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°CLEVER
LOW TEMPERATURE RADIATORS

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clever heating solutions

THE GUIDE TO RADIATORS FOR **LOW TEMPERATURE** HEATING SYSTEMS

DM02303015O602 - 11/2011

# THE GUIDE TO RADIATORS FOR **LOW TEMPERATURE** HEATING

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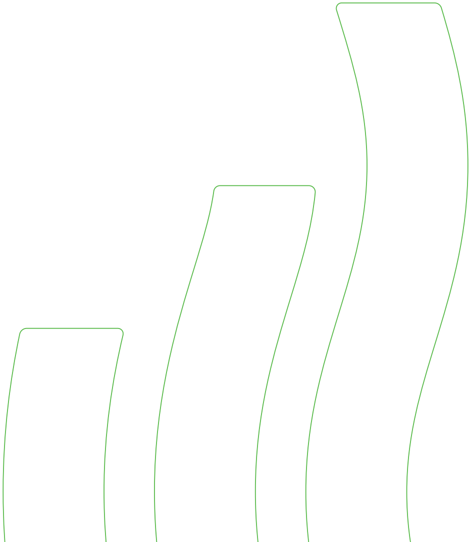
## Why this guide?

This guide aims to give an overview of low temperature heating systems, their benefits, use, and overall contribution to lowered energy use across Europe.

It contains contributions from a number of academics and opinion leaders in our industry, and includes detailed research into the use of radiators in energy efficient heating systems.

The guide is intended for use by wholesalers, installers and planners, to help with making informed decisions about the choice of heat emitters in new builds and refurbished houses.

# TURNING ENERGY INTO **EFFICIENCY**



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Mikko Iivonen

**M. Sc. (Tech) Mikko Iivonen**,
Director R&D, Research and Technical Standards Rettig ICC

# I TURN FIGURES INTO **RESULTS**

As Director of R&D, Research and Technical Standards in Rettig ICC, I am responsible for providing all our markets with new answers, insights, innovations, products and results. All our efforts are based on realistic and independent research conducted in close co-operation with leading industry figures and academics. This has recently included Prof. Dr. Leen Peeters (University of Brussels - Belgium), Prof. Christer Harrysson (Örebro University - Sweden), Prof. Dr. Jarek Kurnitski (Helsinki University of Technology - Finland), Dr. Dietrich Schmidt (Fraunhofer Institut – Germany) and many others. With their help, research and insight, **I turn figures into results.**

## Clever heating solutions

**It is possible to save up to 15% on energy**

By investing heavily in research and development, we live up to our promise to provide you with clever heating solutions. Solutions that make a real difference in terms of cost, comfort, indoor climate and energy consumption. Solutions that make it possible to save up to 15% on energy. With that in mind, I would like to share with you the results of an extensive one-year measurement study conducted by Professor Harrysson. The study involved 130 large and small Swedish family houses and shows that the heating energy consumption of underfloor-heated buildings is 15-25% higher than in radiator-heated buildings. That's not surprising, but it also shows that the increased energy efficiency of modern buildings has once again put low temperature heating systems firmly in the spotlight.

**Because of stricter requirements, the building envelope becomes easier to heat**

As you can see in **Fig. A.1 and A.2**, the design temperatures of radiators have decreased over the years in accordance with the building energy requirements. As building and insulation requirements have become stricter across Europe, the building envelope becomes easier to heat, since less heat escapes. Furthermore, with the excellent responsiveness of a radiator system, it is now more practical than ever to make the most of heat gains in the home and office.

European member states are on a fixed deadline to create and enforce regulations to meet Energy Efficiency Goals for 2020 (Directive 20/20/20). This involves reaching a primary energy saving target of 20% below 2007 levels, reducing greenhouse gases by 20%, and a determination that 20% of gross final energy has to come from renewable energies. For building owners tasked with providing ever more impressive Energy Performance Certificates, it is more important than ever to choose a heating system that offers proven improvements in energy efficiency - radiators in a low temperature system. These targets concern particularly buildings, which consume 40% of the total energy used in Europe.

## 20/20/20

**Primary energy saving target of 20%, reducing greenhouse gases by 20% and 20% of gross final energy has to come from renewable energies**

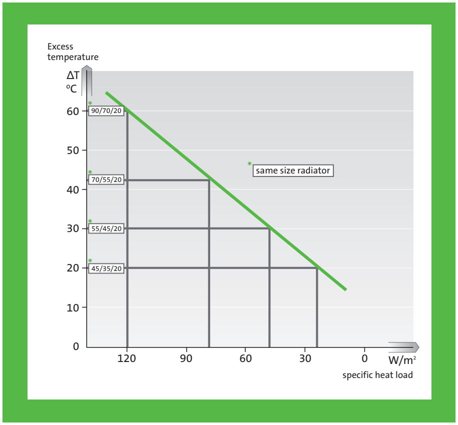
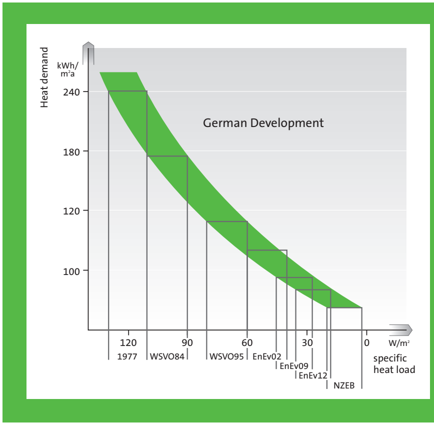


Fig. A.1
Radiator design temperatures have fallen in accordance with the lowered heat loads of buildings.



Energy consumption of buildings continues to fall.

Fig. A.2
Space heating demand – specific heat load diagram for approximation purposes

# CHAPTER 1

# IT'S TIME TO CHANGE OUR WAY OF THINKING

- **Energy regulations >** There are different national regulations across Europe for improvement of energy performance
- **Renewable energy targets >** Strict targets have placed significant pressure on building owners to reduce energy use
- **Innovation of radiators >** Reducing the water content and placing the fins in contact with the hotter channels has increased thermal output. With today's designs, the material is up to 87% more efficient than in traditional models

## Energy regulations

Energy regulation is a key priority for everyone, particularly where buildings are concerned. Homes and offices across Europe are subject to strict regulations regarding energy performance, with EU directives EPBD 2002/91/EC and EPBD recast 2010/91/EC requiring certification of energy consumption levels for owners and tenants. As well as this, European member states are on a fixed deadline to create and enforce regulations to meet Energy Efficiency Goals for 2020 (Directive 20/20/20).

**There are different national regulations across Europe for improvement of energy performance**

There are different national regulations across Europe, with targets for improvement of energy performance agreed in the EU individually for each of the Member States. Despite the varying targets and measurements in each country, the overall trend throughout Europe is to reduce levels of energy consumption.

**Examples of renewable energy targets**

As you can see below, and on the following pages, some targets are incredibly strict, with the underlying trend that the use of renewable energies and reduction of greenhouse gases has been massively prioritised.

| | |
|---|---|
| Finland: | from 28.5% - up to 39% |
| France: | from 10.3% - up to 23% |
| Germany: | from 9.3% - up to 18% |
| UK: | from 1.3% - up to 15% |
| Sweden: | from 39% - up to 49% |

**Strict targets have placed significant pressure on building owners to minimise energy use**

This has placed significant pressure on building owners to find ways to minimise their energy use, and not just to comply with governmental regulations (**Fig. 1.1**). Across Europe, the push towards efficiency is affected by a number of other variables. Fossil fuel prices continue to rise, as the dwindling supplies of oil, coal and gas become increasingly valuable resources.

There is growing public concern about the environment, and increasing consumer preference for environment-friendly products and processes. It is clearly time to re-evaluate the way the heating industry works, as guidelined by Ecodesign directive ErP 2009/125/EC. Our responsibility to end-users is to provide the most energy-efficient and cost-effective way to create a comfortable indoor climate. Although a number of different heating solutions are available, there is continuing confusion about which to choose.

In order for end-users installers and planners to make an informed choice, it is important that accurate information on heating solutions is made available. As of the use of low temperature central heating systems continues to grow, Radson has created this guide to explain the growing role that radiators have to play in the heating technology industry today.

## Examples of reduction targets

**Our responsibility is to provide the most energy-efficient and cost-effective way of creating a comfortable indoor climate**

Fig. 1.1

Roadmap of some countries towards nearly zero energy buildings to improve the energy performance of new buildings.

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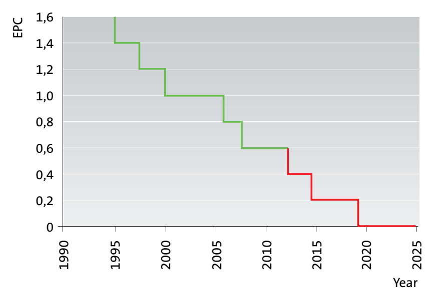
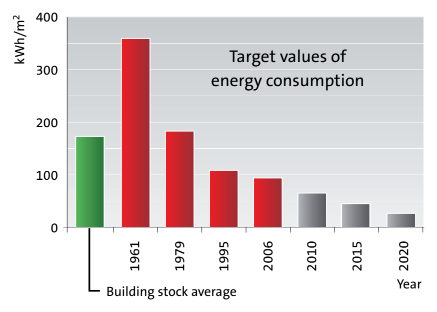
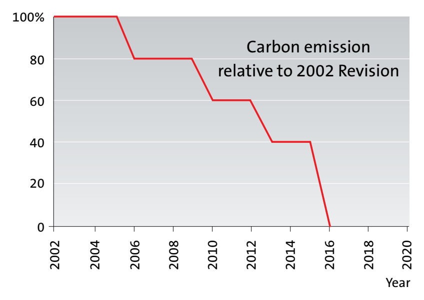
**The Netherlands**



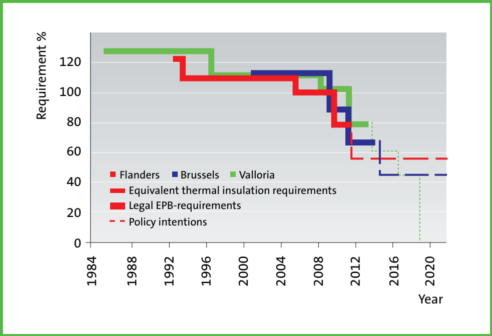
**Denmark**



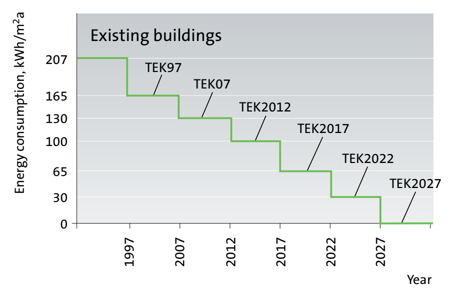
## United Kingdom



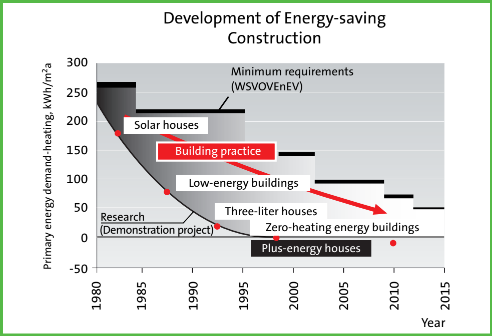
## Belgium



## Norway



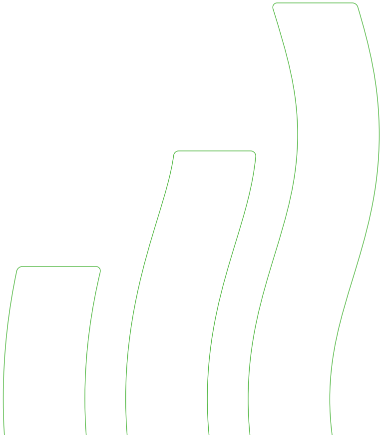
## Germany



## Innovation

Radiators have come a long way from the bulky column designs of 40 years ago (**Fig. 1.2**). The early steel panel forms had a plane panel structure and high water content (**A**). Next came the introduction of convector fins between the water channels, increasing their output (**B**). Over the years, it was discovered that the thermal output could be increased by reducing the water content and placing the fins in contact with the hotter channels (**C**). It wasn’t until the channels were flattened, in the hexagonal optimized form illustrated here, that the contact surface area was maximised and heat output fully optimized (**D**).

