®ISOMAX PassivHaus Technologies basic calculations

12 kWh / (m^2 * a)

Dipl.-Ing., Phys. Edmond D. Krecké

October 2010

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INTRODUCTION

At the moment, around 46% of the energy available to us globally is being used to air-condition existing buildings across the world. A large percentage of this energy is literally wasted and could be saved by implementing a few simple technological measures!

No matter where in the world, we all have at our disposal in summer and winter an endless supply of environmentally friendly and free ground source heat for use in conjunction with solar heat, and potential for using ground-cooling systems in conjunction with solar energy for cooling.

Dipl.-Ing., Phys. Edmond D. Krecké has scientifically researched and developed, tested and successfully trialled the practical application of using this inexhaustible supply of energy to air-condition buildings (heating, cooling, ventilation and supplying air, as well as for heating water) for over 30 years in buildings in all of the world's climatic zones – both for new builds and in the thermal modernisation of buildings all across the world.

®ISOMAX-®TERRASOL buildings have now been built under license as PassivHaus' with 8 – 12 kWh/($m^2 * a$) or even as zero energy buildings for many years in countless countries across the world. This clearly demonstrates that it is both technically and economically feasible to save energy even on large scales as a means of making a fundamental contribution to environmental protection and energy conservation.

Modernising the heating/cooling systems and thermal requirements (i.e. for **etm** – ***e****nergy and* ***t****hermal* ***m****odernisation*) of our buildings, e.g. using internationally proven ®Isomax technologies, i.e. through the **combined use of ground and solar energy**, as well as efficient thermal insulation, could have a rapid and huge impact over the next 10 – 12 years on the vast amounts of fossil fuels wasted each year on temperature regulation and is a cost-effective and environmentally friendly way of substituting these fuels.

Ground and solar energy are vast and inexhaustible sources of energy that are also the most economic and environmentally friendly kind of energy around for air-conditioning buildings across the world.

“The best kind of energy is the kind we do not need.”

“Saying that we want to protect the environment simply isn’t enough – it’s the doing and all of us doing it together that counts!”

(Quotes: E.D. KRECKÉ)

CONTENTS

I ® ISOMAX Climate zones

The following ®ISOMAX climate zone specifications are simply designed to make it easier to design and calculate the pipe and tube lengths as specified in section VI. They are intended as a reference for rough etm estimates. These climate zones can be used by approved engineering firms to calculate energy needs on the basis of indoor temperatures of +20°C.

®ISOMAX CLIMATE ZONE I - Delta-T **10**

- Summer temperatures max. +28°C
- Winter temperatures min. +10°C

®ISOMAX CLIMATE ZONE II - Delta-T **20**

- Summer temperatures max. + 36°C
- Winter temperatures min. +/- 0°C

®ISOMAX CLIMATE ZONE III - Delta-T **30**

- Summer temperatures max. +40°C
- Winter temperatures min. -10°C

®ISOMAX CLIMATE ZONE IV - Delta-T **40**

- Summer temperatures max. + 46°C
- Winter temperatures min. – 20°C

®ISOMAX CLIMATE ZONE V - Delta-T **50**

- Summer temperatures max. +56°C
- Winter temperatures max. -35°C

Fig. 1-3: ISOMAX buildings in climate zones I, III and V

II ® ISOMAX Ground heat storage system

The ® ISOMAX Ground heat storage system – which is installed into open ground* - has successfully proven itself as a heat/cooling energy buffer storage system for air-conditioning buildings for many years across the globe. The ® ISOMAX Ground heat storage system comprises

- a core heat storage system for preheating hot water,
- a heat or heating energy storage system and
- a cooling energy storage system.

In Germany, for example, solar radiation provides approx. 1,100 kWh/m^2 annually. In order to be able to use this valuable free energy, including on less sunny winter days, we use our economical, natural and decentralised, fully insulated ®ISOMAX heat storage system, which is open on the bottom. This storage system stores the collected solar and geothermal heat (see section V – ISOMAX Roof/wall-integrated thermal solar absorber) economically, in an environmentally friendly, decentralised and extremely simple way underneath or in the surroundings of the building. A separate roof-integrated thermal solar absorber circuit on the south side of the building furthermore contributes to meeting seasonal energy demands during the summer as well as winter. This is because the collected solar heat is stored in the ground in separate PP storage systems and accessed – both during the winter and summer – as needed (see section III - ® ISOMAX Temperature barriers). This storage system furthermore also uses recovered heat to ventilate buildings (see section V ® ISOMAX Pipe-in-Pipe counterflow ventilation system). Another great advantage of this system is the free, inexhaustible energy added to the system in the form of geothermal energy.

