roofs. Next to that, a big surface can be used for the implementation of animals in the built environment.

In the Netherlands, dormers are often installed as prefabricated elements, whereas this is not standard practice in Flanders. The unused space within a dormer offers interesting opportunities for biodiversity. he side panels of the dormer can function as roosting spaces for bats, while the front side can accommodate birds. This is mainly because light from the windows is less suitable for bats, making the darker side areas more appropriate for their use. To simplify and accelerate the construction process, prefabricated units can be integrated into the dormer design. In addition, the paneling on the sides provides sufficient space for bats to inhabit, allowing the dormer to serve both architectural and ecological functions.

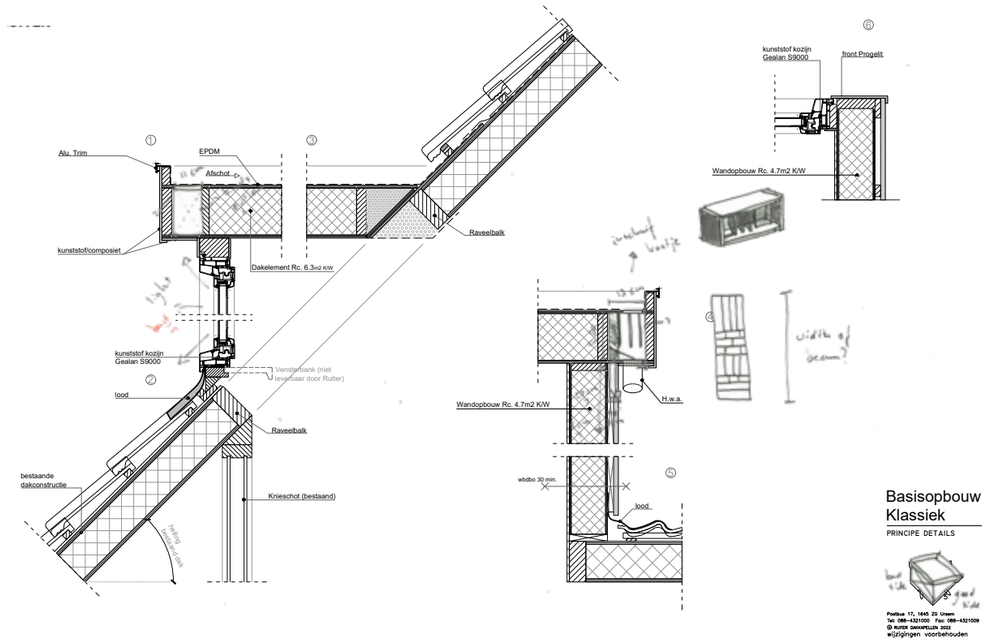


image 3.46: sketch of possibilities, based on Ruiter dakkapellen

DESIGN
dormer

The analysis of the dormer revealed that there is a considerable amount of unused space within both the roof edge and the side panels. These cavities are originally intended for ventilation, but the proposed ecological interventions do not negatively affect this function. Within the roof edge, a standardized wooden box is integrated into the existing structure.

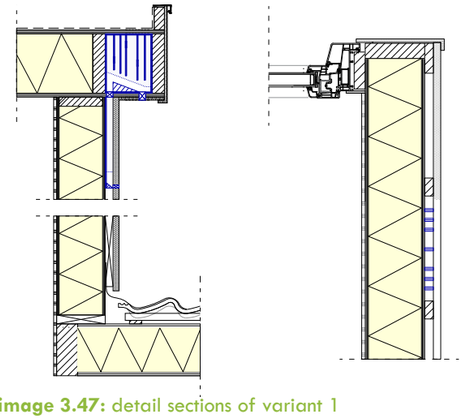


image 3.47: detail sections of variant 1

This box is accessible from below and is constructed entirely of wood or similarly rough, natural materials, allowing bats to easily grip and occupy the space. In addition, extra space is created behind the outer cladding of the dormer. By introducing additional beams and creating an opening at the top, bats are able to enter from the roof edge. Positioned closer to the insulation layer, this space offers increased shelter and a more stable microclimate.

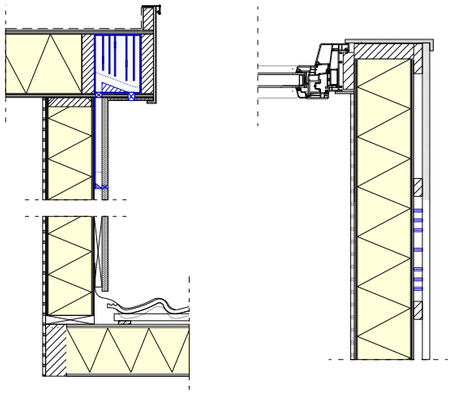


image 3.48: detail sections of variant 2

Variant 2 builds upon the first design but includes an additional insulation layer on the outside. This improves heat retention, which is beneficial for bats as it supports more stable body temperature regulation.

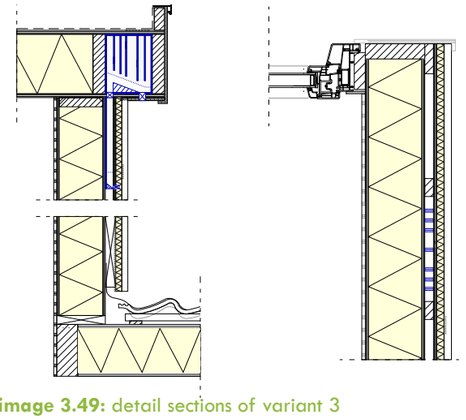


image 3.49: detail sections of variant 3

Variant 3 further develops the concept by introducing a thicker roof build-up. This allows for the integration of a green or brown roof system, which not only benefits certain bird species but also enhances the thermal buffering capacity of the structure. The substrate layer contributes to a more stable temperature within the dormer cavity.

By connecting the roof section, the overhang, and the side panel, a continuous system is created with variation in both temperature and height. This provides bats with the opportunity to select different microclimates within a single structure, depending on their needs. With these relatively small interventions, a valuable habitat is created for multiple bat species. Offering three variants also introduces flexibility, allowing residents to choose the level of investment in nature-inclusive measures.

Variant 4 differs from the previous options and is based on the principle of the voorzet, applied in reverse to function as a bat habitat. However, this solution is less integrated into the dormer itself, as it is added as an external element. To better integrate it, additional modifications would be required to both the dormer and the unit, making this variant less practical in application.

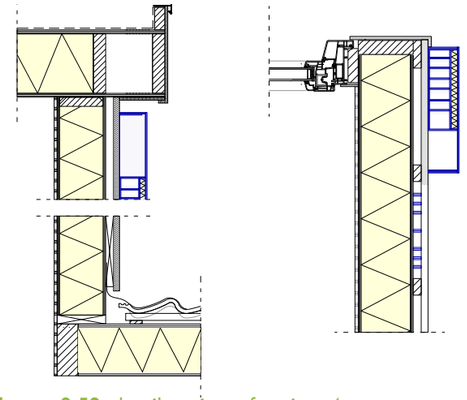


image 3.50: detail sections of variant 4

Dormers also offer opportunities to create nesting spaces for birds. Since birds are less sensitive to light and noise, the roof edge on the window side can be designed as a suitable nesting location. A similar principle as used for bats can be applied here: a standardized nesting box is integrated into the interior of the roof edge. By creating a simple opening in the outer material, birds can easily access the cavity. This solution is particularly suitable for species such as house sparrows, swifts, and black redstarts, which commonly nest in built environments.

