HEAT PUMP APPLICATION RECOVERING EXHAUSTED AIR ENERGY IN LARGE APARTMENT BUILDINGS

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Abstract: Finland belongs to the cold climate zone in Europe where heat pumps are increasingly used for decreasing the space heating costs and CO2 emissions of buildings. Typical applications today can be divided to two main categories. 1. Ground source or air-to-water heat pumps in buildings having either radiators or floor heating. 2. Air-to-air heat pumps for buildings having direct electric heating. A new category in Finland is an application where the energy source for a heat pump is the exhausted air of an existing building. Significant cost savings can be achieved by recovering the energy of the exhausted air and transferring it back to the buildings heating system. Recovery ratio is higher compared to the traditional heat recovery with ventilation. The main markets for this kind of application are the existing large apartment buildings connected to district heating where air is exhausted by one or two centralized roof ventilators without any recovery. First installations in Finland have been made and energy consumption before and after installation has been measured. This presentation describes how this kind of application works, what are the savings and benefits to the customer and the environment.

Key Words: heat pumps, heat recovery, exhausted air, large buildings

1 INTRODUCTION

Finland is a north east country of the European Union where space heating of existing buildings contributes 25% of total final energy consumption.

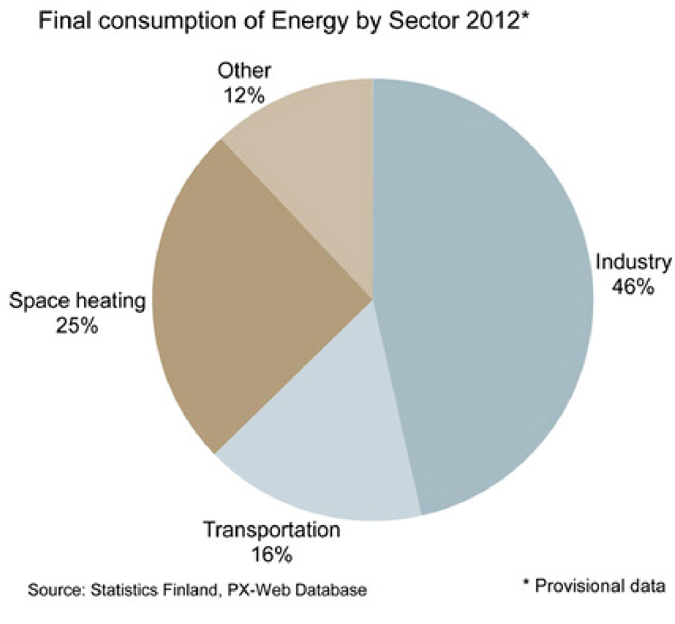


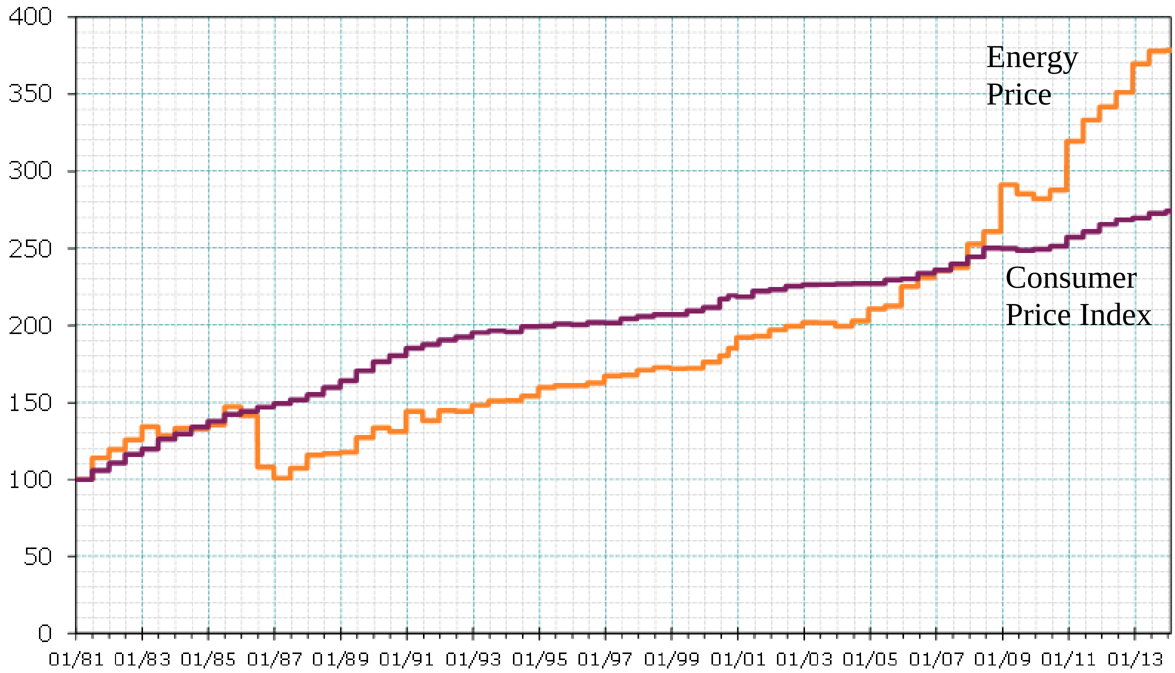
Figure 1: Final consumption of energy by sector 2012 (StatFin 2012_1)

Most common space heating method is district heating which has been available since 1950's. About 2.6 million habitants live in houses or apartments that are heated by district heating. This represents 50% of Finnish population.

