A Renovation Renaissance in the Making

White Paper – Study on improving the energy efficiency of old apartment buildings in Europe

Introduction

Mastering the challenges of European Deep Renovation for existing building stock. The Purmo Group is committed to the European movement of Deep Renovation. We are taking a multi-pronged approach to find solutions in line with European Union aims on fighting climate change. To this end, we have put together a Starter Kit for people who want more knowledge about the new green, sustainable methods of renovation that includes the regulations and targets set by the EU, and the concepts and technologies to get us past the goal post.

We sincerely hope this White Paper provides the reader an insight into Deep Renovation and what it holds for EU Member States and their people.

Abbreviations and terms used

AC	Air conditioning
ADPC	Automatic differential pressure control
CHP	Combined heat and power
CO_2	Carbon dioxide
COP	Coefficient of performance
DC	District cooling
DH	District heating
DHW	Domestic hot water
EED	Energy Efficiency Directive
EPBD	Energy Performance of Buildings Directive
EPC	Energy performance certificate, classes A, B, C etc.
GHG	Greenhouse gases, mainly carbon dioxide and methane
HVAC	Heating, ventilation and air conditioning
IEA	International Energy Agency
KredEx	Financing institution helping Estonian enterprises develop quicker and expand more safely into foreign markets, offering loans, venture capital, credit insurance and guarantees backed by the state
Mtoe	Million tonnes oil equivalent
NECP	National energy and climate plan
NZEB	Nearly zero-energy building
PV	Photovoltaic system, solar power system
RED	Renewable Energy Directive
RFC	Return flow control
STS	Solar thermal system
TRV	Thermostatic radiator valve
U-value	Thermal transmittance

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What are the obstacles to Deep Renovation?

Despite the current and future need for Deep Renovation of European buildings to improve their energy efficiency, there are still obstacles to their realisation that can be overcome.

The key barriers to energy renovation of buildings in the EU:

Financial barriers
- Renovation costs
- Access to finance
- Low energy prices

Technical barriers
- Lack of technical solutions
- Cost of technical solutions
- Lack of knowledge by construction professionals

Process barriers
- Fragmentation of the supply chain
- Burdening of homeowners

Regulatory barriers
- Varying goals of performance requirements
- Multiple definitions for renovation

Awareness barriers
- Lack of awareness

Source: A 2016 report for the European Parliament,
'Boosting Building Renovation: What potential and value for Europe?'

Foreword

The climate is changing fast, much of which is due to human behaviour and activities. Today, buildings and their residents, account for 40% of energy usage and 36% of Greenhouse Gas (GHG) emissions in Europe. We need to further reduce this amount with the aim of lowering carbon dioxide emissions and phasing out the use of fossil fuels.

The European Union is committed to develop sustainable, competitive, secure and decarbonised energy systems for their building stock. With the publication of the new Energy Performance of Buildings Directive (EPBD) 2018/844, EU member states are to establish by 10 March 2020, long-term strategies with targets for 2030, 2040 and 2050. We at the Purmo Group, as one of the leading companies in the European HVAC industry, have developed a select range of solutions to renovate and transform the existing building stock that meet the energy requirements for nearly zero-energy buildings (NZEPs), deliver the best indoor climate comfort at a very attractive cost for the residents, and support local governments to achieve their targets. Europe is a large and diverse continent in terms of climate and construction types, which means that it isn't possible to use just one concept from North to South. Together with European experts and universities, we have identified preferred solutions for each area.

Our focus is on residential heating and ventilation solutions that can be installed without requiring residents to vacate their homes while the work is being done.

Deep Energy Renovation changes the building properties. We can reduce the heat demand by improving the insulation of the building envelope – outer walls, windows, doors, roof and ground floor. But, even a well-insulated building will require heating. This could be accomplished by using existing hydronic heating systems after modification to meet the new conditions.

Buildings, becoming well-insulated and more airtight, will require a mechanical ventilation to obtain a healthy indoor climate. However, these measures could result, during the summer months, in too high indoor temperatures. Sunshades and night free cooling – using the ventilation to cool the rooms during the night – are passive and energy efficient solutions but might be insufficient to reduce the ambient temperature to the preferred level. In that case, other cooling devices and systems should be used.

In order to achieve the desired improvement in the energy performance of a building, our advice is to equip the ventilation system with a heat exchanger from the exhaust air to the supply air, also known as heat recovery ventilation, or with a heat pump from the exhaust air to the heating water and domestic hot water, often referred to as exhaust air heat pump.

Alternatives to fossil fuel heat generators are available in the form of heat pumps, district heating and solar energy. The building's own energy production, heat and electricity, is key to optimise the energy efficiency of buildings and decrease the need for additional and externally purchased heat and power.

We hope that you will find this study, including our proposals for an energy efficient and healthy and indoor comfort climate, informative and helpful for users and decision-makers.

Johan Struyf
Director, Research and Development, Purmo Group

Energy efficient renovation holds tremendous potential

In the fight against climate change, attention is turning more to real estate. While previously the focus was on making sure that all new buildings were sufficiently energy efficient, it has been clear for some time that this will not be sufficient. Also, existing buildings need to be refitted for the new, minimum carbon future.

The European Union is committed to developing a sustainable, competitive, secure and decarbonised energy system of building stock by 2050, in compliance with the Paris Climate Agreement on curbing CO_2 emissions.

With Deep Renovation, we can cut to the core of the problem: take existing aging real estate and bring down the carbon footprint considerably, perhaps even dramatically. The need is certainly there, as evidenced by energy consumption statistics.

According to the EU, about 40% of Europe's energy needs come from heating, cooling, electricity and water in buildings. As nearly half of all European residential buildings were constructed before 1970, retrofitting existing homes to increase energy efficiency must be a high priority for all EU member states. Currently, several EU projects are testing new ways to make these renovations faster, better, cheaper and more energy efficient.

The new Renovation Renaissance is governed by four directives: The Energy Efficiency Directive; the revised Energy Performance of Buildings Directive; the Renewable Energy Directive 2018/2001/EU; and Electricity Market Directive and Regulation. All four directives contain provisions for increasing Europe's renovation rate with an eye to the future, but the key directive for renovation is the Energy Performance of Buildings Directive.

The greatest challenge to reducing energy use in buildings lies in increasing the rate, quality and effectiveness of building renovation, since the current rate is a mere 0.4–1.2% per year. According to EU experts, a renovation rate of 3–4% per year would be needed to institute real change. This calls for effective renovation approaches that need first to be widely demonstrated, and then replicated in appropriate volumes.

This renovation wave would be unprecedented, even globally.

According to the EU Commission, DG Ener, there are presently up to 75% – out of the estimated 210 million buildings in the EU30 – in need of deep energy renovation.

In Europe buildings account for:

50% of the total energy used
50% of the total materials used
50% of the total carbon used

in terms of entire lifecircle.

Source: European Commission, DG Environment

Energy Performance of Buildings Directive (EPBD)

Under the Energy Performance Building Directive (EPBD), the EU member states are required to enact national policy measures to achieve various energy performance objectives. Key among these targets is a path towards a low and zero emission building stock in the EU by 2050, by implementing national road maps to decarbonise buildings. In addition, encouraging more automation and control systems in buildings is high on the agenda.

The first version of the EPBD (2002/91/EC) entered into force on 4 January 2003. The latest version, the revised Energy Performance of Buildings Directive (2018/844/EU) came into effect on 9 July 2018. It includes measures that will accelerate the rate of building renovation towards more energy efficient systems and strengthen the energy performance of new buildings, making them smarter.

Under 2018/844, EU countries will be required to transpose the new elements of the Directive into national law within 20 months.

