Benefits of Flexiwarm Electric Heating Panels

Executive Summary

Heating systems that fulfil the requirements of sustainability and that make commercial sense for the homeowner as well are in high demand. By design, electric heating systems that are used for heating large surfaces like floors, walls or ceilings have a strong point. They allow to do the heating directly where it is needed when it is needed and to control it in a very sophisticated way.

Electric heating systems are different by design from conventional heating in the way that they operate at the same very high efficiency under full load or partial load. For over 25% of the heating period only a small fraction of the capacity of the heating is required, resulting in a sort of stop-and-go operation like a car in the city. Fire-based heating systems use a lot of fuel for that operation and produce a lot of emissions during it. Electric heating systems work at almost 100% of efficiency on the electric power bought by the homeowner in any situation.

Heating can be scaled to the exact needs in terms of single rooms or zones in a room, in terms of amount of heat wanted and in terms of timing over the year. This scalability provides very high energy efficiency.

Flexiwarm covers all the beneficial topics that can possibly delivered by competing systems.

The heating with Flexiwarm electric surface heating is as green as the electric power that goes into it. The consumer can decide to use renewable power from his supplier, he can buy ecopower from wind or small hydro or he can even opt to produce his own electric energy for the heating. The low investment cost of Flexiwarm heating systems compared with fossil fuel heaters (gas, oil), pellets heating centrals or heat pumps are one argument more to switch to Flexiwarm.

You can go carbon-neutral with electric heating systems by Flexiwarm and even save money.

1 Heating: some basics

In order to understand the differences and advantages of the various heating systems it is necessary to look at the facts that influence the performance of heating systems in general.

1.1 Parameters of heating systems

The main interest of the consumers is always the cost of a heating system. To understand what influences the cost, it helps to understand the common basis for all heating systems. The cost differs by heating system and its operation and maintenance, but for all systems there are the same basic facts.

1) Heating degree days: this is a measure of the temperature difference between outside and inside a house at a standard temperature of 20 degrees. It is available as a 10-year or 25-year average value for each region/city. This is a statistical value and the actual value may differ very much for single years, depending on warm or cold winters, wind etc.

2) Level of insulation: this is dependent on the individual building. The same amount of heating degree days will need much more energy to maintain the temperature inside, if there is no or insufficient insulation. The measure of this is the energy demand (loss) of a building in a standard location. This ranges from over 200 kWh/year and m² of floor space down to as little as 15-40 kWh/m² for passive houses that theoretically don't need a heating system.

3) Floor space: the level of insulation and the heating degree days give a value of energy consumption that must be multiplied by the size of the heated building. Typically the floor space is the driving factor, although the energy used is not fully linear to it.

4) Time of heating: All factors above assume that the heating is done for the full year and that the building is inhabited year-round. This is not always true, for example if it is a holiday/weekend home or if the city flat is unused during weekends. Offices and other commercial buildings like hotels have completely different using patterns. The using habit of a house or flat should be considered well in the decision process to avoid unnecessary investments. An additional factor in connection to the using pattern is if the same temperature is kept up all day long or if it is reduced during night and / or during absence of people.

5) Building style and thermal mass: The thermal mass is the material that can store heat in a house, like walls, floors, ceilings. In general the heavier the material is and the more material is there the more energy it can store (buffer). The effect is on the one side that a high thermal mass building gets warm slowly and on the other side cools off slowly as well. Depending on tradition, climate and use of the building different concepts are established. In Mediterranean countries large stone buildings buffer the day temperature and stay warm enough to get over winter. In Scandinavia low-mass wood constructions are used that have very low thermal mass, but can be heated up quickly. Obviously these differences in "behaviour" of the building are important to select the right heating system. Buildings with high thermal mass need to be heated permanently to avoid cooling. Buildings with low thermal mass need a fast reacting heating system that warms the rooms quickly. (Attention: this does not say anything about the amount of energy that has to be put into the building! Permanent heating can be more efficient for buildings that are occupied year-round, but can be very problematic if the temperature is reduced over night or a weekend, because of increased heating that is needed to warm it up again.)

1.2 Short profile of the main heating systems

To simplify the comparison we centre on complete heating systems based on the concept of central heating or an equivalent to it. It seems evident that (fixed or mobile) electric heating devices (like products based on Flexiwarm) will have a big advantage in covering decentral heating demand in single rooms or parts of a house.

1.2.1 Gas-fired central heating

In the last years this heating system was pushed with the argument that it is clean, does not need storage space and that gas supplies will last longer than oil. In the end the heating is based on fossil fuel, even with the use of LNG (liquefied natural gas) or propane/butane in liquid gas tanks. The plus is that it is relatively cheap and can be controlled in a good way; it does not need storage space and is low in NOx and dust emissions.

1.2.2 Oil-fired central heating

Although the technology is similar to gas and offers a wide range of controls to increase efficiency, oil has lost a lot of market share to other fuels. The disadvantage compared to gas is the need for a special tank, which means storage space. The positive aspect of a tank is that interruptions in supply do not stop heating. In all cases (oil, gas, pellets) heating stops if electricity is interrupted because controls and pumps do not work without electricity. The awareness of the end of oil means that oil-fired central heating will continue to lose market share. Replacements for fossil oil like biodiesel and vegetable oil are theoretically possible, but the situation of the supply and the political will to push these energy carriers is not there today and cannot be expected at present.

1.2.3 Pellets-fired central heating

Heating centrals that are fired with pellets (pressed waste-wood and saw-dust) have been booming in the last 8-10 years, especially in Germany, Austria and Switzerland. Short supply of pellets has dramatically increased the cost of the fuel. This has lead to a cooling off of the demand. The technology works at the same comfort level like oil or gas, but it requires a larger space for storage than oil. If the supply is secured by long-term contracts and/or reliable local/regional suppliers, this type of heating has lower fuel costs than oil or gas, but requires higher initial investment. The life-time of the feeding mechanism could also become a problem for re-investment, because it includes mechanical parts which have to endure a lot over the life-time of a heating system. One environmental point against pellets is the high level of dust in the emissions, which cannot be solved for single-households at competitive prices at this time.

1.2.4 Electric heating methods

Electric heating was pushed by the power producer in times when they could not sell their electricity in off-peak periods, like night-time. The concept was to heat up a heavy core of metal, concrete or asbestos at the time of cheap electricity and to use it to heat the rooms for the full days. This concept has mostly disappeared from the markets and is faded out, because the power companies are mostly not interested in it any more. The acceptance on customer side has declined due to the low comfort (dependence on the time-schedule of the power company to heat up) and the bulky, heavy and ugly radiators, many of them with parts of asbestos.

