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Energy Requirements and Energy Intensity

1. Difference Between Energy Requirements and Energy Intensity

From an energy point of view, each heated structure (for instance, a family house) is characterized by both its energy requirements (*need for energy*) and its energy intensity (*energy consumption*). The **energy requirements** depend on the **amount of energy** a specific structure objectively needs to fulfill its function. The **energy intensity** is the factual **amount of purchased 'driving', or rather primary energy** that is consumed by **systems** (equipment) that cover the **energy requirements** in order to operate properly.

The energy intensity **has three relevant aspects**:

- **Energy** aspect – consumption of energy for the operation of flats (heating and other needs for heat) represents nearly 50 % of total energy consumption; most energy requirements are still covered by the consumption of fossil fuels;
- **Economic** aspect – energy intensity, or rather the consumption of purchased, 'driving' energy decides about the expenses necessary for ensuring the comfort of people in a house;
- **Ecologic** aspect – regardless of emission issues, the conservation of energy, or rather the general reduction of energy intensity is a necessary condition for sustainable development.

The energy intensity of s house can be positively influenced, or reduced – either directly by decreasing energy requirements (needs for energy) or indirectly by decreasing its energy intensity (energy consumption) – by choosing systems that purposefully and effectively economize with primary energy and with energy in general.

The following text will deal with issues regarding especially family houses. However, many of the presented conclusions apply in general.

Note: In this information material the term 'energy' means both a type of energy – in connection with a characterizing attribute (for instance, electric energy) – and, for the sake of simplicity, a source or a medium from which energy (in this context, mainly thermal energy) is obtained (for instance, natural gas, liquid propane, extra-light heating oil). This is why this same term is also used in the plural, which would be incorrect from the physics point of view.

The first and the most important **part of the energy requirements of a family house is the need for heat for heating** and ventilation. So far, the ventilation issues have been generally understood as a part of heating and therefore ventilation is not secured by an independent system. This also follows from the fact that the need for heat for heating is based on total heat waste and the **total heat waste of a building is determined as the sum of thermal passage waste and ventilation waste** ($Q_{total} = Q_{passage} + Q_{ventilation}$). Meanwhile, ventilation must ensure at least a minimal sanitation air exchange of 0.5 $hour^{-1}$, i.e. the air in a building must be exchanged at least once in two hours. With regard to a prevalent number of family houses it is assumed that ventilation will be secured in a natural way; i.e. by infiltration and exfiltration.

The other important part of the **energy requirements is the need for heat for the preparation of hot service water - HSW**.

Both the above-referenced energy requirement components are influenced by absolutely different factors. Nevertheless, their coverage must be resolved in an interconnected and complex manner. It is of special relevance when so-called economical systems are applied.

2. Energy Requirements of Heating and Ventilation

Basic facts regarding the energy requirements of heating and ventilation can be summarize as follows (see also figure 1):

- **Total thermal waste and energy requirements of heating and ventilation**, i.e. requirements for the need for heat necessary for both these functions are directly and quite unambiguously **determined by the architectural layout and construction manufacturing** as they define all parameters (except for the thermal ones) in the calculation of the total thermal waste. It applies: $Q_{total} = Q_{passage} + Q_{ventilation}$
- **Thermal passage waste** ($Q_{passage}$) is, in addition to decisive temperatures – internal and external calculation values (t_{iv}, t_{ev}) – and (medium) thermal resistance of building structures limiting a building of a specific built-up volume (V_o), **defined by the area of the limiting structures** (A_{total}).
- **Ventilation thermal loss** ($Q_{ventilation}$) is, in addition to decisive temperatures (t_{iv}, t_{ev}), clearly **defined by the built-up volume** (V_o) of the structure (more precisely, by its interior volume) and by sanitation requirements.
- Thermal waste due to passage through glass surfaces is 5 times greater than the waste in other peripheral structures.

From the energetic point of view, **each building can be characterized by:**

- **The energetic indicator of an architectural design;**
  Which can be expressed by the A_{total}/V_o ratio; whereas, the greater this ratio, the higher the energy requirements of the building;
- **The energetic indicator of construction manufacturing;**
  Which can be considered to be the medium value of the coefficient of heat passage in the entire building – the greater this value, the greater the energy requirements of the building.