Energy Efficiency Directive (EED)

The 2012 Energy Efficiency Directive (2012/27/EU) establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. This means that overall EU energy consumption should be no more than 1,483 million tonnes of oil equivalent (Mtoe) of primary energy or 1,086 Mtoe of final energy. The Directive requires all EU countries to use energy more efficiently at all stages of the energy chain, including energy generation, transmission, distribution and end-use consumption.

In 2018, a new amended Directive on Energy Efficiency (2018/2002) was agreed to update the policy framework in view of 2030 and beyond. The key element of the amended Directive is a headline energy efficiency target for 2030 of at least 32.5%.

Renewable Energy Directive (RED)

The original Renewable Energy Directive (2009/28/EC) establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020.

In December 2018, the revised Renewable Energy Directive (2018/2001/EU) went into effect, aimed at keeping the EU a global leader in renewables. The new Directive establishes a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a revision upwards by 2023.

Electricity Market Directive and Regulation

The new electricity Directive and Regulation were formally adopted in May 2019, which replace Electricity Directive (2009/72/EC) and the Electricity Regulation (EC/714/2009).

The key objective of the Electricity Market Directive is to place the customer at the center of the electricity market by providing the customer with new opportunities to enter the market through, for example, consumer flexibility or through energy communities. The reform will improve the functioning of the market by clarifying the rules of the electricity market, for example, in support of electricity generation capacity.

Standards and technical reports

In addition to directives, development is governed by more than 40 EPB Standards and Technical Reports which provide detailed information to achieve objectives.

Sustainability of renovation:

Deep renovation of old buildings causes only 30% environmental impact of new built.

Source: European Commission, DG Environment

100 years

The building stock in the EU member states is quite old. On average, 21.6% of the building stock was built before 1945, 45.4% was built before 1969, and 75.4% before 1990.

With the exception of Cyprus, Ireland, and Luxembourg, the proportion of residential building stock built after 2000 is below 25%. A relatively old building stock means that without significant investments to improve the energy performance, the average energy performance of the national stock will remain low.

Even if all new European buildings were nearly-zero energy buildings, due to the fact that buildings are assets with a long lifetime, it will take over 100 years at current renovation rates to renovate the entire EU building stock.

Source: EU Building Stock Observatory

Carbon diet for buildings

The revised Energy Performance of Buildings Directive (EPBD, 2018) calls for binding energy requirements for all buildings. This means:

- Carbon emissions down by 90% from the 1990 level
- Building net primary energy use for heating, that is, space heating, ventilation and domestic hot water, recommended not higher than 100 kWh/m^2 per year*. This is around 1/3 of the current primary energy use in building stock in the whole of Europe
- Use of fossil fuels for heating will gradually be phased out as we transition to renewable energies

* Please note! National targets should include broader requirements. Commission Delegated Regulation (EU) No 244/2012: The amount of energy needed to meet the energy demand associated with typical use of buildings includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting.

Prioritise & execute: The implementation of a Deep Renovation agenda

What are the steps needed to achieve this new renovation reality? First, EU member states must establish long-term renovation strategies, targetted for 2030, 2040 and 2050. The deadline for submitting national strategies is 10 March 2020.

Second, the member states are expected to pass legislation which enables renovation of the building stock to the required extent, as well as provide the necessary funding.

Third, in order to get off the ground, the Deep Energy Renovation movement needs innovative concepts to make it all work. Along with groundbreaking ideas and technology, building codes need to be updated to accommodate the transition towards nearly zero-energy building levels also in renovation projects.

The majority of the tools needed for this undertaking are already available and are quite well known to the general public. Heat pumps, for example, with different heat sources, are required to play a bigger role in heat generation.

Heat pumps don't have to start from zero, either. Currently, heat pumps are already heating nearly 10% of all buildings in Europe, with as many as 11.8 million units installed across the continent.

In addition, the transition calls for district heating and cooling to increase where possible, as the use of boiler systems will continue to decrease. In the UK, for instance, gas boilers will be banned in new homes from 2025 onwards.

Deep Energy Renovation calls also for improved insulation in our buildings. Due to climatic conditions, northern countries have traditionally had much higher levels of insulation thickness in walls and roofs. There still remains potential for improvements in northern Europe, but the huge emission reductions can be achieved much easier by focusing on central and southern Europe.

As buildings become well insulated and airtight, the need for heating decreases tremendously. However, the flipside is that the need for cooling increases as houses and apartments get hot. Proper balancing of the heating and cooling pipework will be crucial to make this delicate equation work.

Extra insulation can also result in poor indoor air quality and a whole range of health issues, unless the air ventilation systems are upgraded as well.

In hot countries a good thermal insulation reduces cooling energy need, too.

Furthermore, each emitter needs to be equipped with a thermostat to achieve a better degree of control. To gather proper data for setting targets (in addition to billing purposes), the use of energy and water also needs to be monitored and measured. As people grow accustomed to monitoring their energy consumption, they will soon discover ways to manage it more efficiently.

We are also likely to see increased "citizen power production" in buildings, with photovoltaic energy leading the charge. Solar panels are easy enough for people to grasp as a concept and cost-effective enough to install.

As energy consumers become producers, they can link up to the smart grids of the future – and become both buyers and sellers on the energy market that is rooted in optimisation of all energy use. Smart grids allow us to access power, district heating and district cooling in novel, green ways.

A big part of this transition is electric cars which need recharging stations in those places where their owners live. As energy storage is often an issue, there are already a range of ideas to use the batteries of e-cars for wider storage purposes in connection to real estate.

EPBD requirements for member states

1. Establish a comprehensive strategy aimed at achieving a highly efficient and decarbonised building stock by 2050 and cost-effective transformation of existing buildings into NZEBs (nearly zero-energy building).
2. Set out a roadmap with measures, measurable progress indicators and indicative milestones for 2030, 2040 and 2050.
3. Carry out public consultations on their strategy before submitting it to the Commission and set out arrangements for further inclusive consultations during implementation.
4. Facilitate access to mechanisms through smart financing to support the mobilization of investment.
5. Submit the strategy as part of their final integrated national energy and climate plan (NECP) and provide information on implementation in their integrated national energy and climate progress reports.

Commission recommendation (EU) 2019/786 on building renovation, 8 May 2019

Please note: Renovation of the buildings will be carried out in accordance with national guidelines. It is most advantageous to undertake Deep Renovation measures when the building parts, components and systems require also other refurbishments.

Better buildings

In order to improve existing real estate, there's an entire range of mechanical building services that must come together in the most optimal way.

These include:

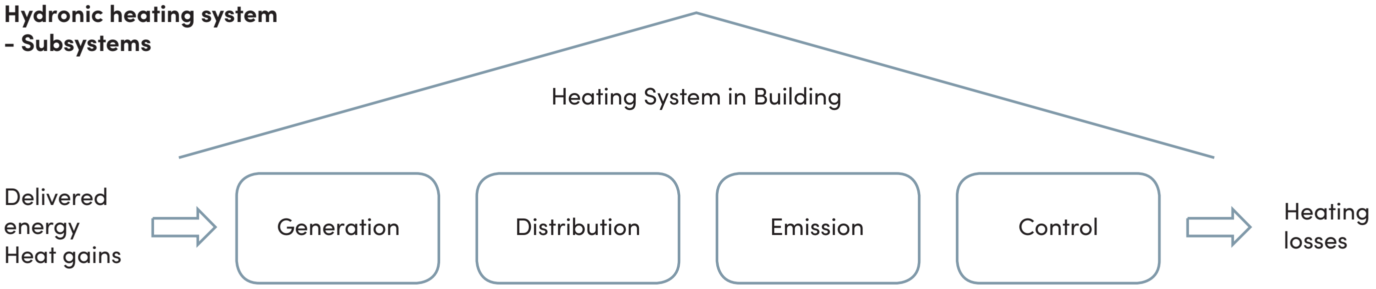
- Heating system
- Cooling system
- Ventilation system
- Domestic water system
- Fire sprinkler system
- Sewerage system
- Electricity network
- Information network
- Gas network
- Energy and water metering
- Building automation – control and security

This White Paper focuses mainly on building heating and ventilation systems and partly also on cooling solutions.