Almost 80 % of district heating is produced in CHP (Combined Heat and Power) plants and the rest is coming mainly from natural gas, coal, peat and oil (Energy Industry 2014 District Heating).

Although district heating has been, and still is, very popular form of heating there are also challenges seen in future. People are interested about methods to decrease their energy consumption due to the continuous increase of energy costs as well as overall awareness about global climate change due to burning of fossil fuels.

Energy industry has started some actions to mitigate this challenge by taking also renewal energy sources such as wood and biogas to produce district heating. This has, together with higher taxation rate, increased the cost of district heating energy.



Source: http://energia.fi/tilastot/kaukolammon-hinnat-tyyppitaloissa-eri-paikkakunnilla

Figure 2: District heating energy average price, 1st Jan 1981 = 100 (Energy Industry 2014 Price)

Especially during the last couple of years district heating costs have increased significantly which has supported heat pump industry to grow. Especially in existing large apartment buildings the interest for the application where heat pump is combined with exhausted air heat recovery has been increased significantly.

The following chapters will introduce this application using also a case example. Brief analysis of potential renovation market is also shown and then conclusions are drawn.

2 BACKGROUND

In Finland the existing large apartment buildings has been mainly built during the last century. Ventilation method has been varying over the time and we can identify three different periods:

- Before 1960's natural ventilation was used
- From 1960's up to the 2002 mechanical ventilation without heat recovery was used
- 2003 and onwards mechanical ventilation has included also heat recovery

The second period i.e. buildings from 1960's to 2002 are the potential target group for this application and during that time totally 38500 apartment buildings where built, representing 62 million square meters of space heating (StatFin 2012_2).