**Reducing the water content and placing the fins in contact with the hotter channels has increased thermal output**



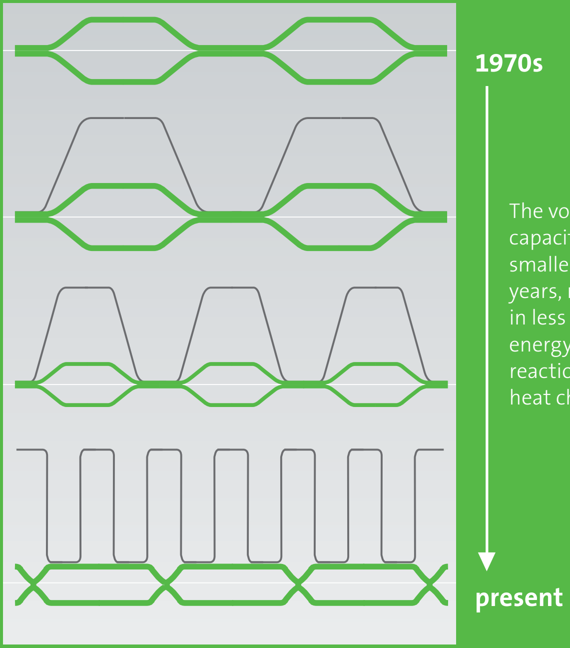


Fig. 1.2:
Innovation in steel panel radiators

A
plane panel structure with high water content

B
convector fins between the water channels increasing their output

C
thermal output was increased by reducing water content and placing fins in contact with the hotter channels

D
An innovative welding technique in combination with the specific shape of the radiator inner panel makes the Radson radiator unique. Radson indeed welds 2 convection fins on each hot water channel (2-on-1 principle). This technique allows Radson to use smaller heating elements.

The volume capacity became smaller over the years, resulting in less water, less energy and quicker reaction to thermal heat changes.

**Up to 87% better**

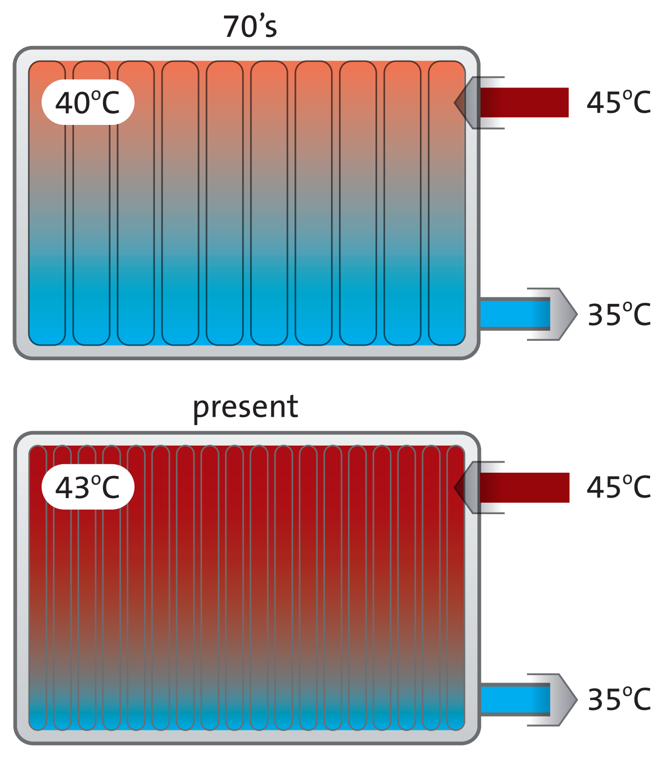
**With today’s designs, the material efficiency is up to 87% more efficient than in traditional models**

Computer simulation has also helped to significantly improve energy efficiency in recent years: optimising the flow of heating water through the radiator, heat transmission to the convector fins, and calculating the optimum radiant and convected heat to the room. With today’s designs the material efficiency is up to 87% better than in traditional models, yet many people still hold on to an outdated image of radiators that was surpassed decades ago (**Fig. 1.3**)

Fig. 1.3:
Innovation in steel panel radiators

More channels, more convectors and less thermal mass – modern radiators increase heat output using less water at the same temperature as traditional models.

What's more, there is an 87% improvement in material efficiency in terms of W/kg of steel.



# CHAPTER 2

# HOW **INSULATION** INFLUENCES HEATING EFFICIENCY

- **Insulation >** Insulation has always played a major role in keeping homes warm and dry
- **The positive impact of changing legislation >** Besides saving energy and reducing costs, the immediate benefit of better insulation is a more comfortable indoor climate
- **Heat gains and heat losses in modern buildings >** When the heat losses and heat gains are all factored in, the effective level of energy efficiency can be determined
- It's important that the heating system can react quickly to the incidental heat gains
- The smaller the thermal mass of the heat emitter, the better the chances of accurately controlling room temperature

## Insulation

Room heat is wasted in two ways: the first is via heat losses through the building envelope, window, walls, roof etc. to outside (transmission losses); the second is via air flow to outside (ventilation and air leak losses). The purpose of insulation improvements is to minimise transmission losses in the most cost effective way.

A human body emits around 20 l/h $CO_2$ and around 50 g/h of water vapour. In addition, household activities and showering bring several litres of additional water vapour into the room air per day. This makes ventilation air flow essential; reducing it would have dramatic consequences, as it would cause health problems to occupants or contaminate the building (with mould etc).

One issue of improved insulation is the increased airtightness of the building. Poor ventilation, increased room humidity, high $CO_2$ content and construction condensation can all appear as a result. This is why properly insulated buildings should also be equipped with mechanical ventilation.

The heat recovered from the ventilation air exhaust can then be utilized as an efficient source of energy.

**Insulation has always played a major role in keeping homes warm and dry**

Insulation has always played a major role in keeping homes warm and dry, from the earliest use of straw, sawdust and cork. Today's modern alternatives, such as fibreglass, mineral wool, polystyrene and polyurethane boards and foams, have helped change building methods, encouraging less reliance on the thermal properties of thicker walls and high temperature radiators.

**€86.000 saved after 20 years**

Obviously, a well-insulated house is easier to heat than its less-insulated counterpart. It loses less heat, and therefore uses less energy. **Fig. 2.1** compares the estimated heating costs of two family homes - one properly refurbished, the other with no insulation. The important contrast between the two becomes even more apparent over time, with a staggering €86.000 saved after 20 years.

Fig. 2.1: Projected heating costs for single family house: insulated vs. uninsulated.

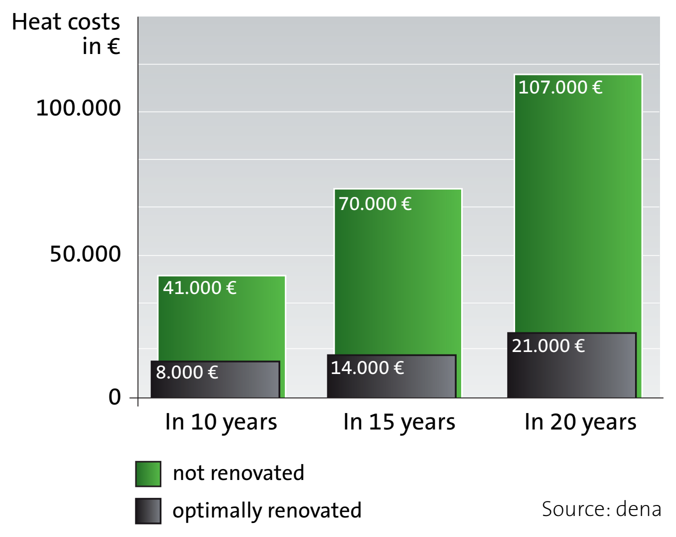


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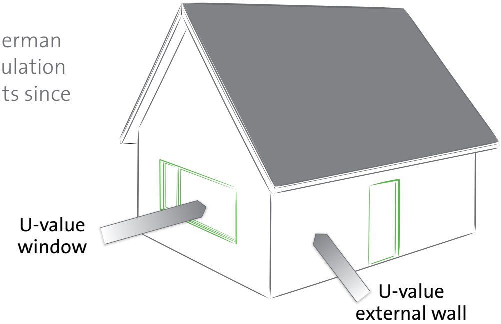
Fig. 2.2:
Changing German building insulation requirements since 1977



| | | Pre 77 | 1977 | WSVO 1984 | WSVO1995 | ENEV 2002 | ENEV 2009 |
|---|---|---|---|---|---|---|---|
| U-value window | $W/m^2K$ | 5 | 3,50 | 3,10 | 1,80 | 1,70 | 1,30 |
| U-value external wall | $W/m^2K$ | 2 | 1,00 | 0,60 | 0,50 | 0,35 | 0,24 |
| Specific heat load | $W/m^2$ | 200 | 130 | 100 | 70 | 50 | 35 |
| $T_{FLOW}/T_{RTN}$ | °C | 90/70 | 90/70 | 90/70 & 70/55 | 70/55 | 55/45 | 45/35 |

In line with energy efficient improvements in insulating methods and effectiveness, legislation has been put in place to ensure new and renovated buildings conform to increasingly strict regulations. Using Germany as an example, here we can see that since 1977 these regulations have steadily lowered the permitted levels of heat loss to the exterior.

