HVAC solutions in standardised bathroom modules

Robert Wikström

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Author:	Robert Wikström
Title:	
Supervisor (Arcada):	M.Sc. Kim Rancken
Expert Supervisor (Bonava):	B.Sc. Tuula Honkala
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Abstract:

The construction industry has started to use more and more modules in its projects. Modules have the advantage that large parts of the project can be built in another place where production takes place in factories indoors, in the protection of weather and wind. In this way, the quality is kept at an evenly high level, the modules can be built in advance and easily installed on the building.

Modular bathroom construction has become more and more popular in recent years. However, standardised modules are still relatively unused. Through standardised modules, the same design is used for several different projects. This way, the companies will use the same materials, components and technic for all production. Production becomes simpler, more efficient and faster through this.

In this thesis, Bonava Suomi's standardized bathroom modules are presented and analysed. The HVAC-solutions are presented and the planning process is analysed, as well as how the standardized bathroom modules affect the floor plan solutions and the construction technology. The standard bathroom modules are also compared to traditional bathrooms.

The material for this thesis comes from the company's bathroom module material, interviews with those who have participated in the planning process, as well as from the Finnish building regulations and other standards.

This thesis will serve as a planning tool for the Bonava Group's foreign construction companies, since the standardized bathroom module work has come the furthest in Finland.

The economical side of the bathroom module process has been left out at the client's request.

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EXAMENSARBETE	
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Författare:	Robert Wikström
Arbetets namn:	
Handledare (Arcada):	DI Kim Rancken
Expert Handledare (Bonava):	Ing. Tuula Honkala
Uppdragsgivare:	Bonava Suomi Oy

Sammandrag:

Byggbranschen har börjat använda mer och mer moduler i sina projekt. Moduler har den fördelen att stora delar av projektet kan byggas på annan ort där produktionen sker i fabriker inomhus, i skydd för väder och vind. På detta vis hålls kvaliteten på en jämnt hög nivå, modulerna kan byggas i förväg och enkelt installeras på bygget.
Modulärt badrums byggande har blivit de senaste åren mer och mer populärt, dock så är standardisera moduler ännu relativt outnyttjade. Genom standardiserade moduler, så används samma design för flera olika projekt. På detta vis kommer företagen åt att använda samma material, komponenter och teknik för all produktion. Produktionen blir simplare, effektivare och snabbare genom detta.
I detta arbete presenteras och analyseras Bonava Suomis standardiserade badrums moduler. VVS-lösningarna presenteras och planeringsprocessen analyseras, samt hur de standardiserade badrums modulerna påverkar bottenplanlösningar och byggtekniken.
De standardiserade badrums modulerna jämförs även med traditionella badrum.
Materialet för arbetet kommer från företagets badrums moduls material, intervjuer med de som har medverkat i planeringsprocessen, samt från de finska byggbestämmelserna och andra standarder.
Examensarbetet skall fungera som ett planeringsverktyg för Bonava koncernens utländska byggföretag, då det standardiserade badrums modul arbetet har kommit längst i Finland. Den ekonomiska sidan av badrums modul processen har lämnats bort på uppdragsgivarens begäran.

Nyckelord:	VVS-planering, standardisering, badrums moduler, byggbestämmelser
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Definitions

AHU- Air handling unit (with heat recovery)

Fresh air- Ambient air brought into the building

Supply air- The air blown into an apartment after it has been through the AHU

Extract air- The air which is extracted from an apartment to the AHU

Exhaust air- Air that has been through an AHU and is being blown out of the building

Manifold- A prefabricated distributing device for water and heating made of brass

FOREWORD

While starting to work at Bonava Suomi Oy, as a working student in the summer of 2018, I was immediately introduced to the bathroom modules, that were being planned. That was nearly two years ago and I have been part of the process in one way or another ever since. I was happy for being asked if I would be interested in writing my thesis about the bathroom modules, as well as the process. The process of working with the bathroom modules and then writing my thesis about the modules, has given me a lot of knowledge and an understanding for the whole planning and production process.

I would like to thank everyone involved in the bathroom module process for their knowledge, their help and for being a part of this thesis.

A special thank you goes to Tuula Honkala, for being my mentor and thesis expert supervisor at Bonava Suomi. I want to thank my supervisor at Arcada UAS Kim Rancken for all his help and guidance.

Helsinki, 19 of May 2020

Robert Wikström

1 INTRODUCTION

The objective of this thesis is to produce and present an overall view of the Bonava Finland bathroom module process, its technical solutions and limitations and the bathroom module product. This thesis is meant to serve as a device for the Bonava Concerns other construction companies throughout Europe on how to learn and design standardised bathroom modules.

Bonava Finland is a construction company that focuses on multi-storey apartment buildings. Since 2018 a prefabricated bathroom module project has been at work. The objective for Bonava Finland with the bathroom modules was to create a module that is as standardised and industrially prefabricated as possible. The aim was also to raise the bathroom quality level compared to traditional bathrooms. Using standardised modules, the profit would come through volume and cost-effectiveness. /1/

In 2018, changes to the HVAC regulations regarding wall-blowing, gave the HVAC designers more freedom when planning the ventilation solutions for multi-storey residential buildings.

The objective from the building system teams standpoint was to create a bathroom module that is as standardised as possible, with all the needed technical solutions built. In order to minimize the time and costs, spent on building traditional bathrooms on the building site. /2/

1.1 Objective for Technical Solutions (HVAC)

The team of planners for the modules wanted to see how much of their technical solutions can be standardised in the modules, with the goals of minimizing the need for pipe-, duct-, shaft- and electrical work at the building site and reducing the man hours needed, cutting time and costs at the site. Having the modules pre-built at site, with all the technical solutions for every apartment already built in at the factories, was supposed to reduce the quality problems as the factory has a production line.

Apartments sharing pipe shafts is a common solutions and team at Bonava Finland´s objective was to find a different/alternative/new solution.
Main target with bathroom modules was to minimize apartment's HVAC installation work on site. When most of the HVAC work can be prefabricated, it saves time in construction process. Also, the quality of installation works is more stable with prefabricated HVAC systems and less manhours for HVAC installations on site.

In HVAC design point of view, one of the targets was to save time in the design process. The full HVAC designs of bathroom modules were made with MagiCad for AutoCad, having premade bathroom plans, which are shared to the designers. This should reduce the planner´s time figuring out HVAC solutions for each bathroom. /3/

1.2 Architectural Objective

Bathroom modules restrict architects in the designing process, as their visions for the bathrooms and apartments are going to be restricted. The objective is, while restricting to still give the architects as much freedom as possible. With enough options to keep it interesting. Keeping the module sizes as small and compact as possible, as it locks up a lot of the possibilities in the apartments.

The bathroom needs to have the most essential components: toilet seat, water basin, shower, storage space and washing machines. It is important that the module, while having all essential equipment, does not feel cramped. Accessibility is important, therefore there needs to be a turning circle, with the diameter of 1300 mm.

When fitting bathroom modules into an apartment, it is obvious that it cannot be too big, bulky or have a weird shape. When planning everything outside the bathroom the architects want the bathroom to be small and vice versa. Having a balance between how modules restrict, versus efficiency is improved, is key. The module and the solution must justify itself. /4/

1.3 Economic objective

Reducing cost is something that the building industry has been and will be struggling with always. The market is looking for affordable homes, keeping apartment costs low enough so that potential buyers are not put off. A huge part of the cost when building apartment buildings comes from the HVAC solutions and how difficult the solutions sometimes become if they are “customized” (conventional way of building) for every project. Being able to reduce the costs and save time, without giving up on the technical solutions, nor the quality, is of essence. The trend has been set in the cruise ship business for decades.

The objective was to shorten the whole building projects schedule by 1-1.5 months, through which building site costs, would be reduced. Cost savings were to be achieved by streamlining procurement and standardising the product. /1/

The idea at the beginning was that if productivity increases from the processes, the company can give the customer a little bit back in design, i.e. choosing materials and colours. /2/

2 FINNISH BUILDING REGULATIONS (HVAC)

In this chapter the most essential building regulations that affect Bonava Finland’s Bathroom modules will be presented and explained. The focus will be on the regulations, which affect the modules from a HVAC point of view. Regulations that affect the technical solutions, layouts and dimensions of said systems and regulations that are important to the overall design of the bathroom modules and their structures.

The regulations are from either the Finnish Ministry of Environment or Finnish Building Services Industries and Trade (Talteka). The Finnish Ministry of Environment, are the ones who have produced the official building regulations and the Finnish Building Services and Trade, a *Finnish cooperation organisation for industrial, economic and environmental issues within the building services industries and trade*, has produced guides based on these regulations. These guides break down the regulations so that they are more coherent and understandable. They also provide tables, examples and dimensioning examples that help planners and designers do their work. The guides for indoor climate, ventilation, HVAC fire safety, water and wastewater are available in Finnish at *Talotekniikkainfo.fi*.

2.1 Wet rooms

The regulations are from the Ministry of Environments and Talteka guides, which can be found at *YM.fi* and *Talotekniikkainfo.fi*.

The main points of this chapter:

- Waterproofing and the effect of moisture in structures.
- Floor slope in wet rooms.

28§ discloses the wet rooms water proofing and structure.
Water must not drain or transfer as capillary flow from the wet space to the surrounding structures and rooms. The structure behind surfaces exposed to run-off water, repeated splash water or surface condensation must be waterproof. Meaning that a coating of waterproof membrane must be applied onto the wall under the tiles or whatever material is being used, as the cement seams between ceramic tiles are not waterproof.

The wet room floor and wall must act and be certified as waterproof or the floor under the surface and the wall behind the first wall must have a separate waterproofing membrane. Waterproofing is not required in the wall of a separate toilet or a saunas wall coating. Wet rooms ceiling must withstand splashing water, occasional high humidity and temporary condensation of moisture on the roof surfaces. It is important that these regulations are followed as mold can form under the surface and affect the health of the people living there. The structure behind or under the surface can start to deteriorate and might not survive the intended lifetime.

The waterproofing of the wet room must form a body of waterproofed surfaces that are waterproof at their joints and penetrations. The waterproof membrane on the floor that serves as the waterproofing of wet rooms or the waterproofing under the floor surface must be water tightly connected to the waterproofing of the wall.
Wet room structures must be rigid enough that heat and moisture movements do not damage the wet room waterproofing or surface structures, e.g. cracked tiles or disformed wooden planks.
If, for a special reason, waterproofing membrane is not used in wet room structures, the building designer and special designer must demonstrate in the plans that the absence of waterproofing does not jeopardize the fulfilment of the essential technical requirements.

In 29§ The slope of the wet room floor must allow water to drain into the floor drain. Waterproofing and the floor drain connection must be tight.

The recommended slope of the wet room floor to allow the water to drain properly is 1:80 towards the floor drain, in the shower area 1:50 (i.e. a total tilt of 10 mm at 500 mm). However, if a slope of 1:80 is not possible at the site, the slope of the floor must be at least 1: 100 (i.e. a total slope of 10 mm for a distance of 1000 mm). /5/

2.2 Ventilation

The regulations are from the Ministry of Environments and Talteka guides, which can be found at *YM.fi* and *Talotekniikkainfo.fi*.

The main points of this chapter:

- Ventilation design principles.
- Apartment design value temperature is 20°C.
- Carbon dioxide levels shall not exceed 1450 mg / m3 (800 ppm) higher than the concentration in the ambient air.
- The airflow in the living quarters shall be dimensioned for a minimum of 6 dm^3/s per person. The outdoor air flow of the whole building shall be

dimensioned to at least 0.35 $dm^3/s/m2$ The air flow in the living quarters/apartment shall be at least 18 dm^3/s.

- The airflow controller can boost the airflow by a maximum of 30 % from normal and lower the airflow to a maximum of 60 % of the normal airflow.

Guides for airflow dimensioning and device placement can be found in the appendixes 4 and 5:

- Room specific airflows
- Guide for wall-mounted air device placement

3§ The starting point for the design and construction of the building's indoor climate is that a healthy and safe indoor climate is achieved in the living area in all normal weather conditions and operating situations.

When designing a building the chief designer, special designer and building designer shall take into account the following factors that affect the indoor climate of the building:

1. internal load factors such as: heat and humidity load, equipment, lighting, personal loads, noise sources, processes, emissions from construction products and other pollutants related to the use of the building.
2. external load factors such as weather and sound conditions, outdoor air quality and other environmental factors.
3. location and construction site.

The chief designer, special designer and building designer shall take into account the indoor climate appropriate to the intended use of the building when:

1. design the thermal and moisture insulation of the building as well as the properties of the windows and sun protection.
2. design the energy performance of the building.
3. determine the airtightness of the building envelope, subfloor and shafts, as well as the airtightness of structures between rooms.
4. planning the sound insulation and noise control of the building.
5. planning the lighting of the premises and the use of daylight.

6. selection of building materials.
7. planning the heating and cooling of the building as well as other building services systems, their reliability and space requirements.
8. design site moisture management.
9. planning the cleanliness of construction work and the ventilation system.
10. establish a timetable for the construction site, reception and commissioning.
11. plan the availability, proper use and maintenance of the building and technical systems and draw up instructions for the use and maintenance of the building.
In order to create an indoor climate appropriate to the intended use of the building. Structural means can be used, internal load factors can be reduced, the effect of external and internal load factors can be limited, and heating, cooling, ventilation and air conditioning techniques and related control and regulation can be used.

4§ The room temperature of the building must be comfortable during the planned period of use and must not be impaired by air movement, temperature radiation, temperature variations, temperature differences and surface temperatures. The design value for the room temperature heating season must be 21 degrees Celsius. In room temperature control design the room temperature can vary between 20 and 25 degrees Celsius during the heating season and between 20 and 27 degrees Celsius outside the heating season. For a special reason, such as due to the operation requiring specific room temperatures or the special nature of the room, temperatures other than these values may be used as the room temperature design value and in the room temperature control design.

5§ Indoor air must be free from particulate matter, physical, chemical or microbiological agents and odours which are detrimental to comfort.
The design value of the instantaneous concentration of carbon dioxide in the indoor air during the planned period of use of the room may not exceed 1450 mg / m3 (800 ppm) higher than the concentration in the ambient air.

8§ Ventilation shall implement healthy, safe and comfortable indoor air quality in living areas. The ventilation system must bring a sufficient flow of outdoor air into the building and remove substances harmful to health, excessive humidity, odours that impair comfort and pollutants from people, construction products and activities into the indoor air. The ventilation system must be designed in such a way that:

1. the functions essential to the operation of the selected ventilation system can be measured, controlled and monitored.
2. when properly used, serviced and maintained, the system will withstand the intended service life.
3. the operation of the system as a whole can be stopped. The mechanical system must have a clearly marked stop switch which must be easily accessible. In a gravity system, the air change valves must be easy to close.

9§ The rooms must be ventilated to ensure healthy, safe and comfortable indoor air quality during use.
The outdoor air flow is primarily determined by the personal criterion. If the future number of users of the premises is not known, area-based sizing is used.

When planning fresh air intake, the air amount is regulated with a minimum airflow per room and apartment. The airflow from the living quarters shall be dimensioned for a minimum of 6 dm^3/s per person during the intended period of use, however, the outdoor air flow of the whole building shall be dimensioned to at least 0.35 $(dm^3/s) / m^2$ per floor area, unless the building requires additional airflow. The outdoor air flow in the living quarters/apartment shall be at least 18 dm^3/s.

Ventilation should always be planned according to the needs of the premises and the activities they carry out. The personal or square dimensions specified in the regulation result in different ventilation needs if the ceiling height differs a lot from the regulation examples, (normal ceiling height 2.5 m) which is not sufficient to maintain indoor air quality. A rule of thumb is a ventilation factor of 0.5 l / h (meaning half a of the space air per hour), meaning that in 2 hours the whole room has to have all air changed.

In addition to the first use, the design of the ventilation system must also take into account the possible operational and conversion flexibility requirements of the premises.

Pollutant loads in the premises, that degrade indoor air quality must be noted, when determining air flows. When planning the target exhausts required to remove contaminants, care must also be taken to ensure that the supply air is brought into the room in a controlled manner, so that the use of the target exhaust does not change the pressure conditions in the room.