Furthermore, each of the above-mentioned systems can be divided into their own subsystems.

Here's a breakdown of the Heating System:

Hydronic heating system - Subsystems



Generation:

- Heat pump
- District heating/ cooling sub-station
- Combustion boiler
- Solar thermal system
- Photovoltaic system
- Heat storage

Distribution:

- Piping network
- Curculation pump
- Balancing valves
- Radiator valves
- Shut-off valves
- Expension system

Emission:

- Heat emitters
  - radiators
  - convectors
  - underfloor systems
  - ceiling panels

Control:

- Thermostats
- CO^2 control
- Timer control
- Humidity control
- Heating automation
  - weather compensation
  - intermitted heating
  - self learning

Renovating the heating network

Upgrading the building envelope, thermal insulation of the exterior walls, attic and roof, and the replacement of windows and exterior doors will obviously change the heat demands in buildings. The transition to heat production, where heat distribution takes place at low water temperatures, also requires the redesign of heat outputs from radiators. Proper dimensioning and hydronic balancing of the heating system is the starting point for the energy savings and comfort.

Heating water temperatures, both flow and return temperatures, have a significant effect on the heat generation efficiency of combustion boilers, district heating and COP of heat pumps. Switching to low temperature systems is very profitable in terms of energy efficiency. Along with yielding energy benefits, new low-temperature radiators also refresh and modernise any renovated interior.

Radiators with natural internal water circulation and distribution have proven to be the most energy efficient heat emitters. They maintain a high heat output at low water temperatures and partial loads, which also results in low return water temperatures. In contrast, in radiators with sequential perfusion and in pipe convectors, the heat transfer capacity is significantly reduced at partial loads, resulting in higher return water temperatures.

In modern energy-efficient buildings, free heat gains, such as heat from residents, electrical appliances and the sun, cover a large part of the building's heat demand. In new and also in energy-renovated old houses, the utilisable share of free heat gains is typically 30–50% of the annual space heating energy and 60–80% respectively in a residential apartment building.

How well these free heat gains can be utilised depends on the characteristics of the building, the heating system and the control system: in energy-efficient buildings it is better to have lightweight and responsive heating systems than slow ones. The heating system must be balanced, and the heat emitters equipped with thermostats. If the heating system is slow and unable to utilise free heat gains, the result will be an undesirable rise in room temperatures and poor energy efficiency.

Further advice

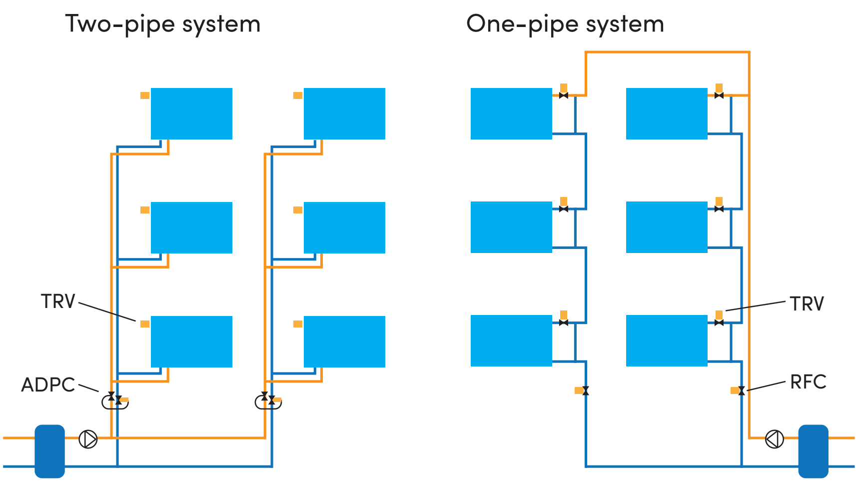
Unless there are shortcomings in the structure of the heating network and corrosion in the pipe materials, the old riser lines can be retained. However, radiator connecting pipes should be renewed when the radiators are being renewed.

In older and larger two-pipe networks, such as apartment buildings, risers and transfer lines are useful to be equipped with automatic differential pressure controllers to balance the operation of preset thermostatic radiator valves and to control the heat output of radiators under all load condition. New construction offers more options for controlling the pressure differences in the heating system.

It is worthwhile converting the one-pipe systems into two-pipe systems to achieve significant energy benefits and to improve comfort.

Domestic Hot Water (DHW) circulation should be equipped with return temperature and flow control to prevent legionella growth, and for a more uniform DHW temperature throughout the building.

The behaviour and habits of occupants has a strong impact on consumption figures. In particular, measurement of heat, electricity and water usage can significantly improve the motivation of residents to save energy.



TRV
Thermostatic Radiator Valve

ADPC
Automatic Differential Pressure Control

RFC
Return Flow Control

The concepts of Deep Energy Renovation

In order to change the game, new concepts must be developed. On the following pages, Purmo Group showcases concepts that the company feels are the most relevant at this time. All concepts presented here rely on existing technology and are rooted in cost-efficiency.

First, some ground rules. The concepts must be demonstrably practical in nature and meet any and all health and energy efficiency requirements.

The concepts are intended for residential buildings (both small houses and apartment buildings). Building systems, such as heating, cooling, ventilation and electricity production, can be either single systems/dwelling-based or centralised systems serving the whole the building.

In order to achieve the energy efficiency required – not exceeding the threshold of 100 kWh/m^2 per year primary energy – thermal insulation improvements must be carried out according to national specific requirements.

Heating systems themselves should be designed in such a way that the use of fossil fuels can be abandoned and the transition to renewable energies is assured. All in all, the building's own electricity production is the preferred option, when applicable. This also enables using electricity in heating.

The required level of energy efficiency cannot be achieved without efficient heat recovery arrangements. Unfortunately, many existing heat recovery systems are currently decidedly underwhelming, showing poor performance.

In houses and apartments, accurate, real time unit-based energy and water use measurement is required. Measurement systems must emphasise user experience in order to be attractive to residents; consumption tends to go down as people start keeping track of their usage.

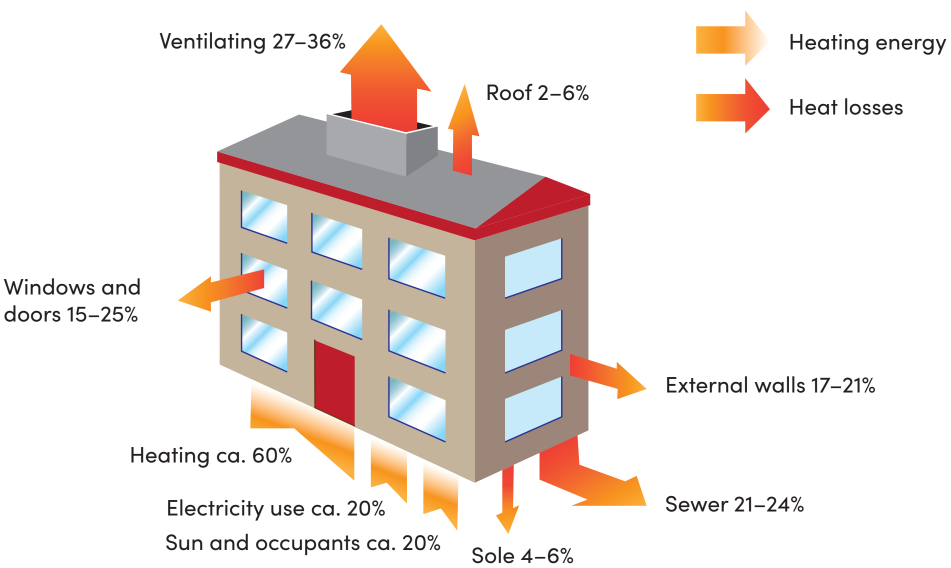
In choosing the right concept for a renovation project, the decision is significantly influenced by whether the residents are present during the renovation work or if the building is uninhabited.