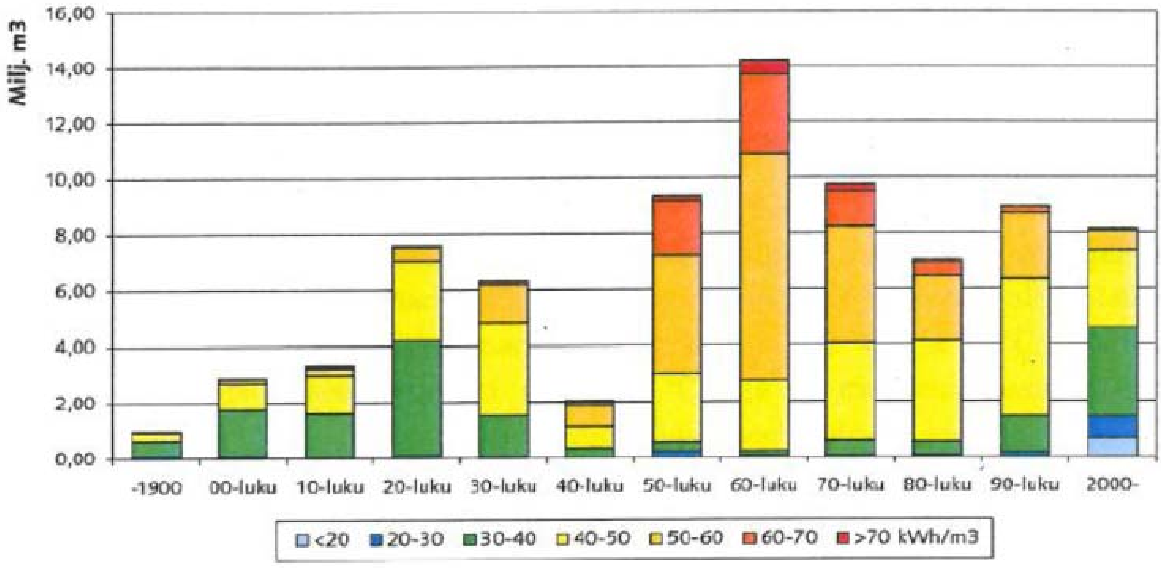


Figure 3: Apartment buildings built in different decades

According to a study made by VTT 46% of heating energy loss is thru ventilation in these buildings (VTT 2010).

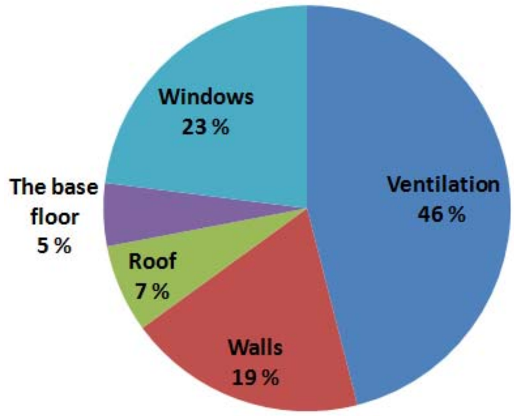


Figure 4: Heating energy loss

Majority of this loss can be recovered by a heat pump application.

3 TECHNOLOGY

In buildings built 2002 and later the energy of exhausted air is recovered by using a mechanical ventilation unit that returns the heat energy to incoming air of the building.