Exterior and exhaust airflows in conventional buildings are usually designed to be equal. Inside the building, the room-specific supply and exhaust air flows can be different (e.g. the supply air in the corridor is led as transfer air to the toilets), but the total supply and exhaust air flows in the compartment served by the ventilation system must be equal. Spaces with significant internal humidity loads (e.g. residential apartments, washrooms and drying rooms) are designed to be slightly vacuum (2-5 Pa) in relation to the outdoor air to prevent moist indoor air from penetrating the structures.

10§ The control of the airflow in the apartments must be designed in such a way that the supply and exhaust airflows can be controlled either on an apartment-by-apartment or living space-by-living space basis. The airflow can be increased by 30 %, compared to the design value. If ventilation can be controlled on an apartment-by-apartment basis, the supply and exhaust airflow of a residential apartment can be reduced by a maximum of 60 per cent of the airflow of the planned operating time.

13§ The exhaust air categories are:
Category 1: the exhaust air contains only a small number of pollutants and these pollutants are mainly of human and structural origin.
Category 2: the exhaust air contains some impurities.
Category 3: exhaust air contains impurities, moisture, chemicals or odours that significantly impair the quality of the exhaust air.
Class 4: Exhaust air contains significant amounts of foul-smelling or unhealthy pollutants or chemicals.

14§

Outdoor air must not be taken in through a structure or building component that degrades air quality or in the vicinity of sources that pollute outdoor air quality.

Outdoor ventilation equipment must not allow snow or rainwater to enter the ventilation system to such an extent that it would damage the system or the quality of the air or interfere with the operation of the system.

The discharge of exhaust air out of a building must be designed in such a way that there is no health or other harm to the building or other buildings, the environment or their users. Exhaust air must be led through the roof of the building, unless otherwise required by the operation of the ventilation system. Exhaust air of exhaust air class 1 or ventilation of residential apartments may also be led out via an exhaust air device in the wall of the building (wall blowing), if the requirements set out in this subsection are met.

Components or structures that degrade the quality of the intake air may include, for example, exterior wall ventilation slots, glazed balconies, atrium spaces and double facades, attic under the roof, roof and wall structures for air preheating and earth ducts, and structural ducts, structural chambers and structural chambers. In these cases, the quality of the intake air may deteriorate due to contaminants from activities, materials or the ground, contaminants from the outside air, and condensation of rainwater and moisture. In order to ensure good quality of the intake outdoor air, it is recommended to use a method of installing the outdoor air grille in which the intake air is not in contact with the external wall structures.

In buildings equipped with exhaust ventilation only, outdoor air can be taken in, for example, through room-specific outdoor air devices. These include, for example, outdoor air valves and supply air windows. With an exhaust ventilation system, it can be difficult to achieve the balanced ventilation required by the regulation and, for example, the necessary air filtration. When outdoor air is taken into a room through outdoor air equipment, a reasonable control of the incoming outdoor air flow requires a pressure difference of at least 10 Pa over the building envelope. In this case, the effect of the wind and the thermal pressure difference does not impair the operation of the ventilation by increasing the variation of the outdoor air flow and, in the worst case, by reversing the direction of air flow in the opposite direction to that planned.

Exhaust air of exhaust air class 1 or ventilation of residential apartments can also be led out via an exhaust air device in the wall of the building. In other cases, too, the exhaust air may be designed to be led out from outside the water roof of the building, if the operation of the ventilation system so requires and there is no inconvenience to the venting. Such cases may include decentralized ventilation systems and other ventilation systems where the ventilation machines and engine rooms are not located on the water roof or on the top floor. Particular attention must be paid to the insulation of ducts carrying cold air, in residential apartments.

Exhaust air class 1 air and exhaust air from stairwells, elevator shafts and technical rooms can be led out of the building without restriction. However, it is not to be directed towards exits or living areas. The sound technical requirements, for the blow-out is an important part of the design.

2.3 Sound

The regulations are from the Ministry of Environments and Talteka guides, which can be found at *YM.fi* and *Talotekniikkainfo.fi*.

The main points of this chapter:

- Average noise level of low-frequency noise shall not exceed 25 dB, in living-spaces meant for sleeping or resting.
- Average sound level maximum $L_{Aeq,T}$ 28 dB in apartments.

Guides for sound regulations can be found in Appendix 6:

- Noises levels in residences (5§)

4§ If the apartments, accommodation or patient room is structurally connected to premises where a strong, particularly annoying or low-frequency sound, designers must pay particular attention to design and implementation. Pulsed, narrowband
or one-hour average noise level of low-frequency noise shall not exceed 25 dB, in living-spaces meant for sleeping or resting.

The sound pressure level generated in a room can be calculated from the sound power levels of individual sound sources. For example, if there are three devices in the living room that produce the same amount of sound, the sound pressure level must not exceed 23 dB in order to meet the average sound level maximum $L_{Aeq,T}$ 28 dB.
The A-weighted maximum sound level of L_{AFmax} in the living-spaces inside the building is 45 dB.

5§ Requirements for noise and vibration control in a new building.
The sound insulation of the external envelope of a building with apartments, accommodation or patient rooms must be designed and implemented in such a way that the sound insulation is at least 30 dB and the average sound level of pulsed, narrowband or low-frequency noise in rooms used for sleeping or resting does not exceed 25 dB.
The installation of lifts and building services in a building shall be designed and carried out in such a way that the sound level does not exceed residential or living quarters, accommodation or patient rooms.

2.4 Water

The regulations are from the Ministry of Environments and Talteka guides, which can be found at *YM.fi* and *Talotekniikkainfo.fi*.

The main points of this chapter:

- Cold domestic water has to be below 20°C.
- Hot domestic water has to be over 55°C.
- Domestic water systems must be able to withstand 1000 kPa excess pressure.
- Safety valves in domestic water systems can hold a maximum of 1000 kPa excess pressure.

Guides for water equipment and pipe dimensioning can be found in the Appendixes 7 and 8:

- Nominal flow for water equipment.
- Flow velocity in pipes.

6§ The cold domestic water system must be designed and installed so that the temperature of the water in the cold-water system must not exceed 20°C. After a period of inactivity of at least eight hours, the water temperature must not exceed 24 °C.
The temperature of the hot domestic water system must be at least 55 °C and must be obtained from the hot water system within 20 seconds. The temperature of the water from the hot water system must not exceed 65 °C.
The water system must be such that harmful crossflow of water from the hot water pipe to the cold-water pipe or vice versa is prevented.

The legionella bacteria is natural bacteria that can reproduce up to harmful concentrations in warm domestic water if the water temperature is not high enough. Legionella multiplies at a water temperature of 20°C to 45°C. Legionella is lethal at its worst, it enters the lungs with the water vapor inhaled in the shower. The most serious infection caused by legionella is pneumonia. Healthy people can die or get very sick from legionella, but the most susceptible to infection are the elderly and children, as well as frail and chronically ill people.

7§ The water device system must be able to withstand 1000 kPa excess pressure. The water devises have to be able to function with designed flow, without any disruptive noises nor harmful water hammer.

The starting point for the design is the lowest and most stable pressure level of the building's water supply network. When the network is designed to be low and flexible, flow rates and pressure losses in the piping system are small, which reduces the risk of noise nuisance. The pressure level in the network is primarily regulated by a building-specific pressure relief valve. Nevertheless, the need for pressure relief may occur in the lower parts of the network, in which case, in addition to the building-specific pressure relief valve, branch-specific pressure relief valves are used in the necessary parts of the network.

8§ The circulating hot domestic water in a new building must not have heat exchangers or underfloor heating.

During repair and alteration work, the heat sinks connected to the domestic hot water supply line can be renewed so that the heat transfer power of the heat sinks to be installed does not exceed 200 watts per room. However, domestic hot water must not be used for underfloor heating.

9§ The water devices must be suitable for its intended use. The functions and directions of movement of the controls for adjusting the water volume and temperature must be safe. The operating device of the plumbing fixture shall be such that its surface temperature does not exceed 40 °C.

10§ The water meter on the property must be in a place where it is easy to install, read and maintain and cannot freeze.
The building must have apartment-specific water meters for measuring the cold and hot water entering the apartment, so that the water consumption indicated by the water meters can be used as a basis for invoicing. Apartment-specific water meters must be in a place where they can be easily installed, maintained and read.

15§ The water in the water system must not freeze at any point. Cold water pipes should be thermally insulated. In addition, water pipes installed in the ground should be located below the frost depth, unless freezing of the water pipes is otherwise prevented. In addition, it is stipulated that in cold rooms, water pipes must be thermally insulated. For example, electric escort cables and frost plates can be used to prevent pipes in the ground from freezing. It is not always possible to install pipes below the frost depth. However, thermal insulation alone may not always be enough.

17§ Safety valves in hot domestic water devices hold max 10 bars = 1000 kPa excess pressure, which can be determined from 7§ as well.

2.5 Drainage

The regulations are from the Ministry of Environments and Talteka guides, which can be found at *YM.fi* and *Talotekniikkainfo.fi*.

The main points of this chapter:

- Drainage design
- Sewer and drainage systems in a building must not cause health hazards, odour nuisance, sewer floods, noise or environmental damage.
- Water traps.

Guides for drainage equipment can be found in Appendix 9:

- Dimensioning of nominal flow in drainage equipment

25§ The sewage and drainage system of the building must not cause health hazards, odour nuisance, sewer floods, noise or environmental damage.

Wastewater must be discharged into the sewer of a water supply plant or for treatment on a property-by-property basis or in a closed tank. The pipe size of the drain must not decrease in the flow direction.

In a multi-storey building, the vertical sewer bend is to be covered, by a solid material at least 100 mm thick and 1 meter long, which is connected with the subfloor or subfloor structure, and the vertical sewer is attached to the structures with sound-insulating brackets.

26§ Whenever there is a water point, there must be a drainage point that is connected to the main drainage pipe.

A maximum of two dry wells may be connected to a floor drain, which must be located at a maximum distance of three meters from the floor drain. The following facilities and spaces must be equipped with a drain point:

1. shower spaces, bathrooms, as well as saunas and washing rooms.
2. laundry rooms.
3. heat distribution rooms.
4. ventilation machine rooms.
5. toilets for general use.

6. technical rooms, with the possibility of water damage.
7. car wash.
8. special rooms which are cleaned by rinsing with water.

A floor drain does not make a space a wet room, however all spaces with a floor drain should be waterproofed and have waterproofing membrane raised 10 cm up the wall.

28§ The drainage system must not cause odour nuisance and must have a water trap that can be cleaned.
The drains must be connected to a ventilated vertical sewer extending above the water roof of the building.

If the water point is equipped with a drainage point, it must have a water trap with a depth of at least 50 mm in the closing part of the building and at least 70 mm in the mine outside the building. The connection of a drainage point to a common water trap is acceptable in the following cases:

1. the sink, tub or shower is connected to a floor drain in the same space
2. Cooling machines and overflow and emptying water from water tanks, etc., have been drained through an air gap into the water trap of another piece of furniture.
3. A dishwasher table with three basins and a dishwasher is connected to a common water trap
4. sink groups in, for example, laboratories and washrooms
5. dry wells. The side connection of the floor drain must be at the water level of the water trap.

At least one ventilated vertical sewer leading to the outside air will be made in the building. The following measures are adopted to ventilate the sewer:

1. The sewer on the ground is usually ventilated through the building that the sewer serves
2. the vertical sewer is ventilated to the roof, unless the sewer is dimensioned unventilated according to the dimensioning instructions in the example Sewer Equipment

3. the horizontal drain is usually ventilated through a vertical drain, unless the drain is dimensioned unventilated, or the drain is not a horizontal part of the vertical drain
4. the connection sewer is ventilated to the collector sewer, but in a special case a separate ventilation sewer may be used, made in such a way that the wastewater cannot penetrate the ventilation sewer
5. The oil separator and grease separator as well as the sewage pumping or treatment wells are fitted with a tight cover and are usually ventilated separately, usually by an internal ventilation drain above the roof. The grease separator can also be ventilated via the ventilation drain of the associated sewer points.
The minimum distance between the mouth of the ventilation drain from the ceiling is 0.5 m, from the flue opening and the exhaust air device 1 m, from the opening window above 5 m horizontally and from the outdoor air device (air intake opening) 8 m horizontally.

In the drainage of unventilated individual sewer points, a quality-tested and inspected vacuum valve can be used to remove the vacuum in the sewer. The vacuum valve is installed so that it is above the highest possible water level at all the sewer points it serves. The vacuum valve shall be placed in a room where it does not freeze or cause noise, odour or similar nuisance and where it is easy to maintain or replace.

If the ground drain is installed under a load-bearing slab, it must be led out of the building the shortest possible route. The sewer of each apartment in the terraced house is led separately to the main sewer outside the building, and each apartment is equipped with its own ventilation drain led to the water roof.

In cold rooms, the vertical sewer pipes ventilation pipe must be thermally insulated to prevent condensation of warm water vapor rising along the pipe into the ice surface during the winter.

2.6 Heating

The regulations are from the Ministry of Environments and Talteka guides, which can be found at *YM.fi* and *Talotekniikkainfo.fi*.

The main points of this chapter:

- For multi-storey apartment buildings the E-figure limit is 90 kWh_E / (m^2 a).
- How the E-figure is calculated.
- The indoor temperature of the wet room must be 22°C

3§ The chief designer, special designer and building designer shall, in accordance with their duties, take care of the design of the new building in such a way that, in accordance with its intended use:
1) in terms of energy efficiency, in accordance with either the calculated energy efficiency reference E-figure or the structural energy efficiency.
2) is creative in creating the conditions for a building with low heat demand.
3) is energy efficient in terms of its calculated summertime room temperature, measurement of energy consumption, heat and electricity power requirements and, when using a mechanical ventilation system, also in terms of the specific electrical power of the ventilation system.

4§ The calculated energy efficiency benchmark (E-figure), which is kWh_E / (m2 a), is the calculated energy consumption of the building per year, heated by the coefficients of the energy forms, weighted by the net heated area of the building. For multi-storey apartment buildings the E-figure limit is 90 kWh_E / (m^2 a).

7§ The e-figure shall be calculated from the calculated energy consumption of the building, broken down by energy form, using the coefficients of the energy forms using the formula:

$$E = \frac{f_{district\ heating}\,Q_{distict\ heating} + f_{distict\ cooling}Q_{distict\ cooling} + \varepsilon_i f_{fuel,i}Q_{fuel,i} + f_{electricity}W_{electricity}}{A_{netto}}$$

8§ The calculation shall be performed using a calculation method that takes into account at least the following factors:

(a) thermal properties of building components and their joints, air tightness of the building, ventilation air flow.

(b) indoor air temperature.

(c) domestic hot water demand.

(d) ventilation heat recovery.

(e) thermal loads on persons, lighting, electrical equipment, domestic hot water and the sun.

(f) the thermal and electrical energy demand of the space and ventilation heating system.

(g) the thermal and electrical energy demand of the domestic hot water heating system.

(h) the electrical energy demand of the ventilation system.

(i) electricity demand for consumer equipment and lighting. And when a solar collector, solar panel or wastewater heat recovery is planned for a building:

(j) heat recovery from the solar collector and its use in the building.

(k) electricity generation from a solar panel and its use in a building.

(l) wastewater heat recovery and its utilization in a building.

The calculated purchase energy consumption of a building can be calculated using the monthly calculation method for a building that does not require cooling for indoor air temperature control or cooling is only required in rooms with a net heated area of less than 10% or a net heated area of less than 50 square meters.

If the control of the indoor air temperature of a building requires cooling, the calculated purchase energy consumption of the building shall be calculated using a calculation method that takes into account the heat and electrical energy needs of the cooling system and the heat transfer characteristic.

10§ The E-figure shall be calculated using the following outdoor airflows during operation and the room temperature heating and cooling limit temperatures:

- 0,5 $dm^3/(s\ m^2)$ Outdoor airflow
- 21°C Heating limit
- 27°C Cooling limit

16§ When calculating the E-figure, the heat loss of the building envelope must be calculated with the internal dimensions of the building envelope. The cold bridges of the structures and their joints must be taken into account in the calculation. Individual cold bridges in the building envelope are not taken into account.
The calculation of heat loss must consider the effect of the soil and crawl spaces heat loss.

