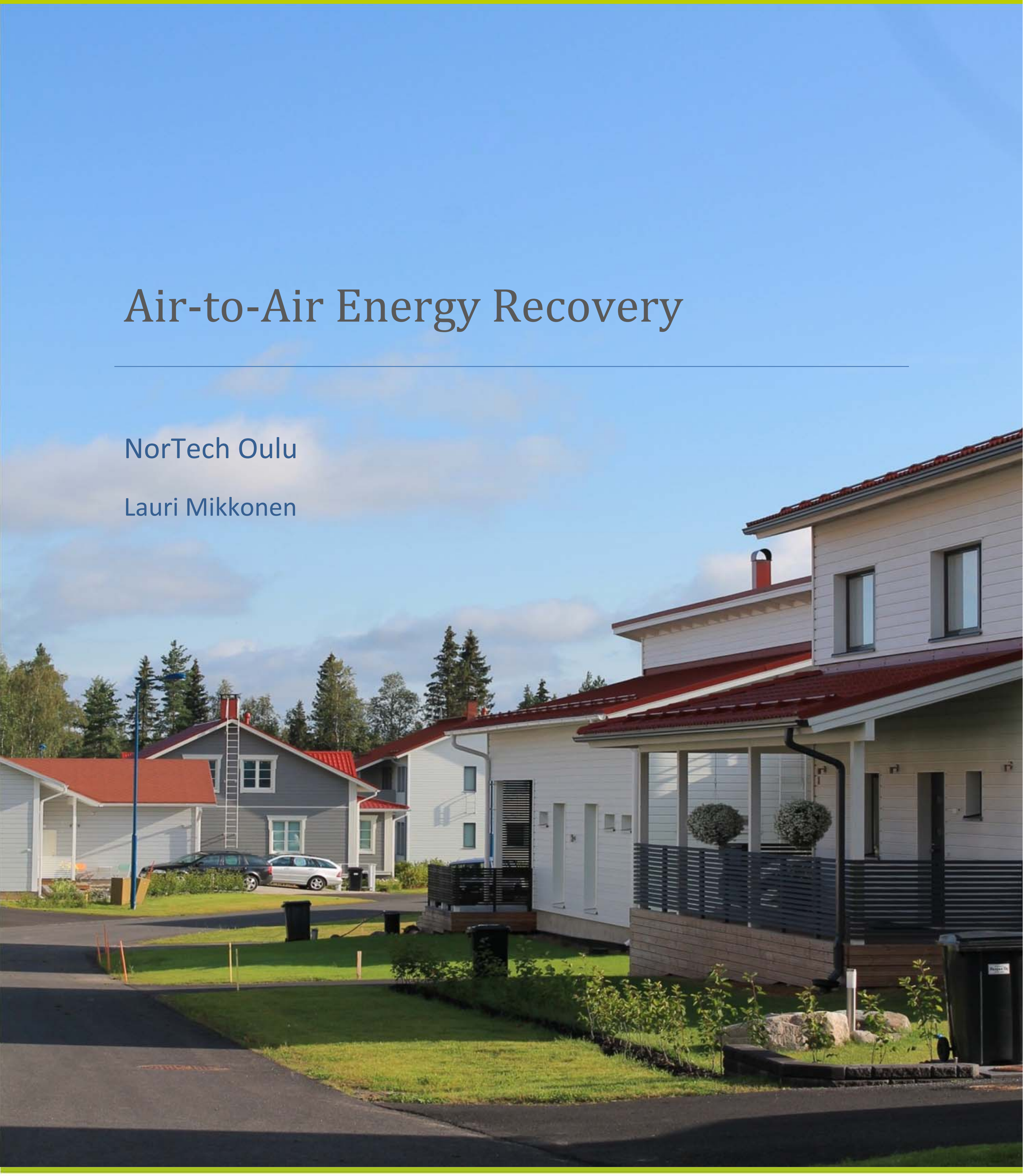
Greensettle

GREEN CITIES AND SETTLEMENTS

UNIVERSITY of OULU
OULUN YLIOPISTO



Air-to-Air Energy Recovery

NorTech Oulu

Lauri Mikkonen

This project is co-funded by the European Union, the Russian Federation and the Republic of Finland

THULE INSTITUTE

Kainuu

KAEEC

Centre of Northern Environmental Technology P.O. Box 7300 Thule Institute FI-90014 University of Oulu, Finland nortech@oulu.fi

Contents

1. Technology review

Air-to-air energy recovery is a process, in which heat or moisture or both are exchanged from high temperature to low temperature (or from high moisture to low moisture) to provide adequate ventilation for occupied conditions. With reduced energy consumption and costs, air-to-air energy recovery technology is considerable option for municipal buildings and households now and in future. [1] [2]

In most small-scale municipal and household applications, air-to-air heat exchangers use fresh outside air as a supply air for buildings and, in proportion, stale air from inside of the building as an exhaust air. In typical situation, when outside air is colder than inside air, air-to-air heat exchanger exchanges heat from the warmer exhaust air to the colder supply air taken from outside. With increased temperature, fresh supply air is ventilated to the building. During hot summer days, warmer supply air exchanges heat to the exhaust air and can thus help to cool down the building interiors. [2]

As defined in the laws of thermodynamics, heat moves from higher temperature to lower temperature. Therefore, by extending the laws of thermodynamics into the laws of mass transfer, also moisture transfers from higher vapor pressure to lower vapor pressure. These are the basic phenomena behind the operation of air-to-air heat exchanger. In some applications, indoor air humidity levels can be controlled by air-to-air energy recovery unit if we allow the transfer of moisture from the exhaust air to supply air. On the other hand, excessive moisture can be removed from the interiors and dryer air can be introduced to the building (protecting from moisture damage). [2] [3]