With most of the concepts presented here, residents can continue to live in their homes throughout the entire renovation.

Energy balance

Each building has an energy balance which means that there is energy – in one form or another – both entering and exiting the buildings. The illustration below shows that the majority of the energy coming in is heating energy; ventilation, sewers, externals walls, windows and doors is how the energy leaves the premises.

Typical apartment buildings from the 1950s–1970s in Finland



In originally better insulated buildings, the change is smaller than in the less insulated ones. Similarly, in colder climates, the change is greater than in warmer climates.

Remarkable phenomenon: In well-insulated buildings, without heat recovery, ventilation heat losses increase to over 50%.

Energy renovation example

Example energy renovation of apartment building – IWU Institut Wohnen und Umwelt

Current stage

U values, W/(m^2K)

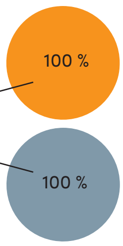
• Roof	0,6
• External wall	1,2
• Window	3,0
• Floor	1,6

Heating system

- Low temperature gas boiler
- Domestic Hot Water storage combined with gas boiler

Heating energy demand, kWh/(m^2a)

• Delivered energy	204
• Primary energy[2]	235



1 Typical living density, heat gains, energy and water usage

2 Primary Energy Factors: Electricity 2,8 and Gas 1,1 (2015)

Typical apartment building between 1958 and 1968[1] in Germany

• Heated living area	2845 m^2
• Number of storeys	4
• Number of apartments	32

Deep energy renovation

U values, W/(m^2K)

• Roof	0,10
• External wall	0,13
• Window	0,80
• Floor	0,25

Heating system

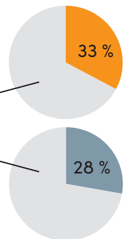
- Condensing gas boiler
- Mechanical supply and exhaust ventilation with heat recovery (heat recovery 80 %)
- Domestic Hot Water storage combined with condensing boiler and solarthermal collectors

Heating energy demand, kWh/(m^2a)

• Delivered energy	45
• Primary energy[2]	66

Results

• Energy cost savings[3]	67 %
• Primary energy reduction	72 %



3 Fossil fuel 8 cent/kWh and electricity 30 cent/kWh

NZEB renovation concept validation together with three leading European universities

Purmo Group R&D in collaboration with Dresden University of Technology, University of Padua and Tallinn University of Technology, has studied the applicability of selected deep renovation concepts to old apartment buildings in three different climatic regions of Europe. In the renovation, the building envelope insulation, air tightness, and heating and ventilation systems were improved so that the renovated building complies with national nearly zero-energy requirement for major renovation. In all concepts, the ventilation rate was doubled to comply with new building requirements, and one concept was additionally equipped with cooling with the aim to avoid excessive overheating in warmer climates.

The results reported in the following are in the form of primary energy use per useful floor area and year (kWh/(m²a)), calculated with national methodologies and with standardised primary energy factors. The primary energy factor of 2.0 has been used for the electricity and 1.0 for gas and district heat. The full documentation of energy analyses will be published as a scientific article.

The primary energy values refer to the annual energy use of a building for space heating, cooling, ventilation, domestic hot water and the auxiliary electricity use of these technical systems. As calculated with national methodology, the results are not fully comparable due to the differences in calculation methods, input data, climate conditions, and some specific assumptions used in different countries.

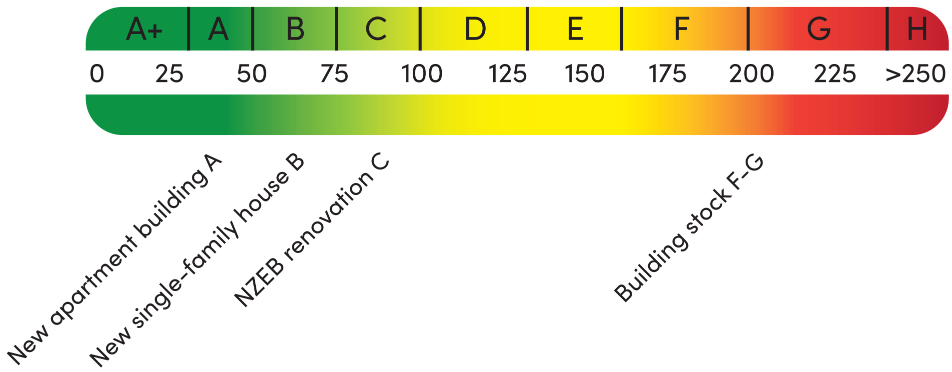
Summary

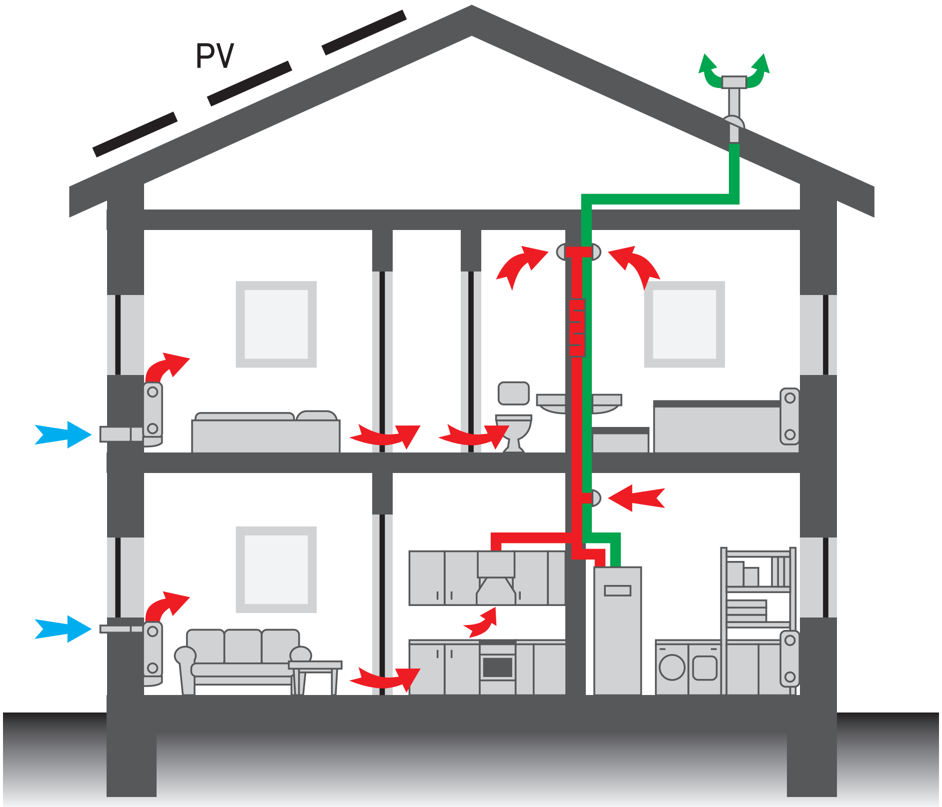
In Germany, all three concepts fulfil the requirements for major renovation, corresponding to energy performance certificate (EPC) class C. The concepts with exhaust air heat pump, both with ventilation radiators and fan coils, resulted in EPC class A+, which is even better than NZEB requirement for new buildings. The concept with central heat recovery ventilation resulted in EPC class C, which still meets the requirements for major renovation.

