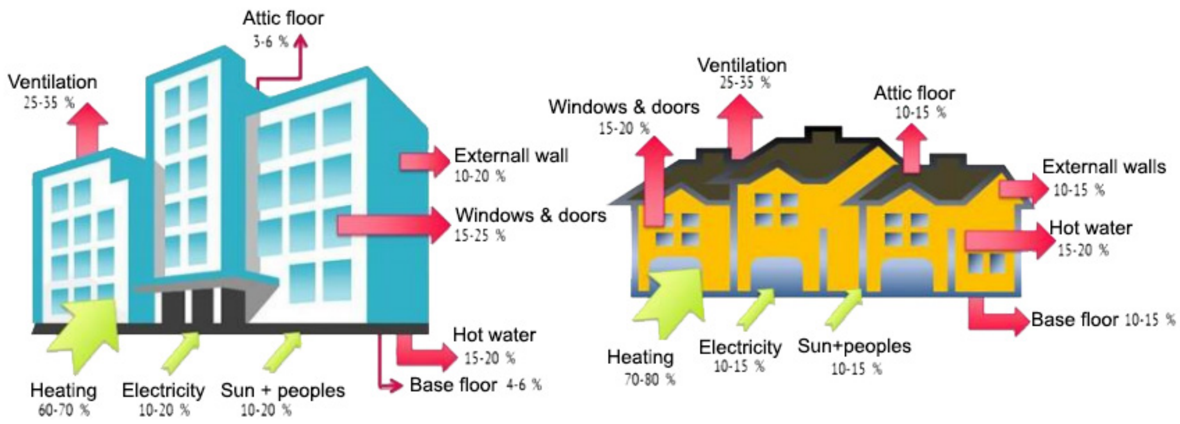
Successful practices with energy efficiency – literature review

Energy efficiency is a key to create reliable, affordable and sustainable energy system for the future. Better efficiencies gives a quick way to answer energy security and environmental challenges beside of cutting costs is the answer to economic challenges. This literature review will propose several successful practice to gain energy efficiency in the sector of renovation.

Due to the existing building stock consumes 26% of energy in Finland, it is important to increase energy efficiency when renovation is timely urgent. (SVT 2016) Especially when it is possible and profitable in technical and financial point of views. The actual need for renovation is important, because energy renovations are rarely feasible, if they are done purely on energy-saving basis. (Häkkinen et all 2012)

Easiest way to start thinking about energy efficiency is take a look on heat balance of the buildings. We can see picture above that, ventilation causes highest heat losses of the buildings. Windows and doors are commonly 2nd highest elements that generates heat loss. In detached houses also roofs and floors are usually leaking heat of as much that external walls. In apartment houses roofs are usually better insulated as well as floor doesn't generate as much heat losses.

Achieving better energy efficiency usually means reducing heat losses, so upgrades are related to them in renovation processes. Of course, heating systems are another target to where reducing potential exist. Old fashioned heating systems, heat recovery systems and household appliances are not as efficiency that what modern applications are. Renovation can make great savings, but it is not as easy to get old buildings extremely energy efficient without massive renovation. (Heljö & Vihola 2012). New constructions are another case, as they could be designed to follow strictly energy efficient concepts with modern energy efficient automation systems.



Picture1: Heat balance in apartment and detached houses (Niemikorpi 2017)

Renovation is usually prepared with a long-term perspective and with the reason of repairing damaged parts of building, indoor climate problems, technical aging or desire to change space divisions. (Häkkinen et all 2012)

During years 2015 and 2016, Lapland UAS has made surveys for every municipality of Lapland and there has been rising several practices, which are common in renovation processes: Better insulations, more energy-efficient lightning (LED), renewing of ventilation systems, installation of air heat pumps, and education/motivation for customers and janitors. (Parkkila & Sirkka 2017)

These formerly mentioned practises are common ways to gain energy efficiency in the building stock scheme. Beside of those, changing of windows may be beneficial for older buildings. Usually, old windows are changed when the frames or glass are in the end of their lifetime. Windows and frames are replaced with the newer and more energy efficient ones or additional glass element is installed to two glassed windows. Energy saving benefits are relatively small, although that glass technology has evolved a lot during the last decades. However, ensuring air tightness between frames and walls should be done when renovating. In addition, new weather strips on windows and doors could reduce air leaks easily and those should be replaced regularly. (Häkkinen et all 2012)

Beside of regular window renovation, window installations on the balcony can save in the best case scenario even 4% of energy. Windows also increase the lifetime of concrete balconies as they cover it from bad weather. (Boström et all 2012)

Sometimes there is no beneficial reason for renovation, but by adjusting heating system, savings are possible. Room temperatures are commonly too high in apartment houses. By adjusting room temperatures, there could be savings up to 15%. Lowering temperature by one degree it gives 5% savings from heating costs. (Alatalo 2012)

Oulu Building Supervision Office has created a website, called Energiakorjaus.info (energy renovation info), where is listed information about energy efficient renovation practices for apartment buildings and terraced houses including their typical saving potentials. (Oulu Building Supervision Office 2018)

Ventilation and heat recovery

Ventilation causes highest heat energy losses (25%-50%) in apartment houses as compared to other building elements. Most common ventilation is a mechanical exhaust system – typically installed apartment houses since 1950. Since 1990, common installed ventilation system was mechanical supply and exhaust, with or without heat recovery. If there could be installed heat recovery to transfer heat from exhaust air to supply air or to water (exhaust only system) it would give 20-40% savings. However, heat recovery is expensive installation due to it usually need installation of new ventilation machine with mechanical supply air system. If there is no economic reason to do expensive ventilation renovation; cleaning ventilation system and adjusting it to work properly, there is saving potential from 3 to 10%. (Motiva 2012 & Niemikorpi 2017)