Air-to-air heat exchanger can recover sensible energy (temperature) or/and latent energy (moisture), as mentioned before. Thus, air-to-air heat exchanger units can be generally distinguished to heat recovery ventilators (HRVs) and energy recovery ventilators (ERVs). HRVs are used for sensible heat exchange applications and ERVs for both heat and moisture transfer applications, respectively. Generally, HRVs are suitable for situations where the supply air is having low moisture and exhaust gas high moisture, such as in swimming pools, chemical exhausts and paint booths. Typically, ERVs are used in residences, schools and offices. [2]

With the air-to-air heat recovery technology, the energy consumption of a building can be reduced. Low energy cost of operation brings also remarkable advantages besides improvements in indoor air quality. Payback period is often rather short, especially in extremely well sealed buildings. Air-to-air heat exchange system can be installed in new buildings and retrofit. [2]

2. Different air-to-air heat exchanger applications

There are numerous amounts of different heat exchanger types and applications available commercially. In this work, only those appropriate for municipal buildings and households are considered, neglecting large-scale process applications.

2.1 Heat exchanger arrangements

Air flows entering to the heat exchanger can have different directions and patterns. Generally, heat exchangers can be distinguished to parallel flow, counter flow, cross flow and multiple-pass heat exchangers. In the parallel flow heat exchanger, both air flows flow in the same direction. Usually the effectiveness of 50 % is obtained by parallel flow heat exchanger. [2]

In counter flow heat exchangers, the supply air and the exhaust air flow in the opposite directions, without crossing each other. Cross flow heat exchange is a variation of the counter flow heat exchanger, which allows the crossing of both supply and exhaust air streams. Counter flow heat exchange can obtain effectiveness from 50 % to approaching almost 100 %, while cross flow heat exchanger gain the effectiveness of 50 – 70 %. In multiple-pass heat exchangers more than one heat exchanger is put in series, performing the effectiveness of 60 – 85 %. [2]

2.2 Various energy recovery systems

2.2.1 Fixed-plate heat exchanger

Fixed-plate heat exchanger consists usually of plates, which are formed by spacers and separators. Plates and separators are sealed by welding, gluing, cementing or combination of these. Most common material used in fixed-plate heat exchangers is aluminum. There are also steel and polymer containing materials available commercially. In most cases, fixed-plate heat exchanger deal with sensible energy, but there are some water permeable materials that allow the transfer of moisture, such as polymeric membranes and treated paper. Both sensible and latent heat is transferred from warm exhaust air to colder supply air. [2]

Figure 1 shows the basic operation of fixed-plate heat exchanger. Generally, cross-flow model is mostly used. Commercial market offers different sizes and types of fixed-plate heat exchangers, including modular options. The properties of a building define the type and size of the heat exchanger. [2]

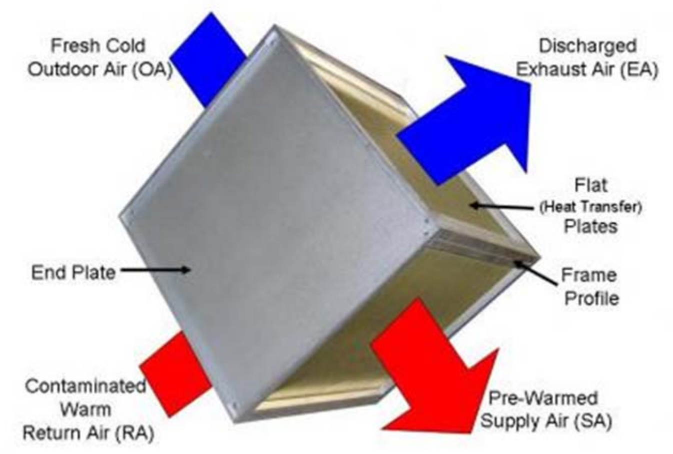


Figure 1. The basic operation of fixed-plate heat exchanger [4]

As the fixed-plate heat exchanger is a static device, there are no air leakages between incoming and outgoing streams. It is also common that the fixed-plate heat exchanger contains condensate drains in order to remove condensate water and possible washing water. Cross-flow fixed-plate heat exchangers are also able to work under cold conditions. Still, pre-heating of supply air has to be considered in order to avoid problems with frost and ice. This kind of procedure increases the overall energy consumption of the building. [2]

2.2.2 Rotary energy exchanger

Rotary air-to-air heat exchangers are usually parallel or counter-flow devices, in which a rotating wheel is having a half of the area for exhaust air and other half of the area for supply air, respectively. A revolving cylinder is filled with an air permeable medium. Internal area of the heat exchanger is designed to be as big as possible to enhance heat transfer between the medium and air flows. Rotary energy exchangers can recover sensible and latent heat. Figure 2 shows the basic operation of the rotary energy exchanger. [2] [5]

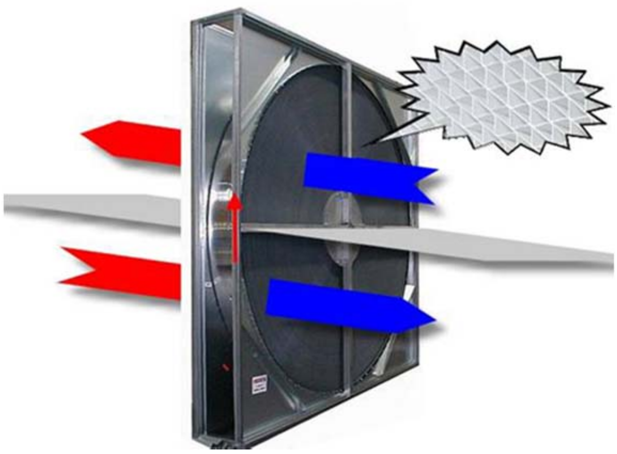


Figure 2. Basic operation of rotary wheel energy exchanger [6]