In Estonia, the major renovation requirement is similarly EPC class C. The best result was achieved with central heat recovery ventilation, which achieved EPC class B. The exhaust air heat pump concept with ventilation radiators resulted in the upper limit value of EPC class C, so it just fulfiled the requirement. Adding the cooling function to the exhaust air heat pump concept with fan coils brought the result to EPC class D, which does not fulfil the requirement. The cooling function was possible to compensate by adding a small PV system, with which the EPC class C requirement was met.

In Italy, major renovation requirements are not given with the EPC scale, but U-values, heating and cooling energy need, primary energy, renewable energy contribution and installation of PV system requirements are to be satisfied. All the concepts studied well satisfied these requirements for major renovation, but small PV systems were needed to add in order to satisfy the minimum amount of renewable energy and the specific requirement of PV installation.

Energy Performance Certificate classes, kWh/(m²a), German residential buildings





Radiator Concept A: Heating

- Mechanical exhaust ventilation with exhaust-air heat pump as the main heating source
- Ventilation radiators as supply air devices
- Photovoltaic system often usable

The "go-to" concept often providing the most cost efficient and energy sufficient renovation solution

For instance, in central and southern Europe exhaust-air heat pumps can cover the heat demand for space heating, ventilation and domestic hot water, all in one unit.

However, when additional heating energy is required, electric heating support can be used in small houses and district heating in larger buildings. A boiler system (using renewable fuel) is also usable as supplementary.

Heat outputs of ventilation radiators are high and thereby the design temperatures are low: the flow/return temperatures may be 45/35˚C and the energy source, ventilation extract air, is year-round even at room temperature.

Taken together, these factors create the conditions for the highest level of heat pump COP_a and of total energy efficiency.

For example, ventilation radiators heat the incoming air even if the thermostat has closed the water flow, thus contributing to a self-heating effect. The flow resistance of incoming air is low, and much lower than in normal air vents.

The air enters the room filtered and controlled by the radiator's ventilation unit. This is necessary for hygiene reasons, to avoid contamination by microbes from the old building structures.

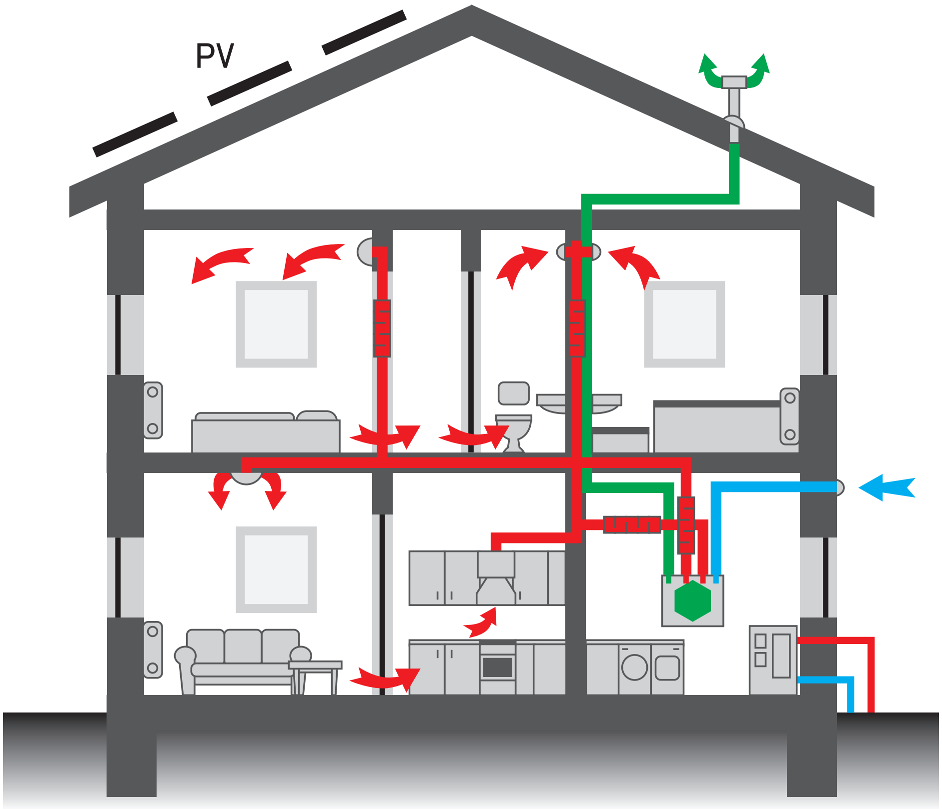
In the summer, this concept also enables an effective night time cooling: the so-called free-cooling which uses adjustable exhaust.

Concept A - Exhaust air heat pump solution with ventilation radiators.

North and East Europe: Prof. Kurnitski et. al.: Primary energy use before renovation 171 kWh/(m²a); after renovation 93 kWh/(m²a) – Heating only

Central Europe: Prof. Felsmann et. al.: Primary energy use before renovation 164 kWh/(m²a); after renovation 51 kWh/(m²a) – Heating only

South Europe: Prof. De Carli at. al.: Primary energy use before renovation 134 kWh/(m²a); after renovation 23 kWh/(m²a) – Heating only, with PV 8.4 kWp



Radiator Concept B: Heating

- Mechanical supply and exhaust ventilation with heat recovery: Balanced ventilation
- District heating or heat pump as the main heating source
- Solar system, PV or STS as an additional energy source

Typically used in renovation projects where fossil fuel boilers are still in use and waiting to be connected to a district heating or heat pump solution

In this transitional concept, geothermal and outdoor air heat pumps can be used, but the heat pump COP_a will not reach the same level as exhaust air heat pumps in Concept A. This is due to the low heat source temperatures and slightly higher radiator water temperatures: typical design flow/rtn temperatures are around 50/40 °C.

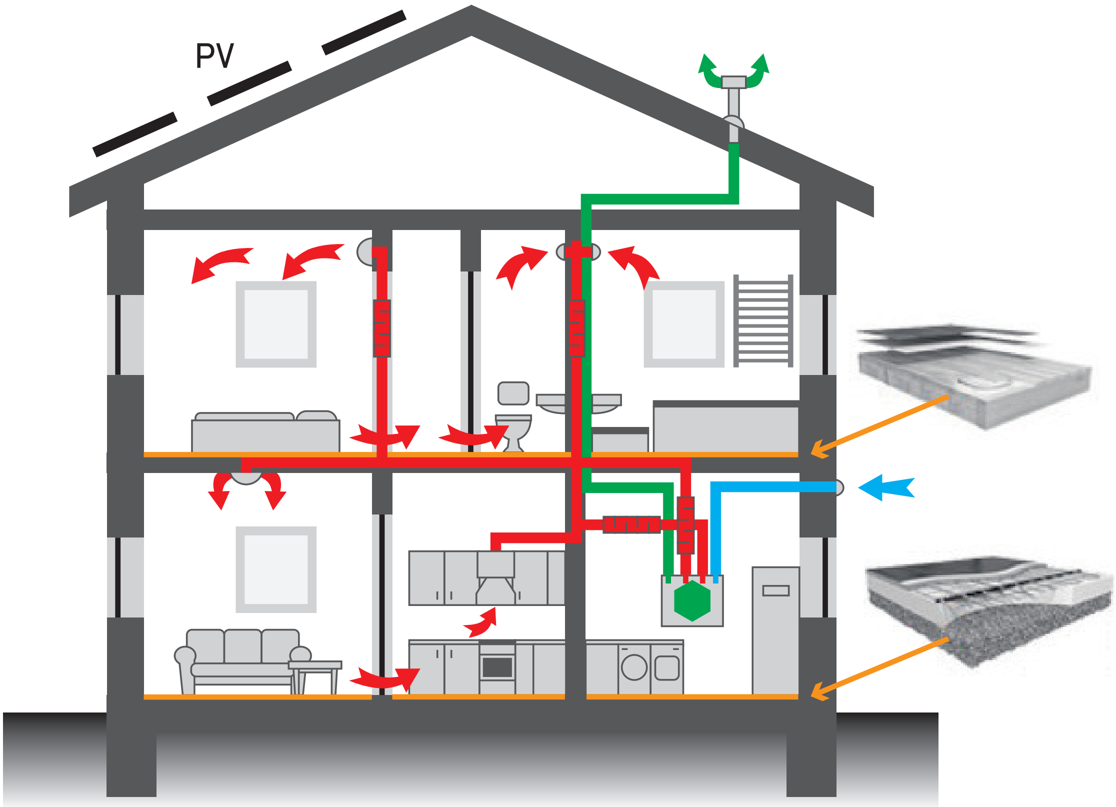
It is important to recognize that the annual efficiency of recuperative (plate heat exchanger) or re-generative (rotating wheel heat exchanger) heat recovery is typically lower than the theoretical value given in technical product information of the air handling units: 70% is often closer to the reality than 95% at colder climate conditions.