The other types of electric heaters are electrically heated radiators which look like conventional radiators and have different thermal mass included (from virtually none up to thermo-oil, concrete or metal cores).

Underfloor-heating with electricity is modelled on the concept of underfloor heating with hot water. It uses much lower temperatures of the heated surface and compensates that with larger heating surfaces. There are different technologies that are all based on the concept of electric resistance, but using wires, carbon fibres, carbon boards or conducting foils. The concept was used on space stations (MIR, Space Lab etc.) and under many situations in industrial environments. Flexiwarm is among the most advanced systems in this field.

1.2.5 Heat pumps

A heat pump is a machine similar to the concept of a refrigerator, where water or air is used to warm a cooling liquid which is then compressed. This increases its temperature and can be used to heat a heating medium (water for radiators or underfloor heating or air for air-flow heating). After that the cooling liquid is de-compressed, gets cold and can take up heat from the outside again.

Depending on climate and available energy source, heat pumps use 1 unit of electrical energy to run the pumps to harvest 2-4 units of heating energy. In general the factor is higher the higher the temperature of the energy source is. Since groundwater keeps a rather high temperature even during cold days, water/water heat pumps have a better efficiency factor than heat pumps that use ambient air. The downside is that water/water heat pumps are much more expensive in investment and installation and are more difficult to build in for retrofitting.

One environmental point against heat pumps is that they use electricity. Depending on supplier this means it runs on coal, oil or nuclear power. The commercial point against heat pumps is the high investment cost and the fact that electric energy is about 3 times as expensive as gas. So the saving in energy consumption is for then biggest part eaten up by the higher cost of electricity versus gas.

1.3 Renewable energy, ecopower and fossil energy

To understand the discussion about environmental issues, it is necessary to have a look at some buzzwords.

1) Renewable energy: this includes all types of energy that are replenished by nature automatically. In the end this is done by the sun shining on the Earth. Solar energy (heat or sunlight used for photovoltaic = “electricity from sunshine”) are the best known. But also wind is indirectly created by the sun heating different areas of the Earth which leads to differences in air pressure and then to wind. Wave energy and hydropower are also counted as renewable energy. Biomass which can be re-grown at the same rate that it is used, and every fuel that is derived from it, is generally counted as renewable. Geothermal power is mostly counted as renewable, because the reservoir (warmer soil or even hot deep rock inside the crust of the Earth) seems inexhaustible.

2) Ecopower: There is a fine distinction to renewable energy with the term “ecopower”. The focus lies on a wider definition of sustainability than in the concept of renewable energy. In order to be called ecopower the production needs also to keep the general impact on nature very low. Therefore the biggest distinction is in hydropower, where large hydro generally is not counted as ecopower, but it still is renewable (think of the huge hydro power dam in China or other big-scale projects in Africa and South America. A similar distinction can be made for biomass that is not re-grown or that is used in an irresponsible way (e.g. cutting rain forests to produce palm oil for biodiesel). In general large scale power stations are very often not accepted as ecopower, even if they use renewable resources.

3) Fossil energy: Oil, natural gas, tar sands and coal are summed up as fossil fuels, because they consist of biomass that was fossilized millions of years ago. (Cynics argue that fossil fuels are principally also renewable, but it takes many millions of years and someone would have to bury the trees now to have coal in future…) Although there are still large reserves of many resources, especially of coal, the supply is getting scarcer, the technology to extract the fossil fuels is getting more expensive and therefore the prices will inevitably increase over the long run.

2 Parameters of environmental friendliness

All producers of heating systems ague that their system is environmental friendly or even the most environmental friendly of all.

- Gas: it is "cleaner", meaning that NOx, sulphur and CO_2 emissions are less than using oil. Gas will be available longer, because oil wells tend to provide gas when they are aging. This is clearly visible in UK; Norway and Netherlands, where oil production is declining, but gas production is still developing well.
- Oil: it claims the longest development time and therefore the highest standard of optimized fuel and burner technology. It compares to old oil heating systems mostly, and of course this "proves" that oil is clean today as compared to the past.
- Pellets: it claims to be carbon-neutral, because the CO_2 emissions are the same than the CO_2 that was captured by the plant when it grew. This again does not tell anything about the source of the pellets. It could be from a sustainable forest in the region as well as from plundering the Brazil rain forest or transported all the way from Canada, vastly reducing the expected benefit.
- Coal: huge efforts are made in Europe to dress up coal as a clean energy source. There are large sums of EU-research money spent on "clean coal", CO_2 separation and sequestration. Test and pilot plants are just starting to work, the technology will not be widely available or applied for one or two decades.
- Nuclear power: the nuclear lobby argues that all renewable energy potentials will not be enough to cover the energy needs, only nuclear power will do it without CO_2 emissions.

So everybody is dressing up the reality to sell their products. It is very likely that this is a must today to sell any product. People still decide by financial arguments, but they seem to need an argument that gives them a good conscience.

As a basic rule it is important to understand that all arguments have their credentials, but also that none of them are universal for all situations and circumstances.

2.1 Input of primary energy

Primary energy input (typically the amount of oil, gas or coal) means the amount of energy that has to be used in the first place to deliver the work or heat that is required. A typical example is the electric light bulb. It uses only 1% of the primary energy for lighting. The remaining 99% are losses and heat. So the primary energy input in this case would be 100 times the effective required output.

The argument of high use of primary energy is often used against electric heating. The claim is that only 35-38% of primary energy input is converted to heat. The remaining amount is due to low-efficiency power plants, the energy input for mining coal and oil, for transport and transmission losses of electricity.

It is very simple to counter the argument: the argument is only valid if the electric power is produced in a certain mix of coal, oil, gas etc. If the power comes from hydropower, the argument is obviously wrong. The primary energy input of electric energy depends on the sources of the electric power. If they are renewable, the argument becomes meaningless.

It can even be argued that wind energy or hydropower have NO primary energy input, since the source is renewable and therefore by definition cannot be consumed.

It is totally meaningless, how many percent of the wind or the water or the sunlight is converted into electric power, because the resource is not used up by this. (The only relevant point is the commercial relation between investment and useable output.)