18§ If the living rooms have circulating water heating and in the wet rooms electric underfloor heating, it can be calculated that 35% of the net heating energy demand of the residential premises will be allocated to the underfloor heating of wet rooms and 65% to the heating system of residential rooms.

The indoor temperature of the wet room must be 22°C. However, the share of electric underfloor heating in wet rooms in the net heating energy demand of residential premises is at most the share calculated on the basis of the installation capacity and 8760 hours of use of electric underfloor heating presented in the plan.

3 HVAC AND PLANNING SOLUTIONS

It was decided that Bonava Finland will have 5 different module sizes S, M, L, XL and KHH (=utility room). Of every module there is a left and right version (see *Figure 1)*, meaning that there are a lot of variations that can be used in the architectural planning. There are also specifications for if the modules are the lowest or highest modules in a bathroom module stack.

The lowest and highest specifications are needed for technical reasons. The noise from the sound insulated vertical sewer bend at the bottom shaft can get loud when it hits the bend under the lowest module. The sound insulated vertical sewer bend (Appendix 2) reduces the sound of going back up to the modules above. For the first-floor module the HVAC design team realised that there still is quite some noise and decided that a by-pass is needed, meaning that the sound insulated vertical sewer bend serves only the modules above the first one. The floor drain from the lowest module by-passes the main vertical sewer and re-joins the sewer pipeline after the sound insulated vertical sewer bend. The change affects the drainage design in the lowest module slightly and affects the lowest modules hole reservations in the concrete slab and forces the prefabrication team to be precise, when getting the orders from Bonava Finland.

The highest module is only affected in the prefabricated shaft, the hot domestic water pipe and circulating domestic hot water pipe needs to connect. The connecting of the hot domestic water pipe and the circulating hot domestic water pipe is done at the building site. It is important that there are no mix-ups with the lowest and highest specifications, as any mix-ups would proof costly when the bathroom modules are installed at the building site.

All this means that there are 6 different variations for every module size and in total 30 variations. Even if the layout and design for the bathroom modules cannot be seen visually when they are in use, all the variations force everyone connected to the building process to be extremely precise. Additionally, there are different interior design packages available that can be chosen. There is a limited time for when the buyer can choose the design package, as this decision needs to be made before the bathroom module order is made to the manufacturing company. See *Figure 2* for the basic interior design.

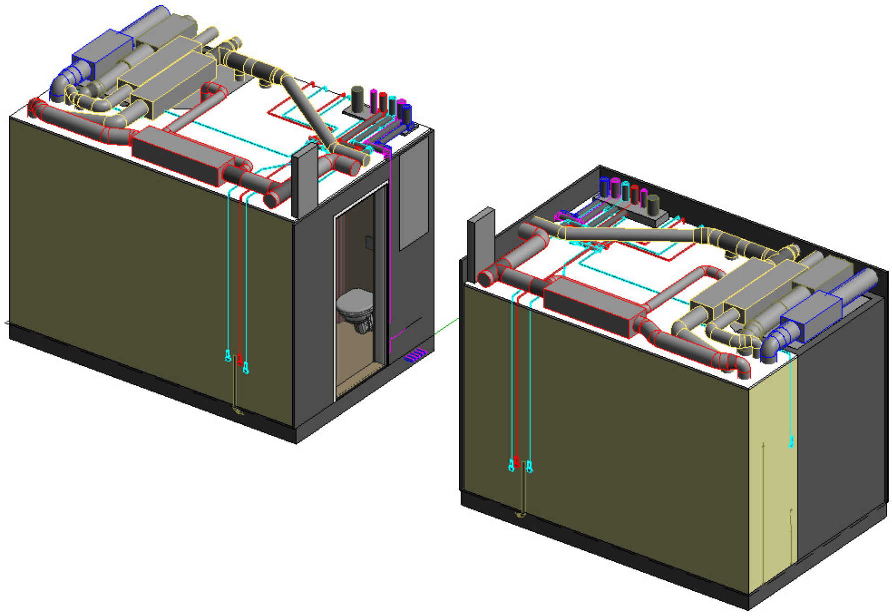


Figure 1: Bonava L-module Right and Left.

<u>S-module</u>

The S-module is meant for apartments which are roughly 40 m^2 or smaller, meaning that the S-module is intended for one and small two room apartments. The S-module is the smallest in size, roughly 3 m^2 yet it does not variate that much in basic layout design. The AHU is smaller than the rest of the modules, as the apartments that the S-module serves does not need as much ventilation capacity. The pipe shaft in the module is the same as in the other apartments.

<u>M-module</u>

The M-module is 4 m^2 and has the same design and layout as the S-module, just with slightly bigger dimensions. The M- module has a bigger AHU model (Salla), which is the same model that the L- and KHH-module uses. The M-module has the same design on its "door" wall, as the L-and XL-module. It is exactly the same size and has the same technical equipment. There is a manifold which serves the apartments floor heating and an electrical shaft. The M-module is meant for apartments between 40 m^2 and 60-70 m^2, two- and three-room apartments.

L-module

The L-module is 7 m^2 and has a small sauna. The technical design is very similar to the M-module, with the same AHU (Salla), same drainage, heating and ventilation principle and similar layout. The big difference is a small sauna built into the module. The sauna is built to fit two persons. The module is meant for apartments that are roughly 60 m^2 to 90 m^2.

XL- and KHH module

XL- and KHH-module are meant to accompany each other. The modules are meant for apartments that are 90 m^2 and larger, typically this apartment size needs two bathrooms. XL-module is 7 m^2, where the sauna is 3 m^2 and the KHH-module is 3 m^2. The AHU Salla is placed into the KHH-module and instead of an AHU the XL-module has a sauna meant for 4 persons. The bigger sauna takes up the space where the AHU would otherwise be located. The KHH-module is similar to the S-module in size (3 m^2) except it does not have a shower and has as mentioned above the bigger AHU model. Both modules have the same pipe shaft, electrical shaft and manifold as all the other modules. Both modules need to have a manifold, as the floor surface in the larger apartments is too great for only one manifold.

Figure 2: S-module interior.

All the modules have the same principles for their domestic water, drainage, heating and ventilation designs, as can be expected when standardised modules are designed. Biggest difference is found in the ventilation layout and the different AHU models. However, the ventilation principle is similar.

The water and drainage points differ slightly in position, however the dimensions, materials, pipe connections and basic layout does not. Examples can be found later. The drainage distances and layout have a great effect on the concrete slab thickness, as there needs to be enough slope in the drainage pipes, otherwise the drainage will not work as intended.

The concrete slab is 180mm thick and there has been attempts at making it thinner. If the concrete slab was thinner it would reduce the weight of the module, making installations at the site easier. It would also reduce the modules height, making hollow slab design easier. However, without changing the drainage layout drastically and adding more vertical sewer shaft points it is not quite possible. Adding vertical sewer shafts would take away space from either the bathroom area or the living quarter area. Adding more vertical sewer shafts will affect labour-, material- and planning time costs.

All modules in one piping shaft line must be the same hand. All the modules in the pipeline must be either right- or left-handed, otherwise the pipe shaft could not be used, as the pipe order does not add up. This will restrict the architectural planning greatly. The apartments electricity comes through an electrical shaft, that is placed inside the wall structure right next to the module door.

The modules are naturally meant to be placed on top of each other and due to the electrical shaft, there are restrictions regarding which modules can be stacked on top of each other. The M-, L- and XL-modules have the same design in the "door" wall design. In these modules the electrical shaft is placed at the exact same place. Meaning that these three versions can be stacked. The S- and KHH-modules differs slightly from the other modules. The electrical shaft is positioned differently, meaning that S- and KHH-module cannot be stacked on the M-, L- and XL modules. However, the S- and KHH- module have the same wall dimensions and shaft positions, meaning that they can be stacked on top of each other. This is a restriction that needs to be mentioned to the architects early on, as not to have any mishaps and misunderstandings that needs redesigning, at a later stage. /3/

All new multi-storey buildings need to have a bomb shelter in the basement. This affects the bathrooms modules to such an extent that Bonava Finland´s prefabricated modules cannot be used right on top of the bomb shelter (first floor), however the rest of the bathrooms above the bomb shelter can be prefabricated. The reasons have to do with that the concrete slab is too thick, as the bomb shelters walls and ceiling is a lot thicker than the rest of the floor. All this means that the bathroom must be built on site.

Those the rear occasions where a bathroom module is not allowed to be used and it has to be built on site. Bonava Finland builds so-called clones. The clone bathrooms use the same materials, ducts, pipes and interior parts for the bathroom on site. Building the exact same bathroom as the bathroom modules, difference is that it is on site. This allows the procurement team to order all the same parts and materials, thus saving time. For the architects and HVAC designers nothing changes as all the same design principles are used.

3.1 Pipe shaft solutions in Bonava modules

At Bonava Finland, most multi-storey buildings being built are 8 floors or lower. The normal amount is 5 to 6 floors. When buildings get higher than 8 floors, there are regulations that affect the buildings, e.g. fire safety regulations. Dry pipes are required in buildings that are 8 floors or higher. A requirement by the cities fire departments. Buildings that are higher than 8 floors are complex and needs more attention to details by everyone involved.

Depending on the city and area there are different specifications for so-called high-rise buildings. In the Greater Helsinki area, buildings are classified as high-rise buildings at 12 floors and higher, or upwards of 40 meters, it depends on which city. These buildings have slightly different regulations, most of them relating to fire safety, domestic water and drainage. Sprinklers has to be fitted into these buildings, meaning that a fully separate water network has to be planned.

Because of these specifications and many others, Bonava Finland has decided that the company will focus on buildings with 8 floors or lower. The prefabricated pipe shaft that is used in all the bathroom modules, is designed specifically for these buildings. The dimensioning of water, heating and sewer pipes are based on the need of these buildings.

The heating, water and vertical sewer pipes are all placed in the same shaft coming up through the module, to reduce the number of pipe shafts in projects. The shaft, pipes and pipe sizes, insulations and waterpoints are all standardised, no matter the project. Traditionally pipe shafts are placed outside of the bathroom's dimensions, to keep the water proofing body whole and save space inside the bathroom. At Bonava, the team was able to design a shaft that is inside the water proofing body and has all the pipes and other components fitted into a compact shaft.

The design team opted for a wall-mounted toilet seat, which is installed directly onto the pipe shaft wall. The wall-mounted toilet seat frame and the toilets water tank are fitted inside the shaft. This is one of the main reasons why the pipe shaft can be inside the water proofing membrane. Usually the wall-mounted toilet seat, the wall-mounted toilet seat frame and its water tank take up a lot of space and are planned outside of the pipe shaft. Below are two module examples, *Figure 3* and *Figure 4*. The modules have different pipe and sewer shaft solutions, with the solution in *Figure 3* being the one used nowadays. The largest difference is that the pipe shaft is outside the modules main structure in *Figure 4* and is not installed inside the module, in fact the pipe shaft was installed on site, meaning that there is an awkward corner in the layout. This means that there was a lot of work that had to be done at the building site, in conditions, which were not always optimal.

The toilet seats and its water tank in *Figure 4* uses up a lot more space than in *Figure 3*. Why and how the solution in *Figure 3* works, is explained later in this chapter.

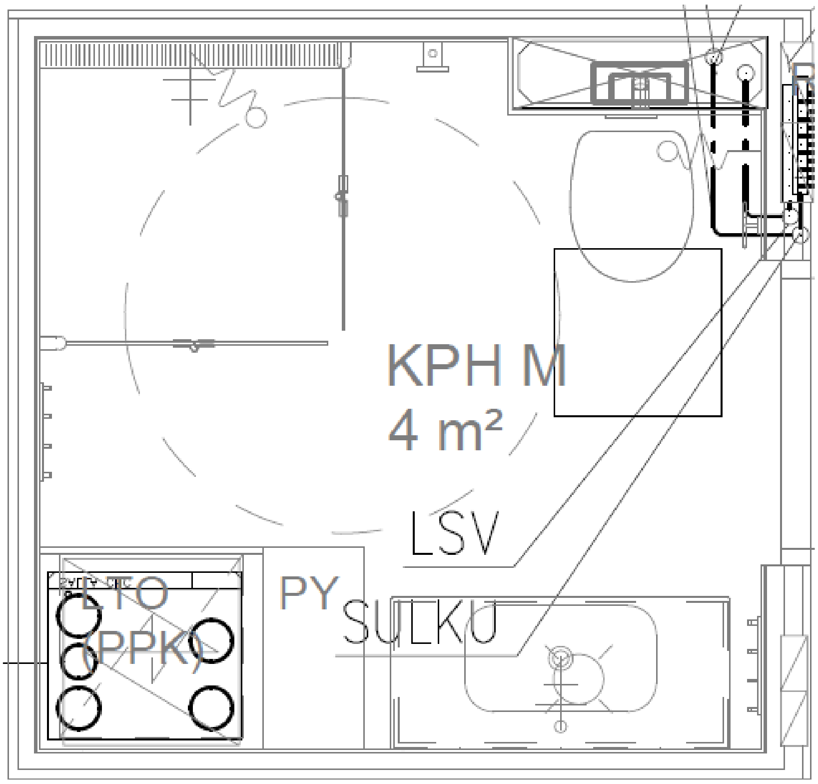


Figure 3: Bonava Finland M-module.

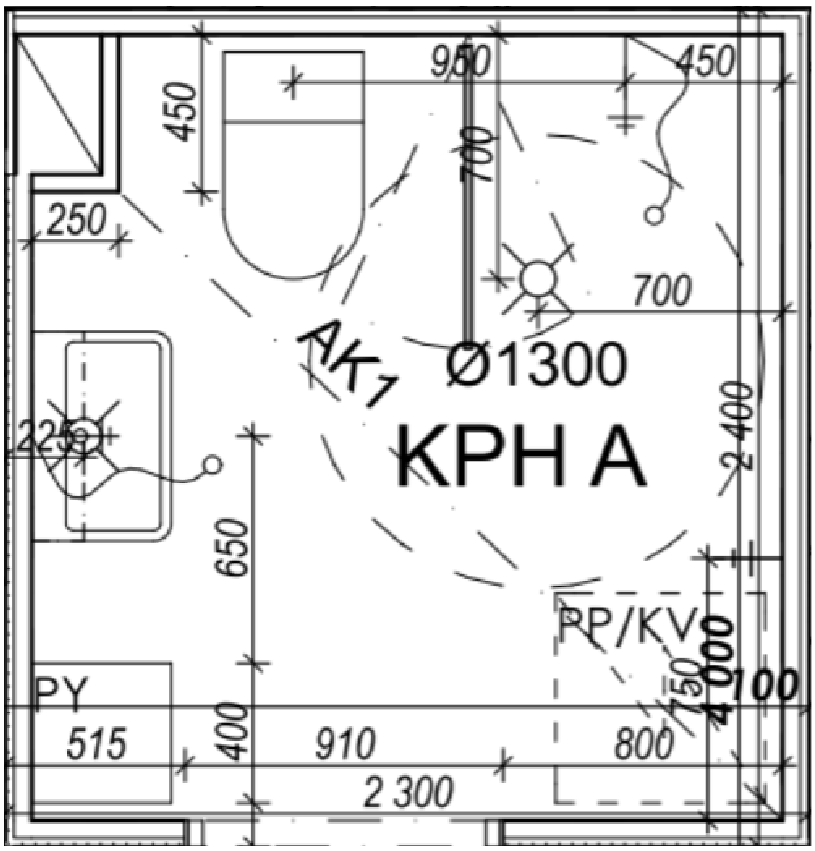


Figure 4: A traditional module example from an earlier Bonava Finland project.

The pipe shaft is prefabricated by a subcontractor and was designed by Bonava Finland´s HVAC design team. The pipe shaft is being shipped to the bathroom module manufacturing company, where it is installed into the bathroom module.

There are left- and right-handed pipe shaft models, as well as lowest and highest models. The left-handed prefabricated pipe shaft is meant for the right-handed bathroom modules and vice versa. The right-handed bathroom modules are mirrored versions of the left-handed bathroom modules, so naturally the pipe shafts are mirrored as well. Nothing else differs. The pipe dimensions, materials and shaft dimensions stay the same.