For homes heated by water-based central heating systems, one of the more remarkable developments shown here is the inlet and return temperatures of the water. Back in 1977, the norm was 90/70 (design inlet/return), almost double that demanded under EnEV 2009. Clearly, this shift towards low water temperature heating systems is made possible by the increasing use of effective energy refurbishment.

**Back in 1977, the norm for design inlet/return was almost double that demanded under EnEV 2009**

### The positive impact of changing legislation

**Besides saving energy and reducing costs, the immediate benefit of better insulation is a more comfortable indoor climate**

Saving energy and reducing costs were not the only effects of tighter regulations. The immediate benefit of better insulation was a more comfortable indoor climate. **Figs. 2.3 - 2.5** (overleaf) illustrate a room interior as it would be when insulated in line with changing building legislation. As you can see, the only constant across all examples is the outdoor temperature, a steady -14 °C. The surface temperature of the window in **Fig. 2.3** is zero, as the glass is a single pane. In order to reach an acceptable 20 °C room temperature, homes insulated to WSVO 1977 standards had to use hot radiators at 80 °C mean water temperature. Even at this very high temperature, the walls would only reach 12 °C, resulting in a large temperature difference and a range of noticeable cold spots.

### Indoor climate

Over time, as building regulations changed, indoor temperatures became noticeably better, as shown in **Fig. 2.4**. With the widespread use of double glazing came relief from freezing windows and protection from sub-zero temperatures.

To reach ideal room temperature, radiators now had to generate only 50 °C output (average heating temperature), while walls reached 18 °C, a more balanced midpoint between the window's 14 °C and the air temperature of 20 °C. This situation improves further still for buildings insulated to EnEV 2009 towards EnEV 2012 standards.

Fig. 2.3: Pre 1977 temperatures in a standard house (90/70/20 °C)

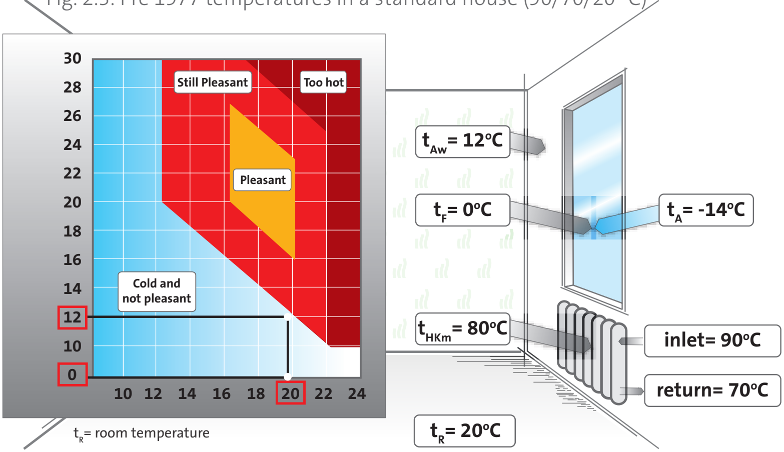


Fig. 2.4. EnEV2002 (55/45/20 °C)

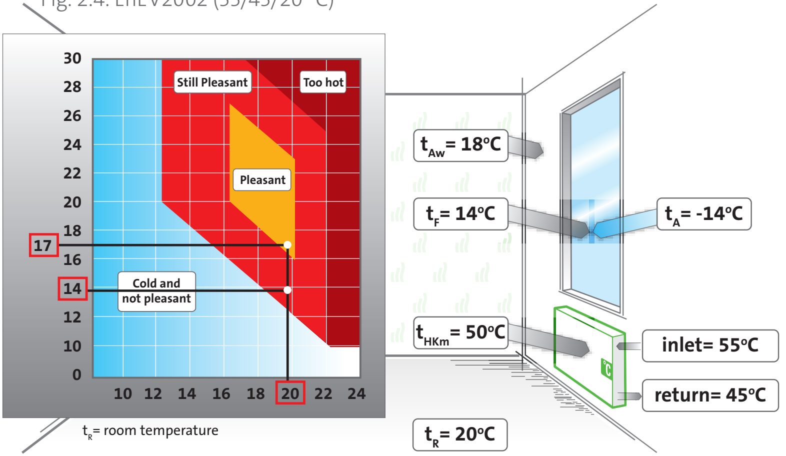
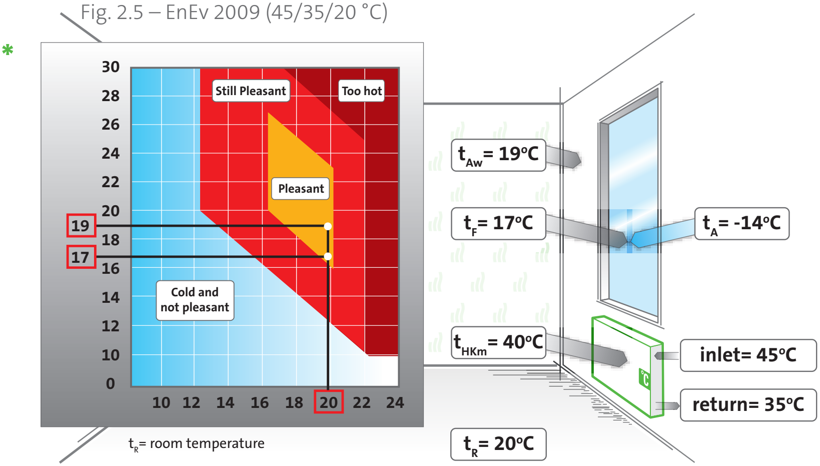


Fig. 2.5 – EnEv 2009 (45/35/20 °C)



The walls in **Fig. 2.5** are almost at room temperature. Even the windows are warm, despite the freezing exterior. Notice that the radiator output now needs only to reach a mean water temperature of 40 °C to achieve this ideal scenario – 50% less than the same building insulated according to the standards of **Fig. 2.3**.

* Thermal Comfort: There are several standard criteria; here are some:

- the average value air temperature and mean surface temperature is around 21°C.
- The difference between air temperatures and mean surface temperatures varies by no more than 3°C.
- The difference between mean surface temperatures in opposite direction varies by no more than 5°C.
- The average temperature between head and ankle heights are less than 3°C.
- The air velocity in the room less than 0.15 m/s.

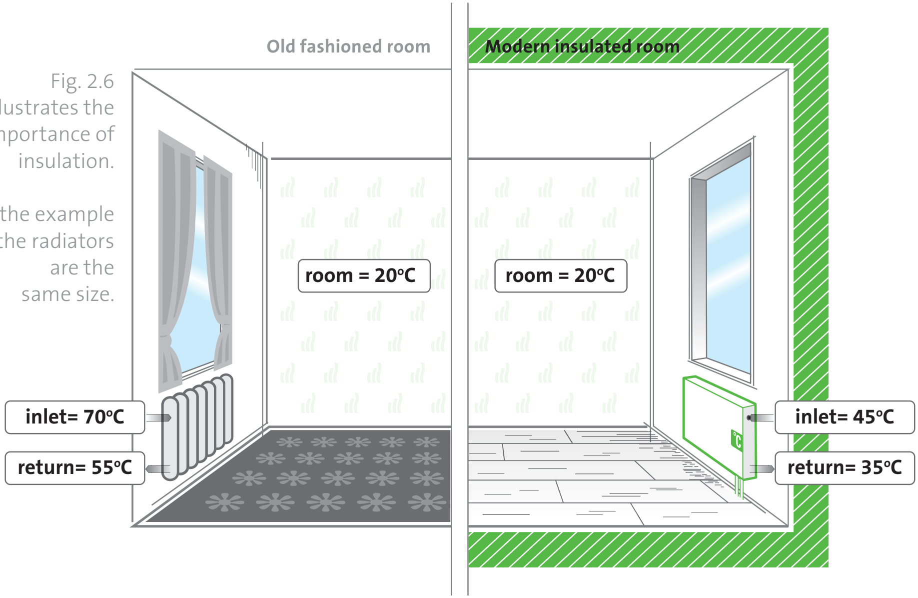


Fig. 2.6 Illustrates the importance of insulation.

In the example the radiators are the same size.

Specific heat demand: **100 W/$m^2$**
living area **x** heat demand:
11 $m^2$ x 100 W/$m^2$= **1100 W**
System temperature: **70/55/20°C**
Radiator dimensions:
**h 580mm, w 1200mm, d 110mm**
n*= **1.25**
Q= **1100 W**

---

**Disadvantages of old cast steel radiators**:

- large water content
  (large pump, high electrical costs)
- bad controllability
  (high weight, large water content)
- long heat up and cool down time
  (not suitable for modern LTR systems)
- old fashioned look

Specific heat demand: **50 W/$m^2$**
living area **x** heat demand:
11 $m^2$ x 50 W/$m^2$= **550 W**
Systemtemperature: **45/35/20°C**
Radiator dimensions:
**h 600mm, w 1200mm, d 102mm** (Type 22)
n*= **1.35**
Q= **589 W**

---

**Advantages of current panel radiators**:

- small water content
- light weight
- optimized for a high heat output
- excellent controllability
- short heat up & cool down time
- modern look, different models, colours and designs for all needs and tastes
- 10 years warranty

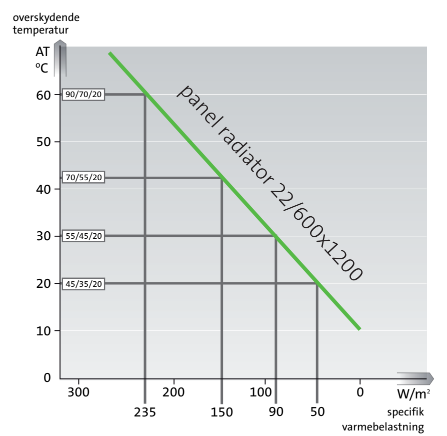
* ***n*** is the exponent that indicates the change in heat output when room and water temperatures differ from the values used to calculate $\theta_0$. The exponent ***n*** is responsible for the relation between radiation and convection of the radiator (this depends on the design). The lower the inlet temperature, the lower the convection.

## Size of radiators

The increased energy efficiency of buildings during the last 30 years has enabled the design temperatures of radiators to be lowered. In the illustration, both radiators have the same approximate dimensions. The desired room temperature in both cases is the same. As you can see, in an uninsulated house, in order to achieve the desired room temperature, the inlet and return temperatures are much higher than those of a well insulated house. The advantage is that the radiator in the modern room can be the same size as that in the old room, due to the insulation resulting in a lower level of heat demand.

Fig. 2.7
Same size radiator conforms to changing building energy requirements.

Parameters shown are the heat output/specific load and the excess temperature ΔT.