2.2 CO2-and other emissions

The amount of CO2 emissions has come into focus over the last years. The value depends on the type of fuel that is used. Chemical differences are responsible for the fact that the same energy output from natural gas has fewer CO2 emissions than oil and that coal has much higher emissions than oil and gas.

Regarding heating there is a very straight link between the fuel of the heating system and the CO2 emissions. Again, electric heating is often treated as a pariah. The argument is the same as above: if you use electric power produced from coal in old and inefficient power plants the CO2 emissions related to this type of heating will be prohibitively high. But if the power is generated from wind and hydropower or other renewable sources, electric heating is emission-free.

None of the other conventional fuels can be as clean as electric power for heating, if the source of power is selected properly. Even pellets, which are – apart from production and transport – CO2-neutral, have emissions in the form of gases and dust that go through the chimney.

Another fact is also clear with electric power: the production of electric power in large-scale power plants that run on oil, gas or biomass has the advantage that expensive state-of-the-art emission controls, filters and gas-cleaning procedures can be installed that are not (at least not economically) available for single houses that heat oil, gas or biomass.

2.3 Renewable vs. fossil sources

Environmental friendliness can also be roughly differentiated according to the type of fuel use. If fossil sources like oil, coal or gas are used, this is the least friendly way (coal being the relatively worst and gas the relatively best). If renewable sources are used, this is in general considered as environmental friendly. (For restrictions on this see the difference between renewable energy and ecopower.)

In this connection it is very often assumed that electric heating is using some sort of "bad mix" of electric energy. This implies that electric energy for heating uses a mix of fossil fuels and (some) renewable sources. As a critique this point is not valid, because the assumption is not correct. It depends on the consumer to decide which energy mix he buys from his electric power company.

2.4 Production and transmission losses

To understand the importance of production and transmission losses of a certain fuel it is enough to remind that drilling and pumping oil, mining coal and extracting and purifying gas requires energy itself. The same is true for refining of oil and gas; the products have to be transported to the destination by ship, pipeline, train and truck. The combined energy input can be counted as loss in the supply chain.

For electric energy the main losses are those of transformation and transmission which replace a part of the transport losses of the fossil and bio fuels. Of course the losses of production and transport of fuel that is burnt in electric power plants must be calculated, if these fuels are part of the energy mix for electric power.

Regarding the transmission and transport losses there is an additional plus for electric heating. This lies within the heated house. The electric power is delivered to the heating area directly. There are no heating central, pipes and radiators to heat. There are no losses for the distribution of the heating inside the house.

2.5 Energy efficiency and efficiency parameters

Consumers and even many technically educated people are confused by the many different energy efficiency parameters that are used by the companies selling their products. It ranges from the isolated – and therefore meaningless – performance of a heating device to the famous efficiency of 111% for caloric value boiler / condensing boiler.

The fact is that thermal energy conversion always has losses and that most modern products operate at a high efficiency of 90% or more. It is hard to find (or even to measure) a correct number for the overall efficiency of a total heating system, but a guideline can be that the number of components is important. If there is only one component with an efficiency of 90%, this would be the system efficiency. If there are 3 of them with 90% each, the result is 72,9 % and if there are 6 of them, if goes down to 53,1 %.

Since oil, gas and pellets heating systems consist of boilers, standby-losses (heat that is lost to the surrounding of the boiler room), heat exchangers, transmission and radiators, the correct efficiency will be much below 75 or 80%. This is a value that can then be compared to that of electric heating. Electric heating converts practically 100% of the energy into heat (neglecting the losses that occur until the energy carrier arrives at the house where it is used).

Another point that should be noted is that all the performance figures are typically given for the best situation, for the optimum working point. It means for example that the efficiency of a boiler is given for full operation over a longer time. This value is never reached over the full year. It is estimated that boilers with an efficiency of 95% at best working conditions reach efficiencies of 60% or even less when they run under partial load only. This will be over a significant part of the year; some estimate that it is true for almost half the year.

Summing up this confusing topic the message for Flexiwarm is clear: never allow critiques to mix up all the different efficiencies. Always ask for comparable data that includes all losses and the efficiency of the full system, not of single components. Never allow people to calculate with the values of caloric value boilers, because the number DOES NOT mean that you get 111% of energy out for an input of 100%. It is a simple phenomenon that comes from the old established way of measuring the output against the so-called lower heating value of a fossil fuel. This basis is the heating value of the input minus the energy content of the flue gas. Flue gas contains water vapour that is condensed in caloric value boilers, adding to the effective heating energy. (in the end, even with an efficiency of 111% there are 5-11% energy losses through the chimney!)

2.6 Life-cycle analysis and use of materials

In assessment of the environmental impact of product the so-called life-cycle-analysis (LCA) is becoming more and more standard. It is beyond the scope of this paper to provide such an analysis, but we want to give a rough idea of the concept and expected outcome.

For an LCA all material and energy streams for the technology are put together. This includes also the energy that is used to produce the heating central, heating pipes and radiators, even the energy that goes into the production of the machines that produce these products.

Following the fact that electric heating, especially Flexiwarm products, has a very low consumption of material for the equipment of a full household, it can be expected that the life-cycle analysis will show a very positive picture in favour of Flexiwarm. We estimate that Flexiwarm will need about 50-60 kg of foil plus another 50 kg for installation material for a full household. This compares to an estimated 500 to 700 kg of material required for a conventional gas heating, plus the material for a tank for oil or a storage chamber and feeding device for a pellets heating. Since most of these materials are copper and steel, some of them with special properties that require energy-intensive production, there seems to be a strong point in favour of electric heating.

2.7 Commercial aspects

2.7.1 Investment cost

Although there are a lot of subsidies and tax credits for installation of modern heating systems in many countries, the initial investment is very high and a big part of the decision is simply based on the ability to finance an expensive investment. Very often it is a trade-off between high initial investment and low fuel costs, like in comparing gas and oil to pellets or heat pumps.

For electric heating system in general and for Flexiwarm in particular the initial investment is much lower, due to a drastically reduced complexity of heat generation and distribution. No heating central is required, no pipes and pumps have to be installed and the electricity is transported to the point of use by a simple pair of wires.

Just to complete the picture it must be mentioned that the cost for the room of a heating central and the fuel storage (oil, pellets) have to be calculated. Also the cost for the chimney must be factored in to arrive at correct and fair results.