Rotary energy exchangers recover sensible heat when the medium transfers it from the warm side to the cold side. Moisture is transferred by the differences in water vapor pressures from high humidity to low humidity, where the medium absorbs and desorbs moisture. Typical materials used in the medium are aluminum, steel, polymers, zeolites, molecular sieves, silica gels and so on depending on the properties of both air flows and application purposes. Heat recovery of the heat exchanger is controlled by revolving speed of the wheel or bypassing of the incoming supply air. [2]

Some leakage happens in rotary energy exchangers in most cases, leading to cross-contamination. The effect of cross-contamination can be reduced by setting a purge section, which circulates a part of the fresh air back to the heat exchanger in order to remove contaminants. In addition, filters can be installed to separate contaminants. Unfortunately, the purge section in a rotary energy recovery system leads to some heat losses. Cross-contamination is more severe in latent heat rotary energy recovery systems, where more rough hygroscopic materials are used. [2] [5]

Recirculation of air can be problem in some cases, such as in hospitals laboratories and cleaning rooms, where contaminated air should be totally led out. However, rotary energy recovery systems can be generally used in municipal buildings and households. [2]

2.2.3 Heat pipe

A heat pipe exchanger is usually a counter flow device (parallel flow is also possible), consisting of a pipe and a partition part. The heat pipe itself is sealed and filled with a refrigerant that evaporates and condensates easily. In a typical heat pipe application, the warm air heats up and evaporate the refrigerant, which flows to the cooler side of the pipe. In the cooler side of the heat pipe, refrigerant condensates and transfers heat to the colder air flow. Cooled refrigerant flows back to the evaporation zone, closing the loop. So heat pipes work as a passive system, where differences in air flow temperatures are the driving force for the system. [5]

In the heat pipe applications, the tilt angle of the pipe can be controlled in order to change from heating to cooling, to improve effectiveness or to decrease effectiveness (prevents from frost formation). Usually, sensible heat is recovered, but if condensation of refrigerant happens, the system recovers also latent heat. Typical materials used in heat pipes are aluminum and copper. Selection of the suitable refrigerant depends on operation conditions. [2]

2.2.4 Other

Other air-to-air energy recovery systems include coil loop energy recovery systems and thermosiphon systems. Coil loop energy recovery systems (also called as runaround systems) consist of a two coils (for supply air and exhaust air), which are connected with counter flow pipes. Pipes are filled with a working fluid, which can be water or other anti-freeze liquid. Other essential units for a coil loop energy recovery system are pump, fan and expansion tank. A three-way valve enables the bidirectional use of the fluid. Basically, the idea of coiling loop energy recovery system is same than in heat pipes: Warmer air heats up the working fluid, which transfer energy to colder air. Efficiency of this process is around 50 %. Pumps and fans are also consuming energy. [6]

Thermosimphon systems are similar to heat pipe systems, consisting of a condenser, evaporator, interconnecting piping and working fluid. The main difference between thermosiphon processes and heat pipes is that the circulation of the working fluid is based on gravity and temperature differences. Thermosiphon process can include also runaround loop. In this case, pumping is not needed because the system utilizes a natural cycle driven by temperature differences and gravity. One of the disadvantages of this technology is that significant difference in inlet and outlet temperatures may be required because the working fluid should reach the boiling point. [2] [7]

3. Adaptation of air-to-air energy recovery units to municipal buildings and households

3.1 Unit processes in air-to-air energy recovery systems

Air-to-air energy recovery system must have other processes besides the heat exchanger unit as well. The most important unit processes for air-to-air applications in buildings are discussed below.

3.1.1 Air distribution systems

Generally, the basic air distribution system in municipal buildings and households consists of dampers, ducts, fans, grilles and diffusers. Dampers are devices that control the air flow rates in ducts and thus the amount of ventilation air in the interiors of a building and other ducts. The design of a ventilation system should minimize the amount of dampers due to their big contribution to increased pressure drops. However, dampers are used in variable air volume (VAV) applications. [5]

Ducts are used for transportation of both supply and exhaust air. Thus, ducts are an essential part of air distribution systems. In residential buildings, ducts should be able to operate under ±125 – ±250 Pa pressure. In municipal buildings, depending on the size and other properties, pressures in ducts can vary from ±125 Pa to ±2500 Pa. Appropriate sealing is necessary in order to avoid leakages and pressure drops. Common materials for ducts in dwellings are steel, plastic and aluminum. In commercial buildings, steel, aluminum, iron and concrete are common. Ducts can be also single zone or multi-zone ducts and single or multi duct systems. [2]

Fans are devices that distribute the air from one place to other with a certain flow rate. Flow rate generated by fans should take into account the pressure drops in ducts and dampers. Moreover, the supply air flow rate generated by fans should be slightly bigger than flow rates for exhaust air in order to maintain bigger pressure inside the building than atmospheric pressure, avoiding draught. [5]

Operation of fans requires electricity. Thus, fans should be as efficient as possible. It is also essential to notice that a substantial amount of the kinetic energy of the fan is transformed to heat because of viscosity and friction. Hence, the additional heat from fans must be taken into account in the design. [5]