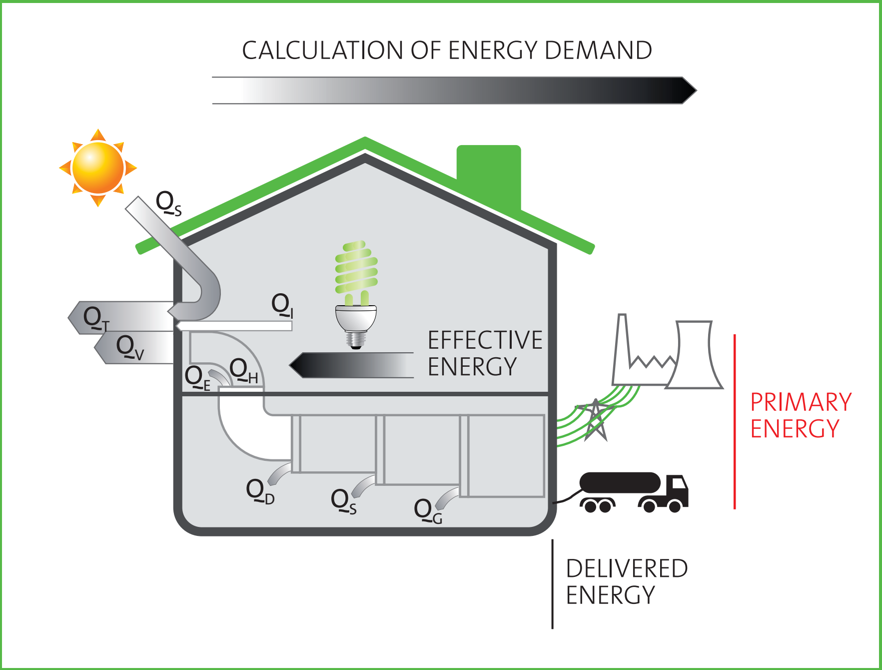
## Heat gains and heat losses

The energy needs of a building's occupants include the demands of their heating system. **Fig. 2.8** illustrates of how energy is brought into the home from its starting point, after it is generated as primary energy.

**When the heat losses and heat gains are all factored in, the effective level of energy efficiency can be determined**

The energy used by a building depends on the requirements of the people inside. To satisfy their needs, and provide a comfortable indoor climate, the heating system has to generate heat from the energy delivered to the building. When the heat losses and heat gains are all factored in, the effective energy can be determined. The way that energy is used depends on the efficiency of the heating system and, as we have seen, on the level of insulation in the building.

Figure 2.8



Qt – Transmission heat losses
Qv – Ventilation heat losses
Qs – Solar heat gain
Qi – Internal heat gains
Qe, d, s, g – Losses through emission, distribution, storage and generation
Qh – Heat load

## Influence of heat gains on modern buildings

Heat gains are often overlooked when discussing effective energy. When electrical equipment is switched on, or additional people enter the building, or sunlight enters a room, these all raise the temperature inside.

Energy efficiency is heavily reliant on two things: how well the heating system can utilize the heat gains and thereby reduce the heating energy consumption; and how low the system heat losses are.

**It’s important that the heating system can react quickly to the incidental heat gains**

Because modern buildings are more thermosensitive, it is important that the heating system can quickly react to the incidental heat gains. Otherwise, the indoor temperature can soon become uncomfortable for the occupants (which can, for instance, have a negative impact on office productivity).

Fig. 2.9

**Thermal heating requirement for a living room of 30 m$^2$.**
**Building standard EnEv 2009, EFH, building location Hanover.**

Thermal load at -14 °C = 35 W/m$^2$ = 1050 W
Thermal load at 0 °C = 21 W/m$^2$ = 617 W
Thermal load at +3 °C = 18 W/m$^2$ = 525 W

**Average indoor thermal gains**
Average in accordance with DIN 4108-10 = 5 W/m$^2$ = 150 W
Person, lying still = 83 W/person
Person, sitting still = 102 W/person
Light bulb, 60 W
PC with TFT monitor = 150 W/unit (active), 5 W/unit (standby)
Television (plasma screen) = 130 W/unit (active), 10 W/unit (standby)

**Example: 2 people, light, TV, etc. = approx. 360 - 460 W**

A state-of-the-art heat emission system must be able to adjust quickly to the different thermal gains indoors!

Christer Harrysson

**Professor Dr. Christer Harrysson** lectures at the Örebro University (Sweden) and is Director of Bygg & Energiteteknik AB

# HOW TO TURN ENERGY INTO EFFICIENCY

**Professor Dr. Christer Harrysson** is a well known researcher who lectures on Energy Techniques at the Örebro University in Sweden. He has conducted extensive research into the energy consumption of different energy systems, sources and emitters.

**Prof. Dr.
Christer Harrysson**

Research is one of the most important tools for increasing knowledge and obtaining a clear, independent insight into the functions of different heating distribution systems. It also makes it possible to rank the performances of a variety of solutions. In my research, I studied the energy used by 130 houses in Kristianstad, Sweden over a one-year period. Their electricity, hot water and heating system energy consumption were all closely monitored. All the houses were built between mid-1980s and 1990, and were grouped in six distinct areas, with variations in construction, ventilation and heating systems. The results were convincing. We recorded differences of up to to 25% in energy use between the different technical solutions in use.

My main objective was to determine the difference between energy efficiency of different types of heating systems and the thermal comfort these systems offer. We compared the recorded results of underfloor heating and radiators, and conducted interviews with residents. We found that homes heated with radiators used a lot less energy. In total – including the energy for the heating system, hot water and household electricity – the average energy consumption measured was 115 kWh/m$^2$. This was in comparison to the average use of energy of 134 kWh/m$^2$ in homes with underfloor heating. In short, our data shows radiators to be 15-25% more efficient than underfloor heating. Measurement data also shows that the 15% difference correlates with houses that have underfloor heating with 200mm ESP insulation beneath the concrete floor tiles.

**Conclusion**

The most important and significant finding of this study is that designers, suppliers and installers need to apply their skills and provide residents with clear and transparent information. In addition to that, we found the level of comfort to be as important as the calculated energy performance and consumption of new, but also renovated buildings. This is something that should be taken into account not only by project planners and constructors, but also by the owners and facility managers of new buildings.

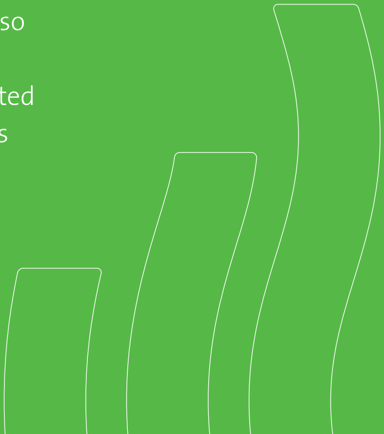
***Note:** Houses in the study are directly comparable with the buildings insulated according to the German EnEV 2009 regulations.*

*A complete summary of the research conducted by Professor Harrysson can be found at*
**www.radson.com/re/clever**

# CHAPTER 3

# THE INCREASING USE OF **LOW TEMPERATURE** WATER SYSTEMS

- **Heat pump and condensing boiler >** Both heat sources in modern and insulated buildings are efficient ways to supply low-temperature water systems
- **Efficiency of heat generation >** Both heat sources also function perfectly with low temperature radiators
- **Energy refurbishment of buildings >** Buildings heated by low temperature radiators systems consume less total energy than underfloor heated buildings
- Improving the energy efficiency of older buildings is a more effective way of saving more energy



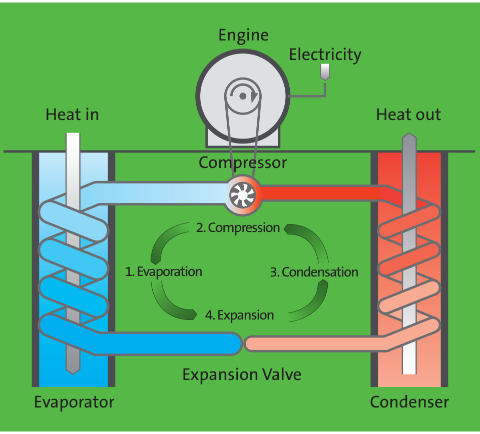
## Heat pump

Thanks to lower heat demand, homes and offices now need less heating energy to keep them warm. This makes the heat pump an ideal companion in a modern heating system.

Temperature a few metres beneath the ground is fairly constant throughout the year, around 10°C. Geothermal heat pumps take advantage of this, with the help of a loop of tubing – the vertical ground loop – buried 100-150m under the soil or alternatively the horizontal grid closer to the surface. Typically a water/ethanol mix is pumped through this loop, where heat exchange occurs before the warmed fluid returns to the pump. From there the heat is transferred to the heating system.

Air-water heat pumps are also good alternatives. They can use outdoor air or/and ventilation exhaust air as a heat source.

Fig.3.1
Diagram of
heat pump



Source:
Pro Radiator
Programme

## Condensing boiler

Traditional boilers had a single combustion chamber enclosed by the waterways of the heat exchanger where hot gases passed through. These gases were eventually expelled through the flue, located at the top of the boiler, at a temperature of around 200°C.  These are no longer fitted new, but in the past many were fitted in existing homes.  Condensing boilers, on the other hand, first allow the heat to rise upwards through the primary heat exchanger; when at the top the gases are rerouted and diverted over a secondary heat exchanger.

In condensing boilers, fuel (gas or oil) is burned to heat water in a circuit of piping, which can include the building's radiators. When the fuel is burned, steam is one byproduct of the combustion process, and this steam is condensed into hot water. Energy is extracted and heat gained from this return flow water, before it is returned to the circuit (**fig.3.2**). While either gas or oil can be used, gas is more efficient since the exhaust of the heated water in a gas system condenses at 57°C, whereas in an oil-based system this does not occur until 47°C. An additional advantage of a gas system is its higher water content.

For all condensing boilers, there is significant energy saving through the efficient use of the combusted fuel: exhaust gas is around 50°C , compared with traditional boilers, whose flue gases escape unused at 200°C.

Both heat pumps and condensing boilers are efficient ways to supply low-temperature water systems in modern and insulated buildings, making them ideally suited to radiators, which can be used with any heat source, including renewable energy.