2.7.2 Fuel cost

As long as there is fuel that has to be purchased in the market it is not objectively and properly possible to give a value to the fuel cost for a longer period than maybe a year. Users of oil and gas are just experiencing this, but also users of pellets had their expected bill increased by almost 100% in some cases in the previous years.

As long as there is no fixed-price contract for the supply of power it is not honestly possible to calculate future fuel cost, so all producers use numbers as they like and as they fit their product. If the fuel is cheap at the time, they will use the price of the day, if it is expensive they will use a long-term average that smoothes the situation for them.

In any case it must be expected that electric power will be the most expensive energy carrier, as long as a big portion of it is produced by oil- and gas-fired power plants. This may change with the increased use of renewable power or a renaissance of nuclear power.

For Flexiwarm we expect that the price differences between the energy sources (oil, gas, pellets and electricity) will be similar to today and will probably get even smaller, due to higher absolute prices that force people to change their type of fuel more flexibly than today.

The great advantage of electricity is that it is a universal energy carrier that can be produced form various sources: oil or gas, if they are competitive - hydropower, wind, biomass or wave energy if that becomes competitive. The user of an electric heating system enjoys the highest flexibility without having to change the entire heating system.

2.7.3 Other operative cost

For electric heating systems there is basically no other operative cost to observe. There are no pumps to operate, no flue gases to be analysed and no boiler to be inspected and maintained.

All these items add to the cost of heating systems with gas, oil or pellets.

2.7.4 Lifetime-cost

The lifetime-costs of the different heating systems are very hard to calculate, but under the assumption that the prices for the fuel will stay proportional to each other for the future, it can be used for taking an investment decision.

The general rule is that the worse the insulation and the higher the energy consumption of the building per m² the more important will be the cost of fuel. Therefore it is very important in that situation to optimize the fuel efficiency of the heating system, paying higher investment costs for sophisticated technology and controls.

On the other hand the trend is towards better insulation standards and lower energy consumption. Logically the lower the consumption is the higher will be the burden of an expensive initial investment compared to the energy use.

This poses a big advantage for electric heating systems, since their investment cost is only a part of the cost of an oil-, gas- or pellets-fired system. The less energy there is consumed the more sense an electric heating system makes, because the difference in fuel cost per unit is not so important any more, while the fixed costs (investment plus inspection/maintenance) weight more and more.

2.8 How green is electric heating in general?

Electric heating is always as green as the electricity that is used. Produce it from coal, and the emissions in CO2, the use of fossil fuels and the typical losses in the power plants make it an ecological nightmare.

Companies that sell oil-, gas- or pellets-fired heating systems always make the assumption that the power is produces according to some national or fictional mix of primary sources.

Due to high presence of this message many people have adopted this as common wisdom.

So, taking the number of only 35% efficiency in primary energy use for electricity may be correct for some countries, but it is for sure not correct for countries like Austria (with about 70% of hydropower, France with a high proportion of nuclear power or for Scandinavia with a mix of hydro and nuclear power).

Since a couple of years it is possible for EU citizens to buy the power from different supplies with different mixes of power sources. It is therefore very simple to select a supplier of electricity that offers renewable only or even ecopower (without large hydro) or wind power only.

Also in this case: electric heating is as green as the power that is used!

So to sum it up it means that it is in the hands of the customer to decide which type of electricity he wants to use, if he accepts higher prices for renewable power or even if he believes in nuclear power and goes carbon-neutral in the sense of the nuclear power industry.

2.9 How green is Flexiwarm?

Compared to the older systems of electric heating, all electric low-temperature systems (wall, floor, and ceiling) offer the same advantages. Ecologically and economically they provide the same comfort level at lower room temperatures, which is the key to low consumption.

Compared to conventional electric surface heating systems (based on heating wires or carbon fibres or carbon boards) Flexiwarm offers the advantage of heating the full area of its heating foils, whereas competing systems heat a small area (around the wire) and then require a heat transport within the heated surface. The consequence is that these systems need thermal mass to spread the heat of the wire over the surface. The advantage of Flexiwarm is that it can do without this thermal mass and so can be much faster in reaction. This makes Flexiwarm ideal for short heating cycles and “instant heating” as well as heating only single rooms or zones within a room.

Summing up it can be said that there is no point where Flexiwarm is less green than other electric heating systems, but there are some advantages for applications that other systems cannot meet.

3 Low-temperature / large surface heating

3.1 Difference convection vs. radiation heating

In general there are two ways how to bring the heat to a room. One is through radiators of some sort; the other is by warming larger surfaces like floor, ceiling or walls.

The difference is that radiators are quite small, so they need a high temperature (50-80°) to give enough heat to the room. On the other side surface heating systems can do with much lower temperatures (25-40°). Such heating systems work primarily by radiation, which means that the objects and persons in the room are warmed, whereas radiator systems warm the air first and the air then warms the objects and persons.

The energy efficiency of surface heating systems is better, because the air temperatures in the room can be several degrees lower, but the comfort level felt by persons is the same. It means that the whole house or room does need a lower temperature to heat up which in turn cuts the losses to the outside and the losses from changing the air in the room.

The limit for surface heating is the energy need of the building. If the building is not insulated the heated surfaces have to be very warm, which is a special problem for underfloor heating, because temperatures of more than 27 ° are felt as too warm. They are also recommended against for older people and people with varicosity or other disorders in the blood circulation of the legs.

All this is independent of the fuel that is used, because all types of systems can be powered by gas, oil, pellets or electricity.

Flexiwarm is in the best position in this context, because due to its low thickness of 1 mm it can be installed on all surfaces without causing problems like thick floors for water-based underfloor heating systems.

3.2 Thermal mass of heating systems

In general a heavy object needs longer to warm up, but stores the energy longer and gives it off distributed over a longer time. The typical example is the tiled stove. It is very slow in warming up, but lasts long, once it has its temperature.

So for keeping a permanent level of heat it makes sense to have this thermal mass in the room or in the distribution system, but for variable temperature levels it is a problem.

Flexiwarm can be installed according to the needs of the house or even to the need of a specific room or a zone in a room. Flexiwarm does not need thick layers of plaster, gypsum, water pipes or other components that add to the thermal mass. So it can be installed as a quick-reacting heating surface virtually without thermal mass, getting warm in minutes.

If required, Flexiwarm can be embedded in layers of heavy material like concrete or thick layers of metal or in plaster at any choice. The effect is that as much thermal mass can be added as the customer wants.