Concept B - District heating/condensing gas boiler solution with radiators and central heat recovery ventilation.

North and East Europe: Prof. Kurnitski et. al.: Primary energy use before renovation 171 kWh/(m²a); after renovation 77 kWh/(m²a) – Heating only

Central Europe: Prof. Felsmann et. al.: Primary energy use before renovation 164 kWh/(m²a); after renovation 90 kWh/(m²a) – Heating only

South Europe: Prof. De Carli at. al.: Primary energy use before renovation 134 kWh/(m²a); after renovation 41 kWh/(m²a) – Heating only, with PV 8.4 kWp



Underfloor Concept C: Heating and cooling

- Mechanical supply and exhaust ventilation with heat recovery: Balanced ventilation
- Outdoor air-water heat pump or geothermal heat pump as the main heating/cooling source (also for domestic hot water)
- Photovoltaic system is often useful

Underfloor heating + balanced ventilation is typically used in renovation projects where underfloor systems already exist

New low thickness underfloor heating systems are expected to become more common, providing a helping hand in new installations in renovation projects. Also, new underfloor systems considerably improve thermal controllability, which remains a weakness of current systems.

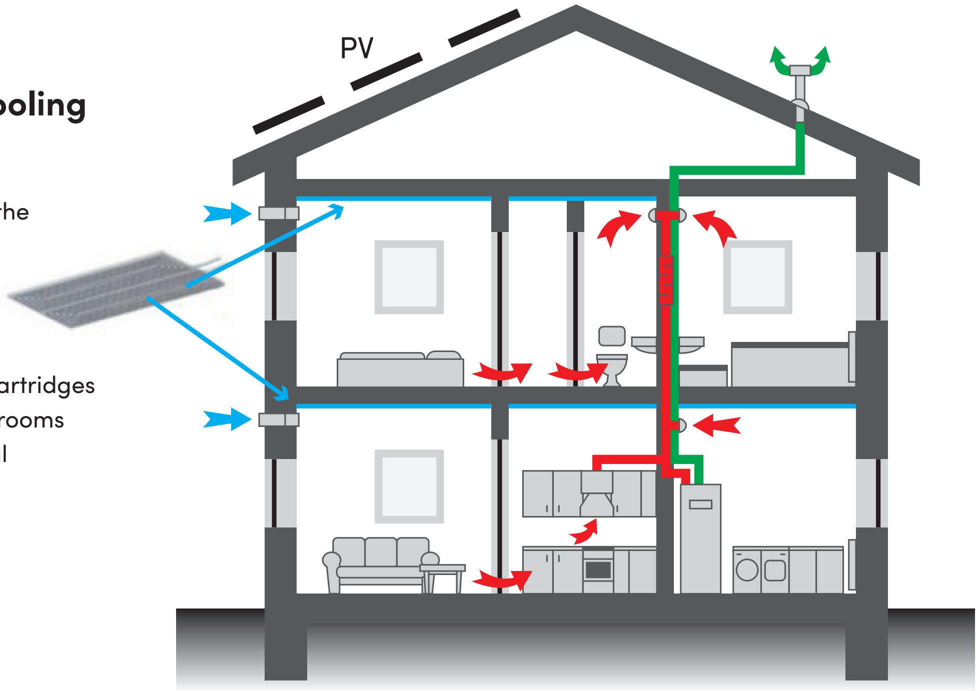
Design temperatures of underfloor systems are low: typically flow/rtn temperatures are about 35/28oC. This is beneficial when using heat pumps as the heat source, leading to a solid COPa and energy efficiency.

Unfortunately, the use of exhaust air heat pumps is not suitable. However, geothermal and outdoor air heat pumps are fully usable, but lower heat source temperatures reduce heat pump efficiency. Underfloor heating systems fit well into district heating due to their low water temperatures.

As with Radiator Concept B, it is important to recognize that the annual efficiency of the recuperative (plate heat exchanger) or regenerative (rotating wheel heat exchanger) heat recovery is typically lower than the theoretical value given in technical product information for air handling units: 70% is often closer to the reality than 95% at colder climate conditions.

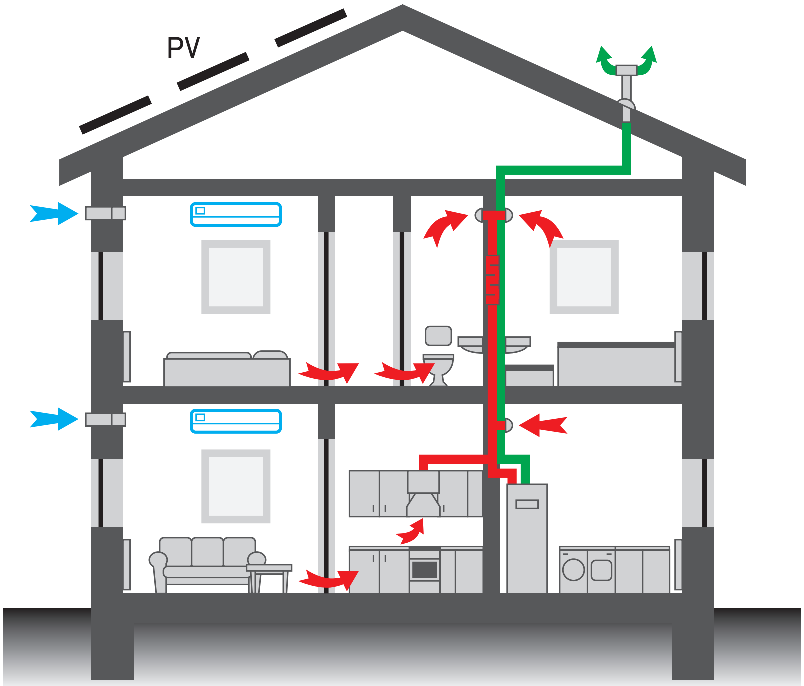
Ceiling Concept D: Panels for heating and cooling