The pipe shaft that is installed into the lowest bathroom module needs to have an inspection hatch installed into the vertical sewer pipe. The inspection hatch enables cleaning of the vertical sewer pipe. The pipe shafts installed into the highest modules will have a pipe connection from the hot domestic water pipe to the circulating hot domestic water pipe. More on this in chapter 3.5.

Due to the shaft dimensions, there is little room for the pipes, see *Figure 5* and *Figure 6*. The pipe sizes are dimensioned to serve buildings that are a maximum of 8 floors high, as mentioned earlier. If the buildings were any higher the pressure to bring the water and heating energy in the pipes higher up, increases to a level where the functionality and safe use of the pipes cannot be relied on. Buildings that have more than 8 floors, will need a by-pass shaft. The prefabricated pipe shaft could be used in floors upwards from the 8th floor after they were connected to the by-pass shaft.

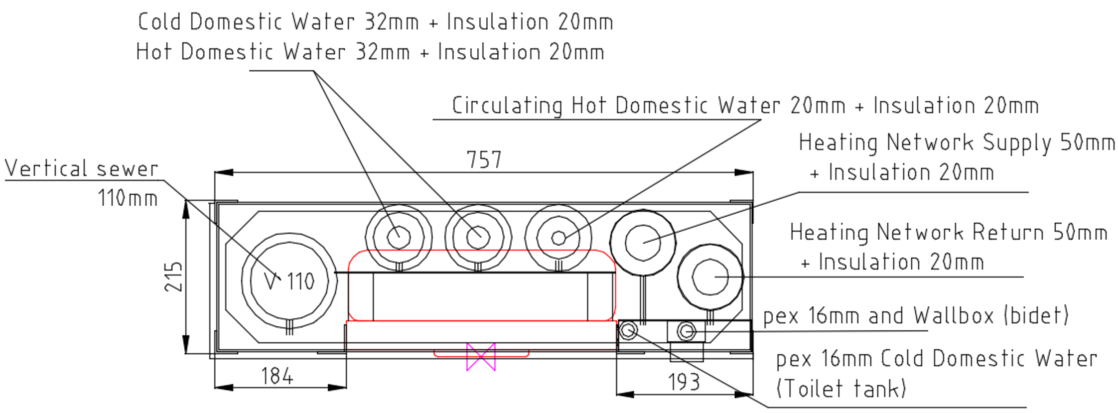


Figure 5: Bathroom module pipe shaft, left-handed model.

Figure 6: Left-handed pipe shaft installation.

The domestic water and heating pipes are composite pipes, made of two layers of PEX plastic and with a layer of aluminium in between. The vertical sewer pipe is a polypropene plastic pipe (PP), with sound-reducing properties. All the pipes are certified and widely used in the Finnish building industry.

3.2 Ventilation

The standardised bathroom modules ventilation started to take shape when the regulation for wall-mounted exhaust and fresh air devices were announced. Apartment- specific ventilation has been used before, with the difference that the exhaust was brought to the roof using a lot of space due to the shafts needed.

For every module size the ventilation duct layout differs, but the basic layout principle is the same (see *Figure 7* and *Figure 8).* M-, L- and KHH-modules have the same air handling unit (Enervent Salla), S-, M- and L-modules have all the same two walls for duct reservations. Even though the size and when to use each module differs, the ventilation solutions inside the perimeters of the module are similar, resulting in similar solutions in the living area side.

S-module has an Enervent Pinion air handling unit, being the smaller of the two models, that Bonava Finland uses. There are five duct ports: Exhaust air, extract air, fresh air, supply air and kitchen hood extract, all the duct ports are 125 mm in diameter. Even though the S-module uses a different AHU the functions are the same and the principle for the duct reservations are the same as in the larger modules.

In all the modules there are two reservations for extract air and supply air. Giving the architects and planners more freedom to how they plan the ducts and the suspended ceilings. For architects, the positions of the ducts affect the suspended ceiling. The suspended ceiling can affect the spatial feeling in an apartment quite a lot, for this there has to be active dialogue, between the HVAC designers and architects. The L- and XL-module, which both have a sauna, need a supply air device and extract air device.

All 7 duct reservations are plugged at the prefabrication factory, in order to lower the risk of dirt and moisture getting into the system, when not in operation. Normally a plastic duct cap is used. At Bonava Finland steel caps are used, as some of the duct reservation will not be used and must hold the bathroom modules whole lifespan.

All ducts have silencers installed onto them, making sure that the sounds from the AHU and airflow are below the levels specified in the regulations. Having the silencers inside the bathroom perimeters saves space in the apartment and minimizes the need for suspended ceilings.

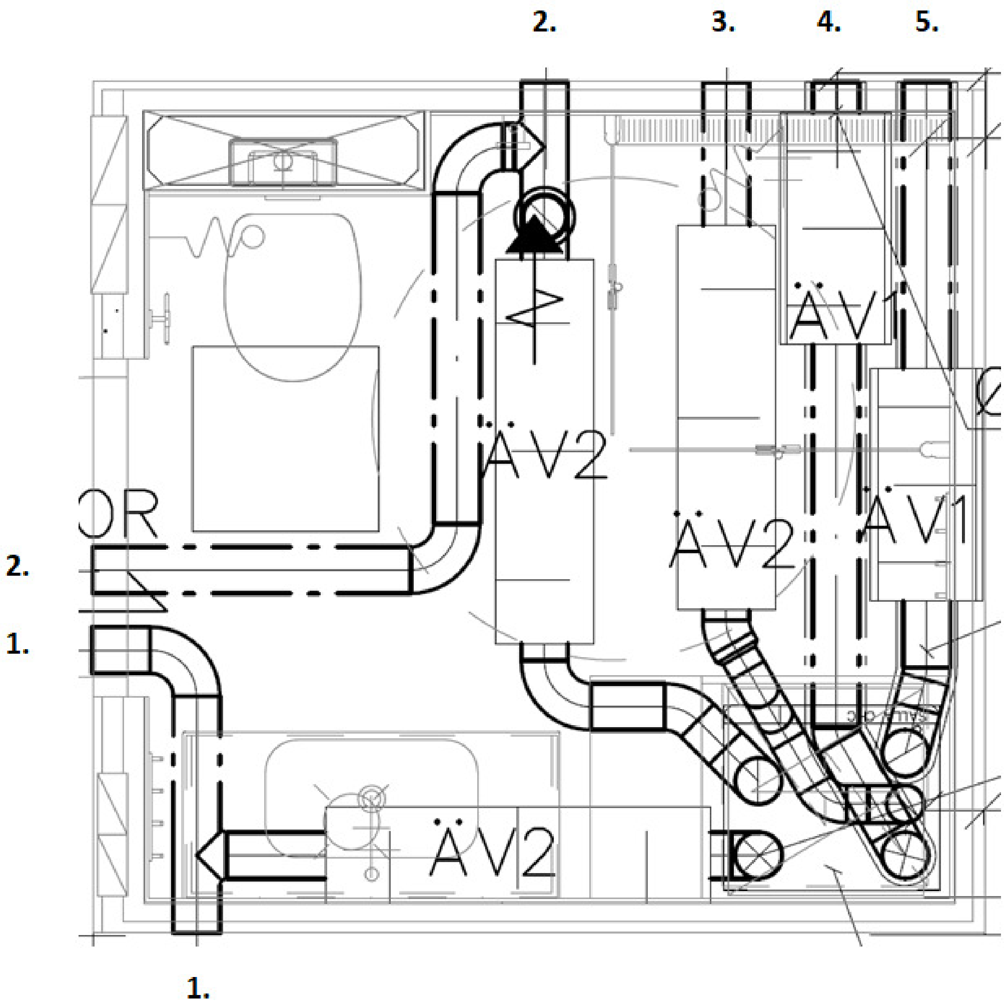


Figure 7: M-module ventilation.

1. *Extract air*
2. *Supply air*
3. *Kitchen extract air hood*
4. *Fresh air*
5. *Exhaust air*

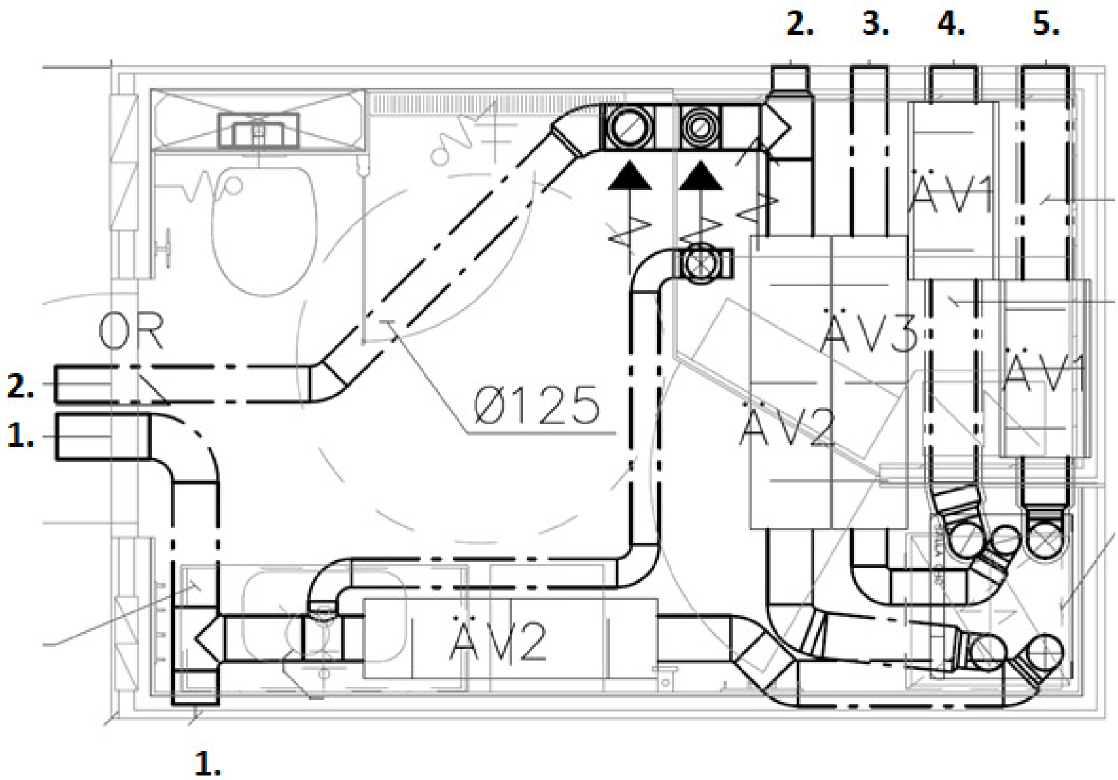


Figure 8: L-module ventilation.

1. *Extract air*
2. *Supply air*
3. *Kitchen extract air hood*
4. *Fresh air*
5. *Exhaust air*

All AHUs installed in the modules have three different settings: away, normal and boost. Normal is for whenever the residents are at home, boost is for when they are cooking, showering or if there are a lot of guests. The boost increases the airflow with 30% from normal. The away setting is for when no one is at home, especially for longer time periods. It decreases the airflow with roughly 30% form the normal level. As an example, in *Figure 9* the apartment airflows are:

- Away 16 l/s
- Home 21 l/s
- Boost 28 l/s

The AHU ventilation settings can be controlled by the resident via a switch placed in the apartment. The resident operates the over-all ventilation according to their need. The kitchen hood is not controlled through the apartment ventilation switch. Instead it has its own switch. The AHU has an own control system, that recognizes the needs of the apartment through a humidity sensor and a connection to the kitchen hood, meaning that if the resident does not want to operate the ventilation switch, they do not have to. The AHU control system, with its sensors is able to control and adjust the ventilation on its own.

All AHU fans must, by law, always be operating. Therefore, a communication channel must be installed into every AHU, making sure that all information about malfunctioning is forwarded immediately. The AHU used at Bonava, Pinion and Salla, comes with an inbuilt Modbus channel, which is a serial communications protocol connecting industrial electronic devices. The Modbus channel allows the AHU to always be connected to the building automations, allowing malfunctioning fans to be mended quickly. More on this in chapter 3.7. /3/

The ventilation layout in the example apartment is quite simple, with the fresh air and exhaust air ducts going through the apartment, close to the apartment wall, in *Figure 9* the exhaust and fresh air ducts go through the apartments balcony to the outside wall. The ducts are installed into a case, which then is covered with a suspended ceiling.

The supply air and extract air ducts and devices are placed in the apartment in positions to make sure that the whole apartment is ventilated. In *Figure 9* there is one extract air device inside the bathroom module and one device in the living area. There are no supply air devices in the bathroom, meaning that the bathroom modules are slightly underpressurised. This is to make sure that all potential odours inside the bathroom does not flow into the living space.

The HVAC-planners try to minimize duct crossings. It is always an extra complication in the installation work, as well as an extra cost. Everything outside the module is installation work that must be done at the actual building site. The silencers, which are needed to keep the noise from the ducts at a low enough level are quite bulky and it helps a lot that the silencers are already installed inside the module, giving the ventilation installation crew an easier job.

There are examples, which are not as easy and simple as the example above. The restrictions of the module can make it complicated, i.e. how the module is turned and how it affects the positions of the modules duct reservations.

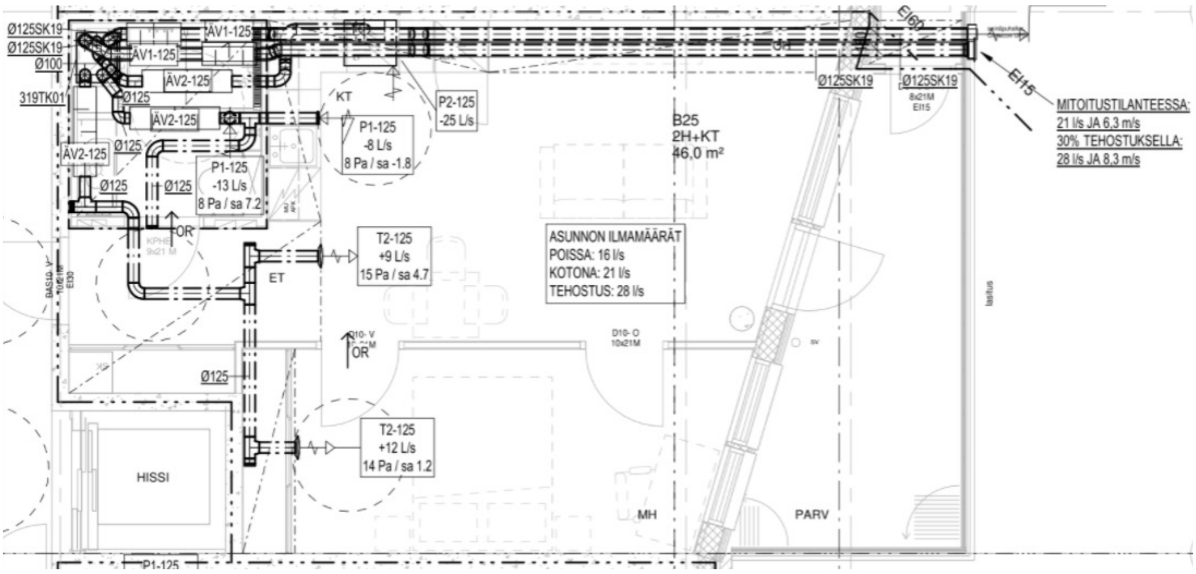


Figure 9: Ventilation plans in an apartment with a M-module.

3.3 Wall-mounted air devices

When the new Indoor Climate and Ventilation Regulation entered into force at the beginning of 2018, many had high hopes that uniform practices could be achieved in the ventilation sector as well, e.g. housing wall blowing. After all, the law is the same for everyone, and the decree states unequivocally that “Exhaust air of class 1 or ventilation of residential apartments can also be led out via an exhaust air device in the wall of a building (wall-blowing/extracting) if the requirements set out in this section are otherwise met. /6/

The ducts on the bathroom modules roof are always in the same positions. The design default is, that the fresh and exhaust air from the AHU would be routed to a combined wall-mounted air device on the building´s façade. In case the location of the wall-mounted air device is other than the default (shortest route to the outer wall and according to the regulations, see Appendix 5), there will be more duct fittings and crossings in the apartments. This may affect the suspended ceiling heights and locations. /3/

When news of the new wall-blowing regulations came, the HVAC team at Bonava Finland started immediately to incorporate the possibility of wall-blowing into their bathroom module design. In order to have the fresh air and exhaust air ducts going through the apartments instead of a ventilation shaft.