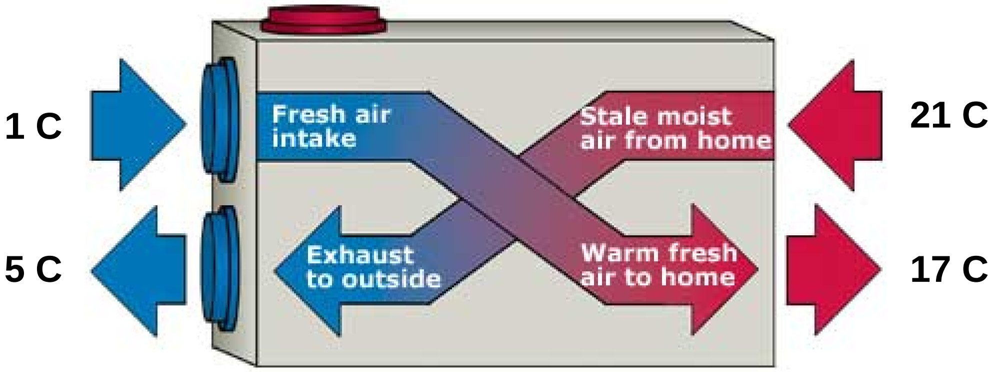
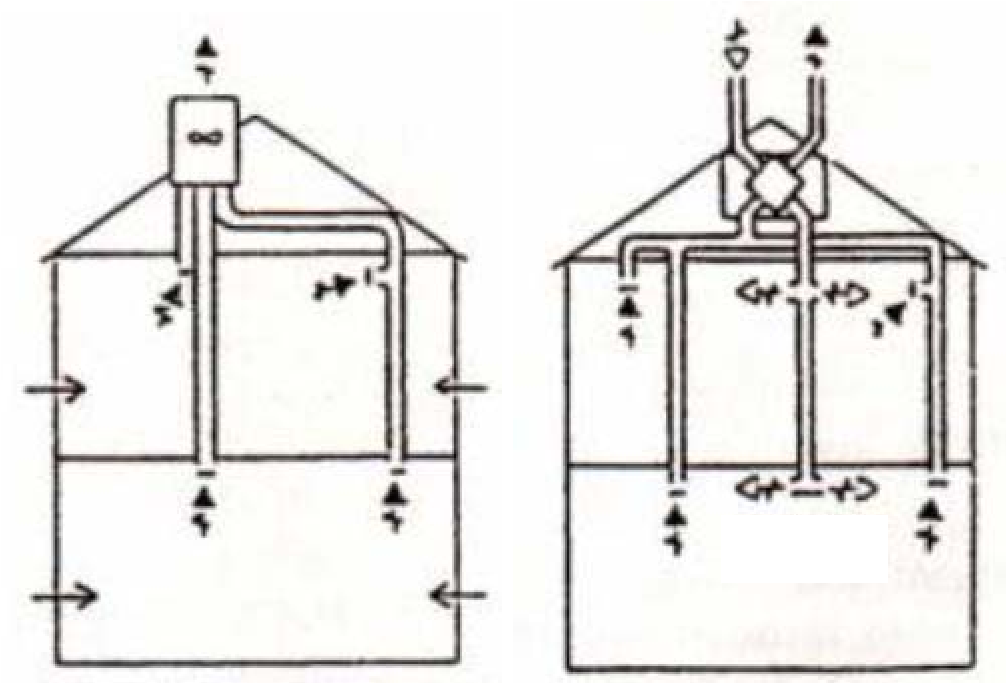


Figure 5: Exhausted air-to-air heat recovery

This method is not suitable for older apartment buildings as the fresh air intake is not coming thru a centralized ventilation unit but from the ventilation valves integrated for example to room windows.



Buildings from 1960 to 2002 **Buildings from 2002 onwards**

Figure 6: Mechanical ventilation methods

In these type of older buildings it is not economically suitable to renovate houses in order to get pre-heated incoming air to each room via a centralized ventilation unit. It is rather much more feasible to replace the exhausted air ventilation unit with a new one including a heat exchanger that recovers the energy to liquid.

Liquid pipes connects then the heat exchanger located on the roof with the heat pump located in the heat distribution room. The heat pump's purpose is to raise the temperature to 40-65 C which can be supplied to heating radiators. In summer time, when there is no need for heating of the house, the heat pump can supply hot tap water, instead of using district heating.