The ® ISOMAX Ground heat storage system furthermore includes an additional, fully insulated core storage system for preheating hot water. A system such as this is a fundamental requirement for a PassivHaus. The recommended size of this storage system is approx. 15 m^3/person in the household.

Fig. 4: Construction of an ® ISOMAX core storage system

*(Unsuitable for installation in ground through which ground water flows)

The various integrated PP storage circuits activate a small circulation pump by means of a temperature differential controller, as a result of which solar heat is then fed into the system and distributed to areas with different temperatures ranges through selectively actuating thermostat valves.

Due to variations in ground quality, local variations in the ground's moisture content, its consistency, the variations in additional geothermal heat gain and numerous other indeterminable parameters, it is rather difficult to record the exact ground storage capacity and cyclical charging and discharging processes of the storage system. This is why it is vital to define a representative uniform minimum capacity standard that can be applied internationally in all climate zones to assess ground storage capacity volumes.

One such standard is the storage capacity standard of 1 kW/m^3, which has now been used successfully for many years.

If no solar heat is collected, the initial temperature in the cooling energy storage system will be +9℃ - +11℃ and approx. +12℃ - +13℃ (in climate zone II and III) in the heat storage system underneath a building.

Fig. 5: Construction of an ® ISOMAX cooling energy storage system

Following the first successful solar energy harvest over a season, the initial temperatures in the cooling energy storage system will generally be around +13℃ – +15℃ and already as high as approx. +17°- +22℃ in the heat storage system.

According to VDI 2067, an approx. 280 m^2-large 4-person household normally requires around 3,736 kWh/a of heating energy.

VDI 2067 also specifies internal energy gain as being approx. 2,500 kWh/a. This means that a house this size and housing 4 people would be adequately served with a storage system of 300 – 500 m^3, as it would also collect additional usable solar energy on less sunny winter days and would be continuously gaining geothermal energy.

Fig. 6: Construction of the ® ISOMAX heat storage system

III ®ISOMAX Temperature barriers

Over years of scientific research, an energy-saving, so-called temperature barrier for extremely slim exterior walls and roofs has been developed as a means to counteract the continuous international explosion of energy prices, the increasing global demand for energy and associated catastrophic global environmental problems. This system has now been successfully used to air-condition buildings for years in all climate zones.

®ISOMAX Temperature barriers work as follows: ®ISOMAX external walls or the walls of existing buildings are vertically fitted with (preferably) PP-20/2 pipes in a meandering pattern at - depending on the energy calculations - a distance of 10-25 cm to each other and connected to the heating or cooling circuit system pipes with a small sensor-controlled circulation pump, and it is this assembly that subsequently forms the ®ISOMAX temperature barrier system.

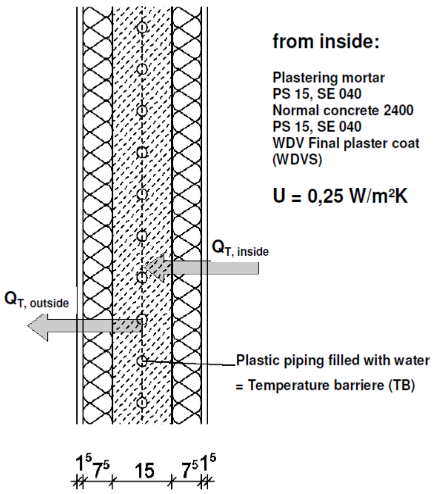

Fig. 7: Schematic diagram of an ®ISOMAX temperature barrier
The heat that flows from the interior to the temperature barriers is

$$Q_{Ti} = 2\ U\ (t_i - t_B)$$

and the heat that flows from the temperature barrier to the outside

$$Q_{Ta} = 2\ U\ (t_B - t_a).$$

The quantity of heat Q_{Ti} is furthermore supplied with a heat quantity Q_S from the ground storage system. This heat can be expressed as

(*) $$Q_{Ti} + Q_S = Q_{Ta}\ ,$$

i.e. energy lost from the interior of the building equals heat quantity Q_{Ta} minus the energy Q_S, which is fed to the temperature barrier from the storage system (which does not involve any costs and is environment neutral).