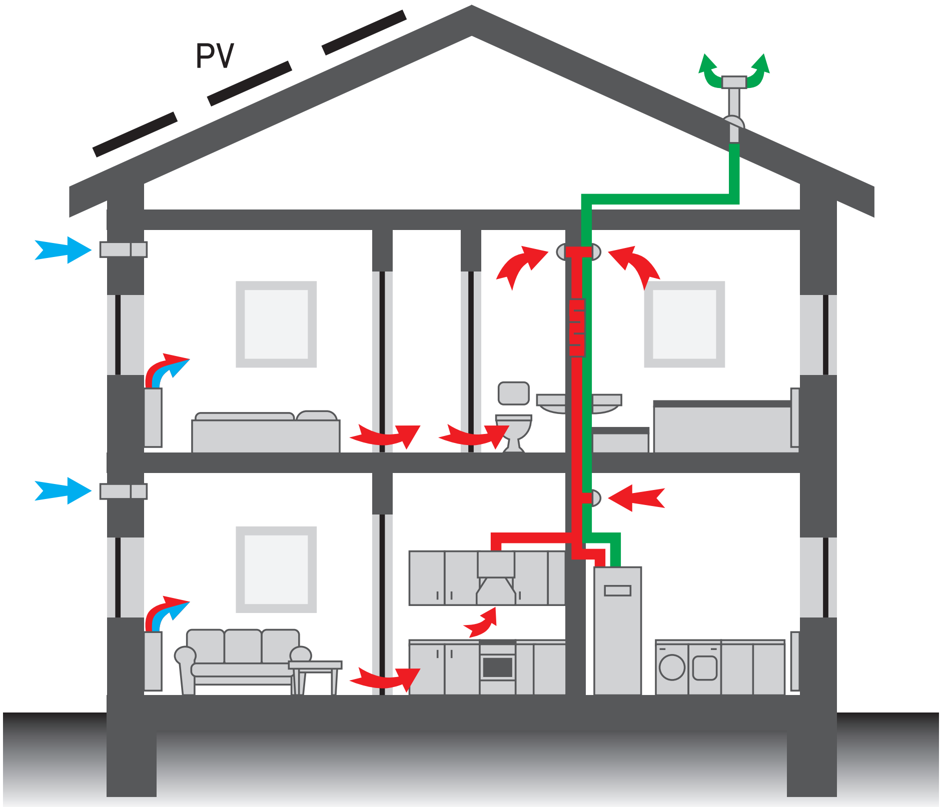
- Mechanical exhaust ventilation with exhaust air heat pump as the main heating/cooling source (also for domestic hot water production)
- Supply air vents with noise silencers and electric heating cartridges
- Electric radiators in secondary rooms
- Photovoltaic system often useful



Electric radiator concept E: Mainly for detached houses

- Electric radiators + Air-heat pump (Split) + Exhaust-air heat pump for DHW
- Applicable when the building has its own electricity production, PV, and the national Primary Energy Factor value for electricity is low
- Air-heat pump also enables cooling





Fancoil Concept F:
Units for heating and cooling

- Mechanical exhaust ventilation with exhaust air heat pump as the main heating and cooling source (including domestic hot water production)
- Dehumidification in cooling mode
- Supply air vents with noise silencers and electric heating cartridges
- Electric radiators in secondary rooms
- Photovoltaic system often useful

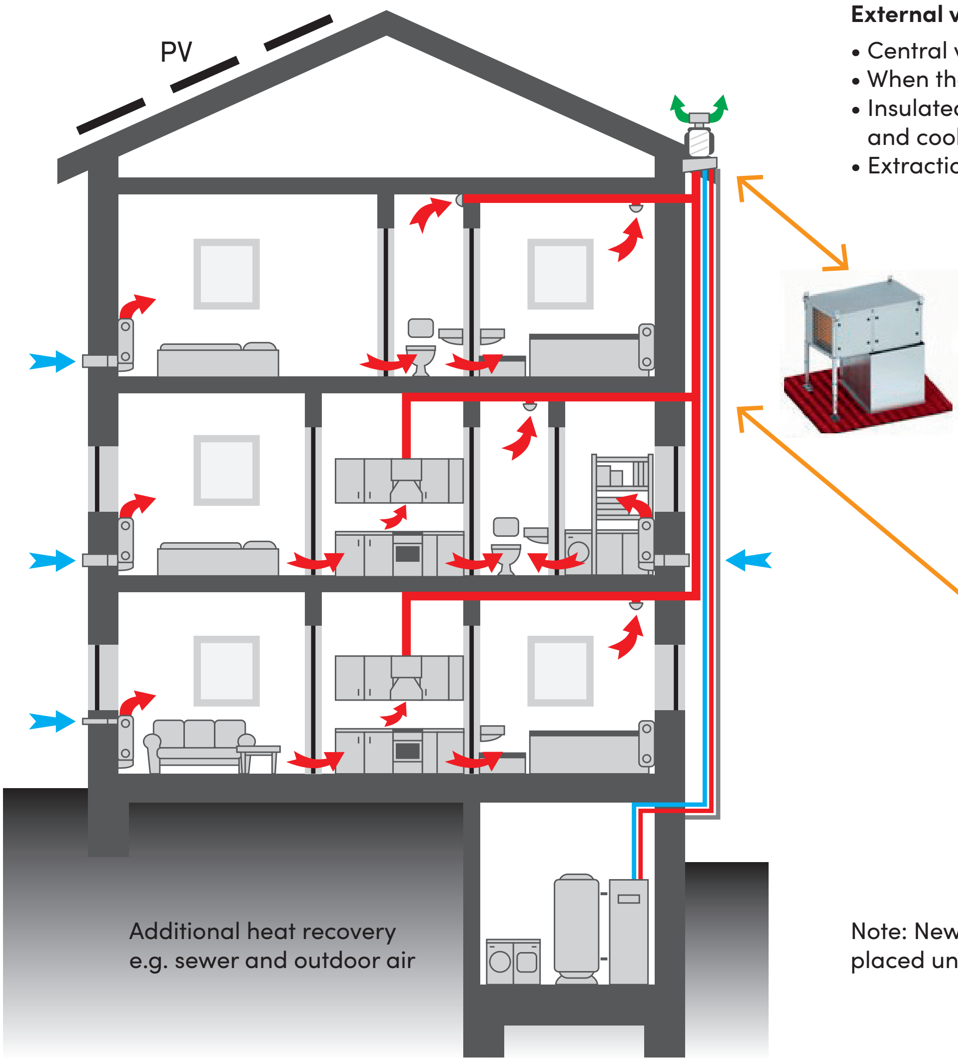
Concept F: Exhaust air heat pump solution with fan coil units.

North and East Europe: Prof. Kurnitski et. al.: Primary energy use before renovation 171 kWh/(m²a); after renovation 98 kWh/(m²a) – Heating and cooling, with PV 10.0 kWp

Central Europe: Prof. Felsmann et. al.: Primary energy use before renovation 164 kWh/(m²a); after renovation 52 kWh/(m²a) – Heating and cooling, with PV 12.0 kWp

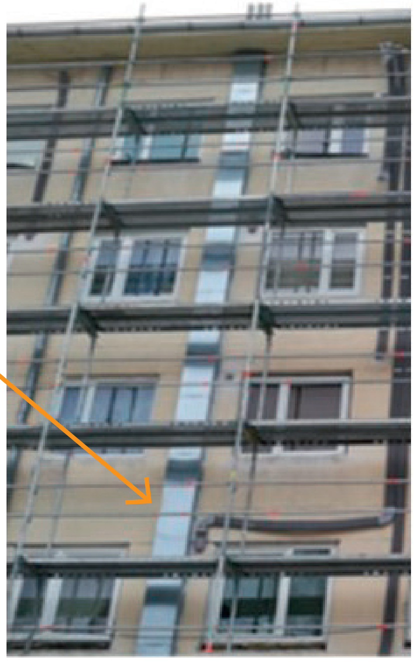
South Europe: Prof. De Carli at. al.: Primary energy use before renovation 134 kWh/(m²a); after renovation 38 kWh/(m²a) – Heating and cooling, with PV 12.6 kWp

Example apartment building



External vertical channel

- Central ventilation and heat pump
- When there is no internal ductwork
- Insulated channel for ventilation ducts and coolant solution pipe lines
- Extraction fan and heating exchanger



Note: New ducts and pipes can also be placed under external wall insulation

Extended systems

Tapping into Smart Grid and Electro-Mobility functions with bi-directional supply.