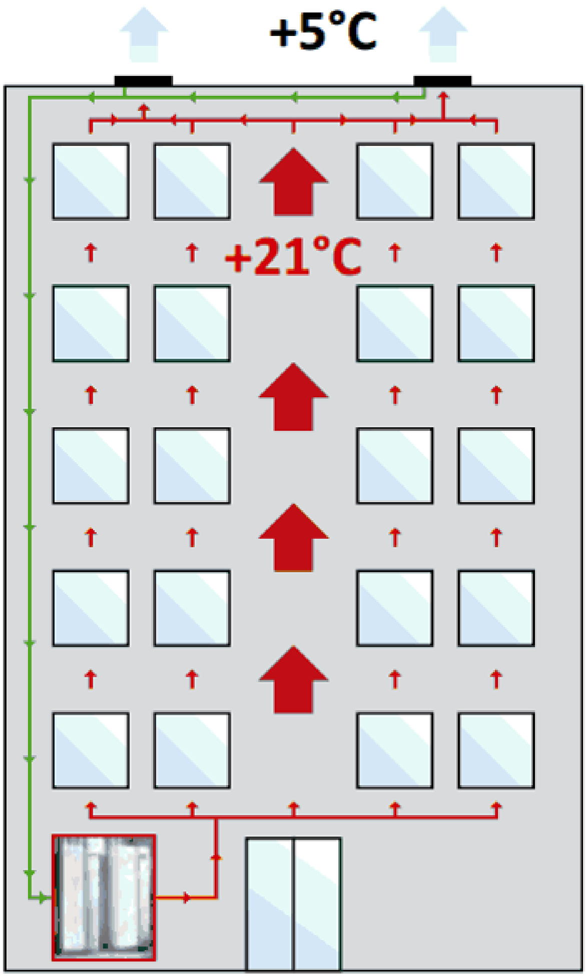


Figure 7: Principal of exhausted air heat recovery with a heat pump

With this method the district energy consumption is halved and when adding the energy needed by the heat pump the net energy saving is typically around 40%. Depending of the energy prices the heating cost saving is typically between 30-40%. Additionally the basic fee of district heating is also reduced by 50% as it is linked to the volume of energy used.

4 CASE EXAMPLE

A heat pump recovering exhausted air system was installed in January 2013 to one large apartment building in the city of Jyväskylä which is located in central Finland. This 6-floor building has been built on 1971 and district heating energy consumption was 750 megawatt hour annually.

Figure 8: Case example building from Jyväskylä city

The heat pump is connected to the radiator heating circuit as well as to the tap water circuit via a buffer tank. Automation takes care of when heating of radiators is needed and when there is a need to heat tap water.