This can be done and decided for each Flexiwarm mat individually. Some other foil-based heating systems theoretically could do the same, but up to now it seems not to be used in marketing the products, because these other systems typically are sold as building material or components and not as complete solutions and applications.

3.3 Optimizing the use

If you look at the advice of different energy agencies and information centres there are some things that can be done by the user to run the heating system in an optimized way.

3.3.1 Night and weekend (weekday) temperature reduction

The temperature can be reduced during times when rooms or houses are not used, which is especially interesting for persons e.g. who live in the city during the week and go to a house in the country over the weekend.

Also the temperature level during night could be reduced or during the days when nobody is at home.

In general the effect is that the average room temperature over a year is lower than at full heating, which means that the difference in temperature to the outside is less in heating degree days. The result is a saving of energy that can be 3-6% per 1° of reduction over the heating period.

Assuming a reduction in night temperature from 21° to 18° for 8 hours per day this comes to the equivalent of one degree in reduction. The same reduction in temperature done for Saturday and Sunday would mean that 28,5 % (2 days out of 7) of the heating period runs at reduced temperatures, resulting in an average reduction of 0,85°.

The critical issue in this matter – also much discussed in the last few years – is the thermal mass of the building. It may not work properly or may even be counterproductive if the building is badly insulated or very slow in gaining temperature.

In any case Flexiwarm can be tailored to the building and the using pattern by adding thermal mass or by leaving it away.

3.3.2 Single room heating and zone heating

With central heating systems the problem of heating/not heating selected zones can be managed by thermostats and valves, but only complete rooms can be reduced in temperature. Electric surface heating systems offer principally a higher flexibility in managing different temperatures at different parts of one room.

Although houses that are well insulated are typically heated in all rooms, there are many situations when heating is not required or not even affordable for the full house.

Examples could be large houses that are used by the parents alone after the children have left or guest rooms and other rooms that are used very scarcely. In both cases it may make economic sense to use less money on an extensive insulation at the expense of additional heating just a few hours per year. The reduction in use of building material could even make this ecologically correct in the sense of a life-cycle analysis (energy consumption for the production, transport, installation and recycling of the insulation material).

In any case it can be expected that increasing energy prices in combination with a bad economic development will take the decision off the hands of many people: many will simply not have the funds to do extensive insulation work and will therefore take the (energetically) second-best alternative: heating single rooms, adding just a little heating in the spaces where it is required most or even locking up parts of the house during winter altogether.

The problem that comes with heating only parts of the house or with heating single zones is that central heating systems would have to run much below capacity. The effect can be compared to the stop-and-go driving of a car: consumption goes up and efficiency of even very good installations declines dramatically.

Flexiwarm is best equipped to solve this problem, since there is no heating central as overhead. Moreover Flexiwarm can "grow" with the size of the house, which is not possible with central heating systems. It means that Flexiwarm heating systems don't have to be over dimensioned, because the homeowner thinks he wants to add more rooms in 10 or 15 years. This type of heating and Flexiwarm especially can be designed to run very close to the optimum point at all times of the lifecycle of a house.

3.3.3 Ceiling – wall – floor

Radiator-based heating systems require at least some space within the room. Surface heating systems in contrast are normally invisible and are hidden in the floor, the wall or the ceiling.

There are technical and simple personal aspects that bring a decision in favour of one or a combination of different surfaces.

A simple guideline is that underfloor systems need more installation work, since the room must be empty and the flooring must carry heavy loads and traffic. A positive aspect for many persons is the feeling of "warm feet".

Using the wall as a surface has the advantage that the area of the wall typically is parallel to the front and back of the persons in the room, which maximises the radiation taken up by the body. The backside is that walls frequently are not free, because they are used for doors, windows and furniture. The problem can be especially big, if a change in furniture or in the interior design is made that would cover parts of the heating.

An alternative is to use the ceiling as heating surface. The advantage is that it is typically easy to access for installation, it is not covered by furniture and it needs no extra strength material like the floor because it does not have to sustain the mechanical stress of walking on it. Thinking of the principle that warm air raises to the ceiling, many people are sceptical of heating the ceiling.

Water-based ceiling heating systems actually do have a problem to radiate the heat to the downside. It can be expected that Flexiwarm will have an advantage there due to its slim design and therefore fast heat emission that leaves enough space for insulation on the upper side. Water based ceiling heating systems require at least 20 mm thickness for the pipes. These 20 mm can be used for insulation if Flexiwarm is used. The other big advantage of Flexiwarm is the very low weight that makes it possible to use it for all ceilings, even for the use in suspended ceilings.

Of all the advantages that electric heating systems have for heating ceiling, wall or floor, Flexiwarm has all of them plus the advantage of very low thermal mass which makes it much faster in reaction than other systems and especially faster than water-based floor-, wall- or ceiling heating systems.

4 Benefits of Flexiwarm

After showing that surface heating in general has many advantages and that electric heating of such surfaces also offers many positive aspects, let us look where Flexiwarm stands within this framework.

What are the key benefits of Flexiwarm?

4.1 Emission free

Electric heating is always as clean as its production. Environmental conscious consumers will buy Flexiwarm and operate it on electricity from hydropower, wind power and biomass. This makes the operation of Flexiwarm heating systems emission free. The decision can be taken and revised any time; it is in the hand of the consumer to decide.

Flexiwarm is on par with the other electric heating systems and producers, but could be the first to market the concept with its product.

4.2 Maintenance free

Electric heating systems don’t require maintenance or inspections, since they have no moving parts, burners or emissions to check.

Flexiwarm is on par with the other electric heating systems and producers.

4.3 Long lifetime, no deterioration

Since electric surface heating systems have no moving parts the material is not under mechanical stress. The operation does not degenerate over time, like with machines or burners that get old or fail. The economic lifetime of a heating central is between 10 and 20 years, frequently a check-up for possible replacement is recommended by the authorities after only 10 years of operation. Electric surface heating systems have a lifetime of at least 30 years and a lot of fantasy is needed to think of a reason why they should not operate for 50 or more years.

Flexiwarm has an advantage to most other systems, because the material is very flexible and there is no risk that it gets brittle and goes out of function. In addition Flexiwarm can be operated room by room, which extends its economic lifetime in the case of a change of use of a house. (Imagine that the parents' home after 30 or 40 years is inherited by the children, but used only as a weekend home by them.)