Beside of energy efficiency, ventilation renovation and heat recovery has other positive effect on living well-being: Better air quality and reducing draught. Commonly heat recovery from exhaust air, demands installation of mechanical exhaust and supply air ventilation systems. However, if supply air ducts are not installed, there are products that could transfer the recovered heat to the water (heat pump technology). With heat recovery in the best-case scenario, there could be utilized 40-70% of the heat energy of waste air in well-insulated apartment houses. (Boström et all 2012)

However, energy consumption can increase depending on the state of original ventilation system. If ventilation has been insufficient, installation of new exhaust-supply air ventilation machine, energy consumption will increase. Even with heat recovery in these cases energy consumptions can't be decreased as compared to original situation. However, renovations are usually providing other benefits for living well-being and could prevent moisture technical problems in the structures. (Boström et all 2012)

Usually energy efficiency renovations are more feasible in northern Finland than in southern Finland. Renovation costs are cheaper and demand of heating energy is higher in the north. Therefore, renovation will achieve more savings. However, heat recovery is not as effective as in southern Finland, due the long winter period reduces recovery's annual efficiency in northern Finland. (Alatalo 2012) Annual efficiency of heat recovery from exhaust air can be over 90% in southern Finland, unlike, in the north the efficiency is usually 75-90%. (Sjöström 2017)

Heat recovery from wastewater

Approximately 7,2 TWh of heat energy is wasted to the sewers from residential estates in Finland. It means that about 15-30% of heat energy consumption of single residential building is lost. Avereage Finnish people uses 140 liters of water per day, and 40% of that is hot water. In the recent years, there have been invented several solutions to recover this heat energy. There have been heat recovery systems for wastewater before, but these have been suited for municipalities wastewater management plants. These new systems makes possible to recover heat as in estates itselfs. Wastewater heat recovery-systems could recover 30-70% of this unutilized energy. (Wasenco 2018)

Heat recovery-systems are installed in sewer line in the basement of the apartment house. Wastewater flows through spiral pipe in the vessel, where heat is exchanged to the liquid and exchanged directly to estates heating system or it is used to heat usage water of the estate. With these systems, energy could be saved about 10-20% from the total heat energy consumption. (Rakennuslehti 2016)

Indoor air quality

The 90% of the Finns are satisfied with indoor temperatures during winters, and there is no difference between the Northern and Southern Finland. (Turunen et al. 2010). The quality and conditions of indoor air quality are the second most important criterion for selecting office premises in the metropolitan area office space (Skanska CDF Oy & KTI Kiinteistötieto Oy 2012). The figure 1 shows the selecting criteria for office space. However, direct association between thermal insulation and health effects were weak and limited to small prevalence differences of respiratory diseases and colds

(Braubach et al 2008).

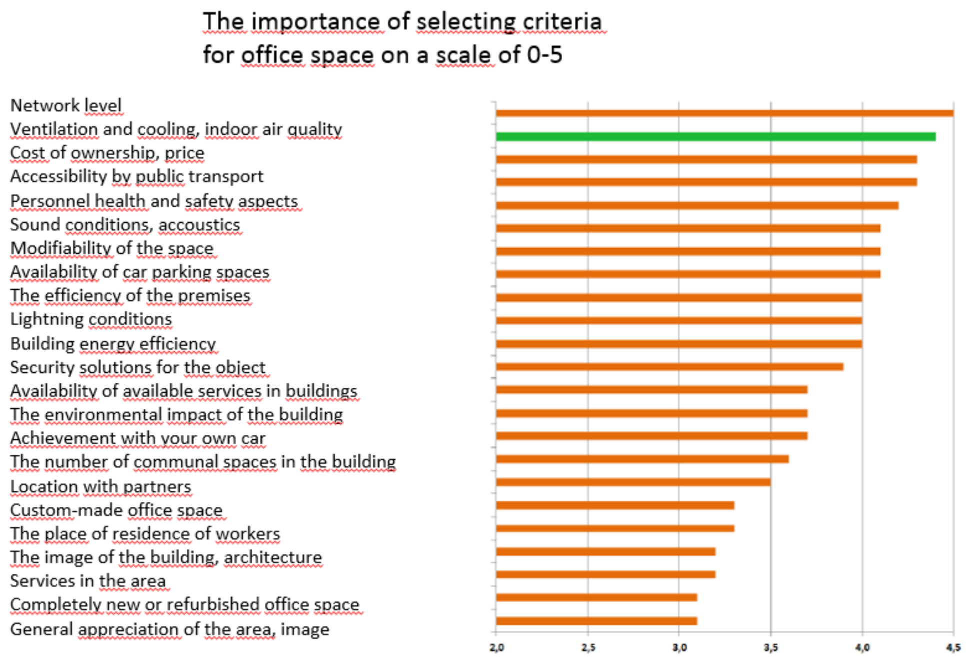


Figure 1: The importance of office selection criteria in the metropolitan area office space.

Indoor air quality and conditions are the second most important criterion for choosing office space, making it even more cost-effective and price-effective (s. 18. Lassila, Ari-Pekka, 2014).

Assessment of energy efficiency follows nationally agreed methods for estimating energy consumption (EU 2012). Before 2012, the main focus was on thermal properties of building structures, aiming to decrease the space heating demand. Table 1 shows how requirement for minimum thermal resistance of building envelope structures have changed across time.