(**) $$Q_{Ti} = Q_{Ta} - Q_S\ .$$

Considering the example of Fig. 7, we have for the inner part of the wall and with inner temperature t_i = 20℃ and temperature of temperature t_B = 16℃ a heat flows Q_{Ti} = 2 W/m². We define now for the complete wall an **effective U-value U_{eff}** for the outer temperature t_a = -16℃: In that way we have

$$Q = U_{eff} * \Delta t \quad \text{or}$$

$$\mathbf{U_{eff}} = Q\ /\ \Delta t\text{, i.e. } U_{eff} = 2\ /\ (20-(-16))\ W/m^2K = \mathbf{0{,}0555\ W/m^2K.}$$

Fig. 8: Structure of an ® ISOMAX wall element with temperature barrier

When needed, a small interposed sensor-controlled circulation pump will transport the ground source (geothermal) energy or cooling energy Q_S of the heat and cooling energy storage system to the water/glycol-filled PP pipes inside the temperature barriers of the external walls and/or roof in the form of waste energy.

During the first year of operation in climate zones II and III, the ground temperature of the ISOMAX ground storage system will be around +9°C - +11℃. This means that the external walls and roof can already be as warm as +7℃ - +9℃. This, in turn, results in an excellent Delta-T at outside temperatures of below 0℃ during the first year of operation - without taking into account any solar heat that may also be fed into the system.

During the following years of operation, the ground storage system will achieve optimal performance and undergo a significant gain in temperatures due to the infeed of solar heat during sunny days, while simultaneously cooling the temperature barrier. This means that the ground source heat storage system's temperature will have increased due to the solar energy and is then able to supply the temperature barrier with heat of up to +20℃! Assuming that indoor temperatures are +20℃, this consequently results in an extremely positive Delta-T for winter operation.

The ®ISOMAX temperature barrier inside external walls and the roof guarantees environmentally friendly, economic, comfortable and healthy living due to the even temperatures of a building's external north- and south-facing walls. In the ®ISOMAX climate zones IV, V and higher, the temperature barrier pipes are laid in the centre of the roof insulation using levelling compound. In these climate zones, it is advisable to fit the external walls with additional solar absorbers, which will also have the potential to simultaneously act as a 2nd temperature barrier.

During the winter, the ground itself, in combination with solar energy, will provide all the energy we could possibly need. During the summer, on the other hand, we can then – thanks to the ®ISOMAX technologies - furthermore use this 'waste heat' to comfortably and cost-efficiently cool our buildings.

®ISOMAX temperature barriers are being used in all climate zones, all international conventional construction systems and in the modernisation of the thermal and energy systems of existing buildings worldwide.

One of our greatest priorities today is to update the thermal and energy systems of those kinds of existing buildings worldwide that consume up to 300 – 400 kWh/(m^2*a) for heating purposes and as much as 5,000 – 7,000 kWh/(m^2*a) for cooling purposes, as these are some of our biggest energy wasters and at the same time create some of the greatest environmental pollution problems. In this age, these kinds of buildings are an extremely negative and sad indictment of our towns and cities and a failure of our civilisation. Following the successful modernisation of their thermal and energy systems and simultaneous refurbishment of their façades, these dismal city districts tend to experience a renewal of life, a return of colour, as well as a significant increase in their commercial value!

Fig. 7: PP pipes of the ®ISOMAX temperature barrier

®ISOMAX temperature barriers will not only generate enormous energy savings through the use of environmentally friendly and sustainable energies if introduced worldwide, but are also extremely cost-effective for those wishing to fit them themselves DIY-style.

This is because all rigid-foam formwork element manufacturers internationally, such as ®ISORAST, ®Magu, ®Quadlock, etc., all prefabricated house manufacturers, concrete wall and roof framework producers can, in the interest of their customers and the environment, take advantage of product-based, exclusive ®ISOMAX know-how agreements. These manufacturers or retailers are subsequently able to offer their customers hugely improved quality products and even meet PassivHaus standards.