With regard to the two components of the total thermal waste, the following applies: **In a building with a specific volume**:

- **Ventilation waste represents a constant value** that is absolutely independent of an architectural layout and construction manufacturing;
- **Thermal passage waste represents a rather variable value** that is pronouncedly dependent on an architectural layout and construction manufacturing.

All interrelated facts are clearly shown in figure 2 where two building of the same built-up volume are compared. The first building is ‘little’ articulated and has little glass areas, whereas the other is ‘amply’ articulated, and has a lot of glass areas. We assume that both building will display identical thermal-technical properties in all peripheral structures, i.e. identical coefficients of heat passage in all peripheral structures. Simply said, the buildings will be built of the same materials (of the same thickness).

Considering that a built-up volume (or more precisely an interior utilizable volume) basically characterizes the utilizable properties of the building, both compared buildings have the same utility properties.

Given the chosen articulation and fenestration, it become obvious that under the existing preconditions and at a certain mean value of heat passage coefficient, an amply ‘articulated’ and glazed building will feature nearly twice the thermal passage waste than a little ‘articulated’ and glazed building.

To sum up: **The more articulated and glazed building** of a specific built-up volume, **the greater** its total thermal waste and **energy requirements**. If we wished to reduce the requirements of an articulated building, we would have to choose a better thermal-technical solution. It is commonplace that both greater articulation and better thermal-technical manufacturing increases cost of acquisition.

Note: The glazing of a building that affects energy requirements must also be considered (or rather should be considered especially) when it is a part of such an architectural layout and construction manufacturing that secure so-called passive utilization of solar energy. The term 'passive utilization of solar energy' means the use of the greenhouse effect for the heating of specific interior structures by means of which the interiors of the building are heated. In these cases it is important to make sake that the energy benefits of the size of glazing be greater than the thermal waste effected by the glazing.

3. The Energy Intensity of Heating and Ventilation

Basic data regarding the energy intensity of heating and ventilation can be summarized as follows:

- **Energy intensity of heating and venting**, i.e. the real consumption of 'driving' energy (in J, MJ, kWh) that secures the function of technical equipment that satisfies these demands, is **defined by the T**echnical **E**quipment of **B**uildings (TEB).
- **In Standard** (classical) solutions used so far ventilation and passage waste is covered by a heating system. By analogy, standard solutions work with **classical heating systems**, i.e. systems in which produced heat is the same as the consumption of usable energy (i.e. energy reduced at a ratio of the system's efficiency), or in which heating output is identical with energy input. It applies to such systems that **energy intensity**, i.e. *consumption of energy* **is identical with energy requirements**, i.e. with *energy consumption* (see drawing 3a, 3b).
- **The reduction of energy intensity is possible** when non-standard (alternative), or **saving solutions** are applied. Their use is characterized with *consumption of paid energy required by a system* that is lower, quite often much lower than energy consumption covered by the system; **energy intensity is lower than energy requirements** (see drawings 3d, 3e).

  As a rule, saving solutions separate the coverage of thermal passage waste and ventilation waste and these **two functions of 'heating' are secured by independent systems**.

  Saving solutions are based on three fundamental principles:

  - ❑ A part of energy requirements is covered directly by natural heat usable at an acquired heating level. This is the case during the so-called active use of **solar energy** by means of solar collectors.
  - ❑ A part of energy requirements is covered by natural (or other low-potential) heat whose thermal level must be enhanced by a **heat pump** for its better utilization.
  - ❑ A part of energy requirements is covered by the use of so-called waste heat; i.e. heat that is otherwise released into the environs without being used. This utilization is secured by the **regeneration of waste heat**.

  Note: The above-referenced passive use of solar energy is not ranked directly among the economical solutions of TEB systems because it is achieved by means of the architectural layout and construction manufacturing of a building, not by the TEB system (see drawing 3c). However, the TEB systems can secure the transfer of the so obtained heat obtained in a building. The transfer is completed either in a standard manner, for instance, by forced air circulation, or in an alternative way, for instance, by transferring heat from a sun-exposed area to a reversed area by a heat pump.