4.4 No plumbing, no risk of pipes breaking

A high resistance to installing an underfloor-, wall- or ceiling- heating system based on hot water is the latent fear that pipes might break or that the pipes might be punctured when hanging a picture or fixing something in the room.

The plumbing work for water-based heating system in general is quite a mess. This is considered a normal nuisance during building a house, but it is extremely stressful for the owners if it occurs during refurbishment.

All these issues are not valid for electricity-based surface heating systems.

Flexiwarm has an additional advantage over other electric systems due to its operation on low-voltage power that makes it much more secure, if the foil gets damaged or wet. The second advantage of Flexiwarm is that due to its full-surface heating properties, damages (cuts, punctures, even nails or screws through it) will not lead to a complete failure of the system. The problem will be locally limited and will probably not even be noticed.

4.5 No heating central

It is obvious that electric heating does not require a heating central, saving on room costs in construction or adding an unused room after conversion to electric heating.

Flexiwarm is on par with the other electric heating systems and producers.

4.6 No fuel storage

Under the assumption that the electric power is purchased from and delivered by the grid, no storage for the "fuel" is required. Under certain circumstances this might not be true, for example if some day cost effective batteries are available that make it possible to buy electricity at off-peak prices, store it and then use it when it is needed. Research efforts are very strong in this direction, with first (but still expensive) products entering the market now. The systems range from advanced batteries to chemical storage and large-scale capacitors.

Flexiwarm is on par with the other electric heating systems and producers.

4.7 Slim

Although the conductive part of all electric surface heating systems are very slim, Flexiwarm has an advantage over them. It results from the fact that other products come as building components / building materials that have to be embedded into plaster, gypsum or some other sort of composite layers.

Flexiwarm can be easily confectioned in plates, cassettes or panels that are ready for mounting. The result is that the thickness of the completely installed heating element is typically slimmer than that of competing products.

4.8 Fast reaction

Linked to their slimness all electric surface heating systems share the fast reaction to heating (and stopping to heat). The differences between the different systems come from the way they are installed and from the thermal mass that is added in the typical way they are mounted. Most systems for wall or ceiling are for example covered by a gypsum board, which has to be heated first before the radiation can reach the room.

Flexiwarm in its form as ready-made cassette, panel or plate has probably the lowest thermal mass included in the standard installation which provides the advantage of super-fast reaction. On top of this Flexiwarm can be equipped with additional features to go to a higher temperature for the starting time, cutting the warm-up time additionally.

4.9 Adjustable additional thermal mass / storage

Theoretically most different electric surface heating systems can be put together with different thickness of thermal storage layers, changing their thermal mass and the ability of storage.

Flexiwarm offers the highest flexibility in this respect, because basically no thermal storage must be included, but any amount of it can be included at request.

4.10 Ideal combination: replace transformers for 12 V with power supply for heating (preparation for use of LEDs)

Most electric surface heating systems run on alternate current at 230 V / 110 V. Several producers of electric heating mats and heating devices for bathrooms offer their products with safety transformers and low voltage.

Flexiwarm is one of these producers that put safety over low cost on the expectation that this will be a selling argument especially for customers who install the heating in walls or ceilings.

To bring an extra benefit for the use of the transformers that are required to run Flexiwarm products under low voltage power, these transformers could be used also to provide a power supply for halogen spots and in future also for LED-lighting elements. Both lighting systems require transformers but very often come with low-cost components that use a lot of standby energy. Especially for use as ceiling heating elements this could provide Flexiwarm products with a strong selling argument, if all these transformers and cables for LED lighting could be saved and integrated into the power supply of Flexiwarm with very low consumption of standby energy consumption.

5 Sources of power for Flexiwarm

In the last years different sources of power for the electric heating have become available, though not all of them are already cost competitive. Since we expect that these sources will arrive at a better price/performance ratio with the extension of the learning curve, we want to show the technically possible ways that are already there or that are on the horizon.

5.1 *Ordinary grid*

The regular power grid is the standard source of power for the electric heating. Until some years ago people had to use the mix of primary input (oil, gas, hydro, nuclear) that was provided by their utility. But since a couple of years the EU-wide deregulation offers the possibility to buy the power from the producer of choice. Only the distribution is linked to the owner/operator of the grid itself.

As outlined above, this enables the consumer to select the supplier that fits best, ideally a supplier of ecopower or renewable power. Changes can also be made over time in line with the contract periods offered in the market. So people could choose the cheapest source as long as they cannot afford higher priced ecopower and then convert to emission free renewable or ecopower if they can afford it.

5.2 *Grid with renewable power package*

In order to simplify the procedure Flexiwarm could look for one or more suppliers of renewable power in each market where the product is sold. Flexiwarm can be bundled with the renewable power electricity. Alternatively the list of possible suppliers for green electricity could be simply offered as a service to the consumers.

The advantage would be to show Flexiwarm in the renewable power surrounding on one side and offer discounts for the customers of the recommended / bundled power producer that reduce or eliminate the price difference between standard power mix and power from renewable sources.

5.3 *Photovoltaic*

It is possible to produce electric power directly on the roof of a private house with the use of so called photovoltaic panels. The power can be used directly in the household or sold under a feed-in tariff like in Germany, Spain, Italy, Greece, Switzerland etc.

The problem is on the one hand that sun is least when heating demand is highest, meaning that storage for the electricity would be required. This will probably be uneconomical for a long time to come, but there is a solution right now.

Since the feed-in tariff is much higher than the price that is paid for the same amount of energy from the grid, the power could be sold at the high price and the heating could be operated with electricity purchased from the grid. This would be a technical zero-emission heating, where the grid functions as "storage" for the power. Depending on the country and the detailed regulations for feed-in of photovoltaic this is commercially possible today already.

This model will become commercially attractive for most countries in South, Central and Western Europe in the coming few years, because the investment cost of photovoltaic is expected to decline to a level by 2012/2013 that allows to produce electric power in most of these countries for the same price that the consumer pays for power from the grid. At least at that stage it would mean that the self-produced electric power is exchanged with the grid, which compensates the different times of production and use of the energy.

Depending on the advances in research for cheap storage of electricity also internal storage in the sense of fully autonomous systems could be realized. At the moment this is not cost competitive, but technically feasibly.