The wall-mounted air device blows the exhaust air out at a minimum of 5 m/s, which is enough to make sure that any unpleasant odours and particles does not come back into the apartment through the fresh air intake, which is located at the bottom of the wall-mounted air device shown in *Figure 10*. The HVAC planners must write or illustrate the air flow in the wall-mounted air device in the ventilation plans. In *Figure 9* the dimensioned airflow and air velocity for the normal and boost settings are shown (Normal setting: 21 l/s and 6,3 m/s. For 30% ventilation boost: 28 l/s and 8,3 m/s)

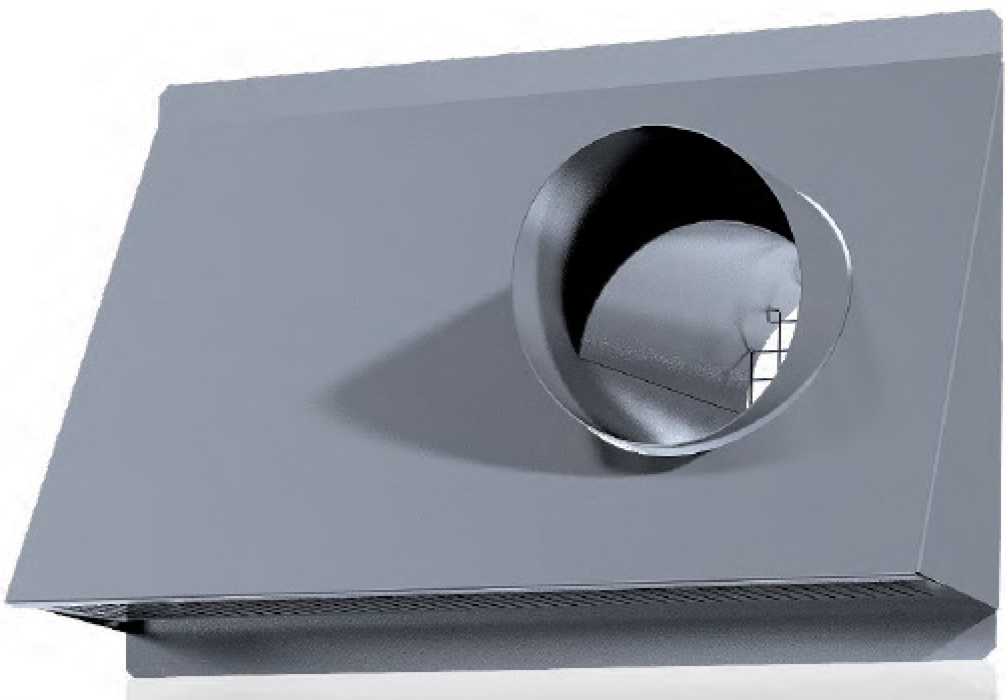


Figure 10: Wall-mounted air device UPSI from Climecon Oy.

The wall-mounted air device must be placed at the wall according to the building regulations. At some sites, the façade consists of glass covered balconies, leaving no space left at the walls for the wall-mounted air device. In these cases, as can be seen in *Figure 9*, the wall-mounted air device is placed outside the balcony glass with the exhaust air and fresh air ducts going through the balcony.

The building control authorities are strict regarding wall-mounted air devices and that the regulations are met. Some cities building control authorities demand computer simulations of projects wall-mounted air devices, making sure that the exhaust air is blown far enough and does not come back into a neighbouring apartments ventilation system. The max amount of exhaust air which is allowed to go into any other device is 5%. The simulations are made with a lot of different weather and wind conditions, in an effort to secure healthy and safe indoor air for all the residents.

These simulations are costly and take a lot of time, one simulation can take upwards of 7 weeks or more. To ensure that the indoor air quality is healthy and safe for all residents, as well as avoiding having to do simulations for the same project many times, the HVAC designers have to be precise when planning. They must follow the regulations and try to place the wall-mounted air devices on the façade that is facing North, as there the air will be cooler and is not affected by sunshine as much. During normal wind conditions in Finland the wind direction will be Southwest. By placing the wall-mounted air devices on the North facing wall, the wind will not affect the wall-blowing as much.

Simulations are done for calm wind conditions and for the most dominant wind conditions simulations are done at 4 m/s and 8 m/s. In *Figure 11*, the most dominant wind condition is Southwest. Simulations are as well done for North, East, South and West. However, only at 4 m/s. The simulations also take into account how the nearby buildings affect the wall-blowing at said project.

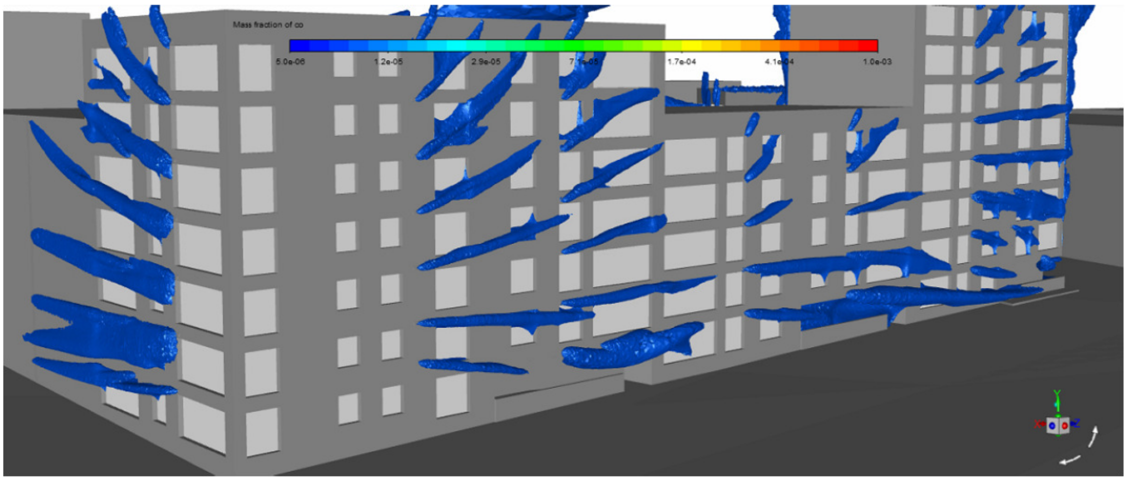


Figure 11: Simulation example of a Bonava Finland project. Southwest wind, 8 m/s.

3.4 Heating

All modules have the same heating principle, both inside the bathroom and outside the bathroom in the living area. The heating inside the bathroom is electrical, using a heating cable that is cast into the concrete slab (see *Figure 15*) at the prefabrication factory. The living area has radiant floor heating, that has a water-based heating network. The radiant floor heating pipes are installed onto the apartments concrete floor and then covered with concrete.

The advantage of a heating cable is that when the floor temperature is adjusted, the change can be felt quickly. Electrical heating cables are faster, than water-based heating, but the heating cables are not as energy-efficient as the water-heated heating systems.

Electrical heating cables are optimal in small spaces for moisture control and comfort, making sure that moisture does not linger inside the bathroom. If rooms are moist for a long time, it could in the long run affect the materials, structures and mold growth both inside the bathroom and outside the bathroom in the apartment.

The possible energy savings from a water-heated floor heating system inside a bathroom are not great enough, as the bathroom would in that case need a separate heating network, with separate pipes and manifolds for the heating energy. The cost, lost space and labour from the materials, larger shaft and designing the network diminishes the use of water-heating bathrooms.

The dimensioning of the heating pipes is based on the average apartment size, floors and need for heating energy, as well as making sure that the heating pipes fit into the shaft. Radiant floor heating is preferred to radiators, as floor heating can have smaller heating water temperature differences, compared to radiators. The low heating water temperature differences works well with the district heating networks in most Finnish cities.

3.5 Water

The domestic water system uses three pipes, which can be seen in *Figure 5* and *Figure 12*. One for cold domestic water, one for hot domestic water and one for circulating hot domestic water.

The circulating hot domestic water pipe brings the hot domestic water back down to the heat distribution room, by constantly circulating hot water through the building, there will always be hot water available in 20 seconds. 6§ in the water and drainage regulation chapter, specifies this amount of time. The calculated heat loss is smaller when the water is circulating compared to only having a domestic hot water pipe, where the water would be stationary and lose its energy into the building. It is also important to follow the temperatures mentioned in 6§ for water and drainage, as the legionella bacteria multiply in temperatures 20°C- 45°C.

The domestic water pipes in the pipe shaft are 32 mm, 32 mm and 20 mm, as can be seen in *Figure 5*. These pipes are insulated, making sure that the water temperature is less affected by the surrounding temperature and making sure that the temperatures stay within the specifications in 6§.

The pipes from the pipe shaft to the domestic water manifold are composite pipes made of PEX and aluminium. The domestic water pipes from the domestic water manifold to the different water points are PEX pipes. The size of these pipes is determined by the flow (dm^3/s) and the speed (m/s). The maximum water velocity for cold domestic water is 4,0 m/s and for hot domestic water 3,0 m/s. These specifications are set to prevent corrosion in the pipes.

Water meters are installed per 10§ (2.1.4), before the domestic water manifolds as can be seen in *Figure 12*.

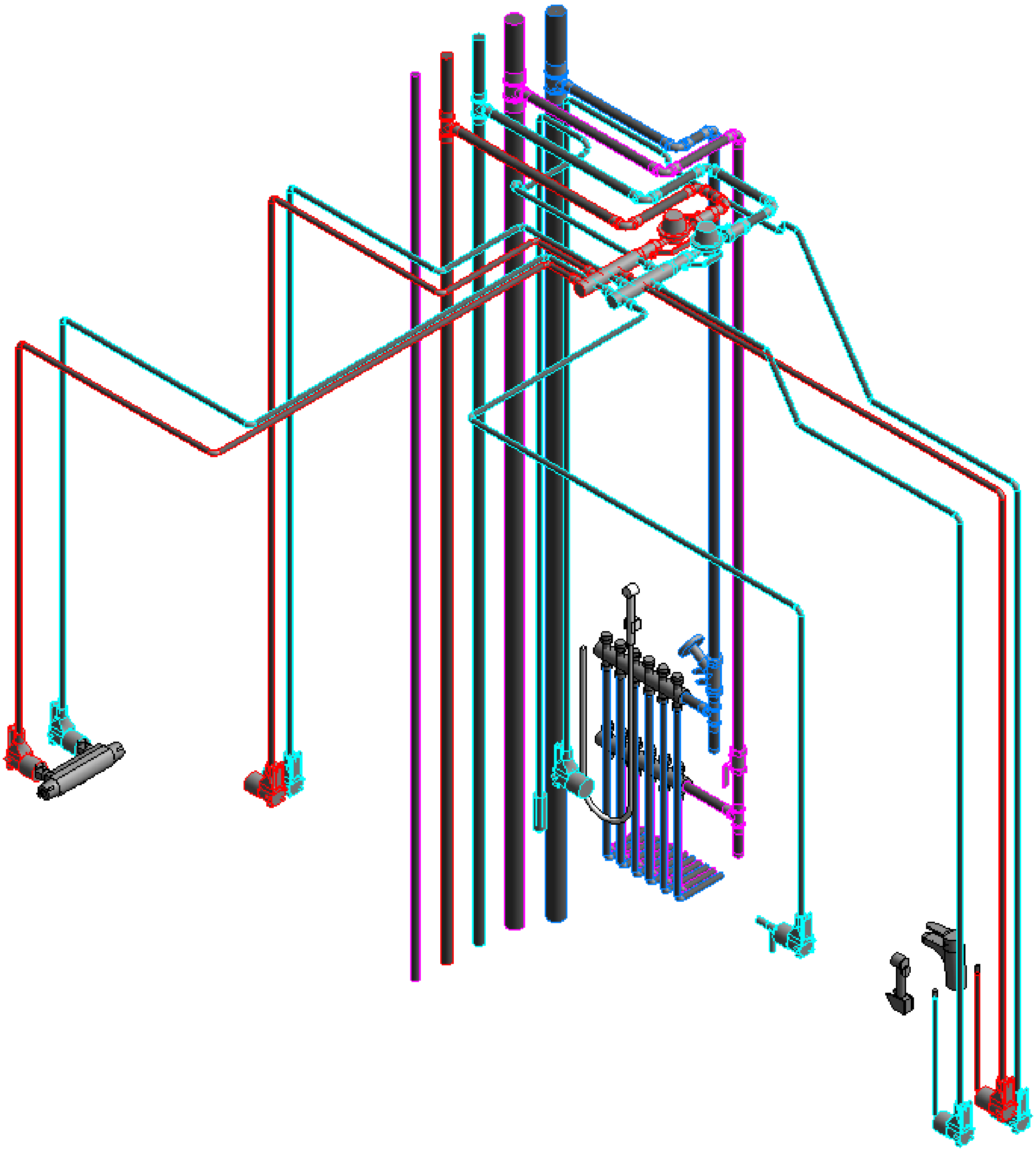


Figure 12: M-module domestic water and heating systems.

3.6 Drainage

The basic drainage design and layout is the same in all Bonava Finland modules, making the manufacturing process easier and minimizing errors.

The drainage pipes vary in size, in *Figure 13* there are 12 mm, 32 mm, 75 mm and 110 mm size drainage pipes. These drainage pipe sizes are widely used in the building industry. The toilet drain and the vertical sewer are 110 mm, the pipes feeding into the vertical sewer are 75 mm (shower drain, floor drain and kitchen drain). The pipes feeding into the floor drain are 32 mm and 12 mm (AHU condensation drain, washing machine drain and the washbasin drain). The drainage pipe dimensions are the same in all the modules.

The drainage pipes from the AHUs, which can be seen by the naked eye are 12 mm chrome plated copper pipes. The rest of the drainage pipes are made of a polypropene plastic (PP), with sound-reducing properties. There is a water trap that services the AHUs, as it is imperative that all unwanted odours are blocked from going into the ventilating system. The larger AHU Salla has a water trap built-in and Pinion, which is the smaller AHU has one installed outside the AHU. The prospect of having odours coming all the way from the vertical sewer into the ventilation system, is why these water traps are installed. The floor drain and shower drain have their own water traps to ensure that these odours do not reach into the module air.

It is important that the drainage system and layout take up as little hight as possible, as it affects the concrete slab thickness. It is important that the shower and floor drain designs are as low as possible, because they are the starting point for the drainage pipes. The floor and shower drain models, which have inbuilt water traps, must be shallow and need to start feeding the wastewater onwards as soon as possible. Wasting drainage height from the beginning must be prevented. This why the floor and shower drain models that are chosen, are connected to the drainage horizontally.

The drainage pipes are cast into the concrete slab at the prefabrication factory. The pipes are placed and reinforced inside a casting frame. When the pipes are installed the whole frame is lifted upside-down, onto a casting mold, which has the whole bathroom modules desired floor slopes premade. After this concrete is cast inside the frame and where the pipes are then covered. An example on how the drainage pipes are assembled and cast into the slab can be seen in *Figure 14* and *Figure 15*.

The kitchen drain reservation forces the kitchen to be designed along the wall of the bathroom module. Having the kitchen in the immediate proximity of the module saves having separate vertical sewer shafts for the kitchen drain. In some cases, larger apartments have been designed with a kitchen that is separate from the bathroom module. An extra vertical sewer shaft must be fitted into the apartment, leading to additional design time and costs at the building site.

The drainage points, that are not positioned on the floor are all inside the modules wall structure, i.e. AHU condensation drain, washing machine drain and the washbasin, with its water trap. These drains still connect into the floor drain. From there the drainage continue into the vertical sewer.