Envelope structures	Year of construction W/m^2 K								
	-1969	1969-	1976-	1978-	1985-	10/2003-	2008-	2010-	2012-
Outer wall	0.81	0.81	0.40	0.35	0.28	0.25	0.24	0.17	0.17
Slab on ground	0.47	0.47	0.40	0.40	0.36	0.25	0.24	0.16	0.16
Slab in crawl space	0.47	0.47	0.40	0.40	0.40	0.20	0.20	0.17	0.17
Floor facing outdoor	0.35	0.35	0.35	0.29	0.22	0.16	0.16	0.09	0.09
Roof	0.47	0.47	0.35	0.29	0.22	0.16	0.16	0.09	0.09
Door	2.2	2.2	1.4	1.4	1.4	1.4	1.4	1.0	1.0
Window	2.8	2.8	2.1	2.1	2.1	1.4	1.4	1.0	1.0

Table1. Minimum U-values of building structures (Du et al 2016.)

According to statistics, the actual U-values of outer wall and roof structures in apartment buildings have followed the development of regulatory values based on year of construction.

Following energy label classifies buildings on a scale ranging from A (high) to G (poor). The limits for energy consumption values for each EE class are depending on the building type. New building must be in class C or higher.

Energy efficiency class	Total energy consumption (include energy source weighting factor, E-value (kWh/m^2, year)
A	E-value ≤ 75
B	76 ≤ E-value ≤ 100
C	101 ≤ E-value ≤ 130
D	131 ≤ E-value ≤ 160
E	161 ≤ E-value ≤ 190
F	191 ≤ E-value ≤ 240
G	241 ≤ E-value

Figure2. Energy efficiency scale (Du et al. 2016).

Preceeding the E-value was so-called ET-value and there were also seven EE classes (A to G) in ET-value classification. However, the calculation rules are different and ET-values are not comparable with E-values.

Researchers recommends that international guideline or reference values are developed for most important indoor environmental quality factors. Researchers also recommends that a basic indoor environmental quality assessment is included in building energy audits. As a minimum, thermal conditions and ventilation adequacy should be assessed, not only from the point of view of energy consumption but also from the point of indoor environmental quality. The basic assessment could be extended based on initial observations and/or feedback from the building occupants. Reporting format related to indoor environmental quality assessment should be further developed pertaining to the international guideline and reference values. Training of energy auditors should cover relevant indoor environmental quality issues.

Air tightness

The number of air leakage rate n_{50} should be 0,5 l/h by The National Building Code of Finland D2. There are also differences between detached houses and apartments. In detached houses, the concrete and masonry houses the volume of the building in relation to envelope area was on average greater than that of log and timber houses. In the project of AISE, the comparison between different types of houses has been made in both the n50-figure and the area of envelope in the normalized q50-figure. The concrete and masonry houses and log houses was founded a weak correlation between the air leakage rates, n50 and volume of the building. The volume of building of air leakage of larger houses were slightly smaller. In the group of wooden houses, the volume of building was not found to have any effect of air leakage rate. The study also compared the effect of different structural factors on the number of air leakage in the detached houses. (Vinha et al. 2009)

The air leakage numbers of apartment houses were average smaller than detached houses according this study. The average air leakage rate n50 was 1,6 1/h and the range of results was 0,3 - 5,3 1/h. Average the smallest air tightness results were obtained by apartments, where intermediate floor was a cast-in-situ (0,7 1/h). (Vinha et al. 2009)

The typical cold bridges in measured detached houses and apartment buildings were in door and window joints as well as doors and windows themselves. Typical air leakage places measured detached houses and apartments were on the outer wall joints with the floor and joints of door and window. According to the results, the structural design of roofs had an impact on the airtightness of stone-build detached houses. On average, leakage rates were lower in stone-based detached houses. Also based on the thermal imaging made in study, the joint of the base and the outer wall is the most common airflow point. Special attention should be paid to the joining of the joint between the heavyweight construction outer wall and the wooden roof. The results shows that the average air leakage rate n50 of detached concrete and masonry houses was 2,3 1/h, it is better than what log houses (6,0 1/h) and the wooden houses have (3,9 1/h). The air leakage rate of the average apartments were 1,6 1/h. (Vinha et al. 2009)

In ventilation the building's air change rate tells how many times per hour the air changes. The air change rate 0,5 1/h means that half of the apartment's air will change in one hour. In detached houses the averages of air change rate were below in the setpoint of The National Building Code of Finland's D2 value 0,5 1/h in both cases of mechanical supply/exhaust ventilation. (Vinha et al 2009)

	Mechanical exhaust	Mechanical supply/exhaust
Number	5	65
The average air change rate [1/h]	0,44	0,38
Standard deviation	0,26	0,15
Minimum [1/h]	0,23	0,13
Maximum [1/h]	0,88	0,91
Median	0,35	0,36

Table 2. Air-change-rates of detached houses in mechanical exhaust ventilation and air-change-rates in mechanical supply/exhaust ventilation (Vinha et al. 2009).

The air-change-rate of mechanical supply/exhaust exceeded the value 0,5 1/h only in 22% of the test targets (Table 2). The lowest measured air-change-rates were under 0,2 1/h in 97% of the targets. As recommended in The National Building Code of Finland D2 and Indoor Air classification 2000 S-3 category the bedrooms should be air at least 6 l/s per one person (current setting). The two-person bedrooms ventilation’s supply air flow are in table 2. Only 7% of the targets exceeded in 12 l/s in two-persons bedrooms and according to Indoor Air classification S1 supply air 24 l/s not achieved in any of the premises with normal use of ventilation. (Vinha et al. 2009).

	Minimum	Operating position	Maximum
Supply air flow [l/s]	4,2	6,67	12,27
Standard deviation	3,46	3,81	6,49
Minimum [l/s]	0	1,25	2,69
Maximum [l/s]	22	22	33,1
Median	3,49	6	11,3

Table 3. The average of the ventilation of supply/exhaust air flows in two-person bedrooms (Vinha et al. 2009).