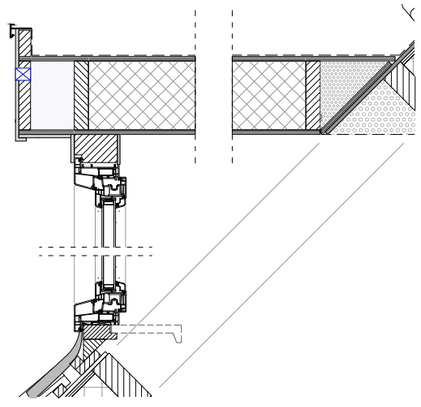
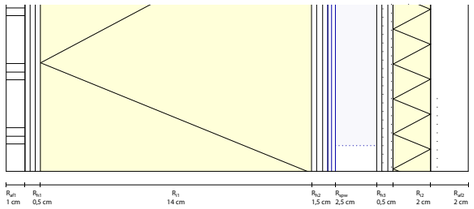


image 3.51: detail sections of bird variant

images 3.47/3.51: based on Ruiter dakkapellen

DESIGN
dormer

Dormers have a relatively large surface area that is frequently exposed to sunlight. This solar gain creates valuable opportunities for bat habitats. As illustrated in Figure 3.52, the construction of a dormer provides sufficient space to integrate a system similar to the voorzet solution. Figure 3.53 presents a simulation of this concept. The results show temperature conditions that are suitable for bats to occupy. By implementing a lamella structure, a range of warmer zones is created, offering favorable living conditions for the animals. When modifying existing buildings, part of the insulation layer may be removed to install the system. This may raise concerns about whether the required thermal resistance (Rc values) can still be maintained. According to building regulations, minimum Rc values must be met for roofs (> 6.3), façades (> 4.7), and floors (> 3.7). This allows some flexibility for introducing small openings, provided the overall thermal performance of the construction is reassessed. A calculation was therefore carried out to evaluate the impact on the Rc value. The results show that the size of the opening is negligible. The affected area represents less than 0.13% of the total wall surface (0.004 m² out of 3.0 m²), meaning its impact can be considered insignificant.



$$R_c = \sum R_i + R_{spw} = R_{af1} + R_{h1} + R_{i1} + R_{h2} + R_{h3} + R_{i2} + R_{af2} + R_{spw}$$
$$= \sum R_i + R_{spw} = R_{af1} + R_{h1} + R_{i1} + R_{h2} + R_{h3} + R_{i2} + R_{af2} + R_{spw}$$
$$= 0{,}077 + 0{,}038 + 4{,}0 + 0{,}12 + 0{,}038 + 0{,}57 + 0{,}71 + 0{,}18$$
$$= \mathbf{5{,}73\ m^2K/W}$$

$$R_{af1} = \frac{d_{af1}}{\lambda_{af1}} = \frac{0{,}01}{0{,}13} = \mathbf{0{,}077}\ m^2K/W$$
$d_{af1} = 1\ cm = 0{,}01\ m$
$\lambda_{af1} = 0{,}13\ W/mK$

$$R_{h1} = \frac{d_{h1}}{\lambda_{h1}} = \frac{0{,}005}{0{,}13} = \mathbf{0{,}038}\ m^2K/W$$
$d_{h1} = 0{,}5\ cm = 0{,}005\ m$
$\lambda_{h1} = 0{,}13\ W/mK$

$$R_{i1} = \frac{d_{i1}}{\lambda_{i1}} = \frac{0{,}14}{0{,}035} = \mathbf{4{,}0}\ m^2K/W$$
$d_{i1} = 14\ cm = 0{,}14\ m$
$\lambda_{i1} = 0{,}035\ W/mK$

$$R_{h2} = \frac{d_{h2}}{\lambda_{h2}} = \frac{0{,}015}{0{,}13} = \mathbf{0{,}12}\ m^2K/W$$
$d_{h2} = 1{,}5\ cm = 0{,}015\ m$
$\lambda_{h2} = 0{,}13\ W/mK$

$$R_{h3} = \frac{d_{h3}}{\lambda_{h3}} = \frac{0{,}005}{0{,}13} = \mathbf{0{,}038}\ m^2K/W$$
$d_{h3} = 1\ cm = 0{,}01\ m$
$\lambda_{h3} = 0{,}13\ W/mK$

$$R_{i2} = \frac{d_{i2}}{\lambda_{i2}} = \frac{0{,}02}{0{,}035} = \mathbf{0{,}57}\ m^2K/W$$
$d_{i2} = 2\ cm = 0{,}02\ m$
$\lambda_{i2} = 0{,}035\ W/mK$

$$R_{af2} = \frac{d_{af2}}{\lambda_{af2}} = \frac{0{,}02}{0{,}028} = \mathbf{0{,}71}\ m^2K/W$$
$d_{af2} = 2\ cm = 0{,}02\ m$
$\lambda_{af2} = 0{,}028\ W/mK$

$$R_{spw} = \mathbf{0{,}18}\ m^2K/W$$

image 3.52: insulation calculations

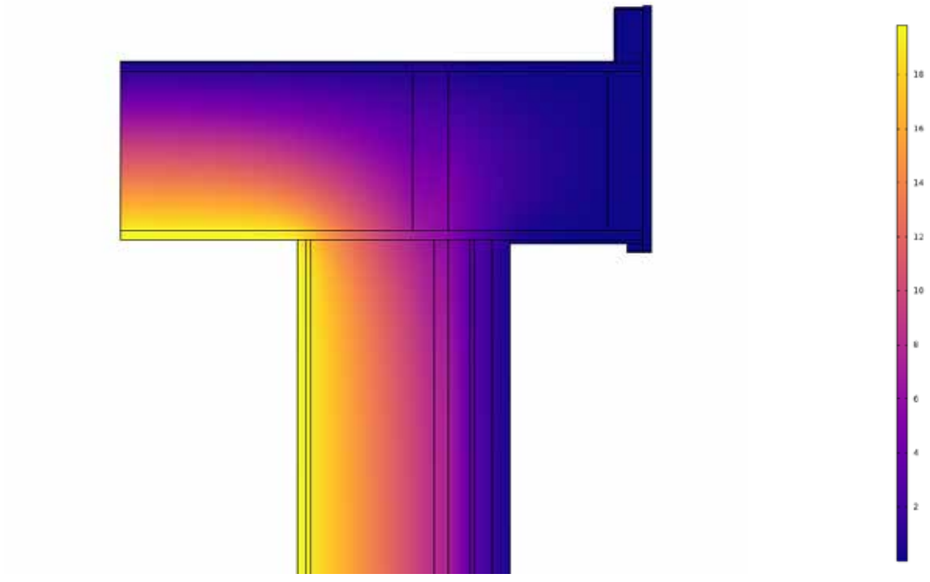


image 3.53: heat simulation

The schematic drawing shown below clearly illustrates how bat provisions can be easily integrated into the existing dormer structure. All components are fully manufactured using CNC milling or laser cutting. This ensures high precision, enabling accurate production and a seamless fit within the dormer construction. After developing the detail, research focused on how it could be optimally integrated into the existing build-up of the dormer. The aim was to maintain the original depth of the wall construction as much as possible. In the revised design, only the insulation layer is locally adjusted at the position of the bat panel. In addition, the fixing method has been simplified, allowing the element to be installed more efficiently within the existing structure.