3.1.2 Contaminant removal

There are several different contaminants in the supply and exhaust air. Removal of different contaminants from the supply air is necessary, so that adequate IAQ can be maintained. Other reason for contaminant removal is that they can also foul ducts, heat exchanger surfaces etc. So filters must be installed for both supply and exhaust air, besides before and after the heat exchanger unit. Typical contaminants are particles, microorganisms and bio aerosols, which are removed by using filters. [5]

Generally, larger particles are removed by using straining or inertial impingement. Interception can be used for medium size particles, diffusion and electrostatic effect can be used for medium and small size particles. Typical particle size to be removed varies from 0,3 to 10 µm and up. Smaller particles (0,3 – 3 µm) are often removed by using bag and box filters. Particle sizes up to 3 µm are separated by fiber glass or panel filters, which often have disposable surfaces. In residential buildings, the limit for particle size to be separated is 10 µm and in municipal buildings even smaller (3-10 µm) However, in order to maintain good IAQ it is important to pay attention to smaller particle size as well, especially because of their notable contribution to health issues. [2] [5]

Filters are also affecting to pressure drop in the air distribution system. In addition, filters have to maintained and switched at times. Dirty and old filter can cause too much pressure drop and increase the amount of contaminants in the air. It is also necessary to keep filters as dry as possible in order to avoid microbial growth on filter surfaces. [2]

3.1.3 Control and measurement systems

The control system for air handling unit can be manual or automatic. In this case, an automatic system is recommended in order to ensure the proper operation of unit processes, while minimizing the operation costs. [5]

There are several parameters, which have to be measured by sensors in air-to-air energy recovery system, including temperature, humidity, pressure and air velocity. Each sensor is connected with controller, which have specific set point value. Moreover, appropriate operation of control devices requires auxiliary devices, such as relays and transducers, switchers and timers. [5]

So, in the end, controllers and controlled devices must be able to adjust for instance fan speeds, air flow rates in ducts, temperature of supply air etc. Thermostat can be used in order to set appropriate temperature and control the fan speed. In addition, safety control systems are needed to minimize damages in a building and process facilities, by avoiding for example too high pressure in ducts and formation of frost. The system can have also a control system, which turns the ventilation on or off according to the amount of occupants in the building. [8] [9]

3.1.4 Other unit processes

The use of other equipment depends on the application and the type of the air-to-air energy recovery unit. The outer unit of air-to-air system is louver, which works as a window or blind, preventing the system from sunshine, rain, snow etc. Furthermore, valves are needed, because there is pressurized gas and/or liquid in the system. Pumps are required to transport liquids, if there is any. [2]

In some application, cooling and heating coils can be used to pre-heat and reheat or pre-cool and re-cool the air mass. Heating and cooling coils affect also the moisture content of the air. These devices require some extra energy, having the contribution to the overall energy consumption and longer payback period. In addition, economizer, which returns and mixes part of the exhaust air to the supply air, can be used in order to avoid overheating of a heat exchanger unit. [5]

In some cases, depending on the application, humidifiers can be used, so that the moisture content in supply air increases. Humidifiers have some disadvantages, such as the contribution to the formation of odor and growth of microorganisms. [5]

3.2 Configurations and installation of air-to-air energy recovery systems in buildings

There are several different configurations for air-to-air energy recovery systems available, depending on the used application, climatic conditions and indoor air quality. Generally, the basic configuration of devices can be seen from figure 3 and 4. In some cases, cooling and heating coils are needed. Without heating and cooling coils, we can take a step towards more energy efficient solution because coils are consuming energy.

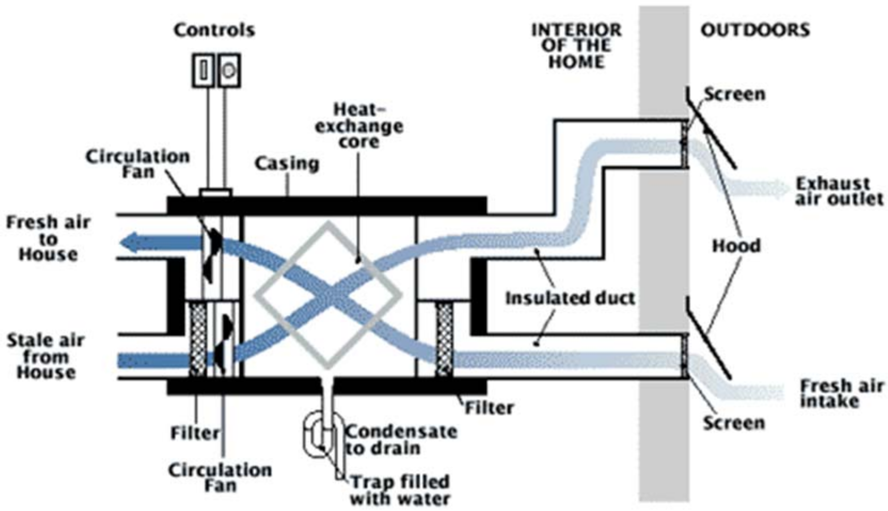


Figure 3. Basic configuration of unit processes in air-to-air energy recovery system [10]

As we can see from Figure 3, filters are installed before the heat exchanger unit in order to separate contaminants entering the heat exchange unit and supply air. If the energy recovery system operates in cold climate, it is necessary to insulate ducts, so that freezing is avoided. Fan speeds are controlled in order to achieve appropriate flow rate.