In apartments the air-change-rates exceeded the average of The National Building Code of Finland’s setpoint 0,5 1/h in centralized and apartment-specific mechanical supply/exhaust ventilation. The average value of the mechanical removal targets was below the setpoint. (Vinha et al. 2009).

	Mechanical exhaust	Centralized mechanical supply-exhaust	Apartment-specific mechanical supply/exhaust
Number (piece)	14	22	15
Average air-change-rate [1/h]	0,39	0,63	0,55
Standard deviation	0,22	0,14	0,13
Minimum [1/h]	0,1	0,33	0,29
Maximum [1/h]	0,8	0,84	0,78
Median	0,33	0,61	0,55

Table 4. The average values of air-changing-rates of the Apartments (Vinha et al. 2009).

70% of all the apartments where is a mechanical air supply, the ventilation were below the setpoint of The National Building Code of Finland's D2 and the targets of the centralized supply/exhaust system and an apartment specific systems 80% of apartment the 0,5 1/h air flow completed (Table 4). The targets of an apartment-specific mechanical air supply/exhaust systems the biggest difference of the apartments was almost 0,3 1/h, because the machines are adjustable in apartment-specifically. Also the centralized supply/exhaust system and apartment-specific systems air flows to the bedrooms below the National Building Code of Finland's D2 value in double-person bedrooms. (Vinha et al. 2009).

	Centralized mechanical supply/exhaust	Apartment-sepicific mechanical supply/exhaust
Number (piece)	16	21
Average supply air flow of bedrooms [l/s]	11,1	6,6
Standard deviation	3,2	2,6
Minimum [l/s]	6,1	3,3
Maximum [l/s]	15,9	12,6
Median	10,8	6,1

Table 5. The average of the supply air flow in two person bedrooms of apartments (Vinha et al. 2009)

The average of air-change-rates was 0,38 l/h which was below of National Building Code of Finland's D2 value 0,5 1/h. 97 % of the targets the air-change- rates value of 0,5 1/h would have been achievable in one of the operating positions of the ventilation unit. The supply air flow of bedrooms were low. The 42% of the targets supply air flow was under 6 l/s in the bedrooms of two persons and 94% of targets under 12 l/s, which was the value of National Building Code of Finland's D2. The average supply air flow was 6,7 l/s. The ventilation of apartment divided to centralized mechanical exhaust, specific mechanical supply/exhaust and apartment-specific system but only the targets of mechanical exhaust systems the average was below of 0,5 1/h. The mechanical supply/exhaust apartments bedrooms air flows were bigger than detached houses. The averages of air flows were 11,1 l/s (centralized supply/exhaust) and 6,6 l/s (apartment-specific-system) (Table 5). (Vinha et al. 2009).

Increasing air-tightness of the building envelope reduces unwanted air-leaks and energy-losses. Air leaks are caused by gaps in joints between building components, lack of insulation and unfitted holes in structures for technical installation. The easiest and most economical way of sealing the house is replace old and bad conditioned sealings of windows and doors. (Häkkinen et all 2012)

Air-tightness also reflects significantly on efficiency of heat recovery system. If building's air is exchanging more frequently than 2-3 times in an hour, air leaks should be taken care of before installing heat recovery system. (Boström et all 2012) Tightly sealed houses have less than one exchange per hour. (Häkkinen et all 2012)

Structural renovations

Additional insulation of external walls can provide 10% savings. It is typically economically feasible if done when other repairing is done for external walls. Typically, additional insulation during structural renovation raises investment cost only 5-15%, so the payback period stays short. (Niemikorpi 2017)

Following table (table 6) describes how additional insulation in externall walls effects on apartment- and detached houses energy economy. Example buildings are built during 1952 – 1980. During the renovation process, thermal insulation was increased by adding mineral wool (50-200mm) on the old wall structure.

	Old externall wall U-value	New external wall U-value	Investment cost €/facade m2	Energy savings %
Detached house 1980	0,29	0,29 (+0mm)	100-140	0
Detached house 1980	0,29	0,23 (+50mm)	150-170	3
Detached house 1980	0,29	0,19 (+100mm)	160-180	5
Detached house 1980	0,29	0,14 (+200mm)	170-190	7
Apartment building 1952	0,86	0,86 (+0mm)	100-140	0
Apartment building 1952	0,86	0,48 (+50mm)	160-180	12
Apartment building 1952	0,86	0,34 (+50mm)	170-190	17
Apartment building 1952	0,86	0,21 (+200mm)	180-200	21
Apartment building 1974	0,4	0,40 (+0mm)	100-140	0
Apartment building 1974	0,4	0,29 (+50mm)	160-180	5
Apartment building 1974	0,4	0,23 (+100mm)	170-190	8
Apartment building 1974	0,4	0,16 (+200mm)	180-200	11

Table 6: (Virta & Pylsy 2011)

Additional insulation of attic floors is economically feasible in detached houses if it is technically possible to do. Possible energy savings can be 5 to 12%. Heat losses through attic floor is relatively small in Apartment buildings but in detached houses heat losses are much higher. Additional insulation for attic floors should be considered, especially when there is enough space between attic floor and roof. Additional insulation could be done with blow wool on the top of old insulation. (Virta & Pylsy 2011)

Following table (table 7) describes how additional insulation on attic floor effects on energy economy of apartment houses and detached houses built in years 1952-1980.