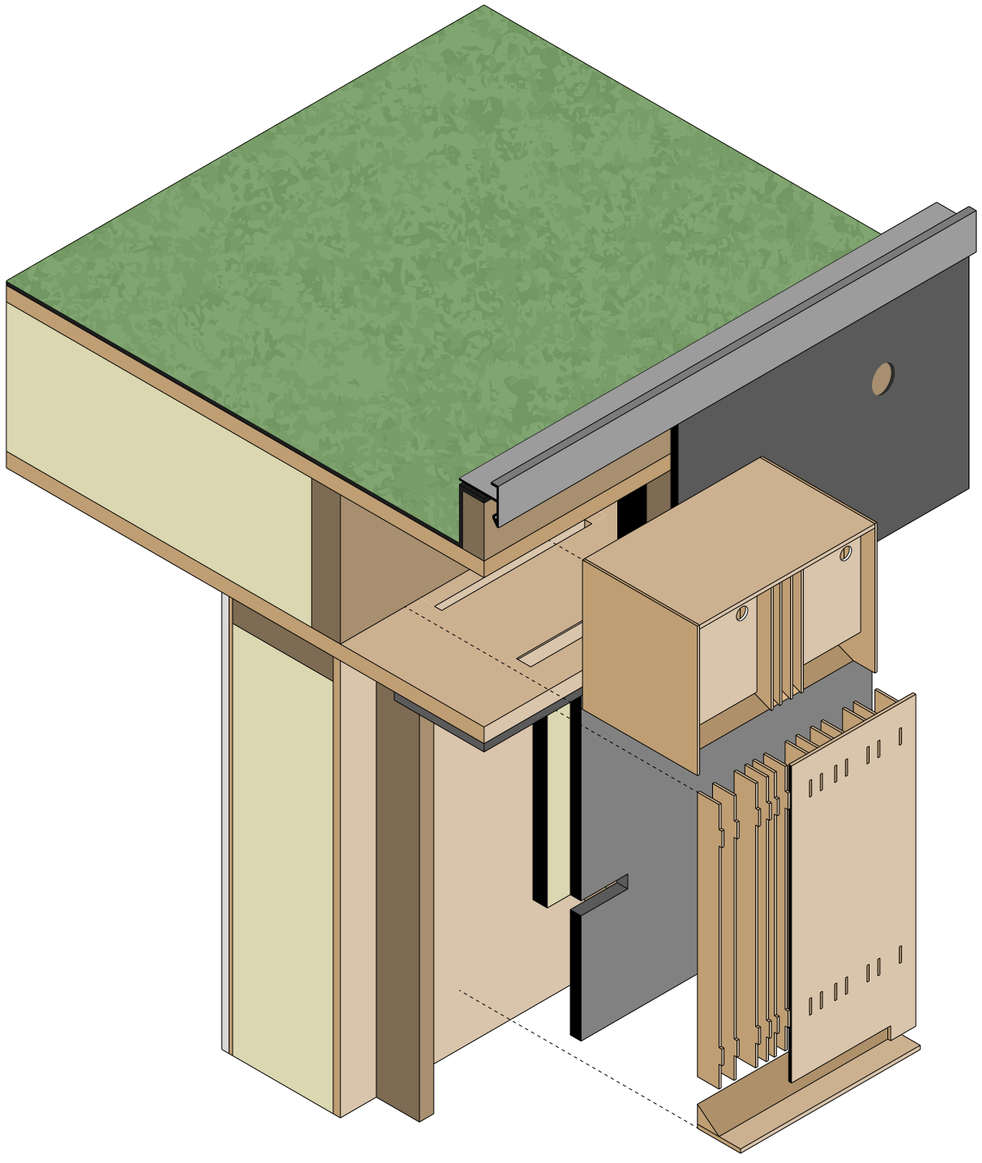


image 3.54: schematic view of implementation

DESIGN
dormer

Due to the simplicity of the bat integration, the development of the construction details was relatively straightforward. A laser-cut file was created to produce the individual components, allowing users to assemble and install the system themselves at a suitable location. The unit consists of two side panels and a top element. Inside the enclosure, both horizontal and vertical wooden elements are integrated, creating a diverse internal structure with a range of microclimatic conditions.

The wall construction of the dormer includes a panel supported by two battens. This creates a connection between the internal box and the outer panel, forming a continuous circulation space for bats. To validate the design, a 1:1 detail of a section of the dormer was constructed. The making of the physical model revealed several areas for improvement. Instead of cutting into the existing structure, two additional battens can be placed within the dormer, simplifying installation. Additionally, the laser-cut files require minor adjustments to improve the fit during assembly. The concept of the dormer detail is to enable easy integration within standard dormer construction processes. Both the panel and the internal box are designed as modular elements, making them straightforward to install.

This modular approach also allows the system to be distributed as a kit. Dormer manufacturers could integrate these elements into their production process with minimal adjustments. The only required modification is the addition of two openings in the lower panel: one for providing access for bats into the internal box, and another connecting the box to the panel system.



image 3.55: 1:1 detail of implementation

After a discussion with an ecologist from Natuurpunt, several adjustments were identified to improve the performance of the dormer design for bats. The prototype was used as a conceptual model to evaluate these improvements. The following modifications are recommended to create a more suitable and comfortable habitat:

The vertical lamellae within the wall should include openings that allow bats to move between different compartments. In contrast, the lamellae within the roof edge should contain fewer openings, one per lamella is sufficient, to retain heat and create more stable microclimates.

The entrance for bats is positioned beneath the roof edge. To improve accessibility, the opening should be located closer to the wall, allowing bats to land and enter more easily. This is illustrated in image 3.56.

The bird habitats are located on the façade side where the windows are positioned. However, birds may not recognize glass surfaces and can collide with them. To prevent this, a visual for birds film should be applied to the windows to increase visibility and reduce the risk of impact.

Considering the available space, suitable dimensions for bird nesting must be taken into account. For house sparrows, a cavity of approximately 15 × 15 cm with a height of 20 cm is required, which fits well within the available space (approximately 20 cm high and 16 cm wide). For swifts, a cavity of around 15 × 15 cm is preferred. In practice, nesting boxes designed for swifts are also frequently used by house sparrows. Therefore, a single standardized nesting box type can be designed and applied for both species.

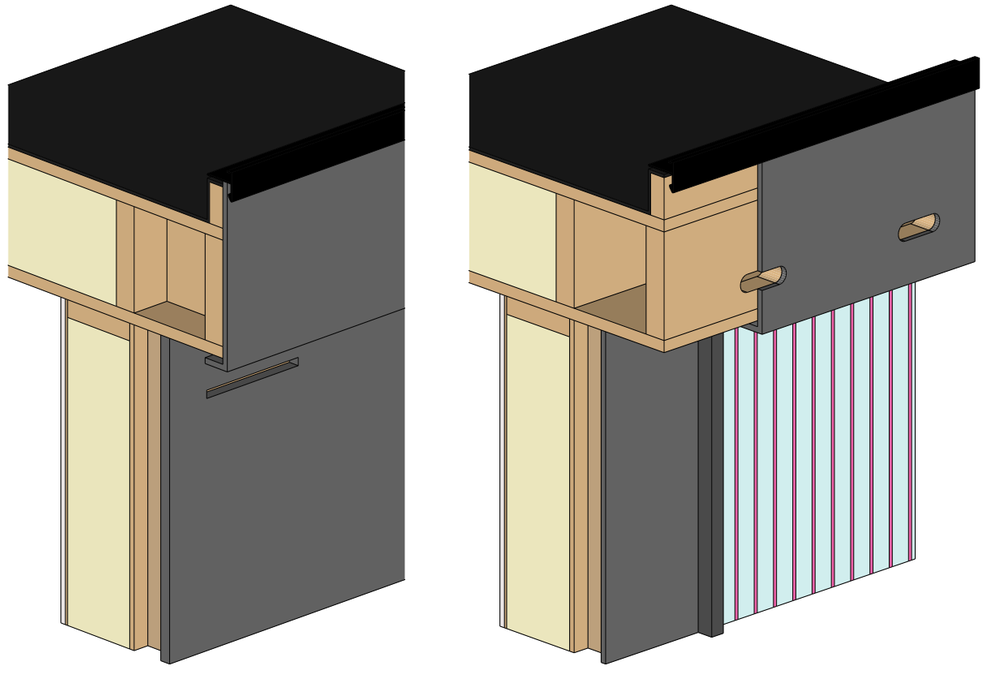


image 3.56: alterations

DESIGN
dormer

Dormers are typically constructed in a factory or workshop environment. This allows them to be produced under controlled conditions and installed quickly and efficiently on site. The integration of the proposed interventions does not significantly impact the standard production process, as the required modifications are relatively minor.

Since the unused cavities within the dormer are utilized, the ecological elements can be easily incorporated into both new and existing structures, without requiring major structural changes.



image 3.57: render of implemented materials

DESIGN
dormer

To ensure that the panel and box system can be applied across different constructions, a parametric model was developed. This allows parameters to be adjusted, making the design adaptable to a wide range of configurations. Image 3.52 illustrates the structure of the script. By iterating variable values, different geometries can be generated based on the selected parameters. Image 3.53 shows the Grasshopper model used for this process. With this model, the system can be adapted to fit within a dormer construction. By adjusting the internal dimensions through the script, the elements can be precisely scaled to fit and be inserted seamlessly into the available space.