In some cases, it can be possible to pre-heat or pre-cool the incoming outdoor air in the ground or water. This kind of procedure can reduce pre-heating / pre-cooling costs. However, installing this kind of system is a matter of design and costs. [8]

In air distribution system, ducts are installed in ceiling, floor and wall structures. This operation does not necessarily need any renovation because ducts can be “hided” in to the structures. However, ducts can be installed as a single duct or dual/multi duct systems, depending on the application. Dampers and air flow regulators are installed in touch with ducts in order to control air flow rates and volumes. Grilles and diffusers are placed in the ceiling and walls, sometimes even floors. Here, it is important to have a certain number of diffusers, besides placing them in correct places, so that air is distributed as efficiently as possible. Diffusers also slow down air flow velocity, having small contribution to the supply air temperature. Figure 4 shows generally the placement of air distribution equipment. [8]

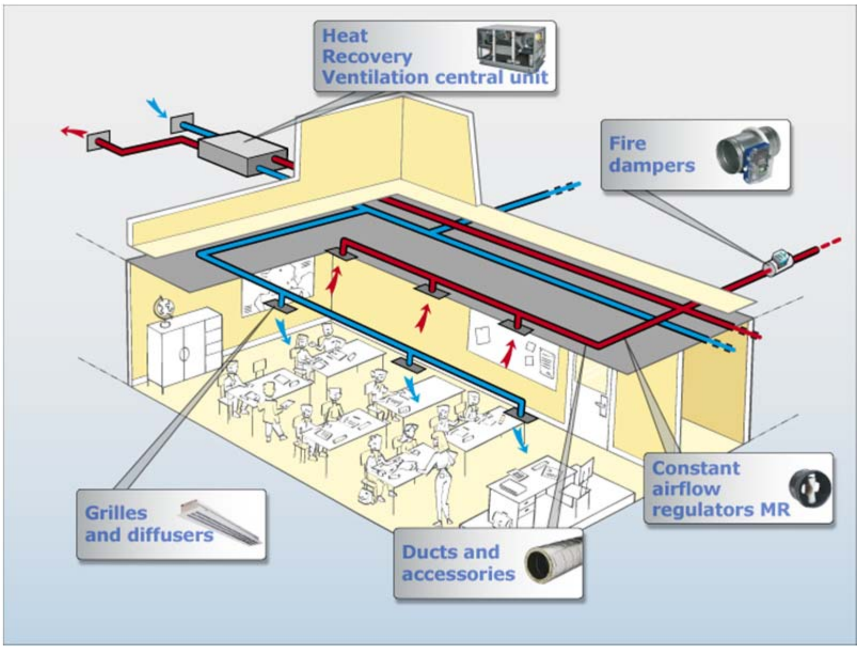


Figure 4. General placement of air distribution equipment [11]

In air-to-air energy recovery applications, the heat exchanger unit can be often situated in an attic, if possible. In some cases, the unit can be situated in storages or other non-occupied rooms in the building. Supply air is generally ventilated to occupied rooms, such as bedrooms and living rooms. Exhaust air removal should be placed in rooms, where formation of contaminants takes place, such as bathroom and kitchen. In that kind of situation, the ventilation of the exhaust air removes excess moisture effectively. Figure 5 shows the basic placement of energy recovery unit in a dwelling. [7] [12]

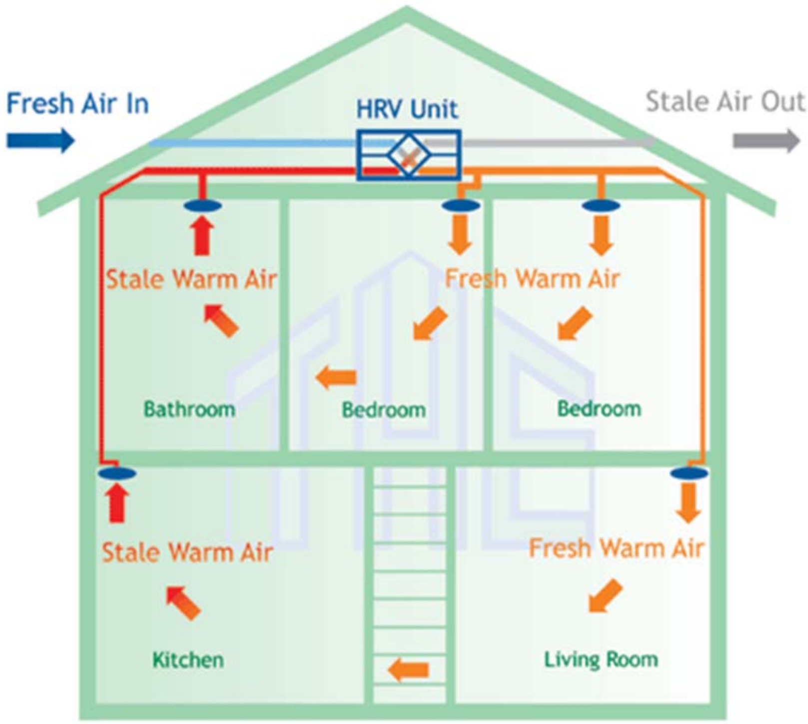


Figure 5. General placement of energy recovery unit in a dwelling [13]

Air-to-air energy recovery system can be utilized in households. There are several small and medium-scale units available commercially. It is also possible to retrofit air-to-air energy recovery units in households, but it will require the construction of ducts and other equipment in the whole building. In addition, it must be ensured, that the insulation and air tightness of the household is good enough before installing this system. In any new building having good insulation, energy recovery process is a considerable technology. [12]