There is also a third strategy of operation for the heating (or in fact for the electric energy supply of the complete house): This strategy does not feed in the power that is produced, but it replaces the power that is consumed, if there is self produced power available. Some countries favour this system with the system of "net metering", which means that the electricity bill will be the difference of power put into the grid and power taken from the grid (at identical prices).

5.4 Mini-wind power

A much cheaper source of "home-grown electricity" is wind in many locations, even in cities. Wind turbines that run very quiet and that are small enough to be set up on a 5-10m tower in the garden or even on the roof are already in the market and this market is expected to explode with falling prices.

Since wind is available in suitable regions for 2000 hours per year, but sunshine is only for 1000 hours, an investment into a mini-windmill with a capacity of 1 kW will deliver about 2000 kWh per year, whereas photovoltaic will deliver only about 1000 kWh. Additionally the investment is lower than in photovoltaic, making a cheaper production cost.

The problem of storage is similar to that when photovoltaic is used, but there is a closer relation between wind and the need to heat than between sun and the need to heat.

The solution of feeding into the grid and taking from the grid for the heating is identical to that in photovoltaic, but the feed-in tariffs that are paid for wind power are less favourable than in photovoltaic.

For people who are aiming for at least partial autonomy a combination of photovoltaic and wind power may make sense, because the two types are mostly available at different times: if there is wind, there is not much sun, if there is sun, there is less wind. Still, this is a general rule and has to be verified for each location.

The strategy of partial autonomy and net metering can be applied in this case as well.

5.5 Pico-Hydropower

For locations that have access to hydropower on the own soil, so called pico-hydropower plants with very small capacities of a few hundred watts up to several kilowatts are available. When there is a chance to use it (for example together with a location for an old waterwheel, maybe with still existing rights to use the water for a waterwheel), this might be a very cost efficient way of covering the energy demand of the heating and of the complete household.

Depending on the seasonality of the available water, hydropower is available normally for 4000 to 6000 hours per year. So one kW of installed capacity will deliver 4000 to 6000 kWh per year. A potential danger is freezing of the water during the time when power for heating is required most. However, this risk is low for almost all except the smallest of brooks.

5.6 What makes commercial sense?

Selection of fuels is tricky for any heating system, because it fixes the fuel source for the lifetime of the heating system. Self-sufficiency is normally simply no option for an average household, maybe with the exception of farms or houses with enough wood growing on site.

With the development of small renewable energy installations like mini-windmills, pico-hydro and photovoltaic this situation is already changing. Producing at least a part of the electricity consumption is feasible in many locations and makes commercial sense already in a wide range of cases (with and even without feed-in tariffs).

This trend is going to be stronger and stronger with increased mass production of the components and falling prices. High or even increasing energy prices for oil, gas and electricity from the grid will give this trend an additional boost.

To get an idea if and under what circumstances self production of electric energy makes also commercial sense, it is important to understand two aspects. One is related to the availability of a renewable energy source that can be used. Wind and sun cannot be “switched on” when you need the electricity you have to produce electricity when wind or sun is available. This may or may not coincide with your actual consumption need. So there is always the question how to get the supply and demand can be brought to matching.

The second aspect to observe is the principal question of production costs. Since the energy sources are free, it depends on the initial investment, the productive hours you get out of it per year and the lifetime of the device. (For simplicity we put operating costs, maintenance and financing costs aside, since they play only a minor role in these small devices that are installed on a household level.)

If these topics are clear it is up to the user to decide if own production of electricity makes sense for him. Preferences for personal independence will also play a role in this decision. The interesting point about own production in any case is that in tendency these sources will become cheaper over time, because investment costs will go down and fuel costs are zero. Practically the price for one kWh is established and fixed when the investment is made; there are no price increases (or general inflation) during the operation, as it must be expected with any other input fuel like gas, oil or pellets.

Simplyfied key data for electricity prodution by a household					
System	Photovoltaic	Mini-Windmill	Pico-Hydropower		
typical capacity (kW)	2	2	5		
investment per kW installed (EUR)	4.500	2.500	8.000		
operating hours per year (h)	1.000	1.800	5.000		
production per year (kWh)	2.000	3.600	25.000		
lifetime (years)	20	15	35		
lifetime-production (kWh)	40.000	54.000	875.000		
investment / kWh produced (ct/kWh)	22,5	9,3	4,6	w/o operating & finance	
Energy required for heating					
type of house	insulated	low energy	Passive House		
consumption kWh/m² and year	120	50	25		
size m²	130	130	130		
energy required for heating kwh/a	15600	6500	3250		
equals production of (kW installed)					
Photovoltaics	15,6	6,5	3,3		
Mini-windmill	8,7	3,6	1,8		
Pico-hydropower	3,1	1,3	0,7		
investment into power supply					
Photovoltaics	70.200	29.250	14.625		
Mini-windmill	21.667	9.028	4.514		
Pico-hydropower	15.600	6.500	3.250		
Electricity from the grid					
typical price EUR including VAT (ct / kWh)	18,0				
excluding VAT to compare to own productior	15,0				
of this price for transmission (ct/kWh)	7,5	should theoretically be independent of energy price			
price of the product (kWh) itself (ct/kWh)	7,5	follows closely oil/gas price			
Energy price inflation					
assumed rate of inflation for energy p.a.	2%	3%	4%	5%	8%
price today	15,0	15,0	15,0	15,0	15,0
price in 10 years	18,3	20,2	22,2	24,4	32,4
price in 15 years	20,2	23,4	27,0	31,2	47,6
price in 20 years	22,3	27,1	32,9	39,8	69,9

Summing up the consequences for electric heating with Flexiwarm it can be said that the option to produce own electricity in general is getting more and more attractive for the people who can afford the initial investment into photovoltaic, mini-windmills or who have the option to use hydropower directly on their land.

The operating strategies range from selling the power under a regulated feed-in tariff, to replace power from the grid with home production whenever there is supply of wind or sun. Storing the energy for later use will always be more expensive, but technically it is feasible. It can make sense for people who accept higher cost for the independence.

Energetically it can be argued that the sum of power produced covers a part or all of the electric power used for heating. In this case the electric heating is emissions free and carbon neutral and therefore perfectly in line with the requirements for a sustainable heating system.

6 Operating scenarios for Flexiwarm

To give a clearer picture for situations where Flexiwarm can help to improve the environmental impact of heating, please find four scenarios. The scenarios are based on a climate and heating degree days as they are found in Central and Western Europe, but can of course be adapted to other climates as well.