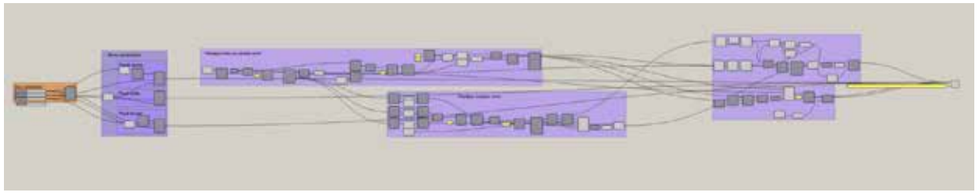


image 3.58: grasshopper script



image 3.59: shape parametric changes

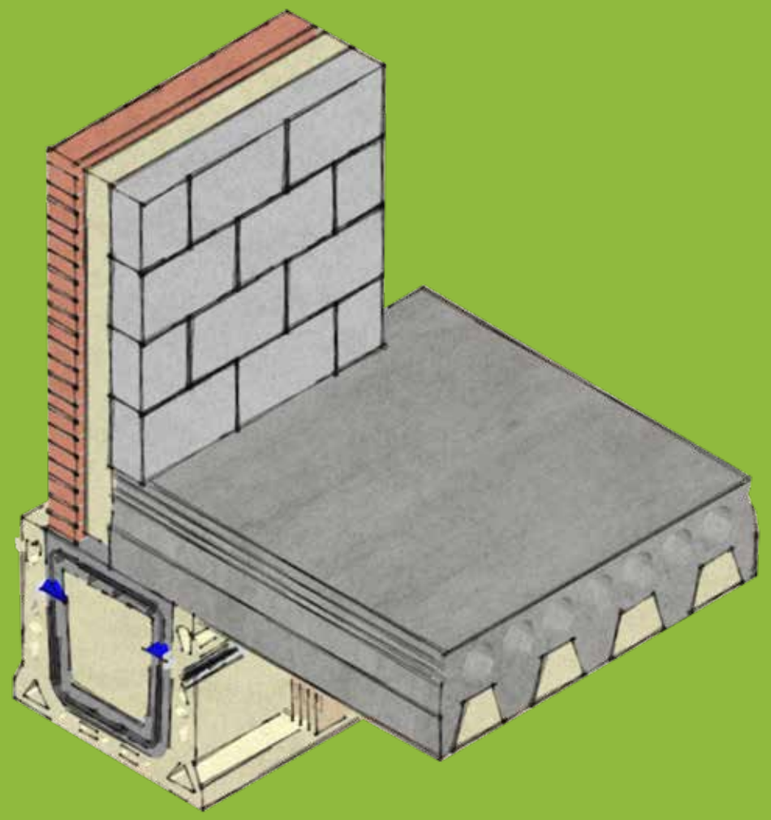
conclusion

The analysis of an existing dormer, focusing on the available unused cavities within the construction, revealed significant potential for creating habitats for bats and birds. These spaces, particularly around the roof structure and within the side panels, can be accessed through simple openings. Since the interventions are designed to integrate seamlessly into the construction process, the solution is developed as a prefabricated element that can be easily incorporated into existing production workflows.

To arrive at the final design, multiple variants were explored, based on factors such as insulation thickness, access points, and the integration of ecological features. For bats, the focus is primarily on the side panels of the dormer, as they tend to avoid light emitted through windows. By connecting these side areas with the roof edge, a continuous and varied microclimatic system is created, allowing bats to move between different conditions. The front side of the dormer provides suitable nesting opportunities for birds, such as house sparrows and swifts.

To ensure technical feasibility, a calculation of the thermal resistance (Rc value) of the wall construction was carried out. For the side panels, the intervention requires only a simple batten fixed to the structural beams, onto which the lamella panel is attached. Both the lamella panel and the bat box in the roof edge are made from rough, natural wood and are precisely fabricated using CNC techniques, ensuring accurate joints and ease of assembly.

In summary, by strategically utilizing the unused spaces within existing dormer constructions and integrating nature-inclusive elements, the dormer becomes not only functional for residents, by providing additional interior space, but also valuable as a habitat for bats and birds. The modular approach allows occupants to determine the extent to which nature-inclusive features are incorporated. With relatively small adjustments, multiple species can benefit, contributing to a more biodiverse and resilient urban environment.



CRAWL SPACE

space optimization for bats and birds

To create a suitable habitat for bats within a crawl space, several key considerations must be addressed. First, access by other animals should be prevented, for example by positioning the entrance at a higher level. A funnel-shaped element can also be introduced to guide bats downward, allowing one-directional access into the space. Within the existing insulation block, a small wooden box is integrated. This box functions as a connecting module to the crawl space and provides a mounting surface for lamellae, creating additional roosting opportunities. As an alternative, a Z-shaped pipe can be routed through the floor insulation and along the foundation beam. This creates a safe and controlled access route for bats to enter the crawl space.

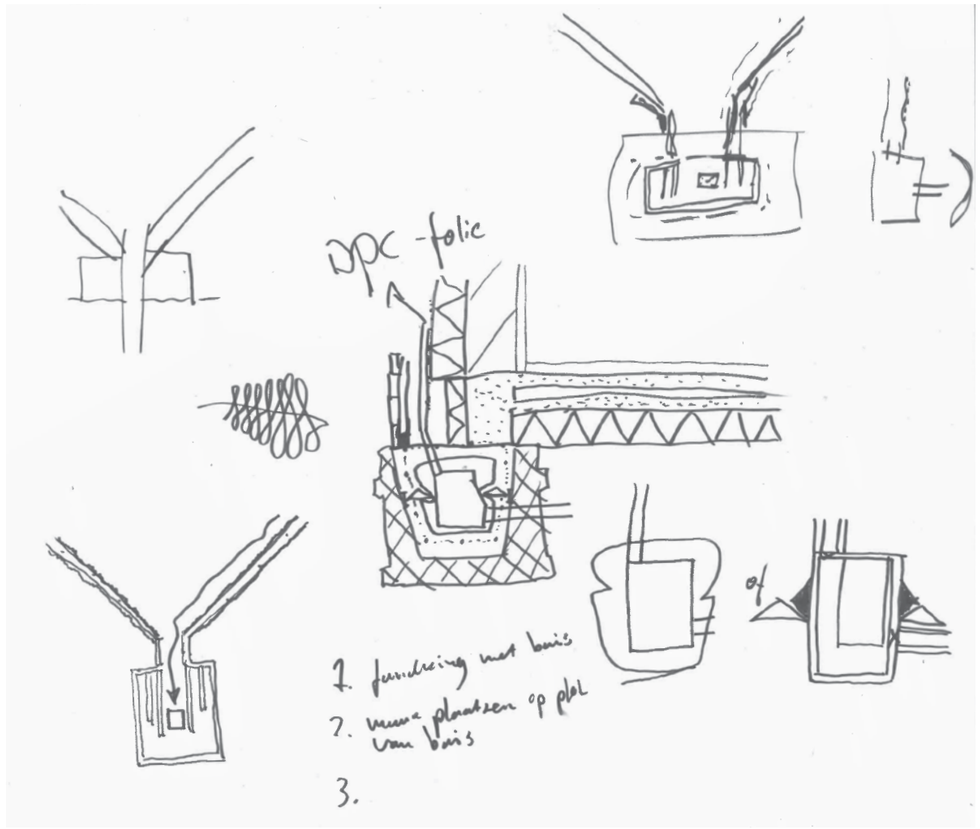


image 3.60: sketch of possibilities

DESIGN
crawl space

The crawl space offers significant potential for ecological interventions, as it typically provides around 60 cm of usable height. This makes it particularly suitable as a winter roost for bats. One effective measure is the application of BatSafe foil over the insulation layer. This material helps bats to grip on to the surface while remaining vapor-permeable, ensuring that the existing building performance is maintained.

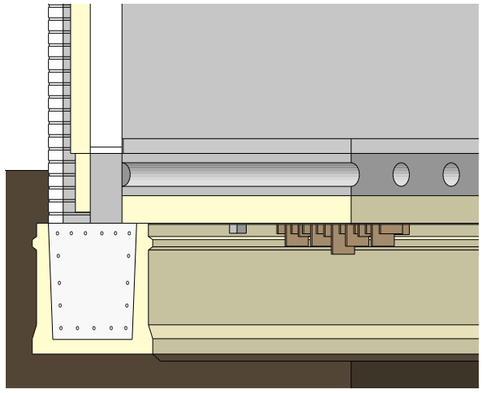


image 3.61: variant 1

A supporting structure can be fixed to the insulation, onto which wooden lamellae can be attached. These lamellae create a range of small cavities with varying thermal conditions, resulting in a beneficial temperature gradient within the crawl space. In addition, horizontal elements such as beams can be introduced, providing hanging opportunities for bats. The floor can be supplemented with stacked reclaimed bricks, creating small crevices that bats may use as shelter. However, it should be noted that bats generally prefer elevated roosting positions rather than lower openings. In situations where the crawl space is partially embedded in a sloped terrain, an opening can be introduced at the exposed side, offering a natural point of entry.

Image 3.62 shows a separate enclosure within the crawl space. The interior of this box is equipped with lamellae and partitions, creating a controlled microclimate for bats. Unlike the first variant, where bats can move freely throughout the crawl space, this solution provides a more enclosed and stable environment. As a result, less additional insulation is required to maintain suitable thermal conditions. The enclosure also allows for the creation of a vertical temperature gradient, giving bats the opportunity to select optimal roosting locations. However, this approach is more complex to integrate during construction.