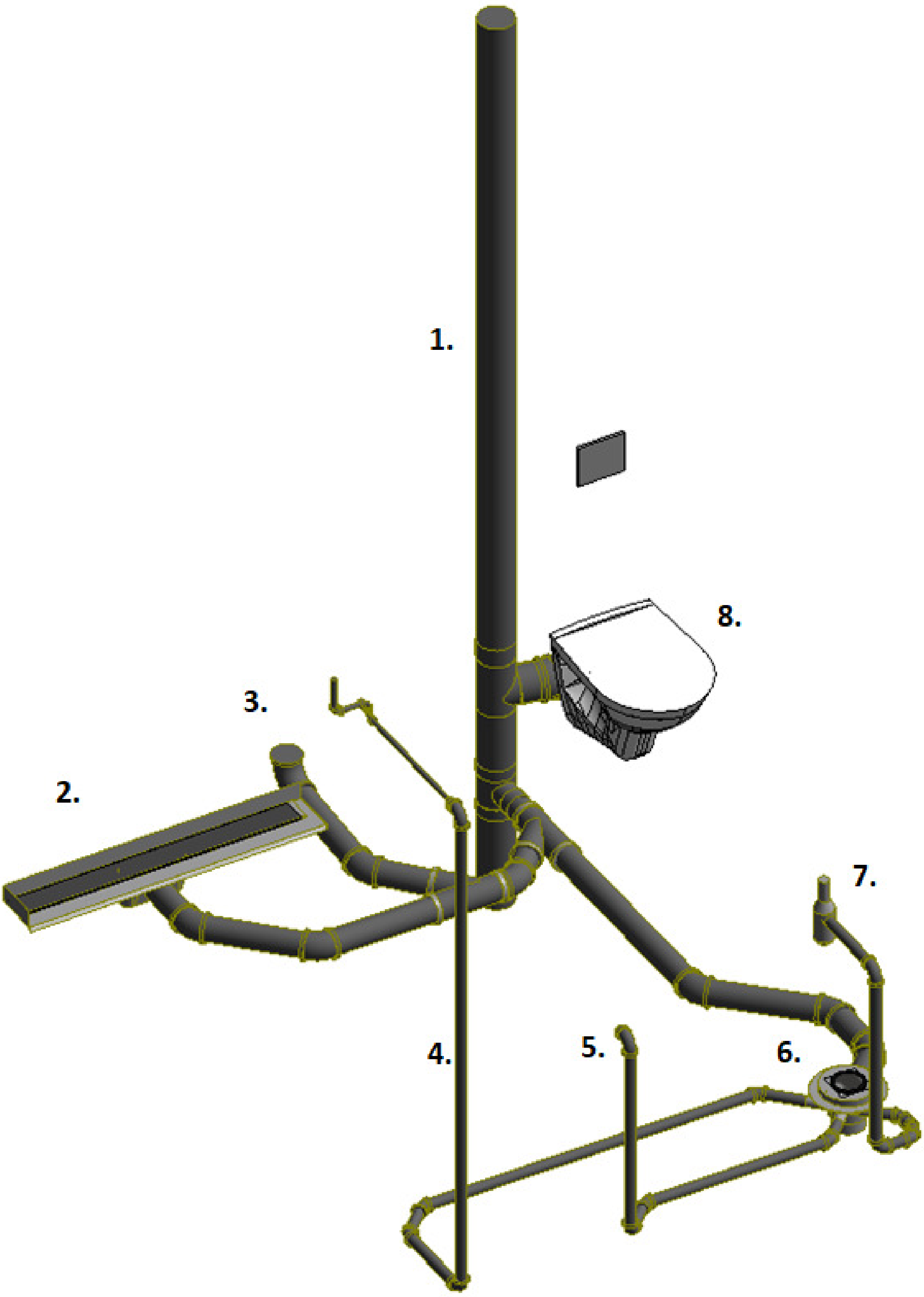


Figure 13: M-module drainage system.

1. *Vertical sewer pipe Ø110 mm*
2. *Shower drainage Ø75 mm*
3. *Kitchen drain Ø75 mm*

4. *AHU condensation drainage*
5. *Washing machine drainage*
6. *Floor drainage DN 75 3×32/40*
7. *Washbasin drainage and trap*
8. *Wall-mounted toilet seat*

3.7 Automation

All Bonava modules have standardised apartment-specific automation, used for communication with the AHUs and apartment-specific water meters.

Modbus is a traditional master / slave serial communication protocol used in industry and building automation, used for communication between electronic devices.
In building automation, it means connecting a field device to a monitoring computer. Modbus enables communication between many devices connected to the same network, such as a system that measures temperature and humidity, and transmits the results to a computer. The Modbus system is an open, royalty-free standard. It transfers raw data without restrictions from device manufacturers. Modbus can be implemented as both wired via cables and wirelessly (in Bonava homes, the AHUs have a wired connection and the apartment-specific water meters are wirelessly connected). /3/

The controls of the apartment-specific AHUs are standardised so that they are easy to use for the resident. The most frequent activities that require ventilation boosts, are cooking, showers, sauna and laundry drying. The AHUs can change the ventilation needs through its sensors and control-unit. However, the resident can also switch the boost on manually. Modbus comes as a standard with the modules control-unit.

Reporting malfunctions of the AHUs and ventilation must not be solely the responsibility of the resident. Apartment-specific AHUs are required by law to run at all times. The housing association cannot take the risk that there are apartments in the property where the AHU fans have been out of operation for long periods of time (the alarm to the building automation only goes out when the fans malfunction).

Malfunctions may go unnoticed even when the resident is at home. Directing alarms to building automation also ensures warranty issues with the AHU supplier. Without Modbus all the AHUs would have to be separately connected to the building automation. Alarm information from AHUs is required either way. /7/

3.8 Electricity

The bathroom modules electrical shaft is placed on the wall with the module door. The electrical shaft restricts which of the modules can be stacked on top of each other. As mentioned earlier (3). The electrical shaft serves all electrical components in each apartment. The electrical distribution board is located on the module wall with the door. Sockets are placed according to where they are needed. The lights are integrated to the ceiling.

3.9 Limitations and restrictions of the solutions

It was accepted at an early stage of the Bonava Finland bathroom module project that the solutions will affect and restrict many aspects of designing and building multi-storey apartment buildings. It was important that the solutions, which were applied were justified and would bring with it more positives than negatives. Bringing modular building principles into a positive light and getting the most out of them.

Visually the most significant limitations of the bathroom modules are how the modules affect the architectural planning, forcing all bathroom modules in one pipe shaft to be the either left- or righthanded, effecting the apartment layouts. There are limits locating bathroom modules on different floors: the location of pipe shafts and electrical riser shafts need to be in exact same location in different floors. Some modules have different door side wall lengths, which limits some modules from being on top of each other. /3/

The installation hight of the bathrooms is very precise. There is very little empty space on it, which forces the structural designers to be precise. They also have to take into account the bending and sinking of the prefabricated concrete hollow slabs. /8/

The kitchen drain reservation in the module forces the architects to plan the kitchen immediately next to the modules. If the kitchen were too far away from the module, there would have to be an additional vertical sewer shaft, meaning that some apartment layouts, which would otherwise be preferred cannot be used. /4/

4 PRODUCTION

Harmet is an Estonian company, which specialises in building modules and they manufacture all Bonava Finland bathroom modules. The relationship between Bonava and Harmet is B2B, Bonava in the role of orderer and Harmet as manufacturer. Bonava has designed and planned the bathroom modules, which Harmet manufactures.

The relationship started in early 2018, first through planning and then producing a demo bathroom module. The first bathroom modules shipped from Harmet to Bonava building sites in October of 2018. Bonava has so far ordered roughly 1400 bathroom modules and Harmet has shipped around 1100 modules, as of March 2020.

4.1 Manufacturing

Harmet manufactures these modules in so-called laboratory conditions, meaning that normally bathrooms are built on-site in dirt, dust and moisture. At a module factory there is none of that. Cleanliness, safety and well-lit working spaces, makes sure that every module is built in the same way and with the same materials.

First thing to happen is the manufacturing of the concrete slab, which is the base of every module. In the casted concrete is the bathrooms drainage pipes, which are assembled and casted in the concrete the same way every time. As concrete is not waterproof, a layer of waterproof rubber is applied, a water seal.

When the water seal has dried, the assembling of tiles and the walls begins. The walls are already tiled when they are assembled to the base.

When the base and the walls are finished, the roof of the module is connected to the walls. The roof is premade, with ventilation pipes, water meters, manifolds and other parts already connected. As the roof is premade, the workers assembling the roof are able to build it on a normal working surface at a normal working height. No need for climbing and working on dangerous heights.

When the base, walls and roof are assembled, most of the work left, is inside the bathroom module. The toilet seat and other furniture is put on their places. Then the lights, Air Handling Unite and the rest of the electrics are assembled and put in place.

4.2 Lieksa Factory

Harmet has two factories which produces bathroom modules for Bonava, of these two factories one is in Lieksa. In Lieksa, they build Bonava's M and S bathroom modules.

The manufacturing procedure is exactly the same for every module model. Some parts are a different size and so forth, but the main order of manufacturing is the same. First the base, then the walls, roof, lastly furniture inside the bathroom and electrics.

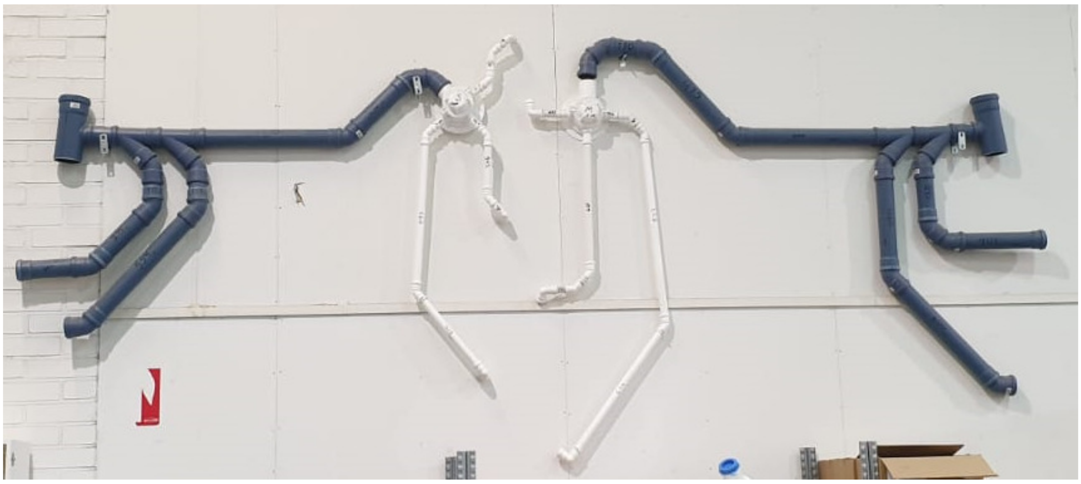


Figure 14: Drainage layout at the prefabrication factory.

Figure 15: Drainage pipes and electrical heating cables installed into the slab cast.

Figure 16: Ventilation equipment assembly.

The module moves from spot to spot on the production line, which makes it easy for the workers as they have their equipment to assemble the bathroom module close and ready. Then the module moves along for the next step.

The factory in Lieksa was in good order and very clean. It probably helps with the fact that in Lieksa they only produce modules for Bonava.

4.3 Kumna Factory

Harmet´s Kumna factory is located in Estonia, 30 km from Tallinn centre. The factory in Kumna is Harmet´s main factory and they produce a lot of different modules for different companies. Bonava´s L, XL and KHH modules are manufactured in Kumna and they only take up a small part of the factory floor.

Kumna´s manufacturing line was not as clean and in order compared to Lieksa. This made everything more disorganised. If the two manufacturing lines, was to be studied the one in Lieksa would probably be the one with the better result. In that sense it is fortunate that Lieksa already produces up to 70-80% of all the Bonava modules as M and S size modules.

4.4 Thoughts on the production

The manufacturing by Harmet is fairly good. The relationship between the two parts seems to be positive and there is a lot of discussion between the two parties. Most of the discussion is regarding changes in the plans of the modules. Harmet have been able to produce the modules according to the plans and with minimal quality problems.

Bonava and Harmet will continue their work together, making sure the process is as effective as possible. It would help out both companies if Bonava would be able to order the modules in a steadier stream, than the current one. This would ensure that the effectiveness is higher at Harmet and Bonava could trust more in the quality and delivery.

4.5 Bathroom module procurement at Bonava Finland

The fact that Bonava have chosen to have 5 standard products, has helped to balance the procurement team´s and the module factories variable load, so that the factory has been able to premanufacture products and thus been able to meet demands during upturns.

To improve supplier, factory and site logistics management it is paramount that all are able to work with one common inventory program. So far, this has not been possible due to company policies. For Bonava Finland all this means that half of one person's workload has to be focused on procurement management and logistics of the bathroom modules.

The bathroom module is co-owned together with Harmet, meaning that the planning and designing of the modules is the responsibility of Bonava Finland. Harmet´s responsibility is the manufacturing of the modules and making sure that everything is according to the Bonava Finland design´s. When there are problems with the product it is not always clear who is responsible. Is the fault in the design or manufacturing. Also, who is responsible to get the authority approvals for the product is not always clear, as Bonava Finland owns and is responsible for the design´s and all visible materials i.e. floor tiles, cabinets and visible water devises. Harmet owns i.e. floor- and wall structures.

For the procurement team one of the challenges has been with the delivery logistics, reclamations and with the component and device suppliers. Bonava Finland and Harmet logistics chain needs some changes to work effectively. Having the right components ready for when they are needed, has been a challenge. Having many parties in the process makes reclamations difficult. Finding out who is responsible for the bathroom modules and their equipment at different stages. Another challenge has been, how to support construction sites in the delivery phase and how to report defects and deficiencies that has been found.
/9/

5 THOUGHTS ON THE PROJECT AND PROCESS

For this chapter, interviews were made with bathroom module design team members and outside collaborators i.e. architects and designers, who works with Bonava Finland at various projects. The team had architects, interior architects, HVAC designers, Building System designers, electrical designers and members from the procurement department in an effort to get a perspective from different areas of expertise.

These thoughts and comments were gathered through interviews and emails. There were different questions according to area of expertise. However, all were asked to share their general thoughts on the project as a whole, the process and the finished product. After this, all were asked more area of expertise specific questions and how the product has affected their work, i.e. how the product effects HVAC designers time spent on a project or how architects are able to work with bathroom module restrictions.

From a HVAC design and planning process point of view the bathroom module has reached the goals, which were set in the beginning. In the future there most likely will be some changes to HVAC equipment brands and materials. Naturally, the HVAC layout will be tinkered with and updated along the possible bathroom layout updates. The main technical principles will most likely stay the same and the design team will strive to keep as much as possible prefabricated. /3/

Once the designers understand and know the measurement and dimensions of the modules, it is easier to find solutions. Planning is speeded up by the fact that bathroom diagrams are not needed, planners do not have to spend time making sure the accessibility standards are met. The bathrooms are already pre-designed (ready-made DWG-files that are functional and practical) and save design time. The HVAC designing of the building is substantially reduced in the residential floors, especially heating, water and sewer design. When HVAC designers understands how the modules dimensions and reservations work in an apartment the restrictions of the modules are not that difficult to work with.

HVAC design inside the modules is eliminated, meaning that the designers can focus on other projects and are more efficient. Having complete bathroom DWG files, which are easy to add to any project, eliminates any extra time spent on trying to figure out where and how a HVAC technology works in the project. /10/

It was challenging for project architects at the start, as all apartment layouts had to be designed from the beginning. As more and more building projects were designed the architects gathered all apartment examples which were determined to be functional, logical and had a nice layout. These apartment designs were used as reference for new projects. Ventilation ducts in apartments are usually problematic as they need to be covered with suspended ceiling. The bathroom ventilation solutions, the fresh and exhaust air duct designs, which comes with the bathroom modules are easy to perceive, meaning that the planning of suspended ceilings is manageable in most cases. /4/

As the Bonava Finland bathroom module project has been ongoing for a long time, it is difficult to see the actual results before the first residents has moved in. From starting the project in the beginning of 2018, to installing the first bathroom modules and having the first residents moving in in the fall of 2019, all calculations on efficiency and time saved are speculative. In 2020 more accurate calculations have been made as more projects have been completed. Time saved has not been achieved in all projects (it is difficult to determine what the reason is), however there has been successes as well. Any time saved at building projects reduces cost.