Energy requirements (resulting from a respective building) and the choice of the design of systems (**T**echnical **E**quipment of **B**uildings) covering such requirements are determined by marginal conditions for the dimensioning of those systems. The dimensioning defines the outputs of these systems (W, kW). Need for heat for heating and ventilation, i.e. the energy requirements of a building and the consumption of energy for heating and ventilation, i.e. the energy intensity of systems covering respective demands during heating seasons (in J, MJ, and kWh) can be determined on the basis of energy balance. The balance must follow from the course of outside temperatures during a heating season. In order to create an economical solution with a heat pump, the course of temperatures must be described in terms of a frequency curve of outside temperatures throughout the year. If the same is described only in terms of average monthly temperatures or even the average temperature of a heating season, the results of the balance will not be objective. As a result, an economical solution will appear more advantageous as the balance will not cover the period with the lowest outside temperatures.

4. Energy Requirements and Energy Intensity of Hot Service Water Preparation

Energy requirements for the preparation of hot service water (HSW) depend on the number of people living in a building as well as their hygienic habits and needs. Related issues are not discussed in detail in this informative brochure.

In order to reduce the energy requirements for the preparation of HSW, we can use all three above-mentioned principles of economical solutions.

5. Difference Between Standard and Economical Solutions of TEB Systems

The proper application of energy-saving, non-standard (alternative) solutions of TEB systems is conditional on the thorough understanding of their functions. Furthermore, it is necessary to understand the full **meaning** of the **terms** defined in the introduction:

- **Energy requirements of a building**
  (i.e. *need for energy*);
- **Energy intensity of the systems that cover such requirements**
  (i.e. *consumption of energy*, which means ‘purchased’, refined, ‘driving’ energy).

The meaning of these terms can be explained graphically by means of so-called Sankey diagrams (drawings 3 through 5). The diagrams display main energy flows at the source and intake of heat in different TEB systems (heating, ventilation, HSW preparation). The width of ‘energy flows’ marked as **S** is directly proportionate to energy intensity (***‘consumption’** of refined ‘driving’ energy*), the width of ‘energy flows’ marked as **P** is proportionate to energy requirements *(**‘need’** for thermal energy*). The different widths of the **S** flows and the identical widths of the **P** flows in equivalent solutions illustrate the varying energy requirements of compared solutions.

Furthermore, the diagrams indirectly define the **energy benefits** conveyed by individual energy-saving solutions. The benefits can be explained as follows:

- Either as **relative energy intensity** (resulting from the S / P ratio);
- Or as **relative energy saving** (resulting from the (P – S) / P ratio).

The relations implied in the diagrams generally correspond with the real benefits of individual energy-saving solutions.

It should be emphasized that a heat source and a heat consumption point, as well as the entire system comprising the heat source and the heat consumption point must meet the principle that the sum of inlet energy flows must be equal to the sum of outlet flows. If an outlet flow is not fully secured with refined, ‘purchased’ energy, the respective difference (‘energy deficit’) must be compensated for with another form of inlet energy – solar energy, natural (generally low-potential) heat or waste heat regeneration – i.e. with energies that are offered by generous nature for ‘free’.

It should also be added that the diagrams describe **all-year requirements of a building and the energy intensity of TEB systems**, i.e. the amount of energy (heat) expressed in kWh/year (MWh/year). They do not describe the output parameters (v kW) of the TEB systems as those parameters are variable and depend on a great number of external conditions.

In addition to the above-stated facts, the difference between TEB systems can be characterized as follows:

The standard solutions of TEB systems are characterized with an **outlet energy flow that is fully covered with refined,** 'purchased' **energy**.

The energy-saving solutions of TEB systems are characterized with an **outlet energy flow that displays** the above-referenced '**energy deficit',** as opposed to **the refined,** 'purchased' **energy**. The deficit must be compensated for with a specific method or with a combination of methods based on the three principles of energy-saving solutions.