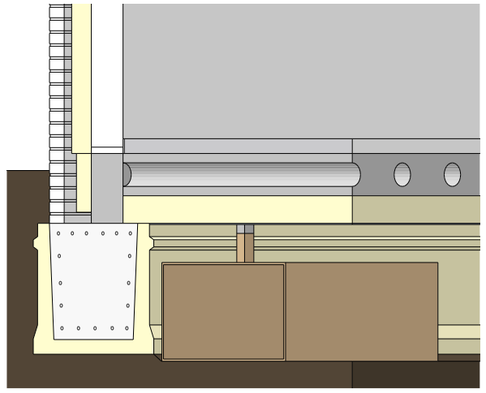


image 3.62: variant 2

Third variant introduces a different approach. Before casting the concrete, a prefabricated insert is placed within the formwork. This insert acts as a bat habitat, similar in structure to the box used in Variant 2. Because the system is surrounded by both soil and concrete, internal climate remains highly stable, with gradual temperature fluctuations. This contrasts with cavity walls, where temperature changes can occur more rapidly. Additionally, the concept aligns with existing concrete-saving systems (such as those used by B-Invented), suggesting that such void-forming methods could also be used to create ecological spaces.

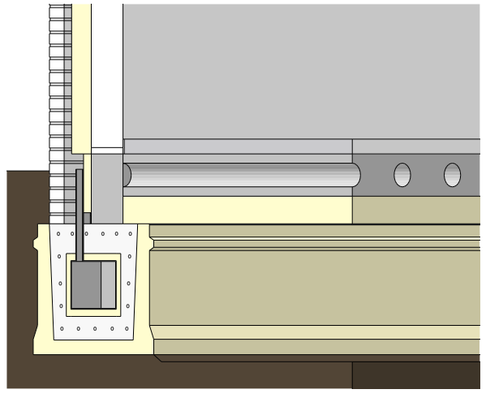


image 3.63: variant 3

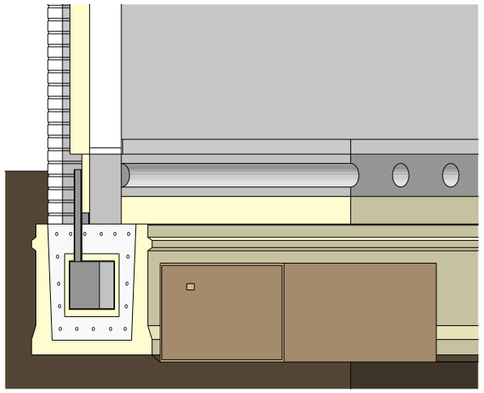


image 3.64: variant 4

The final variant combines elements of both Variant 2 and Variant 3. By connecting a box in the crawl space with one embedded in the foundation, a larger and more diverse habitat is created, offering variation in temperature, height, and spatial conditions. This results in a highly suitable environment for bats. However, integration into the construction process becomes more complex, as openings in the foundation are required to connect the different spaces.

Maintenance may also be more difficult, since the bats occupy enclosed compartments. Nevertheless, as these spaces are primarily intended for hibernation, the feces are expected to be minimal. The crawl space enclosure can also be connected to multiple foundation units, or alternatively, only foundation-integrated habitats may be used. Both approaches provide bats with stable temperatures and sufficient space.

For the experimental variant, an adaptation was made to the insulation block by integrating a dedicated enclosure for bats. This enclosure is connected to a rectangular PVC pipe that extends above the concrete structure.

Inside the PVC pipe, a lining of wood is applied, providing a rough surface that allows bats to grip easily while moving through the passage. Within the enclosure itself, lamellae are incorporated, creating narrow cavities where bats can crawl into and roost. The enclosure also connects to the space beneath the floor, the crawl space, where a stable temperature is maintained. This allows bats to access a range of conditions and select a suitable location for shelter.

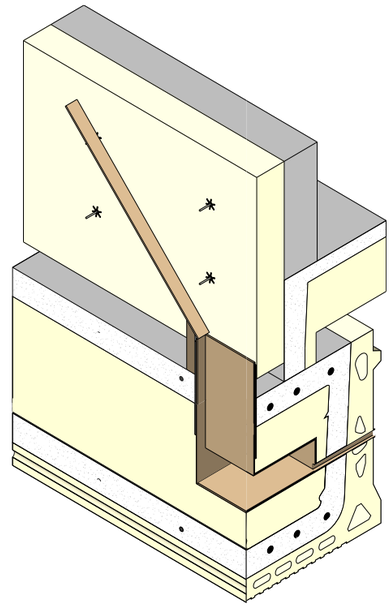


image 3.65: experimental variant

DESIGN
crawl space

The foundation provides a suitable location beneath the building for integrating habitats for fauna. Historically, basements have been used for cold storage due to the relatively stable temperatures in the ground. This principle can be advantageously applied to support bats during hibernation.

To verify whether the ground maintains a stable temperature of approximately 10°C, a simulation was conducted. This simulation shows the predicted temperature distribution within spaces such as the crawl area. The adjacent image illustrates the resulting thermal gradients. One of the scenarios explored involves integrating a habitat within a foundation beam. In this case, a connection is made to the cavity wall, creating a small space that remains linked to the outside. The image demonstrates that the soil beneath the building maintains a relatively constant temperature of around 10°C. This creates a favorable and stable environment for bats, and potentially for insects, although access for these species may be more limited.

In addition to foundation-based solutions, the space beneath the floor also offers opportunities. Here too, relatively stable temperatures are present. By applying thicker insulation, incorporating internal partitions, and using protective materials such as Batsafe foil, this area can be adapted into a suitable habitat for bats.

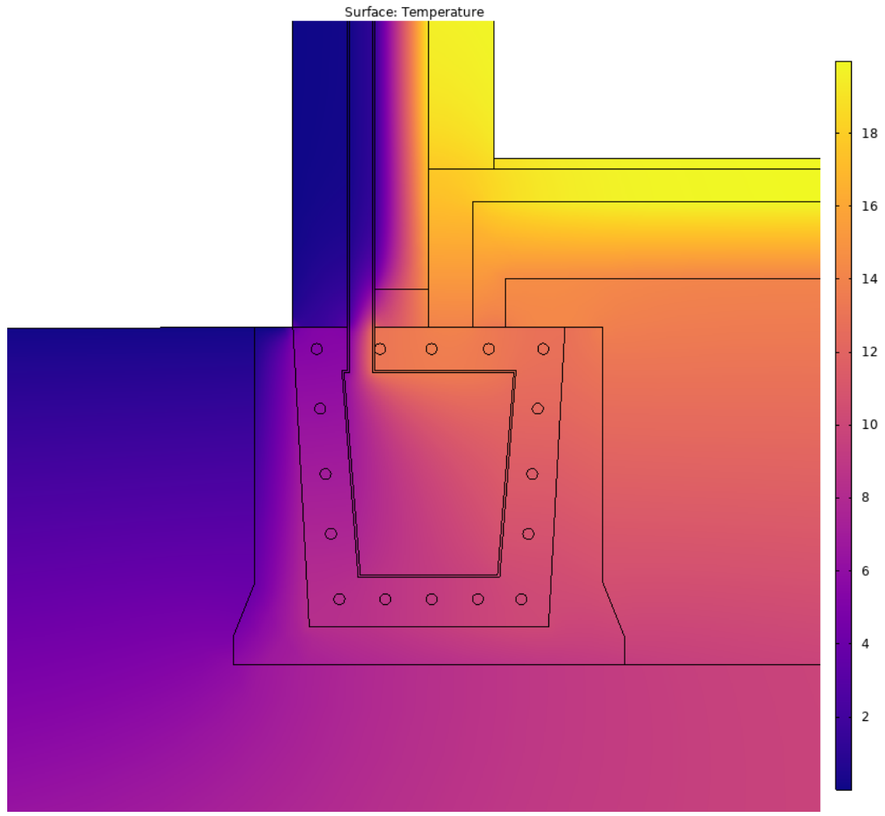


image 3.66: heat simulation of crawl space

Following feedback from ecologists, it became clear that it is preferable to allow bats to move freely, rather than confining them within enclosed boxes. Based on this insight, a final variant was developed. A ventilation pipe connecting the brick façade to the crawl space provides a safe and accessible route for bats. The interior of this pipe is lined with rough material, enabling bats to easily grip and move in and out of the structure.