Regarding cost benefits there are differing opinions, however calculations made by Bonava Finland show that cost benefits have been made and money has been saved. There are benefits and profits through the bathroom module and its solutions. /1/

6 CONCLUSIONS AND CONSIDERATIONS

The goal of this thesis was to showcase the Bonava Finland bathroom modules and to explain the technical solutions and designs, in order to help the rest of the Bonava Concern to design their own bathroom modules. To show and explain the regulations that have the most effect on the bathroom module designs and the whole building industry. The bathroom module process has come the furthest in Finland, with well over a thousand bathroom modules installed, giving everyone involved a lot of experience.

The whole Bonava Finland prefabricated bathroom module project has been extremely time consuming, with a lot of discussion, planning and testing. Figuring out what technical solutions are possible and are they justified. How much can the technical solutions restrict the architectural and structural design and planning.

For new architects, the modules can seem strange and difficult to work with. However, after getting used to them and seeing example apartment layouts, most are comfortable with them and are able to produce enjoyable and functional homes.

The most important aspects that steered the modules to their design, was the team's willingness and desire to design a pipe shaft, that is compact, functional and easy to install, as well as starting to research and implement the new wall-blowing possibilities. The team managed to design the pipe shaft with the wall-mounted toilet seat frame, as well as the toilet seats water tank, saving space both inside and outside the bathroom.

The Bonava Finland bathroom module products and process, are developing constantly, fixing and changing issues, streamlining the logistics and improving on the technical designs. Updates will be made as long as they are improvements.

7 SAMMANFATTNING

Examensarbetet handlar om VVS-lösningar i prefabricerade och standardiserade badrumsmoduler för nybygge av bostadshöghus. Uppdragsgivaren för examensarbetet var Bonava Suomi Oy. Syftet med arbetet är att presentera, förklara och analysera Bonava Suomis standardiserade badrumsmoduler och den teknologi som ingår i dessa badrumsmoduler. Målsättningen med detta arbete är att det skall befrämja Bonava koncernens byggnadsverksamheter och badrumsmodulsplanering i Sverige, Norge, Danmark, Baltikum, Ryssland och Tyskland.

Arbetet med att planera prefabricerade och standardiserade badrumsmoduler på Bonava Suomi har pågått sedan början av 2018. En arbetsgrupp bestående av experter från olika yrkesområden har planerat 5 stycken badrumsmodul modeller som skall användas i alla nybyggen av höghus.

Examensarbetets fokus är speciellt på VVS-lösningarna i de 5 olika badrumsmodulerna, men också på modulernas påverkan på arkitektur, byggnadsteknik, logistik och planering. Arbetet är uppbyggt genom att först presentera arbetsgruppens mål med badrumsmodulerna, sedan de finska byggbestämmelserna. Som följande presenteras badrumsmodulerna och deras lösningar. I nästa kapitel presenteras fabrikerna där badrumsmodulerna blir tillverkade och i sista delen presenteras Bonava Suomis arbetsgrupps tankar om badrumsmodulerna, teknologin i modulerna och själva planeringsprocessen.

Informationen och litteraturen i examensarbetet kommer från Miljöministeriets byggbestämmelser, föreskrifter från *Talotekniikkainfo.fi*, samt intervjuer med experterna i arbetsgruppen och andra samarbetspartner.

Badrumsmodul målen är uppdelade som helhetsmål, VVS-tekniska mål, arkitekturella mål och ekonomiska mål. Denna information är till stor del samlad från experterna i arbetsgruppen. Bland de viktigaste helhetsmålen var att planera och producera standardiserade badrumsmoduler som skall användas i alla Bonava Suomi projekt. Med standardiseringen blir det mindre tid spenderat på badrums design, då när byggprojekten planeras. På det viset effektiveras planeringen och mindre design fel uppstår i själva planeringen.

Följande mål är att förbättra badrumskvaliteten. Badrumsmodulerna byggs skilt i fabrik, där förhållandena är torra, ljusa och ergonomiska. På detta vis förbättras kvaliteten, då det finns mindre störande element som skulle påverka.

För VVS-experterna var det viktigt att planera VVS-system för badrummen, som är moderna, kompakta och simpla. VVS-experterna ville planera ett schakt för VVS rören (Vatten, värme och avlopp), som fyllde kriterierna om att vara moderna, kompakta och simpla. Samtidigt skulle schaktet befrämja standardiserat modulärt byggande på ett bättre vis än traditionella metoder.

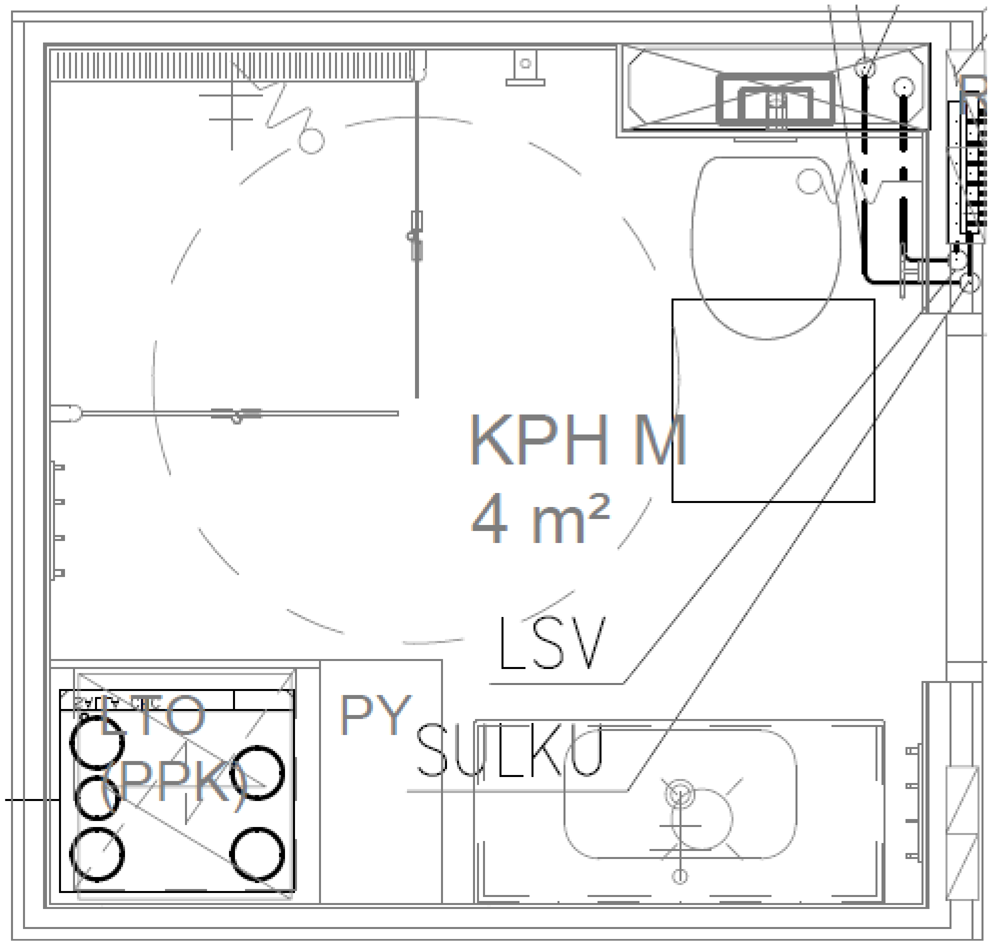
Vid årsskiftet 2018, trädde nya byggbestämmelser för ventilation i kraft. Största ändelsen i bestämmelserna var möjligheten att blåsa frånluft ut genom bostadshusens fasad. Tidigare var det tillåtet att endast ta in uteluftflödet genom husens fasad. Frånluften skulle ut genom taket. Genom att blåsa frånluften genom frånluftsdon på fasaden minimeras mängden frånluftsschakt i byggnaden. Möjligheten att blåsa frånluft genom ytterväggen påverkade planeringen av modulen starkt.

Det är viktigt att presentera de finska byggbestämmelserna, eftersom detta arbete kommer i huvudsak att användas utomlands, där byggbestämmelserna är olika. De VVS-tekniskt viktiga byggbestämmelserna, finns tillgängliga på Miljöministeriets hemsida, samt på *Talotekniikkainfo.fi*. Tankarna, idéerna och lösningarna i Bonava Suomis badrumsmoduler blir enklare att förstå, då byggnadsbestämmelserna också har blivit presenterade. Det är samma byggbestämmelser som gäller för badrumsmoduler och traditionellt byggda badrum i Finland.

Följande del i examensarbetet handlar om badrumsmodulerna och deras tekniska lösningar. Det finns 5 stycken olika badrumsmodul storlekar, S-, M-, L-, XL- och KHH(tvättstuga)-modulen. Av varje modul finns det en vänster och högerhänt version. De vänster och högerhänta versionerna är varandras spegelbilder, med exakt samma design och tekniska lösningar. På det viset får arkitekterna mera frihet i hur de planerar lägenheters bottenplan. Badrumsmodulerna har alla samma VVS principer. Samma avlopps-, vatten-, värme- och ventilationsdesign. Bonava Suomis ventilationsprincip i badrumsmodulerna är balanserad ventilation med ett fläktstyrt till- och frånluftssystem med värmeåtervinning.

Ventilationsaggregaten som används är bostadsspecifika, vilket betyder att varje lägenhet har ett eget ventilationsaggregat. Normalt brukar ventilationen i bostadshöghus vara centraliserat till ett stort ventilationsaggregat. Med bostadsspecifika ventilationsaggregat blir styrningen simplare ur ett planeringsperspektiv och kräver mindre ventilationsschakt. Bonava Suomis lösning med utelufts och frånlufts blåsning ur fasaden, så behöves inga ventilationsschakt. S-modulen har Enervent Zehnder Oy:s Pinion ventilationsaggregat och M-, L- och KHH-modulen har Enervent Zehnder Oy:s Salla ventilationsaggregat. Skillnaden är storleken på aggregaten.

S- och M-modulerna (se *Figur 1*) är de som används mest i Bonava Suomis byggande och de är också de två minsta modulerna. S-modulen är 3 m^2 och används i lägenheter under 40 m^2, vilket betyder enrummare och tvårummare. M-modulen är 4 m^2 och menad för lägenheter mellan 40 och 60–70 m^2 stora. S- och M-modulernas bottenplan är väldigt lika, S-modulen är som en förkrympt version på M-modulen.

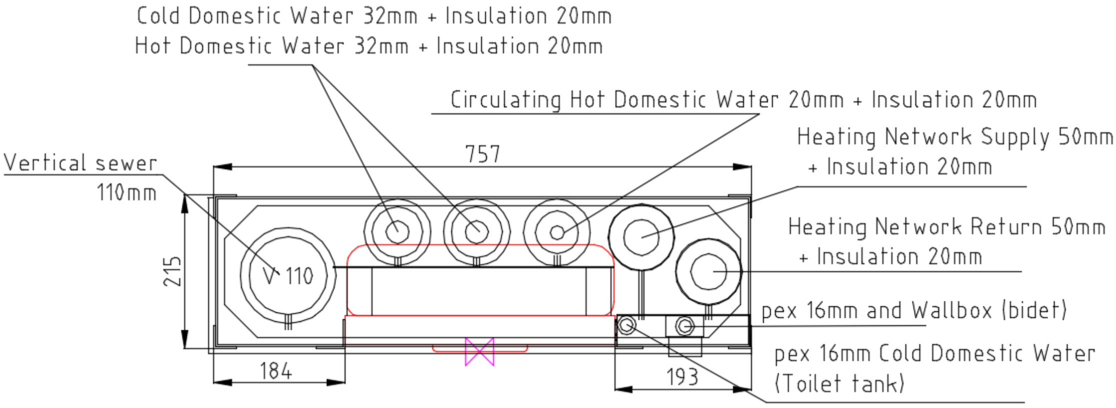


Figur 1: Bonava Suomis M-modul.

L-modulen har liknande design som M-modulen, skillnaden är att den är 7 m^2 och har en bastu för 2–3 personer. Själva dusch, toalettsäte och handfat layout är så gott som identiska. L-modulen används i lägenheter mellan 60 och 90 m^2.

XL- och KHH-modulerna är menade att fungera som ett par i större lägenheter, 90 m^2och större. XL-modulen har en bastu för ca. 4 personer. XL-modulen har inget ventilationsaggregat, utan lägenhetens ventilationsaggregat är placerat i KHH-modulen. KHH-modulen har samma dimensioner som S-modulen.

Rör schaktet som arbetsgruppen planerade är en skild modul som installeras in i badrumsmodulen i fabriken där badrumsmodulerna byggs. Schaktet har avlopps-, vatten- och värmerör, Se *Figur 2*.



Figur 2: VVS-rör schaktet.

Badrumsmodulerna har ett vägghängt toalettsäte, som är installerat fast i schaktet. Toalettsätets installationsram och spolcistern är båda inbyggda i schaktet. På detta vis sparas utrymme i badrummet.

Avlopps-, vatten och värme principen är identisk i alla modulstorlekar. Vissa avstånd skiljer sig då modulerna är olika stora. Rörens storlekar, material och isolering är samma. Vilket gör det väldigt enkelt att införskaffa materialet för modulerna, då samma komponenter används i alla moduler.

Modulerna byggs av Harmet, som är ett estniskt företag som specialiserar sig på att bygga moduler. Harmet har produktion både i Estland och Finland. Modulerna byggs i så kallade laboratorieförhållanden, där det inte finns problem med fukt, dålig belysning och arbetsförhållandena är mer ergonomiska för installatörerna jämfört med själva byggplatsen. Kvaliteten blir bättre och det finns mindre risk för problem med de färdiga badrumsmodulerna.

Bonava Finlands badrumsmoduls arbetsgrupp beddes att uttala sig om de färdiga badrumsmodulerna. Vad de tyckte om själva produkten, hur de påverkar deras arbete och själva planeringsprocessen. VVS-planerna anser att de sparar tid då de inte behöver planera badrummet själv och kan fokusera på det som sker utanför badrummet. Badrum brukar vara den del av planeringsarbetet som är mest krävande.

Arkitekterna menade att i början är det svårt att producera bottenlösningar som är logiska och praktiska, då badrumsmodulen har många begränsningar, t.ex. alla badrumsmoduler måste vara rakt ovanför varandra i en så kallad stapel. Dessutom måste alla badrumsmoduler i en stapel vara samma handa. Antingen måste alla badrumsmoduler i en stapel vara högerhänta hela vägen, eller sedan vänsterhänta hela vägen. Men arkitekterna menade också att sedan då de blivit vana med badrumsmodulerna så är det inte svårt mera.

Anskaffningsavdelningen som ansvarar för beställningen av badrumsmodulerna och deras komponenter, menade att det har blivit simplare då alla badrumsmoduler använder samma komponenter. Men att logistiken och tidtabellsplaneringen för hur och när badrumsmodulerna anländer till byggplatserna ännu kräver mycket jobb.

Bonava Finlands Buildings System avdelning, som ansvarar för badrumsmodulerna som helhet. Har åsikten att de flesta av målen som var gjorda i början av badrumsmodulsprojektet har uppnåtts. Dessutom så visar deras kalkyler att badrumsmodulerna har gett Bonava Finland besparingar. De jämför kalkylerna, med traditionella badrum och badrumsmoduler som använts tidigare (dessa badrumsmoduler var inte standardiserade).

Bonava Suomi´s badrums modul projekt har varit mycket tidskrävande och väldigt många olika delar i sig. Som en helhet är alla som har varit med i projektet varit mycket nöjda med resultatet. De restriktioner som badrums modulerna har fört med sig är inte för svåra att handskas med. Då nya planerare första gången bekantar sig med badrums modulerna så tar det inte långt tid för dem fr att känna sig bekväma med produkten. Lönsamhetskalkylerna som har gjorts, visar att badrums modulerna som en helhet är lönsamma och sparar företaget resurser.

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/9/ Yliollitervo, J. (2020, April 24). Bonava Operational Procurement Manager.