Energy recovery system can be adapted to municipal buildings, such as schools, swimming pools, office buildings and so on. Buildings having high moisture content, energy recovery system can remove and utilize moisture, using latent heat from the exhaust air and supply fresh and dry air to the interiors. This kind of function can be adapted for example in swimming pools. In highly contaminated buildings, for instance in painting rooms, energy recovery system can remove contaminants and bring fresh air to the room (for example fixed-plate heat exchanger, which has no cross-contamination). In addition, above-mentioned procedure can be used e.g. in laboratory rooms and hospitals. [2]

Location for the supply air intake should be considered as well as the location for the exhaust air output. For instance, intake for the supply air in urban areas should be as far as possible from traffic and contaminant source. Moreover, intake for the supply air should not be adjacent to the exhaust air output. The placement for the exhaust air output in a building should not harm surrounding area and the exhaust air should be able to diffuse to the outside air efficiently. Re-entry to a building is not allowed, as well. It is common to have a vertical exhaust air output on the roof. [12]

Before installing the energy recovery unit in a building, it is essential to determine current infiltration rates, wanted ventilation rates and temperatures, humidity etc. After that, the system is designed by following standards. Standards for e.g. air volume rates, indoor air quality, moisture content and temperature depends on application (building type etc.) and can vary from country to country. Nevertheless, air-to-air energy recovery system can be adapted to meet these challenges. [2]

3.3 Installation permissions and requirements

Before the installation of an air-to-air energy recovery system, one must ensure that the building is airtight and has appropriate insulation. Otherwise, the ventilation system is not working efficiently, loosing many advantages. The place for the equipment must be also considered. Usually the heat exchanger unit is placed in a warm or semi-warm space. In addition, places for ducts and both supply air and exhaust air intake/output must be considered. [5]

New buildings in Finland, especially if constantly occupied and having warm interiors include air-to-air energy recovery system. Thus, construction permission and detailed plan of energy recovery ventilation system is needed. If the system is designed to be retrofitted, permission for construction is needed in many cases.

Before installation and seeking suitable energy recovery system for building, it is important to define building conditions. The design and installation of the air-to-air energy recovery system requires the determination of following factors:

- Insulation (heat losses through building envelope)
- Air-tightness of building envelope (air exchange factor)
- Building volume and area

- Heat loads (from occupants, lighting, electric devices and solar radiation)
- Definition of outdoor conditions
- The type and location of the building

After defining the building conditions, there are several requirements and directions for e.g. supply air flow rate, temperature and humidity levels, which have to be determined before installation. After installation, it is also essential to check whether the system satisfies the design properties/conditions or not. Following factors (design criteria) are essential to be considered:

- Temperature
- Airflow rates
- Indoor air and duct pressure
- Humidity levels
- Contaminant concentrations

Directions for different values of design factors are different according to building/room type, so it is essential to deal with correct design and sizing values. Regulations and directions of these design parameters for Finnish buildings can be found from link http://www.finlex.fi/data/normit/37187-D2-2012_Suomi.pdf (D2 Suomen rakentamismääräyskokoelma). Note that these design and reference criteria can vary from country to country. [5]

After the definition of following design factors, a HVAC engineer takes place designing the system and sizing the system according to standards. After the design and choosing the equipment, a closer look for system components and their location is done. The installation of the system is done by a separate HVAC mechanic. If the system contains hazardous refrigerant, the mechanic should have an appropriate qualification to install the system. An electric mechanic is also needed. [13]

After installation, it is necessary to check the adequate operation of the system. At first, the sealing of the system must be checked and measured. The cleanliness of the system must be also checked as well as air flow rates in ducts. Measured and designed air flow rates must match to each other. If not, air flows can be adjusted in many cases. Noise levels and electric power properties must be also measured by a mechanic. [13]

3.4 System economics

The target of the installation of an energy recovery system is to improve energy efficiency. At least in Finland, it is possible to get financial support for installing (especially retrofitting) the energy recovery ventilation. It is also considerable that when the system is designed and installed properly, it can pay itself back, even though installation costs can be higher compared to conventional ventilation systems.

The price of the heat exchanger unit in Finland varies very roughly between 2000 – 12000 euros, depending on the type of the application and the size of the unit. For small and medium scale buildings, the usual price for the system is something like 1000 – 5000 €. [13]

The installation costs of ducts depend on the installation type. Installation can be done either in a warm room side with “hiding” or in building structures and in attic (usually contains colder areas and more insulation). The approximate price for duct in Finland is around 5 – 20 €/m without insulation and excluding other duct parts, such as t-pieces and curved duct parts. With insulation the duct price can be doubled. The installation work for duct system depends also on several factors, such as building type, number of floors and building area, so it is hard to estimate accurate cost for the installation work. In addition, installation work may include the working costs of an electric mechanic. So, one must always make a tender before installing the system.