6. Possible Ways to Reduce the Energy Intensity of Heating And Energy Intensity In General

The energy intensity of heating (and ventilation) and of the preparation of HSW can be reduced in the following main ways:

a) Regulation of a heating system, or, as the case may be, replacement of a heat source with a source with higher efficiency.
These measures can reduce energy intensity in terms of percents, not of tens of percents.
(see also drawing 3a).

b) **Reduction of need for heating**, or rather reduction of the direct thermal waste of a building; in newly built houses this is achieved through the appropriate architectural design and thermal-technical parameters of the building, utilizing the existing range of construction materials. In older buildings, the same is accomplished by their over-cladding and external insulation.

These measures can be extended with the above-mentioned passive use of solar energy (drawing 3c).

c) **Reduction of need for heat for ventilation**. Heat required for heating also includes heat for the ventilation of buildings; the smaller the heat waste in the peripheral structures of a building, the greater the share of heat needed for ventilation. The reduced need for heat for ventilation can be secured by substituting natural ventilation with controlled ventilation or forced ventilation connected with the sealing of windows and doors. Both these methods secure the harmonization of factual and realistically expected needs for ventilation and eliminate possible redundant ventilation through badly sealed windows and doors.

d) **Reduction of consumption of energy for heating** by using energy-saving (alternative) heating systems in which the consumption of 'driving' energy is lesser than the amount of generated heat, or rather the need for heat for heating.

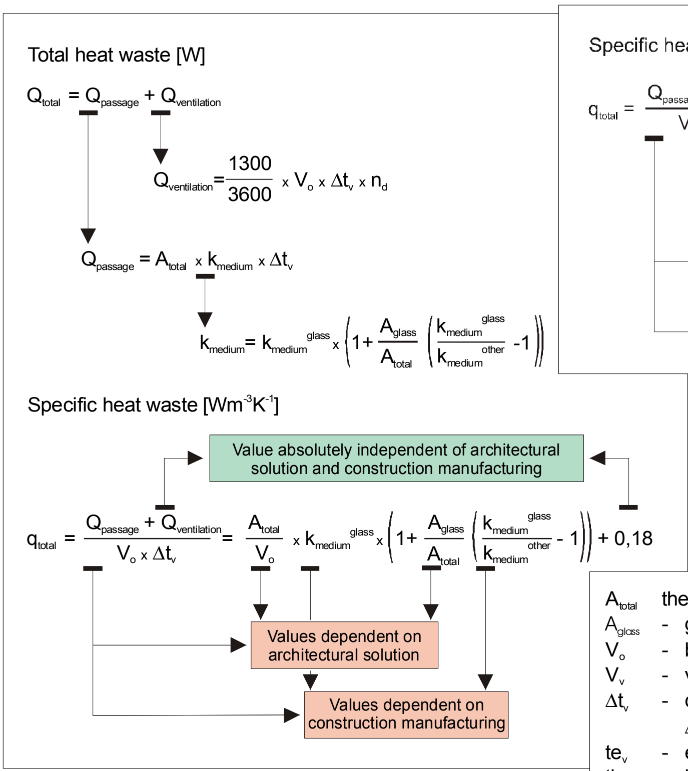
Such systems mainly include heating systems with a heat pump or with solar collectors (see drawings 3d and 3e).

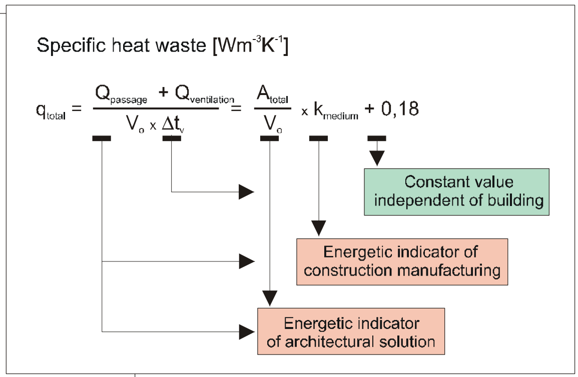
e) **Reduction of consumption of energy for ventilation** by using a ventilation system with heat recovery (HR), i.e. with recuperation, or rather with direct heat recuperation for ventilation purposes or for the preparation of HSW. A heat pump features a convenient option during heat regeneration (see drawings 4a, 4b, and 5).

f) **Reduction of consumption of energy for HSW preparation** by using an energy-saving system for HSW preparation utilizing solar energy, a heat pump (which is mainly convenient where a heat pump is use for heating), or the regeneration of waste heat (see drawing 5).