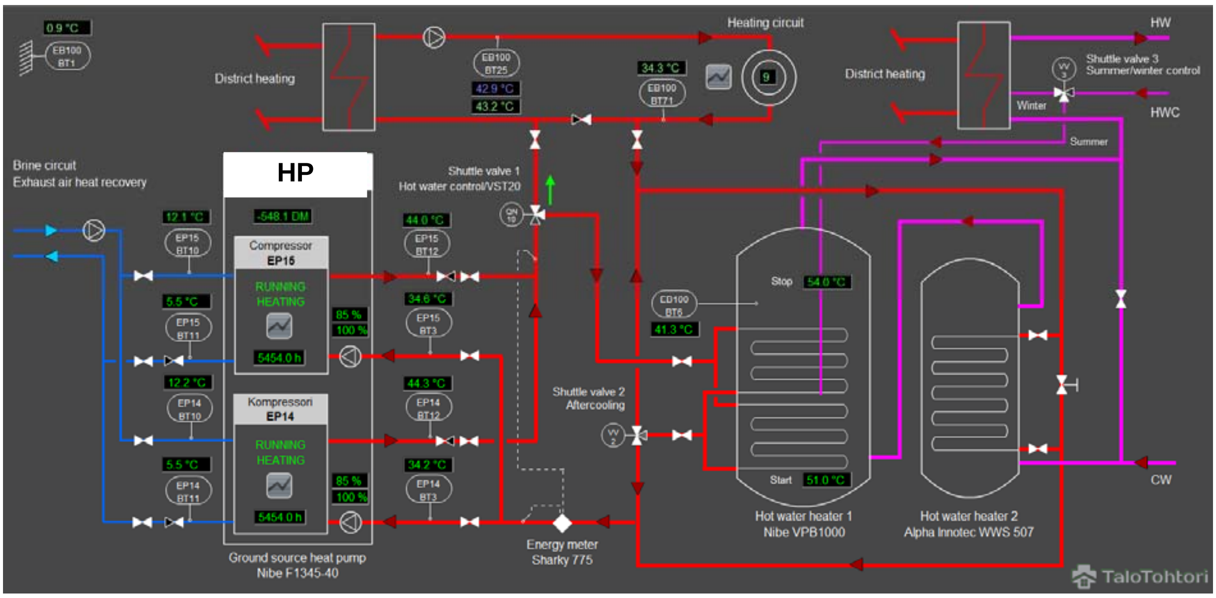


Figure 9: Heat pump connection to heating system

During the installation energy meters were also installed to measure the energy consumed by the heat pump and energy produced by the heat pump. After one year of follow-up the following results has been achieved:

- District heating energy has been decreased by 45.1% from 750 to 412 megawatt hour resulting to 73 tCO2/a reduction of CO2 emissions.

- Heat pump consumed electricity 61 megawatt hour resulting to 13 tCO2/a increase in CO2 emissions.
- Overall net energy consumption has been decreased by 37% from 750 to 473 megawatt hour
- CO_2 emissions has been decreased by 60 tCO2/a[1] (Motiva 2012 CO2-calc)
- Energy costs has been decreased from 53 700 euros to 34 800 euros representing 18 900 euros annual saving[2]
- Energy cost saving was 18 900 euros / 35.2%
- Investment cost was 120 000 euros[3]
- Return on Investment ~16% per year
- Heat pump SCOP (Seasonal COP) was 3.8

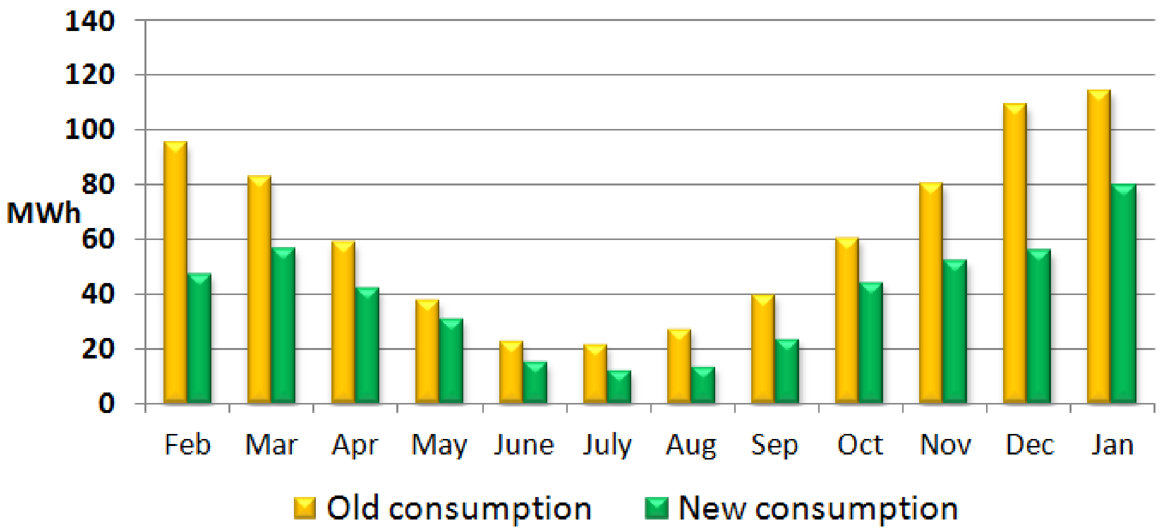


Figure 10: Change in monthly energy consumption

5 MARKET ANALYSIS

5.1 Market potential

As mentioned in chapter 2 the main renovation market for this heat pump application are the large apartment buildings from 1960 to 2002. During this period totally 38 500 apartment buildings have been built. Due various reasons not all of them are applicable for this kind of renovation. Assuming that 80% of them are in the target group, we will end up to 30 800 buildings.

The average investment for one building is 90 000 euros (VAT 0%) so the total market opportunity is 2.8 billion euros. Assuming that such an investment for these buildings will be made during next 20 years, there is 140 Million euro new annual market opportunity.