3.5 Practical considerations

Placement of valves and ducts

The design and installation of ducts play important role in the air-to-air energy recovery system. Fresh supply air intake should be taken as far from contamination source as possible. In many cases, the correct placement for supply air intake is in northern side or other shadow side or area of the building in order to avoid excessive temperature changes. [13]

Exhaust air should have a roof side output on the top of the building. In order to avoid the entering of rain water in ducts, the output should have a specific cover. It is also possible, and in many cases recommended, to design inspection manholes on the roof, so that ducts can be cleaned. In the end, the supply air intake and the exhaust air output should have particular distance between each other (in vertical and horizontal distance). [13]

An exhaust air intake should be placed in rooms, where contaminants and moisture are generated. In residential buildings, such rooms include toilet, kitchen, washroom and utility rooms. In commercial buildings, the intake for exhaust air is placed near the source of contamination. [13]

In residential buildings, supply air should be distributed to the living room, dining room, bedrooms and other occupied rooms, where contamination is not substantially created. In commercial buildings, fresh air should be distributed to places, where it is needed, so that it does not disturb e.g. thermal comfort. [13]

Operation and use

Energy recovery system operates as an air conditioning system. The purpose of the system is to ensure adequate indoor climate in specific rooms. Thus, the system must maintain appropriate indoor air quality:

- Temperature
- Humidity levels
- Air flow rates
- Indoor air pressure
- Separate and removal of contaminants (e.g. particles, CO_2, smoke)

To maintain these conditions, the system design plays important role. However, it is also important to maintain the energy recovery system at times. To ensure the adequate operation of energy recovery system, the control board of the system must be used correctly. In many cases, the control board contains control possibilities for e.g. ventilation air flow rates and supply air temperature. These controls can be also used in the case that building is not occupied. Moreover, it may be possible to have external control system working as a control center. Control system may also have a setting for e.g. a fireplace increasing the amount of supply air.

It is important to the run air-to-air energy recovery system constantly in order to avoid problems with humidity and ensure the removal of contaminants.

Maintenance

Energy recovery system does require some amount of maintenance. At first, filters must be changed at times (varies from 3 to 12 months depended on conditions and application). Filters can be also vacuumed. Too dirty filters can increase the pressure drop, leading to reduced airflow and increased fan electricity consumption. Dirty filters can promote also the growth of microorganisms. [5]

Cleaning of the heat transfer unit is recommended to do at times. In the case that the heat exchanger unit is dirty, it can be washed with water or pressurized air. If you have a rotating wheel heat exchanger, do not use pressure water cleaning or immerse the unit in water. Normal shower plus neutral detergent are recommended. [13]

When changing filters, it is also recommended to check out fans, which should be also cleaned from excess dust and dirt. Cleaning the surroundings of the whole heat exchanger unit from dust (by using e.g. a vacuum cleaner) is recommended to do when changing filters. [13]

Troubleshoot

Sometimes air condition is not working properly, which can be due to reduced air flow in ducts or inadequate temperatures. Noise levels can also increase too much in some cases. Here are some reasons and solutions for these problems.

<u>Decreased air flows</u>

- Dirty filters
- Dirty fans
- Block in supply air intake

} Clean filters, fans and supply air intake

- Fan operation is adjusted too low

<u>Cold supply air</u>

- Auxiliary heating is not put on
- Heat recovery function is put off (rotary wheel exchangers)

- Fan and other electrical malfunctions → Contact repairman
- Dirty filters
- Inadequate insulation of ducts
- Overheating of auxiliary heating unit

High noise levels

- Dirty filters or fans
- Blockage in supply air intake
- Heat exchanger motor/gearing fault

One must always check the control panel first, if the ventilation is adjusted correctly or not. More detailed troubleshoot can be found from instruction manual of a specific energy recovery device. [13]

4 Advantages and technological challenges of energy recovery technology

4.1 Advantages

Air-to-air energy recovery can recover heat with 50 – 95 % efficiency, depending on the application, climatic conditions etc. Energy recovery provides notable energy and cost savings because heat from exhaust air is recovered, not led out. Energy recovery can provide even greater advantage in buildings, where existing heating system is inefficient and where the price of electricity and/or heat is high. So, heating savings can be up to 50 %. [2]

As mentioned before, air-to-air energy recovery system improves indoor air quality. Moisture can be removed efficiently from the inside of a building, preventing mold growth and structural damages, increasing the life time of building structures. Adequate moisture level in buildings prevents also from dust mites and other microbial growth. In addition, good filters ensure that the indoor air is free from pollen, allergens and other particulates. [14]

Energy recovery system removes also odor and other harmful chemical compounds generated by occupancy and replaces this contaminated stale air with fresh air. In noisy areas, for example in cities, window ventilation can lead annoying noise to a building interior. With an energy recovery system, window ventilation is not needed. Energy recovery system operates quietly day and night and it is also notable that the system can improve the safety of the building because windows are kept closed. [14]

As mentioned in the beginning of this chapter, energy saving lead to cost savings. There are always some initial costs for the installation of the energy recovery system, but compared to other HVAC systems, there is no need for fuel-fired equipment, lowering thus installing costs. Initial costs can be paid back in 2 – 6 years, or less, depending on the application, climatic conditions and other factors. In hot and humid climates, payback time can be even less than one year with efficient systems. An energy recovery system is economically and thermodynamically efficient, when there is a large difference between exhaust and supply air. Thus, it can operate efficiently in cold climates as well. [2]

By using an air-to-air energy recovery system, separate humidification and dehumidification is not needed in a building. Thus, the system provides also savings in this context. This is especially true with total energy recovery systems, which can transfer both heat and moisture. [2]

4.2 Technological challenges

4.2.1 Condensation and freezing

Condensation happens in the heat exchanger unit, when warm air side cools down and reaches its dew point, having temperature higher than 0 °C. The surface of the heat exchanger gets wet and, in sensible heat transfer units, increases the heat transfer rate. Condensation can increase the pressure drop in the heat exchanger. For sensible heat applications, collection drains for condensate water are necessary. In colder climates, warmer air side can be situated in supply or exhaust air side, so both sides need drains. [2]