The PP 20/2 pipes of the temperature barriers have to be laid as separate segments for each room and regulated by a thermostatic valve to enable the temperatures of individual rooms to be regulated separately.

When modernising thermal and heating systems in existing buildings, the walls are then coated with a levelling render and, depending on the energy calculations and climate zone, fitted with 7.5-15 cm, fibre-reinforced Neopor insulation covered with textured plaster or scratched render, flat facing bricks or similar. The energy calculations for the temperature barriers are performed similarly to those for underfloor heating.

Among other things, the ®ISOMAX temperature barrier, wall temperature control system will do the following:

- Control the climate during the summer months by both conducting solar heat away and storing excess solar energy.

- Compensate for transmission heat losses during the winter months by heating the walls with the stored solar heat and near-surface geothermal gains.

- Prevent the formation of dew points in high-risk areas of the building.

- Keep areas with rising damp and structural parts that are in contact with the ground dry and protect against condensation

- Can be used to control the temperature in listed buildings and will simultaneously thermally dry out masonry by eliminating the thermal dipole effect of the water vapour molecules in structural parts.

- During the summer, cools the larger external walls with the energy in the cooling energy storage system and, in the winter, supplies heat to the external walls from the heat storage system.

- Makes the external walls' interior surface temperature nearly identical to the room temperature.

- Temperature barriers with temperatures that are lower than room temperatures can regulate the climate inside buildings and adjust room temperature to the set temperature.

- All ISOMAX solar absorbers are filled with antifreeze.

- The low temperature heat storage system's capacity can be increased by filling it with sodium hydrogen phosphate or similar.

- The PP-20/2 pipes in the heating/cooling systems can, where necessary, also be encased in various substances such as hydrophilic chemicals, salts or metal shavings inside the surrounding ground to improve heat transfer.

These properties make ®ISOMAX temperature barriers highly superior
to other thermal control systems, such as concrete internal ceilings activated for cooling, the use of cooling ceilings, etc., both in terms of energy efficiency and cost-effectiveness.

IV ® ISOMAX Roof and wall-integrated thermal solar absorber

In an ISOMAX roof-integrated thermal solar absorber, the space between the roof cladding and roof insulation is likewise fitted with PP-20/2 pipes in a meandering pattern at a distance of max. 30 cm. To increase the absorbers' efficiency, several strands of pipe can also be fitted together at this distance.
®ISOMAX roof-integrated thermal solar absorbers can, depending on the number of strands of pipe installed, collect up to 250 kWh/m^2 of solar energy a year. Over the entire space of a roof, this is an astonishingly high yield of free and environmentally friendly energy gained from a huge and infinite source.

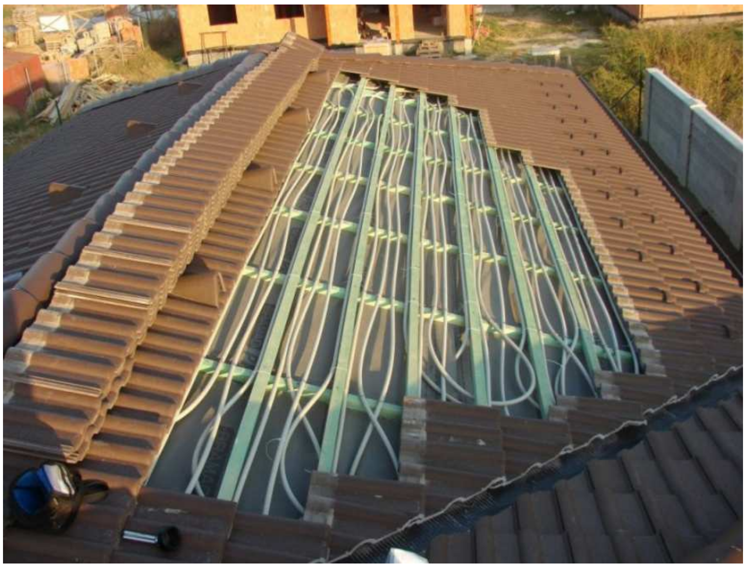

Fig. 8: PP pipes of the ®ISOMAX roof-integrated thermal solar absorber

V - ® ISOMAX Pipe-in-pipe counterflow ventilation system

For optimum energy efficiency, the ®ISOMAX temperature barrier for exterior building shells can furthermore be complemented with the ®ISOMAX ventilation system.