In each specific case it is advised to consider all feasible options. An optimal solution is the selected on the basis of detailed technical and economic calculations.

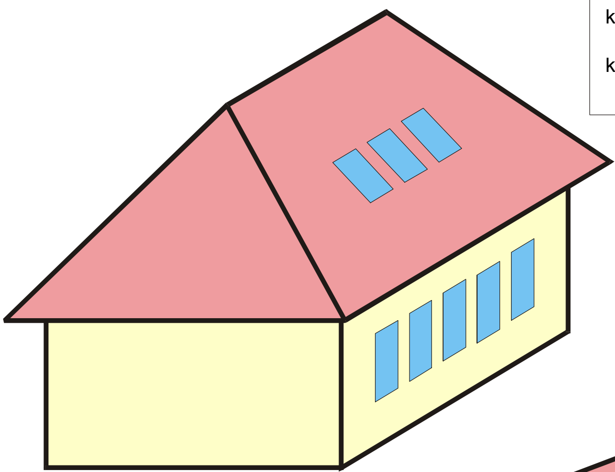
Finally, it should be noted that reducing the energy intensity of building is not accompanied with the equivalent reduction of cost of energy. This is partly due to the fact that energy prices include so-called fixed monthly fees, and partly due to the fact that in addition to monitored requirements a heated building and people living in it also have other, not negligible energy requirements (cooking, laundry washing, refrigerating and freezing, dishwashing, lighting, audiovisual technologies, etc.).





Drawing 1 Basic relations applied to the calculation of the heat waste of a building

A_{total}	the area defining a structure and its environs	[m^2]
A_{glass}	- glazing surface	[m^2]
V_o	- built-up area volume	[m^3]
V_v	- ventilated area volume	[m^3]
Δt_v	- calculated temperature difference $\Delta t_v = ti_v - te_v$	[K]
te_v	- exterior temperature used of calculation	[°C]
ti_v	- interior temperature used of calculation	[°C]
n_d	- air exchange frequency (sanitation requirement) $n_d = 0,5$	[hod^{-1}]
1300	- volumetric thermal capacity of ventilation air at a temperature of 0 °C - approx. 0,5 x ($te_v + ti_v$)	[Jm^{-3}K^{-1}]
k_{medium}	- medium coefficient of heat passage	[Wm^{-2}K^{-1}]
k_{medium}^{glass}	- medium coefficient of heat passage through glazed areas	[Wm^{-2}K^{-1}]
k_{medium}^{other}	- medium coefficient of heat passage trough other structures	[Wm^{-2}K^{-1}]