If the temperature of either supply or exhaust air falls below 0 °C, condensate water freezes. With these temperatures, also frost can be formed. Freezing water expands and can break down process equipment. Freezing can cause also problems in some heat exchanger types containing absorbents, which cannot stand freezing. In addition, ducts must be insulated in order to prevent the formation of frost and freeze and overcooling of air. Frosting and freezing decreases air flow rates in ducts and heat exchanger, decreasing also the heat transfer rate in the heat exchanger unit, or even block the whole duct. [2]

Freezing and frosting can be prevented by selecting appropriate heat exchanger application, using preheating for supply or exhaust air (ground pre-heat, heating coils etc.), tilting heat pipes, controlling the revolving speed of wheel heat exchanger, reducing heat exchanger effectiveness, bypassing a part of the supply air or combining part of these methods. [2]

4.2.1 Corrosion

Corrosion is a conventional and natural chemical process, which happens everywhere over time. In some cases, exhaust gas can contain high concentrations of corrosive compounds, so corrosion-resistant materials for ducts, filters, heat exchanger and other equipment should be considered during the design. Corrosion roughens ducts and can lead to leakages. In addition, the overall heat transfer can be reduced by corrosion. [2]

4.2.2 Contaminants and fouling

Contaminants, such as corrosive chemicals can cause technological challenges. In some cases, these compounds can be filtered or non-corrosive materials used. Particulates can foul heat exchanger surfaces, leading to deceased heat transfer. Thus, particulates must be filtered before the supply and exhaust air enters the heat exchange unit. Particulates are also accumulating on the filter surfaces, so filter surfaces (if manual) must be changed at times. Otherwise, the separation unit can lead to large pressure drop and contaminated supply air. New filter surfaces can emit some volatile organic compounds (VOC). The separation of ultra-small particles can be challenging and expensive. [2] [5]

Besides particulates and other compounds, filters must be used in order to separate microorganisms. These organisms can also foul heat exchanger unit as well as ducts, filters and other process equipment. High moisture content on the filter surfaces leads often to increased microbial growth, plugging filters and contaminating the supply air. Fouling in ducts and process equipment can also increase the resistance for air flow, leading to bigger pressure drop. Thus, it can decrease the rate of airflow and increase the power consumed by fans. [2][5]

Air leakage in the heat exchanger unit or ducts can lead to contaminated supply air (particles, humidity etc.). Thus, filters should be installed also in the downstream side of the supply air. [2]

5 Air-to-air energy recovery unit suppliers in Finland

There are several different suppliers for air-to-air energy recovery unit including full packages, heat exchangers, ducts and other essential parts all over the world. However, here is the list of common Finnish unit suppliers.

- Enervent - http://www.enervent.fi
- Easytiimi Oy - http://www.easytiimi.fi
- RefGroup - http://www.refgroup.fi
- Koja-Yhtiöt Oy - http://www.koja.fi
- Swegon - http://www.swegon.com
- Vallox - http://www.vallox.com
- NIBE Energy Systems - http://www.nibe.fi
- Pemco Oy - http://www.pemco.fi

References

1. Kohler and Lewis 2002. Air-to-air heat exchanger ventilation. Cited: 16.5.2012. [Internet page]. Available from: http://www.kohlerandlewis.com/pdf/hextech.pdf

2. ASHRAE 2008. Handbook of HVAC Systems and Equipment. ISBN: 978-1-931862-71-4

3. Cited: 16.5.2012. [Internet page]. Available from: http://joneakes.com/jons-fixit-database/887-WHAT-IS-AN-AIR-TO-AIR-HEAT-EXCHANGER-HRV-and-ERV

4. XeteX 2012. Flat Plate Crossflow. Cited: 18.5.2012. [Internet page] Available from: http://www.xetexinc.com/flat_plate_crossflow

5. Awbi. H 2008. Ventilation Systems. Design and performance. Taylor & Francis. ISBN 0-203-93689-2.

6. Rotor Industry 2011. Principle of the rotary heat exchanger. Cited: 18.5.2012. [Internet page] Available from: http://www.rotorindustry.com/rotary_heat_exchanger.html

7. Wulfinghoff, D. Energy 1999. Energy Efficiency Manual. Energy Institute Press. ISBN 0-9657926-7-6.

8. Roger W. Haines, C. Lewis Wilson, 1998. Mcgraw - Hill. 3rd edition. HVAC System Design. ISBN: 0-0702-5963-1

9. Herman S.L., Sparkman B.L, 2010. Electricity and controls for HVACR. Delmar, Cengage Learning. 6th edition. ISBN-10: 1-4354-8427-4.

10. Healthy House 2007. Office of Energy Efficiency. What is HRV Technology. [Internet pages]. Cited: 21.5.2012. Available from: http://www.healthyhouse.com/faqs13.html

11. Aldes 2012. Heat recovery ventilation with exchanger. [Internet pages]. Cited: 21.5.2012. Available from: http://www.aldes-international.com/html/aldes-solutions-systemes-commercial-ventilation-for-sector-service-heat-recovery-ventilation-with-exchanger.htm?tab=1

12. Dengusiak M. 2007. Ventilation of School Buildings. Building Bulleting 101. ISBN 011-2711642.

13. Enervent 2012. [Internet pages]. Cited: 23.5.2012. Available from: http://www.enervent.fi/main.asp?menuid=10000&langid=1&countryid=100

14.Genvex Heat Pump and Heat Recovery Solutions 2012. Controlled internal ventilation. [Internet pages]. Cited: 22.5.2012. Available from: http://www.genvex.co.uk/solution.asp

Useful links:

http://www.enervent.fi/sub_menu.asp?menuid=110000&langid=1&countryid=100