**Both heat sources are efficient ways to supply low-temperature water systems**

Fig.3.2
Diagram of condensing boiler

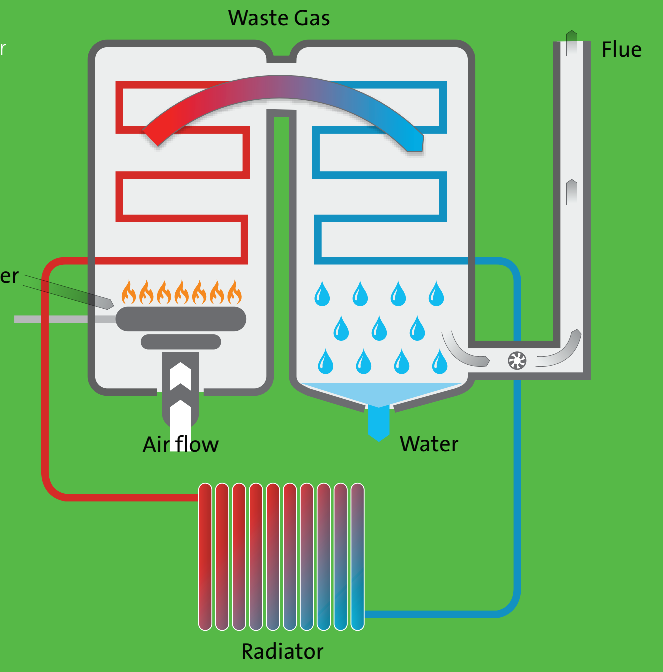
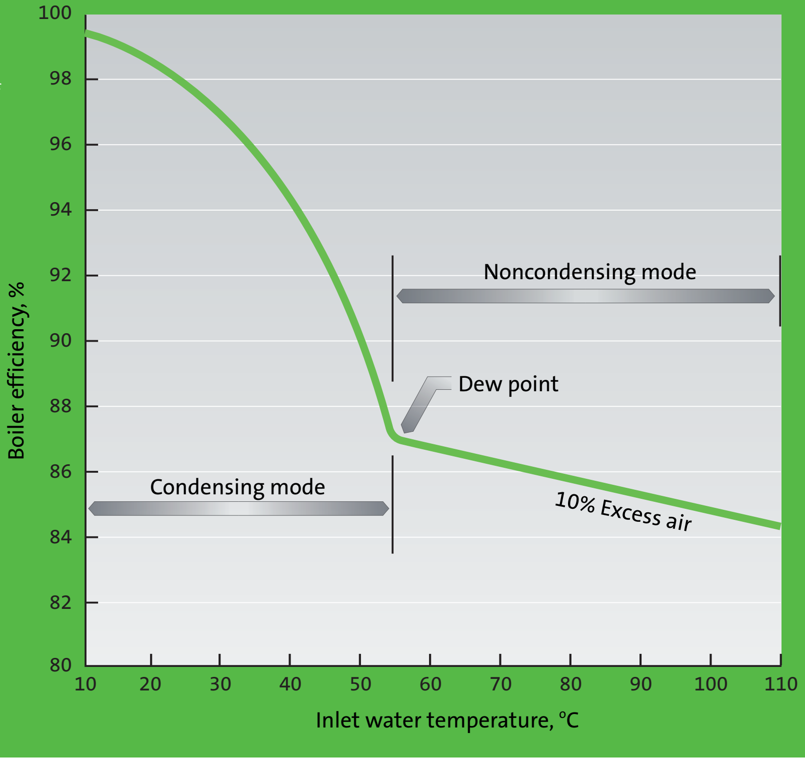


Fig. 3.3
Effect of inlet water temperature on efficiency of condensing boilers.



Source ASHRAE Handbook 2008

## Efficiency of heat generation

Condensing boilers can function in the condensing mode when the inlet water temperatures to the heating network remain below 55°C. Efficiency increase, compared to a standard boiler, is around 6% for oil and around 11% for gas.

## Heat pumps also function perfectly with low temperature radiators

Heat pumps are often assumed to be specific to underfloor heating, when in fact they also function perfectly with low temperature radiators. EN 14511-2 standard describes a simplified method for calculating the seasonal performance factor, SPF, taking only the heating system inlet water temperature into account. This way of calculation can give reasonably accurate SPF values for underfloor heating, where the inlet and return water temperature differences are typically small, often less than 5 K. This simplified method is not applicable for radiator heating, where the inlet and return water temperature differences are larger. For these calculation purposes EN 14511-2 shows an accurate method, also taking into account the return water temperature. In conjunction with SPF is COPa, the annual coefficient of performance, which describes the heat pump efficiency, when the season length is one year.

***Note:*** *The primary energy need of a condensing boiler with solar used for heating and warm water resembles that of the sole water heat pump.*
*Source: ZVSHK, Wasser Wärme, Luft, Ausgabe 2009/2010*

**Fig. 3.4** Table of COPa values for different design water temperatures, combined heating and domestic hot water production, DHW, and heating only. Also shown are the resulting condensing temperatures. The reference building is a modern single-family house in Munich, equipped with electric ground source heat pump. COP values are verified by laboratory measurements (Bosch 2009).

Fig. 3.4

**Annual Coefficient of Performance: COPa**

COPa = Quantity of heat delivered by heat pump divided by the energy needed to drive the process over a one year period

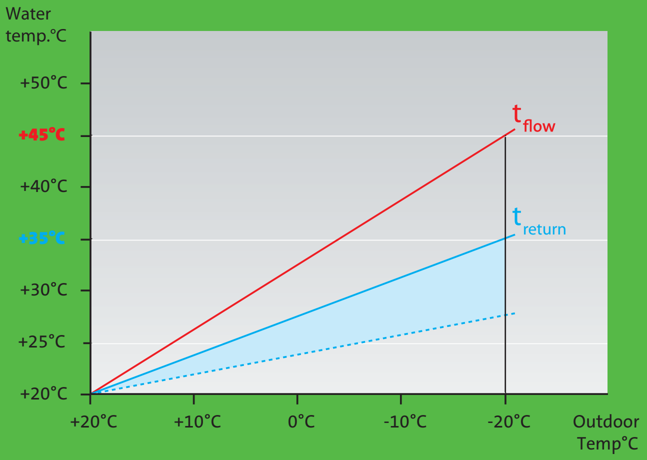
| Design temps | Condensing temp | COPa combined | COPa heating only |
|---|---|---|---|
| 70/55/20 | 62.4 | 2.8 | 3.0 |
| 55/45/20 | 49.2 | 3.2 | 3.6 |
| 60/40/20 | 49.0 | 3.2 | 3.6 |
| 50/40/20 | 44.0 | 3.3 | 3.8 |
| 45/35/20 | 38.8 | 3.5 | 4.1 |
| 50/30/20 | 38.7 | 3.5 | 4.1 |
| 40/30/20 | 33.7 | 3.6 | 4.4 |
| 35/28/20 | 30.2 | 3.8 | 4.6 |

Electric ground-source heat pump. COPa figures from reference building (IVT Bosch Thermoteknik AB)

The results show that it is highly favourable to use low temperatures with radiators, when using heat pumps as a heat generator. Heat pumps for small houses are often combined with DHW production. When comparing the combined COPa values, we can see that design water temperatures of a typical LTR system (45/35) give around 10% higher heat pump efficiency than the 55/45 system. The difference between the 45/35 system and for typical underfloor heating 40/30 system is around 3%, and 9% when compared with the 35/28 system.

**It is highly favourable to use low temperatures with radiators, when using heat pumps as a heat generator**

Fig. 3.5
Radiator return temperature, when using the thermostatic radiator valve, is lower due to the heat gains and corresponding thermostat function



## Energy refurbishment of buildings

**Buildings heated by low temperature radiators systems consume less total energy than underfloor heated buildings**

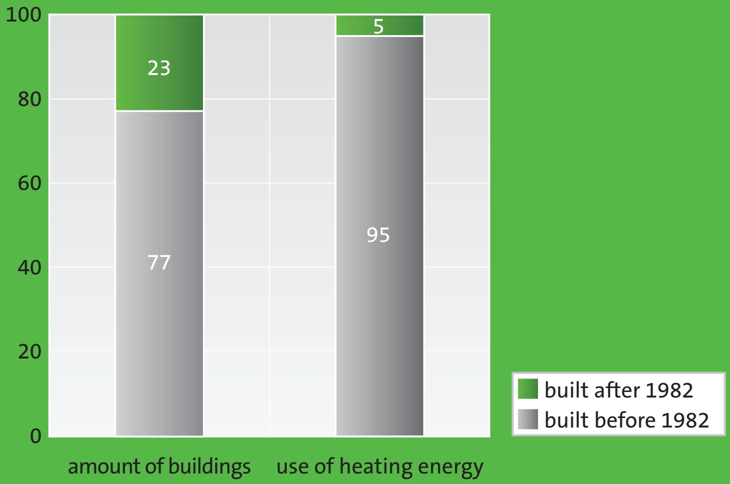
In short, buildings heated by low temperature radiator systems consume less total energy than underfloor heated buildings, even when using heat pumps as a heat generator. Differences of COP values are compensated by the higher energy efficiency of the low temperature radiators.

Buildings, particularly residential buildings are currently in a upward spiral of energy consumption. Energy used in buildings is the biggest single energy consumption sector in Europe. Logically our energy-saving activities should be directed at reducing energy use in buildings. Interestingly though, modern buildings (new or well-renovated) are not of newer buildings built after 1982 make up 23% of the country’s total stock, but consume only 5% of the heating energy. In other words, improving the energy efficiency of older buildings is a more effective way of saving more energy.

**Improving the energy efficiency of older buildings is a more effective way of saving more energy**

Fig.3.6
Focus on old buildings:
Buildings in figures
and in terms of energy
consumption,
Fraunhofer 2011

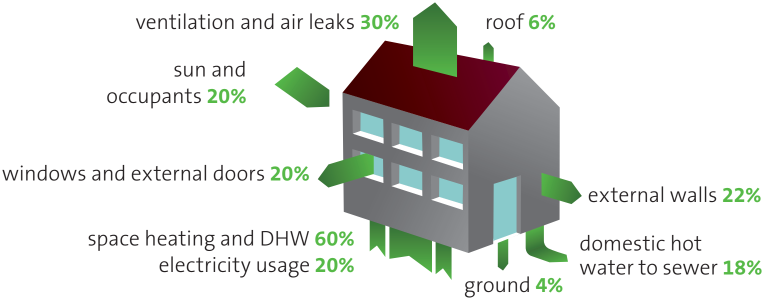
77% of the buildings in Germany built before 1982 use 95% of heating energy.