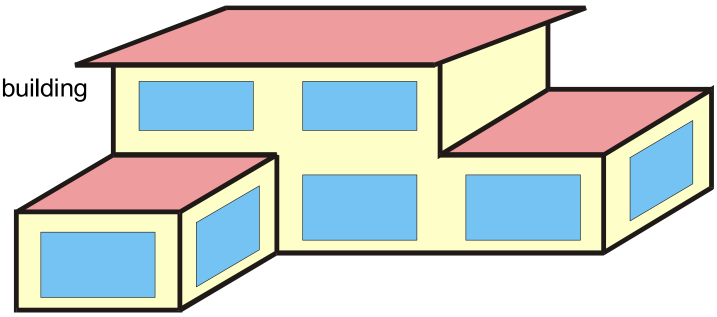


"Little" articulated and glazed building

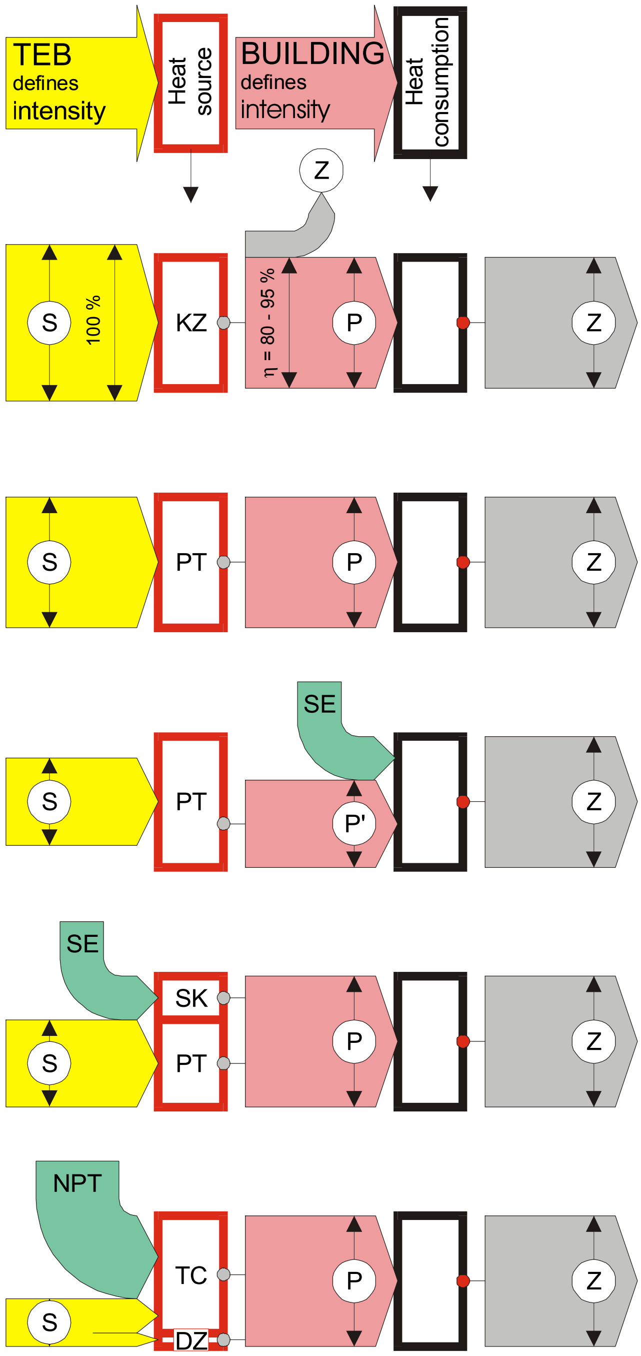
V_o	**=**	**100**	**%**
A_{total}/V_o	=	100	%
A_{glass}/A_{total}	=	10	%
$Q_{passage}$	**=**	**100**	**%**
k_{medium}^{glass}	=	100	%

"Amply" articulated and glazed building

V_o	**=**	**100**	**%**
A_{total}/V_o	=	150	%
A_{glass}/A_{total}	=	20	%
$Q_{passage}$	**=~**	**190**	**%**
k_{medium}^{glass}	=	100	%



Drawing 2 The effects of an architectural solution and construction manufacturing on thermal passage waste



a) Standard TZB design
Heat source = KZ
Standard source (KZ), i.e.
a boiler burning solid, liquid
and gaseous fuel,
characterized with efficiency η

b) Standard TZB design
Heat source = PT
Electrical heating panel using
cheaper electricity rates (PT)
Factual efficiency 100 %

c) Standard TZB design
Passive use of **S**olar **E**nergy
Heat source = PT
Electrical heating panel using
cheaper electricity rates (PT)

d) Economical TZB design
Active use of **S**olar **E**nergy (SE)
Heat source = PT + SK
Electrical heating panel using cheaper
electricity rates (PT) +Solar collectors
(SK)

e) Economical TZB design
Heat source = TC + DZ
Heat pump (TC) employing natural,
low-potential heat (NPT) + Bivalent
additional source (DZ)

Drawing 3 Difference between energy requirements and energy intensity

Solutions generally typical of heating (coverage of passage and ventilation caused waste)