Expanding on the original concepts, heat pumps can be used as a cooling source for the ceiling cooling. Ceiling cooling is an embedded radiant cooling system where water-based panels are installed in the ceiling, providing silent and draft-free cooling. The cooling operation is thermostat controlled.

Putting photovoltaic panels on the roof provides electricity, mostly for usage in the building and for recharging vehicle batteries, for instance.

In this concept, also Smart Grid and Electro-Mobility functions become viable, along with supply that runs both ways.

Here's how it works: When the system is connected to the district heating grid, pre-heating of heating water and domestic hot water becomes possible. Excess heat from the exhaust heat pump can be fed into the district heating grid; excess electricity from the PV system can be fed into the electricity grid.

The thermal mass of the building and water heat storages of the building can be used to equalize district heating and cooling capacity peaks. Electricity storage/batteries of the buildings and vehicles can be used to even out fluctuations in electricity production and usage.

Finland tough on carbon

The Finnish government, which took office in summer 2019, set the goal of making Finland carbon-neutral by 2035 when the previous target was 2050. In committing to this target, Finland is setting one of the world's earliest timelines for reaching carbon neutrality. From December 2019, a new government headed by Prime Minister Sanna Marin aims to legislate the target and review it in 2025.

In keeping with this agenda, the Ministry of the Environment is drawing up the Deep Renovation strategy together with sustainable development specialist Motiva, the Technical Research Centre of Finland (VTT), the Finnish Environment Institute and Tampere University of Applied Sciences.

The Deep Renovation strategy will survey the existing building stock and map out the most cost-effective renovation concepts and methods, along with the appropriate funding mechanisms. In order to receive government funding, the renovation projects must meet certain prerequisites.

The strategy aims to develop, among other things, indicators and measurement methods for 2030, 2040 and 2050, in order to keep track of the Deep Renovation progress. The national long term Deep Energy Renovation strategy is to be submitted to the EU Commission in March 2020.

> "There's a lot of potential in existing building stock. Using Deep Renovation measures, it is possible to achieve even nearly zero-energy buildings in the long term."
>
> Jyrki Kauppinen, Deputy Director, Buildings and Construction Unit, Ministry of the Environment

Estonia, KredEx – A Deep Renovation model for Europe

Estonia has achieved great results in deep renovation, thanks to the KredEx renovation grant system. Backed by the EU since its 2010 kick-off, KredEX features strict technical requirements, focusing on high-level energy efficiency and indoor climate conditions.

Large-scale renovation has generated positive effects on the macroeconomic level, quantified in terms of job creation and tax return. All and all, 17 jobs per 1 million euros of investment in renovation have been created directly and indirectly per year in Estonia. Tax revenue from renovation construction projects has been quantified to be 32–33% of the total renovation project costs. Therefore, evidence from Estonia shows that a state subsidised renovation has been, in practical terms, budget neutral with direct financial support of 25–40% used in last 10 years.

During this decade, around 1,100 apartment buildings out of about 20,000 total old apartment building stock have been renovated. Energy efficiency and indoor climate conditions comparable to modern apartment buildings have been achieved with Deep Renovation. At the same time, it's worth taking note that the cost of deep renovation is approximately 3–4 times lower than building a new apartment building.

Support from the EU first materialised in 2010-2014, as a total of 663 apartment buildings underwent renovation in Estonia. At this time, total investments from apartment associations and the grant scheme was 151 million euros, of which 38 million euros were grants. The average energy savings for each apartment building was 43%, and the total annual energy savings was approximately 60 GWh.

A new grant scheme, KredEX II, emerged for 2015-2017, with a total of 102 million euros in EU Structural Funds used. Under this new scheme, technical requirements and the application process were further developed and more detailed.

The biggest problems with KredEX I were poor ventilation and indoor air quality. Therefore, under KredEX II, special attention was paid to making sure that the renovation works include the installation of a proper ventilation system, as well as full compliance with the requirements.

Financing the Renovation – How KredEx grant scheme II (2015–2017) works in practice

A 15% grant can be applied for when EPC Class E (minor renovation work) is achieved after the completion of any renovation work; a 25% grant can be applied for when EPC Class D (energy efficiency requirement for major renovation work) is achieved after the completion of any renovation work; and a 40% grant can be applied for when EPC Class C (energy efficiency requirement for new apartment buildings) is achieved after the completion of any renovation work. The 40% grant has been the most popular choice – more than 80% of applications are for this grant.

In addition to the EPC class, requirements are also in place for thermal transmittance in the building envelope, the heating system, and the ventilation system. A 15% renovation grant carries no additional requirements for the building envelope, since this grant share is used mainly for minor renovation work and for improving the indoor climate, which may not include the renovation of the entire building envelope. Although there are no specific requirements for the building envelope, a heating energy reduction of at least 20% is required.

The main difference between the 25% and 40% grants is that the 40% grant also has a requirement for the window and external wall thermal bridge. To fulfil these requirements, windows must be moved into the insulation layer.

Another option is to insulate the window jamb with an insulation layer that is at least 50 mm thick, which in practice is often impossible.

Fulfiling the thermal transmittance requirements for external walls usually means the creation of an insulation layer that is between 150–200 mm thick. Fulfiling the thermal transmittance requirements for the roof usually means 300–400 mm of insulation layer.

The requirements for windows are only for those windows that will be replaced, and only for old wooden frame windows that have not yet been replaced but will certainly need replacing.

While mechanical exhaust ventilation is required under the 25% grant, there are much stricter requirements for the 40% grant. With the 40% grant, either mechanical supply and exhaust ventilation with heat recovery or exhaust air heat pump with ventilation radiators must be used. In practice, both of these heat recovery ventilation solutions have resulted in adequate ventilation rates and good indoor air quality.

The heating system itself has only two requirements: the system must be balanced, and radiators have to be equipped with thermostats in order to allow room-based indoor temperature control.

KredEx renovation grant technical requirements

Requirement	25% grant	40% grant
Energy performance certificate EPC class	D	C
Heat recovery	–	required
Supply/intake air preheating	–	required
Room thermostats	required	required
Supply airflow rate in bedrooms and living rooms, L/s	10	10
Extract airflow rate in bathrooms[1], L/s	15/10	15/10
Extract airflow rate in kitchen[1], L/s	8/6	8/6
Extract airflow rate in WC, L/s	10	10
Total aparment air change rate, 1/h	0,5	0,5
External wall U-value (opaque), W/(m² K)	0,25	0,22
Windows, total U-value, W/(m² K)	1,1	1,1
Window perimeter linear thermal bridge, W/mK	–	0,05

[1]smaller values apply in one room flats

> “One key issue for the success of Deep Renovation measures is that residents’ lives continue as smoothly and uninterrupted as much as possible. In addition, the costs of the renovation need to be moderate so that people will accept it.”

> “The Estonian model can be successfully deployed elsewhere in Europe as well. Countries in Central and Eastern Europe are the most natural candidates for a system such as KredEx.”

Jarek Kurnitski, Professor, Head of the Estonian Center of Excellence in Research ZEBE (Zero energy and resource efficient smart buildings and districts)

Experts interviewed for this White Paper:

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