6.1 Flexiwarm A: Heating system with fuel contract for renewable power

Under this scenario a new home is built according to modern insulation standards. The heating required is 50 kWh/m² and year. The house has a size of 120 m², so the heating requires 6.000 kWh per year. The heating central, pipes and radiators for oil- or gas-fired systems cost about 15.000 EUR. The other options like pellets heating and electric heat pump carry prices of 18.000 to 22.000 EUR. Instead of this Flexiwarm is installed as a ceiling heating for about 7.000 EUR.

Flexiwarm arranges a contract between the homeowner and a producer of renewable power. The electricity is 100% emissions free and is produced from run-of-the river hydropower and wind power and costs 18 ct/kWh including taxes.

The price for natural gas as alternative would be 7 ct / kWh. The heating costs would be 660 EUR higher with gas, but about 200-300 EUR of the difference would be offset by savings for inspection and maintenance and savings on electric pumps etc. So the real cost difference is a trade-off with savings of 7-8.000 EUR in the investment versus additional fuel costs of 360-460 EUR per year. The calculation is not entirely correct: the heating central will need replacement after 15-20 years, whereas Flexiwarm will run for 30 or more years. This means an additional savings of 7-9.000 EUR at current prices in the coming 15-20 years (piping and radiators don't need replacement normally, only the heating central and controls.)

This is a typical scenario that shows that emissions free heating can be achieved with Flexiwarm, saving money for the homeowner in the long run and – more importantly - cutting investment cost at the time of building or renovation, when funds are most scarce.

6.2 Flexiwarm B: home-grown electricity

This is a scenario that is based on a weekend and holiday home inherited from the grandparents, somewhere in the countryside. It is surrounded by fields and has a large garden.

The old heating is replaced with Flexiwarm heating in walls and ceilings. Since the bathrooms are completely renewed, they get an underfloor heating with Flexiwarm.

Due to the open space outside there is enough wind to put up a small wind turbine of 2,5 kW capacity.

The house has 100 m² and is mostly built from wood. It is occupied only on weekends and in summer, so the heating is limited to 25% of the annual need. The energy consumption for a full year would be 80 kWh/m². This gives a consumption of about 2000 kWh per year.

The wind turbine produces about 4000-4500 kWh per year which is fed into the grid at a price of 8 ct/kWh. The power for the electric heating is taken from the grid at a price of 15 ct/kWh. It means that twice the consumption of energy for the heating is produced, resulting in a surplus of green energy. Due to the difference in price paid/credited there is only a small surplus in the energy bill. Virtually there are no energy costs for the heating.

The cost of Flexiwarm heating plus the investment for the mini-windmill comes to around 11-13.000,- EUR. This is less than a conventional heating system would cost.

6.3 Flexiwarm C: zoning rooms and buildings vs. full insulation

This scenario shows the way to use Flexiwarm for heating only parts of a building and to deliver the heat exactly where it is needed. The parents live in a large old flat in a historic building in a city. The children who occupied three of the four sleeping rooms are grown up. Sometimes they come for a visit and stay overnight, but most of the time two people live on 180 m², using only about 100 m² of it permanently.

The problem of the house is that there is no good insulation on the outside, because the house is protected as historic building. The four sleeping rooms are especially problematic in heating. They could only be insulated on the inside of the building, reducing the space and making changes of built-in furniture necessary.

When the old heating central has to be replaced, Flexiwarm comes in. It is integrated in the ceiling and on the large free walls in the living room. From then on only the permanently occupied rooms are heated, reducing the space to be heated from 180 to 100 m². The walls and doors to the three guest rooms are insulated a bit to reduce energy losses to them.

When children come to visit one, two or three bedrooms are heated up within a few hours and just for the duration of the visit.

The investment is much lower than a new heating central, the expenses and hassle of an internal insulation of the sleeping rooms is saved. A heating central would have to be dimensioned to 180 m² to have it warm also for Christmas, when all children are home. But for most of the time it would run much below capacity at a dramatically lower efficiency.

The money that was saved compared to buying a new heating central is invested in the stock of a wind farm. For every Euro invested in these shares the wind park produces 4 kWh in power per year. Since Flexiwarm saved the family 8.000,- EUR in investments the shares produce 32.000 kWh in electric power per year. This is more than the flat needs for heating and electricity together.

6.4 Flexiwarm D: Bypass heating central / district heating for low demand times

A number of houses and flats share one district heating system. The system runs on wood chips and everybody is happy about replacing fossil fuel. The cost of the district heating is more or less the same as with individual heating centrals for each household.

After the first few years, costs of the district heating go up and up, mostly because there is always as discussion on when to switch in on. There are always some households that are too cold whereas there are always households that would prefer to save the heating, because they are away most of the week or because they simply have a better insulation.

The problem that results is that any compromise technically leads to the district heating running far away from the optimum operation condition at partial load, increasing costs and fuel consumption that must be shared between the users.

Solutions like installing a range of smaller boilers that can be added are discussed, but the solution comes in a much cheaper form with Flexiwarm heating. Additional ceiling heating elements are offered to the users to buy in a combined purchase contract. Anybody interested can sign up for as much as he desires, he pays for the investment and also pays for the electricity to operate it.

The operation of the district heating is limited to the common consensus that covers 75% to 85% of the heating load over the year. The remaining needs are covered by Flexiwarm as an additional heating system that comes into action whenever a household feels it wants a bit more heating. This is especially during the transition time in spring and autumn, but also on cold summer evenings. The quarrels between the flats in the middle of the block (always too hot) and on the windy top (always too cold) are over and the people with the well insulated houses hardly need the electric heating, whereas the people with the houses with building code insulation only have to decide if they improve the insulation or if they accept a slightly higher energy bill for their comfort.

The inefficient operation of a district heating is eliminated, emissions from it are down, the lifetime is extended and the investment for smaller heating units in the district heating is avoided.

The money that is saved is used to install some photovoltaic panels on the building of the district heating plant that produce clean and silent electric power that is fed into the electric grid under a favourable renewable energy law.

The households that decide to install a ceiling heating panel get the power supply for future LED-based lighting integrated and without other transformers, so they are first to adopt these high-efficiency lighting systems.

On the Author:

Beck & Partner KG is an independent business consulting firm. They provide management and coordination services for renewable energy projects and innovation management. Key activity is to match ideas, innovation and technology with the business and financing world.
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