	Old attic floor U-Value	New attic floor U-value	Investment cost €/attic floor m2	Energy savings %
Detached house 1980	0,23	0,13 (+200mm)	5-6	7
Detached house 1980	0,23	0,10 (+300mm)	7-9	9
Apartment building 1952	0,85	0,21 (+200mm)	5-6	11
Apartment building 1952	0,85	0,15 (+300mm)	7-9	12
Apartment building 1974	0,35	0,15 (+200mm)	5-6	5
Apartment building 1974	0,35	0,12 (+300mm)	7-9	6

Table 7:(Virta & Pylsy 2011)

Windows

New windows can also give 5-10% saving. It needs to be remembered, when structural renovations are done that ventilation and heating systems should be adjusted properly to answer new situation. (Niemikorpi 2017)

Today's typical window's thermal insulation is about three times better than the 1970's window. The U-value of the current basic window is 1,0 W/m^{2}K, which is also the requirement for building construction in the collection of the National Building code of Finland. The best U-values for insulating windows vary between 0,6 W/m^{2}K and 0,8 W/m^{2}K (Virta & Pylsy) .

	Old Window U-value	New Window U-value	Investment cost €/window m2	Energy savings %
Detached house 1980	2,1	1	350-450	8
Detached house 1980	2,1	0,7	450-550	10
Apartment building 1952	2,9	1	350-450	15
Apartment building 1952	2,9	0,7	450-550	17
Apartment building 1974	2,1	1	350-450	11
Apartment building 1974	2,1	0,7	450-550	14

Table 8: The impact of renewal of windows on the energy consumption of the property. The investment cost (includes VAT) means the windows are installed in place. (Virta & Pylsy 2001).

The durability of the window depends essentially on their structure, materials used, and the quality of maintenance. Correspondingly, the necessary maintenance and their practical implementation depend on both the material of the window fittings and the window types. (Virta & Pylsy 2001).

Damage to the windows is due to among other things. Outdoor exposure. The worst are the sloping slope, solar radiation (especially dark windows) and air pollution. Most suffer from weathering the south and west side of the upper floors and windows. Window damage is also caused by the use of windows and poor handling. The general cause of the damage is the failure to observe the regular care of the paintwork and paint surfaces. (Virta & Pylsy 2001).

Usually, a fitness assessment reveals which repair options are to come and where corrective measures should be taken. The fitness assessment of the windows can be connected, for example. A resident survey that gives output information to the fitness calculator for example temperature and traction problems as well as observed defects and damage. (Virta & Pylsy 2001).

Typical repair options for window structures are window upgrades, additional louvers or front windows, and windows with braces. Regular and systematic maintenance of the windows is usually more advantageous than the fact that the windows had to be replaced prematurely due to damage due to maintenance failure. (Virta & Pylsy 2001).

To renew windows, attention must be paid to:

- Additional thermal insulation (U) value of the windows
- The total permeation of the solar radiation of the windows, the so-called g-value
- The purchase of potential blinds
- Airtightness of the windows sound insulation and
- Operation of the ventilation after window shutter.

The new windows must have a U-value of not more than 1,0 W/m^{2}K, and attention should be paid to g-values as it affects the living comfort of the summertime. The old windows have a g-value of about 0,75, which means that 75% of the solar radiation that is affected by the windows comes into the room. There is a difference between the passing values of today's windows: typically, 45-55% penetration, but there are also effective sunscreens that pass through solar radiation by only 23-30%. (Virta & Pylsy 2001).

If the room replacement air has previously been obtained from leakage from old windows, it reduces the number of windows exchanging air volume into the room. In this case, the ventilation becomes insufficient. When replacing the windows, the installation of replacement air valves and the basic regulation of the ventilation system should be ensured. At the design stage of the renovation, it is important to consider what kind of compensation solutions will ensure the best result. For example, incorrectly selected replacement air valves can significantly reduce the sound reinforcement on new windows or cause unnecessary drawbacks in winter. (Virta & Pylsy 2001).

If the property has a mechanical extract air exchange, which is not being transformed into a mechanical intaken-exhaust ventilation system, consideration may be given to installing so-called supply air windows. Their operating principle is simple: outdoor air is led through the upper, lower or lower armrest through the window frame and further into the room air through upper arm or frame. The outdoor air in the window structure can be filtered to meet the purity requirements of the supply air and the window will remain cleaner. (Virta & Pylsy 2001).

When flowing through the window structure, the air flow is warmed up. Heat to the supply air also passes through the window's own heat losses and window-directed solar radiation. The best supply air windows correspond to the thermal insulation of windows with an U-value of 0,8 to 1,0 W/m^{2}K. Improved airtightness and thermal insulation of refurbished windows generally reduces the need for heating rooms. This must be taken into account in technical systems, so that room temperatures do not rise to high. Room temperature increases can be avoided by re-setting the heating curve or by basing the radiator network. (Virta & Pylsy 2001).

The cost of window repairs is 60-90 € per living area, when the window price is 450€/m^2. Energy saving estimates are based on the assumption that the window area is 15% of the residential area. The larger the window area relative to the residential areas, the higher the investment cost and the energy savings. If windows are combined with blinds, the additional cost is 30-50 €/window area. For example, in a 80 m^2 apartment, the installation of a Venetian blinds at the window can cost about 500€. (Virta & Pylsy 2001).

Replacing windows will also improve living comfort. The better the window isolates the heat, the higher the temperature inside the window's inner glass in the winter. Higher glass surface temperature reduces the feel of the cold surface. In addition to thermal insulation, living comfort is also influenced by the sun radiation penetration factor and any blinds – especially in the summer. (Virta & Pylsy 2001).

With a comfortable sunshade window, the maximum indoor air temperature can be up to seven degrees. However, when selecting sunscreen windows, it is important that they prevent the visible light from entering the room, or darkening rooms. Better summertime temperature control also has the other side of the coin: windows prevent sun heat from entering the room even in fall. It follows that heating energy needs to be bought a bit more than in those days if there were normal windows in the rooms (Virta & Pylsy 2001).