Within the insulation block of the foundation beam, a system similar to EPS-based solutions is applied. This allows for the integration of a modular element consisting of vertical lamellae. Openings within these lamellae create connections between different spaces, allowing bats to move freely and select suitable microclimates. Because the lamellae are positioned adjacent to the foam formwork of the foundation, they also contribute to the overall thermal insulation, enhancing the comfort of the habitat. In addition, a custom adaptation of the so-called “Swaenen box” was developed: a square module mounted in the Swaenenbox, with a mesh lining that provides surfaces for bats to hang from. A second module integrates a modified lamella structure, offering additional roosting possibilities.

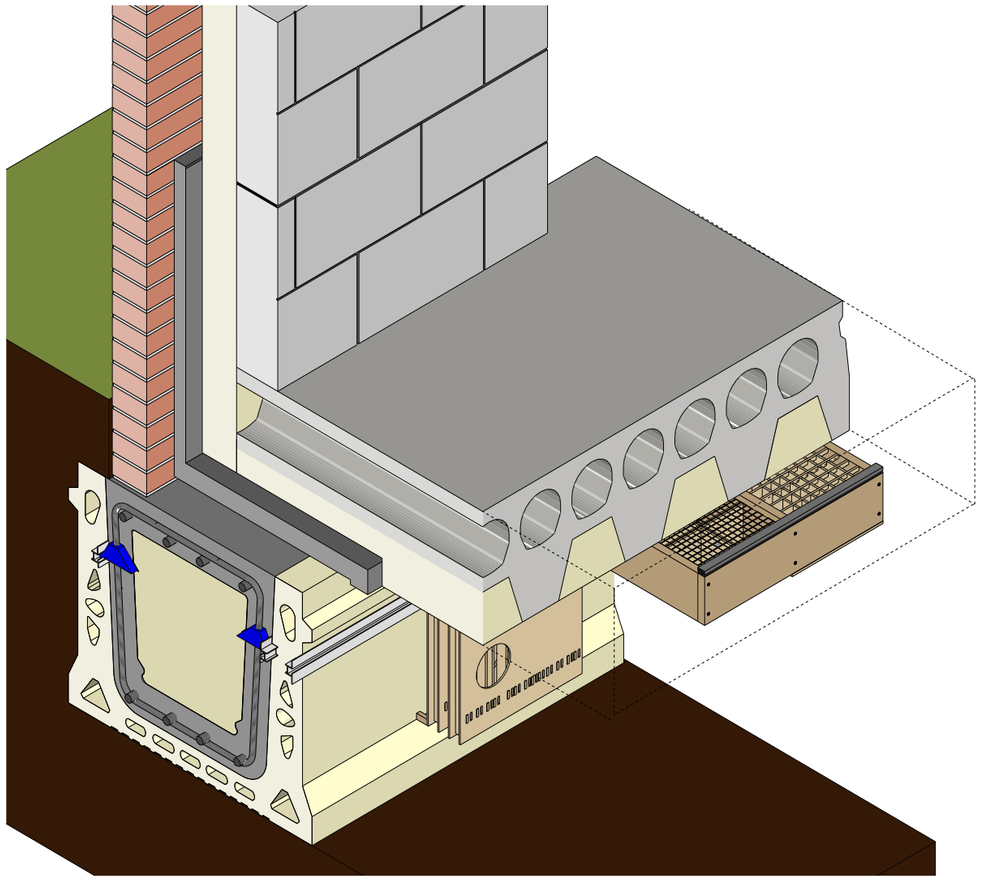


image 3.67: axonometric view of implementation

DESIGN
crawl space

Since the design primarily involves add-on components, the focus was on the fabrication of these elements. Most parts are prefabricated and produced using laser cutting, making assembly straightforward and efficient. Some components, such as the outer shell of the Swaenen box and the internal cross element, were not laser-cut in this version but could be incorporated in future iterations. The lamella element is installed using a similar method to the one applied in the chimney or voorzet.

The Swaenen box was further developed to include an additional lamella system, designed with an interlocking principle similar to a wine rack. This allows for simple assembly, requiring only the outer enclosure and the attachment of mesh as final steps. To demonstrate the application, a mock-up of the wall and floor was constructed using lightweight timber. This allowed for easy transport and assembly, while the focus remained on demonstrating the concept rather than the structural system itself.

Overall, the ventilation pipe system between the façade and insulation layer offers a safe and effective access route to the crawl space. Within this space, simple prefabricated elements can be installed using wood and laser cutting techniques, making the production process both efficient and accessible. During construction, no major issues were encountered. The process confirmed that these interventions are relatively easy to manufacture while effectively functioning as both access routes and habitats for bats.

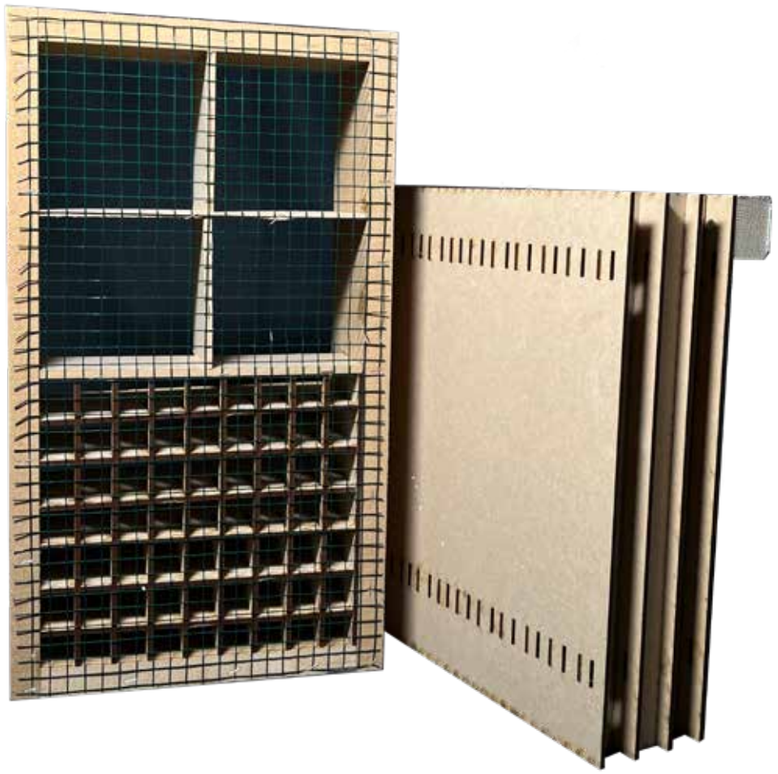


image 3.68: mock-up detail of adaptation



image 3.69: mock-up detail of implementation

DESIGN
crawl space

A range of materials was used in the realization of the design. The element with the vertical lamellae is made from rough Douglas fir wood. Thin wooden planks are used to create a suitable surface and structure, allowing bats to grip and occupy the space effectively. The Swaenen box is also largely constructed from rough Douglas fir. It is designed as a modular kit, enabling easy assembly and efficient construction on site.

In addition, an adaptation of the B-Smart foundation formwork system is proposed. This system incorporates a similar implementation as the interior of the box, allowing vertical lamellae to be attached directly to the structure. Finally, BatSafe foil is applied over the insulation layer. This material makes sure that bats have grip to conventional membranes and remains vapor-permeable.



image 3.70: render of implied materials

conclusion

After an extended period of development, the crawl space intervention was successfully completed. Reflecting on the process, it becomes clear that the design phase was not without challenges, primarily due to the complexity and limited accessibility of the location. The presence of insulating and waterproofing layers required careful intervention when creating an opening.

Access to the crawl space was established through a ventilation pipe, the interior of which is lined with a rough material such as tile adhesive or wood. This provides bats with sufficient grip to move in and out of the structure. Although the entrance is positioned at an unconventional height, this is a deliberate decision. Since the crawl space primarily functions as a hibernation site, bats are not expected to actively exit during this period.

Once access was resolved, a system was developed to enable bats to effectively use the space. To ensure compatibility with the construction process, two sliding systems were introduced. On one side, the existing principle from the foundation formwork was mirrored. On the other, an additional element was placed beneath the concrete floor, designed to be inserted using a rail system. The adaptation of the Swaenen box was positively received by ecologists, particularly due to the addition of an extra lamella element.

This increases the variety of spaces available, allowing bats to rest and shelter more effectively. Although the realization of this type of intervention is technically demanding, it has proven to be feasible. The potential to create a stable and suitable hibernation environment for bats provides a strong motivation to further develop and refine this solution for future applications.