## A building’s total energy balance consists of energy flows into and out of the building

A building’s total energy balance consists of energy flows into and out of the building. Potential cooling energy is not included in these figures. The energy flows of the example building can be defined as follows:

Fig. 3.7 Example of the total building energy balance of a multi-storey building



### Out from building/emissions and losses

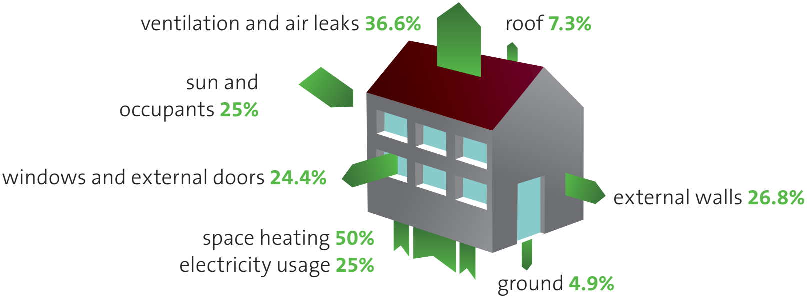
| | | |
|---|---|---|
| - Ventilation and air leaks | 30 % | - Air change rate = 0.5 1/h |
| - Domestic hot water to sewer | 18 % | - 35 kWh/m²a |
| - External walls | 22 % | - U = 1.0 W/m²K |
| - Windows and external doors | 20 % | - U = 3.5 W/m²K |
| - Roof | 6 % | - U = 0.7 W/m²K |
| - Ground | 4 % | - U = 1.0 W/m²K |
| **sum** | **100 %** | **- Uw.mean = 1.3 W/m²K** |

### Into building/inlet

| | |
|---|---|
| - Space heating and DHW | 60 % |
| - Electricity usage | 20 % |
| - Sun and occupants | 20 % |
| **sum** | **100 %** |

If we exclude the DHW energy losses to sewer, which is actually a potentially huge energy saving source, we can see the figures where the energy renovation activities are normally focused.

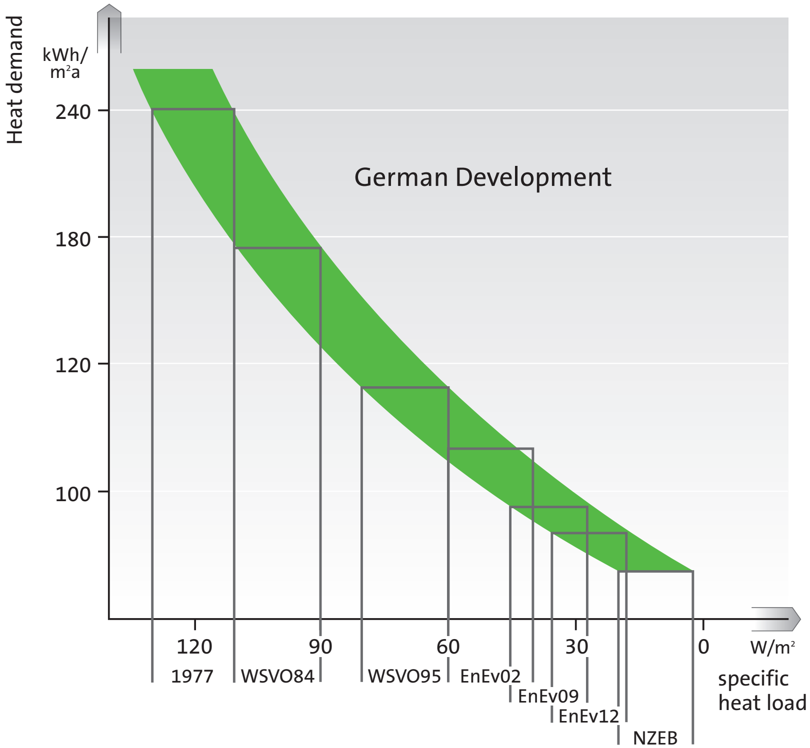
Fig. 3.8
Example of the space heating energy balance of a multi-storey building



| **Out from building/losses** | | **Into building/inlet** | |
|---|---|---|---|
| - Ventilation and air leaks | 36.6 % | - Space heating | 50 % |
| - External walls | 26.8 % | - Electricity usage | 25 % |
| - Windows and external doors | 24.4 % | - Sun and occupants | 25 % |
| - Roof | 7.3 % | | **sum 100 %** |
| - Ground | 4.9 % | | |
| | **sum 100 %** | | |

These figures are example values for older multi-storey buildings, where the typical demand of space heating energy, including transmission losses and ventilation, is around 240 kWh/m$^2$a. If we want to make an approximation of other house types, we should take into consideration the following features: surface sizes, U-values and ventilation air flow rates. For instance, a single-storey house has relatively much higher losses through the roof and to the ground than a multi-storey building.

Fig. 3.9
Space heating demand - specific heat load diagram for approximation purposes



Development of heat demands and specific heat loads in German buildings.

## Space heating energy demand and specific heat loads

We can make a correlation of space heating demands, kWh/m$^2$a, and the specific heat loads, W/m$^2$, based on the available statistics for different German building energy requirement periods.

Let us consider the reference multi-storey building if it is renovated, and recalculate. Specific heat load in the original stage can be rated from the diagram **Fig. 3.9** at space heating demand of 240 kWh/m$^2$a. Heat load value is about 120 W/m$^2$. The building envelope and insulation will be improved. The new U-values of the building elements will be:

| | |
|---|---|
| - External walls | U = 0.24 W/m$^2$K |
| - Windows and exterior doors | U = 1.3 W/m$^2$K |
| - Roof | U = 0.16 W/m$^2$K |
| - Ground | U = 0.5 W/m$^2$K |
| | Uw.mean =0.40 W/m$^2$K |

If there are no surface area changes in the building elements and the ventilation air-flow rates remain unchanged as well, we can calculate the influence of the improved insulation. The transmission losses will be reduced to 31%, when the area weighted U-values, Uw. mean = 1.3 $W/m^2K$ go down to Uw.mean =0.40 $W/m^2K$. Thus the ventilation remains unchanged and the total heat loss reduction will be only 44.3%.

***Note:*** *This type of widespread insulation improvement project is often motivated by a need for better windows and a more attractive façade or by need of higher thermal comfort and healthier indoor environment.*

**The new share of losses will be:**

| | |
|---|---|
| - Ventilation and infiltration | 65.1 % |
| - External walls | 11.4 % |
| - Windows and exterior doors | 16.1 % |
| - Roof | 3.6 % |
| - Ground | 4.4 % |
| | **sum 100 %** |

The heat load will be 44.3% smaller than in the original case. New specific load is about 67 $W/m^2$, and from **Fig. 3.9** we can see that the corresponding heating demand value is about 100 $kWh/m^2a$.


°C 45 ~ 35
MORE EFFICIENT AT LOW TEMPERATURES
SUITED FOR ALL CLIMATES
€
LOWER ENERGY COSTS
HIGHER COMFORT
COMPATIBLE WITH UNDERFLOOR HEATING
BETTER INDOOR CLIMATE CONTROL
READY FOR RENEWABLE ENERGY SOURCES
100% RECYCABLE
HEALTHY LIVING CONDITIONS
°CLEVER
LOW TEMPERATURE RADIATORS

**Professor D.Sc. Jarek Kurnitski**
Helsinki University of Technology

# I TURN SCIENCE INTO **PRACTICE**

**Professor Dr. Jarek Kurnitski,** one of the leading scientists in the HVAC field, is currently working as top energy expert in the Finnish Innovation Fund, Sitra. As a European REHVA awarded scientist, he has published close to 300 papers.

## Bigger is certainly not better

Within the heating industry there is still the myth that within low temperature heating systems you need bigger radiators. Bigger however is certainly not better. During my comparative research into heat emitters, I found that even during the coldest winter period, rapidly changing heat output is needed to keep room temperature in the optimal comfort range. Both systems were set at 21°C, the lowest comfort limit and ideal indoor temperature. As you can see in **Fig. A.1**, when internal heat gains of not more than 0.5°C were detected, the radiator system with its small thermal mass reacted quickly and kept the room temperature close to the setpoint.

However, with the high thermal mass of underfloor heating, reaction time was much slower when heat gains were detected. This meant that underfloor systems kept emitting heat, taking the temperature far above the optimal, with strong uncomfortable fluctuations. In fact, in order to keep the room temperature closer to the optimal 21°C, my research shows that the only solution is to increase the setpoint for underfloor systems to 21.5°C.

For a lot of people 0.5°C may seem a small number. But when you apply that per hour, daily, across a whole Winter heating period, the numbers soon start to multiply and any hope for energy efficiency soon fades. A room temperature difference of one degree correlates to around 6% energy consumption.  Fast response to heat gains and low system losses are key elements of energy efficient heating systems. Central control leads to overheating in some rooms with a consequent energy penalty, which is why my research recommends the use of low temperature systems to reduce system losses, as well as the use of heat emitters that can be individually controlled. This makes radiators the obvious choice.

# CHAPTER 4

# SIGNIFICANT PROOF

- **Professor Dr. Jarek Kurnitski >** overall conclusions of my research show that radiators are around 15% more efficient in single-storey houses and up to 10% in multi-storey buildings.
- **Professor Dr. Christer Harrysson >** under the given conditions, areas with underfloor heating have, on average, a 15-25% higher level energy consumption (excluding property electricity) compared to the mean value for areas which have radiator systems.

**Mikko Iivonen, Director R&D, Research and Technical Standards, Rettig ICC**

In 2008 the R&D department of Rettig ICC started a new project. Its aim, to clarify different misconceptions that persisted in the heating industry. The Pro Radiator Programme - as we named the project - took us two years. In these two years we collected three different types of arguments: ‘In favour of radiator heating’, ‘Against radiator heating’ and ‘ In favour of competitive / other heating systems’.

In total we identified 140 claims and theories. After an initial examination we were able to amalgamate these into 41 practical research issues to test, analyze and reach conclusions. To achieve impartial and independent research results, we asked external experts for their cooperation to help us out with this immense research task. Several leading international experts, universities and research institutes worked closely together with us. The result was a tremendous amount of research data, conclusions and recommendations.

We also found that the industry was saturated with myths and illusions. Although they dominated market discussion, these ranged from irrelevant to untrue. The biggest news for us, however, was that all research results showed how efficiently and effectively radiators functioned in modern well insulated buildings. Once we had identified these results, we started a new dedicated research programme, working with the HVAC Laboratory of Helsinki University of Technology, to examine different heating systems. The accurate simulations and function comparisons of all these different heating systems confirmed that our earlier results and conclusions for radiators were correct.

**Concrete data**

We have already referred to some of our research results in this guide. For you, however, it’s important to realise that our conclusions are based not only on scientific theory, but also on concrete data from recently-built low energy buildings in the Nordic region. Countries like Sweden, Finland, Norway and Denmark have been leading the way in low-energy and high-insulation practices for many years. This fact, coupled with our work with academics including Prof. Leen Peeters (Brussels University - Belgium) and Prof. Dr. Dietrich Schmidt (Fraunhofer Institute – Germany), means that we can now confidently say that all our results and conclusions are valid for the vast majority of European countries. In confirmation of the theoretical savings outlined in previous chapters, a number of studies from the same period measured the efficiency of modern heating systems and compared the energy use of various heat emitters.

## Academic co-operation

Both Prof. Jarek Kurnitski and Prof. Christer Harrysson share their most important findings regarding these specific case studies with you in this chapter.

All the studies we have referenced in this guide have shown that energy efficiency can be increased by at least 15% when low temperature radiator systems are used. This is a conservative estimate - some studies show that the figure can be even higher. Often the reasons for this are occupant behaviour; higher room temperatures, longer heating periods, etc.