It is possible to calculate maximum room temperature summertime temperatures as close as possible to sunlight windows. On the other hand, the blinds do not prevent the sun and heat from heating in the spring and autumn. However, the most important role is the resident who adjusts the position of the venetian blinds. For the best benefit, blinds should be used actively by opening and closing them as needed (Virta & Pylsy 2001).

Quality assurance of moisture and dust

Moisture and microbes have been increasingly present in the various media in recent years, partly because of the moisture and hometown measure program run by the Ministry of the Environment. In the research of HKPro3 the primary goal was to clarify the significance of clearing and quality requirements attached to the grant applications, and in particular, the relevance of the expert assessments attached to the grant applications to the success of corrections and the effective allocation of state subsidies (Marttila et al. 2015).

The objective of quality assurance is that the building complies with the qualitative requirements set for it. The quality assurance required by the authorities for the construction project is based on laws, regulations and building regulations that ensure a minimum level of building construction. The quality assurance of the project also includes the consideration of the objectives of the project on moisture and dust management at various stages of the project (Marttila et al. 2015).

Quality assurance measures for a construction project can be viewed as follows:

1) Project control/procedures in quality control
- Meeting practices, reviews
- Plan change processing
- Documentation
- Task responsibilities, appointment of person

2) The specific features of the object and the risk assessment

- Technically critical working phases
- Operationally critical work phases
- Risk assessment, analysis of expected problems

3) Supervision of work executives and materials

- Approval of subcontractors
- Procurement quality control

4) Quality control of work steps and supervision of work outcomes

- Task planning, control of work stages and inspections

- Contractor quality control, self-delivery
- Supervisor of the developer
- Delivery

Quality assurance measures required by the builder

The quality assurance measures required for the research sites are presented in a number of contract documents. As a requirement, various aspects of quality assurance procedures, risk assessment, and employee and quickly control have been presented. The requirements are generally of a general nature, which is to say that they are suitable for the quality assurance of any construction project. Since the organization of the site and execution of the actual construction work are the tasks of a contractor, the requirements of the developer for quality assurance can be general. In that case, however, the developer must ensure that the contractor's quality assurance measures are adequate on site repairs and on the builder's own quality system (Marttila et al. 2015).

According to the general contract terms of the building contract, the contractor must, on demand, indicate in writing how he will ensure the quality of his performance. Requirements of a written quality plan and approval of the plan by the developer is a reasoned way of working to ensure that the quality assurance measures required by the project are avoided in the quality of the site (Marttila et al. 2015).

Quality assurance help

The grant terms and the application guidelines do not specify the content of a quality assurance instructions of the party that must make this manual. For this reason, the subject of the HKPro3-research has been interpreted differently (Marttila et al. 2015).

The lower level of workplace quality plans is due in particular to the fact that only a few plans have taken into account the measures required by the contractor's contract documents. Many workspace quality plans also appear to be generic that it would be suitable for any quality plan for the site. Documents can often be made on the basis of the documents of the previous project, so that they are not sufficiently carefully adapted to the specific features of each site. The quality management plans of the site have been slightly more carefully taken into account in the construction site's specific features and risk assessment. Avoiding the unnecessary risks to the site and taking special features into account will have an important impact on the time schedule, cost and thus the overall outcome of the work. On the site, you should prepare for the risks in advance. In the guidelines drawn up by the developer, remarks are most closely linked to the guidance of quality control procedures (Marttila et al. 2015).

Realization of quality assurance on site

The implementation of measures required for quality assurance on the site has been assessed on the basis of the interview supervisor or developer's interview response. The success of quality assurance on the site is significant, in addition to the quality assurance measures of the site, the activity of the construction supervisor, the professionalism and the ability to co-operate with the contractor. The building supervisor plays an important role in the quality assurance of the site. Since quality assessment is the subjective view of each interviewee, there may be differences in the level of assessments between different projects (Marttila et al. 2015).

Moisture management

The moisture and mold damage of the building result from excessive moisture in the structures. In order to prevent damage during all stages of a construction project, measures must be taken to prevent the damping of structures. In preparation for the construction phase, the developer guides the site's moisture management according to the target by clearly listing the project's contract documents in terms of its intent and the measures that the builder particularly wants to invest in the project. In the landfill site, the main goal of the developer is to ensure that the site is handled to manage and control the conditions so that the building materials and finished building blocks are prevented from getting wet and the dehydration of the structures is possible. These measures are designed to prevent the formation of harmful humidity in the structures and to reduce the need for drying the site (Marttila et al. 2015).

The site's moisture management is part of the work planning and quality management of the site. The site's moisture management measures and their design ensure the achievement of the goals set by the developer and achievement of a good and demanding construction. Moisture management measures for a building project can be viewed as follows:

1) Moisture risk mapping
- Moisture-technically critical and risky structures
- Planning the implementation of risky structures

2) Drying time estimate / coatability of structures

- Concrete constructions to be coated

3) Planning the construction site management

- Preventing building materials and the hull of the building
- Protection of incomplete construction parts
- Preparing for water damage (pipe leakage, shielding, etc.).
- Design of the curing of the building

4) Humidity measurement plan

- Measuring points and methods
- Qualification of the humidity meter
- Schedule

5) Moisture management organization, monitoring, reporting and control

- Responsibilities and responsibilities of the responsible
- Documenting the measures (Marttila et al. 2015)

<u>Moisture control plan</u>

The site's moisture management plan defines concrete moisture management measures on site. The assessment of the moisture management plans prepared by the builder is above the acceptable level for all the components and there is little difference between the sub-areas estimates. In the assessment of the sub-areas of the site's moisture management plans there is more variation compared to developer's plans. In the workplace's plans, moisture management components have been designed to organize, monitor and monitor moisture management measures. Measures relating to moisture risk mapping, condition management and de-structuring and coatingability have been designed at site on a good assessment level. (Marttila et al. 2015)

Dust control

A lot of dust is generated in the construction work. In the renovation projects, dust is especially generated in demolition work. Breaking of structures, handling, transport and cleaning of unloaded materials will expose workers to impurities from the materials. Repair projects often also demolish damaged structures, where workers can be exposed to microbies. In the repair site, control of dust management is hampered by the unexpected structures or old building materials that were unexplained in advance at the demolition work and which may require special action (Marttila et al. 2015).