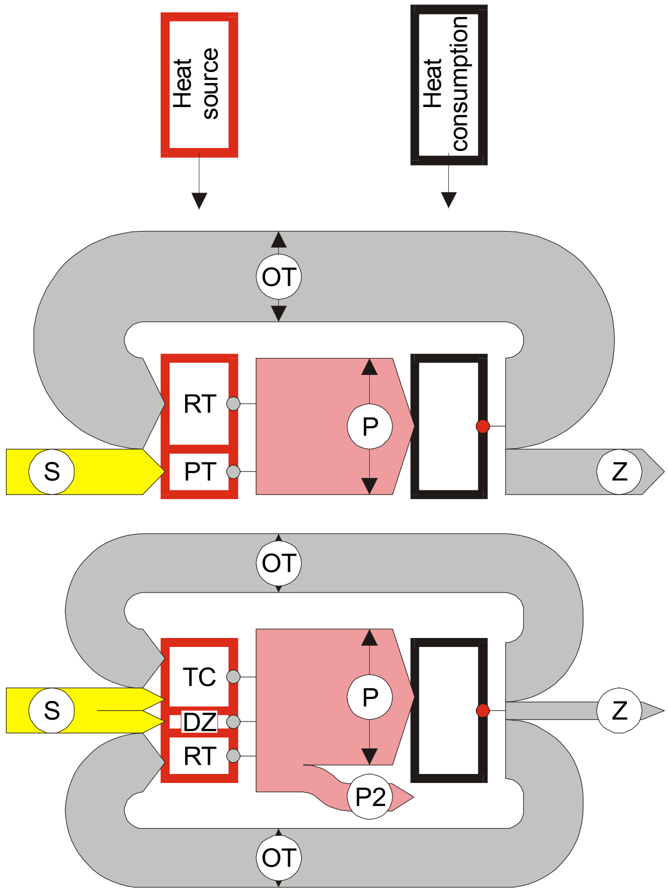
Heat consumption is represented by a heated building - Heat waste is represented by the heat that escapes in the environment due to passage and ventilation.

Solutions according to points a), b), d) and e) are also used during HSW preparation.
Heat consumption is represented by heated service water. - Heat waste is represented by the heat that is removed due to HSW consumption.

S - **Consumption** of refined, 'driving' energy = **Energy intensity**
P - **Consumption of** heat for required function = **Energy requirements**
Z - Energy **loss**: either at a heat source or at a heat consumption point

a) Economical ventilation solution
Heat source = RT + PT
Waste Heat Recuperation (RT) +
Electric Convector (PT)

b) Economical ventilation solution
Heat source = RT + Heat pump
Waste Heat Recuperation (RT) +
Bivalent Heat Pump
using Waste Heat (OT)
as Low-Potential Heat (NPT)



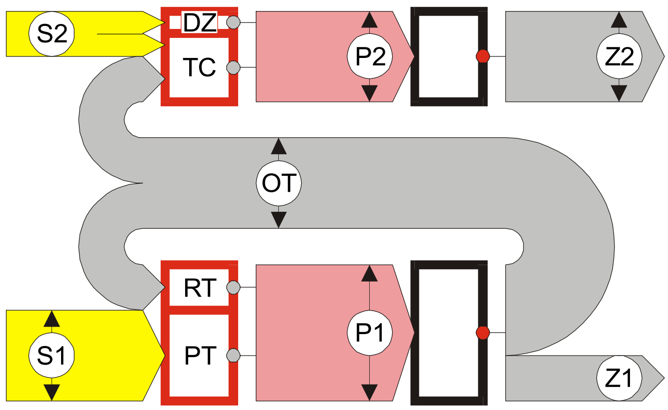
Drawing 4 Difference between energy requirements and energy intensity

Solutions typical of ventilation
Heat consumption is represented by a heated building - Heat waste is represented by the heat that escapes in the environment due to passage and ventilation.

Solution according to point b) displays 'surplus production' of heat (P2) usable for heating.

2) Economical solution of HSW preparation
Heat source = Heat pump + DZ
Bivalent Heat Pump (TC)
using Waste Heat (OT)
as Low-Potential Heat (NPT)
with and Auxiliary Source (DZ)

1) Economical ventilation solution
Heat source = RT + PT
Waste Heat Recuperation (RT) +
Electric Convector (PT)



Drawing 5 Difference between energy requirements and energy intensity

Solution typical of HSW preparation with waste heat from ventilation equipment

S - **Consumption** of refined, 'driving' energy **= Energy intensity**
P - **Consumption of** heat for required function **= Energy requirements**
Z - Energy **Loss:** during heat consumption
OT - Utilizable Waste Heat