4.CLOSURE



EXTRA
zigzag solar panels implementation

One of the reasons the zigzag solar panel concept was not initially included in the main document is that it is not strictly a building detail, but rather an add-on component that optimizes the building. However, further analysis revealed that it provides a highly suitable opportunity for integrating habitats for fauna. The exploded view illustrates the cavity created beneath the solar panels. Research indicates that this space benefits from a more stable temperature gradient, as the panels provide shading and reduce direct solar exposure. Next to that, they also release heat that can be beneficial for bats.

The design explorations demonstrate how a lamella structure can be introduced within this cavity. By incorporating a small slit opening at the bottom, an accessible entry point can be created for bats. The modules can be designed with different façade finishes. This allows the system to be integrated into the architectural streetscape without disrupting the visual quality of the building.

The section shown illustrates how the zigzag solar panel system can be adapted into a nature-inclusive design. By combining both horizontal and vertical lamellae within the void space, a favorable environment is created for bats. When multiple modules are placed side by side, they can also be interconnected. Openings at the sides of the modules allow bats to move between them, enabling access to a wider range of conditions and allowing them to select preferred microclimates

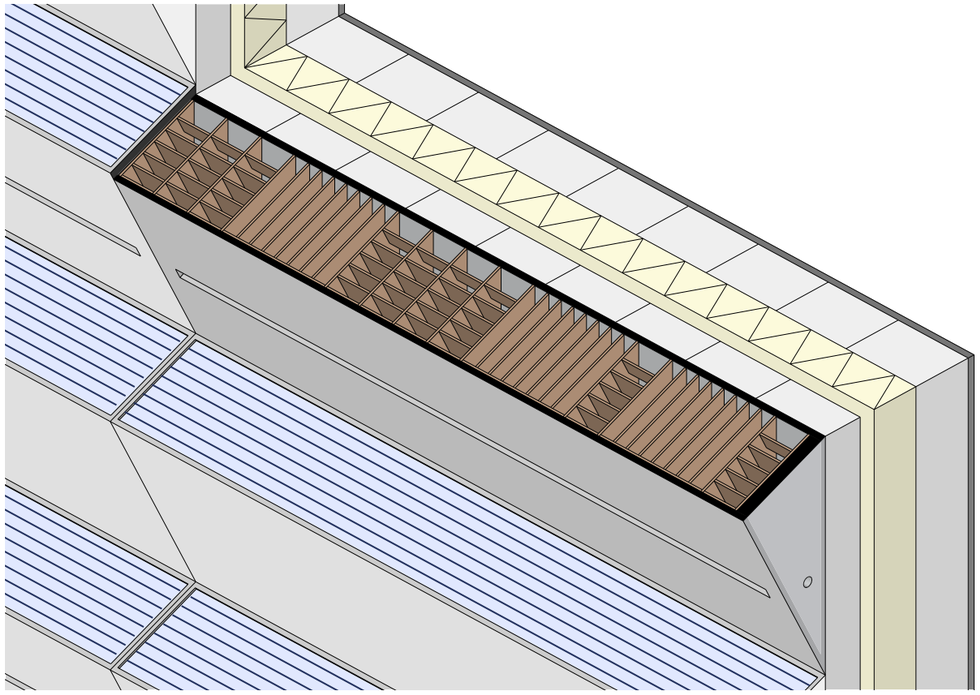


image 4.1: implementation of lamellae under solar panels

overhang implementation

Recent observations and practical insights have led to the idea of integrating bat roosting spaces within canopy structures. A key inspiration is the overhang if carefully designed and properly detailed, has the potential to serve as a suitable habitat for bats. By intentionally utilizing existing architectural elements such as overhangs, nature-inclusive features can be integrated without requiring major modifications to the primary structure.

Figure 4.2 presents a detail of such an implementation. Within this construction, a cavity is created that can function as a bat roost. Based on several quick design explorations, an initial concept was developed that can be integrated within the overhang.

The addition of insulation within the cavity helps to optimize the microclimate, making it more suitable for bats. A slight internal slope is also introduced to guide droppings outward, preventing accumulation within the space. A green roof is applied on top of the structure, contributing to improved thermal regulation of the habitat below. It also creates an extra space for birds to find insects. Internally, a lamella structure is incorporated, creating a sheltered environment with a stable and varied microclimate for the animals.

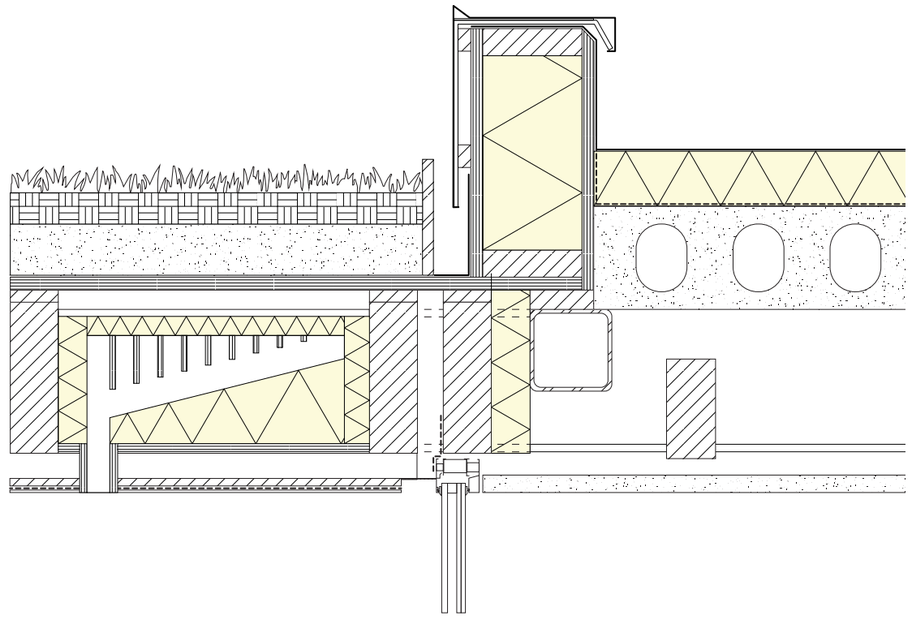


image 4.2: implementation of lamellae in overhang

EXTRA
thermical tricks

A concept that was not further developed within this research, but shows clear potential, is the application of calcium silicate blocks in bat habitats. This material is highly porous and capillary-active, enabling it to absorb moisture and release it over time. Due to this moisture-buffering capacity, calcium silicate can contribute to a more stable internal microclimate. In combination with its thermal mass, the absorbed moisture can store heat and gradually release it, thereby reducing temperature fluctuations *(Zondag, 2010)*.

During colder periods, this can result in a more constant and slightly warmer environment within the habitat, which is beneficial for bats. Although this approach was not explored further in this research, it demonstrates how material choice can play a significant role in improving the performance of building-integrated habitats. In addition, the use of a so-called solar brick could be considered. This concept consists of a glass outer layer, an air cavity, and a metal plate on the inside. The glass alters the wavelength of incoming solar radiation, converting it into heat. This heat is then absorbed by the metal plate and transferred inward. However, this remains a highly experimental application and would require further testing and validation before it can be reliably implemented.

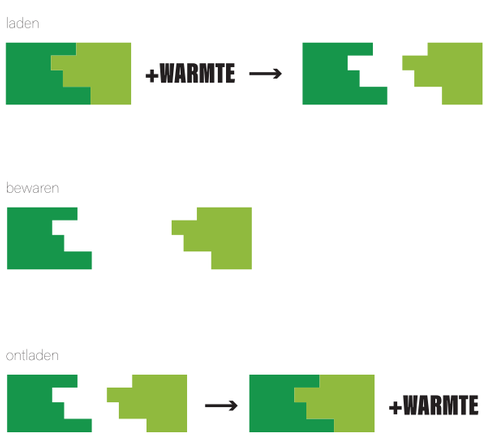


image 4.3: heat deloading

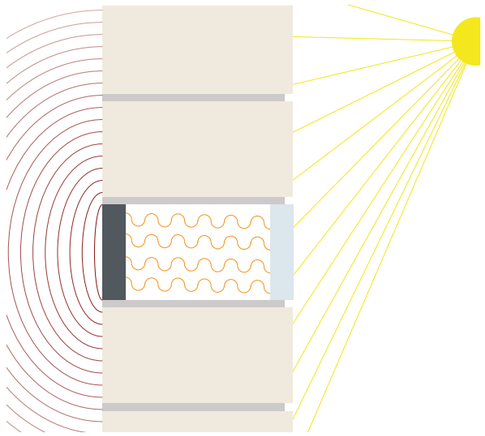


image 4.4: solar radiation

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CONCLUSION

The Interreg project Natuur-Inbouw aimed to facilitate knowledge exchange between the Netherlands and Flanders, with the goal of improving biodiversity in urban environments. This ambition was structured through several work packages. Within the innovation work package, the focus was placed on identifying unused spaces in buildings that could potentially serve as habitats for building-dependent species. Before conducting this spatial analysis, a solid knowledge base was developed on the target species. This included an investigation into their behavior, life cycles, spatial requirements, and threats. Based on this understanding, a generic housing typology was analyzed to identify potential locations for integration within buildings.