The most important dust management objectives of the renovation project are the cleanliness of the areas to be repaired after the repair work and the maintenance of the existing premises clean during the repair work. During the repair work, furthermore, in order to ensure occupational safety, the working environment must meet the hygienie requirements of the authorities. (Marttila et al. 2015)

On a construction site, there is sometimes disagreement between the cleanliness of the work site and the level of dust in the completed building. The constructor should clearly and unambiguously define the contract documents as a requirement for the dust management level of the construction site and the completed building in order to avoid

The dust management measures of a building project can be viewed as follows:

1) dust-free working methods

- Selection of working methods
- Selection of low-dust-materials

2) preventing the spread of dust

- Storage and vacuum
- Spot descent, shutdown mode
- Wet methods
- Adequate ventilation
- Thresholds on the route

3) clearout

- Methods
- Quantity, scheduling

4) avoiding exposure and personal protection

- Guidance and training
- Minimizing exposed workers
- Choice of the right type of protection according to the exposure

5) organization, monitoring, reporting and control of dust management

- PICs
- Target levels and guidelines (Marttila et al. 2015)

Dust management plan

There is a significant difference in the evaluation between the developer and the plans drawn up by the site. Plans drawn up by the builder include sufficient measures for all aspects of dust control. The level of plans drawn up by contractors is clearly below the developer's plans. In all plans, the most commonly planned measures for the organization, monitoring and control of dust management. Dust prevention, cleaning and personal protection are best described in dust control areas. Workplace dust management plans contain measures to prevent the spread of dust and the use of respirators, but there is no mention of their allocation to clearly different stages of work such as dismantling of microbicated structures (Marttila et al. 2015).

Repair plans

Repair plans are drawn up on the basis of information from the condition survey and separate meetings and reviews. The condition survey data and other building information will be delivered to the designer immediately at the design startup stage for familiarization. The condition researcher and repair designer are advised to visit the site for damage, risk analysis, and repair needs (Marttila et al. 2015).

The repair planner shall present the designs to the repaired in the plans, the extent of the repairs required, the repair and repair materials used. In addition, the plans or specifications show other things that may have an impact on the cost of a repair work, schedule or work loss. These may include, for example, the required templates, their scope and their approval, the necessary hedges, quality assurance measures, abnormal drying times of materials, etc. Repairs must be made in the repair plans to the extent necessary so that the damage caused by the health examination presented in the condition survey can be eliminated and the building can be safely used. Repairs must be designed in such a way that the cost of repairs remains reasonable. In the design, the method of repairing the damage must be determined so that the structure can be re-damaged. In this case, the designer has to consider whether the structure can be retained in accordance with the old plan or whether the structure should be corrected in accordance with the current building physics review and knowledge. Depending on the damage site, the repair can also be designed to remedy the damaged materials and structures clearly damaged, but minor repairs or cleaning of the less damaged areas around the damage. In some cases even the molded material inside the structures or in the outside ventilation space will not necessarily need to be changed if the transfer of the homogenous dust or the like to the room space can be prevented by a reliable method. It is recommended that plans are always given to commentators on a condition researcher or other external expert to ensure the adequacy of the corrections (Marttila et al. 2015).

Conclusions

The quality of condition surveys and their reporting is expected to develop with the new condition study guide and new qualification requirements. In the area of quality assurance and in particular in matters relating to local government decision-making, there is still room for improvement in the coming years (Marttila et al. 2015).

Too large-scale assignment, possibly inferior statements, some of the commentators were incompetent and reluctant to evaluate the success of the projects sufficiently thoroughly. In the study of HKPro3, it was not possible to estimate what was the significance of an individual statement to the success of the renovation project. In other words, a formally incompetent statement or its author may have been a very important factor for the success of the project. However, a formally valid opinion has better conditions to influence the quality of the project. In the future, a template form should be used as a reference template to minimize the quality level variation (Marttila et al. 2015).

In the opinions on the subject's condition studies, the conditions of the building and importance of indoor air problems for the users of the building, there were some substantive deficiencies. In the remedial statements, the statement could only assess whether the problems identified in the condition test were corrected. Statements should be made more specific and should be more clearly interlinked. The statements should ensure that the condition of all building blocks is known and all factors affecting indoor air quality have been taken into account in the plans. These measures reduce the variation in the quality of opinions and harmonize the application process, which also facilities the work of State Aid Authorities. The merger of statements would reduce the number of applications because the statements would not have to be submitted. This problem would be eliminated if the application process was a systematic and annual recurring process (Marttila et al. 2015).

Besides the various procedures, to achieve the goal of achieving the goal is of paramount importance in the co-operation between the expert and the subscriber, as well as through the whole repair process and the other parties involved. The aim is to provide a technically, economically and operationally viable remedial action to remove indoor air and health hazards. According to the findings, many consultants receive regular assignments from municipalities and tighter government subsidies have increased co-operation between municipalities and consultants. However, consultancy companies are dependent on the number of orders and may, in the framework of contract terms and generally acceptable practices, provide favorable statements to applicants of state subsidies. It is virtually impossible to verify the complete outsourcing, as many experts may have been working for many years in co-operation with the subscriber (Marttila et al. 2015).