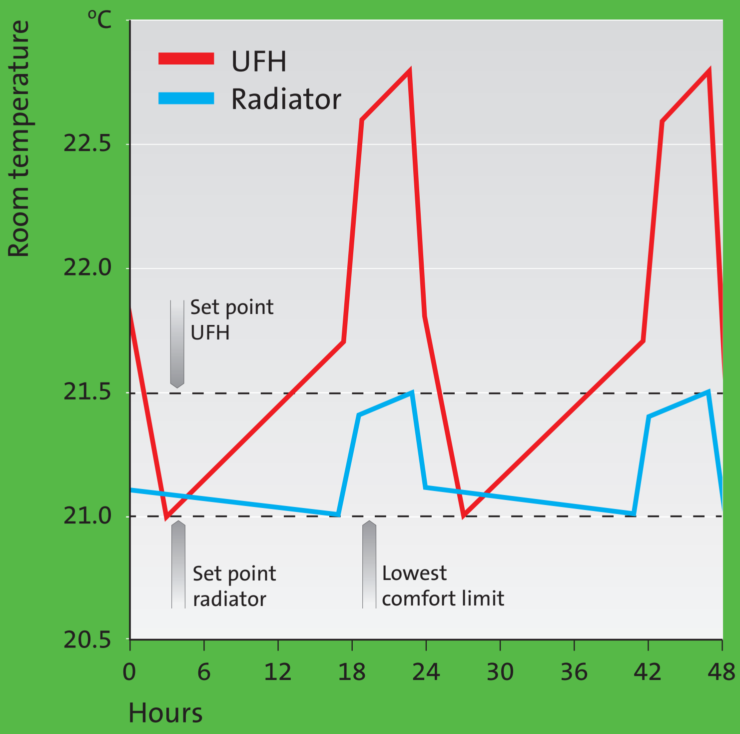
## Professor Jarek Kurnitski: Thermal mass and energy efficient heating

The research of Professor Jarek Kurnitski shows that the thermal mass of heat emitters has a huge influence on heating system performance. Even during the coldest Winter period, rapidly changing heat output is needed to keep room temperature in the optimal comfort range.

**In case of fast-reacting radiator heating systems with small thermal mass, heat gains elevate room temperature not more than 0.5°C**

The principle of the room temperature response to heat gains and losses is shown in **Fig.4.1,** where two systems are compared. In the case of fast-reacting radiator heating systems with small thermal mass, the heat gains elevate room temperature not more than 0.5°C, keeping room temperature close to the setpoint of 21°C. Traditional underfloor heating with high thermal mass fails to keep room temperature constant. Research showed that the setpoint had to be increased to 21.5°C to keep the room temperature above the lower comfort limit of 21°C. The sheer size of the heat emitter meant its output was lagging behind the heat demand, resulting in strongly fluctuating room temperature and wasted energy.

Fig. 4.1.
Room temperature response to thermal mass of the heat emitter in the Winter season when heat gains typically do not exceed 1/3 of the heating demand



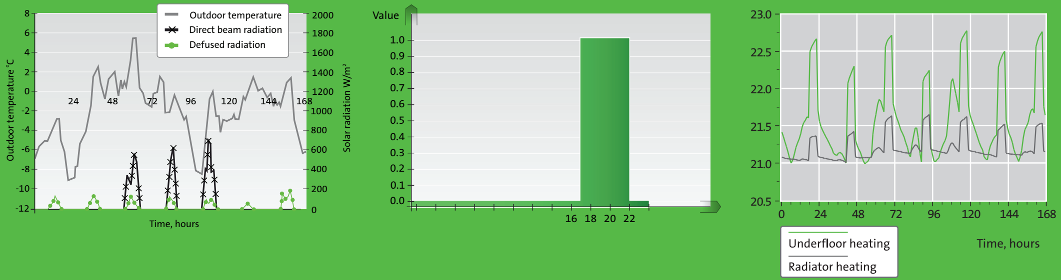
## Maximising heat gains in modern buildings

The situation shown in **Fig. 4.1** is based on detailed, dynamic simulations of a modern house in Germany. Room temperature results for the first week of January are shown in **Fig. 4.2.** Because of the unpredictable nature of solar and internal heat gains, the performance of underfloor heating cannot be improved with predictive control strategies. Heat gains do turn off floor heating, but it still radiates heat to colder external surfaces, such as windows and external walls, for a considerable time. This overheats the room.

At night, when room temperature drops below the setpoint of 21.5°C, it takes many hours before the temperature starts to increase, despite the floor heating switching on. In fact, the research showed that room temperature continued to decrease, which resulted in the need for the elevated setpoint.

Advanced building simulation software, named IDA-ICE, was used to gain the results described above. This software has been carefully validated and has proved to provide highly accurate data in such system comparison calculations.

Fig. 4.2
Simulated room temperatures, first week in January. Outdoor temperature, solar and internal and external heat gains are shown on the left.



External heat gains first week of January - Weather data.

Internal heat gains per day

Resulting air temperatures

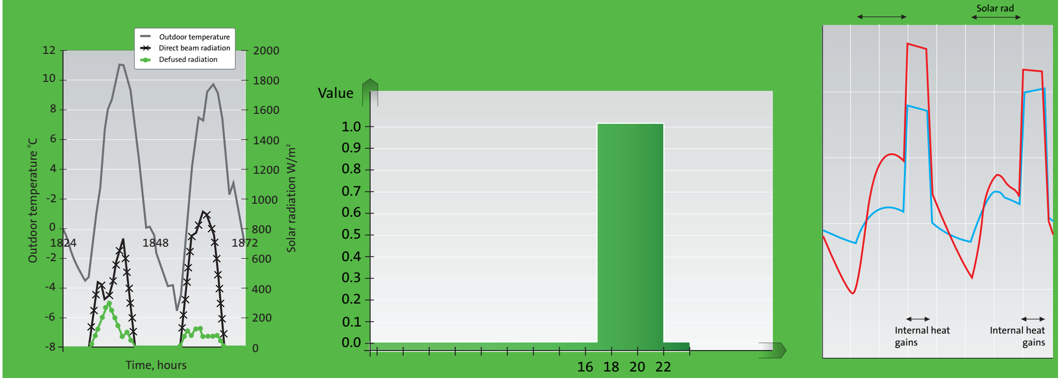
In midseason, heat gains are close to heating needs, which makes it more complicated to control room temperature. **Fig. 4.3** shows the performance during two days in March. Solar gains are significant and outdoor temperature fluctuates strongly. Once again, radiator heating resulted in more stable room temperature and better utilisation of heat gains.

## Conclusion

Fast response to heat gains and low system losses are key elements of energy efficient heating systems. Individual temperature control in each room is also highly important, because heating needs vary strongly from room to room. Central control leads to overheating in some rooms with a consequent energy penalty. For this reason, our research recommends the use of low temperature systems to reduce system losses, and responsive heat emitters with individual/room control.

Therefore, we can also conclude that under floor heating is less effective and less energy efficient, compared to the results we measured with radiators. As a matter of fact the overall conclusions of our research showed that **radiators are around 15% more efficient in single-storey houses** and up to 10% in multi-storey buildings.

Fig. 4.3
Sunny days in March will increase room temperature fluctuation



External heat gains
17-18 March - Weather data.

Internal heat gains per day.

Resulting air temperatures.

**Professor Dr.
Christer Harrysson,
Construction and Energy
Ltd, Falkenberg and
Örebro University**

The primary aim of my research was to increase the level of knowledge about different heating solutions. In particular, underfloor heating and radiator systems were compared. The project, which was initiated by AB Kristianstadsbyggen and Peab, was funded by DESS (Delegation for Energy Supply in Southern Sweden) and SBUF (Development Fund of the Swedish Construction Industry).

Differences in living habits between technically identical single-family homes can result in variations in total energy consumption in household electricity, hot water and heating systems amounting to 10,000 kWh/annum. There are many different technical solutions, i.e. combinations of insulation, seals, heating and ventilation systems. Even the choice of technical solution can result in major differences in energy consumption and the indoor environment. In a Swedish National Board of Housing, Building and Planning study, ten inhabited, electrically heated row house areas (similar to a terrace or town house development), with 330 modest family homes, were examined using various technical solutions as well as the individualised metering of and charging for electricity and water consumption. The study found differences in total energy consumption of approximately 30% between different technical solutions.

Data from Statistics Sweden, among others (including the National Board of Housing, Building and Planning study), show that the total energy consumption for households, hot water and heating systems in new, small family homes can be as much as 130 kWh/m$^2$ per annum.

The National Board of Housing, Building and Planning study also shows that there are energy-efficient technical solutions in small terraced homes, which only require 90–100 kWh/m$^2$ per annum, whilst also providing a good indoor environment. This is the lowest energy level currently considered to be technically and economically sustainable.

The layout and location of heating distribution systems can have a significant impact on energy consumption. Water heating with radiators is a tried and true heating distribution system, which also allows for the use of energy types other than electricity. When using underfloor heating, it should also be possible to use energy sources of lower quality (i.e. low exergy systems) more effectively, by using lower heat transfer media temperatures. For the past few years there has been heated debate on whether radiators or underfloor heating offer the greatest level of comfort as well as the most cost effectiveness and energy efficiency.

**The study**

The study covered residences in six blocks of the AB Kristianstadsbyggen development, with a total of 130 flats and various technical solutions. The blocks have between 12 and 62 flats in each. The individual flats are mainly single storey structures within each block, built on a slab foundation, with underlying insulation. Of the six areas, four have underfloor heating and two have radiator systems. The residences have exhaust or inlet/exhaust ventilation.

The areas were compared to one another, using gathered data and written information and calculated values. Metered energy and water consumption were adjusted according to annual figures, residential floor area, insulation standard, exhaust ventilation, heat recovery (if any), indoor temperature, water consumption, distribution and regulation losses, placement of the electric boiler/control unit, individual or collective metering, culvert losses, heating of auxiliary buildings (if any), and property electricity.

In summary, under the given conditions, areas 3-6 with underfloor heating have, on average, a 15-25% higher energy consumption level (excluding property electricity) compared to the mean value for areas 1 and 2, which have radiator systems.