This system comprises a coaxial stainless steel pipe with a corresponding external and internal pipe diameter and enables fresh air to be fed into a building through the external pipe, and waste air to be transported out of the building through the internal pipe.

The approx. 50 – 60 m long coaxial pipe is ‘coiled’ on the construction site and, depending on the climate zone, up to 40 – 60% of it installed in the heat storage system and up to 40 – 60% of it installed in the cooling energy storage system. This coaxial heat exchanger system has a warm air recovery effectiveness rating of over 96%.

Fig. 9: Laying ® ISOMAX Pipe-in-Pipe air heat exchangers

Due to the fact that the supply air absorbs geothermal energy – heat/cooling energy – whilst in the external pipe, the system benefits from additional energy gains and thus provides ®ISOMAX - ®TERRASOL buildings with yet more free energy. The high level of heat recovered by the coaxial air exchanger means that the heat inside the heat storage system will only be discharged at a very slow rate.

The fresh air supply requirements for buildings must be calculated on the basis of the relevant applicable national guidelines. However, in order to optimise fresh air supply and ensure that the amount of fresh air is reasonable in terms of energy, this calculation should be based on the minimum amount of air per person/hour rather than the building's volume and relevant specified air exchange rate. In ®ISOMAX Comfort buildings, this minimum air quantity should therefore be several times higher than that specified by the guidelines. Thanks to the ®ISOMAX coaxial technology, this ventilation system only loses very small amounts of energy compared to other systems. In order to avoid the noises generally produced by ventilation systems, we recommend using air speeds of no more than 1.5 m/s. This air speed will thus also form the basis for determining the two pipes' diameters.

The basic structure of any building that is temporarily out of use will be adequately ventilated with approx. 0.4 – 0.6 m/s of fresh air.
Empirical data show that, if supplying fresh air at a rate of 1.5 m/s, the ventilation system will – depending on the supply air's temperature, require approx. 4 linear metres of pipe-in-pipe for Delta T = 1.

Fig. 10: ®ISOMAX Pipe-in-Pipe summer/winter air heat exchanger.
Existing ®ISOMAX buildings have to-date made successful use of a so-called winter/summer diversion device, which comprises 3 sections. This system works as follows: during the summer, the warm supply air is fed into section I of the diversion device through the external pipe. From there, it is fed through the hot air system underneath the building, where it will give off heat to the ground, and then make its way to section II of the diversion device, where it will then discharge the remainder of its heat through the cooling circuit, to then supply the ®ISOMAX building with cooled fresh air through a distributor after travelling through section III of the diversion device.

The diversion device's winter/summer setting for the supply/waste air is changed by a thermostat-controlled servomotor.

During the winter, the cold supply air is fed into section I of the diversion device through the external pipe, from where it is fed into section II through the cooling energy circuit to be pre-heated.

The supply air – which will now have been pre-heated – will then be fed into section III of the diversion device through the heating system, and then into the ISOMAX building through the distributor. Due to the negative pressure inside the ventilation system, the waste air is fed through the internal pipe in the opposite direction, through separate diversion chambers, and discharged after it has transferred its heat/cooling energy to the fresh supply air.

In the future, the **alternative I** to this system i.e. a simpler alternative ventilation concept, will be to use a pipe-in-pipe system without a winter/summer diversion device. Depending on the climate zone, 40-60% of the total length of the pipe used in the ventilation system is used for the heating system and 40-60 % as the cooling circuit. The supply air is always primarily fed through – depending on the climate zone - either the heating or cooling circuit both during the winter and summer and then into the building through the distributor.

Years of experience have shown that the heat ground storage systems underneath ®ISOMAX buildings can reach maximum temperatures of +26℃ if also equipped with peripheral insulation.
This means that – depending on the climate zone - cooling circuit temperatures of approx. +9℃ - +11℃ and heating circuit temperatures of +2 2℃ provide ample energy to cost-effectively air-condition a building.