Annual investment in Finland’s heat pump market has been 400 million euros (Hirvonen 2014) so we are talking about 35% increase to that market.

[1] District heating CO2 emission average in CHP areas 217 kgCO2/MWh. Electricity purchase power CO2 emission Finnish average 2013 210 kgCO2/MWh
[2] Energy prices used: Electricity 120 €/megawatt hour, district heating 58 €/megawatt hour, including VAT 24%
[3] Including VAT 24%

5.2 Energy Industry view

The Finnish Energy Industries is an industrial policy and labour market policy association representing the electricity and district heating industry in Finland. It has published instructions and guidelines for district heating of buildings to be adopted by the energy companies (Energy Industry K1 2013). One part of instructions includes technical recommendations how local energy sources, such as this application, should be connected to district heating system. The reason for providing such a guideline is to ensure that cooling requirements of district heating return water temperature are met. This is a valid reason as CHP plants cannot operate optimally if return water temperature is not low enough.

These recommendations, if followed strictly, may however decrease the energy saving opportunity as a heat pump cannot operate in its optimal conditions or all available energy of exhausted air cannot be fully exploited.

At the moment there are various approaches taken by different district heating energy companies in Finland. The two major energy companies in city of Helsinki and Turku have adopted this recommendation very strictly and they do not allow any other kind of installation.

On the other hand, the Energy Companies in city of Jyväskylä and Tampere has a more flexible attitude for the installation. Tampere city especially has shown positive approach towards energy saving and sustainable energy as the city has been selected as one of the EU GUGLE pilot cities (see next chapter for more information) and having committed to the European Covenant of Mayors in 2009 by establishing an ECO2 – Eco-efficient Tampere 2020 project trying to achieve and exceed the EU climate commitments by 2020.

One extreme approach has been seen in the Energy Company of a smaller city in western Finland who decided to increase the charge of district heating energy by 58% for the customers producing more than 50% of their energy locally.

5.3 EU GUGLE – Sustainable renovation models for smarter cities

EU-GUGLE stands for “European cities serving as Green Urban Gate towards Leadership in sustainable Energy”. The project was launched at May 2013 targeting to demonstrate the sustainable renovation of around 226.000m² of living space in six European cities. During the five years of the project, these cities have committed to achieve 40-80% primary energy savings per pilot district while increasing the share of renewable energy sources by 25%.

Tampere is the third biggest city and 2nd biggest growth center in Finland and the biggest inland city in the Nordic countries with 215,168 inhabitants. The Finnish EU-GUGLE demonstration takes place in Tammela district, which is a sparsely built traditional residential area with 6337 inhabitants’ right next to the city center.

The large apartment buildings that are included to EU-GUGLE Tampere project scope have been built during 1960 – 1980 and totally there are 30 000 m2 surface to be renovated. They are high potential candidates for this heat pump application and in fact one of the apartment buildings has been already decided to install a heat pump application recovering exhausted air. This installation will take place during spring 2014.

More information about EU-GUGLE project: http://eu-gugle.eu/.

6 CONCLUSION

Despite of the fact that recovery of exhausted air with heat pump is not a new invention it has not been much utilized in large apartment buildings so far. Interest towards this application has been raised only during the last couple of years as energy prices have gone up and awareness about the potential savings of this application has been growing. Also the reported savings in pilot installations with high return of investment percentage has been taken positively by the market.

It is very likely that this market will grow significantly and hundreds of new installations will be seen in the near future. Market potential is high, heat pumps has been well accepted and energy saving is global trend so there should be no major hurdles that would prevent this growth to happen.

Energy companies are currently having somewhat different and sometimes conflicting views towards this application and how well it works together with district heating. This is natural as this kind of heat pump application is rather new concept for them and it takes some time for all parties to understand how it works.

It can be predicted that consensus will be found after more installations has been made and energy companies have had an opportunity to measure how they behave together with district heating system.

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