## CHAPTER 5

# CHOOSING A **HEAT EMITTER**

- **Heat emitters >** The energy source, heat source and emitters all play a vital role. But the end user, and the function of their living or working space, should always be taken into consideration too
- Only radiators offer the full flexibility required to change our understanding of homes and offices as more than black boxes

## Heat emitters

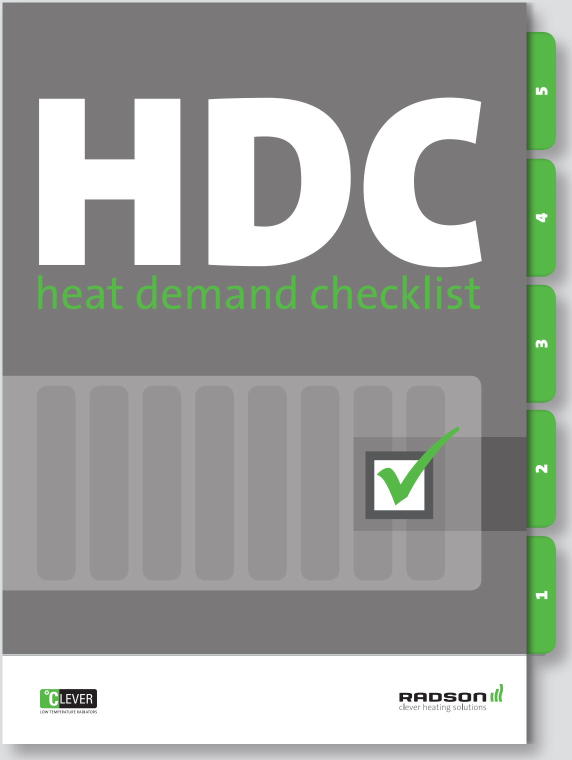
It is important to take a holistic view when discussing heating systems. The energy source, heat source and emitters all play a vital role of course. But the end user, and the function of their living or working space, should always be taken into consideration too.

It can be tempting to view a building as a single unit; a black box that requires heating. However, inside that single unit there is always a larger collection of smaller units; various offices within a building; numerous rooms inside a house. Offices will only be used 8 hours per day, while living rooms are often used only at certain times, and bedrooms only at night. Each has different heating needs and demands and so on throughout the property.

**The energy source, heat source and emitters all play a vital role. But the end user, and the function of their living or working space, should always be taken into consideration too**

When we look further into the function of these spaces, we learn that their function can also change over time. In a family home with children, for example, as they leave infancy they will go to school, reducing the need to heat the house during school hours. As they grow older still, they will eventually leave school and start work, at which time they might also move house, and start a home of their own.

**HDC checklist** Take a look at the checklist on **www.radson.com/re/clever** and try it out with your own home in mind. You may find that there are more considerations than you first thought.



## Some common heating and ventilation systems

**Low temperature radiator system 45/35**

Central heating system where the heating water temperature is max. 55°C at design weather conditions. Heat emission to the rooms occurs in the form of heat radiation and natural convection from the radiators and convectors. They offer highly energy-efficient and comfortable heat emission in low energy buildings.

**Embedded heating systems 35/28**

Central heating system where the heating water temperature is typically under 45°C at design weather conditions. The most typical embedded system is the underfloor heating using floor surfaces for heat emission. Heat emission to the rooms occurs in the form of heat radiation and natural convection. Suited to those buildings with higher heat demand and bigger thermal masses. Particularly comfortable in bathrooms (**Fig. 5.3**), and useful in hallways near external doors, to aid evaporation of water brought in from outside when raining. Lower emission energy efficiency than low temperature radiator heating.

**Ventilation air heating**

Air heating system combined within the mechanical inlet and exhaust ventilation, most often equipped with heat recovery. Typically the air inlet temperature is controlled by the mean dwelling temperature. This causes temperature fluctuations and problems in retaining comfortable temperatures in a single room. Air stratification is also a common problem with this emitter, which requires the building envelope to be airtight and properly insulated in order to reach the target energy efficiency.

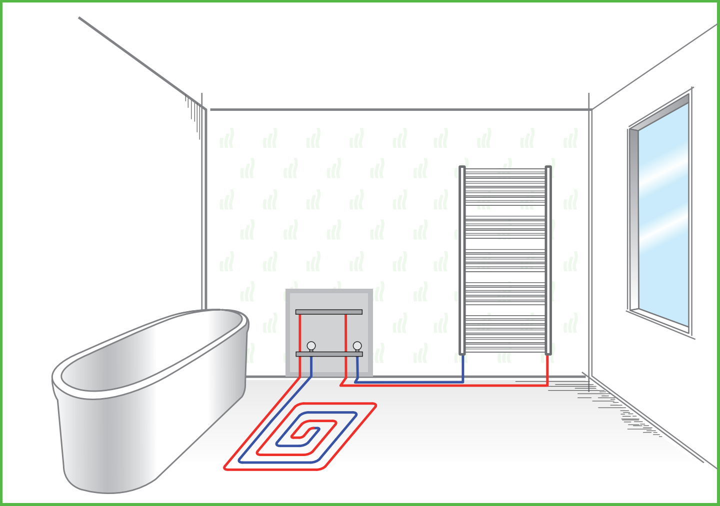
For cases where higher heat outputs are required, fan assisted emission units are available. Typical emitters include radiators equipped with blowers and fan coils - i.e. convectors with fan and air supply often for heating and cooling purposes.

A ventilation radiator is typically a low temperature radiator with an outdoor air intake device. A valid solution for draught free air intake when using mechanical exhaust ventilation systems.

Only a flexible system of heat emitters can effortlessly adapt to the changing function of modern living and working spaces. A system of independently controllable emitters that can be adjusted to suit the purpose and heating needs of individual spaces. In short, only radiators offer the full flexibility required to change our understanding of homes and offices as more than black boxes.

**Only radiators offer the full flexibility required to change our understanding of homes and offices as more than black boxes**

Fig. 5.3
Underfloor heating can bring more comfort to a bathroom, especially when used in combination with towel radiators.



**Elo Dhaene,**
Brand Commercial Director, Purmo Radson

# RADIATORS PLAY A KEY ROLE

**Taking all the facts into account**, we can conclude that low temperate radiators have a key role to play both now and in the future. This future has already started with the introduction of high efficient heating sources as condensing boilers and heat pumps; sources that make low temperature radiators even more effective as they respond extremely quickly and efficiently to heat demands and valuable heat gains. I believe radiators are the only true alternative to create a proven energy efficient heating solution that has all the advantages that builders, planners and installers need and ask for.

Today's high efficiency projects, both in modern new buildings and well-renovated older ones, use advanced materials, have stricter standards and are raising the bar even further for overall efficiencies. But it's not only efficiency, it's also comfort that is important to create a pleasant indoor climate in such buildings.

At Radson we develop clever heating solutions to meet future standards, reducing dependence on finite energy sources, cutting emissions and, of course, lowering overall costs. Contrary to popular misconceptions, these high efficiency low temperature heating systems perform best when combined with radiators.

In this heating guide we've shared, I think, significant proof to support our claim that it's impossible to ignore low temperature radiators. Our investments in research and development have resulted in really clever solutions and products. All researchers underline that our radiators are in almost all cases, the most efficient heating emitter within a modern heating system. Low temperature radiators have proven to be the most energy efficient emitter in low energy buildings. Wherever this building is built or located, and whatever the outside conditions; radiators provide not only the highest energy efficiency rates, but are also able to create the highest levels of comfort.

Science has proven and confirmed the physical fact that using low temperature radiators is indeed more energy efficient than under floor heating.

- Around 15% more efficient in single-storey houses
- Up to 10% more efficient in multi-storey buildings

The main reason for the lower energy efficiency of under floor heating is the unexpected heat losses both to the ground (caused by a so called phenomenon 'downwards heat conduction') and also to external surfaces (caused by heat radiation). It also appears that the thermal mass of under floor heating systems hinders its ability to utilise heat gains, causing unpleasant room temperature fluctuations. These in turn cause people to turn up the room temperature setpoint.

Our extensive research and tests have shown that under floor heated buildings are more sensitive to end user behaviour. In daily practice we've seen that this leads to prolonged heating periods and higher room temperatures. Failures in the construction of, for example, cold bridges between the floor and external walls, also contribute to considerable differences in energy consumption.

While we claim that with our radiators you can save up to 15% on energy, the research of Professor Harrysson shows that this even can be much higher! **The measured differences in modern Swedish houses demonstrated that it's possible to save even up to 25% on energy!**

# CHAPTER 6

# BENEFITS
## TO THE END USER

- Higher efficiency at lower water temperatures
- Suited to all climates
- Lower energy cost
- Higher comfort
- Compatible with underfloor heating
- Better indoor climate control
- Ready for renewable energy sources
- 100% recyclable
- Healthy living conditions

## Renovations and new build

Whether you're working with a new build project or on renovating a building, radiators have the lowest life-cycle costs of any heat emitter. They are an attractive, cost-effective and energy-efficient addition to a new build and are particularly suited to renovations, as they can be quickly and easily integrated into existing systems.  With little effort, no mess, disruption or construction involved and at low cost, radiators in a renovation project can be connected to pipework and balanced in a matter of hours.

Once installed in either a new build or renovation, radiators are practically maintenance-free, since they have no moving parts, and do not experience wear. Radson radiators in particular, have a designated lifetime of more than 25 years of high performance and long endurance. And of course, they are 100% recyclable, making them especially environment-friendly.

## Higher efficiency at lower water temperatures

Low temperature radiator heating brings warmth to a room as effectively as traditional radiators . Benefits are, however, clear; higher indoor comfort and increased total energy efficiency, higher heat generation efficiency and reduced system losses.

## Suited to all climates

Wherever in the world you are, radiators in low temperature water systems can be used. It doesn’t matter what the weather does or how cold it gets, a properly insulated house can always be heated to a comfortable temperature with radiators.

## Lower energy cost

Radiators for low temperature heating systems use less energy to perform efficiently. A modern family home or office building can be heated comfortably to 20°C with radiators designed at system temperatures of 45/35°C. Traditional heating systems use water up to 75°C to achieve the same room temperature, using more energy for the same results, but at higher cost.

## Higher comfort

With a unique combination of convection and radiant heat, a low temperature radiator ensures a constantly pleasant temperature. There are no annoying draughts, nor is there a “stuffy” or “dry” feeling.

### Compatible with underfloor heating

When combined with low temperature radiators, underfloor heating can reach optimal levels of both efficiency and comfort.

### Better indoor climate control

Radiators react quickly to the required temperature signal from the thermostat, distributing warmth rapidly, silently and uniformly. Within a matter of minutes, the room temperature is at a consistent level throughout, from the ceiling to the floor.

### Ready for renewable energy sources

Low temperature radiators are made to deliver top performance, no matter what energy source is warming the system. The cost and availability of a specific type of energy, such as fossil fuels, will not affect the efficiency of the radiator. If the desire is to use other energy sources, including renewables, it’s only a question of adjusting or replacing the boiler.

### 100% recyclable

Radiators have been specifically developed so all components can be separated at the end of the radiator’s lifecycle. All metal parts, primarily steel, are suitable for recycling and reuse – and actually valuable enough to really recycle them.

### Healthy living conditions

Low temperature radiators are safe. No burning effects of room air dust, no deviations of the room air ionization balance, no unpleasant smell. And no risk of burning when you touch a radiator operating at low temperatures.

# CLEVER
# HEATING
# SOLUTIONS

°CLEVER

LOW TEMPERATURE RADIATORS