The stainless steel pipe-in-pipe counterflow ventilation system's fresh air supply section can be equipped with a range of different quality filters. In general, it is recommended to use an exhauster and – infinitely variable – ventilator with a total of 140 W (WE 140 m^2), so as to create a small amount of negative pressure. The negative pressure in the building can also be used for a burglary protection system.

It is furthermore also possible to harvest water from condensation in the pipe-in-pipe system by increasing part of the external fresh air pipe's cross section.

Using pipe-heating registers for each fresh air supply outlet in individual rooms can generate a realistic impression of the room being fitted with heaters for "unbelieving customers". Pipe heating registers might also be temporarily necessary on first heating a building if the building was completed without a first season's solar heat having been fed into the heat storage system. Pipe heating registers could also be made use of on days during which outdoor temperatures are extremely low. Energy consumption will, irrespective of the potential temporary use of the pipe heating registers, always be expressed as an annual average.

If it is not possible to install a ground storage system for geometric or structural reasons, it is possible to use a cyclically stable salt hydrate stored in flat cases as a latent heat storage system. Please see www.rubitherm.com for more information. This will effectively increase the system's specific heat storage capacity for each m^3.

VI - ®ISOMAX – Example pipe and tube lengths for 100 m^2/WE

- empirically established from a large number of ®ISOMAX buildings-

The lengths of the relevant PP/20/2 pipes for the

a) Cooling circuits
b) Heating circuits
c) Temperature barriers
d) Roof-integrated thermal solar absorbers
e) Wall-integrated thermal solar absorbers (only for climate zones IV, V and higher) are installed in linear metres in correspondence with m^2- of indoor space x climate zone.

Example for climate zone II: 100-m living/office space

200 linear metres PP cooling circuit pipes (60 – 40% in the cooling/heating circuit)
200 linear metres PP heating circuit pipes (40 – 60% in the heating/cooling circuit)
200 linear metres PP temperature barrier pipes
200 linear metres PP roof-integrated thermal solar absorber pipes

The lengths of the pipe-in-pipe pipes are also determined by m^2 of living space x climate zone and are laid in 0.15 m sections.
Depending on the energy calculation and heating or cooling requirements, approx. 40 – 60% of these are laid in the heating and approx. 40 – 60% in the cooling circuit. For large, compact buildings with more than 300 m of living/office space, these pipe lengths may – depending on the energy calculations - be less.

If energy requirements are calculated and the pipes are installed carefully, and the basic structure of the building complies with the regulations, the ®ISOMAX pipe-in-pipe counterflow system should be sufficient for all air-conditioning needs (heating, cooling, ventilation) in climate zone I without the use of any other ®ISOMAX technologies.

This means, for example, that a building with 100 m^2 living or office space, an approx. volume of 280 m^3 and an air exchange rate of 0.5 m/s will need a 30 m long external supply air pipe with a diameter of 250 mm and a 30 m long internal waste air pipe with a diameter of 170 mm. Air speed should be no greater than 1.5 m/s.

The above, extremely cost-effective ®ISOMAX air-conditioning technology using the pipe-in-pipe system is suitable for use in most of the global climate zones (®ISOMAX-climate zone I), such as in parts of China, Europe, USA and Brazil, etc.

The following energy balance comparison of the Solar House III in Luxembourg, which has a living space of approx. 310 m^2, clearly demonstrates – even if in a highly simplified way - the efficiency of this approach.

1. Solar energy available 14,000 kWh/a
2. Stored energy 6,000 kWh/a
3. Heating energy requirement 3,900 kWh/a

This represents a cumulative annual energy gain in the ground storage system of approx. 15 – 20% despite the ground storage system's loss of energy along its sides. As temperatures increase over time, this gain will, however, slow down and stabilize.

Alternative II to the pipe-in-pipe system.

ISOMAX technologies provide yet another alternative for larger buildings – both new and existing ones. This alternative comprises replacing the entire stainless steel pipe-in-pipe ventilation system in the heating and cooling storage system with corresponding PP 20/2 pipes. The collected heat or cooling energy is then transported from these storage systems through standpipes to the **H**eat exchangers/**H**eat pump **U**nits (HHU) on every floor or in every flat. The necessary supply air/waste air collected through the roof is then fed into the flats to economically and efficiently ventilate them in an environmentally friendly way.

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