The analysis was structured into four categories: external elements, walls, floors, and roofs. Within each category, building components were assessed for their potential to accommodate different species. Initially, potential habitat locations were mapped and described. These were then evaluated through a SWOT analysis, considering factors such as safety, constructability, maintenance, and thermal performance. This systematic approach resulted in the selection of eight promising details from an initial set of fourteen. Each proposal was evaluated from both a constructional and ecological perspective, ensuring that solutions were not only technically feasible but also suitable for the target species.

To further assess the viability of these selected details, particular attention was given to the internal microclimatic conditions. For bats, a stable microclimate is essential: sufficiently warm in winter, not excessively hot in spring, and protected from strong cooling during summer nights. To evaluate this, thermal simulations were conducted using COMSOL. These simulations provided insights into temperature distributions, material behavior, and the performance of lamella structures in retaining heat. While these results offered valuable guidance, they should be interpreted as indicative rather than definitive representations of real-world conditions. Based on these findings, two details were excluded due to unfavorable climatic performance or limited applicability.

The remaining six details were further developed through an iterative design process, starting with conceptual sketches and gradually evolving into more refined proposals. These designs were continuously evaluated in collaboration with both construction professionals and ecologists. Through feedback sessions and presentations, the selection was narrowed down to four primary solutions: the false chimney, the dormer, the crawl space, and the voorzet. The key criteria in this selection process were safety, feasibility, and ecological value.

To structure the design process, three guiding principles were adopted: social design, participation, and constructability. Social design functioned as an overarching framework, promoting the integration of both human and ecological needs. Participation focused on engaging users, for instance through accessible and educational building kits. Constructability ensured that all solutions remained feasible within existing construction processes, with an emphasis on simplicity, cost-efficiency, and applicability in both new construction and renovation.

Within this framework, a consistent design methodology was applied. The process began with exploratory sketches, followed by digital modeling using tools such as SketchUp to communicate the concepts more effectively. Selected designs were then realized at a 1:1 scale, allowing for a better understanding of construction details, connections, and practical feasibility. These prototypes informed further refinements in the digital models. In addition, cost analyses and visualizations were conducted to support practical implementation.

For the false chimney and dormer, a parametric design approach was developed using Grasshopper. This allowed the designs to be adapted to varying dimensions in real-world applications while maintaining their internal structure. For the crawl space and voorzet, a parametric approach proved less relevant due to the nature of their integration.

In conclusion, this research demonstrates that buildings offer considerable potential for integrating habitats for building-dependent species. As these species are already present in urban environments, improving their living conditions is both achievable and meaningful. The study shows that such interventions can be both technically feasible and ecologically valuable, strengthening the connection between architecture and ecology.

At the same time, it must be emphasized that this research has an experimental character. Further validation is required, particularly through long-term monitoring of actual use by animals and the evaluation of performance over time. The results should therefore be seen not as a final outcome, but as a starting point for further development. Future steps include the scaling of these designs into prefabricated solutions and their integration into broader construction processes and regulatory frameworks. Through continued experimentation and iteration, architecture can play a meaningful role in enhancing biodiversity within the built environment.

DISCUSSION

Reflecting on the approach taken within this project, it can be concluded that the process was generally carried out in a careful and systematic manner. Through a phased distillation, from inventory to analysis, simulation, sketching, and ultimately prototyping, an iterative workflow was followed that proved robust enough to support well-informed design decisions. This approach allowed both architectural and ecological considerations to be addressed simultaneously.

Nevertheless, the project relied primarily on qualitative input, such as expert knowledge and design evaluations, while quantitative validation remained limited. In particular, real-life monitoring of the proposed building details is still lacking. This represents an important next step, as only long-term observation can determine to what extent the interventions perform effectively within an ecological system and are actually used by animal species. In addition, some criticism was raised regarding the voorzet, suggesting that it may need to be enlarged, possibly even beyond the scale explored in the first prototype. The research also highlights the inherent complexity of nature-inclusive design, where different requirements can directly conflict. On the one hand, it is desirable to create accessible and diverse habitats with variation in space and orientation. On the other, such interventions can clash with building performance requirements, such as insulation and airtightness. Ventilation presents a similar tension: while buildings require adequate airflow to prevent moisture and mold, excessive ventilation can negatively affect the suitability of habitats for bats.

A comparable contradiction emerged in relation to green façades. Although these are often considered key components of nature-inclusive design, they are not always compatible with integrated habitats for bats and birds. Vegetation can provide access routes for predators, which may compromise the safety of the animals. This underlines the importance of carefully aligning different nature-inclusive strategies rather than applying them independently. Among the proposed solutions, the crawl space stands out as both promising and experimental.

From both an ecological and constructional perspective, further development and validation are required. Initial analyses suggest that the crawl space can offer a stable microclimate, particularly suitable for hibernation. However, additional research is needed to confirm actual occupancy and to evaluate long-term climatic performance. The thermal simulations should also be viewed critically in this context. While the COMSOL analyses provided valuable insights, they are based on simplified assumptions and models. Without validation through real-world measurements, their results remain indicative.

Furthermore, the simulations focused mainly on solid-to-solid heat transfer. Future work could improve accuracy by including solar radiation and time-dependent analyses, such as day–night cycles. A deeper understanding of these simulation methods will therefore be essential for further development. Despite these uncertainties and challenges, this research does not suggest that nature-inclusive design is too complex to implement. On the contrary, it demonstrates that relatively small, targeted, and creative interventions can already lead to meaningful improvements in habitat quality. The key lies in shifting perspective: rather than viewing the building as an isolated object, it should be understood as part of a broader system involving humans, animals, and the environment.

This approach calls for an integrated design methodology at both building and urban scales, where ecological considerations are included from the earliest stages. Such a shift requires not only technical expertise but also a willingness within the construction sector to experiment and innovate. At the same time, it aligns closely with the broader transition towards more sustainable and inclusive urban development, in which architecture plays a bridging role.

Ultimately, this research shows that nature-inclusive design is evolving from a niche approach into an integral component of the built environment. The primary challenge does not lie in technical feasibility, but in connecting construction practices, ecological knowledge, sufficient surrounding, and societal acceptance. This is a gradual process, driven by experimentation, iteration, and collaboration. In that sense, this thesis does not mark an endpoint, but rather a step within a broader transition, one in which the built environment is reconnected with the natural systems of which it has always been a part.

CONCLUSION

Design principles for bat habitats

Surrounding

Implement the usage of the ‘vijf V’s:

- variatie - *variation*
- veiligheid - *safety*
- voedsel - *food*
- voortplanting - *reproduction*
- verbinding - *connection*

Accessibility

- Position entry openings at a minimum height of 3–4 meters to reduce predation.
- Size openings appropriately (approx. 3–20 cm wide, max. 2 cm high) to allow bats while excluding other species.
- Ensure a clear and unobstructed flight path.

Variation

- Create internal diversity using lamellae or similar structures.
- Provide a range of microclimates (temperature and height differences) so bats can choose suitable conditions.
- Avoid overly compartmentalized spaces and allow sufficient movement.

Material use

- Use rough, natural, untreated materials that provide good grip.
- Avoid harmful or chemically treated materials.
- Introduce surface textures (e.g. ribs or grooves) to improve climbing.

Building integration

- Ensure the design does not compromise insulation, ventilation, or airtightness.
- Minimize drafts and aim for a stable internal climate.

Safety

- Avoid artificial lighting near entrances, as it deters most bat species.
- Limit predator access through careful positioning and detailing of openings.

AI statement

AI tools were used in the preparation of this document. Their role was limited to supporting the improvement of grammar and spelling, as well as translating from Dutch to English. No original content, illustrations, or knowledge was generated by AI. The AI model used was the TU/e-integrated Copilot system.

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BIBLIOGRAPHY

images

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