However, the main research proposal is related to the development of expert opinions. The research team has prepared a draft form based on the form. Filling the form is designed to be plain and unambiguous, but flexible to editable and easy to use. This will help the expert input into the solution of his/her own special skills. The main purpose of the form is to support the project's success, ie the implementation of a healthy building. One purpose of the form is a create a clear understanding of the subject's condition and condition studies for the subscriber, thereby facilitating decision-making related to the implementation method or project prioritization. The form is intended to assist the customer in the repair of a repair project or an existing building replacement project for the purpose of analyzing condition tests, project plan and repair plans. The operating model is designed for use by all property owners (Marttila et al. 2015).

The aim of the form templates is to facilitate the economic problem caused by moisture, mold and other indoor air problems other than just distributing state subsidies. Grants are also used to renew non-indoor building elements. This is, in many cases, profitable in the context of a comprehensive renovation, but it may be more effective to cover government subsidies, especially in indoor air problems, if it is possible to identify grants for grants directly affecting the repair or immediate prevention of indoor airborne problems. The lower cost of a project eligible for a grant should be raised because very small contributions have only a small impact but a lot of work needs to be done to get the grants. Small projects are also often launched without government subsidies. The size of the grand should also be considered as the upper limit for which the overwhelming part will no longer be paid because very large projects may consume an unduly large portion of the grant (Marttila et al. 2015).

State aid granted to a renovation project and the work done to it will be lost if the aided project fails to overcome all indoor air problems. The most significant economic problem is the need for repair and the continuation of the health problem. The form created in the survey is intended to assist all property owners in the analysis of their rehabilitation project (or, if applicable, a new construction project) for analyzing condition surveys, project plans and repair plans. The most significant benefit of the form is to guide the co-operation between the various parties to ensure that all building blocks are properly investigated and repaired. Only with this motive the procedure will benefit all parties (Marttila et al. 2015).

Saving in electrical cost

Basic maintenance of ventilation system can provide 10% savings. Old fashioned lightning bulbs can be replaced with more energy efficient ones and get 5-10% savings. The new building automation system can create 5-10% savings. In addition, basic maintenance of elevators can also save some electricity in apartment houses. (Niemikorpi 2017) In addition, energy efficient household appliances can reduce electricity usage.

Reducing heat energy- and water consumptions

In many cases heat energy is wasted due the radiators does not work as they should. Radiators might be too small, which is compensated by raising temperature of circulating water. Thermostatic valves might not work properly or customers does not know how they are used. Balancing heat loads and repairing heat distribution systems can together provide about 15% savings. (Niemikorpi 2017)

Water could be saved 10% with nozzles and valves, which controls water flow and pressure. If every apartment doesn't have own water meter, it can provide massive savings, due the end user can follow their water consumptions. When larger renovation is done for the pipelines, it is usually feasible to install new water fittings same time. New taps and toilets can save 10-25% water compared as old ones. (Niemikorpi 2017)

Investing in an air-heat pump is a good way to reduce electricity or oil usage for heating. Heat pumps can be also used for cooling in summer time, however active or unnecessary cooling might cancel the savings. If heat pumps are used to support direct electricity heating, the savings in electricity usage are 8-26%.

Summary

Following table shows feasible renovation options for different building types from different eras.

Possible energy efficiency renovations	Building year	1950	1960	1970	1980	1990	2000	2010
Single family house & detached houses	Long term renovation plan should always be done before renovations. Structural renovations always effects on ventilation and envelopes building physical characteristics.							
External wall (wood)	During renovation of external claddings, additional insulation of 100mm							
Roofs	Additional insulations 100-300mm of wool if there is enough space		Flat rooftops; Additional insulations during rooftop renovations		Additional insulations if there is enough space			
Windows	Windows that are in bad conditions are replaced at age of 30-40 years					Windows are replaced at age of 30-40 years or only internall glass is replaced		
Base floor	Additional insulations only for ventilated base floors							
Sealing the envelope	Envelope sealings with ensuring that exhaust only ventilation systems operates correctly.					Replace sealings from windows and doors, during other renovations sealing of wall joints.		
Ventilation and heat recovery	If building could be sealed properly and there is room for air ducts, new ventilation system could be builded. Old ventilation machines could be replaced by newer ones.						Old ventilation machines could be replaced by more energy efficient ones	
Others	After renovation, it is important to adjust ventilation and heating system operate correctly. Adding insulation on pipings and air ducts which goes through to the cold spaces. Solar panel and heat pump installations should be considered.							
Apartment buildings	Long term renovation plan should always be done before renovations. Structural renovations always effects on ventilation and envelopes building physical characteristics.							
External wall	Additional insulation only if building heritage allows it	Additional insulation during renovation caused by technical age						
Roofs	Additional insulations if enough space		Additional insulation if possible during rooftop renovation					
Windows	Precious frames repaired carefully		Bad conditioned windows are replaced at age of 30-40 years or only internall glass is replaced					
Base floor	Only is buildings use is changed radically							
Sealing the envelope	Envelope sealing with ensuring that exhaust only ventilation systems operates correctly.					Replace sealings from windows and doors, during other		
Ventilation and heat recovery	Ventilations renovations could be done during pipe repair process							
Others	After renovation, it is important to adjust ventilation and heating system operate correctly.							

(Heljö & Vihola 2012)

Renovation process should be leading towards to complete solution instead of particular practises. Additional insulation material or products are not the only solutions for energy efficiency building. Practical solutions are combinations of different practises, which needs understanding of how the whole building is working. Better insulation and air tightness effects on the operation of ventilation and demand of heat energy. In the worst case, energy efficiency might get worse, if ventilation and heating systems are not adjusted afterwards. In addition, moisture technical challenges should be also carefully considered when structural renovations are done. (Ojanen, Nykänen & Hemmilä 2017)

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