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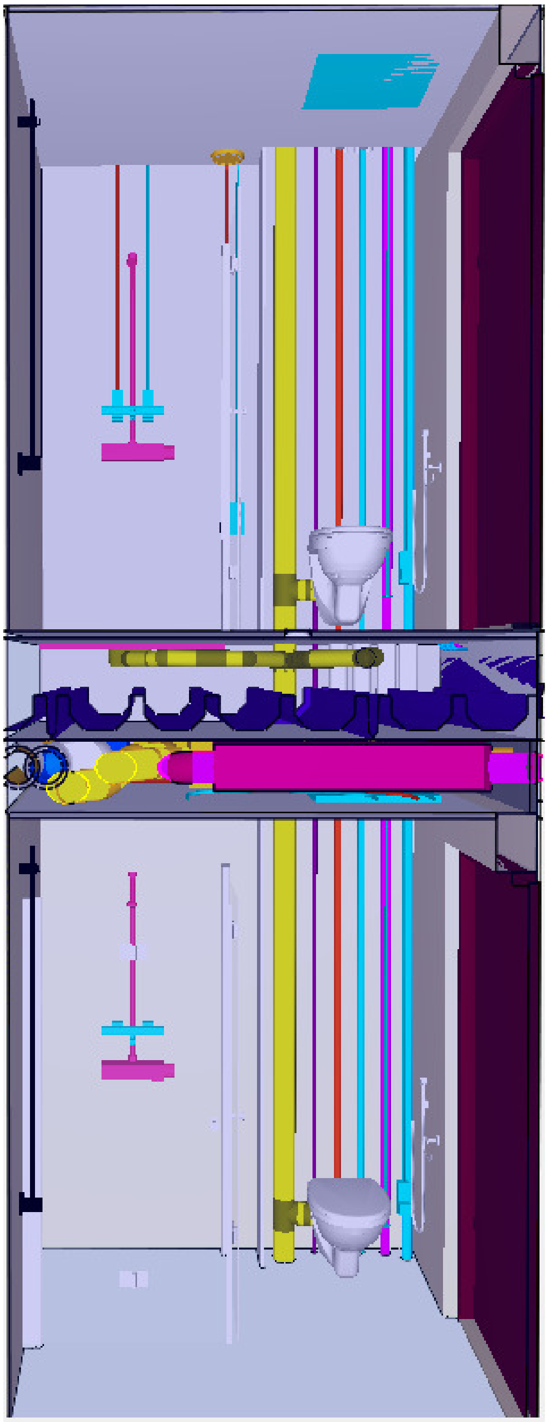
Appendix 1

Pipe shaft Example from a Bonava project

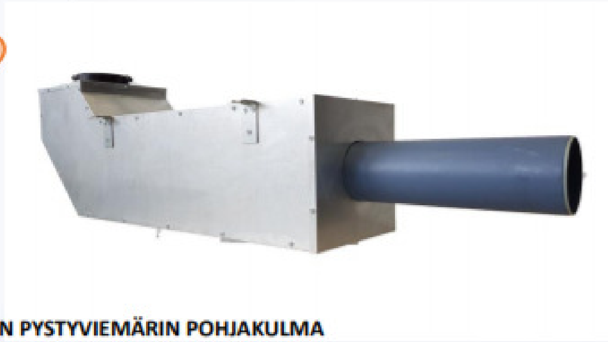


APPENDIX 2

Sound insulated vertical sewer Bend

LINING POHJAKULMA 110

UUTUUS

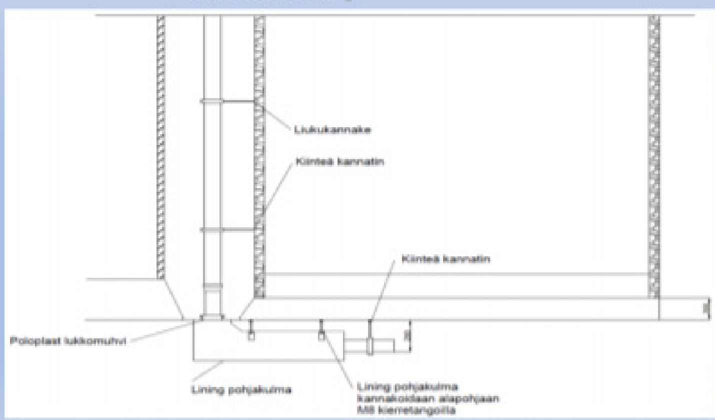


RAKENNUKSEN PYSTYVIEMÄRIN POHJAKULMA

Rakennuksissa pystykokoojaviemärin pohjakulma on kohta, jossa jäteveden virtauksesta syntyy usein voimakasta ääntä.

Lining pohjakulma on ääntä vaimentava valmis osa, joka helpottaa ja nopeuttaa työmaalla tehtävää asennusta. Keveydestään johtuen tuote on asennettavissa yhden henkilön voimin.

- **Ääntä vaimentava.**
- **Koteloitu ja valmiiksi äänieristetty.**
- **Helppo ja nopea asentaa.**
- **Lukkomuhvi takaa varman liitoksen.**
- **Putki 110 mm.**
- **Paino vain 20 kg.**



VERKOSTOTEKNIIKKA

PROJEKTILIIKETOIMINTA

TALOTEKNIIKKA

Tiilenlyöjänkuja 9 B, 01720 Vantaa
Puh. 029 006 160
www.lining.fi

Lining INDUTRADE GROUP

Yhdessä vastuullista vesitekniikkaa

Wall-mounted air devices used at Bonava Suomi projects

CLIMECON

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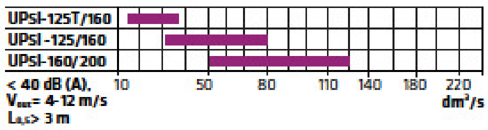
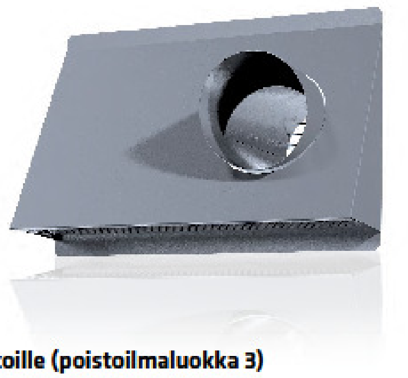
UPSI
Suunnitteluohje

Pikavalinta





Seinäpuhalluksen perusvaatimukset asuinhuoneistoille (poistoilmaluokka 3)

- ulospuhallusilmalaitteen etäisyys toisten huoneistojen ulkoilmalaitteista on vähintään 3 m
- vapaan ulospuhallusaukon keskimääräinen virtausnopeus on vähintään 5 m/s käyttöajan tehostamattomalla ilmavirralla
- ulospuhallusilmalaitteen etäisyys viereisistä seinistä on vähintään 3 metriä, naapuritontista vähintään 4 m ja vastapäisestä seinästä tai rakennuksesta vähintään 15 m
- ulospuhallusilmalaitetta ei sijoiteta umpinaisten sisäpihojen puoleisille julkisivuille
- ulospuhallusilmalaitetta ei sijoiteta julkisivussa oleviin syvennyksiin tai nurkkauksiin
- ulospuhallusilmalaitteen toimivuus suunnitellussa käyttötarkoituksessa on varmistettu

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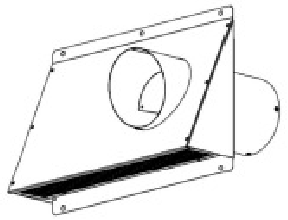

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РУКОВОДСТВО ПО ТЕХНИЧЕСКОМУ ОБСЛУЖИВАНИЮ

Lämmittäjänkatu 4 A
00880 HELSINKI, FINLAND
RCL Climecon
Tel. +358 20 198 6600
Fax +358 20 198 6609
www.rclclimecon.fi

RCLClimecon **UPSI**

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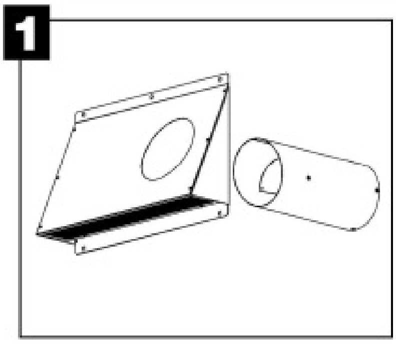
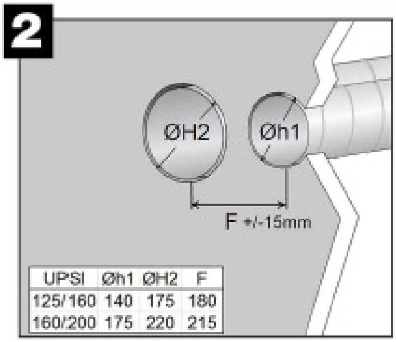
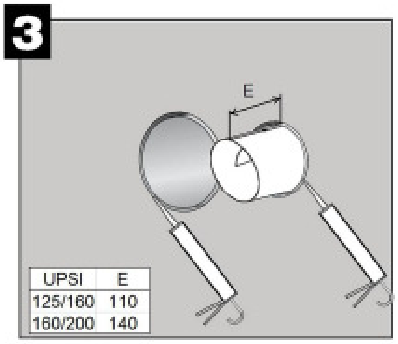
ИНСТРУКЦИЯ ПО УСТАНОВКЕ

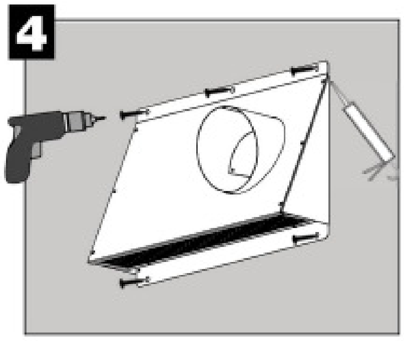


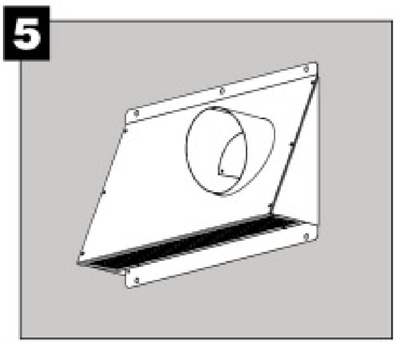


UPSI	Øh1	ØH2	F
125/160	140	175	180
160/200	175	220	215



UPSI	E
125/160	110
160/200	140





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UPSI

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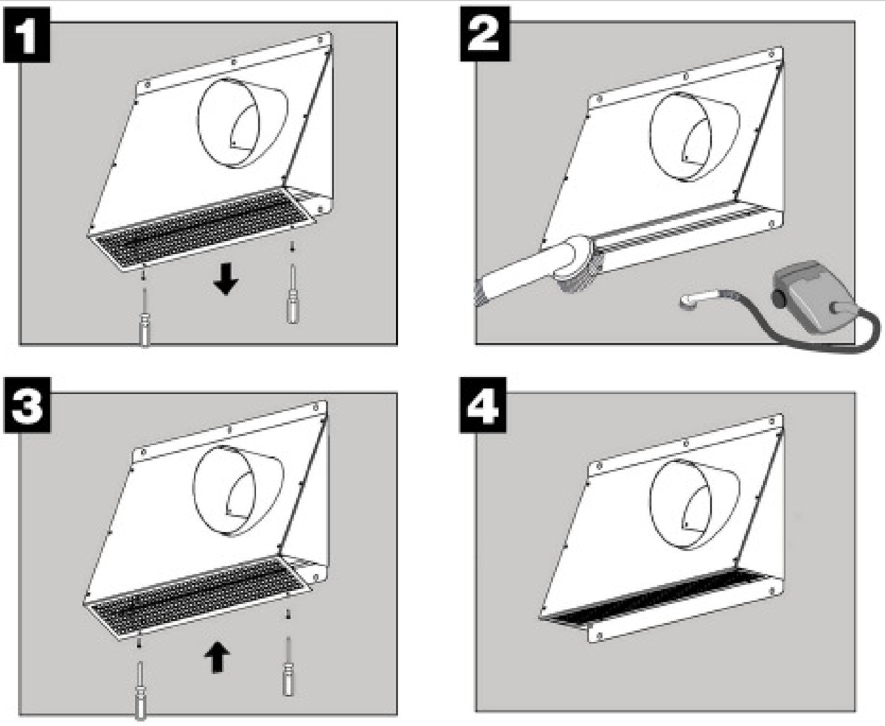
РУКОВОДСТВО ПО ТЕХНИЧЕСКОМУ ОБСЛУЖИВАНИЮ



Appendix 4

Room specific airflows

Apartment space	Supply air dm3/s	Exctract air dm3/s	Note
Largest or only bed room or over 11m2 bedroom	12		
Other bedrooms	8		
Other living spaces, e.g. living room over 22m3, not kitchen	0,35 dm3/s,m2		Supply air can be partially replaced through air transfer from the bedroom
Kitchen area, kitchen, pantry kitchen, is-land kitchen		8 (25)	The kitchen hood extract has to be 25 dm3/s, when intensified (cooking).
Bathroom (WC, showe, etc.)		10	Supply air can be partially replaced through air transfer from an other living-space
Separate bathroom (WC)		7	Supply air can be partially replaced through air transfer from an other living-space
Walk-in closet		6	Supply air can be partially replaced through air transfer from an other living-space
Storage area		6	Supply air can be partially replaced through air transfer from an other living-space
Sauna in apartment	6	6	

Utility or washing room without WC/shower		8	Supply air can be partially replaced through air transfer from an other living-space
Technical area		3	Dimensioning based on heat load, min 3 dm3/s

Appendix 5

Guide for wall-mounted air device placement

Air quality debilitating factors and regulations	Wall-mounted fresh and exhaust air device min distance (m)
Waste storage, combustion-engine vehicle parking, ramp, ventilation drain, chimney opening, cooling-tower, smoking spot, all roads and road junctions	8
Neighbouring apartments balcony	3
Ventilated drain opening, which is max 3m higher than the intake air opening	5
Ground- and gardenlevel	2
Roofsurface, that is located above the intake air opening	0,9
Distance between wall-mounted air devices	3
Exhaust airflow from wall-mounted device	min 5 m/s
Wall along with the device	3
Distance from opposite building	15
The wall-mounted air devices are not to be placed towards inner wards.	

Appendix 6

Noises levels in residences (5§)

Room- and outdoor space	Continuous wideband sound		Impulsive or narrowband sound	
	Average sound level $L_{Aeq,T}$ (dB)	Maximum sound level $L_{AFmax,T}$ (dB)	Average sound level $L_{Aeq,T}$ (dB)	Maximum sound level $L_{AFmax,T}$ (dB)
Living space	28	33	25	30
Apartment kitchen	33	38	30	35
Stairwell or out-door corridor	38	43	35	40
Outdoor space	45	50	40	45

Dimensioning of nominal flow in water equipment

Water point [1)]	Nominal flow q_N, dm^3/s	
	Cold water	Hot water
Kitchen sink	0,2	0,2
Dishwasher	0,2	[0,2]
Washbasin	0,1	0,1
Shower	0,2	0,2
Bathtub	0,3	0,3
Toilet	0,1	-
Washing machine, apartment	0,2	-
Washing machine, building laundry room	0,4	-
Hydrant, multi-storey building	0,4	-
Cold water faucet	0,2	-
Group showers, e.g. changing rooms (n pcs)	0,14n	0,14n

Appendix 8

Maximum allowable water velocity in domestic water pipelines to avoid corrosion

Water pipe	Highest allowed velocity (m/s)	
	Cold water	Hot water
Split connection pipes	4,0	3,0
Connection pipes	4,0	3,0
Pipes with a constant flow *)	1,0	1,0

*) Circulating hot domestic water flow dimensioning value 0,5 m/s

Appendix 9

Dimensioning of nominal flow in drainage equipment

Drainage point [1)]	Nominal flow, dm^3/s	Note
Washbasin	0,3	
Bathtub or showertub	0,9	
Shower	0,6	
Toilet	1,8	
Kitchen sink	0,6	
Dish washer (home use)	0,6	
Washing machine (home use)	0,6	
Floor drain DN 50	≤ 0,9 dm^3/s*	
Floor drain DN 75 (DN70)	≤ 1,5 dm^3/s*	
Floor drain DN 110 (DN100)	≤ 1,8 dm^3/s*	

* Drainage points maximum nominal flow that can be drained through the floor drain